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Morphometric analysis of *Harpodon nehereus*, *Harpiosquilla raphidea*, and *Scylla serrata* in the coastal waters of Tarakan, North Kalimantan, Indonesia

GAZALI SALIM[1,♥], KUN RETNO HANDAYANI[2], SUTRISNO ANGGORO[3], AGUS INDARJO[4], AGUNG DHAMAR SYAKTI[5], ABDUL JABARSYAH IBRAHIM[1], JULIAN RANSANGAN[6], LUKMAN YUDHO PRAKOSO[7]

[1]Department of Aquatic Resource Management, Faculty of Fisheries and Marine Science, Universitas Borneo Tarakan. Jl. Amal Lama No. 1, Tarakan 77115, North Kalimantan, Indonesia. Tel./fax.: +62-551-2052558, ♥email: axza_oke@yahoo.com

[2]Representative of Central Java Province, Ombudsman of the Republic of Indonesia. Jl. Siwalan No. 5, Semarang 50242, Central Java, Indonesia

[3]Department of Aquatic Resource Management, Faculty of Fisheries and Marine Science, Universitas Diponegoro. Jl. Prof. H. Soedarto, S.H, Tembalang, Semarang 50275, Central Java, Indonesia

[4]Department of Marine Science, Faculty of Fisheries and Marine Science, Universitas Diponegoro. Jl. Prof. H. Soedarto, S.H, Tembalang, Semarang 50275, Central Java, Indonesia

[5]Department of Fisheries and Marine Science, Universitas Jenderal Soedirman. Jl. Dr Soeparno No. 63, Purwokerto Utara, Banyumas 53122, Central Java, Indonesia

[6]Borneo Marine Research Institute, Universiti Malaysia Sabah. Jl. UMS, Kinabalu 88400, Sabah, Malaysia

[7]Universitas Pertahanan Indonesia. IPSC Area, Sentul, Bogor 16810,West Java, Indonesia

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Abstract. *Salim G, Handayani KR, Anggoro S, Indarjo A, Syakti AD, Ibrahim AJ, Ransangan J, Prakoso LY. 2020. Morphometric analysis of* Harpodon nehereus, Harpiosquilla raphidea, *and* Scylla serrata *in the coastal waters of Tarakan, North Kalimantan, Indonesia. Biodiversitas 21: 4829-4838.* The Bombay duck (*Harpodon nehereus),* harpiosquillid mantis shrimp (*Harpiosquilla raphidea*), and giant mud crab (*Scylla serrata*) are among the commercially important fishery resources in Tarakan Island, North Kalimantan, Indonesia. This requires sustainable fisheries management to be in place since these resources have now become the main targets of fishing industry. However, sustainable fisheries management of these species is difficult because less is known about the species particularly its condition, fatness, and well-being. Hence, the current study was conducted to analyze the morphometric characteristics in order to deduce fishing pressure of the fish species in Tarakan waters. Data collection was achieved through field between September 2017 and April 2018. Morphometric characteristics (length, weight, width, and thickness) were collected throughout the sampling period. The length-weight relationship and condition factor were then estimated using the morphometric measurements. The data were then statistically analyzed either or combination of *t*-test, Chi-square, and the Mann-Whitney tests. The study revealed that all the three fish species (*H. nehereus*, *Ha. raphidea*, and *S. serrata*) populations in Tarakan waters were dominated by male individuals (M:F ratio; 1:0.81; 1:0.63; and 1:0.66, respectively). The length-weight analysis showed all fish were found to be smaller in size and exhibited negative allometric growth patterns. The analysis of condition factor also showed that the fish were dominated by flat and very flat body shapes. The current study suggests that the fish species may encounter some kinds of ecological disturbances that selectively removed female fish and larger individuals from the populations. However, more studies are needed to accurately identify those factors so that plans to effectively address the root cause could be incorporated in the sustainable fishery management tools of the fish resources.

Keywords: Condition factor, ecological disturbances, fisheries resources, morphometrics, sex ratio

INTRODUCTION

Fisheries resources consist of various types of organisms, such as fishes, shells, crabs, shrimps, mammals, etc. However, species diversity is varied among locations and seasons. Species availability is strongly dependent on habitat suitability(Asadi et al. 2016). Furthermore, the suitability of aquatic habitat for fish species is determined by various environmental parameters (Hashemi et al. 2015). Unfortunately, environmental conditions also keep changing because of seasonal dynamics. Thus, each location has unique characteristics that lead to variation in fish composition as an effect of its ecological and seasonal conditions (Glińska-Lewczuk et al. 2016).

Tarakan City is a small island located in the Northern Borneo, Indonesia. The city has a total area of 657.33 km^2, covering 250.80 km^2 of land area and 406.53 km^2 of marine area (Statistics Tarakan Municipality 2018). The length of the coastline is approximately 65 km (Prihartanto and Roem 2016). With this vast marine area and long coastline, Tarakan City has high potential to develop its economy based on the sustainable exploitation fisheries resources.

