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Preliminary estimation of detection rate of dugong acoustical observation

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ABSTRACT
Dugongs are the only marine mammal that feeds 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. We have established a new methodology to record the presence of dugongs by a passive acoustic monitoring technique using automatic underwater sound monitoring systems for dugongs in the southern part of Talibong Island, Trang, Thailand. This study described the preliminary estimation of detection rate of the dugong acoustical observation system. Visual and acoustical observation was performed simultaneously to compare the detections by each method. The results showed that almost 30% of the dugongs in the monitored area were acoustically detected. It was in the spring tide era when the maximum number of detections was obtained.

KEYWORDS: passive acoustical observation,

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). The 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 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 estimating the detection rate of the dugong acoustical observation. The detection rate is the ratio of the number of acoustical detections to the number of individuals within the monitored area. It is particularly important for passive acoustical observation. The goal of this study is to estimate the detection rate of the dugong acoustical observation.

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

MATERIALS AND METHODS

Study site and the observational design

To evaluate the detection rate of the passive acoustical observation by AUSOSM-Ds, 4 sets of AUSOMS-Ds were deployed off south of Talibong Island (Fig. 2). The recording took place from November 11 to November 15 and from November 17 to November 21, 2006. An acoustic array using AUSOMS-Ds was arranged as illustrated in Fig. 3. Visual observation was conducted simultaneously from the top of a mountain near by the acoustic array. Each of the 4 visual observers used high-resolution binocular Victory 10 x 32 T*FL (Zeiss, Japan) to observe a plot of 260m x 260m, that divided the acoustical monitoring area into 4 plots (Fig. 3).

The visual observation was started at around 9:00 and ended at 12:00, having 10 minutes break between 50 minutes of ceaseless observation. The observation period was selected because wave and wind were calm compared to rough conditions in the afternoon driven by seasonal wind pattern. Exact time in seconds was recorded when the dugongs were found. Then, the underwater sound at the time when the dugong was sighted was replayed. If the acoustical detection was within a 2-minute time window of the visual detection, the visual detection was regarded as "acoustically detected", hereinafter called *DRac*. Additionally, if the distance between the position of the dugong sighting and acoustical localization of the sound source was within 130m, the visual detection was regarded as "acoustically localized", hereinafter *DRloc*. The detection rate was determined by calculating the following Eq. 1.

$$DRac = Na / Nv$$
$$DRloc = Naloc / Nv \qquad \text{(Eq. 1)}$$

where *Na* is the number of "acoustically detected" detections, *Nv* the number of visual detections and *Naloc* the number of "acoustically localized" detections.

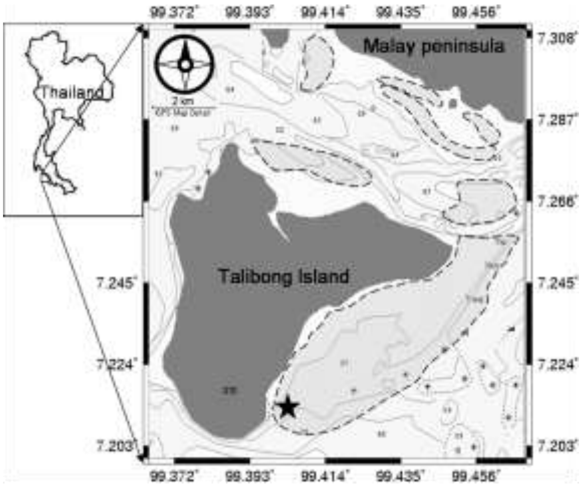

Fig. 2 A map of the study site around the southern part of Talibong Island, Trang, Thailand. AUSOMS-D, represented by the star, was deployed on the sea floor at depths of about 5 m. Visual observation platform on top of a mountain, represented by the triangle, was about 1 km apart from the acoustic array. Shaded areas outlined by break lines indicate seagrass distribution, surveyed by Nakanishi et al. (2005). Most of the dugongs were sighted in/around the seagrass beds (Nakanishi et al., 2005; Hines et al., 2005).

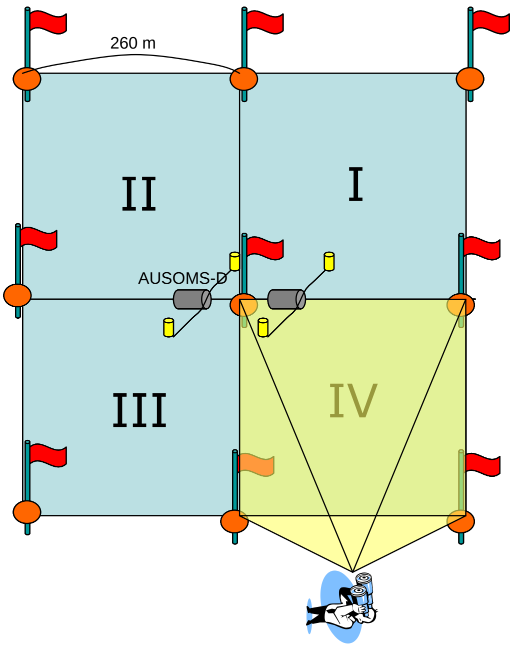

Fig. 3 An illustration of visual observation from the top of a mountain. The monitoring area was divided into 4 quadrants. Each of the 4 observers was assigned to observe one of the quadrants.

