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Fishing area mapping and gear competition in Paiton Waters, East Java, Indonesia

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Abstract. *Sari WK, Rahmalinda WPF, Harlyan LI, Sambah AB, Matsuishi TF, Rust S. 2025. Fishing area mapping and gear competition in Paiton Waters, East Java, Indonesia. Biodiversitas 26: 636-650.* Fisheries in the northern waters of Java Island, Indonesia, particularly in East Java, exhibit high complexity, requiring comprehensive management to effectively address multiple challenges. However, this complexity requires simplification of contributing variables to facilitate sustainable management. One potential solution is spatial clustering. This study aims to analyze species diversity, identify the distribution of fishing gear, cluster areas and fishing gear, and assess indications of competition between fishing gear operating at the Paiton Fish Landing Base (PPI). This study used the Hierarchical Cluster Analysis (HCA) method. The results showed that species diversity in Paiton waters was categorized as moderate (0.00-1.52), with species richness categorized as low (0.00-0.72). Spatial clustering identified two clusters of fishing areas and one cluster of different fishing gears. Fishing areas near the harbor and close to Madura Island are dominated by Indian scad *Decapterus russelli*, while the central part of the Madura Strait is dominated by Bullet tuna *Auxis rochei*. Gear groupings showed competition between gillnets and driftnets, both of which target Savalai hairtail *Lepturacanthus savala*. This research contributes to fisheries management by providing insights into the spatial distribution and competition of fishing activities, supporting better resource allocation and sustainable practices in the region.

Keywords: East Java fisheries, fishing gear clustering, hierarchical cluster analysis, resource allocation, spatial distribution

INTRODUCTION

Capture fisheries in Indonesia have multi-species and multi-gear characteristics, similar to the characteristics of tropical waters in general (Mohamed et al. 2021; Dimarchopoulou et al. 2023). Fisheries in tropical waters are generally characterized by multi-species and multi-fishing gear, which is different from fisheries in subtropical waters that are characterized by single species (Zulbainarni and Khumaera 2020; Harlyan et al. 2022a, b). This complexity is a defining feature of fisheries in tropical regions, contrasting sharply with the more homogeneous, single-species fisheries often found in subtropical areas (Teh et al. 2013). In Indonesia, the diversity of fishing gear employed allows for the capture of various target species simultaneously, which is a hallmark of multi-species fisheries. The use of multiple fishing gears enables the exploitation of a wide range of fish species that often inhabit overlapping ecological niches (Mbaru et al. 2019).

An essential component of fisheries management, particularly in situations involving many species and types of gear, is the interplay between catch and gear on fishing grounds. In these fisheries, many fishing gears vie for the same fish populations, resulting in intricate dynamics that can profoundly affect both ecological equilibrium and the economic sustainability of fishing operations. This struggle for resources can lead to overexploitation, stress on fish resources' availability and quantity, and ecological deterioration in a region (Tromeur and Doyen 2019; Fulton et al. 2022; Heilpern et al. 2022; Sari et al. 2022). The rivalry among several fishing gears frequently results in a situation where the efficacy of each gear is affected by the existence of others, establishing a dynamic interaction that can alter capture rates and species composition. For instance, certain gears may target specific species more effectively, while others may inadvertently catch non-target species, leading to bycatch issues (Eggleton et al. 2010). This complexity necessitates a nuanced understanding of how different gears interact with fish populations and how these interactions can be managed to minimize negative impacts on both the ecosystem and the fishing community (Mulazzani and Malorgio 2013). This complicates fisheries management (Paul 1979; FAO 1994) and thus requires an integrated approach that considers both biological and socio-economic factors, with strategies that can be adapted to address diverse gear types and their impacts on fish populations (Ulrich et al. 2011).

Spatially referenced clustering offers an effective solution for managing multi-species and multi-gear capture fisheries (Mendoza-Portillo et al. 2020; Wang et al. 2024). This method organizes fishing areas based on the spatial distribution of target and non-target species and the relationships between fishing gears. By applying this approach, fisheries management can better understand species' habitat preferences and gear interactions, crucial for sustainable practices (Clarkson and Pollack 2021; Azeez 2024). Spatial clustering provides insights into habitat distribution and proximity relationships among gears, enhancing decision-making processes (Harlyan et al. 2022a, b; Sari et al. 2022). Gear groupings can provide more efficient information for fisheries management actions (Parsa et al. 2020; Frawley et al. 2022). Beyond ecological benefits, this approach addresses socio-economic factors by optimizing fishing areas, reducing gear conflicts, and improving fishers' livelihoods while preserving fish stocks (Karr et al. 2021). For instance, identifying effective areas for specific gear can increase catch efficiency and minimize bycatch (Stephan et al. 2022; Azeez 2024). One area that often operates multi-species fishing gear, such as purse seines, is Probolinggo Waters, precisely at the Coastal Fisheries Port Installation of Paiton (Wiadnya et al. 2023). Fishing gears categorized in the same cluster are expected to compete, as their operational characteristics, target species, and fishing grounds often overlap, creating natural competition in resource utilization. Sari et al. (2023) found that in the Java Sea there are two fishing gear clusters: Cluster 1 consists of bubu and gill nets, while cluster 2 is formed by the close proximity of purse seine, payang, and dogol.

This study aims to identify the diversity of species caught, identify the distribution of fishing gear, classify fishing areas based on catches, classify fishing gear based on catches and identify indications of competition between fishing gear operating at the Paiton Coastal Fishing Port Installation (IPP).

MATERIALS AND METHODS

Study period and area

The research was conducted at the Coastal Fisheries Port Installation of Paiton located at Jalan Lapangan Tembak, Sumber Anyar Village, Paiton Sub-district, Probolinggo District, East Java Province, Indonesia (Figure 1). The research was conducted in January-March 2023. The Coastal Fisheries Port Installation of Paiton is the center of capture fisheries in Probolinggo District. Besides being used by local fishermen, the Coastal Fisheries Port Installation of Paiton is also used by temporary fishermen from Madura Island, Situbondo, and other areas outside Java. Catch production at the Coastal Fisheries Port Installation of Paiton is dominated by small pelagic fish and demersal fish. The Coastal Fisheries Port Installation of Paiton is used as an anchorage for vessels that use several fishing gears such as purse seines, gill nets, and seines. Fishing activities at the Coastal Fisheries Port Installation of Paiton are still included in the traditional fisheries category. Fishermen at the Paiton Fish Landing Base determine fishing areas based on experience or instinct to catch fish and news from other fishermen beforehand. Fishermen at the Paiton Fish Landing Base usually conduct fishing operations with a one-day fishing system.