The waters of Tarakan are included in the SCS-SFM (Sulu-Celebes Sea Sustainable Fisheries Management) Project (Prasetyo et al. 2014). Unfortunately, illegal fishings are still rampantly occurring (Madjid et al. 2018). Thus, the risk of overexploitation of these fisheries resources is profoundly high.

Among the fish resources found in the coastal area waters of Tarakan City are the Bombay duck (*Harpodon nehereus*), the giant harpiosquillid mantis shrimp (*Harpiosquilla raphidea*), and the giant mud crab (*Scylla serrata*). These three species occupy different habitats within the coastal areas of Tarakan including deep sea, brackish water, and mangrove ecosystems. These species are economically valuable and have become fishing targets of local fishermen (Firdaus 2010; Widigdo et al. 2017; Mulyono et al. 2018).

Harpodon nehereus is a typical fish from Tarakan that is often consumed both in fresh and dried forms (Nugroho et al. 2015). Several locations on Tarakan Island, such as at Pantai Amal and Juata have been suggested to be the spawning grounds of the Bombay duck (Nugroho et al. 2017).

In Tarakan, the giant harpiosquillid mantis shrimp is considered bycatch. Thus, during fishing activity, mantis shrimp are discarded (Kalalo et al. 2015). Mantis shrimp are usually caught during the fishing of Bombay duck. However, in some other regions, mantis shrimp are commercially exploited for its high economic value as an export commodity (Arifin et al. 2014). This suggests that the exploitation of mantis shrimp in Tarakan waters has the potential to be improved.

The giant mud crab is an economically valuable resource that inhabits mangrove ecosystem and it often becomes the target of commercial fishing (Widigdo et al. 2017). In Tarakan, the mud crab has also become an aquaculture commodity, especially in traditional ponds (Iromo et al. 2018). However, the culture of mud crab is generally carried out only for fattening, while the gravid crabs are obtained from the wild catch (Jahan and Islam 2016). This emphasizes the importance of mud crabs to the local community.

Considering the importance of the abovementioned species, study concerning their biological condition is needed. Thus, the present study aims to analyze the morphometric characteristics and sex ratio of Bombay duck (*H. nehereus*), giant harpiosquillid mantis shrimp (*Ha. raphidea*), and giant mud crab (*S. serrata*) in the waters of Tarakan City in order to understand the growth status and their fishing pressure.

MATERIALS AND METHODS

Sampling site

The sampling was conducted in Juata waters of Tarakan Island, North Kalimantan, Indonesia (Figure 1) from September 2017 to April 2018.

Data collection

Sampling and data collection methods varied according to species. The sample collection of the Bombay duck (Figure 2a) was carried out by a field sampling using trawl net at 1.5 inches mesh size (common fishing practice in Tarakan) with the help of fishermen. During the sampling period, about 147 specimens of Bombay fish were successfully collected. The data recorded during the sampling included total length and bodyweight of the fish.

Sampling of mantis shrimp (Figure 2b) was also done during the trawling the Bombay fish (mantis shrimp is a bycatch of Bombay fish fishing). During the study period, sampling of mantis shrimp was approximately 214 specimens were successfully collected in sampling. Total length, carapace length, and weight and C/L ratio (carapace to total length) of each mantis shrimp were taken.

Sampling for mud crabs (Figure 2c) was carried out in the selected mangrove areas using 2 inches mesh size trap called the “ambau kurung”. The traps baited with small fish were left overnight in the sampling stations. During the sampling period, 161 specimens of crab were successfully obtained. Then, measurements of carapace length and width, body weight, body thickness, T/L (thickness to length) ratio, and T/W (thickness to weight) ratio of each specimen were taken.

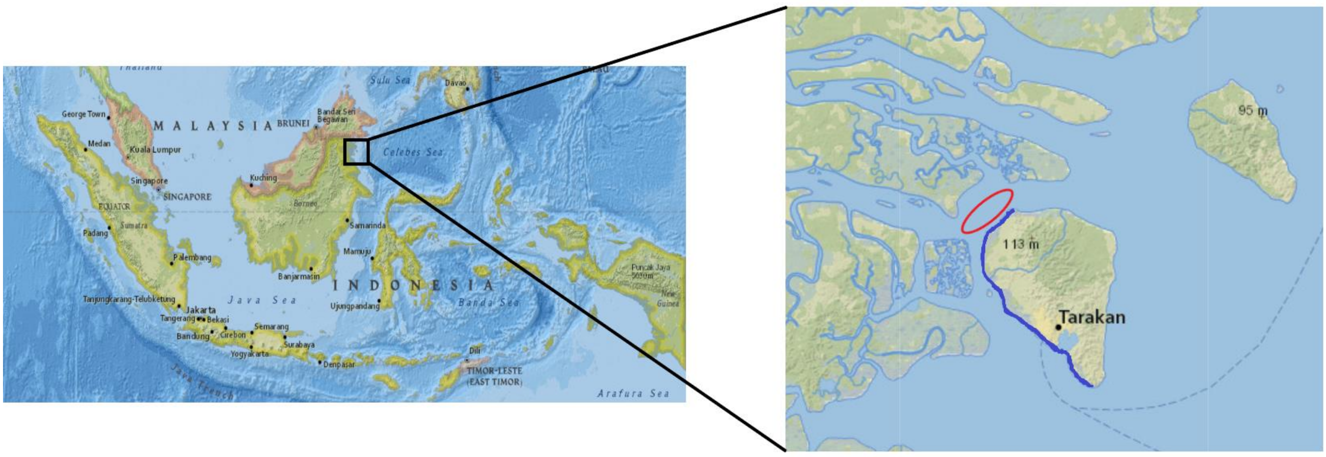

Figure 1. Sampling sites for Bombay duck and mantis shrimp (red circle), and mud crab (dark blue) in the coastal waters of Tarakan City, North Kalimantan, Indonesia

