BELUKHA WHALE (*Delphinapterus leucas*) RESPONSES TO INDUSTRIAL NOISE IN NUSHAGAK BAY, ALASKA: 1983

by

Brent S. Stewart, Frank T. Awbrey, and
William E. Evans

Hubbs-Sea World Research Institute

Final Report
Outer Continental Shelf Environmental Assessment Program
Research Unit 629

1983

TABLE OF CONTENTS

List of Figures 591

List of Tables 593

INTRODUCTION 595

METHODS 595

Collection of Behavioral Data 596
Acoustic Data Collection and Analysis 599
Playback Experiments 599
Playback Experiment Design 600
Aerial Surveys 601

RESULTS 605

Distribution and Relative Abundance of Belukha Whales in Nushagak Bay; 4 June to 18 July 1983 605
Effects of Sound Playback (SEDCO 708) on the Behavior of Belukha Whales in Snake River, AK 605

DISCUSSION 613

REFERENCES 615

LIST OF FIGURES

Figure 1. Map of belukha whale study area on the Snake River during June-July 1982 and 1983.

Figure 2. Route flown on six aerial surveys in Nushagak Bay and its tributaries between 4 **June and 13 July 1983.**

Figure 3. Location of belukha whale individuals and groups seen in aerial surveys of Nushagak Bay and its tributaries.

LIST OF TABLES

Table 1. Effort summary of Belukha whale observations in Snake River, Nushagak Bay, Alaska; 15 June - 13 July 1983.

Table 2. Distribution and abundance of Belukha whales in Nushagak Bay, Alaska; June-July 1983.

Table 3. Schedule of playback (SEDCO 708) experiments.

Table 4. Mean respiration rates (blows/rein) and respiration intervals (sees) of belukha whales in Snake River, Alaska in different environmental and experimental conditions. (Values in parentheses are standard deviations).

Table 5. Summary of Belukha presence in Snake River observation and direction of whale movement.

Table 6. Approximate seasonal abundance of Belukha whales in Nushagak Bay; June to July 1983.

INTRODUCTION

Stewart et al. (1982) reported that belukha whales in Snake River, Alaska did not appear to react strongly to playbacks of oil industry-related noise at levels up to 60 dB above ambient, and they suggested that sound quality is more important than sound quantity in eliciting responses. Noise from outboard rotors, for example, seemed to cause aversion even when it was barely perceptible. Playback experiments with captive belukhas indicated that whales acclimate more quickly to some sounds than to others (Thomas and Kastelein 1983, Awbrey et al. 1984). Observations of free-ranging and captive belukha whales also suggested that responses of belukhas to sounds are affected strongly by habitat and by the whales' activity (Stewart et al. 1982).

Between 15 June and 14 July 1983 we conducted playback experiments with belukha whales in the Snake River, Alaska, using sounds recorded near an operating oil drilling rig. The objectives of these experiments were to quantify behavioral responses of belukha whales to oil drilling noise in an area where foreign acoustic stimuli were absent, and to test the hypothesis that belukha whales would not approach a source of loud sound.

Observations made in 1982 showed that belukhas would leave an area when outboard motor noise was present, regardless of their previous activity, swim direction, or tide conditions. We hypothesized that their response to oil rig noise would be similar. If whales did remain in the river during playback, we hypothesized that they would neither approach nor pass through the area of the playback sound source.

METHODS

Research in the Snake River, Alaska, was conducted from 15 June to 14 July 1983. Observations were made from a 32' motor vessel anchored

about 30m off the east bank near "Belukha Point" (Figure 1). The boat's engines were run infrequently (only to reset the anchor) to prevent that noise source from affecting normal behavior of whales or from interfering with playback experiments.

Collection of Behavioral Data

Data on whale presence, swim direction, group size and composition, distance from shore, spacing between individuals (in body lengths), respiration rates, intervals between blows, general activity and response to disturbances were collected daily between 15 and 21 June and 4 and 13 July (Table I). Data were collected using focal animal and focal group sampling techniques (Altman 1974) similar to those used by Stewart et al. (1982). Observations, including group size and composition, swim direction and timing of respirations, were recorded on cassette tapes. For groups of less than three whales, focal animal sampling was used to record all respirations of each whale. For groups of more than three, the number of whales in the group was first determined and the total number of respirations for the group was recorded for the observation period. Blow interval is defined as the elapsed time between each blow or surfacing; these data were obtained for focal animals only. Respiration rate is defined as the number of respirations per whale per minute; these data were obtained for both focal animals and focal groups.

