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Comparing the size selectivity and exploitation patterns of two T0 codends with T90 codends in demersal trawl fishery targeting white croaker (*Pennahia argentata*) of the northern South China Sea

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ABSTRACT

The size selectivity and exploitation patterns of two T0 (diamond mesh) codends were tested and compared with T90 (diamond mesh turned by 90°) codends in demersal trawl fishery targeting white croaker (*Pennahia argentata*) of the northern South China Sea. The four experimental codends involved two mesh sizes, 30 and 35 mm, respectively. The size selectivity of the T0 codend with mesh size of 30 mm, T0_30, was used as a starting point to compare with the rest codends. The results showed that compared with the T0_30 codend increasing the mesh size to 35 mm or applying the T90 codends would result in significantly larger L50 values, and the retention risk (probability) of undersized white croaker with length < 8.5 cm would significantly reduce. These codends, however, had no effect on improving the size selectivity of undersized white croaker with the length ranging between 10 and 15 cm. The results of our study will have relevant implications for fishing gears management and future direction of codend selectivity research.

1. Introduction

White croaker (*Pennahia argentata* (Houttuym, 1782)), also named as 'Bai-gu-yu' in Chinese, is an economically an ecologically relevant finfish species, widely distributed around most coastal fishing grounds in China, and other countries such as Korea and Japan (Zhu et al., 1963). In 2021, the Chinese national landing was about 96,613 t, in which 23,127 t was from the South China Sea (SCS) (MARA, 2022). However, this volume has been declining when comparing with that of a decade ago, as in 2011 the figure was 124,935 t (MARA, 2012). Moreover, the stock of white croaker has been demonstrated to decline and even overexploit in China and Japan (Yamaguchi et al., 2004; Chen et al., 2005; Kang et al., 2018). Another concern was that a larger fraction of juvenile white croaker was retained as by-catch species. For example, according to the national wide survey by Zhang et al. (2020), in which fish samples were collected from the fishing vessels regardless the fishing gear used including demersal trawls, lift nets, gillnets and stow nets, about 43% of white croaker caught was identified as juvenile individuals in all marine fisheries.

White croaker can be fished by many fishing gears, such as gillnets, stow nets and lines etc. Among these gears, demersal trawl is the most efficient. The bycatch of undersized individuals from demersal trawl targeting white croaker, however, has been an increasing issue. For example, Yang et al. (2008) demonstrated 100% retention efficiency of white croaker independent on size by a demersal trawler targeting shrimp and fish species. The serious by-catch concern of juvenile white croaker can be attributed to poor size selective properties of demersal trawls, especially in the codends which collect the fish and most size selection might occur (Beverton, 1963; Glass, 2000; Herrmann, 2005a).

In order to protect coastal fish resources, including white croaker, several regulations have been established in China. For instance, the seasonal moratorium, which prevents most vessels from fishing for about three and a half months in the summer (from May 1th to August 16th), on marine fishing was introduced in the mid-1990s (Cao et al.,

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2017; Su et al., 2020; Zhang et al., 2020). In 2013, a regulation of minimum mesh size (MMS), in which mesh size of codends in the trawls targeting fish species should be equal or larger than 40 mm and 25 mm for shrimp trawls, for demersal trawls was enforced. In 2018, the minimum landing size (MLS) regulation for white croaker was made to 15.0 cm of total length in China (Yang et al., 2021). Specifically, both MMS and MLS regulations were introduced by the Chinese government to rebuild marine fishing through technical instruments, such as limiting gear specifications (MMS) and ecological incentives (MLS). Though the effectiveness of the regulations was extensively doubted and criticized (Liang and Pauly, 2017; Zhang et al., 2020), very few research work has been conducted to test and evaluate them from technical perspectives. Only Yang et al. (2021) tested the effect of MMS and MLS regulations for trawl fishery targeting white croaker in the northern SCS. They investigated the size selectivity and exploitation patterns of six diamond mesh codends, with mesh-size ranging from 25 to 54 mm, for white croaker. Their results demonstrated that the present MMS and MLS regulations did not perform satisfactorily to protect juvenile white croaker and they urged other gear modifications should be strictly needed (Yang et al., 2021).

There are numerous ways to improve the size selectivity and exploitation patterns for trawl fishery. The easiest one is simply to increase the mesh size of the diamond-mesh codend. This was also regarded as the starting point by Kennelly and Broadhurst (2021). The starting point, however, has been proved to be not efficient at improving the size selectivity for trawl fishery targeting white croaker in the SCS by Yang et al. (2021). To further explore effective ways of improving the size selectivity, another modification should consider applying T90 codends by turning the direction of the traditional diamond mesh by 90°. Many studies have demonstrated that T90 codends would have meshes more open and obtain better selective properties for many species comparing with the diamond-mesh codends (T0) (Herrmann et al., 2007; Tokaç et al., 2014; Madsen et al., 2015; Bayse et al., 2016; Petetta et al., 2020; Cheng et al., 2022; Kennelly and Broadhurst, 2021; Brinkhof et al., 2022). However, there is no study to investigate the size selectivity and exploitation patterns of T90 codends in white croaker trawl fishery in China.