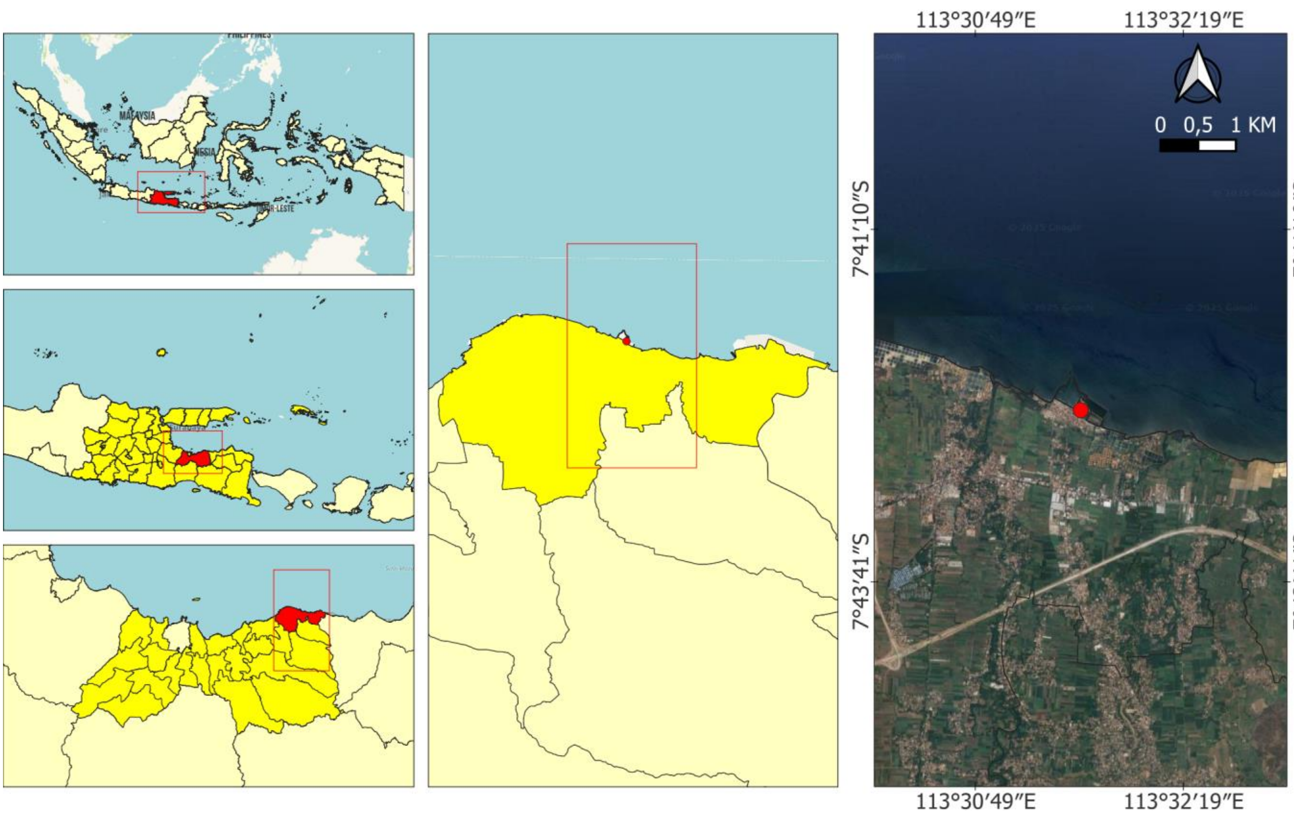


Figure 1. Research location at the Coastal Fisheries Port Installation of Paiton, Paiton, Probolinggo, East Java Province, Indonesia

Data collection procedure

Data collection for this study, conducted in the waters near Paiton, Probolinggo District, East Java, Indonesia, utilized both primary and secondary data sources. Primary data were obtained through direct observations at the Paiton Fish Landing Base (IPPP), which documented fishing activities, species diversity and spatial distribution of fishing gear, providing real-time insights into multi-species and multi-tool fishing practices (Lee et al. 2021; Olden et al. 2022). The identification of fish species in this study was using Carpenter's field guide to marine and freshwater fishes of Southeast Asia, specifically volumes 2 to 6, which provide comprehensive descriptions and illustrations of fish species in the region. The guide, widely recognized for its detailed morphological keys and ecological information, served as a critical reference for species validation during fieldwork and data analysis (Carpenter and Niem 1998; 1999a, b; 2021). Participatory mapping was also conducted, involving local fishers to identify fishing zones and evaluate gear overlap. This approach incorporates valuable local knowledge, improves understanding of fishing practices spatially and encourages community engagement to ensure data accurately reflect ecological and operational realities (Assumpção et al. 2021; Ofir et al. 2023). This approach not only encourages community participation, but also ensures that the data collected accurately represents the reality of fishing practices and ecological conditions in the area (Harlyan et al. 2021).

Secondary data are drawn from statistical records and fisheries reports, which provide a historical and seasonal perspective on fish landings and gear distribution. These data include information on species composition, gear types and spatial fishing patterns. Combining primary and secondary data provides a solid basis for spatial and hierarchical clustering analysis, which is important for understanding ecological and socio-economic dynamics (Stephan et al. 2022; Cheriyan 2023). By integrating these methods, this study provides a comprehensive analysis of fishing patterns in Paiton, using sophisticated clustering techniques to reveal species distribution and gear interactions. This integrated approach supports effective fisheries management and sustainable policy development in multi-species and multi-gear fisheries (Wickrama et al. 2022; Walker 2024).

Data analysis

Species diversity analysis

The analysis of species diversity carried out is the analysis of diversity and species richness calculated using the Shannon-Wiener and Margalef formulas (Omayio et al. 2019; Jahan et al. 2020; Pramudita et al. 2023). The Shannon-Weiner Diversity Index and Margalef Richness Index were calculated using R Studio software with the vegan R package.

Shannon-Wiener Diversity Index (Shannon 1948):

$$H' = -\sum_{i=1}^{S} p_i \ln p_i$$

Where, H' is the Shannon-Weiner Diversity Index, p_i is the division between n_i and N, n_i is the number of individuals of the i-th species, N is the total number of individuals, and S is the number of all species. According to Ulfah et al. (2019) and Sharashy (2022), the Shannon-Weiner species diversity index is categorized into three categories. The low species diversity index category has an index value of less than 1 ($H' \leq 1$). The medium diversity index category has an index value between 1 and 3 ($1 < H' \leq 3$). The high species diversity index category has an index value of more than 3 ($H' \geq 3$).

Margalef Richness Index (Margalef 1957):

$$R = \frac{S-1}{\ln N}$$

Where, R is the Margalef Richness Index, S is the number of species observed, and N is the number of individuals (all species) observed. According to Darmawan et al. (2023), species richness is divided into three categories of index values. The species richness index value is said to be in the low category if the value is less than 3.5 ($R<3.5$). The species richness index value is in the medium category if the value is between 3.5 and 4 ($3.5<R<5$). The species richness index value falls into the high category if the value is more than 4 ($R>5$). Intuitively, the Margalef Richness Index reflects species diversity in relation to the total number of individuals, giving an indication of how evenly species are distributed in an area.

Clustering analysis

Clustering analysis was conducted to determine fishing area clusters based on catches and fishing gear clusters based on catches. Cluster analysis in this study was conducted using Hierarchical Cluster Analysis (HCA) with the agglomerative method. Small clusters that initially contain individual units are grouped into larger clusters using the agglomerative method (Jaya and Folmer 2021; Podruczna 2022; Oti and Olusola 2024). The distance matrix between data is calculated using the Euclidean distance. According to Suwanda et al. (2020) and Sabara et al. (2023), the Euclidean distance can be calculated using the following equation:

$$d_{ij} = \sqrt{\sum_{k=1}^{p} (x_{ik} - x_{jk})^2}$$

Where, d_{ij} is the Euclidean distance of objects i and j, x_{ik} is the value of object i in variable k, x_{jk} is the value of object j on variable k, and p is the number of observed variables.

Cluster analysis was conducted in RStudio software by installing the R cluster package and R pvclust package. Cluster analysis for species and fishing gear variables was conducted by repeating (bootstrapping) the p-value or BP (Bootstrap Probability) value in the Euclidean distance calculation until several clusters were obtained. The p-value used is 0.95. The clusters formed are then presented in the form of a dendrogram which provides information on the unbiased p-value or Approximately Unbiased (AU). An

AU value of p>0.95 indicates that clusters can be formed due to a stable number of observations (Harlyan et al. 2022a, b).

Spatial analysis

Spatial analysis is a data analysis method regarding the spatial pattern of an object/phenomenon and its relationship with other objects/phenomena (Cadrin 2020). Spatial analysis is carried out by plotting the coordinate points (x,y) of the research data along with their attributes and then converting them into shapefile format and visualizing them in the form of maps.

RESULTS AND DISCUSSION

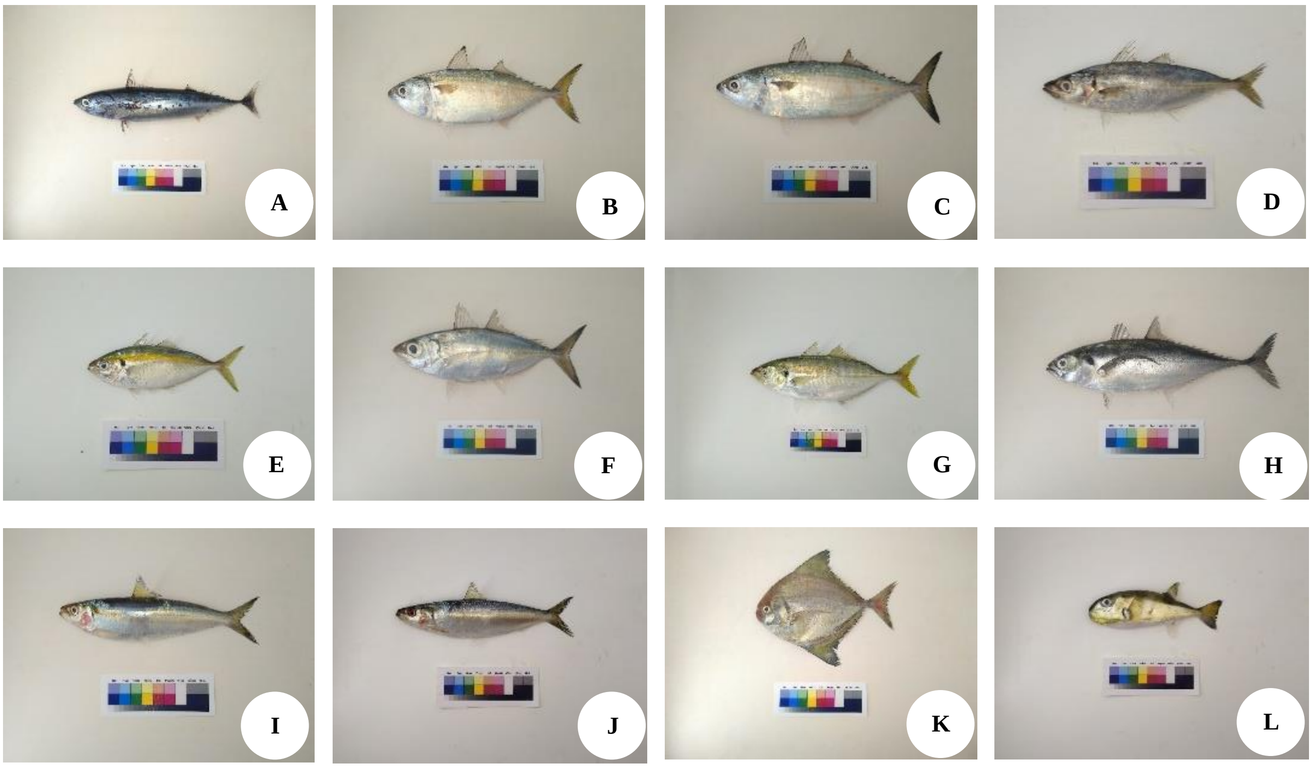
Catches landed at the Coastal Fisheries Port Installation of Paiton

