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Density distribution of *Penaeus merguensis* De Man, 1888 based on habitat in the waters of Merauke District, South Papua Province, Indonesia

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Abstract. *Lantang B, Najamuddin, Nelwan AFP, Samawi MF. 2023. Density distribution of* Penaeus merguensis *De Man, 1888 based on habitat in the waters of Merauke District, South Papua Province, Indonesia. Biodiversitas 24: 4427-4437.* The waters of Merauke District, located in the Arafura Sea area, have relatively high penaeid resources but prawn fishing productivity is the lowest of 11th other Indonesian fisheries management areas. The optimization of the fishery resource utilization remains poor after the moratorium on fishing vessel licensing in 2014, which is only 11%. Hence, a study is needed to determine the resources' distribution, abundance, and sustainability. This research aims to analyze the density distribution of banana prawn (*Penaeus merguensis* De Man, 1888) based on the habitat type, each location separated by ~4-5 kilometers within the coastal ecosystem waters of Merauke District. The research was carried out from March to August 2022. Data were collected within each habitat: the catch, prawn fishing equipment, and oceanographic parameters, and then analyses were undertaken using statistical tests. The results showed that the highest density of banana prawn was obtained in shallow waters adjacent to the mangrove habitat at Bokem (32.68 kg/km^2) and Yobar (20.27 kg/km^2). In waters adjacent to the sandy beach at Payum (17.98 kg/km^2), the density was higher than within the estuarine habitat of Maro River (14.60 kg/km^2) and adjacent to the sandy beach at Lampu Satu (14.39 kg/km^2). This is due to the influx of fresh water in estuarial habitat, sandy beaches in Lampu Satu and Payum, and mangroves in Yobar, resulting in prawn emigration to areas with higher salinity in Bokem mangroves. It is also thought to be associated with increasing turbidity with a similar pattern in salinity and affecting the density of banana prawns.

Keywords: Banana prawn, density distribution, habitat type, oceanographic parameters, *Penaeus merguensis*

INTRODUCTION

The waters of Merauke District have potential for penaeid resources, including *Penaeus merguensis* De Man, 1888 (Hargiyatno et al. 2015; Lantang et al. 2020). These waters are part of the Arafura Sea, and the southern part is directly adjacent to the territory of Papua New Guinea (Sari 2020). These waters are a fishing ground for prawns and fish with high economic value for local fishermen (Lantang et al. 2020). The prawn fishery potential at Merauke District is located from the northern region of Kolepom Island (Yos Sudarso Island, Dolak Island) to the southern at Torasi River (Hargiyatno et al. 2015; Muawanah et al. 2021; Tirtadanu et al. 2022). The characteristics of these waters are shallow, turbid, and gentle waters. Hence, when there is a tide, the seawater covers the coastal area up to approximately two kilometers away and dries again at low tide (Lantang et al. 2020). In addition, there are large river estuaries and extensive mangrove forests that store a diversity of species with high prawn density (Atkinson et al. 2016; Bosma et al. 2016; Carugati et al. 2018; Damora et al. 2019; Vance and Rothlisberg 2020; Muawanah et al. 2021; Ahmed et al. 2023).

Moreover, the Sustainable Development Goals (SDGs) are developed to accommodate several challenges regarding rapid population increase that will bring social, economic, health, environmental, and other impacts, especially for low- and lower-middle-income countries (UN Department of Economic and Social Affairs - Population Division 2021; Hansen et al. 2023). Therefore, the potential of prawn resources should be utilized to meet animal protein and human food needs (Bardera et al. 2020). The potential of these resources is expected to reduce poverty rates, increase community income, especially among fishermen, and increase food security in Indonesia, especially in Merauke District (Bappenas 2019). For this reason, the banana prawns must be optimized to achieve the above goals using a study resource per unit area in the density analysis based on different habitat types in coastal ecosystems (Hargiyatno et al. 2015; Vance and Rothlisberg 2020; Tirtadanu et al. 2022).

This research is part of a study of banana prawn (*Penaeus merguensis* De Man, 1888) fishing potential areas based on five distinct habitat types within a coastal ecosystem. The study focused on determining which habitats have the highest densities as a reference for the best prawn fishing areas (Schooler et al. 2017; Vance and

Rothlisberg 2020; Muawanah et al. 2021; Widiani et al. 2021). Several previous studies have explained the existence of banana prawns based on their respective habitats but have not thoroughly compared the relationship of some habitats with the influence of oceanographic parameters, such as mangrove areas (Damora et al. 2019; Widiani et al. 2021), estuaries and bays (Xu and Sun 2013), and coastal waters (Hargiyatno et al. 2015; Mane et al. 2018; Lantang et al. 2020; Sari 2020). Those various areas are not yet available to answer which habitats are more abundant in density, have optimal environmental parameters, and support the existence of banana prawns as a reference for prawn fishing areas (Muawanah et al. 2021). Mangrove forests are essential for banana prawns, but relatively few studies compare caught from different habitats in the same region (Vance and Rothlisberg 2020). This study examines oceanographic parameters, namely the percentage of mud and sand that have never been studied before in the waters of Merauke District. In addition, after the moratorium on fishing vessel licensing in 2014, there has been no study on the density of banana prawns in southern Merauke (Tirtadanu et al. 2022). For this reason, this study aims to analyze the distribution of banana prawn density based on habitat type and provide input in improving the optimal utilization and management of banana prawn resources in the waters of Merauke District.

