Size selectivity of codend for small trawl using the trouser trawl method

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Abstract

The main target species for small beam trawl fisheries operating in the costal waters of Shimonoseki is Shrimp. For this reason, codend mesh opening needs to be small to catch Shrimp. Excess bycatch is a problem. One method to reduce bycatch is regulating mesh size. When regulating mesh size to reduce bycatch, it is important to know the exact mesh selectivity of the codend currently being regulated. This study was carried out to learn about codend mesh selectivity (mesh opening: 27.6mm) using the trouser trawl method. In the experiment, the trouser trawl we used was equipped with bifurcated codends. The mesh opening of the bifurcated codends were 27.6mm and 17.7mm, respectively. We carried out the experiment in commercial fishing grounds in coastal waters off Shimonoseki on December 18, 2010. The value of 50% selection length of Lizard fish and Shrimp obtained in this experiment was judged to be a little smaller than the value of the cover net method, based on past knowledge. In future, it will be necessary to carry out the cover net method with trawls as used in this experiment.

1. Introduction

Many small beam trawlers operate in the coastal waters west of Shimonoseki in Yamaguchi Prefecture, around 20–50 meters deep, where the sea bottom is sandy or muddy. The main target species for small beam trawlers is whiskered velvet Shrimp (*Metapenaeopsis* spp.). Other target species for this fishery are Cinnamon flounder (*Pseudorhombus cinnamoneus*), Lizard fish (*Saurida* spp.) and so on. The fishing season lasts all year around, except for a short break. Fishermen usually conduct about 4 to 5 tows with trawls each day. Each tow is two hours. Fishing boats under 5 tons are used. Catches for small beam trawls in Shimonoseki were 347 tons in 2002. Subsequently, catches for this fishery continue to decrease every year, amounting to 206 tons in 2012[1]. Small trawls use small-sized mesh at the codend; accordingly, many kinds of juvenile fish are caught in the codend. This is why many fish under commercial size are discarded on the decks of fishing boats.

One factor believed to be decreasing these landings is the catching of many juvenile fish under marketable size. One method of limiting the catch of juvenile fish is using a larger-sized mesh on codends. Many experiments on mesh selectivity of codends have been carried out in the past [2, 3]. Almost all of these experiments used the cover net method. The cover net method makes it easy to calculate mesh selectivity. However, the results may be affected by the masking effect. Thus, it is possible that the resulting mesh selectivity is underestimated. On the other hand, the results of comparative fishing experiment methods are not influenced by the masking effect. The trouser trawl method is one such comparative fishing experiment method, and can be implemented comparatively easier than the other comparative fishing experiment methods.

In this study, we attempt to calculate the mesh selectivity of codends (mesh opening: 27.6mm) for small beam trawls operating in coastal waters off Shimonoseki using the trouser trawl method.

2. Materials and methods

2-1 Main net size using trouser trawl method

The trouser trawl method uses a normal trawl net equipped with bifurcated codends. The lengths of the trawl net and codends were 20m and 5m, respectively. Mesh opening of the bifurcated codends were 27.6mm and 17.7mm, respectively (Fig.1). The mesh opening of codends for small beam trawls operating in the coastal waters of Shimonoseki is 27.4mm, according to current regulations for fisheries in Yamaguchi Prefecture. In this study, the 27.6mm mesh opening codend was the test codend and the 17.7mm mesh opening codend was the control codend.

