GRAY WHALES, *Eschrichtius robustus*, AVOID THE UNDERWATER SOUNDS OF KILLER WHALES, *Orcinus orca*

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ABSTRACT

Underwater sound playback experiments were undertaken to determine if gray whales would avoid the sounds of killer whales. When presented killer whale "screams" from an underwater projector, the gray whales swam directly away from the sound source. Controls of no intended stimulus, pure tones, and random noise generally failed to induce an avoidance. It appeared that gray whales localized the killer whale sounds and avoided them as a sign of potential danger.

Killer whales, *Orcinus orca,* are known to attack large marine mammals, including gray whales, *Eschrichtius robustus* (Scammon, 1874; Morejohn, 1968). Several accounts of such attacks were related to the first author by observers who witnessed these events. Among these were Dr. Carl L. Hubbs of Scripps Institution of Oceanography, University of California, and Alan Baldridge, Hopkins Marine Station, Stanford University. In January 1952, Dr. Hubbs saw a gray whale that swam into the thick kelp beds off La Jolla, Calif., apparently fleeing from a group of killer whales. Off the Point Lobos State Reserve, Carmel, Calif., Baldridge observed a gray whale calf being eaten by six to seven killer whales. Other observers had seen the initial attack which also involved the mother whale. When Baldridge arrived, the killer whales were chewing on the lips, tongue, and throat of the dead young gray whale.

Killer whales produce a variety of underwater phonations, including high pitched "screams" and trains of well-separated clicks (Schevill and Watkins, 1966). Underwater sounds have been recorded from about one-half of the known species of marine mammals, and probably all are capable of some vocal behavior. However, except for the echolocating abilities of porpoises and a few of their own behaviors associated with sound production, very little is known about the significance of underwater sound to marine mammals—virtually nothing where the large whales are concerned.

Taking advantage of the gray whales' migration in nearby waters, we conducted underwater sound playback experiments to find out if they would react to the underwater sounds of killer whales, possibly avoiding them as a sign of danger.

METHODS

The experiments took place off Point Loma, San Diego, Calif., during successive migrations of gray whales in January 1969 and 1970. Each year about 11,000 of these whales pass San Diego on their southward migration to the breeding grounds off Baja California and the Mexican mainland (Rice, 1970). The whales, some with calves, return to our waters in the early spring on their way back to the Bering Sea and the Arctic Ocean.

Field work was done from a large catamaran, RV *Sea See,* which served as a stable and roomy platform, moored in 30 m of water, 33 m seaward of an extensive kelp bed. The ship held a northerly heading at the mooring. Gray whales normally funneled through this location staying relatively close to the coast, but avoiding the thick kelp.

Three kinds of acoustic stimuli were prepared on magnetic tape—a natural sequence of "screams" from killer whales, originally record-

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ed off Dabob Bay, Wash.; a matching sequence of two simultaneous pure tones of 500 and 2000 Hz that resembled the major frequency components in most of the recorded killer whale "screams" and with the same on-off times as the "screams"; and a similarly timed sequence of random noise in the band from 500 to 2000 Hz. Random noise and pure tone were used as control stimuli in addition to a third control wherein there was no playback or any intended stimulus, and the whales were allowed to pass relatively undisturbed. The ship's equipment was silenced throughout the experiments and we made no unnecessary noises.

The sound projector (designed and built at our laboratory) was lowered to 12 m below the surface of the water. It was powered with a 250-w amplifier (Optimation)[2] connected to the tape recorder (Uher 4200) used for playback. We monitored the output from a receiving hydrophone (Wilcoxon, Type M-H90-A) located at the same depth as the projector, 12 m away. Calderon and Wenz (1967) have described this calibrated monitoring system. Underwater signals picked up by the receiving hydrophone led to one track of another Uher stereo tape recorder. The other track carried our running commentary of the whales' behavior. Peak source level of the killer whale signals (Figure 1) and the playback control stimuli was nearly constant—151 db re 1 μNewton/m^2 (= 51 db re 1 dyne/cm^2) at 1 m in the 1969 experiments, and 176 db in 1970. Because of the natural propagation losses measured in the area, we expected sound pressure levels of the projected sounds to reach the prevailing ambient sea noise level in the third-octave band at 500 Hz, at about 1100 to 1400 m.