MATERIALS AND METHODS

Research location

This research was carried out in the waters of Merauke District, South Papua Province, Indonesia, from March to August 2022 (Figure 1). Meanwhile, the analysis of field samples was carried out in the laboratory of the Department of Aquatic Resources Management, Faculty of Agriculture, Musamus University, Merauke, Indonesia.

Procedures

Habitats type determination procedure

Determining habitat type was done by dividing the research areas based on their respective characteristics: the estuarial habitat is the estuary of the Maro River, the path of exit-entry of ships to the port of Merauke. The sandy beach habitats in the Lampu Satu area are not overgrown with mangroves and are a residential area and a berth for fishing boats. Next, the mangrove habitat is situated in a mangrove area in the Yobar region. The sandy beach habitats, a populated village, is situated on Payum Beach. Finally, the mangrove habitat is located in the Bokem area, which is flooded by seawater at high tide.

Oceanographic parameter data retrieval procedure

The water temperature data was collected using a measuring instrument, namely a digital thermometer, water salinity with refractometers, water pH with digital pH meters, water turbidity with digital turbidity meters, and sediment with a hand core sediment sampler (Dias et al. 2018; Equbal et al. 2018; Wan et al. 2020). Water temperature and pH measurements are conducted by dipping the measuring instrument into the water surface and recording the indicated values (Sari 2020). Water turbidity and salinity are carried out by taking water samples and measuring their values, while in sediments, by taking the water bottom substrates (Dalu et al. 2017). The next stage is to dry the sample, sieve it in the laboratory, and calculate the substrate percentage (Nguyen et al. 2019). The water level on the prawn fishing equipment varies greatly from 0.5-1.7 meters, so the depth of data collection also varies (Lantang et al. 2020; Sari 2020). Data collection for all habitats is conducted ten times every month, with details of each habitat two times on the five observed habitats.

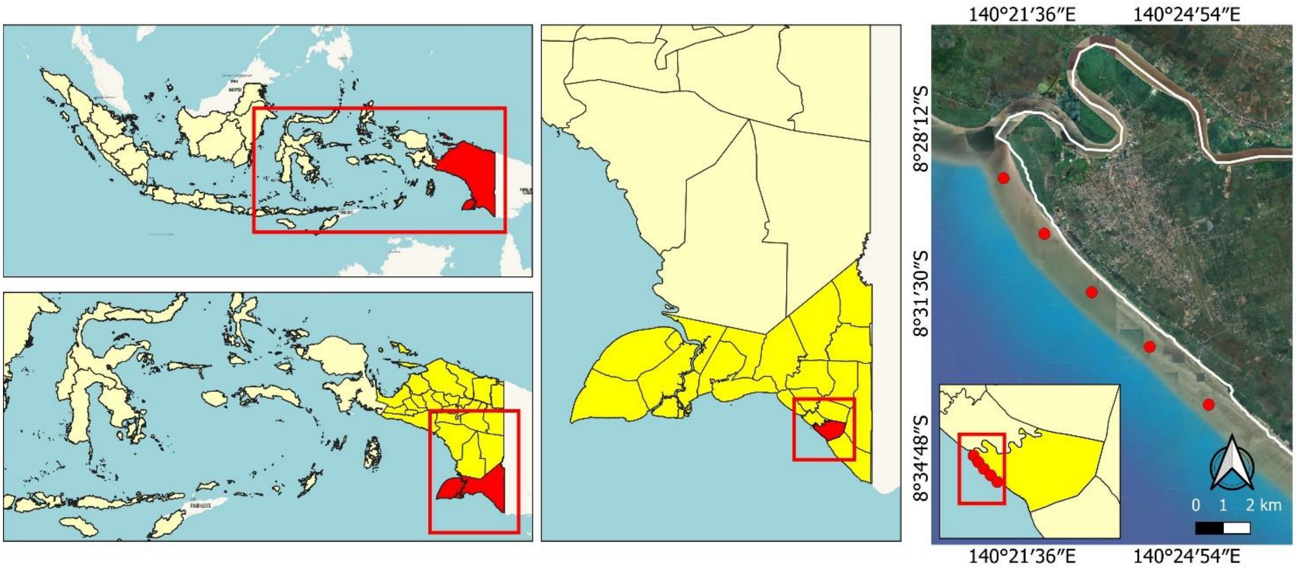

Figure 1. The research locations based on habitats in Merauke District, South Papua Province, Indonesia

Table 1. Number according to habitat, coordinates of each habitat in Merauke District, South Papua Province, Indonesia

Habitats	Coordinates
The estuarial habitat of the Maro River	8°29’58.3"S 140°21’50.8" E
Sandy Beach habitats in Lampu Satu	8°30’40.9"S 140°22’32.0" E
Mangrove habitats on Yobar	8°31’52.6"S 140°23’51.1" E
Sandy Beach habitats in Payum	8°32’51.6"S 140°25’05.4" E
Mangrove habitats on Bokem	8°33’56.4"S 140°25’57.3" E

Banana prawn density

Data were collected within each habitat: the caught, prawn fishing equipment, and oceanographic parameters (Tirtadanu et al. 2022). This study used beach seine, a fishing gear type, to catch banana prawns (Sari 2020). This fishing gear has been modified according to the specific prawns fishing in the waters of Merauke District due to differences in the characteristics of the prawn fishing area. The net pulling is carried out in the direction of the coastline caused by currents and the sloping bottom of the waters using human power on both sides (wings). The beach seine details are wings with a length of 18 meters, a body length of 3 meters, and a cod end (modification of the body) with a length of 2 meters (Sari 2020). The length of the head rope and ground ropes is 50 meters; the length is equal because this fishing gear is operated in shallow water, so the prawn cannot escape by swimming from the top (head rope and bottom net (ground rope). There are floats, sinkers, and wraps with a length of 2 meters and a mesh size of 1 inch, the same in all netting parts. The operation of prawn fishing equipment ranges from 3 to 5 hours (Sari 2020), depending on the operating area (mud or sand), current speed, and human power.

