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# Penaeid shrimps (Crustacea: Decapoda: Penaeidae) from the coast of West Kalimantan, Indonesia

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ABSTRACT: Penaeid shrimps (Crustacea: Decapoda: Peneidae) are crustaceans that live in estuaries, rivers, and marine areas. West Kalimantan coastal waters hold a significant potential for penaeid shrimp production. Eight genera containing 16 species of penaeid shrimps were found during recent study. *Parapenaeopsis gracillima* Nobili, 1903 is dominated the mini trawl catch, while *Penaeus merguiensis* De Man, 1888 is dominated the trammel net catch. Only three species of penaeid shrimp are dominated by males: *Metapenaeus brevicornis* H. Milne Edwards, 1837, *P. gracillima*, and *P. merguiensis*, while females dominate in other species. The results of the canonical correspondence analysis showed no significant effects of environmental variables to the distribution of shrimp species. This study provides baseline information on economically important penaeid shrimp from Dusun Besar waters, North Kayong, West Kalimantan for sustainable management of the bioresources.
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KEY WORDS: allometric growth, environmental variables, penaeid shrimp, West Kalimantan.

# Пенеидные креветки (Crustacea: Decapoda: Penaeidae) побережья Западного Калимантана, Индонезия

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РЕЗЮМЕ: Пенеидные креветки (Crustacea: Decapoda: Peneidae) — ракообразные, обитающие в эстуариях, реках и морских акваториях. Прибрежные воды Западного Калимантана обладают значительным потенциалом для разведения пенеидных креветок. Восемь родов, содержащих 16 видов пенеидных креветок, были обнаружены в ходе нашего исследования этого региона. *Parapenaeopsis gracillima* Nobili, 1903 доминирует в уловах мини-тралов, а *Penaeus merguiensis* De Man, 1888 — в уловах траловых сетей. Только у трех видов пенеидных креветок доминируют самцы: *Metapenaeus brevicornis* H. Milne Edwards, 1837, P. *gracillima* и P. *merguiensis*, в то время как у остальных видов — самки. Анализ канонического соответствия показал корреляцию между встречаемостью пенеидных креветок и такими факторами среды, как глубина, расстояние до ближайших мангровых зарослей, мутность, соленость, прозрачность, электропроводность воды и общее количество растворенных твердых веществ. Данное исследование предоставляет предварительную информацию об экономически важных пенеидных креветках из вод Дусун Бесар, Северный Кайонг, Западный Калимантан, полезную для эффективного менеджмента биоресурсов.
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КЛЮЧЕВЫЕ СЛОВА: аллометрический рост, экологические переменные, пенеидные креветки, Западный Калимантан.

## Introduction

Penaeid shrimps (Crustacea: Decapoda: Penaeidae) hold a very strong economic value (Teikwa, Mgaya, 2004; Okpei *et al*., 2020). During their lifespan (of one to two years) in tropical areas, penaeid shrimps undergo multiple migrations influenced by ecological factors such as tides, temperature, rainfall, food availability etc. (Dall *et al*., 1990). The life cycle of penaeid shrimp begins with spawning in the ocean, followed by a juvenile stage where they migrate to inshore waters (coastal and estuarine) for growth and development. Once they reach adulthood, they return to the sea to mature and spawn (Garcia, 1985; Dall *et al*., 1990; Manzano-Sarabia

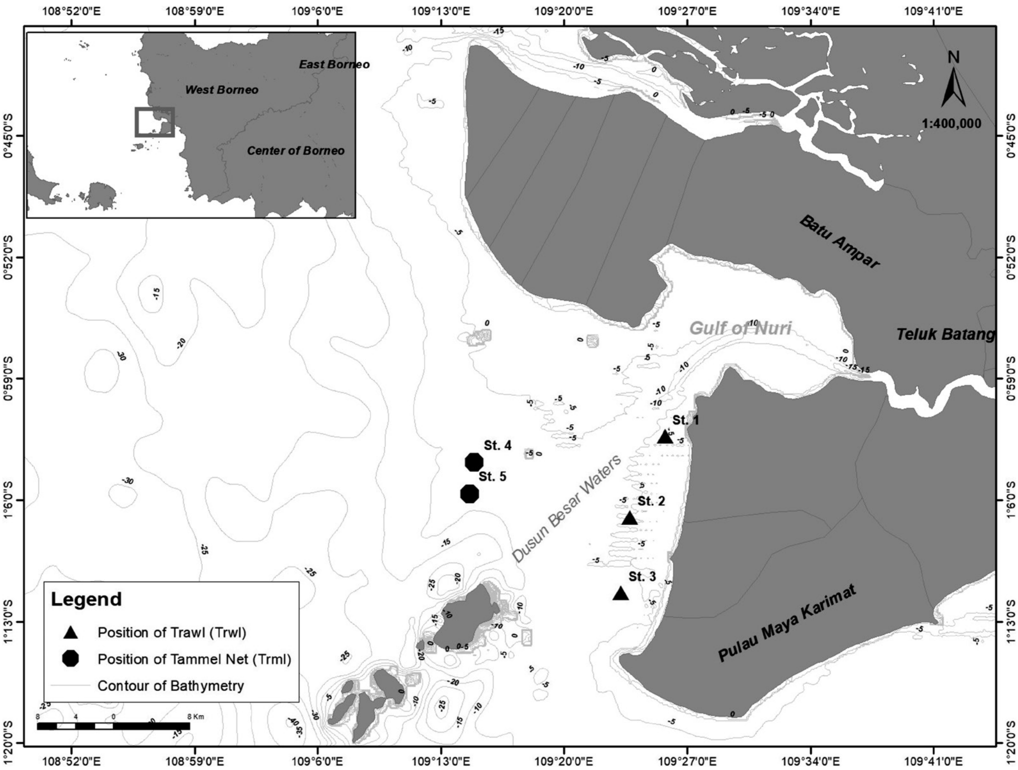


Fig. 1. Map of the study area showing the sampling sites.
Рис. 1. Карта района исследований с указанием мест отбора проб.

