A SYNCHRONISED ACOUSTIC ARRAY, RANGEFINDER & VIDEO SYSTEM WITH EXAMPLES FROM 'SINGING' HUMPBACK WHALES (*MEGAPTERA NOVEANGLIAE*)

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INTRODUCTION

No observations have yet been made to establish the source of sound from vocalising baleen whales, and there are few reliable estimates even of source levels. If the orientation to an animal is unknown and the radiated pattern of sound is not omni-directional, even those source level estimates that are available are of questionable accuracy. As technology improves and microprocessors become both smaller and less power-hungry, several combined acoustic and video systems have been proposed and some built to study marine mammal behaviour, with the intention to provide simultaneous recordings to associate visual behaviour with acoustic emissions. In this paper we present the latest and most capable of these systems to have been deployed on a baleen whale to date.

MATERIALS AND METHODS

The Acoustic Research Laboratory in the Tropical Marine Science Institute has

Fig. 1. Schematic and picture of the ARL video-acoustic system.

developed a PC104-based system that provides an acoustic beamforming capability in both azimuth and elevation via a three-channel planar array, sampled at an aggregate rate of up to 200 kSa/s. The hydrophone array is an equilateral triangle of 600mm on a side. The system is also equipped with a low-power ultrasonic active sonar placed on the front of the PVC pressure case between the two lowest hydrophones, operating at 200 kHz, well above the anticipated hearing range of baleen whales. The rangefinder is able to determine the range of objects in the acoustic and video field of view with an accuracy of 0.5m and record these ranges to disc simultaneously with the acoustic data. High-Definition video is recorded by an infra-red controlled Sony HD camera co-located with the acoustic array and with its axis aligned. A schematic of the final system and photograph with the acoustic elements (three-hydrophone array, rangefinder and backup hydrophone connected directly to the video camera) highlighted in red and the optical element in blue is shown in Fig. 1.

The system was deployed by rebreather divers using Draeger Dolphin semi-closed rebreathers and Ambient Pressure Diving Evolution Vision fully closed rebreathers. The singing whales were approached from the side at the maximum range at which the whale remained visible. Once at depth, the divers moved closer to a range of 15-20m to take data. When the orientation to the whale was most nearly perpendicular (so avoiding foreshortening errors) images were extracted from the video data to make a montage that could be used to measure the length of the whale using conventional videogrammetric techniques. A graph of range during one data acquisition is shown in Fig. 2. with annotations to indicate the phases of the data collection.

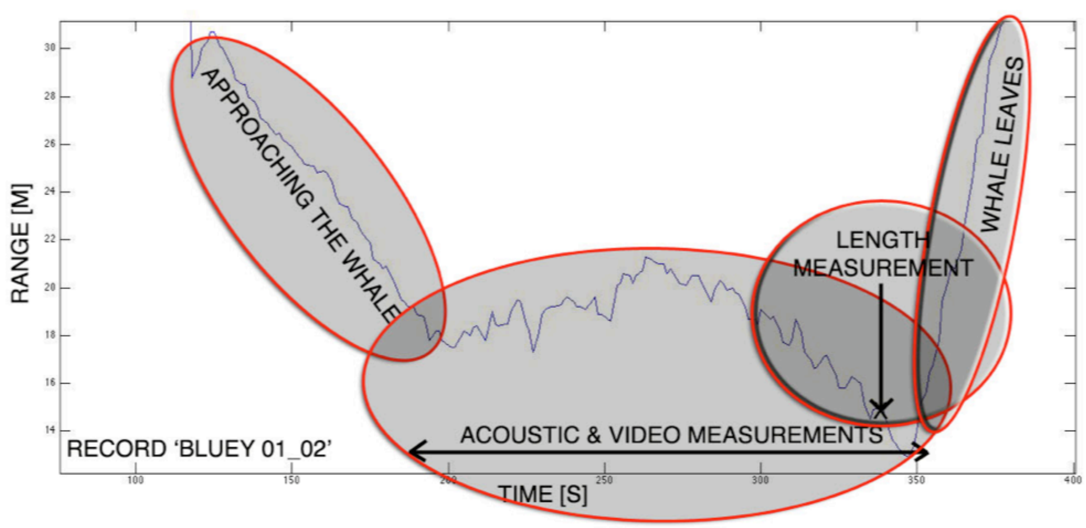

Fig. 2 Annotated plot of diver range during one data collection sequence.

