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A SHORT REVIEW OF ACOUSTIC MONITORING OF LARGE WHALES IN JAPANESE WATERS

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Abstract

Passive acoustic monitoring studies of large whales in the Japanese EEZ are reviewed in this paper. Submarine cables to monitor seismic events have been installed on the Pacific Ocean side of Japan because of the risk of earthquake strikes. Low frequency fin whale *Balaenoptera physalus* calls have been detected mostly in winter time. Many fin whale calls were observed in the waters off Kushiro in the northern part of Japan. A scientific submarine cable in Sagami Bay, 100 km west of Tokyo, revealed frequent presence of sperm whales *Physeter macrocephalus* year around. In the Ogasawara and Okinawa archipelagos, known as breeding grounds of humpback whales *Megaptera novaeangliae*, songs were recorded using stationed or boat-based recordings.

Key words: passive acoustic monitoring, fin whale, sperm whale, humpback whale, underwater sound.

Introduction

As is well known, baleen whales produce low frequency sounds during the breeding season. For example, blue whales produce frequency modulated sounds as low as 15.3 Hz (Stafford *et al.*, 2001), which is similar to the frequency range of earthquake vibrations. In the early 90's, underwater sound data received by military submarine cables was made available for scientific purposes to monitor baleen whales passively. Earlier, Dr. Ohsumi suggested application of passive acoustic monitoring for a survey of baleen whales (Ohsumi, 1994), referring to SOSUS and SURTASS systems (Nishimura and Conlon, 1994). Passive acoustic monitoring is the method of observing animals by receiving their vocalizations. Especially in the ocean, passive acoustic monitoring is a powerful method to identify presence, location, and movement of phonating animals in the water.

However, the passive acoustic method was not widely used in Japanese waters until recent years. Most of the Japanese studies are not accessible from outside of Japan or not yet published. As those studies are not well known internationally, there is the mistaken impression of a "vacuum zone" of passive acoustic monitoring of large whales in the western Pacific Ocean. This paper briefly introduces passive acoustic monitoring studies of large whales in Japanese waters. In contrast, passive acoustic monitoring of small odontocetes has been extensively conducted in Japanese and Asian waters. Many of these scientific papers appeared in international journals, which can be found by searching "A-tag" and "porpoise":

https://scholar.google.com/scholar?hl=0%2C5&q=A-tag+porpoise.

Review

Japan is located at the edge of the Pacific Rim and has suffered severe earthquake strikes many

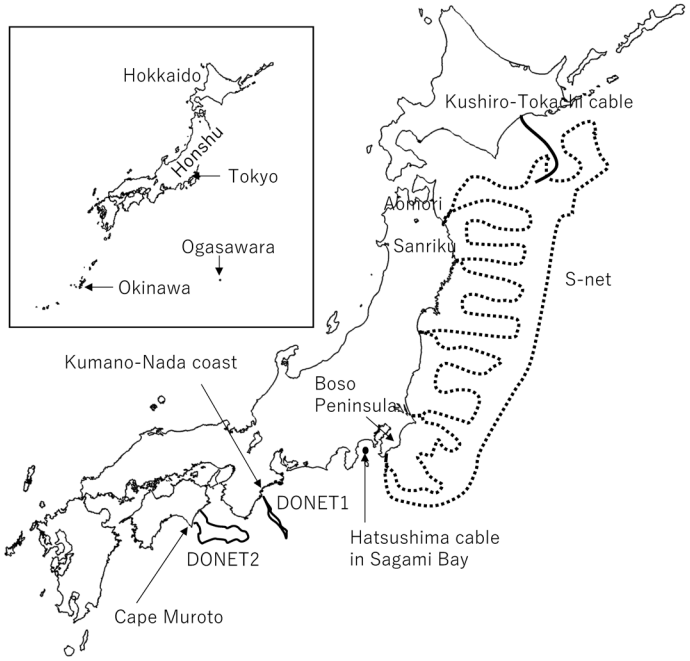

Fig. 1. Location of submarine cables in the Japanese EEZ and two breeding grounds of humpback whales (Okinawa and Ogasawara). Hatsushima cable is for scientific research purposes. The other four cables (Kushiro-Tokachi, DONET1, DONET2 and S-net) are deployed to observe seismic events nearby the trench shafts. The S-net shown in dotted line has seismometers, which provides water acceleration associated with low frequency sounds; no hydrophone data is available.

times. To monitor seismic events, submarine cables have been installed in the Japanese EEZ (exclusive economic zone), as shown in Fig. 1. For example, the Kushiro-Tokachi cable off Hokkaido was deployed in 1999 (Hirata *et al.*, 2002). S-net is the newly installed 5,500 km submarine cable in operation since 2016, which covers the eastern side of Honshu Island from off Hokkaido, Aomori, Sanriku and the Boso Peninsula (https://www.seafloor.bosai.go.jp/S-net/). The installation of DONET1 (Dense Ocean Floor Network System for Earthquakes and Tsunamis) observational equipment on 20 stations at Kumano-Nada was completed in 2011 (https://www.jamstec.go.jp/donet/e/cable/). In addition, DONET2 was deployed off Cape Muroto. DONET systems are currently operated by the National Research Institute for Earth Science and Disaster Resilience (https://www.seafloor.bosai.go.jp/). Hatsushima cable in Sagami Bay has recorded a human audible range of underwater sounds since 1993 (Iwase *et al.*, 2001). These cable systems have hydrophones or seismometers to record underwater sound pressure or water acceleration.

