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# Species Diversity of Trammel Net Fisheries of Kotabaru Waters, South Kalimantan, Indonesia

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**ABSTRACT**

The trammel net shrimp fishery, located in Kotabaru, South Kalimantan, Indonesia, is a small-scale fishery that serves as a primary supplier to the food industry for international markets. PT Sekar Laut, Tbk, one of the companies relying on this fishery for raw materials, particularly yellow shrimp (*Metapenaeus brevicornis*) and banana shrimp (*Penaeus merguensis*), requires Marine Stewardship Council (MSC) certification to access global markets. A pre-assessment for MSC certification of this fishery revealed that limited spatial data, especially species-specific geographic information, hindered the ability to provide the necessary species distribution data for the fishery improvement project (FIP) in Kotabaru. This study aimed to explore spatial diversity in species composition and fishing coordinates collected from trammel net fisheries operating in the Kotabaru Waters from January to August 2024. The data will be used for fisheries management to support the yellow shrimp and banana shrimp FIP in Kotabaru. Using Shannon-Wiener's index (H') and Margalef's richness index (S), the spatial diversity across various fishing grounds was assessed, documenting significant variability in species composition and distribution. The results showed diversity indices ranging from 0 to 1.8 and richness indices from 1 to 15, indicating complex spatial patterns that suggest areas of both high conservation value and fishing pressure. The study also employed cluster analysis to identify patterns in fishing ground usage, which can inform more localized management strategies. These findings highlight the need for adaptive management approaches that consider spatial and temporal biodiversity fluctuations to enhance sustainability and support MSC certification.

## INTRODUCTION

The trammel net shrimp fishery in Kotabaru, South Kalimantan, is a small-scale, traditional fishery with limited data collection capabilities **(Bioinspecta, 2019)**. Despite these limitations, it serves as a major supplier to the food industry, fulfilling both domestic and international market demands, with PT. Sekar Laut, Tbk being one of its key consumers. In order to meet the requirements for entering global markets, PT. Sekar

Laut, Tbk seeks Marine Stewardship Council (MSC) certification for the shrimp resources harvested in the Kotabaru waters. This certification is expected to ensure the sustainability of fish stocks, minimize the fishery's impact on the surrounding ecosystem, and promote effective governance **(Southall *et al.*, 2016; Wakamatsu & Wakamatsu, 2017; Le Manach *et al.*, 2020; Harlyan *et al.*, 2023)**. Consequently, since 2017, the local government of South Kalimantan Province, Indonesia in collaboration with PT. Sekar Laut, Tbk as the industry, has been pursuing MSC certification for the yellow and banana shrimp fishery in Kotabaru **(Bioinspecta, 2019)**.

The yellow shrimp (*Metapenaeus brevicornis*) and banana shrimp (*Penaeus merguensis*) are the dominant catch in the waters of Kotabaru **(Bioinspecta, 2019)**, along with other caught shrimp species such as the endeavour shrimps (*Metapenaeus ensis*), and the tiger cat shrimps (*Parapenaeopsis* spp.) **(Kembaren & Suman, 2013)**. The exploitation of shrimp caught in the waters of Kalimantan has been ongoing since 1975 using trawl fishing gear. Currently, trammel nets have also developed and are predominantly used to catch the yellow shrimp and banana shrimp. PT. Sekar Laut, Tbk utilizes the yellow and banana shrimp fishery as raw material for its shrimp crackers product, which is sold internationally, and aims to obtain the blue ecolabel as a result of meeting the MSC fishery certification requirements **(Bioinspecta, 2019)**.

The MSC certification for fisheries ensures compliance with international best practices in sustainable fishing. The assessment process for MSC certification is based on three fundamental principles: maintaining sustainable fish stocks, minimizing the environmental impact of fishing activities, and ensuring effective fishery management **(Marine Stewardship Council, n.d.; Southall *et al.*, 2016; Le Manach *et al.*, 2020; Harlyan *et al.*, 2023)**. To achieve full certification, a fishery must undergo several stages, including pre-assessment, the development of an action plan, and the implementation of this plan. Collectively, these stages constitute a Fishery Improvement Project (FIP) **(Southall *et al.*, 2016)**. Regarding the fulfilment of the certification, the yellow and banana shrimp FIP in Kotabaru has undergone a pre-assessment phase conducted by the Conformity Assessment Body (CAB), Bioinspecta. It was revealed that the fishery has limited spatial data, particularly on species-specific geographic information, which hinders the ability to obtain necessary species distribution data **(Bioinspecta, 2019)**.

Spatially, the management of the yellow and banana shrimp fishery in Kotabaru is concentrated in several areas of Kotabaru Waters, South Kalimantan. To describe the spatial distribution of fishing grounds and the presence of the yellow and banana shrimp stock, spatial diversity clustering was employed **(Harlyan *et al.*, 2020, 2022)**. Additionally, spatial diversity clustering provides insights into the management strategies of the shrimp fishery. These data can serve as a valuable resource for fishers, enabling them to avoid targeting species that are undergoing stock rebuilding or are currently overexploited **(Harlyan *et al.*, 2021)**.

