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Carapace Width and Weight Relationship and the Estimated Size at Sexual Maturity for Female Mud Crabs (*Scylla serrata* Forskål, 1775) in Batticaloa District, Sri Lanka

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The mud crab, *Scylla serrata* lives in mangrove ecosystems and is widely distributed in the Indo-West-Pacific. The present work was aimed to reveal the carapace width-weight relationships of *S. serrata* and its size at sexual maturity for females from Vakarai, Valaichenai, Nasivanthivu, Panichankerny in Batticaloa districts, east coast of Sri Lanka. The crabs were collected through suitable traps and crab nets from November 2023 to January 2024. A total of 660 individuals were collected, their carapace length, width, and weight were measured, and their sexes male and female were identified. The sex ratio of total collected samples was 1:1.41. CL of *S. serrata* caught in these months ranged from 51 to 108 mm for males and 54 to 126 mm for females, whereas, the CW was 70 to 201 mm for males and 74 to 202 mm for females. The carapace length-weight relationships of total samples are shown in logarithmic equations: W = -7.5200 + 3.1310 Log CL for males and Log W = -7.7623 + 3.1853 Log CL for females. The carapace width-weight relationships are as follows: W = -5.9201+ 2.4440 Log CW for males and Log W = -5.3719 + 2.3231 Log CW for females. The b values of the carapace width-weight relationship, indicate a negative allometric growth pattern. Based on these findings during January the female crabs attain a larger mean size at maturity than in November and December by internal carapace width (ICW). This study explains about variation in mature and immature stages between the smallest to largest female crabs and also shows uneven growth in male and female crab.

Keywords: Mud crab; sexual maturity; sex ratio; carapace width and weight relationship; Batticaloa districts.

1. INTRODUCTION

Sri Lanka is an Island with a 2,000 km shallow shoreline and nearly 10,000 ha of mangroves. The Eastern Province of Sri Lanka has mainly estuarine mangroves and waterways, that involve Batticaloa District, ideal for mangroves. Batticaloa district has a 110 km coast and almost 900 ha of mangroves (Mathiventhan and Jayasingam, 2016). Much has been devastated or reconstructed by war, the 2004 tsunami, and development actions (infrastructure, aquaculture, paddy fields, and encroachment). It is estimated that at least 321 hectares of mangrove (about 15-20% of the total) have been emptied around the Batticaloa estuary (NECCDEP, 2010).

Mud crabs from the genera Scylla belong to the Portunidae family and are widely distributed throughout the Indo-West Pacific mangrove environments (Trivedi and Vachhrajani, 2013). According to Pratiwi, (2011), mud crabs possess significant commercial value due to their savory taste and rich in nutritional values like protein, vitamins, minerals and essential fatty acids (Chanda et al., 2024), making them a valuable component of small-scale coastal fisheries in numerous tropical and sub-tropical nations. The mud crab is a nocturnal animal and mainly burrows during low tide (Hill 1976; Barnes et al. 2002), but they will be very active in foraging when the environment is covered by seawater at high tide (Nirmale et al., 2012). This is abundant in estuaries and mangrove swamps frequently flooded by seawater (Keenan et al., 1998; Barnes et al., 2002). *S. serrata* is considered the largest of the Portunid crabs, weighing up to 2 kg and a carapace width (CW) of 200 mm (Rezaie-Atagholipour et al., 2013). “These crabs play a vital role in bioturbation through burrowing activity, maintaining the nutrient cycle, creating habitat, and providing a food web source” (Pati et al., 2023). “Reproduction occurs year-round in the tropics, accompanying seasonal maxima that appear to coincide with seasonally high rainfall” (Levay, 2001). “Several criteria of the mangrove environment and its ecosystem, such as mangrove vegetation, salinity, temperature, substrate, tides, and topography can influence the existence and distribution of *Scylla* spp. Mangrove density is directly corresponding to the abundance of *Scylla* spp.” (Putra et al., 2016). “Fishing activities of mangrove crabs have hiked in recent years as a result of market demand both locally and internationally. Population decline is characterized by minor catches and smaller sizes of mud crabs have occurred in the last two decades, especially in the Southeast Asian region” (Levay, 2001; Chakraborty et al., 2018).

“The study of carapace width-weight relationships takes an important prerequisite in biology, physiology, and ecology” (Froese 2006; Mohapatra et al. 2010; Thirunavukkarasu and Shanmugam 2011). To know the variations in

weight from the known length or width indicating feeding, growth, breeding, etc., and to estimate the population size of stock for its exploitation, length-weight or width-weight relationships are necessary. “Information about individual carapace width-weight relationships is essential to estimate the population size or stock structure and to use the stock assessment model” (Josileen, 2011; Moutopolos and Stergiou, 2002). The allometric relationship between carapace width and weight in mangrove crabs (*S. serrata*) on Kosrae of Macronesia has been recorded by Bonine et al. (2008). Studies on carapace width and weight relationships, and relative condition determinants of mud crabs *S. serrata* and *S. tranquebarica* have been made by Mohapatra et al. (2010) in Chilka lagoon. “Information about individual carapace width-weight relationships is essential to estimate the population size or stock structure and to use the stock assessment model” (Josileen, 2011; Moutopolos and Stergiou, 2002).

The present work was aimed to reveal the carapace width-body weight relationship and size at maturity of mangrove mud crab (*S. serrata*) in four areas of the mangrove ecosystem of Vakarai, Valaichenai, Nasivanthivu, Panichankerny in Batticaloa District, East Coast of Sri Lanka.

2. MATERIALS AND METHODS

2.1 Sample Collection

The study was conducted using mud crab samples collected between November 2023 to January 2024 from Vakarai (8°08'46.17"N 81°26'04.32"E), Valaichenai (7°55'45.84"N 81°31'31.45"E), Nasivanthivu (7°56'11.67"N 81°32'41.84"E), Panichankerny (8°06'11.38"N, 81°26'22.51"E) in Batticaloa districts, east coast of Sri Lanka (Fig. 1). A total of 660 samples were taken by the local fishermen by using traps and crab nets. The sampling was done conducted three times per week and analyzed in the district fisheries department in Batticaloa, Sri Lanka. The length of the carapace was measured as the distance between the tips of the posterior most lateral carapace spines, and the width of the carapace was measured dorsally along the midline, between the frontal notch and the posterior margin of the carapace (Josileen, 2011). The carapace width (CW) and body weight (BW) were taken using a Vernier Caliper accompanied with an accuracy of up to 0.1 cm and a weight of up to 0.1 g. The maturity of females was determined based on the pigmented abdominal flap (Srinivasagam et al., 2000). All samples were analyzed in live conditions and released at lagoons.