Data analysis

Data analysis included sex ratio, growth pattern, condition factor, and fattiness. For growth patterns, the allometric growth index was determined using the regression analysis between length and weight. The following formula was used in the analysis of the length-weight relationship (Effendie 1979); (Effendie 2002) :

$$W = a \times L^b$$

Where: W: weight; L: length/carapace; a and b: constants

From the formula above, the constant *b* represents the allometric growth index. Fish are categorized as positively allometric when $b > 3$, negatively allometric when $b < 3$, and isometric when $b = 3$ (Karachle and Stergiou 2012).

Santoso (2001) suggested that to find out whether the value of b is different or not, from the equation of the length-weight relationship, it can be tested statistically using the t-student test, where the value of b describes the nature of fish growth.

Hypothesis: H_O: b = 3, isometric growth; H_I: b ≠ 3, allometric growth.

Decision-making rules: With the following conditions: t count <t ((a/2;(n-2)), accept H_O, reject H_I, t count> t ((a/2;(n-2)), accept H_I, reject H_O.

Condition index of the crustacea and fish can be characterized into five criteria i.e. Very thin body shape (0.01-0.50), Thin body shape (0.51-0.99), Proportional/ ideal shape (1), Fat body shape (1.01-1.50), and Very fat body shape (>1.50) (Firdaus and Salim 2011; Salim 2013, 2015; Salim et al 2020a, 2020b; Firdaus et al. 2018, 2020; Indarjo et al. 2020a; 2020b). The length and weight data were also utilized to calculate the plumpness. The following formula was used to calculate Fulton's condition factor:

$$K = W/L^3 \times 100$$

Where: *K* = condition factor

The allometric growth was evaluated following Weatherley (1972), For isometric growth, methods suggested by Lagler (1949) and Effendie (1979) were used.

$$K_{(TI)} = 10^5 \, x \, \frac{W}{L^3}$$

Where: W: total weight (gram); L: total length (mm); 10^5: the equation was taken, so $K_{(TI)}$ value is close to 1.

The crab condition factor with allometric characteristic was obtained using equation (Weatherley 1972) as follow:

$$Kn = \frac{\hat{W}}{W}$$

W: total weight (gram); $\hat{W}$: logarithm of total weight (gram); W: a L^b obtained using the regression equation of length-weight correlation.

A slight modification of the formula was done by multiplying it by 1000 rather than 100 specifically for *S. serrata* in order to keep the index close to 1. Fulton's condition factor assumes that *K* is close to 1. $K = 1$ indicates that the length and weight are proportional, while $K < 1$ indicates that the fish is slim and $K > 1$ indicates that the fish is plump.

Furthermore, the fishes were grouped into 10 length classes. Then, the frequency and average value of Fulton's condition factor were analyzed for each length class.

Statistical analyses used in this study included Chi-square test, t-test, and Mann-Whitney rank test. The Chi-square analysis was carried out for the frequency distribution of length class and Fulton's condition factor between male and female fish. The Mann-Whitney test is a non-parametric statistical analysis method was used instead of the *t*-test in the event of data distribution is not normal. The Mann-Whitney rank test was carried out to compare the length, weight, *K*, and ratio of body measurements.

A B C

Figure 2. Fish species: A. Bombay duck (*Harpodon nehereus*), B. Mantis shrimp (*Harpiosquilla raphidea*), and C. Mud crab (*Scylla serrata*)

RESULTS AND DISCUSSION

Sex ratio of *Harpodon nehereus, Harpiosquilla raphidea,* and *Scylla serrata*

The present study showed that the populations of *H. nehereus*, *Ha. raphidea,* and *S. serrata* in the Tarakan waters were found to be male-biased. The proportions of male and female fish for each species are presented in Table 1. This table shows that the population of female specimens was much lower than the male specimens. Despite being the closest ratio, the female population of *H. nehereus* was only 81% of the male population. The female population of *Ha. raphidea* was 63% of the male population. The female population of *S.serrata* was 66% of the male population.

Morphometric characteristics according to sex

The analysis of morphometric characteristics of the fish species according to sex is presented in Table 2. The analysis showed that there were significant differences in the morphometrics of male and female *H. nehereus*, *Ha. raphidea*, and *S. serrata*. The length and weight of *H. nehereus* were higher for female fish than for males. However, *Ha. raphidea* showed the opposite condition whereby the total length, carapace length, and weight were significantly higher for male compared to female shrimps. Nevertheless, the difference in the C/L ratio was not significant ($p>0.05$). For *S. serrata,* total length, width, and thickness were found significantly higher ($p<0.05$) in females compare to male crabs. Although the weight of male crabs was higher female crabs, the difference was not significant ($p>0.05$). However, analyses of the W/L ratio, T/L ratio, and T/W ratio showed significant differences among crabs of different sexes.