In Indonesia, the Institute of Marine Research and Observation-Bali (BROL-Bali) has developed a comprehensive map of fishing grounds to enhance fisheries management and planning. This map is generated through an integrated approach utilizing environmental factors, remote sensing technologies, and empirical predictions of fishing zones **(Sumadhiharga, 2009)**. However, the current mapping efforts tend to focus on predicting fishing grounds for groups of species, rather than offering species-specific insights **(Sambah *et al.*, 2016, Wiryawan *et al.*, 2020, Harlyan *et al.*, 2021)**. Furthermore, the available data are limited to certain species. Given these constraints, the development of more detailed species-specific distribution maps is crucial for effectively managing both target and non-target species in pelagic fisheries **(Southall *et al.*, 2016; Harlyan *et al.*, 2020, 2021)**.

Spatial analysis is valuable for understanding the habitats of both target and non-target species by examining the distribution of fishing activities. Spatial diversity distribution analysis serves as a tool to map fishing catches using spatial diversity indices, which are combined with Euclidean distance analysis within designated fishing areas **(Harlyan *et al.*, 2020, 2021, 2022; Sambah *et al.*, 2020)**.

Since spatial diversity distribution can reflect fishing ground patterns, it is crucial for fisheries managers to have access to this information as a reference for managing the Kotabaru fisheries. Therefore, this study aimed to investigate whether there are distinct groupings or patterns in the fishing locations of the trammel net fishery, which can serve as baseline data for future research. Additionally, this study supported the FIP of the trammel net shrimp fishery in Kotabaru, South Kalimantan, in its goal of achieving full-assessment MSC certification. By providing insights into spatial distribution and offering a targeted framework to address sustainability challenges, this work not only advances certification purposes but also serves as a model for similar FIPs.

## MATERIALS AND METHODS

### Study area

This study was conducted at several designated landing sites, which are locations where fishing vessels unload their catch. The selected sites included Salino Village, Sungai Pasir Village, Pantai Village, and Rampa Village, and the study took place from January to August 2024 (Fig. 1).

