

**A Field and Captive Study of Repellency and Induced Aversion  
Techniques on 3 Families of Vertebrate Pests:  
Ursidae, Canidae and Cervidae.**

**M.Sc. Thesis by: D. R. Wooldridge, B. Sc.**



A Field and Captive Study of Repellency and Induced  
Aversion Techniques on 3 Families of  
Vertebrate Pests:  
Ursidae, Canidae and Cervidae

by

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B. Sc., Simon Fraser University, 1974

A Thesis Submitted in Partial Fulfillment  
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in the Department  
of  
Biological Sciences

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Aversion Techniques on 3 Families of Vertebrate Pests:  
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A Field and Captive Study of Repellency and Induced Aversion

Techniques on 3 Families of Vertebrate Pests: Ursidae, Canidae

and Cervidae.

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## ABSTRACT

The effectiveness of two non-destructive techniques for repelling vertebrate pests was determined in this study. Biologically significant sounds and aversion conditioning chemicals were studied in experiments on captive and free-ranging animals.

Aggressive vocalizations between two captive polar bears ( Ursus maritimus, Phipps ) were recorded. Analysis of these sounds led to the synthesis of six sounds which duplicated or exaggerated specific components of the natural sounds. Three control sounds, of simplified spectral content and pattern were also synthesized. Experimental and control sounds were tested on five captive polar bears and two captive brown bears ( U. arctos, Linnaeus ) and on thirteen free-ranging black bears ( U. americanus, Pallas ) in British Columbia and on eighteen free-ranging and one captive polar bear in Churchill, Manitoba.

Experiments with aversion conditioning chemicals involved the ingestion of lithium chloride (LiCl), alpha-naphthyl-thiourea (ANTU) or emetine hydrochloride (EHCl) to determine if the generation of an unpleasant physiological response to these chemicals following ingestion could lead to a conditioned aversion to baits or live prey. Experiments were carried out on two captive black bears and seven captive Columbian blacktailed deer ( Odocoileus hemionus columbianus, Richardson ). The acceptability of treated dogfood baits to free-ranging black and polar bears at dump sites in the British Columbia interior and at Churchill, Manitoba was determined.

Sheep and cattle killed by bears and coyotes ( Canis latrans, Say ) were treated with LiCl, ANTU or EHC1 and the time to consume each carcass was determined through field observation.

Biologically significant sounds were effective as repellents on five captive polar bears and on two captive brown bears, and on all free-ranging black and polar bears. A captive polar bear fitted with a heart rate transmitter showed significant increases in heart rate with the same ranking as those sounds which were effective in field tests. Chemical agents were capable of producing conditioned responses to baits in tests on captive and free-ranging black bears, and in tests on free-ranging polar bears. Bait consumption by free-ranging black and polar bears was significantly reduced over controls for all chemicals tested. Tests using carcasses as baits for free-ranging black bears and coyotes, and using apples as baits for captive deer, proved inconclusive. Approximate effective doses for aversion conditioning chemicals for black and polar bears were: ANTU - 25 mg/kg; EHC1 - 2.0 - 4.0 mg/kg, and; LiCl - 100 - 350 mg/kg. All doses were administered orally.

The problems associated with the successful application of both of these techniques, and their implications and potential as management tools is discussed.

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## GENERAL INTRODUCTION

Vertebrate management techniques employing the concept of repellents offer advantages over traditional destructive control methods ( Kalmbach and Linduska, 1948 ). While destructive techniques constitute an important, and in many cases most desirable and economic approach to problem vertebrate wildlife, new philosophies of wildlife control will require more sophisticated management techniques ( Kalmbach, 1948 ). Traditional destructive techniques have included the use of the bounty system ( Plimlott 1962; Paynter 1967 ), traps and cyanide guns ( Leopold 1964 ), den destruction ( Leopold 1964 ), exposure to poisoned meat stations ( Leopold 1964 ), and poisoned grain or other foodstuffs for the control of rodents and birds ( Kalmbach 1948 ). In many cases these methods do not discriminate between true pests and non-target organisms ( Wagner 1972 ).

The mammalian pests considered in this study are members of the families Ursidae, Canidae and Cervidae, and are: blacktailed deer ( Odocoileus hemionus columbianus, Richardson ): forest and orchard pests; coyotes ( Canis latrans, Say ): pests of domestic livestock including calves, chickens and sheep; black bears ( Ursus americanus, Pallas ): which invade dumps and are persistent nuisances around bush camps and parks ( Berghofer 1964; Craighead and Craighead 1972; Inukai 1972; Gilbert 1974 ), and; polar bears ( U. maritimus, Phipps ): which have achieved pest status most noticeably in the past six years as a result of increased human presence in arctic areas.

The polar bear has been responsible for the deaths of several employees of companies operating in the the north, and has been involved in several unprovoked attacks on men ( Sterling 1975a; Jonkel 1975; Pederson 1956; Manning 1973; Parker 1974; Perry 1966, and; Harrington 1964 ).

Dethier (1947) defines repellents as " those substances which as stimuli elicit avoiding reactions." As a subclass of this definition, "learned aversion conditioning" ( Gustavson and Garcia 1974; Gustavson et al.1974 ) can be defined as a technique which seeks to generate an avoidance of a particular food or location through a learned association between the food or location and chemically-induced ill effects ( Rozin and Kalat 1971 ). This is a classical Pavlovian conditioned response where the foodstuff or location itself acts as the repellent stimulus, rather than the chemical. For this to occur, the aversive chemical must remain unnoticed by the target animal, otherwise it becomes the repellent. This technique circumvents the requirement for the continual application of a noxious repellent, and may have long-lasting repellent effects on the target animal ( Gustavson 1974a,b ; Rozin and Kalat 1971 ).

LiCl has been investigated as an aversion conditioning agent in the control of coyotes ( Gustavson et al.1974; Gustavson 1974a,b; Gustavson and Garcia 1974; Gustavson et al.1976 ), and black bear ( Gilbert 1975 ). Gustavson has postulated its mode of action as either an undefined action on the central nervous system leading to gastro-intestinal discomfort, vomiting and elevation of the blood pressure, or as gastro-intestinal discomfort caused by the passage of



the lithium ion across the gut epithelium. No definitive study has been carried out to provide an accurate explanation of the reactions leading to the observed discomfort in animal subjects. ANTU has been investigated as an aversion conditioning agent in the control of Douglas-fir seedling damage by deer mice, Peromyscus maniculatus, Wagner, and P. truei, L. ( Passof et al.1974 ) and as a species-specific Norway rat ( Rattus norvegicus, Berkenhout ) poison (Richter 1945). Fatal doses of ANTU lead to drowning pulmonary edema, a result of increased permeability of the lung capillaries. ANTU possesses strong emetic properties, and as with LiCl, the cause of this symptom has not been clarified. EHCl has not previously been investigated as a wildlife management chemical. It has been used extensively in human medicine as an amoebicide, and as an emetic for poison rescue therapy. Side effects of low doses include vomiting, nausea and gastrointestinal cramps ( Goodman and Gilman 1975 ) thus making it a suitable candidate for use as an aversion conditioning agent.

Repellency may be achieved through presentation of a noxious or threatening stimulus. Acoustic repellents have been investigated by Frings et al.(1955) and Frings and Frings (1956, 1963, 1952). Busnel (1963) and Frings et al.(1955) discussed "biologically significant sounds" such as distress calls. Dracy and Sander (1975), Belton et al. (1975) and Maclean (1974) investigated sonics and ultrasonics as repellents. Workers investigating aversion conditioners have suggested several problems associated with field application. Shumake et al.(1974) observed that coyotes which eat a sub-lethal dose of an aversive agent

stop eating the bait food-type on subsequent exposure. However, only a fraction of those showing this response to baits will transfer that aversion to the live prey animal (Gustavson and Garcia, 1974).

Shumake et al. (1974) suggest that the remainder, unwilling to eat another treated bait, are unlikely to be deterred from the act of killing a live prey animal, although they may not eat the carcass. In addition, they point out the difficulties of ensuring a sufficient dose intake of the chemical lithium chloride as a result of (i) its high required dose (approximately 500 mg/kg for coyotes; Gustavson et al., 1974), and (ii) its "salty" taste, which may act as a taste repellent in itself.

Gilbert (1975) outlines difficulties in packaging the very hygroscopic LiCl, and notes instances of "self-destruction" of gelatine capsules through absorption of H<sub>2</sub>O from the atmosphere. He also notes a lack of uniformity in field results in his current research.

Sterner (1975) concludes that "proper temporal administration, mode of dosing or delivery as well as the animal's response to such treatment...will determine success of the technique."

Problems associated with acoustic repellents have also been noted. Sprock et al. (1967) feel that ultrasonics are probably unsuitable as long-term repellents for several reasons. Firstly, they are highly directional, therefore requiring a multi-source sound

generation system to cover all areas to be protected. Secondly, they do not readily propagate around corners or through solid objects. Thirdly, they are attenuated rapidly in air and hence do not carry as far as lower frequencies of the same intensity. As frequency rises, the beam width decreases and the transmission distance is reduced. Maclean (1974) noted the lack of long term effects and lack of apparent habituation in rodents. Sprock et al. (1967) felt that habituation might be overcome through the employment of irregular pulse intervals in sound production, however no work was done on this idea.

The objectives of this study were to evaluate non-destructive vertebrate pest management techniques, involving both chemical and physical methods.

#### Objectives of Studies of Physical Repellent Techniques

- (1) To record natural aggressive communications between captive polar bears and to analyse these sounds for spectral content, rhythmic patterns and relative amplitude.
- (2) To electronically synthesize aggressive sounds which attempt to duplicate the original sounds or which exaggerate or clarify specific components of the original sounds in order to generate a more effective repellent sound.

(3) To evaluate the potential of the natural and synthesized sounds as acoustic repellents in captive and field tests on black, brown and polar bears.

#### Objectives of Studies of Chemical Repellent Techniques

(1) To determine or confirm, in captive and field studies on bear, coyotes and deer, aversion-producing dose levels for LiCl, ANTU and EHCl.

(2) To resolve questions associated with the successful field application of aversion conditioning chemicals, and to determine the existence, if any, of other undiscovered problems under field conditions.

## CHAPTER 1

Physical Controls: The Effects of Natural and Synthesized  
Aggressive Sounds on the Behaviour of Black ( Ursus americanus Pallas ),  
Polar ( Ursus maritimus Phipps ), and Brown bears,  
( Ursus arctos Linnaeus ).

## Introduction

Many confrontations between man and bears have resulted in death or damage to man or his property. Increased utilization and exploration of Canada's arctic regions has increased the numbers of encounters with polar bears. In January of 1975, an employee of Imperial Oil, stationed on an exploratory drilling island located in the Beaufort Sea north of Inuvik, NWT., was attacked and killed by a polar bear ( Sterling 1975a ). This and other rigs are now under the protection of an armed Inuit surveillance man. Since January 1975, two intruding bears have been shot after unsuccessful attempts to scare them off. Pederson ( 1956 ) cites two cases of attacks on men by polar bears, and Parker (1974), Manning (1973) and Sterling (1975b) report apparently unprovoked attacks on men. Jonkel (1975) reports an attack at Norwegian Bay on a sleeping man, and suggests that the bear may have mistaken the man for a sleeping or loafing ring seal. He also reports an attack in which an employee of the Department of Energy, Mines and Resources was bitten and mauled before he was able to shoot and kill the polar bear.

In August of 1972, an attack was reported at Devon Island. This later proved to be a probable suicide. The bear had presumably found the suicide victim and had been discovered feeding on the dead man, indicating an attack. The Department of National Defence ( Defence Establishment Pacific, Arctic Research Team ) have had some encounters in the high arctic, on arctic islands and on the sea ice, with curious

polar bears in the course of their summer field trips, however no attacks or fatalities have occurred. Safety in their camp is improved through the use of a trip-wire alarm and fence system, which warns of the approach and entry of a bear.

A large number of polar bears are found in the Churchill, Manitoba area for approximately 2 months each fall, but few attacks have been reported. The number of very close encounters is significant, however. Jonkel (1975) notes incidences ranging from surprise face-to-face meetings to bears leaping into living rooms through front windows. During field tests I was approached once by a charging female and once by a male attempting to stalk me while I set up a bait experiment. A British television crew filming in the area attracted three bears when their car stalled at the incinerator. After I rescued them using dogfood patties, which temporarily lured the bears from the BBC car, the largest bear returned and pushed in the front windshield. It seemed likely that the bear might have broken into the occupied vehicle had I not rescued the crew.

On the basis of the behaviour of captive North American bears of all species, Jonkel (1970a,b) concludes that polar bears are probably less aggressive than grizzly bears. A factor evident in the polar bear's existence in the wild is a seasonally induced nutritional stress. This is compounded for the sub-adult bear who must also face continued territorial challenges from mature animals. Both of these factors

work to produce a bear who is apparently curious about any potential food source. From past incidences, it seems likely that man may be considered just such a potential food source, and therefore should take suitable precautions to avoid the consequences of a polar bear's curiosity. A sub-adult male was the cause of a recent ( January 1975 ) fatality at Imperial Oil's Rig No. 3 in the Beaufort Sea.

The use of sound to repel vertebrates has been investigated by Frings et al. (1955) and Frings and Frings (1952, 1956, 1963). Biologically significant sounds ( Busnel 1963 ), such as alarm or distress cries, were observed to be more "activating" and repellent to birds than simple ultrasonic or sonic sounds. Frings et al. (1955) observed the ability of such a biologically significant sound to evoke a flight response in the starling ( Sturnis vulgaris, Linnaeus ). Frings also noted an inter-specific response to recorded alarm calls of the herring gull ( Larus argentatus, L. ) by both the great black-backed gull ( L. marinus, L. ) and the laughing gull ( L. atricilla, L. ).

Maclean (1974) produced repulsion of commensal rodents in both lab and field experiments through the use of intense ultrasonic sound fields ( 20kHz at 130 dB ) although the repellent effects were permanent only if alternate food and water were accessible. Dracy and Sander (1975) were able to induce anxiety in coyotes ( Canis latrans ) by exposing the animals to an 18 kHz sound ( dB unspecified ) at high intensities. Belton et al. (1975) investigated the potentials and applications of



ultrasonic and sonic sounds as repellents in polar bear control, and saw evidence of some discomfort in the bears when they were exposed to a 7 kHz sound ( 120 dB ). No other frequencies appeared to evoke a discomfort or fear response, and the 7kHz sound was not effective in stopping a hungry bear from feeding when presented with meat.

Sprock et al. (1967) found that at sound pressures below 120 dB, frequencies from 4 - 19 KHz were ineffective in deterring wild and laboratory rats ( Rattus norvegicus, Berkenhout ). Effective repellency was achieved when the frequencies were varied over an entire octave ( 6-12 kHz) and were intermittent. Half-octave ranges ( 6-9, 9-12, 12-16 kHz ) were not as effective. An ultrasonic source at 19 kHz proved ineffective in repelling house mice ( Mus musculus, Linnaeus ). Sprock et al. (1967) also noted that recorded distress calls of the rat were capable of repelling lab rats. Stewart (1974) suggests the potential use of his Av-Alarm sound as a vertebrate repellent, theorizing that its value is not in duplicating a specific communication signal, but rather in producing an auditory "jamming" situation, in which the intruding pest is robbed of its hearing as long as it is within effective distance of the sound source. This would presumably lead to an increased psychological stress level in the animal, resulting in a desire to leave the acoustic field.

The objectives of this study were to determine the potential uses of both natural and synthesized aggressive sounds, intra- and

inter-specifically, on captive and wild bears. The ultimate goal of this type of research is the development of a practical and dependable repellent sound system for use in situations requiring protection of personnel exposed to intruding, curious and possibly dangerous bears.

## Methods and Materials

### A. Recording of Natural Aggressive Sounds

Natural aggressive sounds of the polar bear were recorded at the Olympic Game Farm, near Sequim, Washington State, U.S.A. Two male bears were placed in one cage, and were then offered a single piece of meat. The resulting behaviour included physical shoving and a combination of visual and audible dominance displays. The audible component consisted of hisses and growls ranging from low, throaty sounds to groups of three or four loud, directed roars. A series of approximately 30 of the roars was recorded with a Uher 4000-L Report recorder, and a Grampian parabolic reflector. The distance from the bears to the microphone was between 2 and 7 m.

### B. Analysis of Natural Sounds

The recorded natural sounds were analysed for:

- (i) Spectral content: i.e. the frequencies present in a given roar or growl.
- (ii) Amplitude envelope: i.e. the rhythmic patterns, duration of roars, and "shape" of a given roar.
- (iii) Spectral amplitude: i.e. an indication of which of the frequencies present was produced at a higher sound level than the rest (the most important frequencies).

Sounds were analysed for frequency content on a Kay Elemetrics Co. Type 6/85 Sonagraph which gives a frequency versus time plot on a calibrated paper drum ( Fig. I-I ). This analysis differentiates on a general level only between high and low amplitudes. Sounds were then analysed on a Bruel & Kjaer Third-octave Band-pass Filter Analyser which verified the Sonagraph analysis and provided an accurate indication of: amplitude versus frequency ( Fig. I-II:A ) and, amplitude versus time ( Fig. I-II:B ).

