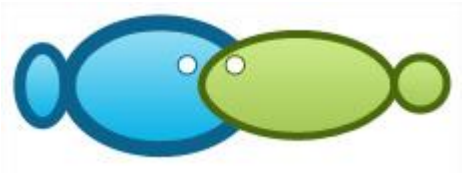

Biological aspects of shrimps *Penaeus merguiensis* and *Exopalaemon styliferus* in Nagan Raya coast, Aceh Province, Indonesia

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Abstract. Shrimps are one of the main fishery commodities in Nagan Raya District, Aceh, Indonesia, and limited information is available on its biological aspects. The purpose of this study, therefore, was to determine several biological aspects of 2 commercial species of shrimp, *Penaeus merguensis* and *Exopalaemon styliferus*, in terms of length-weight relationship, sex ratio, and gonadal maturation rate. Using a mini-trawl, sampling was conducted from September to October 2018 at the Fish Landing Unit of Kuala Tuha, Nagan Raya district. The results show the carapace length range for males and females of *P. merguiensis* from 4.7 to 25.42 mm and 25.4 to 45.5 mm, respectively, and a corresponding body weight between 4.58 and 46.46 g. The carapace length for *E. styliferus* ranged from 15.8 to 23.1 mm and 4.94 to 17.2 mm, for males and females, respectively, with the body weight ranging from 4.58 to 46.46 g and 0.9 to 3.1 g, respectively. In addition, the sex ratio of males and females shrimp was 1:0.47 and 1:1.85, for *P. merguiensis* and *E. styliferus*, respectively. Gonadal maturity was dominated by the mature form. Therefore, the growth patterns of *P. merguensis* and *E. styliferus* shrimp were negative allometric.
Key Words: length-weight, negative allometric, sex ratio.

Introduction. Nagan Raya region is a well-known productive area located on the western coast of Aceh Province, Indonesia. It has suitable habitats for abundant crustacean resources. Furthermore, several commercial shrimp species have regularly been captured, including *Penaeus merguiensis* (De Man, 1888), *Penaeus monodon*, *Metapenaeus* spp., and *Exopalaemon styliferus* (H. Milne Edwards, 1840). Previous studies reported some biological aspects of *P. merguiensis* (Putra et al 2018a), while no prior investigation could be found on *P. merguensis* and *E. styliferus* in this region.

According to Chan (1998), *P. merguensis* widely spreads across the Indo-West Pacific, from the Arabian Sea to the South China Sea and Fiji. This shrimp has a maximum body length of 24 cm (with carapace measuring 6 cm) for females, and a maximum of 20 cm (with 5 cm carapace) in males, normally between 13 and 15 cm. Furthermore, they are known to inhabit sand and mud substrates from the coastline and river mouths, up to depths of 55 m, although usually less than 20 m, with a preference for turbid waters. These species sometimes form very dense shoals, and good catches have often been linked with heavy rainfall. The capturing is conducted with the use of trawls, beach seining, cast nets, pocket netting, and artisanal gear. In addition, the yields are marketed mostly fresh and ice-frozen, and then consumed domestically or sent for exports.

E. styliferus is a small shrimp species, which spreads across the Indo-West Pacific from Pakistan to Thailand and Kalimantan, characterized by a maximum total length of 9 cm for males, and 6.8 to 8.6 cm for egg-bearing females (Chan 1998). This species usually inhabits shallow coastal, marine or brackish waters, and occasionally freshwater (Chan 1998).

Studies on biological aspects, including length-weight relationships, sex ratio and the gonadal maturity levels of fish and shrimp serve an important function in fisheries management and conservation. Generally, length-weight relationships assist in estimating the weight of a specific fish length, which is further used to estimate maturity, rate of feeding, gonad development, metamorphosis, and condition (Richter et al 2000; Mustakim et al 2019). This data is important for shrimp for estimating the population structure, stock assessment model, population evaluation, domestication and conservation (Teikwa & Mgaya 2003; Froese 2006; Rajakumar & Vaseeharan 2014; Olawusi-Peters & Ajibare 2014; Raposo da Silva et al 2014; Carvalho et al 2015; Putra et al 2018a; Muhammadar et al 2019, 2020).

