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Acoustic detection of dugong using automatic underwater sound monitoring systems: AUSOMS-D

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ABSTRACT

Dugongs are the only marine mammals that feed on benthic seagrass. They are found in warm shallow waters of tropical to sub-tropical areas. Many of the dugong populations are close to extinction. Effective protection measures are needed for this species, but the dugongs are one of the most difficult animals to observe in the wild. We have attempted to establish a new methodology to record the presence of dugongs by a passive acoustic monitoring technique. In March, 2004, ten sets of automatic underwater sound monitoring systems for dugong - AUSOMS-D - were deployed on the seafloor in the southern part of the Talibong Island, Trang, Thailand. The underwater sound was recorded in stereo for 5 consecutive days. An acoustical filter was developed to detect the dugong calls automatically out of the background noise. The receiver operating characteristics has been evaluated. False alarm and correct detection rates of the system were 2.9 % and 39.1 %, respectively. The false detection rate was low enough to perform a scientific study on the dugong but the correct detection rate should be improved. The reason for the low correct detection rate appeared to be due to the low signal-to-noise ratio. For calibration purpose, artificially composed dugong calls were transmitted in the water from a research vessel. The GPS position and the acoustically calculated position were compared. The average error of the positioning of the sound source by AUSOMS-D was less than 20 m.

KEYWORDS: passive acoustical monitoring, arrival time difference, localization accuracy, positioning error, artificial dugong calls

INTRODUCTION

The dugong, *Dugong dugon*, (Fig. 1) is one of four extant species in the mammalian order Sirenia, all of which are aquatic herbivores (*e.g.* Marsh et al. 2002, Chilvers et al. 2004 among many others). The dugong is the only marine mammal that feeds on benthic seagrass and has a distinctive figure with the mouth opening ventrally below the broad flat muzzle. The feeding apparatus reflects their role as herbivores specializing on benthic feeding. Dugongs are easily found when they are feeding, with a stream of mud flowing in the feeding pathway of dugongs. The disturbed sediments and these clouds or streaks are assumed to be the result of the animals' rooting deep into the sea bottom. They are found in warm shallow waters of tropical to sub-tropical areas from Indo-West-Pacific between latitudes 26^{o} - 27^{o} North and South (Marsh et al. 2002). Over much of their range, dugongs are believed to be represented by separate, relict populations, many close to extinction or extinct (Marsh et al. 2002). World Conservation Union (IUCN) ranked this species as vulnerable to extinction in the Red List criteria and trade in products is regulated or banned by the Convention on International Trade in Endangered Species of Wild Flora and Fauna (CITES appendix I).

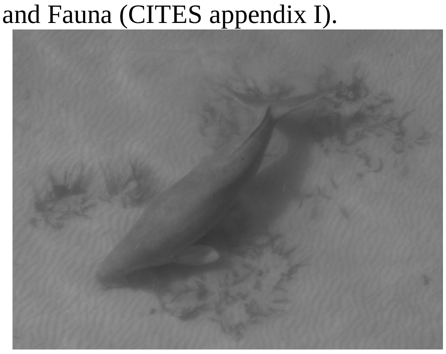

Fig. 1. A dugong generally feeds on seagrass in shallow area. (Photograph: Surasak Thongsukdee)

Acoustic signals produced by dugongs and the roles of these signals in behavior have been little studied. Dugong vocalizations were roughly classified into three types: Chirps, trills and barks by Anderson and Barclay (1995). Chirps are frequency-modulated signals in the 3 to 18 kHz range lasting ca. 60 ms. Trills last as long as 2,200 ms, are frequency-modulated over a bandwidth of 740 Hz within the 3 – 18 kHz band, and have two to more harmonics. Barks are broadband signals of 500 to 2,200 Hz lasting 30- 120 ms with up to five harmonics. Frequency modulation of chirps suggested a ranging function. Trills were more appropriate for affiliative function and barks for aggressive behavior (Anderson and Barclay 1995). Marsh et al. (1978) reported that a captive young dugong produced sounds in two frequency bands (1-2 kHz and 2-4 kHz) and the third sound was a composite of these two.

Although there are some researchers who have studied the vocalization from dugongs, no research has succeeded in obtaining horizontal tongue-positions associated with their vocalizations. Therefore, we applied the passive acoustic observation to meet our goal, establishing a monitoring method for dugongs. The main advantage of this technique is that it has the least impact on dugong movements and it can be performed at constant detection efficiency for over long and continuous hours, even in the pitch-black darkness. Preliminary surveys showed a robust feasibility of the passive acoustic observation of dugongs (Ichikawa et al. 2003). The objective of this study is to construct a dugong monitoring network that consists of multiple recording devices. Wide range and long term monitoring can be performed with this monitoring network, which were absent in previous conventional observation techniques.