Intervals and rates were determined for the following treatments:

1) Whales moving down river/tide falling/undisturbed
2) Whales moving down river/tide falling/disturbed
3) Whales moving down river/tide falling/after disturbance
4) Whales milling/undisturbed
5) Whales milling/disturbed

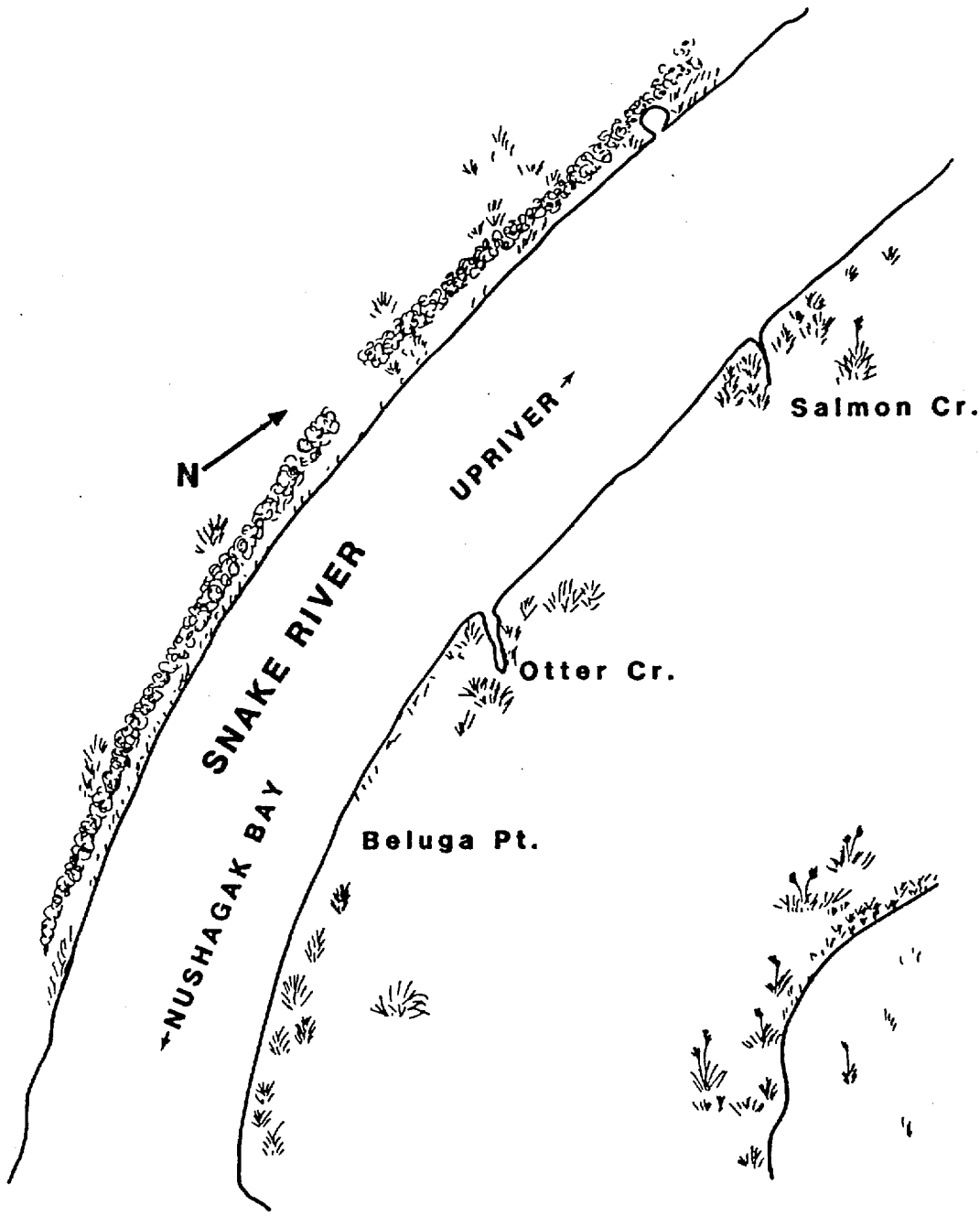

Fig. 1. Map of belukha whale study area on the Snake River during June-July 1982 and 1983

Table 1. Effort summary of Belukha whale observations in Snake River, Nushagak Bay, Alaska; 15 June - 13 July 1983.

