Size selection and exploitation pattern of diamond mesh codends with different mesh sizes in demersal trawl fishery for banded scad (*Caranx (Atule) kalla*) in the South China Sea

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Abstract

Size selection and exploitation pattern of diamond-mesh codends with different mesh sizes, 25 to 54 mm, for demersal trawl fishery targeting banded scad (*Caranx (Atule) kalla*) was tested and compared using the covered codend method in the South China Sea. Our results demonstrated that the selective parameters, L50 (50% retention length) and SR (selection range), would increase as the mesh sizes of codends increase, and the confidence intervals in these parameters became relatively wider when mesh sizes increasing to 40 mm. The results of exploitation pattern showed that catch efficiency of codends would decrease when the mesh sizes increase. Considering compromise of protecting juvenile fish and the profitability of fishermen, the codend with 30 mm mesh size would be the best choice to target banded scad among all tested codends. Our study will be beneficial to the fishery management in the studied area.

Keywords:

Size selection, exploitation patter, diamond mesh codend, banded scad, *Caranx (Atule) kalla*, South China Sea

1. Introduction

Banded scad (*Caranx (Atule) kalla*) is a commercially important fish species in the South China Sea (SCS) (Chen and Jiang, 1990; Chen et al., 2016). It is one of the most important target species of demersal trawl fisheries, such as otter board trawl (Wang et al., 2010; Wang et al., 2016). Due to its characteristic of small body size, banded scad is also a main bycatch species of the shrimp trawl fisheries (often beam trawl) in the SCS (Yang et al., 2017).

The fisheries resources of most traditional fish species have been overexploited in the SCS (Wang and Yuan, 2008), which raised concerns about the situation of small-sized fish, like banded scad. A recent study by Zhang et al. (2020) demonstrated that banded scad was also under great fishing pressure and the resource of this species was even depleted in some important fishing grounds. They contributed the decline of resource of banded scad to several causes, such as the loss of natural habitats, pollution and overfishing. However, they failed to analyze the exploitation pattern, which depends on the selectivity of the gears used and on the extent to which particular size classes are targeted, of the banded scad. Poor selective properties of fishing gears, especially in trawl codends, might be the greatest contribution to decline of banded scad resource in the SCS. For instance, Yang et al. (2017) conducted a two-year catch composition survey for shrimp trawl fishery in the SCS, and showed that more than 39% (in number) of banded scad caught were juvenile fish.

At present, trawl fisheries in the SCS can be classified into fish trawl fishery and shrimp trawl fishery based on their main target species. The minimum mesh size (MMS) regulations differed between these two trawl fisheries. The shrimp trawl fishery is subjected to a 25-mm MMS in the diamond-mesh codend, whereas the MMS is 40-mm for the fish trawl fishery. Despite the fact that these MMS regulations have been formulated and implemented since 2014, very little study has been conducted to investigate their effectiveness. Lack of knowledge about the selective properties of codends with legal mesh sizes to their target species might impact the compliance of the MMS regulations. In particular, only Yang et al. (2018) studied the size selectivity of codends with two different mesh sizes, 25 and 30 mm, for banded scad in shrimp beam trawl fishery of the SCS. Their results demonstrated that the selectivity of the 25-mm diamond-mesh codend was very poor, and when the mesh size increased to 30 mm the selectivity was improved. However, considering the minimum conservation reference size (MCRS) of banded scad (63.5 mm total length), the selective properties of the 30-mm codend was still unsatisfied, due to the L50 of banded scad was smaller than its MCRS value. The implications of these results are that the mesh size of codend should be further increased to improve size selectivity. Because some recent studies of selectivity have proven that increasing mesh size is one of the easiest ways to improve size selectivity (Fry et al., 2016; O'Neill et al., 2020; Kennelly and Broadhurst, 2021). However, to what extent the mesh size should be increased to have good selective properties of codends for banded scad in the SCS is a question to be addressed.

In addition to the size selectivity of a specific fishing gear, it is relevant to investigate how applying this gear would affect the exploitation pattern in the commercial fishery. Estimation of exploitation pattern indicators can enable to assess whether the fishing gear is well suited for a certain fishery. This approach has been widely used in selectivity studies (Wienbeck et al., 2014; Brinkhof et al., 2020; Cheng et al., 2021; Herrmann et al., 2021). For the demersal trawl targeting banded scad, however, there is no study address the exploitation pattern. Specially, there is no scientific work has been done to estimate how applying the codends with different mesh sizes, especially the legal mesh sizes (25 and 40 mm), would affect the exploitation pattern for banded scad in the SCS.

To address the issues mentioned above, the main objective of this study was to investigate the size selection and exploitation pattern of codends for banded scad in the SCS. We focused on the following research questions:

1) To what extent is the size selection and exploitation pattern of the legal 25 mm and 40 mm codends satisfactory of banded scad?

2) Can the size selection and exploitation pattern for banded scad be improved by increasing the mesh sizes of the codend?

2. Materials and Methods

2.1. Sea trials

Sea trials were carried out onboard a commercial trawler, named "Guibeiyu 96899" (280 kW, 38 m), in October 2019. The fishing grounds located in the Beibu Gulf of the northern SCS

(Fig. 1). To make sure that the experimental fishing was identical to the commercial fishery, hauling speed and duration were mainly kept at 3.5 knots and 2 h which was the commercial fishing level. During the sea trials, the experimental fishing was conducted day and night continually, which was typical for the commercial fishery.

2.2. Fishing gear and experimental set-up

The fishing vessel onboard equipped with a double-rigged trawl system, in which two identical trawls, located in the port and starboard, could be hauled and retrieved by the same vessel simultaneously and separately (Fig. 2). They all had a fishing circumference of 860 meshes, with a mesh size of 45 mm, and a total stretched length of ~33 m. The mesh size was 45 mm in the wings and 30 mm in the extension. The length of headline was 28 m, and the length of foot-rope was 36 m. Two identical sets of trawl doors, made of wood and steel with a dimension of 1.90×0.83 m (length×width), were used to spread each trawl. During commercial fishing of this trawl, the vertical height of headline was mainly 1.5 m, and the spread distance of otter boards was about 15 m.