Our research was the first trial to establish a new technique using underwater acoustics. We believe the results of this study will help accumulate the ecological and behavioral information of the dugong to implement evidence-based protections for them.

MATERIALS AND METHODS

RECORDING APPARATUS, AUSOMS-D

An underwater sound monitoring system for the dugong (AUSOMS-D, Fig. 2) was developed by System Intech Co., Ltd (Shinke et al. 2004). under acoustical characteristics of dugong calls obtained from previous reports (Anderson and Barclay 1995) and our preliminary recording which was conducted in February, 2003 (see Ichikawa et al. 2003). The recording device consists of a set of hydrophones which are set 2 m apart from each other and a pressure tight chassis. Inside the pressure tight case are pre amplifiers and post amplifiers for the hydrophones, filters (1 kHz high pass filter), attenuator, HDD, batteries, DC/DC and A/D converter (sampling frequency at 44.1 kHz), clock, computing units (Fig. 3). Each of the hydrophones has flat frequency responses at 1 kHz to 10 kHz (Fig. 4) and nondirectional characteristics (Fig. 5). The underwater sound was recorded in stereo with time-synchronized hydrophones and the sound data sets were stored on a removable hard disk in uncompressed format, .wav format. The maximum recording duration was 120 hours.

Fig. 2. Appearance of AUSOMS-D. The figure shows the pressure-tight case and the hydrophones.

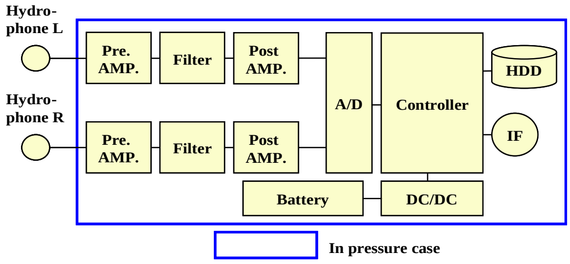

Fig. 3. Block diagram of the AUSOMS-D. The diagram shows the inner package of AUSOMS-D.

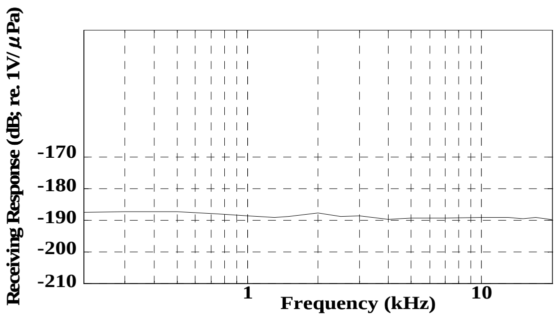

Fig. 4. Frequency characteristics of the hydrophone

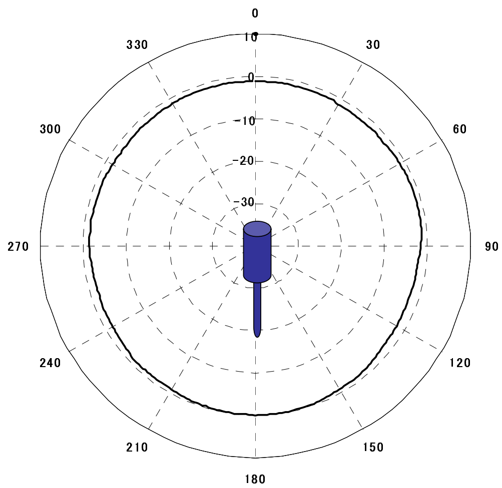

Fig. 5. Directivity of the hydrophone

STUDY SITE

For our survey, behavioral records and vocalization data are indispensable. We set our study site around Talibong Island, Trang, Thailand (longitude N07° 12' 58.4" latitude E99°24'21.9", Fig. 6), where many sightings of dugongs have been reported. Our recording was carried out in the southern part of Talibong Island (in the shaded circle in Fig. 6). There is the largest seagrass bed of 7 km^2 around the Talibong Island. The seagrass beds were mainly composed of *Halophila ovalis*, for which dugongs show a preference (Chansang and Poovachiranon, 1994 and Hines et al. 2002). The seafloor is almost flat with a rather gentle slope and few obstacles in the path of a sound wave are seen in the focal area. A clear path for the sound wave helps perform passive acoustic monitoring. Besides, the largest dugong population in Thailand is also found in this area (Adulyanukosol 1999). Preliminary aerial survey using a light airplane called a microlite suggested there were no other animals that produce calls like dugongs, making it easy for us to identify the species by their calls. Turtles were seen frequently in the area, too.

