Acoustical analyses on the calls of dugong

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ABSTRACT

Dugong, *Dugong dugon*, has become one of highly endangered species in the world. It is said that the decrease in the number of dugong population is mainly due to accidental catches by fishnets. A breakthrough to avoid the accidental catches, by-catches, is in urgent need. In this study, we described the technique to detect the direction of vocalizing dugong and the acoustical characteristics of dugong calls. This study can lead to a new observation method of wild animals. A number of dugong calls were recorded around Libong Island, Trang, Thailand, using two sets of dual channel stereo hydrophones on two research vessels. The center frequency of dugong calls ranged from 3-8 kHz, and the duration of the calls was classified roughly in two: 100-500 ms and over around 1000 ms. Vocalization intervals were classified in two patterns: 0 - 5 s and about over 20 s between each call. We applied the phase difference analysis to dugong calls recorded by a stereo hydrophone. The preliminary results suggested that the acoustical analyses on the dugong calls will be a powerful method to locate the vocalizing dugongs without any impact on them at all.

KEYWORDS: **passive acoustical observation, acoustical characteristics, vocalization interval, direction analysis, arrival direction, arrival phase difference, sound pressure level**

INTRODUCTION

Dugong, *Dugong dugon*, is one of the endangered species. They live in warm and shallow seawaters distributing throughout the world. The northern limit of their habitat is around the main island of Okinawa, Japan. The population of dugong in Okinawa, however, is said to be less than 50 (The mammalogical society of Japan), which is very small compared to other dugong habitats in many parts of the world. The decrease in the number of dugong population is mainly due to accidental catches by fish-nets and a death of an individual can cause a significant damage to the population. It is also of great interest to the fishermen in Okinawa, the area where the most sightings of dugong have been reported overlaps the main fishing area, which is off the north-east coast of the main island of Okinawa. Dugong protection and fishing restriction are the two conflicting matters to be solved. A powerful breakthrough to prevent dugong from these by-catches is in urgent need.

To protect the dugong population, we need to know their behavioral ecology such as moving paths and the usage of seagrass beds in the proposed area. The ecology of dugong, however, is not well-known, yet. Recently, passive biotelemetry techniques using underwater acoustics to locate or to observe presence of vocalizing marine mammals have been developed rapidly. Passive acoustic observation has been applied extensively for non-observable animals such as manatees (Phillips et al., 2004). In the manatee case, collision with boats has been a major cause of its deaths. To avoid the collisions, manatee calls are automatically detected out of the background noise in order to warn boaters of presence of manatee. We applied this technique to study the behavioral ecology of dugong. The passive acoustic observation uses arrival time difference at separated hydrophones to calculate arrival direction of a call. Its' main advantage is that it has no effect on behavior of the animal of study and it can be used to monitor vocal behavior of several individuals at once. To perform an effective monitoring, the animal of study must vocalize frequently and their calls must be easily separated from the background noise.

In this study, detection of arrival direction and acoustic characteristics of dugong call are described. These aspects are necessary in designing a new monitoring device to identify each individual and to warn fishermen of presence of dugong. This study will lead to an innovative monitoring method for dugong.

MATERIALS AND METHODS

Study site

For our survey, behavioral records and vocalization data are indispensable. Because the population of dugong in Okinawa is too small to perform a successive survey, we set our study site around Libong Island, Trang, Thailand (longitude N07°12'58.4" latitude E99°24'21.9"), where many sightings of dugong were reported beforehand. We set 5 study areas (#0 - #4) around the Libong Island (Fig. 1). The survey was conducted from 3rd of March to 6th of March. On the first day (3rd, March), recording was performed around #0, #1, and #2. But the background noise including pulse sounds was very loud and neither sightings of dugong nor the dugong vocalization was observed. On the second day (4th), we moved to the southern part of the Island (#3 and #4), where many sightings of dugong were reported during the proceeding survey that was conducted from 23rd to 29th of January, 2003. The background noise at station #3 was also too loud to record dugong call. Station #4 best suited the survey condition in the matter of recording and the number of dugongs sighted. So, for the rest of the survey (5th and 6th), the recordings were conducted in station #4.

