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THE VOCAL AND BEHAVIORAL REACTIONS OF THE WHITE WHALE, OR BELUGA, (DELPHINAPTERUS LEUCAS) TO UNDERWATER PLAYBACK OF NATURAL AND SYNTHETIC BELUGA SOUNDS

BY

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OF

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ABSTRACT

Underwater playback of natural and synthetic sounds was shown to be an effective tool for investigation of communication in Delphinapterus leucas, the beluga. Natural sounds were used to determine the significance of the sounds to the animals, and synthetic sounds to determine some of the parameters of the sounds that had an effect on their significance. The general, overall response of captive animals was an increase of interest in the sound source during the playback, with decreasing interest in the three minutes following playback. The general response of free-swimming belugas was a decrease of vocal emissions. A strong, stereotyped, vocal response was elicited from one captive animal by the Harmonic Long, Loud Whistle; and synthetic sounds, based on this natural sound, showed that both duration and frequency affected the significance of this sound. It is suggested that the Jaw Clap or Bang should be regarded as a general 'alerting' or 'attention' call, permiting it to serve as either an alarm signal or a threat. The Squeals of the free-swimming herd may have been associated with the calves, being produced either by the calves themselves or by accompanying adults. Both syntax (the combination of individual sounds into sound-series) and context were important in the conveyance of information by the playbacks. 'Scouting behavior' occurred during the playback of some sounds. A functional classification of animal sounds is proposed. Suggestions are advanced for further work with the vocal behavior of the beluga.

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PREFACE

This dissertation has been prepared in the manuscript thesis plan. Accordingly, the tables presented within the body of the paper present only those data pertinent to points fully discussed. Additional raw data are presented as Appendices IV-XIII. Appendices I-III are necessary for a complete understanding of the experimental work and will be submitted for publication as an integral part of the manuscript.

INTRODUCTION

Playback of natural or synthesized sounds has been used as an experimental technique with diverse groups of animals and with varied degreesoof success. Playback of natural sounds is used to elucidate the biological significance of the sounds for the animal producing or receiving them. Playback of synthesized sounds, based on the characteristics of a natural sound but with one or more of the basic parameters varied in a systematic manner, is used to determine which parameters of a sound are necessary for message transfer. Both types of knowledge are necessary for a complete understanding of the acoustical system of a species, as is knowledge of the mechanisms of sound production and reception since these place the physical limits on the range of signals which can be produced and received.

Playback of pure tones has been used to investigate parameters of an acoustic system not directly concerned with communication. These parameters include frequency limits of hearing, effectiveness of auditory masking, direction-finding capabilities, frequency discrimination capabilities, and intensity limits of frequency detection (audiograms).

The research described in this report was designed to determine whether or not the playback technique could be used as an experimental tool for the investigation of the acoustical system of the beluga, or white whale (*Delphinapterus leucas*, Pallas), by modification of sound emissions and/or behavioral patterns. The beluga was chosen as the experimental subject because of its availability in captivity and in the free state, and because of its known ability to produce a wide range of sounds (Schevill and Lawrence, 1949, 1950; Fish and Mowbray, 1962). Natural sounds were played back to study the significance and meaning of these sounds, and synthetic sounds were used to determine some of the parameters of the sounds which had a bearing on their significance.

Playback experiments were first used with cetaceans in 1952 to determine the upper limits of hearing of the bottlenose porpoise, Tursiops truncatus. Kellogg and Kohler (1952) and Kellogg (1953) determined that the upper limit of hearing in this species reached at least to 80 kHz by using playbacks of pure tones. This limit was further extended to 120 kHz by Schevill and Lawrence (1953) and to 150 kHz by Johnson (1967), both of whom also used playback of pure tones as their experimental technique.

Pure-tone playbacks were used by Dudok van Heel (1959) to determine auditory direction finding in Phocoena phocoena and by Johnson (1968) to measure masked frequency thresholds in T. truncatus. Other uses of this technique have included determinations of audiograms for several species, for example Inia geoffrensis (Jacobs and Hall, 1972) and Orcinus orca (Hall and Johnson, 1972), and of auditory frequency discrimination limens in T. truncatus (Jacobs, 1972).

Playback of the sounds of a conspecific animal has been used since 1961 as a means of demonstrating acoustical exchanges between dolphins. In that year, Lilly and Miller (1961) showed that acoustic stimuli from one T. truncatus immediately elicited whistles and click trains from another, isolated animal of the same species. Lang and Smith (1965) also showed that an isolated T. truncatus would respond to the sounds of a second individual until one particular sound was played back. Response then ceased for some time, suggesting that different sounds had different significances. Dreher (1966) also found varied vocal and behavioral reactions to playback of six different whistle contours of T. truncatus to that same species. Caldwell, Hall, and Caldwell (1972) used conspecific playbacks of eight individuals of T. truncatus to show that one dolphin could discriminate between a random assortment of individuals on the basis of a wide assortment of their whistle emissions, and concluded that certain whistles were specific to the individual producing them (signature whistles).

A third type of playback experiment has been the playback of sounds of one cetacean species to another. Fish and Vania (1971) used playbacks of the sounds of the killer whale (Orcinus orca) to keep belugas from entering the Kvichak River in Alaska during the salmon spawning run, and Cummings and Thompson (1971) used these sounds to affect the behavior of the gray whale (Eschrichtius robustus) during their southward migration past California. In both cases, the animals responded with a flight reaction. Caldwell, Caldwell, and Hall (1972) found that T. truncatus was able to discriminate between individuals of Delphinus delphis solely on the basis of the D. delphis whistles played back. Davies (1962) carried this type of playback even further by playing back killer whale sounds to animals of a different class, the Zambezi River shark (Carcharhinus zambezensis). He found that the largest of five sharks was disturbed by the sounds, swimming around the tank at greatly increased speed.

Thus sound playbacks are seen to be a powerful tool in the investigation of many aspects of cetacean sound. However, the playback of conspecific sounds to animals in captivity and in the field for the purposes of correlating behavior and vocal emissions, and determining the significance of sounds, has hardly been utilized. As mentioned above, Lilly and Miller (1961), Dreher (1966), and Caldwell, Hall, and Caldwell (1972) have started work in this direction with captive animals, but no results of investigations of this nature with cetaceans in the field have been published. In fact, the only published field work of this type done with any of the marine mammals is that carried out by Watkins and Schevill (1968) with Weddell seals (Leptonychotes weddelli) in Antarctica. They found that the seals seemed to respond to playbacks of good fidelity, whereas a playback of poor quality elicited only silent interest or annoyance. The research reported herein involved the use of conspecific playbacks to both captive and free-swimming belugas.

MATERIALS AND METHODS

Materials and Experimental Animals

The experiments were carried out with two populations of belugas, one captive and one in its natural environment. The work with captive animals was done at the New York Aquarium of the New York Zoological Society. This population consisted of four animals; two females from Hudson's Bay, one male from the St. Lawrence River, and one male from Kvichak Bay, Alaska. Throughout this report, the names given to the captive animals by the Aquarium staff have been used to designate the individual whales. The two females were named Frances and Ethel, the St. Lawrence male was Blanchon, and the Kvichak Bay male was Alex. All four were adult animals, Blanchon being the dominant male, and Frances the dominant female.

The field experiments were carried out in the Saguenay River, Quebec Provence, Canada during the summers of 1970 and 1971. At least some of the animals were involved in the herd of forty to sixty whales both years, as a few individuals could be recognized by scars or pits on their dorsal surface. The age composition of the herd was mixed, with very small, dark calves; medium-sized, grey, young animals; and large pure-white adults being present both years. Playback experiments were performed at various positions on the river, both when the whales were swimming up or down the river and when milling in the quiet bays and estuaries.

The experimental setup required two simultaneous systems; one for playback and one for recording. At the Aquarium the whales' sounds were picked up by either a Hydro-Products R-130 or a Chesapeake LF-310 hydrophone, fed through a preamplifier box, and recorded on an Ampex 1260 stereophonic tape recorder. Visual observations were recorded on the second track of the same tape, allowing real-time correlation of behavior and sounds. Playbacks were effected from a Uher 4000-L monaural tape recorder, amplified by a Kudelski-Paudex amplifier, and emitted through an LTV University MM-2PPS underwater loudspeaker or a Chesapeake J-9 omnidirectional sound transducer. The University loudspeaker was used only for the first series of playbacks at the Aquarium and as a backup sound source during the rest of the study in case of failure of the J-9 transducer. In the field, recordings were made using a Uher 4400-S Report Stereo tape recorder, and the playback amplifier used was a Realistic PA-25. Frequency response of the system was 50-10,000 Hz, with the possible exception of the University loudspeaker. All field experiments were carried out from a 16-foot Boston Whaler, and all recordings were made at 7½ ips tape speed.

Methods

The captive population was recorded over a period of three days in July of 1968. From these recordings, twelve sounds and a control (background tank noise) were chosen as the primary playback sounds. These sounds are designated throughout this report as PBS 1-13 (PlayBack Sounds 1-13), and are described in Appendix I. Each sound was placed on a tape loop in combination with a ten-second piece of blank tape and re-recorded for three minutes, resulting in alternation of the sound and ten-seconds of silence.

Each playback experiment was made up of three three-minute periods. Sounds and behavior were recorded during the entire nine minutes, with one of the playback sounds being broadcast into the tank during the middle three minutes. The resulting three periods were designated as PrePlayback (PrPb), Playback (Pb), and PostPlayback (PtPb). A time lapse of at least thirty minutes was allowed between all playback experiments at the aquarium, and the sounds were presented in random order. In the field, playback experiments were performed whenever the opportunity arose.

Six series of playback experiments were performed:

(1) Playback of sounds from the captive population to the captive animals.--The first series of experiments involved the playback of the PBS series of sounds to the four captive whales, all in the same tank.

(2) Playback of sounds from the captive population to the Saguenay herd.--In July and August of 1970, eight of the captive sounds, plus a 4.8 kHz pure tone, were played back to the Saguenay herd. This series is designated as FldPBS 104; 6-10 (Field PlayBack Sounds 1-4; 6-10) and is marked with an asterisk (*) in Appendix I.

(3) Playback of sounds from the Saguenay animals to the Saguenay herd.--Seven of the sounds recorded from the Saguenay herd in July of 1970 were re-recorded in the manner described above. These seven sounds, designated as SagPBS 1-7 (Saguenay PlayBack Sounds 1-7) and described in Appendix II, were then played back to the Saguenay herd in August of 1970 and July-August of 1971.

(4) Playback of sounds from the Saguenay herd to three captive

animals.--In 1970 it became necessary to separate Alex from Blanchon, the dominant male. Alex was placed in a separate tank at the aquarium, leaving Blanchon, Frances, and Ethel in the large beluga tank. In 1971, the SagPBS series was played back to these three animals.

(5) Playback of sounds from the Saguenay herd to a single captive animal.--The SagPBS series was also played back to Alex in his separate tank, allowing concentration of observations on a single animal.

(6) Playback of synthesized sounds to a captive animal.--Nine synthesized sounds (SynPBS 1-9), based on the characteristics of one sound that uniformly elicited a vocal response from Alex, were played back to him in his isolated pool. Typical characteristics of two examples of the original sound, the Harmonic Long, Loud, Whistle (Harmonic LLW), are presented in Appendix I. The nine synthetic sounds were combinations of the natural frequencies and durations of the Harmonic LLW, and the abnormal frequency and duration of 3.3 kHz and 30 seconds, respectively. These sounds are described in detail in Appendix III.

Laboratory and Statistical Analysis

Each sound emission recorded from the animals during the playback experiments was counted and categorized with reference to type of sound and time of occurrence in PrPb, Pb, or PtPb. Written transcriptions were made of all observations for each playback experiment and correlated with type of sound emission wherever possible. Activity in the tank was measured by counting instances of investigation of hydrophone and sound source or circuits of the tank (only when working with one animal), and, in the field, by noting dive times and approach or withdrawal to or from the boat.

Each sound was analyzed on a Kay Electric Company Vibralyzer sound spectrograph for frequency, duration, waveform, and harmonic structure. Duration of Harmonic LLW's was measured on a B+K Level Recorder (Model 2305) at a paper drive speed of 1 cm/sec. The types of sounds counted are typical of the playback sounds described in the Appendices. Descriptions of other sounds that were recorded, but were not affected by playback, and accounts of concurrent behavioral observations will be presented in later papers.

The nonparametric sign test (Siegel, 1956) was used throughout the analysis except in the cases where a continuous variable was being measured (dive times and sound durations). In the latter cases the modified t-test for unequal variances and sample sizes (Steele and Torrie, 1960) was used.

RESULTS

I. Playback of Sounds Recorded From the Captive Animals

A. Playback to captive animals at the New York Aquarium

Vocal reaction.--Three of the 13 sounds recorded from the captive animals, the Harmonic LLW, the Contact Sound-Series, and the Whinny, elicited a significant vocal response when played back to these same animals. These results are summarized in Table 1, which shows the significant increases or decreases of emissions of each sound type counted between PrPb and Pb, between Pb and PtPb, and between PrPb and PtPb. The other 10 sounds elicited no significant vocal responses. The data for all 13 sounds are presented in Appendix IV. Since in most cases it was impossible to determine which whale was making the sounds, total numbers of each sound type were counted. However, the Harmonic LLW was generally accompanied by a stream of bubbles from the blowhole of the emitting animal, and thus could be attributed to a single whale. The Harmonic LLW playback, originally recorded from Alex, elicited a highly significant increase in the number of emissions of the Harmonic LLW by Alex in Pb over the number emitted in PrPb. This effect continued into PtPb, the number of Harmonic LLW's emitted in PtPb being consistently greater than the number emitted in PrPb.

Upon playback of the Contact Sound-Series, the Contact Sound-Series was emitted by the whales more frequently in Pb than in PrPb. This effect did not carry over into PtPb, the frequency of emission of

Table 1. Significant increases and decreases in frequency of emission of five sound types during and after playback of PBS 1, 3, and 6 to the four captive belugas.

			Sound Types														
PBS	N	Period Change	Harmonic LLW			Jaw Clap			Contact Sound-Series			Whistle			Totals		
			+	-	0	+	-	0	+	-	0	+	-	0	+	-	0
1		PrPb-Pb	9	0	2**							0	6	5*	6		
Harmonic	11	Pb-PtPb															
LLW		PrPb-PtPb	8	0	3**												
3																	
Contact		PrPb-Pb							6	0	4*						
Sound-	10	Pb-PtPb				0	7	3*	0	6	4*				1	9	0*
Series		PrPb-PtPb															
6		PrPb-Pb															
Whinny	11	Pb-PtPb											0	6	5*		
		PrPb-PtPb															

Key to the symbols used:

PBS	number and descriptive name of the sounds played back
N	number of repetitions of each sound played back
+	increase in frequency of emission
-	decrease in frequency of emission
0	no change in frequency of emission
PrPb-Pb	changes occurring between preplayback and playback
Pb-PtPb	changes occurring between playback and postplayback
PrPb-PtPb	changes occurring between preplayback and postplayback
*	change is significant at the .05 level
**	change is significant at the .01 level

the Contact Sound-Series decreasing once more in PtPb. Jaw Claps and Total Sounds were also decreased in numbers of emission between Pb and PtPb. Playback of the Whinny elicited a decrease in the number of Whistles emitted in PtPb as compared with Pb, and the Harmonic LLW wlicited a significant decrease in number of Whistles emitted in Pb as compared with PrPb.

Changes in interest directed toward hydrophone and sound source.--Table 2 shows significant changes of interest directed toward the equipment placed in the tank for all four whales considered together. The complete data for all 13 sounds are presented in Appendix V. Interest was expressed in two ways; by orienting the head toward the hydrophone or sound source while remaining in position, or by approaching one of the two and often nudging or biting it. An increase (+) in Table 2 means that more of the four whales showed interest toward the equipment in Pb or PtPb than had done so in the preceeding periods of the experiment. Conversely, a decrease (-) means that fewer whales showed interest. A no-change designation (0) indicates that the same number of whales showed interest in both periods under comparison, although different combinations of animals may have been involved.

There were no significant changes in orientation toward the hydrophone, but orientation toward the sound source increased significantly from PrPb to Pb in response to seven of the thirteen sounds: Buzzes, Whinny, Buzz-and-Whinny, Whistles, Harmonic LLW, Type-1 Squawk, and Control. Significant decreases from Pb to PtPb were found with the Harmonic LLW, Whinny, Buzz-and-Whinny, and Whistles. Smaller decreases occurred in response to all other playback sounds except the Jaw Claps and the Jaw Clap-Buzz-and-Whinny combination. This demonstrates that

Table 2. Significant increases and decreases of interest directed toward hydrophone and sound source during and after playback of nine PBS playback sounds to the four captive belugas.

PBS	N	Period Change	Orient Toward Hydrophone			Orient Toward Sound Source			Approach Hydrophone			Approach Sound Source		
			+	-	0	+	-	0	+	-	0	+	-	0
1 Harmonic LLW	11	PrPb-Pb				6	0	5*	0	6	5*			
		Pb-PtPb				0	6	5*						
		PrPb-PtPb												
2 Buzzes	11	PrPb-Pb				7	0	4*						
		Pb-PtPb												
		PrPb-PtPb												
4 Buzz and Whinny	11	PrPb-Pb				6	0	5*				7	0	4*
		Pb-PtPb				0	6	5*						
		PrPb-PtPb												
6 Whinny	11	PrPb-Pb				6	0	5*				8	1	2*
		Pb-PtPb				0	6	5*				0	8	3**
		PrPb-PtPb												
7 Whistles	10	PrPb-Pb				7	0	3*						
		Pb-PtPb				0	7	3*						
		PrPb-PtPb												
9 Type 1 Squawk	11	PrPb-Pb				7	0	4*						
		Pb-PtPb												
		PrPb-PtPb												
10 Jaw Clap, Buzz and Whinny	10	PrPb-Pb												
		Pb-PtPb												
		PrPb-PtPb							0	6	4*			
11 Type 2 Squawk	10	PrPb-Pb										6	0	4*
		Pb-PtPb												
		PrPb-PtPb												
12 Control	9	PrPb-Pb				6	0	3*						
		Pb-PtPb												
		PrPb-PtPb												

For a key to the symbols used, see Table 1.

an initial orientation toward the sound source by at least some of the whales during Pb was the usual reaction and that interest fell off soon afterward. This initial reaction was evident while observing the animals, to the point that it was considered unusual if it did not occur.

Significant decreases of approach toward the hydrophone in Pb occurred only in response to the Harmonic LLW and the Jaw Clap-Buzz-and-Whinny combination. Approach toward the sound source increased significantly in reaction to only three of the playback sounds (Buzz-and-Whinny, Whinny, and Type-2 Squawk), with smaller increases occurring in association with all other sounds except the Contact Sound-Series, the Jaw Clap-Buzz-and-Whinny, and the Pure LLW, which were associated with decreases of interest, and the Harmonic LLW, which caused no changes. The Whinny caused a distinct loss of interest in PtPb.

Tables 3a and 3b present the number of instances, summed over all repetitions of each PBS, that the four whales showed interest in the hydrophone or sound source. Referring to Table 3b, it is seen that there was no significant change in head orientation toward the hydrophone, but that head orientation toward the sound source increased for every playback sound in Pb, and also decreased for all 13 sounds in PtPb to near-PrPb levels. The whales approached the hydrophone significantly less in Pb, but approached the sound source significantly more in Pb, with a decrease in approaching once more in PtPb.

As can be seen from Table 3a, the largest increases in approaching the sound source in Pb occurred with five playback sounds which can be grouped into two series: the Buzz, the Whinny, and the Buzz-and-Whinny; and the Type-1 and Type-2 Squawks. In all of these cases interest fell off rapidly in PtPb. Two playback sounds, the Contact Sound-Series and

Table 3a. Total number of times interest was shown by all four whales toward the hydrophone and sound source, summed over all repetitions of each playback sound.

PBS	N	Orient Toward Hydrophone			Orient Toward Sound Source			Approach Hydrophone			Approach Sound Source		
		PrPb	Pb	PtPb	PrPb	Pb	PtPb	PrPb	Pb	PtPb	PrPb	Pb	PtPb
Harmonic LLW	11	0	0	0	0	13	1	11	5	10	44	6	5
Buzzes	11	0	0	2	2	19	4	11	4	9	6	17	9
Contact Sound-Series	10	0	0	0	1	14	2	5	3	3	9	7	5
Buzz-and-Whinny	11	0	2	1	1	13	1	11	7	12	3	13	7
Jaw Claps	8	0	0	0	2	9	2	5	8	6	7	8	5
Whinny	11	1	0	1	2	14	2	8	6	66	1	14	1
Whistles	10	1	0	0	1	15	1	11	9	6	8	9	8
Blare	9	1	0	0	2	13	1	9	7	8	5	6	8
Type-1 Squawk	11	1	4	2	0	12	3	8	6	9	6	10	7
Jaw Clap-Buzz-and-Whinny	10	0	0	0	0	5	0	10	7	3	17	9	9
Type-2 Squawk	10	0	0	1	2	9	1	6	7	11	6	15	8
Control	9	0	0	0	0	6	3	6	2	6	4	5	7
Pure LLW	88	0	0	0	0	14	1	7	7	7	8	9	6

The changes of interest shown in Table 3a are summarized in Table 3b. For a key to the symbols used, see Table 1.

Table 3b. Summary of the number of playback sounds that elicited increases and/or decreases of interest directed toward hydrophone and sound source from all four whales.

Period Change	Orient Toward Hydrophone			Orient Toward Sound Source			Approach Hydrophone			Approach Sound Source		
	+	-	0	+	-	0	+	-	0	+	-	0
PrPb-Pb	2	3	8	13	0	0**	2	10	1*	11	2	0*
Pb-PtPb	3	2	8	0	13	0**	7	3	3	2	10	1*
PrPb-PtPb	4	2	7	6	2	5	4	7	2	7	4	2

For a key to the symbols used, see Table 1.

the Jaw Clap-Buzz-and-Whinny combination, were associated with a decrease in approaching the sound source in Pb. Both of these playback sounds were made up of a natural grouping of sounds, rather than being one discrete sound. The other six playback sounds elicited only small increases in approaching the transducer.

Tables 4-7 show the changes in interest directed toward the equipment for each individual whale. 'Orienting' and 'approaching' were lumped together and totaled for all repetitions of each sound. The numbers of the 13 playback sounds that elicited increases and decreases are shown at the bottom of each chart in the same manner as in Tables 1-3. All four belugas showed increases of interest in the sound source for a significant number of playback sounds during Pb, and decreases of interest in the sound source for an equally significant number of playback sounds in PtPb. However, the only beluga which showed a significant decrease of interest in the hydrophone during Pb was Alex (Table 4b). Alex was also observed to display the least overall interest in the hydrophone at all times.

The strength of the changes of interest from PrPb to Pb toward the sound source by each whale for each playback sound are compared in Table 8. For example, the number '8' appearing in the column headed 'Alex' and the row entitled 'Buzzes' means that eight out of the eleven times that the Buzzes playback sound was used, Alex showed more interest in the sound source during Pb than he had shown during PrPb. A negative number indicates a decrease of interest. The Buzzes, the Whinny, and the Buzz-and-Whinny combination elicited much interest from all four whales. However, when the Jaw Clap was addĕd to the Buzz-and Whinny (Jaw Clap-Buzz-and-Whinny combination), the responses elicited were the

Table 4a. Total number of times Alex directed interest toward the hydrophone and sound source.