Acoustical localization

A total of 4 sets of AUSOMS-Ds were used for the acoustical array. A couple of AUSOMS-Ds were deployed as an acoustical localization unit, then two units were set at two different positions. Sound source directions were calculated from arrival-time difference at each unit and then converted into deflection angle (θ_1 and θ_2) in a plane with the coordinate system, where one of the units, base unit, is set at the origin. The position of the sound source was localized by working through simultaneous equation (Fig. 4, Eq. 2)

$$L1: y = \tan(\theta_1) * x$$
$$L2: y = \tan(\theta_2) * x + q2 \qquad \text{Eq. 2.}$$

where q_2 is y coordinate relative to the base unit. Therefore the position of the sound source (x, y) was calculated as Eq. 3.

$$x = q2 / (\tan(\theta_1) - \tan(\theta_2))$$
$$y = \tan(\theta_1) * q_2 / (\tan(\theta_1) - \tan(\theta_2)) \qquad \text{Eq. 3.}$$

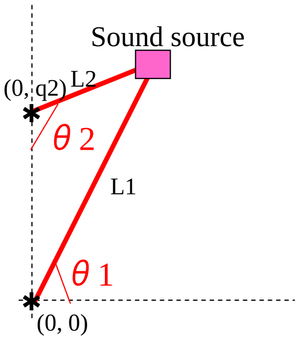

Fig. 4 Concept of acoustical source localization. The asterisks represent the positions of the localization units and the square represents the sound source.

RESULTS

The observation was performed for 1245 hours in total. Sea state and weather conditions were calm and fine throughout the survey. A total of 10 dugongs were "Acoustically detected" and 7 were "Acoustically localized", out of 36 dugongs sighted by the observation. The DRac and DRloc were calculated to be 28.8 and 19.4 %, respectively. Additionally, 70 % of the acoustical detections were localized correctly (table 1).

The numbers of both visual and acoustical detections increased in the spring tide era with the maximum detections by the visual (n = 12) and acoustical (n = 65) observations on the ninth day (Fig. 5).

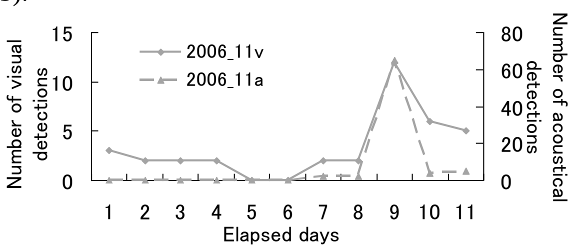

Fig. 5. Time-series change in the numbers of detections by both visual and acoustical observation. The solid line represents the visual detections and the dash line represents the acoustical detections.

Table 1. Results of the visual observation

	No. of sightings	Acoustically detected (localized)	Dugong positions in quadrants	Sea state	Weather	Observation duration (min)
Nov. 11	3	0	I, III	1	Fine	145
Nov. 12	2	0	I+, IV+	1	Cloudy	150
Nov. 13	2	0	I+, III	1	Cloudy	150
Nov. 14	2	0	III, IV	1	Cloudy	150
Nov. 15 (*)	-	-	-	-	-	-
Nov. 16 (*)	-	-	-	-	-	-
Nov. 17	2	1 (1)	I, IV	1-2	Cloudy	100
Nov. 18	2	0 (0)	II, IV	1	Cloudy	160
Nov. 19	12	5 (4)	I, II+, III, IV	0-1	Fine	140
Nov. 20	6	1 (1)	II, III, IV, IV+	1	Cloudy	150
Nov. 21	5	3 (1)	II, II+, III, IV	1	Fine	100
Total	36	10 (7)	-	-	-	1245

* No observation due to the system maintenance

CONCLUSION AND DISCUSSION

The *DRac* showed that almost 30% of the dugongs in the monitored area were acoustically detected. It was in the neap tide era before the system maintenance and spring tide era after the maintenance. The DRac will increase to be 37.0 % when calculated for only the spring tide era. In any case, the detections rates were relatively low compared to other marine mammals, such as finless porpoise (56 %; Kimura et al., submitted). Difference in the function or the use of the acoustical signals may have been the reason for the low detection rate of the dugongs. Finless porpoise use their acoustical signals very often to explore their surroundings (Akamatsu et al., 2005), whereas the dugongs vocalize occasionally (Ichikawa et al., 2006; Hishimoto et al., 2005). The next logical step for better application of the passive acoustical observation should include interpreting the function of the dugong vocalizations.

