Startle Response Level of Japanese Anchovy *Engraulis japonicus* to Underwater Pure Tone Signals

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Reactions of Japanese anchovy *Engraulis japonicus* to 100 to 700 Hz underwater pure tone signals were observed. A mean body length of the anchovy was 11 cm and a mean weight was 10 g. Seven hundred fish were kept in a net enclosure (150 fish/m$^3$). The net enclosure which was 2 m in diameter and 1.5 m in depth was set beside a pontoon in Tateyama Bay where water depth was 7 m. The anchovy ordinarily swam in a circle at almost same speed in the net enclosure.

An underwater speaker (OKI ST 2010) was one meter apart from the side of the net enclosure. Its frequency characteristics is good for up to 1000 Hz. The frequency of the projected pure tone signals was varied among 100, 200, 300, 500, and 700 Hz which included the sensitive frequency range of several species, namely cod: 30 to 470 Hz,$^{1}$ flat fish: 30 to 250 Hz,$^{2}$ and sea bream 50 to 700 Hz.$^{3}$ The projected sound pressure level was measured at the center of the net enclosure.

The startle response behavior was defined as follows: the half of the fish changed their behavior just after the projection of a sound, for example, the acceleration of the swimming speed, dispersion or condensation of a fish group. When no or few anchovy changed their ordinary behavior, it was defined as no response.

The up/down staircase method$^{4}$ was used to determine the threshold level of startle response. At first, 135 to 145 dB re 1 $\mu$Pa sound which was expected to have no response was projected for one second. The sound pressure level was up or down at the next sound projection as follows. When the anchovy did not respond to a level, the projected sound pressure level was increased by 5 dB. When the anchovy responded, the level was decreased by 5 dB. This procedure continued for ten times at each frequency. Some local maximums and minimums appeared as shown in Fig. 1 during this procedure. The startle response level was determined as the average of these local maximum and minimum value during ten sound projections at each frequency.

The startle response levels were 154.5 dB at 100 Hz, 153.3 dB at 200 Hz, 146.8 dB at 300 Hz and 153.8 dB at 500 Hz respectively. The 700 Hz signal did not affect the behavior of anchovy up to 158 dB, so that the startle response level could not be determined at this frequency. The variation of startle response level with frequency was

[Fig. 1. Up/down staircase method to determine the reaction level at 300 Hz signal. ○, indicates the startle response; ×, indicates no response; --, indicates the startle response level.]

[Fig. 2. The startle response level variation with the frequency.]
shown in Fig. 2. The level had a minimum around 300 Hz. The fluctuation of background noise spectrum level was in 4 dB from 32 to 1000 Hz. The over all background noise level was 119 dB.

The audiograms of sea fish1-3) depend on the signal frequency and the minimum threshold level are about 80 to 90 dB, which are below the background noise level of this experiment. The wild fish are usually exposed to such background noise of which sources are snapping shrimp, bubbles, or ship engine and so on. Estimation of behavioral response level by underwater sounds is considered to be practical in a noisy environment for the assessment of underwater acoustic pollution such as underwater explosions and constructions. The startle response level also will be a basic data for control of fish behavior by artificial underwater acoustic signals.

The startle response level of 200 Hz signal differed by 6.5 dB from that of 300 Hz signal. This suggest that the behavioral affectivity of underwater acoustic signal changed by its frequency as the audiogram of sea fish. The most sensitive frequency of sea bream was 200 Hz3) which is 100 Hz lower than the lowest startle response level of Japanese anchovy of the present study. The acoustic energy around the frequency at the minimum reaction level, 300 Hz in this case, is thought to be dominant to estimate the behavioral effects of underwater acoustic signals.

The startle response level is thought to be higher than the auditory threshold level, because induction of the behavioral change needs higher energy. The startle response level of sea bream Pagrus major was reported 150 dB at 200 Hz pure tone signal, and the difference from the auditory threshold level was 65 dB.5) The audiogram of Japanese anchovy has not been measured yet. The pelagic fish is difficult to use for the measurement of auditory sensitivity due to its feebleness in a tank. Only the Japanese horse mackerel Trachurus japonicus was reported to be audible the 100 dB at 300 Hz and 85 dB at 1000 Hz pure tone signal6) which is much lower than the startle response level of Japanese anchovy.

References