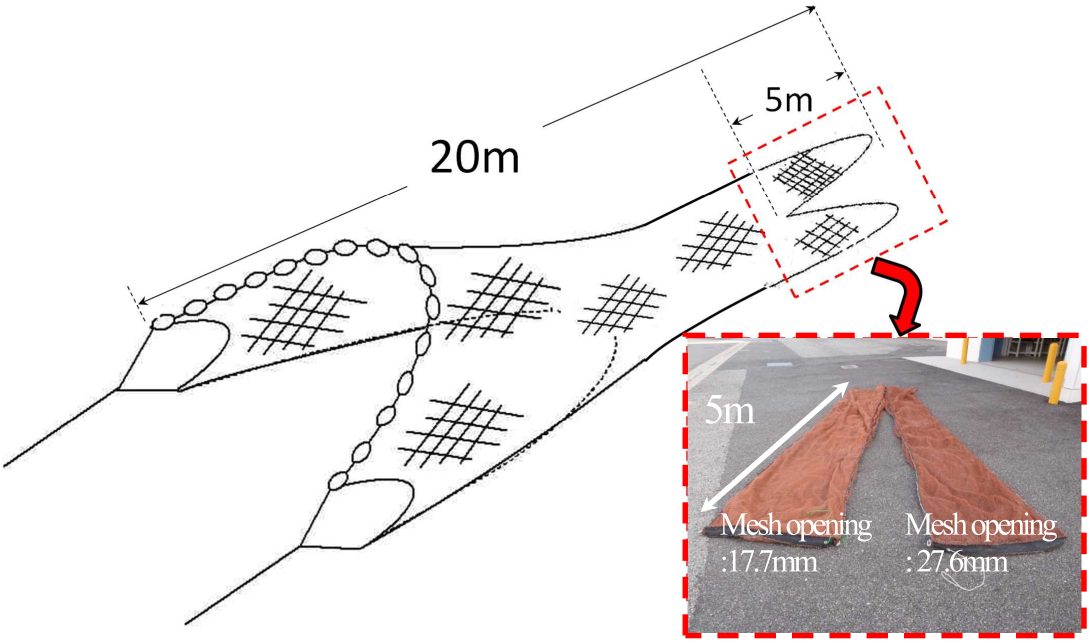

Fig. 1. Size of trouser method net.

2-2. Experimental research method

We carried out this research experiment in commercial fishing grounds in the coastal waters off Shimonoseki on December 18, 2010. We chartered the beam trawler *Dai San Kaikomaru* (2.9 t) belonging to the Izaki Branch of the Yamaguchi Prefecture Fisheries Cooperative Association. A total of four tows were conducted during the research experiment. Tows were conducted for 90 minutes during both day and night in areas with depths of 20 to 30 meters (Table 1). The catch from each tow was sampled from both codends (test and control codend mesh openings of 27.6mm and 17.7mm, respectively) on board the fishing boat and brought back to the laboratory for follow-up measurement of length and weight. Body length was measured in millimeters on a fish body measuring board or in 0.1 mm increments with a digital caliper. Total length (TL) for fish, carapace length (CL) for Shrimp, and maximum carapace width (CW) for small crabs were measured. An electronic scale (minimum readout 0.01 g) was used to measure body weight.

