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Rapid communication

Communication sounds of wild narrow-ridged finless porpoises (*Neophocaena asiaeorientalis*) in Ise Bay, Japan

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Abstract. Captive condition sometimes evokes behaviors that are not observed in animals in the wild. A confirmation of the behaviors in the wild is needed to exclude the possibility of captivity-specific behaviors. Narrow-ridged finless porpoises are reported to produce two sound types for communication: "packet sound", which is a series of pulses with repeated pulse packets (a sound series consisting of a few pulses with irregular, short inter-pulse intervals), and "burst pulses", which are a pulse train with significantly shorter inter-pulse intervals compared to packet sound. Burst pulses were reported from wild narrow-ridged finless porpoises of Seto Inland Sea–Hibiki Nada population in Japan, while the packet sound was only recorded in captive conditions. Here, we report the packet sound as well as burst pulses from wild narrow-ridged finless porpoises of Ise–Mikawa Bays population in Japan. We found six packet sounds and six burst pulses out of 5 h recording of a self-contained underwater sound recorder, at a frequency of 0.020 times/min for each sound type. It is suggested that packet sound is produced by not only captive but wild narrow-ridged finless porpoises. Future studies should focus on the behavioral state when producing communication sounds.

Key words: burst pulses, packet sound, pulsed signal.

Behavioral studies targeting captive animals sometimes reveal behaviors that have not been reported in the wild. This finding often occurs in studies of animals that are challenging to observe in the wild. Such studies can contribute to exploring the fundamental knowledge of these animals. However, animals in captivity sometimes display 'unusual' behaviors that their wild counterparts never exhibit (Birkett and Newton-Fisher 2011). We thus need to investigate whether the novel behaviors observed in captivity also occur in the wild.

This holds true for animal acoustic communication. Chimpanzees (*Pan troglodytes*) produced two sound types, raspberry, and extended grunt, only in captivity to attract human attention (Hopkins et al. 2007). Cetacean species with vocal learning abilities may readily produce captivity-specific sounds. Killer whales (*Orcinus orca*) in captivity mimic the bark sounds of California sea lions (*Zalophus californianus*) (Foote et al. 2006), which may not occur in the wild. "Thunks" are low-frequency pulsed sounds that are used by common bottlenose dolphin (*Tursiops truncatus*) mothers to solicit reunions with their calves (McCowan and Reiss 1995). Thunks were only recorded at the same captive facility; therefore, it is implied that this sound type is a learned signal specific to this group of dolphins (Ames et al. 2017). Thus, the discovery of novel sound types should be followed by the confirmation of the existence of those sound types in the wild.

Cetaceans living underwater rely on sound because it can propagate quickly and over long distances; therefore, most of them use various sounds for communication (Janik 2009). There are several types of communication sounds used by cetaceans. One type of communication sounds is the whistle: a continuous, narrowband, frequency-modulated sound. The whistle is used especially for the "contact call"; this is a communication sound for inter-individual cohesion, movement coordination, and identity advertisements (Kondo and Watanabe 2009). For

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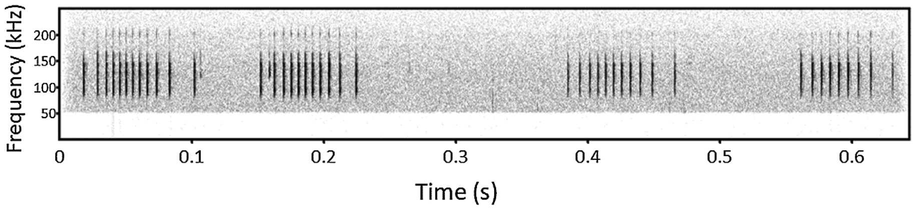

Fig. 1. Sound spectrogram for one packet sound produced by wild narrow-ridged finless porpoise.

example, common bottlenose dolphins produce individually stereotyped whistles, or "signature whistles" (Janik 2013; King and Janik 2013) as contact calls (Janik and Slater 1998). Another type of communication sounds is pulsed sounds: a series of short pulses, each lasting only tens to hundreds of microseconds (Lammers and Oswald 2015). Beluga whales (*Delphinapterus leucas*) produce pulsed sounds with individually stereotyped inter-pulse interval (IPI) patterns, or "creaking calls" (Mishima et al. 2018), which serve as contact calls (Morisaka et al. 2013). Burst pulses, which are discrete, isolated series of significantly short IPI that begin, persist, and generally end with an IPI of less than 10 ms (defined by Martin et al. 2018), are strongly linked to socializing behavior in Heaviside's dolphins (*Cephalorhynchus heavisidii*) and are considered communication sounds in this species (Martin et al. 2019).