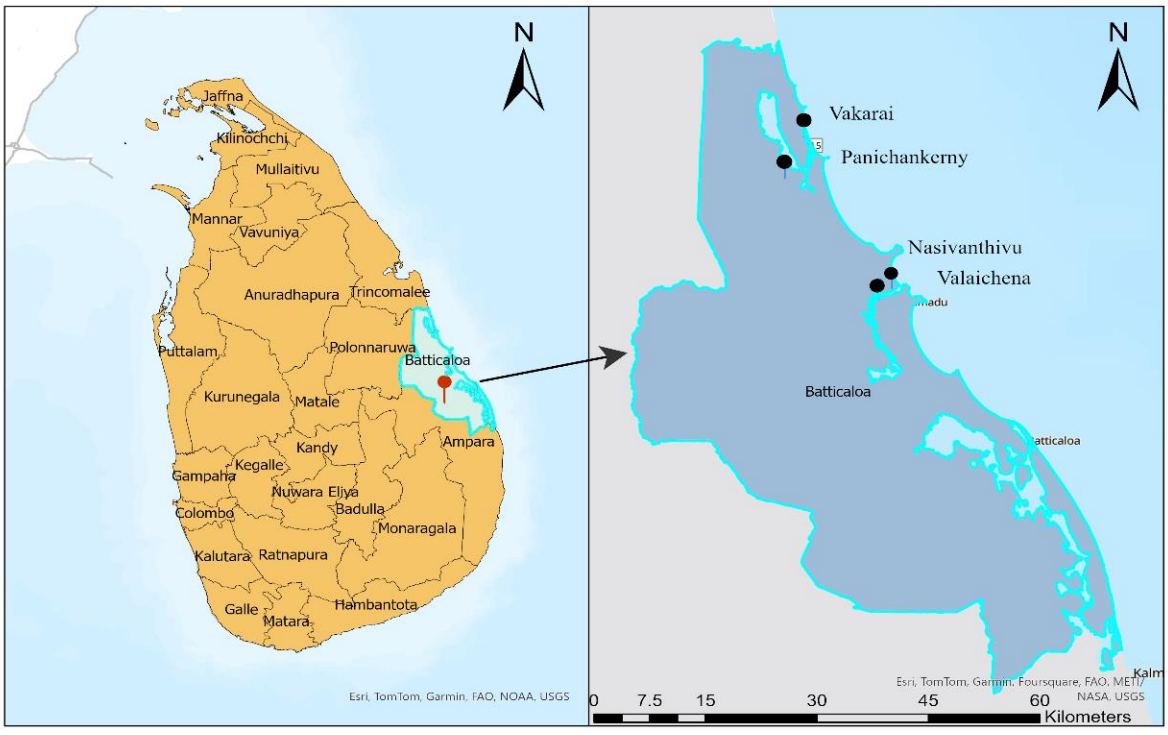


Fig. 1. The four black dots indicate the locations where the mud crabs were collected Vakarai, Valaichenai, Nasivanthivu, and Panichankerny in Batticaloa districts, east coast of Sri Lanka

2.2 Data Analysis

The sex ratio was determined using the formula: the total number of males (M)/total number of females (F). The ratio was tested to observe if it varies from a 50/50 ratio by the Chi-Square test (Steel and Torrie, 1980). The carapace length/width-weight relationship was estimated utilizing the exponential equation of $W = aL^b$ (Ricker, 1975). Where W = weight(g), L = length(mm), a = constant and b = growth exponent. The exponential equation was converted to the linear equation of log W = log a + b log L, where W = weight, L = length, a = 'y'-intercept, and b = the slope or growth coefficient. The R-squared was determined to determine the correlation of two variables. The growth pattern was determined by the value of the growth coefficient (b value). The growth coefficient indicates the relationship between the length and weight of the organism. The pattern was defined as isometric growth (b = 3), positive allometric (b > 3), or negative allometric (b < 3). The dissimilarities of the carapace width weight relationship between the sexes were tested by one-way ANOVA at p = 0.05.

2.3 Size at Maturity

Three methods were used to estimate the size of female sexual maturation in each species: the observed minimum size at maturity, breakpoint analysis, and probit analysis using abdomen-width data. The simplest and most direct method to determine size at maturity in *S. serrata* species is to record the smallest mature and the largest immature female crab encountered. This shows the range of sizes at which the pubertal moult takes place in individual samples. Also, a frequency distribution of mature female mud crabs was constructed using 5 mm Inner Carapace Width (ICW) class intervals.

3. RESULTS

A total of 660 mud crabs were sampled in Vakarai, Valaichenai, Nasivanthivu, and Panichankerny in Batticaloa districts, east coast of Sri Lanka, 65 samples in November, 240 samples in December and 355 samples in January. The sex of mud crabs was determined following Keenan et al. (1998) and shown in Fig. 2. The shape of the abdomen or tail flat is a thin triangular apron for males, while the female is larger.

The sex ratio of male and female in the total collected sample and each month (November, December and January) were 1:1.41, 1:1.72, and 1:1.23, respectively. The chi-square test of sex ratios for November (27 male, 38 female), December (89 male, 151 female), and January (159 male, 195 female) indicated a significant difference ($p < 0.05$). Detailed information on the sex ratio at the two locations is presented in Table 1.

In total carapace length of *S. serrata* caught in the study period ranged from 51 mm to 108 mm for males and 58 mm to 126 mm for females. In terms of months, the carapace length of the crab ranged from 58 mm to 103 mm in November, 43 mm to 126 mm in December and 44 mm to 120 mm in January (Table 1). The minimum size of carapace length was found in January and the maximum size was found in December. The size frequency distribution of carapace length is shown in Fig. 3. Based on the figures, male and female crabs exhibited some size variation. The maximum size of *S. serrata* was found in 100 mm to 108 mm CL for male and 119 mm to 126 mm CL for females. No male was found with a carapace length of more than 108 mm. The situation is the same in December and January, but different in November. In November, no male and female were found more than 103 mm. The dominant size of *S. serrata* in the total study period was found 100-108 mm for males and 119- 126 for females.

The carapace width of *S. serrata* caught in the study period ranged from 70 mm to 201 mm in males and 74 mm to 202 mm in females. The carapace width ranged from 102 mm to 191 mm on November, 70 mm to 202 mm on December and 74 to 201 mm on January. The maximum and minimum size of carapace width were found in December. The size frequency distribution of the carapace width is shown in Fig. 4. Based on the figure, male and female crabs exhibited some size variation. The maximum size group of *S. serrata* was found in 197-201 mm CW for male and 199-202 mm for females. No female was found with a carapace width of more than 202mm. The condition occurred in all these months. The dominant size of *S. serrata* in November was 110-121 mm for males and 115-129 mm for females, but in both December and January were 112-136 mm and 125-147 mm for males and females.

A scatter diagram was composed by plotting the logarithm of carapace length/width against the logarithm of the weight of individual crabs (Figs. 6 and 7). The logarithmic equation log W = log a

+ b log L was used to estimate the carapace length/width-weight relationship of mud crabs as shown in Table 2. The carapace length-weight relationship results of total showed logarithmic equations are as follows: W = -7.5200 + 3.1310 Log CL for male and Log W = -7.7623 + 3.1853 Log CL for females. While the result of carapace length-weight relationship in November is Log W = -7.5712 + 3.1536 Log CL for male and Log W = -7.5208 + 3.1422 Log CL for females, December Log W = -7.1117 + 3.0394 Log CL for male and Log W = -7.0394 + 3.0214 Log CL for female and January Log W = -7.8031 + 3.1926 Log CL for male and Log W = -8.3139 + 3.3067 Log CL for females. The R-squared obtained for the carapace length and weight of males and females were nearly equal to 1 (0.78-0.81). The value indicated a moderate degree of positive correlation between length and weight for male and female crabs.

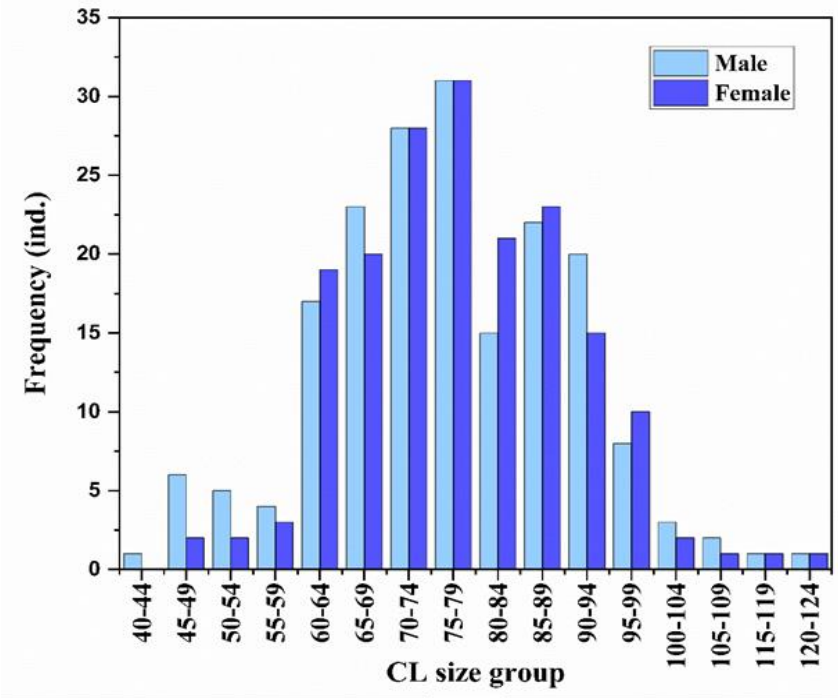
The carapace width-weight relationship results of total showed logarithmic equations as follows: Log W = -5.9201+ 2.4440 Log CW for male and Log W = -5.3719 + 2.3231 Log CW for female. While the result of carapace width- weight relationship in November is Log W = -8.5746 + 2.9914 Log CL for male and Log W = -7.1556 + 2.6931 Log CL for females, December Log W = -3.4329 + 1.9341 Log CL for male and Log W = -3.1144 + 1.8783 Log CL for female and January Log W = -7.7583 + 2.8169 Log CL for male and Log W = -7.8462 + 2.8294 Log CL for females. The R-squared obtained for the carapace length and weight of males and females were nearly equal to 1 (0.74-0.89). The value indicated a moderate degree of positive correlation between length and weight for male and female crabs.