Numerous previous reports have demonstrated shrimp biological aspects in other areas (Wayan 2011; Nurdin & Kembaren 2015; Tirtadanu & Ernawati 2016; Sentosa et al 2017; Suryanti et al 2018), while *P. merguiensis* and *E. Styliferus* have not been investigated in the western waters of Aceh. Therefore, the aim of this present study was to investigate some biological aspects of *P. merguiensis* and *E. Styliferus* in Nagan Raya coast, Aceh Province, Indonesia.

Material and Method

Study area and data collection. Using a mini-trawl, the sampling of *P. merguiensis* and *E. styliferus* was performed in October 2018, at the Fish Landing Unit of Kuala Tuha, Nagan Raya region, Aceh Province, Indonesia. The fishing ground was 5-10 miles away from the coast with a depth of 7-10 m (Figure 1). The determination of the fishing location was based on the existence of muddy sand substrates to facilitate trawl work. This period was determined based on a preliminary survey concerning the time of shrimp maturation in this area. Specimens from both species were measured using a caliper, with an accuracy of 0.01 mm, while a digital scale with an accuracy of 0.01 g was used to evaluate the weight. The carapace length was obtained from the tip of the rostrum to the base of the cephalothorax. Moreover, parameters were acquired after draining the water, and wiping the moisture content from the sample.

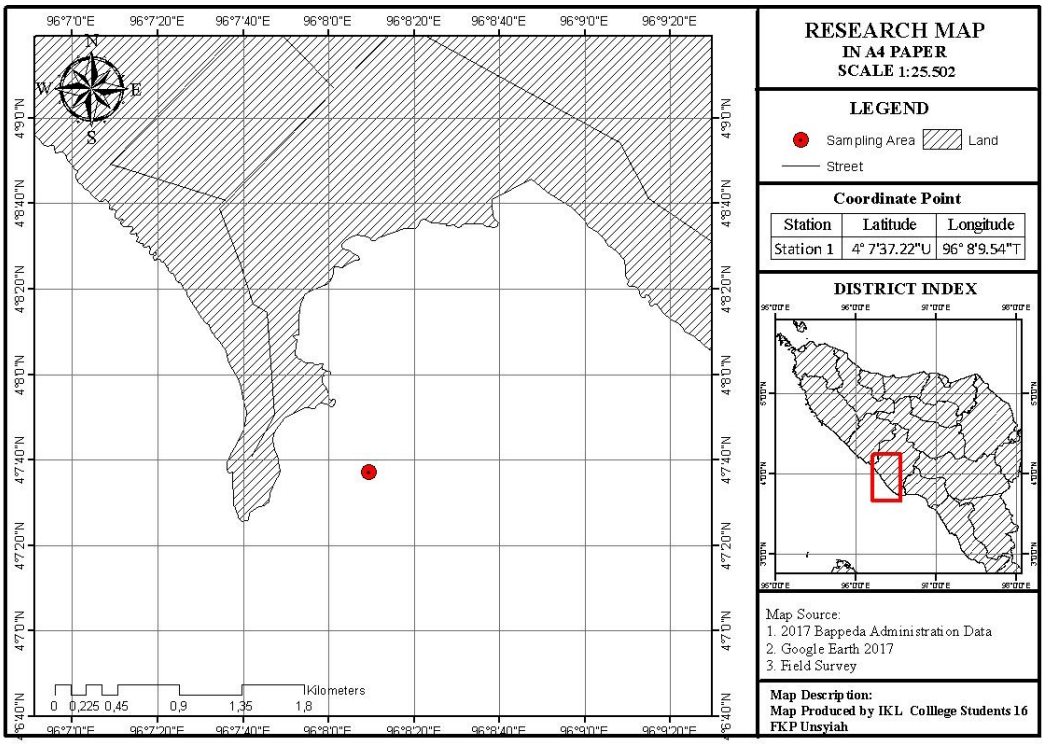

Figure 1. Shrimp sampling site at the Fish landing Unit of Kuala Tuha, Nagan Raya region, Aceh Province Indonesia.

