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Stock Assessment of Blue Swimming Crab *Portunus pelagicus (Linnaeus 1758)* in Kien Giang Waters in 2023 based on the Length Based Spawning Potential Ratio method

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List of Abbreviations

BSC: Blue Swimming Crab

SPR: Spawning Potential Ratio

LBSPR: Length Based Spawning Potential Ratio

CW: Carapace Width

LRP: Limited Reference Point

ASC: Allowed Size of Capture

BT: Bottom Trawl

BG: Bottom Gillnet

CT: Collapsible Trap

ChT: Chinese Trap

M: Natural Mortality Rate

F: Fishing Mortality Rate

L50: Size at 50% of crab matured in population

L95: Size at 95% of crab matured in population

SL50: Size of 50% crab being captured

SL96: Size of 95% crab being captured

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1. Introduction

The Blue Swimming Crab (BSC), *Portunus pelagicus* (Linnaeus 1758) (Family: Portunidae), is widely distributed in the coastal zones of tropical waters. They are found from the intertidal zone to a depth of 50m throughout the Indo–West Pacific. BSC inhabits various environments, including mangroves, seagrass beds, coral reefs, and estuaries, on both sandy and muddy bottoms, with a concentration in the depth range of 5-25m (Williams 1982, Edgar 1990, Clarke and Ryan 2004). In Vietnam, BSC is distributed along the coastal waters from North to South and is densely aggregated in the waters of Kien Giang.

The BSC fishery in the Kien Giang province is localized to the districts of Ha Tien, Kien Luong, Hon Dat, and Phu Quoc Island. Fishers reside in numerous small fishing communities along the coast, relying on this fishery for their livelihoods. They utilize small fishing boats equipped with engines ranging from 20-33HP to catch BSC. Bottom gillnets and traps (Chinese traps and collapsible traps) are the primary fishing gears targeting BSC. Ha Tien and Phu Quoc are the two main landing sites where the majority of the catches are landed. Additionally, along the coasts of Kien Luong and Hon Dat districts, catches are landed locally.

The BSC fishery in Kien Giang is open access, and fishing activities occur throughout the year, with the main season running from April to August. The BSC stock has been heavily exploited since 2009. An MSC pre-assessment identifies the stock status as a medium risk, citing the main issues as:

- Limited knowledge of stock status;
- No harvest strategy
- Limited application of harvest control tools;
- Inadequacy in information systems;
- Uncertainty on bycatch interactions and ecosystem impacts;
- No supporting research implementation;
- Weaknesses in decision-making and consultation processes; and
- Limited enforcement

To promote effective fisheries management for the sustainable use of Blue Swimming Crab (BSC) resources, WWF Vietnam, VASEP Crab Council, and

RIMF have collaborated to support the Kien Giang Department of Agriculture and Rural Development (Kien Giang DARD) in implementing the Fisheries Improvement Project. The Fishery Action Plan, adopted in 2012, concluded in 2019. Stock assessments of BSC indicated over-exploitation during the period 2012-2016; however, there was a gradual recovery observed in the period 2017-2019 (Vũ Việt Hà & Trần Văn Cường, 2020).

Since 2020, the data collection activity supporting the stock assessment has not been implemented, thus the stock status is not updated. To solve this issue, the Vietnam Association of Seafood Exporters and Producers (VASEP) and the Research Institute for Marine Fisheries (RIMF have signed a contract to continuously implement the stock assessment of BSC in Kien Giang by the Length Based Spawning Potential Ratio method (LBSPR).

In 2023, four sampling trips were conducted in February, May, August and November expecting to get the best covering of crab size in BSC landing. This report presents the stock assessment of BSC based on the LBSPR method.

2. Materials and Methods

2.1. Study site and sample collection

Samples of Blue Swimming Crab (BSC), *Portunus pelagicus*, were collected at landing sites along the coast of Kien Luong, Ha Tien, and Phu Quoc districts in Kien Giang Province, where the majority of catches of this species are landed using bottom gillnets (BG), collapsible trap (CT), Chinese trap (ChT), and bottom trawl (BT). The locations of the sampling sites are indicated in Figure 1.

In February, May, August and November 2023, ten-day field visits were conducted each month to collect BSC samples from fishing boat catches. Crab samples, each weighing approximately 2.5 kg, were randomly collected from unloaded boats for size measurement and biological analysis.

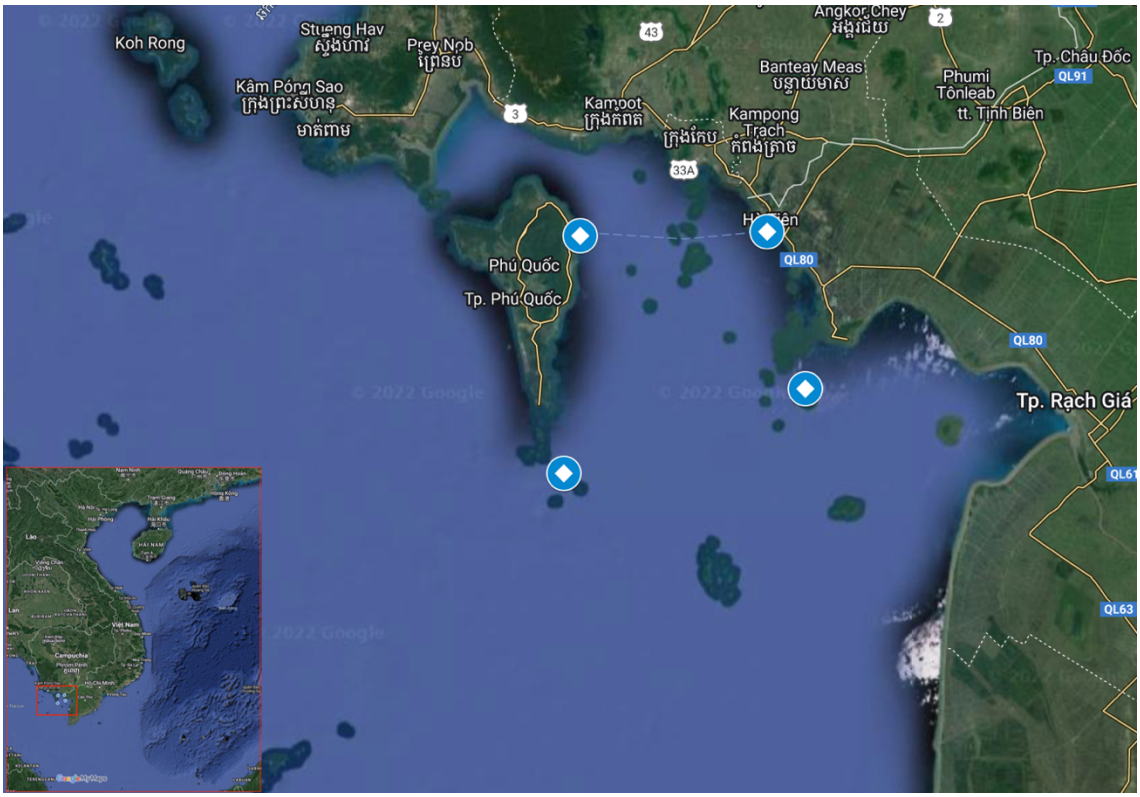


Figure 1. Sampling sites for BSC biological data in Kien Giang Province

Each crab was individually examined for abdominal morphology to determine sex. Carapace width (CW) was measured to the nearest 0.1 mm using a Palme ruler. Body weight (BW) and gonad weight (Wg) were measured to 0.01 grams using an electric weight scale. The gonad maturity stage was determined using a 5-level scale as described by Sumpton et al. (1994).

Stage I: the gonad is underdeveloped and dark

Stage II: the gonad is developing and opaque white

Stage III: the gonad is developed and light yellow

Stage IV: Matured, The gonad is dark yellow and fills the abdominal cavity

Stage V: Matured, eggs are covered in the overalls, eggs when laying have yellow color and switched to dark brown or black.

Figure 2. Maturity stage of BSC female. Photos were taken by Vu Viet Ha in Ham Ninh in 2013 under the BSC FIP project

2.2. Data analysis

Biological indicators such as the mean size, size frequency, sex ratio and maturity stage composition were descriptively analyzed using R packages

"dplyr" (Wickham H, François R et al. 2023), "ggplot2" (Wickham H 2016). Size at first maturity (CW_{50}) was estimated using the Generalized Linear Model (GLM) as described by King (King 1995) and Rubén et al (Rubén, Billy et al. 1999) by fitting a logistic curve between the proportion of mature (P) and size class (CW):

$$P = \frac{1}{1 + e^{[-r(CW - CW_{m50})]}}$$

The package "sizeMat" (Torrejon-Magallanes 2020) was used to estimate CW_{50} and visualize the logistic curve.

2.3. Length-Based Spawning Potential Ratio Assessment

The LBSPR methodology is a simplified form of assessment developed for data-poor fisheries lacking essential information for biomass trend assessments. This method is designed for stocks with only available data on catch size composition (Beverton 1963, Prince, Hordyk et al. 2014, Hordyk, Loneragan et al. 2015, Hordyk, Ono et al. 2016). Prince et al (2020) indicated that the data inputs required for the LBSPR methodology are:

1. Catch size composition data that are indicative of the size of the adult crab in a population. If the type of fishing being conducted fails to catch the largest size classes of a crab species, then the estimate of SPR produced for that species will be too small.
2. Estimates of the size at which crabs become adults (Lm) which is defined by L50 and L95, the sizes at which 50% and 95%, respectively, of a population are observed to be mature.
3. The two life history ratios (LHR) that characterize differing taxa and which determine the relative shape of population size and age compositions (Hordyk et al. 2015a). The LHR are:
    a) L50/L∞ - the relative size of maturity being the size of maturity (L50) divided by the average maximum size individuals might attain if they survived to infinite age (L∞); and
    b) M/K - the rate at which a cohort of crabs dies off from natural causes, divided by the von Bertalanffy growth parameter (K), which is the annual rate of grows to L∞.

