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Ecological Selectivity and Socio-Economic Sustainability in Small-Scale Fisheries: Lessons from Nature for Sustainable Design in Southern Java

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ABSTRACT

Small-scale fisheries play a crucial role in coastal food security and socio-economic development, yet balancing ecological integrity with community well-being poses significant challenges. This study explores a non-FAD small-scale purse-seine fishery in Southern Java, evaluating its ecological selectivity and socio-economic relevance through a nature-inspired design framework. Port-based landing observations conducted from 6 January to 25 February 2025, covering species composition, bycatch, and length-frequency data, alongside gear specifications, reveal a highly selective system with a minimal bycatch ratio (0.4%) and no discards. Four target species were predominantly landed above the size at first maturity (Lm), indicating the avoidance of growth overfishing. However, *Euthynnus affinis* exhibited a higher proportion of sub-mature individuals, signaling a need for species-specific management. The standardized graded-mesh mesh net design, nearshore fishing strategies, and careful handling practices mirror natural size-filtering processes and underpin the observed selectivity. By linking these ecological outcomes to full catch utilization and market-preferred landings, the fishery illustrates how selectivity can support local livelihoods without discarding biomass. This study offers an adaptive, multi-indicator framework focusing on bycatch ratios and maturity-based selectivity as a practical fisheries-management tool for data-limited SSFs. Overall, Tambakrejo provides a model of low-impact, economically relevant purse-seine fishing while highlighting the need to mitigate juvenile catch of *Euthynnus affinis*.

1. INTRODUCTION

Small-scale fisheries (SSFs) are foundational to coastal food security, livelihoods, and social resilience in developing regions, providing affordable animal protein and income for millions [1]. Embedded within local food systems, SSFs channel substantial portions of catch to household consumption and community markets, strengthening customary stewardship and co-management practices [2]. Policy frameworks increasingly recognize these roles: international guidance urges governance that couples poverty reduction and nutrition with biodiversity conservation and responsible use of aquatic resources [3, 4]. Yet climate variability, environmental change, and market instability continue to heighten SSF vulnerability, amplifying the need for tractable, evidence-based indicators that can be applied in data-limited contexts to monitor ecological performance while safeguarding socio-economic well-being [5, 6].

Within Indonesia, purse-seine fisheries are prominent for exploiting schooling small pelagics efficiently. When gear architecture and operating practices are tuned to local conditions, these fleets can achieve low bycatch and favorable size structures [7]. Performance, however, is contingent on mesh configuration, set timing, and handling, and can vary with environmental “windows” that govern school composition and vertical distribution [8, 9]. Offshore modes—especially sets associated with drifting fish aggregating devices—have been linked to elevated interactions with sensitive species, underscoring the need for context-specific controls [10, 11]. Beyond collateral impacts, growth overfishing remains a persistent concern in tropical systems: harvesting below the size at first maturity (Lm) erodes reproductive potential and long-term yields [12, 13]. Consequently, indicator suites that combine bycatch/discard ratios with maturity-based selectivity offer an operationally simple way to gauge ecological performance and inform adaptive management in small-scale, data-limited fisheries.

Sustainability transitions in SSFs require more than ecological diagnostics. Livelihood security, market access, and community nutrition depend on stable, predictable catches of market-preferred pelagics; thus, selectivity gains must be pursued alongside equitable outcomes for fishers and fishworkers. Integrative approaches—combining technical fixes (e.g., mesh gradation, set discrimination, careful handling to minimize slipping) with participatory governance—are favored in the literature to reconcile ecological integrity with socio-economic objectives [14, 15]. In this study, “nature-inspired design” refers to aligning gear architecture and fishing practices with ecological filtering processes (e.g., size-sorting and full biomass utilization) so that form and operation minimize waste while maintaining target catches. At the same time, the "paradox of selectivity" cautions that optimizing a single metric, such as bycatch reduction, can shift species interactions or market dynamics in ways that undermine broader sustainability goals if feedbacks are not monitored [16]. For purse-seine SSFs, this paradox may arise when low overall bycatch still coincides with taxa-specific juvenile pressure or livelihood trade-offs if species- and size-level feedbacks are ignored. Multi-indicator dashboards that link gear design, operational behavior, and ecological outcomes to livelihood metrics are therefore essential to avoid unintended ecological or economic consequences.

