



Using a mobile hydrophone stereo system for real-time acoustic localization of killer whales (*Orcinus orca*)

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Abstract

It is usually impossible to identify the source of underwater sounds using an omnidirectional hydrophone. Traditionally, cetacean sounds are localized using hydrophone arrays, but arrays are bulky to handle and require special software. Here, we describe an easy-to-use, reliable device to localize underwater sounds by ear. It consists of two hydrophones divided by a soundproof disc, which makes them directional. The signal from each hydrophone is fed into one of the channels of a stereo-input recording system. The signal is monitored with earphones, with a signal from each hydrophone going to each ear of the operator. This mobile hydrophone stereo system was used to locate killer whale groups and to separate out the sounds of different killer whale groups when they are close to each other.

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In order to study animal acoustic communication, it is necessary to identify individual animals that produce signals. It is usually easy with terrestrial animals, because sound can often readily be attributed to identifiable individuals or observed motor actions indicative of sound production. But the human ear cannot locate underwater sounds, and cetaceans show no visible movements related to sound production even when they can be observed underwater. While recording cetacean sounds underwater on an omnidirectional hydrophone, a researcher faces a serious problem of individual and group identification of signals, which restricts the potential for investigating acoustic communication. The traditional solution for cetacean sound localization is the hydrophone array. Towed hydrophone arrays of different configurations have been successfully used by many researchers [1,2,5,6,8], but there are limitations while working from an inflatable boat when the situation requires manoeuvrability and a quick response. Hydrophone arrays are usually bulky, needing several operators, as well as being expensive. They also require special software for the localization of acoustic signals. Thus, if a computer system is not available on the boat, it is impossible to identify in real-time which animal or group is making the signal. An easy-to-operate, reliable device to localize underwater sounds by ear is clearly needed.

Such a device has been developed as part of our study of killer whale (*Orcinus orca*) acoustic behaviour in the Avacha Gulf, Eastern Kamchatka, Far Eastern Russia. Long-term investigations of killer whale acoustic behaviour in different parts of the world, such as the Northeast Pacific [3,4,10] and the Northeast Atlantic [9], have shown that each pod has its own dialect, or unique repertoire, of discrete calls. The main aim of our acoustic study is to describe the dialect of each group in the area. However, groups often travel together, and with only one hydrophone, it is impossible to identify which group is making the calls. Another aim is to find out the correlation between the whales' behaviour and their calls, and for this, a method of locating the calls is also useful.

For our field research we use a 4 m long inflatable boat with an outboard motor carrying three people, which restricts our ability to operate with large complex devices such as hydrophone arrays. Moreover, the straight Kamchatkan coastline gives us only modest protection from the weather, and we often work in rough conditions, which also complicates the use of arrays.

We constructed an easy and reliable device which enables us to localize underwater sounds by ear using only two hydrophones. A similar device has already been used for the localization of sperm whale (*Physeter macrocephalus*) clicks (Miller, P.J.O., personal communication), and our goal was to adapt it for working from an inflatable boat in the conditions of Eastern Kamchatka.

The base of the device is a metal disk 300 mm in diameter and 12 mm thick, which also functions as ballast (Fig. 1,a). To the disk is fastened an arm attached to a rotating pole (Fig. 1,b). On both sides of the base are soundproof plastic foam plates (Fig. 1,c) with clips to hold the hydrophones (Fig. 1,d). The telescopic rotating pole consists of three plastic sections, each 1.5 m long (Fig. 1,e). The pole has a compass mounted on the top (Fig. 1,f).

The device works by separating the two hydrophones with the soundproof disc, making them directional. The signal from each hydrophone is fed into one of the stereo-input channels of the recording system. The signal from each hydrophone then goes to a separate ear of the operator. Rotating the device gives the illusion of turning the operator's head, and it enables the operator to find the bearing of the underwater sound by listening to the changes in the sounds coming from the hydrophones.

