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MORALITY BEFORE KNOWLEDGE

Evaluating fishing techniques and sustainability status of spanish mackerel (*Scomberomorus* sp.) under an ecosystem-based fisheries management framework

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ABSTRACT
Background: Spanish mackerel (*Scomberomorus* sp.) is a high-value fishery commodity intensively harvested in the Terubuk Fishery Reserve Area, Buruk Bakul Village. Increasing demand and market value have led to rising fishing pressure, potentially affecting resource sustainability. Evaluating fishing techniques is therefore essential to ensure sustainable management within the Ecosystem Approach to Fisheries Management (EAFM) framework. **Methods:** Data were collected through surveys and interviews with local fishers from November to December 2024 in Buruk Bakul Village, Bengkalis Regency. A multi-criteria analysis using a flag model was applied to assess indicators of destructive fishing practices, gear modification, fishing capacity and effort, gear selectivity, and vessel documentation compliance. **Findings:** The evaluation shows that the Spanish mackerel fishery in the Terubuk Sanctuary Area is categorized as "good," with a composite score of 220. This indicates that fishing practices are relatively sustainable and align with EAFM principles. However, low vessel documentation, moderate gear selectivity, and limited fishing capacity highlight areas that require improvement. **Conclusion:** Overall, the fishery demonstrates good ecological performance but remains limited in institutional and social resilience. Policy efforts should focus on strengthening fisher capacity, promoting selective and environmentally friendly gears, and improving vessel registration systems to ensure long-term sustainability. While this study emphasizes technical aspects, it also underlines the need for future research that integrates socio-economic and governance dimensions to better understand the fishery's resilience as a social–ecological system. The study contributes practical insights for adaptive management and community-based fisheries governance in small-scale contexts. **Novelty/Originality of this article:** This study offers a novel contribution by applying a multi-criteria flag model within the Ecosystem Approach to Fisheries Management (EAFM) framework to evaluate the sustainability of Spanish mackerel (*Scomberomorus* sp.) fisheries in a designated sanctuary area—a context rarely examined in previous research. While most EAFM-based assessments in Indonesia focus on larger-scale or multi-species fisheries, this research uniquely centers on a single high-value species and its localized management practices in the Terubuk Fishery Reserve Area, Buruk Bakul Village.

KEYWORDS: EAFM; capture fisheries; fishery resources; fishing selectivity; socio-ecological system.

1. Introduction

The Terubuk Sanctuary Area, located in the Bengkalis Strait of Riau Province, Indonesia, is a coastal conservation zone of considerable ecological and socioeconomic

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importance. This region supports rich fishery resources that underpin local livelihoods and food security. Among the fish species present, Spanish mackerel (*Scomberomorus* sp.) is a principal target due to its high market value, wide consumer demand, and essential role in sustaining artisanal fishers. Recent studies in the Riau Archipelago have shown that environmental parameters such as sea surface temperature (SST), salinity, and chlorophyll-a concentration, strongly influence the spatial and temporal distribution of narrow-barred Spanish mackerel fishing grounds, emphasizing the species' sensitivity to shifting oceanography (Fardilah et al., 2024).

While Spanish mackerel broadly occurs across the Indo-West Pacific, local fishers in Bengkalis Regency depend heavily on it as a central income and fishery resource. However, concerns about declining catch volumes, changing seasonal patterns, and habitat constraints have emerged. Market demand has steadily increased, but management remains hampered by constraints in data on stock condition, exploitation rates, and gear selectivity. This data scarcity is pervasive among Indonesian small-scale fisheries, many of which are considered data-limited or poorly monitored (Smithrithee & Chamsai, 2022).

The decline in Spanish mackerel abundance in Bengkalis is likely driven by a combination of intensified fishing pressure, market expansion, and environmental variability. In the local waters, artisanal and semi-industrial fishers employ gears such as gillnets, handlines, and trolling lines. As market incentives rise, fishers may increase effort or adopt less selective gear, which risks aggravating stock depletion and ecosystem harm. Such dynamics are consistent with broader national trends: small-scale fishers in Indonesia increasingly operate under ecological degradation, habitat loss, and socio-economic vulnerability (Handayati et al., 2025).

