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Prey conditions, food habits, and their relationship to the catch of *Penaeus merguensis* De Man, 1888 in the waters of Merauke District, Indonesia

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Abstract. *Lantang B, Najamuddin, Nelwan AFP, Samawi MF. 2024. Prey conditions, food habits, and their relationship to the catch of* Penaeus merguensis *De Man, 1888 in the waters of Merauke District, Indonesia. Biodiversitas 25: 1554-1569.* The study of the food habits of commercial crustaceans, namely Penaeus merguensis De Man 1888 in the waters of Merauke District was limited. Hence, research related to this was needed. For this reason, the study aims to analyze the prey fragment, prawn food habits, and their relationship to the catch based on differences in habitat types in the coastal waters of Merauke District. Data measuring oceanographic parameters, gastric contents samples of banana prawn (*P. merguensis*), mollusk samples, and catches were taken twice monthly in five habitats from March 2022 to March 2023. The results showed that for the fragmentation of prey, namely microalgae, 76.12% was found intact, while mollusks were found 97.46% not intact or dismembered. Mangrove leaves, macrophytes, prawn larvae, and fish larvae were found to be 100% incomplete or dismembered. Microalgae and mollusks were the main food in estuarial habitats and sandy beaches in Lampu Satu. While in mangrove habitats in Yobar, sandy beaches in Payum, and mangrove habitats in Bokem, the main food is mollusks, and complementary foods are microalgae. Mangrove leaves, macrophytes, prawns, and fish larvae were found only as supplementary food in all habitats. This was related to the availability of food that varies in each habitat. The catch increased with the discovery of the food habits of mollusks.

Keywords: Banana prawn, food habits, habitat type, *Penaeus merguensis*, prey condition, shallow waters of Merauke

INTRODUCTION

The shallow waters of Merauke District, South Papua, Indonesia, one of them is the estuary of the Maro River up to the mangrove habitats in Bokem, exhibit relatively high biodiversity, one example being penaeid prawn (Lantang and Merly 2017; Lantang et al. 2023). The characteristics of these waters supported the presence of penaeid prawns, such as banana prawns (Hargiyatno et al. 2015). As observed in estuarine regions, several important rivers flow into this area, carrying the necessary nutrients for phytoplankton (Lantang and Pakidi 2015). Furthermore, these rivers also transport fresh water essential for small prawns (Vance and Rothlisberg 2020). The characteristics of these waters, with turbidity levels exceeding 5 NTU, were found throughout the region, ranging from the Maro River to the mangrove habitats in Bokem area (Lantang et al. 2023). In some coastal areas, mangroves grow well, such as in estuarine areas, mangrove habitats in Yobar, and Bokem, making these areas important for banana prawns (Muawanah et al. 2021; Lantang et al. 2023). However, coastal areas without mangrove vegetation were also found on sandy beaches in Lampu Satu and Payum (Lantang et al. 2023). Nevertheless, these waters have strong currents with gently sloping and shallow seabed, so during low tide, this area will dry up approximately 2 km from the coastline (Lantang et al. 2023); Lantang and Merly 2017). Furthermore, the influence of acidic water carried from acidic swamps is one of the problems in these waters, especially in areas near estuaries (McLuckie et al. 2021). Therefore, the development of the prawn-catching sector is more intensive than that of the prawn aquaculture sector due to the less supportive conditions of the waters (Lantang and Merly 2017). The intensification of prawn catching in this area was not accompanied by the provision of supporting data for these activities. Even information about the best prawn-catching zones based on habitat types was unavailable in estuarine habitats, sandy beaches, or mangrove areas (Lantang et al. 2023). Hence, studies related to this matter must be conducted using indicators of food availability in those habitats. This is done by analyzing the types of food preferred by prawns, so it was predicted that if the food is abundant, the catch will also be abundant (Gutierrez et al. 2016).

Studies of the food habits of banana prawns were conducted to determine trophic relationships and analyze the interaction of prey, predators, and their food (Sajana et al. 2019; Dutta et al. 2023). The importance of this study is that, first, each prawn species has different food habits. In addition, there are indications that there have been changes in food habits based on time (month, year, and season) as well as the impact of environmental variables that determine the presence of prey in the habitat (Ocasio-Torres et al. 2015; Parra-Flores et al. 2019; Darodes de Tailly et al. 2021; Spence 2021; Suárez-Mozo et al. 2023). Second, predation was strongly influenced by the number and type of prey in the waters and the ability of predators to utilize the food available in their environment. It is important to know the appropriate types and amounts of food and the behaviors associated with how prawns use those foods (Eddy et al. 2017; Sentosa et al. 2018; Idrus et al. 2021). Third, the life stage of banana prawn was strongly influenced by size so that at a certain size, this organism will migrate. A key reason to migrate is to find available of food types used during the life phase, so it is necessary to know food habits based on size (Mane et al. 2018; da Silva et al. 2018; Vance and Rothlisberg 2020). Fourth, there was a strong relationship between habitat and the presence of prey, so it is necessary to know which habitats support the existence of prey with the increasing availability of food in that area (Hasidu et al. 2020; Tavares et al. 2015; Lorencová and Horsák 2019). Fifth, prawn fishery resources are highly economic resources, so through this study, food habits, amount of food, and suitable habitat for prey can be explained, which will later help in optimizing the management of the prawn fishery (Minello 2017; Sentosa et al. 2018; Parra-Flores et al. 2019; Majeed et al. 2022).

Between habitats, the presence of banana prawns was strongly influenced by food availability and oceanographic parameters as determining factors of distribution linked with their life cycle (Gutierrez et al. 2016; Lantang and Merly 2017; Minello 2017; Stewart et al. 2020; Sreekanth et al. 2020; Amanat et al. 2021). The food habits of banana prawns (*Penaeus merguensis* De Man, 1888) consist of mollusks, detritus, crustaceans, and macrophytes, but some studies also mention that microalgae are one of the essential foods for prawns (Wassenberg and Hill 1993; Lima et al. 2014; Jamali et al. 2015; Gutierrez et al. 2016; Santosa 2018; Mane et al. 2018; Haoujar et al. 2022). In addition, the role of habitat is essential in determining the presence of food (prey); the diet of penaeid prawn was associated with the existence of mangroves, where mangroves provide protection as well as food (Meager et al. 2005; Santosa 2019; Alam et al. 2022). Estuary habitats and sandy beach habitats will be suitable places for banana prawns with the availability of food (prey) in this habitat (Taylor et al. 2017a; Stewart et al. 2020; Pickens et al. 2021). Therefore, the study of banana prawn food is interesting, considering that food habits can be found differently in each habitat and are highly dependent on the carrying capacity of the habitat and the ability of predators to use food in the habitat (Taylor et al. 2017b; Sajana et al. 2019; Tuckey et al. 2021; Vahidi et al. 2021).

Research on feeding habits in the waters of Merauke District has been conducted by Wibowo et al. (2022) on *Neoarius leptaspis* Bleeker 1862 (salmon catfish) in Rawa Biru Lake; there have been no reports on the food habits in penaeid prawns trick. Therefore, studies were needed on banana prawns by analyzing their food habits, the condition of their prey, and their relationship with catches. The existence of this study will answer questions about the types of food eaten by banana prawns. The food types were various, such as mollusks, microalgae, mangrove leaves, pieces of prawn larvae, fish larvae, and insects, or there are other food sources (Lima et al. 2014; Jamali et al. 2015; Kwak et al. 2015; Gutierrez et al. 2016; Mane et al. 2018; Santosa 2019; Haoujar et al. 2022) In addition, it addresses the condition of prey in the stomachs of banana prawns. Also, it explores the relationship between food habits and catches, which have never been reported in the shallow waters of Merauke District. Therefore, this study is very important and serves as an early justification for explaining food habits, condition/fragmentation of prey, and their relationship with catches. Understanding this will help take the necessary action now and in the future (Minello 2017; Parra-Flores et al. 2019; Majeed et al. 2022). This is useful in maintaining the sustainability of coastal aquatic ecosystem resources and obtaining economic and ecological benefits from them (Lantang et al. 2023).

MATERIALS AND METHODS

Research location and habitat criteria

The manuscript focuses on prawns foraging over a suite of habitats within a coastal estuarine and shallow-water ecosystem in Merauke District, South Papua Province, Indonesia (Figure 1). The sample locations are each separated by about 2-5 km along the coast to the east of the Maro River estuary. Data were collected from March 2022 to March 2023 by measuring oceanographic parameters, collecting prawn and mollusk samples, and recording catches twice monthly from five habitats. In this study, habitat division was based on the location of prawn sampling.

First, the estuarine habitat in the Maro River, located at coordinates 8°29'37.2S 140°21'36.1E, is adjacent to a mangrove area, is part of the mangrove forest growing from the river mouth to the inner part of the Maro River. This area is only submerged during high tides, which also occurs in other mangrove habitats. The estuarine was characterized as an estuarine area with high turbidity levels and mangrove growth along its shoreline. (Lantang et al. 2023). Mollusks were found in this habitat, in mangrove forests and at the bottom of the waters. Moreover, this area receives significant nutrients from the land as the Maro River flows into it, which is essential for phytoplankton (Lantang and Pakidi 2015). Second, the sandy beaches at Lampu Satu exhibit characteristics typical of regions with beaches bordered by mangroves, similar to the sandy beach habitat in Payum. This habitat was located at coordinates 8°30'02.0"S 140°22'00.6"E and is less than 2 km away from the estuarine habitat. The oceanographic parameters are almost identical to the adjacent estuarine habitat (Lantang and Pakidi 2015; Lantang and Merly 2017). Mollusks were also found in this habitat and were dominated by bivalves according to the characteristics of waters with a higher percentage of sand than mud. Third, the mangrove habitat in Yobar, with coordinates

8°32'06.0"S 140°24'03.9"E, was located quite far from the estuarine area and was supported by mangrove forests growing along the coastal region, covering an area of more than 5 km (Lantang et al. 2023). The turbidity level also reaches above 5 NTU in this water. Some mollusks live in both mangrove forest areas and the seabed, and they serve as food for banana prawns that live in the vicinity of this habitat. Fourth, the sandy beach habitat at Payum, located at coordinates 8°32'50.4"S 140°25'03.6"E, is distant from estuarine habitats, but along the area bordering the mangrove habitat in Yobar, there are artificial water inlet channels. These channels function to bring fresh water into this area and have an impact on environmental variable changes. Mollusks found in this habitat were predominantly of the class Bivalvia, which differs from mangrove forests dominated by Gastropods. The obtained turbidity is also quite high, similar to other habitats, which is above 5 NTU. However, the percentage of sand is more dominant compared to mud (Lantang et al. 2023). Fifth, the mangrove habitat in Bokem was located at coordinates 8°33'41.2"S 140°25'42.0"E. Mollusks, namely gastropods, were also found in this habitat, supported by a higher percentage of mud compared to other habitats. Turbidity was also higher in this habitat, thus supporting the existence of banana prawns and mollusks (Lantang et al. 2023).

This location was situated further to the east-southeast and was characterized by a wide expanse of mangroves separating the coastal shoreline from the terrestrial habitat. In all the habitats studied, there is a stretch of coastline approximately 14 km long, which features continuous shelving intertidal and shallow sub-tidal 'beach'. This stretch appears to extend around 500-800 meters or more from the shore to the low-tide level, followed by a shallow sub-tidal area that gradually deepens towards the sea. The latitude/longitude location indicates that prawn catching with beach seine nets is done during low tide, with a minimum distance from the mangrove area of 30-50 meters. Prawn catching is greatly influenced by the presence and size of prawns, enabling it to be conducted in both nearby and relatively distant areas from the mangrove habitat. The capture using a beach seine was carried out to catch prawns that migrate daily toward the shore during high tide (Lantang et al. 2023). These prawns were caught when the tide recedes as they attempt to return to deeper waters and get obstructed by the nets pulled by fishermen.