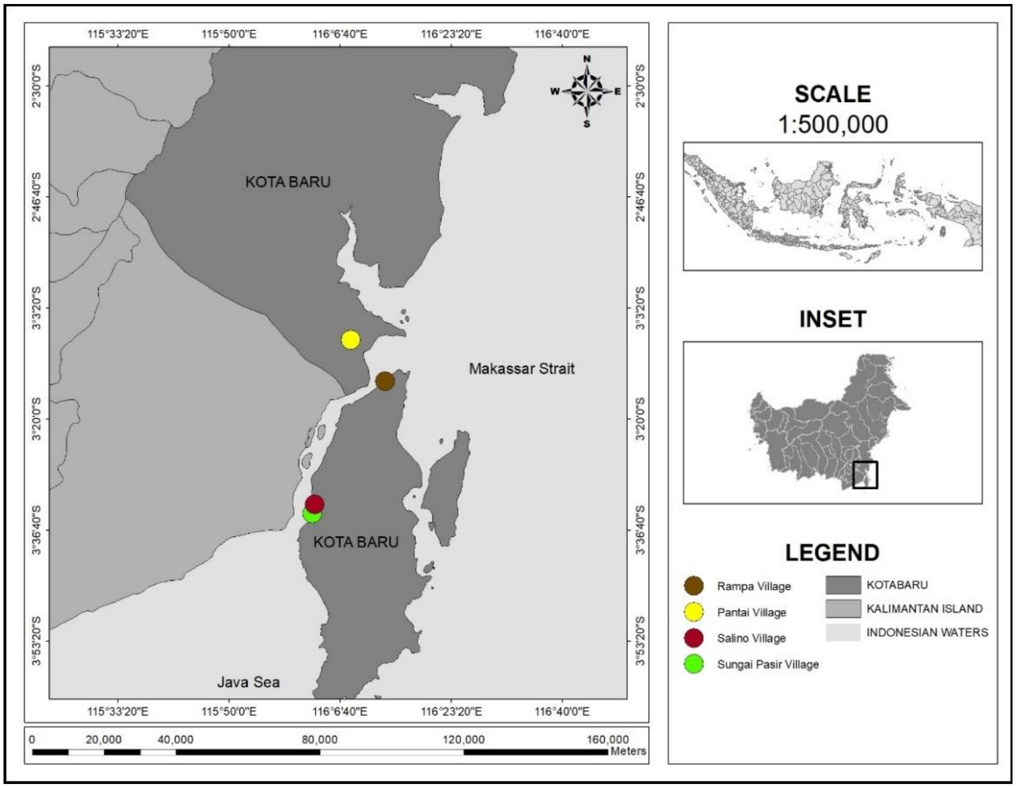


**Fig. 1.** Landing sites in Kotabaru, South Kalimantan, Indonesia

## Data collection

Surveys were conducted to collect data on species by fishing grounds, types of gear used, landing sites, and the volume of landings. Fishing data, including coordinates and catch information, were gathered through structured questionnaires administered in face-to-face interviews with local fishers and enumerators. Species composition data for landings were obtained from fishers who landed their catch at each landing sites. Fishing coordinates were identified through participatory mapping, in which respondents (local fishers) marked their fishing locations. At the time of the survey, the 128 boats were owned by various types of boat owners, including individual fishers and possibly other ownership arrangements. The active boat owners were distributed across the four landing sites: 21 in Salino Village, 41 in Sungai Pasir Village, 16 in Pantai Village, and 50 in Rampa Village. This distribution may reflect differences in ownership types and fishing patterns across the villages.

## Data analysis

To understand the spatial patterns of fishing areas in the Kotabaru waters, two key analyses were conducted: species diversity and cluster analysis, which are detailed in the following sections. To capture the species diversity in each location within the fishing grounds, two well-established diversity indices were applied: the Shannon-Wiener index (H’) and Margalef’s richness index (S) **(Zhu *et al.*, 2011; Boyle *et al.*, 2016)**.

$$\text{Shannon-Wiener's index (H')} = \sum_{i=1}^{s} p_i \ln p_i \qquad (1)$$

Margalef's richness index $(S)=\frac{s-1}{\ln n}$ (2)

In the first equation, H' represents the number of equally common species that would generate the same level of heterogeneity, where *pi* refers to the proportion of each caught species; *i* denotes species 1, 2, 3,..., *s*; and *n* indicates the total weight of all individuals caught. In the second equation, *S* reflects species richness by accounting for the number of individuals collected, where *s* represents the number of species within a sample **(Lipps *et al.*, 1979)**.

To examine the grouping patterns within trammel net fishery grounds, a cluster analysis was performed using Ward's method, with bootstrapped *P*-values generated in the R Package **(Maechler *et al.*, 2018; R Core Team 2018)**. In this analysis, 32 fishing coordinates (locations) were treated as observations and clustered based on several variables. The 29 species caught and their respective weights were used as the primary variables and observed data. Cluster analysis was used to assess the similarities within clusters and the differences between them. A dendrogram was constructed to depict the hierarchical relationships and proximity between clusters of fishing coordinates. These relationships were determined by calculating Euclidean distances between vectors *x* and *y*, using the following formula **(Himmelstein *et al.*, 2010; Roy *et al.*, 2015)**:

$$d_{x,y} = \sqrt{\sum_{i=1}^{n}(x_i - y_i)^2} \quad (3)$$

Where, x and y represent points in Euclidean space, specifically xi and yi are the vectors in n Euclidean space.

The 32 fishing coordinates were categorized by species composition using Euclidean distances based on 29 species. To construct the dendrogram, the bootstrap probability value (BP value) and the approximated unbiased probability value (AU value) were employed. They werer derived from standard and multi-scale bootstrap resampling, respectively. In terms of reliability, the AU values are generally more accurate than BP values. An AU value above 0.95 suggests a high level of consistency in the observations contributing to the cluster's existence **(Suzuki & Shimodaira, 2017)**. In this study, AU values for the identified clusters ranged from 0.73 to 0.98, with clusters surpassing 0.95 being considered robust. By digitizing the fishing coordinate clusters along with their species compositions, potential fishing grounds were identified grouped by these clusters.

## RESULTS

### Species composition

During the fishing surveys, 29 species were landed, and these were divided into seven species groups (Fig. 2). Six species comprised 93% of total weight of samples (143,772kg).