Naturally, the original stock, without the impact of fishing activities, has an SPR of 100%, which varies with the effect of fishing effort on the population. In fishery management, the expected SPR is above 40%, and SPR below

20% indicates that the population is overexploited. The R package 'LBSPR' (Hordyk 2021) is utilized to estimate the SPR for Blue Swimming Crab (BSC) in Kien Giang Province.

In this report, we attempt to estimate the SPR with the available data for an understanding of the stock status.

3. Results and Discussion

3.1. Sample size

A total of 2,533 individuals of BSC were sampled from catches of Chinese traps (655 crabs), bottom trawls (150 crabs), bottom gillnets (1,189 crabs), and collapsible traps (529 crabs). The number of crabs collected in February, May, August, and November was 599, 601, 615, and 718 individuals, respectively.

BSC samples were collected in Ha Tien district, encompassing all fishing gears while bottom trawl samples were not included in Kien Luong, Ham Ninh, and An Thoi. The statistics of BSC samples collected in 2023 among regions are presented in Table 1.

Table 1. Number of BSC samples collected in 2023

Month	Gear	An Thoi	Ha Tien	Ham Ninh	Kien Luong	Total
2	BG	120	30	90	120	*360*
2	BT		30			*30*
2	CT	30	59	60	30	*179*
2	ChT		30			*30*
Total		*150*	*149*	*150*	*150*	*599*
5	BG	60	60	60	90	*270*
5	BT		60			*60*
5	CT		60			*60*
5	ChT		90	60	61	*211*
Total		*60*	*270*	*120*	*151*	*601*
8	BG	84	60		120	*264*
8	BT		30			*30*
8	CT	60	30		81	*171*
8	ChT	30	30		90	*150*
Total		174	150		291	615
11	BG	90	60		145	*295*
11	BT		30			*30*
11	CT	30	30		59	*119*

Month	Gear	An Thoi	Ha Tien	Ham Ninh	Kien Luong	Total
11	ChT	60	30		184	*274*
Total		180	150		388	718
Grand Total		**564**	**719**	**270**	**980**	**2533**
	BG	354	210	150	475	1189
	BT	0	150	0	0	150
	CT	120	179	60	170	529
	ChT	90	180	60	335	665

3.2. Size distribution

The size distribution of BSC captured by ChT, CT, BT, and BG in the Kien Luong, Ha Tien, Ham Ninh, and An Thoi regions is graphically indicated in Figure 4. It is noteworthy that the size of crabs varied among fishing gears and sampling time. BSC caught in BG was bigger than those in BT, ChT and CT (Table 2).

Table 2. Mean of Carapace width (CW, mm) and Body weight (BW, g) of BSC among the fishing gears

	CW (mm)		BW (g)		
Gear	**mean**	**sd**	**mean**	**sd**	**N**
BG	112.2	12.1	109.8	39.4	1189
BT	94.8	11.9	61	25.4	150
CT	96	11.8	65.1	27.5	529
ChT	91.6	12.1	54.8	22.6	665

In February and May, the dominant size class caught by BT was 75-90mm, smaller than those in August (80-110mm) and November (100-110mm). In catches of ChT, the dominant cohort was 90-110mm in January, 60-100mm in May, 75-110mm in August and November (Figure 5). The size of BSC in BT catches in January and May (75-90mm) was smaller than those in August and November (90-110mm)

In CT catches, BSC caught in An Thoi were bigger compared to those in Kien Luong and Ha Tien. The dominant size class varied from 75mm to 115mm depending on landing sites (Figure 5).

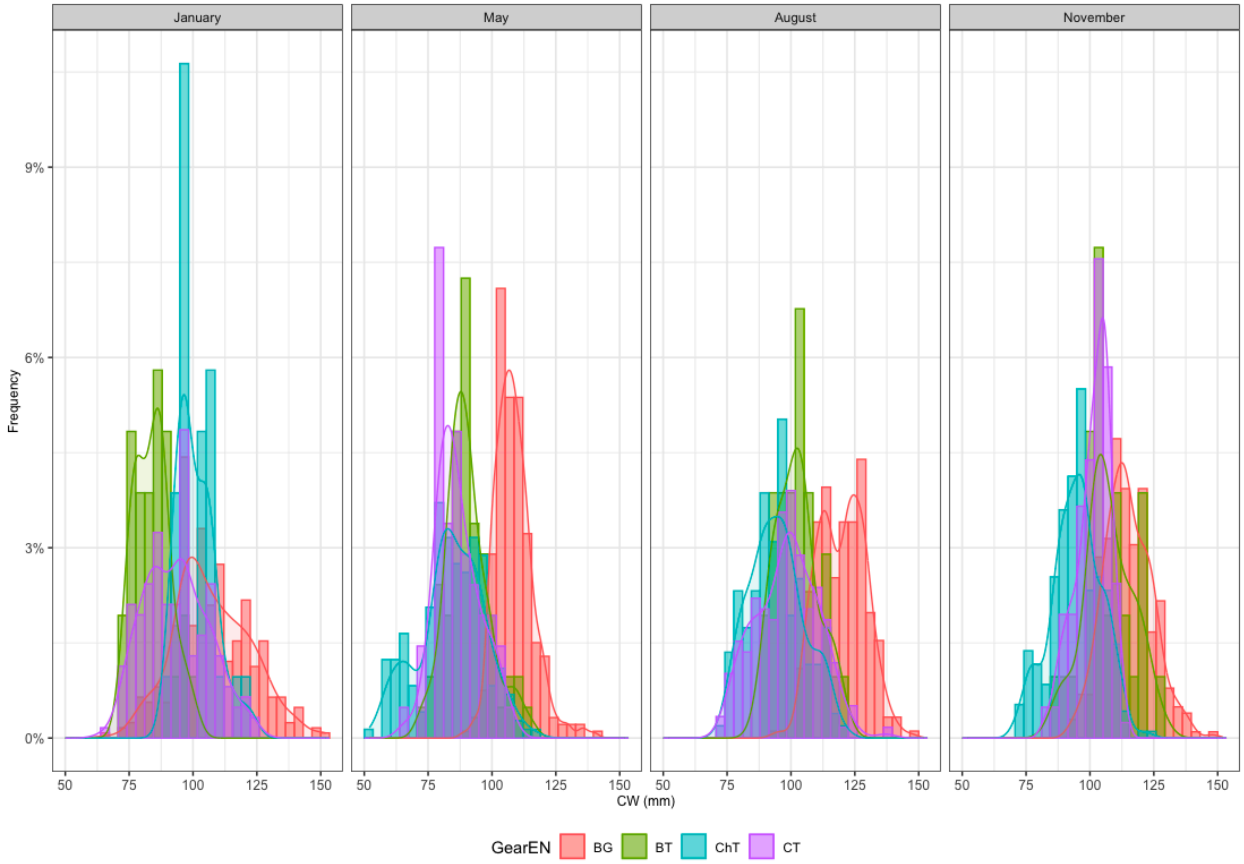


Figure 3. Size distribution (CW) of BSC caught by BG, CT, ChT and BT in Kien Giang waters

Ha Tien Region.

The mean size of crabs was 97.0±18.8mm (74.6±54.1 gram) in January, 89.9±15.0mm (54.6±29.1 gram) in May, 104.6±15.5mm (90.2±45.7 gram) in August, and 106.6±14.9mm (94.1±43.8 gram) in November. The smallest size was 52mm, observed in May in ChT catches, and the largest was 142mm, caught in January and August in BT catches.

Kien Luong Region

The mean size of crabs was 97.6±13.0mm (68.9±29.9 gram) in January, 98.5±14.2mm (72.1±32.6 gram) in May, 107.7±15.7mm (99.7±47.0 gram) in August, and 102±13.5mm (79±36.8 gram) in November. The smallest size was 62mm in ChT catches, observed in May, and the largest was 148mm, caught in November in BG catches.

An Thoi region

The mean size of crabs was 107.4±12.1 mm (95.2±42.1 gram) in January, 106.3±5.6 mm (84.2±13.7 gram) in May, 107.3±14.7 mm (98±41.4 gram) in August, and 108±7.1 mm (93.2±22.6 gram) in November. The smallest size was 74 mm caught by ChT, observed in August, and the largest was 152 mm, caught by BG in January

Ham Ninh Region

The mean size of crabs was 104.4±15.1 mm (94.4±45 gram) in January and 101.2±13.9 mm (78.8±34.6 gram) in May. The smallest size was 74 mm caught by ChT and the largest was 140 mm, caught by BG in January. Size distribution (CW) of BSC caught by BG, CT, ChT and BT in Kien Giang waters.

Figure 3 presents the size distribution of BSC caught by different fishing gears among sampling sites in 2023. The statistical descriptive of crab size is indicated in Appendix 1.