*et al*., 2007; Taylor *et al*., 2016). Understanding the habitat distribution and biology of penaeid shrimp helps close the knowledge gaps regarding shrimp populations in aquatic environments, supports basic estimations for stock assessment, and is essential for effective management (Bayhan *et al*., 2005; Kevrekidis, Thessalou-Legaki, 2011; Montgomery *et al*., 2012; Okpei *et al*., 2020).

Extensive studies on penaeid shrimps have been conducted in Indonesian waters. *Penaeus merguiensis* De Mann, 1888 has been identified as the dominant species in trammel net catches (Fauziyah *et al*., 2018). In the Langsa mangrove ecosystem of Aceh Province, three species of penaeid shrimp, *P. indicus* H. Milne Edwards, 1837, *P. merguiensis*, and *P. monodon* Fabricius, 1798, were found to be dominant (Damora *et al*., 2019). A study in Pemangkat waters (West Kalimantan) revealed two genera — *Metapenaeus* H. Milne Edwards, 1837, and *Penaeus* Fabricius, 1798 and demonstrated that their abundance was correlated with various environmental factors, such as phytoplankton abundance, water salinity, and pH (Kembaren, Sumiono, 2012). However, information on penaeid shrimps in West Kalimantan remains limited, with investigations conducted solely in Pemangkat Regency, North Kayong Regency, Ketapang Regency, and Kubu Raya Regency (Kembaren, Sumiono, 2012; Hedianto, Mujiyanto, 2016). Studies in other areas of West Kalimantan, such as Dusun Besar waters (part of North Kayong), have not yet been conducted.

The aim of this study is to investigate the species composition and biology of penaeid shrimps in the waters of North Kayong, West Kalimantan as well as the environmental factors affecting their distribution.

## Materials and Methods

STUDY AREA. The study was conducted in October 2021 in the coastal waters of Dusun Besar, North Kayong Regency, West Kalimantan (Fig. 1). The

Table 1. Environment factors at five stations from North Kayong Regency waters, West Kalimantan.
Таблица 1. Параметры окружающей среды, измеренные на пяти станциях в водах округа Северный Кайонг, Западный Калимантан.

| **Variables** | **Station** | | | | |
|---|---|---|---|---|---|
| | **1** | **2** | **3** | **4** | **5** |
| Depth (m) | 1.5 | 4.3 | 4.9 | 8.8 | 10 |
| Distance from nearest mangrove (km) | 2.8 | 5.5 | 4.7 | 23 | 23 |
| Temperature (°C) | 29.5 | 29.9 | 30.6 | 30.4 | 30.9 |
| Water clarity (m) | 0.1 | 0.5 | 1 | 2.1 | 2.2 |
| Conductivity (µS/cm) | 42,065 | 45,838 | 46,802 | 47,289 | 48,564 |
| Turbidity (NTU) | 860 | 25.6 | 13.4 | 4.61 | 6.46 |
| TDS (mg/L) | 25,220 | 27,248 | 27,456 | 27,885 | 28,379 |
| ORP (mV) | 228.1 | 154.6 | 134.4 | 198.8 | 163 |
| Salinity (ppt) | 25 | 25 | 25 | 26 | 26 |
| pH | 7.5 | 8 | 8 | 8 | 8 |
| DO (mg/L) | 4.16 | 6.12 | 6.85 | 7.21 | 6.82 |

fishing location was determined from information on fishing grounds provided by local fishermen. Dusun Besar waters in West Kalimantan are characterised by a mixed sand-mud substrate and significant marine litter (Hedianto *et al*., 2014). Samples were collected during the west monsoon season, the optimal time for fishing in southern West Kalimantan waters, including Dusun Besar waters, due to calm conditions. In contrast, fishing activity tends to decrease during the east monsoon season (Wiadnyana *et al*., 2022).

DATA COLLECTION. Specimens were collected with two types of fishing gears, a mini bottom trawl and a trammel net, from five research stations. The mini bottom trawl was employed at stations 1–3, while the trammel net was used at stations 4 and 5.

The mini bottom trawl featured a 2-inch mesh throughout its entire length and was deployed at depths of 2–5 m, approximately 1–5 nautical miles from the coast. The trawl was towed for 30 min at speeds of 2–3 knots, yielding a total catch of 38 kg of fish and shrimp, with catches at stations 1, 2, and 3 being 8, 10, and 20 kg, respectively.

The trammel nets, each 500 m long, were towed by two boats over fishing grounds exceeding 5 m in depth, located approximately 10–15 nautical miles from the coastline. The mesh sizes of the trammel nets ranged from 4 to 5 inches, and the fishing process took about one hour. Catches from the trammel nets at stations 4 and 5 amounted to 10 and 16 kg of shrimp and fish, respectively. The placement of the fishing gear was also influenced by tidal conditions following Tjahjo *et al*. (2023).

In situ measurements of several environmental parameters were taken: depth (m), distance to the nearest mangrove (km), temperature (°C), conductivity (µS/cm), turbidity (NTU), total dissolved solids (TDS; mg/L), oxidation-reduction potential (ORP; mV), salinity (ppt), pH, and dissolved oxygen (mg/L) were all measured at each research site (Table 1).

Species were identified based on morphological characters (Chan, 1998). The scientific names of the identified species, particularly those of *Parapenaeopsis* spp., were verified against existing literature (Sakai, Shinomiya, 2011; Palomares, Pauly, 2024). Morphometric assessments were conducted to measure carapace length (cm) and weight (g) to describe the size distribution of the captured shrimp. The sex of each specimen was also identified to determine the sex ratio.