Procedures

Conditions of prey

Observation of the condition and fragmentation of the prey was conducted by examining the contents of the stomach, determining whether the prey is intact or in a dismembered state (not whole) (Buckland et al. 2017). The observed prey was grouped according to their taxonomic types and separated based on the observed conditions (Lima et al. 2014; Buckland et al. 2017). Each prey type, e.g. mollusks, will be categorized based on whether it was not whole or dismembered. The prey was called intact if no part of its body had been damaged; it was called not whole or dismembered if found was a separate part of the body because it was eaten by prawns or chewed until crushed. Almost all types of food in the stomach were identified based on their shape, such as mollusks, which can be distinguished from other foods based on their indigestible hard components (Buckland et al. 2017). The component is the shell; although it has been found that banana prawns have cracked it, it can still be recognized. Despite being in the form of live feed or carcass, mollusks are still identified based on their shells (Buckland et al. 2017), because the prey's flesh has already mixed with other food as mucus.

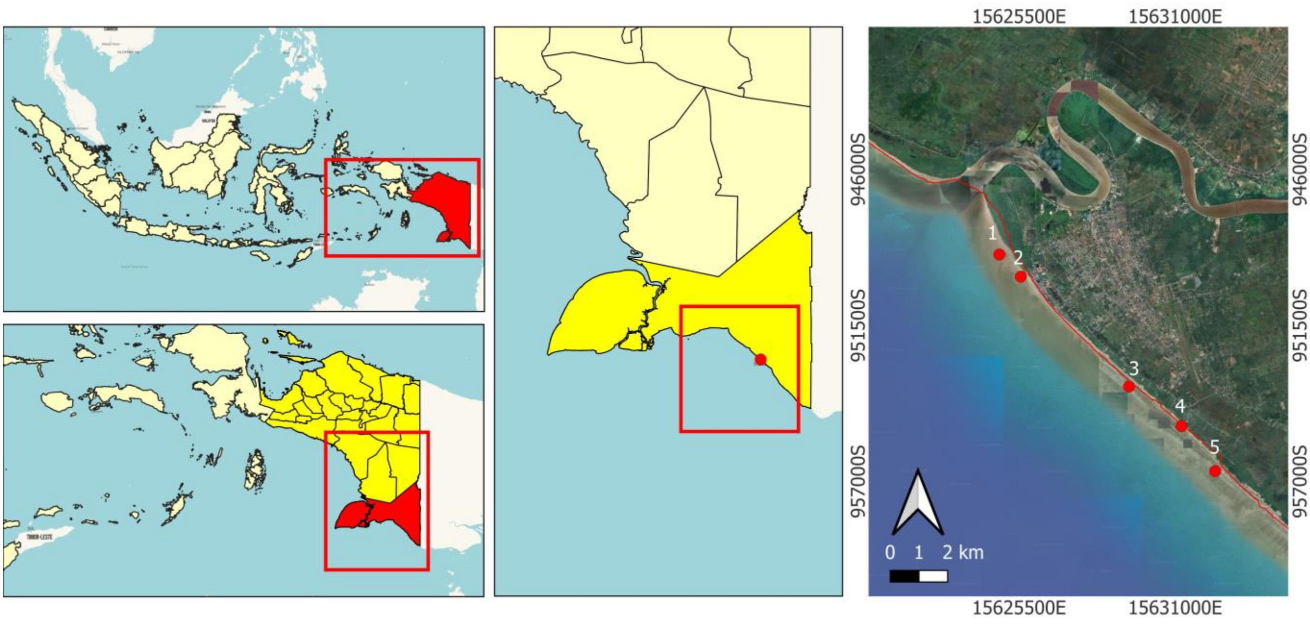

Figure 1. Locations of the research in South Papua Province, Indonesia: 1. Estuary of the Maro River; 2. Sandy Beach in Lampu Satu; 3. Mangrove habitats in Yobar; 4. Sandy Beach in Payum; 5. Mangrove habitats in Bokem

Although sometimes it can still be distinguished based on the color of its flesh, identification and they had the shell will facilitate this process. The same thing happens to prawn larvae and fish, namely the finding of fragmented parts such as bodies, tails, or heads, but they can still be identified based on their shapes (Paramasivam et al. 2020). Furthermore, it can be seen that the prey is somewhat white, but clues based on the shape of the prey are more frequently used. Therefore, careful identification is necessary to ensure that the objects can be well recognized, including parts that are no longer intact. Furthermore, sometimes the color of the prey observed was almost identical, so precision is required in this identification. The condition of each obtained prey was recorded and then calculated to obtain percentages of gut content, as shown in Table 1.

Food habits of banana prawns every month about prey availability

In this study, there was no consideration for molting prawns that do not eat. All prawns were categorized equally, meaning they were not molting, with the same feeding capabilities as other prawns. The reason is that molting prawns do not engage in daily migrations by moving around 1-1.5 km toward the coast. It should be noted that the capture area in this study is an intertidal zone that experiences drought during low tide and will be inundated again during high tide (Lantang et al. 2023). This water area is different from the usual, where elsewhere, it has low tides so that seawater accumulates in it and prawns will settle in it, one of which is for molting, making them caught by nets. Additionally, during data collection, no prawns undergoing molting with soft and weak shells were found. This is because, during that period, the prawn's body is still weak and easily preyed upon by other organisms. Therefore, prawns during this period are not active and usually hide in holes/nests in the subtidal area rather than engaging in daily activities such as daily migration to the shore (Bardera et al. 2019).

The freshly caught banana prawns were stored in iceboxes and transported to the Aquatic Resources Management Laboratory at Musamus University, Merauke, to measure their carapace length and extract their stomach contents (Varadharajan and Soundarapandian 2013). This is done to prevent the rotting process, including the contents of the stomach, and also to prevent a decrease in stomach volume and other possible processes that may occur (Wassenberg and Hill 1993; Heales et al. 1996). The distance between the sampling location is relatively close to the laboratory, approximately 5-15 minutes away. The length of the carapace was measured with vernier calipers with an accuracy of 0.1 mm, using the method by Kembaren and Ernawati (2015). The surgery was performed on the head area to extract the contents of the stomach by splitting the carapace and then preserving it with 10% formalin (Varadharajan and Soundarapandian 2013; Wongyai et al. 2020). The time required from post-capture until preservation with formalin is 25-30 minutes. This process can actually be expedited by directly performing stomach surgery without measuring the carapace, but typically, the dissected carapace must be removed during surgery. This will inevitably cause damage to the carapace, rendering it incomplete and providing inaccurate measurement data. Moreover, carapace measurement does not require much time. The observation of stomach contents was conducted using the method outlined by Sajana et al. (2019). Each type of food obtained was recorded and weighed using a digital scale (0.0001 g) to determine the weight of each type of food (Paramasivam et al. 2020). Additionally, the frequency of occurrence of each type of food was recorded, and the food habits of banana prawns were analyzed using appropriate methods by Bhakta et al. (2019). The stomach contents of a total of 840 banana prawns were observed. Fourteen samples were collected per month, and they are considered sufficient to represent the banana prawn population in this area. This consideration was based on the low capture of banana prawns in these waters rather than the dominant capture of other prawn species. The research data indicates that the banana prawn catch only ranges from 15-25%. This finding has also been replicated in several studies, as demonstrated by Tirtadanu et al. (2022), with a catch rate of 0.80%, which was obtained in a single fishing trip. Additionally, this study utilized a small sample size as it focused on a homogeneous research population of a single prawn species (De Carvalho et al. 2019). In this study, the details of the number of samples observed each month were presented. (Table 2). In this study, mollusks were analyzed to explain the habitat-carrying capacity related to food availability in each habitat. The analysis of these variables is important because mollusks are a food consumed by banana prawns (Gutierrez et al. 2016; Santosa 2019). This analysis will explain the variation in food consumed by banana prawns each month based on habitat. Additionally, it will address whether food abundance correlates positively with the types of food consumed. This is important because banana prawns are selective organisms that utilize food. However, it is often found that preferred foods are consumed even though the quantity is limited in the waters (Lantang and Merly 2017; Sentosa et al. 2018). Therefore, this variable will answer the cause of banana prawns consuming mollusks, whether it is due to prawn size, preference for that food, or its abundance in the waters. The mollusk samples were collected using a trawl net-shaped tool designed with a frame made of iron and dragged along the seabed. The specifications of the tool include a mouth opening width of 1 meter, a mouth opening height of 25 cm, a length of the body and bag each 70 cm, and its walls covered with a net with a mesh size of 0.05 inches. The use of this mesh size was intended to capture mollusks ranging from small to large sizes. The number of mollusks caught was counted, and their abundance was further calculated using the formula Brower et al. (1990). To determine the relationship between the types of food consumed by banana prawns and the catch results, the Pearson correlation was tested.

Food habits in each habitat and their relationship with catches

Index of Preponderance calculation results were grouped according to their respective habitats and processed using average values. This aims to determine food habits according to the percentage values obtained, main food, accompanying food, and additional food (Samad et al. 2022). In this study, turbidity and mud substrate were analyzed to explain the relationship between oceanographic parameters and environmental variables supporting the presence of banana prawns. Data collection was conducted in each habitat using the data collection method according to Lantang et al. (2023). The data were analyzed using Pearson correlation tests to determine the relationship between oceanographic parameters, namely water turbidity, mud substrate, and mollusk abundance (biology) (De Jesús-Carrillo et al. 2020). Additionally, Pearson correlation tests were also utilized to ascertain the relationship between the mollusk abundance obtained in the field and the percentage of mollusks obtained in prawn stomachs.

Data analysis

Analysis of food habits

The food habits of banana prawns were analyzed using appropriate methods by Bhakta et al. (2019) and Sajana et al. (2019).

$$Pi = \frac{Vi \ x \ Oi}{\sum(Vi \ x \ Oi)} x \ 100 \ \%$$

Where:

Pi : the Index of preponderance food type-i

Vi : the weight percentage of one type of food

Oi : the percentage of frequency of occurrence of one type of food

∑VixOi : the number of Vi × Oi of all types of food

If Pi ranges from >40% is the main food, 4-40% is complimentary food, and <4% is supplementary food (Samad et al. 2022).

Substrate analysis

According to Irham et al. (2018), the equation was used to obtain the percentage weight of mud sediment.

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

Analysis of mollusk abundance

The abundance of mollusks was determined using equations from Brower et al. (1990).

$$N = \frac{\sum ni}{A}$$

Where:

N : the abundance of individuals (ind/m^2)

∑ni : the number of individual mollusks

A : area of the entrance opening in the mollusk fishing equipment

RESULTS AND DISCUSSION

Prey conditions

This research observes the stomach contents of banana prawns to identify the types of food to observe the prey's fragmentation and to obtain different conditions from each prey. Several types of food were found intact, such as microalgae (76.12%) and mollusks (2.54%). However, the prey was also found fragmented or in dismembered conditions, such as microalgae (23.88%), mangrove leaves (100%), mollusks (97.46%), macrophytes (100%), prawn larvae fragments (100%), and fish larvae (100%) (Table 1).