The fish catches landed at IPP Paiton are highly diverse, indicating the presence of multispecies in the Java Sea. Images of the types of fish caught are presented in Figure 2. The spatial distribution of catch species landed at the Coastal Fisheries Port Installation of Paiton is presented in the map below. The pie charts on the map show the catch production for each fishing area. On the map that has been formed (Figure 3), there are three species that dominate the most. Bullet tuna *Auxis rochei* (32,686 kg), Indian mackerel *Rastrelliger kanagurta* (10,330 kg), and Bali sardinella *Sardinella lemuru* (6,526 kg).

Diversity of catch species landed at Coastal Fisheries Port Installation of Paiton

Species diversity

The value of species diversity of catches landed at the Paiton Fish Landing Base (PPI) ranges from 0.00 to 1.52) with the lowest value of 0.00 and the highest value of 1.52. The distribution of species diversity of catches landed at the Paiton Fish Landing Base (PPI) is presented in the form of a map in the figure below (Figure 4). There are three categories of species diversity, each represented by a different circle size based on the results of the calculation of species diversity using the Shannon-Wiener Index. The smallest circle illustrates the lowest species diversity category with an interval value of 0.00-0.51 (33 data). The medium circle illustrates the medium species diversity category with a value interval of 0.51-1.02 (27 data). The large circle represents a high species diversity category with a value interval of 1.02-1.52 (10 data). Our findings are in line with Ulfah et al. (2019), which states that the value of species diversity in Paiton Waters is included in the medium diversity category. This indicates that the ecosystem of Paiton Waters is in a fairly stable condition.



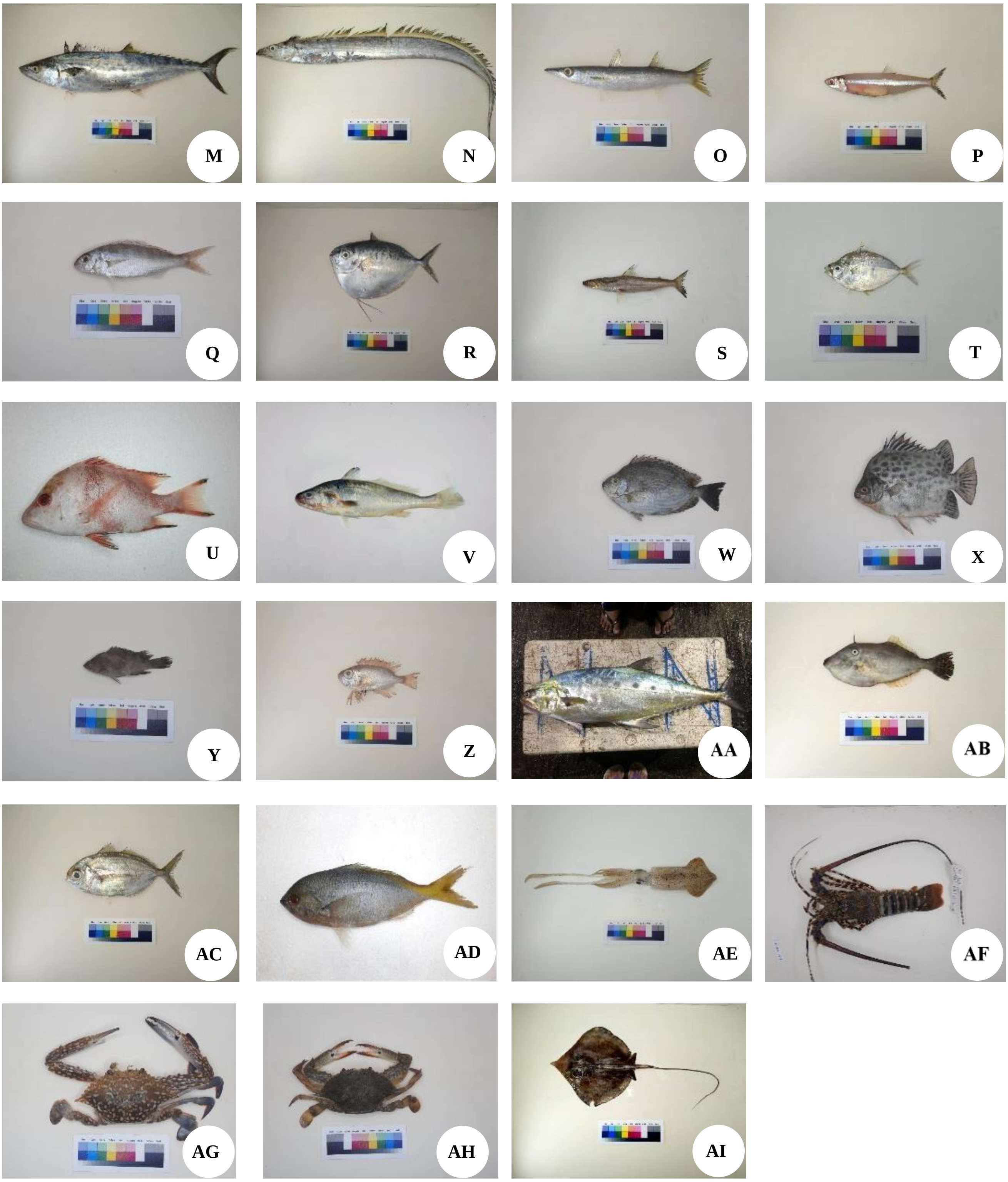


Figure 2. Fish catches landed at IPPP Paiton, Probolinggo District, East Java Province, Indonesia. A. *Auxis rochei*; B. *Rastrelliger brachysoma*; C. *Rastrelliger kanagurta*; D. *Decapterus russelli*; E. *Selaroides leptolepis*; F. *Selar crumenophthalmus*; G. *Atule mate*; H. *Megalaspis cordyla*; I. *Sardinella fimbriata*; J. *Sardinella lemuru*; K. *Parastromateus niger*; L. *Lagocephalus gloveri*; M. *Scomberomorus guttatus*; N. *Lepturacanthus savala*; O. *Sphyraena* spp.; P. *Stolephorus waitei*; Q. *Nemipterus nematophorus*; R. *Mene maculata*; S. *Saurida argentea*; T. *Leiognathus bindus*; U. *Lutjanus argentimaculatus*; V. *Johnius amblycephalus*; W. *Siganus guttatus*; X. *Scatophagus argus*; Y. *Epinephelus* sp.; Z. *Priacanthus tayenus*; AA. *Scomberoides commersonnianus*; AB. *Aluterus monoceros*; AC. *Ariomma indicum*; AD. *Caesio erythrogaster*; AE. *Photololigo duvaucelii*; AF. *Panulirus ornatus*; AG. *Portunus pelagicus*; AH. *Scylla serrata*; AI. *Dasyatis zugei*