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

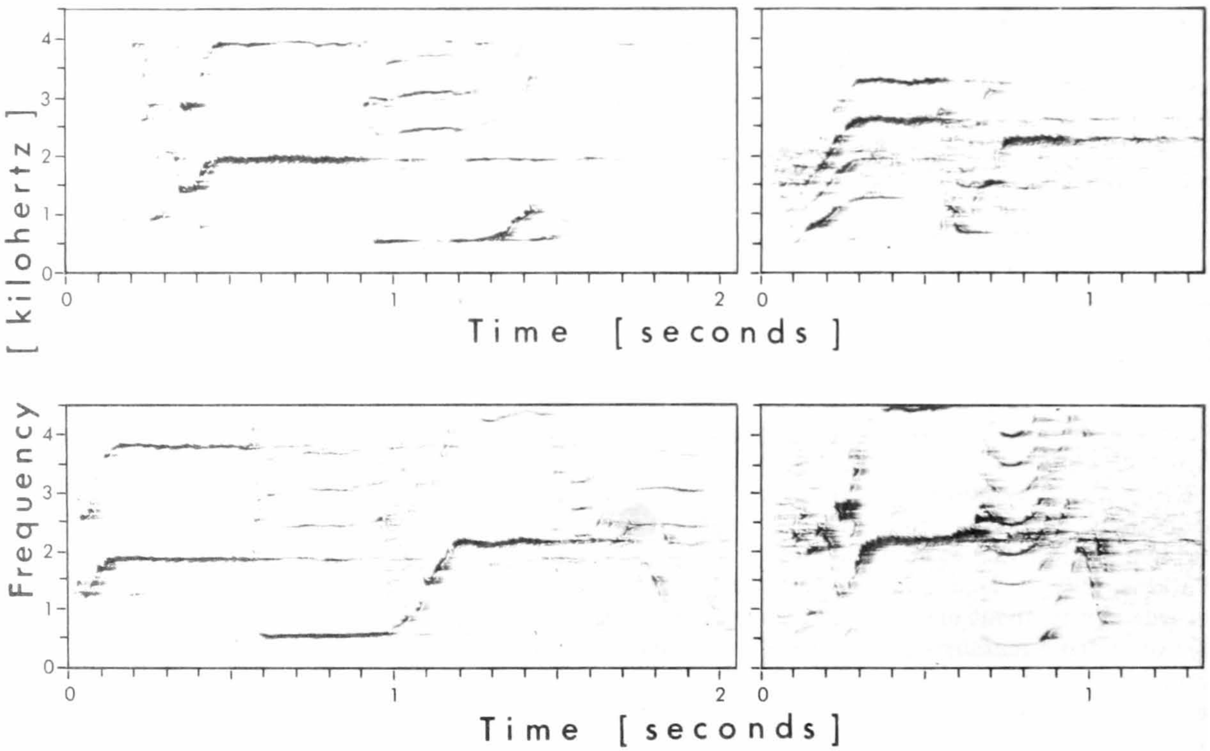

FIGURE 1.—Spectrograms of killer whale "screams" that were played back to migrating gray whales. Of 141 signals on the playback, 83 were very similar to the one at top, left. The others shown are in clockwise order according to their frequency of occurrence on the tape (30, 19, 9). The analyzing filter bandwidth was 20 Hz.

Besides no playback, used in the 1969 experiments, random noise and pure tone served as additional controls in 1970.

Gray whales come by Point Loma at any time during the migration season, day or night, as individuals or in small groups of two to five animals. However, for the total of 5 weeks at sea, we had to work in bright daylight, 0830 to 1630 hr, because of earlier difficulty in seeing the whales in subdued light. Undisturbed whales moved along in a southerly course at average speeds of 10 km/hr, blowing from one to three times every 1 to 14 min. We have also seen killer whales off Point Loma.

Migrating gray whales produce underwater, low-frequency moaning sounds in a band from 20 to 150 Hz (Cummings, Thompson, and Cook, 1968). These sounds last 1.0 to 1.7 sec.

We began an experiment upon seeing an oncoming whale or group of whales that was not encumbered with small boat traffic. Playbacks were generally started when the whales were 150 to 450 m away, toward the north. The experiments were alternated so that successive contacts would not encounter the same situation. Sessions lasted 30 to 100 min, after which the whales had passed the ship or disappeared. There were 77 experiments (77 contacts) involving a total of 132 gray whales. The appearance of "whale-watching" or fishing boats invalidated our work with numerous other contacts. They not only interfered with the whales' progress, but their underwater sounds considerably reduced the playback signal-to-noise ratio.