Food habits of banana prawn every month about prey availability

From March to April, food habits comprised microalgae in mangrove habitats at Yobar, sandy beaches in Payum, and mangrove habitats at Bokem (Table 2). In May, microalgae were only dominant in estuary habitats, while in other habitats, food was dominated by mollusks (Table 2). In June, two main foods, microalgae and mollusks, were consumed in the estuary and mangrove habitats in Yobar. Microalgae was the predominant food in the sandy beach habitat in Lampu Satu. Conversely, the sandy beach habitat in Payum and the mangrove habitats in Bokem consisted of mollusks. In July, there was a shift in food habits in the estuary habitats, sandy beaches in Lampu Satu, and mangrove habitats in Yobar, as prawns consume mainly mollusks (Table 2). Meanwhile, the sandy beach habitat in Payum and mangrove habitats in Bokem still consisted of mollusks. Consequently, all the habitats under study relied on mollusks as their primary food source in July. However, in August, there was a shift in food habits in estuarial habitats and sandy beaches in Lampu Satu, with a transition to microalgae as the primary food source (Table 2). While mangrove habitats in Yobar, sandy beaches in Payum, and mangrove habitats in Bokem exhibit similar data as the previous month, which consisted of mollusks as the primary food. In September, food habits, including microalgae (>40%) and mollusks (>40%), were only observed in estuary habitats, while other habitats food habits consisted of mollusks (>40%) (Table 2). In October, the food habits of mollusks were observed in all habitats (Table 2). In November, food habits were found to be in two types of food, namely microalgae (>40%) and mollusks (>40%), in the mangrove habitat in Yobar and Bokem.

Table 1. Conditions of the prey

Conditions of the prey	Percentage types of prey					
	Microalgae	Mangrove leaves	Mollusks	Macrophytes	Prawns larvae	Fish larvae
Intact (Complete)	76.12	-	2.45	-	-	-
Crushed or dismembered	23.88	100	97.46	100	100	100

Table 2. Food habits of banana prawns in monthly

Habitats	Months	No. of observed samples (ind.)	Weight of prawn catch (kg)	Index of Preponderance (IP) in monthly					
				Microalgae (%)	Mangrove leaves (%)	Mollusks (%)	Macrophytes (%)	Prawn larvae (%)	Fish larvae (%)
The estuary of the Maro River	May	14	3.81	60.90	-	31.2	-	5.95	1.95
	June	14	5.15	55.48	-	43.79	-	0.37	0.36
	July	14	6.40	24.99	1.30	68.17	-	3.05	2.49
	August	14	6.51	71.15	1.06	27.79	-	-	-
	September	14	10.78	54.76	-	44.65	-	-	0.59
	October	14	7.05	13.65	-	81.96	1.97	1.96	0,46
	November	14	6.28	21.06	-	76.75	-	1.76	0.43
	December	14	3.22	76.55	0.13	21.54	0.25	1.29	0.24
	January	14	2.21	68.65	0.75	17.91	-	11.95	0.74
	February	14	5.55	79.50	1.16	16.65	0.67	1.79	0.23
	March	14	10.06	31.10	0.47	67.87	0.09	-	0.47
Sandy Beach at Lampu Satu	May	14	5.57	33.04	-	52.23	-	12.05	2.68
	June	14	3.69	71.01	-	28.40	-	0.59	-
	July	14	5.96	37.67	3.68	47.89	-	10.28	0.48
	August	14	6.	63.44	0.20	31.33	-	-	5.03
	September	14	10.74	34.63	0.13	64.34	0.37	0.25	0.28
	October	14	7.32	27.97	-	71.42	-	0.31	0.30
	November	14	6.43	8.80	-	89.68	0.19	1.14	0.19
	December	14	3.69	54.66	-	40.67	1.70	2.54	0.43
	January	14	2.03	82.88	-	14.92	-	1.10	1.10
	February	14	5.38	44.76	0.19	51.06	-	3.49	0.50
	March	14	10.96	19.67	-	79.24	0.28	-	0.81
Mangroves in Yobar	March	14	7.49	81.09	-	18.53	-	0.38	-
	April	14	5.22	83.58	0.29	13.74	-	-	2.39
	May	14	7.28	20.12	0.84	77.09	-	0.83	1.12
	June	14	7.21	41.18	9.42	48.23	-	0.78	0.39
	July	14	8.32	15.40	-	81.42	-	2.95	0.23
	August	14	9.16	7.08	4.54	88.09	-	-	0.29
	September	14	12.68	24.63	0.37	74.62	0.2	-	0.18
	October	14	9.55	19.59	-	79.6	0.40	0.41	-
	November	14	5.15	54.00	-	43.50	1.00	1.00	0.50
	December	14	5.50	56.85	2.00	38.79	1.03	1.33	-
	January	14	4.33	67.32	0.73	29.91	0.26	0.81	0.97
	February	14	8.69	40.32	0.25	56.59	0.28	1.45	1.11
	March	14	13.05	7.64	0.50	89.12	1.71	-	1.03
Sandy Beach in Payum	March	14	2.14	84.32	-	15.24	-	0.44	-
	April	14	4.04	74.84	-	22.94	-	-	2.22
	May	14	7.59	19.47	0.89	77.85	-	-	1.79
	June	14	7.36	9.70	-	85.45	-	-	4.85
	July	14	6.08	21.00	0.81	78.02	-	0.17	-
	August	14	11.42	10.69	1.52	87.41	0.22	-	0.16
	September	14	9.81	8.28	-	90.50	0.61	-	0.61
	October	14	10.21	5.85	0.19	93.66	-	-	0.30
	November	14	6.27	36.31	0.26	62.10	1.05	-	0.28
	December	14	3.69	61.76	0.29	36.48	0.88	0.59	-
	January	14	4.49	78.32	0.36	20.5	-	0.82	-
	February	14	7.14	24.96	-	73.83	-	1.21	-
	March	14	14.21	4.39	1.25	90.62	0.62	-	3.12
Mangroves in Bokem	April	14	5.24	68.89	-	25.38	4.83	0.60	0.30
	May	14	16.69	17.67	1.02	79.97	-	-	1.34
	June	14	13.23	14.21	1.15	84.15	-	-	0.49
	July	14	14.23	14.29	2.39	83.11	-	-	0.21
	August	14	12.11	17.62	15.17	65.91	1.08	-	0.22
	September	14	13.21	10.14	1.30	88.25	0.16	-	0.15
	October	14	9.01	14.44	0.39	83.19	0.10	-	1.88
	November	14	8.28	40.75	0.38	57.35	0.39	-	1.13
	December	14	4.89	45.34	0.98	51.23	0.49	0.49	1.47
	January	14	4.97	75.45	2.89	18.82	1.19	0.17	1.48
	February	14	12.32	19.72	0.86	76.50	0.86	-	2.06
	March	14	21.27	11.30	1.24	86.34	0.82	-	0.30

However, this differed in other habitats, where they consumed only one food type, mollusks. In December, microalgae emerged as the main food source for banana prawns in estuarine, mangrove habitats in Yobar, and sandy beaches in Payum (Table 2). In sandy beach habitats of Lampu Satu and mangrove habitats in Bokem, microalgae, and mollusks were the primary food sources. In January, there was a pattern of change in all habitats, shifting to consuming microalgae (Table 2). In February, microalgae serve as the main food source in estuarine habitats. However, in nearby habitats, such as sandy beaches in Lampu Satu and mangrove habitats in Yobar, the primary food sources are microalgae and mollusks. In sandy beach habitats in Payum and mangrove habitats in Bokem, mollusks were found as the main food source. In March, the food habits in estuarine habitats shifted from the previous month, with mollusks becoming the main food source. This pattern was also observed in other habitats, where mollusks are the primary food source.

Aside from being a complementary food, mangrove leaves were also utilized as supplementary food, although not found every month (Table 2). Another food source, macrophytes, namely moss, was only found as a complementary food in the mangrove habitats in Bokem during April (Table 2). Macrophytes, serving as both complementary and supplementary food, were not found every month during data collection. In addition to the diet above, banana prawns consume larval prawn pieces as a complementary food (4-40%) in the estuarine habitat in January, and in the sandy beach habitat in May and July, while not found in other habitats (Table 2). Furthermore, prawn larvae fragments also serve as supplementary food (<4%) and were not found every month (Table 2). Fish larvae were found as a complementary food in sandy coastal habitats at Lampu Satu in August and Payum in June (Table 2). These fish larvae also act as supplementary food and were not found every month (Table 2).

The size of banana prawns found in estuarine habitats consists of two dominant sizes, namely juveniles (<32 mmCL) and sub-adults (<38.7 mmCL). Juveniles were found for 5 months, sub-adults were also found for 5 months, and adults (>38.7 mmCL) were only found for 1 month out of a total of 11 months of data collection. In the sandy beach habitat at Lampu Satu, juveniles (<32 mmCL) dominate and were found for 5 months, while sub-adults (<38.7 mmCL) were only found for 4 months, and adults (>38.7 mmCL) were only found for 2 months out of the total 11 months of data collection. The mangrove habitat in Yobar was dominated by sub-adult prawns (<38.7 mmCL) found during 6 months of data collection. Juveniles (<32 mmCL) were only found for 2 months, while adults (>38.7 mmCL) were found for 4 months out of a total of 13 months of data collection. The sandy beach habitat in Payum was dominated by sub-adult prawns (<38.7 mmCL) found during 8 months. For juvenile sizes (<32 mmCL), they were only found for 2 months, and for adult sizes (>38.7 mmCL), they were recorded for 4 months, with a total data collection period of 13 months. In the mangrove habitat in Bokem, adult prawns (>38.7 mmCL) were caught for 7 months, while sub-adults (<38.7 mmCL) were recorded for 5 months; no juveniles were found. The total data collection time was 12 months.

Food habits in each habitat and their relationship with catches

Meanwhile, food habits based on habitats, discovered, the main food for banana prawns in estuary habitats and sandy beaches in Lampu Satu were microalgae and mollusks. In contrast, in mangrove habitats in Yobar, sandy beaches in Payum, and mangrove habitats in Bokem, the main food consisted of mollusks, while supplementary food included mangrove leaves, macrophytes, pieces of fish, and prawn larvae (Table 3).

Based on the distribution of mollusk abundance, it is known that the highest abundance of mollusks was obtained in mangrove habitats from April to September (Figure 2). Although the abundance in the following month was lower than in September and followed by other habitats, it increased again in February until March and was followed by other habitats. This also shows that the abundance of mollusks in the estuarial habitat and sandy beach in Lampu Satu was low compared to the other three habitats (Figure 2).

The percentage of mud obtained in low estuarine habitats below 50%, with the highest percentage reaching 26.59%, was found in March (Figure 3). In the sandy beach habitats of Lampu Satu and Payum, low a percentage of mud below 50% was obtained, with the highest percentage reaching 27.55-27.96%. This percentage was obtained in September in the sandy beach habitat of Lampu Satu and in August in the sandy beach habitat of Payum (Figure 3). Meanwhile, in the mangrove habitats in Yobar and Bokem, the percentage increased from the previous three habitats, although still below 50%, with the highest percentages reaching 33.26% in mangrove habitats at Yobar and 35.15% in mangrove at Bokem (Figure 3).

Table 3. Food habits in each habitat and their relationship with catches

Habitats	Index of Preponderance (IP)						Average prawn catch (kg)
	Microalgae (%)	Mangrove leaves (%)	Mollusks (%)	Macrophytes (%)	Prawns larvae (%)	Fish larvae (%)	
The estuary of the Maro River	50.71	0.44	45.30	0.27	2.55	0.73	6.25
Sandy Beach at Lampu Satu	42.86	0.45	51.97	0.56	2.95	1.21	6.44
Mangroves at Yobar	39.91	1.45	56.92	0.32	0.77	0.63	8.35
Sandy Beach at Payum	33.82	0.43	64.20	0.31	0.17	1.07	7.27
Mangroves at Bokem	29.16	2.32	66.69	0.80	0.11	0.92	11.19

The water turbidity obtained in this study falls within the high category (above 5 NTU). As indicated by this study, the highest turbidity was obtained in the mangrove habitat of Bokem, increasing from March to May, then decreasing until January, and increasing again until March (Figure 4). In the estuarine habitat at the mouth of the Maro River, the turbidity was lower compared to all the habitats studied. Although it peaked at 765 NTU in September, the turbidity decreased the following month and increased again in February and March (Figure 4). Similar patterns were observed in other habitats, including sandy beaches in Lampu Satu, mangroves in Yobar, and sandy beaches in Payum (Figure 4).