Morphometric characteristics and condition factor according to sex

The results of the length and weight relationship and Fulton's condition factor are presented in Table 3 and Table 4, respectively. It was found that the fish species (*H. nehereus*, *Ha. raphidea,* and *S. serrata*) exhibited negative allometric growth patterns regardless of sex.

The condition factor analysis indicated that there was no significant difference ($p>0.05$) in Fulton's condition factor of all the fish species. The analysis also showed that the average *K* index of males and females of *H. nehereus* was similar. However, since the Mann–Whitney test is based on the rank, Fulton's condition factor between male and female fish was suggested to have not significant differences. Based on the frequency distribution of fish plumpness (Table 5), it could be concluded that the population of *H. nehereus*, *Ha. raphidea,* and *S. serrata* in Tarakan waters mostly had flat body shape. Fish with Proportional body shape was only noted in *S. serrata* males. The Chi-square test showed that there were significant ($p<0.05$) differences in the proportion of body shape between males and females for *H. Nehereus*, *Ha. raphidea* and *S. serrata*.

The results of frequency distribution analyses of length classes and Fulton's condition factors of *H. nehereus*, *Ha. raphidea* and *S. serrata* are presented in Tables 6, 7, and 8, respectively.

It was found that the dominant length of *H. nehereus* was within the range of 22.4-23.5 cm (Table 6). However, the dominant class of the male fish was within the upper classes while the females were within the lower classes. Statistical analysis of the proportion length-frequency between male and female fish was not significantly different (χ^2=64.395; p =0.157>0.05). Further analysis on Fulton's condition factor (*K*) within length classes showed some variations, especially the third and fourth classes. However, the Chi-square analysis of *K* between sexes, found the variations were not significantly different (χ^2= 49.00; $p=0.939$ >0.05). The analysis revealed that the average *K* value was higher for male populations compared to the females in all classes.

Analysis of the length-frequency distribution of the male and female shrimps showed that the shrimp population was mainly dominated by small specimens within the length class 12.6-15.2 cm (Table 7). The Chi-square test analysis showed that the variations in the length were significantly different (χ^2= 150.860; p =0.000<0.05). Analysis of Fulton's condition factor could only be carried out for the first, second, and third classes. The other classes could not be analyzed due to data insufficiency. The Mann-Whitney test showed that there were no significant differences in the *K* values within the classes. However, the variations of the *K* value between sexes over length classes showed no significant differences (U=38,50; p= 0.352>0.05).

Analysis of the length-frequency distribution (Table 8) of crabs showed that the male and female specimens did not have certain trends of domination. However, the fifth class (length range: 68.6-72.5 cm) was the range in which both male and female crabs were dominant. Statistical analysis revealed that the length-frequency distribution of crab population showed was not a significant difference (χ^2= 50.795; p=0.796 >0.05). The Mann-Whitney test for the *K* indices within the length classes showed significant differences between male and female crabs in the third through the eighth classes, respectively. It was also noted that the *K* value in each class was higher for the male population compared to the female population. The Mann-Whitney test of the *K* values between sexes over the length also showed no significant differences (U=36.00; p=0.288 >0.05).

Discussion

The data obtained in the present study indicate that the populations of *H. nehereus*, *Ha. raphidea*, and *S. serrata* in the waters of Tarakan City were dominated by male individuals, respectively. Moreover, the proportion of females in the population of respective fish species was considered low. This finding was contrary to the finding of previous study which reported that the population of *H. nehereus* in Tarakan waters consisted of 56.8% females and 43.2% males (Perdana et al. 2016). Generally, wild fish population is always comprised of more females over males. However, male-biased populations may also naturally occur in certain conditions, such as in the early life of shrimp (Fryxell et al. 2015).

Table 1. Sex ratio of *Harpodon nehereus*, *Harpiosquilla raphidea*, and *Scylla serrata* in Tarakan waters

Species	Male		Female		Total abundance	Sex ratio (M:F)
	Abundance	Proportion	Abundance	Proportion		
H. nehereus	81	55.1%	66	44.9%	147	1:0.81
Ha. raphidea	131	61.2%	83	38.8%	214	1:0.63
S. serrata	97	60.2%	64	39.8%	161	1:0.66

Table 2. Morphometric characteristics of *Harpodon nehereus*, *Harpiosquilla raphidea*, and *Scylla serrata* according to sex [range (average ± SD)]