The growth pattern was estimated by the b value from the carapace width-weight relationship. The growth coefficient values (b) of male and female width-weight were 2.4440 and 2.3231. Based on the values, we found (b) a value of less than 3 for both males and females, indicating a negative allometric growth pattern. This means the increase in weight is slower than the increase in carapace width for both male and female mud crabs. The b values were different between male and female crab (ANOVA, $P < 0.05$). A p-value less than 0.05 typically indicates that there is a significant difference between the groups.

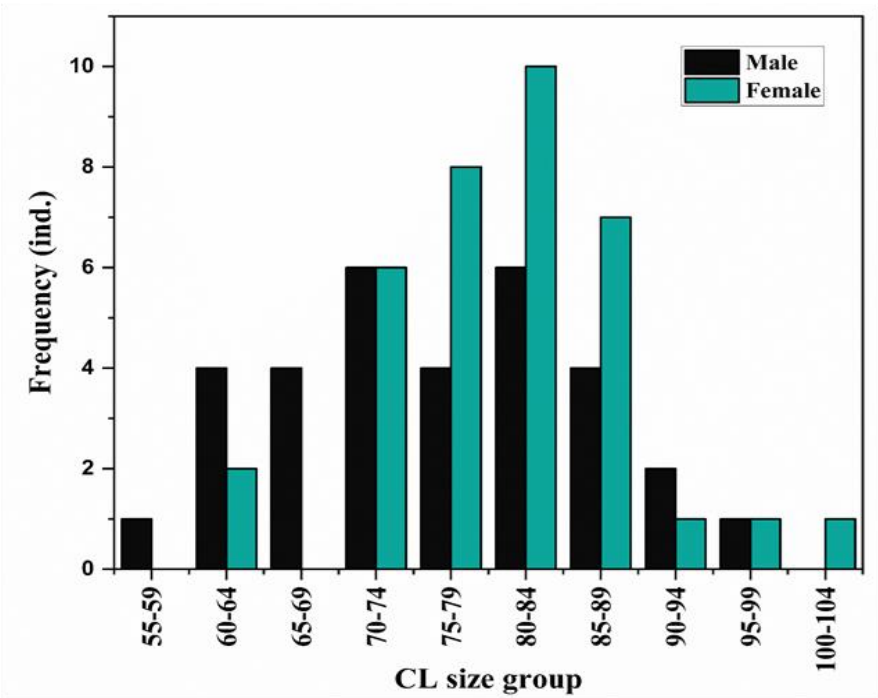
The maturity size of females estimated by the minimum size at maturity for these months is shown in Table 3. The smallest mature females recorded an ICW of 102 mm (November), 71 mm (December) and 73 mm (January). The largest immature females of each month were 112 mm (November), 163 mm (December) and 149 mm (January), respectively. Although there was a considerable difference in the size at first maturity among individual crabs (all the mature females below ICW 160 mm in November), mature females of all the months were recorded over the size range ICW 101 mm to 140 mm (Fig. 5).

A B

Fig. 2. CL was measured across the carapace between the ninth anterolateral teeth and carapace width CW from the tip of the prior margin of the carapace to the prior margin of the first abdominal segment. Sex of mud crabs (A) male, (B) female. The shape of the abdomen or tail flat is a thin triangular apron for males, while the females are larger. The maturity of females was determined based on the pigmented abdominal flap


Male
Female
Frequency (ind.)
CL size group
40-44
45-49
50-54
55-59
60-64
65-69
70-74
75-79
80-84
85-89
90-94
95-99
100-104
105-109
115-119
120-124

(A)


Male
Female
Frequency (ind.)
CL size group
55-59
60-64
65-69
70-74
75-79
80-84
85-89
90-94
95-99
100-104

(B)

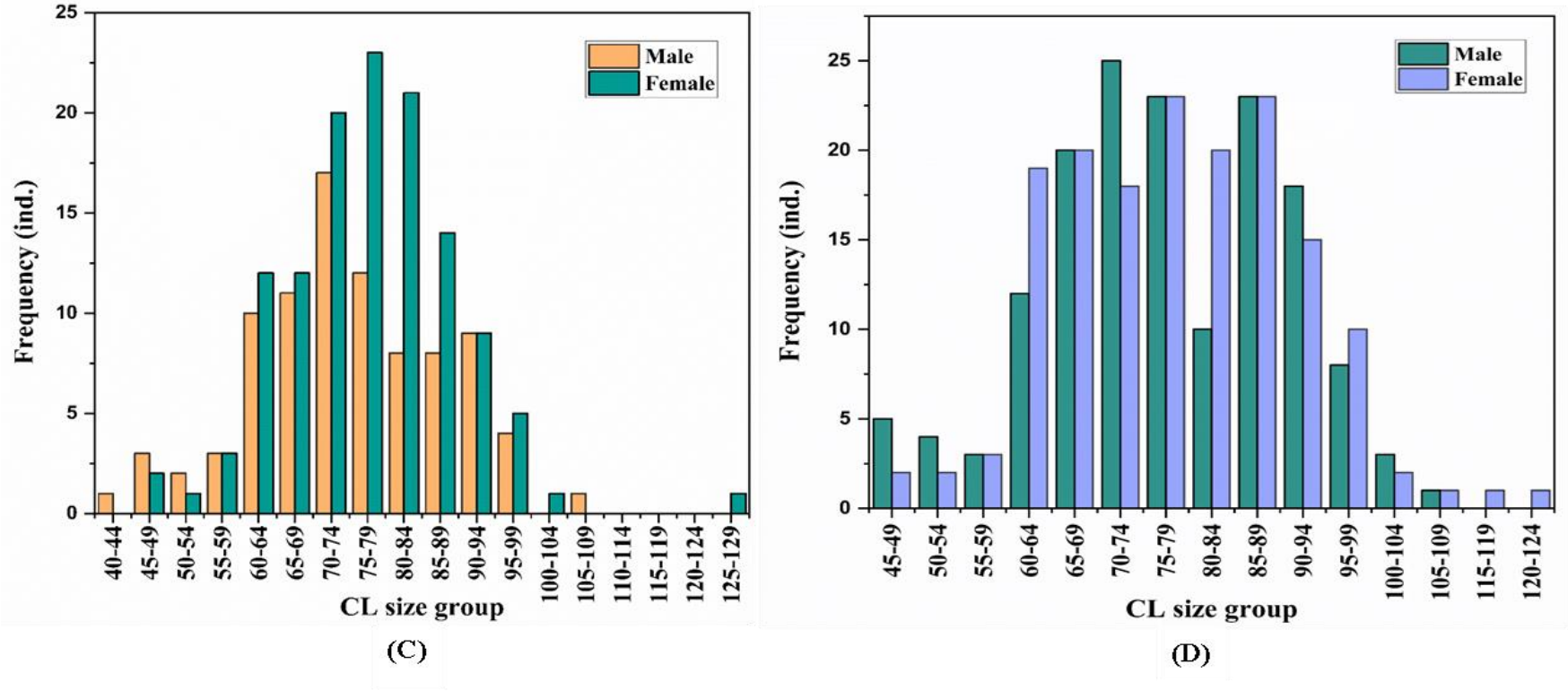
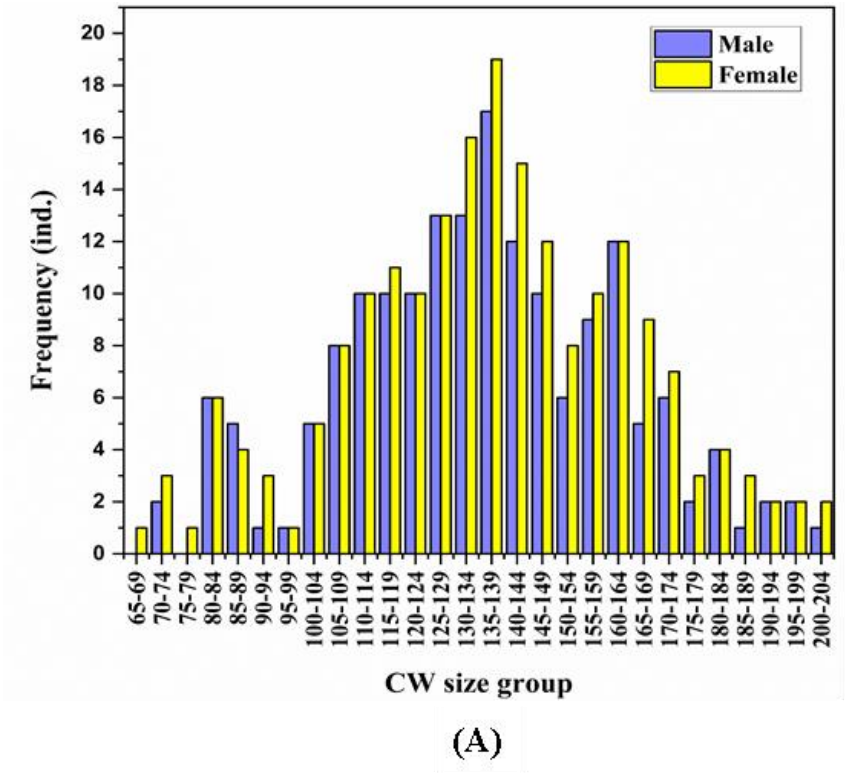
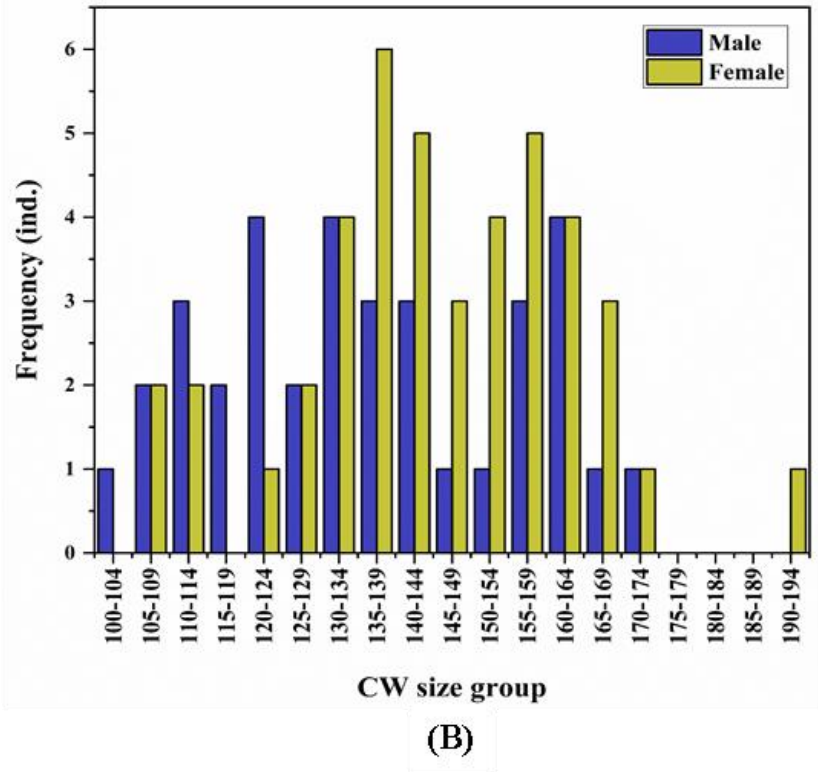