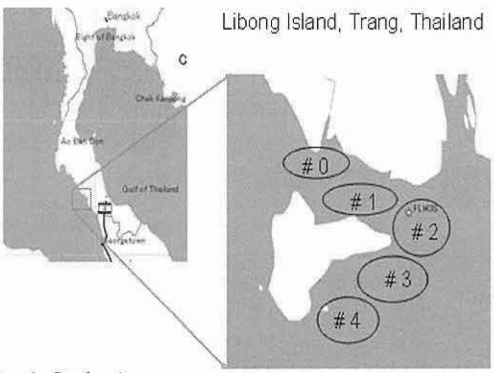
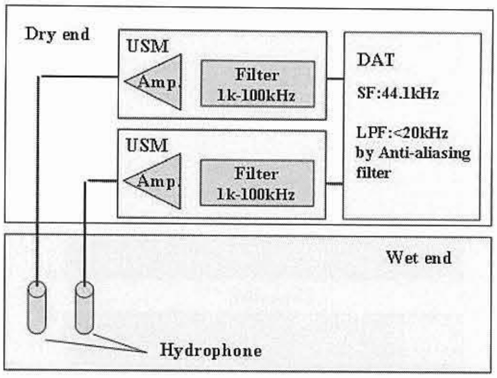


Fig. 1. Study site.

Equipments

Each of the two research vessels (vessel - A, B) were equipped with a set of two dual channel stereo-hydrophones (OKI ST1020), an amplifier (OKI SW1020), a digital audio tape recorder (SONY TCD-D8), GPS (Garmin GPS III), an echo sounder (HONDEX HE-5620), a compass and a distance meter. The array distances of the hydrophones were 5.2m (vessel - A) and 7.0m (vessel-B). (See Fig. 2 for the block diagram of the devices.)



* USM : Under water sound level meter

Fig. 2. Block diagram of the recording system.

Aerial survey

An aerial survey was performed simultaneously to support the visual observation from the research vessels. It is one of the most effective methods to observe the presence of marine mammals. Micro Lite flew at right angles to the shore repeatedly to perform an aerial survey at the same time as the recording of the underwater sound. The pilot of Micro Lite sat in front and the passenger in the back. Since the pilot had a good look out ahead and sideways, the pilot watched the front and the sides, and the passenger watched the both sides. When the observers on the Micro Lite found dugongs, the number of dugongs and their behavior were reported to the recording vessels using mobile phones. Micro Lite flew twice a day, in the morning and the afternoon. The flight duration varied depending on the number of the animals they found.

Recording

Recordings of underwater sound were started soon after the vessels reached the study site, using the DAT recorder, TCD-D8, with sampling rate of 44.1 kHz. The hydrophones were set at 1 m deep. The recording range was 120 dB, and 1 kHz high pass filter was applied. The vessels were anchored to keep the distance between each vessel in 100-300 m. The distance between the research vessels was measured with a distance meter. The direction from vessel - A to vessel - B was measured with a compass. When the observers in the vessels found dugongs, the distance and the direction to dugongs were measured. At the same time, the heading directions of the research vessels were recorded using a compass.

Wave pattern analyses

Wave pattern analyses were done using Cool Edit Pro 2 (CEP2 for short) and Ishmael 1.0 (ISH for short). CEP2 shows the sonar grams of dugong call, in which the horizontal axis is time and the vertical axis is frequency (Fig. 3). Center frequency, duration, and sound pressure level of a call were calculated using CEP2.