Beyond fishing pressure, environmental drivers such as SST anomalies, monsoonal shifts, and upwelling gradients may alter recruitment, distribution, and catchability. In pelagic systems globally, fluctuations in temperature and productivity regimes often translate into spatial shifts of fisheries. Yet in the Bengkalis Strait, long-term monitoring and ecological assessments remain virtually absent, leaving substantial uncertainty in modeling population dynamics or predicting responses to climate perturbations.

Fishing techniques themselves constitute a critical interface in this socio-ecological system. Non-selective or destructive gear can exacerbate overfishing, elevate bycatch, and damage habitat structure, including benthic and nursery zones. Inappropriate mesh sizes may lead to juvenile captures, undermining recruitment and regeneration potential. Conversely, more selective and adaptive gear has the potential to minimize ecological harm while sustaining viable catches. Evaluating the performance and impacts of fishing techniques is thus essential to understanding the linkage between exploiter behavior, stock status, and ecosystem resilience. In a conservation area such as Terubuk, where preserving ecological integrity is explicitly intended, determining which gears maintain ecological health while supporting livelihoods is both practically and scientifically urgent.

To frame this complexity, the concept of socio-ecological resilience offers a powerful lens. Resilience refers to the capacity of a coupled human–environmental system to absorb disturbances without losing essential structure, to adapt, and potentially transform (Biggs et al., 2021). In small-scale fisheries, resilience depends not only on ecological attributes, but also on social factors such as fisher knowledge, institutional support, and diversification options. Studies in Indonesia, e.g. in South Malang have shown that fishing communities are often vulnerable to climate variability, ecosystem degradation, and lacking in adaptive capacity (Handayati et al., 2025). These vulnerabilities can create feedback loops: as catches decline, fishers intensify effort or shift gear, further stressing the ecosystem and reducing long-term resilience.

Effective management of such intertwined challenges calls for frameworks that integrate ecological, technical, economic, and social dimensions. The Ecosystem Approach to Fisheries Management (EAFM) provides precisely such a platform. Originating from FAO guidance and global fisheries policy, EAFM aims to balance ecological sustainability with human welfare by considering multiple domains, such as fishery resources, habitat and ecosystems, fishing techniques, socioeconomic factors, institutional arrangements, and governance mechanisms. Recent applications in Indonesia emphasize that the fishing technique domain often determines the sustainability performance of fisheries because it directly links human actions to ecological outcomes (Haerunnisa et al., 2025). Moreover, integrating EAFM with resilience thinking enables a more adaptive and equitable approach to fisheries governance.

Effective EAFM implementation has demonstrated measurable benefits in both tropical and temperate fisheries worldwide. For instance, emphasized that EAFM facilitates adaptive co-management by explicitly linking ecological indicators with social and economic dimensions, thereby strengthening resilience in small-scale coastal fisheries. FAO highlighted that EAFM serves as a bridge between traditional resource management and ecosystem-based approaches, ensuring that governance decisions consider cumulative impacts across habitats and species (FAO, 2024).

Theoretical perspectives emphasize that the Ecosystem Approach to Fisheries Management (EAFM) is essential because it integrates ecological objectives with social and economic dimensions, rather than focusing solely on maintaining fish stocks or habitats. For example, a study on coral reef fisheries in Hawaiʻi demonstrated that EAFM successfully aligned ecological performance indicators with community well-being objectives through stakeholder participation in defining management criteria (Weijerman et al., 2021). Similarly, research on capelin fisheries revealed that without comprehensive consideration of ecosystem aspects, such as interspecies interactions, climatic influences, and local traditions regulatory measures like catch limits or seasonal closures remain insufficient to ensure long-term sustainability (Singh et al., 2025). These findings reinforce the argument that domains such as fishing techniques, local indicators, and policy adaptability are crucial components of effective EAFM implementation, particularly within the Indonesian context.

