

Echoes of Clicks and Creaks of Sperm Whales Observed on Deep Seafloor in Sagami Bay

相模湾深海底におけるマッコウクジラの click 及び creak のエコー検出

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1. Introduction

Click sounds that have been repeatedly observed with a hydrophone of the deep seafloor cabled observatory off Hatsushima Island in Sagami Bay in central Japan since its replace in 2000 were identified as clicks of sperm whales through the waveform analysis¹⁾. There is another kind of sound called a “creak” that is also vocalized by a sperm whale. The creak is composed of a series of clicks with much shorter inter-click intervals (ICI) less than about 100 ms, compared to usual clicks whose ICI are more than several hundred milli-seconds. It is pointed out that a creak plays the same role as “buzz” of a bat which are used in search of prey²⁾.

Meanwhile, the echoes that follow the clicks were observed in some cases at the observatory. They were originated at the sea surface and have some information about diving depth of a sperm whale³⁾.

This time the author studied the creaks that have been observed with the observatory and found out possible echoes that followed the creaks. In addition, the clicks observed with the observatory before its replace in 2000 were also studied.

2. Observation Data

The observatory is located on deep seafloor at the depth of 1175 m about 7 km south-east off Hatsushima Island in Sagami Bay. It is composed of several kinds of sensors, including a single hydrophone, video cameras, Acoustic Doppler Current Profiler (ADCP) and a seismometer. It was deployed in 1993 and was replaced in March 2000. The existence of biogenic click sounds, although they were not identified as sperm whale clicks until recently, was recognized after the replace. Hydrophone signal before the replace was recorded on soundtrack of S-VHS videotapes only when visual observation with video camera is carried out. However, because rather large electronic noise probably associated with AC power supply from the shore station and with digital circuit noise inside the underwater unit was included, biogenic click sounds had not been recognized before the replace.

Through the study of the sperm whale clicks recorded on the soundtrack of DVCAM tapes after the replace, it was noticed that echoes which were considered as the reflection at sea surface followed clicks in some cases. **Fig. 1** shows an example of a series of 1 second waveforms of clicks that contains echoes. They are high-pass filtered at 1 kHz in order to remove low frequency ambient noise. Origin of horizontal axis at each waveform is the peak of the largest pulse of the click. Vertical axis shows the arrival time of each click. Time interval between each pair of click and echo increased as time elapsed. It indicates that the sperm whale emitting those clicks was submerging and that diving depth and velocity are estimated about 500m and about 1.1 m/s, respectively, assuming that the whale was submerging vertically just above the observatory and that the sound velocity of water was 1500 m/s. Moreover, by the analysis of the inter-pulse interval (IPI) of those clicks which have about regularly spaced pulses of 4 ms interval, the body length of the corresponding sperm whale was estimated to be 10 m or 12 m³⁾.

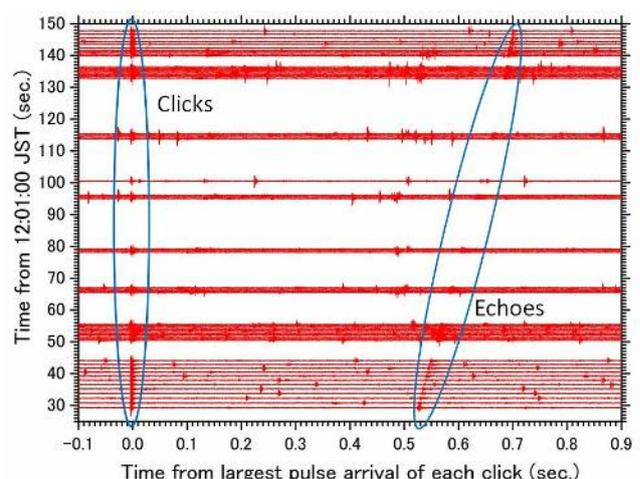


Fig. 1 An example of a series of 1 second click waveforms followed by echoes observed on Jan. 4th 2002³⁾.

On the other hand, the “creaks” have also been observed after the replace, although frequency of their detection is less than that of clicks. They

usually observed within a series of usual clicks. However, in some cases, they were observed when usual clicks stopped and “slow clicks” whose ICI is as long as several seconds were observed. **Fig. 2** shows an example of those cases observed on January 4th 2002.