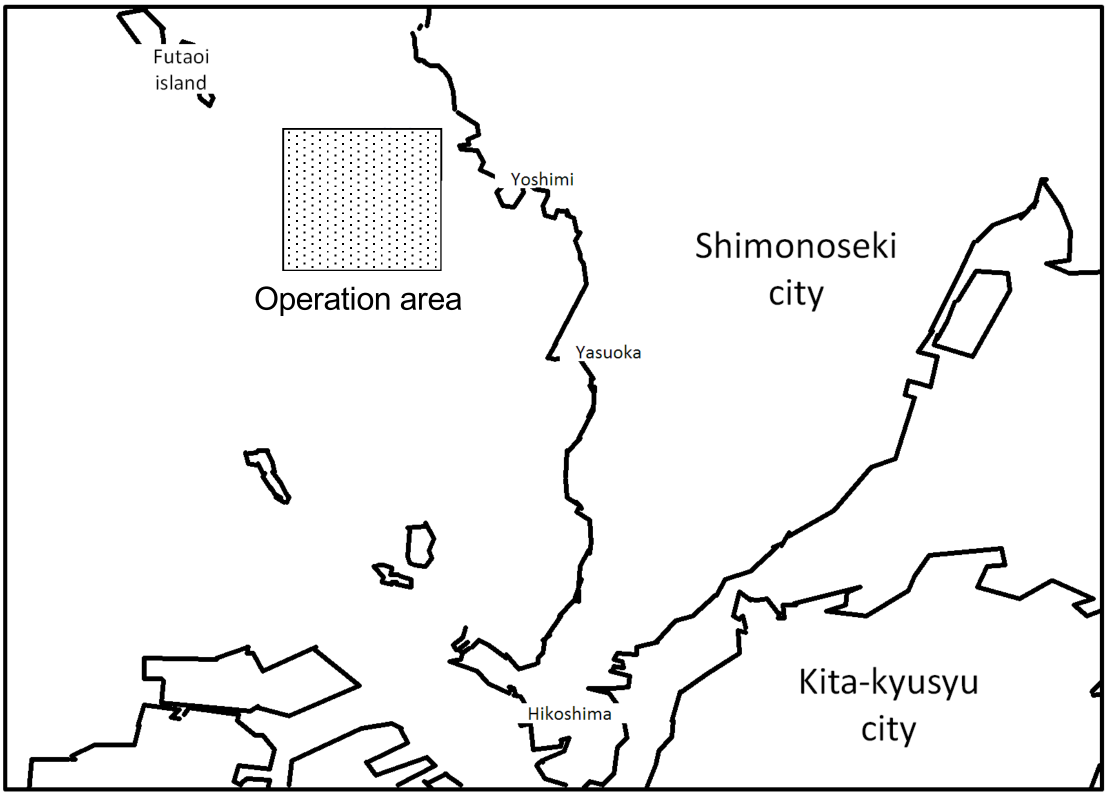

Fig. 2. Operation area.

Table 1 Overview of each tow during experiment

St	Towing time		Towing hours	Towing speed	Towing distance	Depth (m)	
	Start	Finish	(min)	(knot)	(m)	Start point	Finish point
1	15:08	16:37	89	1.8	4874	28	24
2	17:00	18:30	90	1.6	4581	24	28
3	18:52	20:23	91	1.7	4776	33	24
4	20:45	22:15	90	1.5	4289	24	33

2-3 Method of data analysis for size selectivity of codend

The advantages of the trouser trawl method are that can be implemented relatively more easily than the other comparative fishing experiment methods and it allows us to avoid the influence of the masking effect. On the other hand, the disadvantage of this method is that we need to assume that the number of fish entering the two types of codend (the control codend and the test codend) is approximately the same. If there is a difference in the number of fish entering the control codend and the test codend, selectivity would change to include this difference. This would result in incorrect selectivity.

However, this disadvantage can be resolved by introducing the SELECT (Share Each LEngths Catch Total) method[4]. Using the SELECT method, the select separation ratio ϕ_l is defined by the formula below:

$$\phi_l = \frac{n_{Ll}}{n_{Sl} + n_{Ll}} \qquad (1)$$

where n_{Sl} and n_{Ll} are the catch numbers of the control codend and test codend, respectively.

In the SELECT method, Millar has prepared two models that can be applied to cases where there may be either different or the same probabilities of fish entering the test codend and control codend, respectively. One is the equal split model. The other is the estimated split model.

The equal split model is based on the assumption that the numbers of fish entering the test codend and control codend, respectively, are the same. In this case, the encounter probability to the test codend is 0.5. As a function of l, ϕ (l) is described by the following equation:

$$\phi(l) = \frac{n_L(l)}{n_S(l) + n_L(l)}$$

$$= \frac{0.5 \cdot r(l) \cdot N_l}{0.5 \cdot N_l + 0.5 \cdot r(l) \cdot N_l}$$

$$= \frac{r(l)}{1 + r(l)} \qquad (2)$$

where $r(l)$ is the mesh selectivity of the test codend and N_l is the number of fish entering the trawl net mouth.

The estimated split model is based on the assumption that the probabilities of fish entering the test codend and control codend, respectively, are different. $\phi(l)$ is described by the following equation:

$$\phi(l) = \frac{n_L(l)}{n_S(l) + n_L(l)}$$

$$= \frac{p \cdot r(l) \cdot N_l}{(1-p) \cdot N_l + p \cdot r(l) \cdot N_l}$$

$$= \frac{p \cdot r(l)}{(1-p) + p \cdot r(l)} \qquad (3)$$

where p is encounter probability to the test codend.

In equation (3), $r(l)$ is calculated by the following logistic function:

$$r(l) = \frac{\exp(a + bl)}{1 + \exp(a + bl)} \qquad (4)$$

where a and b are parameters of the logistic function for the mesh selectivity curve of the test codend.

In this study, the model that produced a selectivity curve most closely resembling the plots of $\phi(l)$ in the catch data was selected from among the proposed models using the Akaike Information Criterion (AIC) model selection. The encounter probability to the test codend, p and logistic function parameters (a, b) in the model were estimated using the maximum likelihood method.

The log likelihood function to be maximized for parameter estimation was as follows:

$$\ln L = \sum_{l}\left[n_{Ll}\log_e \phi(l) + n_{Sl}\log_e(1-\phi(l))\right] \quad (5)$$

The Solver function in Microsoft Excel was used to maximize the log likelihood function [5].