Fig. 3. Size frequency distribution of carapace length of *Scylla serrata* in (A) total, (B) November, (C) December, (D) January, Batticaloa districts, east coast of Sri Lanka


Male
Female
Frequency (ind.)
CW size group
65-69
70-74
75-79
80-84
85-89
90-94
95-99
100-104
105-109
110-114
115-119
120-124
125-129
130-134
135-139
140-144
145-149
150-154
155-159
160-164
165-169
170-174
175-179
180-184
185-189
190-194
195-199
200-204

(A)


Male
Female
Frequency (ind.)
CW size group
100-104
105-109
110-114
115-119
120-124
125-129
130-134
135-139
140-144
145-149
150-154
155-159
160-164
165-169
170-174
175-179
180-184
185-189
190-194

(B)

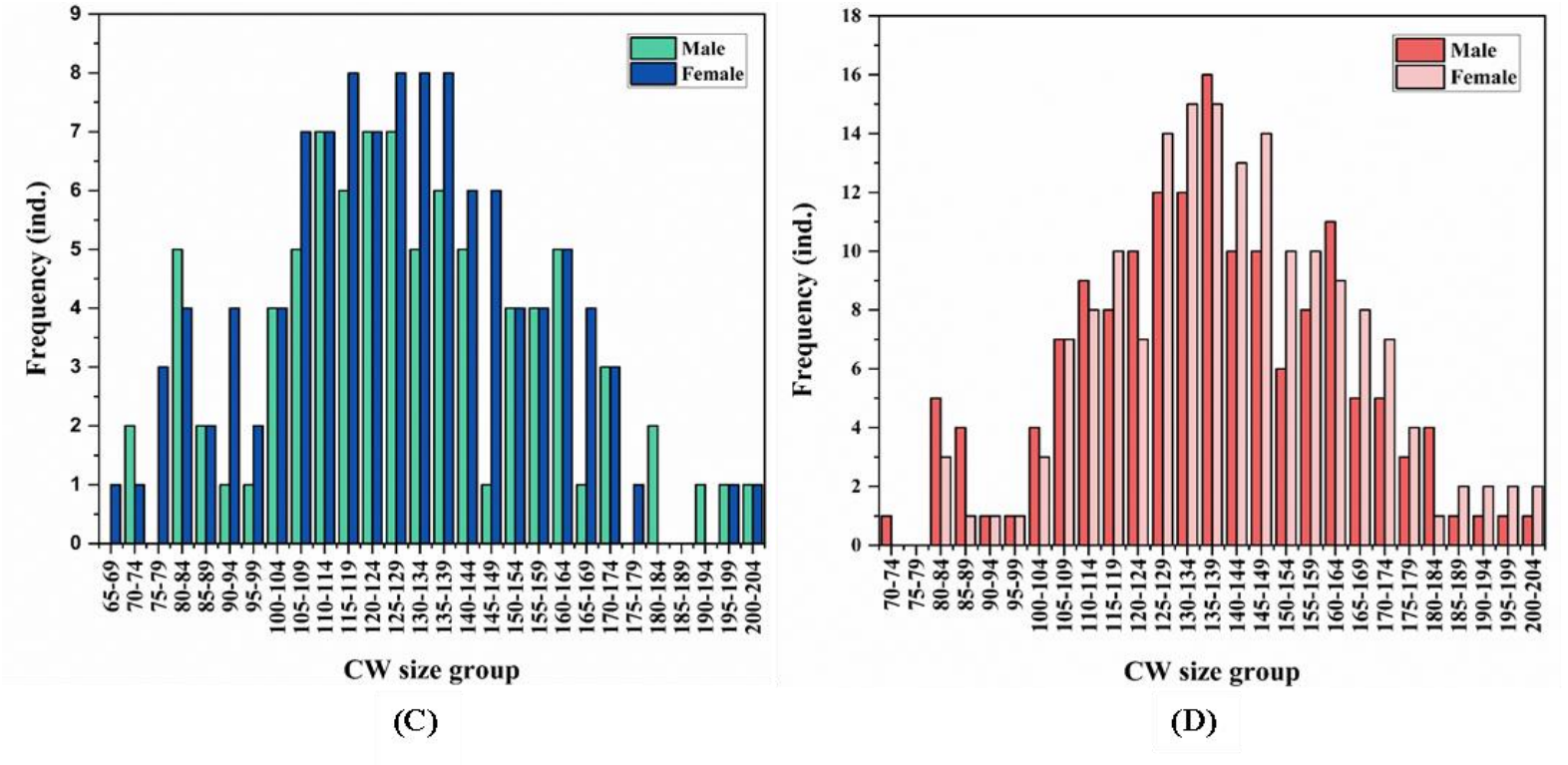


Fig. 4. Size frequency distribution of carapace width of *Scylla serrata* in (A) total, (B)November, (C) December, (D) January, Batticaloa districts, east coast of Sri Lanka

