Population of white shrimp (*Penaeus merguensis*) in a mangrove ecosystem, Belawan, North Sumatra, Indonesia

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Abstract. Widiani I, Barus TA, Wahyuningsih H. 2021. Population of white shrimp (*Penaeus merguensis*) in a mangrove ecosystem, Belawan, North Sumatra, Indonesia. Biodiversitas 22: 5367-5374. White shrimp (*Penaeus merguensis* De Man) is an essential fishery commodity with high economic and ecological value in the coastal area of North Sumatra. The main objective of this study was to determine the density of white shrimp in each harvesting area and to evaluate the current physicochemical factors in the Belawan mangrove ecosystem, North Sumatra, Indonesia. Four sampling sites were chosen as study areas. White shrimps were caught using *ambai* nets with a dimension of 4.5×4.5 m in width and 17 m in length placed from 4:00 - 7:00 PM. Measurement of physicochemical characteristics of sampling sites was conducted in situ and in the laboratory. Based on our study, the highest shrimp density was documented in the fishpond area (station 1) (89 ind/m²), while the lowest density was from the mangrove ecosystem area (station 2) (28 ind/m²). Based on the length class, the population of white shrimps was dominated by 16-18 mm shrimps. The gonad maturity level of the white shrimp population was classified into level 1 (The absence of thin-to-thick threads along the dorsal lining indicated the lowest gonad maturity level). White shrimps exhibited negative allometry in growth with a clumped pattern in population dispersion within the study area. The physicochemical parameters in four sampling sites, such as phosphorus content (P), and nitrate (NO₃), exceeded the standard national quality set by the Ministry of Environment and Forestry.

Keywords: Density, growth pattern, physicochemical characteristics, sex ratio, size class

INTRODUCTION

White shrimp (*Penaeus merguensis* De Man) is an important species for marine fisheries with high economic value in the western Indo-Pacific region with a distribution in the Indonesian waters (Chansela et al. 2012). The white shrimp is a supreme commercial species than vannamei shrimp (*Litopenaeus vannamei*) due to its rapid sexual maturation, fast growth, salt-tolerant, low genetic variability among individuals and resistance to diseases (Wiradana et al. 2020). In Indonesia, white shrimps are widely harvested by fishermen and residents living nearby the coast and mangrove ecosystem because of high consumer demand and economic value. The demand for white shrimp is increasing along with a rapid human population growth which poses a possible threat of overexploitation to the species in the wild (Kantun 2011).

Suman and Umar (2010) stated that shrimp resources need serious consideration with effective management efforts. Although shrimp resources are renewable, the increase in harvesting without any restrictions will lead to the depletion of the population. High intensity of harvesting in an area throughout a year may lead to unsustainable catch and depletion of juvenile and reproductively-mature shrimps in the environment.

Adult shrimps lay their eggs in offshore marine waters. After hatching, the postlarvae stage will move to estuaries and grow for several months, then migrate back to the bottom of offshore (Dall et al. 1990). *Penaeus merguensis*

postlarvae will settle in muddy estuaries covered with mangroves (Staples and Vance 1985; Vance et al. 1990). Juvenile *P. merguensis* remain in the inshore nursery area for about 3 months before migrating to coastal waters, where they gain maturity at ±6 months of age (Rothlisberg et al. 1985). Mangroves play a significant role in the growth and development of white shrimp for several reasons: 1) Mangroves provide shelter and protection from natural predators to the white shrimp population; 2) Mangroves provide a source of nutrition to the shrimp; 3) Mangroves have a hydrodynamic retention capacity or tidal waves that interact with the physical structure mangroves to confine the white shrimp movement in mangrove habitats (Nagelkerken et al. 2008).