Figure 4. Size distribution (CW) of BSC caught by Chinese trap, Collapsible trap, bottom trawl and Bottom gillnet in Kien Giang waters in 2023

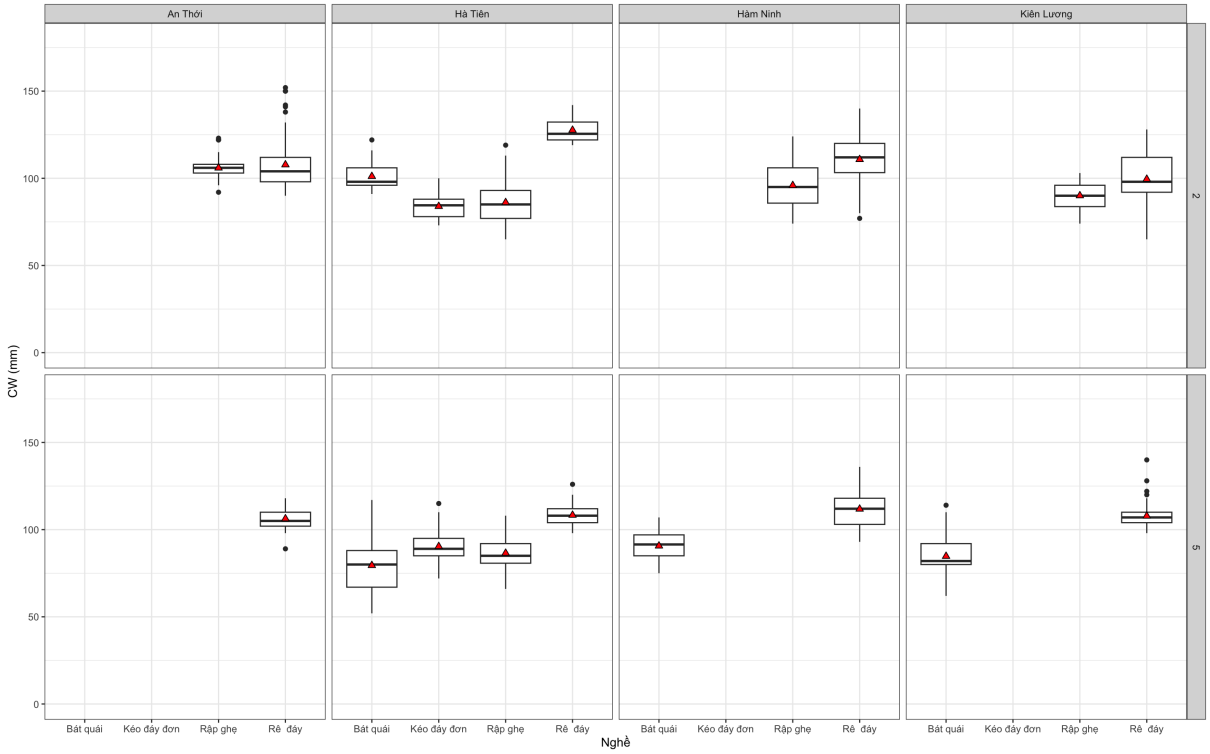


Figure 5. The mean CW of BSC among the fishing gears in Kien Luong, Ha Tien, Ham Ninh and An Thoi during the sampling period in February and May 2023

The smallest size of BSC in catches of the Chinese trap was 52mm in Ha Tien region whilst the biggest size was 72mm in catches of the bottom gillnet.

3.3. Sex ratio

During the sampling period, male crabs were predominant in the catches in all sampled regions except in May, the female crabs comprised about 76,7% of catches of An Thoi region (Figure 6). The observed differences in the expected sex ratio (1.0:1.0) could be owing to behavioral changes and local migration patterns. According to Carpenter et al. (1997), there are differences in habitat preferences of mature males and females. Females seem to be more abundant in deeper water than males (Lee & Hsu 2003).

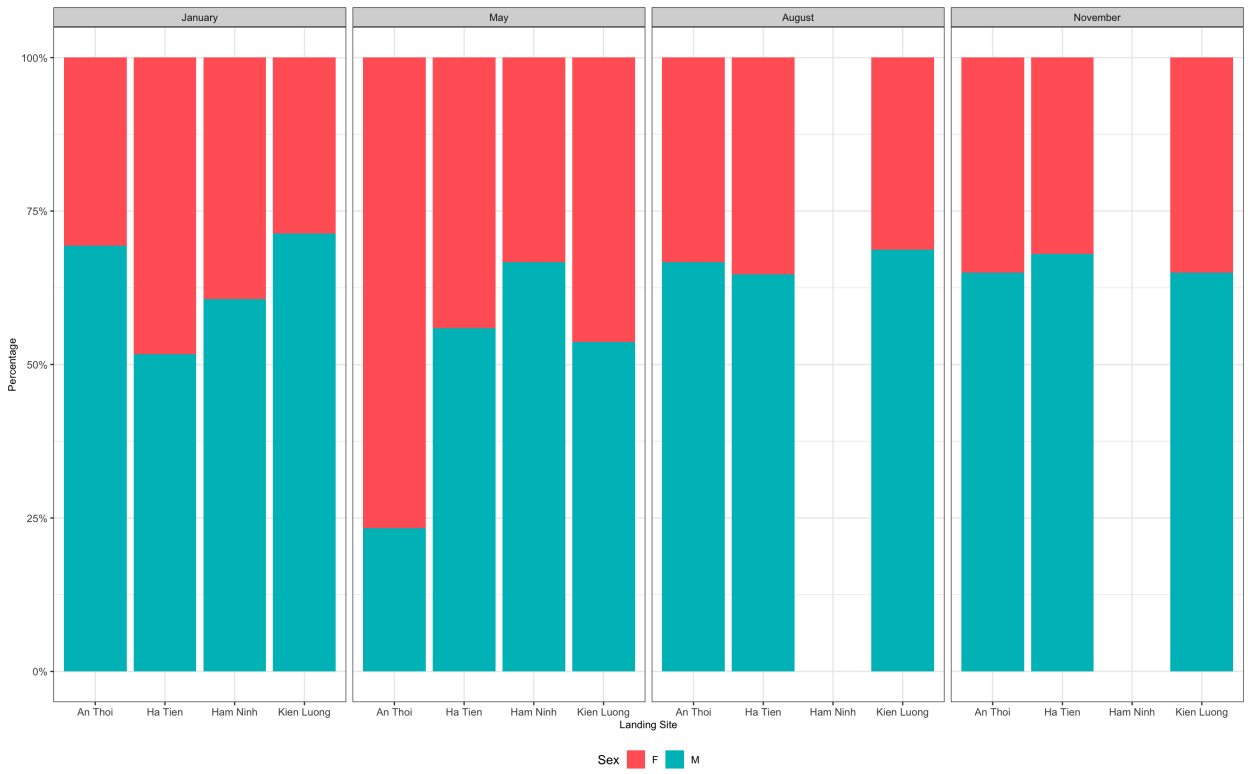


Figure 6. Sex ratio of BSC population in Kien Luong, Ha Tien, Ham Ninh and An Thoi in February, May, August and November 2023

3.4. Maturity stage composition of the Kien Giang BSC population

In the BSC population, mature crabs (stage IV, V) were predominant in An Thoi. The immature crabs under the allowed size of capture (stage I, II, III) were abundant in Ha Tien, Kien Luong and Ham Ninh regions (Figure 7). The mean CW among the maturity stage was 74mm (stage I), 80.7-87.5mm (stage II); 93.3-101.5mm (stage III); 106.2-109.8mm (stage IV) and 106.3-114.1mm (stage V) (Figure 8). The smallest size of BSC maturing at stage IV observed at 82mm in Kien Luong region

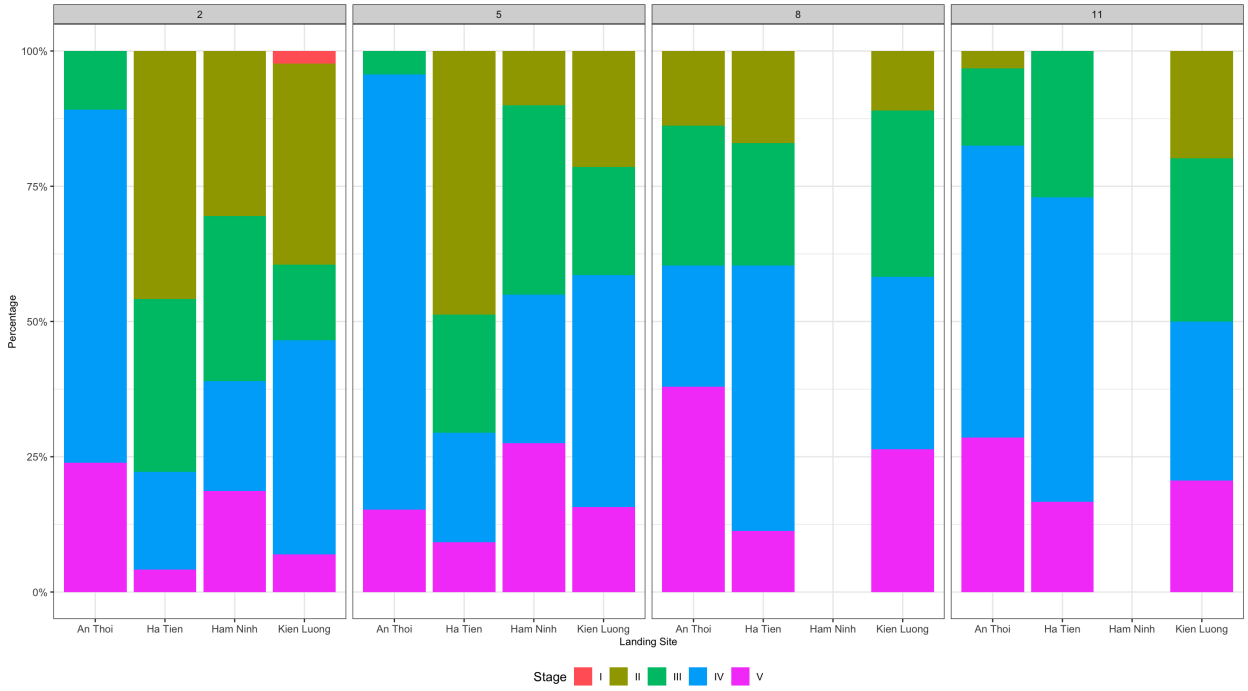


Figure 7. Maturity stage composition of BSC population in Kien Luong, Ha Tien, Ham Ninh and An Thoi in 2023