The present study positions a port-level evaluation of a small-scale purse-seine fishery in Southern Java (Tambakrejo) within this interdisciplinary frame and explicitly applies a nature-inspired design framework to interpret selectivity. Using two pragmatic indicators, the bycatch/discard ratio and the proportion of individuals ≥ Lm across dominant taxa, the assessment links realized selectivity and collateral impacts to technical specifications of the purse seine (graded mesh sequence, lines, float/sinker system) and to observed operating practices (set timing, school targeting, handling). This design responds directly to the need for low-cost, management-ready evidence in data-limited contexts while remaining sensitive to livelihood implications where full utilization and market alignment are central to community welfare. The expectation, informed by regional and global studies, is that coastal, non-FAD purse-seine operations can deliver low bycatch with maturity-skewed catches for most target species, while revealing taxon-specific vulnerabilities that merit targeted mitigation [7, 8]. Accordingly, we use the nature-inspired lens to map specific net features and operational filters to the multi-indicator outcomes reported in this paper.

2. METHODOLOGY

The study was conducted on the small-scale purse seine fleet operating from Tambakrejo, Southern Java, Indonesia, in a non-FAD coastal operating mode. Port-based sampling was carried out from 6 January to 25 February 2025. The spatial extent of fishing grounds and port sampling locations was delineated using vessel log data and local knowledge (Figure 1). Sampling was performed at a frequency of 5 days a week, yielding observations from 1-2 fishing vessels of fishing trips to ensure representativeness of landings during the study window. The analysis applied standardized port-based observations to assess catch composition, bycatch, and selectivity based on size at first maturity (Lm), following protocols for multi-species tropical fisheries.

Catch and bycatch were recorded through direct landing observations, categorizing species by type, size, and biological status (retained or discarded). The approach followed established traditional methods, in which bycatch estimates are influenced by gear type and operational practices [17]. Each sampled haul was assigned time, location, and trip information to support spatial–temporal interpretation, consistent with practices that identify bycatch hotspots for management [18]. Species verification used morphological identification following the catch assessment standard. Although molecular methods such as eDNA or metabarcoding can enhance resolution [19, 20], morphological techniques were appropriate given the well-known pelagic assemblage.

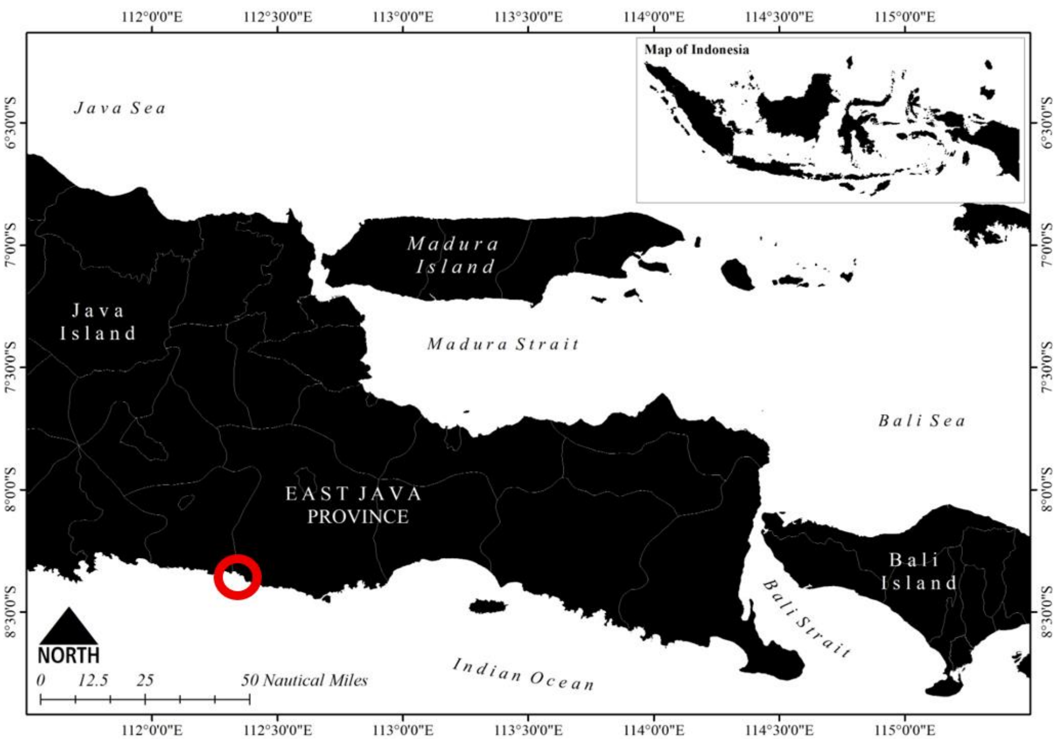

Figure 1. Map of the study area

Operational selectivity assessment included documentation of net design, mesh size, and line configurations, since purse-seine architecture strongly influences species and size retention [8, 9]. Observations of set timing, school behavior, and handling procedures were included to evaluate their effect on non-target capture. Sampling effort followed the recommendation for large, representative datasets to capture species diversity in tropical fisheries [21]. Retention and utilization of non-target organisms were recorded to estimate bycatch and discard ratios and to interpret socio-ecological implications [22, 23]. To capture socio-economic dimensions, we also recorded (i) full biomass utilization (discard ratio), (ii) landing categories of market-preferred species, and (iii) basic livelihood indicators through semi-structured interviews with skippers, crew, and traders covering price ranges, crew share arrangements, and employment dependence on the fishery.