EXPERIMENTAL RESULTS

The reactions of gray whales to the projected killer whale sounds were spectacular. Blowing whales, or those running at the surface, immediately swirled around and headed directly away from the killer whale sound source. We have no idea of how quickly the submerged whales reacted, but subsequent surfacings were away from the killer whale sound source.

Most whales fled towards the north. However, if their previous southerly course had taken them seaward of the ship and the sound source, they turned and swam toward the open sea. Gray whales coming from the general direction of the kelp, or those very close to it, fled into this heavy growth and stayed in one general location until we stopped the killer whale stimulus.

Whales came about and resumed a southerly course for Mexico 5 to 30 min after the killer whale sound stopped. If we renewed the playback, before the whales passed by, they again fled northward from the sound source. On several occasions, we repeated the experiments on the same contact up to three times, each with similar results.

Of the 36 contacts principally involving killer whale playback, 30 avoided the sound source, 3 were questionable because we never saw them after playback, and 3 passed the ship as normal, without an apparent avoidance (Table 1). However, one of the last-mentioned was a single whale that had already come very close to the east-west line arbitrarily set on the projecting transducer. This whale could have just as easily avoided the sound source by swimming to the south.

TABLE 1.—Reaction of gray whales contacted on 77 occasions to various stimuli.
[1-4 whales in a contact; 132 whales in all.]

Reaction	Random noise	Pure tones	No playback	Killer whale "screams"
Avoidance	2	2	0	30
No avoidance	8	8	21	3
Questionable	0	0	0	3

All 21 contacts not encountering an intended stimulus (no playback) moved along towards the south in normal fashion. Two contacts of the 10 that received pure tone avoided the sound source. However, 1 of these 2 turned only momentarily. It then resumed the southerly course, still in the presence of the playback stimulus. Of the 10 contacts presented with random noise, 2 avoided by turning towards the north for a very short distance. However, both of these gray whales seemed to be startled only for the moment; then quickly turned a second time and swam down past the random noise sound source.

Two of the 8 contacts that did not avoid random noise and 2 of the 8 that did not avoid pure tone (Table 1) did flee the killer whale source when we projected it to them before they passed by the sound projector. We did not project killer whale sound to the other contacts that did not avoid random noise and pure tone.

Observers on board noted how little of the avoiding whales' bodies showed above the surface and their unusually small surface disturbance. In many instances their blows were invisible and even blows at close range were scarcely audible. In contrast, the surfacing of undisturbed whales involved the simultaneous appearance of head and blow accompanied by a well-defined surface wake. Their blows were generally visible, and they were audible at close range. After their first appearance, the undisturbed whales showed their backs and sometimes tossed their flukes high into the air. On the other hand, it was difficult to spot the fleeing whales.

We thought that if gray whales associated the projected killer whale "screams" with potential danger, they would have left the area silently to lessen their chance of detection. For example, Schevill (1964) noted that belugas, *Delphinapterus leucas*, became silent in the vicinity of two killer whales. Upon analyzing our data, it turned out that only 2 gray whale phonations appeared on the tapes during killer whale periods, whereas 47 occurred during the control periods.

Gray whales on the breeding grounds frequently exhibit a behavior termed "spying-out" (Gilmore, 1961) wherein the head comes vertically out of the water for several seconds. "Spying-out" in the breeding lagoons seems to be associated with searching for channels; it is also done when the whales are pressed by small boats (communication from Dr. Joseph R. Jehl, San Diego Natural History Museum). Since we have seen this behavior over the past 6 years only three times, we assume that migrating gray whales rarely "spy-out." However, gray whales in the present experiments inevitably "spied-out" after fleeing into the thick kelp following killer whale playbacks.

As a result of these experiments we conclude that gray whales apparently recognize the voice of a killer whale, that they can easily localize the sounds underwater, and that they flee kille whale phonations probably as a sign of potentia danger. Such avoidances consist of several be haviors that appear to function as protectiv mechanisms—sound localization, silence, rapi escape, reduced exposure, and visual search.

