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Repellence Effect of the New Sound for Underwater Speaker of Hydrofoil

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ABSTRACT: In order to prevent hydrofoil colliding with cetaceans, the underwater speaker (UWS) has been installed to repel cetaceans. Yamada et al. (2012) analyzed and devised the UWS sound as it fits the cetaceans' acoustic properties to prevent the collision furthermore. The new UWS sound was devised and synthesized by Yamada et al. (2015) with expectation of avoiding collision with large cetaceans (Patent applied for, JP2014-171411). In this research project, the new UWS sound was investigated by the playback experiment on humpback whale (Megaptera novaeangliae) and by sighting survey in the actual hydrofoil shipping service route. As a result, a physiological and behavioral change of the humpback whale was observed in the playback experiment of the new UWS sound, and the chance of hydrofoil encountering cetaceans of the new UWS sound was smaller than that of the previous UWS sound. Therefore, the improvement of the new UWS sound was confirmed. Lastly, we wish this research project would contribute toward the safer cruise of hydrofoil in the future.

1 INTRODUCTION

Laist et al. (2001) suggested that risk of vessels colliding and causing lethal or severe injuries on large cetaceans would increase at vessel speed of 14 kn or faster. To reduce such risks, the Underwater Speaker (UWS) has been installed to a high speed vessel, Hydrofoil, whose maximum speed reaches at 45 kn. The UWS generates a sound of a cetacean repellant to scare off cetaceans, and decrease a risk of hydrofoils colliding with whales. However, unfortunately, it did not prevent the collisions completely, because the noise level of the sound currently installed on the hydrofoils was too small to trigger a repellant reaction against hydrofoils by cetaceans (Yamada et al. 2012). Thus, the new sound was devised by Yamada et al. (2015). The characteristic of the new sound source would be using a potential repelling sound for cetaceans and synthesizing audible frequency for whale with collision risk (Patent applied for, JP2014-171411). In this research project, the improvement of this new sound was investigated through following two researches:

1.1 *Playback Experiment of the New Sound on Humpback Whale (Megaptera novaeangliae) in Okinawa, Japan*

The effectiveness of the new sound triggering physiological and behavioral changes of Cetacean was investigated with a playback experiment on humpback whale in Okinawa, Japan. Humpback whale was preferred as a subject species for this experiment due to its frequent surface intervals and easy indication of surfacing behavior. Also, humpback whale is listed as a cetacean of highest risk of collision with hydrofoils. The experiment was

analyzed both qualitatively and quantitatively to confirm the new sound triggering the reactions.

1.2 *Sighting Survey from an Operating Hydrofoil with the New Sound in Niigata, Japan*

It is also important to understand the improvement of repellant effect of the new UWS sound in actual usage condition. The new sound was installed to the operating Hydrofoil, and the effectiveness of this sound was investigated through this sighting survey. The probability of sighting of the previous sound and new sound was calculated from the sighting record and compared between the two sounds.

2 METHOD

2.1 *Playback Experiment of the New Sound on Humpback Whale (Megaptera novaeangliae) in Okinawa, Japan*

In order to investigate and examine the effectiveness of the new UWS sound, the playback experiment was conducted at off the coast of Motobu town, Okinawa, Japan (Fig 1). The Furuno Electric Company's UWS (FC-510K) was a used in this experiment.

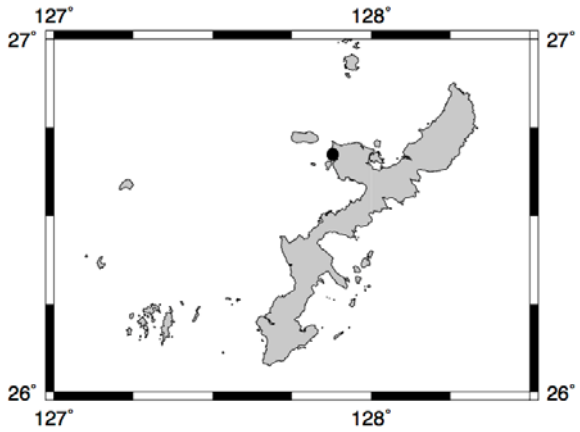


Figure 1. Map of Okinawa, Japan. Black dot indicates Motobu Town.

Before operating the experiment, any surfacing behavior, including surfacing interval time and breath count, of the target humpback whale was monitored and recorded as the research ship follow after the whale with enough distance for at least one hour. These behavioral data was recorded every time the whale surface throughout this experiment. Then, the research ship moved to the next expected surfacing area of the whale and ceased the engine to operate the experiment.