Data analysis

Banana prawn density and substrate analysis

For the calculation of the density of banana prawns by Sparre and Venema (1998) use the following formula:

$$D = \frac{1}{a} x \frac{c}{f}$$

The following formula was used to calculate the area of the net sweep:

a = v x t x hr x X2 x 1.852 x 0.001

Where: A is net sweep area (km^2), v is average speed net pulling time (knots), t is net withdrawal duration, hr is head rope length (50 meters), X2 is a fraction of head rope length, 1.852 is a conversion mile to kilometers, 0.001 is a conversion from meters to kilometers. In the Southeast Asian region, the value of X2 ranges from 0.4 to 0.66. While, D is stock density, c is a caught (kg per hour), and f is escapement factors of 0.5.

Substrate analysis

The equation used to obtain the percentage weight of sediment, according to Poerbandono and Djunasjah (2005) and Irham et al. (2018), is as follows:

$$\text{Percentage weight } = \frac{\text{Weight fraction i}}{\text{Total weight of the sample}} x \; 100\,\%$$

Multiple regression

Field data are grouped into two variables: Y as a catch and X as an oceanographic parameter. Where X1 is water temperature (ºC), X2 is water salinity (psu), X3 is water pH, X4 is water turbidity (NTU), X5 is a sand substrate (%), and X6 is mud substrate (%). Furthermore, the data were processed using Statistical Product and Service Solutions (SPSS) software version 21 with a statistical approach using regression coefficient analysis (t-test).

RESULTS AND DISCUSSION

Description based on carapace length

According to the data on Table 2, the lowest carapace length was found in areas adjacent to estuarial habitats, with a length of 23.74 mmCL, and the highest was found in mangrove habitats in Bokem, with a length of 53.28 mmCL. In the average carapace, four habitats studied were found with life stages as sub-adult, and only in the mangrove habitat in Bokem found adult prawns.

Oceanographic parameters

The results of statistical tests show that oceanographic parameters affecting banana prawns' presence are salinity and water turbidity. At the correlation value of 0.924, the relationship between the two variables is powerful. The R square, which is 0.854, shows that variable X affects 85.4% of variable Y, while other factors cause the rest. F-test results obtained an F cal. signification rate of 0.000 or below 0.05 with very noticeable results; thus, the density of banana prawn can be predicted using a regression model (Table 3).

Table 2. Carapace length measurements of the prawns in each habitat in Merauke District, South Papua Province, Indonesia

Habitats	Carapace length (mmCL)	Average carapace length (mmCL)	Life stages correspond to the average carapace length
The estuary of the Maro River	23.74 - 44.81	36.37	Sub-adult (Hargiyatno et al. 2015)
Sandy beach at Lampu Satu	25.67 - 48.69	37.96	Sub-adult (Hargiyatno et al. 2015)
Mangroves at Yobar	25.45 - 48.27	37.36	Sub-adult (Hargiyatno et al. 2015)
Sandy beach at Payum	24.67 - 48.93	37.38	Sub-adult (Hargiyatno et al. 2015)
Mangroves at Bokem	29.75 - 53.28	39.59	Adult (Hargiyatno et al. 2015)

In oceanographic parameters, water temperature in estuary habitats increases from May to July above 30 ºC, and decreases again in August. In the sandy beach habitat in Lampu Satu, the temperature increase occurs in May and June; in the mangrove habitat in Yobar and mangroves in Bokem, the temperature increase only occurs in April. In comparison, the sandy beach habitat in Payum occurs in March and April. In water salinity, it was found low in several habitats such as estuaries (19.33 ppt-21ppt), sandy beaches in Lampu Satu (18.5ppt-23 ppt), mangroves in Yobar 18.5 ppt-26 ppt), and sandy beaches in Payum (14 ppt-23ppt) and began to increase in mangrove habitats in Bokem (23.33 ppt-28 ppt). In water pH, low pH (< 7) was found in three habitats, namely estuary habitat (May and June), sandy beach in Lampu Satu (July and August), and Payum (March and April). There was an increase in pH (>7) in estuaries (July and August) and sandy beaches in Lampu Satu (May and June). In addition, in mangrove habitat in Yobar, Bokem, and sandy beaches in Payum (May to August) . Water turbidity fluctuated monthly in all habitats, with the highest turbidity obtained in the mangrove habitat in Bokem in May and the lowest in estuarial in May. Sand and mud substrates also fluctuate monthly, with the highest percentage of sand in the sandy beach habitat at Payum in March. The highest percentage of mud was obtained in the sandy coastal habitat at Payum in August (Table 4).