Dugong mating behavior was observed in almost the same time of the year around Talibong Island (Kanjana et al., 2007). Ovarian cycle of a female dugong was determined to be about 53 days throughout the year based on intervals of urinary progesterone measurements (Wakai et al., 2002).

Therefore, the dugong mating behavior may be observed all year round. Relationships between the mating behavior and the vocalization rate of the dugongs have not been documented yet. The future studies should consider the effect of the mating behavior on the vocalization of the dugongs.

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REFERENCES
Adulyanukosol, K., Thongsukdee, S., Hara, T., Arai, N. & Tsuchiya, M. (2007) Observations of dugong reproductive behavior in Trang Province, Thailand: further evidence of intraspecific variation in dugong behavior, *Mar Biol*, Vol. **151**, No. 5, pp. 1887-1891.

Akamatsu, T., Wang, D., Wang, K., Naito, Y., Biosonar behaviour of free-ranging porpoises, (2005) *Proc. R. Soc. Lond. B.* Volume **272**, Number 1565. pp. 797-801.

Anderson, P. K. and Barclay, R. M. R., (1995). Acoustic signals of solitary dugongs: Physical Characteristics and Behavioral Correlates. *Journal of Mammalogy* **76** (4), pp. 1226-1237.

Chilvers, B. L., Delean, S., Gales, N. J., Holley, D. K., Lawler, I. R., Marsh, H., Preen, A. R., (2004) Diving behavior of dugongs, Dugong dugon. *J. Exp. Mar. Biol. Ecol.* **304**, pp. 203-224.

Hines, E. M., Adulyanukosol, K. and Duffus, D. A.: Dugong (*Dugong dugon*) abundance along the Andaman Coast of Thailand. (2005) *Marine Mammal Science*, **21**, pp. 536-549.

Hishimoto, Y., Ichikawa, K., Akamatsu, T., Arai, N (2005) The acoustical characteristics of dugong calls and the behavioral correlation observed in Toba aquarium *Proceedings of the 6th SEASTAR 2000 Workshop*, pp. 25-28.

Ichikawa, K., Akamatsu, T., Shinke, T., Arai, N., Hara, T., and Adulyanukosol K., (2003). Acoustical analyses on the calls of dugong. *Proceedings of the 4th SEASTAR 2000 Workshop*, pp. 72-76.

Ichikawa, K., Tsutsumi, C., Akamatsu, T., Shinke, T., Arai, N., Hara, T., and Adulynukosol K. (2004). Acoustic detection of dugong using automatic underwater sound monitoring systems: AUSOMS-D, *Proceedings of the 5th SEASTAR2000 Workshop*, 83-86.

Ichikawa, K., Tsutsumi, C., Arai, N.,Akamatsu, T., Shinke, T., Hara, T., and Adulyanukosol, K. (2006) Dugong (*Dugong dugon*) vocalization patterns recorded by automatic underwater sound monitoring systems, *J. Acoust. Soc. Am.,* Vol. **119**, No.6, pp. 3726-3733.

Kimura, S., Akamatsu, T., Wang, K., Wang, D., Li, S., Dong, S. and Arai, N. (under review) "Comparison of stationary acoustic monitoring and visual observation of finless porpoises.", *J. Acoust. Soc. Am*.

Marsh, H., Eros, C., Penrose, H., Hugues, J., (2002) Dugong Status Report and Action Plans for Countries and Territories. UNEP Early Warning and Assessment Report Series 1. pp. 162.

Marsh, H., A. V. Spain, and G. E. Heinsohn, (1978) Minireview: Physiology of the dugong. *Comparative Biochemistry and Physiology* **61**, pp. 159-168.

Nakanishi, Y., Hosoya, S., Nakanishi, Y., Arai, N. and Adulyanukosol, K.: The distribution of dugong trenches in the seagrass beds of Libong Island, Thailand. (in Japanese, 2005) *Journal of Advanced Marine Science and Technology Society*, **11**, pp. 53-57.

Wakai, Y., Hasegawa, K., Sakamoto, S., Asano S., Watanabe G. & Taya K (2002). Annual changes of urinary progesterone and estradiol-17β of the dugong (*Dugong dugon*) in captivity, Zoological science, Vol. 19, No. 6, pp. 679-682.