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Optimal Fish Target Strength for Detecting Fish School using Horizontal Echosounder

Muhammad Kurnia[1†], Kohji Iida[1] and Tohru Mukai[1] ([1]Graduate School of Fisheries Sciences, Hokkaido Univ., Japan)

1. Objective

The acoustics target strength (TS) of fish is an important parameter in most application of fisheries research. TS of fish are highly variable. Even for the same fish, values are unlikely to be constant due to changes in morphological, biological and physiological factors (Foote, 1980a; MacLennan 1990; Simmonds and MacLennan, 2005). Swimbladder are the main reflector (90%) of sound (Foote, 1980a), length (Blaxter and Batty, 1990; Frouzova and Kubecka, 2004); orientation (Love, 1977; Foote, 1980b; Hazen and Horne, 2004; Henderson et al., 2007; Boswell and Wilson, 2008; Tang et al., 2008; and Rakowitz et al., 2008).

In most studies, the echosounder transducer was oriented vertically. Nevertheless, this system is due to the relatively small acoustical sampling. It's different, by horizontal beaming, which has provided large sampling volume and have a methodology that incorporates three-dimensional (3D) system. On the other hand, a few studies have investigated the influence of fish orientation (pitch, yaw and roll angle) on 3DTS measurement by horizontal beaming in tank experiment.

Therefore, this study performed to design and discuss of methods of horizontal echosounder for 3DTS measurement and to provide horizontal fish detection sonar feasible of indicating the measurement in tank experiment.

2. Methods

All samples used in this experiments were defrosted fish (horse mackerel, *Trachurus japonicus* and Japanese mackerel, *Scomber japonicus*). Prior to the TS measurement, all fishes were radiographed using a X-ray imaging system (Softex PRO-TEST 100) to image fish body and swimbladder from both lateral and dorsal aspects. Further, X-ray images were digitized to obtain the outline of the fish body and swimbladder which were used to estimate TS by the theoretical models.

The experiments were conducted in freshwater tank (3 m depth and 4 m diameter), which was measured at 50 kHz frequencies by a tethered method. The experimental set up and the target suspension system is shown in Fig.1. The system measuring was calibrated using a 38.1 mm diameter tungsten-carbide sphere with the TS of -40.4 dB before TS measurement of fish.

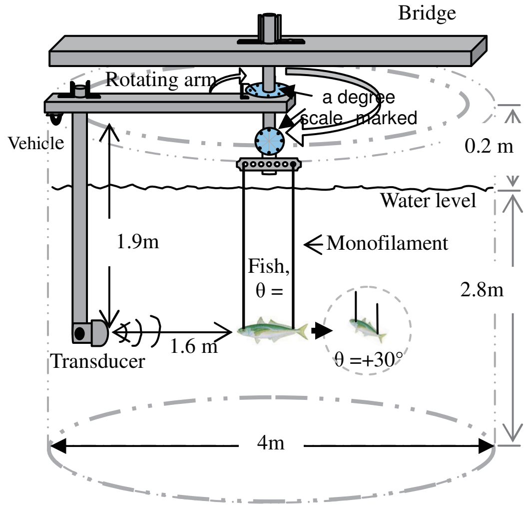

Fig.1.The experimental set up for TS measurement

The reference target sphere was suspended at about the same depth and distance of fish target (160 cm) to the transducer. Then, fish target was suspended horizontally using monofilament (Ø=0,235 mm) as to face the lateral side toward the transducer.

3DTS was measured by rotating the transducer horizontally which represented as yaw angle 0-360° step 1° on 0-90° pitch angle, step 10°. Echo data are recorded at each 1° (in 0-360°).

Further, acoustic backscattering amplitudes of fish were estimated using Prolate Spheroid Model (PSM), which describes by Furusawa (1988) to examine the influence of fish orientation on 3DTS. Finally, the TS estimated by PSM were compared with the measured TS.

3. Results and Discussion

a. TS measurement

First, changes in the fish orientation resulted in TS differences, regardless of the pitch and yaw angle. According to distributions of fish aspects, we found that yaw aspects in horizontal echosounder would be strongly dominant in all aspect TS values. The result confirmed through Fig. 2, which shows horizontally averaged TS of fish is relatively small. The minimum and maximum TS ranged from -55.6 dB to -41.2dB and from -40.1 dB to -38.7 dB, respectively. Meanwhile, the average TS of fish ranged from -46.0 dB to -40.2 dB.

Even if the variation of TS is small, changes in yaw and pitch aspect angle is generally significant affect on TS values. The rotation only a few degrees resulted large changes on the TS values.