Belawan is one of the largest white shrimp harvesting regions in North Sumatra, Indonesia. The region has a mangrove ecosystem area of about 2967.32 ha, with 76.42% modified habitat with reduced ecological provision due to land conversion into settlements, plantations, aquaculture, and tourism (Forest Office of North Sumatra Province 2011). The increasing extent of mangrove habitat destruction due to exploitation and anthropogenic pressure on the aquatic environment may threaten the sustainability of white shrimps in Belawan. Poor water quality will also impact the habitat's carrying capacity to maintain its native marine biota, especially white shrimps. Similarly, the impact of anthropogenic activities on the white shrimp population in Belawan remains unknown. In this study, the research area consisted of some harvesting sites utilized by

fishermen with different environmental hues, namely fishponds, ports, and residential areas. The establishment of human activities in the mangrove area will pose some effects to the white shrimp population. Therefore, it is necessary to gain some biological information on the shrimp density in the area following the assessment on the physicochemical factors that may affect the shrimp population. Studies on the bioecological aspect of white shrimp have been conducted in several regions in Indonesia, such as Karang Gading (Mulya and Yunasfi 2018), Langsa (Damora et al. 2019), and Bali (Siagian et al. 2020). The results of this study provide information on the current status of the white shrimp population in North Sumatra, Indonesia and establish baseline data for the sustainable management effort of white shrimp resources in the waters of the Belawan mangrove ecosystem and its surroundings.

MATERIALS AND METHODS

Study area and sampling sites

The study was conducted in the mangrove ecosystem of Belawan, Hamparan Perak Sub-district, Deli Serdang District, North Sumatra, Indonesia located at 03°47' N, 98°42' E in October 2020. The location of the four sampling

sites is presented in Figure 1. Station 1 is a fishpond area, station 2 is located mangrove ecosystem area or as a control site, station 3 is located harbor area, and station 4 is a residential area.

Shrimp collection

Sampling of white shrimps was conducted once in October 2020. Sampling of white shrimp was conducted in four sampling sites with three replication for each station. Fishing gears or *ambai* were set on the location from 4:00-7:00 PM against the sea current. The dimension of *ambai* was 17 m in length and 4.5×4.5 m in width. The mesh size of *ambai* is divided into four longitudinal sections, namely the fore section (10 mm), the middle section (15 mm), the rear section (12 mm), and the cod end (9 mm) (Figure 2). The harvesting of white shrimp was conducted after 2 hours of *ambai* installation. After the harvesting period, the shrimps were determined for their species and sex by looking at their morphological feature, namely the presence of petasma, an appendage in the first abdominal section for a male shrimp and the presence of thelycum between the fourth and fifth leg for a female shrimp. The measurement of carapace and total length used a digital caliper while each individual's body mass was determined using a digital balance with 0.01 g of accuracy.

Figure 1. Map of study area showing the sampling sites of *Penaeus merguensis* in the mangrove ecosystem of Belawan, Indonesia

The classification of gonad maturity was determined visually by examining the dorsal part on the abdomen of a shrimp (Naamin 1984). The absence of thin-to-thick threads along the dorsal lining indicated the lowest gonad maturity level (Level 1), while the presence of thin-to-thick threads with yellowish or greenish, dark green and greyish green coloration indicated the level of 2, 3, and 4 respectively. Physicochemical parameters of sampling sites were determined in situ and in the laboratory, including water temperature (°C), secchi disk depth (cm), substrate type, water salinity (%), dissolved oxygen (DO, mg/L), biochemical oxygen demand (BOD, mg/L), chemical oxygen demand (COD, mg/L), phosphorus content (P, mg/L), total dissolved solids (TDS, mg/L), total suspended solids (mg/L), pH, and nitrate content (NO₃, mg/L).

Data analysis

The density of white shrimp was calculated using the following formula:

$$\text{Density } (D) = \frac{n}{A}$$

Where, D is the density of white shrimp (ind/m²), n is the number of individuals, and A is the plot size of observation (20.25 m²). Determination of total length or size class was conducted by grouping individuals with the same length in their class range based on Sturge's rule (Walpole 1992) using the following formula:

$$\text{Size class } (K) = 1 + 3.3 \log N$$

Where, K is the number of size class generated based on data and N is the number of data. Sex ratio of male and female white shrimp was tested using the following formula:

$$X = M : F$$

Where, X is the sex ratio, M is the number of male individuals, and F is the number of female individuals. Growth pattern of white shrimp was determined from the relationship between carapace length and body mass generated from a linear regression analysis (Sparre and Venema 1999) using the following formula:

$$W = aL^b \text{ or } \ln W = \ln a + b \ln L$$

Where, W is the body mass (g), L is the carapace length (cm), a and b is the constant from regression analysis. Distribution or spatial pattern of white shrimp in an area was determined using morisita index using the following formula:

$$I_0 = n \frac{\sum_1^n x_i(x_i - 1)}{\sum_1^n x_i[(\sum_1^n x_i) - 1]}$$

Where, I_0 is the morisita index, n is the number of observation plots (1, 2, ..., n), N_i is the total number of

individuals in total plots, and $\sum X_i^2$ is the quadratic number of individuals in total plots.

RESULTS AND DISCUSSION

Density of white shrimp

Density of harvested white shrimp in the area ranged between 28 to 89 ind/m² (Figure 3). The highest density was obtained in the fishpond area, which is an area near the community fishpond. A higher density of white shrimp in the fishpond area (station 1) was due to the abundant organic wastes originating from the fishpond, which also pointed out that the aquaculture activity did not influence the life cycle of white shrimp. The result was supported by the nitrate content in the area (0.023 mg/L) and low BOD (0.5 mg/L). Meanwhile, the mangrove ecosystem area (station 2) was documented for its low density of white shrimps. The result may be due to the fact that the vegetation composition in the mangrove site was still dominated by seedlings, thus providing suboptimal nutrition to the shrimps. Inadequate food supply may initiate stress to white shrimp leading to cannibalism (Hidayat et al. 2013). Safaie (2015) stated that adverse conditions, including food availability, competition and predation, were factors that affected the survival of white shrimps. A complete life cycle must be experienced by each individual of white shrimps to sustain their population in the coastal environment (Mosha and Gallardo 2013).

Size class of white shrimp

Harvested white shrimp ranged in size, with 16-18 mm accounting for 30.95% of the total population, while the lowest number of population was in between 31-33 mm (2.33%) (Table 1). The difference of carapace size in a white shrimp population may indicate the food availability in their habitat. Tirtadanu and Anthony (2018) reported that the size of white shrimps in Kaimana, West Papua were 25-49 mm, which was considered small for its population. Other studies by Suradi et al. (2017) also found small individuals of white shrimp in the northern coast of West Java and the coast of Penyu Bay, respectively. Another indication of the size dominance was the harvesting preference on certain sizes by fishermen, which left the smaller shrimps in the environment (Suman and Umar 2010).

Figure 2. Ambai

Table 1. Size class based on carapace length of white shrimp in all stations

Size class (mm)	Frequency (%)
7-9	1.09
10-12	8.55
13-15	25.35
16-18	30.95
19-21	16.95
22-24	7.93
25-27	2.95
28-30	3.89
31-33	2.33

Gonad maturity level of white shrimp

Observation on the gonadal maturity of each shrimp in Belawan resulted in the highest proportion of level 1, accounting for 59.97% of the total population, while the lowest population was in level 4 for 1.4% (Figure 4). The results then emphasized that the highest proportion of shrimp in the study area was still immature and may be dominant in lesser size. The results also demonstrated that the estuary area of Belawan mangrove ecosystem might not be suitable for the population of mature white shrimps. Siagian et al. (2020) stated that the estuary area was utilized as a nursery and feeding ground for shrimp. Shrimp larvae will migrate to rearing areas in coastal waters close to the estuary until reaching sexual maturity. Our finding was in accordance with the statement by Rothlisberg et al. (1985), who reported that juvenile *P. merguensis* remain in the inshore nursery area for about 3 months before migrating to coastal waters where they gain maturity at ± 6 months of age. Therefore, the size of shrimp found in the estuary was dominated by juvenile shrimps.