Determination of length-weight relationship. The length-weight relationship was calculated using the following formula (Ricker 1975):

$W = aL^b$

Where: W - body weight (g); L - carapace length (mm); a - intercept; ^{b} - exponential value.

Sex ratio. The sex ratio was calculated by comparing the number of males with females. Male and female shrimp were distinguished by the external genitalia and the walking periopod. Sex ratio analysis based on using the chi-square test (X^2), at a 95% confidence level the following formula (Usman & Akbar 2006):

$$X^2 = \sum[(f_0 - f_e)^2/f_e]$$

Where: f_0 - frequency of observed male and female shrimp; f_e - frequency of expectations, which was 1:1.

Gonad maturity level (GML). The gonad maturity level (GML) was determined morphologically, by visual observations, following the length and weight measurement of the specimen. Therefore, the extent of development was classified in 5 levels, according to Motoh (1981): level I - immature, thin ovary, clear and colorless; level II - early maturity, enlarged ovary, with developing front and middle; level III - further maturity, light green ovaries, envisaged through the exoskeleton, with fully developed front and middle; level IV - mature eggs, dark green ovaries, which tend to be bigger than before; level V - soft and wrinkled ovaries, with released eggs, the shrimp body usually feels soft, with an empty upper cavity.

Results and Discussion

Length-weight relationship. A total of 172 *P. merguiensis* and *E. styliferus* specimens were collected during the study (Figure 2). *P. merguiensis* presented a carapace length for males and females between 18.51 and 37.30 mm, and 5.7 and 18.8 mm, respectively. The body weight was between 4.58 and 32.91 g, and 0.9 and 3.10 g, for males and females, respectively. For *E. styliferus*, the carapace length of males and females ranged from 25.4 to 45.50, and 10.2 to 17.2 mm, respectively, and the body weight was between 9.47 and 46.46, and 0.85 and 2.88 g, for males and females, respectively. Both species had a negative allometric growth pattern present for males and females. The data tabulation of the estimated length and weight parameters for both species are presented in Table 1.

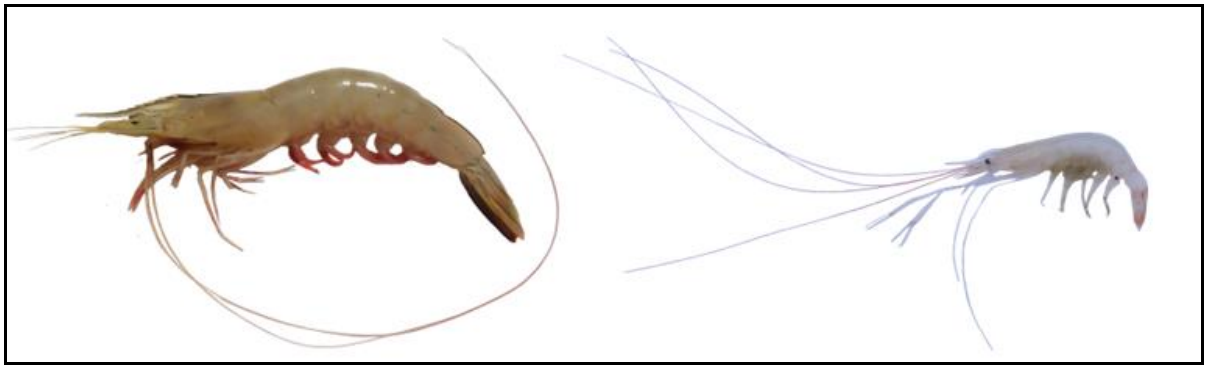

Figure 2. Two commercial shrimps *Penaeus merguensis* (left), and *Exopalaemon styliferus* (right) in Nagan Raya region, Aceh Indonesia.