Narrow-ridged finless porpoises (NRFPs) (*Neophocaena asiaeorientalis*) live in coastal areas that are shallower than 50 m (Kasuya 2017). NRFPs in Japan are genetically divided into five populations: Sendai Bay–Tokyo Bay, Ise–Mikawa Bays, Seto Inland Sea–Hibiki Nada, Omura Bay, and Ariake Sound–Tachibana Bay (Yoshida et al. 2001). NRFPs produce only pulsed sounds over 100 kHz that are mainly used for echolocation (Akamatsu et al. 1998; Li et al. 2005). A recent study reported that captive NRFPs originally from the Ise–Mikawa Bays population produced two sound types for communication: packet sound and burst pulses (Terada et al. 2022). The packet sound is a pulse sequence with repeated pulse packets, which are a series of a few pulses with irregular, short inter-pulse intervals (Fig. 1), and is primarily produced in isolation contexts, suggesting contact call function. A burst pulse is a pulse train with significantly shorter inter-pulse intervals than those in packet sound (Fig. 2) and is produced during affiliative sexual behaviors between individuals of different sexes (Terada et al. 2022). Ogawa and Kimura (2023) reported burst pulses in wild NRFPs of the Seto Inland Sea–Hibiki Nada population in the Seto Inland Sea, Japan. However, there have been no reports of packet sound from wild NRFPs; therefore, the existence of packet sound in the wild needs to be confirmed. Our goal in the present study was to investigate whether wild NRFPs produce packet sound and to report the characteristics of communication sounds recorded from wild NRFPs of the Ise–Mikawa Bays population in Ise Bay, Japan.

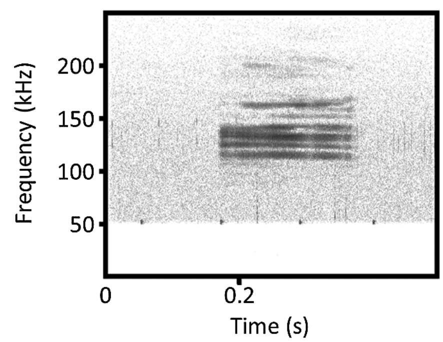

Fig. 2. Sound spectrogram for one burst pulse produced by wild narrow-ridged finless porpoise.

Materials and methods

Study area

This study was conducted in two coastal areas, Tsu City (Tsu Area) and Toba City (Toba Area) in Ise Bay, Japan (Fig. 3), where NRFPs of the Ise–Mikawa Bays population reside. The mean depth, water temperature, and salinity in Ise Bay during winter (mid-January to early February) and spring (the month of May) from 2006 to 2015 were 17 m, 8.8–18.7°C, and 27.2–31.4, respectively (Wang et al. 2019). Our research was conducted in coastal areas shallower than 20 m of water depth.

Data collection

Sound recordings were conducted from a boat belonging to the Fisheries Research Laboratory, Mie University (ZAGA2, 21 ft) in the Toba Area on March 1, 4, and 9 of 2022 and from a fishing boat (Taishomaru, 53 ft) in the Tsu Area on May 17, 18, and 22 of 2023 (Table 1). The

