



Mini-Trawl Fisheries in Lamongan, Indonesia: Catch Composition, Morphological Clustering, and Implications for Gear Selectivity

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ABSTRACT

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mini-trawl, catch composition, species diversity, community structure, morphological clustering

Mini trawl fisheries remain widely used in Indonesian coastal waters despite regulatory bans on trawl operations, raising ecological concerns due to their low selectivity. This study analyzed 125 mini trawl landings in Lamongan, East Java, recording 8,105 kg of biomass across 32 species. The catch was dominated by *Stolephorus* sp. (51.4%) and *Leiognathus splendens* (21.8%). Diversity indices indicated low richness ($R_1 = 2.06$), low evenness ($E = 0.16$), and high dominance ($C = 1.00$), indicating ecological simplification due to intensive fishing pressure. One-way ANOVA showed significant differences in mean catch weight among species ($F = 14.63$; $p < 0.01$), although most demersal and benthic taxa exhibited low and statistically similar weights. Hierarchical Cluster Analysis (HCA) revealed that species with distinct morphologies—such as crustaceans and cephalopods—clustered alongside fishes, confirming gear non-selectivity. These results underscore the need for morphology-based gear modifications, including square mesh codends and bycatch reduction devices (BRDs), to reduce ecological impacts. Integrating biological traits, species grouping, and statistical evidence provides a basis for ecosystem-based fisheries management in tropical coastal systems.

1. INTRODUCTION

Capture fisheries are a key sector of the global economy, food security, and livelihood for coastal communities, particularly in maritime countries such as Indonesia [1-3]. This sector contributes significantly to regional and national economic growth, animal protein supply, and employment. However, the ecological sustainability of fishing practices is under threat, primarily due to the use of non-selective and environmentally damaging fishing gear [4, 5]. In tropical marine ecosystems with high biodiversity and ecological sensitivity, such fishing gear is causing damage to habitats and species communities, exacerbating the sustainability concerns.

Trawling is widely recognised as one of the most destructive fishing methods due to its low selectivity and broad sweeping capacity [6, 7]. It captures target and non-target species, including demersal fish, molluscs, crustaceans, and juvenile organisms. Numerous studies have documented its impacts, such as the degradation of seafloor habitats, disruption of benthic communities, reduced resilience of fish populations, and acceleration of carbon release from sediments [8-10]. High bycatch rates and discards of low-value species exacerbate ecological stress and waste biological

resources [11, 12].

Despite the national ban on trawling under Ministerial Regulation No. 2 of 2015 [13], mini trawl operations remain prevalent in Indonesian coastal regions, including Lamongan [14, 15]. Socioeconomic dependency and enforcement challenges have hindered regulation implementation. Local fishers often perceive Mini trawls as efficient but have been linked to habitat degradation, inter-fisher conflicts, and indiscriminate capture of ecologically important species. However, scientific studies on their ecological impacts remain limited, especially at the local level.

Despite the widespread use of mini-trawls in tropical small-scale fisheries, limited information is available on how this gear influences community composition, biodiversity patterns, and morphological selectivity. Previous studies have primarily focused on biomass yields and economic contributions, whereas ecological implications such as species dominance, recruitment overfishing, and morphological vulnerability have remained insufficiently quantified. Addressing these knowledge gaps is essential for evaluating mini-trawl fisheries' ecological sustainability and informing management interventions that integrate biological and ecosystem-based perspectives.

This study hypothesized that mini-trawl fisheries exhibit low selectivity across morphological groups, resulting in a catch structure dominated by small pelagic species and undersized individuals, with implications for community organization and ecosystem resilience.

Specifically, the objectives of this research were to: describe the catch composition of mini-trawl fisheries in Lamongan waters; analyze community structure, including species richness, diversity, evenness, and dominance indices; and assess morphological clustering of captured species to evaluate patterns of selectivity.

2. METHOD

2.1 Study area

The research was conducted from March to April 2024 at the Labuhan Village Fish Auction Site, Lamongan Regency, East Java, Indonesia (6°52'57.49" S 112°12'16.83" E) (Figure 1). This location was chosen because it is one of the leading centres for fishing activities using mini trawl nets, which have high operational intensity and serve as the primary landing point for local fishermen's catches. The fishing area is located in the coastal waters of Lamongan District, with a depth of 15–20 metres.

2.2 Data collection

A total of 125 vessels were randomly selected during the observation period. All sampling was carried out within the same fishing season at a single landing site to minimize

temporal variation. Gear size and configurations (net length, mesh size, and codend dimensions) were verified through fisher interviews and dockside inspection to ensure comparability across vessels.

Fish identification was performed based on external morphological features such as body shape, total length, fin arrangement, coloration, and tail morphology. Representative samples (1-5 individuals per species) were collected and identified to species level using standard references [16-20]. Identification was validated using expert cross-checks and online databases such as FishBase.

The study employed direct observation and semi-structured interviews with fishers to obtain data on vessel specifications, fishing gear characteristics, and fishing locations. Random sampling was used to select vessels' landing catches during the observation period.

2.3 Data analysis

Catch composition was quantified as the proportion of each species' biomass relative to total catch weight. The number of individuals was estimated using a subsampling approach. For each species, 1-5 representative samples were weighed to calculate the mean individual weight. This mean weight was then divided by the total biomass of each species to estimate the total number of individuals. This method was applied to account for the dominance of small-bodied pelagic taxa that occurred in very high abundance. Community indices included Shannon-Wiener diversity (H'), Pielou's evenness (E), Odum's dominance index (C), and Margalef's richness index (R_1).