### C. Synthesis of Aggressive Sounds

Aggressive sounds were synthesized using the parameters determined above, through analysis of natural sounds. The synthesis was achieved through modulation of three basic sounds:

- 1) a foghorn sound base
- 2) an automotive engine sound base
- 3) an automotive engine ( different type ) sound base

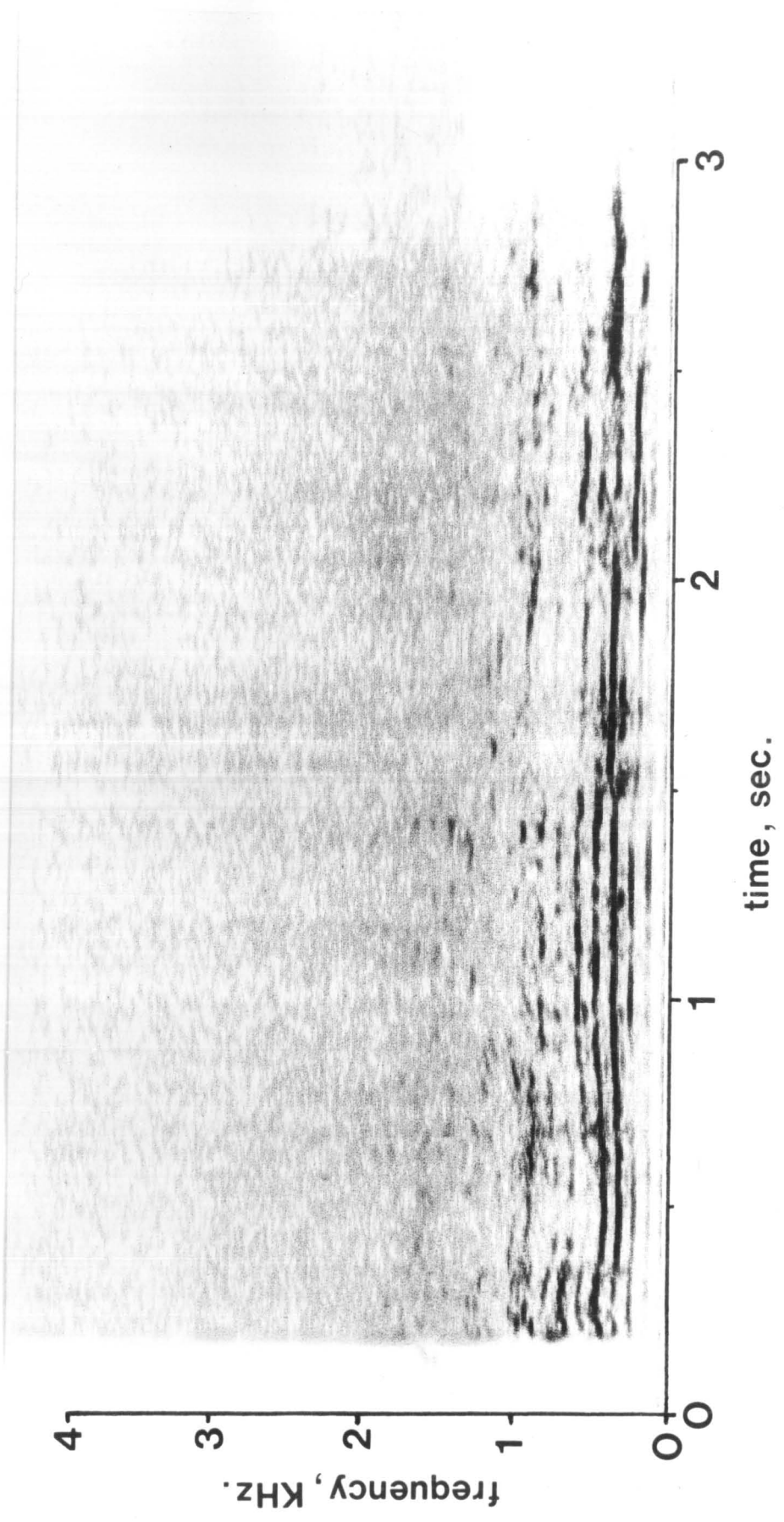
The base sounds were chosen because of their inherent frequency content and because of their inherent rhythmic patterns.

15a.

Figure I-I

A Sonagram of a typical natural polar bear roar.

This Sonagram produced on a Kay Elemetrics Sonagraph. This sonagram indicates the general spectral content of a polar bear roar. The major emphasis is on the frequencies between 100 and 500 Hz.



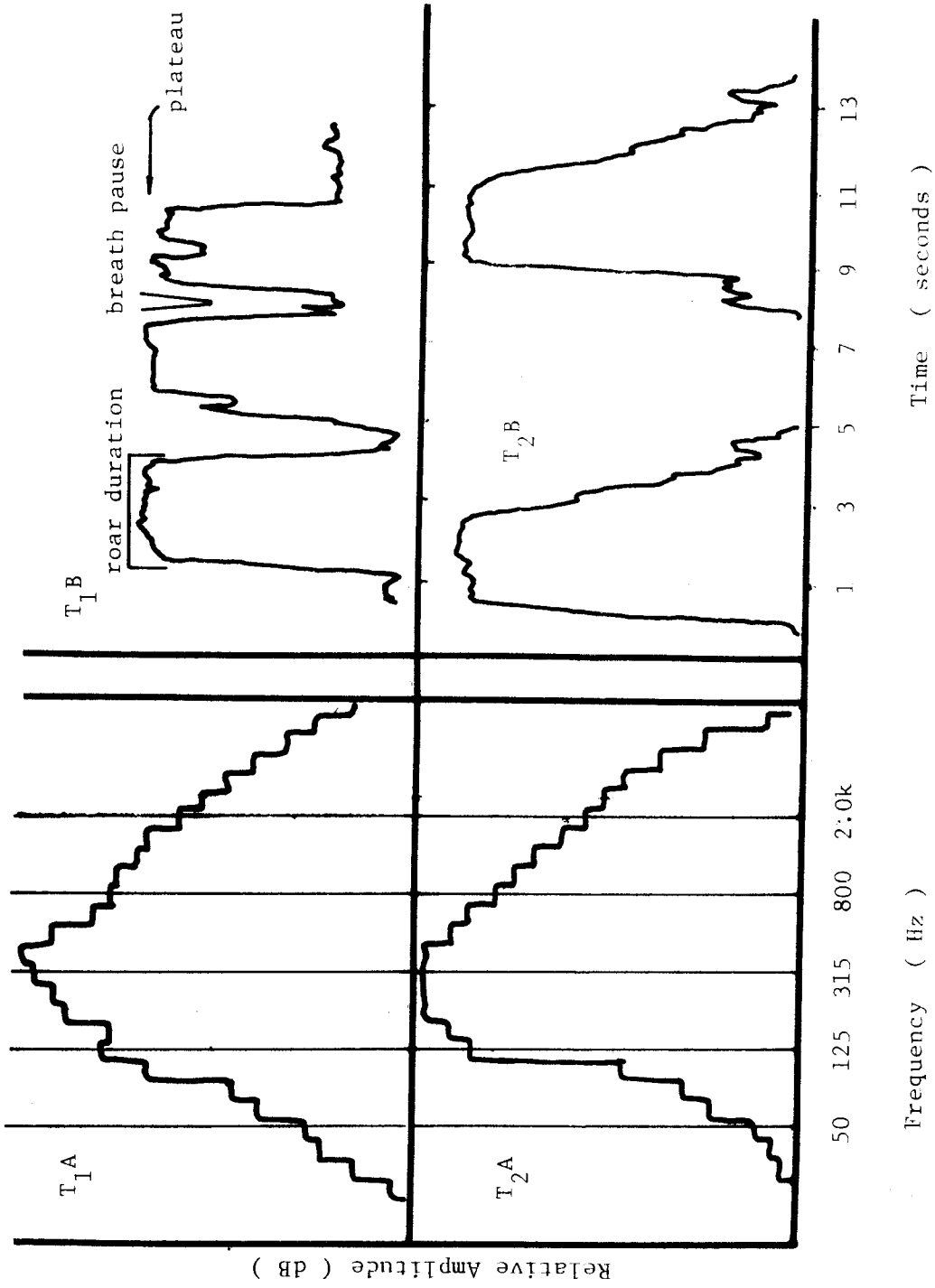
## Figure I-II

Amplitude versus Frequency and Amplitude versus Time Plots,  
Natural ( T1, A&B ) and Synthetic ( T2- 7, A&B ) Sounds.

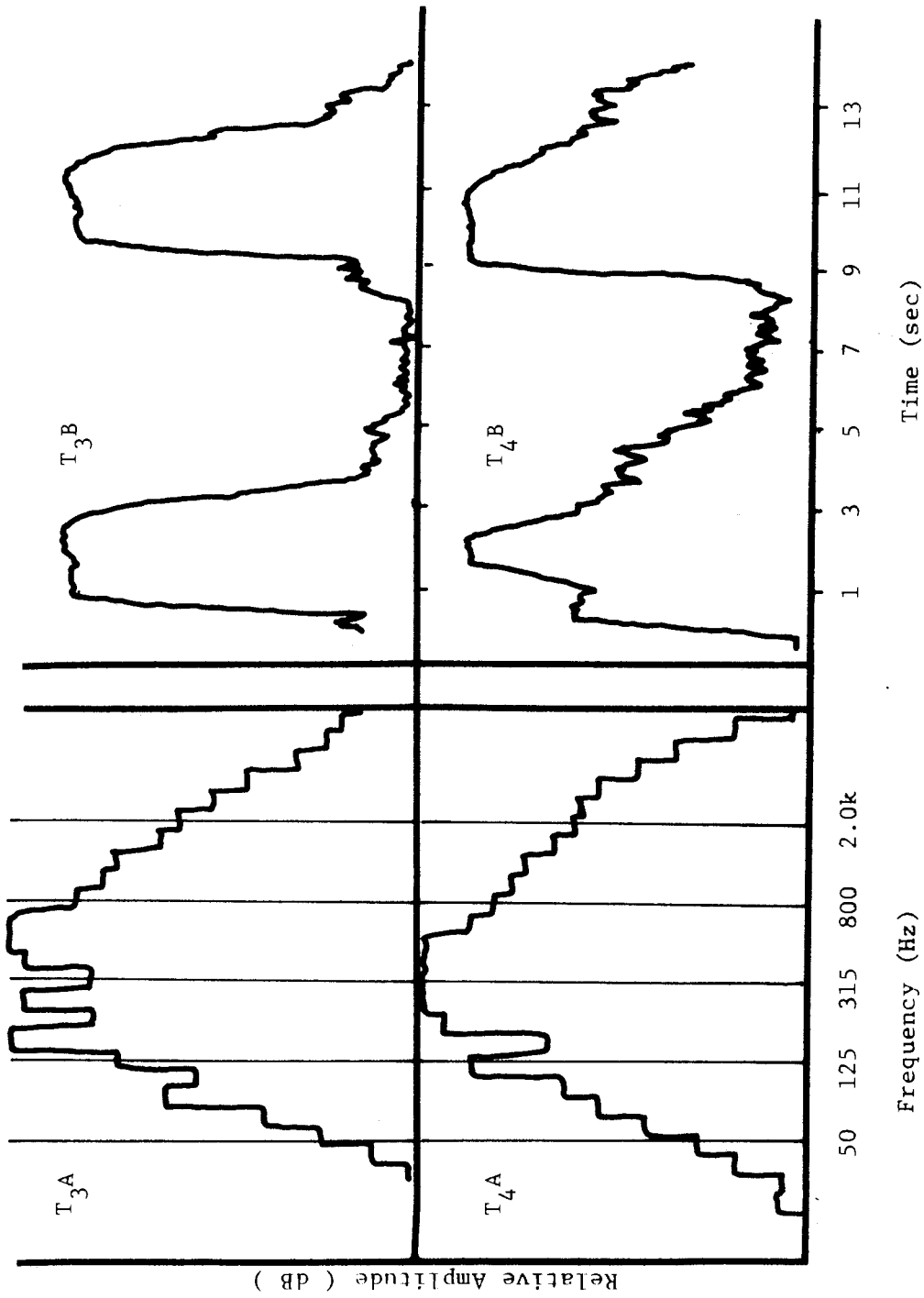
Relative amplitudes for frequencies within third-octave ranges are given for natural ( T1 ) and synthesized ( T2-7 ) sounds in "A" on these plots. Relative amplitudes versus time are given in "B" on these plots.

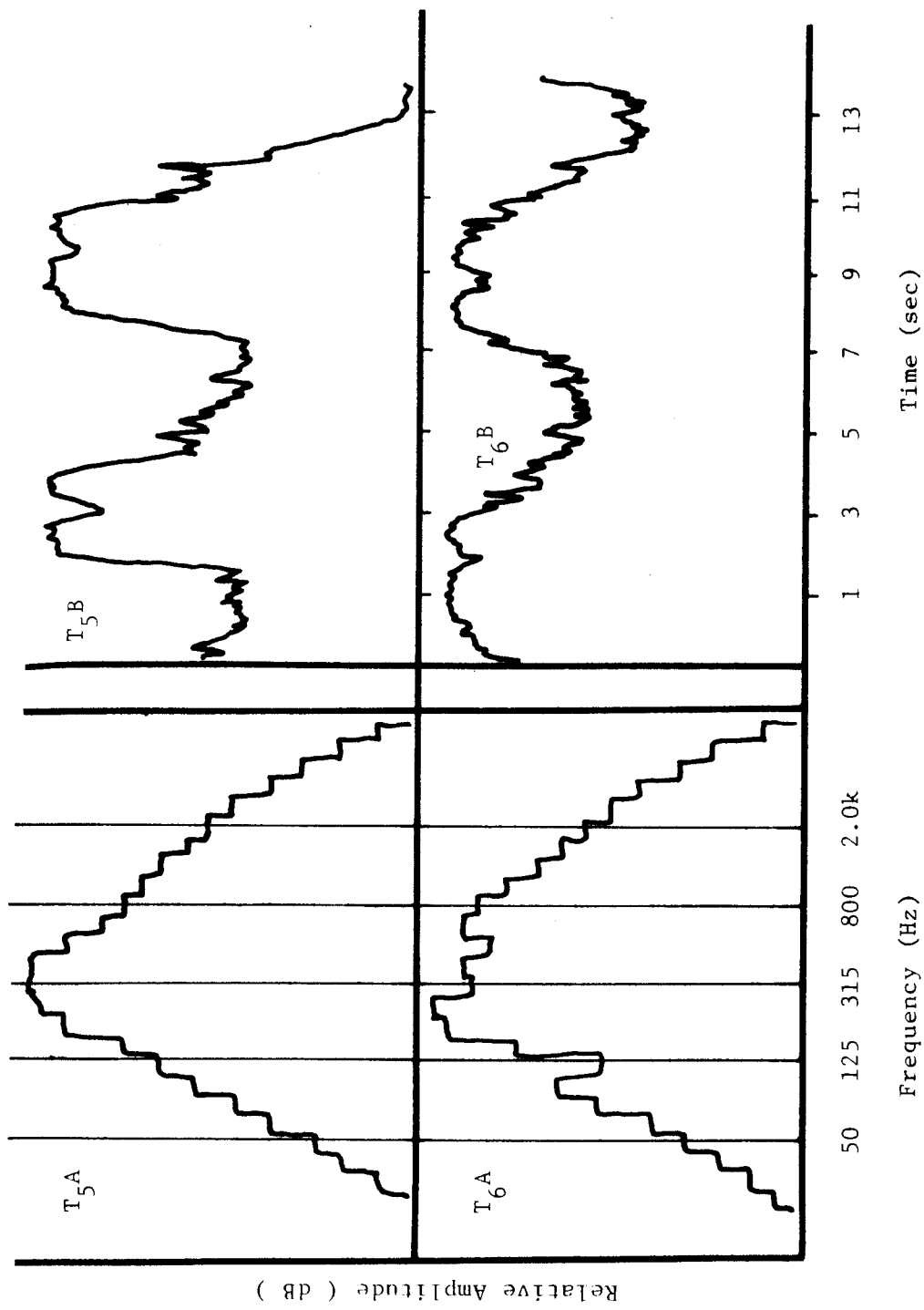
|         |                                    |
|---------|------------------------------------|
| Type 1: | Natural aggressive sound           |
| Type 2: | Foghorn base ( 220 Hz modulation ) |
| Type 3: | " " ( 20 Hz " )                    |
| Type 4: | " " ( 150 Hz " )                   |
| Type 5: | Auto base ( 160 Hz " )             |
| Type 6: | " " ( 25 Hz " )                    |
| Type 7: | " " 2 ( 150 Hz " )                 |

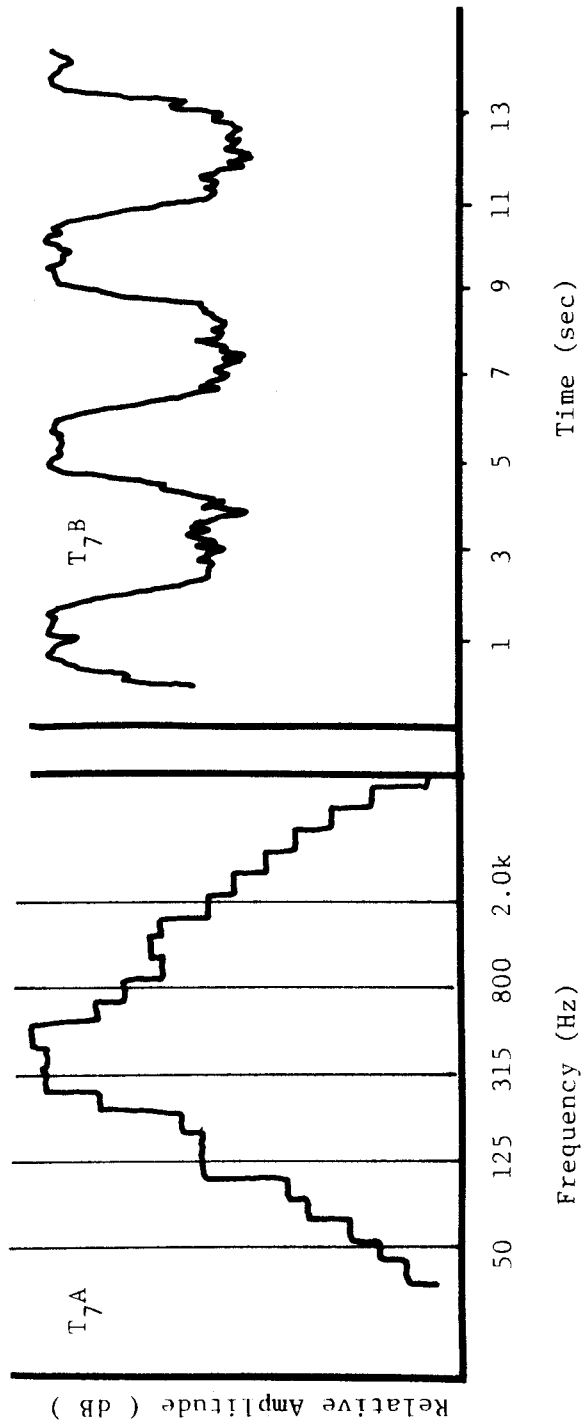
Fig. 1-II Amplitude and Frequency Envelopes; Natural ( $T_1$ ) and Synthetic ( $T_2-T_{10}$ ) Sounds











Modulation of the base sounds was achieved through a series of additions or alterations. The recorded sound was played via a tape loop on an Ampex Studio player at a low level to minimize distortion. This sound was then passed through an R.A. Moog 1/2 - octave filter bank which, through its averaging effect on input frequencies, tended to smooth out the overall envelope. This low level sound was then amplified and passed through a Moog Ring Modulation circuit; an additive unit which produced a pre-programmed modification of the sine wave components of the input frequency ( "F<sub>1</sub>" components ). F<sub>1</sub> sine wave frequencies of the base sound were, in this study, summed with chosen frequencies ( "F<sub>2</sub>" components ) according to the following program:

$$( F_1 \pm F_2 ) + ( 3F_1 \pm F_2 ) + ( 5F_1 \pm F_2 )$$

It is apparent from this program formula that larger values of F<sub>2</sub> would result in a wider but "emptier" sound, while smaller F<sub>2</sub> values would result in a "denser" sound. For instance, F<sub>1</sub>  $\pm$  220 Hz would cover a wider range than F<sub>1</sub>  $\pm$  20 Hz. It was therefore possible to create either heavily "loaded" sounds centred around the main base sound frequencies, or lightly "loaded" sounds, with less white noise in the background, but with a wider overall spectrum.