PBS	N	Total Interest Directed Toward Hydrophone			Total Interest Directed Toward Sound Source		
		PrPb	Pb	PtPb	PrPb	Pb	PtPb
Harmonic LLW	11	4	1	5	1	8	4
Buzzes	11	4	1	3	4	12	5
Contact Sound-Series	10	3	0	0	4	4	5
Buzz-and-Whinny	11	4	3	5	4	12	4
Jaw Claps	8	2	2	2	6	8	6
Whinny	11	6	1	1	2	8	2
Whistles	10	6	2	2	3	8	4
Blare	9	5	3	3	1	5	4
Type-1 Squawk	11	4	3	2	2	8	6
Jaw Clap-Buzz and-Whinny	10	4	3	1	6	6	4
Type-2 Squawk	10	1	1	4	4	11	4
Control	9	2	1	3	3	66	4
Pure LLW	8	2	2	1	4	6	3

Table 4b. Summary of the number of playback sounds that elicited increases and/or decreases of interest toward the hydrophone and sound source from Alex.

Period Change	Total Interest Directed Toward Hydrophone			Total Interest Directed Toward Sound Source		
	+	-	0	+	-	0
PrPb-Pb	0	10	3**	11	0	2**
Pb-PtPb	5	3	5	1	12	0**
PrPb-PtPb	4	8	1	7	2	4

The changes of interest shown in Table 4a are summarized in Table 4b. For a key to the symbols used, see Table 1.

Table 5a. Total number of times Blanchon directed interest toward the hydrophone and sound source.

PBS	N	Total Interest Directed Toward Hydrophone			Total Interest Directed Toward Sound Source		
		PrPb	Pb	PtPb	PrPb	Pb	PtPb
Harmonic LLW	11	2	1	0	1	4	1
Buzzes	11	1	0	1	4	11	5
Contact Sound-Series	10	0	0	0	3	5	1
Buzz-and-Whinny	11	1	1	1	0	7	3
Jaw Claps	8	0	0	0	3	5	2
Whinny	11	0	1	1	1	6	1
Whistles	10	0	0	0	3	6	1
Blare	9	0	0	0	3	5	3
Type-1 Squawk	11	0	1	1	2	8	2
Jaw Clap-Buzz and-Whinny	10	0	1	0	6	3	2
Type-2 Squawk	10	0	0	1	2	6	2
Control	9	0	0	0	1	3	3
Pure LLW	8	0	1	0	2	7	1

Table 5b. Summary of the number of playback sounds that elicited increases and/or decreases of interest toward the hydrophone and sound source from Blanchon.

Period Change	Total Interest Directed Toward Hydrophone			Total Interest Directed Toward Sound Source		
	+	-	0	+	-	0
PrPb-Pb	4	2	7	12	1	0**
Pb-PtPb	2	3	8	0	12	1**
PrPb-PtPb	3	1	9	3	5	5

The changes of interest shown in Table 5a are summarized in Table 5b. For a key to the symbols used, see Table 1.

Table 6a. Total number of times Ethel directed interest toward the hydrophone and sound source.

PBS	N	Total Interest Directed Toward Hydrophone			Total Interest Directed Toward Sound Source		
		PrPb	Pb	PtPb	PrPb	Pb	PtPb
Harmonic LLW	11	3	2	3	0	4	1
Buzzes	11	4	1	4	0	7	1
Contact Sound-Series	10	1	2	3	0	5	0
Buzz-and-Whinny	11	3	3	4	0	5	0
Jaw Claps	8	2	4	2	0	1	1
Whinny	11	2	2	2	0	8	0
Whistles	10	4	4	3	1	4	2
Blare	9	3	2	3	0	4	0
Type-1 Squawk	11	4	4	6	0	2	1
Jaw Clap-Buzz and-Whinny	10	4	1	1	2	1	0
Type-2 Squawk	11	5	5	5	0	2	0
Control	9	2	1	1	0	0	1
Pure LLW	8	4	3	3	0	5	2

Table 6b. Summary of the number of playback sounds that elicited increases and/or decreases of interest toward the hydrophone and sound source from Ethel.

Period Change	Total Interest Directed Toward Hydrophone			Total Interest Directed Toward Sound Source		
	+	-	0	+	-	0
PrPb-Pb	2	6	5	11	1	1**
Pb-PtPb	6	2	5	1	11	1**
PrPb-PtPb	3	4	6	7	1	5

The changes of interest shown in Table 6a are summarized in Table 6b. For a key to the symbols used, see Table 1.

Table 7a. Total number of times Frances directed interest toward the hydrophone and sound source.

PBS	N	Total Interest Directed Toward Hydrophone			Total Interest Directed Toward Sound Source		
		PrPb	Pb	PtPb	PrPb	Pb	PtPb
Harmonic LLW	11	1	1	2	1	3	0
Buzzes	11	2	2	3	0	6	2
Contact Sound-Series	10	1	1	0	3	7	1
Buzz-and-Whinny	11	3	2	3	0	2	1
Jaw Claps	8	1	2	2	0	3	1
Whinny	11	1	2	3	0	6	0
Whistles	10	2	3	1	2	6	2
Blare	9	2	2	2	3	5	2
Type-1 Squawk	11	0	2	2	2	4	1
Jaw Clap-Buzz and-Whinny	10	2	2	1	3	4	3
Type-2 Squawk	11	0	1	2	2	4	3
Control	9	2	0	2	0	2	2
Pure LLW	8	1	1	3	2	5	1

Table 7b. Summary of the number of playback sounds that elicited increases and/or decreases of interest toward the hydrophone and sound source from Frances.

Period Change	Total Interest Directed Toward Hydrophone			Total Interest Directed Toward Sound Source		
	+	-	0	+	-	0
PrPb-Pb	5	2	6	13	0	0**
Pb-PtPb	7	3	3	0	12	1**
PrPb-PtPb	7	3	3	5	5	3

The changes of interest shown in Table 7a are summarized in Table 7b. For a key to the symbols used, see Table 1.

Table 8. Strengths of the changes of interest from PrPb to Pb directed toward the sound source by each whale in response to each playback sound.

PBS	N	Alex	Blanchon	Ethel	Frances	Total
Buzzes	11	8	7	7	6	28
Whinny	11	6	5	8	6	25
Buzz-and-Whinny	11	8	7	5	2	22
Type-1 Squawk	11	6	6	2	2	16
Harmonic LLW	11	7	3	4	2	16
Type-2 Squawk	10	7	4	2	2	15
Pure LLW	8	2	5	5	3	15
Whistles	10	5	3	3	4	15
Blare	9	4	2	4	2	12
Contact Sound Series	10	0	2	5	4	11
Jaw Claps	8	2	2	1	3	8
Control	9	3	2	0	2	7
Jaw Clap-Buzz-and-Whinny	10	0	-3	-1	1	-3

lowest of all playback sounds for all whales. The Jaw Clap itself also elicited a low response. The Contact Sound-Series, which elicited several vocal responses, elicited relatively low interest directed toward the sound source.

B. Playback to the Saguenay River herd.

Vocal reaction.--The significant changes in numbers of emissions of the four affected Saguenay-herd sound types during and after playback of the FldPBS playback series to the Saguenay herd are presented in Table 9. The complete data for changes of all nine sounds counted, in response to all playbacks, are summarized in Appendix VI. All sounds counted were typical of the types described in Appendix II under the same names, with the addition of the Ring and the Click Trains. The Ring was very similar to the Ping, but had a longer reverberation time, and the Click Train was a series of rapid-repetition-rate clicks similar to those used for echolocation in some cetaceans. All changes of significance occurring between PrPb and Pb were decreases in numbers of sounds, while all significant changes between Pb and PtPb were increases. Since, in the field situation, the sound source was relatively close to the hydrophone, it is possible that the playback sounds themselves masked some of the sounds emitted by the herd during playback. However, all significant changes between PrPb and PtPb, with the exception of one sound, were also decreases and may indicate that the overall decrease of sound production observed between PrPb and Pb was the true situation. There was no strong specific response elicited from the Saguenay herd by any one of the New York Aquarium sounds such as was observed from the captive animals in response to playback of the Harmonic LLW.

Table 9. Significant increases and decreases in frequency of emission of four sound types and total sounds during and after playback of FldPBS 2,3,4,6,9, and 10 to the Saguenay herd.

			Sound Types Counted														
FldPBS	N	Period Change	Ping			Ring			Squeal			Click Train			Total Sounds		
			+	-	0	+	-	0	+	-	0	+	-	0	+	-	0
2		PrPb-Pb							0	7	3*	0	6	4*	0	9	1**
Buzzes	10	Pb-PtPb				6	0	4*									
		PrPb-PtPb															
3		PrPb-Pb															
Blare	12	Pb-PtPb				7	0	5*									
		PrPb-PtPb				8	1	3*									
4		PrPb-Pb													0	9	1**
Type-1	10	Pb-PtPb															
Squawk		PrPb-PtPb	0	9	1**										1	9	0*
6																	
Contact		PrPb-Pb										0	7	3*	1	9	0*
Sound-	10	Pb-PtPb													10	0	0**
Series		PrPb-PtPb										0	6	4*	1	8	1*
9		PrPb-Pb															
Pure	10	Pb-PtPb													8	0	2**
LLW		PrPb-PtPb															
10		PrPb-Pb	0	7	3*												
4.8 kHz	10	Pb-PtPb															
Pure Tone		PrPb-PtPb															

For a key to the symbols used, see Table 1.

Behavioral reactions.--There was no stereotyped overt behavioral reaction to any of the sounds from the captive animals that were played back to the free-swimming herd. When the herd was traveling up or down the river, the whales continued their transit. When they were milling about in a bay or quiet area, they neither approached nor withdrew from the boat. However, a gray animal, the gray color indicating a young whale, was sometimes observed close to the boat during or shortly after PtPb. It could not be determined whether or not this was always the same individual. This happened most frequently after playback of the Jaw Claps, being observed in five of the ten instances that this sound was used. With the other playback sounds, the most often that this event was recorded was one out of ten or two out of twelve repetitions.

Diving times.--Diving times were taken for single animals or for a single group of animals within the herd during each playback experiment. The mean dive times for each of the three periods, averaged over all repetitions of each sound, are presented in Table 10. Use of the modified t-test for unequal sample sizes and variances showed no significant changes in diving times in response to any of the playback sounds. The Jaw Claps were associated with the greatest change in the mean dive, showing a trend toward increase in length of dive in Pb, followed by a decrease in PtPb to PrPb levels. Neither of these trends were statistically significant.

To obtain a mean overall diving time for the beluga, the diving times recorded during all PrPb periods (761 dives) were averaged. This mean dive for an undisturbed, free-swimming beluga was found to be 25.7 seconds.

Table 10. Mean diving times of a single or single group of belugas before, during, and after playback of the FldPBS playback series.

FldPBS	PrPb	Pb	PtPb
Harmonic LLW	28.13	21.83	18.03
Buzzes	20.71	18.88	16.58
Blare	18.18	21.88	17.95
Type-1 Squawk	27.50	19.14	26.18
Contact Sound-Series	28.18	31.93	39.71
Jaw Claps	23.65	41.77	24.07
Type-2 Squawk	32.36	25.00	25.19
Pure LLW	37.78	25.81	20.54
4.8 kHz Pure Tone	27.56	24.51	17.88

Each figure represents the mean duration (in seconds) of all dives during that period for all repetitions of that FldPBS.

II. Playback of Sounds Recorded From the Saguenay Herd

A. Playback to the Saguenay River herd

Vocal reaction.--Table 11a shows the significant vocal changes that occurred during playback of the SagPBS playback series to the wild herd in 1970. Table 11b shows the same for the playbacks of 1971. The complete data for both years are presented in Appendices VIIa and VIIb, respectively. None of the significant changes of 1970 were repeated in 1971, although it is believed that the same herd was involved both years. However, all changes of significance involved decreases in sound production, whether in Pb or in PtPb. Once again, the playback sounds may have masked sounds being made by the whales during Pb, but the overall decreases shown in PtPb (to below the levels of PrPb or Pb) suggest that the overall reaction in most cases was a decrease in sound production.

Behavioral reactions.--Observations were recorded concerning any whale or whales coming toward or retreating from the boat, any deviation in the path of the animals in the cases when they were traveling up- or down-river, and any pause in such a transit. Table 12 is a summary of these observations, summed over the two years of field playbacks. The playback situations were divided into two categories: milling (circling or seemingly random swimming in a bay or estuary) or transiting (traveling up or down the river). Reactions to the playbacks of certain sounds were noted much more commonly when the animals were milling than when making their daily passage up and down the Saguenay River. A positive response (+) when milling indicates that at least some of the herd was headed directly toward the boat during Pb and/or early PtPb, and that

Table 11a. Significant increases and decreases in frequency of emission of three sound types during and after playback of SagPBS 1,3, and 6 to the Saguenay herd in 1970.

			Sound Types								
SagPBS	N	Period Change	Ping			Ring			Total Sounds		
			+	-	0	+	-	0	+	-	0
1 Moans	10	PrPb-Pb									
		Pb-PtPb									
		PrPb-PtPb							0	9	1**
3 Screams-and-Wails	12	PrPb-Pb				0	6	6*			
		Pb-PtPb									
		PrPb-PtPb									
6 Squeals	9	PrPb-Pb									
		Pb-PtPb									
		PrPb-PtPb	0	6	3*						

Table 11b. Significant increases and decreases in frequency of emission of two sound types during and after playback of SagPBS 1,3,6, and 7 to the Saguenay herd in 1971.

			Sound Types					
SagPBS	N	Period Change	Click Train			Total Sounds		
			+	-	0	+	-	0
1 Moans	10	PrPb-Pb	0	6	4*	0	8	2**
		Pb-PtPb						
		PrPb-PtPb	0	6	4*			
3 Screams-and-Wails	12	PrPb-Pb				1	10	1**
		Pb-PtPb						
		PrPb-PtPb						
6 Squeals	10	PrPb-Pb				1	8	1*
		Pb-PtPb						
		PrPb-PtPb						
7 Saguenay LLW	9	PrPb-Pb						
		Pb-PtPb						
		PrPb-PtPb	1	8	0*			

For a key to the symbols used, see Table 1.

Table 12. Approaches toward (+) and withdrawals from (-) the research boat during playback of the SagPBS playback series to the Saguenay herd in 1970 and 1971.

SagPBS	N_m	Milling			N_t	Transiting		
		+	-	0		+	-	0
Moans	6	3	1	2	15	1	0	14
Pings	9	1	2	6	11	0	1	10
Screams-and-Wails	22	15	1	6**	13	0	0	13
Blats-and-Ping	16	10	2	4*	14	2	0	12
Jaw Claps	19	13	0	6**	9	1	1	7
Squeals	9	2	1	6	15	7	0	8*
Saguenay LLW	4	1	0	3	8	0	0	8

N_m: number of repetitions of each SagPBS while the whales were milling

N_t: number of repetitions of each SagPBS while the whales were in transit up- or down-river those animals had not been so directed during PrPb. If in transit, a positive response indicates that the animals paused in transit during Pb or redirected their path toward the boat. A negative response (-) indicates that animals moved away from the boat when they had not done so in PrPb.

Three playback sounds often drew the whales toward the boat when milling: the Screams-and-Wails, the Blats-and-Ping, and the Jaw Claps (see Appendix II for descriptions). The Screams-and-Wails playback was an extended series of sounds, and the Blats-and-Ping playback included three 'blats' and one 'ping'. During playback of the Jaw Claps recorded from the New York Aquarium population, only young gray-colored whales had approached the boat. The response to the Jaw Claps recorded from the Saguenay animals was elicited from both young and adults. The only one of the seven sounds that elicited a strong positive reaction when in transit was the Squeals.

Diving times.--Use of the modified t-test for unequal sample sizes and variances showed no significant differences in the mean dive times of PrPb, Pb, and PtPb for any of the seven playback sounds. The data, presented in Table 13, were obtained only from the playback experiments performed in 1970. Although diving times were taken in 1971, many were judged unreliable because of the poorer sighting conditions of 1971 and the attendant questionability of observing the same animal or group of animals throughout the nine-minute experiment.

B. Playback to three captive animals

In 1970, Alex was separated from the other three animals and placed in a separate tank. This was done to prevent him from being in-

Table 13. Mean dive times of a single or single group of belugas before, during, and after playback of the SagPBS playback series.

SagPBS	PrPb	Pb	PtPb
Moans	26.47	28.05	29.09
Pings	23.39	21.15	24.44
Screams-and-Wails	34.02	31.27	24.77
Blats-and-Ping	25.15	24.13	21.82
Jaw Claps	20.29	19.44	29.22
Squeals	20.21	20.33	22.15
Saguenay LLW	29.67	24.52	29.33

Each figure represents the mean duration, in seconds, of all dives during that period for all repetitions of that SagPBS.

jured by Blanchon, the dominant male, and to enable the start of a training program with Alex. The sounds from the Saguenay herd were played back to the three animals remaining in the large beluga tank, and also to Alex alone in the separate pool.

It was immediately apparent when working with the three belugas, that Alex had been either the most vocal of the four whales when they were all together, or that his presence had caused more vocalizations from the other three animals. Overall numbers of sounds were much lower in the group tank after Alex' removal. In fact, Alex was found to be more vocal alone than were the other three belugas together.

Vocal reaction.--There were no significant changes (see Appendix VIII) in the vocal emissions of Blanchon, Frances, and Ethel in response to any of the Saguenay playback sounds.

Changes of interest directed toward hydrophone and sound source.--A summary of the significant changes of interest directed toward the hydrophone and sound source by all three whales considered together is presented in Table 14. The complete data for all seven sounds are presented in Appendix IX. As shown in columns one and three of Table 14, there were no significant changes of interest shown toward the hydrophone in reaction to any of the Saguenay playback sounds. Orientation toward the sound source increased significantly in Pb for five of the Saguenay sounds, the exceptions being the Moans and the Screams-and-Wails. These increases were all followed by decreases in PtPb. No significant changes in approaching or touching the sound source were elicited.

Table 15a shows the total number of times, summed over all repetitions of each SagPBS, a whale or whales oriented toward or approached

Table 14. Significant increases and decreases of interest directed toward hydrophone and sound source during and after playback of SagPBS 1-7 to three captive belugas.

SagPBS	N	Period Change	Orient Toward Hydrophone			Orient Toward Sound Source			Approach Hydrophone			Approach Sound Source		
			+	-	0	+	-	0	+	-	0	+	-	0
1		PrPb-Pb												
Moans	10	Pb-PtPb												
		PrPb-PtPb												
2		PrPb-Pb				8	0	2**						
Pings	10	Pb-PtPb				0	7	3**						
		PrPb-PtPb												
3		PrPb-Pb												
Screams-and-Wails	10	Pb-PtPb												
		PrPb-PtPb												
4		PrPb-Pb				7	0	3*						
Blats-and-Ping	10	Pb-PtPb												
		PrPb-PtPb												
5		PrPb-Pb				8	0	3**						
Jaw Claps	11	Pb-PtPb				0	6	5*						
		PrPb-PtPb												
6		PrPb-Pb				8	0	2**						
Squeals	10	Pb-PtPb				0	8	2**						
		PrPb-PtPb												
7		PrPb-Pb				7	0	3*						
Saguenay LLW	10	Pb-PtPb												
		PrPb-PtPb												

For a key to the symbols used, see Table 1.

Table 15a. Total number of times interest was shown by all three captive whales toward the hydrophone and sound source, summed over all repetitions of each SagPBS.

SagPBS	N	Orient Toward Hydrophone			Orient Toward Sound Source			Approach Hydrophone			Approach Sound Source		
		PrPb	Pb	PtPb	PrPb	Pb	PtPb	PrPb	Pb	PtPb	PrPb	Pb	PtPb
Moans	10	0	0	0	1	8	1	0	0	0	5	10	8
Pings	10	0	0	0	1	14	3	1	1	1	4	7	4
Screams-and-Wails	10	0	0	0	0	10	0	3	1	1	3	8	2
Blats-and-Ping	10	0	0	0	1	11	3	1	2	1	4	9	5
Jaw Claps	11	0	0	0	0	12	3	2	1	2	2	8	3
Squeals	10	0	0	0	2	16	0	1	2	0	7	7	4
Saguenay LLW	10	0	0	0	0	17	7	0	0	0	0	2	2

Table 15b. Summary of the number of playback sounds that elicited increases and/or decreases of interest directed toward hydrophone and sound source from all three whales.

Period Change	Orient Toward Hydrophone			Orient Toward Sound Source			Approach Hydrophone			Approach Sound Source		
	+	-	0	+	-	0	+	-	0	+	-	0
PrPb-Pb	0	0	7	7	0	0*	2	2	3	6	0	1*
Pb-PtPb	0	0	7	0	7	0*	1	2	4	0	6	1*
PrPb-PtPb	0	0	7	4	1	2	0	2	5	4	2	1

The changes of interest shown in Table 15a are summarized in Table 15b. For a key to the symbols used, see Table 1.

the hydrophone or sound source. The whales oriented toward the sound source more often in Pb than in PrPb in response to all seven playback sounds (Table 15b), and approached the sound source more often in Pb in response to all sounds except the Squeals. There were no significant changes associated with either orienting toward or approaching the hydrophone. Again, as was the case when the sounds from the captive animals were played back to the four captive animals, the overall pattern was an increase of interest in the sound source in Pb, regardless of which sound was being played back, followed by a decrease of interest in PtPb.

Considering each beluga separately, no whale showed any significant changes of interest toward the hydrophone, but all three increased interest in the sound source in Pb and decreased interest again in PtPb in response to all seven sounds. Thus, the overall pattern of increased interest in the sound source in Pb (Table 15a,b) was shared by all three whales.

In Table 16 is shown the strength of the increases of interest in the sound source during Pb for each whale in response to each sound. None of the sounds caused a consistently greater increase of interest than any of the others.

Behavioral reactions.--Although there were no consistent behavioral reactions observed to any single Saguenay sound, a series of sexual encounters that may have been induced by the playbacks was observed on February 26, 1971. On that date, successive presentation of five different Saguenay sounds, each presentation separated from the last by at least 25 minutes, was associated with sexual behavior directed from Blanchon toward Frances. In all cases Blanchon initiated the interac-

Table 16. Strengths of the changes of interest from PrPb to Pb directed toward the sound source by each whale in response to each playback sound.

SagPBS	N	Blanchon	Frances	Ethel	Total
Saguenay LLW	10	7	6	6	19
Jaw Claps	11	6	5	7	18
Pings	10	7	3	6	16
Screams-and-Wails	10	5	5	5	15
Blats-and-Ping	10	9	4	2	15
Squeals	10	5	3	6	14
Moans	10	5	6	1	12

tion, and in all cases Frances seemed unreceptive. At 1110 hours, during the PtPb period of the playback of the Pings, Blanchon attempted intromission with Frances. This caused emission of a Contact Sound-Series as Frances drew away and Blanchon followed, swimming upside-down under her. At 1145 hours, the Blats-and-Ping was played back and Blandhon's penis erected fully in late PtPb.