To address the issues mentioned above, the size selectivity and exploitation patterns of two T0 codends were tested and compared with T90 codends in demersal trawl fishery targeting white croaker of the

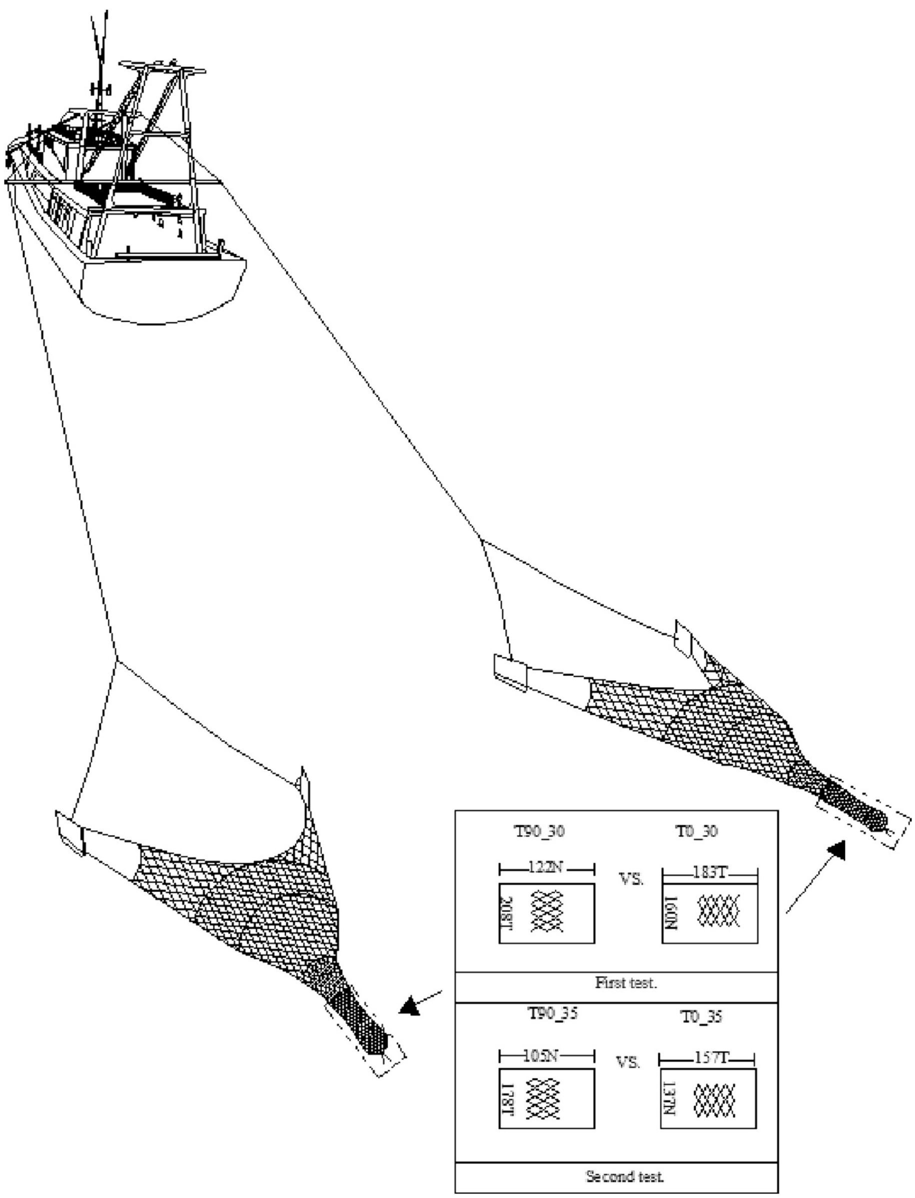

Fig. 1. Schematic view of the out-rigged trawling system and experimental codends.

northern South China Sea. The four experimental codends involved two mesh sizes, 30 and 35 mm, respectively. The size selectivity of the T0 codend with mesh size of 30 mm was used as a starting point to compare with the rest codends.

2. Materials and methods

2.1. Experimental fishing and gear setup

In order to obtain sufficient catch data and make direct comparison with the previous codend selectivity study, experimental fishing was conducted applying the same commercial vessel, 'Gui-bei-yu 96899' with 38 m in total length and a engine power of 280 kW, around the same fishing grounds as Yang et al. (2021) did in November 2020. The fishing areas, which had previously been proven to be ideal for the codend selectivity study, located in the Bei-bu Gulf of the northern SCS (20°53′-21°10′ N and 108°33′-109°09′ E).

The gear systems of the commercial vessel were applied except the codends, on which the gear modification setups focused by our study. The gear systems operated by the selected vessel were out-rigged trawl fishing, in which two identical or similar trawls were hauled simultaneously through two derricks applying trawl doors at each side (Fig. 1). In these trawls, the fishing circle was constructed by 860 diamond meshes, with a mesh size of 45 mm. The length of headrope and footrope was 28 m and 36 m, respectively, while the bridles connected the wing-ends to trawl doors was about 0.5 m. Two sets of trawl doors, weighted about 250 kg each, were applied to spread the mouths of the trawls horizontally. In normally fishing, the spread of trawl doors was about 15 m and the vertical height of headrope was 1.5 m.