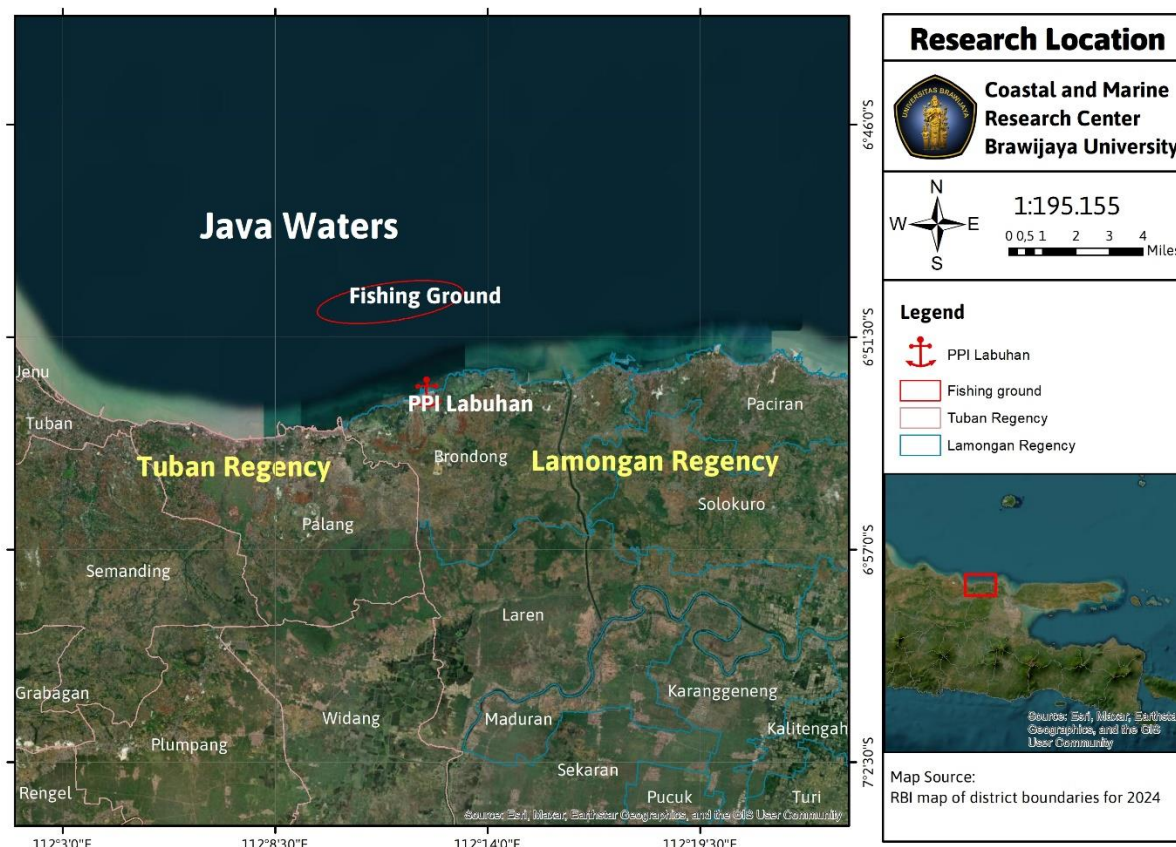


Figure 1. Research location

Hierarchical Cluster Analysis (HCA) was used to classify species based on morphological similarity. The input variable included body shape, fin position, and total length, which were selected because they influence gear retention and mesh escapement. Euclidean distance and the UPGMA method were applied to construct a species cluster.

A one-way Analysis of Variance (ANOVA) was applied to evaluate differences in mean biomass among species. Before analysis, the assumptions of normality and homogeneity of variance were tested using the Shapiro–Wilk and Levene's tests, respectively. As both assumptions were satisfied ($p > 0.05$), the dataset was deemed appropriate for parametric analysis. Where significant effects were detected ($p < 0.05$), Tukey's Honestly Significant Difference (HSD) test was used to identify pairwise differences between species. All analyses used IBM SPSS Statistics version 26.0 [21, 22].

3. RESULT

3.1 Catch composition

The observation (Table 1) revealed that the total biomass of fish and marine organisms caught amounted to 8,105 kg,

comprising an estimated 3,416,234 individuals from 32 distinct species. The catch composition was dominated by *Stolephorus* sp. (anchovy) at 51.42%, *Leiognathus splendens* (ponyfish) at 21.79% and *Loligo* spp at 4.83%. Collectively, these three species accounted for over 70% of the total catch weight, indicating a pronounced dominance in the structure of the fish community (Figure 2).

Taxonomically (Figure 3(a)), the catch was dominated by the Osteichthyes group, comprising 92.17% of the total individuals. Mollusca accounted for 6.75%, followed by Chondrichthyes (*Charcharhinus melanopterus* and *Dasyatis zugei*) at 0.79%, and Crustacea at 0.47%. In terms of ecological habitat, 60% of the captured species were demersal, while the remaining 40% were pelagic.

From an economic perspective (Figure 3(b)), approximately 60% of the catch consisted of high-value target species, including *Stolephorus* sp., *Leiognathus splendens*, and *Rastrelliger kanagurta*; 4% comprised high-value bycatch species such as *Sphyaena sphyaena* and *Epinephelus sexfasciatus*; while the remaining 35% were categorized as low-value bycatch (Figure 3(c)). This composition reflects the dominance of small pelagic and demersal species that typically form schooling aggregations, along with a relatively broad taxonomic diversity.

