A Mobile Measurement System for Sound Source Level of Wild Dolphin Whistles

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Synopsis

This paper reports the feasibility to use a newly-developed mobile measurement system for sound source level of wild dolphin whistles. This system consists of four hydrophones, amplifiers, one 4-channel recorder, and video. One person can handle this system throughout the survey. We successfully took the whistles from free-ranging wild dolphins and calculated the sound source level of the whistles. In future, the system should be smaller and accuracy and precision of the sound source location measured should be higher.

KEYWORDS: dolphin, whistle, sound source level, measurement, hydrophone array

1. Introduction

Dolphins, or small toothed-whales, are communicating with each other by various sounds. A pure-tone like whistle is one of such sounds (Fig. 1). Dolphins use whistles to maintain group cohesion [1,2], for mother-calf interactions [3], to broadband caller's identification and location [4], and for greeting call [5]. Whistles are thus important for dolphins to maintain their social lives.

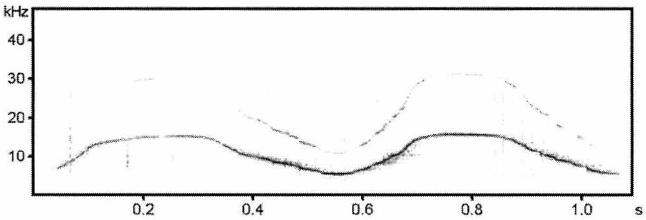

Fig.1 Example of dolphin whistle.

However, human activities around coastal area, such as over-shipping, dolphin-watching, or construction, are now increasing, and resulting artificial background noise increase [6]. If the background noise in the dolphin habitat increase, the dolphin sounds would be masked by the noise, and the communication range, or active space of the whistles becomes dramatically decreased. It will bring mother-calf separation and group separation, resulting increase of mortality.

We need to measure sound source level of the whistles to know how noise influence on the active space of the whistles. To know sound source level from a free-ranging dolphin, the distance between sound source (the vocalizing animal) and the hydrophone and the sound attenuation of the sound from vocalizing animal to the hydrophone should be measured. Since it is difficult to measure the distance between a free-ranging dolphin and the hydrophone directly in a field, researchers usually use hydrophone array system. There are several studies that measures sound source level of dolphin whistles using a hydrophone array [2,7]. Bottlenose dolphins in Moray Firth, Scotland, produce whistles with mean source level of 158 ± 1 dB re 1 μPa at 1 m[2], and those in Koombana Bay, Western Australia produced whistles with mean source level of 147 ± 6 dB re 1 μPa at 1 m[7]. Those studies used

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widely separated hydrophone arrays and did not identify which animal produce that sound. Several previous systems can identify dolphin identity by simultaneous sound and video recording system [8,9)]. But those systems seem to be expensive and large which is not good for field use.

Here we develop mobile system to measure sound source level of wild dolphin whistles and test the feasibility to use this in a field condition.

2. Material and Method

Our system can be divided into two parts, underwater video system and sound recording system (Fig. 2). Underwater video system consists of two commercial products (Underwater housing: RVH-CX700VSD, NTF corp., Japan; Video: HDR-CX590V, Sony, Japan). Sound recording system consists of two commercial product (4-channel sound recorder: R-44, Roland, Japan; 4 hydrophones: AQH-020, Aquasound Inc., Japan), and handmade products (Amplifiers and underwater housing: Aquasound Inc., Japan). Hydrophones had - 193 dB re 1 V / 1 μPa sensitivity and the flat frequency response (± 3dB) between 100 Hz to 20 kHz. The distance between 4 hydrophones are all 13 cm. Amplifiers were fixed 12 dB gain. First version of this system (without underwater video system) had 13.3 kg in air and -2.7 kg under water. New version of the system had 7.3 kg in air and -0.1 kg under water, so the mobility was improved dramatically. One author (TM) was able to handle this system throughout the study period only by himself.