Table 1. Sex ratio of *Scylla serrata* from Batticaloa District, east coast of Sri Lanka

Month	Sex	Number of samples	Carapace length mm		Carapace width mm		R-value		Sex ratio
			min	max	min	max	CW	CL	
November	Male	27	58	97	102	174	0.941	0.946	1:1.41
	Female	38	61	103	109	191	0.953	0.934	
December	Male	89	43	108	70	175	0.810	0.890	1:1.72
	Female	151	67	126	81	202	0.846	0.908	
January	Male	159	44	108	80	201	0.915	0.946	1:1.23
	Female	196	46	120	74	200	0.870	0.963	
Total	Male	275	51	108	70	201	0.849	0.958	1:1.41
	Female	385	54	126	74	202	0.821	0.976	

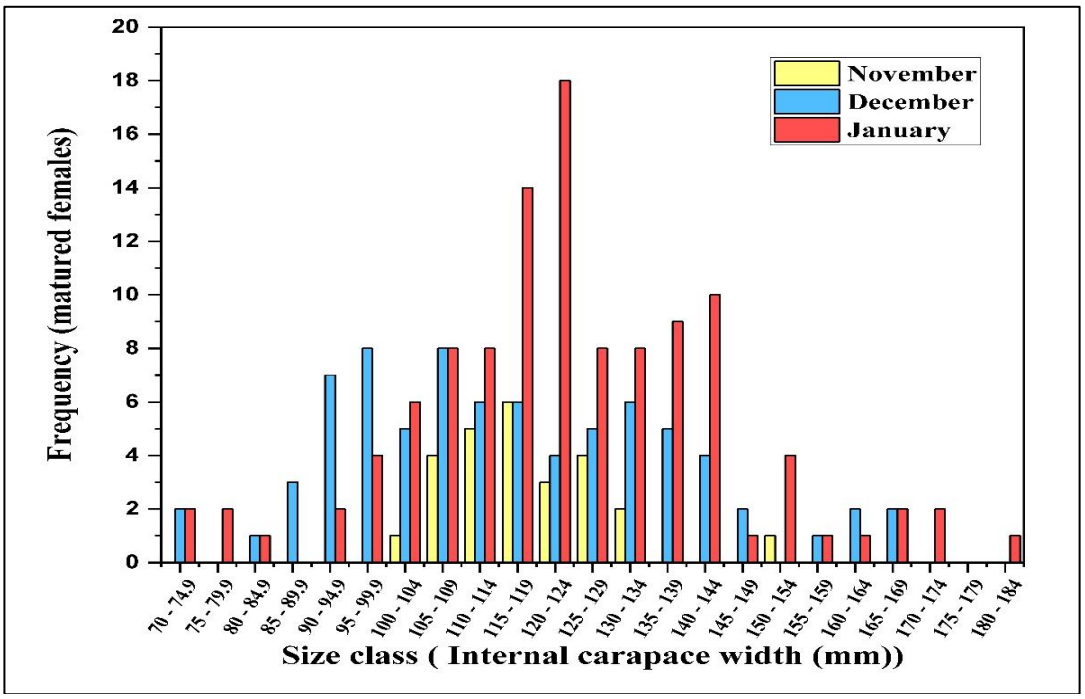


Fig. 5. Frequency distribution of mature female *Scylla serrata* collected from November to January. Size-class interval = 5 mm

Table 2. Growth Coefficient values-b for the carapace width/length-weight relationship of collected *Scylla serrata*

Sex	Location	b Value	Reference
Male	Hooghly-Matlah estuary, India	2.665	Khan et al. (2018)
Female		2.561	
Male	Queensland coast, Australia	2.726	Lee (1992)
Female		2.626	
Male	Karachi Coast, Pakistan	2.481	Khan and Mustaqeem (2013)
Female		2.632	
Male	Batticaloa District, Sri Lanka	2.444	Current study
Female		2.323	

Table 3. The maturity of the female is estimated by the minimum size at maturity during the study period

Life Stages	Number of individuals (individuals)		
	November	December	January
Immature	12	69	79
Mature	27	82	117
Total	39	151	196

4. DISCUSSION

There are no size restrictions for mud crabs in Sri Lanka, which makes it crucial to impose size restrictions at first capture (Bandaranayake et al., 2021). “The information on the sex ratio is important in interpreting the population structure and reproductive performance in crustaceans” (Cheewasedtham, 1990; Wardiatno, 2004; Wardiatno and Mashar, 2010). “A well-balanced sex ratio ensures enhanced mating success, as male and female can find mates more easily, resulting in increased chances of successful reproduction. Furthermore, the sex ratio has a significant impact on the overall population dynamics, affecting growth and sustainability”

(Subramoniam, 2013). In our study, the sex ratio of 1:1.41 showed that females are more than males meaning that the population was not in the balance between the number of males and females across these months in Vakarai, Valaichenai, Nasivanthivu, Panichankerny in Batticaloa District, Sri Lanka. Cobb and Wang (1985) reviewed those "differences in mortality and growth rates between males and females, largely influenced by the female reproductive cycle, leading to variation in sex ratios". Jameson et al. (1982) reported that the overall sex ratio of males to females of *S. serrata* in Tuticorin Bay (India) was 1.5:1 with males dominating the catches for five months due to targeted fishing practices, behavioral differences, habitat preferences, and maturity-related size differences. Prasad and Neelakantan, (1989) reported that "from the backwaters and coastal waters of Kawar, there was a familiar equal proportion of male-to-female *S. serrata* in both biotopes, likely due to similar habitat preferences and mating behaviours that promote balanced sex ratios, even though seasonal and size changes". "Differences in ratios of the sexes in crustaceans could be caused by sex reverse, different lifespan, season, location, migration, method of capture, mortality, and growth rates" (Diaz, 1980 in Diaz and Conde, 1989). Furthermore, reproductive activity is also significant in influencing sex ratios (Kumar et al., 2000). However, this ratio varies depending on the size range of the population, season, and the exploitation of the stock. (Quinn and Kojis, 1987).

"The study of the carapace width-weight relationship is essential in fishery biology because it helps assess the health and condition of the crab population" (Yulianto et al., 2024). It also helps in sustainable fishery management by monitoring growth patterns and environmental impacts on crab. "If data on size frequency is available, it can be used to convert length to weight to estimate biomass" (Effendie, 1997; Froese, 2006). The analysis of the relationship between carapace width and weight was used to predict the growth pattern of mud crabs in the study area during November, December, and January. The t-test result showed that the growth pattern was negative allometric ($p<005$). In terms of size, the crabs collected in November and December were smaller than those in January. Pinheiro and Fiscarelli (2009) mentioned that bigger claws in males enabled them to protect the females successfully during and after copulation. Recent studies suggest that size variations in crabs can be attributed to factors such as molting cycles, environmental conditions, and food availability (Khot & Jaiswar, 2018). This happens often because male mud crabs have bigger claws than females. Pinheiro and Hattori (2006) revealed that "females tend to reduce their chelate growth as they grow bigger, while males tend to do the opposite".

The b value of the carapace width-weight relationship ranged from 2.4440 for females and 2.3231 for males. Similarly, Devi (1985) study on *Scylla* spp. in the Kakinada region, India also showed the same (male b = 2.718; female b = 2.658). Alimuddin (2000) studied *Scylla* spp. in Southeast Sulawesi, Indonesia showed b = 3.283 for males and b = 3.041 for females. "These findings imply that growth patterns of mud crabs vary widely among species of the genus *Scylla*. Each species has a characteristic growth pattern. It probably depends on the habitat of the species" (La Sara, 2010). According to Allen (1938), in "an ideal organism that maintains its shape throughout, the value of 'b' will be '3'. But in a few organisms, the value of 'b' lies between 2.5 and 4.0" (Martin 1949). "The male and female have a b value of less than 3. This condition indicates that male and female crab growth patterns are negative. In unwished populations, female mud crabs can be three-fold outnumbered by males, for example in Kosrae, Micronesia the male: female ratio can be as high as 3:1" (Bonine et al., 2008). "Similar ratios have been reported in other studies" (Heasman, 1980, Tongdee, N. 2001 and Fazhan et al., 2022).