Sex ratio

Sex ratio of white shrimp in the mangrove ecosystem of Belawan was imbalanced by the dominance of female shrimps (67.24%) to male shrimps (32.76%). Based on the observation in four stations, the higher number of female shrimp indicated that in some point, the nursery of juveniles was still appropriate, although an ideal population may have consisted of an almost equal number of males and females for their sustainability. Uddin et al. (2015) stated that the factors affecting the dominant individuals of female shrimp in an area were alteration of harvesting site, fishing pattern and breeding season of both sexes. Our results were also similar to those reported by Uddin et al (2016) in West Bengal, India, Silaen and Mulya (2018) in Perbaungan, Indonesia, Marini et al (2017) in Kupang, Indonesia, Mane et al. (2018) in Mumbai, India, Pulau Sayak waters (Ikhwanuddin et al 2019).

Growth pattern of white shrimp

Carapace size may be used as an indicator of a functional relationship between size and body mass of penaeids. Carapace size is generally considered an independent variable in morphometric studies because it reflects the physiological changes throughout the life history of shrimp (Safaie 2015). The growth pattern of the white shrimp population in Belawan showed a negative

allometry growth ($b < 3$). The highest b coefficient was obtained from the residential area (2.15), while the lowest was obtained from the fishpond area (1.28). The negative allometry indicated that the carapace growth was faster than the body mass. Possible factors affecting the allometry growth including the physiological condition and environmental factors such as pH, salinity, seasonal variation, sex ratio, temperature, geographical locations and sampling technique (Anand et al 2014; Udoinyang et al 2016; Putra et al 2018). Other studies also reported the negative allometry growth of white shrimps in Egypt (El-ganainy 2012), Persian Gulf (Momeni et al. 2018), West Java (Saputra et al. 2019). The relationship between carapace length and body mass of white shrimp is presented in Figure 5.

Distribution or spatial pattern of white shrimp

Based on the results, the distribution pattern of white shrimp in the mangrove ecosystem of Belawan mangrove was classified into a clumped distribution pattern ($I0: 1.14$). The clumped distribution is a pattern formed by each individual that settles in an area with similar resource acquisition such as nutrient sources and other physicochemical factors suitable to support the lives of the individuals. White shrimps were generally harvested in shallow waters and in areas where seawater and freshwater are mixed because in these areas, there are many sources of nutrients in the form of detritus and zooplankton for white shrimp. Siagian et al. (2020) also reported that the crustaceans living in the coastal ecosystem were generally clumped in the pattern due to the synergy of sexual maturity.

Figure 3. Density of white shrimp in each area **Figure 4.** Percentage of white shrimp population based on gonad maturity level

Physicochemical characteristics of waters in Belawan

Temperature is one of the limiting factors in waters and plays an important role in the metabolism of white shrimp. The measurement results show that the temperature range of the four areas in Belawan mangrove waters is not significantly within their tolerance limit, namely the range of 30-30.5°C. This temperature range supports the life of white shrimp both in terms of growth and survival (Staples and Heales 1991). Furthermore, Tung et al. (2020) stated that white shrimps preferred temperature between 27-35°C, indicating that tropical *P. merguensis* was more tolerant to higher temperatures than their subtropical counterparts. In general aquatic organisms in warm climates show more adaptive features to heat stress compared with animals that originate in temperate areas (Carabaño et al. 2019).

The clarity of the water at each station, as indicated from the secchi disk depth, was between 53.1-74.3 cm. The lowest value was found at the fishpond area (station 1) (53.1 cm), while the highest value at a residential area (station 4) was 74.3 cm. This condition illustrated that the waters of the Belawan mangrove ecosystem were relatively cloudy and strongly supported the life of white shrimp. Mulya and Yunasfi (2018) stated that relatively turbid water was more habitable by shrimps.

Within the Belawan mangrove ecosystem, the salinity values ranged between 1.4 and 1.5‰. These results indicated the waters were within the salinity tolerance range for supporting white shrimp (Staples and Heales 1991). High salinity may decrease the growth rate of white shrimp, and a brackish estuary facilitates growth.