Table 1. Catch composition

No.	Species	Fish Name	Weight (Kg)	Taxonomy	Ecological Habitat
1	<i>Stolesphorus</i> sp.	Anchovy	4,167.72	O	Pelagic
2	<i>Leiognathus splendens</i>	Ponyfish	1,766.49	O	Demersal
3	<i>Loligo</i> spp.	Squid	391.63	M	Demersal
4	<i>Rastrelliger kanagurta</i>	Long-jawed Mackerel	271.39	O	Pelagic
5	<i>Lagocephalus spadiceus</i>	Pufferfish	248.76	O	Demersal
6	<i>Trichiurus lepturus</i>	Cutlassfish	241.23	O	Pelagic
7	<i>Sepia officinalis</i>	Common cuttlefish	124.81	M	Demersal
8	<i>Johnius carouna</i>	Croaker fish	181.67	O	Demersal
9	<i>Saurida argentea</i>	Shortin saury	109.36	O	Demersal
10	<i>Nemipterus celebicus</i>	Celebes Threadfin Bream	72.49	O	Pelagic
11	<i>Mene maculata</i>	Moonfish	72.40	O	Demersal
12	<i>Psettodes erumei</i>	Flatfish	70.80	O	Demersal
13	<i>Eleutheronema tetradactylum</i>	Giant threadfin	71.51	O	Demersal
14	<i>Charybdis anisodon</i>	Oceanic rowing crab	53.38	Cr	Demersal
15	<i>Scomberomorus guttatus</i>	Spanish mackerel	46.21	O	Pelagic
16	<i>Sphyaena sphyaena</i>	Barracuda	46.01	O	Demersal
17	<i>Congresox talabonoides</i>	Snake eel	38.37	O	Demersal
18	<i>Carcharhinus melanopterus</i>	Shark	34.70	Ch	Demersal
19	<i>Selar crumenophthalmus</i>	Bigeye scad	12.80	O	Pelagic
20	<i>Pampus argenteus</i>	Silver pomfret	12.65	O	Demersal
21	<i>Placuna placenta</i>	Windowpane oyster	10.86	M	Demersal
22	<i>Cloridopsis scorpio</i>	Mantis Shrimp	9.71	Cr	Demersal
23	<i>Parastromateus niger</i>	Black pomfret	9.30	O	Demersal
24	<i>Caranx ignobilis</i>	Travelly	8.01	O	Pelagic
25	<i>Chirocentrus dorab</i>	Dorab wolf-herring	5.85	O	Demersal
26	<i>Octopus</i> sp.	Octopus	5.60	M	Demersal
27	<i>Epinephelus sexfasciatus</i>	Grouper	5.55	O	Demersal
28	<i>Selaroides leptolepis</i>	Yellowstrip scad	4.50	O	Pelagic
29	<i>Netuma thalassina</i>	Ariid catfish	4.20	O	Demersal
30	<i>Lutjanus vitta</i>	Brownstrip red snapper	3.10	O	Demersal
31	<i>Dasyatis zugei</i>	Stingray	3.10	Ch	Demersal
32	<i>Penaeus merguensis</i>	Shrimp	1.17	Cr	Demersal

