Mesh Selectivity Curves of a Shrimp Beam Trawl for Southern Rough Shrimp *Trachypenaeus curvirostris* and Mantis Shrimp *Oratosquilla oratoria*

Tadashi Tokai,*1 Hiroshi Ito,*2 Yasuaki Masaki,*1 and Takeru Kitahara*3

(Received March 30, 1990)

The purpose of this work is to determine the mesh selectivity curves of a shrimp beam trawl for two shrimps, southern rough shrimp and mantis shrimp. A covered-net fishing experiment is carried out of a shrimp beam trawl with codends of six mesh sizes. The covernet has no effect on number, weight and size distribution of catch in codend in this fishing experiment. The respective mesh selectivities are estimated for the two shrimps. Through Tokai and Kitahara's method, we determine the mesh selectivity master curves for the two shrimps. The respective master curves for the two shrimps can give the mesh selectivity curves of a specified mesh size for them.

Small trawl fisheries exploit many small shrimps and depend greatly on them in the Seto Inland Sea. Southern rough shrimp *Trachypenaeus curvirostris* is the most important target species of small shrimps apart from kuruma prawn *Penaeus japonicus*. Small shrimps registered landings of 20,040 tons in 1981 or about 95 per cent of the total shrimp landings in the small trawl fisheries of the Seto Inland Sea.*4 In particular, a shrimp beam trawl fishery fished 74% of this shrimp catch in the small trawl fisheries. At the same time, the main species of fish concerned are finespotted flounder *Pleuronichthys cornutus*, Japanese flounder *Limanda yokohamae* and stone flounder *Karenius bicoloratus* etc., as well. The landings of flounders amounted to 7,532 tons in 1987.*4 Moreover, mantis shrimp *Oratosquilla oratoria* also is an important target species in addition to shrimps and flounders in the small trawl fisheries.

The shrimp beam trawl net has small-mesh codends, about 16.5–19.9 mm in stretched measure, in the Seto Inland Sea since its main target species is shrimp. Consequently, many juvenile flounders are caught in the shrimp beam trawl fishery and most of them are usually discared at sea, because they are considerably smaller than commercial size, or about 100 mm in body length. We found the annual amount of juvenile finespotted flounder discarded at sea to be about 200,000 in number (1 ton in weight) per a boat in Suo-nada, the western Seto Inland Sea.*6 We believe that the catching and discarding of these juveniles has a detrimental effect on future flounders stock. The importance of the discard effect on fishery resources has so far been emphasized in many other commercial fisheries, especially in shrimp fisheries (e.g., Saito*1 and Atkinson*2). Small shrimps and mantis shrimp under commercial sizes are discarded from the trawls immediately after sorting out the large sizes in the Seto Inland Sea.*3 Studies of mesh selectivities are necessary for reducing the amount of discard at sea.*1,4,5 The purpose of this work is to determine the mesh selectivity curves of a shrimp beam trawl.

---

*1 Nansei National Fisheries Research Institute, Hiroshima 739-04, Japan
*2 Japan Sea National Fisheries Research Institute, Niigata 951, Japan
*3 Department of Fisheries, Faculty of Agriculture, Kyoto University, Kyoto 606, Japan
for two shrimps, southern rough shrimp and mantis shrimp. Moreover, this paper attempts to examine effects of covernets on number, weight and size distribution of catch in codend.

Materials and Methods

We conducted a covered-net fishing experiment of a shrimp beam trawl in Suo-nada, the western Seto Inland Sea, on July 7-9, 1984. The mesh size of the used cover was 13.8 mm in stretched measure. The six codends used were of mesh sizes 16.5, 22.1, 25.1, 46.1 and 69.3 mm in stretched measure. Here, the mesh size is the average of ten mesh sizes sampled at random from the net after towing. The fishing gear and the towing conditions used were shown in Fig. 1 and Table 1 in the paper presented by Tokai et al.6) According to Fujiishi's proposal,7) the cover was 1.5 times larger than the codend in order to prevent the masking effect. The two fishing gears were towed at the same time and the duration of towing (30-60 min) was less than one-third of that of commercial fishing. The total number of hauls was 20. Two different codends with the same mesh size of 19.9 mm were used to examine an effect of covernet on catch; one being the covered and the other being the uncovered codend. These two gears were towed simultaneously and data necessary for this analysis were obtained from haul nos. 2 and 8.6)

In the i-th haul, after we had removed rubbish from the catch, we sampled one part of the catch at random on deck and recorded the ratio of the samples to the catch in weight, pi. The samples were classified into species. The number and wet weight of each species were recorded. Consequently, the respective estimates of catch number and weight, Nij and Wij, are given for the j-th species fished in the i-th haul by nij/pi and wij/pi. Here, nij and wij refer to sample number and weight of the j-th species in the i-th haul, respectively.

