Pattern analyses of the vocal structure of dugong calls

NAOKO OKUMURA[1], KOTARO ICHIKAWA[1], TOMONARU AKAMATSU[2], NOBUAKI ARAI[1], TOMIO SHINKE[3], TAKESHI HARA[4], and KANJANA ADULYANUKOSOL[5]
[1]*Graduate School of Informatics, Kyoto University, 606-8501 Kyoto, Japan*
Email: naoko@bre.soc.i.kyoto-u.ac.jp
[2]*National Research Institute of Fisheries Engineering, 314-0421 Ibaraki, Japan*
[3]*System Intech Co.,Ltd. R&D Center, 108-0023 Shizuoka, Japan*
[4]*Japan Fisheries Resource Conservation Association, 104-0054 Tokyo, Japan*
[5]*Phuket Marine Biological Center, 83000 Phuket, Thailand*

ABSTRACT
Dugongs (*Dugong dugon*) produce different types of vocalization such as chirps, trills, and barks. Previous reports showed that dugongs have two kinds of phonemes: long duration calls (trills) and short duration calls (chirp-squeaks hereinafter called chirps). However, the function of these calls was not revealed. The objective of this study is to classify the vocalization patterns of dugong calls and discuss the functional use of call sequences among a local population of dugongs. We recorded the underwater sound for 120 continuous hours by an automatic underwater sound recording system conducted in the southern part of Talibong Island,Trang,Thailand. We analyzed the underwater sound data sets that were obtained by the system. Call durations differ among local populations. Short duration calls with less than 300 ms were defined as chirps and trills were defined as a call lasting over 300 ms. The end of a call sequence was defined as a silence over 1 second. A total of 1559 audible calls were detected from a total of 15 hours data set (from 3:50 to 6:50 29 February 01-04 March 2004). Chirps were observed more than trill calls (1470 chirps and 89 trills). Chirp-to-chirp transitions were most frequency observed (83.70%), whereas trill-to-trill transitions were the least (3.97%). Transitions between the two types of calls were also observed (6.80%, 5.53%). The stability of the sequence of each type of calls in a call sequence is investigated. The call sequence analysis as well as the behavioral context observation will provide the key to interpret the function of dugong calls.

KEYWORDS: *Dugong dugon*, AUSOMS-D, chirp, trill, call sequence, state transition probability

INTRODUCTION

The Dugong (*Dugong dugon*) is a herbivorous sea mammal that lives in tropical or subtropical shallow waters in the Indian and the Pacific Oceans (Marsh *et al.*, 2002). Their vocalization resembles bird's calls (Ichikawa *et al*, 2004). Figure 1 shows a sonogram of dugong calls. There are 4 calls in Fig. 1.

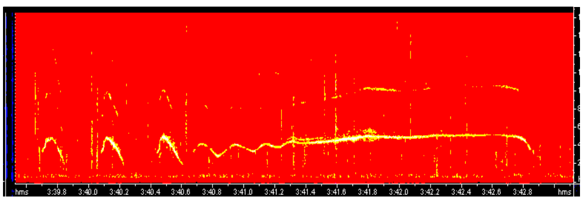


Fig.1 dugong calls

Dugong are listed as vulnerable to extinction in World Conservation Union (IUCN) red list. However, it has been difficult to protect them because their behavioral information was too limited. To try to find a common interest with the dugong, it is therefore important that we achieve information about how the dugongs live. Generally, animal calls are used for communication between individuals. For example, humpback whale calls are cyclic and in class structure (Yamada *et al.* 2003). Common finch has several types of phonemes. They sing songs that are composed of some phonemes. Their songs are used when they court, defend their territory, and so on (Okanoya. 1999).

Dugong calls were classified into 3 groups: chirps, trills, and barks by Anderson and Barclay (1995). In the previous study, 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.

Vocalization patterns have important meanings within the behavioral context of the animal. For example, songs of humpback whales are said to play unique roles in their reproductive strategy. However there had been no study on the dugong vocalization pattern.

OBJECTIVES

The objectives of this study are to decompose the vocalizations of dugongs and to classify the vocalization pattern. As in the case of common finches and whales, the dugong may use their calls as a means of their communication. Study on the acoustic characteristics and the function of the dugong vocalization probably will contribute to gather information about the dugong behavior.