The Screams-and-Wails, the Squeals, and the Moans were presented at 1235 hrs., 1325 hrs., and 1425 hrs. respectively, and attempted intromissions occurred in late Pb or in PtPb in all three cases. The attempt elicited by the Moans seemed less intense and was not followed by the Contact Sound-Series as was the case after the Screams-and-Wails and the Squeals. Following this less intense attempt, Blanchon emitted a 'hissing' type of sound, rapidly turned over, and emitted bubbles from his blowhole. As these events occurred, jerking movements were observed around the penis, and ejaculation may have occurred. The sixth sound played back, at 1520 hrs., was the Harmonic LLW originally recorded from Alex, the adult male that had previously been in the tank with Blanchon, Frances, and Ethel. There was no indication of sexual behavior in reaction to this playback, but Blanchon became very excited, swimming rapidly around the tank in Pb and early PtPb. During PrPb he had been lying quietly on the bottom of the tank, and in late PtPb he seemed to calm down, swimming more slowly around the tank. These sounds were played back repeatedly to these same whales in July and November of 1971, but no sexual behavior was observed during any of these playback experiments.

C. Playback to one captive animal.

Vocal reaction.--Two of the sounds recorded from the Saguenay herd, the Screams-and-Wails and the Squeals, elicited one response each at the .05 level of significance. When the Screams-and-Wails was played back, the number of Harmonic LLW's emitted by Alex increased in Pb. Upon playback of the Squeals, the total number of sounds emitted decreased in PtPb to less than in Pb. Complete sound count data for the playback of the SagPBS series to Alex are presented in Appendix X.

Changes of interest directed toward hydrophone and sound source.--The only significant change of interest in the equipment elicited from Alex during this playback series was an increase in orientation toward the sound source during Pb of the Jaw Claps playbacks. The complete summary of interest changes in response to the SagPBS series is given in Appendix XI.

The number of times Alex oriented toward or approached the hydrophone or sound source during the three experimental periods, summed over all repetitions of each sound, is presented in Table 17a. The results are summarized for the seven sounds in Table 17b. This table shows a change in a significant proportion of the seven sounds only with respect to orientation toward the sound source, with orientation increasing in response to all seven Saguenay playback sounds during Pb.

Behavioral reactions.--There were no consistent behavioral patterns observed in reaction to any one of the SagPBS series, nor to this group of sounds as a whole.

Activity as measured by number of tank circuits.--The total number of times that Alex circled his tank during PrPb, Pb, and PtPb of each playback, summed over all repetitions, is presented in Table 18.

Table 17a. Total number of times interest was shown by Alex toward the hydrophone and sound source, summed over all repetitions of each SagPBS.

SagPBS	N	Orient Toward Hydrophone			Orient Toward Sound Source			Approach Hydrophone			Approach Sound Source		
		PrPb	Pb	PtPb	PrPb	Pb	PtPb	PrPb	Pb	PtPb	PrPb	Pb	PtPb
Moans	11	2	1	2	1	5	3	4	4	4	7	10	7
Pings	11	0	0	1	0	2	4	4	3	4	9	15	8
Screams-and-Wails	11	0	1	5	3	6	5	5	5	6	13	12	14
Blats-and-Ping	11	1	1	0	2	4	1	6	6	4	9	12	13
Jaw Claps	11	0	2	0	4	13	7	5	4	3	13	10	9
Squeals	10	1	5	2	1	4	5	6	3	1	10	9	10
Saguenay LLW	11	0	2	2	3	4	0	6	10	7	8	6	10

Table 17b. Summary of the number of playback sounds that elicited increases and/or decreases of interest directed toward hydrophone and sound source from Alex.

Period Change	Orient Toward Hydrophone			Orient Toward Sound Source			Approach Hydrophone			Approach Sound Source		
	+	-	0	+	-	0	+	-	0	+	-	0
PrPb-Pb	4	1	2	7	0	0*	1	3	3	3	4	0
Pb-PtPb	3	3	1	2	5	0	2	4	1	4	3	0
PrPb-PtPb	4	1	2	5	2	0	2	3	2	3	2	2

The changes of interest shown in Table 17a are summarized in Table 17b. For a key to the symbols used, see Table 1.

Table 18. Total number of circuits of the tank completed by Alex during the SagPBS playback experiments.

		Number of Tank Circuits		
SagPBS	N	PrPb	Pb	PtPb
Moans	11	13.50	24.50	30.25
Pings	11	19.50	30.00	25.75
Screams-and-Wails	11	22.50	29.25	30.75
Blats-and-Ping	11	25.50	32.50	27.50
Jaw Claps	11	20.33	24.00	32.50
Squeals	10	17.00	25.50	19.00
Saguenay LLW	11	26.50	34.25	25.25

These totals show that Alex' activity increased during playback for all seven Saguenay sounds. With six of the seven, activity remained higher in PtPb than in PrPb.

III. Playback of Synthesized Sounds to a Single Captive Animal

A series of nine synthesized sounds (SynPBS 1-9), recorded from a pure-tone oscillator and based on the Harmonic LLW that elicited the strong vocal response from Alex, was played back in random order to Alex in his separate tank. The frequency and temporal characteristics of these sounds are presented in Appendix III. The Harmonic LLW was used as the control sound in this series.

Vocal reaction.--Table 19 summarizes the Harmonic LLW reactions to these playbacks having probabilities less than 0.1, with respect to the frequencies and durations used. The complete frequency of emission data are presented in Appendix XII. The Harmonic LLW control induced a highly significant increase of emission of the Harmonic LLW during Pb, followed by a decrease of emission in PtPb.

Since the frequencies of greatest energy content in the natural Harmonic LLW were about 4.8 and 2.4 kHz, these were two of the frequencies used in the synthesized sounds. Both of these frequencies produced highly significant increases of Harmonic LLW emissions during Pb when presented at a 30-second duration, followed by an equally significant decrease in PtPb.

The third frequency used for synthetic playbacks was 3.3 kHz, an atypical frequency in the sense that the Harmonic LLW was never emitted

Table 19. Changes in number of emissions of the Harmonic LLW by Alex in response to the SynPBS playback series having probabilities with $p < 0.1$

	Duration		
Frequency	30 sec.	2.7 sec.	1.7 sec.
4.8 kHz	PrPb-Pb, incr., p=.002** Pb-PtPb, decr., p=.004**	NONE	Pb-PtPb, decr., p=.070
2.4 kHz	PrPb-Pb, incr., p=.002** Pb-PtPb, decr., p=.002**	Pb-PtPb, decr., p=.062	PrPb-Pb, incr., p=.016* Pb-PtPb, decr., p=.070
3.3 kHz	(Pb-PtPb, decr., p=.032*)	(PrPb-Pb, incr., p=.008**)	PrPb-Pb, incr., p=.062 (PrPb-Pb, incr., p=.002**) (Pb-PtPb, decr., p=.008**)

NOTE: see text for explanation of meaning of figures in parentheses.

at this frequency. Synthetic 3.3 kHz sounds were played back only six times at each duration and are thus difficult to compare statistically with the natural-frequency playbacks, which were played back 11 or 12 times each. Treating only the data observed from the 6 playbacks, there were no significant increases or decreases of Harmonic LLW's in Pb or PtPb, respectively, for the 3.3-kHz, 30-sec. playback. However, if the trend shown in the 6 experiments completed were to continue for an additional 6 experiments, a significant decrease would appear from Pb to PtPb. Such projected data in Table 19 are noted by being presented in parentheses.

At the 2.7-second duration (the mean of the natural sound), the 2.4 kHz synthetic sound elicited a tendency toward decrease of emission in PtPb. The 4.8 kHz sound at this duration showed no tendency to elicit a reaction from Alex. The 3.3 kHz, 2.7 sec. playback, with respect to the 6 playbacks completed also showed no tendency to elicit a reaction, but when projected to a repetition of 12 experiments, would have been expected to elicit a highly significant increase from PrPb to Pb.

The third duration used in the synthetic-sound series was 1.7 seconds (the mode of the natural sound). The 4.8 kHz playback at this duration elicited a tendency toward decreasing emission in PtPb. The 2.4 kHz playback elicited a significant increase in Pb and a tendency toward decrease again in PtPb. The 1.7-second, 3.3-kHz playback elicited a tendency toward an increase in number of Harmonic LLW emissions during Pb when only the 6 completed playbacks were considered. When projected to a repetition of 12 playbacks, these data would have been expected to show a highly significant increase in Pb, and a highly significant decrease in PtPb.

In Table 20 are presented the average durations of the Harmonic LLW's emitted during PrPb, Pb, and PtPb for each sound of the SynPBS series. Use of the modified t-test for unequal variances and sample sizes showed that no significant changes of duration of the Harmonic LLW were elicited by any of the durations or frequencies used.

Changes of interest directed toward hydrophone and sound source.--There were no significant changes of interest with respect to the hydrophone in reaction to the SynPBS playback series or to the control Harmonic LLW. One significant change was elicited toward the sound source; SynPBS-1 (4.8 kHz, 30 sec.) caused an increase in orientation toward the sound source in Pb. The complete summary of interest changes in response to the SynPBS series is given in Appendix XIII.

Table 21a shows the total number of times, summed over all repetitions of each SynPBS, that Alex either oriented toward or approached the hydrophone or sound source. Table 21b shows the number of the nine playback sounds that elicited changes of interest. These tables show that the only significant changes were in orientation toward the sound source, where eight of the nine sounds elicited increases during Pb, with seven of these being followed by decreases in PtPb. However, contrary to what was shown in response to the SagPBS playbacks, interest in PtPb was generally lower than the level shown in PrPb. Interest directed toward the hydrophone remained relatively constant throughout.

Behavioral reactions.--There were no consistent behavioral changes noted in reaction to any sounds of the SynPBS series.

Activity as measured by number of tank circuits.--Alex' number of circuits of the tank increased significantly during Pb in reaction to SynPBS-1 (4.8 kHz, 30 sec.), and decreased significantly during Pb

Table 20. Average durations of Harmonic LLW's emitted by Alex in each period of the SynPBS series of playbacks.

	Mean Duration					
	PrPb		Pb		PtPb	
SynPBS	n	sec.	n	sec.	n	sec.
4.8 kHz 30 sec.	10	2.31	74	2.38	15	2.30
2.4 kHz 30 sec.	50	2.88	115	3.33	32	2.22
4.8 kHz 1.7 sec.	14	1.68	42	2.71	13	1.80
2.4 kHz 1.7 sec.	9	1.66	23	1.63	12	4.13
2.4 kHz 2.7 sec.	29	1.69	39	2.10	10	1.36
4.8 kHz 2.7 sec.	18	1.66	57	2.17	31	4.40
3.3 kHz 30 sec.	2	1.40	6	1.87	0	----
3.3 kHz 1.7 sec.	1	1.70	15	1.49	2	1.20
3.3 kHz 2.7 sec.	0	----	15	1.95	5	1.38
Harmonic LLW	6	1.75	98	2.35	27	2.68

n represents the number of sounds used to obtain each average (mean), and consequently the number of Harmonic LLW's emitted during each period.

Table 21a. Total number of times interest was shown by Alex toward the hydrophone and sound source, summed over all repetitions of each SynPBS.

SynPBS	N	Orient Toward Hydrophone			Orient Toward Sound Source			Approach Hydrophone			Approach Sound Source		
		PrPb	Pb	PtPb	PrPb	Pb	PtPb	PrPb	Pb	PtPb	PrPb	Pb	PtPb
4.8 kHz 30 sec.	11	1	0	0	2	13	4	0	0	0	10	11	17
2.4 kHz 30 sec.	12	0	1	1	4	10	2	2	2	3	10	9	8
4.8 kHz 1.7 sec.	12	2	1	1	3	7	1	2	1	0	7	10	8
2.4 kHz 1.7 sec.	12	0	0	0	7	10	4	4	2	1	7	10	9
2.4 kHz 2.7 sec.	12	1	0	1	2	3	0	2	1	0	7	13	9
4.8 kHz 2.7 sec.	12	0	2	1	3	2	2	1	1	2	14	11	12
3.3 kHz 30 sec.	6	0	0	0	0	3	0	0	0	3	0	1	2
3.3 kHz 1.7 sec.	6	0	0	0	0	1	1	1	0	1	6	5	1
3.3 kHz 2.7 sec.	6	0	0	0	0	2	0	3	2	2	5	3	2
Harmonic LLW	13	1	4	1	5	9	5	0	1	1	12	8	11

Table 21b. Summary of the number of playback sounds that elicited increases and/or decreases of interest directed toward hydrophone and sound source from Alex.

Period Change	Orient Toward Hydrophone			Orient Toward Sound Source			Approach Hydrophone			Approach Sound Source		
	+	-	0	+	-	0	+	-	0	+	-	0
PrPb-Pb	2	3	4	8	1	0*	0	5	4	5	4	0
Pb-PtPb	1	1	7	0	7	2*	4	3	2	2	7	0
PrPb-PtPb	2	2	5	2	5	2	3	4	2	4	5	0

The changes of interest shown in Table 21a are summarized in Table 21b. For a key to the symbols used, see Table 1. NOTE: The lower table does not include the control sound (Harmonic LLW).

in reaction to SynPBS-4 (2.4 kHz, 1.7 sec.). During PtPb of SynPBS-4, the number of tank circuits remained lower than the level during PrPb in a significant number of repetitions. Also, during the playbacks of SynPBS-2 (2.4 kHz, 30 sec.), the number of tank circuits decreased in PtPb to below the number during Pb in a significant number of repetitions.

The overall tendency, when total number of circuits during all repetitions of each sound were compared (Table 22), was an increase of activity in Pb and a decrease in PtPb.

Table 22. Total number of circuits of the tank completed by Alex during the SynPBS playback experiments.

		Number of Tank Circuits		
SynPBS	N	PrPb	Pb	PtPb
4.8 kHz 30 sec.	11	14.25	24.25	19.50
2.4 kHz 30 sec.	12	15.00	21.00	14.25
4.8 kHz 1.7 sec.	12	18.50	19.00	16.25
2.4 kHz 1.7 sec.	12	26.75	18.00	16.75
2.4 kHz 2.7 sec.	12	14.00	14.50	13.50
4.8 kHz 2.7 sec.	12	15.75	15.33	8.50
3.3 kHz 30 sec.	6	11.25	15.25	9.50
3.3 kHz 1.7 sec.	6	9.50	14.33	11.50
3.3 kHz 2.7 sec.	6	7.50	12.75	16.00
Harmonic LLW	13	9.50	22.00	15.50

DISCUSSION

I. Playback of Sounds Recorded From the Captive Animals

A. Playback to captive animals at the New York Aquarium

Vocal reaction.--The most significant vocal response elicited by any of the playback sounds was that elicited from Alex upon playback of the Harmonic LLW. This sound was originally recorded from Alex in 1968 and was seldom heard during later recording sessions except in response to the playback.

Altogether, it was played back to Alex 27 times: 11 when Frances, Ethel, and Blanchon were also present, and 16 when isolated in his separate tank. During these 27 playbacks Alex increased the number of Harmonic LLW's emitted during Pb 23 times, never decreased the number emitted, and made no changes four times. These results were highly significant by the two-tailed sign test. With regard to PtPb as compared with Pb, there were three further increases, 20 decreases, and four no-changes. This was also highly significant by the sign test. Finally, in comparing PrPb and PtPb, it was found that the positive response was significantly carried over into PtPb from Pb so that the number of Harmonic LLW's remained higher than in PrPb in 15 of the 27 cases, with three repetitions showing decreases, and nine showing no change.

The Harmonic LLW was never heard from the free-swimming herd in the Saguenay River, nor did it elicit any reaction from the Saguenay animals. It also was not recorded from any of the other animals held captive at the New York Aquarium, and did not elicit a vocal response from any of them.

The biological significance or 'meaning' of the Harmonic LLW is not known, but it seemed to occur in situations that might have been described in humans as productive of 'impatience' or 'expectation', such as at the expected time of feeding or before times of training sessions or public exhibitions. The very fact that it occurred so seldom, but was so uniformly elicited by playback of the same sound, suggested that it oocurred only in a very specific context. This was in sharp contrast to such commonly occurring sounds as the shorter less strident 'whistle' which was heard at any time of day and under almost any circumstance. Also, since the effect of the Harmonic LLW playback carried over into PtPb, it can be assumed that the effect on Alex was not merely that of a stimulus-response reflex action, but was instead an increase in his overall level of arousal that continued after cessation of the initiating stimulus.

The Contact Sound-Series was an extended combination of various sound types (Barks, Squawks, Jaw Claps, Whistles, Squawls, Buzzes, Whinnys, and Chirps) emitted at times of physical contact or close proximity between two or more whales, or at times of major disturbance. Apparently the Contact Sound-Series was indicative of a high state of arousal. Further, the specific sounds responsible for conveying this context may have been the Squawk and the Jaw Clap, two of the more prominent sounds occurring at the time of maximum disturbance during the emission of the Contact Sound-Series (Morgan, 1970). Playback of a Contact Sound-Series to the captive animals resulted in increased emission of the Contact Sound-Series, with the usual inter-individual contact, during the Pb period (Table 1). This response could have been elicited in two ways. First, the playback might have merely increased the level of activity in the tank by conveying a disturbance context to the animals, thereby increasing the chances for inter-individual contact. In this manner the playback would have indirectly increased the incidence of Contact Sound-Series, its direct effect having been an increase of activity within the enclosed area of the tank. Secondly, the playback might have directly initiated contact between individuals. It is not known which of these two mechanisms produced the observed reaction, but the data on interest directed toward the hydrophone and sound source support the latter. Approach toward both pieces of equipment decreased in Pb (Table 3, Appendix V), indicating that this interest was directed elsewhere in the tank, possibly at the tankmates.

The other vocal changes noted during playback of the Contact Sound-Series were decreases in the number of Jaw Claps not involved in a Contact Sound-Series, and Total Sounds emitted during playback (Table 1). The latter change might have been expected as a secondary effect of the increase of Contact Sound-Series since the Contact Sound-Series was a relatively long sound emission, thus leaving less time for the production of other sounds. The Jaw Clap was one of the sounds included in the Contact Sound-Series, and thus its emission was included in the count of Contact Sound-Series rather than as a separate sound emission.

However, the three other sounds nearly always found associated with the Contact Sound-Series, the Squawk, the Whistle, and the Chirp, neither increased nor decreased significantly as separate sounds during playback of the Contact Sound-Series (Table 1, Appendix IV). Because of the context of emission of these three sound types, they would not have been expected to show such a decrease. The Squawk was not a common sound out of the context of the Contact Sound-Series. It was apparently a sound associated with a high state of arousal (Morgan, 1970) brought on by either fright or inter-individual contact or proximity, and was thus of uniform low occurrence as a separate sound in all playback experiments. The situation with regard to the Whistle and the Chirp was exactly the reverse. These sounds were associated with any disturbance, however slight, inside or outside the tank, and were thus taken as being indicative of a very low state of arousal when occurring alone (Morgan, 1970). They were of uniform high occurrence throughout most of the playback experiments and would not have been expected to decrease in occurrence during playback. They were also the 'finishing sounds' of nearly all Contact Sound-Series, seeming to occur for some time after the cessation of the Contact Sound-Series, much as a small bird will occasionally 'peep' while calming down after being frightened.

Changes of interest directed toward hydrophone and sound source.--Whenever any sound was played back to the captive whales the general, overall response was an increase of interest in the sound source during Pb with consequent decrease of interest in other objects in the tank. This was followed by a decrease of interest in the sound source in PtPb (Tables 2 and 3). Tables 4-7 demonstrate that this general reaction was true for all four belugas. This reaction showed some especially interesting relations existing between three separate sounds: the Buzz, the Whinny, and the Jaw Clap (refer to Table 2 for the following discussion). The Whinny was never observed to occur alone; it was always emitted in combination with the Buzz, and may have been incidental to the production of the Buzz. The Buzz was often heard without the accompanying Whinny. The PBS designated the Whinny was actually such a Buzz-and-Whinny combination, with the Whinny being louder relative to the Buzz than was generally the case. The Whinny was found to elicit significant increases, during Pb, of both orientation and approach toward the sound source, and also to elicit a decrease in total sound production in PtPb (Table 1). During PtPb there was a significant decrease of both orientation and approach toward the sound source. With the Buzzes alone, the only significant reaction observed was an increase in orientation toward the sound source in Pb. There was no significant change in vocal emissions in response to the Buzzes. The overall reaction of the animals to the Buzz was thus less than to the Whinny. When the Buzz-and-Whinny combination (with the Buzz being dominant, as was usually the case) was played back, the reaction seemed to be a combination of those seen in response to the Whinny and the Buzz separately (Table 2). Interest during Pb increased significantly with respect to both orientation and approach toward the sound source. This was followed by a decrease in orientation toward the sound source during PtPb, but not by a decrease in approaching the sound source such as was observed with the Whinny. Thus, interest remained higher in PtPb than in PrPb. Therefore the Buzz-and-Whinny combination was as effective or more effective with regard to increasing interest in the sound source than were either of the component sounds alone, and produced a longer-lasting effect, carrying over into PtPb.

The Jaw Clap, when played back to the four captives, produced no significant changes of interest toward the sound source. When a combination of the Jaw Clap, the Buzz, and the Whinny was played back, there was also no significant changes of interest observed toward the sound source (Table 2). Thus, the Jaw Clap inhibited the effect of the Buzz-and-Whinny. In fact, the Jaw Clap-Buzz-and-Whinny combination was one of only 2 sounds of the 13 in the PBS series that showed a trend toward producing a decrease of interest in the sound source during Pb (Table 3a). The other sound showing this tendency was the Contact Sound-Series which, like the Jaw Clap-Buzz-and-Whinny combination, was a combination of various sound types, was of relatively longer duration, and included the Jaw Clap. As discussed above (p. 51), the Contact Sound-Series may have affected the whales by redirection of interest from sound source to tankmates. Perhaps a similar response to the Jaw Clap-Buzz-and-Whinny combination was responsible for the decrease of interest shown toward the equipment during playback of that sound also. There was, however, no vocal response associated with playback of the Jaw Clap-Buzz-and-Whinny combination such as occurred in the case of the Contact Sound-Series playbacks (Table 1).

One of the major differences between the two types of sound series just mentioned was the occurrence of the Squawk as a dominant sound in the Contact Sound-Series, while Squawks did not occur in the Jaw Clap-Buzz-and-Whinny combination. When two types of Squawks were played back to the four belugas, interest toward the sound source increased significantly during Pb in reaction to both sounds (Table 2), and there was no vocal reaction to either sound. The two dominant sounds of the Contact Sound-Series were the Jaw Clap and the Squawk. The Jaw Clap caused no changes of interest in the equipment and no vocal changes. When these two sounds were combined in the context of the Contact Sound-Series and played back to the animals, approach toward the sound source decreased, and number of emissions of Contact

Sound-Series during Pb increased significantly. Once again, this shows the inhibitory effect of the Jaw Clap on interest in the sound source, perhaps by redirection of interest toward tankmates. This reaction also suggests that the Squawk, when added to an extended series of sounds including the Jaw Clap, elicited physical contact or close proximity leading to the emission of a Contact Sound-Series by the animals involved.