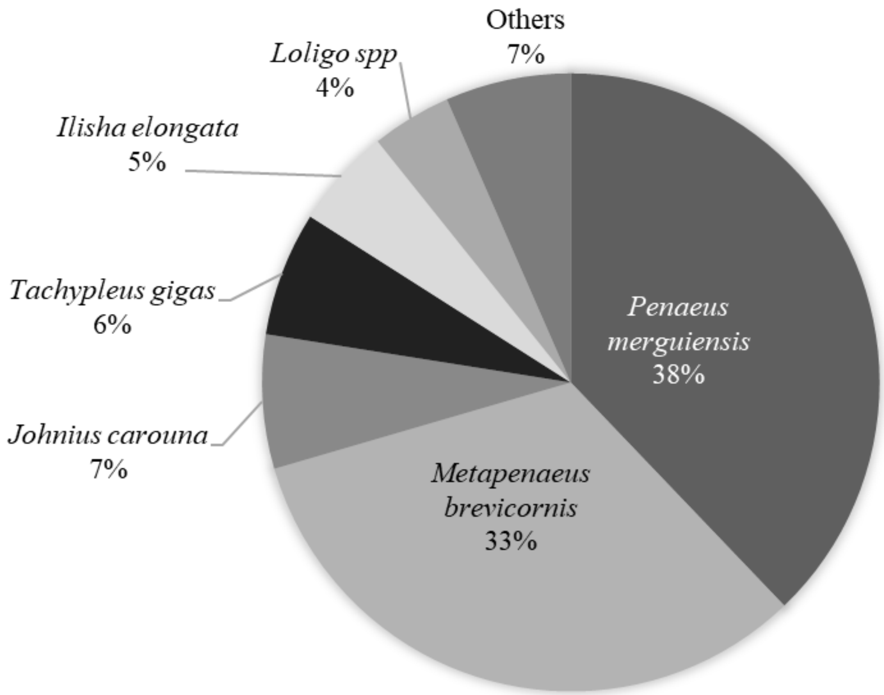


**Fig. 2.** Landing composition at four landing sites in Kotabaru waters, based on survey January – August 2024

Among the species that accounted for the majority of the capture were *Penaeus merguensis* (38%), *Metapenaeus brevicornis* (33%), *Johnius carouna* (7%), *Tachypleus gigas* (6%), *Ilisha elongata* (5%), and *Loligo* spp. (4%) (Fig. 2). The distribution of these species groups was as follows: 51.87% in Sungai Pasir Village, 30% in Rampa Village, 16.68% in Pantai Village and 1.42% in Salino Village.

**Species diversity**

During the field surveys from January to August 2024, 32 fishing locations were mapped along with the composition of their catches (Fig. 3). Several species were commonly found across all fishing grounds.

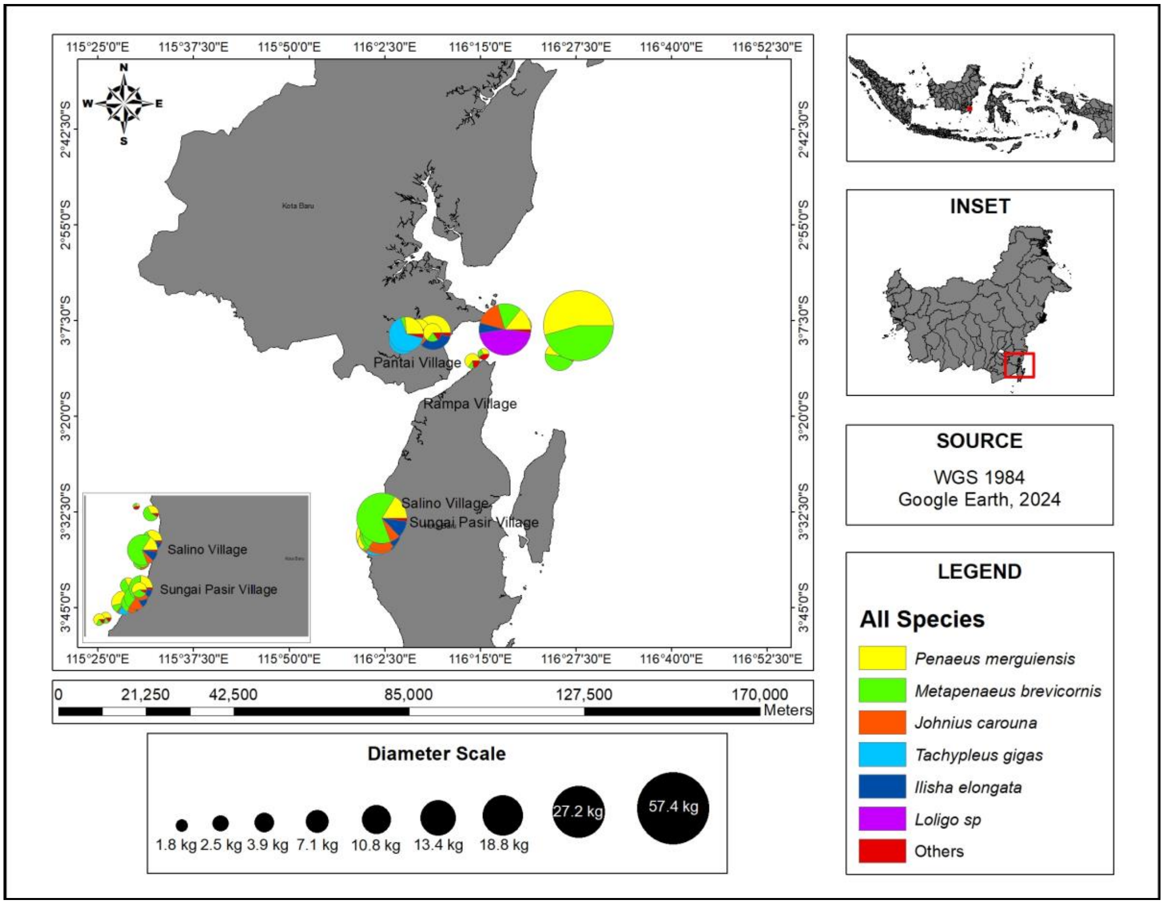


**Fig. 3.** The distribution of fishing grounds in Kotabaru Waters, South Kalimantan, Indonesia, is illustrated with circles whose diameters correspond to the total catch sizes. The colored segments within each circle indicate the composition of the landings