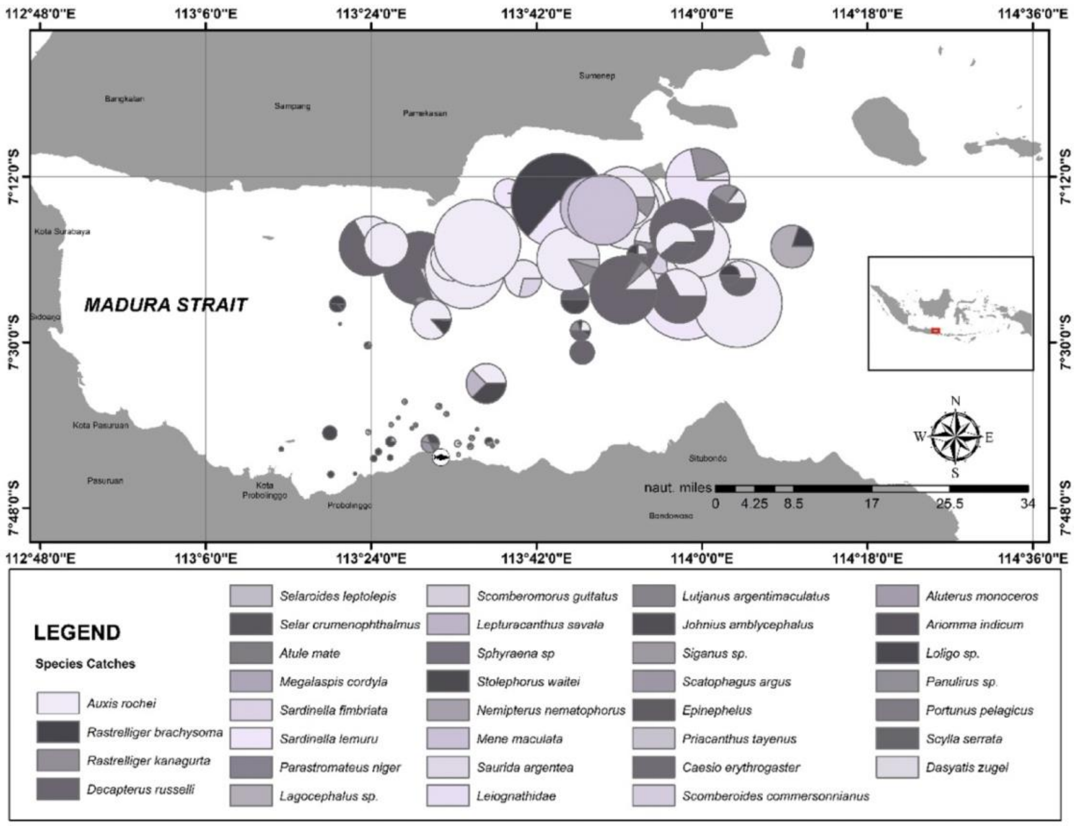


Figure 3. Distribution of species caught at the Coastal Fisheries Port Installation of Paiton, Probolinggo, East Java Province, Indonesia

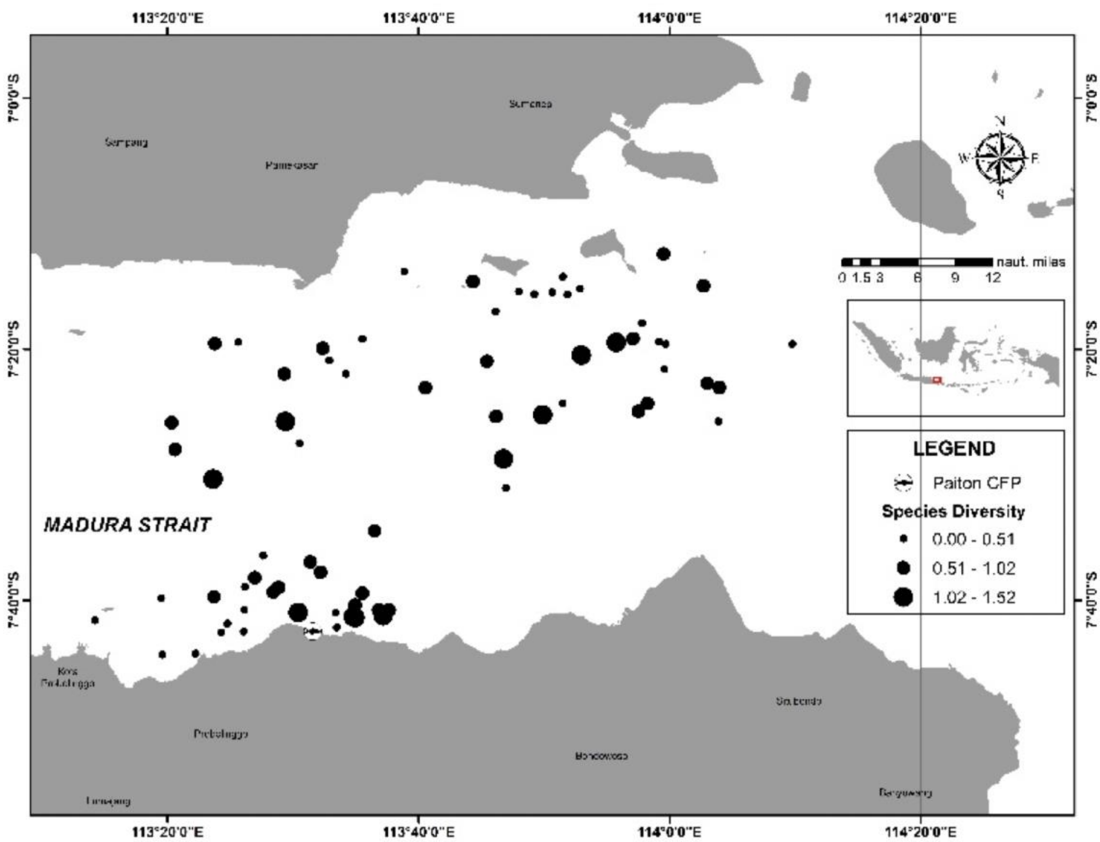


Figure 4. Distribution map of captured species diversity

Species richness

The species richness of catches landed at the Paiton Coastal Fishing Port Installation ranges from 0.00 to 0.72 with the lowest value of 0.00 and the highest value of 0.72. The distribution of species richness of catches landed at the Paiton Fish Landing Base (PPI) is presented in map form in the figure below (Figure 5). There are three categories of species richness represented by circles of different sizes on the map. The smallest circle has a low range with a value range of 0.0-0.24 (47 data). The medium circle has a medium range with a value range of 0.24-0.48 (12 data). The largest circle has a high range with a value range of 0.48-0.72 (11 data). According to Darmawan et al. (2023), species richness in Paiton Waters is included in the low category, which indicates that the ratio of a species to all species in Paiton Waters is not high.

Distribution of fishing gear at Coastal Fisheries Port Installation of Paiton

The fishing gear operating at the Coastal Fisheries Port Installation of Paiton consists of purse seine, gill net, and umbrella net. These three fishing gears have fishing areas that are distributed in the waters of the Madura Strait. Purse seine is distributed in the middle waters of the Madura Strait to near Madura Island (14.6-44 nautical miles). The gill net is distributed in the north, northeast, and northwest of the Coastal Fisheries Port Installation of Paiton (1.8-18 nautical miles). Payang is mostly distributed in the waters of the Madura Strait to the West and Northeast of the Paiton Coast Fishing Port Installation. (6-17.5 nautical miles). The distribution of fishing gear operating at the Paiton Fish Landing Base (PPI) in more detail is presented in the fishing gear distribution map which can be seen in the Figure 6.

Grouping

Grouping of fishing areas based on catches

Fishing areas in Paiton Waters were grouped based on the similarity of species of catches landed at the Coastal Fisheries Port Installation of Paiton. The results of the clustering analysis of fishing areas based on catches are presented in the clustering dendrogram in Figure 7. Of the 70 points of fishing areas in Paiton Waters, two large sub-clusters were formed based on the results of the clustering analysis of bootstrap p-values with p-values>0.95. The first cluster consists of 42 data with dendrogram heights from 0-5000. The second cluster consists of 28 data with dendrogram heights in the range of 10,000-15,000.

The proportion of species caught in each cluster formed is presented in the diagram in Figure 9. There is a difference in the amount of catch in each cluster. The first cluster had a production volume of 5887.18 kg. The most dominant type of catch was Indian scad with a total production of 1675 kg, followed by Pufferfish with a total production of 739 kg, and Spotty-face anchovy with a total production of 780 kg. The second cluster had a larger production volume than the first cluster, at 59,147 kg. The most dominant type of catch in the second cluster was Bullet tuna with a total production of 31,976 kg, followed by Indian scad with a total production of 8655 kg, and Bali sardinella with a total production of 6126 kg.