Based on the basic data of the codend, which was T0 codend with a 25-mm mesh size, a total of 220 mesh around and the stretched length was 4.8 m, used in commercial fishing, we designed and manufactured four experimental codends. Two moderate mesh-sizes, 30 and 35 mm, were applied to construct the two T0 codends and two T90 codends. We termed the codends as T0_30, T0_35, T90_30 and T90_35, respectively. Specifically, T0 or T90 represent the mesh shape of the codend, while 30 or 35 was the mesh size used. For instance, the T0_30 codend indicated the T0 codend with a mesh size of 30 mm; similarly the T90_30 codend was a T90 codend with the same mesh size of 30 mm. In order to ensure comparable gear modifications, the T0 codends had the same stretched circumference and length to the commercial codend, while the T90 codends would be smaller (33%) in circumference and longer (30%) in the vertical direction than the relative T0 codends with identical mesh-sizes (Bayse et al., 2016; Robert et al., 2020). These codends were constructed using the netting with same material, colour and diameter. The inner stretched mesh size for T0_30 and T90_30 codend was 29.79 ± 0.65 mm, while the relative value was 35.66 ± 1.06 mm for the T90_35 and T0_35 codend. More information about these codends can be found in Fig. 1.

Once these codends had been constructed, they were mounted to the extension of the out-rigged trawls to collect data using the covered codend method. Comparing with the codends tested, the cover-nets were 1.5 longer and larger (Wileman et al., 1996), and with a smaller mesh opening of 12 mm. In total, 12 flexible kites were attached around the cover-nets to make it clear from the tested codends (He, 2007; Grimaldo et al., 2009; Yang et al., 2021). Moreover, to check how the kites would work, underwater video recordings systems, which were constructed by GoPro HERO4 (black edition), were applied during the experimental fishing. These underwater video recordings systems could not only show us the state of the cover-nets, but also provide some information about the behaviours of the escapees. Finally, to easily handle the catch from the tested codend and remove the potential 'wash-out' effect, which might impact the estimation of size selectivity, two pieces of zipper, about 1.1 m, were mounted to the cover-nets.

Due to that two trawls were hauled simultaneously, we arranged the experimental fishing as pairwised tests: T90_30versus T0_30 as the first test and T90_35 versus T0_35 as the second test, respectively (Fig. 1). In each haul, all catch from the tested codends was handled firstly using the zippers, and then white croaker from each compartment was handled and sub-sampled when the number was huge. All catch of white croaker was kept in special containers, frozen, and biological measurement was conducted once we were back on land.

2.2. Estimation of size selectivity

The experimental approach would allow us to handle the data as binominal, due to that for a specific white croaker in one test it was either retained by the codend or the cover attached outside. The catch data from all hauls for each codend tested were pooled for further analysis, as our main interest was the retention probability ($r_{codend}(l)$) of the target species summed over all hauls. This would provide us an estimate on how the experimental codends would actually perform in the specific fishery on average. Based on the same procedure in Yang et al. (2021), the size selectivity of experimental codends was estimated by applying the maximum likelihood estimation method. Four basic models, including Logit, Probit, Gompertz and Richards, were considered as candidate models to represent $r_{codend}\ (l,\ \boldsymbol{v}_{codend})$ for the tested codends. Normally, two selectivity parameters, L50 (50% retention length) and SR (selection range, =L75-L25) can be used to describe the first three models (Logit, Probit, and Gompertz). For the last model (Richards), another parameter (δ) was required.

Firstly, Akaike's information criterion (AIC) values (Akaike, 1974) of four candidate models were calculated and the best model, the one with the lowest AIC, was selected for each codend tested. Then, applying the chosen best model, we applied a double-bootstrapping technique to estimate the Efron percentile 95% (Efron, 1982) confidence intervals (CIs) for the selectivity parameters and selectivity curves, by accounting for uncertainties from within-haul and between-haul variations (Millar, 1993; Herrmann et al., 2012; Herrmann et al., 2018; Yang et al., 2021; Yang et al., 2023). The ability of the best models to represent the catch data could be judged by their *p*-values (Wileman et al., 1996).

2.3. Delta selectivity

The differences of size selectivity between codends with different configurations (mesh sizes and mesh shapes) can be compared by delta selectivity using the following equation:

$$\Delta r(l, \mathbf{v}_a, \mathbf{v}_b) = r_a\ (l, \mathbf{v}_a) - r_b\ (l, \mathbf{v}_b) \tag{1}$$

in which $r_a\ (l,\ \boldsymbol{v}_a)$ represented the size selectivity of the codend with one configuration, while $r_b\ (l, \boldsymbol{v}_b)$ was the size selectivity of the other codend with different configuration. The 95% CIs of delta selectivity could be calculated by creating a new bootstrap population using the bootstrap results from both $r_a\ (l,\ \boldsymbol{v}_a)$ and $r_b\ (l,\ \boldsymbol{v}_b)$. The procedure was widely used in selectivity studies to test and compare selective properties of different gear modifications (Larsen et al., 2018; Cheng et al., 2019; Petetta et al., 2021; Yang et al., 2021; Yang et al., 2023; Sistiaga et al., 2021; Sistiaga et al., 2023).