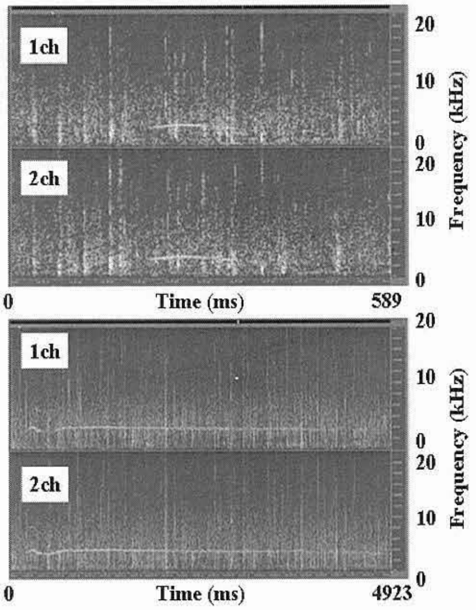
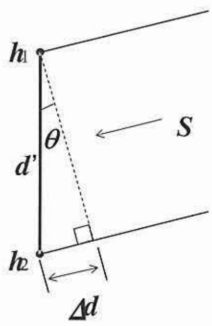


Fig. 3. Sonar grams of dugong call, which is shown in horizontal white lines. A typical example of short duration call with duration and frequency approximately of 1.9 s and 3.6 kHz respectively (upper) and long duration call with approximately of 4.6 s and 3.8 kHz (lower).

Then, phase difference between the two hydrophones in each vessel was calculated by cross-correlation using ISH to have the corresponding time difference. The arrival direction of a call at each vessel is calculated using trigonometric function as follows, where the two hydrophones are h1 and h2, and d' is distance between the hydrophones and $\Delta\tau$ is the arrival time difference and C is the underwater sound speed (1500 m/s). The calculation is done under assumption that the call is coming from S and the source of the sound is far enough to treat the sound wave as a plane wave (Fig. 4). There is one ambiguity in this calculation. It should be noted that the S can be on the other side of the hydrophone array, for the arrival direction θ would be exactly the same value in the case.



$$\sin\theta = \frac{\Delta d}{d'}$$

$$\Delta d = \Delta\tau \times C$$

Fig. 4. Geometry of calculating arrival direction θ.

RESULTS

Total of 1175 audible calls were recorded through the survey. There's a risk that CEP2 and ISH fail to distinguish between dugong calls and short pulse sounds from the background noise. To avoid this confusion, only the calls with frequency of over 1 kHz and duration of over 50 ms were selected for the analyses. The reason for the threshold is that a 1 kHz high pass filter was applied to the original recordings and the duration of typical pulse sounds was around 40 ms. The number of the calls became 774 after the selection. No available data was obtained from the recordings on 3rd of March.

Acoustical characteristics of dugong call

Figure 5 and Table 1 show the acoustical characteristics of dugong call. The calls of dugong were categorized roughly in two in the matter of duration. One was a short call with duration of 100-500 ms and the other was a long call with over around 1000 ms. The center frequency of dugong calls ranged from 3 to 6 kHz. Only in the short calls, 8 kHz calls were observed.

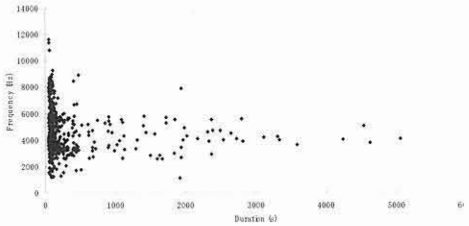


Fig. 5. Duration vs frequency of dugong call.

Table 1. Acoustical characteristics of dugong call

Duration	100-500ms	1000ms-
Number	704	74
Average of duration	126	1737
S.D of duration	87	1049
Average of frequency	4521	4152
S.D. of frequency	1615	1111

Figure 6 shows the distribution of vocalization intervals. Horizontal axis is time between each call in seconds. Vertical axis is number of call. Dugongs were most likely to vocalize once in 0 - 5 seconds.