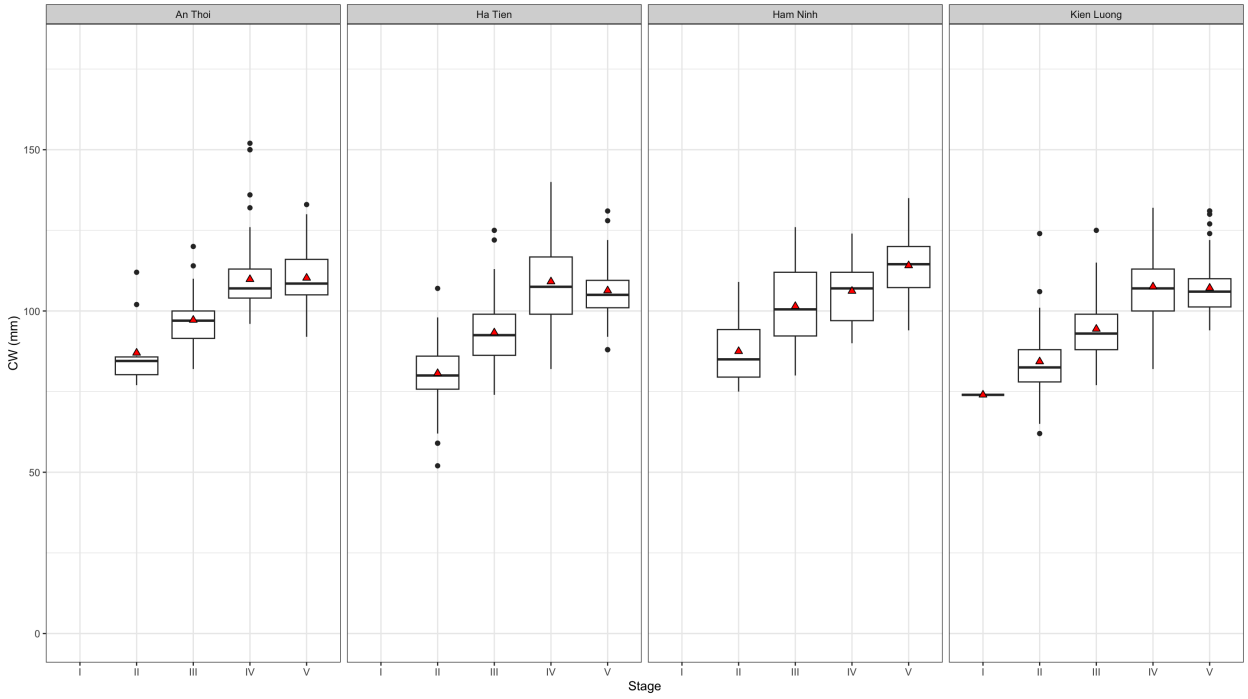


Figure 8. The boxplot of crab size against the maturity stage

3.5. Size at first maturity

Based on biological data collected in February, May, August, and November, the estimated size at first sexual maturity of female BSC was 98,1mm with a 95% confidence interval of 97.1 – 99.2 mm. The CW_{50} curve of BSC is shown

in Figure 9. It is noted that the CW_{50} size is smaller than the previously estimated (CW=99.28mm) by Trần Văn Cường và Vũ Việt Hà (2014) based on data collected in 2013.

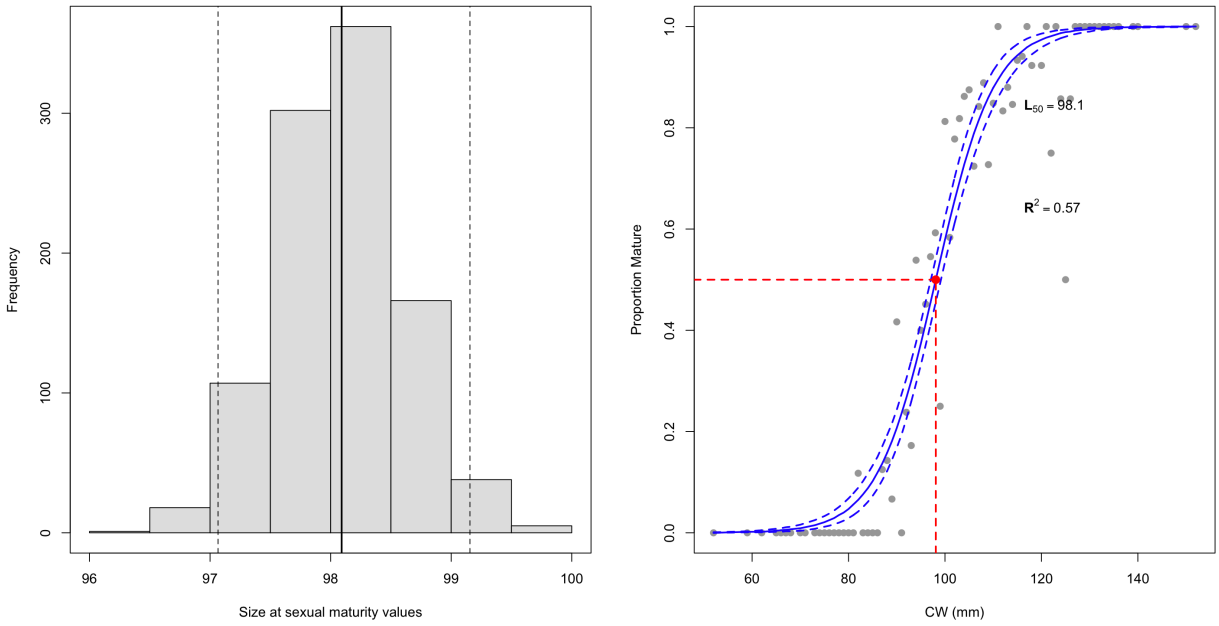


Figure 9. The 95% confidence interval of CW_{50} (on the left) and the CW_{50} curve of BSC show the relationship between the proportion of mature and crab size in Kien Giang province (on the right)

3.6. Stock Assessment of the BSC based on the Length-Based Spawning Potential Ratio method

Based on the available parameters ($CW_{infimity}$, K and M) estimated in 2018, M/K is 1.2. L50 and L95 values estimated from data sampled in 2023 are 98.1mm and 116mm.

The SPR estimated for BSC stock based on data collected in 2023 is graphically shown in Figure 10 and Figure 11. The mean SPR for all data combined was 0.16, with a 95% confidence interval of 0.14-0.17 (SL50~98.01mm; SL95~123.23mm) (Appendix 7). In May, the mean estimate of SPR was relatively low (0.09; range 0.04-0.14) in comparison to those in February (0.17 range 0.14-0.2); in August (0.2; range 0.14-0.26) and in November (0.16; range 0.13-0.19).

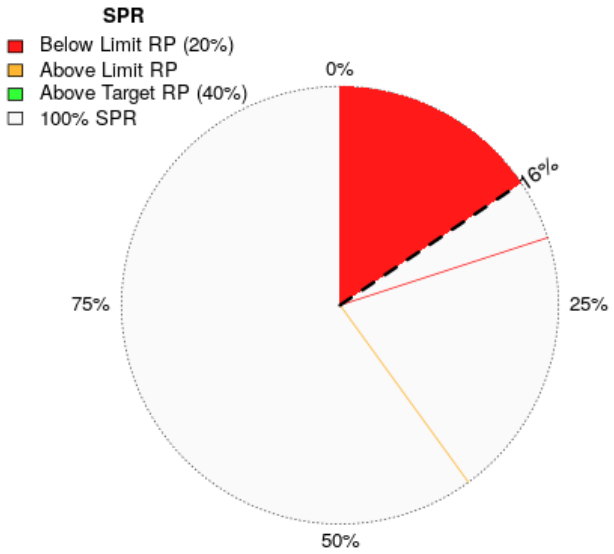


Figure 10. The LBSPR estimates for BSC stock in Kien Giang waters based on the data collected in 2023

When analyzing data by fishing gears, we found that all of which predictably produced low SPR estimates with only the SPR value of the BG exceeding the below-limit referent point (SPR = 0,23; range 0.2-0.25). The SPR values of the BT, ChT and CT were relatively low with the mean SPR value of 0.09 and SL50 ~ 84.47mm; SL95~97.03mm for the BT; SPR is 0.08 and SL50 ~ 87.91mm; SL95~113.41mm for the CT and SPR is 0.05 with SL50 ~95.08 and SL90 ~118.68 for the ChT (Appendix 8).