2.4. Estimation of exploitation pattern indicators

Exploitation pattern indicators have been extensively used to provide another perspective and supplement the results of the size selectivity in selectivity studies of fishing gears (Santos et al., 2016; Cheng et al., 2019; Melli et al., 2020; Yang et al., 2021; Cuende et al., 2022; Sistiaga et al., 2023). These indicators are based on the specific size structure of the fishing population scenario encountered by the tested gear in the specific time; they will enable us to quantify the performance of the gear tested under the conditions in the specific fishery. In our study, three commonly used indicators, *nP-*, *nP+*, and *dnRatio*, were estimated as:

$$nP- = 100 \times \frac{\sum_{l<MLS}\{r_{codend}(l, v_{codend}) \times nPop_l\}}{\sum_{l<MLS}\{nPop_l\}}$$
$$nP+ = 100 \times \frac{\sum_{l\geq MLS}\{r_{codend}(l, v_{codend}) \times nPop_l\}}{\sum_{l\geq MLS}\{nPop_l\}} \quad (2)$$
$$dnRatio = 100 \times \frac{\sum_{l<MLS}\{r_{codend}(l, v_{codend}) \times nPop_l\}}{\sum_{l}\{r_{codend}(l, v_{codend}) \times nPop_l\}}$$

where $nPop_l$ is the population size structure of white croaker encountered by the experimental codends. In these indicators, *nP*- and *nP*+ represents the percentage of white croaker below and above its MLS, respectively, while *dnRatio* represents the percentage of white croaker below the MLS caught by the tested codends. By summing all catch data of white croaker both from cover and codend, we obtained two independently different size structure population scenarios for white croaker. The CIs of the three indicators could also be calculated by applying the bootstrap method mentioned above. Based on the length distribution of white croaker in all hauls, we generated an average population scenario in terms of relative frequency in 2020. Additionally, the other population scenario was presented using the data of sea trials conducted by Yang et al. (2021) in 2019 (Fig. 2).

The catch data was analyzed applying SELNET (Herrmann et al., 2012; Herrmann et al., 2018; Herrmann et al., 2019; Yang et al., 2021), in which the bootstrap technique was implemented. More information about the software can be found in Yang et al. (2021). Finally, statistical tool R (R Core Team, 2021) was applied to produce the plots taking advantage of the ggplot2 package (Wickham, 2016).

3. Results

3.1. Overview of catch data

For each codend tested, nine replicate hauls were conducted and the validate hauls were 36 in total. During the sea trials, towing speed of the vessel was mainly 3.5 knots, fishing duration was about 2 h, while the depth of water in the fishing grounds ranged from 18 to 39 m. During these hauls, white croaker was one of the most relevant catch species in terms of number. The sub-sampled ratios of white croaker varied between 0.25 and 1.0. In all hauls, 1403 individuals of white croaker were sampled and length measured to the nearest 0.1 cm. Most of individuals of white croaker caught were smaller than the MLS in length; the highest relative frequency length was 5.0 cm in the population scenario of 2019, while the highest was 4.5–5.5 cm in 2020 (Fig. 2). The other main species captured were southern velvet shrimp (*M. palmensis*), finespot goby (*Chaeturichthys stigmatias*) and burrowing goby (*Trypauchen vagina*), and results for some of these are reported in (Yang and Herrmann, 2022; Yang et al., 2023).

3.2. Size selectivity estimation

By comparing the AIC values from the candidate models, the Logit was the best for the T0_30 and T90_30 codend, whereas for the rest two codends (T0_35 and T90_35) best model was Richards (Table 1). The chosen models could fully represent the catch data, as they all obtained *p*-values higher than 0.7 (Table 2). The results of the size selectivity demonstrated that L50 of the T0_30 codend was significantly lower than the other three codends, in which no significant differences were observed due to overlapped CIs. The difference in SR of all codends tested was also not significant, because of overlapped CIs (Table 2). The selectivity curves demonstrated that the retention risk (probability) was 100% for the fish with a length larger than 10.0 cm for all codends tested