Passive acoustic monitoring of fin whales *Balaenoptera physalus*

Low frequency calls of fin whales were detected in winter time off Hokkaido by the Kushiro-Tokachi cable (Matsuo *et al.*, 2017). Four stations (DSO, OBS1, OBS2, OBS3) with hydrophones are located between 41°40.050′N–42°15.168′N, 144°20.454′E–145°3.372′E and 2,124 m–3,428 m in depth. Over a total of 2,981 recording days, 2,865,403 calls were identified by an automatic detector designed for this study. Clear seasonal differences were observed, being high during October and February, and low in the summertime. The number of calls received in a month showed a double peak structure in October and January. Call detection did not show a diurnal pattern. Nishida *et al.* (2018) developed a web system to visualize detections of fin whale calls. Yoshida (2017) independently analyzed Kushiro-Tokachi cable data and reached a similar conclusion of the seasonal presence of fin whales.

Ocean bottom seismometer data of S-net well supported the above results. Using 150 points of S-net observatory data, Nakamura (2020) documented the frequent call detections during October to

April. In areas off Kushiro and Aomori, the number of detections were high during December to January. After January, the area of the highest reception shifted to the south-west, in waters off Aomori and Sanriku. In addition, calls were detected on the shore side of the trench shaft, approximately 200 km off Honshu Island. The seismometers in the southern part of S-net located off Boso Peninsula received fin whale calls in winter time, although the number of received calls was far smaller compared with those observed off Kushiro.

According to the DONET1 data, no fin whale calls were identified year round (Ikuo Matsuo, pers. comm.). The location of DONET1 is approximately 400 km southwest of Boso Peninsula. This area might not be a breeding ground of fin whales. For DONET2, data analysis of baleen whale sounds has not been conducted.

Passive acoustic monitoring of sperm whales *Physeter macrocephalus*

Hatsushima Island Cabled Observatory (Hatsushima cable) is located on the seafloor at a depth of 1,175 m about 7 km southeast off Hatsushima Island in the western part of Sagami Bay, which is approximately 90 km southwest of Tokyo. Iwase (2012) retrieved audio sounds recorded from the soundtrack of videotape, which was received by the hydrophone of this observatory. Sperm whale clicks including creaks (series of very rapid clicks, inter-click intervals less than about 0.2 second) were observed. Iwase (2012) reported that no seasonality of the detections of sperm whale clicks was observed during the 1994–2012 period. The data suggested that sperm whales appeared around Hatsushima cable all year.

Amano *et al.* (2014) recorded sperm whale sounds by towed or suspended hydrophone off the Kumano-Nada coast and Ogasawara waters. Statistical differences in the number of clicks and inter-click intervals were identified. They suggested different vocal clans in the two study sites.

Passive acoustic monitoring of humpback whales *Megaptera novaeangliae*

Since Payne and McVay (1971) reported the songs of humpback whales, song structure of baleen whales produced in the breeding season is one of the major subjects of underwater bioacoustics. Maeda's (2002) doctoral dissertation at Nagasaki University gives a systematic description of the song structure of humpback whales in Okinawa waters. Using boat-based recordings during 1991–1998, unit structure and unit sequence in a phrase were analyzed. Individual variations and year-by-year change of song structure were reported. In addition, Maeda (2002) compared song recordings between Okinawa and Ogasawara waters during 1992–1995 and found no significant difference in song structures of humpback whales. As Darling and Mori (1993) reported, the same humpback whales were identified in both waters, consistent with the comparisons of acoustic features.

In recent years, singing behavior and the location of humpback whales in Ogasawara waters were examined to assess the effect of ship noise (Tsujii *et al.*, 2018). They installed two fixed underwater recorders separated by 3.0 km. Recorders were exchanged every two or three weeks before their batteries ran out. Each recorder had a stereo hydrophone. This monitoring method enabled localization of singers by triangulation from the two locations, simultaneously with the recording of song structure. Fewer whales sang nearby, within 500 m, of the shipping lane. Humpback whales reduced sound production after a ship passed, when the minimum distance to the whale from the ship trajectory was 1,200 m.

Discussion

Passive acoustic monitoring is a powerful method to observe presence, location, and movements of cetaceans. Even density can be estimated when phonating intervals, directionality, and source level are available. In Japanese waters, several already-existing submarine cables are available. Most of the data is available for research purposes judged to be conducive to the management of baleen whales in the Japanese EEZ. To accelerate passive acoustic studies of large whales, several future directions can

be suggested.

1. Encourage open data policy of underwater sounds. Data classification and masking will be needed to avoid conflict with national security in the low frequency range. For high frequency sounds of sperm whales and other large odontocetes, this constraint will be relaxed.
2. For automatic detection and classification of species or families, collections of species' annotated sounds are required to ensure acceptable performance of machine learning applications.
3. Improvement of density estimation models will serve for abundance estimation of offshore baleen whale populations. In the winter time when survey vessels are difficult to operate, the area of breeding grounds of large baleen whales will be an appropriate target for passive acoustic monitoring studies.

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