Date	Begin observations	End observations	Hrs. observations
15 June	0900	1800	9.0
15 June	1900	21 00	2.0
16 June	0700	1400	7.0
16 June	1600	2200	6.0
17 June	0700	2230	15.5
18 June	0830	2300	14.5
19 June	0800	1200	4.0
19 June	1400	1500	1.0
19 June	1645	2300	6.25
20 June	0800	1400	6.0
20 June	1830	2100	2.5
21 June	0900	2300	15.0
4 July	1900	2230	3.5
5 July	0700	2200	15.0
6 July	0730	2230	15.0
7 July	0730	2230	15.0
8 July	0730	2300	15.5
9 July	0730	2300	15.5
10 July	0630	2330	17.0
11 July	0500	2230	17.5
12 July	0500	2330	18.5
13 July	0500	0800	3.0
		Total	224.25

6) Whales milling/after disturbance

7) 'Whales moving upriver/tide falling/undisturbed

8) Whales moving upriver/tide falling/disturbed

9) Whales moving upriver/tide falling/after disturbance

A t-test was used to test for differences among 'disturbed', 'undisturbed' and 'post-disturbed' treatments.

Acoustic **Data Collection and Analysis**

The system used to collect and record sound pressure level and spectral data consisted of a calibrated ITC 6050C hydrophore (sensitivity 11.75mv/Pa; frequency response 30 Hz to 50 kHz $\pm$ 3 dB) and a Nagra IV SJS tape recorder (frequency response 20 Hz to 35 kHz $\pm$ 2 dB at 38.1 cm/s). The hydrophore was suspended from the boat by an elastic band to reduce acceleration noise. The recorder has precision 1 dB step attenuators and is designed to be used for making sound level measurements. Its meter reads "peak" (5 ms time constant) sound level (SL). Insert calibration voltages corresponding to known underwater SL'S were recorded on each tape and used to set the engineering units scale of a Spectral Dynamics model 345 FFT spectrum analyzer to read directly in decibels re 1 Pa or re 1 Pa^2/Hz, as appropriate, when the tapes were analyzed. Ambient sound pressure and spectral levels were measured and recorded at various sites in the river. Results were the same as reported in the Year I report.

Playback Experiments

All playback experiments used an Acoustic Systems, Inc. TS107A underwater sound projector (a specially modified battery-operated 100 watt per channel 2-channel amplifier driving a LuBell Labs model 98

underwater loudspeaker), which can produce SL's as high as 180 dB re 1 Pa at 1m. Recordings of the sounds from SEDCO 708 semi-submersible drilling platform recorded at 0.1nmi, hydrophore depth 30m, were supplied by Polar Research Labs (PRL). The source level of this sound computed by PRL is 154dB re 1 Pa. The actual average levels on the tape vary about 5dB. The tape segment recorded at this distance and hydrophore depth on the cassette supplied to us was about 7 min. long. It contained numerous signal' dropouts where high voltages generated by acceleration of the hydrophore as it was moved by wave action caused the preamplifier to block. This problem was surmounted by copying the cassette onto reel-to-reel tape at 38 cm/sec, cutting out the segments with no signal, and then splicing together the taped segments containing good signals. This procedure yielded a 4 minutes long tape with no obvious splice noise or signal dropouts. Eight duplicates of this tape were spliced together to make a 32 minute submaster for making playback cassettes. These cassettes were recorded on the same Sony TCD5 used for field playback. A spectrum analyzer was used to compare the signal on the final cassette with that on the Polar Research Labs cassette to ascertain that signal degradation was acceptably low. Belukha whale vocalizations were analyzed with the FFT spectrum analyzer and a Kay Elemetrics Model 6061B sonagraph.

Playback Experiment Design

Two kinds of playback experiments were conducted. Both used a 30 minute cassette of SEDCO 708 semi-submersible drilling platform as the noise source. Eleven of 13 playbacks involved whales first seen approaching within 1.5km or less of the boat. With the amplifier's level control set at minimum, the playback system was turned on, the tape started and then the level control was advanced smoothly within about 5 seconds

to a preset point. At this setting the playback level measurer! with the hydrophore 1 m from the projector ranged between 158 and 163 dB re 1 ups. Any effects on the whales' behavior were noted. Playback was stopped when no whales had been seen for at least one minute.

The second type of experiment tested the hypothesis that the whales would not approach and pass the sound source. In these two sessions, playback was started as soon as possible after the whales came into view around a river bend 4.6km upstream. It continued until (i) the cassette ended, (ii) the whales passed the boat or (iii) turned back.