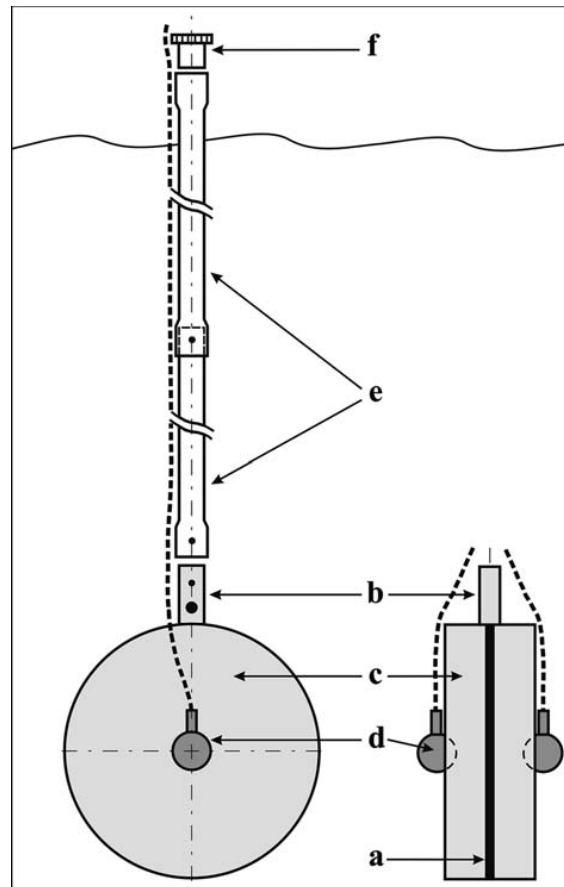


Fig. 1. Construction of a mobile hydrophone stereo system (MHSS).

Locating the sound consists of two stages. First, the operator finds the side, where the sound comes from, rotating the device until the signal can be heard in only one hydrophone; this occurs when the other hydrophone is shielded by the soundproof disc (Fig. 2). At the next stage, for more accurate direction-finding, the operator rotates the device until the signal can be heard in both hydrophones, which occurs when the edge of the disc is directed to the source of the underwater sound (Fig. 3). The azimuth to the source of the signal is found using the compass built into the rotating pole. The accuracy of localization is 5–10°, which was estimated in the experiment with the artificial sound source.

The stereo system (MHSS) makes a good alternative to traditional hydrophone arrays due to its facility in finding underwater sound direction by ear, its compactness, the low cost of its component materials and the comparative simplicity of constructing the device. Recording the sound for subsequent analysis does not require expensive multichannel devices. The working principle of the device is intuitively obvious, and the operator needs no special qualifications.

The main drawback of this device is the difficulty in finding more than two sources at the same time. For example, when several randomly vocalizing whales are present, the operator can only divide the area in half to try to determine which side each call comes from. But if different whales cry different calls, and you can distinguish between them, or if they make different sounds uninterruptedly, you can find the accurate direction to the sources one after another. Of course, with a hydrophone array in the same situation, an operator can readily find the exact bearing of each call.

