Studies on evaluation of factors affecting efficiency of MOHT nets for sampling fish juveniles
稚魚採集装置 MOHT の効率に及ぼす影響要因の評価に関する研究

氏名：　朱　媛媛
学籍番号：1461005

The objective of the study

Research on fish juveniles plays an important role in estimating the abundance of recruitment in fish stock assessment. In order to obtain accurate information about young fish, various sampling trawl gears are widely used. However, estimation of biomass from sampling trawl gear was often underestimated because all of mesopelagic fishes were not captured. For example, Isaacs-Kidd midwater trawls (IKMT), one of the most popularly used fishing gears had disadvantages that net mouth shape and towing depth were variable due to towing speed, which cause net avoidance of larger juvenile. To overcome these disadvantages of the sampling trawl gears, Matsuda-Oozeki-Hu Trawl (MOHT) were developed for quantitative catching. It has a rigid square frame net mouth and a cambered V-shaped depressor, which allow to be towed at high speed of 4 knots and to keep towing depth stable, irrespective of variation of towing speed. Based on MOHT, a new multi-layer quantitative sampling trawl gear with a net mouth opening/closing control system (MOC-MOHT) and with a codend opening/closing control system (COC-MOHT) were also developed. Catching efficiency is defined as the ratio of the number of caught fish to the number of fish existing in front of the net. This study assumed two hypothesis: before entering the net larger individuals to evade due to their faster swimming speed, that is, net avoidance; after young fish entering the trawl net, fish with enough small body escape through the mesh space of the net, which is called mesh selectivity. In this study, we attempted to clarify factors affecting the catching efficiency such as fish size associated with swimming ability, net mouth dimension, and towing speed, and through established models for mesh retention and net avoidance, evaluate the effect of net avoidance on fish stock assessment in comparison of fish density with acoustics survey results.

Materials and methods

Comparative experiments were carried out to analyze mesh selectivity of the MOHT polyethylene net and size selectivity of net avoidance for small MOHT and IKMT nets. Four types of trawl net were used as follows: two size MOHT (standard and small one) with net of 1.59 mm-mesh polyethylene (PE) material, and two types of IKMT (one with net of 1.59 mm-mesh PE material and the other for plankton with net of 1.00 mm-mesh nylon material, hereafter IKPT). Of the four nets, selected two or three nets were alternatively towed: standard and small MOHTs and IKPT in Sagami Bay in 2003; standard and small MOHTs off Ibaraki and Iwate Prefecture in 2005;

and standard MOHT, small MOHT and IKMT off Fukushima Prefecture in 2007, Pacific. Larvae and juveniles of Japanese anchovy *Engraulis japonicas* caught during the trials were sorted for measurement of body length in millimeter. Five models expressing net avoidance in small MOHT and two IKMTs and mesh selectivity of 1.59 mm-mesh net were performed, on the two assumptions: no net avoidance in standard MOHT with enough large net mouth to prevent fish evading in front of net mouth during towing; and no mesh selection in IKPT with 1.00 mm-mesh codend, i.e. enough small mesh to retain all larval and juvenile fish in the codend. The SELECT approach was applied to estimate model parameters from body length data of the successive two hauls for estimating the model parameters. The model which small MOHT and two IKMTs had different size selection for net avoidance was selected as an optimal model by Akaike' information criterion (AIC).

Effect of towing speed on net avoidance was tested by using the MOHT nets in each sea trials. These trials included standard MOHT sampling in the East China Sea in August 2016, MOC-MOHT sampling in Sagami Bay in July 2015, and COC-MOHT sampling in Sagami Bay in October 2014. In each trial, the net was casted for targeting depth where fish aggregation was observed by acoustics, and towing speeds were changed into the three stages of 4, 3, and 2 knots in this order. Compared with alternative experiment of standard MOHT, multi-layer sampling MOC-MOHT and COC-MOHT with five codends have advantages on catching the same fish school at speed of 2, 3 and 4 knots in one cast. All lantern fish were picked out for body length measurement and grouped into 5mm standard length intervals. They were identified into species level as follows: *Diaphus Kuroshio*, *Diaphus* spp, *Ceratoscopelus warmingii*, *Myctophum asperum*, *Myctophum nitidulum*, *Diogenichthys atlanticus*, *Lampanyctus alatus*, *Lampanyctus* sp, *Myctophidae* spp. Length distribution of each species showed that the catch number of large fish decreased at lower towing speed. Here, several models were assumed with linear functions of towing speed V to express logistic parameters α and β. In addition, the split parameters p in two hauls (4 and 3 knots, 4 and 2knots) was estimated by log-likelihood method or calculated with practical filtered water volume in the experiments. Total of six models were tested to examine the effect of towing speed on net avoidance.

Catching efficiency for lantern fish by MOC-MOHT sampling was evaluated in comparing densities with acoustics survey. In Sagami Bay in July 2015, Sonic KFS-3000 echo-sounder system, operating at 38 kHz frequency, was also used to record acoustic data during all tows of MOC-MOHT. The area backscattering strength (SV) for the water column swept by MOC-MOHT was recorded automatically at Echoview® software. In order to calculate the mean TS for all the lantern fish, we made two assumptions: all the lantern fishes had a swim bladder; and for all the lantern fish, the same formula for *Diaphus garmani* estimated at 38 kHz between target strength and standard length was applicable. Meanwhile, lantern fish densities estimated by MOC-MOHT net sampling were calculated based on the actual fish number and filtered water in each haul.