Finally, the resultant complex sounds were passed through a Krohn-Hite 3100R Band-pass filter, adjusted in such a way as to limit the

harmonics and excess white noise present, while maintaining the sharp "attack" or initiation of the sound which was characteristic of the natural sounds. The resultant sound envelopes were then analysed on the Bruel & Kjaer equipment to verify their fit with respect to the original natural sounds.

The  $F_2$  modulation frequencies supplied to the ring modulator were:

- 1) Foghorn Source: 220, 20, 150 Hz
- 2) Auto source: 160, 25 Hz
- 3) Auto source; 150 Hz

Three control sounds ( $T_8$ ,  $T_9$  and  $T_{10}$ ) were generated and taped to evaluate the response of the bears to sounds which were, theoretically, not biologically significant. The sounds were simple square wave tone bursts of: 150, 220, and (150+220) Hz frequencies; these frequencies corresponded to the frequencies most evident in the analysis of frequency envelopes of the natural sounds.

#### D. Test Methods on Bears

Sounds played to captive and wild animals were produced through a Heath 40 watt amplifier, and a University Sound reflex horn speaker. The duration of the sound in each test was limited to the time

required to elicit a response. If no response occurred after two or three trials, that sound was considered to be ineffective on the test animal. It was not my intent to permanently drive off a potential test subject, since cooperative bears were not numerous.

I defined a significant response in wild bears as an immediate and visually obvious response to a given sound, resulting in the rapid retreat of a bear. In addition, the animal had to continue running away as long as the sounds were continued. This was usually terminated when the animal was an estimated 250 m away. Any result which was less than my defined strong reaction was discarded as not being of value in a practical situation. Consideration of the eventual goal of this study, that of defining an effective acoustic repellent, dictated that only strong negative responses be considered in the tests.

#### a) Captive Polar and Brown Bears

Five polar and two brown bears, located at the Olympic Game Farm in Washington State, were tested with sound types  $T_1$  to  $T_7$ . In order to minimize any cumulative effects, a 15 minute interval was maintained between sound tests. Evaluation of captive subjects was difficult. Conditions of their captivity may have prevented a normal flight response, however an intense fear response was generally obvious.

b) Wild Black Bears

The responses of 13 wild black bears to natural and synthesized aggressive sounds were observed at a dump in the lower mainland, at two dumps in the Rocky Mountains, at a dump and at a forestry camp on the Columbia River; all sites within British Columbia.

To keep the bears within the immediate vicinity of the test site, and as a result on preliminary tests on captive and free-ranging bears, those sounds which appeared to produce the least observable flight reaction were tried first, in order that the subject not be permanently scared away from the test area. Bears were generally identifiable by body colours, markings and overall size. Seven to 10 min. intervals were maintained between tests, except when a sound proved effective. In such cases the bear involved was allowed approximately 20 min to a half-day after returning to the test site before another sound was tried. In many instances it was necessary to continue on a subsequent day, when a bear returned to an area. As more than one sound was effective in most trials on a particular animal, some bears did not return, and evaluation of all sound types was not always possible. In tests of these and the wild polar bears, an attractant was used to ensure that the bears had at least a partial interest in staying or returning to the test area. Molasses and honey were used to attract black bears to test sites in British Columbia.

### c) Wild Polar Bears

The annual fall polar bear migration onto the sea ice or to denning grounds near Churchill, Manitoba allowed for the study of a relatively large number of polar bears. Approximately 200 bears move through the area each fall. Areas under scrutiny included the main dump, the incinerator and areas surrounding each. Most of the animals came to the dump during the day to scavenge, and then moved away, lying on the frozen lakes or in the scrub brush nearby. Dogfood patties soaked in sardine oil were used to attract polar bears. The sardine oil appeared to remain odorous even at the low temperatures experienced at Churchill in November.

### d) Captive Polar Bears - Telemetry

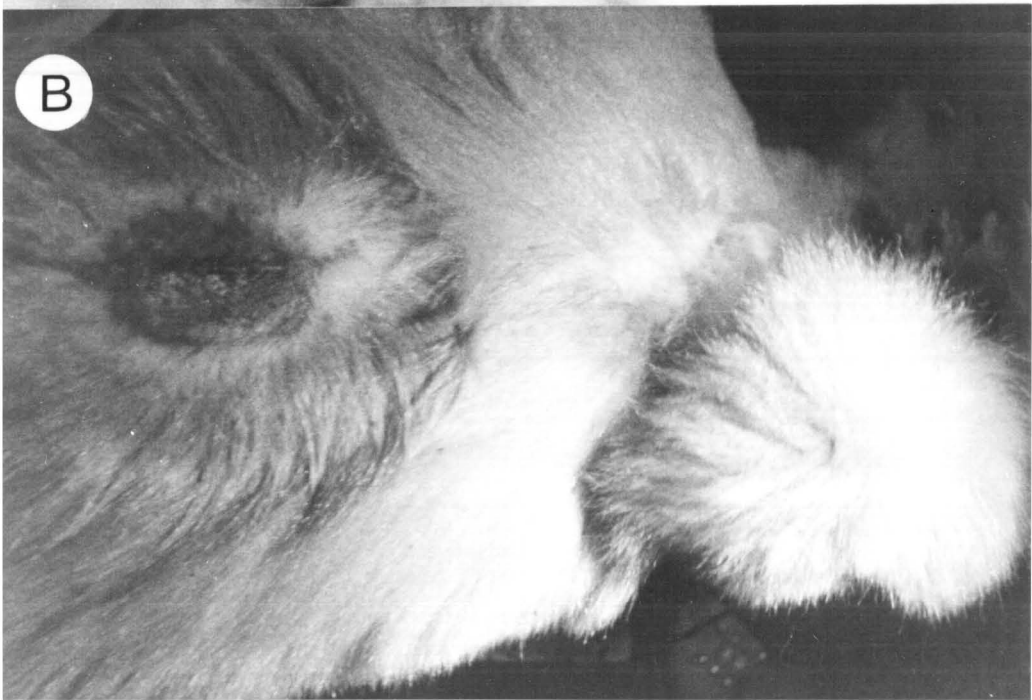
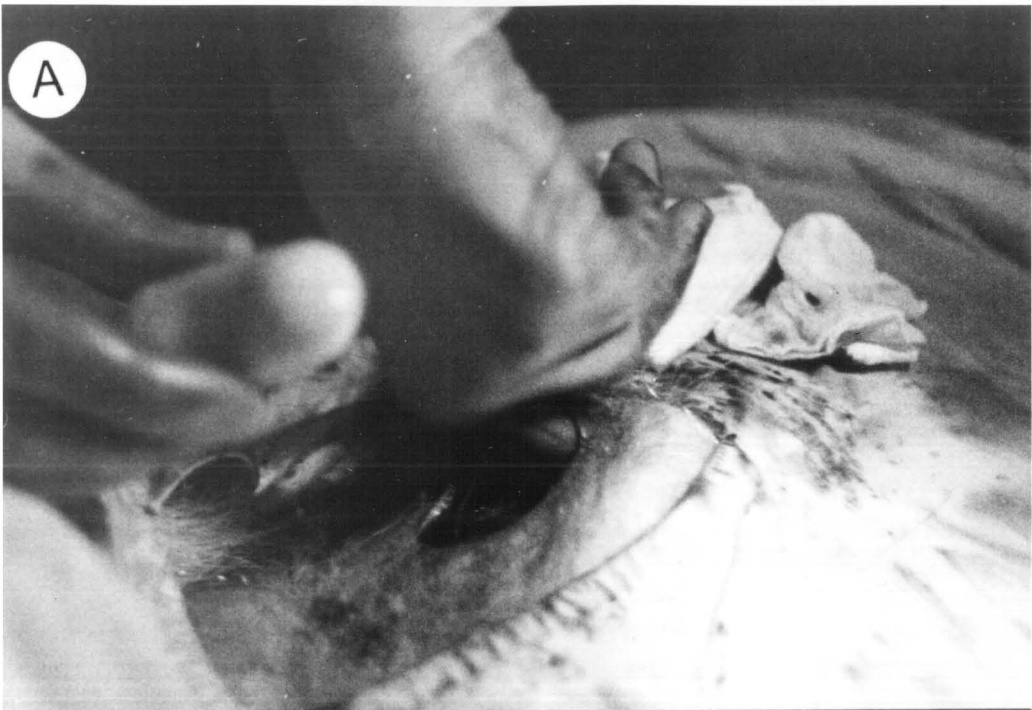
The responses of a recently captured polar bear to aggressive sounds were observed and quantified through FM telemetry. A male bear was trapped and immobilized in Churchill by the Manitoba Wildlife Department. The animal was then sedated, and an FM transmitter was inserted under its skin ( Plate I-I, A & B ). The transmitter was a silicon-wax imbedded unit which was placed in the bear for the purposes of Dr. N. Oritsland's physiology studies. Two stainless steel electrodes ran laterally from the transmitter unit, and these wires picked up signals of the heart's electrical activity. The output from the transmitter was picked up on an antenna located near the bear cage, and was audibly reproduced on an FM radio tuned to a clear frequency. The impulses were also recorded on a Gould-Brush Accuchart recorder for later analysis.



Plate I-I

Surgical Implantation of a Heart Rate Transmitter

- A: Insertion of heart rate transmitter into thoracic region of ventral surface.
- B: Closed incision.



Three tests of each of the ten sound types were run, and average heart-rate increases were subjected to a one-tailed "t" test for significance at the 0.05 level of probability. Beyond a level of approximately 70 dB ( measured on a sound level meter 1 m from the speaker ) all sound types produced significant heart-rate increases. Therefore a sound level of approximately 60 dB was used in the tests in order to give adequate discrimination between results. In actual field conditions, attenuation of sound over distance would produce this sound level at approximately 75 m, using a 100 dB source.

e) Field Test: Beaufort Sea Drilling Rig

In December of 1975 I travelled to the Beaufort Sea where Imperial Oil was involved in exploratory drilling. General conditions of location, climate, visibility and facilities were evaluated with an eye towards a reliable and dependable polar bear deterrent system. A public address sound system was installed, with a recording of all of the natural and synthesized aggressive and control sounds. A 70 watt amplifier played the sounds into four speakers located on various structures around the rig. These speakers were directed to cover all approaches to the rig, to discourage intruding bears in the immediate area of the rig.

## Results

### A. Analysis and Synthesis of Sounds

The Sonagraph ( Fig. I-I ) gave the frequency spectrum of typical aggressive polar bear roars. The apparent frequencies ( determined from analysis of 5 roars ) are in the 80, 100, 150, 200 and 220 Hz bands, with some less obvious emphasis in the range of 250 - 500 Hz. Some higher-frequency harmonics are also apparent. Results of the Bruel & Kjaer analyses of frequency and amplitude envelopes are shown in Fig. I-II.

Fig. I-II, "A" sections indicate that the synthesized sounds follow the general frequency versus relative amplitude expressed in the natural sounds. Frequencies in the 80 - 500 Hz range are emphasized, with harmonics of diminishing amplitude above this range. Fig. I-II, "B" sections show the rhythmic patterns of natural and synthesized roars. Fig. I-II, T<sub>1</sub>"B" indicates the typical three-burst roar of a polar bear's roar, each burst interrupted by a breath pause. Roars which were effective in tests generally consisted of two - four bursts. The lung capacity of a bear may limit the duration, or plateau of each burst, and this possibility suggested the synthesis of longer-duration bursts, thereby simulating a "super bear" roar. Types T<sub>2</sub>, T<sub>4</sub> and T<sub>6</sub> are all of longer duration than the natural roar. The rapid attack slope of the sound is evident in the amplitude ("B") envelopes of types T<sub>2</sub>, T<sub>4</sub> and T<sub>5</sub>. This is exaggerated over the T<sub>1</sub> sound.

T<sub>5</sub>, T<sub>6</sub> and T<sub>7</sub> show a level of "white" sound represented by the higher baseline sound level between bursts. This is also a characteristic of the T<sub>1</sub> natural sound and probably reflects sounds generated by breathing in between roar bursts. The T<sub>7</sub> sound has duplicated the duration and relative amplitudes of the T<sub>1</sub> natural sounds without exaggeration.

## B. Tests on Bears

### a) Tests on Captive Brown and Polar Bears

A total of five polar bears and two brown bears were subjected to seven sounds in the same sequence as the sounds were synthesized. Two trials per sound were carried out on each bear ( Table I-I ). Two of the polar bears were the "source" bears used to record the original aggressive sounds, and they responded the least to subsequent playbacks of these sounds. Possibly they were able to recognize their own "voice" in the playbacks. Polar bear number 1 did not respond to any of the sound types. Polar bears 3, 4 and 5 were either younger than the source bears, female, or both, and could be scared quite easily. They all attempted to escape through the cage screening at the rear of their pen, and when they were unable to do so, they cowered in the furthest rear corner of their pen, away from the sound source. The two brown bears gave the most dramatic performance, both trying to run through the rear of their cages, and then attempting to climb the bars of the rear wall. Towards the end of tests on these bears, my

Table I-I

Responses of five captive polar and two captive brown bears  
to natural (1) and synthesized (2-7) sound types.

| species &<br>no. of bear |   | Sound Type <sup>1</sup> |   |   |   |   |   |   |   |   |   |   |   |   |   |
|--------------------------|---|-------------------------|---|---|---|---|---|---|---|---|---|---|---|---|---|
|                          |   | 2 <sup>1</sup>          |   | 2 |   | 3 |   | 4 |   | 5 |   | 6 |   | 7 |   |
|                          |   | a                       | b | a | b | a | b | a | b | a | b | a | b | a | b |
| polar                    | 1 | 0 <sup>3</sup>          | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
|                          | 2 | 0                       | 0 | 0 | 0 | S | 0 | 0 | 0 | 0 | 0 | S | 0 | 0 | 0 |
|                          | 3 | S <sup>4</sup>          | S | 0 | S | 0 | S | 0 | S | 0 | 0 | 0 | S | 0 | 0 |
|                          | 4 | S                       | S | 0 | 0 | 0 | 0 | 0 | S | 0 | 0 | S | S | 0 | 0 |
|                          | 5 | S                       | S | S | 0 | 0 | 0 | S | S | 0 | S | S | S | 0 | S |
| brown                    | 1 | S                       | S | S | S | S | S | S | S | 0 | S | S | S | S | S |
|                          | 2 | S                       | S | S | S | S | S | S | S | S | S | S | S | S | S |

1 = Sound types 8, 9 and 10 were not tested on these bears.

2 = two trials per sound type; a = trial 1; b = trial 2.

3 = 0 ; no response to sound

4 = S ; response ( immediate retreat from sound source ).

Percentage responses summarized in Fig. I-III.

approach alone would effect the same response; they had readily become conditioned to the fact that I was associated with the sounds.

#### b) Tests on Wild Black Bears

Table I-II summarizes individual tests on wild black bears.

Of the 13 black bears involved in these tests, none failed to respond to at least one of the sounds; most responded to three or more. These bears were permanent summertime residents of the test site dumps and it was therefore possible to return and try different sounds. One black bear at the Columbia River dump was kept on the retreat for an estimated distance of 300 m; he continually looked over his shoulder but did not stop running. A few hours prior to this test, the same bear had had a rifle fired over his head and he had not responded.