Table 1

Length-weight relationship analysis of *Penaeus merguiensis* and *Exopalaemon styliferus*

Parameter	*Penaeus merguensis*		*Exopalaemon styliferus*	
	Male	Female	Male	Female
Carapace length (mm)	18.51-37.3	25.4-45.5	5.7-18.8	10.2-17.2
Weight (g)	4.58-32.91	9.47-46.46	0.9-3.1	0.85-2.88
b value	2.42	2.69	0.0961	-0.215
The correlation coefficient (r)	0.877	0.983	0.109	0.085
Regression equation	$y=0.0047x^{2.4211}$	$y=0.0018x^{2.697}$	$y=1.391x^{0.0961}$	$y=3.1088x^{-0.215}$
Growth pattern	Negative allometric	Negative allometric	Negative allometric	Negative allometric
Number of samples (n)	49	23	35	65

The intercept of the regression curve (a) and growth coefficient (b) were different for males and females in both species. The correlation coefficients (r) for males and females of *P. merguiensis* were 0.877 and 0.983, respectively, indicating the existence of a relationship between an elevation in length and weight gain in males, ranging from 87.7% to 98.3%. Meanwhile, 0.109 and 0.085 were recorded for males and females of *E. styliferus*, respectively, indicating an 8.5% to 10.9% relationship between length increase and weight gain for both males and females. Furthermore, the coefficients of determination (R^2) for males and females of *P. merguiensis* were 0.769 and 0.966, while 0.012 and 0.073 were estimated for *E. styliferus* (Table 1).

Sex ratio. The calculation of sex ratio was based on a gender comparison, presented in Table 2. The male and female percentages of *P. merguiensis* were 68% and 32%, respectively, while 35% and 65% were reported for *E. styliferus*. Therefore, the sex ratio of *P. merguiensis* was 1:0.47, and the chi-square (χ2) test showed an X^2_{count} of 9.38 and X^2_{table} of 3.84, indicating significant difference between the number of both sexes, at the 95% confidence level ($X^2_{count}>X^2_{table}$). Hence, the ratio was in an unbalanced state. However, the sex ratio for *E. styliferus* was 1:1.85, with the chi-square (χ2) test showing an X^2_{count} of 54.5 and X^2_{table} of 3.84, which denote significant differences at 95% confidence level ($X^2_{count}>X^2_{table}$).

Table 2

Sex ratio parameters of *Penaeus merguensis* and *Exopalaemon styliferus*

No	*Parameter*	*Penaeus merguensis*		*Exopalaemon styliferus*	
		Male	*Female*	*Male*	*Female*
1	Percentage (%)	68	32	35	65
2	Sex ratio	1	0.47	1	1.85
3	Chi square test (χ2)	9.38>3.84		54.5>3.84	
4	Conclusion	not balanced		not balanced	

Length-weight relationships. This study involved the length-weight relationship assessment of *P. merguiensis* and *E. styliferus* (Figures 3 to 6), which are shrimp characterized by economic value, and predominantly caught in the investigated area. This parameter is commonly used in biological fisheries research to explain changes in individual size, determine aquatic organism growth pattern, gain the physical condition index of a population, and examine habitat conditions (Gayon 2000; Saleky et al 2016). The analysis of the length-weight relationship demonstrated a typical negative allometric growth pattern in both species. This was evidenced by the b values of both *P. merguiensis* males and females, which were less than 3, indicating a slower weight gain than length.

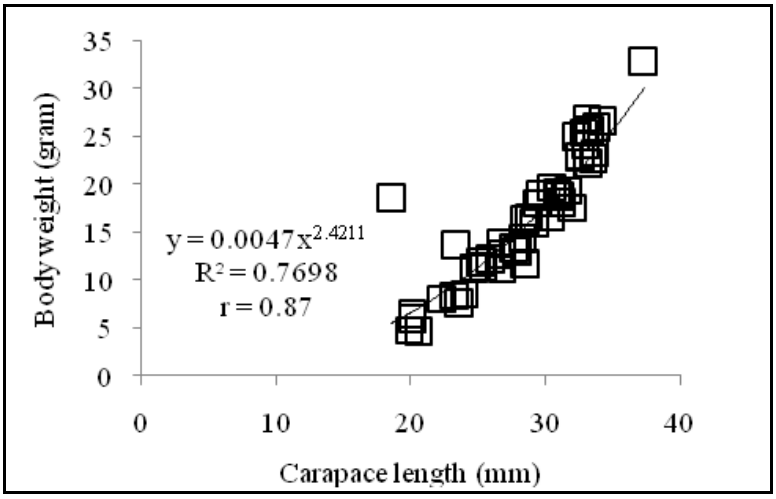

Figure 3. The length-weight relationship of *Penaeus merguensis* males from Nagan Raya district, Aceh Indonesia.