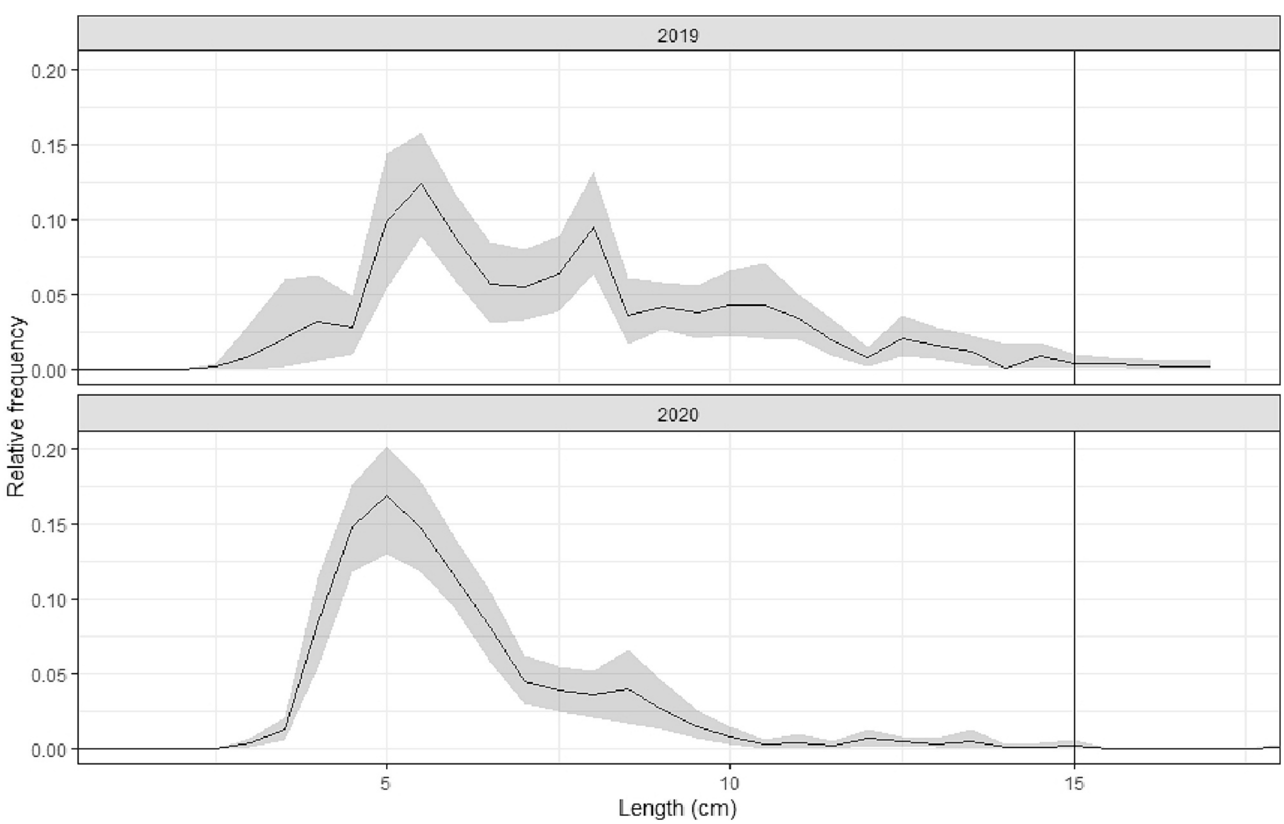

Fig. 2. Estimated average population scenarios of white croaker based on catch data from the sea trials in 2019 (from Yang et al., 2021) and 2020. Shaded areas show the 95% confidence intervals, and the vertical line represents the MLS (minimum landing size, 15 cm) of white croaker in the South China Sea.

Table 1
Akaike's information criterion (AIC) values obtained from candidate models for the tested codends. Selected models in bold.

	Model			
Codend	Logit	Probit	Gompertz	Richards
T0_30	**227.98**	230.04	242.81	229.89
T0_35	83.06	89.72	103.04	**81.71**
T90_30	**272.46**	276.92	292.35	274.39
T90_35	94.57	101.03	117.64	**90.26**

(Fig. 3).

3.3. Delta selectivity

The delta selectivity curves demonstrated that modifications in codend mesh-sizes and mesh-shapes would affect the retention probability for white croaker, while these differences were length-dependent and most of them were statistically significant. When comparing with the T0_30 codend, for instance, the T0_35 and T90_30 codend would have significantly lower retention probability for individuals ranging from 5.0 to 7.5 and 6.1 to 8.5 cm, respectively (Fig. 4). The T90_35 codend would have significantly lower retention probability for white croaker in length range of 5.0–7.5 and 6.2–7.7 cm than the T0_30 codend and T90_30 codend, respectively (Fig. 4). The T90_30 codend

Table 2
Selectivity parameters and fit statistics obtained from the selected models for the tested codends. The selectivity parameters of D25, D30, D35, D40, D45 and D54 were from the previous study by Yang et al. (2021).

		Parameters					
Codends	Model	L50 (cm)	SR (cm)	δ	*p*-value	Deviance	DOF
T0_30	Logit	6.23 (5.80–6.67)	0.95 (0.51–1.28)		0.9915	8.05	20
T0_35	Richards	7.82 (7.24–8.47)	0.54 (0.01–0.97	0.10 (0.10–10.00)	0.8683	9.17	15
T90_30	Logit	7.16 (6.92–7.44)	0.96 (0.61–1.29)		0.7692	15.12	20
T90_35	Richards	8.00 (7.60–8.43)	0.55 (0.01–0.95)	0.10 (0.10–1.97)	0.8235	9.12	14
D25	Probit	6.75 (6.50–8.00)	0.10 (0.10–0.10)		1.0000	0.00	19
D30	Richards	7.30 (6.95–7.93)	0.64 (0.01–0.97)	0.10 (0.10–0.62)	0.9947	5.75	17
D35	Gompertz	7.52 (6.78–8.84)	1.65 (0.84–2.87)		0.9984	5.78	19
D40	Probit	7.85 (7.18–8.52)	1.45 (0.95–1.88)		0.9989	6.52	21
D45	Probit	9.66 (9.09–10.06)	1.50 (0.62–2.31)		0.4498	17.07	17
D54	Gompertz	10.79 (9.03–16.44)	4.07 (1.86–13.68)		0.0356	28.88	17

