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Spatial distribution of dugongs by acoustic and visual observation in Thailand

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ABSTRACT
Dugong calls were collected using a towed stereo hydrophone system around Talibong Island and Muk Island in Thailand in January 2008. Standard visual observation was conducted simultaneously to record the dugong distribution. A total of 223 dugong calls and 80 dugongs were detected. Spatial distributions of both of the acoustical and visual detections were analyzed using $I\delta$-index. The spatial distribution of the visual detections showed almost uniform distribution and that of the acoustical observations showed concentrated distribution ($I\delta$=0.85 and 3.18, respectively). The number of snapping noises per minute was less in the areas where dugong calls were observed (P < 0.001). It was suggested that dugongs vocalized selectively in less noisy areas.

KEYWORDS: passive acoustical observation, towed hydrophone system, distribution pattern, I_δ-index

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). 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).

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.

We applied the passive acoustic observation to study dugong behavior. 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. Previous surveys using automatic underwater sound monitoring systems for dugongs (AUSOMS-D for short) showed a robust feasibility of the passive acoustic observation (Ichikawa et al. 2003; Ichikawa et al., 2004) and biological evidence that their vocal activities showed circadian and/or circatidal rhythms (Ichikawa et al., 2006).

Although there are some reports on the dugong vocalizations, no research has succeeded in examining spatial distribution of acoustical and visual detections. It is particularly important to examine and compare the distribution of them both, because thereby detection rates of the detection methods can be estimated. The estimation of the detection rates will be more accurate when the distributions of both detections match well.

Morisita (1962) proposed an index called I_δ-index for measuring dispersion of individuals in a population. The goal of this study is to estimate the distribution pattern of both the acoustical and visual detection of the dugongs using I_δ-index.

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

MATERIALS AND METHODS

Acoustical observation

A towed stereo hydrophone system (Towed Aquafeeler, System Intech Co. Ltd., Japan) was operated off of Trang province, Thailand. The study area for the towed system was from Muk Island (7^o 12’28”N, 99 ^{o} 23’56”E) to the southwest end of Talibong Island (7, 24’.31”N, 99, 20’.11”E) via Hat Yao port (7, 18’.4’’N, 99, 24’.0”E) (Fig. 2). We operated a wooden boat (11.3 m in length and 2.4 m in width) for daily trips around the focal area. The distance of this trip was 60 km, and it took 6 hours a day at a towing speed of 10 km/h.

The Towed Aquafeeler consisted of a 10 m draw, a 4 m flexible polyvinyl chloride rubber tube with two hydrophone elements (100 Hz～100 kHz) inside, a 60 m towed electric cable, a receiving unit, and a 2-channel conditioning amplifier. The towed cable eliminated interfering noise from the towing boat. The cable had neutral buoyancy that enabled towing even in shallow waters of 1 m depth, which is close to the minimum depth of 0.8 m that dugong forage in (Tsutsumi et al., 2006). The stereo hydrophone (two hydrophone elements) was separated at 2 m from the preamplifier near the hydrophone element. The receiving sensitivity of the hydrophone was -193 dB (re 1 V/μPa). The amplifier had a variable high-pass filter (cut-off frequencies of 200 Hz, 1 kHz, 4 kHz). In the present study, we selected a 1 kHz high-pass filter to eliminate flow noise interference. Stereo signals were recorded using a hard disk recorder (R-4 pro, Roland, Japan).

Two experienced audio listeners (TA and TS, authors of this paper) monitored underwater sounds using headphones (MDR-Z600, SONY, Japan). The two listeners took turns listening, alternating every 30 minutes. The time at which dugong calls were received, with a one second resolution, was recorded by the listener. Automatic track logging of the GPS (GPS 76s, Garmin, USA) was used to assess the location with respect to the detection time. Onboard detections were confirmed by off-line listening using Cool Edit Pro software (Syntrillium Software Corp., AZ., USA). The detection threshold level was 90 dB rms re 1 μPa using a 1024-point fast Fourier transform.

Ichikawa (2007) estimated the source level of dugong calls to be approximately 141.6 $\pm$ 4.6 dB *re* 1 μPa with the mode value of 138 dB using spherical spreading model assumption for the transmission loss. Given the mode of the source level of dugong calls and the detection threshold level, the acoustic detection range was calculated to be 251.2 m.

Visual observation

Four experienced visual observers performed visual observations, conducted without magnification. Two were professional dolphin watching guides and the other two were researchers who have been conducting visual observation of dugongs in Thai waters for many years. Observers focused on the sector 90 degrees to the left of the bow during the first 30 minutes and then focused on the 90 degree sector on the right side for another 30 minutes, followed by one hour of rest. Observers recorded time and location of detection using GPS.

Analysis of distribution pattern of detections

We segmented the transecting line into 833 m sample blocks and tallied both acoustic and visual detections for each block. Analysis of dispersion using an I_δ-index was performed to examine the spatial distribution of locations where detections were made. The I_δ-index was proposed by Morisita (1962) as a measure of the dispersion of individuals in a population. The statistical significance of the index value was tested by F (b-$1,\infty; 0.01$). The index value and F value for a given group of N individuals was computed as:

$$I_\delta = \sum x_i (x_i - 1) / N (N - 1); \text{ and}$$
$$F = (I_\delta (N - 1) + b - N) / (b - 1),$$

where x_i is the number of individuals in the i-th sample block of the total b blocks (i=1,2,3,4,…,b). If the index is greater (smaller) than 1, then the distribution is concentrated (uniform). An index equal to 1 indicates a random distribution.