Table 3. Statistical test results

Variable	T-test	Anova (F-test)	Correlation value (R)	R square
Water temperature (ºC)	0.69 > 0.05	sig. 0.000 (<0.05)	0.924	0.854
Water salinity (psu)	0.04 < 0.05			
Water pH	0.06 > 0.05			
Water turbidity (NTU)	0.00 < 0.05			
Sand substrate (%)	0.16 > 0.05			
Mud substrate (%)	0.13 > 0.05			

Table 4. Oceanographic parameters based on habitat type in Merauke District, South Papua Province, Indonesia

Habitats	Data retrieval time	Temperature (ºC)	Salinity (psu)	pH	Turbidity (NTU)	Sand (%)	Mud (%)
The estuarial at the Maro River	*March	-	-	-	-	-	-
	*April	-	-	-	-	-	-
	May	30.01	21	6.9	256	95.6	4.4
	June	30.07	21	6.93	423	93.55	6.45
	July	30.1	19.33	7.05	486	87.25	12.74
	August	29.91	20.5	7.01	582	86.82	13.18
Sandy beach at Lampu Satu	*March	-	-	-	-	-	-
	*April	-	-	-	-	-	-
	May	30.05	23	7.05	476	89.41	10.59
	June	31.24	20	7.02	378	94.86	5.14
	July	29.62	18.5	6.99	528.5	87.67	12.33
	August	29.82	19	6.85	536	91.28	8.71
Mangrove in Yobar	March	29.14	26	7.21	687	81.33	18.67
	April	31.35	24	7.13	467	92.04	7.96
	May	29.84	20	7.23	678	83.94	16.06
	June	29.87	20	7.33	677	82.38	17.62
	July	28.56	18.5	7.27	767	79.32	20.67
	August	29.54	24	7.33	791	79.03	20.97
Sandy beach in Payum	March	31.35	14	6.93	302	99.59	0.41
	April	30.03	23	6.8	421	95.06	4.94
	May	29.82	20	7.1	684	83.89	16.11
	June	29.13	19	7.26	683	84.05	15.95
	July	29.92	19	7.09	519	84.2	15.8
	August	28.48	19.5	7.33	883	72.04	27.96
Mangrove in Bokem	*March	-	-	-	-	-	-
	April	30.51	24	7.11	437	91.29	8.71
	May	28.75	28	7.4	1074	76.61	23.39
	June	28.23	27	7.1	956	74.47	25.53
	July	28.67	27	7.41	954	73.39	26.61
	August	28.26	23.33	7.27	926	74.01	25.96

Note: *Fishermen do not engage in prawn fishing

Table 5. Average oceanographic parameters and density of banana prawn based on habitat type in Merauke District, South Papua Province, Indonesia

Habitat	Water temp. (°C)	Water salinity (psu)	Water pH	Water turbidity (NTU)	Sand (%)	Mud (%)	The density of banana prawn (kg/km^2)
The estuary of Maro River	30.02	20.46	6.97	436.89	90.81	9.19	14.61
Sandy beach at Lampu Satu	30.18	20.13	6.98	479.79	90.81	9.19	14.39
Mangroves at Yobar	29.72	22.08	7.25	677.92	83.01	16.99	20.27
Sandy beach at Payum	29.79	19.08	7.09	582.08	86.47	13.53	17.98
Mangroves at Bokem	28.88	25.87	7.26	869.53	77.95	22.04	32.68

Density

In all studied habitats, the highest density of banana prawns was obtained in shallow waters adjacent to mangrove habitats in Bokem Beach at 32.68 kg/km^2 and mangrove in Yobar at 20.27 kg/km^2. In the waters adjacent to the sandy beach in Payum, which is 17.98 kg/km^2, the density at the estuary of the Maro River is 14.61 kg/km^2 and the lowest at the sandy beach in Lampu Satu at 14.39 kg/km^2. The water salinity was low in areas adjacent to estuarial habitats, sandy beaches at Lampu Satu and Payum. The mangrove habitat in Yobar began to increase compared to the previous two habitats, and the highest was cultivated in the mangrove habitat in Bokem. Meanwhile, there has been an increase in water turbidity ranging from estuarial habitats, sandy beaches in Lampu Satu, and Payum to mangroves in Yobar. The highest turbidity was found in mangrove habitats in Bokem (Table 5). An increase in salinity and turbidity was followed by an increase in banana prawn density.

Discussion

Specimen description

Penaeus merguensis De Man, 1888, also known as banana prawn (FAO, Australia, Iran), white prawn (Hong Kong), white banana prawn (Australian Fisheries Management Authority) (Vance and Rothlisberg 2020). According to the research, the morphological characteristics of banana prawns distinguish them from other prawns: a thick rostrum with a length not exceeding the antennular. The spines of the rostrum are more blunt and sparse, and the upper part is six to seven in number, and the lower part is three to four (Figure 2). There are a few spots; the body color is not transparent or slippery when touched. The color of the pereiopods or legs is whitish-pink (Kembaren and Ernawati 2015). It is a species of high commercial value with a wide distribution area ranging from tropical to subtropical Indo-West Pacific region (Vance and Rothlisberg 2020). Banana prawns have a complicated life cycle, spawning at sea, then enlargement period in coastal areas, and returning to deeper waters when mature (Mane et al. 2018; Momeni et al. 2018). The prawn fishing area from Kolepom Island to the border of the Republic of Indonesia with Papua New Guinea, using beach seine and trammel net; this product ranks 3rd in the total fisheries production of Merauke District in 2018 (Lantang et al. 2020; Sari 2020).