We applied the commercial fishing gears except for the codends, of which six different mesh sizes (inside stretched length), 25 to 54 mm, were designed. All the tested codends were designed based on the dimension of the commercial codend, which had circumference of 220 meshes with 25 mm size and a total stretched length of 4.8 m. The major changes were the mesh sizes used. However, to neutralize the potential bias of the circumference to the experiment, the mesh number reduced as the mesh sizes increased for the tested codends. Based on the mesh size used, we termed these codends as D25, D30, D35, D40, D45 and D54, respectively (Table 1, Fig. 2). The covered codend method was used for the experimental fishing with the recommendation of Wileman et al. (1996). In order to avoid the masking effect, 12 kites made of waterproof canvas (He, 2007; Grimaldo et al., 2009) were equipped in the front, middle and back part (potential catch accumulation zone of codend) of the cover. Before the formal experiments, two underwater video recording systems (GoPro HERO 4 BLACK Edition) were used to check whether the cover would mask the tested codend.

As the fishing vessel was able to haul two trawls simultaneously, we arranged three pairwised tests: D25 vs. D30, D35 vs. D40 and D45 vs.D54. Using the covered codend method mentioned above, one pairwised test was conducted at a time for several hauls then turned to another pairwised test. To remove the potential bias, we made sure that fishing procedure of the two trawls was conducted simultaneously. After the retrieval of the tested gears, catches from each compartment, codend and cover, were processed separately for each codend. All catch of banded scad were collected, sub-sampled (if needed), and frozen for length measured in the laboratory. Once in the laboratory, total length of all banded scad collected were measured to the nearest millimetre, providing count number of catch in each compartment, cover and codend, for further selectivity analysis.

2.3. Data analysis and parameter estimation

Analysis of each codend for the specific species was conducted separately using the method described below. For each tested codend, the experimental design enabled to analyze catch data as binominal data, whereby fish either were retained by the cover or the codend. The catch proportion (probability), of a given fish with length l by a specific codend in haul j was expressed as $r_j(l)$. The value of $r_j(l)$ can be calculated by the catch number of the codend and the total number. For the same codend, however, the value of $r_j(l)$ would be expected to vary between hauls (Fryer, 1991). In the present study, our main interest was the length-dependent values of $r\ (l)$ averaged over hauls, because this would provide information about outcomes for size selection process of using a specific codend in the fishery. Thus, it was assumed that size selective performance of the tested codend in the experiment was representative of how the codend would perform in a commercial fishery (Millar, 1993; Sistiaga et al., 2010; Herrmann et al., 2016a).

We used $r_{av}(l)$ to represent the estimation of the average size selection by pooling data from all hauls (Herrmann et al., 2012). A parametric model was tested for $r_{av}(l)$, where v is a vector consisting of the parameters of the model. The purpose of this analysis is to estimate the values of parameter v that make experimental data (averaged over hauls) most likely to be observed, by assuming that the model is able to describe the data sufficiently well. Thus, expression (1) was minimized the respect to parameter v, which was equivalent to maximizing the likelihood for the observed data in form of the length-dependent number of fish caught by the codend (nR_{jl}) versus those escaping to the cover (nE_{jl}):

$$-\sum_{j=1}^{m}\sum_{l}\left\{\frac{nR_{jl}}{qR_j}\times\ln\left(r_{av}(l,v)\right)+\frac{nE_{jl}}{qE_j}\times\ln\left(1.0-r_{av}(l,v)\right)\right\} \quad (1)$$

Where the outer summation is over the m hauls conducted, while the inner summation is over length class l; qR_j and qE_j are the sub-sampling factors for the fraction of the fish length measured in the codend and cover, respectively.

The Logit model was chosen to describe $r_{av}(l)$ (Wileman et al., 1996). This model can be fully presented by two selection parameters L50 (50% retention length) and SR (selection range =L75-L25):

$$r_{av}(l,v)=\frac{\exp(\frac{\ln(9.0)}{SR}\times(l-L50))}{1+\exp(\frac{\ln(9.0)}{SR}\times(l-L50))} \quad (2)$$

The ability of the model to describe the data sufficiently well can be evaluated by inspecting the corresponding p-value, which expresses the likelihood of obtaining at least as big a discrepancy between the fitted model and the observed experimental data as would be expected by coincidence. For the fitted model to be able to model the size selection data, the *p*-value should not be less than 0.05 (Wileman et al., 1996). In case of a poor statistical fit (*p*-value < 0.05), the residuals would be inspected to determine whether the result was due to structural problems when modelling the experimental data using the selection curve or if it was due to overdispersion in the data (Wileman et al., 1996).

We applied the software tool SELNET (Herrmann et al., 2012) for the size selection analysis and used the double bootstrap method implemented in the tool to obtain confidence intervals (CIs) for the size selection curve and the corresponding parameters. This bootstrapping approach, which takes both within-haul and between-haul variation into account, is identical to the one described in Millar (1993). A “pooled” set of data was analyzed using the identified selection model, then 1000 bootstrap repetitions was conducted to estimate the Efron percentile 95% CIs for the selection curve and its parameters (Herrmann et al., 2012).