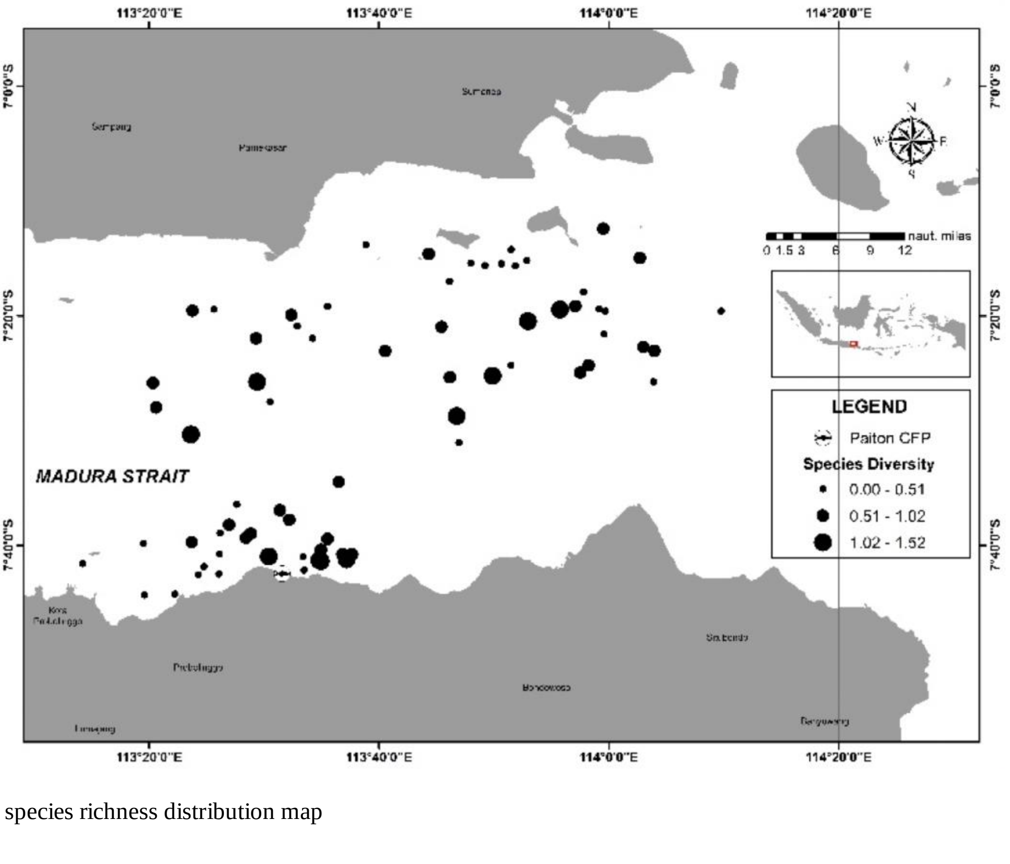


Figure 5. Catch species richness distribution map

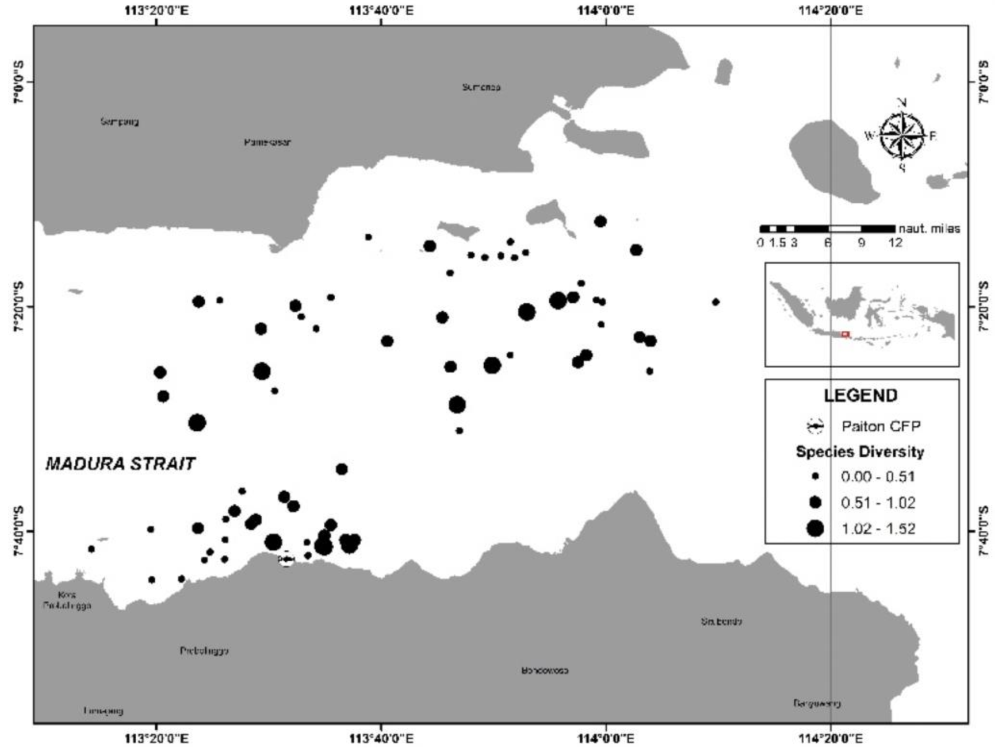


Figure 6. Distribution of fishing gear operating at the Coastal Fisheries Port Installation of Paiton, Probolinggo, East Java Province, Indonesia