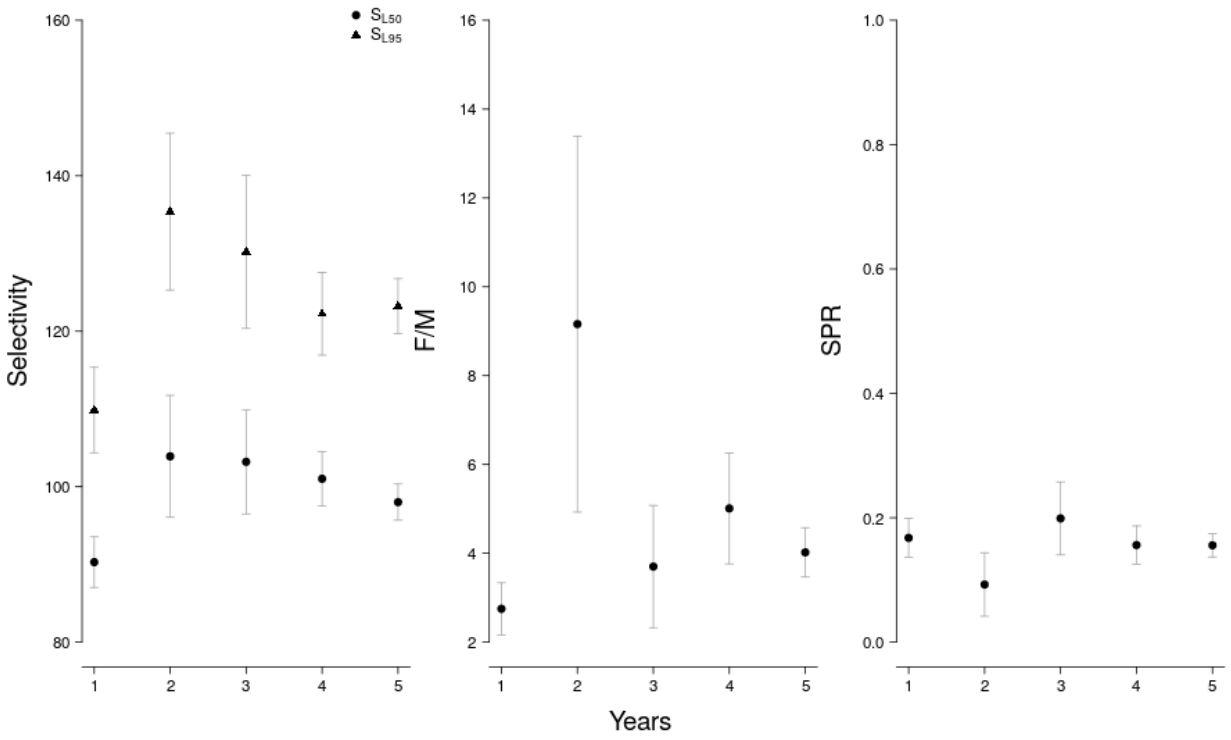


Figure 11. Plots of selectivity, F/M and SPR of BSC based on data collected in February (1), May (2), August (3), November (4) and All data collected in 2023 (5)

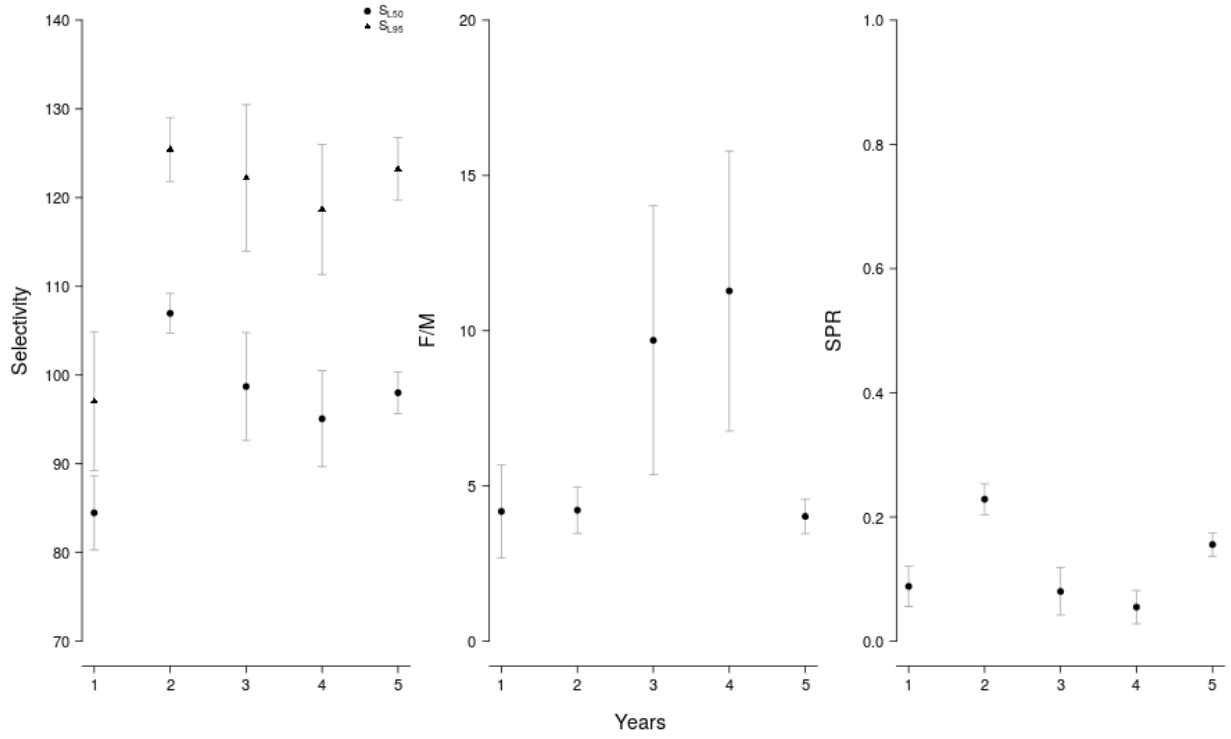


Figure 12. Plots of selectivity, F/M and SPR of BSC by different fishing gears based on data collected in 2023 (1, 2, 3, 4, 5 indicate data collected in catches of BT, BG, CT, ChT and All data combined)

The growth of BSC in Kien Giang province was first studied by (Cường and Hà (2014) using the size frequency collected monthly from January to December 2013, with a proposed von-Bertalanffy parameters as $CW_{infinity}$ = 175.9 mm; K = 0.99 $year^{-1}$ (n=4370).

The mortality rate of BSC has been monitored annually since 2013 showing that the natural mortality rate (M) decreased and fishing mortality was increasing (Ha and Cuong 2020). The re-estimated von-Bertalanffy growth function for BSC in 2018 showed that the $CW_{infinity}$ was smaller than those estimated in 2013 ($CW_{infinity}$ = 168mm, K = 0.9 for both sexes combined and M = 1.05).

In 2023, the CW of crabs ranged from 52mm to 152mm (min, max), smaller than those collected in periods 2017-2019 (Ha and Doan 2018, Ha and Doan 2019, Ha and Doan 2020). The main spawning season of BSC was known from February to April with a peak in March (Ha and Doan 2014). Thus, crabs caught in May were dominated by small-size groups that could be from the new successful recruitment cohorts of the previous spawning season. The size of crabs was smaller than the size at first maturity and the undersize comprised a high ratio in catches resulting in the low SPR obtained. Increasing the mesh size of the fishing gears is required to enhance the size capture of crabs.

3.7. Risk of fishing to BSC population

Based on the size distribution of BSC in catches landed in Kien Giang province, it is suggested that the BSC population is at high risk since most of the crabs were undersized. The ratio of undersized crabs comprised 96.7% in trawl catches in January; 86.7% in May; 36.7% in August and 13.3% in November. In catches of the ChT, the undersize crabs were reported at 53.3%-96.7% in Ha Tien region; 63.3% - 90.2% in Kien Luong region; 88.3% in Ham Ninh and 23.3-83.3% in An Thoi region.

The CT is also considered a high-risk fishing gear for the BSC population. The undersize crab ratio varied by time and space within the fishing grounds in Kien Giang province, however, the small-size crab was estimated relatively high, at about 80- 89.9% in Ha Tien region; 65% in Ham Ninh and 90% in Kien Luong region (Table 3). The BG is a selective fishing gear for the BSC with most of the crabs in catches being bigger than the expected

size of capture. The ratio of undersized crabs was comprised less than 10% in the catches of the BG except for the crabs caught in January in An Thoi, Kien Luong and Ham Ninh regions (Table 3).

Table 3. The ratio of crabs at different size categories in catches landed in Ha Tien, Kien Luong, Ham Ninh and An Thoi region

Month	Gear	Size of crab in catches	An Thoi	Ha Tien	Kien Luong	Ham Ninh
January	BG	≥ ASC	71.7	100	43.3	81.1
January	BG	< ASC	28.3	-	56.7	18.9
January	BT	≥ ASC	-	3.3	-	-
January	BT	< ASC	-	96.7	-	-
January	CT	≥ ASC	76.7	10.2	10	35
January	CT	< ASC	23.3	89.8	90	65
January	ChT	≥ ASC	-	46.7	-	-
January	ChT	< ASC	-	53.3	-	-
May	BG	≥ ASC	93.3	93.3	98.9	88.3
May	BG	< ASC	6.7	6.7	1.1	11.7
May	BT	≥ ASC	-	13.3	-	-
May	BT	< ASC	-	86.7	-	-
May	CT	≥ ASC	-	11.7	-	-
May	CT	< ASC	-	88.3	-	-
May	ChT	≥ ASC	-	11.1	9.8	11.7
May	ChT	< ASC	-	88.9	90.2	88.3
August	BG	≥ ASC	100	100	98.3	-
August	BG	< ASC	-	-	1.7	-
August	BT	≥ ASC	-	63.3	-	-
August	BT	< ASC	-	36.7	-	-
August	CT	≥ ASC	60	20	51.9	-
August	CT	< ASC	40	80	48.1	-
August	ChT	≥ ASC	16.7	16.7	36.7	-
August	ChT	< ASC	83.3	83.3	63.3	-
November	BG	≥ ASC	96.7	96.7	95.2	-
November	BG	< ASC	3.3	3.3	4.8	-
November	BT	≥ ASC	-	86.7	-	-
November	BT	< ASC	-	13.3	-	-
November	CT	≥ ASC	100	13.3	79.7	-
November	CT	< ASC	-	86.7	20.3	-
November	ChT	≥ ASC	76.7	3.3	17.9	-
November	ChT	< ASC	23.3	96.7	82.1	-

4. Conclusions

Four filed surveys for biological data of BSC have been conducted in landing sites of Kien Giang province with a total of 2,533 individual BSC sampled and analyzed for biological information supporting LBSPR stock assessment.