Note: O = Osteichthyes; Ch = Chondrichthyes; M = Mollusca; Cr = Crustacea

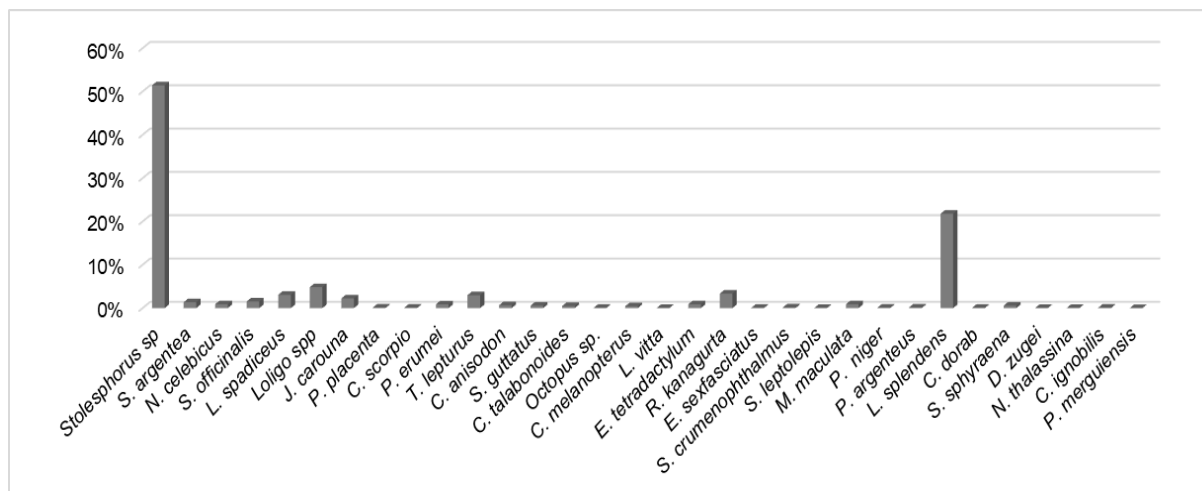


Figure 2. Catch composition in Lamongan mini trawl fisheries

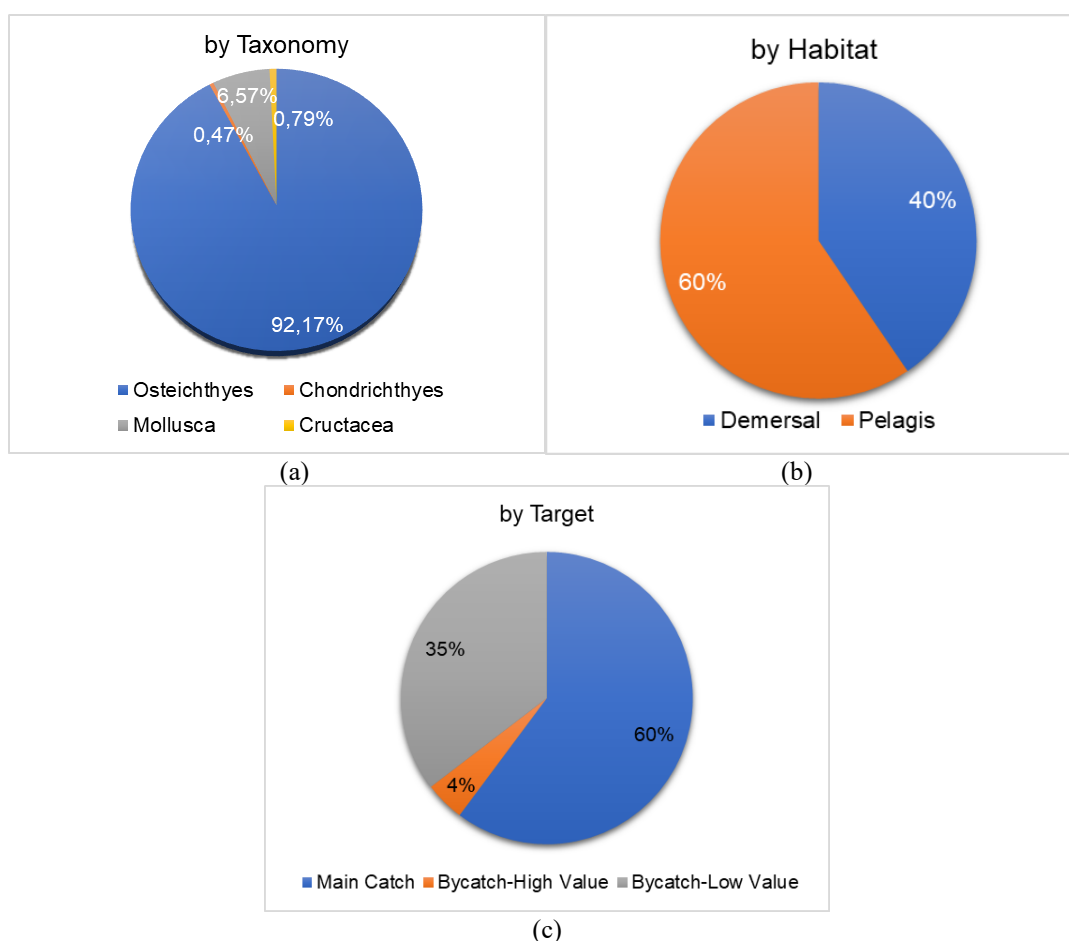


Figure 3. Proportion of catch based on (a) taxonomy; (b) ecological habitat; (c) catch target

Figure 4 illustrates the relative biomass composition of target and bycatch species, categorized based on habitat (pelagic and demersal) and major taxonomic groups (Osteichthyes, Crustacea, Mollusca, and Chondrichthyes). The target catch was predominantly composed of pelagic, Osteichthyes, which accounted for over 51% of the total biomass. This group was mainly represented by small schooling species such as *Stolephorus* sp. and *Rastrelliger kanagurta*. A smaller fraction of demersal Mollusca, including *Loligo* sp. and *Sepia officinalis*, was also recorded, suggesting a degree of vertical overlap in gear operation that extends into both pelagic and demersal strata.

3.2 Species diversity index

Based on the calculated indices (Table 2), the fish community structure in Lamongan waters exhibited low species diversity ($H' = 0.56$), very low evenness ($E = 0.16$), and complete dominance by a single taxon ($C = 1.00$), indicating a highly imbalanced assemblage. Species richness ($R_1 = 2.06$) was also low, suggesting limited taxonomic representation within the catch. These results are further visualized in Figure 5 (bar plot) and Figure 6 (heatmap), emphasizing the disparity between diversity components.

The bar plot displays the absolute index values, while the

heatmap accentuates the contrast in community metrics through color gradients. Together, these visualizations support the interpretation that the mini trawl fishery exerts high pressure on the ecosystem, promoting opportunistic dominance (e.g., *Stolephorus* sp.) and reducing overall ecological complexity. Such structural patterns are commonly associated with the long-term use of non-selective fishing gear in tropical multispecies fisheries.

Table 2. Community structure index value

Parameter	Index Value
Number of species (S)	32
Number of individuals (N)	3,416,234
Diversity indices (H')	0.56
Evenness indices (E)	0.16
Dominance indices (C)	1
Species richness indices (R_1)	2.06

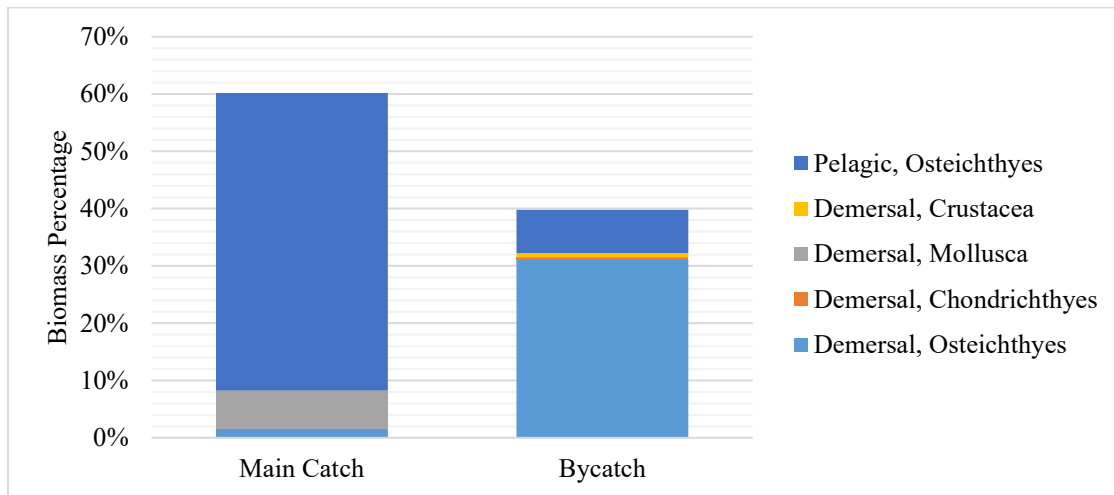


Figure 4. Biomass composition of main catch and bycatch based on taxonomy and habitat in Lamongan mini trawl fisheries. Target species include commercially valuable fish; bycatch includes high-value and low-value species.