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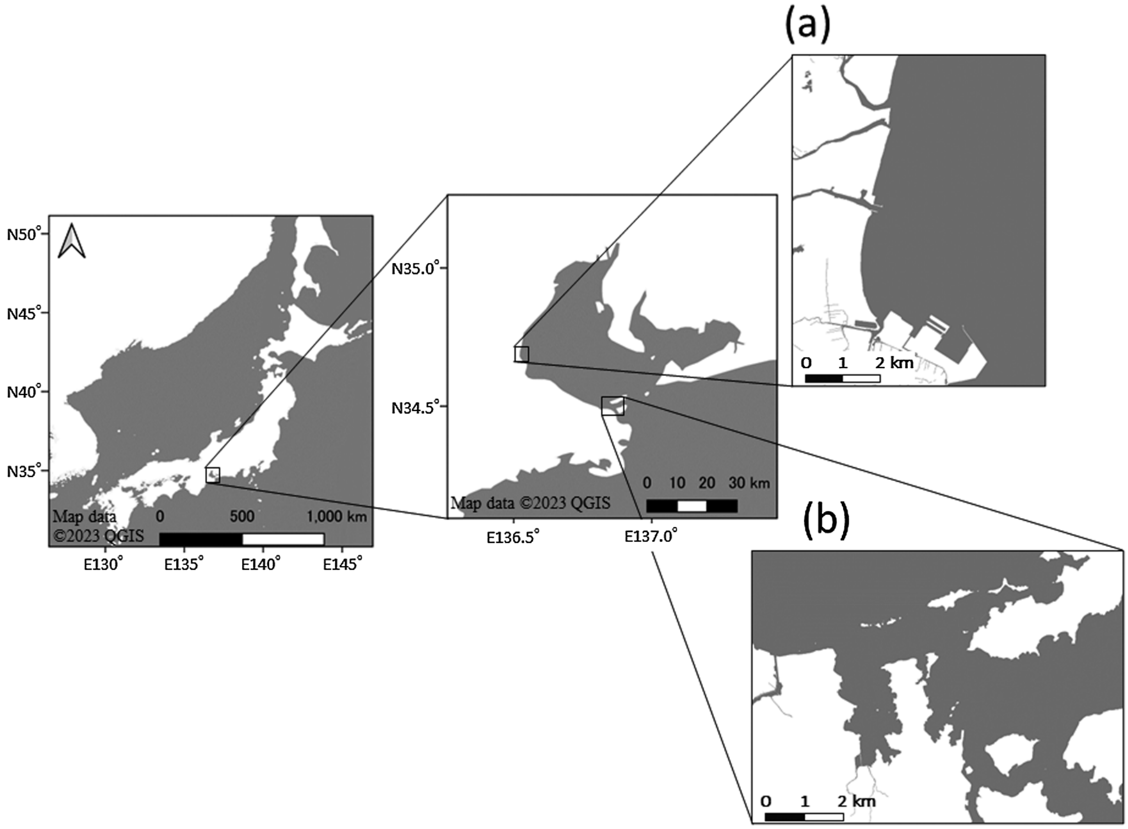

Fig. 3. Maps of the study area in Ise Bay, Japan. (a) Tsu Area; (b) Toba Area. These maps were generated by the open-source software QGIS (QGIS Development Team, http://www.qgis.org, Accessed December 5, 2022) and the Geospatial Information Authority of Japan (https://www.gsi.go.jp/ENGLISH/index.html, Accessed December 5, 2022).

data from March 1, 2022, were used elsewhere by Terada et al. (unpublished). The pulsed signals of the NRFPs were recorded using a self-contained underwater sound recorder (SoundTrap; ST300-HF; Ocean Instruments, Auckland, New Zealand). The parameters of this sound recorder were set as follows: sampling frequency, 576 kHz; high-pass filter, 600 Hz; clip levels, 172 dB re 1 μPa; and self-noise, 37 dB re 1 μPa (> 2 kHz), with 16-bit resolution. Once the NRFPs were visually located from the boat by 2–5 investigators, the boat stopped, and the sound recorder was then suspended vertically with a terminal weight (2 kg) approximately 3–5 m below the water surface for a continuous period of 15–60 minutes. After NRFPs left, we moved to locate other NRFPs.

Data analysis

We used Avisoft SASLab Pro version 5.2.13 (Avisoft Bioacoustics, Inc., Glienicke/Nordbahn, Germany) to generate sound spectrograms with a good signal-to-noise ratio using the fast Fourier transform (FFT) algorithm with an FFT length of 512 or 1024, frame size of 100 %, and the Hamming window function. All sounds below 50 kHz were filtered using a high-pass filter in the software; most sounds of NRFPs have peak frequencies over 100 kHz (Kamminga et al. 1996; Li et al. 2005). We visually looked for communication sounds or packet sound and burst pulses, referring to Terada et al. (2022), according to the graphical aspects of the sound spectrograms in the software. The sound level was adjusted to improve the visibility of sound spectrograms. The parameters of the communication sounds were extracted using the software. The recording duration of pulsed sounds, including sounds produced for echolocation, was defined as the time between the first and final pulsed sounds that have inter-pulse intervals [IPIs; Supplementary Fig. S1(a)] of less than one minute in one recording, excluding pulsed sounds with a low signal-to-noise ratio. The frequency of sound communication per minute was calculated as the total number of communication sounds divided by the summed recording duration of pulsed sounds in all recordings. The number of communication sounds was counted with reference to the definition of Terada et al.