RESULTS

Surveys were conducted for 12 days from January 11 to 23 in 2008. In total, 85 dugongs were observed visually. On average, seven animals per day were observed along the 60 km cruise. The maximum detection distance of visual observations was 220 m from the observer to the animal. In addition, three dugongs were observed by off-duty observers. These observations were not used for the analysis.

Acoustic surveys detected sequences of dugong vocalizations 237 times. Once a dugong started to vocalize, the sequence of chirps and trills was recognized, which is consistent with former observations in these waters (Ichikawa et al., submitted).

Areas surveyed were segmented into 33 sample blocks. Acoustical detections were concentrated in two specific areas that were located on the east side of Muk Island and on the south side of Talibong Island ($p < 0.01$, $I_\delta = 3.52$, $F = 21.08$, $n = 33$). The distribution of visually detections showed an almost random distribution ($p > 0.05$, $I_\delta = 0.97$, $F = 1.07$, $n = 34$) (Fig. 2).

We defined the pulse noise as more than 120 dB peak-to-peak re 1 µPa with duration between 0.9 and 6.9 ms. The dugong calls were frequent in relatively silent areas (Fig. 3). The area between off Hat Yao port and the south of Muk Island was also a less noisy environment, but we did not observe frequent vocalization of the dugongs.

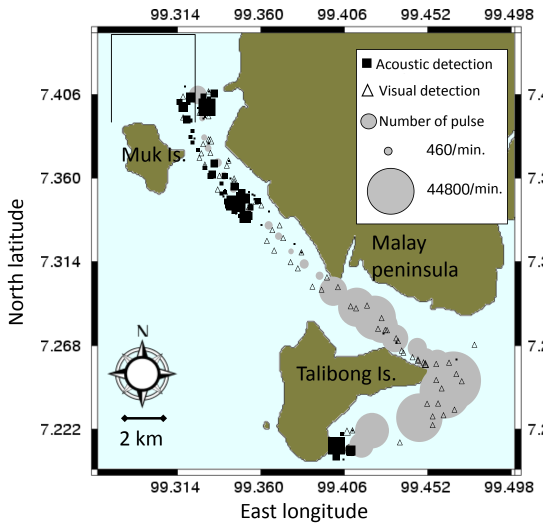

Fig. 2 Dispersion of acoustic and visual detections and noise hot spots. Solid squares, empty triangles and shaded circles represent acoustic and visual detections and noise hot spots, respectively.

Dispersion of the acoustic detections and the visual detections were significantly different. I_δ-index of the acoustic detections was 3.18 indicating concentrated distribution and that of the visual detections was 0.85 indicating uniform distribution ($P < 0.01$, $n1 = 32$, $n2 = \infty$)。

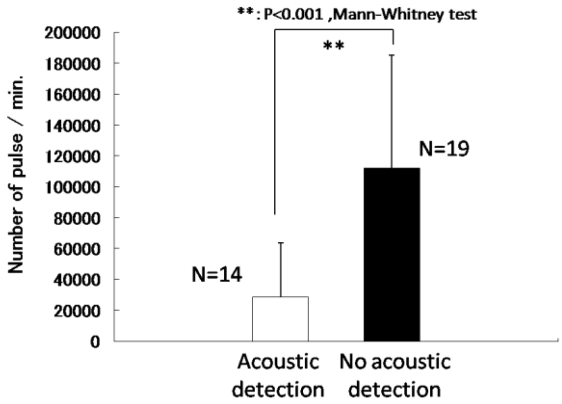

Fig. 3 Number of pulse detected in one minute. Acoustic detections were significantly less in the noisy environment ($P < 0.001$, Mann-Whitney test).

CONCLUSION AND DISCUSSION

The visual observers covered distances of up to 220 m from the cruise line and the estimated acoustic detection range was 251.2 m from the hydrophone. Although the detection performance of both methods should be low, close to the limit of the observable range, the detection range of the acoustic method was likely wider than that of visual observation.

The analysis of dispersion suggests distinctive vocal "hot spots" despite uniform visual detection. In the area around Muk Island, few dugongs had been observed by the previous aerial surveys (Hines et al., 2005). Pollock et al. (2006) noted that the availability of animals for observation should be taken into account. It should thus be noted that acoustic availability may depend on the location, especially at the east end of Talibong Island. In the present study, each 833 m section was used as the unit section and associated with the presence or absence of dugongs as determined by acoustic or visual observation. Thus, the use of passive acoustic surveys for dugongs was more suitable for assessing the presence of animals rather than counting the number of animals in the focal area. Assessing presence or absence is the first step in the conservation of highly endangered aquatic animals. However, it should be noted that passive acoustic surveys are capable only of assessing the presence of the focal animal and should not be used to confirm the absence of endangered animals.

The vocal hotspots were found in less noisy areas. Those results suggest that the dugongs selectively vocalized in less noisy environments. The future studies should consider the environmental effect of the dugong vocalization.

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