TUMSAT-OACIS Repository - Tokyo

University of Marine Science and Technology

(東京海洋大学)

Individuality embedded in contact calls of beluga whales Delphinapterus leucas

メタデータ	言語: eng 出版者: 公開日: 2016-07-04 キーワード (Ja): キーワード (En): 作成者: 三島, 由夏 メールアドレス: 所属:
URL	https://oacis.repo.nii.ac.jp/records/1295

［課程博士・論文博士共通］

博士学位論文内容要旨
Abstract

専　攻 Major	応用環境システム学	氏　名 Name	三島　由夏
論文題目 Title	Individuality embedded in contact calls of beluga whales *Delphinapterus leucas* ベルーガのコンタクトコールに見られる個体性		

Individual identity advertisement and recognition are important for inter-individual social networks. Individual identification is found in the “contact calls” of several social animals, which are used for vocal exchange to maintain group cohesion. The degree of individuality is linked to social structure, and complex social interactions might favor strongly recognizable individual identity. Systematic studies of contact calls in odontocetes, or toothed whales, have focused on only three species—sperm whales, killer whales, and bottlenose dolphins. Sperm and killer whales have long-term, stable social structures and possess group-specific contact calls with less prominent individual differences; these are akin to voice features. However, bottlenose dolphins live in a fluid fission-fusion society, and more strongly recognizable individual identity has evolved in their contact calls, which are called signature whistles. The frequency contours of signature whistles carry identity information independent of voice cues. To elucidate the evolutionary processes and adaptive significance of all forms of acoustically embedded individuality, it is necessary to enhance our understanding of contact calls in other odontocete species.

Beluga whales are a circumpolar and annual migratory species; although little is known about beluga society, they appear to have a fluid social structure. Therefore, a high degree of individuality may exist in their contact calls. It was recently reported that they might use one type of broadband pulsed sound “PS1” for individually specific contact calls. The present study provides insight into the function of PS1 as a contact call and the individuality within PS1. Firstly, beluga vocalizations were recorded at two aquariums to investigate PS1 function and individuality. Next, playback experiments would be needed to elucidate whether belugas use PS1 for individual recognition and which acoustic parameter is the recognition cue. However, conventional underwater speakers cannot faithfully reproduce broadband pulse trains such as PS1 because they have transmitting sensitivity only below 20 kHz. Therefore, I developed a broadband underwater speaker and established a broadband transmitting system for effective PS1 playback.

Firstly, vocalizations were collected from five belugas kept at the Port of Nagoya Public Aquarium from September 2013 to May 2014. Each individual was isolated in a sub-pool to elicit contact calls from them. Vocalizations were classified into five broader categories, including PS1. Sound arrival time differences to two hydrophones were used to discriminate between PS1 calls from isolated and non-isolated belugas. Temporal and spectral parameters of the identified PS1 calls of isolated belugas were compared among individuals.

A total of 6,817 calls were recorded in 46 isolation events over 22 h and 40 min. PS1 was the predominant call type (38% in total) in the isolation context, which suggested that PS1 functioned as a contact call. Individual comparison of PS1 calls revealed that changes in inter-pulse intervals (IPIs) as a function of time, termed “IPI contours”, were consistent intra-individually and different inter-individually. A discriminant function analysis (DFA) based on five parameters classified PS1 calls into individuals with an overall correct classification rate of 80.5%, and the most informative parameter was an average IPI.

Next, to investigate whether the PS1 function and individuality suggested by one captive group were common features in beluga species, I recorded vocalizations from another captive group kept at Shimane Aquarium from October 2014 to March 2015. There were two pools, A and B, which contained three and four

belugas, respectively. Because the belugas could not be placed in an unexpected isolation context, the role of PS1 in group cohesion could not be directly confirmed. However, if the subjects used PS1 as a contact call, PS1 would be expected to be produced in affiliative contexts and used for vocal exchange. Thus, the affiliative function of PS1 was explored by assessing the relationship between PS1 bouts and aggressive/submissive behavior. The frequency distribution of inter-PS1 intervals was constructed to reveal whether PS1 was used for vocal exchange. Individual differences in PS1 calls were also investigated.

A total of 2,421 calls were collected in 12 sessions over 6 h in pool A, and a total of 3,260 calls were collected in 16 sessions over 8 h in pool B. PS1 calls accounted for 40% and 39% of the total calls in pool A and B, respectively. Most of the aggressive/submissive behavior occurred out of a PS1 bout, and it suggested that PS1 was produced in affiliative contexts. In both pools, most PS1 sequences by the same individuals occurred after 1 s, whereas half the PS1 sequences by different individuals occurred within 1 s. These results suggested that PS1 was used for vocal exchange and was approximately regulated by a 1-s response rule. Individual comparison of PS1 calls revealed that IPI contours were stereotyped within individuals and different between individuals. A DFA based on five parameters classified PS1 calls into individuals with an overall correct classification rate of 94.8%, and the most powerful discriminator was an average IPI.

These findings from two aquariums provided compelling evidence that PS1 functions as an affiliative contact call and contains individuality. Therefore, it is highly possible that IPI contours convey strongly recognizable individual identity information as seen in frequency contours of signature whistles.

A broadband transmitting system was established for PS1 playback experiments. The requirements of the system were that it should cover the frequency band from 1 to 170 kHz in which PS1 has consistent energy, and project sounds with at least 130–160 dB in source level (SL), which is the typical SL of PS1 in RMS value. Firstly, I created a broadband underwater speaker using two types of multilayer piezoelectric actuators. One has resonant frequency at 131 and 164 kHz. The other has resonances at 8 and 20 kHz. Seven high-frequency actuators and one low-frequency actuator were placed in the same acryl disk with a diameter of 110 mm and a thickness of 13 mm. Only high-frequency actuators were Langevin structured using another acryl disk for a rear mass. This structure was embedded in a vinyl chloride housing. The transmitting system was composed of the developed broadband speaker, a power amplifier (GTO 504, JBL Inc.), a data acquisition device (NI USB-6351, National Instruments Co.), and MATLAB software (2015).

This system had a flat sensitivity from 5 to 175 kHz with ±12 dB ripple. It was enhanced by cross-correlation between the transmitting signals and inverse characteristics of the transmitting system, and consequently, a flat frequency response from 7 to 175 kHz with ±5.5 dB ripple was obtained. Although it had low sensitivity below 7 kHz, it does not appear crucial as hearing sensitivity in belugas tends to drop sharply at frequencies lower than 8 kHz. The system could project signals at least 130–170 dB in SL and did not generate mechanical noise and waveform distortion. Thus, the system is useful for PS1 playback. However, an attempted playback experiment to investigate whether belugas discriminate PS1 calls of familiar and unfamiliar individuals failed to elicit clear vocal and behavioral responses, possibly due to the abnormal experimental situation; therefore, I need to redesign the playback protocol.

The present study provided compelling evidence of striking individuality in contact calls in belugas, and established a broadband transmitting system for broadband pulse trains. If future playback experiments determine that the IPI contours of PS1 serve as signatures, this will prove that belugas show similar individuality to that of bottlenose dolphins. However, bottlenose dolphins copy conspecific signatures and use them to address particular individuals, similarly to human names; I did not observe any apparent copying of individualized PS1 in belugas. Therefore, bottlenose dolphins may have a more sophisticated individual recognition system than belugas. Further investigation of beluga society and PS1 recognition would enhance our understanding of differences in individual recognition mechanisms of the two species.