Conditions of oceanographic parameters based on habitat type

The estuarial habitat is one of the important habitats for organisms and is a habitat for prawn larvae to begin living (Pickens et al. 2021; Taylor et al. 2017a); one of them is the banana prawns as in the estuary at Maro River. The fluctuating temperature according to the month of data collection was due to the different times and locations of capture (Sari 2020). If the capture is done during the day, the temperature of the waters will increase, and if the capture was done at night or dawn, the temperature value will decrease. Rising temperatures in April at mangrove habitats in Yobar, Bokem, and sandy beaches at Bokem were due to low rainfall (Plagányi et al. 2021). In those months, catches are low, so fishermen only catch in shallow waters with a maximum depth of 1 meter. This certainly impacts increasing the temperature of the waters; shallow and sloping areas are strongly influenced by the strong intensity of sunlight that warms sea water ((Lantang et al. 2020; Sari 2020). The lowest temperatures were found in August in habitats adjacent to the estuary, although relatively narrow. The water temperature affects prawn fishing sites' shift from low depths to deeper parts (Effendi et al. 2016). It also happens on several months of data retrieval in areas adjacent mangrove habitat in Yobar, sandy beaches in Lampu Satu, Payum, and mangroves in Bokem. In addition, the catch began to increase in these habitats, so fishermen increased the fishing time at night and dawn (Sari 2020), so the temperature became low. The movement of banana prawns in this area is related to prawns migration based on size. The large size is caught more in areas far from the coast, indicating a gradual prawn movement offshore according to their growth or size (Vance and Rothlisberg 2020). In addition, the distribution of banana prawns is influenced by temperature changes as one factor affecting its life cycle (Sreekanth et al. 2019; Vance and Rothlisberg 2020). Temperature changes have a behavioral impact on banana prawns. With increased temperature, prawns change living by moving into deeper waters and avoiding high temperatures in shallow coastal areas (Amanat et al. 2021; Sari 2020). This behavior is to find a suitable zone and support the existence of banana prawns in the waters by avoiding extreme areas in the form of high temperatures (Hoang et al. 2020); this statement is consistent with this research, where fishermen move to another location to get higher catches (Turschwell et al. 2022).

Figure 2. *Penaues merguensis* De Man, 1888

However, banana prawns in their life cycle have adapted to temperature changes, such as living in coastal and shallow areas with higher temperatures when in the larval and juvenile phases, to move later when adults return to deeper waters with lower temperatures (Momeni et al. 2018; Hoang et al. 2020). But in each phase, banana prawns will search for the optimal temperature because each stage has different optimum temperature preferences (Vance and Rothlisberg 2020). For this reason, the density of banana prawns in water can vary according to the optimum temperature range (Lantang et al. 2020; Vance and Rothlisberg 2020). Within the optimum temperature range, banana prawns will be active in movements such as foraging, making nests, and looking for shelter, making banana prawns grow to form a large population with high abundance (Hoang et al. 2020).

In areas adjacent to estuarial habitats, low salinity of 19.33-21 psu (Table 3) is due to the entry of freshwater from the river, namely the Maro River. It causes salinity dilution (Vance and Rothlisberg 2020). The Maro River is one of the largest rivers in South Papua, with a width of up to 900 meters; it drains fresh water with almost the same amount during the rainy and dry seasons (Sari 2020). The low salinity from this river flow affects several areas adjacent to estuarial habitats, sandy beaches in Lampu Satu, mangroves in Yobar, and sandy beaches in Payum. Although in areas adjacent to mangrove habitats at Yobar, a salinity of 26 psu was in March, in another month, low salinity was found, similar to the Maro River estuary, except for August, which differed. The waters adjacent to sandy coastal habitats at Payum are also in low salinity, such as the salinity of estuarial habitats. In addition, there were small rivers that enter this region carry fresh water and reduce the salinity and water pH values (Amanat et al. 2021). In areas adjacent to the mangrove habitat in Bokem, the influence of Maro River water has begun to decline, not affecting the salinity of 19.3 psu-21 psu as in the estuarial habitat. Furthermore, the influx of freshwater has a diverse impact on the organisms in it, including banana prawns. The correlation between low salinity and catch can be observed from the size of prawn caught dominated by sub-adult sizes that usually live on the beach and prefer a slightly low salinity (Mane et al. 2018; Momeni et al. 2018; Taylor et al. 2017b).

In areas adjacent to estuarial habitats, pH is low in May and June (Table 3) due to the flow of acidic water originating from acidic soil swamps and into the waters through the Maro River (McLuckie et al. 2021). The pH distribution in some habitats is also strongly influenced by acidic water masses from the Maro River, such as in areas adjacent to sandy beach habitats in Lampu Satu from May to August and at Payum in March and April, with pH found in the same range in estuaries. In the waters adjacent to the mangrove habitat in Yobar, the pH has increased higher, as well as in the mangroves in Bokem (Table 3). The increase in pH in both mangrove habitats is caused by the ability of mangroves to absorb hydrogen ions and produce tannins that, when oxidized, can form alkaline compounds that can increase pH (Hilmi et al. 2021). Acidic soils are one of the problems in lowlands and have a large impact on organisms and reduce the productivity of prawn fisheries (McLuckie et al. 2021). Furthermore, pH is one factor that affects the presence of organisms in water, such as prawns (Widiani et al. 2021). Its changes strongly influence the density of organisms and can have a direct impact (McLuckie et al. 2021). Therefore, the changes in pH affect the physiological system, metabolism, reproduction, presence of food, and stress and reduce $CaCO_3$ levels in carapace banana prawns and other organisms (Yu et al. 2020; Widiani et al. 2021; He et al. 2022). However, prawns are tolerant to pH changes, as in this study by finding prawns at a low pH. Supposing it exceeds the tolerance limit, this can certainly affect the density of prawns because it will disrupt the life cycle and result in a low survival rate (Chen et al. 2015).