#### c) Tests on Wild Polar Bears

Table I-III summarizes individual tests on 19 free-ranging polar bears at Churchill. These bears were exposed to nine aggressive sounds in a sequence determined by the effectiveness of these sounds on captive polar and brown bears and on free-ranging black bears. The sequence was: types 8, 9, 10, 2, 4, 7, 1, 3, 5 and 6. This was done to reduce the possibilities of permanently scaring off a bear. A female with two cubs was the first wild polar bear tested at Churchill. Her response to the  $T_1$  ( natural ) sounds was inquisitive, and then aggressive. She charged in the direction of the sound source.

Table I-II

Responses of 13 wild black bears to natural (1), synthesized (2-7), and control (8-10) sound types.

| Bear No. | Sound Type     |   |   |   |   |   |   |   |   |    |
|----------|----------------|---|---|---|---|---|---|---|---|----|
|          | 1 <sup>1</sup> | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 1        | 0 <sup>2</sup> | 0 | 0 | 0 | S | S | 0 | 0 | 0 | 0  |
| 2        | S <sup>3</sup> | 0 | S | 0 | 0 | S | 0 | 0 | 0 | 0  |
| 3        | S              | 0 | 0 | 0 | 0 | S | S | 0 | 0 | S  |
| 4        | S              | S | S | 0 | 0 | 0 | 0 | 0 | 0 | 0  |
| 5        | 0              | 0 | S | 0 | S | S | 0 | 0 | 0 | 0  |
| 6        | S              | 0 | S | S | S | S | S | 0 | 0 | S  |
| 7        | S              | 0 | S | 0 | S | S | 0 | 0 | 0 | 0  |
| 8        | S              | 0 | S | S | S | S | 0 | 0 | 0 | S  |
| 9        | S              | 0 | S | 0 | S | S | 0 | 0 | 0 | 0  |
| 10       | S              | 0 | 0 | 0 | S | S | S | 0 | 0 | 0  |
| 11       | 0              | S | S | 0 | S | S | 0 | 0 | 0 | 0  |
| 12       | S              | 0 | S | 0 | 0 | S | 0 | 0 | 0 | 0  |
| 13       | 0              | S | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0  |

1 = One trial per sound      2 = 0 ; no response to sound      3 = response

Percentage responses summarized in Fig. I-III



Table I-III

Responses of 19 wild polar bears to natural (1), synthesized (2-7) and control (8-10) sound types.

| Bear No. | Sound Types     |    |    |                |                |    |   |   |   |    |
|----------|-----------------|----|----|----------------|----------------|----|---|---|---|----|
|          | 1               | 2  | 3  | 4              | 5              | 6  | 7 | 8 | 9 | 10 |
| 1        | OS <sup>1</sup> | OS | OS | O <sup>2</sup> | S <sup>3</sup> | S  | 0 | 0 | 0 | S  |
| 2        | S               | 0  | S  | 0              | OS             | S  | 0 | 0 | 0 | 0  |
| 3        | S               | 0  | S  | 0              | S              | S  | 0 | 0 | 0 | 0  |
| 4        | S               | S  | S  | S              | S              | S  | S | S | 0 | S  |
| 5        | S               | 0  | 0  | S              | S              | S  | S | 0 | 0 | 0  |
| 6        | S               | S  | 0  | 0              | S              | 0  | 0 | 0 | 0 | 0  |
| 7        | S               | 0  | S  | 0              | 0              | OS | 0 | 0 | 0 | 0  |
| 8        | 0               | 0  | S  | S              | 0              | SS | S | S | 0 | S  |
| 9        | S               | 0  | S  | 0              | S              | S  | 0 | 0 | 0 | 0  |
| 10       | S               | S  | S  | 0              | S              | S  | 0 | 0 | 0 | 0  |
| 11       | S               | S  | S  | S              | S              | S  | 0 | 0 | 0 | S  |
| 12       | S               | S  | S  | 0              | S              | S  | 0 | 0 | 0 | 0  |
| 13       | S               | 0  | S  | 0              | 0              | S  | 0 | 0 | 0 | 0  |
| 14       | S               | 0  | S  | 0              | S              | S  | 0 | 0 | 0 | 0  |
| 15       | S               | S  | S  | 0              | 0              | S  | 0 | 0 | 0 | 0  |
| 16       | 0               | 0  | S  | 0              | S              | S  | 0 | 0 | 0 | 0  |
| 17       | S               | 0  | S  | 0              | 0              | S  | 0 | 0 | 0 | 0  |
| 18       | S               | 0  | S  | 0              | 0              | S  | 0 | 0 | 0 | 0  |
| 19       | 0               | 0  | 0  | 0              | 0              | S  | 0 | 0 | 0 | 0  |

1 = first & second responses ( repeat trials )

2 = 0 ; no response

3 = S ; response

Percent responses summarized in Fig. I-III

Fig. I-III presents a summary of the percentage of strong responses for each sound type tested. Wild polar bears generally responded most strongly to their own aggressive sounds. The captive brown bears reacted strongly to all sound types ( no control sounds were tested on them ), indicating that the conditions of their confinement may have had an effect on their response. Free-ranging black bears were also strongly repelled by both natural and synthesized sounds; both free-ranging black and polar bears gave greater percentage responses than captive polar bears. This class of animal has to deal with such aggressive sounds in typical territorial challenges, while captive animals become habituated to the presence of men and man-made noises. Fig. I-III indicates that the type 6 sound was the most effective sound overall, followed by types 3, 1 and 5. The type 10 control sound also had a slight effect on free-ranging bears.

### C. Telemetry Studies

Table I-IV shows the results of the heart-rate versus sound type tests. Percent increases were greatest for types 1, 3, 5 and 6, with corresponding values of 54%, 75%, 138% and 180% increases. Types 4 and 10 gave increases of 30% and 31% respectively. Rates before and after each sound were averaged for three tests, and these values were tested for significance at the 0.05 level of probability. Since I was only considering heart-rate increases, I considered the data as being one-tailed. Sound types which showed significant increases are ranked in the data. In some instances, if the sound

Figure I-III

Response versus Sound Type

Frequency distribution of the total number of avoidance responses ( expressed as a percentage ) to each sound type, including the three control types ( T-8, 9 & 10 ) for captive polar and brown bears, and for free-ranging black and polar bears.

Fig. I-III: RESPONSE versus SOUND TYPE

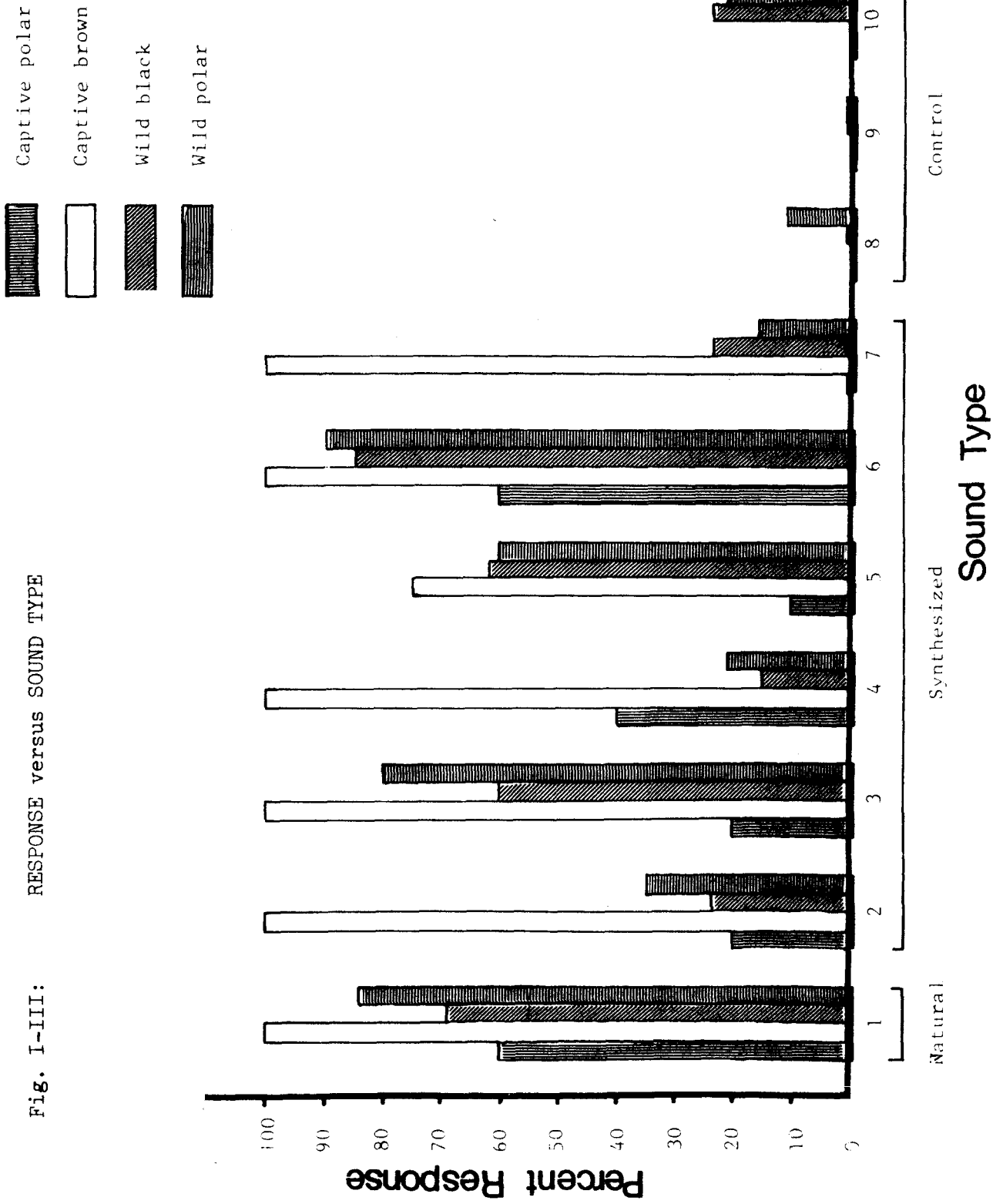


Table I-IV

Effects of natural and synthesized sounds on the heart-rate of a captive polar bear.

| Sound type        | Test 1 |     | Test 2 |     | Test 3 |     | $\bar{X}_a$ | $\bar{X}_b$ | % increase | "t" <sup>3</sup> | rank |
|-------------------|--------|-----|--------|-----|--------|-----|-------------|-------------|------------|------------------|------|
|                   | b1     | a2  | b      | a   | b      | a   |             |             |            |                  |      |
| 1                 | 105    | 170 | 110    | 168 | 100    | 150 | 163         | 105         | 54         | 8.26             | 2    |
| 2                 | 120    | 135 | 105    | 110 | 100    | 98  | 108         | 114         | 5          | .48              |      |
| 3                 | 100    | 160 | 65     | 140 | 75     | 120 | 80          | 140         | 75         | 3.86             | 4    |
| 4                 | 90     | 125 | 80     | 95  | 100    | 130 | 90          | 117         | 30         | 2.16             | 6    |
| 5                 | 105    | 175 | 60     | 155 | 36     | 150 | 67          | 160         | 138        | 4.30             | 3    |
| 6                 | 55     | 170 | 45     | 160 | 72     | 150 | 57          | 160         | 180        | 10.51            | 1    |
| 7                 | 72     | 88  | 80     | 90  | 110    | 98  | 87          | 92          | 5          | .39              |      |
| 8                 | 60     | 72  | 85     | 87  | 95     | 100 | 80          | 86          | 8          | .48              |      |
| 9                 | 70     | 100 | 90     | 96  | 100    | 110 | 87          | 102         | 17         | 1.57             |      |
| 10                | 70     | 95  | 95     | 120 | 80     | 110 | 82          | 108         | 31         | 2.60             | 5    |
| Mean heart rates: | 129.0  |     |        |     | 121.6  |     |             |             |            |                  |      |

Notes: 1: "b" = heart rate before test

2: "a" = heart rate after test

3: "t" = one tailed "t" test for  $(n_1 + n_2 - 2) = 4$  d.f., at 0.05 probability.

was played to the animals when it was sleeping or resting, its heart rate would increase but it would not attempt to get away. At percent increases over 50%, in general, the bear would move in response to sounds. At increases above 70%, it would exhibit apparent "fear" responses. They were not aggressive responses, which I was able to observe from the safety of a steel door. When this barrier was approached by workers, the animal would often "attack" the door, slamming into it only to be stopped by its substantial construction. "Fear" responses which I observed were characterized by movements away from the door and speaker, and on several occasions, by attempts by the bear to climb out through the high, barred window at the rear of its cage.

The mean increase in heart-rate fell off over the test period ( three days ) indicating a degree of habituation to the sounds ( a 6% decrease over 3 days ). The small enclosure and lack of any positive reinforcement accompanying the recorded sounds may have been responsible for this decrease in response.

#### D. Tests at a Drilling Rig; Beaufort Sea

In late February, 1976, a polar bear was reported near Imperial Oil's Delta Rig number 3. After the animal was sighted, the repellent sounds were initiated by the crew. No immediate effect was observed, but the bear did move off after approximately 1 min of the sounds. Observations of the behaviour of the animal were reported by a number of individuals; these reports were not all in agreement. The bear

was eventually chased and shot. Sounds were initiated when the bear was an estimated 600 m from the speaker. The dead bear was examined and found to be in a semi-starved condition. This condition is not uncommon for sub-adult males during the mid- to late-winter months.

## Discussion

Studies of the responses of captive and free-ranging bears to both natural and synthesized aggressive sounds indicate that these sounds possess considerable potential as repellents. Comparison of response versus sound type ( Fig. I-III ) has allowed speculation on the required components of an effective fear-inducing sound.

1) The frequency content should be in the range of 100 to 600 Hz and should contain several emphasized frequency bands within this range. The Sonagraph and Bruel & Kjaer analysis indicated five to 10 distinct frequency bands in the natural sounds, predominantly in the 100, 125, 150, 200, 250, 400 and 600 Hz regions.

2) The frequencies suggested should "fit" a specific frequency envelope ( frequency versus relative amplitude, as in Fig. I-II, "A" plots ), with the major emphasis on those bands between 180 to 300 Hz. White noise appears at higher frequencies in all analyses, however it is of low relative amplitude.

3) The amplitude envelope ( Fig. I-II, "B" plots ) which specifies sound initiation, duration and rhythmic patterns, should conform to a specific shape; a rapid attack, a plateau of 2 - 4 sec, and a rapid sound attenuation after the plateau.

4) Each individual burst should be repeated at least twice and more generally three to four times with a 1 - 3 second break between bursts.



5) The amplitude in the field must be above 100 dB ( measured 1 m from the speaker ) in order that the sounds be effective at ranges up to 250 m. This is extremely loud, and the amplitude alone may effect a retreat at distances up to 30m. At test amplitudes of 120 dB, I was able to roust polar bears at distances of 250 m, and continuation of the effective sound resulted in a continued retreat of these animals to an estimated 500 m, at which point the sounds were terminated.

Positive responses of the bears to the sounds included my defined response criteria, and also weaker positive responses which I did not feel were sufficiently strong to be of practical, safe use. Approximately 30% of these weaker responses were characterized by the bear stopping his advance in my direction or by a hesitant retreat for a short distance. Such weak responses would be of no value in a life-saving situation involving an aggressive polar bear, and they were therefore not included as defined responses.

The four polar bears subjected to repeat exposures of the same sound showed an increased response on subsequent trials. This apparent lack of habituation is probably due to the reinforcement that these animals receive in territorial challenges and aggressive behaviour relating to food. Such real threat encounters are often coupled with either a visual display, such as a short charge, or with actual physical blows. The natural and synthesized sounds may act as releasers of responses which are conditioned by the bears' normal aggressive encounters.

Habituation may have occurred in the captive bear fitted with the FM heart-rate transmitter ( Table I-IV ). His overall heart rate increase for all sounds decreased from an average of 129 b.p.m. to 121 b.p.m., a 6 % drop from Day 1 to Day 3 tests. In this case, the animal was receiving no external stimuli and his continuous exposure to the sight and sound of human activity coupled with the sound presentation may have been responsible for the observed habituation. In addition, earlier playbacks of sounds which proved to be ineffective may have compounded the reduced response. The average of all "before" heart rates for this animal was 84 B.P.M. ( s.d. = 13.93 ), his average "after" heart rate was 102 B.P.M. ( s.d. = 29.77 ). The variation in "before" rates is probably due to normal physiological variations, relating to varying activity levels and excitement. The greater variation in "after" rates is due to the variable effects of the sounds. In the field, this deviation would be expected to be greater, since this bear proved to be more affected by the sounds ( as a result of the experimental setup ) than free-ranging bears.

Polar bear control at arctic oil rig sites may include the repulsion of an extremely hungry, possibly aggressive bear who is intent on exploring any possible food source. This type of situation is potentially dangerous to men in the area who might "happen" on the intruding bear.

Observations on the Beaufort Sea were inconclusive. A report by the firstaid attendant indicated that the repellent sounds were initiated when the animal was approximately 600 - 800 m away, resulting in a very reduced sound level. The tape which was played included

sounds which later proved ineffective, and the tape was left running for a long time. The bear did retreat, but was chased and shot, a reaction which may not have been necessary.

Repellent sounds offer advantages over other current methods of bear management. They require no physical contact with the animal, as does an immobilizing device, and human involvement in the immediate area is not required, as would be the case with flares or Thunderflashes ( a military explosion simulator ). They are effective at moderately long ranges, as a direct result of their biological significance to the subject. They are electronically produced and are therefore compatible with other electronic devices such a perimeter bear intrusion detection device. Habituation does not appear to occur in the field as a result of positive reinforcement from other mature bears.