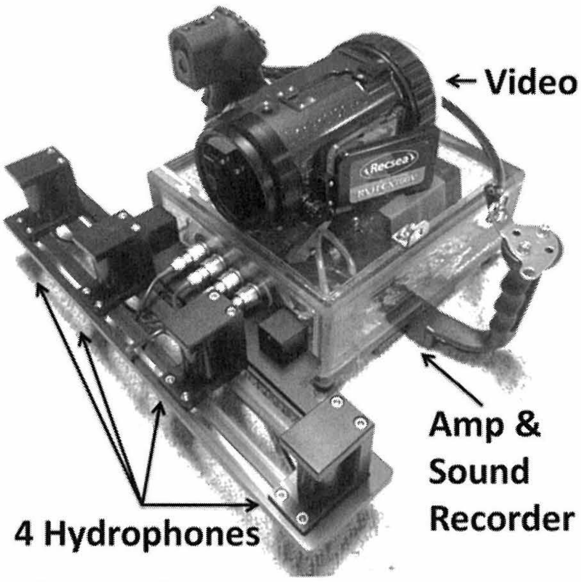

Fig.2 System for measuring sound source level of dolphin whistles.

Underwater video system and sound recording system do not connected directly, so we need to synchronize video image and sounds recorded by hydrophone array. Underwater video system also records sounds, so we can synchronize video and sounds using recorded dolphin sounds. We identified who was the caller of the sounds from the image using ID catalogues provided by Mikura Island Tourist Information. The sounds recorded by 4 hydrophones were first analyzed using Avisoft-SASLab Pro Ver. 5 (Avisoft Bioacoustics, Germany). We selected sounds with good S/N ratio and adopt appropriate band-pass filters to reduce noise. After that, Time-delay-of-arrival (TDOA) measurement function in Avisoft-SASLab Pro was used to measure time difference of arrival between 4 hydrophones (Fig. 3). Received levels of the whistles were also measured using Avisoft-SASLab Pro. To know absolute value of the sound pressure level, a calibration signal (sine wave, 8 kHz) was recorded before each recording using Minirator MR1 (NTI, Liechtenstein).

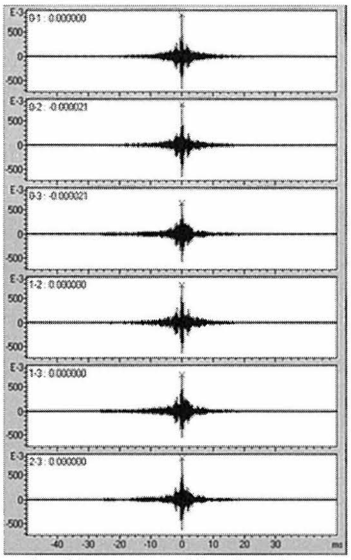

Fig.3 An example of time difference of arrival between 4 hydrophones using Avisoft-SASLab Pro. X-axis: Cross-correlation function; Y-axis: Time difference of arrival.

To back-calculate the sound source level from the sound received level we need to know the sound transmission loss between the system and the dolphin whistle. Sound transmission loss can be calculated by the distance between hydrophones and a dolphin whistle and sound speed at the location using Pythagorean theorem [10,11]. Sound speed can be calculated from water temperature and salinity using Francois & Garrison (1982) equation [12]. For each hydrophone pairs produced 6 hyperbolas. In ideal condition, all hyperbolas intersect on one point. In our recordings, hyperbolas usually did not intersect on one point (Fig. 4), but several adjacent points. We selected the feasible points from the video image, and averaged the points. Then we calculated the sound transmission loss using Francois & Garrison (1982) which needed the distance between the dolphin and the hydrophone, water temperature, salt concentration and pH [12]. We built custom-written program for calculating the 2-dimensional relative place and distance to the system from TDOA data using IGOR Pro ver. 6 (Wevemetrics, USA).

Field studies were all conducted the shallower water off Mikura Island, Tokyo, Japan. Indo-Pacific bottlenose dolphins (*Tursiops aduncus*) inhabit throughout the year. Almost all dolphins, around 120 dolphins, are identified by the Mikura Island Tourist Information Center using video-image identification technique [13].