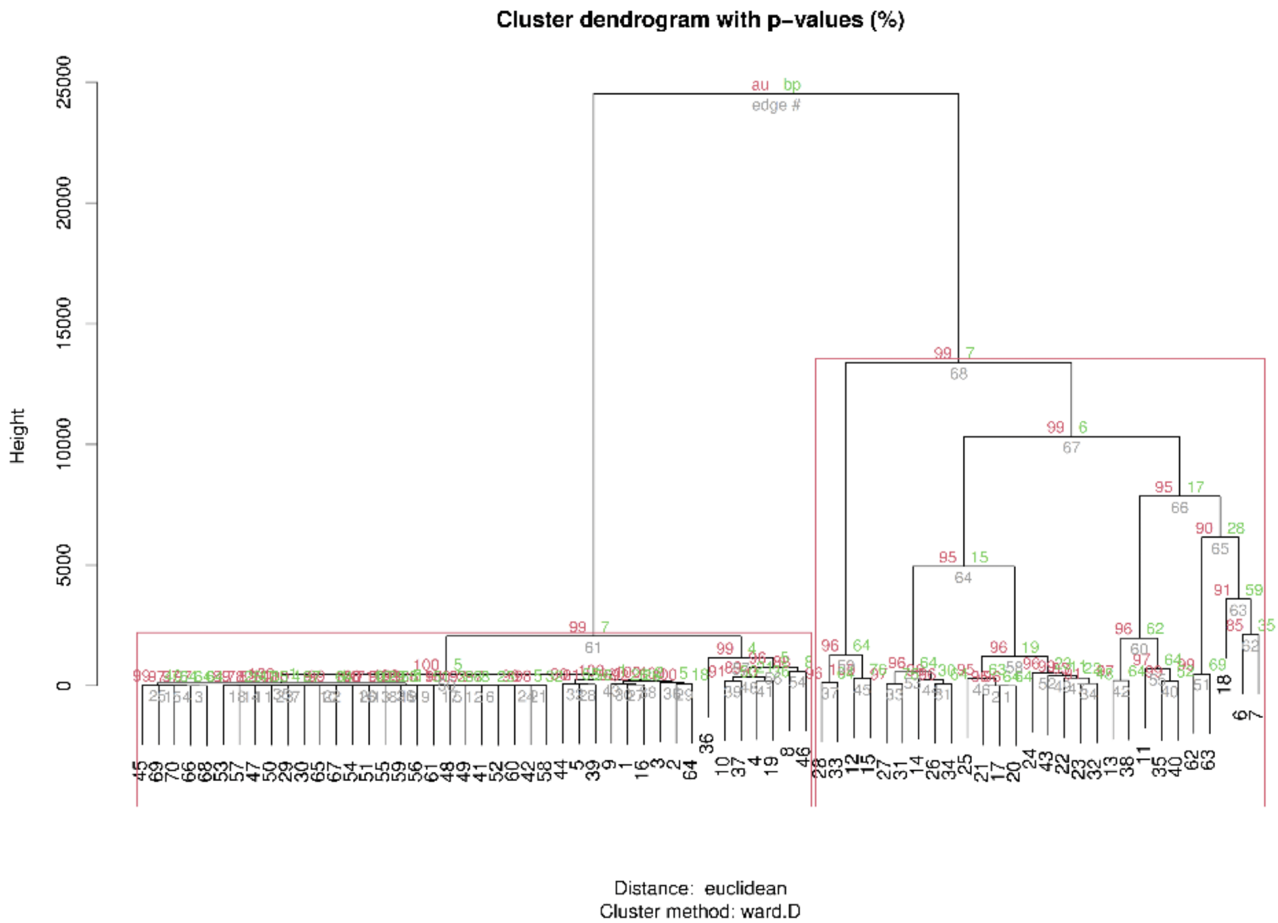


Figure 7. Dendrogram of fishing area clustering

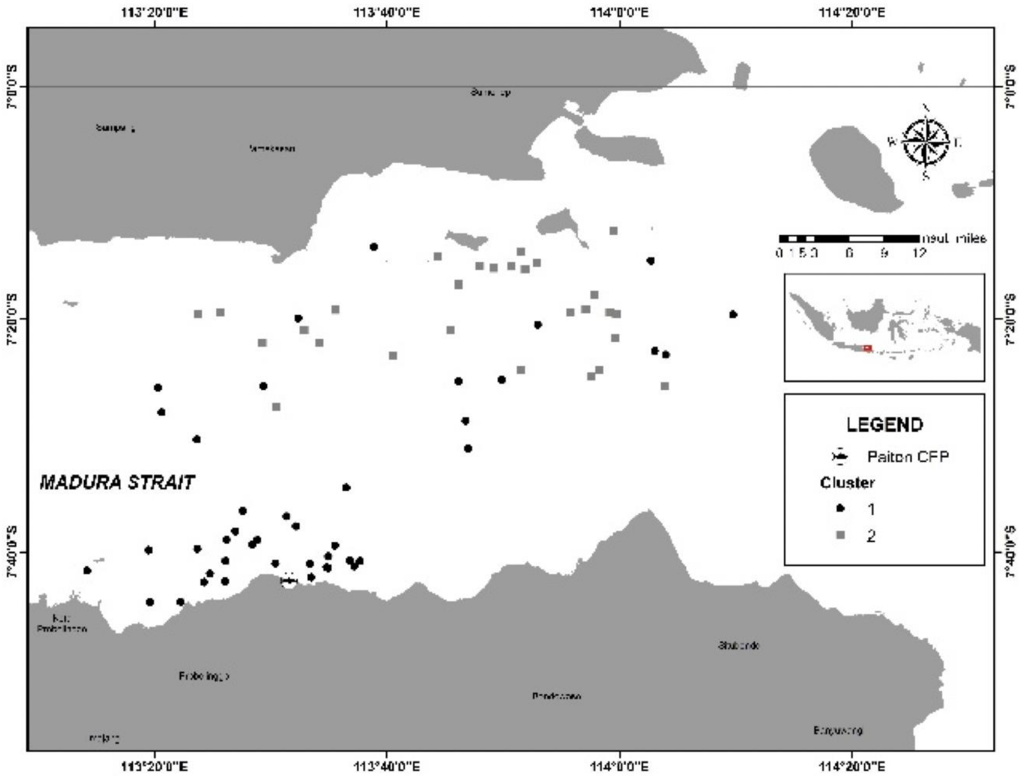


Figure 8. Fishing area grouping map

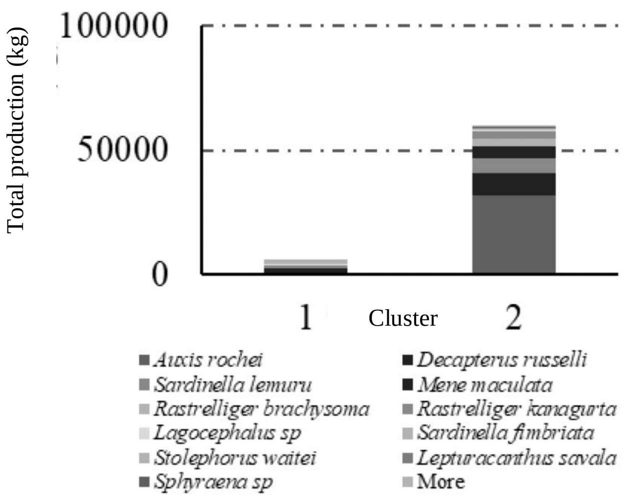


Figure 9. Proportion of species grouped in fishing areas

The results of the clustering analysis are then visualized using a spatial approach in the form of a map to see the distribution of clusters that have been formed. The clustering map of fishing areas based on catches is presented in Figure 8. The black circle represents the first cluster that spreads from waters close to the Coastal Fisheries Port Installation of Paiton, waters in the middle of the Madura Strait, to waters close to Madura Island. The gray box represents the second cluster spread from the waters in the middle of the Madura Strait to the waters close to Madura Island.

Classification of fishing gear based on catch

The clustering analysis of fishing gear based on catch was conducted by grouping fishing gear operating at the Paiton Fish Landing Base (PPI) that had similar types of catch into the same cluster. The results of the clustering analysis of fishing gear based on catch are presented in the clustering dendrogram in Figure 10. Purse seines, gill nets, and umbrellas form a sub-cluster with many members of two data consisting of gill nets and umbrellas. Clusters with members of gill net and seine are at a dendrogram height of 648.61. Based on the results of the bootstrap p-values clustering analysis with p-values>0.95, one cluster can be formed. The AU value shows the results of AU: 100 and BP: 100.

The fishing gear cluster formed is a cluster with members of gillnet and drift gillnet fishing gear. These two gears are in the same cluster because of the similarity of the species caught. The proportion of fish species caught in the formed cluster is presented in the diagram in Figure 11. The total production in the formed cluster was 1415.38 kg. The species with the highest production volume was Spotted-face anchovy at 530 kg. The distribution of the clusters formed is presented on the fishing gear grouping map based on the catch which can be seen in Figure 12. The black color on the map is the data points that show the cluster members that have been formed. The gray color on the map is the purse payang data points that are not included in the formed clusters but are still in one large cluster along with gill net and payang in the final dendrogram results. The distribution of cluster members formed is spread in the area around the west and east of the Coastal Fisheries Port Installation of Paiton.

Discussion

Species diversity

The result of high species diversity in a fishing area indicates the overlap of fishing areas for some of the species caught. The results of this study show that the high diversity value is directly proportional to the species diversity in the pie chart presented in the map in Figure 2. The more diverse the components that make up the diagram, the higher the species diversity index value. Species diversity is used to see species distribution patterns in multi-species and multi-gear fisheries management. The results obtained from the analysis of species diversity in this study have not been able to provide information on species distribution patterns in Paiton Waters. The species distribution pattern generated from the species diversity analysis is still too random and there is no specific information about the fishing grounds that can be identified for each species. The results of the species diversity analysis only provide information on fishing grounds that have many species and overlapping fishing grounds. The same results were also shown in the study of Harlyan et al. (2022a, b) where the analysis of species diversity has not been able to show specific patterns in the distribution of species caught. Further analysis needs to be done in the form of cluster analysis to see the pattern of species distribution along with the fishing grounds.

Distribution of fishing gear at Coastal Fisheries Port Installation of Paiton

The difference in the distribution of the three fishing gears is influenced by the size of the fishing fleet. Small vessels usually find it difficult to reach farther fishing grounds, so fishing operations are conducted near the coast and not too far into the open sea. The existence of a correlation between the size of the fishing fleet and the distribution of fishing gear in the fishing grounds is supported by the statement of Chaliluddin et al. (2019) and Prayitno et al. (2022), which states that larger vessels will be better able to carry and operate fishing gear and fishing aids. Vessels that have a larger capacity to carry fishing gear can also reach farther fishing grounds more safely (Apriliani et al. 2020; Kincl et al. 2023).

The distribution of purse payang at the Coastal Fisheries Port Installation of Paiton has previously been studied. However, there are differences between the distribution of fishing gear obtained from this study and previous studies. According to Wiadnya et al. (2023), who conducted research in 2022, purse payang was operated at a distance of two nautical miles from the coastline in Probolinggo and Situbondo waters. This difference may occur due to differences in data collection time. The characteristics of fishermen at the Paiton Fish Landing Base tend to catch by relying on instinct and information from other fishermen who get a lot of catches in certain areas. Fishermen receive information that in a fishing area there is an abundant catch, so the next day the fishermen will go to the waters around the fishing area. The presence of migrant fishermen from Madura Island who land their catch at the Paiton Fish Landing Base (PPI) can also affect the difference in the distribution of fishing gear. The fishing area of andon fishermen will look very far away when viewed from the Coastal Fisheries Port Installation of Paiton, but in reality the area is aimed at Madura Island which is closer. The possibility of a shift in the fishing area of fishing gear at the Coastal Fisheries Port Installation of Paiton can occur in a short time. The distribution of purse payang in Paiton Coastal Fishing Port Installation in 2022 can be seen in Figure 13 while the distribution of purse payang in Paiton Coastal Fishing Port Installation in 2023 can be seen in Figure 14.