2.4. Estimation of exploitation pattern indicators

To quantify and compare how these codends with different mesh sizes perform under the same fishery population of banded scad, a specific scenario of population, $nPop_l$, was generated by pooling data from both codend and cover for all tests over all hauls (Melli et al., 2019; Einarsson et al., 2021). Applying the size selection predicted in section 2.3, four exploitation pattern indicators, *nP-*, *nP+*, *nRatio*, and *dnRatio* (Eq. 3), were calculated for each codend with a MCRS of banded scad.

$$
\begin{aligned}
nP- &= 100 \times \frac{\sum_{l<MCRS}\{r_{codend}(l) \times nPop_l\}}{\sum_{l<MCRS}\{nPop_l\}} \\
nP+ &= 100 \times \frac{\sum_{l\geq MCRS}\{r_{codend}(l) \times nPop_l\}}{\sum_{l\geq MCRS}\{nPop_l\}} \\
nRatio &= \frac{\sum_{l<MCRS}\{r_{codend}(l) \times nPop_l\}}{\sum_{l\geq MCRS}\{r_{codend}(l) \times nPop_l\}} \\
dnRatio &= 100 \times \frac{\sum_{l<MCRS}\{r_{codend}(l) \times nPop_l\}}{\sum_{l}\{r_{codend}(l) \times nPop_l\}}
\end{aligned}
\quad (3)
$$

where $r_{codend}(l)$ is the size selection obtained for the specific codend, while $nPop_l$ represents the size structure of banded scad entering the codends in terms of individuals with length class l. nP- and nP+ are the percentage of retained fish below and above the MCRS (in number), respectively, taking the size structure of the population encountered into account. It would be preferable to have an nP- value close to 0 and an nP+ value close to 100. *nRatio* is the landing ratio between captured fish below and above the MCRS. The *dnRatio* is the percentage of fish individuals below the MCRS retained by the codend. Both *nRatio* and *dnRatio* should be as low as possible. The double bootstrapping approach was applied to estimate the Efron percentile 95% CIs for the indicator values, taking both within- and between-haul variation into consideration (Herrmann et al., 2012; Herrmann et al., 2018; Melli et al., 2019; Einarsson., 2021).

2.5 Delta selectivity

In order to quantify length-dependent selectivity differences between codends with different mesh sizes and to infer how changing mesh size would impact the size selectivity, delta selectivity, $\Delta r(l)$, was estimated by:

$$\Delta r(l) = r_B(l) - r_A(l) \quad (4)$$

Where $r_A(l)$ is the size selectivity for codend A with a small mesh size, and $r_B(l)$ represents the size selectivity for codend B with a relatively larger mesh size. Efron 95% percentile CIs for $\Delta r(l)$ could be obtained based on two bootstrap population of results for both $r_A(l)$ and $r_B(l)$. As they were obtained independently, a new bootstrap population of results was created for $\Delta r(l)$ by:

$$\Delta r(l)_i = r_B(l)_i - r_A(l)_i \quad i \in [1 \ldots 1000] \quad (5)$$

where i is the bootstrap repetition index. As the bootstrap re-sampling was random and independent for the two groups of results, it is valid to generate the bootstrap population of results for the difference based on (5), by using the two independently generated bootstrap files (Hermann et al., 2018; Herrmann et al., 2019).

3. Results

3.1. Experimental data

A total of 47 valid hauls, eight hauls for each tested codend except the D45 codend, for which seven hauls were obtained, were conducted. The average towing duration was about 130 min, and the water depth in the fishing grounds was mainly 12-20 m. Subsampling ratios of catch for length measurement ranged from 0.20 to 1.00. We measured the lengths of 2004 banded scad, in which 1098 individuals retained by the tested codends and 906 individuals by the covers. The total length of banded scad caught was in the range of 5.2 to 13.6 cm, and most of these fish with a length above the MCRS with a mode at 9-10 cm (Table 2, Fig. 3)

3.2. Size selectivity of banded scad

Fit statistics results from the three codends, the D30, D45 and D54, showed good fit as *p*-values were larger than 0.05. For the rest codends, the D25, D35 and D40, since the fitted curves reflected the main trend of the catch proportion well (Fig. 4), we considered that the p-values < 0.05 were probably a case of overdispersion in the data and we were confident in using the models for selective estimation.

In general, both the L50 and SR of the tested codends for banded scad increased as the mesh sizes enlarged (Table 3). For instance, the L50 was 6.99 cm for the D25 codend, whereas the relative value was 14.91 cm for the D54 codend. Meanwhile, the CIs of selective parameters became wider as the mesh sizes of codends increased, especially when the mesh size increased to 40 mm. Differences of selective parameters, both L50 and SR, between codends with different mesh sizes were not statistically significant as their CIs overlapped with each other. For all tested codends, the estimated L50 values were larger than MCRS of banded scad (6.4 cm), indicating that the retention risk of undersized fish was relatively low.

This fishing pattern was also reflected by the low retention of codends for banded scad with a MCRS length (Fig. 4). The L50 values of codends larger mesh sizes, D45 and D54, were significantly larger than the codends with smaller mesh sizes. As the CIs of SR from all codends overlapped, there was no significant difference.

3.3. Exploitation pattern indicators

The exploitation pattern indicators showed that catch efficiency, both undersized and preferred size fish, would decrease as the mesh sizes increased. For example, the D25 codend caught 20.37% of undersized fish (*nP-*) and 94.69% of marketable one (*nP+*), by comparison the D54 codend obtained 4.86% and 16.41% for *nP-* and *nP+*, respectively (Table 3). The catch efficiency of codends for undersized fish did not significantly differ, while the codends with smaller mesh sizes, D25, D30, and D35, would have significant higher catch efficiency for marketable size fish than those codends with relatively larger mesh sizes. Very low values of *nRatio* and *dnRatio* were obtained for all codends.

3.4. Delta selectivity

The results of delta selectivity curves demonstrated that applying codends with larger mesh sizes would reduce retention probability for fish with a given length range, and most of these reduction were statistically significant. For instance, the D35 codend had lower retention probability for banded scad in the length range of 8.4 to 12.7 cm when comparing the D30 codend (Fig. 5). Compared with codends with smaller mesh sizes (25, 30 and 35 cm), the D40 codend significantly caught fewer fish with length range, 9.2-11.7 cm, >8.1 cm and 9.1-11.0 cm, respectively. Similar trend was obtained for the D45 and D54 codend, when comparing with codends of smaller mesh sizes. For the three pairwised comparisons, D30 vs. D25, D35 vs. D25, and D54 vs. D45, no significant difference was obtained due to the delta curves contained 0.0 (Fig. 5 and Fig. 6).