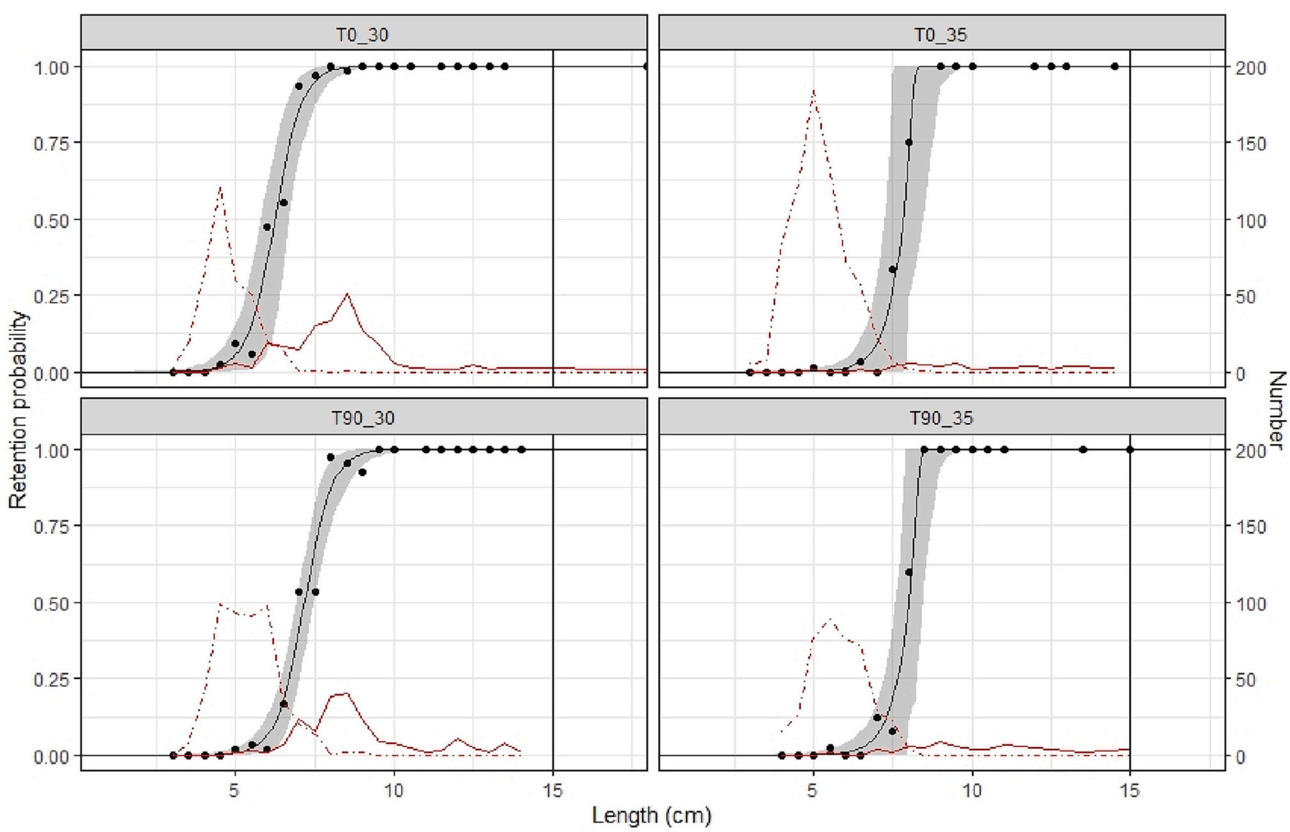

Fig. 3. Experimental catch proportion and selectivity curves obtained for the T0 and T90 codends. Black dots represent experimental catch proportion of the codends tested. Solid black curves represent selectivity curves and the shaded areas describe the 95% confidence intervals. Red solid curves represent the size distribution of fish caught by the codends, while the red dotted curves represent the one caught by the covers. Vertical lines represent the MLS (minimum landing size, 15 cm) of white croaker in the South China Sea. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

