The influence of warp length on trawl dimension and catch of walleye pollock *Theragra chalcogramma* in a bottom trawl survey

Running title: Changes in trawl dimension with warp length

Yasuzumi FUJIMORI,[1*] Kenji CHIBA,[1] Tatsuki OSHIMA,[2] Kazushi MIYASHITA,[3] Satoshi HONDA[4]

[1]Graduate School of Fisheries Sciences, Hokkaido University, 3-1-1 Minato, Hakodate, Hokkaido 041-8611, [2]Marine Fisheries Research and Development Department, Fisheries Research Agency, 2-3-3 Minato-mirai, Yokohama, Kanagawa 220-6115, [3]Field Science Center for Northern Biosphere, Hokkaido University, 3-1-1 Minato, Hakodate, Hokkaido 041-8611, [4]Hokkaido National Fisheries Research Institute, Fisheries Research Agency, 116 Katsurakoi, Kushiro, Hokkaido 085-0802, Japan

[*] Corresponding author: Tel & Fax: +81 138-40-8832. Email: fujimori@fish.hokudai.ac.jp

Abstract

We examined variation in trawl dimension, bottom contact, and catch with differing warp lengths during walleye pollock surveys conducted by the Fisheries Research Agency. The ratio of warp length to fishing depth (scope ratio) was set at 2.5, 3.0 and 3.5 at depths of 110 m. At a 2.5 scope ratio, the net mouth shape and footgear contact fluctuated, as the trawl door did not contact the bottom. Footgear contact was complete when the scope ratio was 3.0 or more. Walleye pollock, sculpins, and flatfishes were the main catch in all tows, and the catch increased with scope ratio. There was no difference in the length frequency of n= 300 walleye pollock captured at 2.5 and 3.0 scope ratio. However, the length frequency at 3.5 was significantly different from that of other scope ratios. These results suggest the following: at a scope ratio of 3.0 or more, the trawl door will not leave the bottom at any depths. To compliment echo surveys for walleye pollock, a 3.0 scope ratio would be optimal, since the catch data for a 3.5 scope ratio was dissimilar from that of scope ratios

Keywords: Walleye pollock, Trawl survey, Trawl dimension, footgear contact, Warp length

Introduction

The FRA (Fisheries Research Agency of Japan) has completed annual trawl and acoustic surveys for walleye pollock (*Theragra chalcogramma*) off the coast of eastern Hokkaido and Sanriku, Japan. The fish species and length composition from trawl catches are used to correlate acoustic data with actual fish density. Inevitably, acoustic abundance estimates are influenced by the sampling error or variance in the trawl survey data.

Hylen et al.[1] have shown that these errors in bottom trawl catches cause small fish to be underestimated in cod stocks. The facts for small cod and haddock close to the seabed (Valdermarsen JW, Engas A, Isaksen B., ICES CM, 1985) supported their results, that is, there is a possibility that small fishes escape under the trawl. Engås and Godø[3] experimented with a bottom trawl with small under bags that were placed under the main net and showed that escape of cod and haddock under the trawl varied with fish length. These results demonstrated that footgear contact was an important factor in increasing the accuracy of abundance estimates by bottom trawl survey. Size selection of cod and flatfishes by trawl footgear was confirmed by some studies using an auxiliary net.[4-5] Factors affecting footgear contact have also been studied. Somerton and Weinberg[6] investigated the effect of towing speed on footgear contact. Some researchers have also studied the effect of trawl dimension on fish response during capture, [7,8] and Engås and Godø[9] showed a considerable effect on catch efficiency by variation of vertical opening and wing spread. Koeller[10] tried to decrease the bias in catches due to variation of wing spread, and Rose and Nunnallee[11] compared capture efficiency between narrow and wide spread.

The towing condition of trawls used in surveys should be constant, specifically to maintain sampling accuracy, because sampling results are likely to vary with towing conditions. This study examines the variation of trawl dimension and footgear contact with differing warp length during walleye pollock surveys. In addition, the influence of warp length on catch was investigated.