Species diversity and richness were assessed to characterize the trammel net fisheries in the Kotabaru waters. Species diversity (H') varied between 0 and 1.8, and species richness (S) at different fishing locations ranged from 1 to 15 (Fig. 4). Overlaps between areas with low and high were noted for both species diversity and richness. The area around of Pantai village and Rampa village exhibits an increased number of fishing grounds with low diversity compared to the areas adjacent to Salino village and Sungai Pasir village. Concerning species richness, nearly all fishing grounds showed a low species richness index. It was reported that, on average, most regions possess only 1 to 5 species.

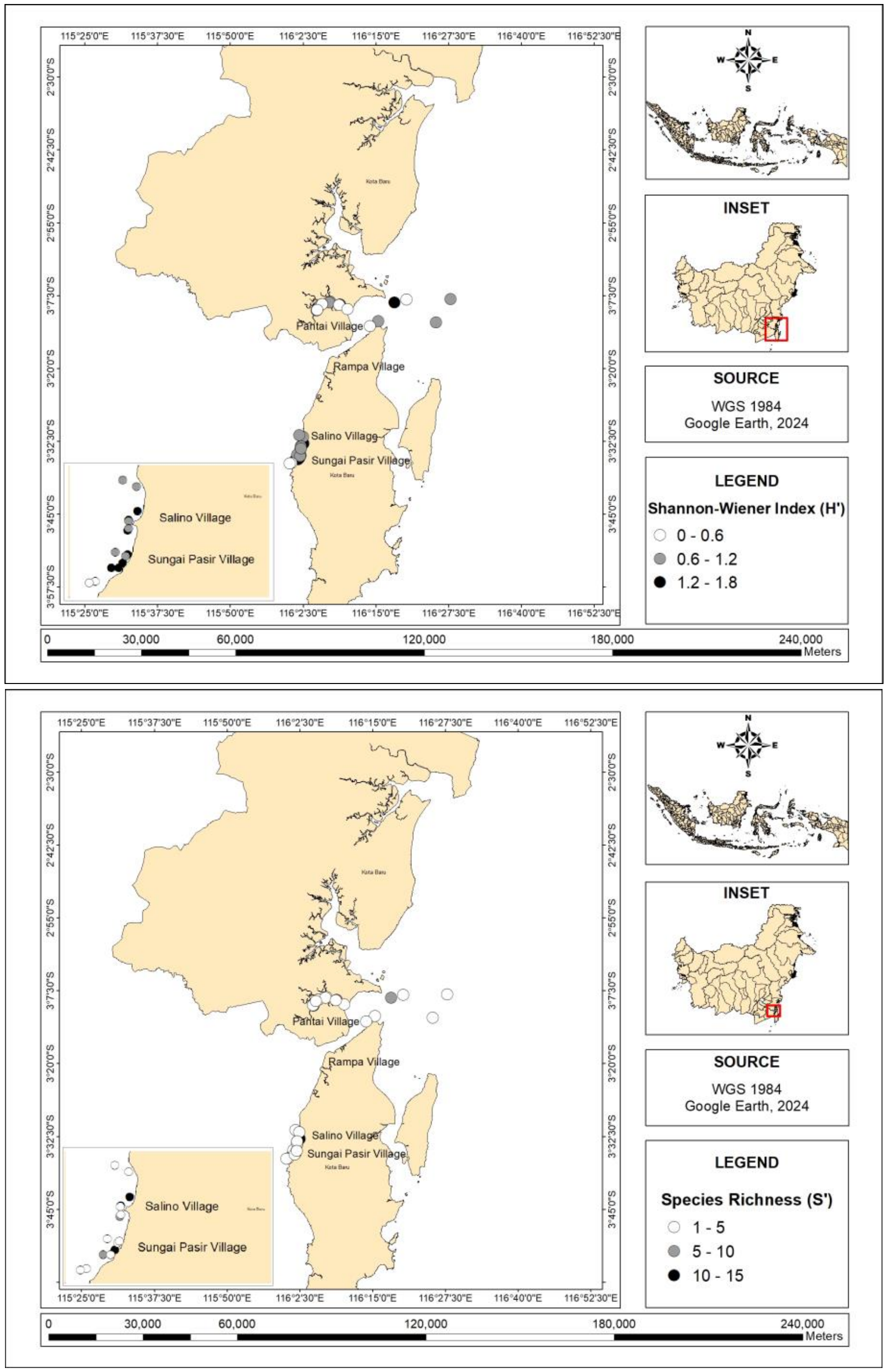