DATA ANALYSIS. The Carapace Length-Weight (CLW) relationships were calculated as $W = a \times CL^b$, where CL — the carapace length, W — the total weight, a and b — the equation parameters. The growth type was described by performing a *t* test at a 95% confidence interval ($\alpha = 0.05$) (Ihsanoğlu, 2021; Putri, Syamsudin, 2021). We calculated the CLW relationship and condition factor for shrimp species represented by more than 30 individuals to establish a reliable length-weight relationship, as Froese (2006) described.

The relationships between environmental variables and study sites were analysed by a Principal Component Analysis (PCA) (Alvarez *et al*., 2017). To explore the relationships between environmental variables and the presence of certain species at sampling sites, a Canonical Correspondence Analysis (CCA) was performed (Zimina *et al*., 2015). All statistical tests were conducted using PAST 4.14 software (Hammer *et al*., 2001).

Table 2. Composition of penaeid collected from five stations.
Таблица 2. Состав пенеид, собранных на пяти станциях.

| No. | Genera/Species | Shrimp composition (%) | | | | | |
|---|---|---|---|---|---|---|---|
| | | St. 1 | St. 2 | St. 3 | St. 4 | St. 5 | Total |
| I. | *Metapenaeopsis* | | | | | | |
| | 1. *Metapenaeopsis toloensis* Hall, 1962 | | 0.7 | | | | 0.2 |
| II. | *Metapenaeus* | | | | | | |
| | 2. *Metapenaeus affinis* H. Milne Edwards, 1837 | 20.8 | 6.2 | 9.8 | | | 6.7 |
| | 3. *Metapenaeus brevicornis* H. Milne Edwards, 1837 | 27.6 | 2.3 | 5.3 | | | 6.2 |
| | 4. *Metapenaeus dobsoni* Miers, 1878 | 0.9 | 3.9 | | | | 1.1 |
| | 5. *Metapenaeus ensis* De Haan, 1844 | | | | 16.6 | | 3 |
| | 6. *Metapenaeus lysianassa* De Man, 1888 | 4.1 | 11.1 | | | | 3.3 |
| | 7. *Metapenaeus tenuipes* Kubo, 1949 | 19 | | 6.7 | | | 4,4 |
| III. | *Parapenaeopsis* | | | | | | |
| | 8. *Parapenaeopsis stylifera* H. Milne Edwards, 1837 | | | 0.4 | | | 0.1 |
| | 9. *Parapenaeopsis gracillima* Nobili, 1903 | 22.6 | 0.3 | 71.6 | | | 16.4 |
| IV. | *Alcockpenaeopsis* | | | | | | |
| | 10. *Alcockpenaeopsis hungerfordi* Alcock, 1905 | 1.4 | 1.3 | 0.9 | | | 0.7 |
| V. | *Kishinouyepenaeopsis* | | | | | | |
| | 11. *Kishinouyepenaeopsis maxillipedo* Alcock, 1905 | | 0.3 | 2.2 | | | 0.5 |
| | 12. *Kishinouyepenaeopsis cornuta* Kishinouye, 1900 | | 46.6 | 0.9 | | | 11.1 |
| VI. | *Mierspenaeopsis* | | | | | | |
| | 13. *Mierspenaeopsis hardwickii* Miers, 1878 | 0.9 | | | | | 0.2 |
| | 14. *Mierspenaeopsis sculptilis* Heller, 1862 | 2.7 | 26.6 | 1.8 | | | 7 |
| VII. | *Trachypenaeus* | | | | | | |
| | 15. *Trachypenaeus granulosus* Haswell, 1879 | | | 0.4 | | | 0.1 |
| VIII. | *Penaeus* | | | | | | |
| | 16. *Penaeus merguiensis* De Man, 1888 | | 0.7 | | 83.4 | 100 | 39.1 |
| | **N (ind.)** | **221** | **305** | **225** | **235** | **308** | **1294** |
| | **N species** | **9** | **11** | **10** | **2** | **1** | **16** |

## Results

SPECIES COMPOSITION. Eight genera containing 16 species of penaeid shrimps were identified (Table 2). *Penaeus merguiensis* was the most common species (39.1% of total catch), while *Parapenaeopsis stylifera* and *Trachypenaeus granulosus* represented rare taxa (0.1% of total catch). The number of penaeid shrimp species identified at stations 1–3 was higher than at the stations 4 and 5 (Table 2). This discrepancy reflects use of different fishing gears at the two groups of research locations: the trammel net tends to be more selective, resulting in fewer shrimp species captured as compared to the mini trawls.

Mini trawls captured 15 species of penaeid shrimps, whereas trammel nets were limited to only two dominant shrimp species (Table 3). Variations in penaeid shrimp species were,

Table 3. Composition, carapace length, total weight, and weight of shrimp species from two fishing gears from North Kayong Waters, West Kalimantan.
Таблица 3. Состав, длина панциря, общий вес и масса видов креветок, собранных двумя типами орудий лова в Норт-Кайонг-Уотерс, Западный Калимантан.