The UWS was put two meters under surface, and the sound was generated as the whale surfaces. The loudness of the sound was controlled based on distance to the whale with audio power amplifier. The voltage gain of -35 dB for those surfaced near the research ship (300 meters or less), and -18 dB for those at further distance (300 meters or more) and those appeared to be no reaction against the -35dB sound. The sound was stopped when the whale dive down or an intensive reaction was observed. The behavior was continuously monitored after the playback experiment for at least another one hour until its behavior was appeared to be back to normal. All the experimental procedures were recorded on video for further analysis.

The effectiveness of the new UWS was analyzed based on any change in recorded behavioral data; any significant difference in behavior from before and after generating sound was considered as the reaction against the sound.

2.2 *Sighting Survey from an Operating Hydrofoil with the New Sound in Niigata, Japan*

The repellant effect of the new UWS sound was investigated through the sighting survey from May 12th, 2014 to June 10th, 2014 in Niigata, Japan. This survey was conducted with a support of Sado Steam Ship Co, Ltd, who owns three hydrofoils for shipping service between Niigata city and Sado Island (Fig 2).

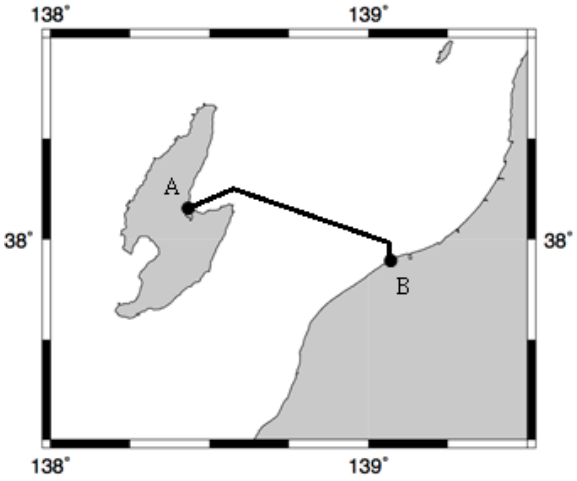


Figure 2. Map of Niigata, Japan. (A) is Ryotsu Port of Sado Island, and (B) is Niigata port. The hydrofoil shipping service route is indicated as black line.

The purpose of this survey was to investigate the repellent effect of the new UWS sound under normal hydrofoil operating service condition. The new UWS sound was installed to one of their hydrofoils, and cetacean sighting records were collected from all the three hydrofoils, one with the new UWS sound and two with the previous UWS sound, under normal operating service condition. The sighting records were collected from the cockpit of hydrofoil.

From the sighting record, the probability of sighting, which equals to the total number of cetacean sighting records divided by total number of shipping services of hydrofoil during the survey period, was calculated for both the new and previous UWS sounds. This probability indicates a chance of hydrofoil encountering cetaceans in one shipping service basis, thus, smaller probability means less chance of encountering cetaceans and so that less chance of collision with cetaceans.

3 RESULT

3.1 *Playback Experiment of the New Sound on Humpback Whale (Megaptera novaeangliae) in Okinawa, Japan*

Total of three trials of playback experiment were conducted. In each trial, the route and speed of research ship was recorded. The direction, speed, or both had changed after generating the new UWS sound, which implies that the target whale also had changed its direction and swimming speed since the research ship follow after the whale throughout the experiment (Fig 3).

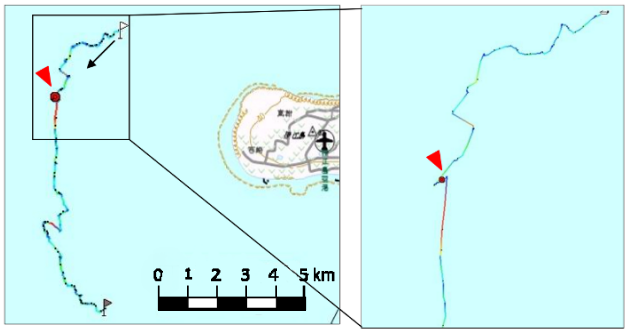
In the first trial, the whale quickly changed its direction, moving away from the ship, with increased swimming speed after the new UWS sound was generated. The distance became even further in one surface period, and thus, the voltage gain was increased from -35dB to -18dB in this surface period. The result of the second trial was distinctive from other two trials because the target whale was lost after generating the new UWS sound. A change of direction and an increase of speed were also observed in the third trial.