In statistical tests using Pearson correlation (Table 4), microalgae correlate negatively with the catch, namely banana prawn. Other types of food, such as mangrove leaves, were found to correlate positively with the catch. Similarly, for mollusks as a food type, a positive correlation with the catch was found. Microphytes, according to the statistical tests, correlate negatively with the catch. Whereas the food types of prawn larvae and fish both show negative correlations with the catch. The Pearson correlation on oceanographic parameters indicates that water turbidity correlates positively with catch results. Other variables, such as mud substrate and mollusk abundance, were found to correlate positively with catch results. Meanwhile, the relationship between mollusk abundance obtained in the field and the percentage of mollusks found in the stomachs of banana prawns shows a positive correlation.

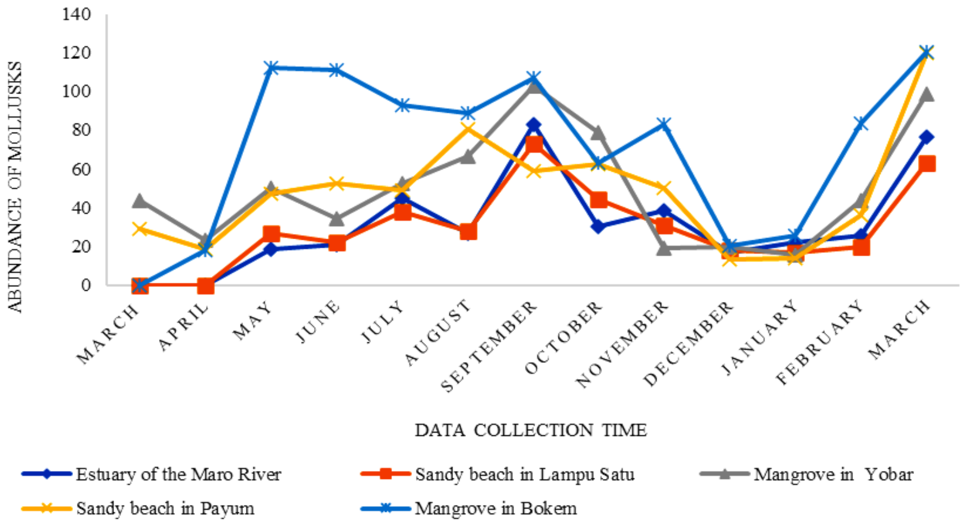

Figure 2. Distribution of mollusk abundance during the research

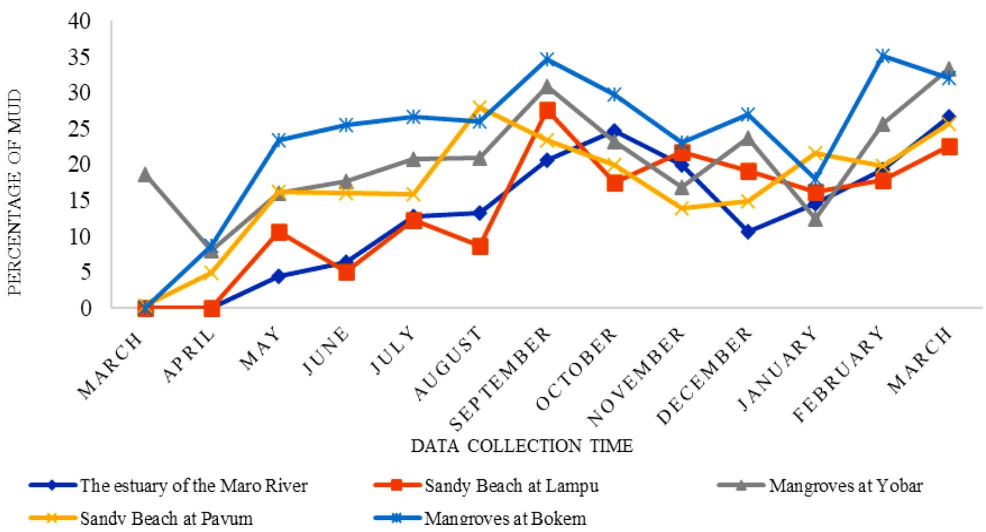

Figure 3. Percentage of mud during the research

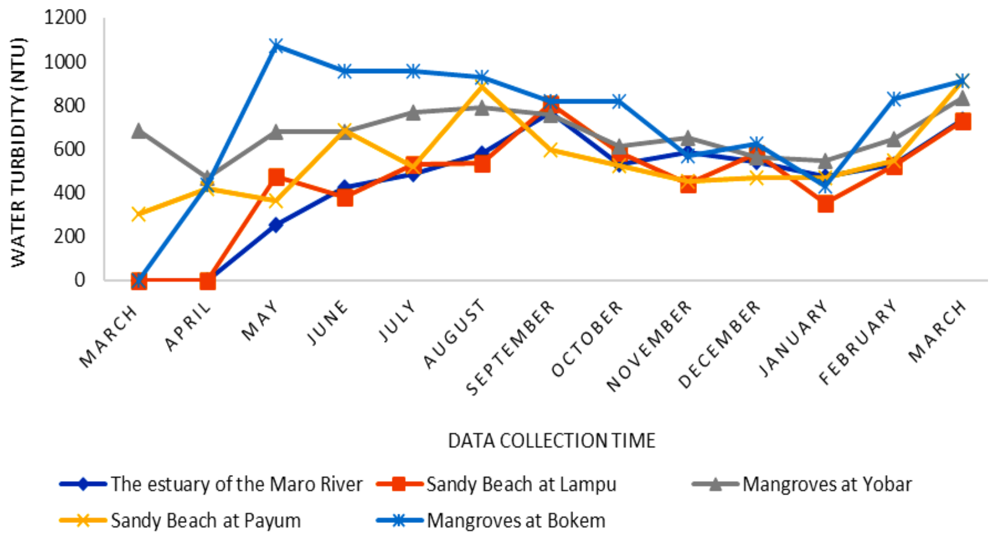

Figure 4. Distribution of water turbidity during the study

Table 4. Pearson correlation on types of food, oceanographic parameters, and food availability

Variables tested	Pearson correlation	Category
Correlation of type of food with catch.		
Microalgae	-.701	Negative correlation
Mangrove leaves	.193	Positive correlation
Mollusks	.713	Positive correlation
Macrophytes	-.027	Negative correlation
Prawn larvae	-.344	Negative correlation
Fish larvae	-.027	Negative correlation
Correlation of oceanographic parameters with catch		
Water turbidity	.490	Positive correlation
Mud substrate	.001	Positive correlation
Abundance of mollusks (biology)	.411	Positive correlation
Correlation of mollusk abundance with the percentage of mollusks in prawn stomachs	.709	Positive correlation

Discussion

Prey conditions

The type of food was the dominant factor determining the integrity of food items ingested by the banana prawns (prey condition) (Table 1). The fragmentation of microalgae was low as algae tissue is soft and easily ingested, with 76.12% remaining intact in the prawn stomach (Pattarayingsakul et al. 2019). *P. merguensis* can swallow its prey efficiently without requiring a large amount of energy. This is because the food captured by its periopods or legs was inserted into the mouth, and small digestible pieces were passed through the digestive tract. However, large-sized prey were reduced in size by the mandibles and the tips of the upper jaw (Hunt et al. 1992; Silva et al. 2019). A few studies have also explained that ingestion takes place quickly, and microalgae reach the stomach intake due to their small size and protective layer in the stomach, which prevents physical damage during ingestion (Pattarayingsakul et al. 2019). In addition, the silica content of microalgae makes their physical structure difficult to decompose (Mooij et al. 2016; Ahmed et al. 2017). The same type of foods were found whole, their small size not requiring prawns to chew them (Lima et al. 2014). Large food types require fragmentation to be ingested. For mollusks, the other dominant prawn food type, 97.46 % found in prawn stomachs were masticated (Table 1). Banana prawns eat mollusks that are relatively small in size, either mollusk species that are small and fragile or early life-stage species whose shells are soft and fragile because the content of $CaCO_3$ from a shell is rudimentary and easily broken (Ahmed et al. 2017; Kintsu et al. 2021; Škundrić et al. 2021). In addition, banana prawns have a deep tooth structure capable of chewing food prior to ingestion (Vance and Rothlisberg 2020). The penaeid prawn also has strong claws to break their prey, including cracking the shells of mollusks (Varadharajan and Soundarapandian 2013). As Pattarayingsakul et al. (2019) explain, decapod crustacean stomachs have a filter that selects food that passes further down the digestive tract. Large particles must be masticated and digested to pass the filter, while small particles pass and enter the digestive tract.

Using a pair of legs with chelae and the prawn's mouthparts, banana prawns manipulate and tear mangrove leaves into edible pieces able to be ingested and digested in the stomach efficiently (Kim et al. 2015; Ocasio-Torres et al. 2015). The presence of fragmented pieces expands the surface area exposed for digestive enzymes to facilitate easy digestion (Rubio-Ríos et al. 2017). The presence of food that is not whole but recognizable was facilitated by the habit of banana prawns manipulating prey into sizes that are easily put in the mouth (Hunt et al. 1992). Prawns have legs called maxillipeds with chelae that grasp and tear their prey apart (Hunt et al. 1992; Kembaren and Ernawati 2015). In addition, the morphological structure of maxillipeds influences food intake and food habits (Kim et al. 2015).

Food habits of banana prawns every month about prey availability

The increase in food habits in microalgae from March to April (Table 2) was. also indicated consistently low numbers of mollusk abundance ranging from 18 ind/m^2 to 29.2 ind/m^2, except in March in the mangrove habitat in Yobar, where the abundance reached 44 ind/m^2 (Figure 2). This suggests that banana prawns selectively utilize the available food in the water (Lantang and Merly 2017; Sentosa et al. 2018). The consumption of microalgae as feed by penaeid prawn was not only found in this study but also by Varadharajan and Soundarapandian (2013), However, it was not found in the study by Sentosa et al. (2018). In May, microalgae dominated only in estuarine habitats, attributed to changes in the abundance of available food within these habitats. In estuarine habitats with the lowest mollusk abundance, only 18.80 ind/m^2, banana prawns in this habitat utilized available microalgae as their primary food source (B-Béres et al. 2023). In different habitats, there was a change in the abundance of mollusks from the previous month, ranging from 26.80-112 ind/m^2 (Figure 2). Therefore, the shift in food sources from microalgae to mollusks was driven by the availability of mollusks in the waters (Lantang and Merly 2017). The relationship between the abundance of mollusks obtained in the field and the mollusks found in the stomach of banana prawns indicates a positive correlation (Huang et al. 2024). This suggests that if the abundance of mollusks increases, the percentage of mollusks found in the prawn's stomach will also increase, and vice versa (Table 4). However, in some cases, different occurrences happen, with banana prawns found consuming microalgae despite an increase in mollusk abundance. However, this was related to the size of prawns in each habitat, where juveniles still consume microalgae, unlike mature prawns, which predominantly consume mollusks (Gutierrez et al. 2016; Vance and Rothlisberg 2020). Furthermore, there is a selection of food that will be consumed, where preferred food will still be consumed even though its quantity decreases in the water, and to avoid food competition during predation (Sentosa et al. 2018). In July, the mollusk abundance data did show an increase in all observed habitats, although not reaching the highest value (Figure 2). This indicates that the food source for banana prawns can be consistent across all habitats, depending on the environment's carrying capacity, particularly regarding the availability of sufficient food to support the organisms (Sentosa et al. 2018). In the following month, August, the presence of mollusks in the mangrove habitat demonstrates that the mangrove habitat provides a suitable environment for them (Hasidu et al. 2020). It presents the same data in different habitats as the previous month, with mollusks as the primary food source. Compared to the data on mollusk abundance in estuarine habitats in September, which showed a relatively high abundance of 82.80 ind/m², banana prawns consumed mollusk and microalgae as observed in their stomachs. Observations over 11 months reveal that adult prawns inhabit this habitat, especially in September. Therefore, the increased consumption of mollusks during that month, in addition to the high abundance of mollusks, is also due to the presence of adult prawns. Regarding the finding that microalgae are also a primary food source in this area, it was caused by the fact that this habitat is a living space for juvenile and sub-adult prawns (Lantang et al. 2023). Although the diet was extensive, juveniles and sub-adults consumed microalgae as food compared to adult prawns (Li et al. 2016). One factor that affected the breadth of the diet was the width of the mouth; the wider the mouth, the wider the food consumed (Kwak et al. 2015; Aguilar-Betancourt et al. 2017). The presence of mature prawns in September was associated with the availability of food due to the increased abundance of mollusks and increased water turbidity (Lantang et al. 2023). Meanwhile, the percentage of mud is still low, only 20.58%, so these two variables are the ones influencing the presence of mature prawns in estuarine habitats. Lantang and Pakidi (2015) explain that the availability of food sources in coastal areas to support larvae and juveniles was elucidated. They found that there were 14 species of phytoplankton genus in estuarine habitats, 14 species on sandy beaches in Lampu Satu, 12 species in mangrove habitats at Yobar, and 11 species in mangrove habitats at Bokem. Although the number is still relatively low, there are other food sources available for prawns. Varadharajan and Soundarapandian (2013) reported that *Penaeus monodon* Fabricius 1798, a penaeid prawn at the larval stage, does not engage in predation. During the zoea to mysis stages, it feeds by filtering phytoplankton and zooplankton. In the post-larval stage, this prawn consumes phytoplankton, polychaetes, mollusks, and small crustaceans such as crabs and small prawns. From the post-larval to juvenile stages, it feeds on mollusks, crustacean remnants, detritus, mud, and fish. Additionally, *P. monodon* was referred to as a bottom-feeding omnivorous that preys on seaweed, algae, various crustaceans, mollusks, detritus, sand, mud, and fish.