| Shrimp species | Composition | | Carapace length (cm) | | Total weight (g) | | Mean weight (g) | |
|---|---|---|---|---|---|---|---|---|
| | N | % | Mean ± SD | Range | g | % | Mean ± SD | Range |
| **Mini trawl** | | | | | | | | |
| *A. hungerfordi* | 9 | 1.20 | 1.56 ± 0.21 | 1.20–1.80 | 19.85 | 0.64 | 2.21 ± 0.72 | 0.99–3.29 |
| *K. cornuta* | 144 | 19.17 | 1.91 ± 0.35 | 1.00–2.90 | 577.25 | 18.49 | 4.01 ± 1.79 | 0.67–9.74 |
| *K. maxillipedo* | 6 | 0.80 | 1.95 ± 0.48 | 1.40–2.70 | 29.37 | 0.94 | 4.90 ± 3.76 | 1.60–12.02 |
| *M. toloensis* | 2 | 0.27 | 1.30 ± 0.14 | 1.20–1.40 | 2.32 | 0.07 | 1.16 ± 0.41 | 0.87–1.45 |
| *M. affinis* | 87 | 11.58 | 1.92 ± 0.38 | 1.30–2.90 | 487.52 | 1.61 | 5.60 ± 3.09 | 1.24–14.84 |
| *M. brevicornis* | 80 | 10.65 | 1.74 ± 0.11 | 1.40–2.10 | 321.93 | 10.31 | 4.02 ± 0.51 | 2.59–6.30 |
| *M. dobsoni* | 14 | 1.86 | 2.41 ± 0.31 | 1.80–2.80 | 133.67 | 4.28 | 9.55 ± 2.71 | 3.86–12.72 |
| *M. lysianassa* | 43 | 5.73 | 1.17 ± 0.28 | 0.70–2.00 | 66.77 | 2.14 | 1.55 ± 1.00 | 0.33–4.98 |
| *M. tenuipes* | 57 | 7.59 | 1.93 ± 0.44 | 1.20–3.10 | 366.82 | 11.75 | 6.44 ± 3.79 | 1.75–17.59 |
| *M. hardwickii* | 2 | 0.27 | 1.45 ± 0.35 | 1.20–1.70 | 4.29 | 0.14 | 2.15 ± 1.32 | 1.21–3.08 |
| *M. sculptilis* | 91 | 12.12 | 1.93 ± 0.45 | 1.00–4.00 | 388.98 | 12.46 | 4.27 ± 3.42 | 0.49–24.71 |
| *P. stylifera* | 1 | 0.13 | 1.30 | | 1.15 | 0.04 | 1.15 | |
| *P. gracillima* | 212 | 28.23 | 1.68 ± 0.21 | 1.10–2.20 | 663.94 | 21.26 | 3.13 ± 0.94 | 0.97–5.70 |
| *P. merguiensis* | 2 | 0.27 | 3.75 ± 0.21 | 3.60–3.90 | 55.05 | 1.76 | 27.53 ± 16.62 | 15.77–39.28 |
| *T. granulosus* | 1 | 0.13 | 2.10 | | 3.43 | 0.11 | 3.43 | |
| **Trammel net** | | | | | | | | |
| *M. ensis* | 39 | 7.18 | 3.27 ± 0.48 | 2.10–4.02 | 812.90 | 5.41 | 20.84 ± 6.72 | 6.26–34.96 |
| *P. merguiensis* | 504 | 92.82 | 3.27 ± 0.47 | 2.30–5.40 | 14,216.6 | 94.59 | 28.21 ± 10.99 | 14.11–88.71 |
| **Grand Total** | **1294** | | | | **18,151.84** | | | |

therefore, more commonly found in the mini trawl catch. *Parapenaeopsis gracillima* was the most abundant species in the mini trawl catch, comprising 28.2% of the total individuals and 21.3% of the biomass. In contrast, *P. merguiensis* dominated the trammel net catch, representing 92.8% of the total individuals and 94.6% of the biomass.

Significant differences were also observed in the sizes of the shrimps collected with mini trawls and trammel nets (Table 3). The species of shrimp captured with mini trawls primarily consisted of relatively small individuals (carapace lengths of 0.7–3.1 cm) across 14 species. Only *P. merguiensis* was represented by large individuals (carapace lengths of 3.6–3.9 cm) in the mini trawl catches, though these were present in limited quantities, accounting for only 0.27% of the overall sample. The trammel net yielded larger shrimp, specifically *P. merguiensis* and *Metapenaeus ensis* De Haan, 1844.

SEX RATIO OF PENAEID SHRIMP. Females tend to dominate the catches of nine species of penaeid shrimp: *Metapenaeus affinis*, *M. dobsoni*, *M. ensis*, *M. lysianassa*, *M. tenuipes*, *Mierspenaeopsis sculptilis*, *Kishinouyepenaeopsis maxillipedo*, *K. cornuta* and *Alcockpenaeopsis hungerfordi*. Meanwhile, *Metapenaeus brevicornis*, *Parapenaeopsis gracillima* and *P. merguiensis* are dominated by males. Females tend to be larger than males, as shown by the average carapace lengths by sex (Table 4).

Table 4. Sex ratio and summary statistics of the morphometric parameters, weight and carapace length in males and females of penaeid shrimp from West Kalimantan.
Таблица 4. Соотношение полов и сводная статистика морфометрических показателей, массы, и длины панциря самцов и самок креветок Западного Калимантана.

| No. | Shrimp species | N | Sex ratio (Male = 1) | Carapace length (cm) | | Mean weight (g) | |
|---|---|---|---|---|---|---|---|
| | | | | Mean ± SD | Range | Mean ± SD | Range |
| **Mini trawl** | | | | | | | |
| 1 | *A. hungerfordi* | | | | | | |
| | M | 4 | 1.25 | 1.50 ± 0.24 | 1.20–1.70 | 2.00 ± 0.88 | 0.99–3.00 |
| | F | 5 | | 1.60 ± 0.19 | 1.30–1.80 | 2.37 ± 0.61 | 1.80–3.29 |
| 2 | *K. cornuta* | | | | | | |
| | M | 46 | 2.13 | 1.60 ± 0.21 | 1.10–2.30 | 2.48 ± 1.00 | 0.67–6.37 |
| | F | 98 | | 2.05 ± 0.32 | 1.00–2.90 | 4.73 ± 1.62 | 0.71–9.74 |
| 3 | *K. maxillipedo* | | | | | | |
| | M | 2 | 2.00 | 1.60 ± 0.28 | 1.40–1.80 | 2.80 ± 1.70 | 1.60–4.00 |
| | F | 4 | | 2.13 ± 0.49 | 1.50–2.70 | 5.94 ± 4.27 | 2.00–12.02 |
| 4 | *M. toloensis* | | | | | | |
| | M | 1 | 1.00 | 1.40 | | 1.45 | |
| | F | 1 | | 1.20 | | 0.87 | |
| 5 | *M. affinis* | | | | | | |
| | M | 23 | 2.78 | 1.90 ± 0.30 | 1.40–2.40 | 5.66 ± 1.98 | 2.83–9.79 |
| | F | 64 | | 1.93 ± 0.41 | 1.30–2.90 | 5.58 ± 3.42 | 1.24–14.84 |
| 6 | *M. brevicornis* | | | | | | |
| | M | 75 | 0.07 | 1.74 ± 0.11 | 1.40–1.90 | 4.03 ± 0.41 | 2.59–5.25 |
| | F | 5 | | 1.78 ± 0.19 | 1.60–2.10 | 3.97 ± 1.39 | 2.64–6.30 |
| 7 | *M. dobsoni* | | | | | | |
| | M | 1 | 13.00 | 1.80 | | 3.86 | |
| | F | 13 | | 2.45 ± 0.26 | 1.80–2.80 | 9.99 ± 2.25 | 4.72–12.72 |