Size selectivity was analyzed through length–frequency data of dominant species compared with published Lm values. Fish lengths were measured as fork length (FL) for scombrids; total length (TL) for non-scombrids, to the nearest 0.1 cm, using a measuring board at the landing site. A total of 58,137 individuals were measured across species, based on random subsampling from each haul when catches were large, or complete measurement when catch sizes were small (Species-specific Lm are presented in Section 3.2). The Lm threshold, a proxy for reproductive maturity, serves as an indicator of sustainable exploitation [24]. Species-specific Lm values were taken from peer-reviewed regional studies for the Indo-West Pacific, and were selected because these sources represent comparable stocks and latitudinal settings to Southern Java; corresponding references for each taxon are provided alongside Lm. Environmental variation was considered because habitat conditions can influence growth and maturation. Reference Lm values from related populations were applied cautiously, recognizing regional variability [25]. Sampling was aligned with reproductive periods to reduce bias in maturity representation [26].

Catch composition was summarized by species mass and relative abundance. Bycatch and discard ratios were calculated as proportions of total catch mass. Length-frequency data were grouped in 2–4 cm bins, and the proportion of individuals ≥ Lm was estimated with binomial confidence limits. Observed bycatch rates were compared with values reported for other tropical purse-seine fisheries to contextualize ecological performance [7].

Data quality control included double entry of field sheets, random re-measurement of 10% of length samples, and cross-checking species counts with photographic records. Unverified specimens were retained at higher taxonomic levels for biomass estimates. The overall methodological framework integrates conventional bycatch observation protocols [17, 18, 27] with maturity-based selectivity benchmarks [24-26, 28] and current guidance for low-impact purse-seine operations, generating concise ecological indicators for sustainable small-scale fisheries management.

3. RESULTS

The small-scale purse-seine units operating from Tambakrejo display a standardized configuration optimized for encircling schooling pelagics in nearshore waters. The net measures approximately 400 m in length and 80 m in depth, assembled from vertically graded nylon panels (D6–D24) with nominal bar mesh sizes of roughly 0.78–0.88 inches. This graded-mesh sequence functions as a size-filter analogous to natural ecological sorting, allowing smaller non-target organisms to escape while retaining market-preferred schooling pelagics. Running rigging comprises polyethylene ris lines (upper and lower), float and sinker lines, and a 24.7 mm purse line; buoyancy and ballast are provided by PVC floats and lead sinkers/rings. Vessels fall in the 24–29 GT class, supporting short-range sets, rapid pursing, and efficient hauling. The architecture enables tight school encirclement and consistent purse closure, providing a technical foundation for selective outcomes when paired with appropriate set timing and careful handling (Table 1). A labeled structural schematic of the purse seine (grading meshes, float line, sinker line, purse line, and bunt) is provided in Figure 2 to clarify the design basis of selectivity. Such standardization is consistent with purse-seine practices shown to enhance efficiency and, when properly tuned, minimize collateral capture in coastal and offshore contexts [17, 29].

Table 1. Technical specifications of the small-scale purse seine used in Tambakrejo

No.	Component	Material	Size/Count
1	Net (overall)	—	400 m (length) × 80 m (depth)
2	Net segments (bottom to top)	Nylon D6; D9; D12; D15; D18; D24	Mesh size (inch): 0.86; 0.78; 0.80; 0.88; 0.80; 0.80
3	Upper ris line	PE (polyethylene, multi)	Ø 12.6 mm; length 400 m
4	Float line	PE (polyethylene, multi)	Ø 10 mm; length 400 m
5	Lower risk line	PE (polyethylene, multi)	Ø 10.8 mm
6	Sinker line	PE (polyethylene, multi)	Ø 3.1 mm
7	Purse line (tali kolor)	PE (polyethylene, multi)	Ø 24.7 mm
8	Floats	PVC	147 × 88 mm
9	Sinkers	Lead	57 × 28 mm; 2000 units
10	Rings	Lead	Ø 10 cm; 135 units
11	Vessel size (context)	—	24–29 GT

3.1 Catch composition, bycatch, and utilization

Landings during the observation period (6 January–25 February 2025) were dominated by five small pelagic taxa typical of Southern Java's nearshore assemblages. Frigate tuna (*Auxis rochei*) contributed 6,833 kg (35.3%), Indian mackerel (*Rastrelliger kanagurta*) 5,480 kg (28.3%), bluefish (*Scomberoides tol*) 4,645 kg (24.0%), skipjack (*Katsuwonus pelamis*) 1,735 kg (9.0%), and longtail tuna (*Euthynnus affinis*) 570 kg (2.9%). The only recorded bycatch was needlefish (*Tylosurus acus*) at 75 kg (0.4%). The discard ratio was 0%, indicating full utilization of landed biomass across all hauls and species (Table 2). This zero-discard utilization reflects not only ecological efficiency but also socio-economic alignment, because all landed biomass contributes to local food and market value rather than being wasted at sea. Port records adopting local taxonomy reiterate this pattern, classifying the five pelagic taxa as main catch and *Tylosurus acus* as bycatch (Table 2).