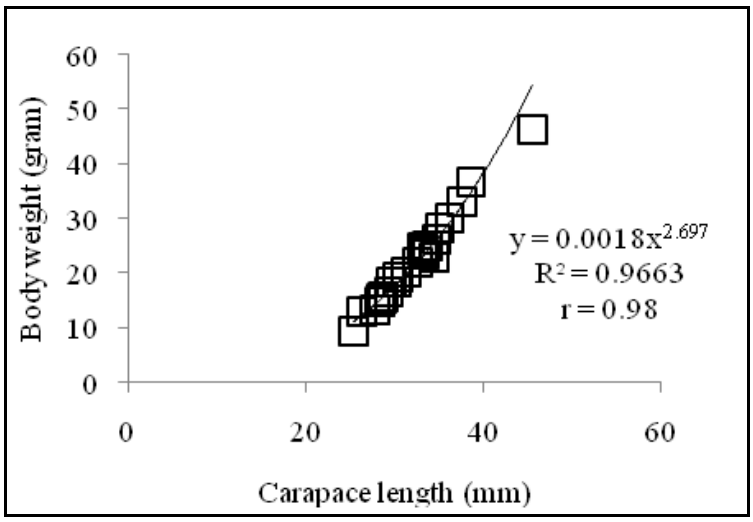

Figure 4. The length-weight relationship of *Penaeus merguensis* females from Nagan Raya district, Aceh Indonesia.

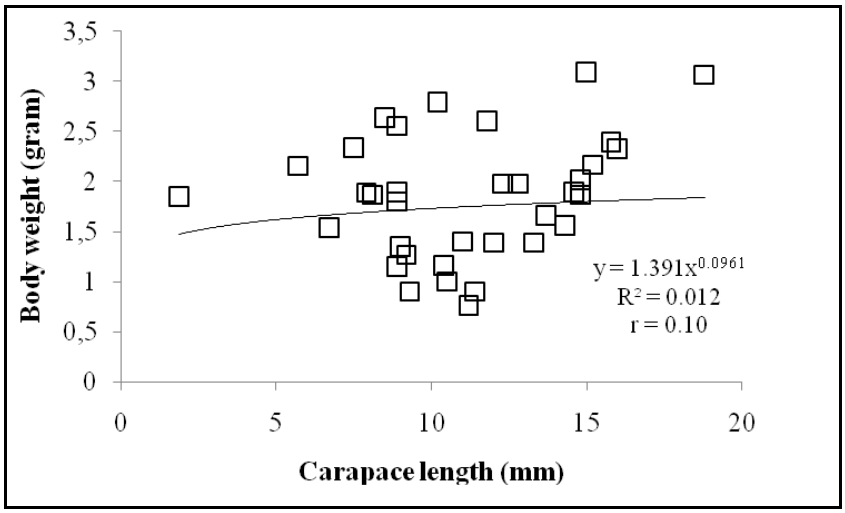

Figure 5. The length-weight relationship of *Exopalaemon styliferus* males from Nagan Raya district, Aceh Indonesia.

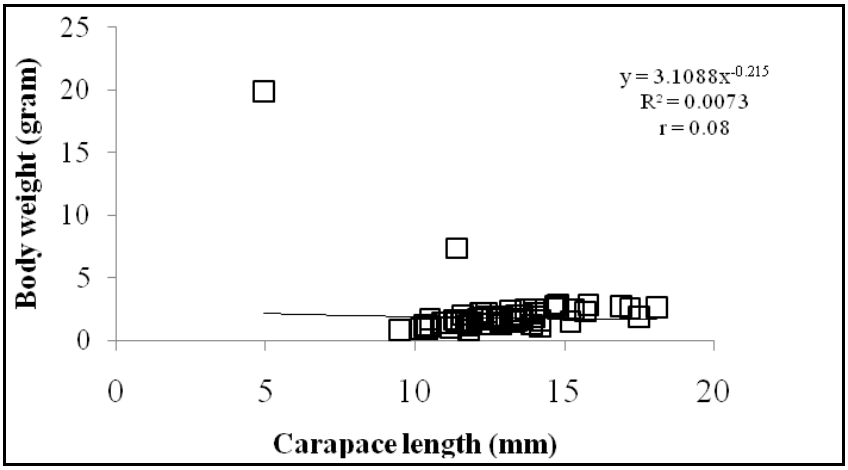

Figure 6. The length-weight relationship of *Exopalaemon styliferus* females from Nagan Raya district, Aceh Indonesia.