Materials and Methods

The experiment was carried out offshore of Kushiro (Fig. 1), Hokkaido on board RV "Kaiyo-Maru No.3" (47.1m, 1300HP) in January, 2002. A JAMARC99-type bottom trawl (Fig 2) constructed of 60 mm mesh with a 11 mm mesh liner in the codend was used in the experiment. It was connected to the trawl door (1.65 x 2.55 m, 1050 kg each in water) through 60 m hand ropes (2.2 cm wire rope) with 50 m bridles (1.6 cm wire rope). The headrope and footgear were 27.1 m and 33.6 m long, respectively. The footgear consisted of roller gear with rubber disks on both ends (11.8 m each) and a 49 cm diameter bobbin section (10 m). This trawl is the standard sampling gear for walleye pollock surveys by the Fisheries Research

Agency.

A series of two tows using different warp lengths were completed twice over the same area at a depth of about 110 m. Standard surveys for walleye pollock are conducted at depths from 70-300 m. The relationship between warp length (*W*) and depth (*D*) when the net touched with the bottom was obtained as $W = 2.70\ D$ ($R^2 = 0.99$). With this knowledge, in this experiment the ratio of warp length to depth, known as scope ratio, was set at 2.5, 3.0 and 3.5. All tows were conducted during daylight for 10 minutes after net contact with the bottom, at a speed of four knots. The tow distance in each haul were almost the same (0.81 ± 0.03 nm). Prior to every tow, echograms (38 kHz Simrad EK-500) confirmed that there were no major differences in fish abundance at the bottom. After each haul, captured fish were sorted by species and the total weight of each species was calculated. In addition, the total number of walleye pollock was counted and the fork length of 300 specimens was measured to the nearest millimeter.

Trawl Instrumentation

To measure wing spread and bottom clearance, acoustic devices (SCANMAR sensors) were attached to both wings and the headrope. To measure trawl height, small depth recorders (Resolution: 12.5 cm, Alec Electronics Co.,Ltd.) were attached to the center of the head line and the fishing line. The same recorders were attached to the trawl door and also the wing and both sides of the bosom line to estimate mouth shape and degree of footgear contact (Fig. 3). The sea depth was estimated as the sum of the fishing line center depth obtained from the depth recorder and the bottom clearance measured with the SCANMAR height sensor. These data were recorded with a PC every 10 seconds. Depth recorder data was collected every second, and these data were read with a PC after hauling and averaged every 10 seconds to synchronize with the data from SCANMAR sensors. The trawl dimension was analyzed using these data in ten-minute blocks .

Trawl mouth shape

The trawl mouth shape was determined using the depth data measured with depth recorders and the SCANMAR sensors. Fig. 4 shows the schematics of the head line and fishing line during towing. In Fig. 3 the bold line at front view illustrates the trawl mouth shape defined in this study, and this is approximated by the polygon P'_1, H, S'_1, S_2, G', P_2 in Fig. 4. An estimate of the horizontal distance between P'_1 and S'_1 (D_h), P_2 and S_2 (D_g) is needed to determine this shape. D_h is estimated easily when the side line formed by P_1 and P'_1 or S_1 and S'_1 (WL), is assumed to be linear. That is,

$$D_h = WS - 2WL \sin\theta \tag{1}$$

where, WS is the wing spread and WL is the length of the segment P_1 - P'_1 or S_1 - S'_1. This length is 11.5 m in the net used in this experiment. θ is the angle that shows the difference in horizontal position between P_1 and P'_1 or S_1 and S'_1, and this value is fixed at ten degree, which is the mean value of geometric estimates based on the net plan when the wing spread ranged from 16 to 20 m. To estimate D_g, the shape of the fishing line is assumed to be a catenary curve. Here, the length of the fishing line, L_g and the length between P_2 and S_2, L_b are obtained as:

$$L_g = 2a\sinh\left(\frac{WS}{2a}\right) \tag{2}$$

$$L_b = 2a\sinh\left(\frac{D_g}{2a}\right) \tag{3}$$

The length of L_g ($P_1 - S_1$) and L_b ($P_2 - S_2$) were 33.6 and 14.6 m respectively in the study net. Hence, from equation 2 the parameter *a* can be estimated to a certain value of WS, and simultaneously, D_g is obtained by equation 3 using the value of *a* estimated.