In December, microalgae served as the main food for banana prawns in estuarine, mangrove habitats in Yobar, and sandy beaches in Payum. In the sandy coastal habitats of Lampu Satu and mangrove habitats in Bokem, the main food consisted of microalgae and mollusks (Table 2). The shift in food habits observed in the sandy beach habitat in Lampu Satu and mangroves habitat in Yobar was attributed to the decline in mollusk abundance within these habitats. Consequently, prawns started consuming microalgae, which had increased in the surrounding waters (Gutierrez et al. 2016). The decline occurred not only in these two habitats but also in other habitats. This indicates a selection of the desired type of food, so even though it had decreased in availability, it was still consumed by banana prawns (Lantang and Merly 2017). In estuarine habitats, this case also occurred in September, when mollusk abundance increased, but the main food sources were still found in two types of food, namely mollusks and microalgae. The food habits of penaeid prawns can vary depending on environmental conditions and food availability, as explained by Varadharajan and Soundarapandian (2013). Regarding food types, Singh (2020) explains that aquatic organisms' food was divided based on four criteria. Firstly, natural food consumed and preferred by aquatic organisms in their natural habitat was the main food. This indicates that this type of food is a favorite for aquatic organisms. Secondly, if food is abundantly available in the water and consumed by aquatic organisms, it is called secondary food. This indicates that aquatic organisms do not always consume this food unless it is plentiful in the water. Thirdly, food that enters the digestive tract coincidentally with other food is called incidental food. Fourthly, food is eaten by aquatic organisms to survive during extreme conditions when primary food is no longer available in the water. According to Samad et al. (2022), food was categorized into three main categories: main food is the dominant food consumed by the prawn, complementary food is consumed in small amounts, and supplementary food is the least consumed. Although there are several criteria for food division, they are essentially the same in explaining this matter. From the explanation, it can be seen that food was divided into the most frequently consumed or dominant foods. This is due these foods are favorites and readily available in nature, as well as the least consumed foods because there other foods are available. Therefore, according to Samad et al. (2022), classifying food into three categories aims to explain the percentage of food found in the stomach according to the existing values. These categories include main food (if IP is in the range >40%), complementary food (if IP is in the range 4-40%), and supplementary food (<4%).

In January, food habits changed in all habitats, with increased microalgae consumption due to decreased mollusk abundance during that month (Gutierrez et al. 2016). This decline in mollusk abundance occurred in all habitats with abundance below 20.50 ind/m^2 (Figure 2). In February, there was no change in food habits in the estuarial habitat from the previous month due to predation on microalgae. This is because this region is rich in nutrients and coincides with increased rainfall, thereby causing the abundance of microalgae to continue increasing (Lantang and Pakidi 2015; Pickens et al. 2021). Another thing to consider is that the prawn caught are relatively small and their diet consists of microalgae. This phenomenon was associated with the month of data collection, as smaller sizes appear in December and persist until February (Hargiyatno et al. 2015; Gutierrez et al. 2016). In other habitats, food availability in mollusks in waters, such as in sandy beach habitats of 36.4 ind/m^2 and mangrove habitats in Bokem of 83.60 ind/m^2, increases mollusk consumption (Figure 2). In March, the main food is mollusks due to the increasing abundance of these foods in the waters from 63-120 ind/m^2 (Gutierrez et al. 2016).

In other food sources, specifically mangrove leaves, it is interesting to note that they were consumed by banana prawns as a complementary food (4-40%) in June (9.41%) and August (4.52%) in mangrove habitats in Yobar. This also occurred in August (15.7%) in mangrove habitats at Bokem, when microalgae consumption was low, making mollusks their primary food source. Except in June at mangrove habitats in Yobar, where the primary food was still found to be microalgae (41.1%) and mollusks (48.22%) (Table 2). This occurred because banana prawns substituted their food source (microalgae) with mangrove leaves (Tavares et al. 2015). The mangrove leaves are often found on the prawn stomach, and the highest ones were obtained from the prawn caught in the mangrove habitat in Bokem, mangrove habitats in Yobar, sandy beaches in Payum and estuaries. The lowest in the sandy beach habitat in Lampu Satu. If reviewed according to food availability, the banana prawn food can be associated with its environment (Sentosa et al. 2018). In this case, mangrove leaf consumption increases in mangrove areas (Tavares et al. 2015). Plant leaves were often found in the stomachs but with a low percentage (Samad et al. 2022). In April, other foods, such as macrophytes, were found as complementary foods in the Bokem mangroves. Macrophytes in a habitat are vital components, provide many benefits as food, and are affected by herbivores in seawater and freshwater habitats (Bakker et al. 2016; Thomaz 2021). Macrophytes were frequently discovered in the stomachs of banana prawns captured in mangrove habitat areas in Bokem, mangrove habitats in Yobar, sandy beaches in Payum, and least in sandy beach habitats in Lampu Satu and estuaries. This suggests the influence of prawn size on their consumption of this feed (Table 2). This data also indicates that prawn larvae, as complementary food, only occur in estuarine habitats in May and January, and on the sandy beach in Lampu Satu in May and July. In contrast, they were not found in other habitats. This relates to food, where prawn larvae are more abundant in estuarine areas and areas adjacent to estuaries (Lantang and Merly 2017; Vance and Rothlisberg 2020; Widiani et al. 2021). Therefore, the consumption of these foods increases in both habitats (Vance and Rothlisberg 2020). Additionally, pieces of prawn larvae were utilized as supplementary food, albeit found at a low percentage (Sajana et al. 2019; Majeed et al. 2022). Predation in prawn larvae is often observed in sandy beach habitats in Lampu Satu, mangrove habitats in Yobar, estuaries, and sandy beaches in Payum. It is lowest in mangrove habitats in Bokem. The food habits of prawn larvae involve cannibalism, where banana prawns prey on smaller or weaker individuals (Kim et al. 2015; Sentosa et al. 2018). The occurrence of cannibalism in penaeid prawns was caused by the lack of food in the waters or empty stomach conditions, as well as a high level of aggressiveness to attack and kill the weak (Varadharajan and Soundarapandian 2013).

The data show that banana prawns eat fish larvae as a complementary food, coinciding with the absence of prawn larvae in the stomach. This indicated that banana prawns replaced prawn larvae by preying on fish larvae. Additionally, they exhibit cannibalistic behavior by preying on fish larvae (Kim et al. 2015). This is also caused by the increased prawn size and improved ability to catch moving prey, which consume larger food items such as fish larvae (Aguilar-Betancourt et al. 2017). The highest consumption of fish larvae was found in banana prawns captured in the mangrove habitat in Bokem, during twelve months of data collection. In the estuarine habitat, sandy beaches in Lampu Satu, and mangrove habitat in Yobar, it was found for ten months. The lowest was found in the sandy beach habitat in Payum, for eight months. This differs from the consumption of prawn larvae, which increases in banana prawns in estuarine habitats, and this was related to the function of the estuarine area as a nursery ground for larvae, making them easy to find (Momeni et al. 2018; Vance and Rothlisberg 2020).

Food habits and their relationship with catches in each habitat

In the estuarine habitats and sandy beaches of Lampu Satu, banana prawns have been observed to consume microalgae and mollusks (Table 3). This behavior was attributed to the abundance of food in their habitat, particularly microalgae, and their ability to utilize food even in limited quantities (Lantang and Merly 2017). The number of mollusks decreased in waters with an abundance of only 36.71 ind/m^2, so prawns utilize the feed available in their habitat (Sentosa et al. 2018). The abundance of mollusks was relatively low in these two habitats compared to others. Therefore, banana prawns did not obtain the appropriate amount and type of food (Lantang and Merly 2017). This can trigger movement in prawn populations due to food availability (Mane et al. 2018). The size of prawns caught in estuary habitats was dominated by juveniles (<32 mmCL) and sub-adults (<38.7 mmCL), as evidenced by the finding of the smallest carapace size of 19.4 mmC (Hargiyatno et al. (2015). In the sandy beach habitat of Lampu Satu, prawns with carapace sizes <38.7 mmCL as sub-adults (Hargiyatno et al. 2015). The distribution of size and habitat in this study was also found in other penaeid prawns, such as *P. monodon*, where juveniles inhabit estuarine environments, while sub-adults typically move to coastal areas (Varadharajan and Soundarapandian 2013). From this size, it can be seen that there were still juvenile or small prawns present and although the variety of food started to change, microalgae was still necessary as a food source (Gutierrez et al. 2016; Santosa 2019). Microalgae are essential organisms as live feed for certain organisms such as crustaceans and certain fish species due to their high content of protein, omega-3, carotenoids, and fatty acids (Tanyaros et al. 2016; Maizatul et al. 2017; Haoujar et al. 2022). So, the food habits of microalgae in the two habitats were also related to nutritional needs (Maizatul et al. 2017; Rachmansyah et al. 2021). In relation to size, which is juvenile, food in microphagous such as microalgae is very important and suitable for the needs of penaeid prawns, especially when other food is not available, although this has not been tested (Hunt et al. 1992). While mollusks serve as food for sub-adult and adult prawns, offering a wider range of food options than to juveniles (Sentosa et al. 2018). The predation phase on mollusks begins during the postlarval stage, with prawns consuming shellfish and snail larvae. At this stage, prawns were more aggressive in foraging than in the previous phase (Kwak et al. 2015). Two types of food were found in estuarine habitats due to increasing sizes and followed by a greater variety of foods consumed by penaeid prawns (O'Brien 1994).