Current research in this area centres on the development of a reliable bear detection system which will be integrated with the acoustic repellents. Incorporation of these devices and repellents offers the potential of reducing the numbers of dangerous bear-man encounters in the harsh arctic environment.

## CHAPTER II

Chemical Controls: The Effects of Illness-inducing Chemicals on the Behaviour of Captive and Wild Black Bears (Ursus americanus Pallas), Wild Polar Bears (Ursus maritimus Phipps), Captive Blacktailed Deer (Odocoileus hemionus columbianus, Richardson), and Wild Coyotes (Canis latrans Say)

## INTRODUCTION

If an animal eats a noxious substance or receives some other form of aversive treatment during or immediately following ingestion of a novel food, intake of that food is reduced upon subsequent exposure ( Rozin and Kalat 1971; Seligman and Hager 1972 ). This is currently viewed as a potential technique for reducing predator attacks on sheep ( Gustavson 1974, 1976 ), bear damage to beeyards ( Gilbert 1975 ), raptor attacks on lambs ( Brett et al. 1976 ) and in various other omnivorous and carnivorous pest situations ( Gustavson 1976 ). Gustavson ( 1974a,b ) theorizes that if coyotes ( Canis latrans ) can be attracted to mutton which has been baited with LiCl they will subsequently avoid live sheep. Gilbert ( 1975 ) reduced damage to beeyards by the black bear ( Ursus americanus ) using LiCl and honey baits ( 6g LiCl per gelatine capsule, imbedded in honeycomb ). An electric fence was also employed in some of Gilbert's experiments.

Shumake et al. ( 1974 ) experimented with four live-trapped coyotes which were adapted to killing and eating both albino house mice and deer mice. Each was allowed to eat a deer mouse carcass and was then injected peritoneally with a single dose of chemical within 5 - 10 min of eating the carcass. Three of the coyotes were given LiCl and one was injected with NaCl as a control. Dosage consisted of 300 ml of a warmed 0.14M solution ( = 1.78 g LiCl or 2.459 g NaCl ). In 1 h trials, the control coyote

continued to eat dead deer mice and to kill and eat live mice of both species. Of the three LiCl-treated coyotes, one avoided both live and dead deer mice, but continued to kill and eat albino mice; the other two avoided dead deer mice but continued to kill and eat live mice of both species. This finding agrees with Gustavson and Garcia's ( 1974 ) and Gustavson et al's(1974) conclusions regarding the unsuccessful transfer of aversion from baits to live prey, and is the basis for some criticism of the technique by Shumake et al.(1974). The time delay between ingestion of a carcass and treatment with LiCl, as well as the previously free-ranging coyotes' experiences with deer mice may have been partially responsible for the low percentage of aversion transference. Gustavson et al's (1974) initial work had several design faults. The use of laboratory-reared coyotes may have led to conclusions which are not relevant to field situations. A salt control was lacking. Interperitoneal injections are virtually useless for field applications. Later studies ( Gustavson 1976 ) have corrected these earlier design flaws. Gustavson has conducted aversive experiments on a wide range of omnivorous and carnivorous species ([cougar, Felis concolor, Linnaeus; Gustavson 1976],[Timber wolf, canis lupus, L.; Gustavson et al. 1976],[coyote, C. latrans; Gustavson 1974a,b, 1976],[black bear, U. americanus, Gustavson 1976],[wild mice, Microtus montanus, Peale, and Peromyscus maniculatus, Wagner; Gustavson 1976], and

[the magpie, Pica pica, Linnaeus; Gustavson 1976 ].

He observed conditioned emesis in F. concolor after LiCl treatment in deer meat ( 6g: 1 trial ); supression of attack behaviour on mature sheep by C. lupus following LiCl treatment in mutton ( LiCl in capsules, no amount mentioned: 1 trial ), and; rejection of marshmallows and occasional emesis, followed by a 65 day aversion after LiCl treatment in C. lupus ( 3 - 7.5 g LiCl in gelatine capsules, placed into marshmallows; 9 trials ).

Gustavson (1976) noted the unreliable occurrence of emesis following treatment with aversive chemicals. He suggests that learned aversions serve to protect the animal from further exposure to risk. Carnivores vomit readily and may employ this function in feeding offspring, implying that regurgitation per se in carnivores is not likely to be aversive. Emesis may, however, facilitate a complete aversion response when coupled with other discomforts associated with the treatment.

Recent taste aversion studies indicate that many species are sensitive to the technique ( Gustavson 1976 ). Responses of an animal to an unacceptable food may be catagorized in three ways: [1] movement of the animal away from the food; [2] disgust behaviours, or, [3] displacement behaviours, such as ground pawing, food dish biting, or aggression towards other animals in the area. The

extent to which the development of an aversion to the flavour of a food will interfere with the appetative or approach phase of feeding appears to be different across species. Successfully conditioned animals appear not to waste energy approaching and attacking foods which they cannot eat.

Deer are pests in forests and orchards, killing or seriously damaging douglas-fir seedlings through tip browsing and orchard trees through bark ringing ( Stith 1969 ). Repellent studies have been carried out using a wide range of chemicals and solutions ( Kverno and Hood 1963 ). Investigations of emetics ( Gustavson 1976; Olsen and Lehner 1974 ) have indicated that carnivores are readily capable of vomiting once an effective emetic dose has been ingested. Deer are incapable of vomiting ( they have no duodenal sphincter ) and therefore retain whatever dose is administered to them in experiments and field studies.

Coyotes have long presented the domestic sheep and chicken rancher with serious pest problems, both in losses to predation and difficulties in control ( Cain Report 1972; Pearson 1974; Terrill 1974; McKay 1974; Shelton 1974a; Howard 1974: Early 1974; Bowns 1974; McAdoo 1974; Tigner 1974; Nass 1974; Henne 1974; DeLorenzo 1974, and Howard Jr. 1974.). Lethal and non-lethal control techniques have been investigated ( Linhart 1974; Linhart and Enders 1964; Kennelly 1974; Donick 1974, and; Blaser 1964).



The objectives of this study were:

(1) To establish approximate effective dose levels on captive deer and bears for three potential aversion-conditioning chemicals

( LiCl, ANTU and EHC1 );

(2) To investigate techniques for the field application of effective aversion-conditioning chemicals; specifically:

(i) chemical and bait "packaging"

(ii) baiting techniques in the field to minimize chemical and human scent.

(3) To evaluate the effectiveness of aversion-conditioning techniques in reducing specific food or live prey consumption by free-ranging bears and coyotes.

## A: Tests with Captive Blacktailed Deer

### a) Preference tests for two alternate foods

#### Objectives

Two tests were conducted on captive blacktailed deer in order to establish a preference of food types. Subsequent tests involving potential aversion-conditioning chemicals would be considered successful if these chemicals were capable of altering the animals' initial preference through a learned association between chemically-induced sickness and a previously preferred food.

#### Methods and Materials

A total of seven captive deer, located in Dr, Sadleir's pens at the University of British Columbia Research Forest, were offered a choice of two different food types in two test series. The test series were separated by 3 months. Each test consisted of four trials per animal, and each trial was separated by 2-day intervals. The two bait foods used in all tests were:

- 1) Red Delicious apples, sectioned into fours, and;
- 2) Buckerfield's No. 16 Full-Flow Dairy pellets.

These pellets were the deers' normal food. Apples were offered to each deer for 5 days prior to each test series in order to decrease the possibility of a preference for apples solely due to the presentation of a novel stimulus. Preference for a food was defined as an immediate selection of one of the two baits offered, followed by feeding for a minimum of 2 sec.. The two foods were offered in red or green plastic pans ( Plate II-I ). Baits were presented in alternating colour pans and in alternating positions ( Table II-I ). Both preference and time to make the decision were noted. Deer were deprived of food for varying periods prior to each trial ( Table II-I ).

## Results

Results of preference tests are summarized in Table II-I. Test 1 indicated a preference for apples by all deer except deer number 5. He was removed from experiments with LiCl because I did not wish to condition him away from his normal food. Results from Test 2, 3 months later, indicated that deer number 5 preferred apples, and he was used in that series of experiments. Colour and position of plastic pans had no observable effect on each animals' choice in either Test 1 or Test 2. Visual evaluation of offered baits appeared to be the major factor in each animal's initial decision; decision times

of greater than 1 sec were usually followed by olfactory investigation of the alternate food bait, and then a return to the preferred type. Deprivation of food prior to tests had no apparent effects, however deer number 4, Test 1, Trials 1, 3 and 4, took slightly longer to make a choice. He had not been deprived of food at all prior to the trials.

#### b) Effects of LiCl, EHC1 and ANTU as conditioning chemicals

##### Objectives

Tests with potential aversion conditioning chemicals were conducted at varying dose levels to determine the ability of each chemical to produce a learned aversion relative to a specific food type. Preferred foods, as determined in a) above, were used as the baits. Success of a chemical would be indicated by rejection of the previously preferred food following treatment with the test chemicals.

##### Methods and Materials

Three tests were carried out in the following sequence:

Test 1: ( Deer no.s: 1, 2, 3 and 4 )

NaCl - 1 trial

LiCl - 5 trials

Plate II-I

Preference Test Apparatus for Blacktailed Deer

Alternate food choices (apples and pellets) offered to test deer.

51b.



Table II-I

## Captive Blacktailed Deer Preference Test: Untreated Apples vs Feed Pellets

A = apples      P = pellets

Trial positions (both test series):

|             | Food  | Tray  | Position |
|-------------|-------|-------|----------|
| Trial No. 1 | apple | green | left     |
| 2           | apple | red   | right    |
| 3           | apple | red   | left     |
| 4           | apple | green | right    |

## Test 1

| Deer Number | Trial number and<br>decision time (sec) |   |   |   | Choice |
|-------------|---|---|---|---|--------|
|             | 1                                       | 2 | 3 | 4 |        |
| 1           | 1                                       | 1 | 1 | 1 | A      |
| 2           | 1                                       | 1 | 1 | 2 | A      |
| 3           | 1                                       | 1 | 1 | 1 | A      |
| 4           | 2                                       | 1 | 3 | 2 | A      |
| 5           | 1                                       | 1 | 2 | 3 | P      |

Deer No.'s 1,3 and 5: deprived of food for 18 hr before test

2 : deprived of food for 6 hr before test

4 : deprived of food for 0 hr before test

## Test 2

|   |   |   |   |   |   |
|---|---|---|---|---|---|
| 3 | 1 | 1 | 1 | 1 | A |
| 5 | 1 | 1 | 1 | 1 | A |
| 6 | 1 | 1 | 2 | 2 | A |
| 7 | 1 | 1 | 2 | 1 | A |

All animals deprived of food for 18 hr before tests

Test 2: ( Deer no.s: 3, 5, 6 and 7 )

3 weeks after the end of Test 1

EHC1 - 6 trials

Test 3 ( Deer no.s: 3, 5, 6 and 7 )

2 weeks after the end of Test 2

ANTU - 5 trials

Baits consisted of quartered apple sections carrying gelatine capsules. Gelatine capsule controls were carried out prior to each test series; empty capsules were placed in sectioned apples and were allowed to soften for 10 min before being offered to the deer. Treated baits consisted of apple quarters carrying filled gelatine capsules. Sufficient numbers of capsules were used to carry each test dose. Deer were offered untreated apples at 2h and 72h intervals after receiving treated baits and their acceptance or rejection of these apples was noted.

i) LiCl tests

Deer no.s 1, 2, 3, and 4 were involved in this experiment. All animals were initially offered apple baits treated with NaCl at a dose level of 25 mg/kg as a "salt" control, approximating the salty taste of LiCl. Two g of LiCl were lightly compressed



into a single No. 00 gelatine capsule on a small hydraulic press. Normal capacity of this capsule was approximately 1 g. Capsule numbers per trial varied from 1 capsule ( .52g; Deer 1, 10 mg/kg ) to 5 capsules ( 9.5 g compressed, Deer 3, 160 mg/kg ). Sufficient apple quarters were used to accomplish this.

ii) EHC1 tests

Deer no.s 3, 5, 6 and 7 were used in this experiment. No control was employed. Uncompressed loads of EHC1 in No. 5 gelatine capsules weighed 110 mg. No compressed loads were used in this test. Capsule numbers per trial varied from 1 capsule ( 3.4 mg, Deer 6, .1 mg/kg ) to 6 capsules ( 590 mg, Deer 3, 10 mg/kg ). More than one capsule per apple quarter was used to reduce the numbers of apples required per trial.

iii) ANTU tests

Deer no.s 3, 5, 6 and 7 were used in this experiment. No control was employed. Uncompressed loads of ANTU in No. 5 gelatine capsules weighed 100 mg. No compressed loads were used in this test. Capsule numbers per trial ranged from 1 capsule ( 3.4 mg, Deer 6, .1 mg/kg ) to 22 capsules ( 2.36 g, Deer 3, 40 mg/kg ). More than one capsule per apple

was used to reduce the numbers of apple sections per trial.

## Results

Trial deer ate all the empty capsules ( gelatine control ) without hesitation, indicating that softened gelatine capsules did not act as repellents or as stimuli for capsule or apple rejection. Capsules were not used in the same numbers as chemical-containing capsules were.

### i) LiCl tests

Table II-II summarizes the results of NaCl and LiCl tests. NaCl baits ( 25 mg/kg ) were readily accepted by all test animals, and no indication of a repellent effect was visible at the test dose level. No apparent aversion conditioning appears to have occurred after treatment with LiCl. Capsule rejection appears to have occurred after the third trial, and was characterized ( as were all other capsule rejections ) by an observable taste reaction and by spitting out of the capsule. The taste reaction included a "grimace", and atypical open-mouthed chewing and excess salivation. In these instances, the test animal rid its mouth of the capsule, its contents and often parts of the apple. The three 40 mg/kg compressed loads ( Deer no. 2 ) were chewed and rejected whole, as they were apparently too hard for the animal to crush with his teeth. All

animals in post-treatment trials ( at 2h and 72 h ) readily accepted untreated apples.

ii) EHCl tests

Table II-III summarizes the results of EHCl tests.

Indications of a conditioned response to untreated apples may be seen in the inconsistent rejection of untreated apples 2 h or 72 h after treatment ( Deer 6, 4 and 10 mg/kg; Deer 7, 10 mg/kg ). No taste reaction, as was observed in tests with LiCl, was observed with EHCl. In trials at 4 and 10 mg/kg, as noted in Table II-III, animals were observed to reject the gelatine capsules even though the capsule size in this experiment was considerably smaller than those used in LiCl tests.

iii) ANTU tests

Table II-IV summarizes the results of ANTU tests. Animal No, 7 may have indicated a degree of conditioned aversion, since he rejected untreated apples 2 h after a 20 mg/kg dose, and again 72 h after a 40 mg/kg dose. All other animals rejected bait capsules on third or fourth trials. No observable taste reaction was seen. Possible toxic side effects ( Richter 1945 ) at doses higher than 40 mg/kg prevented further studies.

Table II-II

## Dose Levels and Acceptance of LiCl-treated baits by Captive Blacktailed Deer

T = treated, U = untreated, A = accept, R = reject, Ar = accept but reject capsule

| Deer No. & Weight: | 1       | 2       | 3       | 4       |
|--------------------|---------|---------|---------|---------|
|                    | 52.0 kg | 53.0 kg | 59.1 kg | 58.7 kg |

Gelatine Control (4 No.00 capsules; 1 per quartered apple section)

|         |   |   |   |   |
|---------|---|---|---|---|
| T (0 h) | A | A | A | A |
|---------|---|---|---|---|

Dose: 25 mg/kg NaCl (salt control)

|                    |   |   |   |   |
|--------------------|---|---|---|---|
| Treatment: T (0 h) | A | A | A | A |
|--------------------|---|---|---|---|

|         |   |   |   |   |
|---------|---|---|---|---|
| U (2 h) | A | A | A | A |
|---------|---|---|---|---|

|          |          |  |  |  |
|----------|----------|--|--|--|
| U (72 h) | not done |  |  |  |
|----------|----------|--|--|--|

10 mg/kg LiCl (+ 96 h)

|         |   |   |   |   |
|---------|---|---|---|---|
| T (0 h) | A | A | A | A |
|---------|---|---|---|---|

|         |   |   |   |   |
|---------|---|---|---|---|
| U (2 h) | A | A | A | A |
|---------|---|---|---|---|

|          |   |   |   |   |
|----------|---|---|---|---|
| U (72 h) | A | A | A | A |
|----------|---|---|---|---|

20 mg/kg LiCl

|         |   |   |   |   |
|---------|---|---|---|---|
| T (0 h) | A | A | A | A |
|---------|---|---|---|---|

|         |   |   |   |   |
|---------|---|---|---|---|
| U (2 h) | A | A | A | A |
|---------|---|---|---|---|

|          |   |   |   |   |
|----------|---|---|---|---|
| U (72 h) | A | A | A | A |
|----------|---|---|---|---|

40 mg/kg LiCl

|         |   |             |   |   |
|---------|---|-------------|---|---|
| T (0 h) | A | Ar(comprsd) | A | A |
|---------|---|-------------|---|---|

|         |   |   |   |   |
|---------|---|---|---|---|
| U (2 h) | A | A | A | A |
|---------|---|---|---|---|

|          |   |   |   |   |
|----------|---|---|---|---|
| u (72 h) | A | A | A | A |
|----------|---|---|---|---|

80 mg/kg LiCl

|         |    |             |    |    |
|---------|----|-------------|----|----|
| T (0 h) | Ar | Ar(comprsd) | Ar | Ar |
|---------|----|-------------|----|----|

|         |   |   |   |   |
|---------|---|---|---|---|
| U (2 h) | A | A | A | A |
|---------|---|---|---|---|

|          |   |   |   |   |
|----------|---|---|---|---|
| U (72 h) | A | A | A | A |
|----------|---|---|---|---|

160 mg/kg LiCl

|         |    |             |    |    |
|---------|----|-------------|----|----|
| T (0 h) | Ar | Ar(comprsd) | Ar | Ar |
|---------|----|-------------|----|----|

|         |   |   |   |   |
|---------|---|---|---|---|
| U (2 h) | A | A | A | A |
|---------|---|---|---|---|

|          |   |   |   |   |
|----------|---|---|---|---|
| U (72 h) | A | A | A | A |
|----------|---|---|---|---|

00 gelatine capsules held up to 1 gram of uncompressed LiCl.