The mean CW of BSC was in the range of 83.9-111.8 mm. The smallest crab was 52mm caught by ChT and the biggest size was 152mm in catches of the BG. The CW_{50} was estimated at 98.1mm with a 95% confidence interval of 97.1 - 98.2mm. Male crabs were predominant in the BSC population during the survey periods.

The BSC population in Kien Giang province was estimated at high risk since the ratio of undersized crabs was relatively high, especially in catches of the BT, ChT and CT.

The estimated LBSPR showed below the limit referent point (LBSPR = 0.16; range 0.13-0.19), particularly in May when a high ratio of recruits from the previous spawning season was captured. Except for the SPR estimated from BG data, which exceeded the limited reference point (LRP), all LBSPRs estimated from BT, CT, and ChT were relatively low, below the LRP. Therefore, there is a need to increase the mesh size of the fishing gear to enhance the capture size of crabs.

References

Beverton, R. J. H. (1963). "Maturation, growth and mortality of Clupeid and Engraulid stocks in relation to fishing." Rapp.P.-V.Réun.CIEM(154): 44-67.

Clarke, K. and S. Ryan (2004). Ecological assessment of the Queensland bleu swimming crab pot fihsery. Department of Primary Industhi.

Cường, T. V. and V. V. Hà (2014). "Đánh giá nguồn lợi ghẹ xanh (Portunus pelagicus) ở vùng biển Kiên Giang, Việt Nam năm 2013." Tạp chí Nông nghiệp và Phát triển Nông thôn 9/2014(Chuyên đề Nghiên cứu Nghề cá biển): 50-60.

Edgar, G. J. (1990). "Predator-prey interactions in sea grass beds. II. Distribution and diet of the blue manna crab P. pelagicus Linnaeus at Cliff Head, Western Australia." Jounrnal of Experimental Marine Biology and Ecology 139: 23-32.

Ha, V. V. and T. V. Cuong (2020). "The Management of Blue Swimming Crab Fishery in Kien Giang Province, Vietnam: the knowledge gaps and some priority actions to gain scientific information." Science and Technology Journal of Agriculture and Rural Development(Marine Fisheries Research): 25-34.

Hà, V. V. and T. V. Cường (2020). "Quản lý nghề khai thác ghẹ xanh ở vùng biển Kiên Giang, Việt Nam: Những thiếu hụt thông tin và một số hoạt động ưu tiên để cải thiện dữ liệu khoa học." Tạp chí Nông nghiệp và Phát triển Nông thôn(Chuyên đề Nghề cá biển): 25-35.

Ha, V. V. and N. S. Doan (2018). Stock Assessment of Blue Swimming Crab in Kien Giang Province in 2017. Fishery Improvement Project, Research Institute for Marine Fisheries: 75.

Ha, V. V. and N. S. Doan (2019). Stock Assessment of Blue Swimming Crab in Kien Giang Province in 2018. Fishery Improvement Project, Research Institute for Marine Fisheries: 38.

Ha, V. V. and N. S. Doan (2020). Stock Assessment of Blue Swimming Crab in Kien Giang Province in 2019. Fishery Improvement Project, Research Institute for Marine Fisheries: 29.

Ha, V. V. and T. H. N. T. V. C. N. S. Doan (2014). Stock anh Fishery Assessment of Blue Swimming Crab Portunus pelagicus (Linnaeus, 1758) in Kien Giang waters, Vietnam. Fishery Improvement Project, Research Institute for Marine Fisheries: 52.

Hordyk, A. (2021). LBSPR: An R package for simulation and estimation using life-history ratios and length composition data.

Hordyk, A. R., et al. (2015). "An evaluation of an iterative harvest strategy for data-poor fisheries using the length-based spawning potential ratio assessment methodology." Fisheries Research 171: 20-32.

Hordyk, A. R., et al. (2016). "A simple length-structured model based on life history ratios and incorporating size-dependent selectivity: application to spawning potential ratios for data-poor stocks." Canadian Journal of Fisheries and Aquatic Sciences 73(12): 1787-1799.

King, M. (1995). Fisheries biology, assessment and management, Fishing New Books.

Prince, J., et al. (2020). "Length based assessment of spawning potential ratio in data-poor fisheries for blue swimming crab (Portunus spp.) in Sri Lanka and Indonesia: Implications for sustainable management." Regional Studies in Marine Science 36: 101309.

Prince, J., et al. (2014). "Revisiting the concept of Beverton-Holt Life History Invariants with the aim of informing data-poor fisheries assessment." Ices Journal of Marine Science.

Rubén, R., et al. (1999). "Estimation of size at sexual maturity: an evaluation of analytical and resampling procedures." Fishery Bulletin 97(3): 570-580.

Sumpton, W. D., et al. (1994). "Reproduction and growth of commercial sand crab, portunus pelagicus (L.) in Moreton Bay, Queensland." Asian Fisheries Science 7: 103-113.

Torrejon-Magallanes, J. (2020). sizeMat: An R Package to Estimate Size at Sexual Maturity. Available from: https://cran.r-project.org/web/packages/sizeMat/vignettes/sizeMat.html.

Wickham H (2016). ggplot2: Elegant Graphics for Data Analysis. Springer-Verlag New York. ISBN 978-3-319-24277-4.

Wickham H, et al. (2023). dplyr: A Grammar of Data Manipulation. https://dplyr.tidyverse.org, https://github.com/tidyverse/dplyr.

Williams, M. J. (1982). "Natural food and feeding in the commercial sand crab Portunus pelagicus Linnaeus 1766 (Crustacea: Dcapoda: Portunida) in Mereton Bay, Queensland." Experimental Marine Biology and Ecology 59.

Appendices

Appendix 1. Mean Carapace Width (CW, mm) and mean Body Weight (BW, gram) of BSC caught by different fishing gears among the regions in Kien Giang provinve