Species	Parameters	Male	Female	Statistic*
H. nehereus	Total length	18,50-24,50	19,30-28,40	1671,000.00
		21,79 ± 1,44[a]	23,06 ± 1,90[a]	0.000
	Weight	37,00-100,00	39,00-142,00	1814,500.00
		61,88 ± 11,93[a]	72,48 ± 20,41[a]	0.001
Ha. raphidea	Total length (L)	10,00-35,10	10,40-35,70	4037,500.00
		14,01 ± 4,13[a]	12,92 ± 2,74[a]	0.002
	Carapace length (C)	1,60-6,50	1,80-6,00	4339,000.00
		2,50 ± 0,70[a]	2,33 ± 0,48[b]	0.012
	Weight	4,40-165,50	4,50-181,50	4203,000.00
		16,1 ± 26,10[a]	11,71 ± 19,06[a]	0.005
	C/L ratio	0,14-0,26	0,15-0,22	5301,000.00
		0,18 ± 0,01[a]	0,18 ± 0,01[a]	0.745
S. serrata	Total length (L)	53,50-85,00	62,00-92,00	1452,000.00
		65,92 ± 7,90[a]	73,54 ± 7,01[a]	0.000
	Width (W)	73,00-124,00	89,00-177,00	1598,500.00
		95,38 ± 11,86[a]	106,52 ± 14,62[a]	0.000
	Thickness (T)	27,00-48,00	32,00-49,00	2007,500.00
		35,37 ± 4,77[a]	37,92 ± 3,73[a]	0.000
	Weight	113,00-490,00	135,00-365,00	2705,000.00
		219,63 ± 89,09[a]	217,23 ± 52,09[a]	0.168
	W/L ratio	1,27-1,56	1,30-2,19	2278,000.00
		1,45 ± 0,04[a]	1,45 ± 0,12[a]	0.004
	T/L ratio	0,49-0,66	0,47-0,56	1252,500.00
		0,54 ± 0,02[a]	0,52 ± 0,01[b]	0.000
	T/W ratio	0,34-0,42	0,23-0,40	2034,500.00
		0,37 ± 0,02[a]	0,36 ± 0,02[b]	0.000

Notation: *Statistical analysis with Mann-Whitney test. Different letters in the same row indicate significant difference

Table 3. Length and weight relationships of *Harpodon nehereus*, *Harpiosquilla raphidea*, and *Scylla serrata* according to sex

Species	Male		Female	
H. nehereus	$W = 0.0785L^{2.1602}$	(R^2 = 0.5571 & r =74.64%)	$W = 0.0787L^{2.1665}$	(R^2 = 0.4784 & r = 69.17%)
Ha. raphidea	$W = 0.0070L^{2.8343}$	(R^2 = 0.9706 & r = 98.52%)	$W = 0.0067L^{2.8573}$	(R^2 = 0.9085 & r = 95.32%)
S. serrata	$W = 0.0012L^{2.8836}$	(R^2 = 0.8735 & r = 93.46%)	$W = 0.0208L^{2.1491}$	(R^2 = 0.7463 & r = 86.39%)

Table 4. Fulton's condition factor and sex-based differences of *Harpodon nehereus*, *Harpiosquilla raphidea*, and *Scylla serrata* in Tarakan waters

Species	Male	Female	Statistic*
H. nehereus	0.40-0.80	0.30-0.90	2315,500.00
	0.60 ± 0.09[a]	0.58 ± 0.12[b]	0.946
Ha. raphidea	0.30-0.60	0.30-0.70	1476,500.00
	0.46 ± 0.06[a]	0.46 ± 0.07[b]	0.181
S. serrata	0.50-1.00	0.40-0.70	579,000.00
	0.73 ± 0.10[a]	0.55 ± 0.08[b]	0.000

Note: *Statistical analysis with Mann–Whitney test

Table 5. The plumpness index and body shape of *Harpodon nehereus, Harpiosquilla raphidea,* and *Scylla serrata* according to sex

Plumpness index	Body shape	*H. nehereus*		*Ha. raphidea*		*S. serrata*	
		M	F	M	F	M	F
< 0.5	Very flat	2	7	58	39	-	2
0.5 – 0.99	Flat	79	59	73	44	96	62
1	Proportional	-	-	-	-	1	-
1.01 – 1.50	Rounded	-	-	-	-	-	-
> 1.50	Very Rounded	-	-	-	-	-	-
Total		81^{a}	66^{b}	131^{p}	83^{q}	97^{x}	64^{y}
Statistics*		0.000^{a}	1.000	0.000^{p}	1.000	0.000^{x}	1.000

Note: *Statistical analysis with chi-square test

Table 6. Sex-based length-frequency distribution and Fulton's condition factor of *Harpodon nehereus* in Tarakan waters

Class	Length range	Frequency		Average condition factor	
		Male	Female	Male	Female
1	$18.0\text{-}19.1^{\#}$	2	-	$0{,}70 \pm 0.17^{a}$	-
2	$19.1\text{-}20.2^{\ddagger}$	14	3	$0{,}70 \pm 0.11^{a}$	$0{,}80 \pm 0.17^{b}$
3	$20.2\text{-}21.3^{\ddagger}$	14	10	$0{,}60 \pm 0.09^{a}$	$0{,}60 \pm 0.09^{a}$
4	$21.3\text{-}22.4^{\ddagger}$	20	12	$0{,}60 \pm 0.07^{a}$	$0{,}60 \pm 0.13^{a}$
5	$22.4\text{-}23.5^{\ddagger}$	22	16	$0{,}50 \pm 0.08^{a}$	$0{,}60 \pm 0.12^{a}$
6	$23.5\text{-}24.6^{\ddagger}$	9	15	$0{,}60 \pm 0.08^{a}$	$0{,}50 \pm 0.08^{b}$
7	$24.6\text{-}25.7^{\#}$	-	3	-	0,50 ± 0.10
8	$25.7\text{-}26.8^{\#}$	-	6	-	0,60 ± 0.18
9	26.8-27.9	-	-	-	-
10	$27.9\text{-}29.0^{\ddagger}$	-	1	-	0,40
	Total/Average	$81^{x\phi}$	66^{y}	$0.60 \pm 0.09^{a*}$	0.58 ± 0.12^{a}