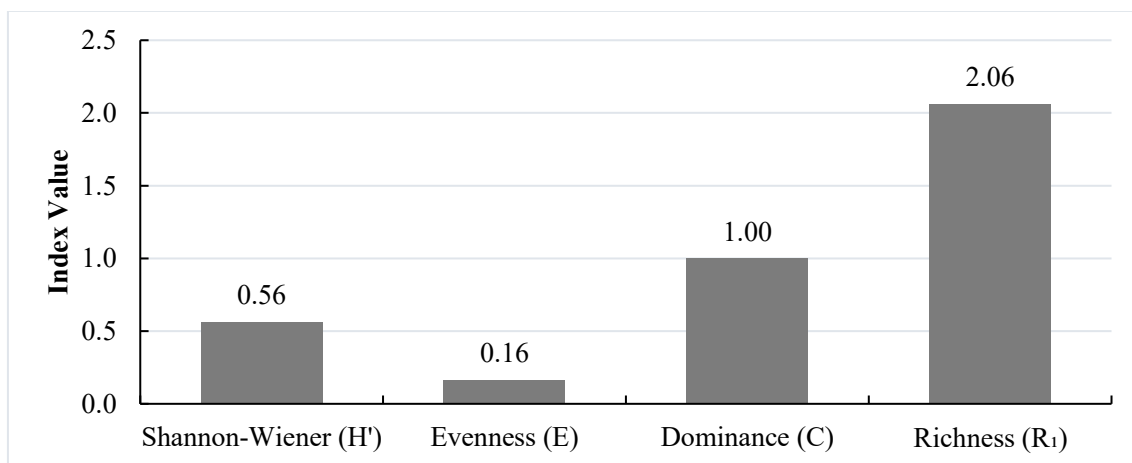


Figure 5. Bar plot of community structure indices showing low diversity ($H' = 0.56$), low evenness ($E = 0.16$), high dominance ($C = 1.00$), and low richness ($R_1 = 2.06$)

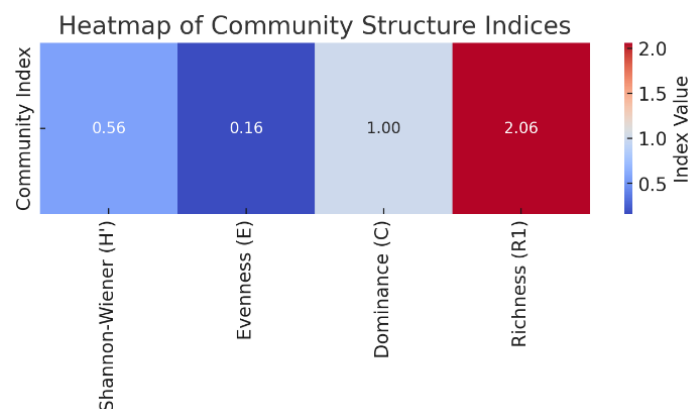


Figure 6. Heatmap of community structure indices illustrating index value gradients, indicating an ecologically simplified fish community

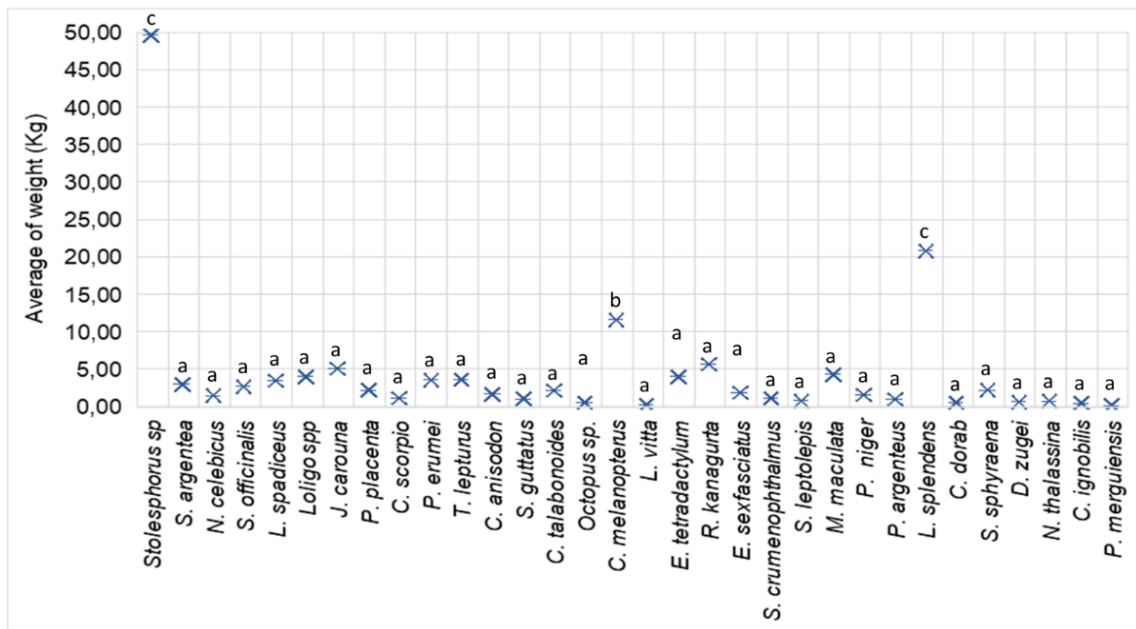


Figure 7. Mean catch weight per species (kg/unit) based on one-way ANOVA with Tukey's post hoc test ($p < 0.05$)