Figure 5. Growth pattern of white shrimp in each area. A. Fishpond area (station 1), B. Mangrove ecosystem area (station 2), C. Harbor area (station 3), D. Residential area (station 4)

Table 2. Physicochemical characteristics of water in each station

Parameter	Area (station)			
	Fishpond (1)	Mangrove (2)	Harbor (3)	Residential (4)
Physical				
Water temperature (°C)	30	30.5	30	30
Secchi disk depth (cm)	53.1	66.5	65.5	74.3
Substrate type	Sand, silt, clay	Sand, silt, clay	Sand, silt, clay	Sand, silt, clay
Chemical				
Water salinity (‰)	1.4	1.5	1.5	1.4
Dissolved oxygen (mg/L)	7.6	9.3	7.1	9.6
Biochemical oxygen demand (mg/L)	0.5	0.7	0.7	1.3
Chemical oxygen demand (mg/L)	2587	2956	2956	2217
Phosphorus (mg/L)	0.044	0.071	0.081	0.089
Total dissolved solids (mg/L)	19,861	24,084	19,835	24,323
Total suspended solids (mg/L)	64	63	74	71
pH	6.9	7.1	6.7	6.9
Nitrate (mg/L)	0.023	0.025	0.020	0.023

Dissolved oxygen (DO) is a major component of the metabolism of aquatic biota, including white shrimp. The results showed that the highest DO content was at a residential area (station 4) with 9.6 mg/L while the lowest DO content was at the harbor area (station 3) with 7.1 mg/L. The low level of DO at the harbor area was due to its location adjacent to the port, where shipping traffic caused water pollution, which can interfere with phytoplankton productivity leading to low DO levels. However, the DO level at the harbor area was not below the quality standard for marine biota as regulated by the Ministry of the Environment, which was >5 mg/L. Water temperature can also affect DO levels. High temperatures in aquatic habitats can cause an increase in metabolism and respiration, which will lead to an increase in oxygen consumption (Mulya and Yunasfi 2018). According to Radiarta and Erlania (2015), dissolved oxygen in saturation conditions is affected by water temperature, salinity, and altitude. When water temperature, salinity, and altitude are at a higher level, the solubility of oxygen will tend to decrease. Dissolved oxygen levels fluctuate daily and seasonally depending on the mixing and turbulence of water masses, photosynthetic activity, respiration, and effluent entering the water bodies.

In the four research areas, the pH value of water was found in the range of 6.9-7.1. The overall results of this measurement show that the pH value of the water at each area was within the tolerance range to support the life of white shrimp (Silaen and Mulya 2018). The pH value of water that is too low can cause the CaCO_3 content in the shrimp shell to decrease because it was absorbed internally. Under this condition, oxygen consumption will increase, body permeability will decrease and shrimp gills will be damaged. Silaen and Mulya (2018) suggested that a good pH for crustaceans in mangrove habitats found at Belawan was 5.6-7.8, a pH range that supported the growth of jering shrimp.

The biochemical oxygen demand (BOD5) value indicated the pollutant load in the waters due to human activities such as waste disposal from residential areas and surrounding industries. Based on the measurement results, it can be seen that the highest BOD5 value was at a residential area (station 4) with 1.3 mg/L while the lowest BOD5 value was at the fishpond area (station 1), which was 0.5 mg/L. The difference in the BOD5 value at each area was caused by the difference in the number of organic compounds at each area which was known to reduce DO levels because oxygen was used by microorganisms in the decomposition of organic matter. The BOD5 from the four areas still met the qualification of water quality standard set by the Ministry of the Environment, which was 20 mg/L.

Based on the measurement results, it can be seen that the highest phosphate content was obtained at a residential area (station 4) with 0.089 mg/L while the lowest was at the fishpond area (station 1) with 0.044 mg/L. The high phosphate content at the residential area was influenced by the presence of waste disposal from the activities of the surrounding community. Phosphate derived from sediment was infiltrated into groundwater and entered water bodies. In addition, phosphate may originate from the atmosphere and rainfall, thus entering the aquatic system. The

phosphate content in all stations exceeded the quality standard for marine biota regulated by the Ministry of the Environment, which was 0.015 mg/L. Phosphate is a nutrient compound that is important in determining the primary productivity of waters which also determines the DO levels in waters which will affect the presence of white shrimp in an area.