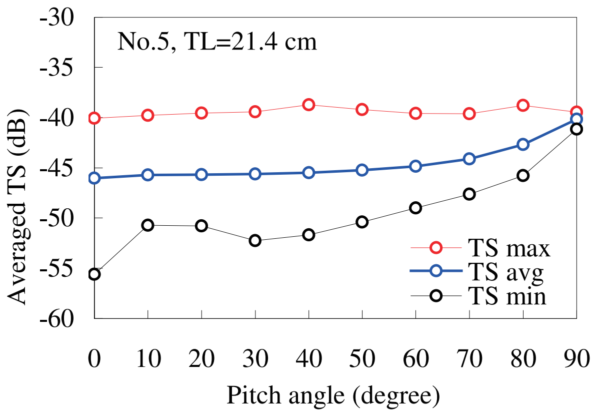

Fig.2. TS measurement patterns of Japanese mackerel as a function of pitch angle.

This results, agree with some researcher (Henderson et al., 2007; Boswell and Wilson, 2008; Tang et al., 2008; and Rakowitz et al., 2008), reported that fish orientation have a significant influence on variation of fish TS.

Furthermore, the contour plot visualization was used to describe the relationship between pitch, yaw angle and TS which shows the affect fish orientation on TS of fish.

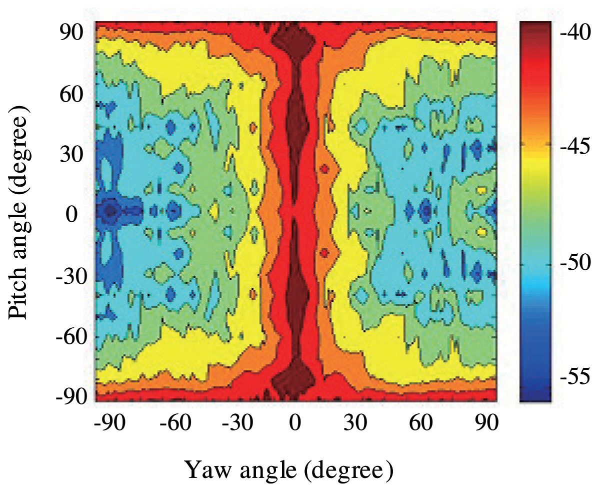

Fig.3. Contour plots of the relationship between pitch and yaw aspect angle and fish TS

Figure3 shows that the variation of TS is strongly associated with changes in the fish orientation. Changes in orientation away from the cross section area (yaw, θ= 0°) to head/tail aspect (θ= ±90°) showed drastically decrease. Conversely in pitch angle, variability of TS is small variation.

b. Simulations backscatter model

The PSM model simulations were used to investigate the influence of pitch, yaw and roll angle on fish 3D TS. In horizontally oriented beam, the change in yaw and pitch angle is significant. Nevertheless, the change in the roll angle is negligible. The simulation result is shown in Fig.4, which indicated the 3D average TS as a function of the yaw angle (standard deviation, 10°).

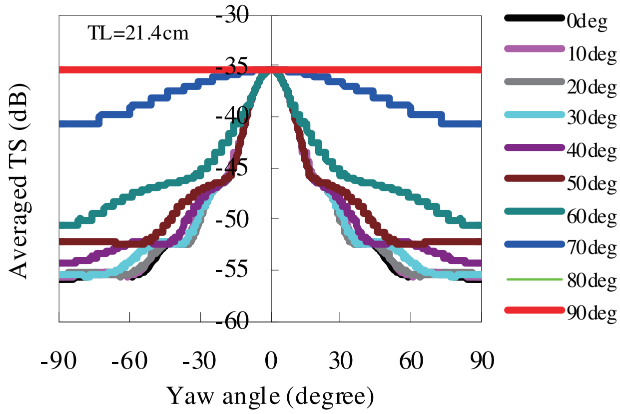

Fig.4. Fish TS patterns as functions of tilt angle that obtained by the PSM simulation (STD = 10°).
The pitch angle of fish (θ=0-90°) is shown.

The results show that TS patterns were contoured at increasing in range ± 30° and the largest TS were found when oriented perpendicular to the lateral side of fish (yaw 0°). The TS was equal at lateral side of fish even if the pitch angle changes from 0° to 90°. As a fish changes in pitch angle TS distribution will have the same TS, because fish are insonified at the same incident angle. Conversely, in yaw angle; change only a few degrees have a large effect on TS.

On the other hand, the relationship between TS measurement and theoretical TS value are relatively agreed well

Conclusion

Horizontal direction TS of fish is normally at pitch angle ± 30° and changes in fish TS as large as 20 dB attributable to changes in yaw angle.

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