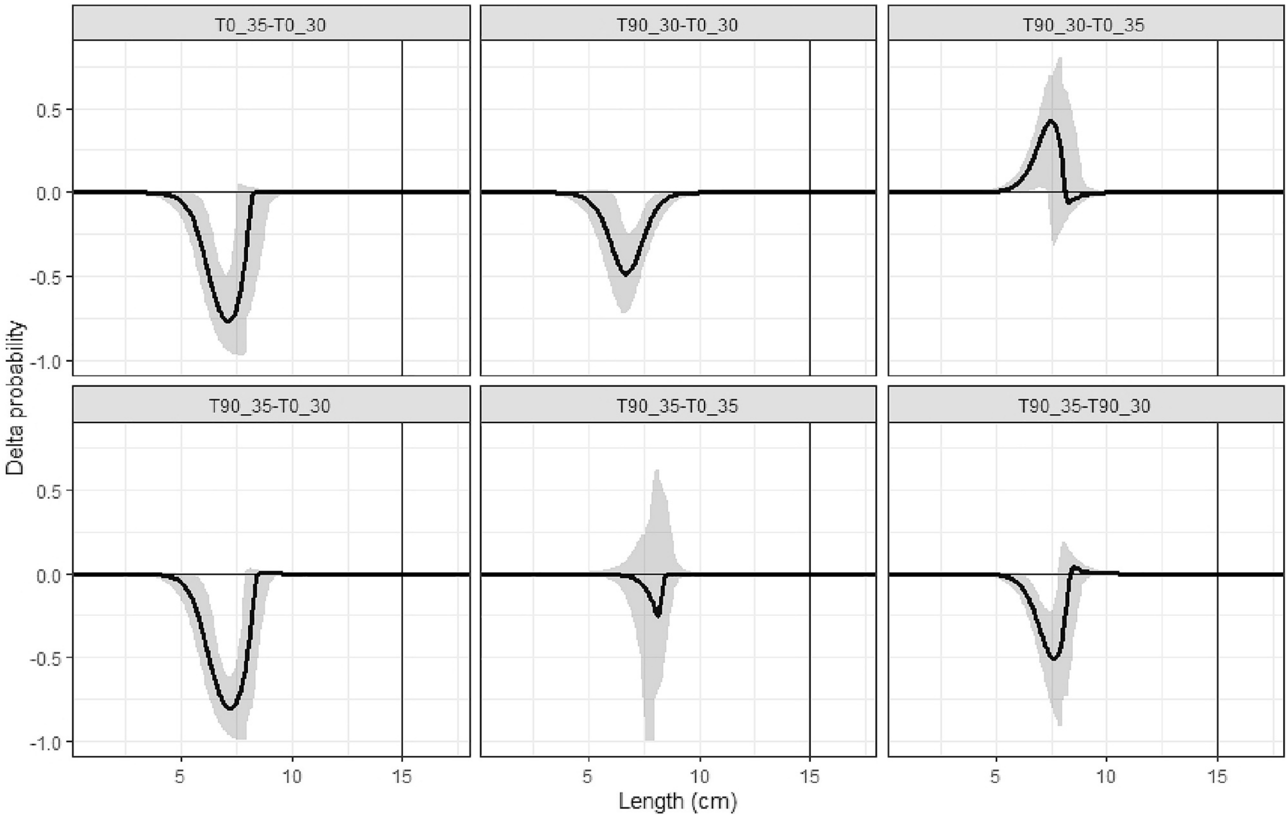

Fig. 4. Delta selectivity of comparisons between the tested codends. The black curves represent the delta selectivity, while the shaded areas are the 95% confidence intervals. Vertical lines are the MLS (minimum landing size, 15 cm) of white croaker in the South China Sea.

would obtain significantly higher retention for individuals ranging from 6.3 to 7.3 cm than the T0_35 codend (Fig. 4). Only the difference between the T0_35 codend and the T90_35codend wasn't statistically significant due to CIs contained the value of 0.0 for all sizes of white croaker. However, results indicated a reduction in retention probability for some sizes.

3.4. Exploitation pattern indicators

In two population scenarios, the T0_30 codend would have higher retention fraction of undersized white croaker (*nP*-) than the rest codends. These differences, however, weren't statistically significant due to that CIs overlapped in all codends tested, except that the T90_35 codend would have significantly lower ***nP***- than the T0_30 codend under the fishing population scenario of 2020 (Table 3). Nearly 100% retention probability was observed for fish with length above the MLS value (*nP*+), while relatively high discarded ratios, >96%, were obtained and no significant difference was found for all codends tested (Table 3).

Table 3
Exploitation pattern indicators obtained for the tested codends in two fishing population scenarios.

Population	Codend	*nP*-(%)	*nP*+ (%)	*dnRatio* (%)
2019	T0_30	61.97 (49.21–73.61)	100.00 (100.00–100.00)	97.96 (95.83–99.21)
	T0_35	41.53 (30.35–54.83)	100.00 (100.00–100.00)	96.98 (93.75–98.86)
	T90_30	48.87 (39.25–59.20)	100.00 (100.00–100.00)	97.43 (94.83–98.98)
	T90_35	38.67 (28.74–51.82)	100.00 (100.00–100.00)	96.77 (93.60–98.76)
2020	T0_30	36.12 (23.69–48.35)	100.00 (100.00–100.00)	99.34 (85.77–99.81)
	T0_35	16.49 (9.82–24.97)	100.00 (100.00–100.00)	98.57 (84.91–99.62)
	T90_30	22.11 (14.83–30.32)	100.00 (100.00–100.00)	98.93 (85.36–99.70)
	T90_35	15.14 (9.24–23.15)	100.00 (100.00–100.00)	98.45 (84.85–99.59)

4. Discussion

In present study, the size selectivity and exploitation patterns of two T0 codends were tested and compared with T90 codends in demersal trawl fishery targeting white croaker of the northern SCS. Taking full advantage of the commercial fishing practice, we investigated how codend modifications (the mesh sizes and mesh shapes) would impact the size selectivity and exploitation pattern for the studied species. Our results demonstrated that comparing with the T0_30 codend, increasing the mesh size to 35 mm or applying the T90 codends would have significantly larger L50 values and significantly lower retention probability for undersized white croaker in some length ranges. The T90_35 codend would have significantly lower retention probability for undersized individuals in some length ranges comparing with the T90_30 codend. Similarly, increasing the mesh size, from 30 to 35 mm, of the T0_30 codend or applying the T90 codends would reduce the captured proportion of undersized individuals for white croaker (*nP*-). The T90_35 codend would have significantly lower ***nP***- comparing with the T0_30 codend under the fishing population scenario of 2020.