The inhibitory effect of the Jaw Clap on the Buzz-and-Whinny is further demonstrated in Table 8, which shows the strengths of the changes from PrPb to Pb associated with each sound for each animal. The Buzz, the Whinny, and the Buzz-and-Whinny produced large changes, while the Jaw Clap-Buzz-and-Whinny combination showed the least response toward the equipment for all four whales.

These intersound relationships may be summarized in the following manner:

(1) Combinations of sounds apparently had a different significance for the belugas than did the component sounds by themselves. This was seen with the Buzz-and-Whinny combination, which had a longer lasting effect than either the Whinny or the Buzz, and with the Jaw Clap-Buzz-and-Whinny combination, where the addition of the Jaw Clap inhibited the reaction to the Buzz-and-Whinny. This effect was further shown with the Contact Sound-Series, which elicited an increase in number of Contact Sound-Series emitted in Pb with a consequent tendency toward decreased interest in the sound source. The Squawk alone elicited no increase in vocalizations, and increased interest in the sound source. The Jaw Clap alone elicited no response at all. Both Squawk and Jaw Clap are components of the Contact Sound-Series.

Thus the syntax of the sounds presented was important in the conveyance of the significance of the sounds, probably by placing the sounds in a meaningful context.

(2) The Contact Sound-Series and the Jaw Clap-Buzz-and-Whinny combination were the only two playbacks that showed a tendency toward eliciting decreased interest in the sound source during Pb. Both were series of sounds, with inclusion of the Jaw Clap, and both were of relatively long duration. These results suggest that interest in the tank was directed somewhere other than the sound source. In the case of the Contact Sound-Series, the interest was directed toward the tankmates and it is possible that this mechanism was also the reason for the reaction to the Jaw Clap-Buzz-and-Whinny combination. However, the increase in emission of the Contact Sound-Series did not occur in reaction to the Jaw Clap-Buzz-and-Whinny. Since the major difference between these two series was the omission of the Squawk as a dominant sound from the Jaw Clap-Buzz-and-Whinny combination, it is suggested that the Squawk, in association with a series of sounds, increased levels of arousal in the tank to the point where contact or near-contact was made between animals, leading to emission of a Contact Sound-Series.

B. Playback to the Saguenay River herd

<u>Vocal reaction</u>.--As stated in the results, there was no specific vocal response elicited from the Saguenay animals by playback sounds recorded from the New York Aquarium population. The significant vocal changes that did occur (Table 9) were associated with the general pattern of decreasing emissions during Pb, increasing emissions during PtPb, and an overall decrease from PrPb to PtPb. The decrease in Pb

and the increase in PtPb may have been associated with the experimental arrangement used during the field playbacks. The sound source was close enough to the hydrophone that the sounds played back could have masked the sounds being made concurrently by the whales. This problem could have caused the apparent decrease in Pb and increase in PtPb. The fact that several sounds did decrease from PrPb to PtPb, however, indicates that the decrease during Pb may have been real.

Behavioral reactions.--There were no significant behavioral reactions observed to the playback of any of the 'captive' sounds to the free-swimming animals, nor were there any significant changes of duration of diving times (Table 10). Either these sounds carried no significance for these animals or, conversely, whatever significance was normally associated with each sound was not conveyed to the animals in the conditions under which the playbacks were carried out. Morgan (1970) suggested four possible reasons to explain the absence of behavioral reaction. These are:

(1) The background noise levels in the recordings from the aquarium tank may have masked the sounds or affected their 'reliability' to the animals.

(2) The sounds themselves may have been modified by the standing waves or multiple echoes in the concrete aquarium tank, thus affecting their 'reliability' to the unrestrained animals.

(3) The sounds produced by the captive belugas may have been modified by the animals themselves during their period of captivity.

(4) Animals from different localities or herds may have differ-

ent dialects.

All four of these possibilities concern the suggestion that the sounds, as presented to the animals, carried no significance due to modification by the tank conditions or the animals, or by being unfamiliar sounds. The fact that a young animal was observed close to the boat during or shortly after playback is puzzling, but may be regarded as supportive evidence for 1-3 above. This reaction, if indeed it was a reaction, was observed most often after playback of the Jaw Clap, an abrupt, loud 'crack' or 'bang' usually associated in the beluga with rapid closing of the jaws. This sound has been associated with alarm or threat in several cetacean species (Wood, 1953; Caldwell, Haugen, and Caldwell, 1962; Fish and Mowbray, 1962), including the beluga. There were no frequency variations or amplitude modulations associated with this sound, and it probably conveyed its meaning by being a very loud sound with a sharp onset. When heard in the Saguenay River, the Jaw Clap resembled a rifle shot and dominated any other sounds being emitted at the same time. Since this sound did not rely upon subtle frequency variations or amplitude modulations to convey its significance, it, of all the aquarium sounds used, would have been the least modified by standing waves or background noise.

With reference to the nearness of the younger whales after playback of the Jaw Claps, perhaps they were less able to determine the 'reliability' or 'unreliability' of sounds than were the adult whales. Thus, it would have been expected that if any reaction was to have been elicited by the playback of sounds recorded in aquaria, it would have been from the younger animals and in reaction to the least modified of the sounds. If true, this would mean that learning plays a part in the developing effectiveness of the sonic system of the beluga.

There are two more possibilities that could have accounted for the absence of any reaction to the aquarium sounds, both having to do with the idea that although the sound types may have been familiar, and not modified before or during playback, the normal significance of the sounds was not conveyed in the conditions under which they were played back:

(5) The significance of the sounds may have been context-specific. That is, they may have had no meaning to the animals if not received in the same context in which they were produced.

(6) The sounds may have had to be presented within a particular syntax, at the same time dependent upon context, in order to be of significance.

If either of these possibilities was the case, a weaker or no reaction would have been expected to the playback of single sounds recorded in captivity. As was suggested above (p.56), syntax may well have been of importance in the effectiveness of information transfer. Evidence that context was also important will be presented in the following section of this paper.

II. Playback of Sounds Recorded From the Saguenay Herd

A. Playback to the Saguenay River herd.

Vocal reaction.--None of the seven sounds recorded from the Saguenay River herd that were used as playbacks elicited a consistent vocal reaction from these same animals. All of the few significant changes during the playbacks of both 1970 and 1971 (Tables 11a and 11b, respectively) were decreases in numbers of sounds emitted in Pb or PtPb as compared with PrPb. As was discussed above, the decreases that occurred between PrPb and Pb could have been due to the close proximity of hydrophone and sound source. However, as was the case with the sounds from the captive animals, decreases were also observed between PrPb and PtPb, and these are regarded as a reaction to the playback sounds. Since the results can not be attributed to one particular sound, but were all decreases in sound emissions, it seems that the belugas reacted to extraneous sounds in their environment by decreasing the number of sounds that they emitted themselves. This interpretation was supported by the observation that the vocal activity of the free-swimming belugas decreased markedly in the presence of the noise from passing boats. This decrease was noted well in advance of the time the boats approached the beluga herd.

Behavioral reactions.--The behavioral reactions to the playbacks depended on the context in which the sounds were played back (Table 12). Three sounds drew the whales toward the research boat a significant number of times when the animals were milling in a bay or estuary, but had no effect when the whales were traveling up or down the river. On the other hand, one sound was found effective in drawing the whales toward the boat during transit, but had no effect while they were milling. No sound was found effective in both the milling and the transiting contexts, and no sound elicited a significant change in durations of dives (Table 13).

Two of the sounds that attracted the whales while milling were in reality combinations of sounds (Table 12). The Blats-and-Ping was a combination of three Blats with one Ping at the end, and the Screams-and-Wails was an extended series of several sounds (see Appendix II for complete descriptions). Again, combinations of sounds were more effective in eliciting a reaction from the belugas, and thus presumably were more effective in conveying information to the animals.

The third sound found effective during milling was the Jaw Clap (Table 12), which in this case attracted both young and adult belugas. As was discussed above (p. 58), the Jaw Clap, Crack, or Bang has been described as an alarm or fright call for several cetacean species. In the light of the present experiments, it is felt that a better description of the significance of this sound might be as an 'attention' or 'alerting' call, produced in reaction to an alarm or antagonistic context. A sound that had evolved for this purpose would be expected to have been startling, loud, and definitive. The Jaw Clap, with its abrupt onset, wide frequency spectrum, and high intensity fulfilled these requirements. The reaction to such an 'alerting' sound might have been expected to be an approach toward the animal producing the sound in order to gather more information concerning the cause of the disturbance, or for mutual protection. The Jaw Clap was the only single sound used as a playback that produced a significant response in the milling context (Table 12). In captivity, when combined with other sounds, it inhibited reaction to the other sounds (Table 8), suggesting that it dominated the significance of the combination. Regarding this abrupt intense sound as an attention or alerting call would have allowed it to serve as either a threat or an alarm call, with its particular meaning being determined by the context in which it was emitted and/or perceived. Further reaction would then be dependent upon other information (visual, acoustical, or tactile) perceived after the receiving animals had been alerted to a situation of immediate and overriding significance.

Only one of the seven Saguenay sounds used as playbacks, the Squeals, elicited an approach from at least a part of the herd while it was moving up or down the river. When the whales were making such a transit the calves were found concentrated toward the rear of the herd, which was usually very strung out. These calves were nearly always accompanied by an adult beluga, presumably the mother. This was the portion of the herd from which the most Squeals were recorded, and it is suggested that these sounds were associated with the calves. They could have been produced by the young themselves, by the females accompanying the calves, or by both. Although the Squeals were heard while the whales were either milling or transiting, the playback was effective in attracting them only while they were transiting. Possibly it was more likely that a young beluga would have become separated from its attendant female while the herd was moving than while it was milling in quiet water. If the Squeal functions for maintenance of contact between calf and mother or between calf and entire herd, or as a general distress call of the young, it would have been most effective as a playback in the situation where loss of contact or distress was most likely. The response was usually elicited from more than one adult beluga, often accompanied by calves. There are numerous reports concerning several species of cetaceans that more than one female is involved in the care of one calf (Caldwell and Caldwell, 1966).

Usually, when a positive reaction was elicited by one of these playback sounds only a few of the animals were involved. However, on one occasion during the 1970 season, the response was shown by the entire herd. This was the strongest response observed during both years of field work and was elicited by two playback sounds, the Screams-and-Wails and the Blats-and-Ping. Since this is regarded as further evidence that syntax was important in the transfer of information and thus in eliciting responses, it will be described in some detail. The entire series, from start to finish, lasted approximately one hour.

On the morning of August 8, 1970, the beluga herd was slowly working its way across Baie Ste. Catherine toward the mouth of the Saguenay River. The research boat was positioned in their path, and during the three-minute PrPb period the herd was passing by the boat and heading toward the river. The experiment began with the playback of the Screams-and-Wails, and the animals turned from their previous course and came toward the boat. The Screams-and-Wails was played back four times in succession, with short intervals between while the playback tape was being rewound. During two of these intervals the belugas began to move away, but turned and reapproached when playback began again. The Blats-and-Ping was then played back and the animals continued to approach, to within approximately eight feet of the boat, swimming on top of the water without submerging.

The Blats-and-Ping was immediately followed by the playback of the Squeals. During the first two minutes of this three-minute playback no whales were observed on the surface. Three groups then surfaced about thirty yards from the boat and remained at that distance until the playback ended. After the Squeals ended the animals moved on past the boat and started to swim away. The Screams-and-Wails was then played back again, and the herd turned once more to approach the boat. At this time an adult white animal passed beneath the sound source at an estimated depth of six or seven feet. Once again, when this playback ended the belugas started to move off. When the Screams-and-Wails started again, the herd turned and approached to within twenty-five yards, where they stopped and began milling about. At this time two large adult belugas separated from the herd and swam directly and steadily toward the boat. One of these two was not seen again, but the other came to a position directly under the sound source, stopped, turned onto its side, then onto its back, and inclined its head upward toward the sound source. This animal then swam from view, and although the Screams-and-Wails playback continued for more than five minutes afterward, the entire herd moved away and proceeded on toward the mouth of the Saguenay River. Further playback was not effective in drawing the herd back toward the boat.

This reaction, elicited by the playback of natural sound combinations, was a clear demonstration of scouting behavior in the beluga. Other instances of scouting behavior in this species were observed during the field work and will be fully described in a separate report. Instances of scouting behavior have also been reported in other cetacean species (Evans and Dreher, 1962; Caldwell and Caldwell, 1964; Caldwell, Caldwell, and Siebenaler, 1965).

B. Playback to three captive animals

Vocal and behavioral reactions.--The playback of sounds from the free-swimming animals elicited no specific vocal or behavioral reaction from the captive animals (Appendix VIII and Table 14, respectively). This was also the case when aquarium sounds were played back to the free-swimming animals. The overall increase of interest in the sound source during Pb was observed again (Table 15a,b) and was shared by all three whales. Also, the interest decreased to near-PrPb levels during PtPb. This was the same effect as was seen in reaction to playback of the aquarium sounds to the captive belugas (Tables 3-7). It would thus seem that the normal reaction of captive animals to the presentation of a sound in their tank was an increase of interest directed toward the source of the sound. When such sounds were originally recorded from the same captive population, the strength of the increase was dependent on the specific sound being played back, whereas when the sounds were recorded from a different population, the response was not graded in relation to the sound type.

This latter fact is shown by comparison of Tables 8 and 16, which show the magnitudes of the changes of interest from PrPb to Pb directed toward the sound source by each captive beluga. In response to the sounds from the same population (Table 8), certain sounds are seen to have had a consistently greater effect in all four whales than did others of this series of sounds. In response to sounds from a different population (Table 16) the numbers of responses showed less variation within individual whales inrregard to the different sounds.

Two of the possibilities suggested as reasons for the lack of response shown by the Saguenay animals to the aquarium sounds can be postulated as also having been important in the lack of specific response shown by the captive belugas to the Saguenay sounds. These are the possibility of dialects in different populations, and the possibility that sounds are context specific. Also, the sounds may have been rendered 'unreliable' when introduced into the reverberatory concrete tank.

It is difficult to place any meaning on the sexual behavior observed in February of 1971 in response to five different, consecutive Saguenay playback sounds, especially since this was the only time that such a reaction was observed. As was noted above (p. 35), Blanchon tried to mate with Frances during late Pb or during PtPb of each of these experiments. Frances seemed unreceptive in all cases. The sixth sound played back was the Harmonic LLW recorded from Alex, who at this time was in a separate tank. Although Blanchon became quite excited during Pb, he did not attempt intromission after this sound, nor was an erection of the penis observed. One interpretation of this series of reactions is that the sounds from the wild, unfamiliar animals sexually excited Blanchon, acting as a releaser for his mating activities. If belugas can recognize individuals on the basis of their sounds, as has been shown for Tursiops truncatus (Caldwell, Hall, and Caldwell, 1972), then Blanchon may have recognized the Harmonic LLW as a sound emitted by a previous tankmate and competitor, thus becoming aggressively rather than sexually aroused.

Kleinenberg, et al (1964) stated that the main mating period of belugas in all seas seemed to be late April to early May, with isolated matings taking place from the end of February until the end of August. Vladykov (1944) noted that the belugas of the Gulf of St. Lawrence mated from February until August, while Doan and Douglas (1958) described the mating season of the belugas in Hudson's Bay as being from March to September, with most activity in early May. Since Blanchon was captured in the St. Lawrence River, and Frances in Hudson's Bay, Blanchon may have been in mating condition in February, whereas Frances would not have been expected to be receptive at this time according to Doan and Douglas. Also, since scattered mating attempts by the males were observed at nearly all times of the year at the New York Aquarium, the time of mating in belugas may be determined by the period of receptivity of the female, with the males in reproductive condition the year round.

C. Playback to one captive animal

Vocal and behavioral reactions.--There was no strong vocal response elicited from Alex by the playback of the Saguenay sounds. No explanation is offered for the two responses elicited at the .05 level of significance (p. 38), although it will be remembered that both of these sounds, the Screams-and-Wails and the Squeals, elicited significant behavioral responses when played back to the Saguenay animals.

Activity increased during Pb in response to all seven of the Saguenay sounds. This is demonstrated in Table 17b, which shows that orientation toward the sound source increased during Pb of all seven sounds, and in Table 18, which shows that the number of times Alex circled the tank also increased in response to all seven sounds.

In general then, the two patterns found previously were also evident in this playback series to a single animal. First, the overall pattern of reaction to playback was an increase of interest in the sound source during Pb, falling off again during PtPb. Secondly, sounds recorded from one population had less effect when played back to an animal from a second population than when played back to that same population.

III. Playback of Synthetic Sounds to
a Single Captive Animal

Vocal reaction.--When synthetic sounds, based on the Harmonic LLW, were played back to Alex, the effectiveness of the playback was dependent upon both frequency and duration (Table 19). At the natural frequencies

(2.4 and 4.8 kHz), the most effective duration was 30 seconds, an atypical duration much longer than that of any Harmonic LLW emitted by Alex during the period of observation. At the natural durations (1.7 and 2.7 seconds), the most effective frequency (using the projected results for the 3.3 kHz playbacks) was 3.3 kHz, an atypical frequency never recorded in a Harmonic LLW from Alex. Thus, each of the four combinations that involved either a natural frequency combined with an atypical duration of a natural duration combined with an atypical frequency produced a highly significant increase of Harmonic LLW's in Pb, followed by a highly significant decrease in PtPb in three of the four cases. When both parameters were atypical, there was no significant increase, although the projected data showed a significant decrease in PtPb. In the four cases where both parameters were natural, the 1.7-second duration and the 2.4-kHz frequency were most effective. The only significant reaction in these four cases occurred as an increase of Harmonic LLW's in Pb when the 1.7-second duration and the 2.4-kHz frequency were combined.

Thus it seems that the most effective combination of parameters for producing a normal reaction was one made up of one natural and one atypical component. It can not be said at this point what these data mean in regard to the meaning of the Harmonic LLW, especially since the discussion was based on projected data in the case of the 3.3 kHz playbacks. However, the data do show that both frequency and duration are important parameters in transmitting the significance of sounds in the beluga.

It is possible that a combination of the 2.4 and 4.8 kHz frequencies, as occurred in the 'normal' sound, would have elicited a significant response at the 2.7 and/or 1.7 second durations. It is also possible that other harmonics of the 2.4 kHz fundamental frequency might have elicited responses at the various durations. These, as well as more repetitions of the 3.3 kHz playbacks and other atypical frequencies, should be used in further playback experiments.

Durations of Harmonic LLW's emitted during the experiments showed no significant changes (Table 20).

Behavioral reactions.--As was the case when using natural sounds as playbacks to captive animals, the overall reaction to the playback of the synthetic sounds was increased interest in the sound source (Tables 21 a,b) and increased activity (Table 22) during Pb, followed by decreased interest and activity once again in PtPb.

CONCLUSIONS

The results of this research show that the underwater playback of both natural and artificial sounds to captive or free-swimming animals is an effective tool for studying the vocal behavior of at least one cetacean species, the beluga (Delphinapterus leucas). Not the least benefit of this method is that it forces the investigator to concentrate on vocal emissions of the animal while closely observing its behavior, thus encouraging correlation of sounds with their attendant behavior patterns. In this manner correlations are made both passively and actively by the investigator. While watching the animals in captivity or in their natural environment associations between sounds and behavior, sounds and contexts, and sounds and particular animals become evident. During the active experimentation, these associations are further elucidated by occurring as direct responses to the playbacks. These responses are used either to support or refute associations suspected from observation, or to point out new, unsuspected associations.

In the present research the use of sound playbacks has elucidated several aspects of the vocal behavior of the beluga, some of which may have general significance in the study of cetacean communication. First, it was found possible to elicit a stereotyped vocal response from a captive beluga to a single sound, the Harmonic LLW, originally recorded from that same captive animal. This reaction occurred uniformly at all times of day or night and during all seasons of the year without regard to the conditions surrounding the animal. The sound seldom occurred in the absence of the playback stimulus, apparently requiring a specific context, or set of conditions, to trigger its emission. Since the playback of the Harmonic LLW elicited the emission of the sound so regularly, it would seem that the sound itself served as the trigger for its production, taking precedence over whatever other conditions existed in the immediate environment of the whale. Therefore, certain sounds normally associated with a specific set of conditions, or context, and elicited by this context, may themselves elicit the same response from the animal involved as does the specific context itself. This perhaps occurs by way of the sound causing the same set of internal conditions within the whale as does the external environmental conditions normally associated with the sound's production.

This brings up the question of whether sounds and behavior patterns are produced in reaction to a particular context (are responsive), or whether the sounds themselves are the stimulus for the production of other sounds or behavior patterns (are causal). The results just mentioned in relation to the Harmonic LLW playbacks suggest that at least some sounds may be both responsive and causal. However, not all sounds produced by a species would necessarily be expected to act in this manner. Some would be expected to occur only in response to a particular context and not elicit further reactions from other animals, while others might be produced expressly for the purpose of eliciting a reaction from another animal. This latter type of sound is the type used for communication in the human species, assuming purposive thought and action on the part of the emitting individual, and so far not definitively shown to be used by any non-human species, although such use has been suggested in at least two cetacean species, T. truncatus (Lilly, 1963) and T. gilli (Evans and Dreher, 1962).

All sounds of animal origin may thus be classified, as one of three types:

(1) Responsive

(2) Causal-unintentional

(3) Causal-purposive

Sounds classified as responsive would not be associated with communication between animals, but would be produced in a manner analagous to that of a human absent-mindedly humming or whistling while he works. In other words, these are sounds produced in response to a certain context that serve no function in transmitting information from one individual to another. This is not to say that the sounds may not serve some function for the individual emitting them. The whistling of a youngster walking home in the dark does not constitute a form of communication, but does perform the function of allaying the fears of the youngster. Such outward expression of internal emotions may also be important in non-human species. One must not assume at the outset that all animal sounds are communicative in function.

If we assume, as we must until it is proven otherwise, that non-human animals do not produce sounds of the third division (causal-purposive), then all animal sounds must be regarded as either responsive or causal-unintentional. Causal-unintentional sounds may be defined as those uttered in response to a particular stimulus-context and which, when received by another animal, transmit information regarding that context to the receiving animal, causing it to react vocally and/or behaviorally as it would to the original context. If one looks at the playback of natural sounds to animals in the light of these two divisions it is easy to realize that not all sounds would be expected to elicit a reaction from the animals regardless of the context in which they were played back. Only those sounds which would be classified as causal-unintentional would be expected to elicit a reaction.

Context may also influence the effectiveness of sounds in eliciting a response in playback experiments of the nature reported in this paper. The causal-unintentional sound is normally emitted in reaction to a certain set of conditions, or context, which serves as the stimulus for the production of that sound. Would it not be reasonable, then, to assume that some of these sounds would be effective in eliciting a normal reaction only if played back in a context similar to that under which the sounds are normally produced? In other words, all sounds are context-dependent regarding production, but may be either context-dependent or -independent in reference to reception. The results presented herein support this contention. Sounds recorded from the Saguenay herd were played back to the same herd in two contexts: while milling in bays or estuaries along the river, or while moving up or down the river. Of the four sounds found to be effective in eliciting a response from the belugas, three were significantly effective only while the herd was milling, and one was significantly effective only while the herd was moving. In addition, none of the sounds recorded from the belugas at the New York Aquarium elicited a significant response from the Saguenay animals, and none of the Saguenay sounds elicited a response from the captive animals.