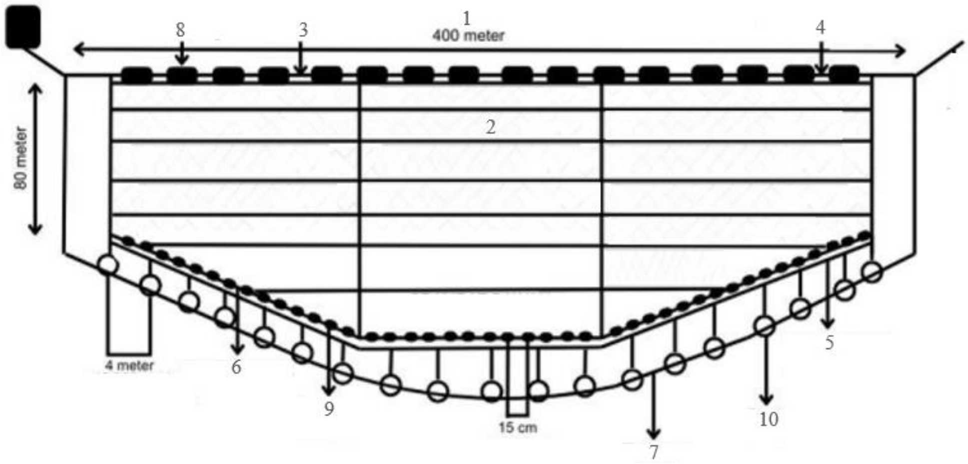

Figure 2. Construction design of a small-scale purse seine operated in Tambakrejo

Table 2. Species composition, relative abundance (%), and bycatch rate of the purse-seine catch

Scientific Name	Catch (kg)	Relative Abundance (%)	Category
Auxis rochei	6,833	35.3	Main catch
Rastrelliger kanagurta	5,480	28.3	Main catch
Scomberoides tol	4,645	24.0	Main catch
Katsuwonus pelamis	1,735	9.0	Main catch
Euthynnus affinis	570	2.9	Main catch
Tylosurus acus	75	0.4	Bycatch

The concentration of landings in a small suite of species matches prior observations that purse-seine catch can be highly selective where fleets consistently target prevalent schooling pelagics [29]. The very low bycatch proportion falls at the lower end of typical purse-seine ranges and is markedly below values reported for gears such as trawls or some longline modes [7, 30]. Although offshore and DFAD-associated purse-seine sets may elevate interactions with vulnerable taxa [11, 31], the Tambakrejo fishery's coastal, non-DFAD operations, combined with standardized net configuration and handling, likely contributed to the 0.4% bycatch and zero discards, supporting efficient use of resources and minimizing ecological collateral [10]. Together, the graded meshes and nearshore school-targeting act as operational "filters" that parallel natural prey-size selection, explaining why non-target capture is rare in this system.

3.2 Length distributions and size-at-maturity signals

Length-frequency distributions were compiled for the principal taxa and evaluated relative to species-specific size at first maturity (Lm) of the main target fish. Species-specific Lm values were obtained from relevant literature, ensuring that maturity thresholds reflect local conditions for Southern Java stocks. Across species, modal structures tended to center on mid-to-large size classes, indicating selective retention above Lm for most taxa and implying a reduced risk of growth overfishing under the observed operational conditions [32]. The distributions also reflect mechanisms described for purse seines, where mesh architecture, set discrimination, and handling can shape realized selectivity [9, 33].

3.2.1 *Rastrelliger kanagurta*

Length modes were concentrated at 24.4-27.4 cm, with minimal representation of small juveniles (Figure 3). All measured individuals met or exceeded Lm = 21 cm [34], indicating favorable size selectivity and low risk of growth overfishing for this species. The absence of sub-Lm mackerel is consistent with the upper graded panels acting as an effective size threshold for this taxon.