SIGNAL PROCESSING

The Visual field of view of the HD video camera was determined by calibrating the image while on full wide-angle using a rectilinear test image filmed underwater in a swimming pool at a range of 1m. The acoustic data from the three-hydrophone array was beamformed at all frequencies in 1 kHz bands from 0-8 kHz using the high-resolution MUSIC algorithm that attains an angular acoustic resolution of approximately 0.5 deg. for high signal-to-noise ratio signals.. The 2-D acoustic intensity map, formed over the matching Visual Field of View was calculated for each frame (1/24 s) of the video and contours of the beamformed output plotted at -3, -6 and -9 dB levels for each of the 8 frequency bands onto each video still image. The estimated source level was obtained by correcting the received source level over 0-20 kHz by the measured range to the singer, assuming spherical spreading and neglecting absorption.

RESULTS

The system was first deployed in 2006, recording Humpback Whales at ranges of 1-20m on their 'wintering grounds' in the Caribbean on the Silver Banks of the Dominican Republic and in the AuAu channel off Maui in Hawaii. Several whales were approached and useful data collected from perhaps five encounters, of which two are selected as exemples here. The primary results are the composite video output that unfortunately cannot be shown in a printed document.

For singer A, source levels were estimated to be 162.5-170 dB +/- 3 dB re 1 μPa at 1m. Three different units were recorded which we shall refer to as 'Violin', 'Groan A' and 'Groan B'. The Violin source level was, on average over all recorded violin units, 170 dB re 1 μPa at 1m, with sound energy recorded dorsally being some 3 dB higher than laterally. The Groan A mean source level was 165 dB re 1 μPa at 1m, invariant with respect to aspect to the singer. The Groan B mean source level was 162.5 dB re 1 μPa at 1m with 5 dB higher levels dorsally compared to laterally. Source location, as given by a concensus of the plotted contours, appears to be at the rear of the head just behind the eyes and in front of the leading edge of the pectoral fins. A bar chart of all recorded units, colour coded as to type, is shown in

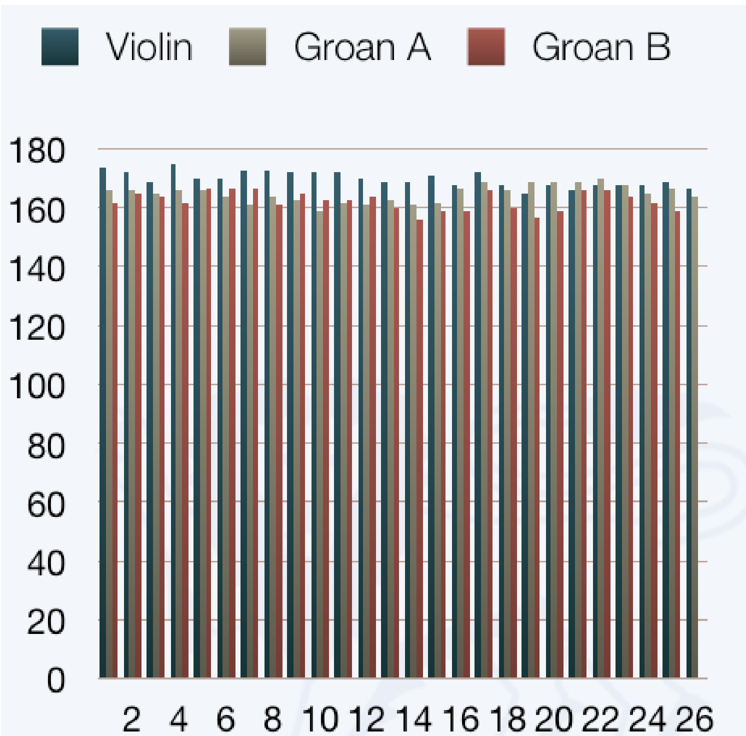

Fig. 3 Bar chart of all units recorded from singer 'A'

chronological order for singer A in Fig. 3, with the vertical axis giving the estimated source level in dB re 1 µPa at 1m.