Table 4 (continued).
Таблица 4 (окончание).

| No. | Shrimp species | N | Sex ratio (Male = 1) | Carapace length (cm) | | Mean weight (g) | |
|---|---|---|---|---|---|---|---|
| | | | | Mean ± SD | Range | Mean ± SD | Range |
| **Mini trawl** | | | | | | | |
| 8 | *M. lysianassa* | | | | | | |
| | M | 9 | 3.78 | 1.14 ± 0.19 | 1.00–1.60 | 1.37 ± 0.90 | 0.80–3.68 |
| | F | 34 | | 1.17 ± 0.30 | 0.70–2.00 | 1.60 ± 1.04 | 0.33–4.98 |
| 9 | *M. tenuipes* | | | | | | |
| | M | 23 | 1.48 | 1.63 ± 0.13 | 1.20–1.90 | 3.48 ± 0.65 | 2.49–5.57 |
| | F | 34 | | 2.14 ± 0.46 | 1.30–3.10 | 8.44 ± 3.73 | 1.75–17.59 |
| 10 | *M. hardwickii* | | | | | | |
| | F | 2 | – | 1.45 ± 0.35 | 1.20–1.70 | 2.15 ± 1.32 | 1.21–3.08 |
| 11 | *M. sculptilis* | | | | | | |
| | M | 32 | 1.84 | 1.68 ± 0.24 | 1.20–2.80 | 2.88 ± 1.38 | 1.21–9.89 |
| | F | 59 | | 2.06 ± 0.48 | 1.00–4.00 | 5.03 ± 3.93 | 0.49–24.71 |
| 12 | *P. stylifera* | | | | | | |
| | F | 1 | – | 1.30 | | 1.15 | |
| 13 | *P. gracillima* | | | | | | |
| | M | 112 | 0.89 | 1.55 ± 0.11 | 1.10–1.70 | 2.61 ± 0.53 | 1.17–3.85 |
| | F | 100 | | 1.82 ± 0.20 | 1.10–2.20 | 3.72 ± 0.96 | 0.97–5.70 |
| 14 | *P. merguiensis* | | | | | | |
| | F | 2 | – | 3.75 ± 0.21 | 3.60–3.90 | 27.53 ± 16.62 | 15.77–39.28 |
| 15 | *T. granulosus* | | | | | | |
| | F | 1 | - | 2.10 | | 3.43 | |
| **Trammel net** | | | | | | | |
| 1 | *M. ensis* | | | | | | |
| | M | 2 | 18.50 | 2.40 ± 0.14 | 2.30–2.50 | 10.16 ± 2.06 | 8.70–11.62 |
| | F | 37 | | 3.31 ± 0.45 | 2.10–4.02 | 21.42 ± 6.40 | 6.26–34.96 |
| 2 | *P. merguiensis* | | | | | | |
| | M | 293 | 0.72 | 3.00 ± 0.24 | 2.30–3.90 | 21.69 ± 3.50 | 14.11–40.89 |
| | F | 211 | | 3.64 ± 0.45 | 2.60–5.40 | 37.26 ± 11.44 | 16.79–88.71 |

CARAPACE LENGTH-WEIGHT RELATIONSHIP AND CONDITION FACTOR OF PENAEID SHRIMPS. Table 5 shows the Carapace Length-Weight relationship for penaeid shrimp overall in Dusun Besar waters, West Kalimantan. The determination coefficient ($r^2$) values varied from 0.85 in *P. gracillima* to 0.99 in *M. sculptilis*. Of the nine species, seven had $r^2$ values greater than 0.90, while two had $r^2$ values less than 0.90. The estimated b value ranged from 1.09 for *M. brevicornis* to 2.71 for *M. affinis*. The b value was significantly different from 3 (b < 3) for all penaeid species ($p < 0.05$), showing negative allometric growth. The mean condition factor for *M. lysianassa* was the highest among all measured species (1.02), while the lowest mean condition factor was observed in *M. affinis*.

HABITAT CHARACTERISTICS. The PCA results (Fig. 2) illustrate the environmental fac-

Table 5. The length-weight equation, allometry type, condition factor value (K) of nine shrimp species from Dusun Besar Waters, West Kalimantan.
Таблица 5. Соотношение длины и веса, тип аллометрии и значение фактора упитанности (K) девяти видов креветок из Дусун-Бесар-Уотерс, Западный Калимантан.