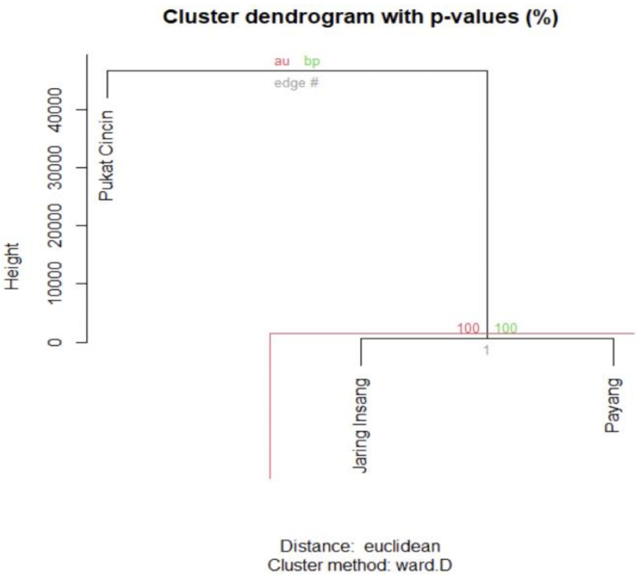


Figure 10. Dendrogram of fishing gear groupings

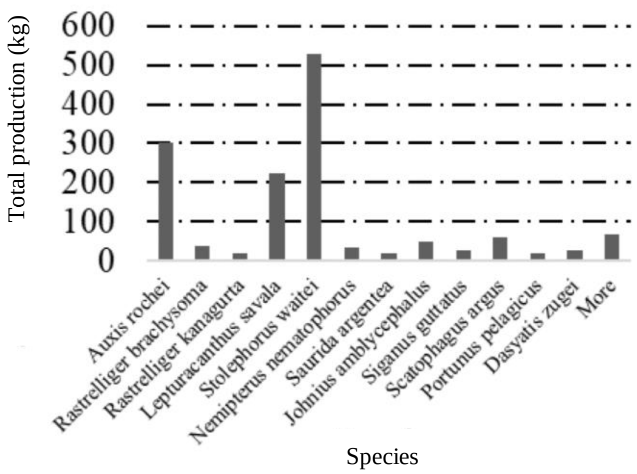


Figure 11. Proportion of species clustered in fishing gear

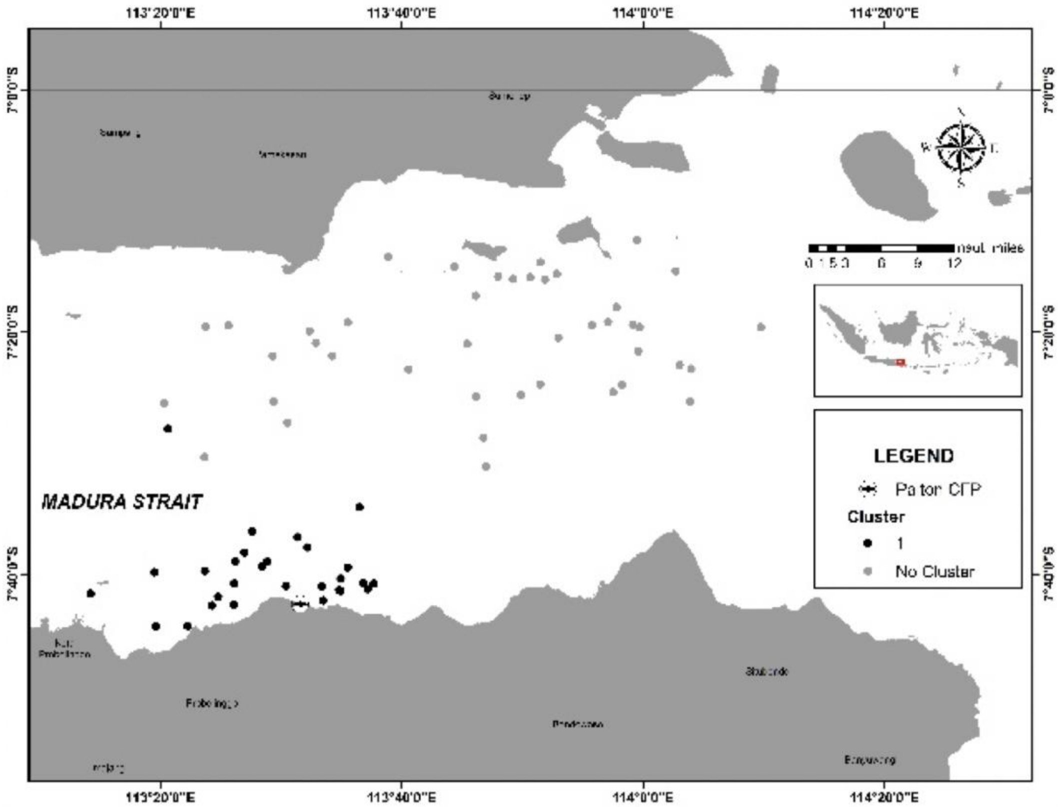


Figure 12. Gear clustering map

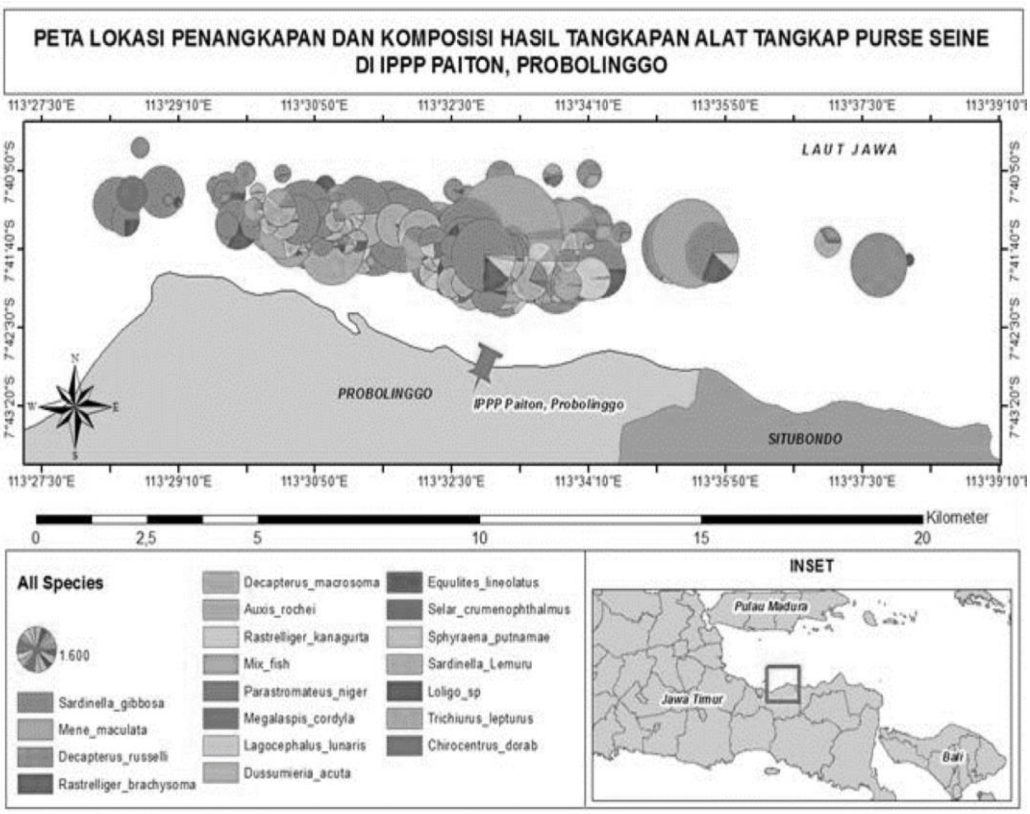


Figure 13. Purse seine distribution at the Coastal Fisheries Port Installation of Paiton in 2022

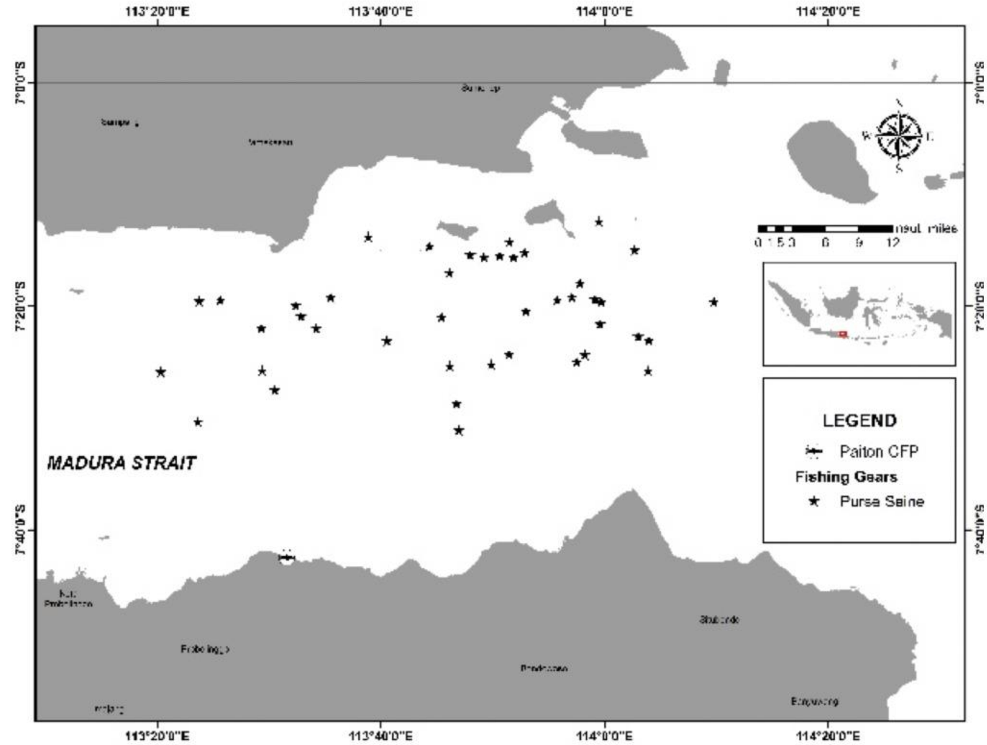


Figure 14. Purse seine distribution at the Coastal Fisheries Port Installation of Paiton in 2023