Compressed loads ("comprsd" above) held 2 grams of LiCl.

Table II-III

## Dose Levels and Acceptance of EHC1-treated Baits by Captive Blacktailed Deer

T = treated, U = untreated, A = accept R = reject, Ar = accept but reject capsule

|                    |         |         |         |         |
|--------------------|---------|---------|---------|---------|
| Deer No. & Weight: | 3       | 5       | 6       | 7       |
|                    | 59.0 kg | 37.7 kg | 34.0 kg | 57.7 kg |

## Gelatine Control (4 No.5 capsules; 1 per quartered apple section)

|         |   |   |   |   |
|---------|---|---|---|---|
| T (0 h) | A | A | A | A |
|---------|---|---|---|---|

## Dose: 0.1 mg/kg EHC1

|                    |   |   |   |   |
|--------------------|---|---|---|---|
| Treatment: T (0 h) | A | A | A | A |
| U (2 h)            | A | A | A | A |
| U (72 h)           | A | A | A | A |

## 0.5 mg/kg EHC1

|         |   |   |   |   |
|---------|---|---|---|---|
| T (0 h) | A | A | A | A |
| U (2 h) | A | A | A | A |
| U 72 h) | A | A | A | A |

## 1.0 mg/kg EHC1

|          |   |   |   |   |
|----------|---|---|---|---|
| T (0 h)  | A | A | A | A |
| U (2 h)  | A | A | A | A |
| U (72 h) | A | A | A | A |

## 2.0 mg/kg EHC1

|          |   |   |   |   |
|----------|---|---|---|---|
| T (0 h)  | A | A | A | A |
| U (2 h)  | A | A | A | A |
| U (72 h) | A | A | A | A |

## 4.0 mg/kg EHC1

|          |    |   |    |   |
|----------|----|---|----|---|
| T (0 h)  | Ar | A | Ar | A |
| U (2 h)  | A  | A | A  | A |
| U (72 h) | A  | A | R  | A |

## 10.0 mg/kg EHC1

|          |    |    |   |    |
|----------|----|----|---|----|
| T (0 h ) | Ar | Ar | R | Ar |
| U (2 h)  | A  | A  | A | R  |
| U (72 h) | A  | A  | R | A  |

All loads in No.5 gelatine capsules, uncompressed.

Table II-IV

## Dose Levels and Acceptance of ANTU-treated Baits by Captive Blacktailed deer

T = treated, U = untreated, A = accept, R = reject, Ar = accept but reject capsule

|                    |         |         |         |         |
|--------------------|---------|---------|---------|---------|
| Deer No. & Weight: | 3       | 5       | 6       | 7       |
|                    | 59.0 kg | 37.7 kg | 34.0 kg | 57.7 kg |

Gelatine Control (4 No.5 capsules; 1 per quartered apple section)

|         |   |   |   |   |
|---------|---|---|---|---|
| T (0 h) | A | A | A | A |
|---------|---|---|---|---|

Dose: 0.1 mg/kg ANTU

|                    |   |   |   |   |
|--------------------|---|---|---|---|
| Treatment: T (0 h) | A | A | A | A |
| U (2 h)            | A | A | A | A |
| U (72 h)           | A | A | A | A |

1.0 mg/kg ANTU

|          |   |   |   |   |
|----------|---|---|---|---|
| T (0 h)  | A | A | A | A |
| U (2 h)  | A | A | A | A |
| U (72 h) | A | A | A | A |

10.0 mg/kg ANTU

|          |   |   |    |   |
|----------|---|---|----|---|
| T (0 h)  | A | A | Ar | A |
| U (2 h)  | A | A | R  | A |
| U (72 h) | A | A | A  | A |

20.0 mg/kg ANTU

|          |    |    |    |   |
|----------|----|----|----|---|
| T (0 h)  | Ar | Ar | Ar | A |
| U (2 h)  | A  | A  | A  | A |
| U (72 h) | A  | A  | A  | R |

40.0 mg/kg ANTU

|          |    |    |    |    |
|----------|----|----|----|----|
| T (0 h)  | Ar | Ar | Ar | Ar |
| U (2 h)  | A  | A  | A  | A  |
| U (72 h) | A  | A  | A  | A  |

All loads in No.5 gelatine capsules; no compressed loads.

The practical application of the technique would be in a situation involving a preferred food. Controls with more empty gelatine capsules should have been carried out; large numbers of capsules were required in experiments and this alone may have had a repellent effect.

A successful chemical for repelling deer would have to have a low specific dose, an undetectable taste to deer, and a fast mode of action in order to be effective.

#### Discussion

The results from preference tests indicated that test deer shared a strong preference for apples. Altering this preference in favour of regular food proved successful in only three instances ( Table II-IV; Deer 6 & 7: @ 4 and 10 mg/kg EHC1 ). Deer proved capable of selectively removing undesirable capsules in treated apples. Previous trials with the same chemicals at lower doses may have led to this behaviour, since gelatine controls were accepted. A taste or other unpleasant factor associated with the actual chewing of treated apples may have been the reason for rejection on subsequent trials. In addition, all deer used in these experiments had previous exposure to apples, both from my pre-experiment feeding and from occasional handouts from other people working with these deer. Thus, I was not working with a novel bait food. A less attractive bait ( and presumably one more easily rejected by these deer ) would not have tested the technique as accurately.

## B; Tests with Free-Ranging Coyotes

### a) Chemical Treatment of Coyote-killed Sheep Carcasses

#### Objectives

Coyote-killed sheep carcasses were treated with LiCl and ANTU to determine: 1) reductions, if any, in the consumption of carcasses, and; 2) the effectiveness and acceptability of bait packaging methods under field conditions.

#### Methods and Materials

A flock of 25 - 30 sheep, located at the Chilancoh Ranch on the Chilcotin Plateau in central British Columbia occupied a 2 ha. pasture. Parts of the pasture were observed from a nearby hillside, and were checked in the early morning and in the evening for freshly killed sheep carcasses. Areas around new kills were investigated for tracks, hair or droppings from predators. Live sheep were herded into a shed each night by the rancher.

Seven carcasses were studied in this experiment. Three animals ( a ewe and two lambs ) were used as controls, and four animals ( two ewes and two lambs ) were treated with LiCl or ANTU ( see Table II-V ). All carcasses were approached on



foot because the presence of man in the pasture apparently did not deter coyotes from frequenting the area. The experiment was carried out over a three week period. All seven sheep were killed in the first 10 days of the study.

Fifteen g doses of LiCl in powder form, and 1 g doses of ANTU in No. 00 gelatine capsules, were applied to shoulder incisions made in carcasses. Handled controls received the same shoulder incisions but remained untreated with either LiCl or ANTU. One control was completely untouched. Consumption of carcasses was determined visually by approaching to within approximately 4 - 5 m of the carcass. This inspection was carried out twice daily and the time for the predators to completely consume the carcass was noted. Carcasses were observed for a total of 10 days.

Information on the mean period of consumption for a carcass was obtained from this study and from other ranchers in the area. Four ranchers in the Alexis Creek area supplied information on predation and carcass consumption based on their combined observations in the field for many years. This data was not collected in the strictest scientific manner ( no calculated average, mean or s.d. ) but nevertheless represented observations of thousands of kills. In addition, the Predator Committee of the British Columbia Cattlemen's Association supplied similar information based on predation events from the entire province. These data indicated that the average time for complete consumption of a mature sheep was 2.5 days. Lambs at the time of this study

weighed approximately one-half of the weight of adults, so the times-to-consume juveniles in this experiment were doubled for comparison with consumption times of adults.

## Results

Table II-V summarizes the results of this experiment. Handling of two carcasses ( kills 1 and 3 ) increased consumption times over known times by 30 percent. The mean increase in consumption times ( corrected for the control increase ) was 190 percent. Coyotes were seen in and around the pasture area after the experiment however they were not observed feeding on treated carcasses. Presence of tracks in the pasture, and observations which I made from the nearby hillside indicated a coyote pack size of 4 - 8 animals. Shoulder baiting appeared to be readily accepted by free-ranging coyotes. All carcasses prepared in this manner ( numbers 4 - 7 ) showed little or no consumption of other body areas in the first day of feeding by coyotes. Capsules of ANTU were apparently consumed completely and bait areas covered with LiCl were completely consumed.

The Effects of LiCl and ANTU on the Rate of Consumption of  
Coyote-killed Sheep Carcasses

Kills occurred in the sequence given

| Animal & Chemical<br>(Dose) | Status                  | Days to Consume<br>(% increase)            | % Increase<br>over controls |
|-----------------------------|-------------------------|--|-----------------------------|
| Kill No.1 lamb              | control<br>(handled)    | 3.0 (corrected) <sup>1</sup><br><u>20%</u> |                             |
| 2 lamb                      | control<br>(untouched)  | 2.5 (corrected)<br><u>0</u>                |                             |
| 3 ewe                       | control<br>(handled)    | 3.5<br><u>40%</u>                          |                             |
| 4 ewe<br>(LiCl=15 g)        | experiment              | 6.5<br><u>160%</u>                         | 130.0 <sup>3</sup>          |
| 5 ewe<br>(ANTU=1 g)         | experiment <sup>2</sup> | 10.0<br><u>300%</u>                        | 270.0                       |
| 6 lamb<br>(LiCl=15 g)       | experiment              | 7.5 (corrected)<br><u>200%</u>             | 170.0                       |
| 7 lamb<br>(ANTU=1 g)        | experiment              | 8.0 (corrected)<br><u>220%</u>             | 190.0                       |

1) Corrected Days to Consume: lamb weights were approximately .5 of adult weight, therefore times were doubled

2.5 days = the average time to consume (from ranchers' data)

2) Animal removed at Day 10; no consumption

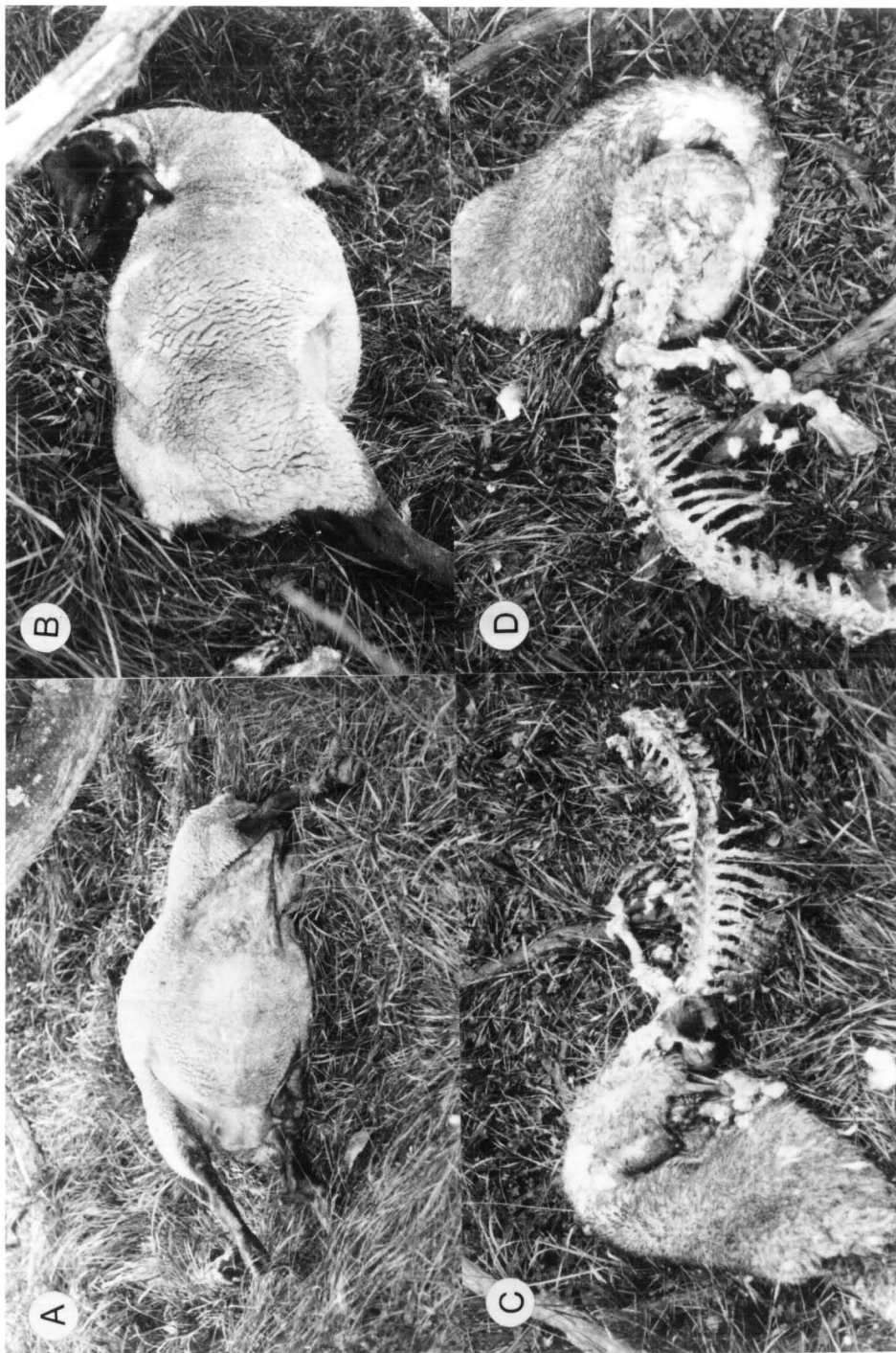
3) 30% of the apparent increase was subtracted to compensate for the controls.

Mean % Increase in days to consume: 190% ± 58.9%.

Plate II-II

Field Condition of Coyote-Killed Sheep Carcass

Plate II-II indicates the general field condition of sheep carcasses. (A) is kill number 5, which was removed after 10 days for sanitary reasons. This carcass was untouched except for removal of the treated, prepared bait area on the left shoulder. This viscera had not been touched. (B) is kill number 3; a handled but untreated carcass which was reduced to (C) and finally (D) in 3.5 days.



b) Chemical Treatment of Mutton Baits and Placement of  
Baits Around a Sheep Pasture.

Objectives

Baits treated with LiCl or EHC1 were placed around a sheep pasture in order to determine: 1) bait acceptability by coyotes, and ; 2) reduction in predation on live sheep by coyotes following their consumption of the treated baits.

Methods and Materials

This experiment began one week after the previous carcass baiting experiment had been terminated. The rancher left his sheep out overnight for five days prior to this experiment in order to confirm pre-experiment predation rates and to establish an attraction for the coyote pack living in the area. Predation rates for this five day period were noted, and data from the British Columbia Cattlemen's Association allowed me to establish a baseline predation rate for the sheep in the experiment ( 3 kills in 5 days ). Coyotes in the area had been previously exposed to LiCl and ANTU treated carcasses, and this was expected to alter the predation rate which I might observe in the pre-experiment control period.

Baits were made up from mutton strips consisting of muscle tissue, fat tissue and a covering of wool-hide. This resulted in a bait of approximately 250 g with a size of approximately 10 X 10 X 5 cm. Either 15 g of LiCl or 120 mg of EHC1 ( in both cases, approximately twice the probable effective dose for a 15 kg coyote ) were incorporated into the strip, which was rolled and tied with string. Baits were frozen prior to placement to reduce deterioration.

Baits were placed by the rancher along trails within the pasture in areas where tracks and droppings indicated probable coyote activity. The bait was lightly covered, either with soil or leaves, allowing odors to escape, but possibly reducing visual detection by crows ( Corvus brachyrhynchos, Linnaeus ), ravens ( C. corax, Linnaeus ) or magpies ( P. pica ), typical scavenging birds seen in the area. One of these bait stations, visible from the ranch house and nearby hillside, was observed for indications of bait removal by these birds.

Baits were examined twice daily, early in the morning and again late in the evening. Sheep kills were recorded for 14 days after the baits were placed. The experimental kill rate was then compared to information on normal predation rates, as supplied by local ranchers and the Cattlemen's Association. Observations and records of predation for the last 18 days of this experiment were carried out by the rancher and his sons according to my specific instructions.

## Results

Results of this experiment are summarized in Table II-VI. The baits were apparently investigated ( tracks near bait stations ) on the first night after placement, and all were taken after five days. After a kill on the 20th day, the rancher terminated the experiment by returning his sheep to their shed in the evenings. Although I underwrote his losses during the experiment, he was apparently not prepared to risk losses after the experiment in the event that the techniques under test proved to have some detrimental effect.