4. Discussion

In the present study, we investigated size selection and exploitation pattern of diamond mesh codends for banded scad in the SCS. Our results demonstrate that codend selectivity for banded scad, in terms of selective parameters L50 and SR, can be improved by simple modification of mesh sizes. The values of L50 increased as the mesh sizes enlarged, from 6.99 cm for the D25 codend to 14.91 cm for the D54 codend, indicating the larger mesh size used in the codend the more undersized fish will release. The mesh size is, however, not the larger the better. When the mesh size increase to some extent, for instance above 40 mm, the CIs in selective parameters, both L50 and SR, would become wider, implying some uncertainty in the selective properties. Using codends with larger mesh sizes might give rise to the loss of marketable fish, which is the main concern of fishermen. This can be represented by the exploitation pattern indicators. For example, the D25 codend retained 94.69% of fish with legal length, whereas the D54 codend only retained 16.41%. Special attention was given to the two legal codends, the D25 and D40 codend. Both codends had mean L50 values larger the MCRS of banded scad, while the D25 codend significantly retained more marketable fish than the D40 codend. Considering compromise of protecting juvenile fish and the profitability of fishermen, the D30 codend will be the best choice to target banded scad among all tested codends. Because it had narrower CI in L50 and with its lower limit larger than the MCRS of banded scad, and it retained more than 96% of marketable fish.

Previously, the size selectivity of diamond mesh codends has been perceived to be poor for many fish species (Graham, 2010; Cheng et al., 2020). Our experiments, however, showed that all tested diamond mesh codends had good selective properties for banded scad considering the low retention of juvenile fish. Our results showed that size selectivity of diamond mesh codends might be species specific. Good size selective properties of tested codends for banded scad might be contributed to its morphology and swimming ability, which may facilitate escapement activity from the codend-mesh. For one thing, banded scad is a small-sized fish species, with a ship-like cross section in the body that might make it easy to pass the diamond-shaped mesh. For the other, although there is no literature related to the swimming behaviour and/or capacity of banded scad, our underwater video recordings showed that this fish could readily swim and escape from open meshes of the codend.

Testing and quantifying size selectivity of fishing gears not only allows us to track the effect of management regulations, but also enables the development of sustainable fisheries for specific fish stock (Froese et al., 2016; Prince and Hordyk, 2019; Vasilakopoulos et al., 2016). Although the minimum mesh size regulations for trawl fisheries have been enforced since 2014 in the SCS, few works has been done to evaluate their effectiveness. In particular, only Yang et al. (2018) investigated the size selectivity of diamond mesh codends, with two different nominal mesh sizes, 25 and 30 mm, for banded scad in shrimp beam trawl fisheries of the SCS. Their results indicated that the selective properties of codend with 25 mm mesh size was poor as few individuals of banded scad could escape from it (only 2 individuals of 326 banded scad caught by the codend escaped), while the codend with 30 mm mesh size had a mean L50 of 5.9 cm (CI: 5.6-6.3 cm) and SR 2.5 cm (CI: 1.1-4.0 cm). Despite the fact that both experiments applied the same sampling method, the covered codend approach, the selective properties of the two codends, the D25 and D30, in the present study were much better, representing by larger L50 values. These differences may be contributed to the following factors. First, the mesh opening (two bars without knot) was larger in our experimental designs; the value comparison was 21.10±0.93 vs. 25.91±1.05 mm, and 26.64±0.73 vs. 29.74±0.70 mm, for the D25 and D30 codend, respectively, in their experiment and ours. Second, we minimized the effect of covered net by using kites, while

Yang et al. (2018) did not. Last by not least, the fishing gear construction, hauling speeds and fishing grounds might vary between the two experiments.

As demonstrated by Wileman et al. (1996) that size selectivity of trawl codend is not only affected by design parameters, such as mesh size, shape and twine diameter, but also by some uncontrolled factors, like catch weight, fish condition and environmental factors (Fryer, 1991). Our experimental aim, however, is not to quantify the potential explanatory variables of size selectivity, but to investigate how the mesh sizes would selectivity of codends for banded scad. So we applied the double bootstrap method to account for the uncertainties from both between-haul and with-haul variation, which enabled us to concentrate on our research purpose.

Some precaution should be required since our study was based on about 8 hauls for the tested codends, and finite number of banded scad was obtained, especially for the D25 codend. This might give rise to a degree of uncertainty in the estimation of selectivity parameters and curves. However, the CIs of selective parameters for the D25 codend were at an acceptable level. A previous study by Herrmann et al. (2016b) demonstrated that the number of fish required for length measurement was much less using the covered codend method, which was the one we applied, than the paired gear method. Based on these considerations, we believe that our results will be beneficial to the management issue for the commercial fishery. Additionally, the exploitation pattern indicators estimated in this study might be population context. When the fishing scenario changes different results could be obtained.

In conclusion, our results demonstrate that the size selectivity of diamond mesh codends can be improved by simple option such as increasing the mesh sizes. This simple option, however, is not a panacea. When the mesh sizes increase to some extent (40 mm for instance), uncertainties in the selective properties may be given rise, and the loss of marketable fish could be considerable. By comparing the selective properties and exploitation pattern of six codends with different mesh sizes, we conclude that the D30 codend is the best choice to target banded scad in the SCS.