On the other hand, one should not assume that all animal sounds have meaning only in a particular context. There are many types of sounds of general meaning that would be expected to convey their meaning in any context of the animal receiving the sound. Examples of such sounds would be those associated with danger, distress, threat, and other states of high emotional arousal, and the signature whistle, which serves for individual recognition (Caldwell, Hall, and Caldwell, 1972). Since the Harmonic LLW elicited responses from Alex at all times of day or year and when alone or with other belugas, it is concluded that it was one of these types of sounds, being produced in response to some particular context, but having meaning to the receiving animal regardless of the context in which it was received. A suggestion concerning the reason this sound affected only Alex will be discussed later. Thus sounds classified as causal (unintentional or purposive) can be further subdivided as being context-dependent or context-independent with reference to the context in which they are received. Responsive sounds, by definition, are context-dependent only as regards their production. They are context-independent regarding reception since they are uniformly ignored by the receiving animal in any context.

Syntax may be defined as the ways in which individual sounds or words are combined to form a code, or message. The results presented herein support the conclusion that syntax was important in the transfer of information from one beluga to another by sound. When played back to the captive belugas, the Buzz-and-Whinny combination was found to be as effective or more effective in regard to increasing interest in the sound source during Pb than were either of the two component sounds alone, and to produce a longer lasting effect, carrying over into PtPb. The Jaw Clap alone produced no significant changes of interest in the sound source, but when combined with the Buzz-and-Whinny, completely inhibited the increased interest response normally shown in reaction to the Buzz, the Whinny, and the Buzz-and-Whinny. In fact, the Jaw Clap-Buzz-and-Whinny combination showed a tendency to decrease interest in the sound source, as did the Contact Sound-Series, the only other extended series of sounds played back to the captive animals. This decrease of interest may have occurred by way of a redirection of interest from sound source to tankmates as a result of the stimulus presented by these two types of sound-series.

The conclusion that syntax was important in information transfer between belugas was further supported by the fact that there was a significant increase in emission of the Contact Sound-Series during playback of the Contact Sound Series, but not during playback of the Jaw Clap-Buzz-and-Whinny combination. The Contact Sound-Series was normally emitted only during instances of major disturbance in the tank such as outside interference, or contact or close proximity between individuals. Since there was no outside interference during these playbacks, the stimulus for the sound series' production must have arisen from contact or near-contact between the belugas. It is concluded that this contact was induced by playback of the Contact Sound-Series.

If both the Contact Sound-Series and the Jaw Clap-Buzz-and-Whinny combination increased interest in tankmates, why did not the emission of Contact Sound-Series increase in reaction to the latter as it did to the former? This difference in reaction may have been due to the presence of one sound which occurred as a dominant part of the Contact Sound-Series, but was not present in the Jaw Clap-Buzz-and-Whinny combination. This sound was the Squawk. Thus, while an extended series of sounds may have elicited interest toward other animals in preference to the sound source, the combination of the Squawk, Jaw Clap, and other sounds in the Contact Sound-Series (primarily Whistles and Chirps) was necessary for actual inter-individual contact to be elicited leading to the emission of a Contact Sound-Series.

As further evidence of the importance of syntax, the sound found most effective in eliciting a reaction from the free-swimming belugas in the Saguenay River was also a series of sounds, the Screams-and-Wails. This playback sound-series was made up of sounds with a wide range of both frequency and duration (see Appendix II). Since none of these sounds were used as single playbacks, it cannot be said which of the sounds individually, or in what combinations, would have elicited the same reaction, or if the entire series would have been required.

Syntax is thus concluded to have been of importance in the transfer of information by sound in the beluga, with series of sounds carrying additional orddifferent meaning to the receiving animal than did the component sounds individually. It should be noted that this difference in reaction elicited by combinations of sounds as compared with the component sounds necessarily leads one to the conclusion that at least some of the sounds (causal-unintentional) of the beluga are communicative in function. Syntax is meaningful only in a communicatory context.

Of the four captive belugas, only Alex reacted vocally to the playback of the Harmonic LLW. Also, the beluga herd in the Saguenay River showed no response to this sound. On the other hand, Alex' vocal reaction was strong and stereotyped. Why should such a dichotomy of response be shown by animals that had been in captivity together for several years? One possible explanation of this dichotomy is the different localities of origin of the captive belugas. Blanchon, Frances, and Ethel were all captured on the East Coast of North America, whereas Alex was obtained from a West Coast population. It is suggested that different populations of belugas may possess different dialects, "in which (the sounds are) similar among most or all individuals living in a particular locality, but are different from one locality to another" (Lemon, 1967). As Lemon states in reference to birds, it seems reasonable that animals exhibiting dialects should respond more to sounds of their own particular dialect. If indeed dialects do occur in cetaceans, one would surely expect to find them in populations as widely separated as those of the belugas of the East and West Coasts of North America.

It has been shown by numerous investigators that sounds differ between cetacean species, and also between individuals of one species with enough regularity that individual recognition is possible (Caldwell, Hall, and Caldwell, 1972), even to the point of recognition of individuals of a different species (Caldwell, Caldwell, and Hall, 1972). It would seem unreasonable, then, not to expect differences between sounds of populations as geographically isolated as the Pacific and Atlantic belugas. Such dialects might even be expected to occur between herds along one coast, in which context they would serve to maintain individual herd-integrity during the times of congregation which are reported to occur for fattening and migration (Kleinenberg, et al; 1964).

When working with both captive and free-swimming animals, a general reaction was observed to all sounds played back which, although different between the captive and free contexts, would serve the purpose of putting the animals in a better condition for receiving further information about the sound stimulus. With captive animals this general reaction was an orientation or actual approach toward the sound source (except in the cases of the Jaw Clap and the two sound-series, as discussed above, p. 74). With the free-swimming animals the general response was a decrease in number of sound emissions, a reaction which was also noted upon the approach of a motorboat toward the herd. Whether these reactions were merely those prompted by curiosity, or were a conscious attempt to discover further information about the stimulus cannot be said at this time. The end result however, would have been the same in either case; i.e., the animals would have been in a more appropriate state for the reception of more information about the stimulus, its source, and its reason for occurrence. The single instance of scouting behavior described would suggest a purposeful attempt to learn more about the sound and its source, but such a teleological explanation can only be advanced as a suggestion at present.

Synthetic playback segments, based on the characteristics of the Harmonic LLW, were constructed by use of a pure tone oscillator. From the results of these playbacks it is concluded that both frequency and duration were important in the ability of a sound to transfer information from one beluga to another.

SUGGESTIONS FOR FURTHER WORK

Looking at the present work as essentially a pilot study of the vocal behavior of the beluga, several lines of future research are suggested. First, it is evident that the meaningful breakthroughs in determining relationships between sound emissions and behavior patterns will come from work done with animals in the field. A group of captive individuals from different localities thrown together in a small tank for extended periods of time can in no way be considered a natural population. Such animals could hardly be expected to demonstrate behavior normal to their free existence in association with other animals of similar background and long-standing familiarity.

It is also evident that this association of sound and behavior can not be carried out to best advantage by working with an entire herd in a large and deep river such as the Saguenay. This leaves open but one path: that of enclosing a restricted number of animals in a natural, shallow, relatively large area. Furthermore, the animals to be observed in such a natural enclosure should be of known relationship to one another. It is thus concluded that the next step in selected-sound playbacks should be performed using a mother-calf pair held in one of the natural estuaries along the Saguenay River, or some other enclosable bay within the natural range of the beluga. Such an experimental setup, using the methods described in this paper, would permit the observer to determine the positions of the two animals relative to one another, and, by the use of three or four calibrated hydrophones simultaneously, which was producing the sounds (Watkins and Schevill, 1971).

Starting with the mother-calf pair should elucidate the nurturant epimeletic behavior of the beluga and the sounds involved in this relationship. Knowledge of the sounds thus involved in care of the young would then give one an immediate key to some of what is happening out of range of sight when recording the entire herd. Once the base-line behavior had been established for these animals, another beluga could be introduced to determine the effects of interactions on the numbers and types of sounds produced, and on the behavior of the mother-calf pair.

With regard to the specific sounds used in the present work, several further playbacks are suggested. The Contact Sound-Series and the Jaw Clap-Buzz-and-Whinny combination were found to decrease interest in the sound source, possibly by causing a shift of interest toward tankmates. Whereas the Contact Sound-Series elicited a significant increase of emissions of this same sound, the Jaw Clap-Buzz-and-Whinny did not elicit such an increase. This difference was suggested as having been due to the presence of both Jaw Claps and Squawks in the former, while the Squawk was missing from the latter. Thus a further playback segment should be used uniting the Jaw Clap-Buzz-and-Whinny combination and the Squawk to determine if the presence of the Squawk would indeed raise the level of arousal of the animals to the point where actual contact occurred, leading to the emissions of a Contact Sound-Series. Also, a combination of the Squawk and the Jaw Clap should be used as a playback to determine if these two sounds alone would elicit the same reaction.

The sound found most effective as a playback in the field (Screams-and-Wails) was also an extended series of sounds, of varied frequencies and durations. The component sounds played back separately might determine which sound was responsible for the reaction, or if the syntax of the entire series was necessary.

Other synthetic-sound playbacks would be required to definitively delineate the respective importances of frequency and duration in the Harmonic LLW. While synthetic sounds were constructed using the two frequencies of major energy content, no playback was made up using a combination of these two frequencies. This should be done. Further, other harmonic frequencies which occur in the natural sound should be used as separate playbacks and in combination with the two major harmonics already used. More atypical frequencies should also be tried, both as separate playbacks and in combination with the natural frequencies which normally elicited a positive response. This latter type of playback would determine if an atypical sound with normal components would be regarded as a meaningful sound, or as an unreliable sound to which the animals would not respond.

The suggestion that belugas from different populations may possess different dialects should be further investigated. If it were possible to characterize an individual population on the basis of its sound emissions, then these characteristic sounds could be used as a natural tag for following the movements of these populations, and estimating the number of separate populations, their ranges, and their relations to one another. It is suggested that this work be started by making extensive recordings of a Pacific beluga population which would then be exhaustively compared with the recordings of the Atlantic population. If differences were found between these widely separated populations, the next step would be to make equally extensive recordings of a second Atlantic population, for example in Hudson's Bay, which would be compared with the Saguenay and Pacific sounds. Whether such 'tagging by sound' would be possible remains to be seen, but it is felt that dialects may occur, and that this line of research warrants attention in the near future.

SUMMARY

(1) Underwater playback of natural sounds from captive and free-swimming belugas (<u>Delphinapterus</u> <u>leucas</u>), and of synthetic sounds based on a single natural sound, to conspecifics was used to determine the usefulness of this method for the investigation of cetacean communication. Correlations between behavior and vocal emissions and possible significances of the sounds are discussed. Experiments were carried out at the New York Aquarium and in the Saguenay River, Quebec Province, Canada.

(2) The Harmonic, Long, Loud Whistle elicited a strong stereotyped vocal reaction in captivity from the animal that originally emitted the sound. The response was positive twenty-three out of twenty-seven trials. This sound may have occurred normally in association with 'impatience' or 'expectation' contexts.

(3) In captivity, contact between individuals or major disturbance led to emission of an extended series of sounds designated the Contact Sound-Series. Playback of this sound-series elicited increased emission of the Contact Sound-Series with the usual inter-individual contact being present in each case. The mechanism by which this response was elicited might have been either direct, by initiating contact, or indirect, by increasing the level of activity in the tank. Other changes elicited by playback of the Contact Sound-Series are also discussed.

(4) It is suggested that the Jaw Clap or Bang emitted by several

cetacean species should be regarded as an 'attention' or 'alerting' call, rather than as a sound of specific meaning. This sound would then be able to serve as <u>either</u> an alarm or a threat, with its particular meaning being determined by the context in which it was emitted and/or received.

(5) The Squeals recorded from the Saguenay herd may have been associated with the presence of beluga calves.

(6) The effectiveness of synthetic-sound playbacks was dependent upon both frequency and duration.

(7) The general, overall response of the captive animals to playback sounds was an increase of interest directed toward the sound source during the playback, with consequent decrease of interest directed toward other objects in the tank. Interest in the sound source then fell off in the three minutes following playback.

(8) The general, overall response of the wild animals to playback sounds was a decrease of vocal emissions during the playback, followed by increasing emissions after playback, but with an overall decrease from the three minutes preceeding playback to the three minutes following playback. Thus belugas may react to extraneous sounds in their environment by decreasing the number pf sounds that they emit themselves.

(9) Combinations of sounds had different significance for the belugas than did the component sounds by themselves. This suggests that the syntax of beluga sounds was important in the conveyance of the significance of the sounds, probably by placing the sounds in a meaningful context.

(10) Behavioral reactions of free-swimming belugas to playback

of sounds from their own herd depended on the context in which the sounds were played back. Three sounds were found effective only when the whales were milling in a bay or estuary, and one sound was effective only when the whales were moving up or down the river.

(11) 'Scouting behavior' was demonstrated in reaction to the playback of natural sounds in the field.

(12) It is suggested that different beluga populations have different dialects.

(13) A basic, functional classification of animal sounds is proposed. With this classification, sounds fall into one of three categories:

a. Responsive; sounds produced in response to a certain context that serve no function in transmitting information from one individual to another.

b. Causal-unintentional; sounds emitted in response to a specific or general stimulus-context which, when received by another animal, transmit information regarding that context to the receiving animal, causing it to react vocally and/or behaviorally as it would to the original stimulus-context.

c. Causal-purposive; sounds produced expressly for the purpose of eliciting a reaction from another individual.

Sounds classified as causal (unintentional or purposive) can be further subdivided as being context-dependent or context-independent.

(14) It is concluded that the underwater playback of both natural and synthetic sounds to captive and free-swimming animals is an effective tool for studying the vocal behavior of the beluga.

(15) Suggestions are advanced for further work with the vocal behavior of the beluga.

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APPENDIX I

DESCRIPTION OF THE PBS AND F1dPBS SERIES OF PLAYBACK SOUNDS

* PBS-1. HARMONIC LONG, LOUD WHISTLE (Harmonic LLW)(Fig. 1a)

Two whistles, as follows;

Whistle 1.--Duration; 2.56 sec. Begins with a short segment (0.35 sec.) at 2.75 kHz. Followed by a longer segment (0.32 sec. to end) at a constant frequency of 2.45 kHz. Strong harmonics at 5.50 and 4.90 kHz respectively. Rising slightly and gradually at the end to 2.55 and 5.10 kHz.

Interval between whistles.--1.03 sec.

Whistle 2.--Duration; 2.87 sec. No elevated section at beginning, but a short elevated section of 0.21 sec. duration beginning at 2.31 sec. into the sound. Frequency of the main section of the sound begins at 2.50 kHz, rises gradually to 2.55 kHz just before the elevated section, and drops to 2.45 kHz after the elevated section. Strong harmonic beginning at 5.0 kHz, rising to 5.1 kHz, and dropping to 4.9 kHz at the respective positions. The elevated section is centered at 2.7 kHz, with a harmonic at 5.4 kHz.

Duration of the entire playback; 6.46 sec.

* PBS-2. BUZZES (Fig. 1b)

Three buzzes, as follows:

Each individual sound is of the rapid-pulse-train type, showing strongly banded harmonic structure with the harmonic interval sometimes narrowing gradually from beginning to end of each sound, indicating a slowing of repetition rate throughout the sound. At the end slowing to individually-spaced pulses in one of the three buzzes.

Buzz 1.--Duration; 3.15 sec. Slowing from 167 to 18 pulses/ sec. from beginning to end. Frequency range; 200 to 3600 Hz, with most energy below 2500 Hz.

Silent interval 1.--0.76 sec.

Buzz 2.--Duration; 2.28 sec. Constant repetition rate of 200 pulses/sec. from beginning to end. Frequency range; 950-2750 Hz.

Silent interval 2.--0.98 sec.

Buzz 3.--Duration; 2.62 sec. Slowing from 143 to 110 pulses/ sec. from beginning to end. Frequency range; 900-3450 Hz.

Duration of the entire playback.--9.79 sec.

* PBS-3. CONTACT SOUND-SERIES (Figs. 1c-1h)

Extended series of sounds, as follows:

1. Short 'bark'.--Duration; 0.08 sec. Frequency; 1.35 kHz with harmonics above and below at 450 Hz intervals indicating a pulsed sound with repetition rate of 450 pulses/sec.
2. Silent interval 1.--0.08 sec.
3. Short 'bark'.--Duration; 0.11 sec. Frequency; 1.40 kHz with no visible harmonics.
4. Silent interval 2.--0.94 sec.
5. Type-1 'squawk'.--Duration; 0.60 sec. (Type-1 and type-2 squawks are described below as PBS-9 and PBS-11, respectively.)

Strongly harmonic, pulsed sound with repetition rate increasing from 220 pulses/sec. at the onset to 400 pulses/sec. at the termination.

6. Silent interval 3.--0.25 sec.
7. Type-1 'squawk'.--Duration; 0.25 sec. Pulse repetition rate from onset to termination; 320 to 400 pulses/sec.
8. Silent interval 4.--0.08 sec.
9. 'Jaw clap'.--Duration; 0.03 sec. Most energy below 2.7 kHz. (see description of PBS-5)
10. Silent interval 5.--0.23 sec.
11. Type-1 'squawk'.--Duration; 0.32 sec. Pulse repetition rate from onset to termination; 390 to 420 pulses/sec.
12. Silent interval 6.--0.30 sec.
13. Type-1 'squawk'.--Duration; 0.31 sec. Pulse repetition rate from onset to termination; 250-300 pulses/sec.
14. Silent interval 7.--0.19 sec.
15. 'Whistle'.--Duration; 0.30 sec. Frequency; wavering, starting at 3.0 kHz, falling to 2.90 kHz at termination. No harmonics.
16. Silent interval 8.--0.39 sec.
17. 'Squawl'.--Duration; 0.84 sec. Same type of pulsed sound as the 'squawk', showing the strongly harmonic structure on a spectrogram, but with a longer duration. Pulse repetition rate; 200 pulses/sec. throughout.
18. Silent interval 9.--0.08 sec.
19. 'Whistle'.--Duration; 0.33 sec. Frequency starting at 3.10 kHz for 0.04 sec., followed by a sharp dip to 2.00 kHz for 0.06 sec., then rising sharply to 3.10 kHz at 0.13 seconds into the

sound, and remaining at that frequency to termination.

20. Silent interval 10.--0.33 sec.
21. 'Squawl'.--Duration; 0.98 sec. Pulse repetition rate from onset to termination; 150 to 110 pulses/sec. (The lower pulse rate of this squawl, as compared with the squawl above, leads to the sensation of a lower pitch to the human ear, producing a sound that might better be described as a 'chuckle'.)
22. Silent interval 11.--1.61 sec.
23. 'Buzz'.--Duration; 0.78 sec. Pulse repetition rate starting at 100 pulses/sec., rising to 280 pulses/sec. near the middle of the sound, and slowly falling to 170 pulses/sec. at termination.

24-27. Four 'jaw claps'.--Overlying the buzz just described at the following intervals: 0.03 sec., 0.26 sec., 0.52 sec., and 0.74 sec. from the onset of the 'buzz'.

28. Silent interval 12.--2.24 sec.
29. Weak 'buzz and whinny'.--Duration; 2.94 sec. (see description of PBS-4) In the 'buzz', two strong harmonics at 1.7 and 2.0 kHz; with the 'whinny' centered at 3.1 kHz. Changes to a 'buzz' centered at 1.7 kHz by loss of the 'whinny' component and the 2.0 kHz harmonic band, at 1.63 sec. from the onset of the sound. Very low intensity.
30. Silent interval 13.--1.81 sec.
31. Weak 'buzz and whinny'.--Duration; 1.26 sec. Very low intensity.
32. 'Chirp'.--Overlying previous 'buzz and whinny' at 0.87 sec. from onset. Duration; 0.07 sec. Short, high-pitched sound with rising inflection from 3.65 to 3.75 kHz.

33. Silent interval 14.--0.59 sec.

34. 'Chirp'.--Duration; 0.07 sec. Short, high-pitched sound with rising inflection from 3.4 to 3.6 kHz.

35. Silent interval 15.--1.23 sec.

36. 'Chirp'.--Duration; 0.10 sec. Rising inflection from 3.55 to 3.75 kHz.

Duration of the entire playback; 19.20 sec.

PBS-4. BUZZ AND WHINNY (Figs. 1b and 1i)

Another combination sound consisting of the 'buzz' described above, with a high-pitched wavering sound above it, reminiscent of the whinnying of a horse. One sound, described as follows: Duration; 0.74 sec. Pulse repetition rate of the buzz slowing from 190 to about 35 pulses/sec. Frequency of whinny wavering between 2.95 and 3.1 kHz and strongly harmonic at about 95 Hz intervals.

* PBS-5. JAW CLAPS (Fig. 1e)

Four sounds, described as follows:
Duration of entire series; 0.88 sec. Jaw claps occurring at t=0.0 sec., t=0.26 sec., t=0.52 sec., and t=0.78 sec. Frequency is broadband to at least 5 kHz. The group is underlayed by a weak buzz matching the total duration of the group.

PBS-6. WHINNY (Fig. 1i)

In reality another 'buzz and whinny' combination, but with the 'whinny' much more intense than usual, appearing on the spectrogram as a series of banded 'wows' within the 2.8 to 3.6 kHz frequency band. The upper frequency limit of the buzz in this sound is 2.45 kHz. The 'wows' occur above similar waverings in the buzz, and appear to have similar harmonic intervals, thus suggesting that the whinny may be produced by a pulse-excited resonance in the cephalic cavities of the beluga. Twenty seven 'wows', or 'whinnys', are produced in the total duration of 4.11 sec., or about 6.6 whinnys per second.

PBS-7. WHISTLES (Fig. 1f)

Eight whistles, as follows, without harmonic structure, but with complex frequency sweeps:

Whistle 1.--Duration; 0.17 sec. Simple rise-fall pattern starting at 3.0 kHz, rising to 3.25 kHz, and returning to 3.1 kHz.

Silent interval 1.--Duration; 0.18 sec.

Whistle 2.--Duration; 0.30 sec. Rise-fall-rise pattern starting at 3.1 kHz, rising to 3.32 kHz, falling to 3.22 kHz, and rising once more to 3.95 kHz.

Silent interval 2.--Duration; 0.41 sec.

Whistle 3.--Duration; 0.43 sec. Rise-level-rise-fall pattern starting at 3.1 kHz, rising in two steps to 3.7 kHz and leveling off there for 0.15 sec., rising to 4.15 kHz, and falling at the end to 3.68 kHz.

Silent interval 3.--Duration; 0.40 sec.

Whistle 4.--Duration; 0.23 sec. Fall-rise-fall pattern starting at 4.1 kHz, falling to 3.95 kHz, rising to 4.0 kHz, and falling to 3.65 kHz at termination.