Fig. 6. Study site: Talibong Is., Trang, Thailand.

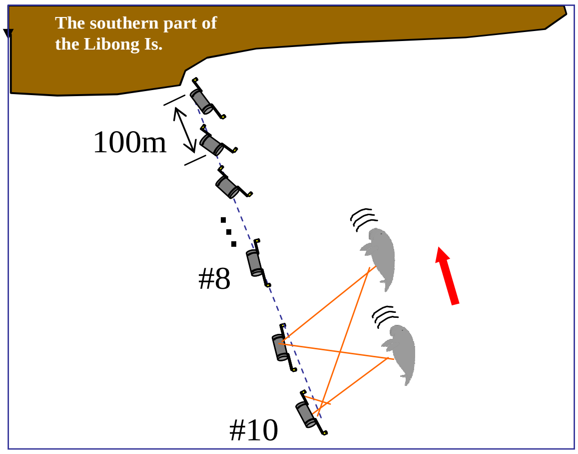

Fig. 7. Concept of the dugong monitoring network

Ten sets of AUSOMS-D were deployed on the sea floor off the southern part of Talibong Island (Fig. 7). Each recording device was set about 100 m apart to make a straight-lined monitoring array, which we called "the dugong monitoring network". The recording took place for 5 consecutive days from the 22nd of February, 2004 to 26th of February, 2004 and 28th of February, 2004 to 4th of March, 2004.

RESULTS

Extraction of vocalizations of dugongs

A total of over 1.1 TB of underwater sound data sets were obtained through the recording. Dugong calls were detected automatically out of the ambient noise by newly developed software working on MATLAB. The detection algorithm is explained as follows.

1. Underwater sound data, with the vertical axis of 0 to 22 kHz, are segmented into 80 points (which is equivalent to 1.8 ms) vertical strips.
2. The frequency component with the maximum spectrum level for each segment is then measured after adding up the fast Fourier transform (FFT) of the neighboring 25 segments.
3. The frequency components are then filtered to discriminate dugong calls from ambient noise. We defined the acoustical filter by the user-defined spectrum threshold, frequency band-path of 2.0 kHz to 12.0 kHz. Besides, the filter only allows the smooth modulation of the frequency components, which must last longer than use-defined duration threshold. To roughly summarize the above procedures, smoothly continuous sequences of the frequency components with high spectrum levels were defined as dugong calls (Fig. 8).

After the detection of dugong calls, time of the start of the vocalization, dominant frequency, maximum and minimum frequency, duration and sound source direction were measured for each call

Sound source directions were converted into deflection angle, θ, in a plane with coordinate system, where the Y-axis represents the north to south and the

X-axis the east to west. The position of the sound source was localized by working through simultaneous equation (Eq. 1).

$$L1 = \tan(\theta 1)*(x - p_1) + q_1$$
$$L2 = \tan(\theta 2)*(x - p_2) + q_2 \qquad \text{Eq. 1.}$$

Where, the coordinates of the recording devices are represented by (p1, q1) and (p2, q2), respectively.

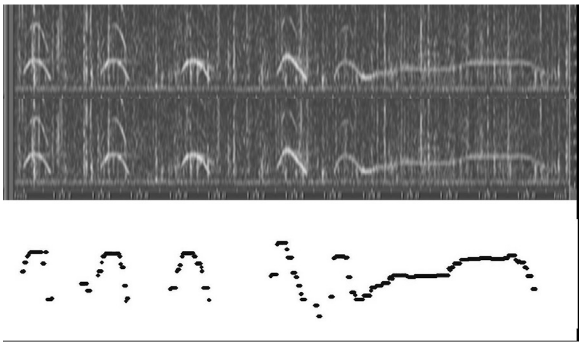

Fig. 8. An example of the automatic detection of the dugong calls. The results are shown by the blue plots.

Detection rate

The filtering thresholds were altered in terms of sound pressure levels, and duration for each detected call. The evaluation was made by comparing correct detection rate, false detection rate and number of missed calls. The detection was made for two different sound data sets, each containing high S/N signals (n = 355) and low S/N signals (n = 73). It is important not to mistake noise as dugong calls, for the confirmation of the presence of dugongs in the recording area. The detection setting that provided the best overall performance was composed of the thresholds of 60 ms in duration and 87.8 dB in sound pressure level. The setting resulted in a false detection rate of 2.9 %, although the correct detection rate was only about 36 %, which seemed to be due to low signal to noise ratio. All of the underwater sound data sets were analyzed with these detection parameters.