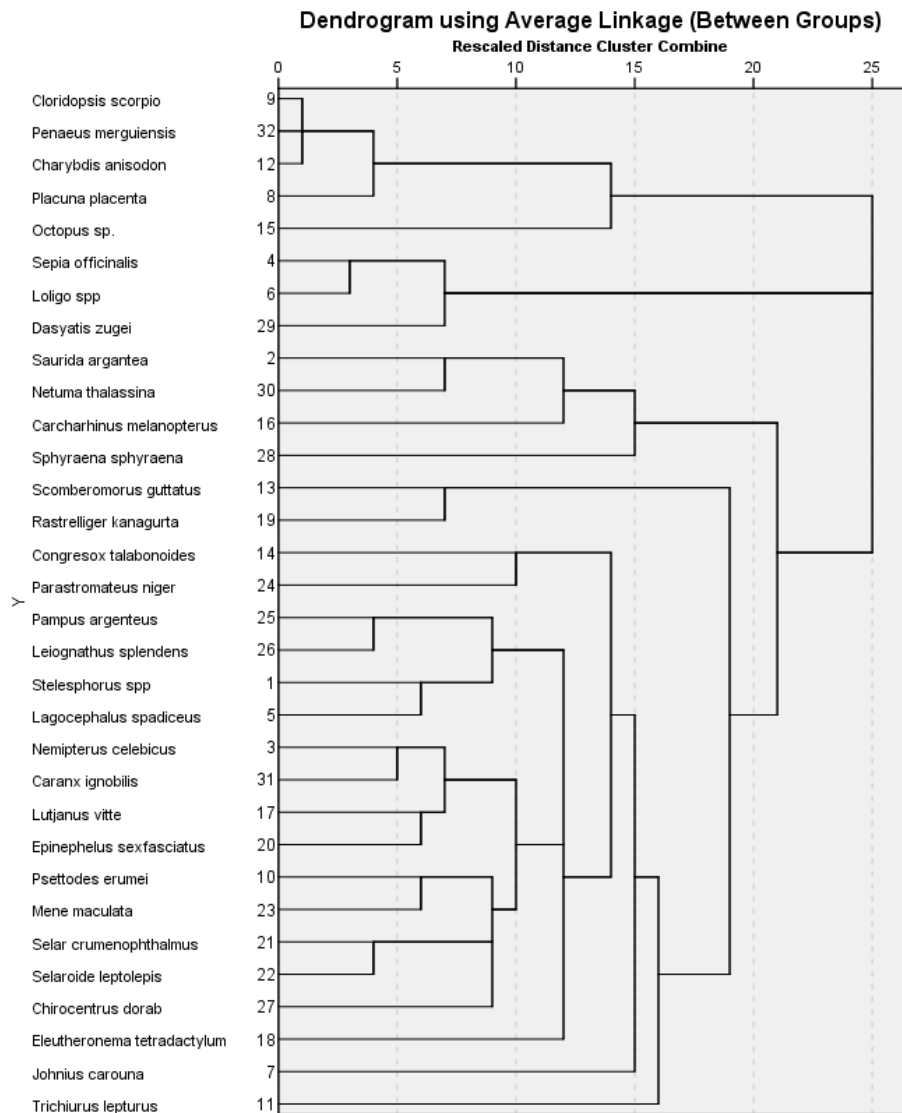


Figure 8. Dendrogram of Hierarchical Cluster Analysis (HCA) showing species groupings based on morphological

3.3 Testing variations in catch weight between species

One-way Analysis of Variance (ANOVA) showed a statistically significant difference in mean catch biomass among the five dominant species ($F = 14.63$; $p < 0.001$; Figure 7). The post-hoc Tukey's Honestly Significant Difference (HSD) test revealed that *Stolephorus* sp. (33.34 ± 5.71 kg) differed significantly from all other species ($p < 0.01$), followed by *Leiognathus splendens* (14.13 ± 2.30 kg), which also showed significant differences from *Loligo* sp. (3.13 ± 1.05 kg), *Penaeus merguensis* (0.009 ± 0.002 kg), and *Placuna placenta* (0.087 ± 0.015 kg). No significant difference was observed between *Penaeus merguensis* and *Placuna placenta* ($p > 0.05$). As visualized in Figure 6, the biomass distribution was skewed toward pelagic species, with clear separation indicated by distinct statistical groupings.

3.4 Hierarchical Cluster Analysis (HCA)

Species relationships were analysed using Hierarchical Cluster Analysis (HCA) (Figure 8) with an average linkage method, resulting in a dendrogram delineating several major clusters. Based on morphological similarities, the captured species were grouped into clusters exhibiting varying levels of taxonomic distance. Species with comparable body forms and tail morphologies, such as *Sepia officinalis*, *Loligo* sp., and *Octopus* sp., were grouped at lower similarity distances. In contrast, *Cloridopsis scorpio*, *Penaeus merguensis*, and *Placuna placenta* formed distinct clusters, reflecting greater morphological divergence from the Osteichthyes group.