The lowest turbidity among all habitats was recorded in these two habitats, ranging from 436.89-479.79 NTU, with mud comprising only 14.61-14.39% (Figure 3 and Figure 4). The Pearson correlation also indicates that turbidity and mud are positively correlated with the presence of banana prawns (Table 4) (Huang et al. 2024). This positive correlation suggests that an increase in water turbidity and mud will support the presence of banana prawns in the waters, implying an increase in catch yields. The correlation between turbidity, mud percentage, and food elucidates that banana prawns exhibit a preference for waters with high turbidity and predominantly mud substrates (Silaen and Mulya 2018; Lorencová and Horsák 2019). This occurs not only in banana prawns but also in another prawn species, *Penaeus indicus* H.Milne Edwards 1837, as Plagányi et al. (2021) reported. This relates to food availability in mollusks, which increases in waters with high turbidity and mud substrates and is favored by mollusks, especially gastropods (Silaen and Mulya 2018; Widiani et al. 2021). Therefore, these changes will cause prawns to move due to their limited tolerance to environmental changes, insufficient food, and the types of food unsuitable for banana prawns' size. As a result, this affects the low catch in these two habitats (Vance and Rothlisberg 2020).

Mollusks dominate as the primary food source in mangrove habitats at Yobar, sandy beaches at Payum, and mangrove habitats at Bokem (Gutierrez et al. 2016). This dominance was attributed to habitat conditions influenced by environmental variables, including increased turbidity ranging from 582.08 NTU-869.53 NTU, and a corresponding rise in mud percentage from 13.53-22.04% (Figure 3 and Figure 4). This facilitates banana prawns in finding food, namely burrowed mollusks in mud or sand, while avoiding predators (Lorencová and Horsák 2019; Hasidu et al. 2020; Penning et al. 2021). The low correlation value of mud substrate according to Pearson correlation (Huang et al. 2024), is caused by the still low percentage of mud compared to sand (Table 4). This results in banana prawns not obtaining the desired environment, which is a higher percentage of mud than sand (Kenyon et al. 2004). The abundance of mollusks in the mangrove habitat in Yobar and on the sandy beach in Payum ranges from 48.64-50 ind/m^2 (Figure 2). The mangrove habitat in Bokem, with an abundance of 77.43 ind/m^2, enables prawns to consume more mollusks than other habitats. This study differs from Mane et al. (2018), who state that prawns obtain their best food in estuarine areas. However, our study found that prawns thrive in mangrove habitats, particularly in the Bokem area. This disparity can be attributed to variations in research locations and the types of prey identified. For instance, Mane et al. (2018), reported the presence of polychaetes in offshore and nearshore low-depth waters, which were not found in this study. Nevertheless, similar findings were observed in estuarine habitats, where both studies identified mollusks, predominantly gastropods, as the primary food source for prawns.

In the mangrove habitat in Yobar and sandy beach in Payum, the dominance of prawns with carapace size <38.7 mmCL was observed, which included sub-adult prawns, whereas, in the mangrove habitat in Bokem, prawns with a size >38.7 mmCL were identified as adult prawns (Hargiyatno et al. 2015). The size of the banana prawns in the mangrove habitat in Yobar, although classified as sub-adult, was larger than those found in the estuarial habitat and sandy beach in Lampu Satu and Payum. The sub-adult and adult sizes that dominate the prawns caught in these three habitats, with a wider variety of food, did not even dominate in consuming microalgae (Lantang and Merly 2017). This is caused by the change in the feeding pattern of adult *P. merguensis*, which begins to reduce small-sized prey as its food (Wassenberg and Hill 1993). Therefore, the food habits of mollusks reveal four main points. First, the banana prawn is an opportunistic animal that utilizes available food in its environment, whereas mollusks are organisms often abundant in water (Mane et al. 2018). Second, the increase in banana prawn size corresponds to a wider mouth opening, prompting prawns to transition to larger and more diverse diets. They can even take advantage of various types of food available in their environment, including preying on mollusks (Kwak et al. 2015; Aguilar-Betancourt et al. 2017). At this stage, organs such as clamping legs, teeth, and jaws function effectively to break the shells of mollusks and consume their flesh (Lima et al. 2014). Third, the increasing consumption of mollusks in adult prawns indicates that during this phase, the nutritional requirement, particularly protein, is escalating, and mollusks serve as a significant source of essential nutrients (Ab Lah et al. 2017; Tabakaeva et al. 2018; Bityutskaya et al. 2021). Fourth, the increasing need for nutrition is influenced by the life stage, where after the adult phase, it continues to the spawning phase on the sea, which requires considerable energy (Mane et al. 2018; Momeni et al. 2018; Vance and Rothlisberg 2020; Matmor et al. 2022). The increase in mangrove leaf consumption indicates that prawns replace their food source from microalgae to plants (Tavares et al. 2015). The results demonstrate the significant role of habitat for prey, particularly in mangrove habitats, as banana prawns can utilize them directly (Eddy et al. 2017; Sentosa et al. 2018).

Based on the food habits (Table 3), it is evident that the catch of banana prawns increases with the increase in their food source, namely mollusks (Gutierrez et al. 2016). This is because mollusks are one of the important types of food for penaeid prawns. In fact, in the study by Sentosa et al. (2018), it was stated that 71.9% of the food found in the gut of banana prawn prawns is mollusks. However, there was a slight decrease in catches observed in the sandy beach habitat in Payum, which showed an increase compared to the estuarial habitat and sandy beach in Lampu Satu. The highest catches were obtained in mangrove habitats in Bokem, surpassing catches in all other habitats. The Pearson correlation results indicate that mollusks have the highest positive correlation value among all tested food types (Table 4) (Huang et al. 2024). The increased consumption of food consisting of mollusks suggests that catch will increase if mollusk consumption increases, as observed in these three habitats (Gutierrez et al. 2016). This also answers the discovery of microalgae, which correlates negatively with catch results (Table 4) (Huang et al. 2024). This was caused by the dominance of sub-adult prawns in almost all habitats, except in the mangrove habitat in Bokem with adult prawns and in Lampu Satu with juveniles. Meanwhile, in estuarine habitats, although dominant juveniles were found, sub-adults also dominate those areas. Therefore, that size is no longer dominant in consuming this food (Sentosa et al. 2018), although monthly data reveals that the main food is microalgae. One reason is the low abundance of mollusks and also the size of the predators consuming this food is juvenile (Varadharajan and Soundarapandian 2013). Despite being juvenile, consumption of microalgae still occurs (Gutierrez et al. 2016). Therefore, according to the results of statistical tests, if microalgae increase, the catch yield will decrease due to the inadequate availability of food that no longer matches the prawn size. This research also indicates that the increasing consumption of microalgae, caused by the low abundance of mollusks, occurs in estuarine and sandy coastal habitats in Lampu Satu. The impact is that prawns consume available food in their environment, including microalgae, to avoid food competition (Bhakta et al. 2019). On the other hand, the consumption of mangrove leaves correlates positively (Huang et al. 2024), indicating that an increase in mangrove leaf consumption will enhance catch yields (Table 4). These findings reaffirm the role of mangrove habitat as a food provider (Vance and Rothlisberg 2020). Other food sources, namely macrophytes, prawn larvae, and fish larvae, were found to have a negative correlation with catch yields (Huang et al. 2024). This is because these three food sources only serve as supplementary food and were not consumed every month, as indicated by the collected data (Table 2).

The three habitats serve as good locations due to the positive correlation between mollusks and increased catch yields, driven by the highest abundance of mollusks, especially in the mangrove habitat in Bokem, as indicated by this research (Huang et al. 2024). This phenomenon can be attributed to the movement of banana prawn populations, transitioning from other habitats as sub-adult prawns to continue their life cycle as adult prawns in this specific habitat (Vance and Rothlisberg 2020). This movement was supported by food availability, which was determined by the quantity and type of mollusks found in abundance in this area (Mane et al. 2018). Thus, the mangrove habitat in Bokem serves as a residence for adult prawn populations, facilitated by ample food availability, before they migrate to deeper waters to complete their life cycle (Hargiyatno et al. 2015; Momeni et al. 2018; Vance and Rothlisberg 2020). The role of habitat is to protect prey with suitable vegetation such as roots, stems, branches, and leaves, which serve as shelters and natural habitats (Meager et al. 2005; Tavares et al. 2015; Taylor et al. 2018; Lorencová and Horsák 2019; Hasidu et al. 2020). Banana prawn is a natural predator of mollusks (Mane et al. 2018). If the mollusk population is abundant, prawns will easily access plentiful food resources (Gutierrez et al. 2016). This could increase the banana prawn population inhabiting the habitat and provide valuable information for optimizing prawn fishery resources.

In conclusion, 76.12% of microalgae were found intact in the stomachs of banana prawns, while 97.46% of mollusks were not intact or dismembered. Among other food items, such as mangrove leaves, macrophytes, pieces of prawn larvae, and fish larvae, 100% were found to be crushed or dismembered. The main food for banana prawns in estuarial habitats and sandy beaches in Lampu Satu were microalgae and mollusks. Conversely, in mangrove habitats in Yobar, sandy beaches in Payum, and mangrove habitats in Bokem, mollusks were the main food, with microalgae serving as a complementary food. In all habitats, leaves, macrophytes, prawn larvae, and fish were found only as supplementary food sources. This disparity was attributed to the varying availability of food in each habitat and differences in size, with sub-adults and adults demonstrating a wider dietary range than juveniles. The catch of banana prawns increases with a rise in mollusk consumption.

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REFERENCES

Ab Lah R, Smith J, Savins D, Dowell A, Bucher D, Benkendorff K. 2017. Investigation of nutritional properties of three species of marine turban snails for human consumption. Food Sci Nutr 5 (1): 14-30. DOI: 10.1002/fsn3.360.

Aguilar-Betancourt CM, González-Sansón G, Flores-Ortega JR, Kosonoy-Aceves D, Lucano-Ramírez G, Ruiz-Ramírez S, Padilla-Gutierrez S, Curry RA. 2017. Comparative analysis of diet composition and its relation to morphological characteristics in juvenile fish of three lutjanid species in a Mexican Pacific coastal lagoon. Neotrop Ichthyol 15 (4): 1-12. DOI: 10.1590/1982-0224-20170056.

Ahmed NB, Ronsin O, Mouton L, Sicard C, Yéprémian C, Baumberger T, Brayner R, Coradin T. 2017. The physics and chemistry of silica-in-silicates nanocomposite hydrogels and their phycocompatibility. J Mater Chem B 5 (16): 2931-2940. DOI: 10.1039/C7TB00341B.

Alam MI, Rahman MS, Ahmed MU, Debrot AO, Ahsan MN, Verdegem MCJ. 2022. Mangrove forest conservation vs shrimp production: Uncovering a sustainable co-management model and policy solution for mangrove greenbelt development in coastal Bangladesh. For Pol Econ 144 (8): 1-8. DOI: 10.1016/j.forpol.2022.102824.

Amanat Z, Saher NU, Qureshi NA. 2021. Seasonal variation in the abundance and species diversity of penaeid shrimps from the coastal area of Sonmiani Bay Lagoon, Balochistan, Pakistan. Indian J Geo-Marine Sci 50 (3): 228-235. DOI: 10.56042/ijms.v50i03.66132.

Bakker ES, Wood KA, Pagès JF, Veen GF (Ciska)., Christianen MJA, Santamaría L, Nolet BA, Hilt S. 2016. Herbivory on freshwater and marine macrophytes: A review and perspective. Aquat Bot 135 (4): 18-36. DOI: 10.1016/j.aquabot.2016.04.008.

Bardera G, Owen MAG, Pountney D, Alexander ME, Sloman KA. 2019. The effect of short-term feed-deprivation and moult status on feeding behaviour of the Pacific white shrimp (*Litopenaeus vannamei*). Aquaculture 511 (May): 734222. DOI: 10.1016/j.aquaculture.2019.734222.