We measured the carapace length in 0.01 mm units with slide calipers for southern rough shrimp and body length at 5 mm class intervals by a card punching method for mantis shrimp. The total number of the measured shrimps was 14,027 for southern rough shrimp and 4,388 for mantis shrimp.

The mesh selectivity can be estimated for each length class by the ratio of catch in the codend to the sum of ones in the codend and the cover at the length class. The mesh selectivities thus estimated give the mesh selectivity curves of a specified mesh size for the two shrimps through Tokai and Kitahara's methods.9)

Results

Covernet Effects on Catch Number and Weight in Codends

Before going further, let us examine the effects of covernets on the catch in codend with the catch data obtained from haul nos. 2 and 8. The respective catches taken in haul nos. 2 and 8 consisted of 34 and 35 species including fishes and crustaceans. Of these species, we excluded the following species in examining the effect of covernet on catch number and weight caught in codends: the species of which the catch numbers were 1 both in covered codend and in uncovered one; and the species which contained extremely large individuals. Consequently, the catch

![Fig. 1. Relation between the logarithm of catch in uncovered and covered codends in number and weight (gram). Solid and open circles show catches in haul nos. 2 and 8, respectively. Solid line, regression line; dashed line, the regression line through the origin; dotted line, the line with the slope of 1 through the origin.](image-url)
numbers of 33 species and the catch weights of 32 species were available for the examination. The logarithms of catch numbers in the uncovered codend were plotted against those in the covered one, and the same analysis was performed on catch weight (Fig. 1). Both the plots seem to show linear relations. The slope and y-intercept of the two regression lines are 0.909 and 0.248 (correlation coefficient, $r=0.955$) for catch number; and 0.815 and 0.516 ($r=0.914$) for catch weight, respectively. Neither of the y-intercepts are significantly different from 0 at the level of 0.05. Moreover, the slope of the regression lines obtained through the origin are 0.815 ($r=0.943$) for catch number and 1.018 ($r=0.827$) for catch weight. Neither of the two slopes are significantly different from 1 at the level of 0.05.

It follows from the above t-tests that there is no significant difference in catches between the covered and uncovered codends both in number and in weight. In this experiment, therefore, the covernet has no effect on the catch numbers and weights of species caught in the covered codend.

**Covernet Effects on Size Distributions of Southern Rough Shrimp and Mantis Shrimp**

Fig. 2 shows the carapace length distributions of southern rough shrimp caught in haul nos. 2 and 8 every codend (A, uncovered and B, covered). As seen from these length distributions,
the codends employed here begin to catch the shrimp from 8 or 9 mm in length regardless of the covernet. In the length distributions, moreover, modes appeared at the nearly same length classes between the uncovered and covered codends in haul nos. 2 and 8. That is, a mode appears at the carapace length classes of 11 or 12 mm in haul no. 2; and there occur two modes at the length classes of 13 and 18 mm in haul no. 8. Thus, it is likely that the carapace length distributions are not so different between the covered and uncovered codends in the two hauls.

Fig. 3 shows the body length distributions of mantis shrimp fished in haul nos. 2 and 8 every codend (A, uncovered and B, covered). Fig. 3 indicates that the length distributions caught in the covered codend are not greatly different from the every other haul. Most of the caught shrimp are between 45 and 105 mm in length in haul no. 2 and between 65 and 115 mm in length in haul no. 8. In addition, both of the distributions are skewed to the left in haul no. 2 and most frequent at 66-70 mm length class, but are skewed toward large size classes in haul no. 8.

Let us compare the size distributions between the uncovered and covered codends every haul in detail. Certain length distributions of the covered codend seem to be slightly more skewed toward small size than ones of the uncovered codend (Figs. 2 and 3). According to Kolomogorov-Smirnov Two-sample test,10) however, there are no significant differences in any size distribution between the two codends at the level of 0.05. Consequently, it can be interpreted that the covernet has little influence on the size distributions of the two shrimps in this experiment. Therefore we neglect the effect of the covernet on size compositions of the two shrimps in the subsequent treatments.