The female size at maturity is a significant aspect of fisheries management. The samples of *S. serrata* had a carapace width of 74.3 – 202.4 mm ICW. The size range for *S. serrata* is based on carapace width (CW): juveniles (CW<100), sub-adults (CW 100-149), and adults (CW≥150) (Heasman, 1980; Hill et al., 1982). These are the most adult and subadult stages (Phelan and Grubert, 2007). "In our study, in total 50% of females attain their maturity at ICW= 120–130 mm. In females, physiological maturity is reached during the last pubertal molt when the ovaries are fully developed. Growth between stages takes place over a wide size range, their growth rates are dependent on seasons and geological positions" (Knuckey, 1996). "This may be related to the availability of the natural diet of *S. serrata* and different environmental aspects. Female crabs mature only after reaching a given size, with the first sexual maturity typically occurring at a carapace width of 83-87mm" (Prasad and Neelakantan, 1989; Waiho et al., 2016).

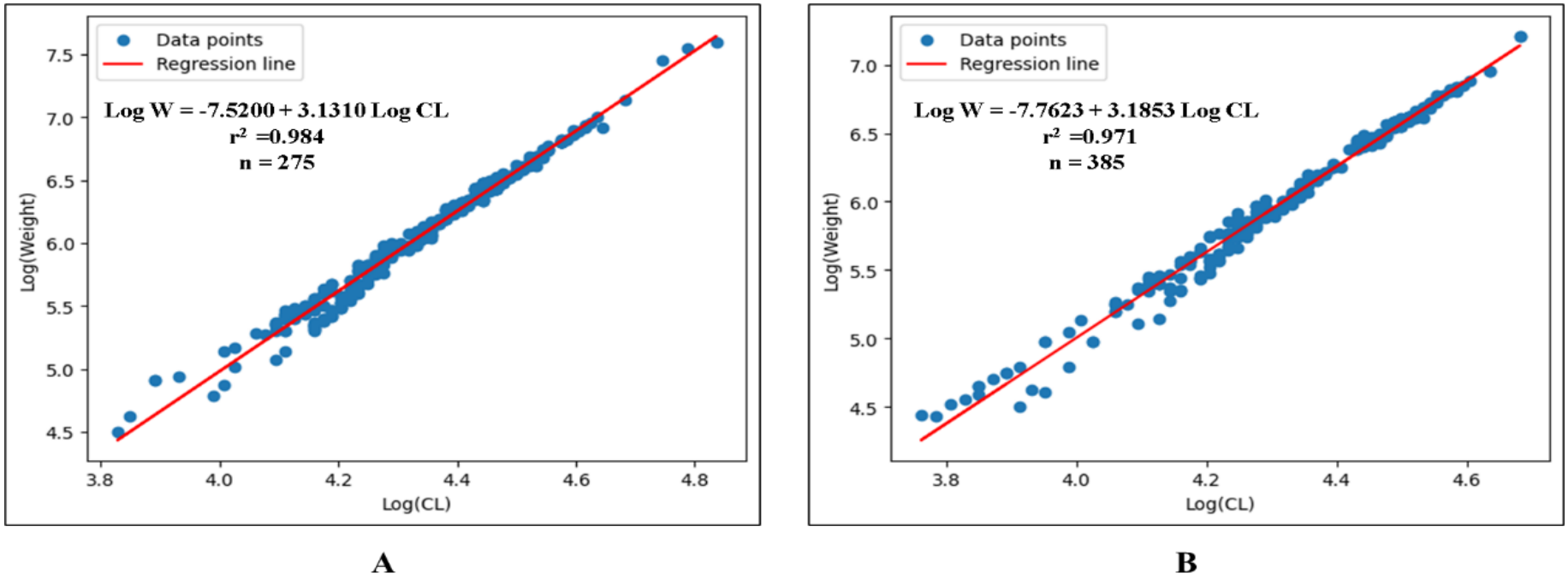


Fig. 6. Carapace length (CL)-weight (W) relationship of *Scylla serrata* (A) total male n = 275, (B) total female n = 385

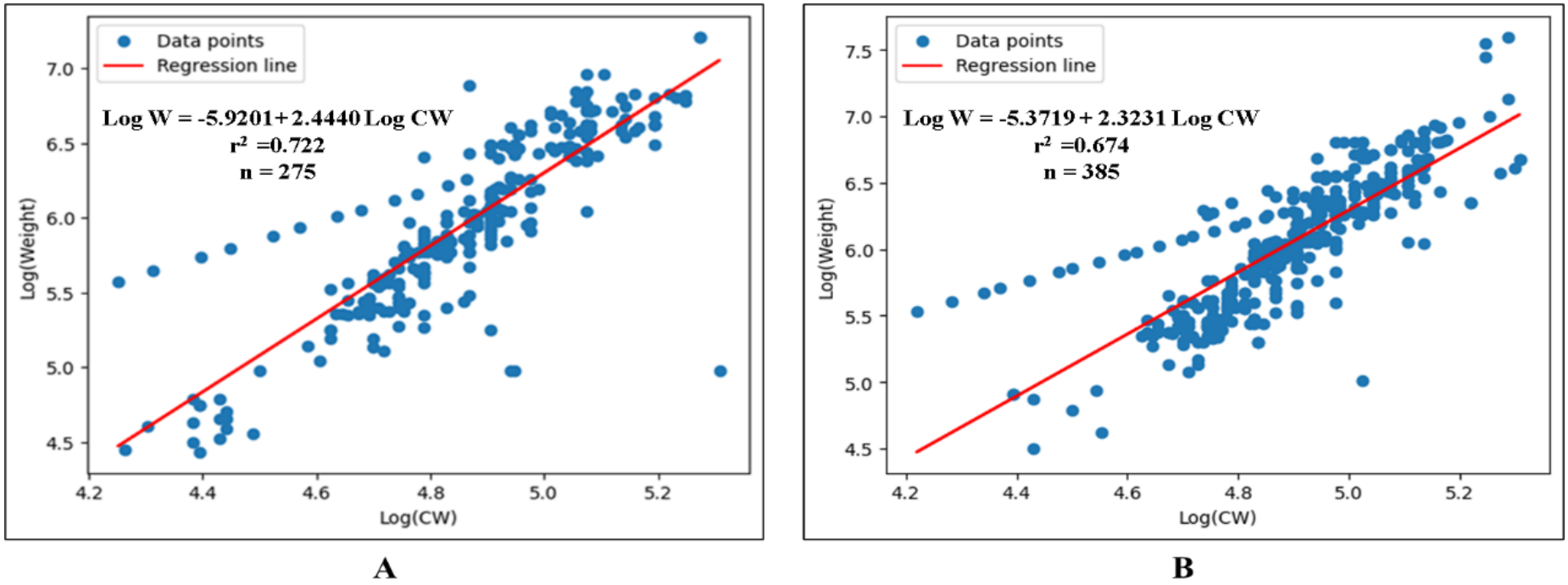


Fig. 7. Carapace width (CW)-weight (W) relationship of *Scylla serrata*. (A) total male n = 275 (B), total female n = 385

"The amount at which crabs reach sexual maturity is key for setting a minimum legal size necessary to ensure a reproduction population" (El-Zarka and El-Sedfy, 1970). Morphological maturity is characterized by the development of a mature abdominal flap (wider and more rounded than in adolescent females) (Robertson and Kruger, 1994) and sometimes by the ability to extrude eggs (Hill, 1975). "Mature females utilize much of their energy in egg production and reduce their somatic growth" (Pinheiro and Fransozo, 2002; Ferkau and Fischer, 2006). "Physiological maturity in males is characterized when spermatophores develop in the vas deferens after the pubertal molt, but the external characteristic of the crab's ability still be the one of an adolescent/juvenile crab" (Robertson and Kruger, 1994; Knuckey, 1996).