Aerial Surveys

Number and distribution of belukha whales in Nushagak Bay and its estuaries was documented from six aerial surveys (Table II). Surveys were flown in a single engine, high wing, Cessna 185 (bubble windows) or a Cessna 210 Station Air at altitudes of 150m to 300m. Survey routes were parallel to the coastline (.5km offshore or along one hank when rivers were surveyed) and were essentially identical on all flights (Fig. 2). Survey teams consisted of a senior observer, pilot (who also spotted whales), and occasionally a third observer. Both sides of the track line were monitored on all flights. The track line itself was monitored when surveys were flown in the Cessna 185. A specified transect width was not surveyed but, instead, observers recorded all whales observed at the surface. Position, size and composition of whale groups, and direction of whale movement were recorded on maps and cassette tapes for all sightings.

Table II. Distribution and abundance of Belukha whales in Nushagak Bay, Alaska; June-July 1983,

Date	Lat./Long	Total No. whales	No. groups
4 June	58°47'N/158°34'W	24	3
4 June	59°01'N/158°41'W	9	2
11 June	58°43'N/158°42'W	5	1
11 June	59°03'N/158°23'W	15	1
11 June	58°47'N/158°45'W	13	1
11 June	58°52'N/158°45°W	2	1
11 June	58°47'N/158°53'W	5.	1
23 June	58°49'N/158039'W	3	1
23 June	58°52'N/158°36'W	20	1
23 June	58°53'N/158°37'W	3	1
23 June	59°02'N/158°24'W	3	1
23 June	59°02'N/158°21'W	10	1
23 June	58°45′N/158046′w	22	1
23 June	58°49'N/158°45'W	9	1
23 June	58°50'N/158°45'W	13	1
23 June	58°50'N/158°45'W	12	1
23 June	58°54'N/158°46'W	1	1
23 June	58°56'N/158°45'W	4"	1
23 June	58°57'N/158°48'W	1	1
23 June	58°58'N/158°47'W	3	1
23 June	58°47'N/158°51'W	1	1
23 June	58°48'N/158°49'W	2	1
23 June	58°48'N/158°50'W	4	1

23 June	58°48'N/158°52'W	5	1
23 June	58°48'N/158°52'W	4	1
30 June	59°42'N/158°42'W	60-70	1
30 June	58°47'N/158°41 'W	40	1
30 June	58°51'N/158°33'W	1	1
30 June	58°50'N/158040'N	4	1
30 June	58°52'N/158038'W	2	1
30 June	58°53'N/158°37'W	1	1
30 June	59°03'N/158°23'W	7	1
30 June	59°04'N/158°22'W	2	1
30 June	58°47'N/158°53'W	8	1
30 June	58°48′N/158050′W	12	1
30 June	58°57′N/158048′w	1	1
30 June	58°56′N/158046′W	1	1
14 July	58°48'N/158°35'W	3	1
14 " July	58°53'N/158°33'W	70	1
14 July	58°55′N/158034′W	15	1
14 July	58°56'N 158°32'W	200	1
14 July	59°01'N/158°27'W	40-50	1
14 July	58°49′N/158044′W	25-30	1
14 July	58°56'N/158°45'W	2	1
14 July	58°58'N/158°46'W	10	1
14 July	58°47'N/158°51 'W	2	1
18 July	58°44′N/158038′W	400	1
18 July	58°47'N/158°34'W	40	1
18 July	59°03′N/158023′W	12-15	1