MATERIALS AND METHODS

Data acquisition from wild dugongs

The underwater sound data was recorded by an Automatic Underwater SOund Monitoring Systems for Dugong (AUSOMS-D, Fig. 2) in the southern part of Talibong Island, Trang, Thailand. AUSOMS-D is a stereophonic recording device that consists of a set of hydrophones which are set 2 m apart from each other and a pressure tight chassis. The dugong calls were recorded with CD quality. The AUSOMS-D records the underwater sound with a set of stereo hydrophones at 44.1 kHz sampling rate for over 110 hours (Ichikawa *et al.* 2004-b).

Fig. 2 AUSOMS-D

The recording took place from 29th February, to 4th March 2004. We analyzed 15 hours of recorded dugong calls.

Data acquisition from a captive dugong

In order to compare wild dugong calls with captive dugong calls, we analyzed calls of a captive individual in Toba aquarium in Japan. The target animal was a male dugong, Junichi. The animal was captured in the Philippines in 1978. Measured in 1999, his body size was 257 cm and his weight was 308 kg. The tank was connected with the tank of a female dugong (Serena) by the holding pool, but they couldn't swim through. The tank volume is about 200t (10.0m × 5.9m × 3.4m). A hydrophone was set at a corner of the tank. The recording was conducted from 18th to 19th of December, 2003, and from 9th to 10th of December, 2004. Each of our experiments was performed for 31 continuous hours, from 9 a.m. to 4 p.m. the next day.

Definition of "call sequence"

The previous study on acoustic characteristics of the dugong was made in Australia. Dugong calls in Thailand are different from those in Australia. We classified the calls into two groups: chirps and trills. Dugong calls with high frequency components had a duration of less than 300 ms (Fig. 3). We defined "Chirps" as "the phonemes with a duration of less than 300ms". "Trills" have a duration of more than 300ms. We didn't define "barks", because we had not heard one before with the dugong population in Thailand. Besides, we applied 1 kHz high pass filter to cut off any low frequency noise. Barks are described to be vocalized at low frequency. It is therefore out of the recording range of AOUSOMS-D. The most frequent inter-call interval of dugong vocalizations was less than 1 second (Fig. 4). In this study, we defined "a call sequence" as "a group of phonemes that has an interval less than 1 second". For example, there are 3 chirps and 1 trill in Figure. 1. And if all intervals of these phonemes are less than 1 second, they are included in the same call sequence.

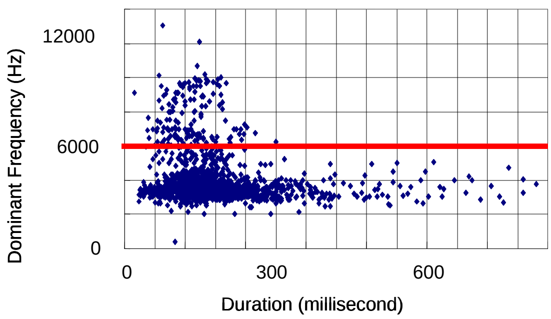
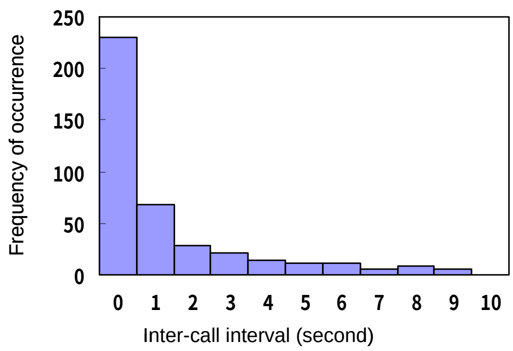


Fig. 3 Frequency and duration of dugong calls

Fig. 4 The histogram of inter-call intervals of the dugong vocalizations.



Phonetic structure of call sequences

We investigated a structured array of call sequences. We calculated the position of trill's in a call sequence (Eq.1). Each phoneme was assigned to a phoneme number in a sequence. Then we calculated the position of trills by dividing the phoneme number by total phoneme counts in a sequence.

P: position of trill
N: phoneme number of trill's
C: total counts of phoneme in a sequence

Position of trill = N / C **Eq.1.**

For example, this case, trill's phoneme number is 0.6 and 1.0 (Fig. 5).