3. Results and discussion

3-1 Catch data from fishing experiments

In the fishing experiments, the catch numbers of fish, Crustacean, Cephalopods and others were 724, 195, 133, and 13, respectively. Among them, the most numerous species was Lizard fish with 301 individual fish caught. The second-most numerous species was Silver croaker (*Pennahia argentata*) with 110. The third-most numerous caught was Cinnamon flounder with 108. The fourth was Shrimp with 105. The fifth was sea bream (*Pagrus major*) with 86. In this paper, we have analyzed the top four species measured in total catch of number: Lizard fish, Silver croaker, Cinnamon flounder, and Shrimp. The total catch of these top four species accounts for 59% of the total catch number. The top 3 caught rates for St.1 was 86%. The top 4 caught rates were 77% for St.2, 71% for St.3, and 52% for St.4 (Fig.3.).

3-2 Body length composition of top four species

Body length composition of the top four species was obtained from the catch data pooled in all four hauls for the 27.6mm mesh opening codend and the 17.7mm mesh opening codend, respectively (Fig.4.).

The mode in TL distribution of the Lizard fish caught in both codends (27.6mm mesh opening and 17.7mm mesh opening) was in the 140–160mm class, while the TL range was 60–320mm for both codends (27.6mm mesh opening and 17.7mm mesh opening).

Shrimp were caught within a CL range of 6–24mm for the 17.7mm mesh opening codend and 8–26mm for the 27.6mm mesh opening codend. Modes in CL distribution of Shrimp caught in the 27.6mm mesh opening codend and the 17.7mm mesh opening codend were in the 10–12mm class and the 14–16mm classes, respectively.

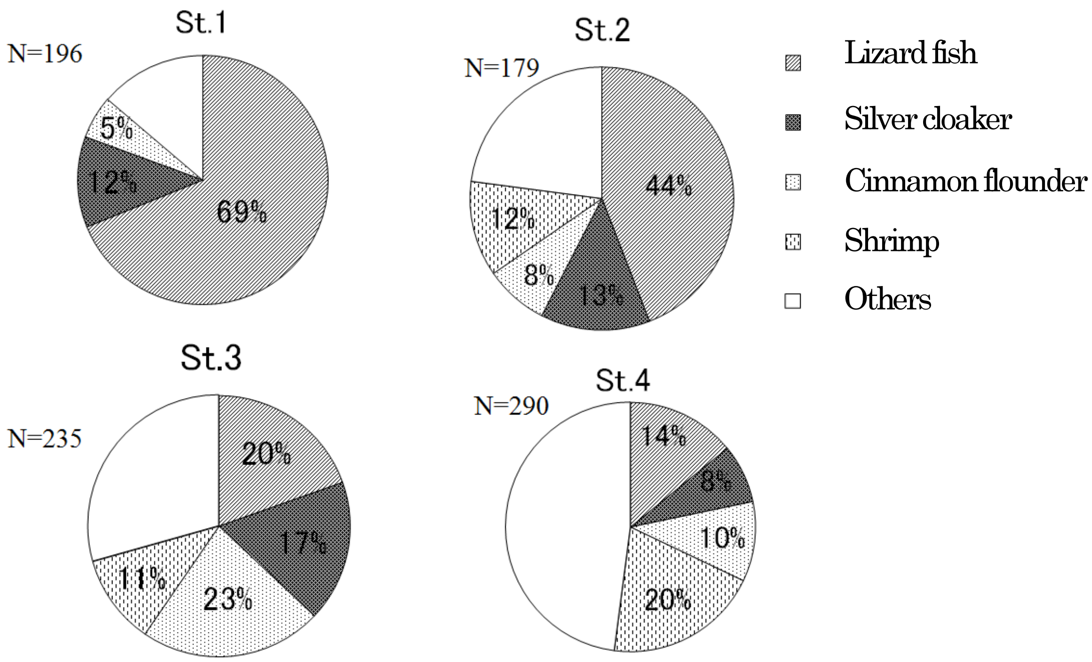

Fig.3. Catch composition of top four species.

The range of TL for Cinnamon flounder was 60–260mm for the 27.6mm mesh opening codend and 60–240mm for the 17.7mm mesh opening codend. The mode in TL distribution of Cinnamon flounder caught in both codends (27.6mm mesh opening and 17.7mm mesh opening) was in the 80–100mm class. 83% of all catch captured in the

27.6mm mesh opening codend was in the 60–80mm and 80–100mm TL classes. 56% of all catch captured in the 17.7mm mesh opening codend was in the 60–80mm and 80–100mm TL classes. Other body length classes were less than 5 individuals in both codends.