Silent interval 4.--Duration 0.66 sec.

Whistle 5.--Duration; 0.45 sec. Rise-fall-rise pattern starting at 3.6 kHz, rising sharply to 3.8 kHz, falling to 3.65 kHz, and rising gradually to 4.1 kHz at termination.

Silent interval 5.--Duration; 0.64 sec.

Whistle 6.--Duration; 0.40 sec. Fall-rise-fall-rise pattern starting at 4.2 kHz, falling to 4.05 kHz, rising gradually to 4.15 kHz, falling sharply to 4.0 kHz, and rising sharply to 4.25 kHz at the end.

Silent interval 6.--Duration; 0.60 sec.

Whistle 7.--Duration; 0.30 sec. Fall-rise-fall pattern starting at 4.1 kHz, falling to 4.0 kHz, rising sharply to 4.5 kHz, and falling to 4.25 kHz at termination.

Silent interval 7.--Duration; 1.14 sec.

Whistle 8.--Duration; 0.29 sec. Rise-level-rise-fall pattern starting at 3.5 kHz, rising sharply to 4.0 kHz, and leveling off there for 0.09 sec., rising sharply to 4.3 kHz, and falling gradually to 4.15 kHz at termination.

Duration of the entire playback; 6.60 sec.

* PBS-8. BLARE (Fig. 1j)

A single, simple, pulsed sound of 0.90 sec. duration, with pulse repetition rate of 110 pulses/sec. throughout. Most energy content below 2.5 kHz.

* PBS-9. SQUAWK (TYPE-1) (Fig. 1d)

A raucous-sounding noise with harmonics of alternating intensity suggesting a burst-pulsed sound (Watkins, 1967) with burst-pulse repetition rate of 400/sec. and rising pulse tone from 1.2 kHz at onset to 1.3 kHz at termination. The type-1-

squawk shows this simple rising inflection (compare with the type-2 squawk; PBS 11). Duration in this case is 0.60 sec. The rising inflection of a type-1 squawk may occur smoothly, as in this case, or in stepwise fashion.

PBS-10. JAW CLAP, BUZZ, AND WHINNY COMBINATION (Figs. 1b, 1e, and 1i)

Five separate sound-combinations, as follows:

Combination 1: Jaw clap, buzz, and whinny.--Duration; 2.45 sec. A single 'buzz and whinny' (see PBS-4) overlaid by four 'jaw claps' at 1.22, 1.52, 1.83, and 2.14 sec.

Silent interval 1.--Duration; 0.89 sec.

Combination 2: Buzz and whinny.--Duration; 1.27 sec.

Silent interval 2.--Duration; 0.18 sec.

Combination 3: Jaw clap, buzz, and whinny.--Duration; 1.72 sec. A single 'buzz and whinny' overlaid by four 'jaw claps' at 0.03, 0.34, 0.67, and 1.06 sec.

Silent interval 3.--Duration; 0.24 sec.

Combination 4: Jaw clap.--A single jaw clap (see PBS-5) without the 'buzz and whinny'.

Silent interval 4.--Duration; 0.66 sec.

Combination 5: Jaw clap, buzz, and whinny.--Duration; 1.86 sec. A single 'buzz and whinny' overlaid by seven 'jaw claps' at 0.02, 0.33, 0.64, 0.93, 1.25, 1.57, and 1.73 sec.

Duration of the entire playback; 9.27 sec.

* PBS-11. SQUAWK (TYPE-2) (Fig. 1k)

A raucous sound similar to the type-1 squawk (PBS-9), but with a rise-fall inflection rather than the simple rising inflection of the type-1 squawk. Again, an alternating harmonic structure suggests a burst-pulsed sound with burst-pulse repetition rate of 400 bursts/sec. (determined from the harmonic interval; Watkins, 1967) and pulse tone (determined by pulse repetition rate; Watkins, 1967) of 450 Hz at onset, increasing to 1 kHz at the peak of the curve, and falling back to 450 Hz at termination. Duration; 0.41 sec.

PBS-12. CONTROL

Background tank noise. Most energy below 300 Hz, nearly all energy below 1 kHz.

* PBS-13. PURE LONG, LOUD WHISTLE (PURE LLW) (Fig. 1l)

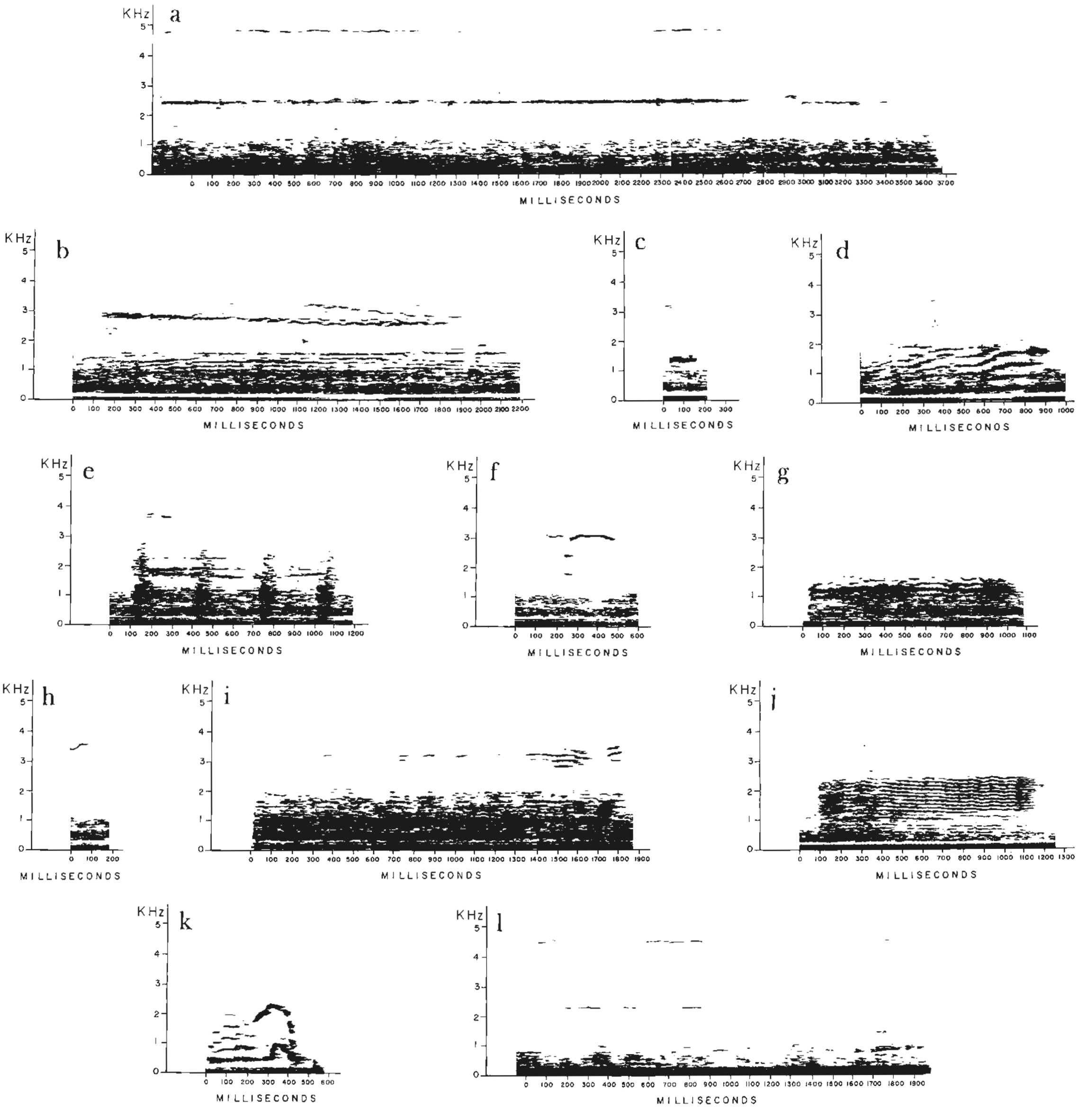
A single, thin, high, whistling sound somewhat resembling the harmonic LLW, but much lower in intensity, and without strong harmonics. Frequency is constant at 4.5 kHz throughout, with a weak harmonic sometimes apparent at 2.25 kHz. Accompanied by a pulse-train with pulse rate of about 50/sec. Duration; 3.12 sec.

* indicates these sounds were used as field playback sounds (FldPBS 1-4; 6-9) for playback to the Saguenay herd in 1970.

Figure 1. Typical examples of the sound-types used in the PBS and FldPBS series of playbacks. The individual examples of these types that were used as playbacks are fully described in Appendix I. Analyzer effective bandwidth 60 Hz.

a. Harmonic Long, Loud Whistle (Harmonic LLW)
b. Buzz
c. Bark
d. Squawk (Type 1)
e. Jaw Clap
f. Whistle
g. Squawl
h. Chirp
i. Whinny
j. Blare
k. Squawk (Type 2)
l. Pure Long, Loud Whistle (Pure LLW)

Note the high level of background tank noise below 1.5 kHz.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APPENDIX II

DESCRIPTION OF THE SagPBS SERIES OF PLAYBACK SOUNDS

SPBS-1. MOANS (Fig. 2a)

Three moans, as follows;

Moan 1.--Duration; 0.73 sec. Tonal pulse train with repetition rate rising from 290 pulses/sec. at onset to 500 pulses/sec. in the level mid-section, and falling back to about 250 pulses/sec. at termination. Pulse tone in mid-section at 1.2 kHz with harmonics at 0.7 and 1.7 kHz. Pulse tone falls at both ends of the sound as repetition rate changes.

Silent interval 1.--Duration; 0.52 sec.

Moan 2.--Duration; 0.69 sec. Tonal pulse train with repetition rate starting at 300 pulses/sec., increasing to 500 pulses/sec., and decreasing to 300 pulses/sec. at termination. Pulse tone in mid-section at 1.15 kHz with harmonics at 0.65 and 1.65 kHz. Pulse tone falls at both ends of the sound as repetition rate changes.

Silent interval 2.--Duration; 0.69 sec.

Moan 3.--Duration; 2.27 sec. Tonal pulse train with repetition rate starting at 300 pulses/sec., increasing to 500 pulses/sec., and falling to about 130 pulses/sec. at termination. Pulse tone in mid-section at 1.1 kHz with harmonics at 0.6 and 1.6 kHz. Upper harmonic very weak in last 1.69 sec. Pulse tone falls toward both ends of the sound as repetition rate changes.

Duration of the entire playback.--4.90 sec.

SPBS-2. PINGS (Fig. 2b)

Two sounds, reminiscent of the ping of a depth recorder, as follows:

Ping 1.--Duration; 0.42 sec. Frequency at 1.5 kHz, with a secondary element at 3.0 kHz. This is probably not a harmonic, as the waveform varies more than that of the constant-frequency 1.5 kHz element. Intensity of all pings decreases rapidly from onset to termination.

Silent interval.--Duration; 0.69 sec.

Ping 2.--Duration; 0.59 sec. Frequency beginning at 2.85 kHz and rising almost immediately to 3.2 kHz where it remains constant throughout the rest of the sound. Subharmonic at 1.65 kHz lasting only as long (0.05 sec.) as the 2.85 kHz section of the upper element, then dying out.

Duration of the entire playback.--1.70 sec.

SPBS-3. SCREAMS-AND-WAILS (Figs. 2c and 2d)

An extended series of sounds, as follows:

Wail 1.--Duration; 3.30 sec. Frequency constant at about 650 Hz throughout. The wails increase gradually in intensity from background levels, then fade back into this background at termination. There is no sharp onset or termination in any of the wails.

Scream 1.--Duration; 1.34 sec. Beginning at 1.18 sec. into Wail 1, and ending before the termination of that sound. Frequency at onset; 1.95 kHz, falling to 1.75 kHz by termination.

All screams are very intense relative to any other sounds heard in the Saguenay, with the loudest portion of each scream toward the center of the sound, rather than at onset or termination.

Silent interval 1.--Duration; 0.57 sec.

Scream 2.--Duration; 1.25 sec. Frequency falling slightly and gradually from 1.80 to 1.75 kHz from onset to termination.

Silent interval 2.--Duration; 0.51 sec.

Scream 3.--Duration; 1.37 sec. Frequency falling from 1.80 to 1.75 kHz from onset to termination.

Roar 1.--Duration; 1.83 sec., beginning at 0.16 sec. into Scream 3. Broadband roaring sound below 1 kHz. A prolonged, throaty roar.

Wail 2.--Duration; 2.96 sec., beginning at 1.17 sec. into Scream 3. Frequency starting at 750 Hz, and falling gradually to 600 Hz at termination.

Scream 4.--Duration; 1.38 sec., beginning at 0.73 sec. into Wail 2, and ending just before termination of Roar 1. Frequency beginning near 1.7 kHz, rising to 1.8 kHz in the mid-section, and falling back to 1.7 kHz by termination.

Roar 2.--Duration; 1.42 sec., beginning at 0.76 sec. into Scream 4 and ending just before termination of Wail 2. Broadband below 700 Hz.

Scream 5.--Duration; 1.73 sec., beginning at 2.72 sec. into Wail 2. Frequency constant at 1.7 kHz throughout.

Roar 3.--Duration; 1.47 sec., beginning at 0.79 sec. into Scream 5 and ending 0.51 sec. into Scream 6. Broadband below 800 Hz.

Wail 3.--Duration; 1.92 sec., beginning at 1.49 sec. into Scream 5 and ending 0.11 sec. into Scream 7. Frequency constant at 720 Hz throughout.

Scream 6.--Duration; 1.50 sec., beginning at 0.27 sec. into Wail 3 and ending 1.74 sec. into Wail 3. Frequency constant at 720 Hz throughout.

Scream 7.--Duration; 2.54 sec., beginning at 1.81 sec. into Wail 3. Frequency at onset; 1.7 kHz, rising to 1.75 kHz at 0.37 sec. into the sound and remaining at that frequency to termination.

Roar 4.--Duration; 0.96 sec., beginning at 1.77 sec. into Scream 7. Frequency broadband below 800 Hz.

Duration of the entire playback.--15.55 sec.

NOTE: All three sounds involved in the Screams and Wails rise from and fall into background levels at onset and termination. Therefore, points of onset and termination used in duration measurements were arbitrarily set as those points from and to which the sound showed as a continuous band on the spectrogram.

SPBS-4. BLATS AND PING (Figs. 2b, 2e, and 2f)

Blat 1.--Duration; 0.35 sec. A 'barking' type of sound with nearly all energy between 1 and 2 kHz. The banded-harmonic structure of the spectrogram suggests a burst-pulsed sound with pulse tone at about 1.45 kHz and pulse repetition rate of 200 pulses/sec.

Silent interval 1.--Duration; 0.53 sec.

Blat 2.--Duration; 0.38 sec. Nearly all energy between 1 and 2 kHz; pulse tone at 1.45 kHz; and pulse repetition rate of 200 pulses/sec.

Silent interval 2.--Duration; 0.77 sec.

Blat 3.--Duration; 0.35 sec. Nearly all energy between 1 and 2 kHz; pulse tone 1.7 kHz at onset, falling to 1.3 kHz, and rising to 1.70 kHz at termination. Pulse repetition rate of 200 pulses/sec.

Silent interval 3.--Duration; 0.82 sec.

Ping.--Duration; 0.25 sec. Two elements, probably not harmonics since onset is different.

Primary element-Duration; 0.15 sec. Frequency constant at 1.7 kHz.

Secondary element--Duration; 0.15 sec., beginning at 0.09 sec. into the primary element. Frequency constant at 3.25 kHz.

Jaw Clap.--Instantaneous at 0.03 sec. into the secondary element of the ping. Broadband with most energy below 1.4 kHz.

Duration of the entire playback.--3.44 sec.

SPBS-5. JAW CLAPS (Fig. 2f)

Three sounds, described as follows:

Duration of entire series; 2.01 sec. Jaw claps occurring at t=0.0 sec., t=0.89 sec., and t=1.94 sec. Frequency is broadband below 1.9 kHz. There is no buzz underlying the combination, as was seen with the jaw claps from the captive animals.

SPBS-6. SQUEALS (Figs. 2g and 2h)

The squeals are high-pitched, thin, wavering sounds. Also occurring toward the end of this playback sound are three sounds designated as 'crys'. All crys have a rising inflection.

Squeal 1.--Duration; 1.38 sec. Frequency of 4.0 kHz at onset, rising rapidly to 4.4 kHz, falling gradually to 4.1 kHz, then rising gradually to 4.2 kHz at termination. The frequency of the squeals always wavers about a central frequency, producing a 'warbling' effect. Single harmonics present both above and below this fundamental at the sum and difference of the fundamental and 2.0 kHz. This indicates a rapid-pulsed sound with pulse rate of 2000/sec.

Silent interval 1.--Duration; 0.92 sec.

Squeal 2.--Duration; 1.50 sec. Frequency of 3.4 kHz at onset, rising rapidly to 4.2 kHz, and then falling gradually to 4.0 kHz at termination. Single harmonics present above and below, following the waveform of the fundamental, at the sum and difference of the fundamental and 2.0 kHz, as above.

Silent interval 2.--Duration; 0.86 sec.

Squeal 3.--Duration; 1.31 sec. Frequency of 3.6 kHz at onset, rising rapidly to 4.2 kHz, then gradually to 4.3 kHz at termination. Single harmonics above and below at the sum and difference of the fundamental and 2.0 kHz, as in Squeal 1.

Cry 1.--Duration; 0.28 sec., beginning at 0.44 sec. into Squeal 3. Frequency beginning at 0.5 kHz and rising throughout to 1.3 kHz at termination. A single harmonic sweeping from 1.1 kHz at onset to 2.4 kHz at termination.

Silent interval 3.--Duration; 0.69 sec.

Cry 2.--Duration; 0.20 sec. Frequency beginning at 0.7 kHz and rising throughout to 1.2 kHz at termination. A single harmonic sweeping from 1.3 kHz at onset to 2.4 kHz at termination.

Squeal 4.--Duration; 1.02 sec., beginning at 0.14 sec. into Cry 2. Frequency of 3.5 kHz at onset, rising rapidly to 4.2 kHz, then rising gradually to 4.6 kHz, and falling to 4.4 kHz at termination. Single harmonics above and below as in Squeals 1-3.

Cry 3.--Duration; 0.39 sec., beginning at 0.75 sec. into Squeal 4. Frequency beginning at 0.6 kHz and rising throughout to 1.3 kHz at termination. One complete and one partial, weak harmonic above the fundamental. Complete harmonic beginning at 1.2 kHz and sweeping upward to 2.5 kHz at termination.

Duration of the entire playback.--7.94 sec.

SPBS-7. SAGUENAY LONG, LOUD WHISTLE (Saguenay LLW) (Fig. 2i)

One very loud sound, as follows:

Duration; 0.97 sec. Frequency constant at 1.4 kHz throughout. Weaker harmonics at 2.8 and 4.2 kHz.

Figure 2. Typical examples of the sound-types used in the SagPBS series of playbacks. The individual examples of these types that were used as playbacks are fully described in Appendix II. Analyzer effective bandwidth 60 Hz.

a. Moan

b. Ping

c. Scream (upper band) and Wail (lower band)

d. Roar

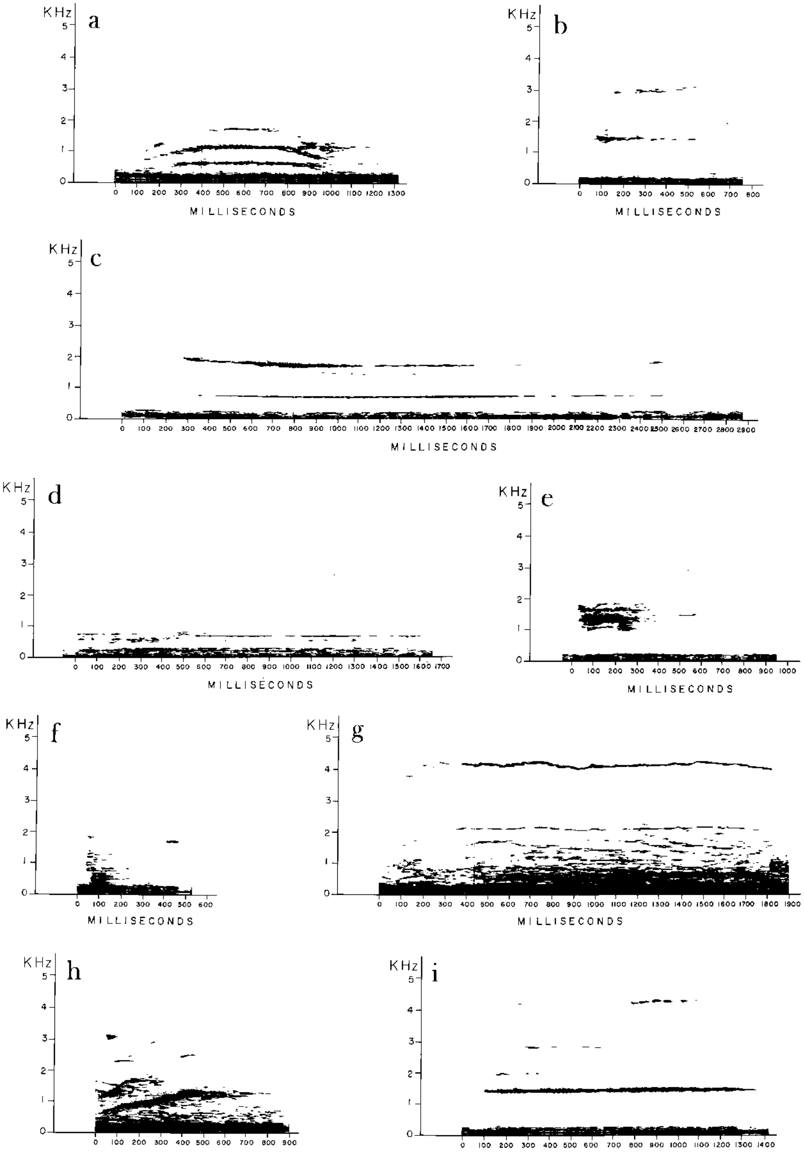
e. Blat

f. Jaw Clap

g. Squeal

h. Cry

i. Saguenay Long, Loud Whistle (Saguenay LLW)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5
MILLISECONDS
0 100 200 300 400 500 600 700 800 900 1000 1100 1200 1300
0 100 200 300 400 500 600 700 800
0 100 200 300 400 500 600 700 800 900 1000 1100 1200 1300 1400 1500 1600 1700 1800 1900 2000 2100 2200 2300 2400 2500 2600 2700 2800 2900
0 100 200 300 400 500 600 700 800 900 1000 1100 1200 1300 1400 1500 1600 1700
0 100 200 300 400 500 600 700 800 900 1000
0 100 200 300 400 500 600
0 100 200 300 400 500 600 700 800 900 1000 1100 1200 1300 1400 1500 1600 1700 1800 1900
0 100 200 300 400 500 600 700 800 900
0 100 200 300 400 500 600 700 800 900 1000 1100 1200 1300 1400