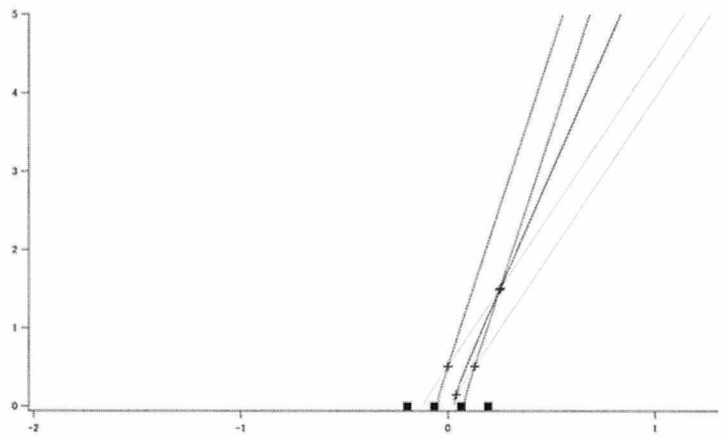

Fig.4 Possible sound source location calculated from time difference of arrival by 4 hydrophones. Square: Hydrophone location; Line: Hyperbolas calculated by hydrophone pairs; Cross: Possible sound source location

3. Results

Field recordings were made 14th Sept. 2012 for 1st system and 2nd July 2013 for 2nd system. Sound speed of the environment was calculated to 1539 m/s using measurements of the water temperature (27°C), salinity (34 ppt) and pH (8.2) from the Francois & Garrison (1982) equation.

We identified several sounds from two individuals (27 whistles from #008 adult male (Kobuhei) and 2 whistles from #314 adult female (Oonami-Konami)) using 1st system, and from three (6 whistles from #609 juvenile female, 2 from unidentified calf #32, 2 from #600 subadult female (Shasen)) using 2nd system.

The distance between the dolphin and the hydrophone was 1.6 m in average (0.7 – 3.1 m) resulting 4.6 dB of sound transmission loss in average. Sound source level of the dolphin whistles was 130 ± 8 dB re 1 μPa for 1st system, and 165 ± 4 dB re 1 μPa for 2nd system.

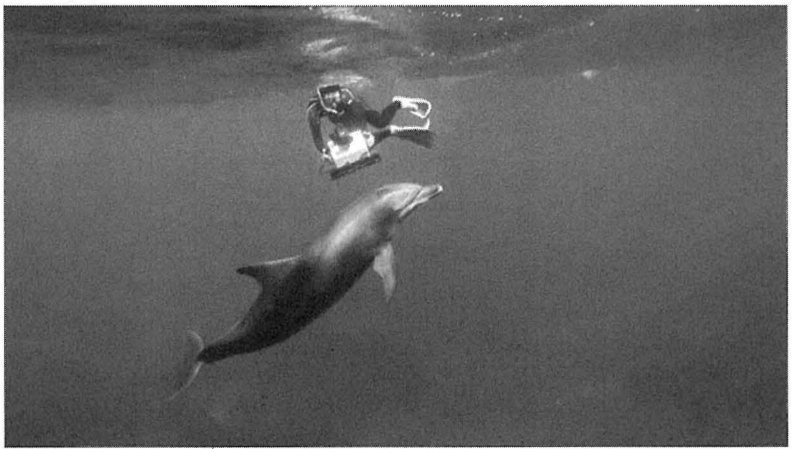

Fig.5 1st system and a dolphin in Mikura Island.

4. Conclusion

We successfully recorded dolphin sounds and calculated the sound source level from each identified individual. However, the sound source level of the 1st recordings seemed too low considering those in other published data [2,7]. We need to check that this difference was the 1st recording system problem or the individual difference of sound source level of the whistles. We must test the accuracy and precision of acoustic localizations of the system in near future.

For field use, the systems were still large even the smaller 2nd system. We still need to make it smaller to take good data because dolphins move fast and quick.

Sound source level of the whistles presents the active space of the dolphin whistles. It needs not only for conserving dolphins from artificial ocean noise such as boat noise, but also for pursue the function of the whistles. If dolphins adjust their sound source level of the whistles in different conditions, it means that they have the distance where their "voice" should be and not be transferred. Our system will contribute such important topics of dolphins.

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