KILLER WHALE, *Orcinus orca*, SOUNDS REPEL WHITE WHALES, *Delphinapterus leucas*

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ABSTRACT

This study was conducted to determine if the migration of white whales up the Kvichak River, Bristol Bay, Alaska, could be stopped by playing high-intensity underwater sounds to them. While in the river the whales feed on salmon smolt migrating down to the sea. Transmission of killer whale sounds was found to be an effective means for keeping the whales out of the river. During control periods when sound was not projected, the whales moved freely in and out of the river. A permanent playback system could be installed with little difficulty and would result in a significant reduction in the number of smolts consumed by belugas in the Kvichak River.

White whales, or belugas, *Delphinapterus leucas*, commonly travel 20 to 30 km up Alaska's Kvichak River (Figure 1) on the flood tide and back down on the ebb, foraging on available food organisms along the way. This twice-daily movement of from 50 to over 500 whales occurs during May and throughout most of June. It ceases only after boat traffic from the seasonal salmon fishery becomes heavy.

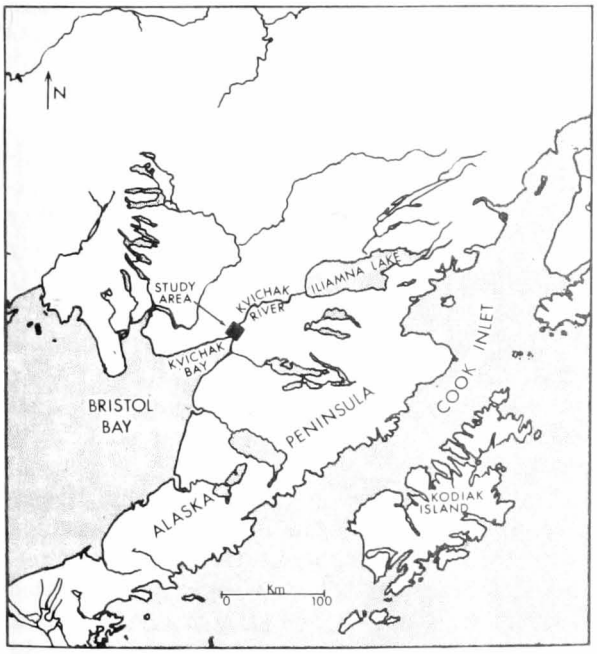

FIGURE 1.—Location of the study area.

The Kvichak River supports the most extensive run of red salmon, *Oncorhynchus nerka*, in the world. These runs range from 1 to 45 million fish per year. Lake Iliamna, the largest lake in Alaska, located about 80 km up the Kvichak, is the principal rearing area for the young salmon before they migrate to the sea as 1- or 2-year olds. The annual migration of smolt occurs during the end of May and the first 2 weeks in June with the peak of migration occurring about the first of June.

Field studies by the Alaska Department of Fisheries (1956) in the early 1950's showed that beluga predation on the salmon smolt occurred when the young fish were migrating to sea and appeared to be most extensive in the confines of the river. As the smolt moved into Kvichak Bay, they scattered and became less vulnerable to predation. Attempts were made to keep the belugas out of the river by chasing them with motorboats and by dropping small charges of explosives into the river. These methods were not very successful and were difficult to use during inclement weather or at night.

From 1963 to 1968 Vania projected various sounds, including killer whale sounds, noise, and music, underwater to the belugas in an attempt

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to keep them out of the river. There was no reaction to the noise or music. The killer whale sounds were only partially successful, apparently because the playback level was too low. His equipment was not designed for underwater sound transmission. Most other workers attempting to influence the movement of wild whales with sound have been unsuccessful. However, in nearly all of these experiments the projected sounds did not exceed 140 to 150 db, re 1 μNewton/m^2 (= 40 to 50 db, re 1 dyne/cm^2) at 1 m. One exception was a sound playback experiment on California gray whales, *Eschrichtius robustus*, by Cummings and Thompson (this issue of *Fishery Bulletin*) where a high-power transmitting system was used and the whales did react to the sounds. Their transmitting system was similar to the high-power system described here which we used to transmit killer whale sounds to belugas in the Kvichak River in June 1970.

METHODS

The primary high-power transmitting system, operated from Station A (Figure 2), consisted of a Uher tape recorder,[3] a small impedance-matching preamplifier, a 250-w Optimation power amplifier, and a sound projector developed and built by the Naval Undersea Research and Development Center. Frequency response of this system was ±3 db from 250 to 4000 Hz, limited by the projector. A secondary, battery-operated playback system, operated from a small boat at Station B (Figure 2), utilized a Uher tape recorder, a 40-w Bogen amplifier powered by a motorcycle battery, and a J-9 sound projector; system response was ±3 db from 200 to 6000 Hz.