Notation: $^{\#}$The number of samples was not sufficient for statistical analysis; $^{\phi}$Statistical analysis with chi-square; *Statistical analysis with Mann-Whitney test; ‡Statistical analysis with *t*-test. Different letters in the same row show significant difference

Table 7. Sex-based length-frequency distribution and Fulton's condition factor of *Harpiosquilla raphidea* in Tarakan waters

Class	Length range	Frequency		Average condition factor	
		Male	Female	Male	Female
1	$10.0\text{-}12.6^{\ddagger}$	50	42	0.46 ± 0.05^{a}	0.48 ± 0.07^{a}
2	$12.6\text{-}15.2^{\ddagger}$	60	38	0.47 ± 0.07^{a}	0.45 ± 0.07^{a}
3	$15.2\text{-}17.8^{\ddagger}$	16	2	0.45 ± 0.05^{a}	0.40
4	17.8-20.4	-	-	-	-
5	20.4-23.0	-	-	-	-
6	23.0-25.6	-	-	-	-
7	25.6-28.2	-	-	-	-
8	$28.2\text{-}30.8^{\#}$	1	-	0.40^{b}	-
9	$30.8\text{-}33.4^{\#}$	2	-	0.35 ± 0.07^{b}	-
10	$33.4\text{-}36.0^{\ddagger}$	2	1	0.40^{b}	0.40^{b}
	Total/Average	$131^{x\phi}$	83^{y}	$0.46 \pm 0.06^{a*}$	0.46 ± 0.07^{a}

Notation: $^{\#}$The number of samples was not sufficient for statistical analysis; $^{\phi}$Statistical analysis with chi-square; *Statistical analysis with Mann–Whitney test; ‡Statistical analysis with *t*-test. Different letters in the same row show significant difference

Table 8. Sex-based length-frequency distribution and Fulton's condition factor of *Scylla serrata* in Tarakan waters

Class	Length range	Frequency		Average condition factor	
		Male	Female	Male	Female
1	$53.0\text{-}56.9^{\#}$	12	-	0,83 ± 0.06	-
2	56.9-60.8	16	-	$0{,}71 \pm 0.11^{a}$	-
3	$60.8\text{-}64.7^{\ddagger}$	18	7	$0{,}74 \pm 0.07^{a}$	$0{,}63 \pm 0.08^{b}$
4	64.7-68.6	18	9	$0{,}67 \pm 0.07^{a}$	$0{,}56 \pm 0.07^{b}$
5	$68.6\text{-}72.5^{\ddagger}$	16	14	$0{,}73 \pm 0.13^{a}$	$0{,}57 \pm 0.08^{b}$
6	$72.5\text{-}76.4^{\ddagger}$	5	13	$0{,}70 \pm 0.12^{a}$	$0{,}54 \pm 0.09^{b}$
7	76.4-80.3	6	10	$0{,}80 \pm 0.09^{a}$	$0{,}54 \pm 0.07^{b}$
8	$80.3\text{-}84.2^{\ddagger}$	4	7	$0{,}75 \pm 0.10^{a}$	$0{,}49 \pm 0.04^{b}$
9	$84.2\text{-}88.1^{\#}$	2	2	$0{,}75 \pm 0.07^{a}$	$0{,}50^{b}$
10	$88.1\text{-}92.0^{\#}$	-	2	-	$0{,}50^{b}$
	Total/Average	$97^{x\phi}$	64^{y}	$0.73 \pm 0.10^{a*}$	0.55 ± 0.08^{b}

Notation: $^{\#}$The number of samples was not sufficient for statistical analysis; $^{\phi}$Statistical analysis with chi-square; *Statistical analysis with Mann-Whitney test; ‡Statistical analysis with *t*-test. Different letters in the same row show significant difference

The sex ratio of the *Ha. raphidea* obtained in the present study was not in agreement with the findings of previous studies. The global population structure of *Ha. raphidea* was reported to have the tendency of female-biased. For example, the population of *Ha. raphidea* in Tanjung Jabung Barat exhibited a male: female ratio of 1:0.68 (Wardiatno and Mashar 2010), while in Andaman Sea, Thailand, the average ratio was reported to be 1:1.54 (Samphan and Ratanamusik 2018). However, studies also showed that the sex ratio of *Ha. raphidea* can fluctuate causing a change in population structure from female-biased to male-biased (Chandra et al. 2014; Kalalo et al. 2014; Salim and Wiharyanto 2015; Salim and Wiharyanto 2016). Nevertheless, the female-biased condition is still more common than male-biased.