Results and discussion

In this study, we assumed two hypotheses: before entering the net larger individuals tend to evade due to their faster swimming speed, that is, net avoidance; after young fish entering the trawl net, fish having enough small body escape through the mesh space of the net, which is called mesh selectivity. As a result, we clarified factors affecting the catching efficiency such as fish size associated with swimming ability, net mouth dimension, and towing speed. For sampling gears with different mesh size, net with smaller mesh size caught more small sized fish. For various sampling gears with different net mouth, net avoidance more obviously occurred in smaller and unfixed net mouth. For the same sampling gear at various towing speeds of 2, 3 and 4 knots, net avoidance was more prevalent at lower towing speed.

Comparative experiments were carried out to analyze mesh selectivity of the polyethylene net and size selectivity of net avoidance for small MOHT, IKPT and IKMT nets. In this study for polyethylene net, 50% retention length and selection range were 12.20 and 2.82mm, respectively. MOHT trawl can collected almost all anchovies larger than 15mm. Saiura *et al* (2006) illuminate that in seine fisheries, mesh size of minnow netting was 1.56mm, the similar mesh size as MOHT trawl (1.59mm), which has 50% retention length of 8.34~12.54mm and selection range of 2.40~2.76mm. Hence, our results agree with that of Saiura *et al* (2006). When compared with standard MOHT, large sized fish were not efficiently collected in IKPT, IKMT and small MOHT. It indicated that net avoidance occurred in IKPT, IKMT and small MOHT. When compared small MOHT and standard MOHT, confirming net avoidance of larger anchovies due to the smaller mouth area. When compared IKPT and IKMT, there were no anchovies larger than 25mm collected in IKPT. The filter efficiency may also be lower in smaller mesh size, so we need to discuss the influence of filtered water on different mesh size in the future.

We clarified that net avoidance not only occur at relatively lower towing speed of 2 and 3 knots, but also occur at relatively higher towing speed of 4 knots. Further, we established linear model to obtain the relationship between towing speed and standard length of lantern fish. For specimen of lantern fish, we used length distribution of *Diaphu*s spp for data analysis due to their dominance in retained catch of each MOHT net. The result showed that the 50% retention length of 4, 3 and 2 knots were 38.19, 29.06 and 23.46mm for MOC-MOHT, 42.35, 35.87 and 29.40mm for COC-MOHT, and 27.38, 22.12 and 18.56mm for standard MOHT, respectively. This suggested that the net avoidance was more apparent in standard MOHT than MOC-MOHT and COC-MOHT. The experimental areas were Sagami bay for MOC-MOHT and COC-MOHT, and the East China Sea for standard MOHT. *Diaphus* spp were ranged from 10 to 32mm in standard MOHT, 10 to 40mm in MOC-MOHT and 10 to 44mm in COC-MOHT. As can be seen from the length distribution of lantern fish, *Diaphus* spp collected in standard MOHT were smaller than the other two sampling gears, and the size of *Diaphus* spp were similar in MOC-MOHT and COC-MOHT. Therefore, the different experimental areas might cause the difference in length distribution. For MOC-MOHT and COC-MOHT in Sagami bay, the net avoidance of 4, 3 and 2 knots were larger in MOC-MOHT than COC-MOHT. For these two kinds of sampling gears, they have different mouth dimensions. For MOC-MOHT, it has a frame mouth of 4 m^2 and a main frame with a vertical bar of net stacking structure. In contrast, COC-MOHT has a frame mouth the same as standard MOHT of $5m^2$. The difference in net avoidance between the two fishing gears was probably because smaller mouth exihibit larger net avoidance, and complex frame structure of MOC-MOHT might also cause larger net avoidance.

Under the influence of net avoidance, density estimates by MOC-MOHT was underestimated, found to be about 2 orders of magnitude smaller than that estimates of acoustic. Taking into consideration of net avoidance, large fish with higher swimming ability could not be caught effectively. When we calculate target strength (TS), it would be an underestimation because few larger fish with higher TS were collected. In this study, we used the standard formula of *Diaphus garmani* to express all species of lantern fish. The formula was denoted as TS (dB) = $34.5 \times \log (Ls) - 89.2$, where TS is in dB and Ls is standard length in cm. Using this formula, we can see that target strength becomes larger with the increase of standard length. However, large sized fish has higher swimming speed to escape in front of the net. As selection curve was calculated in previous chapter, it indicated that fish with standard length larger than 35, 40 and 55 mm were difficult to be captured at towing speed of 2, 3 and 4 knots. Therefore, TS estimated by observed data using sampling gear was underestimated in state of net avoidance. In order to estimate catch number of lantern fish under no influence of net avoidance, we compensated length distribution of lantern fish using selection curve. As a result, density estimates by MOC-MOHT was 1 order of magnitude less than that of acoustic survey.

This study is the first to use actual sea experimental field data to establish evaluation model of main factors affecting fishing efficiency, including fish size, net mouth dimension, mesh size and towing speed of several sampling trawl gear, and evaluated the effect of net avoidance on fish stock assessment in comparison with the acoustics. The methods and approaches established in this study are useful for many other species to obtain better estimation of fish stock from sampling trawl gear surveys. In understanding of catching efficiency for these sampling gears, we are looking forward to contributing of more precise resource assessments.