## Discussion

Initial reports of predation on sheep appear to be exaggerated by ranchers. Losses experienced during the experimental period at this ranch, including data gathered after I left, suggest a lower rate of predation than expected. The rather low number of kills precludes a definitive statement on the efficiency of the technique. Increases in the time for a predator to consume a carcass ( Table II-V ) were based on inadequate experimental numbers and as such only allow speculation as to the cause of the observed increases. Increases in



Table II-VI

The Effects of LiCl- and EHCl-treated Baits on the Rate of  
Sheep-killing by Coyotes

8 bait stations: 1 bait per station

4 baits LiCl: 15 g

4 baits E HCl: 120 mg

| Day No.        |                        | No.'s of sheep killed |
|----------------|------------------------|-----------------------|
| 1              |                        | 0                     |
| 2              |                        | 0                     |
| 3              |                        | 1 (PM) adult          |
| 4              |                        | 0                     |
| 5              | 8 baits placed (PM)    | 1 (PM)                |
| 6 <sup>1</sup> | 1 bait taken           | 0                     |
| 7              | 2 baits taken          | 0                     |
| 8              | 4 baits taken          | 0                     |
| 9              |                        | 0                     |
| 10             | 1 bait taken           | 0                     |
| 11-17          |                        | 0                     |
| 18             |                        | 0                     |
| 19             |                        | 1 (PM) adult          |
| 20             | sheep returned to shed | 0                     |

% reduction over 15 day period: 78% decrease over known predation rates.

<sup>1</sup>Author left on day 6; data from this point collected by rancher.

: bait placement by rancher.

consumption times of handled controls as compared to untouched controls was large. LiCl, ANTU and EHC1 may possess repellent qualities not associated with ingestion; odor and taste may be detectable by coyotes. Baited areas were, however, consumed first in all observed cases. The control period of five days was insufficient to establish an accurate pre-treatment predation rate relative to this ranch; a longer control period may have affected the results in either direction.

A 78 percent reduction in predation in relation to baseline information from the Cattlemen's Association ( Table II-IV ) compares to an observed 91 percent decrease demonstrated in Jowsey's longterm study in Saskatchewan ( Jowsey; Gustavson 1971, personal comm.). This reduction may have been due to migration of predators out of the area, however animals were observed in and around the pasture area during the experiment. The previous experiment using baited carcasses must have had some effect on the predation rate observed in this experiment; treated carcasses were effectively treated mutton baits in and around the pasture. Discussions with ranchers in the surrounding area indicated that they had not experience any increases in predation on their sheep by coyotes, indicating that the coyotes at the Chilancoh ranch had probably not moved out of the area.

## C; Bear Tests

### a) Tests with Two Captive Black Bears

#### Objectives

Two captive black bears were offered control and test baits to determine if they could be conditioned to later exposures of untreated baits.

#### Methods and Materials

Two male 100 kg black bears at the Olympic Game Farm, near Sequim, Washington State, were kept off their feed for 3 days prior to these experiments. During the tests, the animals were kept in separate sections of a large divided holding cage ( Plate II-III ). The attractant bait consisted of either 250 ml of homogenized honey ( LiCl experiments ) or raw beef ( EHC1 experiments ).

Three trials per bear were done with honey:

- 1) Honey alone
- 2) Honey plus NaCl ( "salt" control )
- 3) Honey plus LiCl ( Bear 1: .3g/kg; Bear 2: .5 g/kg )

The first two trials were separated by a 1 h interval, while the LiCl trial was separated from the NaCl trial by a 5 h interval. Both animals were then offered 100 ml untreated honey baits each afternoon for a period of 10 days after the LiCl

Plate II-III

Test Enclosure for Captive Black Bear Tests, Sequim, Washington

Two bears in 1 cage (left) and 1 smaller enclosure (right).



treatments, and their acceptance or rejection was noted. This was done under varying conditions of starvation ( see Table II-VII for feeding regimes ). The normal diet of these bears consisted of "Bear Bread", a cereal loaf made at the game farm for these animals.

The EHC1 experiments were initiated 10 days after the termination of the LiCl tests. It was necessary to use a different bait for the study of EHC1 because an aversion to honey had been developed following LiCl treatment. Tests were carried out as with honey. EHC1 was used at 2.5 mg/kg ( Bear 1 ), and at 4.0 mg/kg ( Bear 2 ). Evaluation of the bears' acceptance or rejection of untreated raw beef was carried out for a seven day period, once each day, beginning 24 h after the administration of the EHC1 baits. These observations were made by the gamekeeper according to my specific instructions after the first day ( Table II-VIII ). The rejection of an offered food bait was defined as ranging from an observable hesitation and partial consumption to a complete rejection of the bait upon olfactory or visual investigation by the bear.

## Results

Table II-VII summarizes the results of LiCl tests. Both bears were apparently conditioned by LiCl to avoid later offerings of untreated honey. This conditioned response lasted

for the duration of the experiment. Bait investigation and acceptance was immediate during the first day trials. Hesitant acceptance of untreated honey ( Day 7, Bear 2; Day 9, Bear 1 & 2, Day 10, Bear 2 ) may represent the beginning of extinction ( loss ) of the conditioned response, however, 1 month after the EHCl tests were terminated, the gamekeeper, for his own interest, offered both bears untreated honey. Neither animal would accept the baits after investigating them. Both animals were on normal diets at this time, and this may have contributed to the continuing conditioned response.

NaCl apparently caused an increase in the time before a bait was consumed. All baits offered and accepted by both bears after NaCl bait treatment were taken without hesitation ( hesitation in this instance refers to a 5 - 30 sec delay before consumption but after investigation ).

Table II-VIII summarizes the results of EHCl tests. Both bears were apparently conditioned by EHCl to reject later offerings of untreated raw beef; Bear 1 accepted untreated raw beef only after 3 days, and was starved for 1 day prior to his acceptance. Following a resumption of his regular feeding schedule, he again rejected offered baits. Bear 2, treated with 4.0 mg/kg EHCl, did not accept baits even during and after starvation, but took an offered bait on Day 7. The rejection of both untreated honey and untreated beef was consistent up to the time that

Table II-VII

## Effects of LiCl-treated Baits on Two Captive Black Bears

Test 1: LiCl in 250 ml homogenized honey

Both bears: 100 kg weight, both male

In following table: A = accepted and ate bait; R = rejected bait

Bears fed on "Bear Bread" manufactured at Game Farm

| Bait + Dosage                   | Bear 1       | Bear 2     |
|---------------------------------|--------------|------------|
| Untreated honey                 | A rapidly    | A rapidly  |
| Honey + NaCl (300 mg/kg = 30 g) | A hesitate   | A          |
| Honey + LiCl ( " )              | A hesitate   | not tested |
| Honey + LiCl 500 mg/kg          | not tested   | A hesitate |
| Untreated honey: Day 1 feed     | R            | R          |
| 2 feed                          | R (hunching) | R          |
| 3 feed                          | R            | R          |
| 4 feed                          | R            | R          |
| 5 starve                        | R            | R          |
| 6 starve                        | R            | R          |
| 7 starve                        | R            | A hesitate |
| 8 feed                          | R            | R          |
| 9 feed                          | A hesitate   | A hesitate |
| 10 feed                         | R            | A hesitate |

Time to visually apparent onset of discomfort (e.g. "hunched" walking, diarrhoea) for both bears (LiCl-treated baits) - Bear 1, 9 min, Bear 2, 11 min



Table II-VIII

## Effects of EHC1-treated Baits on Two Captive Black Bears

Test 2: EHC1 in raw meat bait

Both bears: 100 kg weight, male.

A = accepted and ate bait (immediately following investigation)

R = rejected bait

| Bait + Dosage                    | Bear 1     | Bear 2     |
|----------------------------------|------------|------------|
| Untreated meat                   | A rapidly  | A rapidly  |
| EHC1 + meat (2.5 mg/kg = 250 mg) | A rapidly  | not tested |
| EHC1 + meat (4.0 mg/kg = 400 mg) | not tested | A rapidly  |
| Untreated meat: Day 1 feed       | R          | R          |
| 2 feed                           | R          | R          |
| 3 starve                         | R          | R          |
| 4 starve                         | A hesitate | R          |
| 5 feed                           | R          | R          |
| 6 feed                           | A          | R          |
| 7 feed                           | A hesitate | A hesitate |

Time to visually apparent onset of nausea after EHC1 treatment

Bear 1 - 15-18 minutes

Bear 2 - 12-15 minutes

baits were hesitantly taken. The bears approached baits and always smelled them. Rejection was immediate, and the animals moved away from the baits. Bear 1 showed symptoms of discomfort after eating untreated honey, by hunching and then lying down in the cage corner furthest from the location of the offered food. "Hunching" refers to a hesitation in walking, followed by a curving and compression of the body with the head down.

b) Tests on Free-ranging Black Bears: Carcass Baiting.

Objectives

Cows killed by black bears were used as controls and experimental baits to determine: 1) reductions in consumption of carcasses following treatment with LiCl and ANTU, and; 2) acceptability of chemical packaging in field situations.

Methods and Materials

Four cows killed by black bears on the Chilcotin Plateau in central British Columbia were used to evaluate the field application of aversion conditioners. The tests involved a comparison between the time taken to eat treated, untreated and control carcasses, measured in days.

A total of three animals were found killed on the range during this experiment. In addition, I had information on a kill which had occurred 1 week before the experiment began. Two cows were used as treated baits, while one yearling was used as a control ( handled but not treated ). LiCl and ANTU were placed into incisions cut into the shoulder of each test carcass. Since the first part of a killed animal appeared, in all instances, to be the viscera, this area was also treated.

Handling of the carcass involved several procedures to minimize the effects of human odor. The carcasses were usually approached on horseback and disposable poly-gloves were used whenever the carcass was touched. Incisions were made with a new scalpel blade, and were recovered with hide after the test chemical had been placed inside. Subsequent inspection of the carcass for signs of consumption or visits from predators was done from horseback, and only once did I approach a kill on foot. At that point, the kill had been completely consumed. The yearling ( kill number 4; handled control ) was handled in an identical manner. The shoulder was skinned off, and incisions were made in the muscle. At this point, however, the hide was pulled over the area, with no placement of chemicals into the shoulder.

Approximately 2.5 g of LiCl were placed into each of four incisions ( total: 100 g ), in Kill 2. An additional 10 g of LiCl was placed in the visceral area of this kill. Kill 3

received approximately 2 g of ANTU in each of four incisions ( total 8 g ). Evaluation of the amount of each carcass consumed was based on a twice-daily check; once early in the morning and again just prior to sundown ( Plate II-IV ).

## Results

Table II-IX summarizes the results of this experiment. Data supplied by four ranchers in the area and from the Cattlemen's Association indicated an average time for complete consumption of a killed cow as 5 days ( as with previous data from this source, no statistical information as to sample size, mean or s.d. were available, however the observations were based on thousands of kills over many years ). The consumption time included time for the original predator as well as the consumption due to secondary scavengers such as coyotes ( C. latrans ) or wolves ( C. lupus ). It was noted by ranchers that these scavengers were generally present after each kill.

The first kill took place two days before my experiment began, and was completely consumed by the end of the third day. Kill 2 was found approximately 6 h after death, and was photographed over a 10 day period ( Plate II-IV ). The shoulder area was the first area to be consumed by the predator after treatment. The visceral cavity had already been consumed when this carcass was found. Tracks in the area ( 19 cm ) indicated that a bear had

been feeding on this carcass.

Secondary scavengers were observed in the area on the fourth evening; coyotes and ravens were observed feeding on the kill. No bear tracks were seen near the kill from day 3 to day 7.

Kill 3 was in a secluded area. It was treated with ANTU, as outlined in Table II-IX. Similar observations as above were made on it, including observation of tracks on day 4. No bear tracks were found near the kill after day 4, and the carcass was consumed or removed by other predators or scavengers by day 11.

Kill 4 was a yearling. I observed a bear at this kill until my presence was discovered. It then ran off. The visceral cavity had been opened but nothing had been eaten yet. This carcass was consumed ( or removed with no trace ) in 2.5 days, despite handling as described in Methods.

#### c) Tests on Free-ranging Black Bears: Dump Sites

##### Objectives

Baits were used as controls and experiments to determine if any reduction in consumption of these baits occurred following ingestion of LiCl, ANTU or EHC1.

##### Methods and Materials

The responses of free-ranging black bears to untreated

Plate II-IV

The carcass of a cow killed by a black bear, Chilcotin Plateau, British Columbia. This kill is number 2, Table II-IX.

- (A) carcass 1 day after treatment
- (B) carcass 4 days after treatment ( note shoulder incision )
- (C) skeleton 9 days after treatment

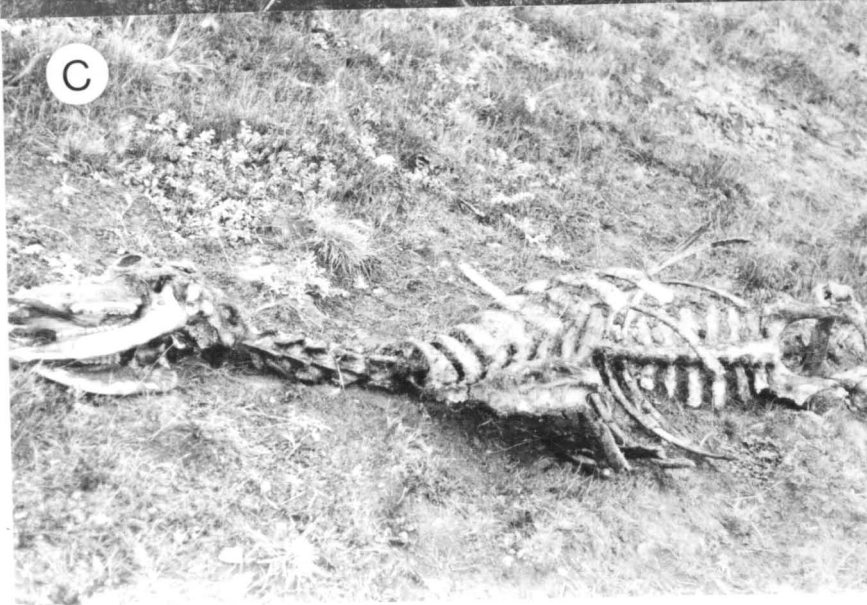


Table II-IX

The Effects of LiCl and ANTU on the Consumption of Cattle  
Carcasses by Black Bears

| Cow + Dosage + Chemical  | Days to Consume <sup>1</sup> | % increase<br>over 5-day average |
|--|------------------------------|----------------------------------|
| Kill 1: ( prior to expt ) Cow<br>( control )                                     | 5                            | 0                                |
| Kill 2: Cow<br>( 4 (25g) LiCl; shoulder incision )<br>10 g LiCl powder on visera | 9                            | 44                               |
| Kill 3: Cow<br>( 4 (2 mg) ANTU, shoulder incision )                              | 11                           | 55                               |
| Kill 4: Yearling<br>( handled control )  | 5 ( adjusted <sup>2</sup> )  | 0                                |

1 = The average time for the complete consumption of a full-grown cow by a black bear and scavengers in approximately 5 days ( Information from Predator Committee, B.C. Cattlemen's Association ).

2 = Assume 2 yearlings ( mean wt = 140 kg ) approximate 1 adult ( mean wt. = 280 kg ).

Mean increase for kills 2 and 3: 49.5%



and treated baits was evaluated in a series of tests at garbage dumps at the following locations:

- Golden, B.C. ( Rocky Mountains )
- Parson, B.C. ( Rocky Mountains )
- Bush River Camp ( Columbia River, Rocky Mountains )
- Roger's Pass dump ( Rocky Mountains )
- Mission dump ( Lower Mainland )

In this experiment, baits made from dog-food patties were placed at bait stations in the above sites in the late morning. For the first 5 days these baits consisted of dog-food patties soaked in sardine oil. The numbers of baits consumed was noted. This was followed by a 2 day treatment of dog-food baits laced with LiCl, EHC1 or ANTU, Chemicals were applied in powder form in all cases, between two patties. The patties were then tied with string. Following a 1 day wait after treatment, untreated patties soaked in sardine oil were placed at the same bait stations, and the numbers of baits consumed over 5 days was noted. At the Mission dump, the baits were observed for alternate days for an additional 10 days. No compensation was made for bait removal by scavengers as they were present in both experimental and control baiting periods. Differences in percent consumption were noted for each dump site. Chemical doses were calculated on a bear weight of 100 kg.

## Results

Table II-X summarizes the results of this experiment.

ANTU-treated baits showed the greatest percent reduction in consumption, versus EHC1 ( 61.7 % vs 36.2% ). Variability was greatest in ANTU, while LiCl was almost as effective, with a much lower variability. Only one bait station was treated with EHC1 ( Roger's Pass dump ). 100 percent consumption of untreated baits ( pre-treatment ) tended to underrate the percent reduction in consumption after treatment, since it was not possible to determine just how much more of the pre-treatment baits an individual bear might have taken. During the 15 day test period at the Mission dump, the bears found new baits quickly and consumed them before scavengers found them.

#### d) Tests on Free-ranging Polar Bears; Dump Sites

##### Objectives

Baits were used as controls and experiments to determine the reduction in consumption of these baits following treatment with LiCl, ANTU or EHC1.

##### Methods and Materials

The response of wild polar bears to untreated and treated dog-food patties was evaluated at Churchill, Manitoba at the following locations:

The Effects of LiCl, ANTU and EHC1-treated Baits on Bait Consumption by Black Bears at Five British Columbia Dumps

Doses administered:

LiCl (200 mg/kg) = 20g, ANTU (25 mg/kg) = 2.5 g, EHC1 (3.0 mg/kg) = 300 mg

| Location<br>and<br>Chemical used           | No. of<br>bait<br>stations | No. of<br>baits<br>per station | Mean %consumption     |                    |                      |
|--|----------------------------|--------------------------------|-----------------------|--------------------|----------------------|
|  |                            |                                | Untreated:<br>5 days  | Treated:<br>2 days | Untreated:<br>5 days |
| Golden (LiCl)                              | 5                          | 2                              | 85                    | 80                 | 42                   |
| Parson (ANTU)                              | 6                          | 2                              | 96                    | 92                 | 21                   |
| Bush River Camp<br>(LiCl)                  | 4                          | 2                              | 100                   | 88                 | 63                   |
| Roger's Pass<br>(EHC1)                     | 4                          | 2                              | 69                    | 56                 | 44                   |
| Mission (ANTU)                             | 6                          | 2                              | 100                   | 100                | 54*                  |
| LiCl mean percent consumption              |                            |                                | 92.5 ± 10.61 ( s.d. ) |                    | 52.5 ± 14.85         |
| LiCl mean percent reduction in consumption |                            |                                |                       |                    | 43.2                 |
| ANTU mean percent consumption              |                            |                                | 98.0 ± 2.83           |                    | 37.5 ± 23.3          |
| ANTU mean percent reduction in consumption |                            |                                |                       |                    | 61.7                 |
| EHC1 percent reduction in consumption      |                            |                                |                       |                    | 36.2                 |

$\chi^2$  test on expected vs observed differences in numbers of baits consumed:

LiCl: 3.97; p: 0.10; ANTU: 12.97; p: 0.005; EHC1: 2.21; p: 0.30

\* Observations for 15 days.