Silver croaker was caught within a TL range of 80–240mm for the 27.6mm mesh opening codend and 20–160mm for the 17.7mm mesh opening codend. The mode in TL distribution of Silver croaker caught in both codends (27.6mm mesh opening and 17.7mm mesh opening) was 100–120mm. 83% of all catch captured in the 27.6mm mesh opening codend was in the 80–100mm and 100–120mm TL classes. 75% of all catch captured in the 27.6mm mesh codend was in the 100–120mm TL class. 67% of all catch captured in the 17.7mm mesh opening codend was 100–120mm TL class. Other total length classes were less than 5 individuals in both codends.

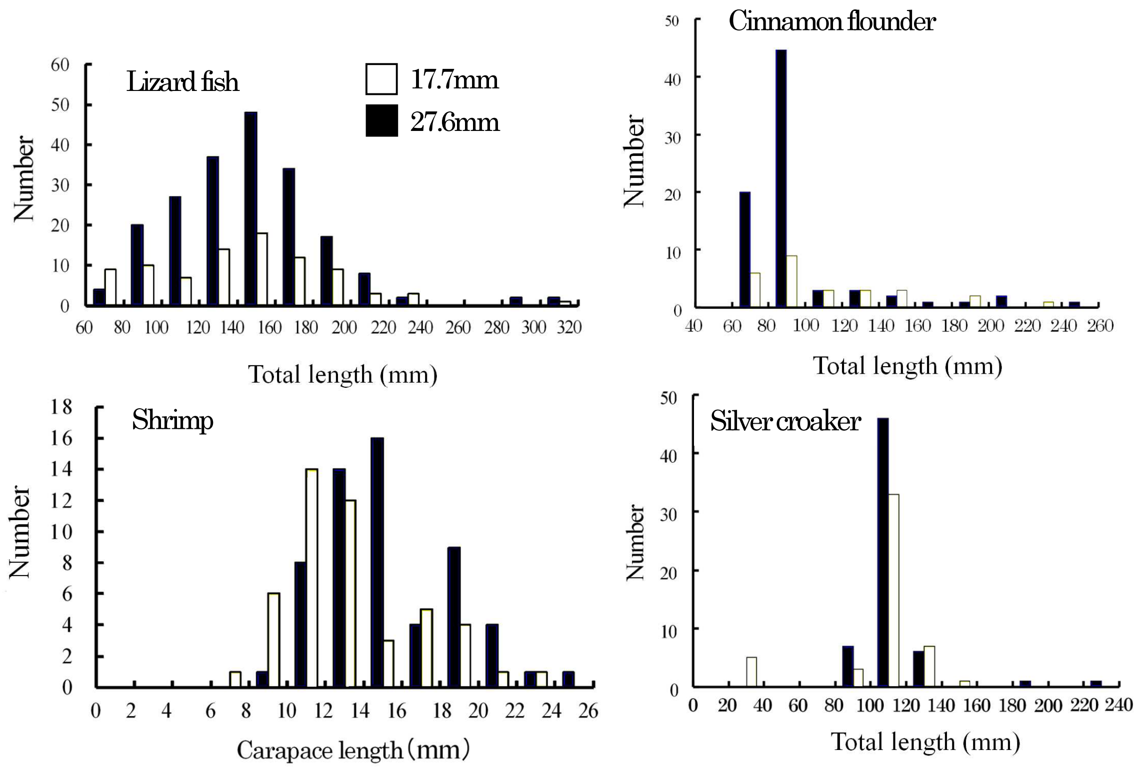

Fig.4. Body length composition of four species.

3-3 Estimated curves of the select separation ratio

In this study we considered four species, for which we obtained body length composition and calculated the select separation ratio ϕ_l, then applied the equal split model and estimated split model of the SELECT method. Subsequently, the parameters of the SELECT model were estimated using the MS Excel solver function. In this paper, the parameters for Silver croaker and Cinnamon flounder could not be converged using the SELECT method; thus, the select separation ratio ϕ_l fitted to the models for Lizard fish and Shrimp are shown in Figs. 5 and 6.