4. DISCUSSION

4.1 Catch composition

The composition of mini-trawl catches in Lamongan waters was dominated by small pelagic and small to medium-sized demersal fishes, reflecting the gear's low selectivity and broad sweeping capacity. The predominance of *Stolephorus* sp. and *Leiognathus splendens* can be explained by several technical and ecological factors. Mini-trawls are typically operated in shallow coastal waters where small pelagic fishes naturally concentrate. The small mesh size in the codend reduces gear selectivity, allowing juveniles and undersized individuals to be retained [23, 24]. In addition, the frequent one-day fishing operations increase exploitation pressure in nearshore ecosystems. These operational characteristics collectively explain the skewed species composition, where small pelagic taxa dominate while larger demersal and benthic organisms are underrepresented. Such outcomes highlight how gear design and fishing practice strongly shape ecological patterns in mini-trawl fisheries.

The catch was dominated by bony fishes (Osteichthyes), accounting for 92.17% of the total individuals, followed by Mollusca (6.57%), Chondrichthyes (0.79%), and Crustacea (0.47%). Although these non-target taxa occurred in small proportions, their capture indicates a significant bycatch potential, particularly for groups with ecological or conservation value such as cephalopods, sharks, and rays [8, 11, 25]. From a habitat perspective, 60% of the species were demersal and 40% pelagic. While mini-trawls are categorized as bottom trawls, their configuration and towing dynamics allow the nets to sweep demersal and pelagic strata

simultaneously. This overlap explains why pelagic schooling species dominate the catch while demersal invertebrates and benthic fishes are also consistently present. Such cross-strata exploitation not only broadens the ecological footprint of mini-trawls but also exacerbates conflicts between efficiency (high pelagic biomass) and sustainability (incidental capture of ecologically sensitive taxa) [9, 26].

Classification by economic value indicated that only 60% of the catch consisted of high-value target species, 35% was low-value bycatch, and 4% comprised high-value non-target species. This composition illustrates economic benefits and inefficiencies: while pelagic schooling fishes such as *Stolephorus* sp. provide substantial biomass, the incidental capture of low-value or juvenile fishes represents a loss of potential future yield. Retaining juveniles of commercially important species suggests hidden economic costs by reducing recruitment into the fishery [27, 28]. Moreover, the disproportionate capture of small, short-lived taxa reflects the "fishing down the food web" phenomenon [29], where lower trophic levels replace top predators due to gear selectivity and stock depletion. Such outcomes emphasize that mini-trawls generate immediate catch efficiency but at the expense of long-term sustainability, underscoring the trade-off between short-term economic gain and the ecological resilience of tropical coastal fisheries [23].

The predominance of small-bodied, fast-growing species such as *Stolephorus* sp. and *Leiognathus splendens* in the catch composition reflects the strong selectivity of mini-trawl gear toward schooling pelagic taxa inhabiting surface and subsurface strata. These species are classified as r-strategists, meaning they can adapt ecologically to disturbance. However, they are also vulnerable to continuous fishing pressure due to their short life cycles and high reproduction rates [24]. The observed catch structure is consistent with the "fishing down the food web" hypothesis, where lower trophic-level species gradually replace long-lived top predators as a result of overexploitation and gear-induced selectivity [9, 29].

Such shifts in trophic structure have been widely documented in tropical multispecies trawl fisheries, particularly those lacking spatial management or size-selective regulations [12]. Although the capture of resilient species can maintain short-term yields, continued capture of ecologically valuable pelagic, demersal, crustacean, and elasmobranch species can lead to trophic decline, homogenisation, and disruption of ecosystem services [8, 11].

These findings emphasize the need for ecosystem-based management strategies, including spatial closures during critical life stages, adoption of bycatch reduction devices (BRDs), and modification of gear dimensions to minimize habitat overlap with non-target assemblages. Incorporating habitat-specific knowledge into gear design and effort allocation could enhance sustainability while maintaining economic viability in small-scale tropical bottom-trawl fisheries [30].

4.2 Community structure

The structure of the fish community in the study area was indicative of ecological imbalance commonly associated with intensive fishing pressure. Such assemblages have been characterized by low species diversity, uneven distribution of individuals, and disproportionate biomass dominance by one or two taxa, while others occur in marginal quantities [11, 24]. This condition reflects a state of ecological degradation that

may compromise ecosystem functioning, including energy transfer, resilience, and regenerative capacity [9].

Compared to similar tropical systems, such as the open estuarine ecosystem along India's northwest coast [31], the mini-trawl catch in Lamongan exhibited greater ecological stress. The consistently low diversity and dominance of *Stolephorus* sp. suggest potential trophic shifts and intensifying exploitation, which could impair habitat structure and disrupt recovery processes [9, 32].

These findings reinforce the necessity of implementing ecosystem-based fisheries management that considers yield optimization, community structure, and ecosystem functioning. Recommended management strategies include the designation of protection zones, seasonal closures, gear-use restrictions, and the adoption of selective fishing technologies tailored to reduce ecological impacts while maintaining socio-economic viability [8, 9].

4.3 Variations in catch weight between species

The significant differences in mean catch biomass among species reflect the low selectivity of mini trawl gear, favouring the capture of small-bodied, schooling pelagic species. *Stolephorus* sp. contributed the highest biomass, consistent with its ecological traits—high abundance, tight schooling behaviour, and susceptibility to mass capture in tropical systems under intensive fishing pressure [23, 33]. These attributes raise concerns regarding long-term stock sustainability and trophic integrity.

In contrast, most demersal and pelagic fish, crustaceans, and molluscs exhibited no significant biomass variation and low average weights, indicating incidental capture of non-target species. Despite their limited contribution to total biomass, these species are functionally important within benthic ecosystems. Study [8] emphasised that non-selective gears such as trawls exert uniform pressure on slow-growing invertebrates and elasmobranchs, underscoring the need for targeted conservation measures.