Localization accuracy

Three different types of dugong-like sounds were played in the water from the research vessel. The research vessel cruised along the hydrophone array and the location of the playback-vessel was measured by GPS. The research vessel that played the artificial dugong calls was located using passive acoustic observation. The localization accuracy was evaluated by comparing the calculated locations of the sound source of the artificial dugong sounds to the GPS logs. Continuous change in the arrival time delay was successfully observed with #8 and #10 AUSOMS-D (Fig. 9). The position of the playback-vessel was measured by processing the sound data obtained at #8 and #10 AUSOMS-D (Fig. 10). The result of the localization matched well with the GPS-logged trajectory of the ship. Errors in meters between GPS logs and the results of calculation had an average of 17.43 m (n = 204, S.D. = 11.32, the minimum and the maximum error was 2.42 m and 39.35 m, respectively). The errors according to distance from #10 AUSOMS-D is described in Fig. 11. The biggest error was distributed around #9 AUSOMS-D, which was located the furthest from both #10 and #8 AUSOMS-D. Thus, distance-dependent error of the passive acoustic localization method was suggested.

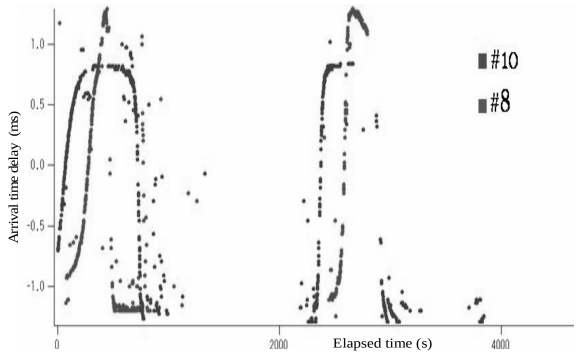

Fig. 9. Time series change in the arrival time delays recorded by #8 and #10 AUSOMS-D.

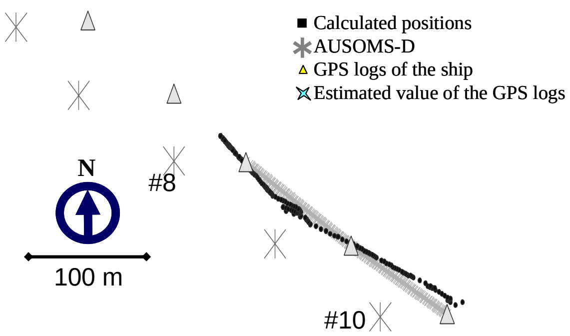

Fig. 10. Result of the localization of the sound source of the artificial dugong calls.

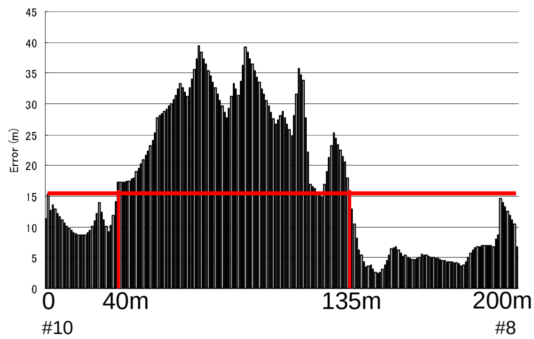

Fig. 11. Spatial distribution of the positioning errors. The error would be expected to be less than 15 m within the detection range of 40 m.

CONCLUSION AND DISCUSSION

The first local scale observation of dugongs in the wild has been described in this paper. Briefly summarizing the results, dugong calls were detected with a low false alarm rate of 2.9 %. The moving path of the source of dugong call was traced.

In regard to the automatic detection of dugong calls, although the false alarm rate was low at 2.9 %, correct detection was only about 36 %, which seemed to be due to low signal to noise ratio. Most of the noise consisting of pulse sounds was considered to be created by some snapping shrimp. The major difference between dugong calls and noise components was continuity of frequency component in time.

The accuracy of the localization ranged from 2.4 m to 39.3 m, depending on the distance. The results of localization matched relatively well with the GPS logs, given the GPS accuracy of a few dozens of meters. This can be considered to be good enough for dugong monitoring. The localization accuracy is to be improved by recording an identical call with three or more AUSOMS-D at once.

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