Figure 7 shows the vocalization intervals on 4th and 5th of March. Horizontal axis is elapsed time from the start of recording. Vertical axis is accumulated number of vocalization. The steep parts of the slope mean that dugongs were vocalizing frequently. The steep parts on the 4th (2.0 s between each call) and the 5th (1.69 s, 1.74 s, 1.93 s, 1.71 s chronologically) of March had very similar slope. On the other hand, the value of the moderate parts ranged widely from 7 to 180 seconds between each call. Dugong had started vocalize very frequently at some points. It has been made clear that dugong had two patterns in vocalization interval

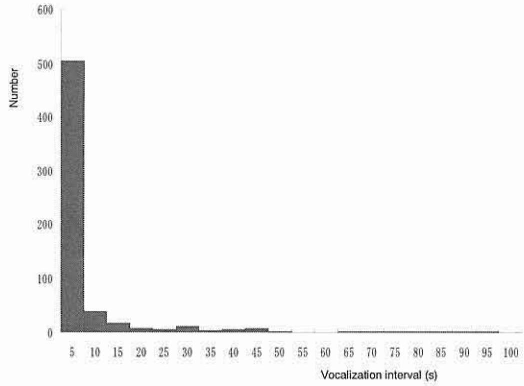


Fig. 6. Distribution of vocalization interval.

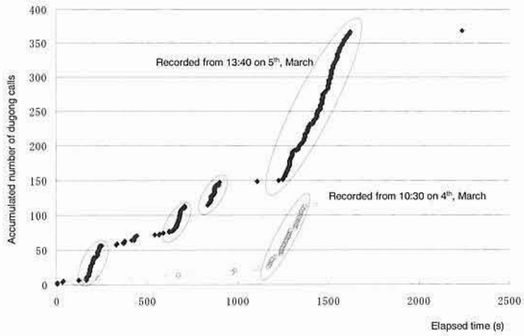


Fig. 7. Vocalization interval on 4th and 5th, March. ○,◆ corresponds to the data recorded from 10:30 on 4th, 13:40 on 5th respectively.

Actually, according to both the visual observations from Micro Lite and from our research vessels and to overlapping calls in the sonar gram, there had been more than one dugong near the ships on 4th and 5th of March (Fig. 8).

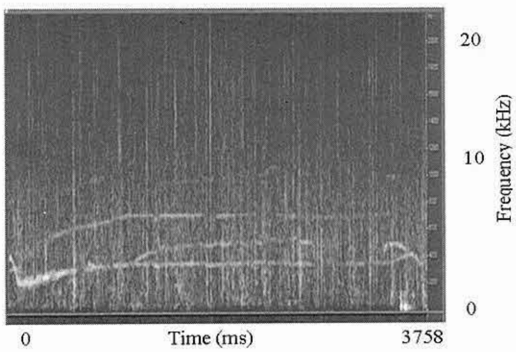


Fig.8. Overlapping calls. A long duration calls overlaps the first call in the middle. In the last moment, a short duration call overlaps the long calls.

Direction analyses

For the direction analyses, vocalization data recorded from 12:25 on the 6th of March were used. On 6th, there had been apparently only one individual nearby our research vessels according to the visual observations and no overlapping calls.

Figure 9 shows the change in the arrival direction and the sound pressure level at vessel-A. Horizontal axis is elapsed time from the start of the recording. Vertical axis is sound pressure level (dB) and arrival direction (degree), which are shown in the upper and lower graphs, respectively. The arrival direction of the dugong call is changing moderately as time goes by. The sound pressure level increased accordingly to the change in the arrival direction.

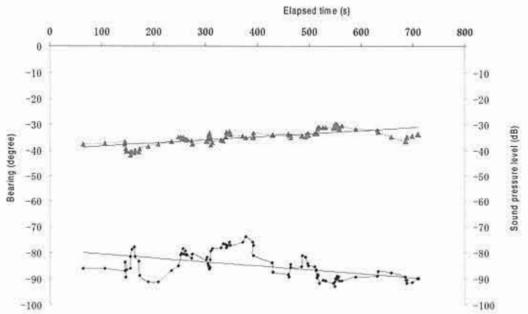


Fig. 9. Change in the sound pressure level (upper) and the arrival direction (lower).

Figure 10 shows the vocalization interval (upper) and the sound pressure level (lower). The frequency of vocalization is low at first, and is high for the next 2000 s and is low again at last. This alternation in the vocalization rate is due to the detectability of the recording devices. The farther the distance between dugong and the vessel, the less audible vocalizations are recorded. These preliminary results suggest that a dugong was coming closer at a steady angle to the research vessel.