| No | Shrimp species | N | Length-weight Equation | $r^2$ | Allometry | K | |
|---|---|---|---|---|---|---|---|
| | | | | | | Range | Mean±SD |
| 1 | *K. cornuta* | 144 | log W = –0.174 + 2.6532 log L | 0.9526 | Negative | 0.6923–1.5307 | 1.0063±0.1130 |
| 2 | *M. affinis* | 87 | log W = –0.06096 + 2.7083 log L | 0.9498 | Negative | 0.5852–2.0419 | 0.9002±0.1946 |
| 3 | *M. brevicornis* | 80 | log W = 0.33954 + 1.0894 log L | 0.3453 | Negative | 0.6368–1.2847 | 1.0053±0.1004 |
| 4 | *M. ensis* | 38 | log W = 0.0929 + 2.3722 log L | 0.9663 | Negative | 0.6888–1.4562 | 0.9981±0.1111 |
| 5 | *M. lysianassa* | 43 | log W = -0.0221 + 2.4709 log L | 0.9436 | Negative | 0.6629–1.7274 | 1.0181±0.2016 |
| 6 | *M. tenuipes* | 57 | log W = 0.0523 + 2.4938 log L | 0.9556 | Negative | 0.8064–1.4190 | 1.0112±0.1568 |
| 7 | *M. sculptilis* | 91 | log W = –0.1563 + 2.5878 log L | 0.9889 | Negative | 0.5082–1.2245 | 1.0066±0.1084 |
| 8 | *P. gracillima* | 212 | log W = –0.0408 + 2.3240 log L | 0.8553 | Negative | 0.6674–1.6549 | 1.0077±0.1266 |
| 9 | *P. merguiensis* | 506 | log W = 0.2762 + 2.2485 log L | 0.8719 | Negative | 0.4552–1.5911 | 1.0088±0.1282 |

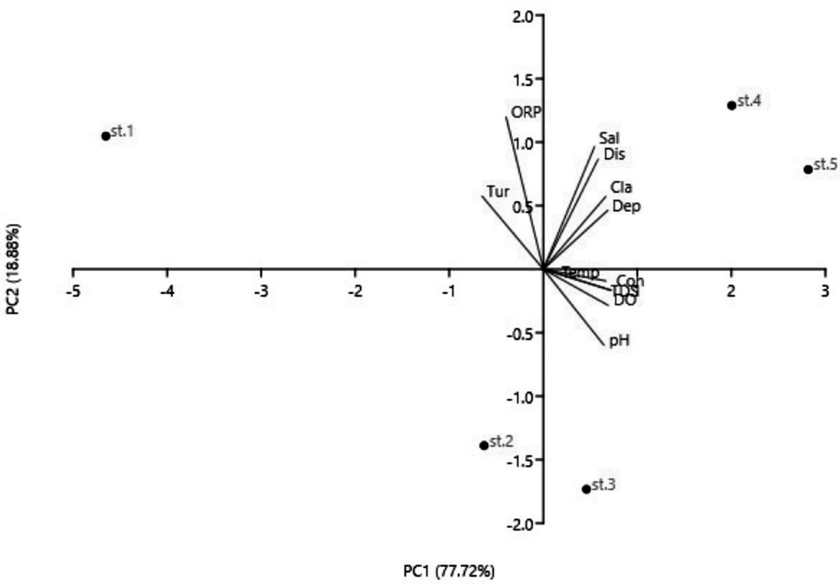


Fig. 2. Principal component analysis (PCA) of the environmental factors.
Abbreviations: Cla — water clarity; Con — conductivity; Dep — water depth; Dis — distance to the nearest mangroves; DO — dissolved oxygen; ORP — oxidation reduction potential; Sal — salinity; TDS — total dissolved solids; Temp — water temperature; Tur — turbidity).
Рис. 2. Анализ главных компонент (PCA) факторов окружающей среды.
Сокращения: Cla — прозрачность воды; Con — проводимость; Dep — глубина воды; Dis — расстояние до ближайших мангровых зарослей; DO — растворенный кислород; ORP — окислительно-восстановительный потенциал; Sal — соленость; TDS — общее количество растворенных веществ; Temp — температура воды; Tur — мутность.

Table 6. Loading value of PCA analysis of two principal components (PC1 and PC2).
Таблица 6. Значение нагрузок переменных окружающей среды на две главные компоненты (PC1 и PC2).

| **Environmental Variables** | **PC 1** | **PC 2** |
|---|---|---|
| Depth | **0.94587** | 0.31507 |
| Distance to the nearest mangrove | **0.80391** | 0.58861 |
| Temperature | **0.9172** | –0.062849 |
| Water clarity | **0.91572** | 0.38888 |
| Conductivity | **0.9909** | –0.11353 |
| Turbidity | **–0.89826** | 0.39051 |
| TDS | **0.99003** | –0.1115 |
| ORP | –0.5463 | **0.8147** |
| Salinity | **0.75269** | 0.65685 |
| pH | **0.88928** | –0.40646 |
| DO | **0.95086** | -0.19338 |

tors in different stations. PC 1 explains 77.72% of the variance, while PC 2 explains 18.88%. Table 6 depicts the positive correlation between PC 1 and depth, distance to the nearest mangrove, water clarity, temperature, conductivity, TDS, salinity, pH, and Dissolved Oxygen. In contrast, PC 1 shows a negative correlation with turbidity. Additionally, there is a positive correlation between PC 2 and ORP.

Four species were rare (fewer than five individuals per sample), so only 12 species were used for the CCA. According to the CCA, the first two axes account for 92.29% of the variance (Fig. 3); CCA1 and CCA2 axes accounted for 73.83% and 18.46% of the variation, respectively. The permutation test (n=999) showed that relationship between species occurrence and environmental variables from the current research had not reached the significance level ($p = 0.74 > 0.05$).

## Discussion

We identified 16 species in North Kayong waters, while previously, researchers reported 19 species from five genera in West Kalimantan waters and 11 species in Batang Bay and Sukadana Bay in North Kayong waters. *M. affinis*, *M. brevicorrnis*, *M. lysianassa*, *M. tenuipes*, *P. gracillima*, *A. hungerfordi*, *M. sculptilis*, *P. stylifera coromandelica* and *P. semisulcatus* were also identified by them (Hedianto, Mujiyanto, 2016).

It is well-known that the fishing gear type strongly influences the dominance of penaeid species in a catch (Samphan *et al.*, 2015; Maheswarudu *et al.*, 2018). In the North Kayong waters of West Kalimantan, mini trawls captured 15 species of penaeid shrimps, with *Penaeus gracillima* being the predominant species. Conversely, trammel net catches were dominated by *P. merguiensis*, which constituted over 90% of the catch. Previous studies have documented similar findings, showing varied shrimp compositions in mini trawl catches across different locations (Can *et al.*, 2004; Tirtadanu *et al.*, 2018; Tirtadanu *et al.*, 2022). The relatively high shrimp diversity in North Kayong waters suggests that these areas provide suitable habitat conditions for their growth.