**Fig. 4.** Species diversity (H') and richness (S) in the Kotabaru Waters

## Cluster analysis

The fishing locations of trammel net fisheries in Kotabaru Waters were grouped by cluster analysis (Fig. 5). There were seven clusters found in this fishery based on each species's similarity distance. Each cluster has different numbers of fishing locations. More locations were placed in cluster I, followed by cluster VI and other clusters.

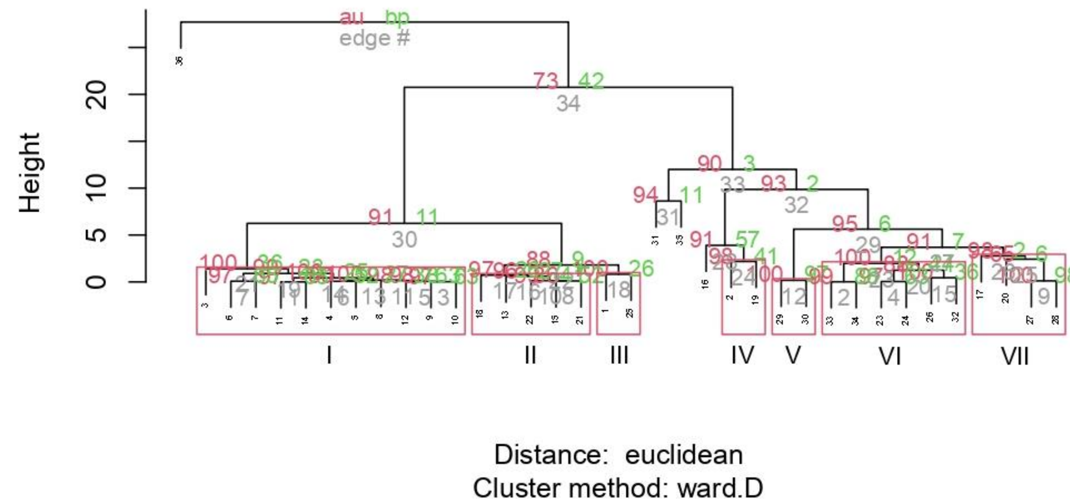


**Fig. 5.** Dendrogram of clustered fishing locations. The approximated unbiased probability (AU) values are in red, while bootstrap probability values are in green. The red frames specify clusters with AU values more than 0.95