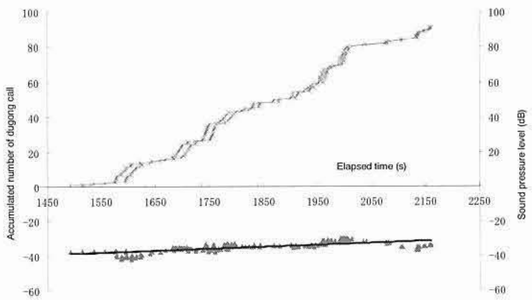


Fig. 10. Vocalization interval (upper) and the sound pressure level (lower).

DISCUSSION

The acoustical characteristics of dugong calls were described.

Vocalization interval

The values of short intervals showed very similar range: 0-5 s between each call. Periods of long interval, or almost non-vocalizing were also observed. There were sudden changes in the vocalization frequency on 4th and 5th of March, when a number of dugongs were observed near the research vessels. It was suggested that dugong had started to vocalize frequently on a certain occasion. Subjectively speaking, the occasion might have been an encounter with another individual. These preliminary results made the authors to think that dugong appear to be exchanging their calls with each other.

Duration and frequency of calls

Short calls lasted for 100-500ms and long calls were over around 1000ms. Frequency band was very narrow, ranging 3 to 6 kHz, and about 8 kHz just in the short calls. High frequency modulated call can easily be masked in the background noise. The length of the calls may be decided according to the distance between the vocalizing individual and the others. If the distance between individuals is far, short and successive calls are easier for the receiver individual to recognize the calls. In close distance to each other, the long calls may be vocalized.

Direction analyses

Movement of a dugong was described with the change in the arrival distance at vessel-A. With the results of the direction analyses from more than one research points, some intersection points of the directions for each call can be obtained, which can be supposed as a position of a dugong. Using a number of hydrophones eliminates the ambiguity that has been mentioned before.

The basic concept of the positioning of a vocalizing dugong is shown in figure 11, where the dugong calls are to be recorded by the sets of dual-channel hydrophones at each of A (0, d) and B (0, 0), and d is a distance between A and B. θ_1 and θ_2 are the arrival directions of a call at site A and B, and the position of the sound source is S (x, y).

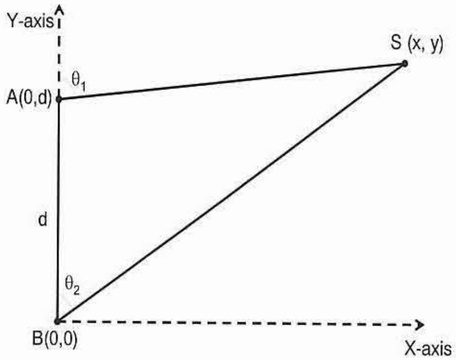


Fig. 11. Geometry of dugong positioning using trigonometry.

The unknown position S is estimated using trigonometric function as shown in Eq. (1.a), (1.b), (2.a) and (2.b).

$$\tan\theta_1 = \frac{x}{y-d} \qquad (1.a)$$

$$\tan\theta_2 = \frac{x}{y} \qquad (1.b)$$

These simultaneous equations are solved and then tan θ is converted to result in Eq. (2.a) and (2.b).

$$x = \frac{\sin\theta_1 \cos\theta_2}{\sin(\theta_1 - \theta_2)} d \qquad (2.a)$$

$$y = \frac{\sin\theta_1 \sin\theta_2}{\sin(\theta_1 - \theta_2)} d \qquad (2.b)$$

Once the positions of vocalizing dugongs are obtained, by plotting the located positions in chronological order, the swimming path of dugong would be described. If the moving path is described, we would be able to study the behavior of dugong that is directly related to their vocal activity. This innovative tracking technique is completely new in monitoring dugong and does not affect the behavior of dugong at all. It is, then, possible to warn the fishermen of the presence of dugong before the animal is accidentally caught in the fishing net, and to rescue the dugong before drowning. The authors believe that the proposed technique contributes greatly as a first step to achieve peaceful coexistence of dugong protection and coastal fishing.

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