**Mesh Selectivity Curve for Southern Rough Shrimp**

We calculated the mesh selectivities of 16.5, 19.9, 22.1 and 25.1 mm mesh sizes for southern rough shrimp every carapace length class (Fig. 4). Here, the mesh selectivities of 46.1 and 69.3 mm mesh sizes were almost 0 in the length range of 6 to 26 mm. In Fig. 4, the selectivities of each mesh sizes increase with length in certain length ranges, respectively. The respective selectivities of 16.5, 19.9, 22.1 and 25.1 mm mesh seizes reach 1 at the lengths of 13, 15, 17 and 19 mm.

Next, let us determine the mesh selectivity master curve by Tokai and Kitahara’s method.9) The lengths for the selectivities of 50 and 90% were plotted against mesh size in Fig. 5. The plots show good linear relations for both the selectivities. Now, let us denote the intersection of the two regression lines by \( m = m_0 \) and \( l = l_0 \), in which \( m_0 \) and \( l_0 \) are constants. Then the regression lines give \(-8.16\) and \(-4.60\) as estimates of \( m_0 \) and \( l_0 \), respectively. Using \( m_0 = -8.16 \) and \( l_0 = -4.60 \), we plot the mesh selectivities against \( R = (l-l_0)/(m-m_0) \) (Fig. 6). The mesh selectivities increase with increase in \( R \) and reach 1 at \( R \) of about 0.7 regardless of mesh size. Applying the cubic spline function11) to these plots gives...
Mesh Selectivity Curves of a Shrimp Beam Trawl

the master curve of the mesh selectivity as follows:

\[
S(R) = \begin{cases} 
-0.5004 + 4.791 R - 16.41 R^2 + 19.73 R^3 & \text{for } .304 \leq R < .460 , \\
35.62 - 210.8 R + 408.9 R^2 - 257.1 R^3 & \text{for } .460 \leq R < .586 , \\
-14.38 + 59.34 R - 76.30 R^2 + 32.68 R^3 & \text{for } .586 \leq R \leq .845 . 
\end{cases}
\]

Using this equation, we can obtain the selectivity curve of an arbitrary mesh size for southern rough shrimp.

Mesh Selectivity Curve for Mantis Shrimp.

This subsection treats the mesh selectivity curve for mantis shrimp in the same manner as in the preceding subsection. Fig. 7 shows the mesh selectivities of 16.5, 19.9, 22.1 and 25.1 mm mesh sizes every 5 mm body length class. The selectivity is nearly zero for 46.1 and 69.3 mm mesh sizes in the length range of 35 to 145 mm. In Fig. 7, the selectivities of each mesh size increase with length in certain length ranges although they fluctuate more or less at classes of small body length. The respective selectivities of 16.5, 19.9, 22.1 and 25.1 mm mesh sizes attain to 1 at the length classes of 60-65, 80-85, 90-95 and 100-105 mm.

Fig. 8 shows the plots of the body lengths for the selectivities of 50 and 90% against mesh size. The regression lines in Fig. 8 give 3.65 and 5.07 as estimates of \( m_0 \) and \( l_0 \) respectively. The mesh selectivities are represented as a function of \( R \), using the estimates of \( m_0 \) and \( l_0 \) de-
determined above (Fig. 9). The master curve thus
determined shows a sigmoidal pattern and rises
from 0 to 1 in the range of $R=2.0$ to about 4.0
irrespective of mesh size. The master curve
can be approximately represented by
\[
S(R) = \begin{cases}  
-0.9189 + 0.1677R - 0.9515R^2 + 0.03514R^3 
& \text{for } 1.05 \leq R < 3.34, \\
-13.90 + 9.768R - 2.132R^2 + 0.1548R^3 
& \text{for } 3.34 \leq R \leq 4.39.
\end{cases}
\]
(2)

Eq. (2) gives the selectivity curve of a specified
mesh size for mantis shrimp.

Discussion

In the preceding section, we compared the
numbers and weights for every species of catch
between the covered and uncovered codends.
Consequently, it was found that the covernet
had no significant influence on them in all of the
species examined. First, we will discuss the
masking effect of covernet in more detail.

Fujiishi\textsuperscript{7}) proposed 1.5 times the length of the
codend as a appropriate length of the cover for
preventing the latter from masking the former.
When he proposed it, however, he presented
little data on the masking effect of the covernet.
As stated above, there occurred no significant
masking effect of the covernet in our covered-
net fishing experiment. In our experiment, the
length of the used covernet was 1.5 times that of
the codend. This finding supports Fujiishi’s
proposal.