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Lists of Figures

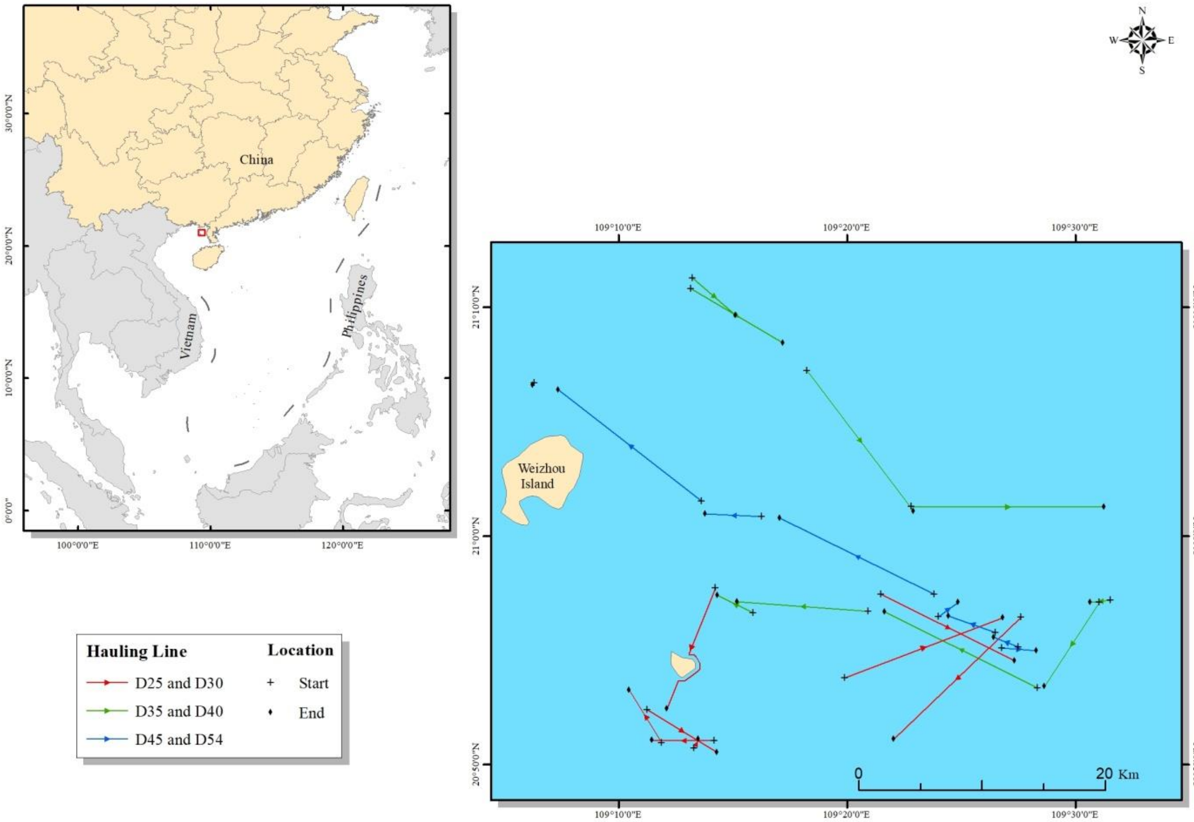

Fig. 1. Location of fishing grounds: the colorful lines represent hauling lines of the codends. Rred lines represent the D25 and D30 codend, purple lines represent the D35 and D40 codend, and green lines represent the D45 and D54 codend, respectively.

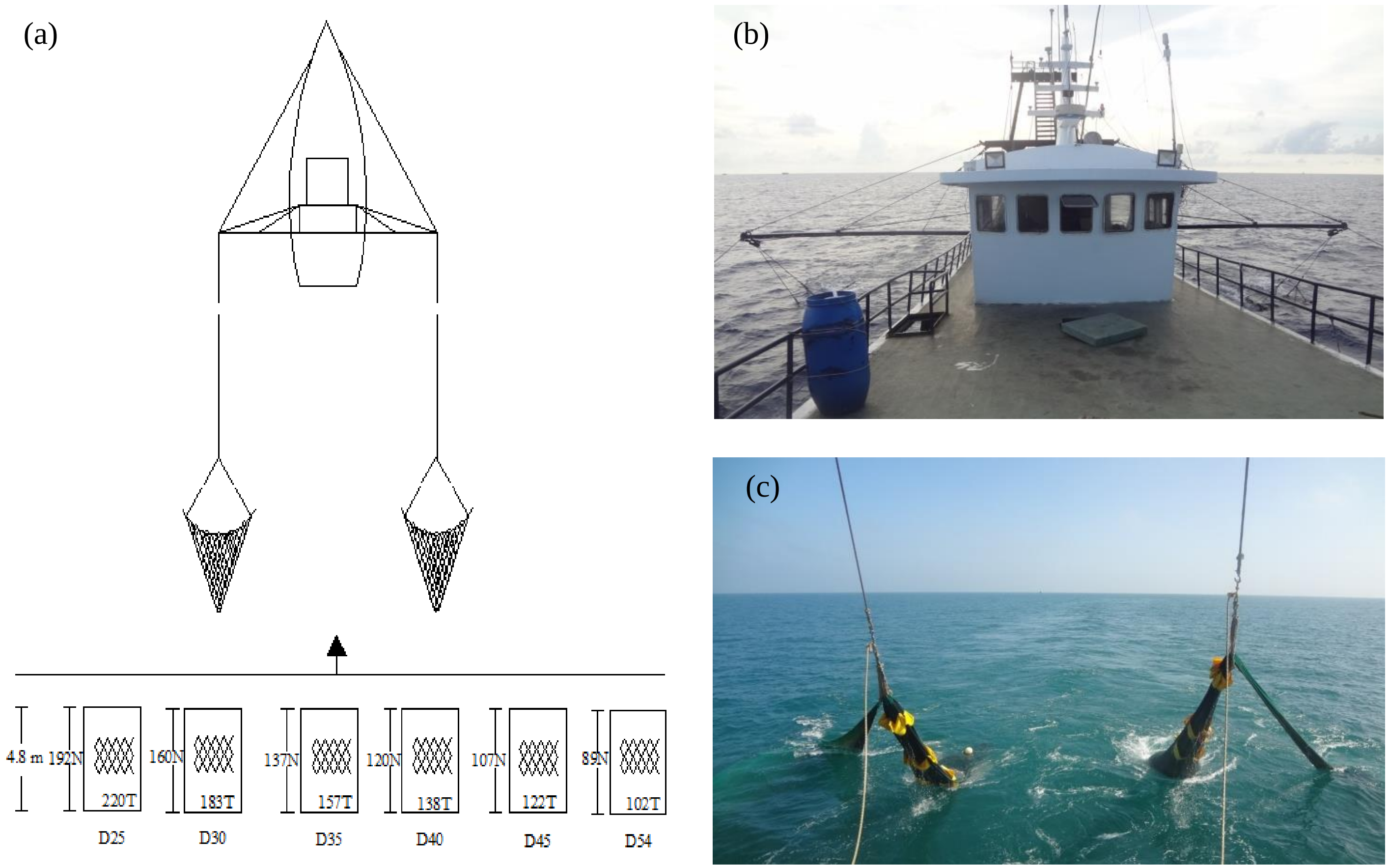

Fig. 2. Schematic view of the fishing gear configuration tested in the experiments. (a): the fishing vessel and specification of the tested codends, (b): the vessel towing two trawls simultaneously, and (c): the haul-back process of the tested codends.