The highest turbidity was obtained in areas adjacent to the mangrove habitat in Bokem and is thought to be related to the presence of mangroves in the area as mud traps (Widiani et al. 2021). The prawn fishing location also influences the turbidity level; therefore, if the fishing is done on the sand bottom waters, the turbidity level decreases slightly; that influence is different if the bottom is mud substrate (Lantang et al. 2020). Sedimentary deposits, especially small particles, may have been flown away from the coast and from the study site by the Maro River currents into deeper waters, which is why banana prawns are caught in deeper waters (Duan et al. 2013; Yonggui et al. 2013; Naden et al. 2016). In addition, the turbidity level and percentage of mud also increase in general (Warrick et al. 2015).

The fluctuating percentage of sand and mud is due to the changing fishing grounds. If prawn fishing is done in areas near the coast, then the percentage of sand will increase, and the percentage of mud will increase, but if prawn fishing is in distant areas, the opposite will happen (Lacharité and Metaxas 2017; Lantang et al. 2020; Sari 2020; Naden et al. 2016; Mathers et al. 201). The distribution of substrate at the study site showed that the increase in the value of mud substrate (fine substrate) increased based on the distance from the beach; the farther from the beach, the percentage of mud increased, and the percentage of sand decreased (Lacharité and Metaxas 2017; Gao et al. 2022). There is a pattern of substrate distribution in the form of high composition of sand in the estuary of the Maro River and decreasing in areas adjacent to the mangrove habitat in Bokem. That explains the substrate sediments mud and sand caused by the Maro River's land (Duan et al. 2013; Yonggui et al. 2013). This is evidenced by the increased mud substrate in deeper coastal waters while sand dominates shallow coastal areas (Gao et al. 2022; Naden et al. 2016). This data also explains that the percentage of sand is more dominant than mud during the study; this is related to the location of prawn fishing, which is only carried out in waters with a fairly low depth (Lantang et al. 2020; Vance and Rothlisberg 2020). The substrate sediments are preferred by organisms living in habitats, as done by crustaceans, including prawns, by avoiding rough substrates and burrows or nests (Leoville et al. 2021).

Density distribution of Penaeus merguensis *De Man, 1888 based on habitat type*

Salinity is at the requirement level for banana prawns in areas adjacent to estuarial habitat and sandy beaches at Lampu Satu and Payum (Hargiyatno et al. 2015; Vance and Rothlisberg 2020). Although lower than other habitats, banana prawns can tolerate such salinity (Hargiyatno et al. 2015). This is because banana prawns require a mixture of fresh water and seawater in their life cycle, and this is why these prawns are found to fluctuate in each waters (Hargiyatno et al. 2015; Widiani et al. 2021; Turschwell et al. 2022) In addition, tolerance to salinity is influenced by the size of banana prawns as caught on areas adjacent to estuarial habitats with carapace length 23.74 mmCL -44.81 mmCL with an average of 36.37 mmCL (Table 4). In the sandy beach habitat in Lampu Satu, the carapace length measures 25.67 mmCL-48.69 mmCL with an average of 37.96 mmCL (Table 4). That shows banana prawns caught in these two areas are, on average sub-adult prawns, and in estuarial habitats, the lowest average value of all habitats studied (Hargiyatno et al. 2015. These data suggest low salinity is more suitable for small prawns (juvenile) (Hargiyatno et al. 2015, and low-density effect on sub-adult prawns moving to other places (Vance and Rothlisberg 2020). The existence of this movement is suspected by the entry of fresh water from the Maro River, which reduces the salinity value in the waters so that sub-adult prawns respond to this by moving to other places (Duggan et al. 2019; Vance and Rothlisberg 2020). In addition, predominantly sub-adult prawns in these waters and small prawns (below sub-adult size) indicate that this habitat is a nursery ground. The prawns will move to other places to continue their life cycle, so their existence in this habitat is relatively short (Hargiyatno et al. 2015). As per salinity value, Vance and Rothlisberg (2020) have divided salinity according to its function; namely, a salinity of 20 psu will increase survival, a salinity of 25 psu will increase biomass and production, while a salinity of 30 psu will increase length growth. From the salinity value, especially in areas adjacent to estuarial habitats, Lampu Satu plays a more significant role in increasing survival, making it suitable for small prawns (Table 5). This strengthens the suspicion of low density due to the emigration of sub-adult prawns due to the entry of salinity that is still low (Hargiyatno et al. 2015). In addition, there is a possibility that the size of banana prawns with the lowest carapace length of 23.74 mmCL is the lowest size caught by the beach seine, and below this size, it cannot be caught, so this certainly affects the calculation of density in this habitat (Momeni et al. 2018; Widiani et al. 2021). Another factor is the low prawn fishing in areas adjacent to estuarial habitats and sandy beaches in Lampu Satu compared to other habitats (Xu and Sun 2013; Morrongiello et al. 2014; Minello 2017). The cause is that there is a strong current out of the Maro River in the estuary, and this area is quite deep except in the area adjacent to the Lampu Satu area, which is the factor that affects the presence of prawn in the estuary (Vance and Rothlisberg 2020). As a comparison for prawn density in the same habitat (low salinity) by Xu and Sun (2013), prawn densities were low in estuarial in Minjiang, with 22.05 kg/km^2.