DISCUSSION

Walker (1971) has expressed the opinion tha the function of "spy-hopping" ("spying out" by gray whales is not that ". . . the whale look around, spying out possible dangers such a ships, or even spotting shore landmarks as aid to navigation." In reply he points out that "I the vertical posture the law of gravity take over, conveying food from the whale's mouth t a capacious four-chambered stomach. Althoug a gray whale can swallow when horizontal, th vertical position allows it to clean entangled de bris from the filter and to wash food down to th throat for quick ingestion." Walker further re ported ". . . that in the 'spy-hopping' positio their [gray whales'] range of vision is limite and that they navigate mostly by echolocatio . . . ." On the other hand, in the same report i the following portion of a caption to a photo graph showing a breaching gray whale. "Th catapulting action, he [Dr. Walker] believe enables the animals to scan the waters aroun them and make course corrections when inte fering noises prevent them from navigating b echo-location."

We are not aware of any experimental ev dence that shows whether a gray whale "sp hops" to look around or to swallow food. N is there any substantial evidence that migratin or breeding gray whales feed very much. T the contrary, there is hard evidence (summa rized by Gilmore, 1968) that gray whales fa on their way to the breeding grounds, at th grounds, and on the return trip north.

Relative to the killer whale attack cited earlie Baldridge reported that the mother frequent "spy-hopped" from a distance as the killer wha chewed on her dead calf.

In view of the above, the context of "sp hopping" exhibited by gray whales during o experiments would seem to imply that this b havior had a visual function, i.e., they were probably looking for killer whales. This implication does not necessarily exclude swallowing, but we doubt that the gray whales were feeding under these circumstances.

Moreover, concerning Walker's assertion that gray whales "navigate mostly by echolocation," although it has been clearly demonstrated that porpoises can echolocate underwater objects (reviewed by Norris, 1969), it is not known whether they normally navigate at sea by this means. "Echolocation-like" (Asa-Dorian and Perkins, 1967) and "echolocation" sounds (Poulter, 1968) were recorded in the presence of gray whales, but there was little evidence that the sounds actually were from the whales. There are innumerable sounds in the ocean and many possible sources, but the matching correlations are often difficult to achieve. In any event, we prefer not to use the term "echolocation" in describing the underwater sounds of animals unless they are known to have such a function. Although we have recorded a few clicklike sounds during five seasons of work with gray whales, we have never been able to associate them with the whales. The clicklike sounds that were recorded, while using an array of hydrophones and a technique of computing sound source locations, originated from an area where, apparently, there were no gray whales.

Bioacousticians are not in a position to say with any certainty that gray whales do not echolocate; future experimental work could possibly show that they do. However, our own research with 7 of the 10 species of mysticate whales has yet to reveal any data to suggest that a member of this order uses underwater echolocation.

Whales normally exhale at the surface of the water with the blowholes exposed, but Hubbs (1965) has reported underwater blows by four species of whales—humpback, *Megaptera novaeangliae*; fin, *Balaenoptera physalus*; striped dolphin, *Lagenorhynchus obliquidens;* and the gray whale. In addition, he noted gray whales to refrain from spouting, skip an inhalation, or barely protrude their blowholes in the presence of killer whales. In the same report, Hubbs associated these behaviors with "strange or frightening stimuli." We were not close enough to see if fleeing gray whales exhaled underwater, but our other cited observations of gray whales covertly avoiding the killer whale sounds certainly parallel Hubbs' observations.

Unfortunately, there was no record of the killer whales' behavior during the original recordings of the phonations used for playback. We advise others who may be involved with sound playback to use appropriately meaningful signals, whenever possible. For example, underwater sounds that are part of an animal's reproductive behavior may have little or no effect on nonbreeding animals. Likewise, feeding sounds may not affect animals that are in a state of alarm. If possible, we would have compared the results of playing back two sets of killer whale sounds in the present experiments —one recorded from attacking whales in a predator-prey situation, if indeed killer whales utter sounds at this time, and another from killer whales that apparently were not feeding or preying.

Based on the methods of this study, our coworkers, Dr. James F. Fish, and John S. Vania subsequently used killer whale sound playback to keep white whales, *Delphinapterus leucas*, from entering the Kvichak River, Alaska, where they eat young salmon before the fish can get to the open sea (Fish and Vania, 1971).

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