A calibrated recording system, consisting of a Wilcoxon hydrophone, a Uher tape recorder, a sonar calibration box, and a modified GR Octave-Band Analyzer, was used to measure the sound pressure level of the playback signals at various points throughout the river and to record the vocalizations from the belugas. This system was described by Calderon and Wenz (1967).

[3] The use of trade names is merely to facilitate descriptions; no endorsement is implied.

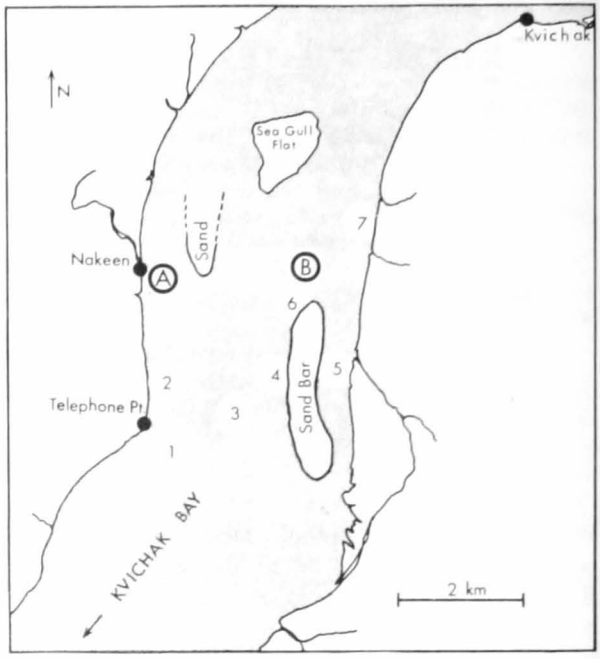

FIGURE 2.—Enlarged drawing of the study area. Transmitting stations were located at A and B. The regions indicated by numerals are locations where playback sound pressure levels were measured.

We selected killer whale, *Orcinus orca*, vocalizations for transmission because of their outstanding acoustic properties and because killer whales are known to kill and eat the relatively slow-swimming white whales (Scammon, 1874: 92; Dergerböl and Nielsen, 1930; Kleinenberg et al., 1964: 292). A long-play tape was made from "screams" and clicks recorded from killer whales at sea. We do not know, however, what behavior was associated with their sound production.

In the first 10 playback trials, the sound, transmitted only from Station A, was not turned on until the approaching belugas were sighted. But in subsequent trials, when we transmitted from both A and B, we started the playback as soon as the tide changed. Weather and light permitting, a new trial started with each flood tide and lasted from 15 min to 2 hr—as long as necessary to either move the whales back down the river (in those trials where they were permitted to move part way up before the sound

was turned on) or keep them from moving up the river (when the sound was turned on before the whales started upriver).

We had an excellent view of the river from the third floor of a building about 25 m above the water at Station A. Frequent low-altitude flights in small planes provided a check on the exact location of the whales when they could not be seen from the building. The white-colored whales were easy to see in the muddy brown river.

In all, there were 14 playback trials plus 7 control trials in which the whales were observed but sounds were not transmitted. The number of whales involved in each trial ranged from 50 to near 500 with about 100 being the average group size. Because several years of observations indicated the belugas move up the river on every incoming tide, we did not feel it was necessary to have an equal number of transmission and control trials. Consequently, we introduced a control after no more than four successive transmissions, primarily to determine if the belugas had stopped using the river as a result of the sound playbacks.

The sound pressure level of the playback sounds transmitted from Station A was measured at 6 locations in the river within 4 km of the source (Table 1). All levels reported in this paper are in db, re 1 $\mu N/m^2$. Sandbars prevented good transmission across the river, particularly during the early stages of the flood tide when some of the bars were covered by less than 0.5 m of water. For example, the sounds projected from Station A were below the background noise level at Location 6 (Figure 2). The best transmitting channel was downriver toward Telephone Point (Location 2), where a level of 132 db was measured for the playback signals. Beyond this area, the signal level dropped off quickly because of the shallow water which extended out a considerable distance from the Point. Most of the energy of the playback sounds occurred in a frequency band from 500 to 5000 Hz; thus we measured ambient levels in this band in addition to making broadband ambient measurements.

TABLE 1.—Sound pressure level (db re 1 $\mu N/m^2$) of playback signals and ambient noise at the indicated locations.