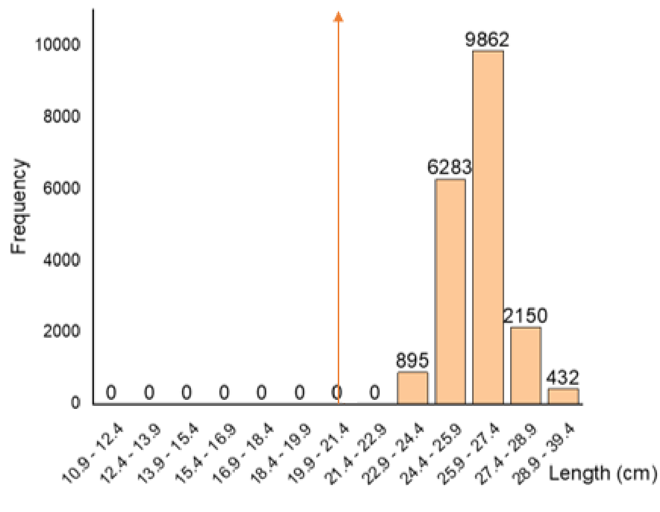

Figure 3. Length distribution of *Rastrelliger kanagurta* (Lm = 21 cm)

3.2.2 *Auxis rochei*

The length distribution was strongly concentrated between 23.34–30.54 cm, with the highest mode at 26.94–28.74 cm (Figure 4). Length classes below 21.54 cm were absent, and only a small share of observations occurred close to the updated Lm threshold (22.76 cm) [34], yielding a mature-dominated profile and confirming generally favorable size selectivity under the observed operating conditions, consistent with graded-mesh retention mechanisms reported for purse seines. The limited sub-Lm component, confined to fish near the lower edge of the observed size range, still reflects a net design that preferentially retains mature-size frigate tuna.

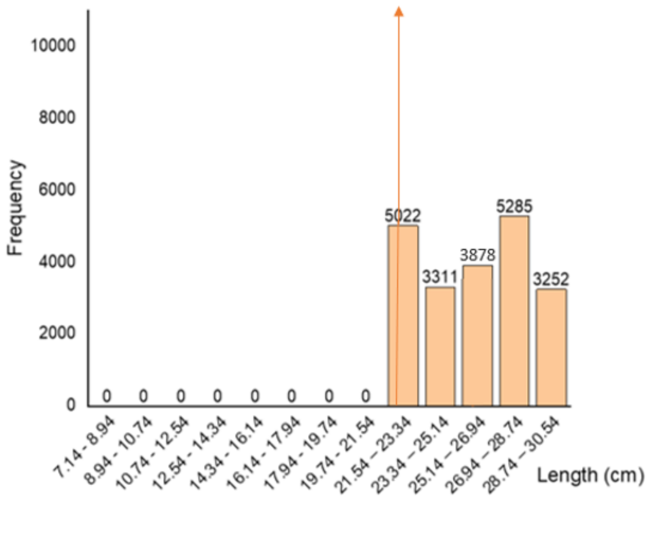

Figure 4. Length distribution of *Auxis rochei* (Lm = 22.76 cm)

3.2.3 *Katsuwonus pelamis*

Dominant modes occurred at 56.42-58.82 cm, and all measured fish were above Lm (44.7 cm) [35], confirming very strong size selectivity for skipjack in these nearshore, non-FAD sets (Figure 5). This outcome aligns with reports that properly tuned purse seines can target mature schooling cohorts while minimizing juvenile retention.

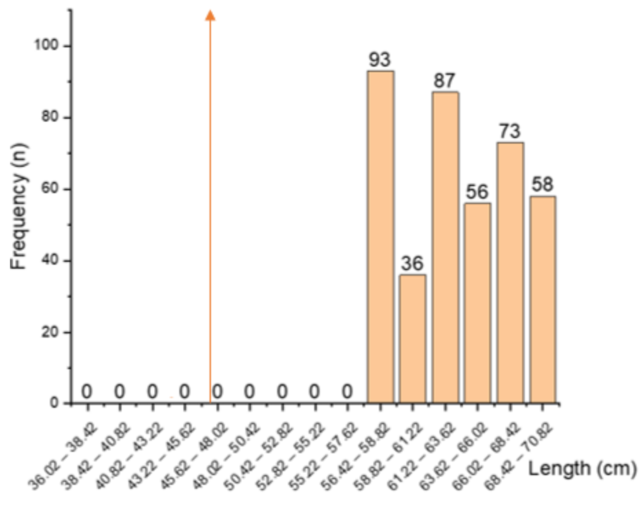

Figure 5. Length distribution of *Katsuwonus pelamis* (Lm = 44.7 cm)

3.2.4 *Scomberoides tol*

Fish sizes ranged from 24.5 to 51.5 cm, with very few individuals below 27 cm (Figure 6). Over 95% of the catch was ≥ Lm = 26.0 cm [36], evidencing selective retention toward mature size classes for this species. Combined with low bycatch and zero discards, these length outcomes reinforce the fishery's low-impact profile for the most dominant taxa.