Next, we take up differences in the size dis-
tributions between haul nos. 2 and 8. For
southern rough shrimp, the carapace distribution
has only one mode in haul no. 2 but two
modes in haul no. 8 (Fig. 2). On the other
hand, the body length distribution of mantis
shrimp is skewed to the left in haul no. 2 but to
the right in haul no. 8 (Fig. 3). These
differences are probably due mainly to a slight
difference in the operating area between the hauls.
In examining the masking effect of covernet,
therefore, fishing experiments must be carried out
in the same area as much as possible.

Thirdly, let us discuss methods of examining the
masking effect of covernet. Parrish and Pope\textsuperscript{13})
used the analysis of variance technique to test
the significance of a difference in the lengths
of caught fishes between the covered and un-
covered hauls. Aoyama\textsuperscript{14}) indicated that the
masking effect of covernet is observed only in
the case of very small fishes on the basis of the
medians and standard deviations of their lengths.
Unfortunately, however, the above two methods
cannot be applied to size compositions which
show non-normal distributions. In fact, as
stated above, the size composition of southern
rough shrimp is a skewed distribution in haul
no. 2 and the bimodal ones in haul no. 8. Now,
the present paper has used Kolomogorov-Smirnov
Two-sample test to examine the significance of
a difference between the two size distributions.
This is a nonparametric test and calculates a
difference in the entire size distributions of the
two samples.\textsuperscript{10)} This method is therefore more
powerful and useful for examining the masking
effect of the covernet.

Finally, we attempt to compare the mesh se-
lectivity curve determined here with the one
reported so far by Fujiishi.\textsuperscript{7}) No mesh se-
lectivity curve has been determined for mantis
shrimp. We will therefore deal only with the
mesh selectivity curve for southern rough shrimp.
The mesh selectivities determined by Fujiishi
are expressed as a function of body length, whereas
$l$ in Eq. (1) is carapace length. For comparison,
length $l_c$ (in mm) is converted into body length
$l_b$ (in mm) by the following relation:
\[
l_b = 11.02 + 2.871 l_c
\]
(correlation coefficient $r=0.976$).

Thus, Eq. (1) can be represented as a function of
$l_b$ instead of $l_c$ (Fig. 10).

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{fig10.png}
\caption{Comparison between the mesh selectivity
curves of 23 mm mesh codend. Solid line shows
the mesh selectivity curve based on the master
curve for southern rough shrimp in this paper.
Solid and open circles show mesh selectivities
for southern rough shrimp $T.\ curvirostris$ and
tora velvet shrimp $M.\ acclivis$ respectively
determined by Fujiishi.\textsuperscript{7)}
\end{figure}
Fujishi\textsuperscript{7} determined the mesh selectivity of 23 mm mesh codend for southern rough shrimp and tora velvet shrimp \textit{Metapenaeopsis acciivis}, which resemble each other in shape and size. His mesh selectivities for the two shrimp are remarkably similar to each other, and increase from 0.2 at 37.5 mm body length with body length and reaches 1 at 67.5 mm body length (Fig. 10). As seen from Fig. 10, these mesh selectivities seem to be slightly lower in the high selectivity range than our mesh selectivity curve of 23 mm mesh codend calculated from the master curve for southern rough shrimp. Taking into account differences of the operating conditions, however, it should be interpreted that his mesh selectivities show a relatively good agreement with ours as estimated from the master curve for southern rough shrimp. The above statements support at least the master curve determined for southern rough shrimp.

The present paper determined the mesh selectivity master curves of the beam trawl for southern rough shrimp and mantis shrimp. As stated previously, this study was undertaken for the purpose that the amount of the two shrimps discarded was made as small as possible. Accordingly, it is necessary to estimate an appropriate mesh size for decreasing discards of the two shrimps. A main subject of the following paper is to determine an appropriate mesh size of the shrimp beam trawl, using these master curves.

\textbf{Acknowledgments}

We wish to express our sincere thanks to Messrs. Y. Kamijyou, Y. Yokomatsu and K. Andou, Oita Prefectural Fisheries Experimental Station, and R. Watanbe, the captain of Shinrkimaru, for assistance in conducting the fishing experiment.

\textbf{References}

5) R. Jones: Mesh regulations in the demersal Fisheries off the South China Sea area. Regional, Manila, 1976, pp. 79.