Gonad maturity levels. The GML of *P. merguensis* females were dominated by level V with 83%, indicating the highest extent of maturation. *E. styliferus* presented mainly the level IV (77%) of maturation. Little to no early GLM were obtained during the study (Figure 7), in accordance with the preliminary survey, stipulating the sampling period as a time for shrimp maturation in the study area. Therefore, it is recommended to avoid shrimp fishing during October, to avoid threatening the sustainability of populations and, consequently, decreasing future productivity. Conversely, better management is obtainable through the creation of fishing regulations and policies by the local government, in order to preserve shrimp populations and ensure futuristic conservation.

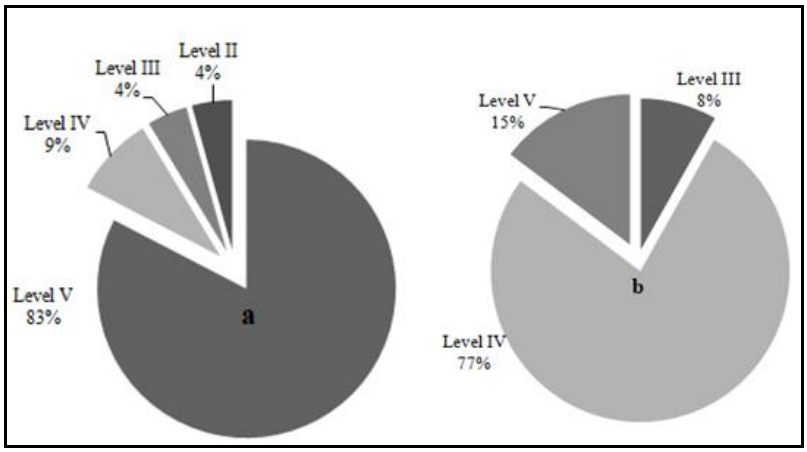

Figure 4. Gonad maturity levels of female shrimp (a) *Penaeus merguensis* and (b) *Exopalaemon styliferus* in Nagan Raya region, Aceh province, Indonesia.

There have been some similarities in the growth pattern of samples obtained from the Strait of Hormoz, Persian Gulf, Iran, Perbaungan, North Sumatera, Indonesia, northern part of the Persian Gulf, Iran, north coast of Central Java, Indonesia, Cilacap, Central Java, Indonesia and Langkat, North Sumatera, Indonesia (Siregar et al 2013; Safaie 2015; Tirtadanu & Ernawati 2016; Momeni et al 2018; Silaen & Mulya 2018). However, an isometric pattern was reported in West Aceh waters, Cilacap, Central Java, and Bagan Asahan, Tanjung Balai, Asahan, North Sumatra, Indonesia, as presented in Table 3 (Saputra et al 2013a; Putra et al 2018a; Suryanti et al 2018). The differences in b values amongst shrimps have been affiliated to several factors, including environment, sex, gonad maturity levels, and shrimp development stage (Bagenal 1978).

Table 3

Reports of the growth pattern of *Penaeus merguiensis* and *Exopalaemon styliferus* in other areas