3.2.5 *Euthynnus affinis*

The catch clustered between 28–41.5 cm, with a notable share of individuals below Lm = 40.17 cm (Figure 7) [37]. This species constituted the principal exception to the otherwise maturity-skewed landings, indicating a species-specific vulnerability that may be linked to seasonal recruitment pulses during the study window, nearshore nursery–feeding overlap, and mixed-schooling with smaller pelagics that are preferentially targeted by the fleet, which can increase juvenile exposure to sets despite overall low bycatch. These mechanisms are consistent with regional observations of juvenile-dominated *Euthynnus affinis* catches in Indonesian waters.

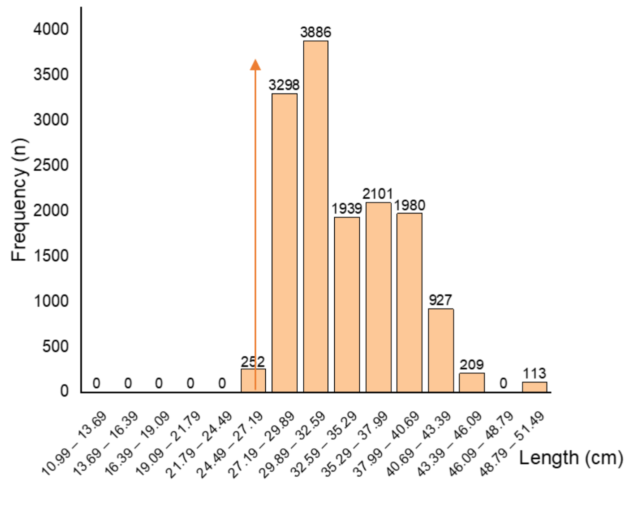

Figure 6. Length distribution of *Scomberoides tol* (Lm = 26 cm)

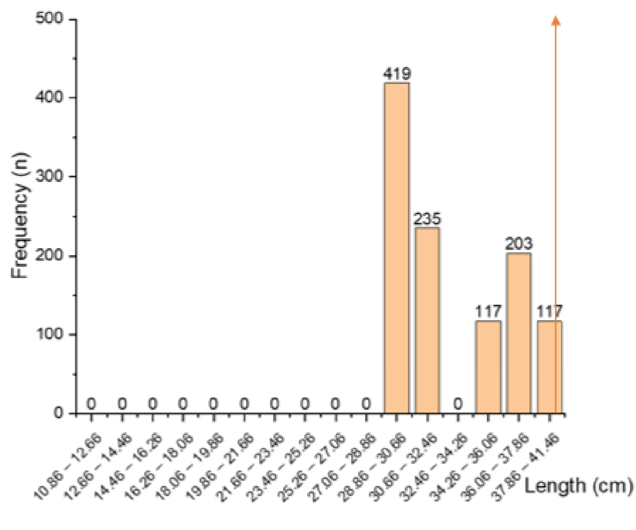

Figure 7. Length distribution of *Euthynnus affinis* (Lm = 40.17 cm)

3.3 Immature proportions relative to Lm

Proportions of immature individuals, calculated from the length distributions using species-specific Lm thresholds, reinforce the selectivity patterns. For *Rastrelliger kanagurta* (Lm = 21.0 cm) and *Katsuwonus pelamis* (Lm = 44.7 cm), immature proportions were effectively 0%, consistent with the dominance of mid-to-large modes. For *Auxis rochei* (Lm = 22.76 cm fork length (FL)), the mature share was approximately 94%, implying an immature fraction of 6%. For *Scomberoides tol* (Lm = 26.0 cm) [36], the mature share reached 99.2%, indicating 0.8% immature individuals. For *Euthynnus affinis* (Lm = 40.17 cm), almost all (99.7%) observed individuals during 6 January–25 February 2025 were < Lm, implying a high immature proportion during the sampling window. The bycatch species *T. acus* was dominated by mature individuals. These summary proportions are shown in Table 3, providing a quantitative benchmark for risk of growth overfishing by taxon and offering a straightforward indicator for management tracking in data-limited settings [24-26, 28].