Lizard fish: The select separation ratio ϕ_l values for Lizard fish showed a sigmoidal increase from 0.3 to 0.7, with increasing TL from 80 to 140 mm, which was almost constant at 0.7 for TL>140mm. The AIC value selected the estimated split model (Table 2). The encounter probability of the estimated split model was larger than 0.5. The reason for the large catch of Test codend is that the mesh size of the test code is larger than the mesh size of Control codend. If the mesh size of the codend is large, it is considered that the catch has increased as the water current is larger than it is in the smaller mesh size.

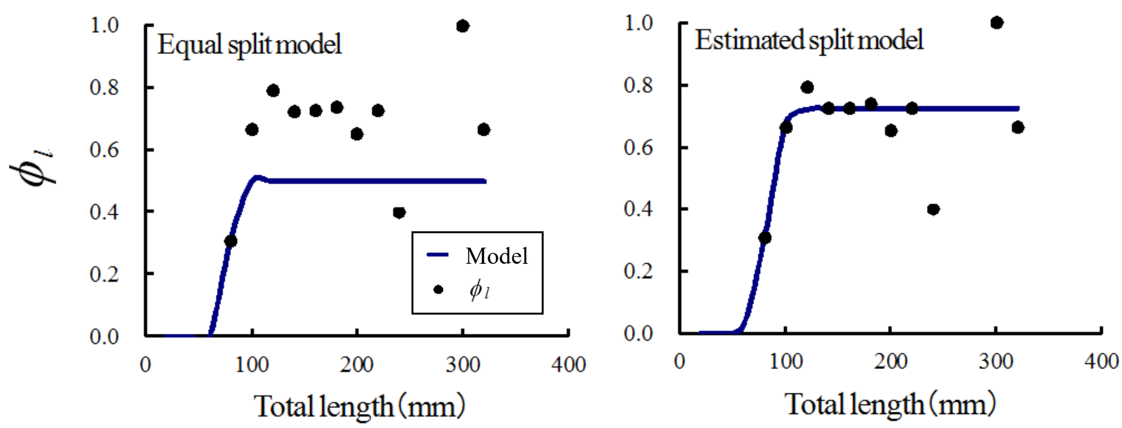

Fig.5. Select separation ratios and estimated curve by each models for Lizard fish.

Shrimp: The select separation ratio ϕ_l values for shrimp showed a sigmoidal increase from 0 to 0.8, with increasing CL from 8 to 16 mm, which were from 0.4 to 1.0 for CL>16mm. However, select separation ratio ϕ_l values for CL over 20 mm were calculated using a number of individuals of 5 or fewer, and reliability is thus low. The AIC value selected the estimated split model (Table2). As in the case of lizard fish, the encounter probability of the estimated split model was larger than 0.5.

As in the case of lizard fish, the mesh size of the test codend is larger than control codend. Then, it is considered that the catch has increased as the water current is larger in the large mesh size of test codend than in the small mesh size of control codend.

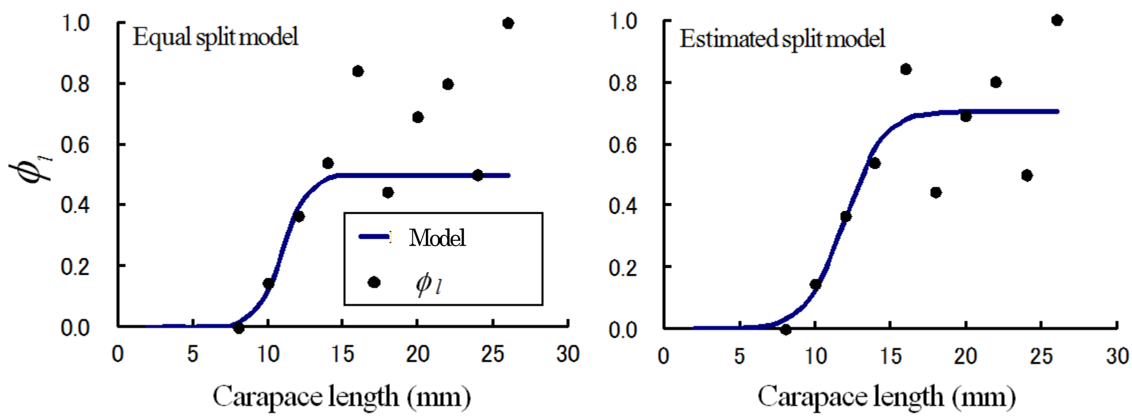

Fig. 6. Select separation ratios and estimated curve by each models for Shrimp.