"There may be a divergence in the evolution of body sizes in closely related species, and therefore in the size at sexual maturity, that is linked to the ecology of these species" (Schluter, 1996; Nagel and Schluter, 1998). Some authors (Quinn and Kojis, 1987; Robertson & Kruger, 1994) suggested that "the different maturation sizes depend on the latitudinal distribution of the crabs, resulting in faster maturation in tropical regions". "The growth is influenced by internal and external factors such as sex, age, nutrition, and disease resistance include of internal factors, while water quality, predators, and habitat include external factors" (Effendie, 1997; Levay and Walton, 2007).

5. CONCLUSION

This study has shown that the number of female crabs is increasing, meaning that the population is not balanced between males and females across November, December, and January. In unfished populations, female mud crabs can be three-fold outnumbered by males. The primary peaks are from December to March and September to November (Prasad and Neelakantan, 1989). The sex ratio of the total collected samples (male to female) was 1:1.41. The carapace length-weight relationship of total samples showed logarithmic equations: W = -7.5200 + 3.1310 Log CL for males and Log W = -7.7623 + 3.1853 Log CL for females. The carapace width-weight relationships are as follows: Log W = -5.9201+ 2.4440 Log CW for males and Log W = -5.3719 + 2.3231 Log CW for females. Based on the b values of the carapace width-weight relationship, the growth pattern of a male and female was a positive allometric growth pattern. More than half of the collected individuals are mature, maybe because of their tropical climate. The spawning and maturation are high in the tropical region. Most studies neglect the evidence that the species shows high variations in terms of size, maturity, spawning seasonality, and also exposure to human exploitation at various locations throughout its range.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declares that generative AI technologies such as Large Language Models, etc. have been used during the writing or editing of manuscripts. This explanation will include the name, version, model, and source of the generative AI technology and as well as all input prompts provided to the generative AI technology.

Details of the AI usage are given below:

1. Copilot, 2024
2. Grammarly, 2024

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

Alimuddin, A. (2000). Study on Scylla spp. in Southeast Sulawesi, Indonesia. Journal of Crustacean Biology, 20(3), 123-130.

Allen, K. R. (1938). Some observations on the biology of the trout (Salmo trutta) in Windermere. Journal of Animal Ecology, 7(2), 333-349.

Atar, H. H., & Secer, S. (2003). Width/length-weight relationships of the blue crab (Callinectes sapidus Rathbun, 1896) population living in Beymelek Lagoon Lake. Turkish Journal of Veterinary and Animal Sciences, 27(2), 443-447.

Bandaranayake, K. H. K., Gunasekara, S. S., Jayasinghe, R. P. P. K., Herath, D. R.,

Ranasinghe, V. K., & Yatawaka, S. (2021). Reproductive morphology, morphometric aspects and molecular identification of Scylla (Mud Crab) species in Sri Lanka.

Barnes, R. S. K., Calow, P., Olive, P. J. W., Golding, D. W., & Spicer, J. I. (2002). The Invertebrates: A New Synthesis (3rd ed.). Blackwell Science.

Bonine, K. M., Bjorkstedt, E. P., Ewel, K. C., & Palik, M. (2008). Allometric relationships and growth patterns in mangrove crabs (*Scylla serrata*) on Kosrae, Micronesia. Journal of Crustacean Biology, 28(4), 607-615.

Chakraborty, B. K., Azad, S. A., & Sarker, S. (2018). Present status of mud crab population in Bangladesh. *Aquaculture*, 36.

Chanda, S. K., Boxi, K., Manna, S., Mukherjee, P. A., Mondal, M., & Khalua, R. K. (2024). THE MUD CRAB (SCYLLA SERRATA): NUTRITIONAL COMPOSITION AND THERAPEUTIC HEALTH BENEFITS. *Bulletin of Pure and Applied Sciences-Zoology*, 1579-1584.

Cheewasedtham, C. (1990). Study on the sex ratio and reproductive performance in crustaceans. Journal of Marine Biology, 35(3), 145-152.

Cobb, J. S. and D. Wang. 1985. Fisheries biology of lobsters and crayfishes, pp. 167 – 247. In: The biology of crustacea Vol. 10. Economic aspect: fisheries and culture. A. J. Provenzano, Jr. (ed). Academic Press, Orlando.

Díaz, H., & Conde, J. E. (1989). Population dynamics and life history of the mangrove crab Aratus pisonii (Brachyura, Grapsidae) in a marine environment. *Bulletin of marine science*, *45*(1), 148-163.

Effendie, M. I. (1997). Biology of fishery resources. Yayasan Pustaka Nusatama.

El-Zarka, S. E., & El-Sedfy, H. M. (1970). The biology and fishery of Mugilsaliens (Risso) in lakeAuarh. *VAR. Bull. Inst. Oceanogr. Fish., VAR., 1: 3*, *26*.

Fazhan, H., Azra, M. N., Halim, S. A., Naimullah, M., Abualreesh, M. H., Shu-Chien, A. C., ... & Ikhwanuddin, M. (2022). Species composition, abundance, size distribution, sex ratios, and movement of Scylla mud crabs within the mangrove ecosystem at Setiu Wetland, Terengganu, Malaysia. *Frontiers in Marine Science*, *9*, 899789.

Ferkau, C., & Fischer, K. (2006). Costs of reproduction in male Bicyclus anynana and Pieris napi butterflies: Effects of mating history and food limitation. Ethology, 112(11), 1117-1127.

Froese, R. (2006). Cube law, condition factor and weight-length relationships: History, meta-analysis and recommendations. Journal of Applied Ichthyology, 22(4), 241-253.

Heasman, M. P. (1980). Aspects of the general biology and fishery of the mud crab *Scylla serrata* (Forskal) in Moreton Bay, Queensland (Doctoral dissertation, University of Queensland).

Hill, B. J. (1975). Abundance, breeding and growth of the crab *Scylla serrata* in two South African estuaries. Marine Biology, 32(2), 119-126.

Hill, B. J. (1976). Natural food, foregut clearance-rate and activity of the crab *Scylla serrata*. Marine Biology, 34(2), 109-116.

Hill, B. J., Williams, M. J., & Dutton, P. (1982). Distribution of juvenile, subadult and adult Scylla serrata (Crustacea: Portunidae) on tidal flats in Australia. *Marine Biology*, *69*, 117-120.

Jameson, J. D., Murugan, A., & Natarajan, P. (1982). Studies on the distribution pattern and morphometry of *Scylla serrata* (Forskal) along Tuticorin coast. *Seafood export journal*.

Josileen, J. (2011). Carapace width-weight relationships and condition factor of the mud crab *Scylla serrata* (Forskal) from Pichavaram mangroves, Tamil Nadu, India. Indian Journal of Fisheries, 58(2), 35-38.

Keenan, C. P., Davie, P. J. F., & Mann, D. L. (1998). A revision of the genus Scylla De Haan, 1833 (Crustacea: Decapoda: Brachyura: Portunidae). Raffles Bulletin of Zoology, 46(1), 217-245.

Khan, M. A., & Mustaqeem, J. (2013). Carapace width weight relationship of mud crab Scylla serrata (Forskal, 1775) from Karachi Coast. Canadian Journal of Pure and Applied Sciences, 7(2), 2381-2386.

Khan, M. A., Das, S. K., & Bhakta, D. (2018). Dynamics of bioindices in mud crab Scylla serrata (Forsskål, 1775) occurring in Hooghly-Matlah Estuary of West Bengal, India. Journal of Fisheries, 6(3), 650-653.

Khot, M., & Jaiswar, A. K. (2018). Carapace length-weight and Carapace width-weight relationship and condition factor of intertidal crabs from Maharashtra, India. *Int. J. Fish Aquat. Stud.*, *6*, 48-51.

Knuckey, I. A. (1996). Maturity in male mud crabs, *Scylla serrata*, and the use of mating scars as a functional indicator.

Journal of Crustacean Biology, 16(3), 487-495. https://doi.org/10.2307/1548738.

Kumar, R. S. (2000). A review of biodiversity studies of soil dwelling organisms in Indian mangroves. *ZOOS'PRINT JOURNAL*, *15*(3), 221-227.

Le Vay, L. (2001). Seasonal abundance and recruitment in an estuarine population of mud crabs, *Scylla paramamosain*, in the Mekong Delta, Vietnam. Hydrobiologia, 449(1-3), 231-240.