No	*Location*	*Year*	*Growth pattern*	*Source*	*Species*
1	Strait of Hormoz, Persian Gulf, Iran	2016	Negative allometric	Momeni et al 2018	*Penaeus merguiensis*
2	Kampung Nipah waters of Perbaungan North Sumatera, Indonesia	2018	Negative allometric	Silaen & Mulya 2018	*Penaeus merguiensis*
3	The Northern part of the Persian Gulf, Iran	2015	Negative allometric	Safaie 2015	*Penaeus merguiensis*
4	West Aceh waters, Indonesia	2018	Isometric	Putra et al 2018a	*Penaeus merguiensis*
5	North Coast Of Central Java, Indonesia	2016	Negative allometric	Tirtadanu & Ernawati 2016	*Penaeus merguiensis*
6	Cilacap, Central Java, Indonesia	2013	Isometric	Saputra et al 2013a	*Penaeus merguiensis*
7	Langkat, North Sumatera, Indonesia	2013	Negative allometric	Siregar et al 2013	*Penaeus merguiensis*
8	Bagan Asahan, Tanjung balai, Asahan, North Sumatra, Indonesia	2018	Negative allometric (male), positive allometric (female)	Suryanti et al 2018	*Penaeus merguiensis*
9	Sindh, Pakistan	2014	Negative allometric	Sarwar & Kazmi 2014	*Exopalaemon styliferus*
10	Bangladesh	2000	Positive allometric	Zafar et al 2000	*Exopalaemon styliferus*

The b values of *E. styliferus* for both genders were less than 3, denoting a negative allometric growth pattern. A previous study conducted by Sarwar & Kazmi (2014) in Pakistan indicates a similar pattern, with b values of 0.928 and 0.389, for males and females, respectively. However, differences were observed in samples obtained from Bangladesh, displaying isometric growth, with a b value of 3.184 (Zafar et al 2000). Older shrimps tend to gain more weight than length, and the inverse is true for the young. Therefore, there is a faster increase in weight than length at a certain age, after which a point of maturity is reached, where the organism is not subjected to growth changes. The speed of development is in line with the amount and quality of food, as well as nutrient assimilation ability (King 1995; Effendie 2002). This is also influenced by internal factors, including sex, age, nutrition, and disease resistance, and also external factors, consisting of water quality, habitat and competition (Effendie 2002; Teikwa & Mgaya 2003; Raposo da Silva et al 2014; Carvalho et al 2015; Putra et al 2018a, 2018b; Safriani et al 2019; Putra et al 2019).

The results showed a sex ratio of 1:0.47 for *P. merguiensis*, indicating an unbalanced composition of males and females (Table 2), which is similar with the outcome for *E. styliferus,* with a ratio 1:1.85. Furthermore, this parameter serves as a benchmark in determining the expected availability of male and female broodstock for spawning. The shrimp have a sex ratio of 1:1 in areas with low exploitation, although the number of males tend to decline during spawning because of earlier mortality (Darmono 1991). This research revealed the presence of variation in the life cycle and sex ratio for both *P. merguiensis* and *E. styliferus*. Naamin (1984) reported the relatively higher amount of female shrimps compared to males during the period of fishing exploration. This condition, as well as the incidence of balance between both genders is interpreted as an ideal population, with preserved sustainability (Saputra et al 2013b). Kim (2005) affiliated the differences in sex ratio to mortality or variations in behavioral characteristics, including migration. Courtney et al (1996) described the dominance of single-sex as unusual, and further linked the occurrence to several factors, consisting of spawning season, life cycle and sampling location.

The present study demonstrated that levels IV and V are the highest maturity levels of caught shrimp *P. merguensis* and *E. styliferus*, respectively (Figure 7). However, a different outcome was reported by Saputra et al (2013a), who indicated the domination of level I (immature) gonad maturity for *P. merguensis* in Cilacap waters, which was similar to the results of Hargiyatno et al (2013) in Dolak waters, Arafura Sea. According to Motoh (1981), female shrimp with gonadal development in level III and above are classified as matured, and some determining factors include fishing time, location and season (Courtney et al 1996). In addition, it was assumed that at the time of exploration, the shrimp in the study area were in the spawning season.

To the best of our knowledge, this is the first report on the biological aspects of *P. merguensis* and *E. styliferus* in Nagan Raya District, Aceh, Indonesia. Therefore, the data presented is expected to be useful in the management and conservation of shrimp resources, and also for future domestication purposes by government, academicians and other stakeholders.

Conclusions. Based on the results of this study, the shrimps *P. merguiensis* and *E. styliferus* demonstrated a negative allometric growth pattern in Nagan raya coast, Aceh, Indonesia. In addition, the sex ratio showed an unbalanced composition of males and females in both species, while the gonadal development levels show the domination of mature shrimp.

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