In areas adjacent to the sandy beach habitat at Payum, low salinity was found (Table 5), although still tolerable but thought to be associated with a low density of banana prawns (Hargiyatno et al. 2015). Following the size, banana prawns were found to have a carapace length of 24.67 mmCL-48.93 mmCL with an average of 37.38 mmCL (Table 4). According to this size, the prawns found on average are sub-adults (Hargiyatno et al. 2015) and respond to the influx of freshwater from artificial waterways on the right side of this region by moving to other places (Duggan et al. 2019). The conjecture is reinforced by the fairly low salinity value in this habitat, even lower than the salinity division based on Vance and Rothlisberg (2020), thus triggering the emigration of sub-adult prawns. In addition, there is a dominance of sand in areas adjacent to estuarial habitats and sandy beaches in Lampu Satu (Table 5), which is certainly not liked by banana prawns, who prefer clay substrates mixed with sand (Silaen and Mulya 2018). This causes the bottom of the waters to become unstable, moving continuously and making it difficult for prawns to make nests (Minello 2017). In addition, this habitat is a port and repair place for fishing boats and is not overgrown with vegetation, so prawns do not get protection (Vance and Rothlisberg 2020; Leoville et al. 2021). Low diversity of organisms in sandy beach habitats, as reported by Schooler et al. (2017). As per salinity value, in habitats adjacent to the sandy coastal area at Payum, with a salinity of 19.08 psu (<20 psu), it is suitable for improving survival and also a nursery ground for banana prawns (Table 5). Following the carapace length, where sub-adult shrimp are found in this habitat, also still found smalls prawn with 24.67 mmCL (Hargiyatno et al. 2015; Vance and Rothlisberg 2020).

In areas adjacent to the mangrove habitat in Yobar, salinity is higher than in the previous three habitats. It is still suitable to support the presence of banana prawns in the zone, albeit with a fairly low density (Table 5). In this habitat, prawns caught with a carapace length of 25.45 mmCL-48.27 mmCL with an average of 37.36 mmCL (Table 4). That shows prawns in this habitat are, on average, sub-adults requiring slightly higher salinity than juveniles (Hargiyatno et al. 2015). The low density of prawns in this area is caused by the influx of fresh water and decreased salinity as in previous habitats, causing the dominance of sub-adults to move to other places; hence, this area found with a fairly low density (Duggan et al. 2019). In addition, the mud substrate is also still low, like the previous three habitats, even though this area is a mangrove area. There are allegations of current influences from the Maro River, small rivers, and tides that elevate fine sediments such as mud into deeper parts of the water (Lacharité and Metaxas 2017). This habitat is also a nursery ground for banana prawns with almost the same salinity found as the previous three habitats and small prawn sizes below the size of 37.36 mmCL (Hargiyatno et al. 2015). Although in all habitats ranging from estuaries, sandy beaches in Lampu Satu, Payum, and mangroves in Yobar are also found adult prawns but not dominant as well as small prawns (juvenile).

In areas adjacent to mangrove habitats in Bokem, the highest water salinity of all habitats is obtained in this habitat (Table 5). According to the length data, banana prawns caught in mangrove habitat with a carapace length of 29.75 mmCL-53.28 mmCL with an average of 39.59 mmCL (Table 4). This is different from the previous four habitats, with the discovery of adult prawns that dominate the density of banana prawns in this habitat (Hargiyatno et al. 2015). The presence of adult prawns in this habitat still corresponds to salinity values, which is associated with increased density, although higher salinity is needed for adult prawns (Hargiyatno et al. 2015). Increased salinity values are required by banana prawns, not only in this habitat but in all habitats. This is proven by comparing salinity in other habitats, such as the area adjacent to the mangrove habitat in Yobar, by 22.08 psu. When salinity increases by 3.77 psu, and salinity to 25.85 psu, according to data in this habitat, the density will increase by 12.38 kg/km^2 (Table 5). That suggests increasing salinity within a narrow range would increase the density of banana prawns (Vance and Rothlisber 2020). In comparison, Hargiyatno et al. (2015) reported that a salinity < 27 psu is suitable for juveniles, so adult prawns should be higher than salinity in this habitat. Although according to Vance and Rothlisberg (2020), the salinity of 25 psu is suitable for banana prawns, which can increase biomass and production, but it is suspected that if there is an increase above this salinity, then biomass and production will increase; it also increases the density in this habitat. Thus, salinity as the main parameter determines banana prawns' life cycle and density distribution (Hargiyatno et al. 2015). Due to two aspects, there is an influx of fresh water in areas adjacent to estuarial habitats, sandy beaches in Lampu Satu, Payum, and mangroves in Yobar. First, it is a signal for sub-adult to move due to the low salinity of the region and find a location suitable for their life cycle. Second, a high density was obtained in the mangrove habitat in Bokem from emigrants who moved from low salinity to higher salinities (Duggan et al. 2019; Vance and Rothlisberg 2020). Some studies also explain that freshwater flows entering the dry season result in low salinity, lower feed availability, and increased prawn emigration, decreasing their abundance in estuarial (low salinity) habitats (Duggan et al. 2019). Duggan et al. (2019) explained that unlike in places with no freshwater inflow (high salinity), the density of prawns increases. Salinity is a factor that determines the abundance, survival, recruitment, osmotic pressure, and distribution of penaeid prawns in waters (Torres et al. 2020; Yang et al. 2020; Minello 2017; Jiang et al. 2021; Plagányi et al. 2021; Rahi et al. 2021; Amalia et al. 2022; Azwar et al. 2023; Schlenker et al. 2023).