Le Vay, L., & Walton, M. E. (2007). Development of aquaculture systems for mud crabs. In C. P. Keenan & A. Blackshaw (Eds.), Mud crab aquaculture and biology (pp. 103-121). Australian Centre for International Agricultural Research

Lee, C. (1992). A brief overview of the ecology and fisheries of the mud crab Scylla serrata in Queensland. The mud crab, 65-70.

Martin, W. R. (1949). The mechanics of environmental control of body form in fishes. University of Toronto Studies, Biological Series, 58, 1-91.

Mathiventhan, T., & Jayasingam, T. (2016). Present status of Mangrove restoration i n Batticaloa district, Sri Lanka: is it success. Mangrove Macrobenthos Meeting MMM4 Abstract Book. University of Florida, Gainesville, USA, 222.

Mohapatra, A., Mohanty, R. K., & Das, P. (2010). Length-weight relationship and condition factor of *Scylla serrata* in Chilika Lagoon, India. Indian Journal of Fisheries, 57(2), 65-69.

Moutopoulos, D. K., & Stergiou, K. I. (2002). Length-weight and length-length relationships of fish species from the Aegean Sea (Greece). Journal of Applied Ichthyology, 18(3), 200-203.

Nagel, L. M., & Schluter, D. (1998). Body size, natural selection, and speciation in sticklebacks. Evolution, 52(1), 209-218.

NECCDEP. (2010). Batticaloa Lagoon Special Area Management Plan “BL SAM”. Final. Eastern Province Integrated Coastal Resources Management Plan (EPICRMP) 2010-2013. The Green Blue Sunrise Plan. Anzdec Ltd., Resource Development Consultants. ADB LOAN 2027 SRI (SF): North East Coastal Community Development Project (NECCDEP).

Ng, P. K. L. (1998). FAO species identification guide for fishery purposes. Food and Agriculture Organization of the United Nations.

Nirmale, V. H., Mane, U. H., & Deshmukh, V. D. (2012). Foraging behavior of mud crabs (*Scylla serrata*) in mangrove ecosystems. Journal of Coastal Research, 28(3), 707-713.

Pati, S. G., Paital, B., Panda, F., Jena, S., & Sahoo, D. K. (2023). Impacts of habitat quality on the physiology, ecology, and economical value of mud crab Scylla sp.: a comprehensive review. Water, 15(11), 2029.

Phelan, M. J., & Grubert, M. A. (2007). The life cycle of the mud crab. Department of Primary Industries, Fisheries and Mines.

Pinheiro, M. A. A., & Fiscarelli, A. G. (2009). Length-weight relationship and condition factor of the mangrove crab Ucides cordatus (Linnaeus, 1763) (Crustacea, Brachyura, Ucididae). Brazilian Archives of Biology and Technology, 52(2), 397-406.

Pinheiro, M. A. A., & Fransozo, A. (2002). Reproductive biology of the swimming crab *Callinectes ornatus* (Ordway, 1863) (Decapoda, Portunidae) in Ubatuba, São Paulo, Brazil. Crustaceana, 75(1), 117-127.

Pinheiro, M. A. A., & Hattori, G. Y. (2006). Growth patterns of the mangrove crab *Ucides cordatus* (Linnaeus, 1763) (Crustacea: Brachyura: Ucididae) in the estuarine region of Cananéia, São Paulo, Brazil. Journal of Crustacean Biology, 26(2), 217-225.

Prasad, P. N., & Neelakantan, B. (1989). Maturity and breeding of the mud crab, *Scylla serrata* (Forskal) (Decapoda: Brachyura: Portunidae). Proceedings of the Indian Academy of Sciences - Animal Sciences, 98(5), 341-349.

Pratiwi, R. (2011). An ecological study and its fishery potential of the mud crab, *Scylla serrata* (Forskål, 1775) in Segara Anakan mangrove waters, Cilacap, Indonesia. Journal of Natural Resources and Environmental Management, 12(3), 404-413.

Putra, D. F., Bengen, D. G., Zamani, N. P., & Kleinertz, S. (2016). Mangrove habitat structure and its relationship with the abundance of mud crabs (Scylla spp.) in Bee Jay Bakau Resort, Probolinggo, Indonesia. Journal of Coastal Research, 32(5), 1075-1083.

Quinn, N. J., & Kojis, B. L. (1987). Reproductive biology of *Scylla serrata* (Crustacea: Portunidae) from the Labu Estuary in

Papua New Guinea. Bulletin of Marine Science, 42(2), 234-241.

Rezaie-Atagholipour, M., Savari, A., Naderloo, R., & Sari, A. (2013). Population structure, carapace width-weight relationship and sex ratio of the blue swimming crab (*Portunus pelagicus*) in the Persian Gulf. Journal of the Marine Biological Association of the United Kingdom, 93(1), 1-8.

Ricker, W. E. (1975). Computation and interpretation of biological statistics of fish populations. Bulletin of the Fisheries Research Board of Canada, 191, 1-382.

Robertson, W. D., & Kruger, A. (1994). Maturation and reproductive activity of *Scylla serrata* (Forskal) in Natal, South Africa. *South African Journal of Marine Science, 14*(1), 185-193. https://doi.org/10.2989/025776194784287206.

Sara, L. (2010). Study on the size structure and population parameters of mud crab Scylla serrata in Lawele Bay, Southeast Sulawesi, Indonesia. *Journal of Coastal Development*, *13*(2), 133-147.

Schluter, D. (1996). Ecological causes of adaptive radiation. American Naturalist, 148(S1), S40-S64.

Srinivasagam, R. T., Rajamani, M., & Manickam, C. (2000). Study on the reproductive biology of mud crabs. Journal of Marine Biology, 45(2), 123-130.

Steel, R. G. D., & Torrie, J. H. (1980). Principles and procedures of statistics: A biometrical approach (2nd ed.). McGraw-Hill.

Subramoniam, T. (2013). Origin and occurrence of sexual and mating systems in Crustacea: a progression towards communal living and eusociality. *Journal of biosciences*, *38*, 951-969.

Thirunavukkarasu, N., & Shanmugam, A. (2011). Carapace width-weight relationship and condition factor of the mud crab *Scylla serrata* in Pichavaram mangroves, southeast India. Journal of the Marine Biological Association of the United Kingdom, 91(2), 305-310.

Tongdee, N. (2001). Size distribution, sex ratio and size at maturity of mud crab (Scylla spp.) in Ranong Province, Thailand.

Trivedi, J. N., & Vachhrajani, K. D. (2013). Distribution and habitat preference of brachyuran crabs in the Indo-West Pacific mangrove environments. Journal of Marine Biology, 59(2), 107-117.

Waiho, K., Fazhan, H., & Ikhwanuddin, M. (2016). Size distribution, length–weight relationship and size at the onset of sexual maturity of the orange mud crab, Scylla olivacea, in Malaysian waters. *Marine Biology Research*, *12*(7), 726-738.

Wardiatno, Y. (2004). Biological information on the mantis shrimp, *Harpiosquilla raphidea* (Fabricius 1798) (Stomatopoda, Crustacea) in Indonesia with a highlight of its reproductive aspects. Journal of Crustacean Biology, 24(2), 123-130.

Wardiatno, Y., & Mashar, A. (2010). Population dynamics of the Indonesian mantis shrimp, *Harpiosquilla raphidea* (Fabricius 1798) (Crustacea: Stomatopoda) collected from a mud flat in Kuala Tungkal, Jambi Province, Sumatera Island. Journal of Marine Science, 29(4), 215-223.

WIDIGDO, B., Rukisah, R., LAGA, A., HAKIM, A. A., & WARDIATNO, Y. (2017). Carapace length-weight and width-weight relationships of Scylla serrata in Bulungan District, North Kalimantan, Indonesia. Biodiversitas Journal of Biological Diversity, 18(4), 1316-1323.

Yulianto, H., Ihsan, Y. N., Sumiarsa, D., Ansari, A., & Hendarmawan. (2024). Assessing the sustainability of the blue swimming crab (Portunus pelagicus) on the Eastern Coast of Lampung: a holistic approach to conservation and resource stewardship. *Frontiers in Marine Science*, *11*, 1304838.

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