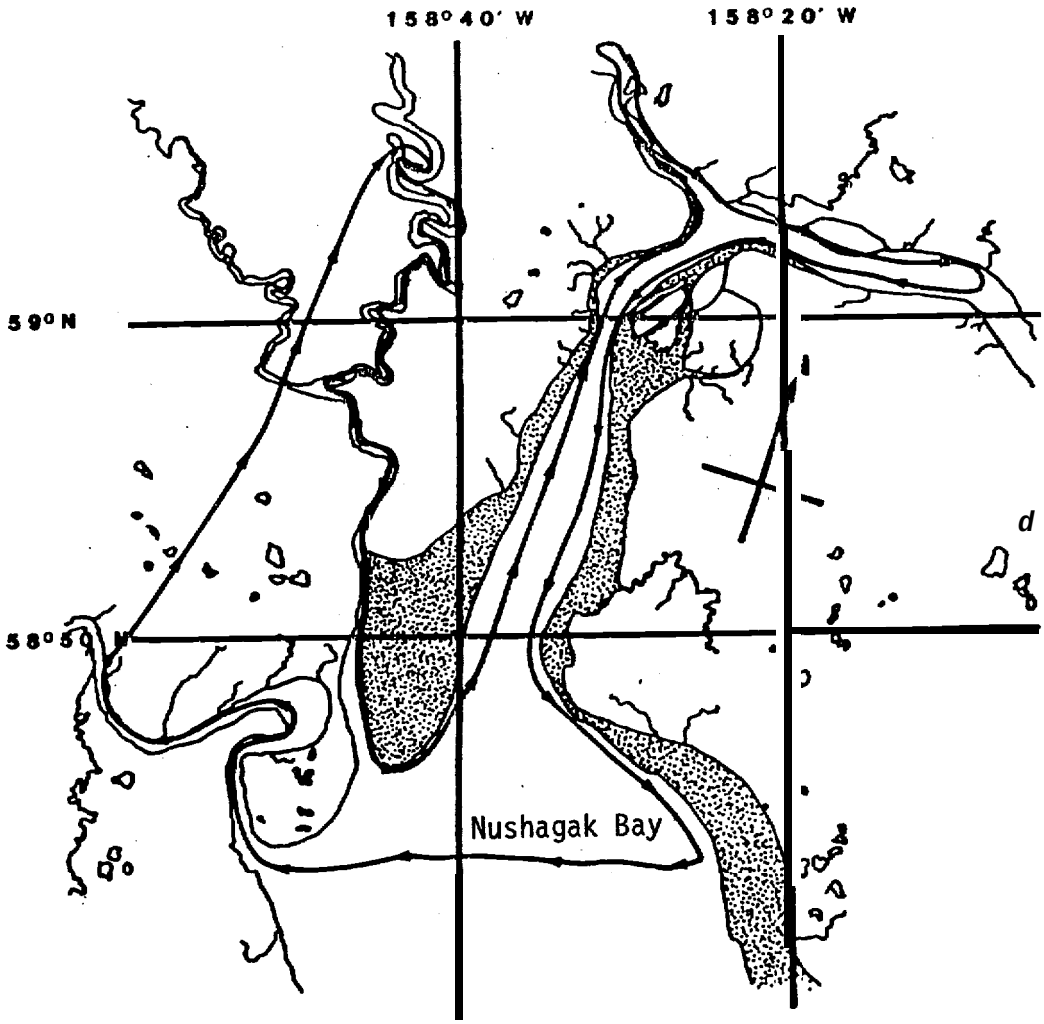

Fig. 2. Route flown on six aerial surveys in Nushagak Bay and its tributaries between 4 June and 18 July 1983.

RE SULTS

Distribution and relative abundance of belukha whales in Nushagak Bay; 4 June to 18 July 1983.

Few whales were seen in Nushagak Bay in early June (Table VI). Abundance apparently increased steadily through mid-July when about 454 whales were seen, most just outside the mouths of the Snake and Igushik Rivers (Table VI, Fig. 3). Throughout' the study period most whales were seen outside the mouth of the Snake River and near Clark's Point. Smaller numbers, however, were seen regularly near the mouth of the little Muklung River, at the confluence of Wood and Nushagak Rivers. The largest number of groups were seen between 23 June and 14 July, when whales were the most dispersed. Belukha whales prey on adult salmon beginning mid June (Brooks 1954, 1955, 1956; Lensink 1961; Seaman et al. 1982; Frost et al. 1984, Stewart and Awbrey, unpublish. data) and their presence and relative abundance in Nushagak Bay and its tributaries is apparently related to salmon abundance. Our observations in 1982 and 1983 indicate that calves are born in early to mid June. The presence of whales in the Snake and Igushik Rivers at this time may be related to calving.

Effects of sound playback (SEDCO 708) on the Behavior of Belukha Whales in Snake River, AK.

Thirteen playback experiments (using recorded noise from the drilling Rig SEDCO 708) were conducted from 19 June to 13 July (Table III). Data were sufficient only for comparisons of whales milling or moving upriver or downriver on falling tides before, during, or after disturbances (Table IV).

Table VI. Approximate seasonal abundance of Belukha whales in Nushagak Ray; June to July 1983.