Yet practical implementation of EAFM in Indonesia remains limited. Institutional fragmentation, limited stakeholder coordination, and paucity of context-specific indicator data often constrain progress (Ditya et al., 2022). In particular, the domain of fishing techniques is under-evaluated in many coastal systems, despite its central role in mediating ecological and social trade-offs. Recognizing this, conducting a rigorous assessment of fishing techniques under EAFM in a conservation-sensitive area like Terubuk could bridge a critical translational gap between theory and practice.

Although the Spanish mackerel fishery constitutes a cornerstone of local livelihoods in Bengkalis Regency, management remains largely conventional and narrowly focused on effort limitation. There is no explicit, integrated assessment of how different fishing techniques influence stock sustainability, habitat integrity, and community resilience within the Terubuk Sanctuary Area. Even more critically, the interplay between environmental variability and fisher behavior is poorly understood in this locale. The absence of such knowledge undermines the ability of local policymakers to design adaptive, evidence-based strategies that reconcile conservation and livelihood objectives.

Prior research on Spanish mackerel in Indonesia has largely addressed catch composition, distribution, and life-history traits, while seldom engaging socio-ecological frameworks or integrating technical, biological, and social indicators in concert. While Fardilah et al. (2024) provide spatial-temporal insight into distribution shifts in the Kepulauan Riau, comparable studies in Bengkalis are missing. Addressing these gaps is vital not only for local fisheries governance but also for advancing global debates on sustainable small-scale fisheries management, especially in data-poor tropical systems. Moreover, such inquiry helps align Indonesia's fisheries policies with SDG 14 (Life Below Water) and the FAO Voluntary Guidelines for Securing Sustainable Small-Scale Fisheries (FAO, 2025).

Accordingly, this research aims to assess the management status of the Spanish mackerel fishery in the Terubuk Sanctuary Area, Bengkalis Regency, through the lens of EAFM, focusing specifically on the fishing techniques domain. This study will evaluate gear selectivity, fishing effort, ecological impacts, and fishers' perceptions and adaptation capacity. The expected outputs are a comprehensive indicator-based assessment of sustainability performance, and policy-relevant recommendations for improving fisheries governance in a conservation-sensitive coastal zone.

2. Methods

This research was conducted in the Terubuk Sanctuary Area, Bengkalis Regency, Riau Province, specifically in Buruk Bakul Village. The research location map is presented in Figure 1. The method applied in this study was a mixed-method survey approach, combining quantitative assessments and qualitative inquiry to obtain a comprehensive understanding of fishing techniques and management conditions. The survey included field observations, structured interviews, and semi-structured discussions with key informants at the research site.