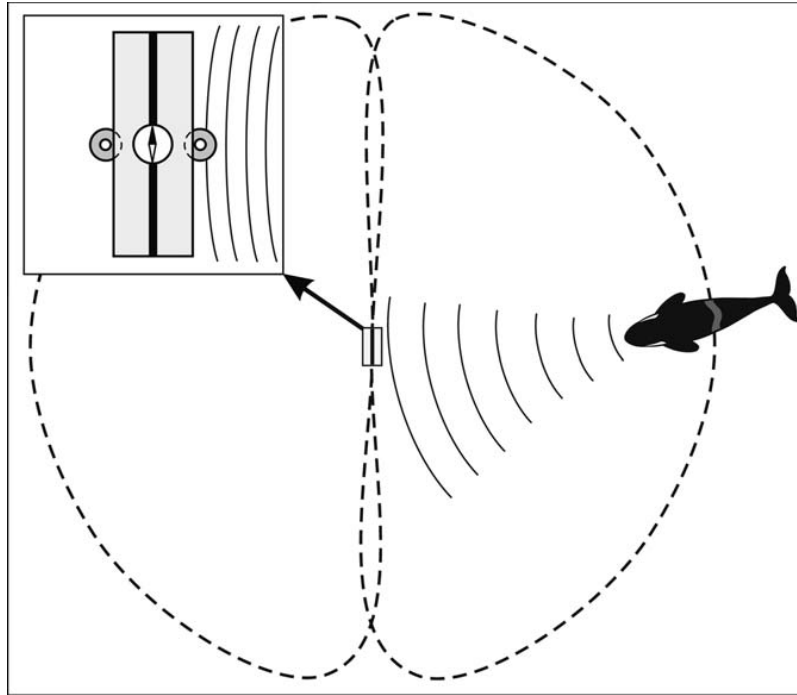


Fig. 2. Arrangement of the stereo system (MHSS) and sound source for audibility of signal in only one of the hydrophones.

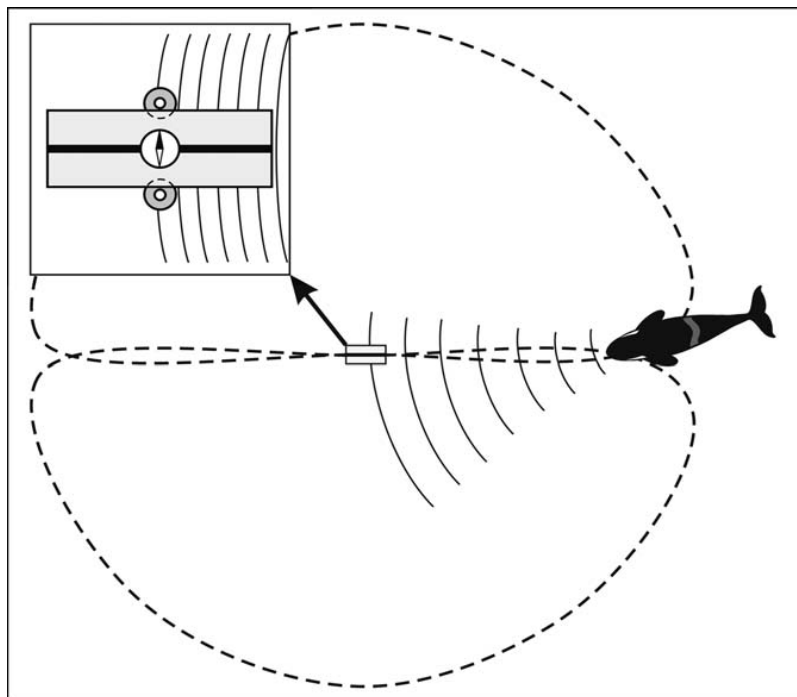


Fig. 3. Arrangement of the stereo system (MHSS) and sound source for audibility of signal in both of the hydrophones.

For direction-finding and recording we used two identical hand-made hydrophones with a frequency range from 300 Hz to 20 kHz and a Sony DAT TCD-D100 digital audio tape-recorder. We also used an Offshore Acoustics omnidirectional hydrophone to control the recording quality of the hand-made hydrophones. It had a flat response with a 3 dB

rolloff between 6 Hz and 14 kHz, a 10 dB rolloff between 5 Hz and 40 kHz, along with a sensitivity of $-154 \text{ dB} \pm 4 \text{ dB re } 1 \text{ V}/\mu\text{Pa}$ at 100 Hz.

We used the stereo system for finding killer whale groups within listening distance when visual localization was impossible. The maximum distance for reliably listening to killer whale underwater calls usually exceeds the distance of visual detection from the boat [7]. Observers often listen to killer whale calls on a hydrophone, but cannot detect them visually. The stereo system enables the researcher to find the direction to the vocalizing animals in order to approach them to a distance sufficient for visual detection.