Survey Date	Time	Total No. whales	Total NO. groups	Average group size
4 June	1340-1540	33	5	7 ± 3
11 June	1435-1556	40	5	8 ± 6
23 June	1410-1604	120	18	7 + 6
30 June	1355-1530	144	12	12 ± 19
14 July	1500-1627	375	9	42 ± 63
18 July	1401-1550	454	3	151 ± 215

Table V. Summary of Belukha presence in Snake River observation and direction of whale movement.

Date	Hours whales present	Direction of movement		
		Upriver	Downriver	Milling
15 June	No whales seen			
16 June	0930-1030		x	
	1800-1830	x		
17 June	No whales seen			
18 June	1000-1030		x	
19 June	1920-2130		x	
	2215-2230		X	
20 June	1300-1330		X	
	2100-2130			
21 June	2015-2350	X		
	2245-2300			X
4 July	No whales seen			
5 July	0915-0930	X		
	1945-2015			X
6 July	0750-0800	X		
	0830-0835		X	
	0850-0900	X		
	1100-1115			
7 July	0830-1030			
	1630-1640		X	
	2100-2130			X
8 July	0930-0950		x	X
	1140-1200		X	
	2200-2230		X	X

9 July	1830-1ss0	x		
	1920-1950	x		
	2110-2130	x		
	2220-2230	x		
10 July	0650-0720	x		
	1020-1030	x		x
11 July	0520-0550		x	
	0830-0930	x		
12 July	0515-0600		x	
	0620-0650		x	
13 July	0520-0630	x	x	
	0750-0820		x	