Table 2 Parameters and AIC values estimated using the SELECT method

	Lizard fish		Shrimp	
	Equal	Estimated	Equal	Estimated
p	0.50	0.73	0.50	0.71
a	-65.4	-10.3	-12.8	-9.85
b	0.81	0.11	1.22	0.79
Log likelihood	-46.0	-19.3	-18.1	-13.7
AIC	95.9	44.6	40.3	33.5

3-4. Estimated selectivity for test codends using the SELECT method

The selectivity curves estimated by the estimated split model are shown in Fig.7. Here we compared the selectivity curves for Lizard fish and Shrimp calculated by the cover net method, which was obtained from past knowledge [6]. The 50% selection length and selection range (S.R.) of Lizard fish and Shrimp calculated by the trouser trawl method which resulted from this current experiment as well as the cover net method which was from previous knowledge are shown on Table 3. The $r(l)$ values for shrimp showed from 0 to 1.0, with increasing CL from 8 mm to 20 mm at both methods

On the other hand, the $r(l)$ values of Lizard fish were from 50 to 140 mm using the trouser trawl method and from 80 to 140 mm using the cover net method. The 50% selection length of Shrimp estimated by the trouser trawl method and the cover net method were almost the same at 12 mm and 13 mm respectively. In contrast, the 50% selection length of Lizard fish differed between 90 mm and 103 mm (Table 3). The mesh size of the test codend of the trouser trawl method used in this experiment was larger than the mesh size of the test codend using the cover net method from past knowledge. Thus, it is estimated that the 50% selection length and selection range of the selectivity obtained using the trouser trawl method are larger than the values using the cover net method. However, the values using the trouser trawl method and the cover net method were equivalent for Shrimp, while for Lizard fish, the values using the trouser trawl method were demonstrably smaller than the values using the cover net method. The size selectivity of Lizard fish is believed to be have been affected by the lack of catch of small individuals (<80mm) in this experiment. The results obtained by the cover net method in past experience may have differed from this current experiment in aspects such as towing time, towing speed, size of codends, and quantity of catch. These factors are believed to affect the results of mesh selectivity. In the future, in order to verify the accuracy of the mesh selectivity required, it is necessary to compare the results obtained using the cover net method with the fishing gear used in this current experiment. By analyzing the results using the trouser trawl method with the SELECT method, we were able to clarify that these can be obtained without much difference from the results obtained by the cover net method.

Table 3 Estimates of 50% selection length and selection range values [6]

	50% selection length		Selection range	
	Trouser trawl method	Cover net method	Trouser trawl method	Cover net method
	Mesh opening: 27.6mm	Mesh opening:25.0mm	Mesh opening: 27.6mm	Mesh opening:25.0mm
Lizard fish (Total length)	90mm	103mm	19mm	17mm
Shrimp (Carapace length)	12mm	13mm	2.8mm	3.2mm

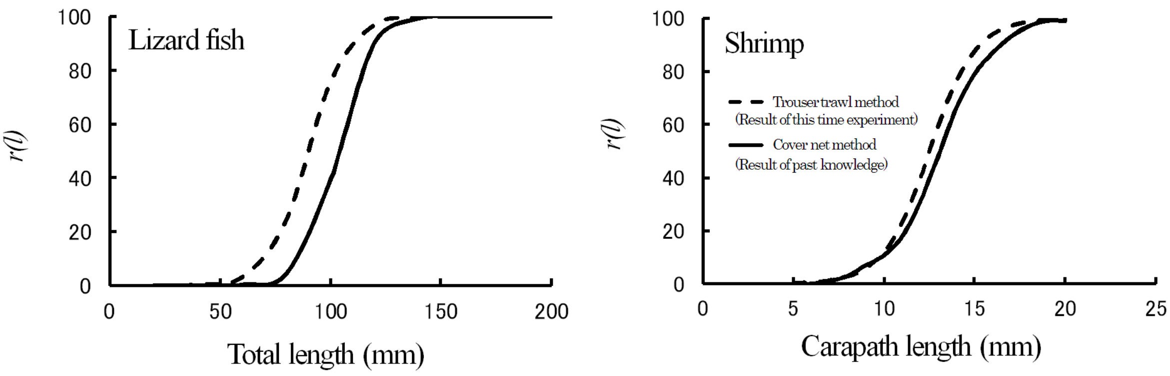

Fig. 7. Selectivity curves by the trouser trawl and the cover net methods[6].

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