Location, Fig. 2	Signal broadband	Ambient noise	
		Broadband	500-5000 Hz band
	db	*db*	*db*
1 m from Source A	170	120	No data
1	115	103	96
2	132	90	84
3	107	91	85
4	103	95	90
6	Below ambient	98	95

RESULTS OF PLAYBACK EXPERIMENTS

In the first seven transmission trials, we let the whales move up the river on the west side to within approximately 2 km of the sound source before turning on the playback. The first six times, the animals turned immediately when the sound began and swam directly out of the river against the strong incoming tide. Their rate of blowing increased and they spent more time at the surface of the water, making it very easy for us to observe their course. On the 7th trial, some of the animals crossed to the opposite side of the river when the sound started and swam downstream along the sandbar (Location 4). The others remained just off Telephone Point for an hour, then moved out of the river.

It was difficult to see the approaching belugas on the 8th trial because of low light, and they had already moved up to Location 6 before we started transmitting. About half of the 100 whales continued up the river; the others turned and swam back out along the sandbar. On the next trial, the animals were first seen moving up the river along the sandbar. Possibly they learned from the previous eight transmissions to avoid the side of the river where the sound projector was located. They continued up to the end of the bar, even after the sound was turned on, but then rounded it and moved back down the river on the other side of the bar (Location 5).

The belugas similarly rounded the upriver end of the sandbar on the 10th trial; but, instead of turning around, they swam to the shore (Location 7) and continued up the river very close to the bank. Poor transmission to this location

from Station A and the reaction of the whales during the 10th trial made it necessary to use a second transducer simultaneously at Station B. A copy of the Station A playback tape was used at Station B, but it was not possible to synchronize the playback sounds from the two projectors. In the subsequent four trials, we turned on the playback as soon as the tide changed, thus eliminating the possibility of the whales going by us unnoticed before the start of transmission. The whales stayed at least 1.5 km down the river from the sound sources during the four transmissions using both projectors.

In each of the seven control trials, when no sound was played, the whales moved directly up the river with the incoming tide, past the transmitting stations. They behaved the same as they did before any of our experiments, with many individuals passing near the pier at Station A. However, we could see very few whales from the viewing station during the killer whale playbacks. Low-altitude reconnaissance flights confirmed our suspicion that numerous whales were remaining well down the river out of view during the transmissions.

Belugas vocalize extensively (Schevill and Lawrence, 1949; Fish and Mowbray, 1962). We recorded their sounds many times at various places throughout the river, often under ideal conditions of flat-calm water with no boat traffic. Once, we drifted in a small boat for over 2 hr during a no-playback control with a group of about 500 whales and recorded a spectacular variety of vocalizations from this relatively undisturbed herd. The belugas emitted very few sounds, however, when the killer whale signals were being transmitted. Quieting of belugas in the presence of killer whales was noted by Schevill (1964).

CONCLUSIONS AND RECOMMENDATIONS

Our experiments showed that playback sounds of killer whales can be used to keep belugas out of Alaska's Kvichak River. This method was very effective and practical. Installing and maintaining such a playback system for 2 to 3 weeks each year would seem to be an economically feasible way of reducing beluga predation on red salmon smolts. Such a system could be started automatically at the beginning of the flood tides and, if necessary, left on for their duration, both day and night. It would not be seriously affected by adverse weather conditions, except for a possible reduction in the range over which the belugas could hear the sounds—because of higher ambient noise levels in the river from wind and rough water.

We recommend using two sound projectors, properly situated to provide good signal levels all the way across the river. Initially, our trials with one projector stopped the whales, but the belugas eventually learned to go up the opposite side of the river where the playback signals were very weak or nonexistent. There were too many sand bars in the river to achieve good signal levels across the river with one projector, regardless of its source level.

Although we only used the two-projector system for four trials, we do not feel the whales would habituate and ignore the playback sounds with continued use. The avoidance of the belugas to this system was striking. The fact that the whales began swimming up the river again after nine trials using the single projector was due, we feel, to their learning to avoid the source, rather than to habituating to the sounds. With sound projectors located on both sides of the river there is probably no channel where the whales can go up the river without hearing the playback sounds. On the other hand, even if the belugas were to habituate after 2 weeks of playback, this would not significantly affect the usefulness of the technique. Playback could be timed to coincide with the 2-week peak of the smolt run.

After completing this experiment with killer whale playbacks, we projected a 2500-Hz continuous tone and 2500-Hz randomly pulsed tones. The belugas continued up the river during the continuous-tone playback, but turned back on the two occasions when pulsed tones were transmitted. Since these playbacks were tried after the white whales had been subjected to the killer whale sounds for 2 weeks, we cannot speculate on how naive whales would have reacted.

More experiments are necessary before we can conclude whether or not the belugas recognized the killer whale sounds as such.

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