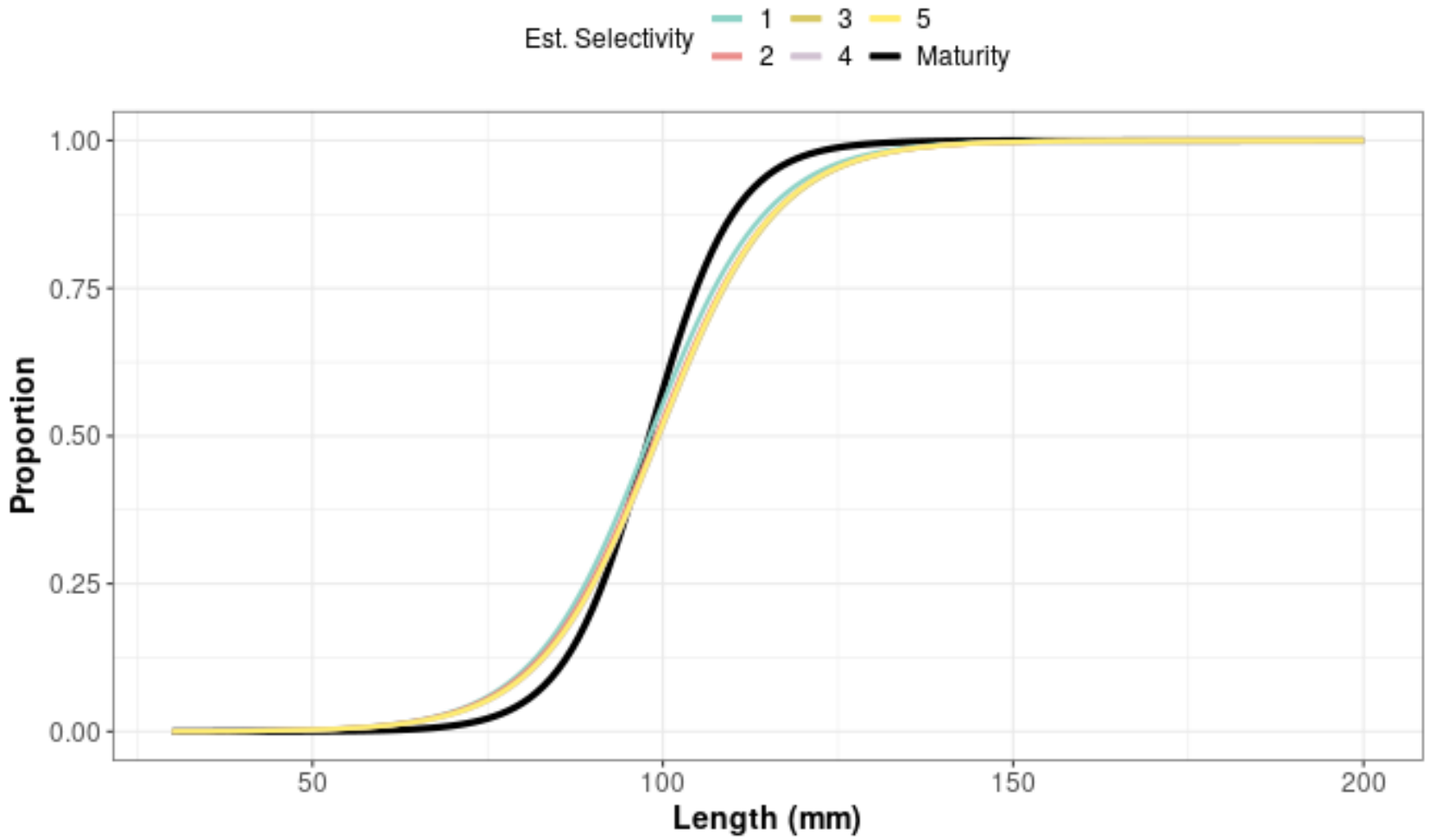
Month	Landing Site	Fishing Gear	CW (mm)		BW (g)		N
			mean	sd	mean	sd	
January	An Thoi	BG	107.8	13	96.8	45.9	120
January	An Thoi	CT	105.9	7.7	88.9	20.7	30
January	Ha Tien	BG	127.6	7.3	172	26.1	30
January	Ha Tien	BT	83.9	6.8	39.7	10.6	30
January	Ha Tien	CT	86.1	11.1	44.7	20.5	59
January	Ha Tien	ChT	101.1	7.5	71	19.4	30
January	Ham Ninh	BG	110.8	13.9	109.2	44.8	90
January	Ham Ninh	CT	95.9	12.3	62.2	27.1	60
January	Kien Luong	BG	99.5	13.4	73.3	31.3	120
January	Kien Luong	CT	90	7.4	51.1	12.8	30
May	An Thoi	BG	106.3	5.6	84.3	13.7	60
May	Ha Tien	BG	108.3	6	94.8	19.4	60
May	Ha Tien	BT	90.4	8.6	51.6	16.6	60
May	Ha Tien	CT	86.5	8.6	46.1	15.2	60
May	Ha Tien	ChT	79.5	14.5	35.4	21.3	90
May	Ham Ninh	BG	111.8	10.2	104.1	30.6	60
May	Ham Ninh	ChT	90.7	7.7	53.6	13.7	60
May	Kien Luong	BG	107.8	6.3	94.1	20.9	90
May	Kien Luong	ChT	84.7	11.2	39.8	15.1	61
August	An Thoi	BG	116.8	9.8	124.8	30.3	84
August	An Thoi	CT	101.8	12.4	81.9	35.2	60
August	An Thoi	ChT	92	11.7	55.2	23.9	30
August	Ha Tien	BG	119.3	7.9	135.1	33.6	60
August	Ha Tien	BT	102.2	8.2	79.8	19.7	30
August	Ha Tien	CT	90.6	9.5	49.2	15.2	30
August	Ha Tien	ChT	91.4	10.2	52	17.5	30
August	Kien Luong	BG	122.1	8.8	143.3	29.3	120
August	Kien Luong	CT	99	11.4	72.5	34.2	81
August	Kien Luong	ChT	96.3	10.1	65.9	24.2	90
November	An Thoi	BG	112.8	6.5	105.6	23.6	90
November	An Thoi	CT	105.2	2.4	80	6.9	30
November	An Thoi	ChT	104	5.6	81.4	14.7	60
November	Ha Tien	BG	120.2	10.3	134.5	38.2	60
November	Ha Tien	BT	107.2	9.4	82.4	27.4	30

November	Ha Tien	CT	92.8	5.3	58.7	9.2	30
November	Ha Tien	ChT	92.6	4.6	60.5	8.2	30
November	Kien Luong	BG	113.9	9.7	112.5	33.8	145
November	Kien Luong	CT	103.6	4.8	79.3	10.6	59
November	Kien Luong	ChT	92	9.7	52.6	18.2	184

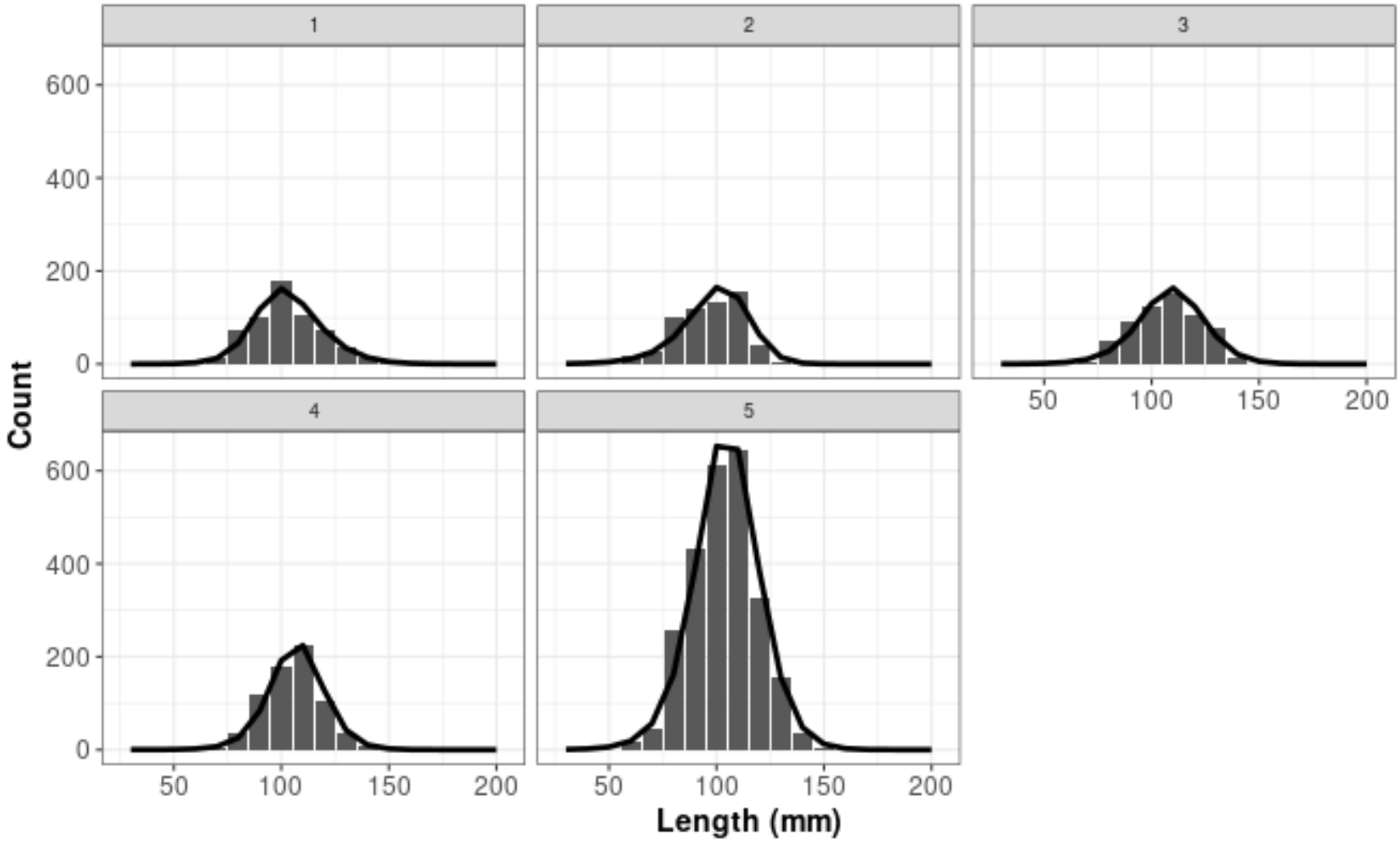
Appendix 2. Sex ration of BSC population among regions in 2023

Month	LandingSiteEN	Sex	N	Sex Ratio (%)
January	An Thoi	F	46	30.7
January	An Thoi	M	104	69.3
January	Ha Tien	F	72	48.3
January	Ha Tien	M	77	51.7
January	Ham Ninh	F	59	39.3
January	Ham Ninh	M	91	60.7
January	Kien Luong	F	43	28.7
January	Kien Luong	M	107	71.3
May	An Thoi	F	46	76.7
May	An Thoi	M	14	23.3
May	Ha Tien	F	119	44.1
May	Ha Tien	M	151	55.9
May	Ham Ninh	F	40	33.3
May	Ham Ninh	M	80	66.7
May	Kien Luong	F	70	46.4
May	Kien Luong	M	81	53.6
August	An Thoi	F	58	33.3
August	An Thoi	M	116	66.7
August	Ha Tien	F	53	35.3
August	Ha Tien	M	97	64.7
August	Kien Luong	F	91	31.3
August	Kien Luong	M	200	68.7
November	An Thoi	F	63	35
November	An Thoi	M	117	65
November	Ha Tien	F	48	32
November	Ha Tien	M	102	68
November	Kien Luong	F	136	35.1
November	Kien Luong	M	252	64.9