For singer B, mean source levels over all units were estimated to be 165 dB +/- 3 dB re 1 µPa at 1m and there were no statistically-significant variations in level between the units. The data do not allow comparison of source levels at different orientations to the singer, as all the data were taken predominantly from the side. Once again, the source of the sounds appears to be approximately just behind the eyes, as viewed from the side, consistent with the results from singer A. A bar chart of all recorded units, colour coded as to type, is shown in chronological order for singer B in Fig. 4, with the vertical axis giving the estimated source level in dB re 1 µPa at 1m.

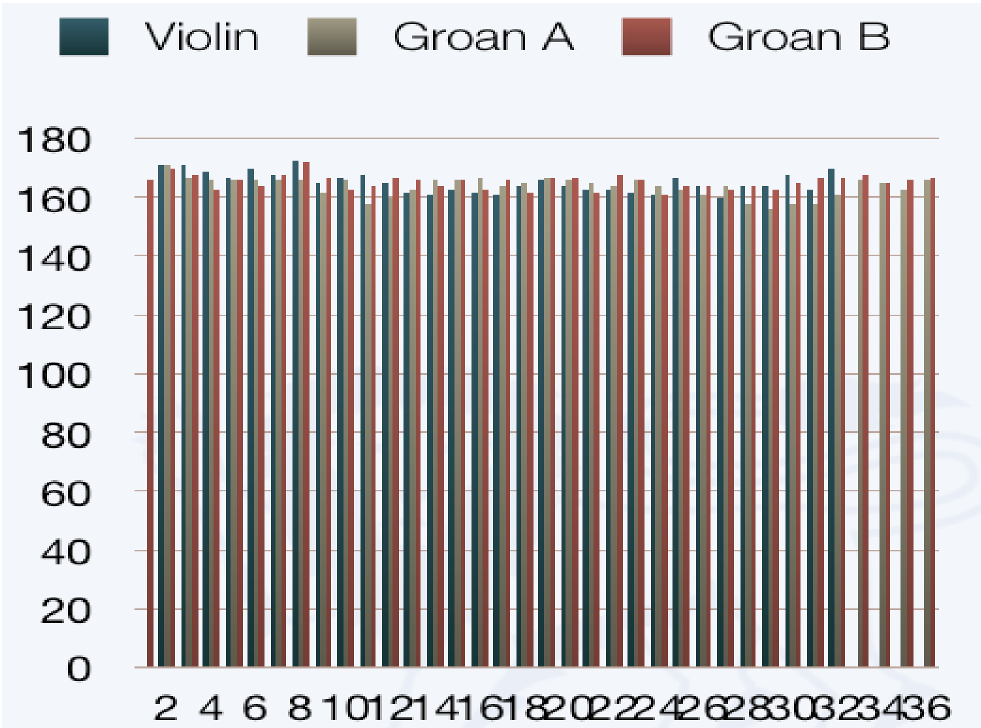

Fig. 4 Bar chart of all units recorded from singer 'B'

CONCLUSIONS

Humpback whale 'singers' typically produce sound levels of 162.5-170 dB re 1 µPa at 1m at the peak of each song unit. Different singers accentuate different units. The ARL system is capable of providing information critica to formulating representative models for potential communication masking, detection and abundance issues for endangered marine mammal conservation and management. Some directionality in the source radiaton pattern has been observed, consistent with the hypothesis that singers orient themselves in an inclined pose to maximise the range of propagation of their song.

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