The population of *S. serrata* in the waters of Tarakan City was also found to be male-biased with sex ratio (male: female) of 1:0.66. This finding was found to be consistent with the observations in other places. A study carried out in Bulungan, North Kalimantan showed a sex ratio of 1:0.79 (Widigdo et al. 2017) while the Persian Gulf and the Gulf of Oman showed a ratio between 1:0.13 to 1:0.69 (Rezaie-Atagholipour et al. 2013).

In nature, sex bias population in some fish species could occur during its life cycle. The proportion of male and female individuals may change any time during the new hatch, young, adult, and mature stages. The change may also occur as a result of dispersal and migration patterns (Szekely et al. 2014).

Skewed sex ratios could indicate the possibility of environmental disturbances within the habitat of the fish population that selectively removed or retained favorable individuals. For example, a change in temperature could induce sex differentiation (Budd et al. 2015), while some predators prefer female prey over males or vice versa (McKellar and Hendry 2011; Fryxell et al. 2015). Environmental pollution could also induce hormonal changes which may influence sex determination (Sanchez et al. 2011).

In some cases, the increase in the male population (or reduced female population) could be due to the selective fishing gear. According Froese (2006), noted that in their early stages the fishes grow in length in a greater ratio than they grow in other dimensions and their length-weight ratio, thus differs from what obtains among larger individuals. Finally, he noted that the variation in weight at a given size in the same species increases very much as the fish grows in length. Females fish are generally larger, resulting in an increased probability of capture during fishing, especially with the use of large net mesh size. Thus, a population that is actually female-biased can change to become male-biased over a prolonged uncontrolled fishing activity (Côté 2013). Changes in the sex proportion may also occur during mating season. The proportion of ready-to-mate males usually decreases during the mating season (Wacker et al. 2013). Unfortunately, it was unknown whether the current state of the observed sex ratio in the three fish species investigated in the present study was related to mating season or not. In the case of the Bombay fish and the mantis shrimp, the trawl net used to catch them has a mesh size of 1.5 inches. However, it is difficult to ascertain if this mesh size selectively caught only the small-sized fish which mostly consist of male fish. Studies show that sex ratio within a fish population has wide implications for the population strength (Fryxell et al. 2015). According to Wacker et al. (2013), male-biased populations have been seen to exacerbate the competition between males for mates.

The present study also observed that the range of length and weight of Bomby duck (*H. nehereus*) in the waters of Tarakan City was relatively narrower than that in Kakdwip, West Bengal, which had a range of lengths between 7.3-32.1 cm and weighs between 2-250 g (Behera et al. 2015). However, previous study by Firdaus et al. (2013) showed that the growth of *H. nehereus* in Tarakan waters could reach maximum lengths of 33.847 cm for males and 35.743 cm for females. The length-weight relationship also showed positive allometric growth patterns (b= 3.4262) for the global population (Behera et al. 2015). However, the finding of the present study revealed that the growth pattern of the male and female fish was characterized by negative allometric (b values of 2.1602 and 2.2665), respectively. This was slightly different from the findings of previous observations of the species in Juata and Amal waters, which showed a b value of 2.59 and 3.00, respectively (Taqwa et al. 2018). This implies that there is a possibility that individuals of the Bombay duck in Tarakan waters are getting smaller.

The male and female mantis shrimp (*Ha. raphidea*) populations in the waters of Tarakan were recorded to have average length of 14,01 ± 4,13 cm and 12,92 ± 2,74 cm, respectively. A study in Malaysia recorded length distribution of 10.3 to 20.7 cm (average 15.9 ± 3.35 cm) and 10.4 to 22.2 cm (average 15.8 ± 3.47 cm) for male and female shrimps, respectively (Antony et al. 2014). In Thailand, the shrimp was recorded to range from 19 to 32 cm (average 27.39 ± 2.17 cm) for males and 22 to 33.5 cm (average 28.44 ± 1.80 cm) for females, respectively (Samphan and Ratanamusik 2018). This indicates that the mantis shrimp population in Tarakan waters consisted of smaller individuals than that in Malaysia and Thailand. However, the growth coefficients (2.8343 and 2.8573, respectively) of the male and female mantis shrimp populations in Tarakan waters, although slightly higher, are in agreement with the b values (2.4718 and 2.5571; 2.7425 and 2.4810, respectively) of the species in Malaysia (Antony et al. 2014) and Thailand (Samphan and Ratanamusik 2018). This implicates that individuals of *Ha. raphidea* in Tarakan waters tend to have a smaller size but faster weight gain.

Previous studies on *S. serrata* in Bulungan showed that the carapace length was ranged from 40-89 mm and 32-91 mm, respectively for male and female crabs, while the carapace width ranged from 59-128 mm and 53-122 mm, respectively (Widigdo et al. 2017). The study in the Persian Gulf and the Gulf of Oman showed the carapace width between 89.7-196.5 mm and 91.7-170.1 mm, respectively for male and female crabs (Rezaie-Atagholipour et al. 2013).