In areas adjacent to mangrove habitats in Bokem, turbidity is higher than in other habitats (Table 5). Compared with the suitability value of marine organisms, turbidity in this habitat is higher than the standard seawater quality of 5 NTU (Ministry of Environment Republic of Indonesia 2004). Although above the standard of seawater quality standards, this parameter significantly supports the existence of banana prawns in the habitat. That shows the higher the turbidity value, the more the density of banana prawns increases (Silaen and Mulya 2018), suggesting that *P. merguensis* requires a high turbidity level and is caught with higher density in areas with high turbidity (Vance and Rothlisberg 2020; Widiani et al. (2021). This can be explained by the fact that increased turbidity will provide protection from predators and make it easier for banana prawns to find food in the form of mollusks that immerse themselves in mud (Sreekanth et al. 2019; Hasidu et al. 2020; Penning et al. 2021; Taylor et al. 2017b). In addition, the possibility of prawns movement as in salinity patterns, following the level of turbidity; especially prawns caught are adult prawns with increasingly extensive food and are widely available in waters with high turbidity levels (Silaen and Mulya 2018; Lorencová and Horsák 2019). Mane et al. (2018) explain that the movement of sub-adult and adult prawns at the bottom of the waters, swimming with occasional stirring of the soft bottom, maybe one way for the water to become cloudy and facilitate escaping predators. Directly, fishermen can correlate between turbidity and the density of banana prawns by catching when turbidity increases by observing the water color changes (boiling mud), which is related to the caught (Mane et al. 2018; Lantang et al. 2020; Vance and Rothlisberg 2020). In addition, as a habitat, the function of mangroves supports banana prawns to be a high density in this habitat (Vance and Rothlisberg 2020). Mangrove habitats as coastal protection areas (Atkinson et al. 2016; Barbier 2016; Blankespoor et al. 2017), and mangrove root systems as shelters for prawns and provide food (Carugati et al. 2018) for organisms such as banana prawns. In comparison, the percentage of banana prawns preferred the mangrove areas is conveyed by Damora et al. (2019) at 51.61%, while according to Atkinson et al. (2016), the total species studied are associated with mangrove habitats at 67.5%. Thus, the mangrove habitat was good for organisms (Carugati et al. 2018; Damora et al. 2019; Alam et al. 2022). Research by Ahmed et al. (2023), Bosma et al. (2016), Giri et al. (2014) also report that prawn density is related to mangrove vegetation, and prawn stocking densities depend on mangrove coverage. This is supported by suitable oceanographic parameters such as turbidity and salinity in the Merauke District waters suitable for prawn growth (Table 2). Related to this study, research by Muawanah et al. (2021) in the Arafura Sea also found that *P. merguensis* was caught more in areas bordering mangrove forests. Therefore, the density of banana prawns will always be different in each water because of habitat preferences (Tirtadanu et al. 2022). According to the size of prawns caught in all habitats, on areas adjacent to estuarial habitats, sandy beaches in Lampu Satu and Payum, and mangroves, only averaged size of >38.7 mmCL are suitable for commercial prawn fishing, and this size is predominantly found in mangrove habitats in Bokem (Hargiyatno et al. 2015). The size of the carapace length in this study is greater than Widiani et al. (2021), with a carapace length of 16-33 mmCL in Belawan, North Sumatra.

The density of banana prawns in this study was lower (Table 5) than in Hargiyatno et al. (2015) because prawn fishing on the coastal coast of Merauke District is only carried out in shallow waters with low depths. In addition, there are limitations in terms of technology; the fishing equipment pulling is still done manually, using human labor. This is certainly different from this study, which uses prawn trawlers that can access depths of up to 10 meters and is a zone for the presence of banana prawns (Tuckey et al. 2021; Tirtadanu et al. 2022). In addition, using machines speeds up the prawn fishing equipment withdrawal and will increase the catch.

In conclusion, the highest density of banana prawn was obtained in shallow waters adjacent to the mangrove habitat at Bokem (32.68 kg/km^2) and mangrove at Yobar (20.27 kg/km^2). In waters adjacent to the sandy beach at Payum (17.98 kg/km^2), the density was higher than within the estuary of Maro River (14.61 kg/km^2) and adjacent to the sandy beach at Lampu Satu (14.39 kg/km^2). This is due to the influx of fresh water in areas adjacent to estuarial, sandy beaches in Lampu Satu and Payum, and mangroves in Yobar. That results in prawns' emigration to areas with higher salinity in areas adjacent to mangroves at Bokem. This phenomenon is also thought to be related to the distribution of turbidity that continues to increase in each habitat and is the highest in areas adjacent to mangroves in Bokem, affecting the movement of banana prawns.

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