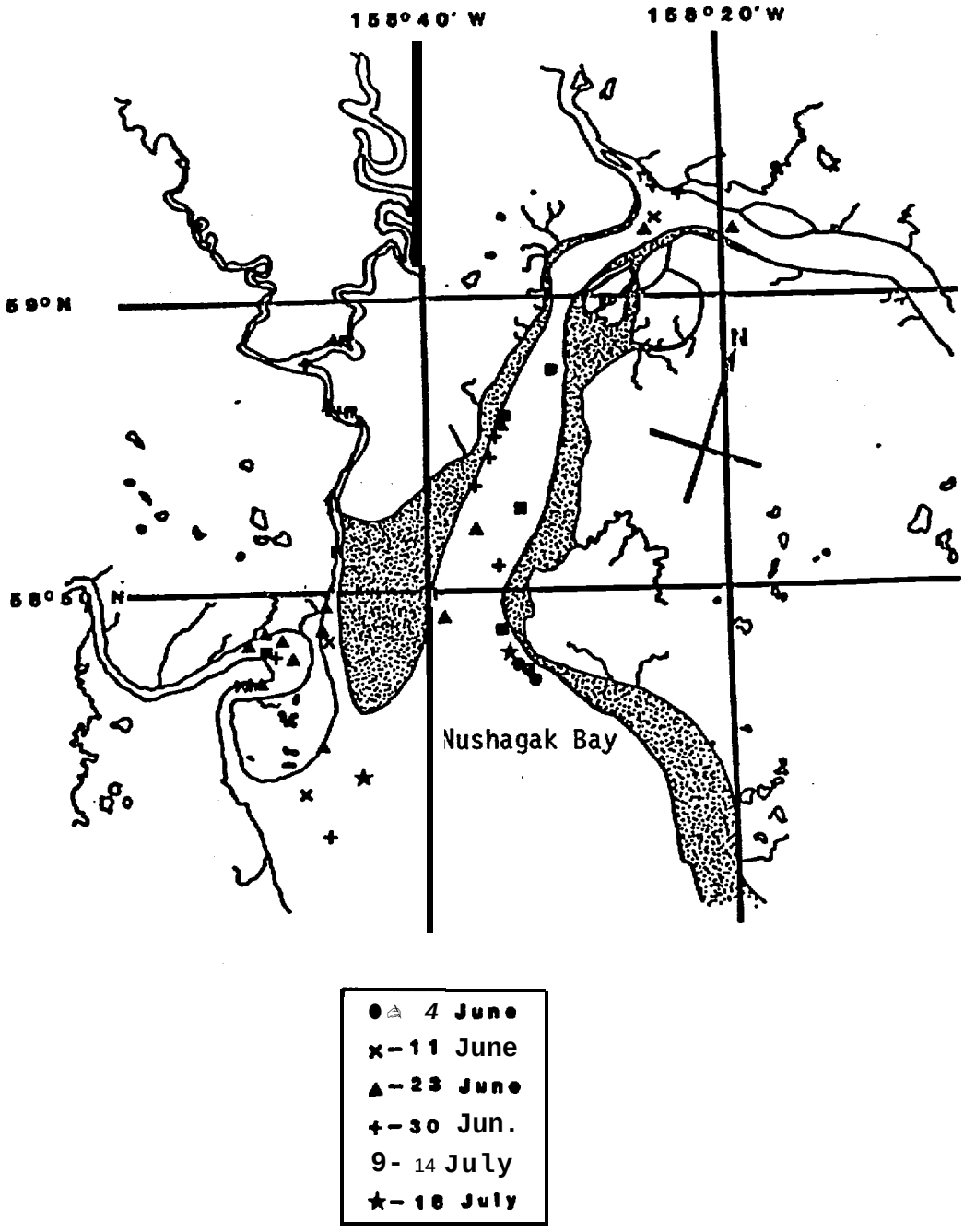

Fig. 3. Location of beluka whale individuals and groups seen in aerial surveys of Nushagak Bay and its tributaries.

Table III. Schedule of playback (SEDCO 708) experiments.

Date	Begin	End	Tide stage	Number of whales exposed to playback	Before experiment	After and during experiment
19 June	2048	2118	Rising	9-11	Downriver	Downriver
6 July	0856	0910	Rising	10	Upriver	Upriver
7 July	1032	1042	Slack	13	Milling	Milling
7 July	213'4	2141	Rising	12-15	Upriver	Upriver
9 July	1840	1844	Falling	4-6	Upriver	Upriver
9 July	1930	1933	Slack	,3	Upriver	Upriver
9 July	2217	2220	Rising	7	Upriver	Upriver
11 July	0545	0549	Falling	8-10	Downriver	Downriver
.11 July	0838	0841	Slack	6-8	Upriver	Upriver
11 July	0911	0945	Slack	6-7	Upriver	Upriver
12 July	0554	0557	Falling	16-18	Downriver	Downriver
12 July	0620	0650	Falling	10-13	Downriver	Downriver
13 July	0759	0822	Falling	14-16	Downriver	Downriver/uprive r

Table IV. Mean respiration rates (blows/min) and respiration intervals (sees) of belukha whales in Snake River, Alaska in different environmental and experimental conditions. . (Values in parentheses are standard deviations).

	Undisturbed		Disturbed		Post disturbed	
	Resp. Rate	Resp. intervals	Resp. Rate	Resp. intervals	Resp. Rate	Resp. intervals
Moving downriver on a falling tide	1.4 (.7)	45 (30)	2.9 (.8)	29 (9)	2.6 (.8)	24 (10)
Moving upriver on a falling tide	2.6 (.6)	25 (23)	3.8 (2.2)	33 (26)	2.2 (.6)	18 (14)
Milling	1.5 (.5)	21 (14)	2.7 (.6)	16 (7)	2.5 (.4)	24 (6)

Activity, respiration rates and respiration intervals were moderately affected by sound play back. At the onset of playback, whales within 1.5 km usually swam faster in the direction they had heen drifting or moving before the noise began. In only one case (discussed below) did whales change swim direction" in response to playback sound (Table III). Whales apparently did not leave the river in response to playback noise during any experiment.

Only when playback started while whales were moving downriver on a falling tide (Table IV) did the whales' respiration rate and respiration interval appear to change significantly. Respiration rate was faster ($p<0.05$) and respiration interval shorter ($p<0.05$) during than before the disturbance. After the playback, respiration rate was slightly greater than before the disturbance and slightly less than during the disturbance, but neither difference was significant ($p>0.1$). Respiration interval was significantly shorter ($p<0.05$) after playback. The same trend occurred when the whales were milling and when they were moving upriver on a falling tide, but differences were not significant.

To test the whales' response to a constant sound source, we started playback when a group of whales came into view 4.6km upstream on 12 July, at 0650. Belukhas' hearing threshold at 1 and 2kHz is about 100dB (White, et al. 1978, Awbrey, et al. 1984). The sound level 3.5 to 4.5km away would be above the whales' threshold assuming cylindrical spreading loss, but below it assuming spherical spreading loss. Given the complex effects of the river's configuration and tidal flow on sound attenuation and the unknown effects of water flow on the swimming whales' auditory sensitivity, we cannot say for certain that they could or could not hear the sound when it came on. We know only that the whales showed no overt response. They continued to move steadily downriver until they were

within 50 to 7.5m of the boat. They then submerged, swam rapidly between the boat and the bank within 15-20m of the sound source, and surfaced about 50-75m downstream from the boat. The next day, playback was started when approaching whales were about 3.5km upstream. Eleven whales were strung out in groups of 2 to 4 over about 1/2km. Most of these whales turned around after approaching within 300 to 500m of the boat, but one group of 3 approached to within 300m, submerged, and swam past within 15m of the sound source.