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(2022); however, the definition of one communication sound was conservatively established in the present study because the previous study defined the cutoff time based on limited data. It was defined as one packet sound of the IPI within 160 ms (Terada et al. 2022); therefore, we conservatively defined it as one packet sound of the IPI within 200 ms. We measured six parameters within a single packet sound (Supplementary Fig. S1): IPI, number of pulses within a pulse packet, duration of a pulse packet, inter-pulse-packet interval, duration of a packet sound, and number of pulse packets within a packet sound. It was defined as one burst pulse of the IPI within 30 ms (Terada et al. 2022); therefore, we conservatively defined it as one burst pulse of the IPI within 50 ms. We measured three parameters within a single burst pulse: IPI, number of pulses, duration of a burst pulse. We were unable to identify the individuals that produced pulsed sounds and it was difficult to count the number of individuals around the boat; therefore, the communication frequency per individual was not calculated.

Results

The summed recording duration of pulsed sounds was for 5 h 5 min 58 s (1 h 11 min 58 s in the Toba Area, 3 h 54 min in the Tsu Area) from the sound data of 10 h 19 min 34 s (3 h 54 min 7 s in the Toba Area, 6 h 25 min 27 s in the Tsu Area) (Table 1). Six packet sounds and six burst pulses were recorded on May 22, 2023 (Figs. 1 and 2). The parameters of the packet sound (Supplementary Fig. S1) and burst pulses were listed in Tables 2 and 3, respectively. All six packet sounds were recorded between 9:44:00 and 9:45:54. The inter-packet-sound intervals were 11.90, 16.53, 22.10, 24.92, and 35.97 s. Two burst pulses were recorded at 8:29:42 and 8:34:36 (the inter-burst-pulses interval was 4 min 54 s) and four were recorded between 8:56:26 and 8:56:30 (the inter-burst-pulses intervals were 0.14, 0.09, 3.19 s). The IPI and the number of pulses in one burst pulse were excluded because it was not possible to measure them due to a low signal-to-noise ratio, except for the duration. The frequency of sound communication in NRFPs was found to be 0.039 times/min (12 communication sounds divided by 5 h 5 min 5 s) (packet sound, 0.020 times/min; burst pulses, 0.020 times/min).

Discussion

Narrow-ridged finless porpoises produced both packet sound and burst pulses in the wild. This is the first report of packet sound from wild NRFPs. Unlike raspberry and extended grunt by captive chimpanzees (Hopkins et al. 2007), imitative bark sounds of California sea lion by captive killer whales (Foote et al. 2006), thunks by mother common bottlenose dolphins (McCowan and Reiss 1995), which do not occur in the wild, it is confirmed that packet sound is not a captivity-specific sound type but is a type originally produced in the wild. This is the first report of burst pulses from wild NRFPs of the Ise–Mikawa Bays population. Because Ogawa and Kimura (2023) reported burst pulses from wild NRFPs of the Seto Inland Sea–Hibiki Nada population, the burst pulses were found in at least two out of five genetically separated NRFP populations in Japan, suggesting that it is a common sound type of NRFPs. The findings of both burst pulses and packet sound in the wild imply that NRFPs are vulnerable to anthropogenic noise pollution such as underwater noise from vessel traffic (Wang et al. 2021). The packet sound is a type of sound used for maintaining relationships between conspecifics, including mother-calf pairs. The burst pulses

Table 1. Recording day, time, area, total recording time, recording duration of pulsed sounds, and recorded number of communication sounds of narrow-ridged finless porpoises in Ise Bay

Day	Time (start and end of the investigation)	Area	Total recording time	Recording duration of pulsed sounds	Number of burst pulses	Number of packet sounds
1-Mar-22	9:28–11:04	Toba	20 min 48 sec	20 min 48 sec	0	0
4-Mar-22	9:01–11:30	Toba	1 h 16 min 25 sec	17 min 56 sec	0	0
9-Mar-22	9:13–15:33	Toba	2 h 16 min 54 sec	33 min 14 sec	0	0
17-May-23	9:13–12:03	Tsu	1 h 32 min 12 sec	16 min 34 sec	0	0
18-May-23	5:05–10:00	Tsu	1 h 30 min 56 sec	17 min 25 sec	0	0
22-May-23	5:30–10:20	Tsu	3 h 22 min 19 sec	3 h 20 min 1 sec	6	6

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Table 2. Sound parameters of packet sounds produced by wild and captive narrow-ridged finless porpoises