B-Béres V, Stenger-Kovács C, Buczkó K, Padisák J, Selmeczy GB, Lengyel E, Tapolczai K. 2023. Ecosystem services provided by freshwater and marine diatoms. Hydrobiologia 850 (12): 2707-2733.D OI: 10.1007/s10750-022-04984-9.

Bhakta D, Das SK, Das BK, Nagesh TS, Behera S. 2019. Food and feeding habits of *Otolithoides pama* (Hamilton, 1822) occurring from Hooghly-Matlah estuary of West Bengal, India. Reg Stud Mar Sci 32 (9): 1-10. DOI: 10.1016/j.rsma.2019.100860.

Bityutskaya OE, Donchenko LV, Moshenec KI. 2021. Analysis of technical and chemical characteristics as well as the nutritional value of clams from the Sea of Azov. IOP Conf Ser Earth Environ Sci 640 (3): 1-7. DOI: 10.1088/1755-1315/640/3/032045

Brower J, Zard J, Ende CN. 1990. Field and Laboratory Methods for General Ecology. Third edition. WMC Brown Publishers, United States of America.

Buckland A, Baker R, Loneragan N, Sheaves M. 2017. Standardising fish stomach content analysis: The importance of prey condition. Fish Res 196 (8): 126-140. DOI: 10.1016/j.fishres.2017.08.003

da Silva VEL, Teixeira EC, Batista VS, Fabré NN. 2018. Spatial distribution of juvenile fish species in nursery grounds of a tropical coastal area of the south-western Atlantic. Acta Ichthyol Pisca 48 (1): 9-18. DOI: 10.3750/AIEP/02299.

Darodes de Tailly JB, Keitel J, Owen MAG, Alcaraz-Calero JM, Alexander ME, Sloman KA. 2021. Monitoring methods of feeding behaviour to answer key questions in penaeid shrimp feeding. Rev Aquac 13 (4): 1828-1843. DOI: 10.1111/raq.12546.

De Carvalho C, Keunecke KA, Lavrado HP. 2019. Morphometric variation in pink shrimp populations at Rio de Janeiro coast (SE Brazil): Are they really similar in closer areas? Anais da Academia Brasileira de Ciências 91 (2): 1-17. DOI: 10.1590/0001-3765201920180252.

De Jesús-Carrillo RM, Ocaña FA, Hernández-Ávila I, Mendoza-Carranza M, Sánchez AJ, Barba-Macías E. 2020. Mollusk distribution in four habitats along a salinity gradient in a coastal lagoon from the Gulf of Mexico. J Nat Hist 54 (19-20): 1257-1270. DOI: 10.1080/00222933.2020.1785030.

Dutta S, Paul S, Homechaudhuri S. 2023. Food web structure and trophic interactions of the Northern Bay of Bengal ecosystem. Reg Stud Mar Sci 61 (2): 1-15. DOI: 10.1016/j.rsma.2023.102861.

Eddy TD, Lotze HK, Fulton EA et al. 2017. Ecosystem effects of invertebrate fisheries. Fish Fish 18 (1): 40-53. DOI: 10.1111/faf.12165.

Gutierrez JCS, Ponce-Palafox JT, Pineda-Jaimes NB, Arenas-Fuentes V, Arredondo-Figueroa JL, Cifentes-Lemus JL. 2016. The feeding ecology of penaeid shrimp in tropical lagoon-estuarine systems. Gayana (Concepción) 80 (1): 16-28. DOI: 10.4067/s0717-65382016000100003.

Haoujar I, Haoujar M, Altemimi AB, Essafi A, Cacciola F. 2022. Nutritional, sustainable source of aqua feed and food from microalgae: A mini review. Intl Aquat Res 14 (3): 157-167. DOI: 10.22034/IAR.2022.1958713.1278.

Hargiyatno IT, Anggawangsa RF, Sumiono B. 2015. Spatial-temporal distribution of size and density of banana prawn (*Penaeus merguiensis* De Man, 1907) In Dolak Sub area, Arafura Sea (FMA 718). Jurnal Penelitian Perikanan Indonesia 21 (4): 261-269. DOI: 10.15578/jppi.21.4.2015.261-269.

Hasidu LOAF, Jamili, Kharisma GN, Prasetya A, Maharani, Riska, Rudia LOAP, Ibrahim AF, Mubarak AA, Muhsafaat LO, Anzani L. 2020. Diversity of mollusks (bivalves and gastropods) in degraded mangrove ecosystems of Kolaka District, Southeast Sulawesi, Indonesia. Biodiversitas 21 (12): 5884-5892. DOI: 10.13057/biodiv/d211253.

Heales DS, Vance DJ, Loneragan NR. 1996. Field observations of moult cycle, feeding behaviour, and diet of small juvenile tiger prawns *Penaeus semisulcatus* in the Embley River, Australia. Mar Ecol Prog Ser. 145(12): 43-51. DOI: 10.3354/meps145043

Huang R, Hanif MF, Siddiqui MK, Hanif MF. 2024. On analysis of entropy measure via logarithmic regression model and Pearson correlation for Tri-s-triazine. Comput Mater Sci 240 (5): 112994. DOI: 10.1016/j.commatsci.2024.112994.

Hunt MJ, Winsor H, Alexander CG. 1992. Feeding by penaeid prawns: The role of the anterior mouthparts. J Exp Mar Bio Ecol 160 (1): 33-46. DOI: 10.1016/0022-0981(92)90108-M.

Idrus FA, Aziz F, Lee AC. 2021. Length-weight relationship, condition factor and feeding habit of fishes from mangrove of Santubong estuary, Sarawak, Malaysia. Borneo J Resour Sci Technol. 11(2): 10-18. DOI: 10.33736/BJRST.3700.2021.

Irham M, Quriadi S, Setiawan I, Miswar E, Purnawan S, Affan JM. 2018. The analysis of d90 and d50 sediment grain size in Alue Naga estuary, Banda Aceh City. IOP Conf Ser Earth Environ Sci 216 (9): 1-8. DOI: 10.1088/1755-1315/216/1/012020.

Jamali H, Ahmadifard N, Abdollahi D. 2015. Evaluation of growth, survival and body composition of larval white shrimp (*Litopenaeus vannamei*) fed the combination of three types of algae. Intl Aquat Res 7 (2): 115-122. DOI: 10.1007/s40071-015-0095-9.

Kembaren DD, Ernawati T. 2015. Guide to Identification of Prawn and Other Crustacea. Marine and Fisheries Research and Development Agency of the Ministry of Marine Affairs and Fisheries. Jakarta. Indonesia.

Kenyon RA, Loneragan NR, Manson FJ, Vance DJ, Venables WN. 2004. Allopatric distribution of juvenile red-legged banana prawns (*Penaeus indicus* H. Milne Edwards, 1837) and juvenile white banana prawns (*Penaeus merguiensis* de Man, 1888), and inferred extensive migration, in the Joseph Bonaparte Gulf, Northwest Australia. J Exp Mar Bio Ecol 309 (1): 79-108. DOI: 10.1016/j.jembe.2004.03.012.

Kim SK, Guo Q, Jang IK. 2015. Effect of biofloc on the survival and growth of the postlarvae of three penaeids (*Litopenaeus vannamei*, *Fenneropenaeus chinensis*, and *Marsupenaeus japonicus*) and their biofloc feeding efficiencies, as related to the morphological structure of the third. J Crustac Biol 35 (1): 41-50. DOI: 10.1163/1937240X-00002304.

Kintsu H, Pérez-Huerta A, Ohtsuka S, Okumura T, Ifuku S, Nagata K, Kogure T, Suzuki M. 2021. Functional analyses of chitinolytic enzymes in the formation of calcite prisms in *Pinctada fucata*. Micron 145 (4): 1-8. DOI: 10.1016/j.micron.2021.103063.

Kwak SN, Klumpp DW, Park JM. 2015. Feeding relationships among juveniles of abundant fish species inhabiting tropical seagrass beds in Cockle Bay, North Queensland, Australia. New Zeal J Mar Freshw Res 49 (2): 205-223. DOI: 10.1080/00288330.2014.990467.

Lantang B, Merly SL. 2017. Analysis of penaeid fishing areas based on physical, chemical and biological factors in Payum beach waters-Lampu Satu Merauke Papua District. Agricola 7 (2): 109-120. DOI: 10.35724/ag.v7i2.636

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 (8): 4427-4437. DOI: 10.13057/biodiv/d240824.

Lantang B, Pakidi CS. 2015. Identification of types and influence of oceanographic factors on phytoplankton in Payum beach waters-Lampu Satu beach in Merauke Regency. Agrikan Jurnal Agribisnis Perikan 8(2): 1-7. DOI: 10.29239/j.agrikan.8.2.13-19.

Li M, Wang J, Song S, Li C. 2016. Molecular characterization of a novel nitric oxide synthase gene from *Portunus trituberculatus* and the roles of NO/O_2--generating and antioxidant systems in host immune responses to Hematodinium. Fish Shellfish Immunol 52 (6): 263-277. DOI: 10.1016/j.fsi.2016.03.042.

Lima J de F, Garcia J da S, da Silva TC. 2014. Natural diet and feeding habits of a freshwater prawn (*Macrobrachium carcinus*: Crustacea, Decapoda) in the estuary of the Amazon River. Acta Amaz 44 (2): 235-244. DOI: 10.1590/s0044-59672014000200009.

Lorencová E, Horsák M. 2019. Environmental drivers of mollusc assemblage diversity in a system of lowland lentic habitats. Hydrobiologia 9 (3): 1-16. DOI: 10.1007/s10750-019-3940-9.

Maizatul AY, Mohamed RMSR, Al-Gheethi, Adel A, Hashim MKA. 2017. An overview of the utilisation of microalgae biomass derived from nutrient recycling of wet market wastewater and slaughterhouse wastewater. Intl Aquat Res 9 (3): 177-193. DOI: 10.1007/s40071-017-0168-z.

Majeed A, Liang Z, Liu C, Zhu L, Kalhoro MA, Memon KH. 2022. Feeding behavior and fecundity rate of shrimp scad Alepes Djedaba along Balochistan Coast, Pakistan. J Anim Plant Sci 32 (6): 1763-1769. DOI: 10.36899/JAPS.2022.6.0584.

Mane S, Deshmukh VD, Sundaraam S. 2018. Dimensional relationships of *Fenneropenaeus merguiensis* (de Man,1888) Banana Prawn, from Mumbai Waters. Intl J Life Sci 6 (4): 927-936.

Matmor NA, Manan H, Kasan NA, Jalilah M, Amin-Safwan A, Ikhwanuddin M. 2022. Gonad quality of banana shrimp male broodstock *Penaeus merguiensis* (De Man, 1888) fed different natural diets. Trop Life Sci Res 33 (2): 19-30. DOI: 10.21315/tlsr2022.33.2.2.

McLuckie C, Moltschaniwskyj N, Gaston T, Taylor M. 2021. Effects of reduced pH on an estuarine penaeid shrimp (*Metapenaeus macleayi*). Environ Pollut 208 (10): 1-35. DOI: 10.1016/j.envpol.2020.115929.

Meager JJ, Williamson I, Loneragan NR, Vance DJ. 2005. Habitat selection of juvenile banana prawns, *Penaeus merguiensis* de Man: Testing the roles of habitat structure, predators, light phase and prawn size. J Exp Mar Bio Ecol 324 (2): 89-98. DOI: 10.1016/j.jembe.2005.04.012.

Minello TJ. 2017. Environmental factors affecting burrowing by brown shrimp Farfantepenaeus aztecus and white shrimp *Litopenaeus setiferus* and their susceptibility to capture in towed nets. J Exp Mar Bio Ecol 486: 265-273. DOI: 10.1016/j.jembe.2016.10.010.