APPENDIX III

DESCRIPTION OF THE SynPBS SERIES OF PLAYBACK SOUNDS

AS	FREQUENCY (kHz)	DURATION (sec.)
1	4.8	30.0
2	2.4	30.0
3	4.8	1.7
4	2.4	1.7
5	2.4	2.7
6	4.8	2.7
7	3.3	30.0
8	3.3	1.7
9	3.3	2.7

APPENDIX IV

Increases and decreases in frequency of emission of 11 sound types during and after playback of the PBS series to the four captive belugas

			Sound Types Counted																																				
PBS	N	Period Change	Harmonic LLW			Jaw Clap			Buzz			Buzz-and-Whinny			Contact Sound-Series			Type-1 Squawk			Type-2 Squawk			Whistle			Chirp			Blare			Whinny			Total		
			+	-	0	+	-	0	+	-	0	+	-	0	+	-	0	+	-	0	+	-	0	+	-	0	+	-	0	+	-	0	+	-	0	+	-	0
Harmonic LLW	11	PrPb-Pb	9	0	2**	2	3	6	2	0	9	1	4	6	3	0	8	2	2	7	2	2	7	2	5	4	1	4	6				0	1	10	5	6	0
		Pb-PtPb	2	7	2	0	3	8	0	2	9	4	2	5	2	2	7	0	2	9	2	3	6	1	4	6	3	3	5				0	0	11	2	8	1
		PrPb-PtPb	8	0	3**	0	3	8	1	0	10	3	5	3	4	1	6	0	2	9	2	2	7	0	6	5*	2	4	5				0	1	10	6	5	0
Buzzes	11	PrPb-Pb	1	1	9	3	1	7	4	1	6	5	2	4	4	2	5				2	1	8	5	4	2	1	1	9				1	0	10	7	4	0
		Pb-PtPb	1	1	9	0	3	8	3	3	5	2	5	4	0	2	9				3	3	5	3	5	3	4	1	6				0	1	10	4	7	0
		PrPb-PtPb	0	1	10	0	1	10	3	0	8	2	2	7	2	2	7				4	1	6	2	5	4	4	1	6				0	0	11	6	4	1
Contact Sound-Series	10	PrPb-Pb	1	0	9	6	1	3	1	1	8	2	3	5	6	0	4*	1	1	8	1	2	7	5	3	2	3	2	5							7	3	0
		Pb-PtPb	0	1	9	0	7	3*	1	2	7	2	2	6	0	6	4*	1	0	9	1	3	6	1	4	4	1	3	6							1	9	0*
		PrPb-PtPb	0	0	10	0	1	9	1	1	8	2	4	4	0	1	9	2	1	7	1	3	6	2	3	5	0	4	6							2	6	2
Buzz-and-Whinny	11	PrPb-Pb	0	2	9	0	0	11	3	0	8	5	2	4	2	0	9	0	0	11	2	1	8	4	3	4	2	3	6							7	3	1
		Pb-PtPb	0	0	11	0	1	10	0	2	9	1	6	4	0	2	9	1	0	10	3	2	6	4	2	5	3	3	5							5	6	0
		PrPb-PtPb	0	2	9	0	1	10	1	1	9	2	2	7	0	0	11	1	0	10	3	1	7	5	2	4	5	2	4							5	6	0
Jaw Claps	9	PrPb-Pb	0	1	8	1	1	7	2	0	7	2	2	5	5	1	3	2	1	6	2	1	6	4	1	4	5	1	3							6	2	1
		Pb-PtPb	1	0	8	1	1	7	1	3	5	0	3	6	0	3	6	0	2	7	0	3	6	3	4	2	0	5	4							4	5	0
		PrPb-PtPb	1	0	8	1	2	6	1	1	7	0	2	7	2	1	6	0	1	8	0	1	8	4	1	4	1	4	4							4	5	0
Whinny	11	PrPb-Pb	1	0	10	2	0	9	3	1	7	4	1	6	5	1	5	0	1	10	0	2	9	5	3	3	2	1	8							6	4	1
		Pb-PtPb	0	1	10	1	2	8	0	3	8	0	4	7	1	6	4	1	0	10	3	0	8	0	6	5*	3	1	7							3	7	1
		PrPb-PtPb	0	0	11	2	0	9	1	1	9	0	1	10	0	1	10	0	0	11	2	1	8	1	5	5	3	1	7							5	4	2
Whistles	10	PrPb-Pb	2	1	7				4	0	6	2	2	6	2	2	6	1	0	9	1	1	8	2	5	3	1	3	6				0	0	10	5	3	2
		Pb-PtPb	3	2	5				2	2	6	0	2	8	1	2	7	0	2	8	2	1	7	4	4	2	4	0	6				1	0	9	3	6	1
		PrPb-PtPb	4	2	4				3	1	6	2	2	6	0	2	8	0	1	9	1	1	8	3	5	2	2	3	5				1	0	9	4	5	1

Appendix IV (cont.)

Sound Types Counted

PBS	N	Period Change	Harmonic LLW			Jaw Clap			Buzz			Buzz-and-Whinny			Contact Sound-Series			Type-1 Squawk			Type-2 Squawk			Whistle			Chirp			Blare			Whinny			Total		
			+	-	0	+	-	0	+	-	0	+	-	0	+	-	0	+	-	0	+	-	0	+	-	0	+	-	0	+	-	0	+	-	0	+	-	0
Blare	9	PrPb-Pb	0	1	8	1	0	8	1	1	7	5	0	4	2	1	6	1	1	7	1	1	7	6	2	1	1	2	6	0	0	9				7	2	0
		Pb-PtPb	0	1	8	0	1	8	2	1	6	2	5	2	1	2	6	0	1	8	2	1	6	4	4	1	3	2	4	2	0	7				2	7	0
		PrPb-PtPb	0	1	8	0	0	9	2	2	5	2	1	6	1	1	7	0	1	8	2	2	5	4	2	3	3	1	5	2	0	7				4	5	0
Type-1 Squawk	11	PrPb-Pb				3	0	8	3	1	7	1	3	7	2	2	7	1	2	8	5	1	5	2	4	5	4	4	3							4	6	1
		Pb-PtPb				1	3	7	0	3	8	1	1	9	2	1	8	1	1	9	1	4	6	4	3	4	1	4	6							4	5	2
		PrPb-PtPb				1	1	9	1	1	9	1	2	8	3	1	7	0	1	10	2	2	7	3	4	4	2	3	6							4	5	2
Jaw Clap-Buzz-and-Whinny	10	PrPb-Pb	0	1	9	1	1	8	2	0	8	1	2	7	1	1	8	1	0	9	2	2	6	3	4	3	3	3	4							3	6	1
		Pb-PtPb	3	0	7	0	1	9	1	2	7	1	1	8	3	2	5	0	1	9	2	3	5	4	2	4	2	2	6							6	3	1
		PrPb-PtPb	2	0	8	0	1	9	1	0	9	0	3	7	3	3	4	0	0	10	4	2	4	3	4	3	3	3	4							3	6	1
Type-2 Squawk	10	PrPb-Pb	0	1	9	0	1	9	1	0	9	2	2	6	2	0	8	0	1	9	2	1	7	4	2	4	2	2	6	0	1	9				4	4	2
		Pb-PtPb	0	0	10	0	1	9	0	1	9	0	4	6	1	1	8	0	0	10	1	3	6	2	5	3	1	4	5	0	0	10				2	7	1
		PrPb-PtPb	0	1	9	0	1	9	0	0	10	0	2	8	3	0	7	0	1	9	1	3	6	2	4	4	1	3	6	0	1	9				2	8	0
Control	9	PrPb-Pb	2	1	6				1	1	7	4	0	5	1	0	8	0	1	8	1	0	8	4	2	3	2	2	5							6	2	1
		Pb-PtPb	0	2	7				2	1	6	3	2	4	0	0	9	0	0	9	0	1	8	4	4	1	2	1	6							5	3	1
		PrPb-PtPb	0	1	8				2	0	7	5	0	4	1	0	8	0	1	8	0	0	9	5	1	3	2	3	4							5	1	3
Pure LLW	8	PrPb-Pb	4	0	4	0	0	8	0	0	8	1	1	6	2	0	6	1	1	6	4	2	2	1	4	3	1	2	5							5	1	2
		Pb-PtPb	0	3	5	2	0	6	0	0	8	2	1	5	2	4	2	0	2	6	3	1	4	5	1	2	2	2	4							3	4	1
		PrPb-PtPb	2	0	6	2	0	6	0	0	8	1	1	6	2	2	4	0	1	7	4	0	4	2	2	4	2	3	3							4	2	2

For a key to the symbols used, see Table 1.

APPENDIX V

Increases and decreases of interest directed toward hydrophone and sound source during and after playback of the PBS series to the four captive belugas

PBS	N	Period Change	Orient Toward Hydrophone			Orient Toward Sound Source			Approach Hydrophone			Approach Sound Source		
			+	-	0	+	-	0	+	-	0	+	-	0
Harmonic LLW	11	PrPb-Pb				6	0	5*	0	6	5*	3	2	6
		Pb-PtPb				0	6	5*	5	0	6	2	2	7
		PrPb-PtPb				1	0	10	1	2	8	3	2	6
Buzzes	11	PrPb-Pb	0	0	11	7	0	4*	1	6	4	7	1	3
		Pb-PtPb	2	0	9	1	7	3	5	1	5	1	6	4
		PrPb-PtPb	2	0	9	2	1	8	2	3	6	5	3	3
Contact Sound-Series	10	PrPb-Pb				7	1	2	1	3	6	1	4	5
		Pb-PtPb				1	7	2	0	0	10	2	3	5
		PrPb-PtPb				2	1	7	1	3	6	2	6	2
Buzz-and Whinny	11	PrPb-Pb	2	0	9	6	0	5*	1	5	5	7	0	4*
		Pb-PtPb	0	1	10	0	6	5*	5	2	4	1	6	4
		PrPb-PtPb	1	0	10	1	1	9	2	1	8	4	1	6
Jaw Claps	8	PrPb-Pb				5	1	2	4	2	2	2	1	5
		Pb-PtPb				0	3	5	1	3	4	1	3	4
		PrPb-PtPb				2	1	5	2	1	5	1	4	3
Whinny	11	PrPb-Pb	0	1	10	6	0	5*	3	5	3	8	1	2*
		Pb-PtPb	1	0	10	0	6	5*	2	2	7	0	8	3**
		PrPb-PtPb	0	0	11	0	0	11	2	5	4	1	1	9
Whistles	10	PrPb-Pb	0	1	9	7	0	3*	1	3	6	3	2	5
		Pb-PtPb	0	0	10	0	7	3*	2	5	3	2	3	5
		PrPb-PtPb	0	1	9	1	1	8	0	5	5	4	2	4
Blare	9	PrPb-Pb	0	1	8	5	1	3	1	3	5	1	0	8
		Pb-PtPb	0	0	9	0	5	4	3	1	5	3	1	5
		PrPb-PtPb	0	1	8	0	1	8	1	2	6	3	0	6
Type-1 Squawk	11	PrPb-Pb	1	1	9	7	0	4*	1	3	7	4	1	6
		Pb-PtPb	2	1	8	0	5	6	1	0	10	1	2	8
		PrPb-PtPb	1	0	10	3	0	8	2	2	7	3	1	7
Jaw Clap-Buzz-and-Whinny	10	PrPb-Pb				3	0	7	1	4	5	2	7	1
		Pb-PtPb				0	3	7	1	4	5	3	3	4
		PrPb-PtPb				0	0	10	0	6	4*	2	4	4
Type-2 Squawk	10	PrPb-Pb	0	0	10	5	1	4	2	1	7	6	0	4*
		Pb-PtPb	1	0	9	0	5	5	4	1	5	1	5	4
		PrPb-PtPb	1	0	9	1	2	7	4	0	6	2	1	7
Control	9	PrPb-Pb				6	0	3*	0	3	6	2	2	5
		Pb-PtPb				1	5	3	3	0	6	2	0	7
		PrPb-PtPb				1	0	8	2	1	6	3	1	5
Pure LLW	8	PrPb-Pb				5	0	3	2	2	4	3	4	1
		Pb-PtPb				0	5	3	2	2	4	2	4	2
		PrPb-PtPb				1	0	7	2	2	4	2	3	3

For a key to the symbols used, see Table 1.

APPENDIX VI

Increases and decreases in frequency of emission of 9 Saguenay-herd sound types during and after playback of the FldPBS series to the Saguenay herd

FldPBs	N	Period Change	Sound Types Counted Ping			Ring			Squeal			Chirp			Cry			Squawk			Jaw Clap			Moan			Click Train			Total		
			+	-	0	+	-	0	+	-	0	+	-	0	+	-	0	+	-	0	+	-	0	+	-	0	+	-	0	+	-	0
Harmonic		PrPb-Pb	3	6	2	1	5	5	1	3	7	2	4	5	2	4	5	0	3	8	1	3	7	0	1	10	2	4	5	3	6	2
LLW	11	Pb-PtPb	3	5	3	3	4	4	4	1	6	3	3	5	2	4	5	3	0	8	4	1	6	2	0	9	3	3	5	7	2	2
		PrPb-PtPb	2	6	3	2	4	5	3	1	7	2	2	7	1	4	6	1	0	10	3	1	7	2	0	9	3	3	5	6	3	2
		PrPb-Pb	2	5	3	0	5	5	0	7	3*	2	5	3	1	4	5	2	3	5	1	0	9	0	4	6	0	6	4*	0	9	1**
Buzzes	10	Pb-PtPb	5	3	2	6	0	4*	1	0	9	4	2	4	3	1	6	3	2	5	0	1	9	1	0	9	2	1	7	5	3	2
		PrPb-PtPb	6	3	1	5	2	3	1	7	2	3	3	4	1	2	7	3	2	5	0	0	10	1	4	5	1	5	4	2	6	2
		PrPb-Pb	3	6	3	4	2	6	2	2	8	3	4	5	3	0	9	1	2	9	0	2	10	0	2	10	0	5	7	5	4	3
Blare	12	Pb-PtPb	3	6	3	7	0	5*	2	2	8	4	3	5	4	3	5	2	1	9	2	1	9	1	1	10	3	2	7	6	5	1
		PrPb-PtPb	4	7	1	8	1	3*	4	2	6	5	3	4	4	3	5	2	1	9	2	1	9	0	1	11	3	5	4	7	4	1
Type-1		PrPb-Pb	1	6	3	2	5	3	2	2	6	2	4	4	3	3	4	2	2	6	1	1	8	3	1	6	0	3	7	0	9	1**
Squawk	10	Pb-PtPb	2	5	3	3	3	4	1	3	6	2	4	4	0	4	6	2	2	6	1	1	8	0	2	8	1	1	8	4	5	1
		PrPb-PtPb	0	9	1**	2	4	4	0	1	9	2	4	4	0	5	5	1	1	8	1	0	9	1	1	8	1	3	6	1	9	0*
Contact		PrPb-Pb	5	5	0	1	7	2	1	2	7	1	4	5	1	4	5	2	2	6	0	1	9	0	1	9	0	7	3*	1	9	0*
Sound-	10	Pb-PtPb	5	4	1	7	1	2	1	1	8	3	1	6	6	1	3	0	2	8	2	0	8	0	0	10	2	1	7	10	0	0**
Series		PrPb-PtPb	4	5	1	4	5	1	1	2	7	3	3	4	4	2	4	0	2	8	1	1	8	0	1	9	0	6	4*	1	8	1*
Jaw		PrPb-Pb	4	4	2	2	4	4	1	1	8	1	5	4	3	3	4	2	0	8	1	0	9	0	1	9	0	5	5	3	6	1
Claps	10	Pb-PtPb	4	4	2	5	2	3	3	0	7	3	1	6	5	2	3	1	2	7	1	1	8	3	0	7	4	1	5	6	3	1
		PrPb-PtPb	4	4	2	4	4	2	3	1	6	1	5	4	3	2	5	3	0	7	1	0	9	3	1	6	3	4	3	5	4	1
Type-2		PrPb-Pb	1	3	6	3	4	3	0	2	8	0	5	5	1	4	5	0	2	8	0	4	6	1	1	8	2	5	3	3	5	2
Squawk	10	Pb-PtPb	5	0	5	4	4	2	3	0	7	4	0	6	3	1	6	2	0	8	2	0	8	2	1	7	3	3	4	6	3	1
		PrPb-PtPb	4	2	4	2	4	4	3	1	6	1	5	4	2	4	4	1	2	7	0	3	7	2	1	7	5	3	2	3	6	1

Appendix VI (cont.)

Sound Types Counted

FldPBS	N	Period Change	Ping			Ring			Squeal			Chirp			Cry			Squawk			Jaw Clap			Moan			Click Train			Total		
			+	-	0	+	-	0	+	-	0	+	-	0	+	-	0	+	-	0	+	-	0	+	-	0	+	-	0	+	-	0
		PrPb-Pb	2	4	4	3	5	2	1	3	6	3	1	6	0	5	5	2	1	7	0	2	8	0	0	10	1	3	6	1	5	4
Pure LLW	10	Pb-PtPb	4	2	4	3	1	6	3	1	6	4	2	4	3	1	6	1	1	8	4	0	6	1	0	9	4	1	5	8	0	2**
		PrPb-PtPb	2	3	5	3	5	2	2	2	6	4	2	4	2	3	5	2	1	7	2	1	7	1	0	9	4	2	4	5	3	2
4.8 kHz		PrPb-Pb	0	7	3*	2	5	3	0	1	9	1	5	4	2	5	3	0	1	9	0	2	8	0	1	9	0	5	5	1	7	2
Pure Tone	10	Pb-PtPb	3	1	6	3	3	4	2	0	8	4	2	4	3	1	6	2	0	8	3	0	7	0	0	10	3	0	7	6	1	3
		PrPb-PtPb	1	6	3	2	5	3	2	1	7	4	3	3	3	4	3	1	1	8	3	1	6	0	1	9	1	4	5	4	4	2

For a key to the symbols used, see Table 1.

APPENDIX VIIa

Increases and decreases in frequency of emission of 9 Saguenay-herd sound types during and after playback of the SagPBS series to the Saguenay herd in 1970

SagPBS	N	Period Change	Sound Types Counted Ping			Ring			Squeal			Chirp			Cry			Squawk			Jaw Clap			Moan			Click Train			Total		
			+	-	0	+	-	0	+	-	0	+	-	0	+	-	0	+	-	0	+	-	0	+	-	0	+	-	0	+	-	0
Moans	10	PrPb-Pb	2	2	6	2	5	3	0	1	9	3	1	6	1	2	7	0	4	6	1	1	8				1	3	6	2	7	1
		Pb-PtPb	1	2	7	0	5	5	2	0	8	2	4	4	2	0	8	1	1	8	1	1	8				1	1	8	2	6	2
		PrPb-PtPb	2	3	5	1	7	2	1	1	8	1	1	8	2	2	6	0	4	6	1	1	8				0	4	6	0	9	1**
Pings	11	PrPb-Pb	2	1	8	1	6	4	2	0	9	2	3	6	1	2	8	1	4	6	1	0	10				2	3	6	2	8	1
		Pb-PtPb	3	1	7	3	1	7	0	2	9	5	1	5	3	1	7	5	0	6	1	1	9				2	1	8	5	4	2
		PrPb-PtPb	3	1	7	2	3	6	0	0	11	4	2	5	4	2	5	4	2	5	1	0	10				1	3	7	3	6	2
Screams-and-Wails	12	PrPb-Pb	1	4	7	0	6	6*	1	2	9	2	4	6	0	2	10	1	4	7	1	2	9	0	0	12	3	2	7	3	7	2
		Pb-PtPb	1	1	10	4	4	4	3	1	8	2	2	8	1	1	10	4	2	6	2	2	8	1	0	11	2	1	9	8	2	2
		PrPb-PtPb	0	3	9	3	6	3	2	0	10	2	4	6	1	2	9	4	4	4	2	2	8	1	0	11	2	3	7	4	4	4
Blats-and-Ping	9	PrPb-Pb	1	3	5	2	3	4	0	1	8	2	2	5	0	3	6	0	2	7	0	2	7	0	0	9	1	2	6	2	5	2
		Pb-PtPb	2	1	6	3	2	4	1	1	7	2	2	5	1	0	8	0	1	8	1	0	8	0	1	8	2	0	7	5	1	3
		PrPb-PtPb	2	2	5	2	3	4	1	2	6	2	1	6	1	2	6	0	2	7	0	1	8	0	1	8	2	1	6	4	3	2
Jaw Claps	10	PrPb-Pb	1	2	7	1	6	3	0	1	9	2	5	3	2	1	7	1	2	7	0	2	8	0	0	10	1	3	6	3	6	1
		Pb-PtPb	3	2	5	5	1	4	2	0	8	3	3	4	2	2	6	4	1	5	3	0	7	1	0	9	3	2	5	5	3	2
		PrPb-PtPb	4	2	4	1	7	2	2	0	8	4	3	3	2	2	6	2	2	6	2	1	7	1	0	9	2	3	5	4	5	1
Squeals	9	PrPb-Pb	1	5	3	4	4	1	0	1	8	1	4	4	0	3	6	4	3	2	0	1	8	0	2	7	3	2	4	3	5	1
		Pb-PtPb	0	2	7	4	1	4	3	0	6	5	1	3	0	0	9	4	3	2	0	0	9	1	0	8	1	3	5	6	3	0
		PrPb-PtPb	0	6	3*	4	4	1	3	0	6	5	2	2	0	3	6	3	2	4	0	1	8	1	2	6	1	3	5	4	5	0
Saguenay LLW	3	PrPb-Pb	0	0	3	0	1	2	0	0	3	1	0	2	0	0	3	0	2	1							2	1	0	2	1	0
		Pb-PtPb	0	1	2	1	2	0	1	0	2	1	1	1	1	0	2	1	1	1							0	3	0	1	1	1
		PrPb-PtPb	0	1	2	1	2	0	1	0	2	1	1	1	1	0	2	0	2	1							1	1	1	2	1	0

For a key to the symbols used, see Table 1.