Grouping of fishing areas based on catches

The clusters formed contain information about the distribution patterns of species in a water body. Species of Savalai hairtail and Spotty-face anchovy were only found in the first cluster with fishing grounds in waters closer to the coast. Moonfish was only found in the second cluster with fishing grounds in the Madura Strait waters closer to Madura Island. Other species are scattered in both clusters of fishing areas. The species of hairtail fish and spotty anchovy were only caught in the first cluster with nearshore fishing areas because these two species are pelagic fish in neritic waters (Jawad and Adams 2022; Wang et al. 2023; Wu et al. 2023). Semar fish was only found in the second cluster with fishing grounds farther from shore because semar fish are demersal fish (Fitriya et al. 2021; Rossi et al. 2022). The capture of this semar fish occurs due to the behavior of Moonfish that migrate vertically to find food and their attraction to the light used by purse payang which causes an accumulation of plankton and small fish in the fishing area (Puspito et al. 2022). Other species found in both clusters are because most of the fish caught are pelagic fish. Pelagic fish have schooling behavior and migrate vertically and horizontally near the surface of the water, which results in a wider distribution in the area (Holubová et al. 2020; Putri et al. 2020; Baker et al. 2023).

The distribution patterns of anchovy, anchovy and mackerel species can be identified. However, the relationship of species to each other is of concern here, as seen in the distribution map in Figure 3. Spotty-face anchovy is a species caught with Bullet tuna and Savala hairtail. Savala Hairtail is a species caught with Bullet tuna, Short mackerel, Indian mackerel, Indian scad, Yellowtail scad, Indo-Pacific king mackerel, Spotty-face anchovy, Doublewhip threadfin snapper, Shortfin saury, Mangrove red snapper and Indian squid. Moon fish are self-caught species. This suggests that when anchovy and seaweed fishing activities are conducted, the species caught alongside these two fish will also be affected, while moonfish fishing will not affect other species.

Classification of fishing gear based on catch

Clustering of fishing gear was conducted to see the distribution of fishing gear operating at the Paiton Fish Landing Base (PPI), along with indications of competition between fishing gear. The grouping of fishing gear based on catch is done by grouping fishing gear that has the same catch into the same cluster. Fishing gear that is in the same cluster means that they both have the same target species to catch, so there will be a possibility of competition between fishing gear. This is in accordance with the statement of Picaulima et al. (2020), which states that when several fishing gears are grouped in the same cluster, the fishing gear is thought to have a close kinship so that there will be competition in fishing activities. Hairtail fish is a species caught by gillnets and drift gillnets. This indicates that there is competition between gillnet and payang in catching hairtail fish.

Clusters formed in clustering analysis using the Bootstrap *p* values method are closely related to the AU and BP values. If the AU value>0.95, then the cluster formed is declared valid and acceptable (Harlyan et al. 2022a, b). The formation of competition between gill net and payang in the results of this study is only at the value of AU: 1 (AU>0.95) which indicates that clusters are formed and competition occurs in gill net and payang.

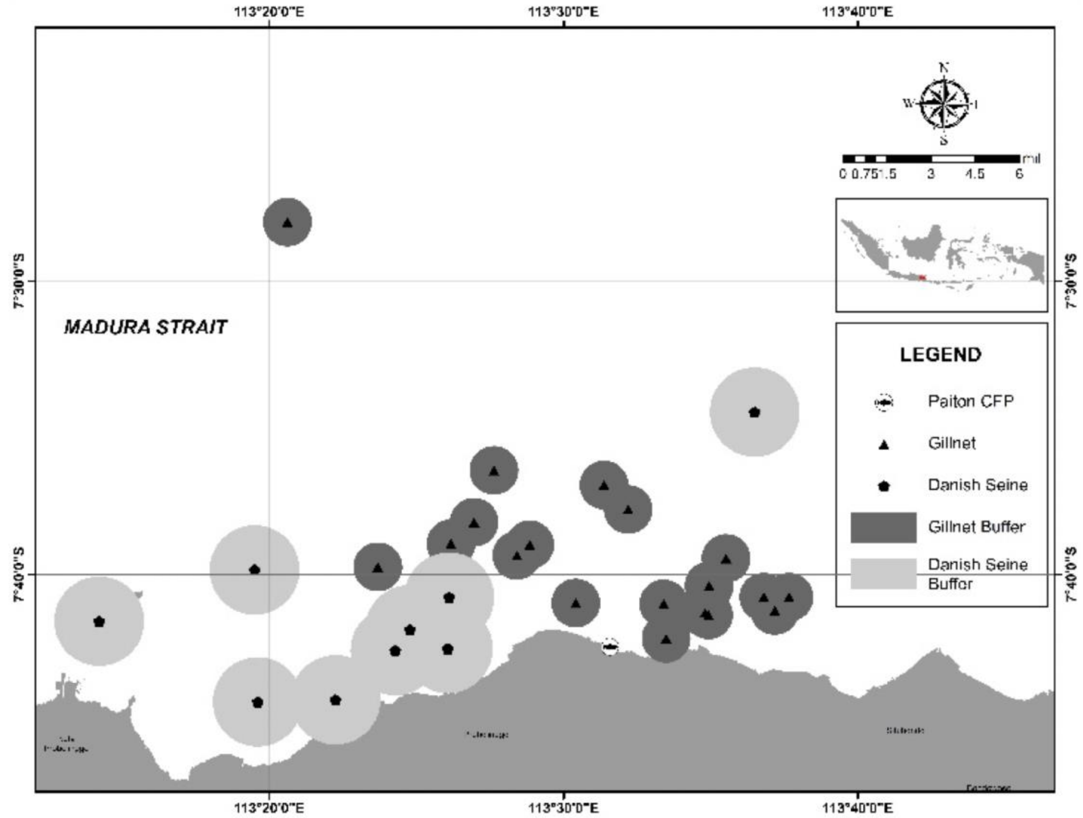


Figure 15. Map of potential competition between gillnets and paying

Competition between gillnet and payang occurs because the target catches are similar. Apart from being based on catch, potential competition between fishing gear can also be related to the proximity of the fishing area (Sukimin et al. 2021). The proximity of fishing gear can be identified using buffer analysis. Based on the buffers that have been carried out, there is an overlap between the gillnet and payang buffers formed. This indicates the potential for competition between gill net and payang operating at the Coastal Fisheries Port Installation of Paiton. The map of potential competition between gill net and payang is presented in Figure 15.

The potential proximity of gillnet and payang fishing areas does not only occur in the proximity of coordinate points represented in two dimensions (x, y). The fishing grounds of the two gears meet at essentially the same depth (z), indicating that there is encounterability between the two gears. Encounterability is the vertical overlap of fishing gear in the water column (Roberson et al. 2022). Based on the specifications of the fishing gear, gill nets and payangs are operated until they float and are in the middle of the water column (Thomas 2019; Atikasari et al. 2022; Yapanto et al. 2022). The similarity of the depth of the operating area results in the possibility of the two fishing gear meeting each other, resulting in equal catches that result in competition.

In conclusion, the species diversity of catches landed at the Paiton Fish Landing Base (PPI) is in the medium category and species richness is in the low category. Fishing gear operating at the Coastal Fisheries Port Installation of Paiton is distributed from the waters near the Coastal Fisheries Port Installation of Paiton to the waters close to Madura Island, with a distance of 1.8-44 nautical miles. The fishing area in the waters near the Paiton Coastal Fishing Port Installation to the waters near Madura Island is dominated by tuna, while the fishing area in the middle waters of the Madura Strait to the waters near Madura Island is dominated by mackerel. In Paiton Waters, there is competition between gillnet and drift gillnet gear to catch layur fish.

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