Momeni M, Kamrani E, Safaie M, Kaymaram F. Population structure of banana shrimp, *Penaeus merguiensis* de Man, 1888 in the Strait of Hormoz, Persian Gulf. Iran J Fish Sci 17 (1): 47-66. DOI: 10.22092/ijfs.2018.115584.

Mooij PR, de Jongh LD, van Loosdrecht MCM, Kleerebezem R. 2016. Influence of silicate on enrichment of highly productive microalgae from a mixed culture. J Appl Phycol 28 (3): 1453-1457. DOI: 10.1007/s10811-015-0678-2.

Muawanah U, Kasim K, Endroyono S, Rosyidi I. 2021. Technical efficiency of the shrimp trawl fishery in Aru and the Arafura Sea, the Eeastern Part of Indonesia. Asian J Business Environ 11 (2): 5-13. DOI: 10.13106/jbees.

O'Brien CJ. 1994. Ontogenetic changes in the diet of juvenile brown tiger prawns *Penaeus esculentus*. Mar Ecol Prog Ser 112 (1-2): 195-200. DOI: 10.3354/meps112195.

Ocasio-Torres ME, Crowl TA, Sabat AM. 2015. Effects of the presence of a predatory fish and the phenotype of its prey (a shredding shrimp) on leaf litter decomposition. Freshw Biol 60 (11): 2286-2296. DOI: 10.1111/fwb.12654.

Paramasivam P, Chakraborty RD, Ganesan K, Gidda M. 2020. Feeding ecology of deep-water Arabian red shrimp, Aristeus alcocki Ramadan, 1938 (Decapoda: Penaeoidea: Aristeidae) from southwestern India (Arabian Sea). Reg Stud Mar Sci 40: 1-14. DOI: 10.1016/j.rsma.2020.101500.

Parra-Flores, AM. Ponce-Palafox J, Spanopoulos M, Martinez-Cardenas L. 2019. Feeding behavior and ingestion rate of juvenile shrimp of the genus Penaeus (Crustacea: Decapoda). Open Access J Sci 3 (3): 1-7. DOI: 10.15406/oajs.2019.03.00140.

Pattarayingsakul W, Pudgerd A, Munkongwongsiri N, Vanichviriyakit R, Chaijarasphong T, Thitamadee S, Kruangkum T. 2019. The gastric sieve of penaeid shrimp species is a sub-micrometer nutrient filter. J Exp Biol 222 (10): 1-11. DOI: 10.1242/jeb.199638.

Penning E, Govers LL, Dekker R, Piersma T. 2021. Advancing presence and changes in body size of brown shrimp Crangon crangon on intertidal flats in the western Dutch Wadden Sea, 1984-2018. Mar Biol 168 (11): 1-12. DOI: 10.1007/s00227-021-03967-z.

Pickens BA, Carroll R, Taylor JC. 2021. Predicting the distribution of penaeid shrimp reveals linkages between estuarine and offshore marine habitats. Estuaries Coast 44 (8): 2265-2278. DOI: 10.1007/s12237-021-00924-3.

Plagányi É, Deng RA, Hutton T, Kenyon R, Lawrence E, Upston J, Miller M, Moeseneder C, Pascoe S, Blamey L, Eves S. 2021. From past to future: Understanding and accounting for recruitment variability of Australia's redleg banana prawn (*Penaeus indicus*) fishery. ICES J Mar Sci 78 (2): 680-693. DOI: 10.1093/icesjms/fsaa092.

Rachmansyah, Makmur, Taukhid I, Tampangallo BR, Tahe S, Undu MC. 2021. The application of progressive systems in high density vannamei shrimp culture. IOP Conf Ser Earth Environ Sci 860 (1): p.012022. DOI: 10.1088/1755-1315/860/1/012022.

Rubio-Ríos J, Fenoy E, Casas JJ, Moyano FJ. 2017. Modelling hydrolysis of leaf litter by digestive enzymes of the snail *Melanopsis praemorsa*: Combination of response surface methodology and in vitro assays. Mar Freshw Behav Physiol 50 (5-6): 313-328. DOI: 10.1080/10236244.2017.1404429.

Sajana N, Bijoy Nandan S, Radhakrishnan CK. 2019. Feeding behaviour and reproductive biology of the shrimp scad *Alepes djedaba* (Forsskal, 1775) off Cochin coast, Kerala. Indian J Fish 66 (3): 32-40. DOI: 10.21077/ijf.2019.66.3.76411-04.

Samad APA, Fazillah N, Humairani R, Ilhamdi, Hua NF. 2022. Biological aspects and feeding ecology of Sembilang *Plotosus canius* in Langsa Estuary. HAYATI J Biosci 29 (6): 782-788. DOI: 10.4308/hjb.29.6.782-788.

Sentosa AA, Hedianto DA, Suryandari A. 2018. Food habits and trophic interaction of penaeid shrimps communities in the waters of East Aceh. BAWAL Widya Riset Perikanan Tangkap 9 (3): 197-206. DOI: 10.15578/bawal.9.3.2017.197-206.

Silaen SN, Mulya MB. 2018. Density and white shrimp growth pattern (*Penaeus merguiensis*) in Kampung Nipah Waters of Perbaungan North Sumatera. IOP Conf Ser Earth Environ Sci 130: 1-8. DOI: 10.1088/1755-1315/130/1/012044.

Silva JF, Hamilton S, Rocha JV, Borie A, Travassos P, Soares R, Peixoto S. 2019. Acoustic characterization of feeding activity of Litopenaeus vannamei in captivity. Aquaculture 501 (11): 76-81. DOI: 10.1016/j.aquaculture.2018.11.013.

Singh M. 2020. Food and Feeding Habits of Finfish. Bihar Animal Sciences University. India.

Škundrić T, Zagorac D, Zarubica A, Matović B. 2021. Theoretical investigation of mollusk shells: Energy landscape exploration of $CaCO_3$ polymorphs and element substitution: A short review. Adv Technol 10 (1): 73-80. DOI: 10.5937/savteh2101073s.

Spence C. 2021. Explaining seasonal patterns of food consumption. Int J Gastron Food Sci 24 (12): 1-24. DOI: 10.1016/j.ijgfs.2021.100332.

Sreekanth GB, Jaiswar AK, Zacharia PU, Pazhayamadom DG., Chakraborty, S K. 2019. Effect of environment on spatio-temporal structuring of fish assemblages in a monsoon-influenced tropical estuary. Environ Monit Assess 191 (3): 1-27. DOI: 10.1007/s10661-019-7436-x.

Stewart J, Hughes JM, Stanley C, Fowler AM. 2020. The influence of rainfall on recruitment success and commercial catch for the large sciaenid, *Argyrosomus japonicus*, in eastern Australia. Mar Environ Res 157 (2): 1-8. DOI: 10.1016/j.marenvres.2020.104924.

Suárez-Mozo NY, Papiol V, Enriquez C, Brenner M, Simões N. 2023. Molluscs along a salinity gradient in a hypersaline coastal lagoon, southern Gulf of Mexico. J Mar Biol Assoc UK 103 (11): 1-17. DOI: 10.1017/S0025315423000085.

Tabakaeva OV, Tabakaev AV, Piekoszewski W. 2018. Nutritional composition and total collagen content of two commercially important edible bivalve molluscs from the Sea of Japan coast. J Food Sci Technol 55 (12): 4877-4886. DOI: 10.1007/s13197-018-3422-5.

Tanyaros S, Tarangkoon W, Klomkleing T. 2016. Evaluation of flocculated concentrates from intensive shrimp pond water as a substitute for microalgal concentrates in the nursery culture of juvenile oyster (*Crassostrea belcheri*). Intl Aquat Res 8 (2): 149-160. DOI: 10.1007/s40071-016-0130-5.

Tavares DS, Maia RC, Rocha-Barreira C, Matthews-Cascon H. 2015. Ecological relations between mangrove leaf litter and the spatial distribution of the gastropod *Melampus coffeus* in a fringe mangrove forest. Iheringia-Ser Zool 105 (1): 35-40. DOI: 10.1590/1678-4766201510513540.

Taylor MD, Becker A, Moltschaniwskyj NA, Gaston TF. 2018. Direct and indirect interactions between lower estuarine mangrove and saltmarsh habitats and a commercially important penaeid shrimp. Estuaries Coast 41 (3): 815-826. DOI: 10.1007/s12237-017-0326-y.

Taylor MD, Fry B, Becker A, Moltschaniwskyj N. 2017a. Recruitment and connectivity influence the role of seagrass as a penaeid nursery habitat in a wave dominated estuary. Sci Tot Environ 584 (3): 622-630. DOI: 10.1016/j.scitotenv.2017.01.087.

Taylor MD, Fry, B., Becker A, Moltschaniwskyj N. 2017b. The role of connectivity and physicochemical conditions in effective habitat of two exploited penaeid species. Ecol Indic 80 (8): 1-11. DOI: 10.1016/J.ECOLIND.2017.04.050.

Thomaz SM. 2021. Ecosystem services provided by freshwater macrophytes. Hydrobiologia 850 (12): 2757-2777. DOI: 10.1007/s10750-021-04739-y.

Tirtadanu, Amri K, Makmun K, Priatna A, Pane ARP, Wagiyo K, Yusuf HN. 2022. Shrimps distribution and their relationship to the environmental variables in Arafura Sea Shrimps distribution and their relationship to the environmental variables in Arafura Sea. IOP Conf Ser Earth Environ Sci 119 (012003): 1-10. DOI: 10.1088/1755-1315/1119/1/012003.

Tuckey TD, Swinford JL, Fabrizio MC, Small HJ, Shields JD. 2021. Penaeid shrimp in Chesapeake Bay: Population growth and black gill disease syndrome. Mar Coast Fish 13 (3): 159-173. DOI: 10.1002/mcf2.10143.

Vahidi F, Fatemi SMR, Danehkar A, Mashinchian Moradi A, Musavi Nadushan R. 2021. Patterns of mollusks (Bivalvia and gastropods) distribution in three different zones of Harra Biosphere Reserve, the Persian Gulf, Iran. Iran J Fish Sci 20 (5): 1336-1353. DOI: 10.22092/ijfs.2021.124955.

Vance DJ, Rothlisberg PC. 2020. The Biology And Ecology Of The Banana Prawns: *Penaeus merguiensis* De Man and *P. indicus* H. Milne Edwards. Adv Mar Biol 86 (1): 1-139. DOI: 10.1016/bs.amb.2020.04.001.

Varadharajan D, Soundarapandian P. 2013. Science of advance in aqua farming study of food and feeding habits of jumbo tiger shrimp, *Penaeus monodon* (Fabricius, 1798) from Parangipettai, South East coast of India. J Aquac Res Dev 4 (6): 4-11. DOI: 10.4172/2155-9546.1000196.

Wassenberg TJ, Hill BJ. 1993. Diet and feeding behaviour of juvenile and adult banana prawns *Penaeus merguiensis* in the Gulf of Carpentaria, Australia. Mar Ecol Prog Ser 94 (3): 287-295. DOI: 10.3354/meps094287.

Wibowo DN, Rukayah S, Rahayu NL, Mote N. 2022. Feeding ecology of *Neoarius leptaspis* in the Rawa Biru Lake, Merauke, Indonesia. Biodiversitas 23 (3): 1327-1335. DOI: 10.13057/biodiv/d230317.

Widiani I, Barus T, Wahyuningsih H. 2021. Population of white shrimp (*Penaeus merguiensis*) in a mangrove ecosystem, Belawan, North Sumatra, Indonesia. Biodiversitas 22 (12): 5367-5374. DOI: 10.13057/biodiv/d221218.

Wongyai N, Jutagate A, Grudpan C, Jutagate T. 2020. Condition index, reproduction and feeding of three non-obligatory Riverine Mekong Cyprinids in different environments. Trop Life Sci Res 31 (2): 159-173. DOI: 10.21315/tlsr2020.31.2.8.