The dominance of fast-growing, short-lived species, coupled with the scarcity of long-lived demersal predators, indicates potential ecosystem-level shifts consistent with the "fishing down the food web" phenomenon [28]. Technical modifications, including square mesh codends and bycatch reduction devices (BRDs), have been proposed to mitigate these impacts. Study [34] reported that such measures can reduce bycatch by up to 40% in tropical bottom trawl fisheries. Incorporating morphology- and size-based selectivity into gear design is critical to support sustainable exploitation and preserve functional community structure in coastal demersal systems.

4.4 Hierarchical Cluster Analysis (HCA) analysis

Hierarchical Cluster Analysis (HCA) based on morphological similarity identified three primary species groupings, reflecting shared structural traits (Figure 8). Cephalopods such as *Sepia officinalis*, *Loligo* sp., and *Octopus* sp. were clustered due to soft-bodied composition, bilateral symmetry, and similar body elongation ratios. Crustaceans, including *Penaeus merguensis* and *Charybdis anisodon*, formed a separate cluster, highlighting their exoskeletal segmentation and locomotor adaptations. Meanwhile, demersal bony fishes such as *Psettodes erumei* and *Lagocephalus spadiceus* exhibited functional convergence,

likely due to dorso-ventral flattening despite taxonomic divergence.

These morphological clusters carry significant implications for fishing gear selectivity. Species with similar body forms are more likely to pass through or be retained by similar mesh configurations, suggesting that body morphology can predict gear vulnerability. Studies [35, 36] demonstrated that integrating morphometric parameters—such as body length and girth—into net design improves species selectivity and reduces bycatch.

The broad linkage distances observed in the dendrogram reflect the low selectivity and wide functional range of mini trawl gear. These findings support the argument that morphology-informed fishing gear, including species-specific mesh panels or exclusion zones, is essential to mitigate incidental capture and preserve functionally diverse assemblages. Therefore, incorporating such morphological insights into gear development is a priority for sustainable trawl fisheries in tropical ecosystems [8, 30].

4.5 Integration of ANOVA and HCA results for fishing gear selectivity recommendations

The integration of ANOVA and HCA results highlights the low selectivity of mini trawl gear. ANOVA revealed significant differences in catch weight, with biomass dominated by *Stolephorus* sp. and *Leiognathus splendens*, while most demersal and crustacean species exhibited low and statistically similar catch weights. HCA further confirmed the gear's non-selectivity, as species with distinct morphologies and ecological roles—such as crustaceans (*Charybdis anisodon*, *Penaeus merguensis*) and molluscs (*Loligo* sp.)—clustered alongside pelagic and demersal fishes, suggesting indiscriminate capture.

Based on these findings, three key recommendations emerge: (1) High-biomass species may be designated as target species; (2) Small, low-value species within shared morphological clusters could be excluded through gear modifications (e.g., square mesh codends, selective panels); and (3) Non-target taxa of conservation importance (e.g., crustaceans, molluscs, elasmobranchs) should be protected using bycatch reduction devices (BRDs) or excluder devices. Supporting evidence from study [34] demonstrates that square mesh panels and sorting grids can reduce non-target catch by up to 40%. Accordingly, mini trawl modifications in Lamongan should include increased mesh size, codend panel installation, time-area closures during spawning periods, and zoning adjustments in critical benthic habitats. These measures are expected to enhance economic efficiency, reduce bycatch, and mitigate ecological impacts on coastal fish communities.

4.6 General synthesis and ecosystem-based management implications

The findings of this study indicate that mini-trawl operations in Lamongan waters are strongly associated with the exploitation of small-bodied pelagic fishes such as *Stolephorus* sp. and *Leiognathus splendens*. At the same time, shrimps and cephalopods are consistently retained as bycatch. This catch structure is characterized by low gear selectivity, which simultaneously intercepts pelagic schooling fishes and demersal organisms. Consequently, ecological balance is diminished, recruitment overfishing is promoted, and

economic inefficiencies are generated by capturing juveniles and non-target taxa.

Management recommendations should therefore be formulated by incorporating the morphological characteristics of the dominant bycatch species. The laterally compressed bodies of *Leiognathus splendens* and other ponyfishes suggest that use of square mesh with a condensate ≥ 25 mm is expected to enable the escape of undersized individuals while retaining larger target species [31]. Shrimps, characterized by rigid exoskeletons and elongated appendages, can be effectively released by applying rigid-grid BRDs or escape gaps positioned before the condend [32]. Cephalopods, including squids, possess flexible and elongated mantles that can be selectively excluded through separator panels providing vertical escape openings [33].

In addition to gear modification, temporal closures during the spawning seasons of the key taxa, such as shrimps, should be implemented to safeguard recruitment processes, while restrictions on trawl operations in shallow coastal habitats are expected to minimize the capture of juvenile pelagic fishes. These measures demonstrate that integrating species-specific morphological knowledge into technical gear design, supported by spatiotemporal management, provides a practical and implementable pathway to balance short-term fishing efficiency with long-term ecological sustainability. Such integration is consistent with ecosystem-based fisheries management (EBFM) principles, where ecological, biological, and socio-economic considerations are jointly incorporated into management frameworks [34, 35].

5. CONCLUSION

Mini-trawl fisheries in Lamongan waters were dominated by small pelagic fishes, particularly *Stolephorus* sp. and *Leiognathus splendens*, while shrimps, cephalopods, and demersal taxa constituted consistent bycatch. The catch structure was characterized by high richness but low diversity and evenness, reflecting ecological simplification and poor size selectivity that increase the risk of recruitment overfishing. Technical modifications, including square mesh codends, rigid-grid BRDs, and separator panels, together with seasonal closures and habitat restrictions, are recommended to mitigate these impacts. The integration of species-specific morphological knowledge into gear design is therefore essential for aligning catch efficiency with ecosystem-based sustainability.

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