Results

Trawl dimension

The 10 sec interval measurements of wing spread, trawl height and bottom clearance were averaged (Table 1). There was no difference in wing spread between both experiments; however, the trawl height was slightly higher at Exp. 2. The wing spread increased and the trawl height inevitably decreased as the scope ratio increased. The bottom clearance and its variation seemed to decrease when the scope ratio was 3.0 or more. The trawl door never contacted the bottom at a 2.5 scope ratio (Fig. 5), which would cause inconsistent footgear contact.

Fig. 6 shows the net mouth shape, estimated by the geometric method mentioned above, at intervals of ten seconds at different scope ratios in each experiment. It was clear that mouth shape was compressed horizontally by spreading of the wings with increasing scope ratio. There was no relationship between the horizontal variations of both upper sides and scope ratio, while the vertical variation decreased when the scope ratio was >3.0. At a 2.5 scope ratio, the averaged shape was slightly distorted, and a gap between the footgear and bottom appeared in each experiment. This tendency disappeared as the scope ratio increased.

Catch results

Walleye pollock *Theragra chalcogramma*, sculpins (*Hemilepidotus gilberti*, *Icelus cataphractus*, etc.), and flatfishes (*Pleuronectes herzensteini*, *Pleuronectes punctatissima*, etc.) were the main catch (Table 2). Walleye pollock, which mainly consisted of one year-class, occupied about 50% or more of the total catch in any tow. The total catch weight at a 2.5 scope ratio was less than that of other scope ratios in each experiment. The catch weight of walleye pollock at 3.0 and 3.5 scope ratios was considerably greater than at 2.5. On the other hand, the catch weight of sculpins and flatfishes, which are undoubtedly demersal fishes, was greater at a 3.5 scope ratio. In experiment 2, the catch weight of these species was 12.6 and 19.5 times greater than at a 2.5 scope ratio. Thus, change in scope ratio influenced species composition of the catch in each experiment ($p<0.01$, chi-square test for the catch weight data excluding Pacific cod).

Fig. 7 shows the length frequency of pollock from the 300 fish sampled in each tow. In any tow, most fish ranged from 8 to 20 cm, and the number of fish within this range accounts for 95% or more of the total catch, though a few larger fish were caught. Length frequency seemed to vary independently of scope ratio in experiment 1. In experiment 2, the length frequency at a 3.5 scope ratio was clearly different in modal length and shape of the distribution from that at 2.5 and 3.0, though frequency at 2.5 and 3.0 corresponded well. In both experiments, the modal and mean length at a 3.5 scope ratio were greater than those at other scope ratios (Fig.7, Table 3), and length frequency at 3.5 was statistically different from those of other scope ratios (Kolmogorov-Smirnov test, α=0.05).

Discussion

Trawl dimension and footgear contact

The trawl height decreased and width increased as the scope ratio increased, that is, mouth shape collapsed. This change in mouth shape was most notable at scope ratios between 2.5 and 3.0, while there was little difference between 3.0 and 3.5. Additionally, at a 2.5 scope ratio, the vertical movement in the head rope was greater than at other scope ratios, and contact between the footgear and the bottom was intermittent. At a 2.5 scope ratio, it is apparent that the trawl door never touched the bottom. Actually, this lack of contact by the trawl door at a 2.5 scope ratio was predicted by geometric calculations, when the shape of the trawl warp was a straight line under towing speed conditions of: 2 m/s, gear drag: 6.3 ton, total weight in water: 2.23 ton.

There were no great differences between trawl dimensions at 3.0 and 3.5 scope ratios, but the catch of flatfishes and sculpins increased at 3.5. This could indicate differences in clearance under the footgear between 3.0 and 3.5. However, we found that there was a margin of error in measurements from the depth recorder and SCANMAR sensors. It is necessary to use a bottom contact sensor[6,12,13] that can physically detect contact with the bottom to confirm that footgear is in contact with the bottom.