APPENDIX VIIb

Increases and decreases in frequency of emission of 9 Saguenay-herd sound types during and after playback of the SagPBS series to the Saguenay herd in 1971

Sound Types Counted

SagPBS	N	Period Change	Ping			Ring			Squeal			Chirp			Cry			Squawk			Jaw Clap			Moan			Click Train			Total		
			+	-	0	+	-	0	+	-	0	+	-	0	+	-	0	+	-	0	+	-	0	+	-	0	+	-	0	+	-	0
		PrPb-Pb	0	4	6	1	3	6	0	1	9	1	0	9	0	0	10	0	1	9				1	0	9	0	6	4*	0	8	2**
Moans	10	Pb-PtPb	3	2	5	2	1	7	2	0	8	0	1	9	0	1	9	0	0	10				0	1	9	0	5	5	4	4	2
		PrPb-PtPb	2	3	5	2	1	7	2	0	8	0	0	10	0	1	9	0	1	9				0	0	10	0	6	4*	3	6	1
		PrPb-Pb	0	1	8	1	2	6	0	1	8	1	1	7	0	0	9	0	2	7	0	0	9				2	6	1	4	5	0
Pings	9	Pb-PtPb	2	1	6	1	1	7	1	0	8	2	0	7	0	1	8	1	0	8	1	0	8				1	4	4	3	4	2
		PrPb-PtPb	2	1	6	1	2	6	1	0	8	2	0	7	0	1	8	1	1	7	1	0	8				1	7	1	3	4	2
Screams-		PrPb-Pb	3	2	7	0	4	8				2	2	8	1	0	11	0	2	10				0	1	11	2	6	4	1	10	1*
and-Wails	12	Pb-PtPb	4	3	5	4	1	7				1	2	9	1	2	9	2	0	10				0	0	12	1	6	5	3	7	2
		PrPb-PtPb	3	2	7	3	3	6				1	1	10	1	1	10	1	1	10				0	1	11	1	7	4	3	8	1
Blats-		PrPb-Pb	1	4	6	1	5	5	1	1	9	3	2	6	1	1	9	2	0	9							4	5	2	4	7	0
and-Ping	11	Pb-PtPb	5	2	4	2	1	8	1	2	8	2	2	7	0	1	10	1	1	9							4	3	4	3	6	2
		PrPb-PtPb	3	3	5	3	4	4	1	1	9	2	2	7	0	1	10	2	0	9							3	5	3	5	6	0
Jaw		PrPb-Pb	2	4	4	1	2	7	1	1	8	2	1	7	0	0	10	0	2	8	0	1	9	0	0	10	3	6	1	2	7	1
Claps	10	Pb-PtPb	2	3	5	3	3	4	1	2	7	2	2	6	1	0	9	3	0	7	1	0	9	1	0	9	2	5	3	4	4	2
		PrPb-PtPb	2	2	6	3	3	4	1	1	8	1	1	8	1	0	9	2	2	6	0	0	10	1	0	9	1	7	2	4	5	1
		PrPb-Pb	1	4	5	1	1	8	1	1	8	0	3	7	0	2	8	1	1	8	0	1	9				2	6	2	1	8	1*
Squeals	10	Pb-PtPb	3	2	5	2	0	8	0	1	9	2	1	7	0	0	10	2	1	7	0	0	10				3	2	5	4	2	4
		PrPb-PtPb	3	3	4	1	1	8	0	1	9	1	2	7	0	2	8	1	1	8	0	1	9				3	6	1	3	5	2
Saguenay		PrPb-Pb	0	2	7	1	2	6				1	1	7	1	1	7				0	0	9				2	7	0	2	6	1
LLW	9	Pb-PtPb	2	1	6	1	1	7				0	1	8	0	0	9				1	0	8				1	4	4	2	5	2
		PrPb-PtPb	2	2	5	1	2	6				0	2	7	1	1	7				1	0	8				1	8	0*	1	7	1

For a key to the symbols used, see Table 1.

APPENDIX VIII

Increases and decreases in frequency of emission of 11 sound types during and after playback of the SagPBS series to three captive belugas

SagPBS	N	Period Change	Harmonic LLW			Jaw Clap			Buzz			Buzz-and-Whinny			Contact Sound-Series			Type-1 Squawk			Type-2 Squawk			Whistle			Chirp			Blare			Whinny			Total		
			+	-	0	+	-	0	+	-	0	+	-	0	+	-	0	+	-	0	+	-	0	+	-	0	+	-	0	+	-	0	+	-	0	+	-	0
Moans	9	PrPb-Pb				0	0	9							1	0	8				1	0	8	5	1	3	1	2	6							4	2	3
		Pb-PtPb				1	0	8							0	1	8				2	0	7	4	4	1	5	1	3							5	3	1
		PrPb-PtPb				1	0	8							0	0	9				2	0	7	5	1	3	4	2	3							6	2	1
Pings	8	PrPb-Pb				1	1	6							1	0	7	0	1	7	1	0	7	2	1	5	1	3	4							3	3	2
		Pb-PtPb				0	2	6							0	0	8	0	1	7	0	1	7	1	3	4	1	3	4							1	6	1
		PrPb-PtPb				1	1	6							1	0	7	0	1	7	0	0	8	2	3	3	1	3	4							3	3	2
Screams-and-Wails	9	PrPb-Pb				0	0	9	0	1	8				1	0	8	0	1	8	0	3	6	2	3	4	3	2	4							2	4	3
		Pb-PtPb				4	0	5	2	0	7				3	2	4	2	0	7	1	1	7	4	2	3	4	3	2							4	3	2
		PrPb-PtPb				4	0	5	2	1	6				3	1	5	2	0	7	1	3	5	6	2	1	5	2	2							6	3	0
Blats-and-Ping	9	PrPb-Pb				0	0	9	1	0	8				0	0	9	0	1	8	0	2	7	3	2	4	3	1	5							5	2	2
		Pb-PtPb				1	0	8	0	1	8				1	0	8	0	0	9	1	0	8	2	2	5	3	5	1							3	5	1
		PrPb-PtPb				1	0	8	0	0	9				1	0	8	0	1	8	1	2	6	2	3	4	3	3	3							3	4	2
Jaw Claps	9	PrPb-Pb				0	1	8							0	2	7	0	1	8	1	1	7	3	1	5	1	2	6							3	4	2
		Pb-PtPb				0	0	9							0	0	9	1	0	8	2	1	6	3	2	4	4	1	4							6	2	1
		PrPb-PtPb				0	1	8							0	2	7	1	1	7	1	1	7	4	2	3	4	2	3							4	3	2
Squeals	9	PrPb-Pb				1	0	8	1	0	8				2	1	6	0	1	8	3	0	6	4	2	3	1	3	5							5	2	2
		Pb-PtPb				0	1	8	0	1	8				1	1	7	2	0	7	1	2	6	4	3	2	2	2	5							4	4	1
		PrPb-PtPb				0	0	9	0	0	9				2	1	6	2	1	6	2	0	7	4	0	5	2	3	4							4	3	2
Saguenay LLW	9	PrPb-Pb				0	1	8							1	0	8	1	0	8	1	0	8	1	2	6	3	0	6							2	3	4
		Pb-PtPb				0	0	9							0	1	8	0	1	8	0	1	8	1	1	7	4	2	3							4	2	3
		PrPb-PtPb				0	1	8							0	0	9	0	0	9	1	0	8	1	3	5	5	0	4							4	3	2

For a key to the symbols used, see Table 1.

APPENDIX IX

Increases and decreases of interest directed toward hydrophone and sound source during and after playback of the SagPBS series to three captive belugas

SagPBS	N	Period Change	Orient Toward Hydrophone			Orient Toward Sound Source			Approach Hydrophone			Approach Sound Source		
			+	-	0	+	-	0	+	-	0	+	-	0
Moans	10	PrPb-Pb				4	1	5				3	1	6
		Pb-PtPb				0	4	6				2	2	6
		PrPb-PtPb				1	1	8				2	0	8
Pings	10	PrPb-Pb				8	0	2**				3	1	6
		Pb-PtPb				0	7	3*				0	3	7
		PrPb-PtPb				3	1	6				2	2	6
Screams-and-Wails	10	PrPb-Pb				5	0	5	0	2	8	3	1	6
		Pb-PtPb				0	5	5	1	1	8	1	3	6
		PrPb-PtPb				0	0	10	0	2	8	1	2	7
Blats-and-Ping	10	PrPb-Pb				7	0	3*	1	0	9	3	0	7
		Pb-PtPb				1	6	3	0	1	9	2	4	4
		PrPb-PtPb				3	1	6	0	0	10	2	1	7
Jaw Claps	11	PrPb-Pb				8	0	3**	0	1	10	5	0	6
		Pb-PtPb				0	6	5*	1	0	10	0	5	6
		PrPb-PtPb				3	0	8	1	1	9	2	1	8
Squeals	10	PrPb-Pb				8	0	2**	1	0	9	3	3	4
		Pb-PtPb				0	8	2**	0	2	8	1	4	5
		PrPb-PtPb				0	2	8	0	1	9	0	3	7
Saguenay LLW	10	PrPb-Pb				7	0	3*				2	0	8
		Pb-PtPb				0	5	5				1	1	8
		PrPb-PtPb				4	0	6				2	0	8

For a key to the symbols used, see Table 1.

APPENDIX X

Increases and decreases in frequency of emission of 11 sound types during and after playback of the SagPBS series to Alex

SagPBS	N	Period Change	Sound Types Counted																																			
			Harmonic LLW			Jaw Clap			Buzz			Buzz-and-Whinny			Contact Sound-Series			Type-1 Squawk			Type-2 Squawk			Whistle			Chirp			Blare			Whinny			Total		
			+	-	0	+	-	0	+	-	0	+	-	0	+	-	0	+	-	0	+	-	0	+	-	0	+	-	0	+	-	0	+	-	0	+	-	0
Moans	7	PrPb-Pb	2	2	3	1	0	6	2	0	5	1	2	4				1	0	6				1	0	6							0	0	7	4	2	1
		Pb-PtPb	0	3	4	0	1	6	1	2	4	4	1	2				1	1	5				1	1	5							1	0	6	2	3	2
		PrPb-PtPb	2	2	3	0	0	7	1	0	6	4	1	2				2	1	4				1	0	6							1	0	6	6	1	0
Pings	7	PrPb-Pb	3	0	4	1	0	6	3	1	3	2	2	3				1	0	6				0	0	7										5	2	0
		Pb-PtPb	0	3	4	0	1	6	0	3	4	2	4	1				2	1	4				1	0	6										3	4	0
		PrPb-PtPb	1	1	5	0	0	7	0	2	5	1	4	2				2	1	4				1	0	6										3	3	1
Screams-and-Wails	7	PrPb-Pb	6	0	1*	2	1	4	0	1	6	1	4	2				1	1	5				1	0	6										4	3	0
		Pb-PtPb	1	5	1	0	2	5	1	0	6	2	2	3				2	0	5				1	0	6										1	4	2
		PrPb-PtPb	2	1	4	0	1	6	1	1	5	1	4	2				2	1	4				1	0	6										4	3	0
Blats-and-Ping	7	PrPb-Pb	4	1	2	0	1	6	1	2	4	4	3	0				1	2	4				1	1	5										4	2	1
		Pb-PtPb	1	3	3	0	1	6	0	1	6	2	3	2				1	1	5				1	1	5										1	6	0
		PrPb-PtPb	1	2	4	0	1	6	0	2	5	4	2	1				1	2	4				0	1	6										2	4	1
Jaw Claps	7	PrPb-Pb							0	3	4	0	3	4				1	1	5				2	0	5	0	1	6							1	5	1
		Pb-PtPb							3	0	4	2	1	4				2	0	5				1	1	5	0	0	7							2	0	5
		PrPb-PtPb							2	2	3	1	2	4				2	0	5				1	1	5	0	1	6							2	4	1
Squeals	6	PrPb-Pb	3	0	3	0	1	5	2	1	3	4	2	0				3	1	2				0	3	3				1	0	5	0	0	6	4	1	1
		Pb-PtPb	1	2	3	0	0	6	2	2	2	2	4	0				0	4	2				0	1	5				0	1	5	1	0	5	0	6	0*
		PrPb-PtPb	2	1	3	0	1	5	4	0	2	3	1	2				0	3	3				0	3	3				0	0	6	1	0	5	2	4	0
Saguenay LLW	7	PrPb-Pb	2	0	5	2	1	4	0	1	6	2	3	2				3	1	3				0	1	6	1	0	6	0	1	6				3	4	0
		Pb-PtPb	0	2	5	1	2	4	3	1	3	4	2	1				3	2	2				2	0	5	0	1	6	0	0	7				3	4	0
		PrPb-PtPb	0	1	6	1	2	4	3	2	2	3	3	1				2	1	4				1	1	5	0	0	7	0	1	6				3	4	0
Harmonic LLW	7	PrPb-Pb	5	0	2				0	0	7	1	2	4				1	0	6				1	0	6										5	0	2
		Pb-PtPb	0	5	2				2	0	5	1	1	5				1	0	6				1	0	6										1	4	2
		PrPb-PtPb	3	1	3				2	0	5	1	2	4				1	0	6				1	0	6										4	1	2

For a key to the symbols used, see Table 1.

APPENDIX XI

Increases and decreases of interest directed toward hydrophone and sound source during and after playback of the SagPBS series to Alex

SagPBS	N	Period Change	Orient Toward Hydrophone			Orient Toward Sound Source			Approach Hydrophone			Approach Sound Source		
			+	-	0	+	-	0	+	-	0	+	-	0
		PrPb-Pb	1	1	9	3	0	8	3	1	7	4	2	5
Moans	11	Pb-PtPb	1	0	10	1	4	6	3	3	5	2	4	5
		PrPb-PtPb	1	1	9	1	1	9	2	2	7	3	3	5
		PrPb-Pb	0	0	11	2	0	9	1	1	9	6	1	4
Pings	11	Pb-PtPb	1	0	10	1	1	9	2	1	8	2	6	3
		PrPb-PtPb	1	0	10	1	0	10	2	1	8	3	3	5
Screams-		PrPb-Pb	1	0	10	3	1	7	0	1	10	2	3	6
and-Wails	11	Pb-PtPb	1	1	9	2	4	5	2	3	6	2	3	6
		PrPb-PtPb	1	0	10	2	1	8	2	3	6	3	4	4
Blats-		PrPb-Pb	0	0	11	3	2	6	3	1	7	4	3	4
and-Ping	11	Pb-PtPb	0	1	10	1	3	7	1	2	8	4	2	5
		PrPb-PtPb	0	1	10	0	1	10	3	3	5	3	1	7
Jaw		PrPb-Pb	2	0	9	6	0	5*	2	2	7	1	3	7
Claps	11	Pb-PtPb	0	2	9	1	6	4	0	2	9	3	4	4
		PrPb-PtPb	0	0	11	3	1	7	1	3	7	1	5	5
		PrPb-Pb	2	1	7	4	1	5	0	3	7	2	2	6
Squeals	10	Pb-PtPb	1	2	7	3	2	5	0	2	8	2	2	6
		PrPb-PtPb	1	1	8	4	1	5	0	4	6	2	3	5
Saguenay		PrPb-Pb	2	0	9	2	2	7	6	1	4	1	3	7
LLW	11	Pb-PtPb	1	2	8	0	3	8	1	3	7	4	1	6
		PrPb-PtPb	1	0	10	0	2	9	4	2	5	3	1	7

For a key to the symbols used, see Table 1.

APPENDIX XII

Increases and decreases in frequency of emission of 11 sound types during and after playback of the SynPBS series to Alex

			Sound Types Counted											
SynPBS	N	Period Change	Harmonic LLW	Jaw Clap	Buzz	Buzz-and-Whinny	Contact Sound-Series	Type-1 Squawk	Type-2 Squawk	Whistle	Chirp	Blare	Whinny	Total
			+ - 0	+ - 0	+ - 0	+ - 0	+ - 0	+ - 0	+ - 0	+ - 0	+ - 0	+ - 0	+ - 0	+ - 0
4.8 kHz		PrPb-Pb	10 0 1**	2 0 9	0 0 11	5 2 4		3 0 8		0 0 11				9 1 1*
30 sec.	11	Pb-PtPb	0 9 2**	0 2 9	1 0 10	2 6 3		0 3 8		1 0 10				0 10 1**
		PrPb-PtPb	3 1 7	1 0 10	1 0 10	3 3 5		2 0 9		1 0 10				4 4 3
2.4 kHz		PrPb-Pb	10 0 2**	0 2 10	0 3 9	2 4 6		5 0 7		3 1 8	1 0 11	1 0 11		10 1 1*
30 sec.	12	Pb-PtPb	0 10 2**	1 1 10	1 0 11	3 2 7		2 4 6		2 3 7	0 1 11	0 1 11		0 10 2**
		PrPb-PtPb	3 2 7	1 2 9	0 2 10	3 4 5		2 1 9		2 0 10	0 0 12	0 0 12		6 3 3
4.8 kHz		PrPb-Pb	5 1 6	3 0 9	3 1 8	3 5 4		3 1 8		3 1 8				6 3 3
1.7 sec.	12	Pb-PtPb	1 7 4	3 1 8	3 2 7	3 4 5		1 3 8		0 3 9				3 6 3
		PrPb-PtPb	3 2 7	3 1 8	3 1 8	2 5 5		1 2 9		0 2 10				3 6 3
2.4 kHz		PrPb-Pb	7 0 5*	0 1 11	4 2 6	3 6 3		2 2 8	0 1 11	2 1 9	0 0 12	1 0 11		6 4 2
1.7 sec.	12	Pb-PtPb	1 7 4	1 0 11	3 4 5	4 3 5		5 1 6	0 0 12	3 1 8	1 0 11	0 0 12		4 5 3
		PrPb-PtPb	3 2 7	0 1 11	3 1 8	2 7 3		4 2 6	0 1 11	3 1 8	1 0 11	1 0 11		5 6 1
2.4 kHz		PrPb-Pb	5 2 5	1 0 11	1 0 11	4 1 7		4 2 6	1 1 10	3 2 7	0 2 10	1 0 11		8 2 2
2.7 sec.	12	Pb-PtPb	0 5 7	0 1 11	2 2 8	3 2 7		2 4 6	1 0 11	3 1 8	1 0 11	0 1 11		1 8 3*
		PrPb-PtPb	3 3 6	0 1 11	2 1 9	2 3 7		2 2 8	1 1 10	2 2 8	1 1 10	1 0 11		4 5 3
4.8 kHz		PrPb-Pb	6 2 4	1 0 11	1 2 9	0 4 8		4 2 6	2 0 10	3 1 8	1 0 11			9 2 1
2.7 sec.	12	Pb-PtPb	1 6 5	0 1 11	2 1 9	4 1 7		1 4 7	1 2 9	0 3 9	0 1 11			3 7 2
		PrPb-PtPb	1 6 5	0 1 11	1 3 8	3 3 6		0 2 10	1 0 11	1 1 10	0 1 11			5 6 1
3.3 kHz		PrPb-Pb	3 1 2		3 0 3	3 1 2		2 1 3		3 1 2		0 0 6		3 2 1
30 sec.	6	Pb-PtPb	0 3 3		1 3 2	3 1 2		3 2 1		1 2 3		1 0 5		2 3 1
		PrPb-PtPb	0 2 4		1 0 5	4 1 1		3 1 2		1 1 4		1 0 5		4 1 1

APPENDIX XII (cont.)

Sound Types Counted

SynPBS	N	Period Change	Harmonic LLW			Jaw Clap			Buzz			Buzz-and-Whinny			Contact Sound-Series			Type-1 Squawk			Type-2 Squawk			Whistle			Chirp			Blare			Whinny			Total		
			+	-	0	+	-	0	+	-	0	+	-	0	+	-	0	+	-	0	+	-	0	+	-	0	+	-	0	+	-	0	+	-	0	+	-	0
3.3 kHz		PrPb-Pb	5	0	1	1	0	5	1	1	4	4	1	1				2	2	2				0	1	5										4	1	1
1.7 sec.	6	Pb-PtPb	0	4	2	0	1	5	0	0	6	2	3	1				2	2	2				2	0	4										2	4	0
		PrPb-PtPb	1	1	4	0	0	6	1	1	4	2	3	1				2	1	3				2	1	3										2	4	0
3.3 kHz		PrPb-Pb	4	0	2	2	0	4	0	0	6	1	2	3				3	1	2				0	2	4	0	0	6	1	0	5				5	1	0
2.7 sec.	6	Pb-PtPb	2	3	1	0	2	4	2	1	3	2	1	3				2	4	0				0	0	6	1	0	5	0	1	5				2	3	1
		PrPb-PtPb	3	0	3	1	0	5	2	1	3	3	1	2				2	2	2				0	2	4	1	0	5	0	0	6				4	1	1
Harmonic		PrPb-Pb	11	0	2**	1	1	11	0	0	13	1	4	8				3	1	9				3	0	10	0	0	13							10	1	2*
LLW	13	Pb-PtPb	1	10	2**	1	1	11	2	1	10	2	3	8				5	0	8				3	1	9	1	0	12							5	6	2
(control)		PrPb-PtPb	4	3	6	1	2	10	2	1	10	2	3	8				5	1	7				5	0	8	1	0	12							7	2	4

For a key to the symbols used, see Table 1.

APPENDIX XIII

Increases and decreases of interest directed toward hydrophone and sound source during and after playback of the SynPBS series to Alex

SynPBS	N	Period Change	Orient Toward Hydrophone			Orient Toward Sound Source			Approach Hydrophone			Approach Sound Source		
			+	-	0	+	-	0	+	-	0	+	-	0
4.8 kHz		PrPb-Pb	0	1	10	6	0	5*				3	2	6
30 sec.	11	Pb-PtPb	0	0	11	1	6	4				2	4	5
		PrPb-PtPb	0	1	10	2	0	9				2	4	5
2.4 kHz		PrPb-Pb	1	0	11	3	3	6	1	1	10	2	3	7
30 sec.	12	Pb-PtPb	0	0	12	0	3	9	1	0	11	2	2	8
		PrPb-PtPb	1	0	11	1	3	8	2	1	9	1	3	8
4.8 kHz		PrPb-Pb	1	1	10	3	1	8	0	1	11	6	1	5
1.7 sec.	12	Pb-PtPb	1	1	10	1	5	6	0	1	11	1	3	8
		PrPb-PtPb	1	1	10	1	3	8	0	2	10	3	1	8
2.4 kHz		PrPb-Pb				3	2	7	2	3	7	3	2	7
1.7 sec.	12	Pb-PtPb				0	4	8	1	2	9	2	3	7
		PrPb-PtPb				2	4	6	1	3	8	3	1	8
2.4 kHz		PrPb-Pb	0	1	11	1	0	11	0	1	11	4	0	8
2.7 sec.	12	Pb-PtPb	1	0	11	0	3	9	0	1	11	2	5	5
		PrPb-PtPb	1	1	10	0	2	10	0	1	11	3	1	8
4.8 kHz		PrPb-Pb	1	0	11	1	1	10	0	0	12	1	3	8
2.7 sec.	12	Pb-PtPb	1	1	10	2	2	8	1	0	11	3	1	8
		PrPb-PtPb	1	0	11	1	2	9	1	0	11	3	3	6
3.3 kHz		PrPb-Pb				2	0	4	0	0	6	1	0	5
30 sec.	6	Pb-PtPb				0	2	4	1	0	5	1	0	5
		PrPb-PtPb				0	0	6	1	0	5	1	0	5
3.3 kHz		PrPb-Pb				1	0	5	0	1	5	2	3	1
1.7 sec.	6	Pb-PtPb				1	1	4	1	0	5	0	3	3
		PrPb-PtPb				1	0	5	1	1	4	1	3	2
3.3 kHz		PrPb-Pb				2	0	4	1	1	4	1	3	2
2.7 sec.	6	Pb-PtPb				0	2	4	0	0	6	0	1	5
		PrPb-PtPb				0	0	6	1	1	4	0	3	3
Harmonic		PrPb-Pb	3	1	9	3	1	9	1	0	12	2	5	6
LLW	13	Pb-PtPb	0	3	10	1	4	8	1	0	12	6	2	5
(control)		PrPb-PtPb	1	1	11	1	1	11	1	0	12	4	5	4

For a key to the symbols used, see Table 1.