In West Kalimantan, *Penaeus merguiensis* and *Metapenaeus ensis* are the primary targets of shrimp fisheries, predominantly captured using trammel nets rather than mini trawls. In the North Kayong waters, both types of fishing gear are employed in coastal areas near estuaries, with mini trawls capturing a significant number of smaller individuals (Table 3).

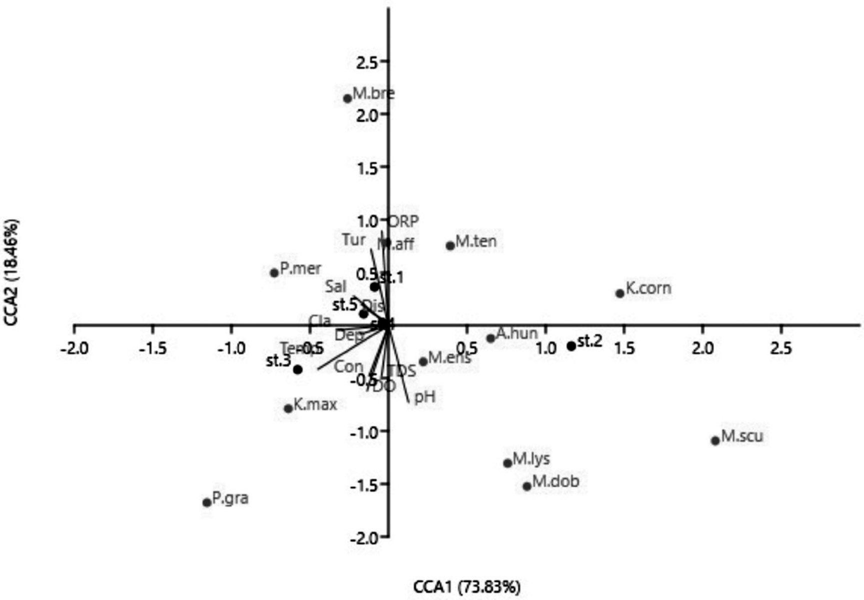


Fig. 3. Canonical correspondence analysis (CCA) biplot, showing 5 sites, 12 species and environmental variables. Abbreviations: A. hun — *A. hungerfordi*; Cla — water clarity; Con — conductivity; Dep — water depth; Dis — distance to the nearest mangroves; DO — dissolved oxygen; K.corn — *K. cornuta;* K.max — *K. maxillipedo*; M.aff — *M. affinis*; M.bre — *M. brevicornis*; M. ob — *M. dobsoni*; M.ens — *M. ensis*; M.lys — *M. lysianassa*; M.scu — *M. sculptilis*; M.ten — *M. tenuipes*; ORP — oxidation reduction potential; P.gra — *P. gracillima*; P.mer — *P. merguiensis*; Sal — salinity; TDS — total dissolved solids; Temp — water temperature; Tur — Turbidity.

Рис. 3. Биплот анализа канонического соответствия (CCA) для пяти точек пробоотбора, 12 видов и переменных окружающей среды.

Сокращения: A. hun — *A. hungerfordi*; Cla — прозрачность воды; Con — проводимость; Dep — глубина воды; Dis — расстояние до ближайшие мангровые заросли; K.corn — *K. cornuta*; K.max — *K. maxillipedo*; M.aff — *M. affinis*; M.bre — *M. brevicornis*; M.dob — *M. dobsoni*; M.ens — *M. ensis*; M.lys — *M. lysianassa*; M.scu — *M. sculptilis*; M.ten — *M. tenuipes*; ORP — окислительно-восстановительный потенциал; P.gra — *P. gracillima*; P.mer — *P. merguiensis*; Sal — соленость; TDS — общее количество растворенных веществ; Temp — температура воды; Tur — мутность.

Overfishing of shrimp in coastal areas can negatively impact recruitment and stock recovery, (Arellano-Torres *et al*., 2006; Burgos-León *et al*., 2009; Suradi *et al*., 2017). To address these concerns, Regulation No. 18 of the Minister of Marine Affairs and Fisheries of the Republic of Indonesia prohibits the use of fishing gear that disrupts resource sustainability, including various types of trawls. However, the specific impacts of different fishing gears on shrimp populations and environmental health need a further examination. While extensive research, such as that by Freese *et al*. (1999), has documented the harmful effects of trawling on seafloor habitats and invertebrate densities, Costa and Netto (2014) found that mini trawling in small-scale fisheries had a minimal impact on benthic diversity and caused negligible harm to estuarine organisms. This suggests that the effects of fishing gear can vary considerably depending on the type of gear and the specific environment in which it is employed. Moreover, our observations suggest that locations studied here may serve as important nursery and spawning grounds for penaeid shrimp, as indicated by their life cycle patterns and size variations.

The research location is also identified as both a nursery and spawning ground based on the average size of female shrimp captured, compared to the size at first maturity (Lm) of the same species at other locations. The average size of *M. affinis* (1.93 cm CL) and *M. brevicornis* (1.74 cm CL) indicates they are still in the juvenile stage, whereas the smallest females with mature ovaries at other locations were 2.71 and 3.35 cm, respectively (Gerami *et al*., 2013; Maulana *et* *al*., 2024). The survey site's role as a spawning ground is further demonstrated by the larger average size of captured shrimp compared to Lm from other studies. For instance, *M. dobsoni*, *M. sculptilis*, and *P. merguiensis* had an average carapace length of 2.45, 2.06, and 3.64 cm, respectively, while Lm reported in other studies for these three species were 1.3, 2, and 3.5 cm, respectively (Amani *et al*., 2015; Hedianto *et al*., 2017; Tirtadanu, Panggabean, 2018).