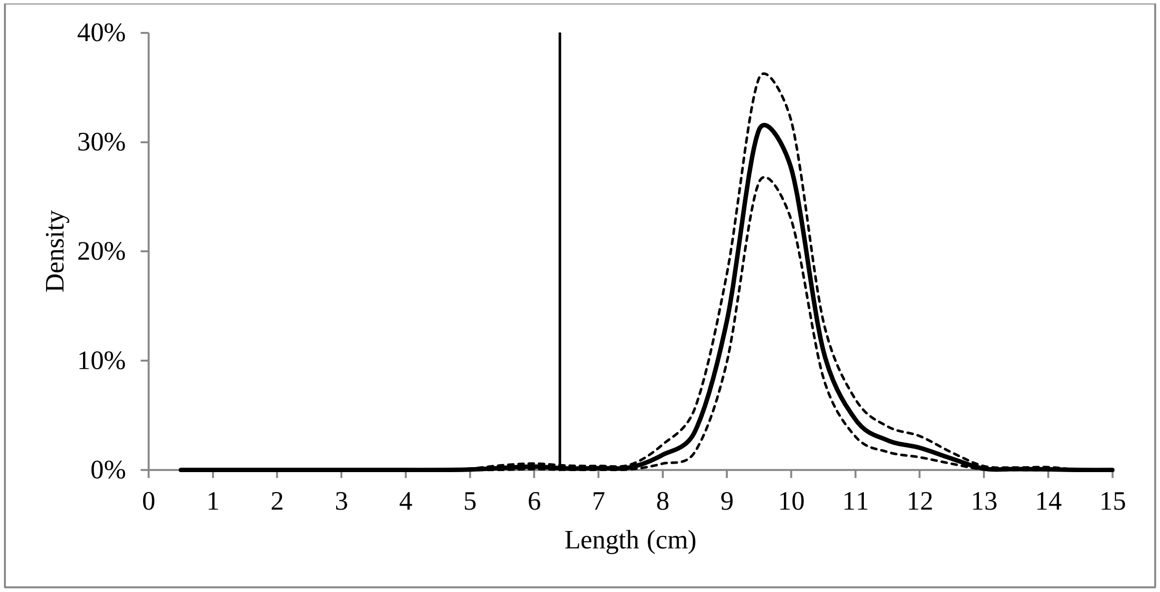

Fig. 3. Estimated average population of banded scad from all hauls during the sea trials. Stipple lines show the 95% Efron confidence intervals, and the vertical line represents the MCRS (minimum conservation reference size) of banded scad.