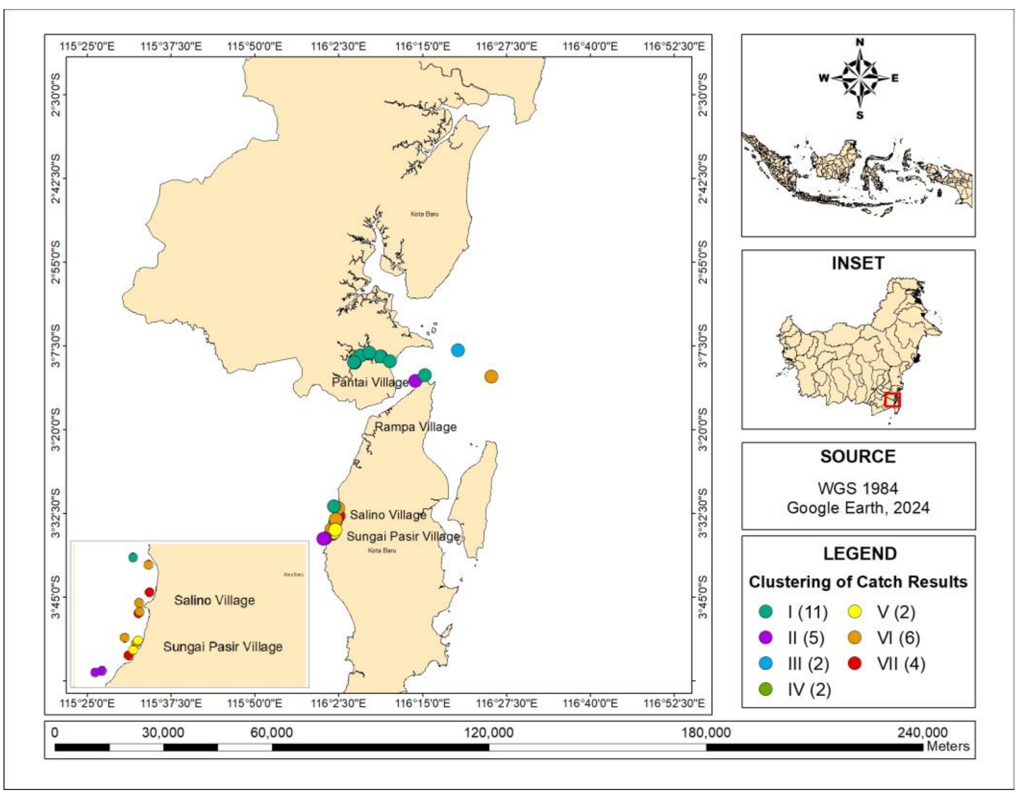


**Fig. 6.** Distribution of fishing locations in cluster I-VII of trammel net fisheries in Kotabaru Waters

Cluster I, identified as the cluster with the highest number of fishing locations (Fig. 5), is situated near Pantai village (Fig. 6). This cluster includes three species: *Penaeus merguensis*, *Metapenaeus brevicornis*, and *Tachipleus gigas* (Fig. 7). On the other hand, Cluster VII, which contains four fishing locations (Fig. 5), is situated near Salino and Sungai Pasir villages. It includes a greater number of species captured (Fig. 7) and has the highest weight composition (Fig. 8). The fishing zones adjacent to Salino and Sungai Pasir village exhibited higher landings compared to those near Pantai village, despite a relatively lower species count in that region.

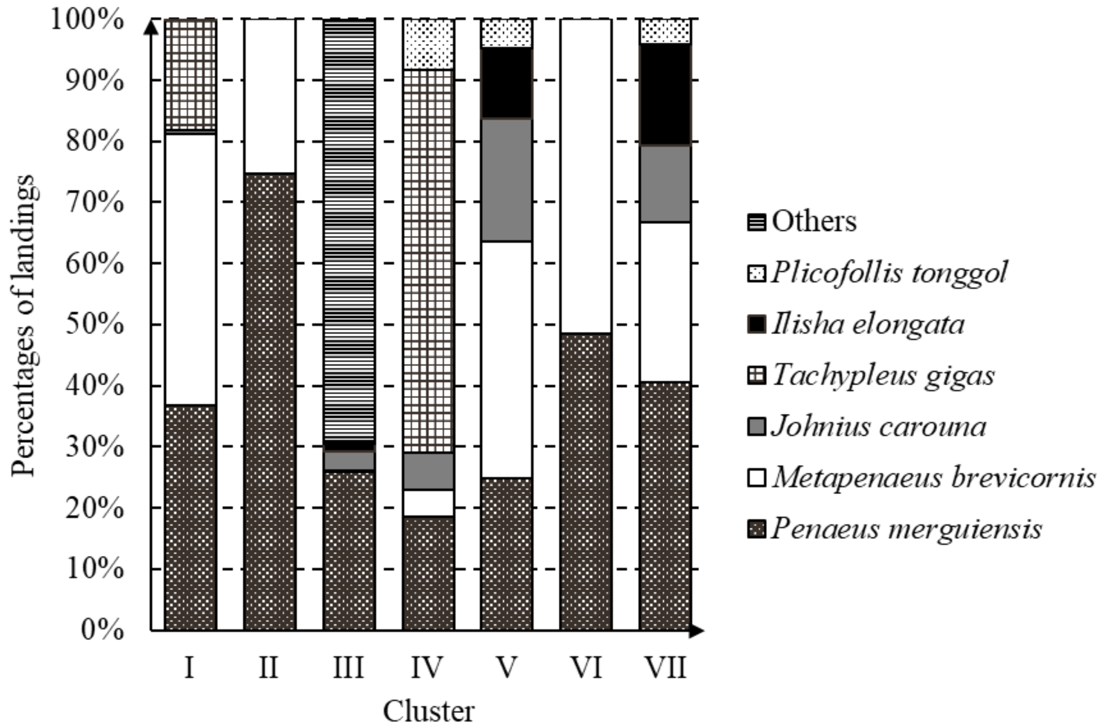


**Fig. 7.** Species composition by weight of Cluster I – VII, based on samples from the trammel net fishery in Kotabaru Waters, South Kalimantan

*Penaeus merguensis* (35 mmCL) is the species present in all clusters within the waters of Kotabaru. A comparable situation exists for *Metapenaeus brevicornis* (30.57mmCL), which predominantly appears in clusters, with the exception of the Salino and Sungai Pasir village regions (Fig. 6-7). *Tachypleus gigas*, an endangered, threatened, and protected (ETP) species, was found in Clusters I and IV (near Pantai village) with significant landing percentages (Fig. 8). In Cluster II and VI, located in Pantai village and Salino-Sungai Pasir village, two targeted species, the yellow shrimp and banana shrimp were present (Fig. 7).