	Packet sound in the wild (present study)		Packet sound of captivity (Terada et al. 2022)	
	Median	Average ± *SD*	Median	Average ± *SD*
IPI (inter-pulse interval) (ms)	7.6	14.5 ± 22.8	NA	15.5 ± 10.4
Number of pulses	10.0	9.4 ± 2.5	NA	5.4 ± 3.2
Duration of pulse packets (ms)	73.6	70.3 ± 16.6	NA	47.4 ± 32.3
Inter-pulse-packet interval (ms)	68.0	78.9 ± 36.1	NA	NA
Duration of packet sounds (ms)	596.3	596.0 ± 176.1	NA	NA
Number of pulse packets	5.0	4.8 ± 1.2	NA	NA

Table 3. Sound parameters of burst pulses in this study with comparisons with those from the different population and from captive narrow-ridged finless porpoises

	Burst pulses in the wild, Ise Bay (present study)		Burst pulses in the wild, Seto Inland Sea (Ogawa and Kimura 2023)		Burst pulses of captivity (Terada et al. 2022)	
	Median	Average ± *SD*	Median	Average ± *SD*	Median	Average ± *SD*
IPI (inter-pulse interval) (ms)	0.9	0.9 ± 0.2	NA	5 ± 1	NA	3 ± 3
Number of pulses	57.6	90.4 ± 57.8	NA	63 ± 37	NA	138 ± 127
Duration (ms)	48.0	87.2 ± 71.5	NA	306 ± 138	NA	372 ± 374

are related to sexual behaviors (Terada et al. 2022). Anthropogenic noise can mask cetacean sounds, negatively affecting their fitness (Erbe et al. 2016). Our present findings suggest that the impact of anthropogenic noise should be considered for the conservation of these endangered NRFPs. Restricting ship speeds in ecologically important areas for NRFPs could be one mitigation measure for the impact of anthropogenic noise (Wang et al. 2021).

As a whole, the frequency of sound communication was 0.039 times/min, which was less frequent than the other communication sounds produced by other odontocetes in the wild, cf. whistles by wild common bottlenose dolphins: 0.28 and 0.32 times/min/individual (dos Santos et al. 2005; Esch et al. 2009). However, caution is needed in determining that NRFPs infrequently produce communication sounds. Compared to the whistles with an average peak frequency of 9.2 kHz (dos Santos et al. 2005), the pulsed sounds of NRFPs have a much higher frequency, exceeding 100 kHz. High-frequency sounds, like those produced by NRFPs, generally attenuate quickly and are directional, potentially leading to lower detection rates compared to low-frequency sounds such as whistles. It is necessary to investigate all sounds produced by wild NRFPs using biologging techniques.

The average ± *SD* of IPI, number of pulses, and duration of the pulse packet were 14.5 ± 22.8 ms, 9.4 ± 2.5, and 70.3 ± 16.6 ms, respectively. When comparing these parameters to those investigated under captive conditions by Terada et al. (2022), the IPI (15.5 ± 10.4 ms) was similar to the results of the present study (Table 2). However, the number of pulses (5.4 ± 3.2) and the duration of pulse packet (47.4 ± 32.3 ms) under captive conditions were smaller than those in the present study (Table 2). It is possible that wild NRFPs produce more pulsed sounds in a pulse packet to increase detectability. Further studies are needed, both in captivity and in the wild, to explain these differences.

For burst pulses, the average ± *SD* of IPI, number of pulses, and duration of the burst pulses were 0.9 ± 0.2 ms, 90.4 ± 57.8, and 87.2 ± 71.5 ms, respectively. When comparing these parameters to those investigated under captive conditions by Terada et al. (2022) and Ogawa and Kimura (2023) from different wild populations, the IPI (3 ± 3 ms and 5 ± 1 ms), number of pulses (138 ± 127 and 63 ± 37), and duration (372 ± 374 ms and 306 ± 138 ms) were larger than those of the present study, except the number of pulses in Ogawa and Kimura (2023) (Table 3). The present study and Terada et al. (2022) investigated NRFPs in the populations of Ise–

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Mikawa Bays, while Ogawa and Kimura (2023) did the same for the Seto Inland Sea–Hibiki Nada population. It is possible that the parameters of communication sounds of NRFPs may differ between captive and wild conditions and/or populations.

Further study may reveal specific factors that contribute to differences in packet sound and burst pulses, including individual characteristics, sexes, or environmental variations. Simultaneous recordings by a drone and sound recorder may help determine the actual frequency of sound communication by identifying individuals who produce sounds. Also, further studies are needed to investigate whether all NRFP populations, as well as subspecies in the Yangtze River, produce these sound types and to investigate their frequency of sound production.

Supplementary data

Supplementary data are available at *Mammal Study* online.
Supplementary Fig. S1. The analyzed parameters of packet sound.

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