Our study was the second documentation concerning gear modifications to address the bycatch issue in demersal trawl fishery targeting white croaker of the SCS. The first one was carried out by Yang et al. (2021), and they investigated how codend diamond-mesh sizes would impact the size selectivity for undersized white croaker by testing six sizes of 25, 30, 35, 40, and 54 mm, respectively. Their results showed that the codend selectivity could be improved by increasing the mesh sizes; however, none of codends tested was efficient enough to mitigate the bycatch of undersized individuals for the target species. They finally suggested that other gear modifications should be considered (Yang et al., 2021). In general, our results of the T0 codends were consistent with those of Yang et al. (2021) as that increasing the mesh sizes did improve the size selectivity. However, when considering the MLS regulation of white croaker in China, the improvement in size selectivity of all codends tested was again inefficient. Additionally, we expected that the T90 codends would have much better the size selectivity and exploitation pattern comparing with the T0 codends with identical mesh sizes. The actual results, however, were that the T90_30 codend obtained better results whereas this was only indicated for the T90_35 codend. This might be a result of the relative wide CIs.

Considering that parts of our experimental designs were identical or similar to those by Yang et al. (2021), it is relevant to compare the selectivity results between these two experiments. The two diamond-mesh codends, D30 and D35, in Yang et al. (2021) were the same as the T0_30 and T0_35 codend in this study. The results demonstrated that L50 of the T0_30 codend would be significantly lower than that of the D30 codend, 6.23 vs. 7.30 cm (CI: 5.80–6.67 vs. 6.95–7.93 cm) while L50 values were comparable between the D35 and T0_35 codend, 7.82 vs7.52 cm (CI: 7.24–8.47 vs. 6.78–8.84 cm) (Table 2). The T90_30 and T90_35 codend had similar L50 values comparing to those from the D30 and D35 codend in Yang et al. (2021). One possible explanation about lower L50 of the T0_30 codend comparing with the D30 codend could be the variations in fishing conditions between two sea trials, such as fishing seasons, fishing grounds and fishing populations. Another reason could be the variation in size selection of the T0 codends (Herrmann, 2005a; Herrmann, 2005b).

There are also other common results should be highlighted and discussed between the present study and the one conducted Yang et al. (2021). The most important ones are that both studies obtained smaller L50 values for white croaker comparing with the established MLS, high retention probability for juvenile individuals. For instance, all codends tested, including T0 and T90 codends, presented L50 values <11.0 cm, which was far less than the MLS of white croaker (15.0 cm) in the SCS. The selectivity curves in our study demonstrated that the retention probability came to 100% (full retention) when the length of target species got close to 10.0-cm. A similar trend was presented in the results of Yang et al. (2021) for codends with similar mesh sizes. The implication is that the juvenile individuals of white croaker with some length range, for instance 10.0 to 15.0 cm, will suffer full retention risk (i.e. 100%) in the trawl fishery in which the mesh sizes used in the codends are <40 mm. Meanwhile, the exploitation pattern indicators demonstrated that high discarded ratios (*dnRatio*), >93%, were obtained all codends tested, implying that serious bycatch issues is induced.

Although our experiment seems not making great progress in improving the size selectivity for the species investigated, these results still have implications to fisheries management and future direction of selectivity work. First, our study further confirmed that the T0 codends with mesh-sizes less or around 35 mm presented poor size selectivity for the species investigated. If the fishing fleet encounter abundant juvenile population of white croaker in the fishing ground, they should consider changing locations or times to avoid bycatch issues or turn to other gear modifications. Second, our study shows that applying the T90 codends could improve the size selectivity for white croaker in the studied area. This improvement, however, might be insufficient. Other gear modifications, such as adding sorting grids (Larsen et al., 2019), applying square mesh panel (Graham et al., 2003; Graham et al., 2004; Brčić et al., 2018), and other optical or physical stimulus (Krag et al., 2017; Melli et al., 2018; Grimaldo et al., 2018; Ingólfsson et al., 2021; Geraci et al., 2021), should be considered and tested in future research works.

5. Conclusion

Our study concluded that increasing the mesh size, from 30 to 35 mm, of the T0 codends or applying the T90 codends would result in significantly larger L50 values and significantly lower retention probability for undersized white croaker with length <8.5 cm. These modifications, however, had no effect on improving the size selection of juvenile white croaker in the length range of 10 to 15 cm, considering its MLS of 15 cm.

CRediT authorship contribution statement

Bingzhong Yang: Writing – review & editing, Writing – original draft, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation. **Bent Herrmann:** Writing – review & editing, Writing – original draft, Software, Methodology, Formal analysis. **Rong Wan:** Writing – review & editing, Writing – original draft, Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.seares.2024.102495.

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