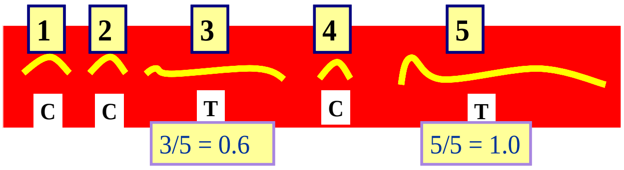


Fig.5 Trill's position in a sequence

RESULTS

Dugong calls were collected from 3 a.m. to 6 a.m. each day. We observed 1559 phonemes in total: 1470 chirps and 89 trills. We observed 255 call sequences. The number of phonemes in a sequence was 5.96 ± 5.59 (SD). We observed 169 sequences that consisted of only chirps and 11 sequences that consisted of only trills. We also observed 75 sequences that include chirps and trills. We investigated the transition of phonemes in call sequences. We calculated the state transition probability of call sequences.

The number of chirp-to-chirp transitions is shown in the upper left box. The number of chirp-to-trill transitions is in the upper right box. In the lower left box, trill-to-chirp transition. In lower right box, trill-to-trill transition. The number written in the parenthesis is the percentage of transitions. Chirp-to -chirp transition was the most frequent.

	C	T
C	1058 (83.7%)	86 (6.80%)
T	70 (5.53%)	50 (3.97%)

Fig. 6 wild dugong's phoneme transition

We compared the vocalization transition with that of a captive individual, Junichi in Toba aquarium. We calculated Junichi's phoneme transition (Fig. 7). As observed in the case of the wild dugongs, the most frequent transition was the chirp-to-chirp transition.

	C	T
C	118 (50.4%)	52 (22.2%)
T	28 (12.0%)	36 (15.4%)

Fig. 7 Junichi's phoneme transition

Fig. 8 shows trills position in a sequence. The upper figure is a histogram of the trill's position of wild dugong calls (Fig. 8-a). The lower figure is the histogram of the trill's position of Junichi's calls (Fig. 8-b). Trills were found to appear in the middle and the end of a call sequence.

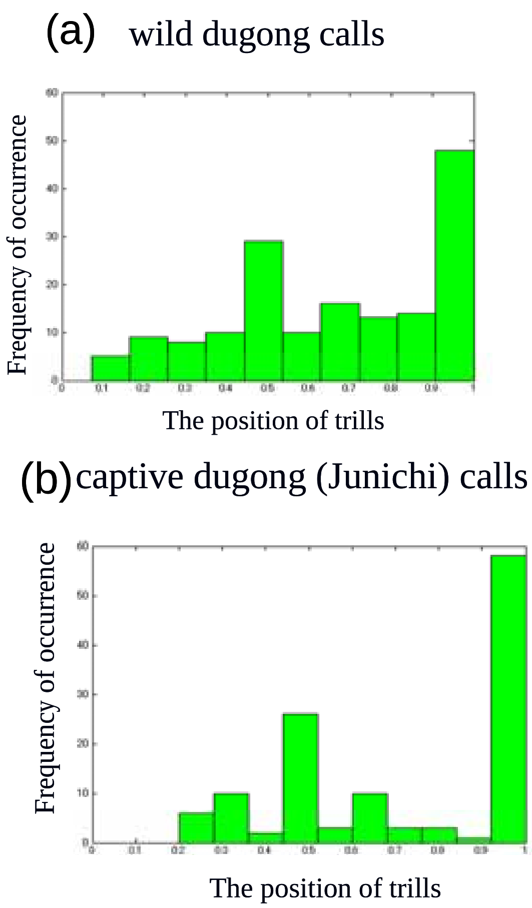


Fig. 8 Trill's position in a call sequence of wild dugongs (a) and that of a captive individual (b).

CONCLUSION

Vocalization patterns were compared between the Thailand originated (wild) and the Philippines originated (captive) dugong. The transition from chirp-to-chirp was the most frequent in both wild dugong data and captive dugong data. Transition of both wild dugong calls and captive dugong calls were similar. Trills often appear in the middle and the last part of a sequence.

Similarities between geographically and genetically separated areas imply converged vocalization patterns. The dugong call pattern should be collected and analyzed from a sea area other than Thailand and Philippines.

This time, we classified the dugong calls based on duration. Additional classification parameters that characterize dugong calls, for example, the highest frequency, the lowest frequency, and harmonics components should be studied carefully. Detailed classification of the dugong call would help to better understand the various uses of the vocalization in the context of acoustic communication.

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