Table 3. Percentage of immature individuals in the catch for the main target species (based on Lm)

Scientific Name	Lm (cm)	Immature (%)	Mature (%)	Basis in Manuscript
Rastrelliger kanagurta	21.0	0	100	From length classes; all ≥ Lm
Auxis rochei	22.76	6	94	From length-frequency counts vs Lm
Euthynnus affinis	40.17	99.7	0.3	Almost all observed < Lm
Scomberoides tol	26.0	0.8	99.2	From length-frequency counts vs Lm
Katsuwonus pelamis	44.7	0	100	All observed ≥ Lm

3.4 Integrated ecological performance in regional context

Taken together, the technical profile, catch composition, and maturity signals indicate that the Tambakrejo fishery operated with a selective, low-impact footprint over the observation period. The dominance of a few target pelagics and the near absence of juveniles in four of five principal taxa suggest a low risk of growth overfishing and align with literature emphasizing that well-tuned purse-seine operations can minimize bycatch and improve size selectivity [7, 30, 38]. This performance is consistent with the nature-inspired filtering role of the graded mesh architecture and nearshore school-selection, which jointly favor mature pelagic cohorts while allowing smaller non-targets to escape. The very low bycatch ratio and zero discards reinforce this interpretation, contrasting with concerns raised for DFAD-associated offshore fisheries where bycatch of vulnerable species—particularly juvenile silky sharks—has been documented [10, 39, 40]. The coastal, non-DFAD operating mode and standardized net configuration likely reduced exposure to such risks in the present case [11].

The species-specific signal for *E. affinis* warrants attention. Elevated sub-Lm capture in longtail tuna can depress long-term yields and reduce average market size, with potential knock-on effects for fisher income in the absence of mitigation [41]. Based on the juvenile-skewed size structure observed in January–February 2025, management should prioritize species-specific levers such as: (i) seasonal or area-based avoidance when sub-mature cohorts dominate nearshore schools, (ii) refining set timing to target larger *Eufinnis affinis*-dominated schools, and (iii) evaluating adjustments to the smallest graded-mesh panels if monitoring shows persistent juvenile retention. Port-level monitoring of ≥ Lm proportions offers a low-cost, management-ready signal to guide such adjustments. These measures directly address the paradox of selectivity by ensuring that an overall low-bycatch fishery does not mask taxon-specific growth-overfishing risk.

4. DISCUSSIONS

The Tambakrejo purse-seine fishery exhibits a selective, low-impact profile consistent with outcomes achievable when gear and operations are tuned to local schooling dynamics. Targeted school selection in coastal waters, combined with an appropriate graded-mesh configuration, maximizes size-selectivity and minimizes juvenile capture. Catch composition concentrated in a few small pelagic taxa with negligible bycatch and zero discards aligns with evidence that purse seines can deliver highly selective landings where fleets target prevalent schooling species in coastal waters [17, 29]. Length structures strengthen this interpretation: skipjack displayed dominant modes at 56.42–58.82 cm with all fish above Lm = 44.7 cm [35], *Scomberoides tol* spanned 24–51.5 cm with very few individuals below 27 cm and > 99.2% ≥ Lm = 26.0 cm, [36], and *Auxis rochei* peaked at 26.94–28.74 cm with a lower tail at 21.54–23.34 cm yet still a majority ≥ Lm = 22.76 cm [37]. Together with the mature-skewed profile for *Rastrelliger kanagurta* (21.0 cm) [34], these outcomes indicate that realized selectivity favored reproductive-sized fish across most dominant taxa.

The bycatch ratio (0.4%) lies at the low end of values reported for tropical purse-seine fisheries and below rates commonly associated with other gears, though variability across regions and set modes is well documented [7]. Drifting FAD–associated sets often elevate incidental capture of vulnerable species, including juvenile silky sharks [10, 31]. The coastal, non-DFAD operating mode at Tambakrejo likely reduced exposure to such risks. Nevertheless, diurnal and seasonal shifts in school behavior can alter bycatch composition, with high juvenile catch potential during recruitment periods if cohort structure shifts. This variability underscores the need for context-specific monitoring and readiness to deploy targeted avoidance or release protocols where risk indicators change, such as timing set operations around cohort distributions or using selective mesh shifts [39, 40, 42].

Maturity-based indicators provide tractable diagnostics for growth overfishing in data-limited fisheries. The universal ≥ Lm status for *Katsuwonus pelamis* (Lm = 44.7 cm) and the >90% ≥ Lm share for *Scomberoides tol* (Lm = 26.0 cm), combined with majority-mature *Auxis rochei* (Lm = 22.76 cm) and Lm-conforming *Restraligger kanagurta* (Lm = 21.0 cm), indicate low near-term risk of eroding reproductive potential for these taxa [12, 13]. The principal exception remains *Euthynnus affinis* (Lm = 40.17 cm), which showed a higher sub-Lm fraction, suggesting species-specific vulnerability potentially linked to seasonal cohort structure or mixed-school encounters. Given the seasonal recruitment window observed for *Eufinnis affinis* during January–February 2025, management attention is warranted where juvenile-biased harvest persists, even when fishery-wide indicators are favorable. Persistent juvenile-biased harvests are known to depress long-term yields and reduce average market size, with implications for fisher income [41]. Management attention is therefore warranted where sub-Lm capture persists, even when fishery-wide indicators are favorable.