In this study, the size of females tends to be larger than that that of males, what is commonly observed in penaeid shrimp (de Croos *et al*., 2011; Garcia *et al*., 2016; Putri, Nastiti, 2017). Okpei *et al*. (2020) noted that the sex ratios of penaeid shrimp can vary considerably between species. Some species display a balanced ratio close to the expected 1:1, while others may show significant deviations from this ratio. In our study, *K. cornuta*, *M. affinis*, *M. dobsoni*, *M. lysianassa*, *M. sculptilis*, and *M. ensis* exhibited a higher proportion of females, while *M. brevicornis*, *P. gracillima* and *P. merguiensis* demonstrated a male dominance (Table 4). A balanced sex ratio was observed in this study only in *M. toloensis*, however this conclusion based on few specimens only. A female dominance of penaeid has also been reported by many previous authors (de Croos *et al*., 2011; Chakraborty *et al*., 2014; Metin, Aydin, 2017; Razek *et al*., 2022). Additionally, the sex ratio of the similar species can vary (Safaei, 2015) as it is affected by several interacting factors, such as their movement patterns, feeding habits, growth rates, spawning cycles, and differences in the type and method of fishing gear (Okpei *et al*., 2020; Safaei, 2015).

The t-test results indicate that both male and female penaeid shrimp from West Kalimantan exhibit a negative allometric growth pattern. *M. brevicornis* (b = 1.08) and *P. merguiensis* (b = 2.25) had the lowest b values. In Kaimana waters, *P. merguiensis* also showed low coefficient values (b = 1.88–2.24), while higher coefficients were reported in Aceh waters (b = 2.95–3.12) (Putra *et al*., 2018; Tirtadanu, Panggabean, 2018). The low b-values for *M. brevicornis* and *P. merguiensis* in North Kayong suggest a slender body shape, that can be influenced by various factors such as food availability, stress levels, and environmental conditions.

No significant effects were observed between environmental variables and the distribution of shrimp species in this study, although previous studies have shown that specific environmental factors influence their distribution (Magara and Boury-Jamot, 2024). In Rembang Regency, fishing for penaeid shrimp can extend to 40 m deep (Umam *et al*., 2021), in contrast to our study sites, which was performed in relatively shallow waters (<10 m). The presence of penaeid shrimps in deeper waters is related to their spawning migration patterns (Dall *et al*., 1991). In Mozambique, mature *P. indicus* females occur up to 45 m deep, although they are more common in inshore waters (5–25 m) (Malauene *et al.,* 2021).

In our study, salinity was similar in different sampling points, ranging from 25 to 26 ppt. It is clearly demonstrated that salinity impacted the relative abundance of shrimp in the estuaries (Ab-doroh *et al*., 2023). Tirtadanu *et al*. (2022) stated that *P. merguiensis* highly influenced by depth and salinity and predominating in shallow waters with salinities of less than 33 ppt. *P. gracilima* was also found in the brackish waters of the Mekong Delta, Vietnam (Dinh *et al*., 2010). However, according to Amanat *et al*. (2021), penaeid shrimps can be found in brackish waters and waters with a salinity of up to 37 ppt.

Turbidity and water clarity, which indicate turbidity levels (Munga *et al*., 2013), influence strongly the shrimp behaviour. Dall *et al*. (1990) stated that turbidity affects light penetration; in highly turbid conditions, light levels on the bottom can drop significantly during the day, prompting shrimp to come to the surface. This condition appears to be observed at the study site, where higher turbidity levels are associated with a greater diversity of shrimp species caught as found in stations 1, 2, and 3. In less turbid water and deeper area only *P. mergueisis* and *M. ensis* were recorded in the present study.

The effect of adjacent mangrove ecosystems on penaeid shrimps also has been revealed in several previous studies. These communities have provided shrimps with a valuable food source for growth, and favorable habitat for protection and survival (Primavera, Lebata, 2009; de Abreu, 2017; Ab-doroh *et al*., 2023). However, Sheaves *et al.* (2012) stated that the level of access to mangroves did not significantly influence the distribution of *P. merguiensis*. This statement is supported by our study, which shows that *P. merguiensis* is more abundant in the waters located further from mangroves. Meanwhile, in the areas close to mangroves, the abundance of other species was higher. According to Pickens *et al.* (2021), the decline of wetlands is predicted to affect not only the density or catch per unit effort (CPUE) of juvenile shrimp in estuaries and inshore areas but also lead to changes in the distribution of shrimp offshore and a decrease in overall CPUE. Therefore, fostering the awareness of local communities and fishermen to conserve the mangrove ecosystem remains crucial as part of the investment in the shrimp fisheries business in West Kalimantan waters.

Species diversity and biological aspects of penaeid shrimps in the West Kalimantan were not studied previously. Understanding biodiversity and distribution is essential for shrimp conservation (Damora *et al*., 2019). The study area is part of a marine protected area established by the Ministry of Marine Affairs and Fisheries of the Republic of Indonesia under Ministerial Decree No. 89 of 2020. Our research provides scientific evidence and reinforces the justification for protecting this area by identifying critical habitats for the nursery and spawning of penaeid shrimp. As a vital habitat for the life cycle of penaeid shrimp, the study site could be designated as a fisheries refugia area for sustainable management (Paterson *et al*., 2013). Torres *et al*. (2020) suggested that understanding the habitat distribution of penaeid shrimps, as key estuarine species, can serve as a basis for modelling species distribution. Our data can be used as preliminary information to delineate areas that will serve as fisheries refugia for penaeid shrimp in West Kalimantan, considering the distribution of penaeid shrimp and the environmental factors that influence it. Thus, further research with more locations and longer sampling periods is needed to check our preliminary conclusions.

**Compliance with ethical standards**

CONFLICTS OF INTEREST: The authors declare that they have no conflicts of interest.

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