The length-weight relationship analysis showed that the *S. serrata* in Tarakan waters had a negative allometric growth pattern. The *b* values recorded at 2.8836 and 2.1491, respectively for male and female crabs. This is in agreement with the finding (2.3968 and 3.2012 respectively) of Widigdo et al. (2017). Study by Rezaie-Atagholipour et al. (2013) also showed that the *b* value of male giant mud crab was higher than for females (3.47 and 2.55), respectively. In comparison to these studies, it can be suggested that the weight growth rate of *S. serrata* in Tarakan waters was slower. Further consideration judged on the basis of *b* values, it could suggest that environmental quality in Tarakan waters may not be in optimal condition to support the growth of giant mud crab. However, this phenomenon could also be caused by the intense fishing activity over a long period that selectively removes large size mud crab. In addition, high fishing frequency also means it does not provide sufficient time for young crabs to grow bigger.

Analysis of Fulton's condition factors (K_n) of *H. nehereus* (0.40-0.80; 0.30-0.90, respectively), *Ha. raphidea* (0.30-0.60; 0.30-0.70, respectively) and *S. serrata* (0.50-1.00; 0.40-0.70, respectively) revealed that the species were characterized to have flat bodies. In this study, the use of Fulton's condition factor for determining length-weight parameters was preferred because of its exact and standardized value for length base weight reference. The use of relative weight to calculate condition factor was avoided since it resulted in the unstandardized weight reference and is highly relative to the population's condition. However, most of the studies concerning *H. nehereus* used relative weight as the preferred analytical method for condition factor (e.g. Firdaus et al. (2013) and Laga et al. (2015)).

The use of the relative condition factor is not comparable to Fulton's condition factor. By applying the relative condition factor, the fish population would always be dominated by the "thin/flat" and "fat/rounded" categories even though the weight distribution was different among populations, as proven by Chandra et al. (2015). Thus, it cannot be used as a reference condition for the global population.

A study carried out by Mulyono et al. (2013) showed an average Fulton's condition factor of 1.19 and 1.21 respectively for male and female shrimp in Banten Bay. These results were much higher than the findings of this study. This indicates that *Ha. raphidea* in Tarakan waters are less plump. This may be attributed to the environmental quality of the waters around Tarakan City but further study is needed to ascertain.

Mohapatra et al. (2010) studied the condition factor of *S. serrata* relating carapace width and weight using a hundred-based multiplier. The result showed that the condition factor of *S. serrata* was ranged from 0.0350-0.0719 and 0.0368-0.0671, respectively for male and female crabs. However, data obtained in the present study showed that using carapace width to estimate the condition factor was less appropriate due to the increasing number of outliers. Study of Sentosa and Syam (2011) showed a much higher value but similar pattern i.e. the range of condition factors for females was wider than for males. The authors also noted that the frequency distribution for length class of *S. serrata* did not have certain size domination which is consistent with the results of the current study.

Overall, the sex ratios, length and weight ranges, length-weight relationships, and condition factors of *H. nehereus*, *Ha. raphidea*, and *S. serrata* in Tarakan waters were different from those in other places referred to in this study. The differences could be attributed to certain factors such as behavioral, spatial, and temporal variations or the impacts of environmental conditions. Some aquatic species are considered migratory. Migration may affect reproduction and/or feeding activity of the species. Migratory species may also inhabit different places depending on their life stages. This influences the spatial distribution of species and so as the morphometric characteristics (Olson et al. 2018). Spatial distribution can refer to horizontal or vertical movements, and in some migratory species, spatial variation occurs along with temporal variation (Arocha et al. 2017). Even though spatial and temporal variations may occur in fish species, this may not be appropriate in the current study since all three species exhibited low condition factors which imply that inappropriate environmental conditions may exist that affect the growth condition of fish. Disturbances in environmental conditions can reduce food availability which may result in insufficient supply of food availability hence hinder the growth performance of fish species in a particular environment (Lourenço et al. 2012). This condition may severely affect the sedentary species more than the migratory species.

Environmental condition is an important factor that affects growth rates because metabolism can potentially induce genetic modification (Besson et al. 2016). Various environmental stresses induce adaptation processes that cause morphological and genetic differentiation (Saleky et al. 2016). However, genetic modification requires a very long time to occur, but initial change can be foreseen in morphological modification. Fish condition indices such as the *b* value and Fulton's condition factor represent the symptoms of food insufficiency (Koffi et al. 2014). Thus, there might be a possibility of higher rate of genetic differentiation in the populations of *H. nehereus*, *Ha. raphidea*, and *S. serrata* in Tarakan waters compared to regions.

In conclusion, the current study suggests that the populations of Bombay duck (*Harpodon nehereus*), giant harpiosquillid mantis shrimp (*Harpiosquilla raphidea*), and giant mud crab (*Scylla serrata*) in the Tarakan waters were found to be dominated by male individuals and are relatively smaller in body size compared to the same species occurring in other regions. The more males proportion in the population coupled with the low *b* values and Fulton's condition factor of the three important fishery species investigated in the current study warrant a more thorough study to be conducted on the ecological parameters and the fishing activity in the Tarakan waters as to obtain fundamental scientific information for establishing effective sustainable fishery resource management in the area.

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