Based on the substrate type, it was found that the Belawan mangrove ecosystem consisted of sand, silt, and clay. The highest sand fraction was obtained at a residential area (station 4) (78.75%), while the lowest was obtained at the fishpond area (station 1) (49.03%). The highest silt fraction was at the fishpond area (46.12%), while the lowest was at the harbor area (station 3) (18.89%). The highest clay fraction was obtained at the fishpond area (4.85%), while the lowest was at the harbor area (2.30%). According to Nybakken (1992), most estuary waters were dominated by soft and muddy substrates. These substrates are derived from sediments carried to the estuary, both by seawater and freshwater. Rivers as a source of freshwater bind the silt particles in the form of suspension. When these suspended particles mix with seawater that carries sand particles in the estuary, the ions coming from the seawater along with the sand will cause the two particles to agglomerate to form heavier and larger particles, then settle and form a typical mud bottom.

Chemical oxygen demand (COD) was the amount of oxygen needed in the chemical oxidation process. By measuring the COD, it describes the amount of oxygen needed for the total oxidation process of organic compounds. Based on the results, it can be seen that the highest COD was recorded at the mangrove ecosystem area (station 2) and harbor area (station 3), which was 2956 mg/L while the lowest was at a residential area (station 4), which was 2217 mg/L. COD was not included as parameters of seawater quality standards required by the Ministry of the Environment for marine biota. This was caused by the technical issue in measuring COD in seawater due to the interference or disturbance of high chloride (Cl^-) in seawater to the analytical reaction.

Based on the measurement results, the highest TDS value was found at a residential area (station 4), which was 24323 mg/L and the lowest TDS value was at the harbor area (station 3), which was 19835 mg/L. According to Sastrawijaya (2000), total dissolved solids (TDS) in water greatly affect water quality. The value of dissolved solids in water also affects the penetration of sunlight into the waters. If the TDS value is high, sunlight penetration will decrease, which ultimately reduces the level of water productivity. Similar to COD, the TDS value was also not included as parameters of seawater quality standards required by the Ministry of the Environment for marine biota.

Based on the measurement results, the highest TSS value was found at the harbor area (station 3), which was 74 mg/L and the lowest TSS value was at the mangrove ecosystem area (station 2), which was 63 mg/L. The high and low TSS in waters is strongly influenced by tides and pollutant discharge activities into the waters. According to Mumin (2004), waters with high turbidity and low

brightness will cause light penetration to be hampered so that the productivity of aquatic organisms also decreases. According to the State Minister for the Environment No. 51 of 2004, it can be said that the TSS value at the four research stations is still below the specified threshold, thus it can be said that the TSS value in the Belawan mangrove ecosystem is not harmful to marine life including shrimp.

Nitrogen is a part of the nutrient elements needed in the photosynthesis process, which are absorbed in the form of nitrate, then converted into protein and used as a food source for estuary aquatic organisms. The results of nitrate measurements at the four stations showed that the highest nitrate level was found at the mangrove ecosystem area (station 2), namely 0.025 mg/L and the lowest value was at the harbor area (station 3), namely 0.020 mg/L. The high level of nitrate at the mangrove ecosystem area is influenced by the high abundance of mangroves. Litter production at the time of sampling and the high abundance of mangroves affect the nitrate and phosphate content, where NO_3 and PO_4 are mostly utilized by mangroves for their growth. The nitrate content at the four stations violated the quality standard for a suitable nitrate concentration for marine biota set by the Ministry of the Environment, which was 0.008 mg/L.

Based on the results, it can be concluded that the physicochemical factors of Belawan waters still support the growth and development of white shrimp. However, the nitrate and phosphate levels in Belawan waters have exceeded the water quality standards set by the Ministry of the Environment. This indicates that Belawan waters have been polluted by various anthropogenic activities, although the output still poses insignificant impacts on the density of white shrimp.

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