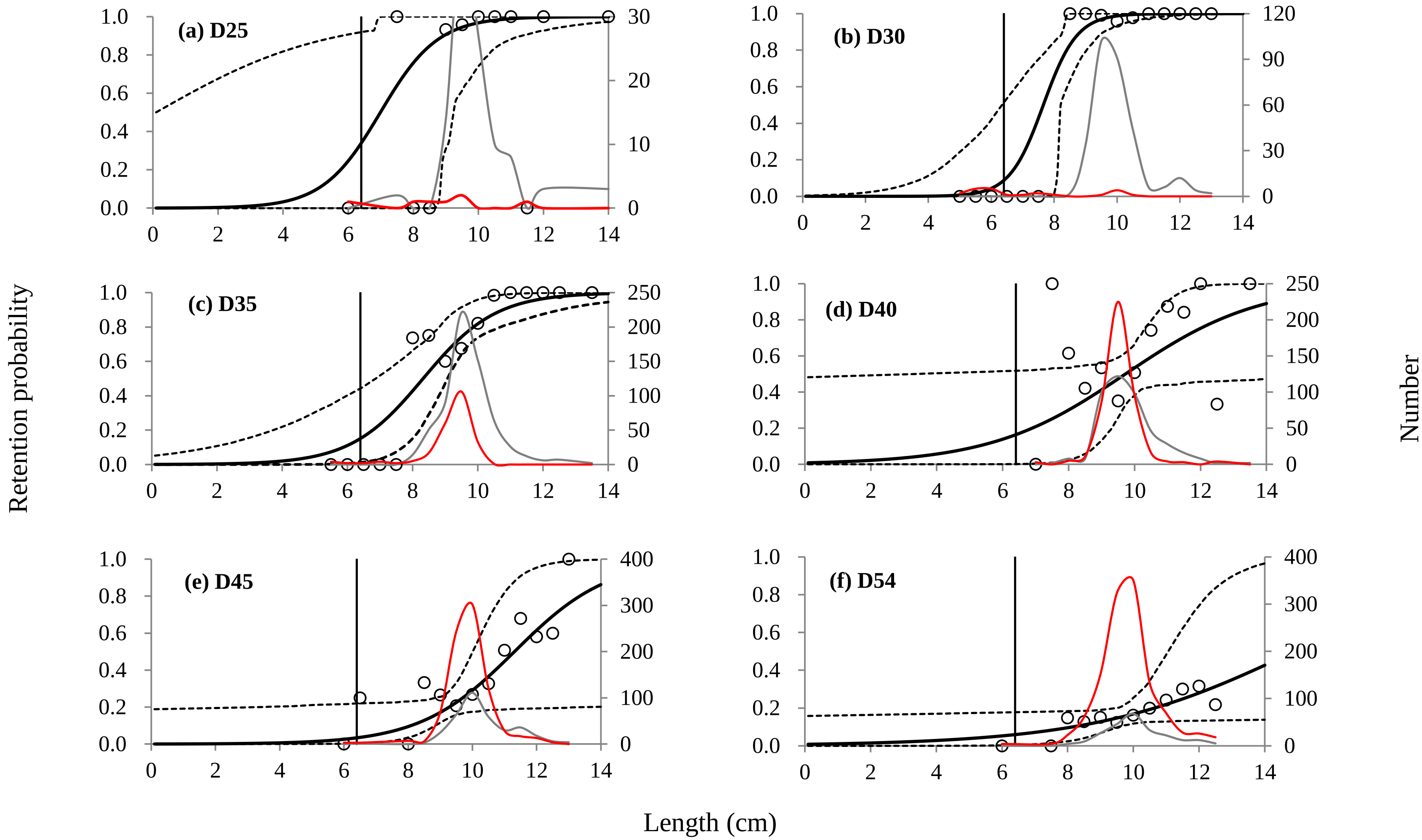

Fig. 4. Experimental catch proportion and selectivity curves obtained for the codends. Circle marks represent experimental catch proportion. Red curves represent the size distribution of fish caught by the cover, grey curves represent the one caught by the tested codend. Solid black curves represent selectivity curves and stippled curves describe the 95% confidence intervals. Vertical lines represent the MCRS (minimum conservation reference size) of banded scad.

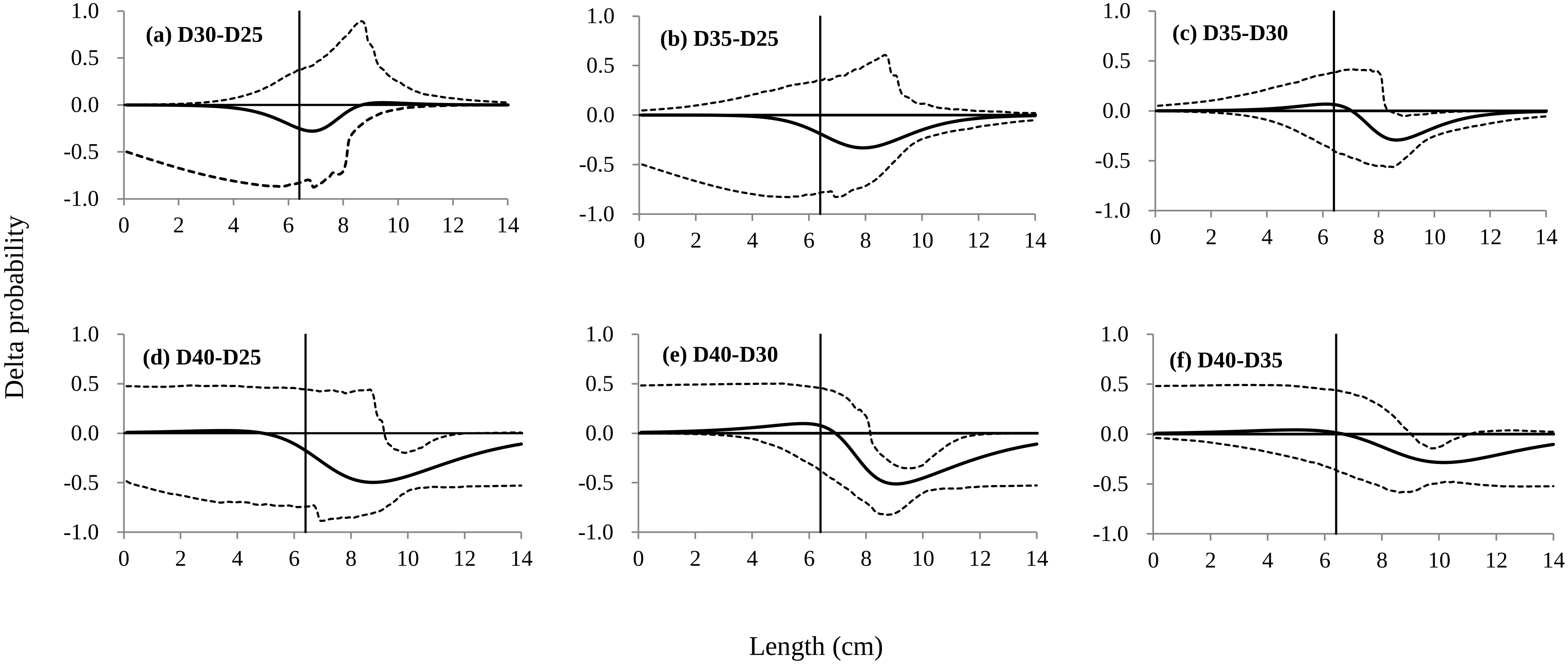

Fig. 5. Delta selectivity from comparison between four codends, the D25, D30, D35 and D40 codend. The solid black curves represent the delta selectivity for each comparison, and the stippled curves represent the 95% confidence intervals. Vertical lines represent the MCRS (minimum conservation reference size) of banded scad.