The graded mesh sequence and standardized rigging documented for Tambakrejo (Table 1) are consistent with mature-skewed retention in most taxa, in line with demonstrations that appropriate mesh windows reduce juvenile capture while preserving target size classes [43, 44].

For *Auxis rochei* (Lm = 22.76 cm), the peak at 26.94–28.74 cm with a secondary presence at 21.54–23.34 cm suggests vigilance during periods when smaller cohorts increase. For *Euthynnus affinis* (Lm = 40.17 cm), feasible levers include temporal or spatial avoidance of juvenile-rich aggregations, refined set timing to target mature-dominated schools, and, where permitted, modest mesh adjustments that shift the selectivity curve toward desired sizes [45, 46]. These measures would minimize juvenile catch during recruitment periods while supporting sustainable longtail tuna yields. These measures align with ecosystem-based guidance emphasizing selectivity improvements and protection of spawning potential while maintaining operational viability.

Low bycatch, zero discards, and maturity-skewed landings support local provisioning and income stability in small-scale fisheries, reinforcing policy guidance that links responsible fishing to poverty reduction and nutrition [14, 47]. At the same time, the "paradox of selective fishing" warns that optimizing a single indicator can trigger unintended ecological or economic effects if feedbacks are not monitored [16]. For example, persistent juvenile capture, even with low bycatch, may redistribute longtail tuna biomass pressure across cohorts, reducing yields and lowering average fish sizes for markets. Evidence from tuna and shrimp systems shows that mitigation altering set behavior or catch composition can redistribute trophic pressures or generate compliance costs, potentially constraining revenues when quota or market limits bind [48-52]. Multi-indicator dashboards—pairing bycatch and ≥ Lm proportions with signals of species composition and livelihood metrics—help detect emerging trade-offs before they compromise ecosystem integrity or socio-economic equity.

Oceanographic variability influences school size, depth, and species mix, conditioning realized selectivity even under constant gear [53]. High-productivity phases can amplify mature-mode catches, whereas adverse conditions may increase mixed-school encounters and juvenile capture [54, 55]. Port-level time series linking indicator trends to environmental covariates can distinguish management-relevant changes from transient forcing. To enhance selectivity monitoring, low-cost enhancements like photographic validation of tallies, confidence intervals for ≥ Lm proportions, and, where feasible, eDNA/metabarcoding for rare bycatch verification, would improve accuracy without adding a significant cost burden [19, 20].

An important limitation of this study is the restricted temporal coverage of the data. Landings and length–frequency observations were collected from 6 January to 25 February 2025, representing a sampling window of only about seven weeks. As a result, the patterns of catch composition, bycatch, and size structure documented here should be interpreted as a seasonal snapshot rather than a definitive description of year-round fishery performance. In particular, the juvenile-skewed size structure of *Euthynnus affinis* may reflect recruitment pulses or seasonal use of nearshore waters as nursery or feeding habitat during this period, and may differ under other monsoonal or transitional conditions. Future research should therefore extend monitoring across multiple seasons and years to test whether the maturity-based selectivity patterns and low bycatch ratios observed here remain consistent over time, and to link these ecological indicators with environmental drivers and socio-economic metrics in a longer-term port-level time series.

5. CONCLUSIONS

The findings from the Tambakrejo small-scale purse-seine fishery illustrate a robust example of how sustainable fisheries management can be achieved by integrating ecological selectivity with socio-economic stability. The low bycatch ratio (0.4%) and zero discards, coupled with maturity-skewed landings, reflect the potential for designing fishing systems that optimize ecological performance without compromising livelihood outcomes. This study underscores the importance of designing fishing practices that mimic nature's efficiencies, where, together with careful handling practices, these operational strategies enable both biodiversity conservation and the economic stability of local communities.

The application of adaptive eco-dynamics to fisheries management reveals that adaptive design improvements, such as targeted species avoidance and refined mesh adjustments, can enhance both ecological sustainability and socio-economic equity. By mimicking nature's filtering processes, these strategies provide a pathway for reconciling biodiversity conservation with the livelihoods of small-scale fishers. This approach emphasizes the intersection of nature-inspired design and fisheries management, offering practical solutions for sustainable, low-impact fisheries.

The study contributes to the growing body of knowledge on nature-inspired design solutions in marine resource management. By leveraging ecological indicators such as maturity-based selectivity and bycatch ratios, it provides practical, scalable tools for managing fisheries in data-limited contexts. Future research should focus on refining these indicators, especially in coastal fisheries where dynamic environmental and socio-economic shifts occur frequently. Expanding the application of eco-dynamics through multi-indicator dashboards and participatory governance frameworks will empower local communities and stakeholders to monitor and adapt to ecological and socio-economic changes in real-time, ensuring long-term sustainability.

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