Discussion

Our observations of belukha whale responses to playbacks of oil drilling sounds indicates that direction of whale movement and general activity (feeding, traveling) was not greatly affected by these sounds, especially if the sound source was constant. Whales continued to move in the direction they were traveling before playbacks began. On several occasions, whales within 2 km of the sound source appeared to feed during playback experiments. Whales also approached and quickly passed closely by the underwater speaker while sounds were being projected. By contrast, Stewart et al. (1982) found that whales responded to outboard motor noise by immediately swimming downriver, regardless of their behavior before the outboard motor noise began.

Whales did not abandon the river in response to playbacks of oil drilling noise in 1983, but their behavior did appear to change somewhat. Whales breathed more often and intervals between blows were shorter on average when these sounds started while the whales were nearby. The data on respiration rates, primarily, suggest that whales usually resumed normal behavior shortly after the termination of sound playbacks.

Our qualitative observations of belukha whales in Nushagak Bay, where whales are frequently exposed to fishing and processing boats with diesel engines, suggest that their behavior there differs from that in rivers and estuaries. In the open waters of the bay, whales appeared to remain much longer at the surface between blows and also to rise much higher out of the water. Reactions to outboard motors, however, seemed to be similar in both situations, perhaps because outboard powered boats are used to hunt belukhas.

Experiments exposing captive belukha whales to the same Sedco 708 sounds (Thomas and Kastelein 1983, Awbrey et al. 1984) indicated that belukha whales can acclimate quickly to oil-drilling sounds at typical sound levels. This agrees with McCarty's (1981) observations. He reported that belukha whales (including mother-calf pairs) regularly approached oil production platforms in Cook Inlet to within 10 m. He also reported that as long as noise from these platforms was constant it did not seem to affect whales, but that a sudden change in noise levels elicited a temporary avoidance reaction. Our observations also indicate that whales usually respond to sudden acoustic disturbance but are less likely to avoid a constant sound source.

REFERENCES

Altman, J. 1974. Observational study of behavior sampling methods. Behaviour. 49: 227-265.

Awbrey, F. T., J. A. Thomas, W. E. Evans, and R. A. Kastelein. 1984. Behavioral and physiological responses of Belukha whales to oil-related noise as determined by Playbacks of Underwater drilling noise and hearing threshold tests. HSWRI Technical Report. March 1984.

Brooks, J. W. 1954. Beluga. Annual. Report for 1954. Alaska Department Fisheries, PP. 51-57.

_____ 1955. Beluga investigation. Annual Report for 1955. Alaska Department Fisheries. pp. 98-106.

_____ 1956. Marine predator control and investigation. Annual Report for 1956. Alaska Dept. Fisheries. pp. 50-59.

Frost, K. J., L. F. Lowry, and R. R. Nelson. 1984. Belukha whale studies in Bristol Bay Alaska. pp. 187-200. In: Proceedings of the workshop on biological integrations amen.q marine mammals and commercial fisheries in the Southeastern Bering Sea. Alaska Sea-Grant Report 84-1. University of Alaska.

LensInk, C. J. 1961. Status Report: beluga studies, unpubl. manuscripts. Division of Biological Research, Alaska Dept. Fish and Game, Juneau, AK. 2(-J p.

McCarty, S. 1981. Survey of effects of Outer Continental Shelf Platforms on Cetacean Behavior. Appendix C. Vol. II in: Gales, R. S. Effects of noise of offshore oil and gas operations on marine mammals. An introductory assessment. NOSC Tech. Rept. 844.

Seaman, G. A., L. F. Lowry , and K.J. Frost. 1982. Foods of Belukha whales (Delphinapterus leucas) in Western Alaska. Cetology 44: 1-19.

Stewart, B. S., F. T. Awbrey, and W. E. Evans. 1982. Effects of man--made waterborne noise on behavior of belukha whales (Delphinapterus leucas) in Bristol Flay, Alaska. HSWRI Tech. Rept. No. 82-145.

Thomas, J. T. and R. Kastelein. 1983. Behavioraland physiological responses of captive beluga whales to playbacks of drilling noise. J. Acoust. Sot. Amer. Suppl. 74(S1): S54(A).