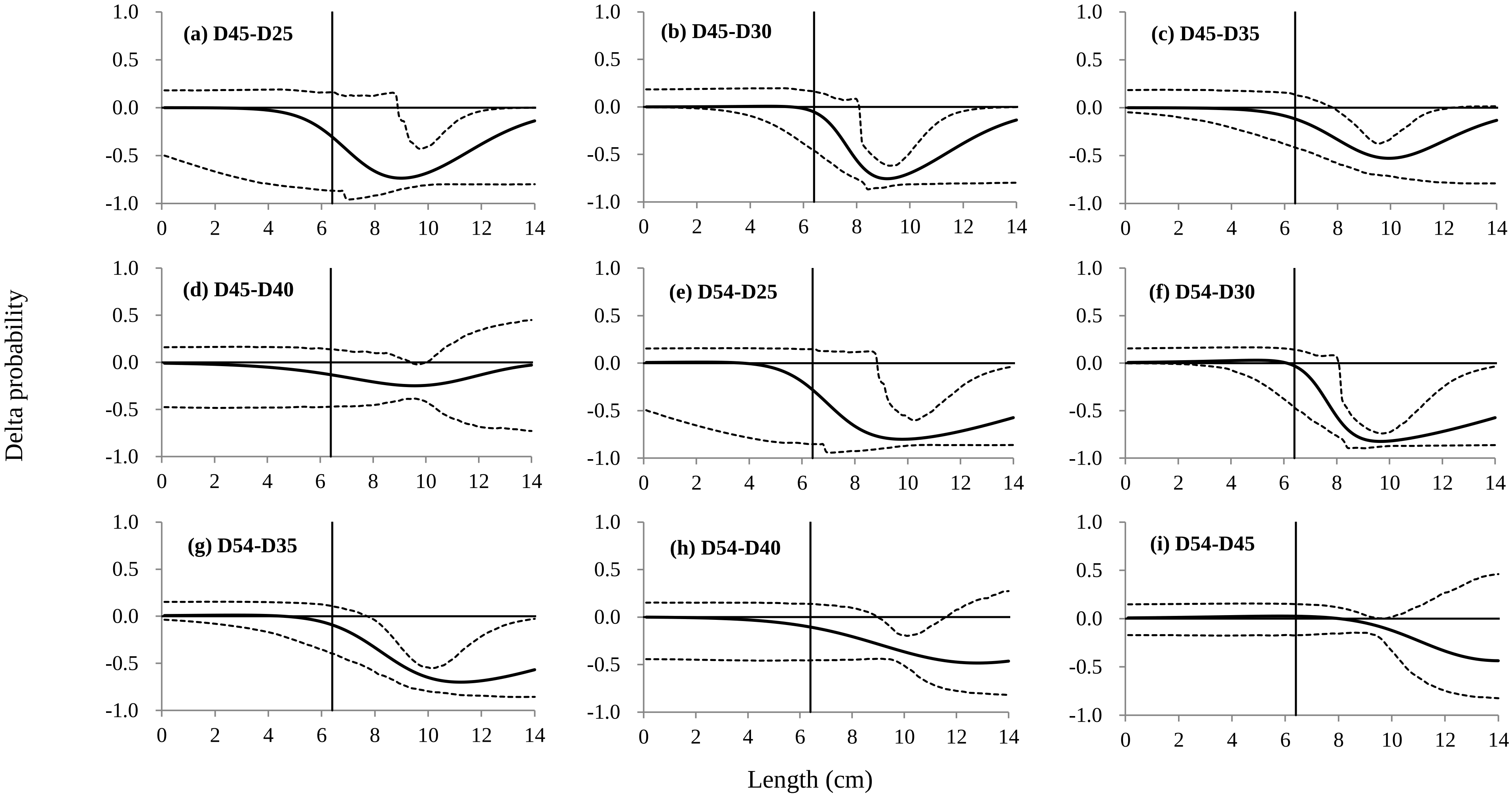

Fig. 6. Delta selectivity from comparison between six codends, the D25, D30, D35, D40, D45 and D54 codend. The solid black curves represent the delta selectivity for each comparison, and the stippled curves represent the 95% confidence intervals. Vertical lines represent the MCRS (minimum conservation reference size) of banded scad.

Lists of Tables

Table 1. Specification of the tested codends and covers. SD represents standard errors.

codend	mesh opening±SD (mm)	twine diameter±SD (mm)	mesh number in length	mesh number in circumference
D25	25.91±1.05	1.40±0.36	220	192
D30	29.74±0.70	1.24±0.11	183	160
D35	35.70±1.14	1.31±0.10	157	137
D40	40.40±0.85	1.36±0.17	138	120
D45	44.28±0.66	1.24±0.09	122	107
D54	54.54±0.86	1.26±0.09	102	89
cover	12.51±0.78	1.18±0.10	550	480

Table 2. Overview of the fishing condition and catch data.

	Codend					
data specification	D25	D30	D35	D40	D45	D54
No. of hauls	8	8	8	8	7	8
Duration range (min)	118-156	118-156	128-153	128-153	120-128	120-128
No. in codend	54	150	314	220	219	141
No. in cover	7	22	128	213	246	290
Sub-sampling factor in codend	0.33-0.50	0.33-0.50	0.33-0.50	0.50-0.50	0.50-1.00	0.50-1.00
Sub-sampling factor in cover	1.00-1.00	1.00-1.00	0.33-1.00	0.25-1.00	0.25-0.33	0.20-0.33
Length range (cm)	6.2-14.0	5.2-12.8	5.7-13.6	6.8-13.5	6.1-12.7	6.0-12.7

Table 3. Selective parameters, fit statistics and performance indicators obtained for the codends. DOF indicates degree of freedom.

codend	*L50* (cm)	*SR* (cm)	*p*-value	deviance	DOF	nP_- (%)	nP_+ (%)	*nRatio*	*dnRatio* (%)
D25	6.99 (0.10-9.22)	1.94 (0.10-6.41)	0.02	21.54	10	20.37 (0.00-89.97)	94.69 (67.43-99.90)	0.00 (0.00-0.01)	0.12 (0.00-0.55)
D30	7.65 (6.34-8.21)	1.18 (0.10-2.49)	0.25	17.12	14	3.18 (0.00-37.86)	96.10 (89.39-98.47)	0.00 (0.00-0.00)	0.02 (0.00-0.22)
D35	8.32 (6.87-9.07)	2.45 (1.24-5.19)	<0.01	36.36	14	9.28 (0.43-37.64)	77.19 (68.23-91.65)	0.00 (0.00-0.00)	0.07 (0.00-0.30)
D40	9.72 (3.40-18.01)	4.49 (1.15-100.00)	<0.01	39.52	11	12.63 (0.03-51.37)	51.20 (38.85-62.33)	0.00 (0.00-0.01)	0.13 (0.00-0.71)
D45	11.31 (10.01-76.48)	3.22 (1.42-100.00)	0.29	13.06	11	2.25 (0.13-21.52)	27.84 (17.27-44.25)	0.00 (0.00-0.01)	0.04 (0.00-0.63)
D54	14.91 (11.06-97.25)	6.76 (1.92-100.00)	0.95	3.90	10	4.86 (0.19-17.59)	16.41 (11.67-24.95)	0.00 (0.00-0.01)	0.16 (0.00-0.75)