The physiological and behavioral change was also confirmed by the results of surface period and breathes count record (Fig 4). In the first trial, the surface period and breath count had increased as the whale swim away from the ship. The new UWS sound caused a physiological change in whale's behavior. For the second and third trials, either surfacing interval time or breath count increased relatively as well at the point when the new UWS sound was generated.

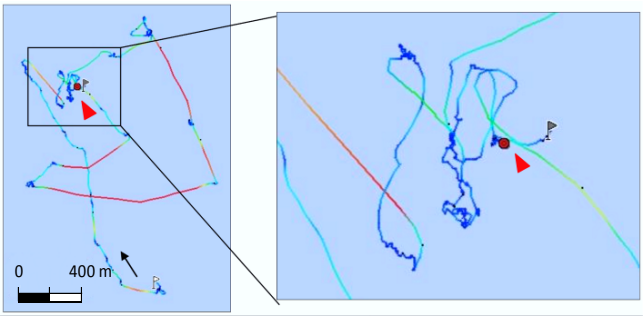
3.2 *Sighting Survey from an Operating Hydrofoil with the New Sound in Niigata, Japan*

In this survey, the new UWS sound was installed to the operating hydrofoil, and the cetacean sighting record was collected under normal operating service condition. The sighting record was collected from one hydrofoil with the new UWS sound and two hydrofoils with the previous UWS sound. In order to compare the sighting records based on the type of installed sound, the probability of sighting, which equals the number of sighting record divided by total number of hydrofoil service, was calculated.

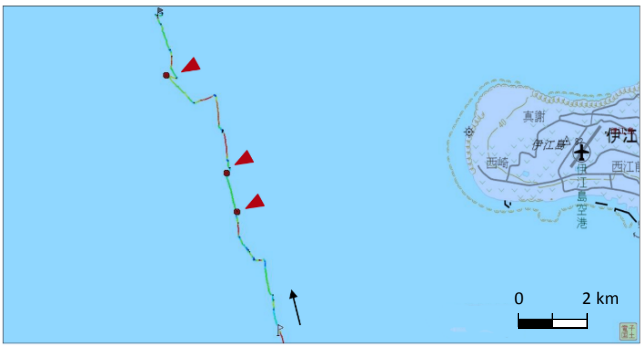
For the previous UWS sound, during the survey period, total of six sighting record was collected out of 343 services, while only one sighting record was collected out of 185 services for the new UWS sound (Fig 5).



A. Playback Experiment: Trial 1 (February 28th, 2014)



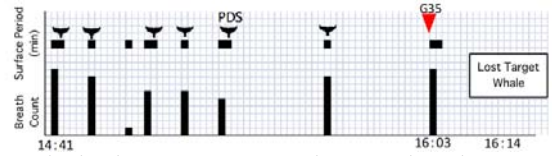
B. Playback Experiment: Trial 2 (March 11th, 2014)



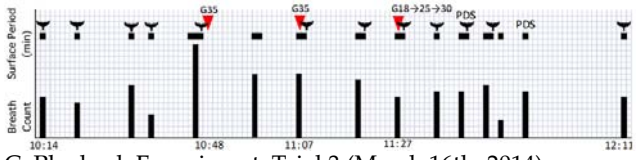
C. Playback Experiment: Trial 3 (March 16th, 2014)

Figure 3. Route and speed of research ship during the playback experiment. The white flag is the start point and the black flag is the end point of each trial. The red triangle points out the red circle, which is the place where the new UWS sound was generated. The color of the route indicates the speed of the research ship following after the target whale. The color changes from blue to red as its speed increases.

A. Playback Experiment: Trial 1 (February 28th, 2014)



B. Playback Experiment: Trial 2 (March 11th, 2014)



C. Playback Experiment: Trial 3 (March 16th, 2014)

Figure 4. The surface period (upper row) and breath count (lower row) of the target whale during playback experiment. For the surface period, one filled square is one minute of surface period, and one blank square is one minute of diving period. The fluke mark is shown above the surface period if the whale did fluke up dives. For the breath count, one filled square is one breath count. Red triangle indicates the point when the new UWS sound was generated, with voltage gain of number shown above the triangle (for example, G35 as -35dB). Each letter on surface period indicates behaviors as follows: BR: Breach (Jump), HS: Head Slap, TS: Tail Slap, PS: Pec Slap, and PDS: Peduncle Slap.