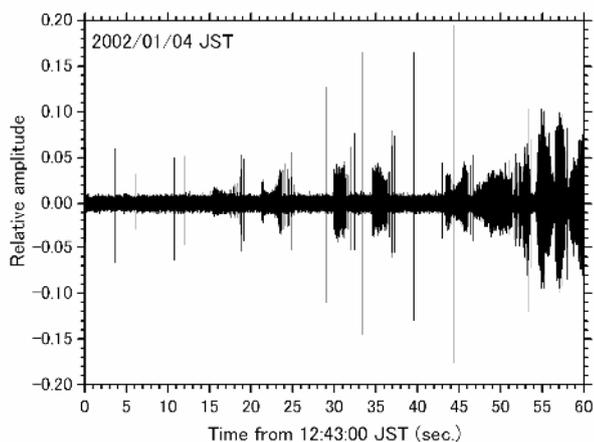


Fig. 2 1-minute waveform of creaks and slow clicks observed at 12:43 on Jan. 4th 2002.

In Fig. 2, creaks of several sperm whales seem to be included. Most of the ICIs of clicks composing those creaks distribute between 30 ms and 70 ms. Of creaks shown in Fig. 2, those observed at around 44, 50, 53 and 56 second were followed by possible echoes.

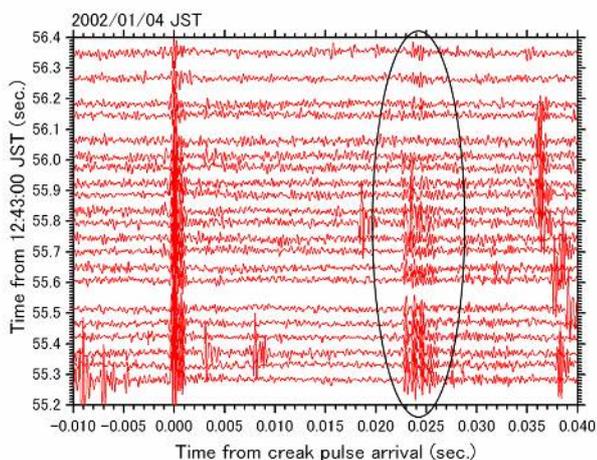


Fig. 3 A series of 50 msec. waveforms of clicks within a creak around at 12:43:56 JST.

Fig. 3 shows a series of 50 ms click waveforms within a creak observed at around 12:43:56 JST. It is obvious that a group of pulses with constant delay time suggested by an ellipse follows each click. The delay time is about 23 msec. and this value is too large for pulses that compose a click, i.e. pulses that were reflected inside a sperm whale. It is appropriate to conclude that those pulses were reflected outside a sperm whale. Considering that creaks might be used in search of

prey²⁾, possibly those are echoes from prey target.

Meanwhile, hydrophone signals recorded on the soundtrack of S-VHS video tapes before replace of the observatory in 2000 was studied this time. By listening carefully to the sounds of those videotapes so far, in spite of rather large electronic noise, a number of clicks could be recognized by ears probably as frequently as those after the replace. Not only clicks but echoes were also detected in some cases as is shown in **Fig. 4**. The waveforms are high-pass filtered at 1 kHz. In this case time difference between clicks and echoes are much smaller than that in the case of Fig. 1, i.e. the diving depth of the whale is shallower than two hundred meters. Also, the combination of creaks and slow clicks similar to the case in Fig. 2 was detected on December 29th 1995. As a result, it seems to be possible to some extent to identify the acoustic signals of sperm whales in the same way to those recorded after the replace.

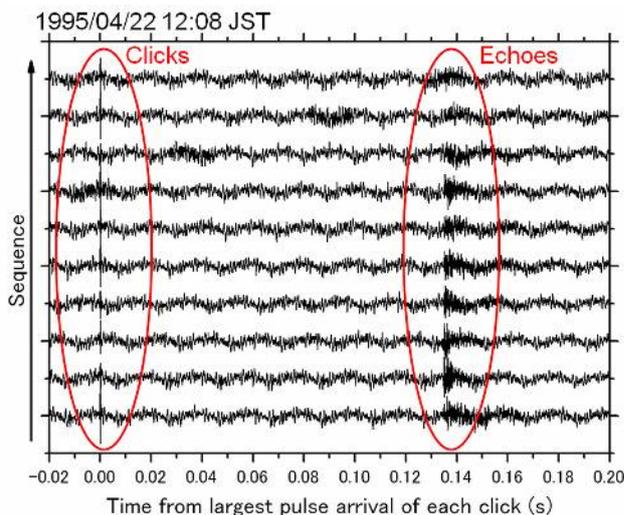


Fig. 4 An example of a series of 220 ms click waveforms followed by echoes observed at 12:08 JST on Apr. 22th 1995.

3. Concluding remarks

Through the study of clicks and creaks of sperm whales observed with a single hydrophone of deep seafloor cabled observatory in Sagami Bay, echoes of those signals were detected. They indicate diving depth and possibly distance between a whale and prey target. It is possible to study long term activity of sperm whales as long as 18 years since 1993, first deployment of the observatory.

References

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3. R. Iwase et al., Proc. UT/SSC 2011 (2011) 10.1109/UT.2011.5774125.