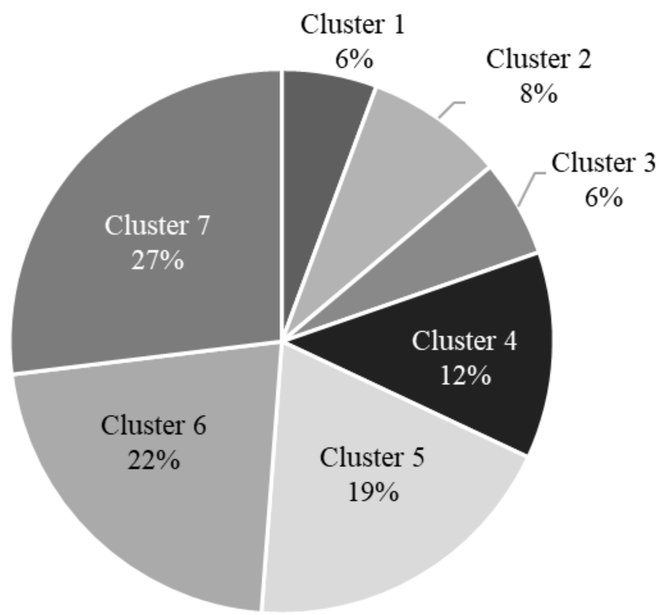


**Fig. 8.** The cluster composition of fishing grounds in Kotabaru Waters, South Kalimantan, Indonesia.

## DISCUSSION

The results of this study highlight significant spatial variability in species diversity and richness within the trammel net fisheries of Kotabaru Waters, South Kalimantan. The observed diversity indices indicate a complex ecological structure that requires careful management to ensure the sustainability of these fisheries. These findings are consistent with the observations of **Zhu *et al.* (2011)** documenting that species richness can exhibit wide variations due to the localized nature of fisheries and habitat-specific differences in catch compositions.

The predominance of the yellow and banana shrimp in the catch composition, which together constitute over 70% of the total landings, is unsurprising given the target species status of these shrimps for both domestic and international markets. These species play a crucial role in the regional economy, particularly in supporting the shrimp processing industry, as seen in other Southeast Asian fisheries **(Wakamatsu & Wakamatsu, 2017)**. However, the clustering analysis reveals that certain fishing grounds, such as those near Pantai village, demonstrate relatively low species diversity despite high catch volumes. This suggests that intensive fishing pressure may be disproportionately concentrated in specific areas, potentially leading to localized overexploitation **(Ault *et al.*, 2005)**.

Conversely, fishing grounds near Salino and Sungai Pasir villages exhibited both higher species diversity and landings, indicating a more balanced ecosystem. These patterns of spatial heterogeneity underline the need for spatially explicit management strategies, which have been effective in other small-scale fisheries **(Prince *et al.*, 2015)**. Additionally, the presence of endangered species like *Tachypleus gigas* in certain clusters further underscores the importance of incorporating conservation measures into fisheries management plans **(Klaer *et al.*, 2012)**.

The spatial clustering and diversity analyses provide essential data for improving the FIP currently underway for the yellow and banana shrimp fisheries in Kotabaru. Achieving Marine Stewardship Council (MSC) certification requires not only sustainable stock management but also minimizing the broader environmental impacts of fishing activities. The results of this study, especially the identification of high-diversity areas that may serve as critical habitats for both target and non-target species, can inform adaptive management practices aimed at reducing habitat degradation and ensuring the long-term viability of the shrimp stock **(Southall *et al.*, 2016)**.

The use of species-specific geographic data is a cornerstone for MSC certification, as it allows for the implementation of measures to avoid overfishing in vulnerable areas. This study's identification of distinct clusters with varied species compositions suggests that different management interventions may be required for each fishing ground. For example, the low-diversity, high-catch areas around Pantai village could benefit from stricter harvest regulations or temporal closures to allow for stock recovery **(Le Manach *et al.*, 2020)**. In contrast, the more diverse fishing grounds around Salino and Sungai Pasir villages could serve as reference sites for monitoring the impacts of management strategies over time.

Despite the valuable insights gained from this study, there remain several challenges. One of the key issues is the limited temporal scope of the data, which was collected over only eight months. As fisheries are subject to seasonal variations, future research should aim to capture a full annual cycle of fishing activities to better understand temporal patterns in species diversity and catch composition **(Hordyk *et al.*, 2015)**. Furthermore, while the cluster analysis effectively highlighted spatial patterns, additional environmental data, such as water temperature and habitat structure, could enhance the understanding of the ecological drivers behind the observed patterns **(Prince *et al.*, 2015)**.

## CONCLUSION

The findings of this study provide a critical baseline for the management of the Kotabaru trammel net fisheries. By integrating spatial diversity data with targeted management practices, it is possible to enhance the sustainability of the shrimp fisheries while supporting their certification under the MSC framework. These efforts not only benefit the local fishing communities but also contribute to global sustainable seafood supply chains.

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