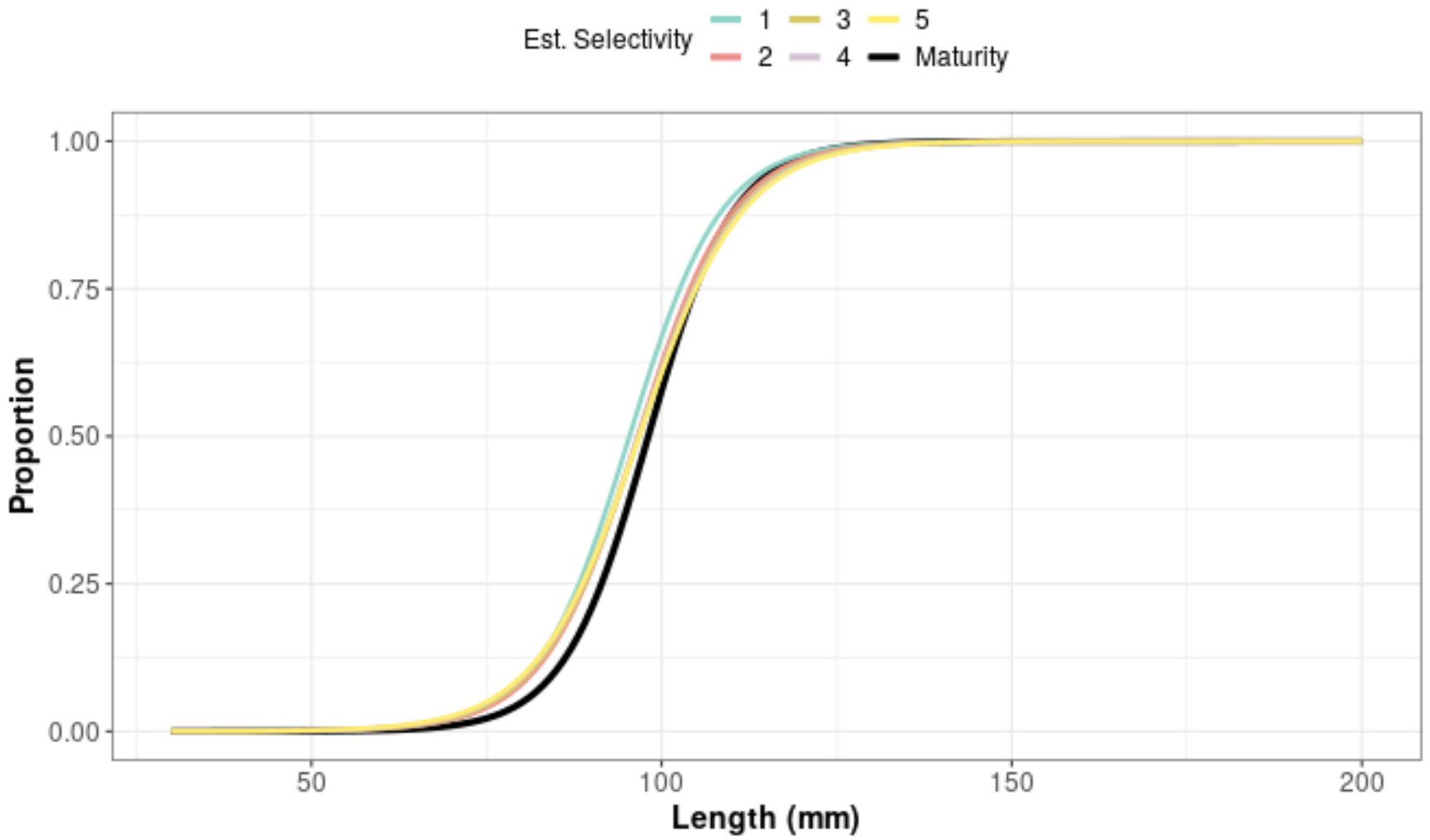
Appendix 3. Plots of size selectivity and maturity curve of BSC based on data collected in February (1); May (2); August (3); November (4) in 2023 and (5) indicated all data combined



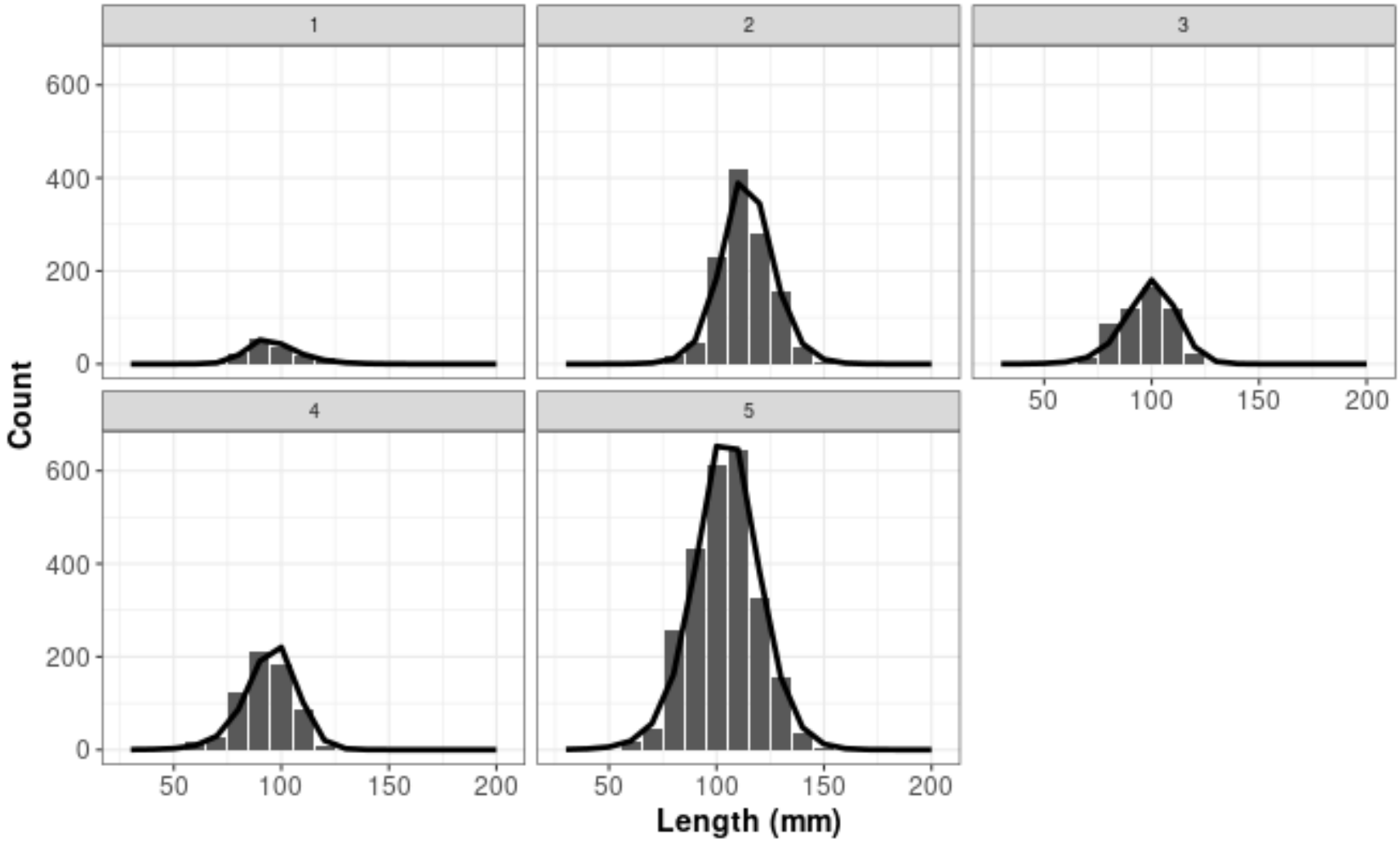
Appendix 4. Plots of size frequency (Length indicates the CW, mm) of BSC based on data collected in February (1); May (2); August (3); November (4) in 2023 and (5) indicated all data combined



Appendix 5. Plots of size selectivity and maturity curve of BSC based on data collected from the catches of the BT (1); BG (2); CT (3); ChT (4) in 2023 and (5) indicated all data combined



Appendix 6. Plots of size frequency (Length indicates the CW, mm) of BSC based on data collected from the catches of the BT (1); BG (2); CT (3); ChT (4) in 2023 and (5) indicated all data combined



Appendix 7. The estimates of SPR of BSC stock based on the data collected in 2023

Sampling time	SPR	SL50	SL95	F/M
January	0.17 (0.14 - 0.2)	90.29 (87.03 - 93.55)	109.86 (104.36 - 115.36)	2.75 (2.16 - 3.34)
May	0.09 (0.04 - 0.14)	103.9 (96.07 - 111.73)	135.39 (125.29 - 145.49)	9.16 (4.93 - 13.39)
August	0.2 (0.14 - 0.26)	103.19 (96.49 - 109.89)	130.21 (120.35 - 140.07)	3.7 (2.32 - 5.08)
November	0.16 (0.13 - 0.19)	101.01 (97.51 - 104.51)	122.23 (116.92 - 127.54)	5.01 (3.76 - 6.26)
All Data	0.16 (0.14 - 0.17)	98.01 (95.68 - 100.34)	123.23 (119.7 - 126.76)	4.02 (3.47 - 4.57)

Appendix 8. The estimates of LBSPR of BSC stock captured by different fishing gears based on the data collected in 2023

Fishing gear	SPR	SL50	SL95	F/M
BT	0.09 (0.06 - 0.12)	84.47 (80.28 - 88.66)	97.03 (89.22 - 104.84)	4.18 (2.69 - 5.67)
BG	0.23 (0.2 - 0.25)	106.96 (104.71 - 109.21)	125.42 (121.83 - 129.01)	4.22 (3.47 - 4.97)
CT	0.08 (0.04 - 0.12)	98.71 (92.62 - 104.8)	122.21 (113.95 - 130.47)	9.69 (5.36 - 14.02)
ChT	0.05 (0.03 - 0.08)	95.08 (89.67 - 100.49)	118.68 (111.35 - 126.01)	11.28 (6.77 - 15.79)
All Data	0.16 (0.14 - 0.17)	98.01 (95.68 - 100.34)	123.23 (119.7 - 126.76)	4.02 (3.47 - 4.57)