Churchill main dump

Churchill incinerator

Surrounding areas

These experiments duplicated the design of the black bear tests with two exceptions; (i) the baits were observed continuously during the day in two instances, for any observable effects of the test chemicals on the bear, and; (ii) the baits were observed and checked for indications of bait removal by ravens and arctic foxes ( Alopex lagopus, Linnaeus ). Scavengers were discouraged from eating the baits by covering them with snow or paper. Doses were based on a bear weight of 250 kg. The percent reduction in bait consumption was noted.

#### Results

LiCl showed the greatest percent reduction in consumption, while EHC1 produced the least reduction ( Table II-XI ). In four instances, 100 percent consumption of pre-treatment baits may have resulted in underrated reductions since it was impossible to determine how much the bear might have consumed if given the chance. Plate II-V (A) shows a bear eating a paper-covered bait near the incinerator. (B) and (C) show a bear eating a bait and subsequently vomiting ( EHC1 ).

Plate II-V

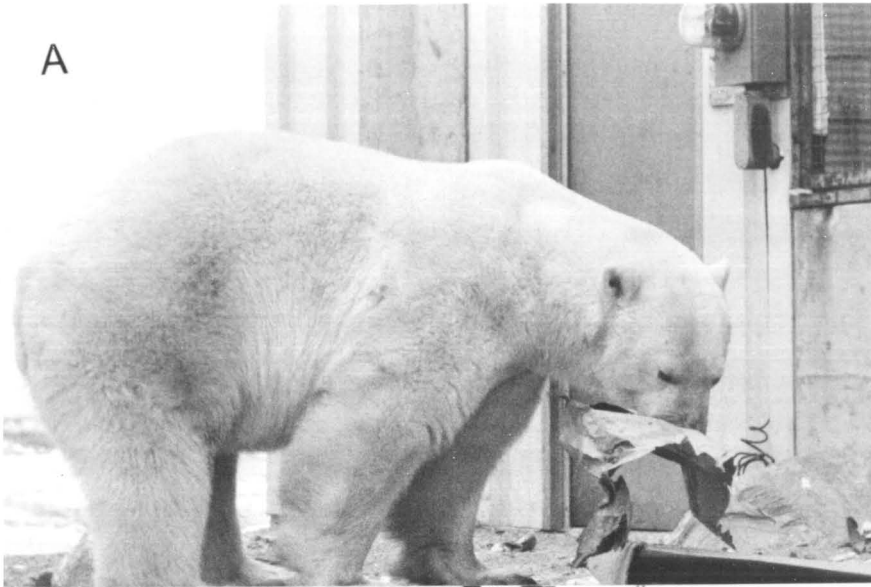
Wild Polar Bears, Eating Treated Baits at Churchill, Manitoba

A: Bear eating a paper-covered bait

B: Bear eating a treated bait and;

C: vomiting approximately 6 minutes later

A



B



C



The Effects of LiCl, ANTU and EHC1-treated Baits on the Rate of  
Bait Consumption by Polar Bears at Churchill, Manitoba

Dose administered:

LiCl (100 mg/kg) = .25 g, ANTU (25 mg/kg) = 6.3 g, EHC1 (3.0 mg/kg) = 750 mg

| Location<br>and<br>Chemical used              | No. of<br>bait<br>stations | No. of<br>baits<br>per station | Mean %consumption    |                    |                      |
|---|----------------------------|--------------------------------|----------------------|--------------------|----------------------|
|   |                            |                                | Untreated:<br>5 days | Treated:<br>2 days | Untreated:<br>5 days |
| Site 1 Dump <sup>1</sup><br>(LiCl 25 g)       | 6                          | 6                              | 100                  | 78                 | 20                   |
| Site 2 Dump<br>(LiCl 25 g)                    | 5                          | 6                              | 90                   | 75                 | 30                   |
| Site 3 Incinerator<br>(LiCl 25 g)             | 4                          | 6                              | 85                   | 65                 | 25                   |
| Site 4 Incinerator <sup>2</sup><br>(EHC1 5 g) | 6                          | 2                              | 75                   | 80                 | 60                   |
| Site 5 Rocket range<br>(EHC1 5 g)             | 5                          | 2                              | 100                  | 100                | 45                   |
| Site 6 Rocket range<br>(EHC1 5 g)             | 5                          | 2                              | 100                  | 98                 | 35                   |
| Site 7 Incinerator <sup>1</sup><br>(ANTU 6 g) | 6                          | 2                              | 85                   | 90                 | 40                   |
| Site 8 Dump<br>(ANTU 6 g)                     | 4                          | 2                              | 100                  | 95                 | 35                   |
| Site 9 Dump<br>(ANTU 6 g)                     | 5                          | 2                              | 75                   | 60                 | 22                   |
| LiCl mean percent consumption                 |                            |                                | 91.67±7.64 ( s.d. )  |                    | 25.0±5.0             |
| LiCl mean percent reduction in consumption    |                            |                                |                      | 72.7%              |                      |
| EHC1 mean percent consumption                 |                            |                                | 91.67±14.43          |                    | 46.7±12.6            |
| EHC1 mean percent reduction in consumption    |                            |                                |                      | 49%                |                      |
| ANTU mean percent consumption                 |                            |                                | 86.7±12.6            |                    | 32.3±9.3             |
| ANTU mean percent reduction in consumption    |                            |                                |                      | 62.7%              |                      |

<sup>1</sup>Hunching observed

<sup>2</sup>Vomiting observed

$\chi^2$  : LiCl: 55.23; EHC1: 9.33; ANTU: 14.85; all sign. @ p: 0.01

ANTU- and LiCl-treated bears did not appear to vomit, however both of these chemicals appeared to have an effect on the polar bears similar to that observed with black bears ( hunching and rolling on the ground; leaving the area ).

Secondary scavengers were not observed near bait stations, either during direct observation during the day, or by tracks or other sign. Once the dog-food patties became frozen, they probably were too hard and heavy for ravens or other scavengers to remove.

An unquantified observation was that the numbers of bears apparent at the baiting sites seemed to decrease over the last 7 to 8 days of the test period. This may indicate migration of bears away from the area, however, the bears were observed in locations surrounding the sump. This may indicate a degree of location avoidance associated with the bait avoidance. This will be evaluated in future experiments.

#### Discussion

Aversion-inducing dose levels of LiCl and EHC1 on black bears were established in captive animal trials ( Table II-VII, II-VIII ). No duration of aversion or extinction curve was determined. While the use of only two animals precludes a definitive statement on an exact 50- or 100-percent effective



dose (  $ED_{50}$  or  $ED_{100}$  ) for the species, the emetic properties of all three drugs in near lethal doses would serve to protect the animal from ingesting a lethal dose. Test animals at the Olympic Game Farm were not available for long-term tests. Aversion conditioning specifically reduced bait consumption by free-ranging polar and black bears ( Tables II-X, II-XI ). Human odor was not a factor in this reduction, since pre-treatment baits were handled in the same manner as treated baits. Early migration of the polar bears out of Churchill prevented the establishment of an extinction curve. Unfortunately, the control baits were not duplicates of later experimental baits; the experimental baits consisted of two patties, tied with string, while the control baits consisted of one or two patties stacked but not tied with string. The bait material and soaking with oil was, however, identical, and no hesitation in eating the tied baits was ever observed.

Location avoidance ( Rozin and Kalat 1971 ) may have been occurring at Churchill but was not quantified. Polar bears were seen near the dump and incinerator, however they did not approach these sites in the expected numbers after exposure to treated baits. This phenomenon has also been casually observed by Gustavson ( 1977, pers. comm. ) in his studies with coyotes and LiCl.

A study of aversion extinction and location avoidance would require observation and assessment for a period of two to three months, difficult indeed for studies on large,

free-ranging carnivores. Extinction of an aversive response may have been occurring at the Olympic Game Farm. Both test animals accepted untreated baits after a few days ( Tables II-VII, II-VIII). Feeding no doubt contributed to this acceptance. Early extinction indicates that initial discomfort levels produced by LiCl or EHC1 may not have been strong enough to generate a longer-term avoidance reaction. It may have indicated that hungry bears are willing to accept a food despite an aversion to it if they are sufficiently hungry or if no other foods are available to them. These bears had also had previous tastes of honey and were thus familiar with honey without discomfort.

The potential for subsequent reinforcement counters the objections of Shumake et al ( 1974 ) that a marginally effective exposure to an aversive agent would preclude subsequent intake of treated baits ( i.e: reinforced aversion ) by another dose of that chemical in a bait. Shumake et al. (1974) developed several arguments against LiCl as an effective aversion conditioner. They question the large doses of chemical required to produce an effective aversion, suggesting that emesis would prevent intake of an effective amount of LiCl. LiCl does indeed represent just such a problem, particularly because a bear weighs considerably more than a coyote. Gustavson's 1974 experiments on 12 kg coyotes indicated a specific dose of 500 mg/kg for effective

conditioning while I achieved results with bears at levels of 100 to 350 mg/kg. This still presented the problem of feeding a black bear 10 to 35 g of a salty tasting chemical. The captive animals were sufficiently hungry that this did not deter bait consumption, however a free-ranging animal that is not hungry or who has alternate food sources might avoid treated baits or carcasses. In fact, by presenting the bear with a distinct taste, LiCl may not always act as a true aversion conditioner, but rather as a gustatory repellent. The distinction lies in my definition of a conditioning agent: a chemical which produces sufficient discomfort that a classical Pavlovian conditioned response to an otherwise attractive substance is produced. The stimulus for this response ( if it is to be effective in preventing the killing of live, untreated prey, preventing the consumption of baits, or reducing visitations to specific areas ) must be the sight or odor of the prey, bait or area alone, rather than the sight or odor of the chemical. The conditioning agent should be undetectable by the target animal during ingestion. It should be odorless, tasteless, and in a sufficiently small quantity that no apparent clue to its presence is available to the target animal. Thus, after conditioning, the conditioned stimulus will be the prey, bait or area, not the chemical.

In this respect, Shumake et al. (1974) are correct.

LiCl might act as both a taste repellent and as an aversion

conditioner. The results of captive bear tests at Sequim ( Tables II-VII, II-VIII ), however indicate that a conditioned response to untreated baits had been achieved. The differences in consumption rate for a cow carcass treated with LiCl ( Table II-IX ) cannot be directly attributed to handling, although a sample size of one precludes any definite statements.

In an analysis of all of the experiments with black and polar bears, it appears that the test chemicals were all capable of generating conditioned responses to the specific foods which they were used with. Insufficient numbers in experiments with range cattle kills and black bears still lead to the possibility that the observed reductions in consumption relate to other reductions in consumption seen in experiments on captive black bears and on free-ranging polar and black bears at dumps. Alternate food sources would probably serve to enhance the effectiveness of this technique. This was observed by Maclean (1974) in experiments on the effects of ultrasound on commensal rodents; repellency was effective if an alternate food source was available in another area free of the sound. In addition, the novelty of the food will affect the degree of aversion attained in rodents ( Rozin and Kalat 1971 ), and it seems logical to assume that such a psychological mechanism exists in larger, more intelligent animals. The experienced sheep-killing coyote, with 30 lambs to his credit, is probably less likely to be easily conditioned from further killing by a single exposure to

a nauseating carcass than the young pup who is sickened after his first exposure to treated mutton.

The several design flaws in these experiments have been corrected in my current work on the subject, and it is hoped that these studies will clarify unanswered questions about the field applications of aversion conditioners.

## GENERAL CONCLUSIONS

Aggressive sounds of polar bears were successfully recorded and analysed, allowing synthesis of six variants of the natural sounds. Three control sounds, lacking harmonics, and with simplified spectral content and frequency envelopes were also produced. Field and captive animal tests using these sounds indicated that four of the seven aggressive sounds, including the natural recordings, were capable of eliciting repellent responses in bears exposed to them. These biologically significant sounds are currently under continued study in the Canadian arctic in order to determine their effectiveness under varied conditions.

Biologically significant sounds offer the potential for effective long term repulsion of wild, dangerous, intruding bears, in situations where the intruder has an alternative resource or area to explore. A bear which happens upon a remote human habitation may possibly be successfully re-routed around or away from such a site by an effective repellent. Habituation to the aggressive sounds does not appear to occur, probably because reinforcement often accompanies such sounds in actual aggressive encounters between bears. Confrontations between sub-adults and dominant adults is often characterized by vocalizations and physical attacks, and while this may lead to deperate sub-adults, such animals are also likely to heed very loud threat vocalizations

which have been electronically generated.

The effects of LiCl, ANTU and EHC1 were observed in experiments on captive black bears and blacktailed deer, and in tests on free-ranging black and polar bears and coyotes. Tests on deer proved inconclusive because the chemicals used were not acceptable to the test animals. Insufficient numbers of test animals prevented any specific conclusions about the efficiency of each of the test chemicals. Data from ranchers and the Cattlemen's Association did not allow a strict scientific analysis of observations. An overview of all tests, coupled with results from recent studies on aversion conditioning ( Gustavson 1976 ) does, however, indicate that the technique may be capable of altering feeding and visitation behaviour of target animals. Bait consumption reductions observed in dump-baiting tests indicate this effectiveness. These tests would have benefited from a longer experimental period. It remains a major problem in dealing with free-ranging carnivores that sufficient numbers of test animals and test situations are rarely available for long periods of time, particularly when the test animals are subjected to various repellent stimuli.

Important questions still to be answered with respect to the technique of aversion conditioning concern such aspects as: (1) the relative effectiveness of aversion conditioning chemicals on young animals exposed to treated baits for the first time versus experienced predators who happen to eat one treated bait;

(2) the long-term effectiveness of aversion conditioning under conditions of starvation, or in situations where alternative food sources are available ( it seems likley that a suitable, attractive, alternate food would enhance the technique );

(3) situations involving groups or packs of predatory animals or pests, such as occurs with wolves or coyotes, or groups of bears sharing a single resource such as a dump. In many instances, such facilities as dumps or livestock ranches are supporters of resident pest ( predator or scavenger ) populations. Effective repellent techniques will then only serve to produce starving, and presumably desperate, animals.

(4) the effects of temporal delays between ingestion of an aversion conditioner and the onset of discomfort should be investigated. Nachman (1970) found evidence in rats of successful aversion conditioning to saccharine following several hours delay between ingestion of the saccharine and treatment with LiCl. Delays did not apparently decrease effectiveness, thus fast-acting chemicals may not necessarily be a prerequisite for the development of an aversive response.

Laboratory studies of aversion conditioning have produced a vast body of literature, mainly dealing with rodents and hand-raised carnivores ( Riley and Baril 1975; Gustavson 1976 ). Only a limited amount of literature now exists on the functional role of learned food aversions for free-ranging animals.



Variables which affect the feeding behaviour of free-ranging animals include:

1) morphological, anatomical and physiological characteristics of the species which determine the limits of food items available to that animal;

2) the availability of the specific food in the environment, as determined by the accessibility of prey;

3) the availability and accessibility of alternate food sources, and;

4) the wholesomeness and palatability of that food.

For practical purposes, the manipulation of food wholesomeness and palatability can be achieved by altering the wholesomeness of some specific dietary component. The other three sets of variables listed above require drastic modification of either the prey, the predator, or the ecosystem. Fences, as a highly localized environmental modification, are successful in altering prey accessibility, however their extensive use has both economic and aesthetic considerations which are unacceptable. Physiological or morphological changes to either predator or prey would not be acceptable on the basis of economics, even if the technology existed for such changes. Drastic manipulation of predator numbers has been demonstrably disastrous to natural controls on prey populations, and has, in the case of the coyote, proved to be of limited value as a management or control tool.

Food wholesomeness, as manipulated by aversion conditioning techniques, is best suited to the problem, and is also best studied by observations made under field conditions, rather than in captive situations.

Field trials of acoustic and chemical repellents presented problems which are not encountered in studies on smaller, more controllable species. It was difficult to obtain adequate numbers of trials when dealing with free-ranging coyotes, black and polar bears, and even captive bears. A comparison of captive and field results does indicate that both biologically significant sounds and chemically induced aversions are effective at least temporarily in manipulating the behaviour of these vertebrate pests. Long term effects require further study.

Application of non-destructive methods under actual field conditions is subject to another hinderance; rancher and public distrust of new, non-traditional methods of pest control. The author's experiences with some cattle and sheep ranchers, as well as the experiences of Gustavson ( Jowsey 1976; personal comm. with Gustavson ) and others indicate that a successful chemical or acoustic repellent will have to be accompanied by an intensive education program which presents not only the theory of these repellents, but also outlines the nature and value of

predators and other "pests". This is a particularly difficult task on view of general public sentiment towards nuisance animals and may, in fact, only be achieved through a long-term effort and the demonstration of successful use of any new technique in the field.

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