Relationship of scope ratio to catch of walleye pollock

The catch of walleye pollock increased significantly with increasing scope ratio. This was very apparent in experiment 2 where the difference in catch weight between 2.5 and 3.0 scope ratio more than doubled. All of the observed differences in catch rate may not be explained by the different scope ratios, as fish density targeted in each tow is not necessarily the same. However, it has been confirmed that footgear must have firm contact with the bottom to catch walleye pollock.[14] We therefore believe that differences in footgear contact are the main reason for the great increase in catch of walleye pollock. Walsh[15] confirmed that cod and flatfishes escaped through the gap between the footgear and bottom by using an auxiliary net installed under the main net body. Such gaps allow demersal fish to avoid entering the net but also walleye pollock, since they are known to school in high density in both the pelagic and demersal zones.

The length composition of the catch at a 3.5 scope ratio was slightly different from those at other scope ratios. We believe that there may be a bias in size distribution near the bottom, with larger individuals being more common near the bottom. Among adult fish, the larger individuals are often found quite close to the bottom.[14] However, in this study the one year class were the main catch, and the length range was narrow (10-20 cm), Therefore, it is necessary to observe fish shoals with an underwater camera to confirm whether there is a bias in size distribution of walleye pollock near the bottom.

Warp length in fisheries surveys

Scope ratios will be different according to the intention of the survey. The trawl operation is implemented to estimate fish density or to complete echo surveys. In the acoustic surveys, the trawl is used to obtain data on fish species and size composition, but the catch amount is not used for echo analysis. The zone within 0.5 m of the bottom, where fish cannot be detected by echo survey is popularly termed the acoustic “dead zone”.[16] Therefore, it might be meaningless to be concerned over footgear contact, since acoustic surveys cannot acquire data here near the bottom. However, it is necessary to stabilize trawl dimensions by contact of the trawl door with the bottom, since the trawl dimensions fluctuate when there is not contact. Our results suggest that the trawl door will remain in bottom contact at any depths when the scope ratio is set at 3.0 or greater as long as the warp shape doesn’t change. When the acquisition of useful data for echo integration near the bottom is necessary, as in the case of walleye pollock, the scope ratio might have to be restricted to 3.0 to maintain consistency between the echo data and catch data.

The need for quantitative bottom surveys for walleye pollock

Presently, there is no quantitative bottom survey used in the assessment of walleye pollock stocks in Japan. However, it will be necessary plan such surveys in the future to respond to an international standard.[17] Some points to be considered when the quantitative bottom trawl survey is executed follow.

Since trawl dimensions have a direct effect on swept area estimates, this is the most important factor when the CPUE from the trawl survey is utilized for estimating stock abundance.[18] Moreover, the footgear contact influences catch efficiency, as we have described. Therefore, the monitoring of trawl dimensions during survey should be indispensable, and the relationship between dimension and catch data must be understood. In this study, we have demonstrated that changing footgear contact parameters greatly influences the catch of walleye pollock as well as cod.[16] Engås and Godø showed that not only the footgear contact but also the bridle length was important as the factor that influences the catch.[19] Somerton,[20] however, reported the herding effect of bridles was not found in walleye pollock and pacific cod and Inoue et. al.[21] reported walleye pollock were unreactive to the net, as were cod[7]. In addition, Weinberg[22] reported that the capture efficiencies for pacific cod and walleye pollock were not related to fish length or trawl speed. These characteristics of walleye pollock will reduce the anxiety for quantitative trawl survey. However, we require further information on the influence of their vertical distribution and movement on catch.[9,23] These additional information is necessary to make trawl surveys for walleye pollock more successful regardless of the aims of the survey.

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Figure captions

Fig. 1 Location of the experimental area offshore of Kushiro, Hokkaio.

Fig. 2 Plan of the net used in the walleye pollock survey (JAMARC 99).

Fig. 3 Positions of devices used to measure trawl dimension and the definition of the net mouth.

Fig. 4 Schematics of the geometry of the head line and fishing line.

Fig. 5 The depth of the net and trawl door with elapsed tow time, as measured with the depth recorders in experiment 1.

Fig. 6 Net mouth shape at intervals of 10 sec. in each scope ratio, estimated by the geometrical method based on the data from the depth recorder and the scanmar sensors. Each dot and the line show the observed value and the averaged shape, respectively.

Fig. 7 Relative frequency distribution of walleye pollock (N=300).