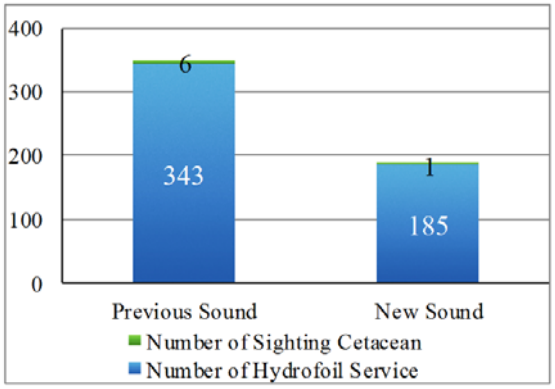


Figure 5. Number of Sighting Cetacean and Number of Hydrofoil Service for hydrofoil with the previous UWS sound and hydrofoil with the new UWS sound during survey period.

The probability of sighting was calculated from these data. The probability of sighting cetaceans in one hydrofoil service for the previous UWS sound was 1.7%, but on the other hand, that of the new UWS sound was 0.54%, which was less than a third of the previous UWS sound (Fig 6).

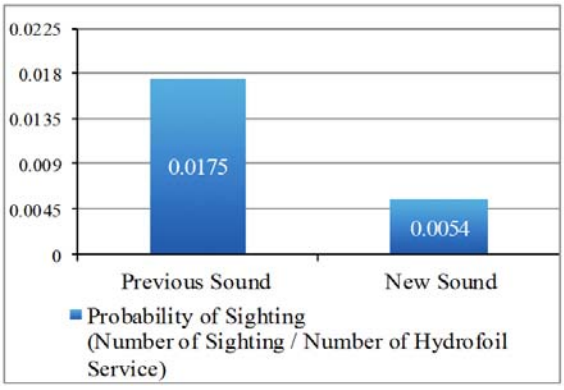


Figure 6. Probability of Sighting Cetacean of hydrofoil with the previous UWS sound and hydrofoil with the new UWS sound during survey period.

4 DISCUSSION

Through this research project on the new UWS sound, its effectiveness of repelling cetaceans was investigated. From the playback experiment, physiological changes, such as increase of surface period and breath count, were observed after generating the new UWS sound. This result supported the hypothesis of these physiological and behavioral changes were due to development of an uncomfortableness and nervousness by the new UWS sound. Thus, the repelling reactions, such as changing swimming direction and increasing swimming speed, were observed as a result of this experiment. Therefore, the new UWS sound conceivably triggered the repellence reaction of whales and led them to swim away from the research ship.

Based on the result of sighting survey, the probability of sighting cetaceans, or chance of hydrofoil encountering cetaceans, became relatively smaller for the new UWS sound. This result verified that the new UWS sound obtained more repellent effect than the previous UWS sound. The Fisher's exact test was performed to analyze the significant difference in the two probabilities (Table 1). Although, there was no significant difference between the effectiveness of the previous and new UWS sound under normal operating service condition (P-value: 0.2314), this research project as a whole supported the effectiveness of the UWS sound devised by Yamada et al. (2015). The repellent effect of the new UWS sound was verified in the playback experiment, and the tendency of decreasing the chance of hydrofoil encountering cetaceans was observed from the sighting survey. However, both the playback experiment and the sighting survey need more trials; more samples are needed for further research.

Table 1. Fisher's exact test on the probability of sighting whale for the previous and new UWS sound.

	Sighting	No Sighting	Total
New UWS Sound	1	184	185
Previous UWS Sound	6	337	343
Total	7	521	528
P-value:	0.2314		

5 CONCLUSION

The Underwater Speaker (UWS) has been installed to the high speed vessel, hydrofoil. The UWS generates the repellence sound for cetaceans to decrease a risk of ship strike to cetaceans. The previous sound was devised by (Yamada et al. 2015). In this research project, which is consist of playback experiment and sighting survey, of devised new UWS sound was investigated and examined. As a result, physiological and behavioral changes were observed in the target whale; it changed its swimming direction and speed, and swam away from the research ship. Furthermore, there was a tendency of decreased chance of sighting cetacean for hydrofoil with the new UWS sound. Therefore, the repellent effect of the new UWS sound was verified.

ACKNOWLEDGEMENT

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