The stereo system was also used for separating the sounds of killer whale groups when they were in acoustic contact. During the recording, the boat was placed between the two groups, and the stereo system was positioned so that the signal from each group went into a separate hydrophone. Using this method we could record the dialect of each group separately even when they traveled together (Fig. 4). We also used this method for behavioural studies to isolate and record separately whales in a group that exhibited some particular type of activity.

The stereo system can also find specific killer whales that cannot be located visually. For example, in the 2005 field season we found a new “offshore” clan which often stayed 10–30 km or more from shore. We found them only by their calls at a distance of 10 km from the open sea. In 2005, we also met the first Kamchatkan killer whales which appeared to be transients (killer whales that eat marine mammals). They differed from residents by their appearance, behaviour, calls, and the number of animals in the group. These presumed transients had only two whales in a group, while the least number of whales in the groups of our resident killer whales is four, and usually more than five. By all these parameters they looked like the transient, mammal-eating orcas from Canada and Alaska. It is noteworthy that we found these first transients in our area only by their calls, which differed from the calls of the usual resident killer whales.

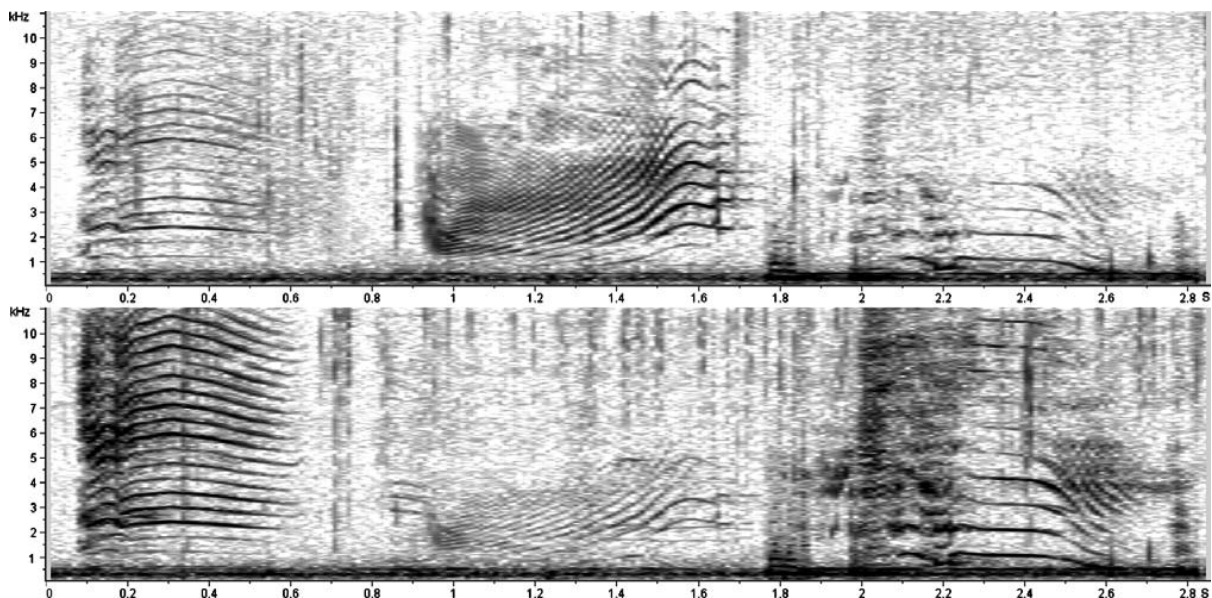


Fig. 4. Recordings of two different groups, separated by the stereo system. The calls of each group are strongest on the channel facing the group. Note also that the amplitude discrimination diminishes with decreasing frequency due to the size limitations of the soundproof disc.

It seems likely that the mobile hydrophone stereo system will have other applications. One application would be the recording of individual killer whale calls in order to study the individual variability in calls, which can help to illuminate the origin of the dialects. At present, we have only a few recordings of individual whales. Another possible application is to localize other cetaceans, for example sperm whales, which can be easily detected acoustically but disappear during their long dives.

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