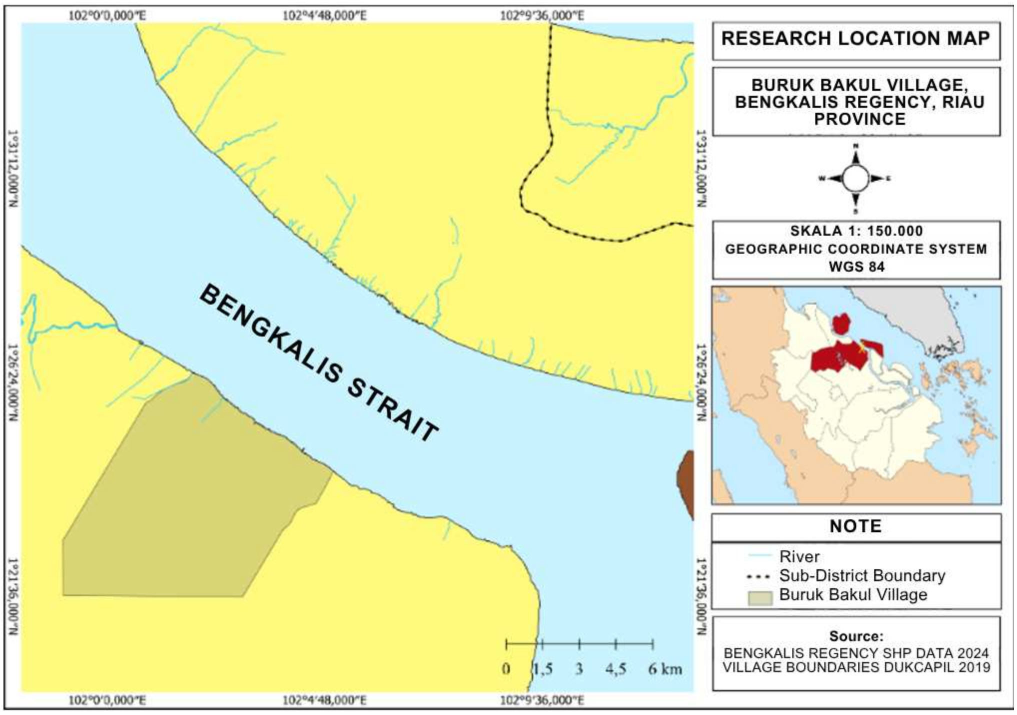

Fig. 1. Research location

The data collected consisted of both primary and secondary sources. Primary data were obtained through direct observation and interviews, while secondary data were gathered from various literature sources, fisheries statistical reports, and relevant institutions, including the Riau Province Marine and Fisheries Agency and the Bengkalis Regency Fisheries Agency. Number of respondents and informants are summarized in Table 1. Respondents and informants were selected using purposive sampling, a non-probability technique that enables the deliberate selection of participants who possess in-depth knowledge and experience relevant to the study objectives. This approach was chosen to ensure that the information obtained was contextually rich and specific to the fisheries management conditions in the Terubuk Sanctuary Area.

Table 1. Number of respondents and informants

No.	Respondents	Number (Persons)
1.	Riau Province Marine and Fisheries Agency	3
2.	Bengkalis Regency Fisheries Agency	2
3.	Head of Buruk Bakul Village	1
4.	Fishers	10
5.	Non-Governmental Organization	1

The primary respondents were fishers from Buruk Bakul Village with at least ten years of fishing experience in the Bengkalis Strait, representing those most familiar with the local fishing practices and resource trends. Additional informants included fisheries officers, local leaders, and representatives from non-governmental organizations actively involved in community-based fisheries management. The final number of respondents (n = 17) was determined based on the principle of data saturation, ensuring that no new information emerged from subsequent interviews.

To enhance the reliability and validity of data collection, triangulation techniques were applied. Methodological triangulation was conducted by cross-verifying interview responses with direct field observations and official fisheries records. Source triangulation involved comparing information obtained from different respondent categories (fishers, government officials, and NGOs). Data validity was further supported through respondent validation, where key informants reviewed preliminary findings to confirm accuracy and interpretive consistency. The data collected in this study referred to the fishing technique domain indicators established by the Directorate of Fish Resources, Ministry of Marine Affairs and Fisheries, as summarized in Table 2.

Table 2. Indicator od the fishing technique domain

Indicators	Description	Criteria	Weight
Destructive and illegal fishing methods	Fishing practices that damage ecosystems	1 = >10 cases per year 2 = 5–10 cases per year 3 = <5 cases per year	30
Modification of fishing gear and auxiliary devices	Modifications that negatively affect resource populations	1 = >50% of target size < Lm 2 = 25–50% < Lm 3 = <25% < Lm	25
Fishing capacity and effort	Ratio of fishing capacity to fishing activity	1 = ratio < 1 2 = ratio = 1 3 = ratio > 1	15
Selectivity of fishing gear	Ability of gear to capture target species and minimize bycatch	1 = low >75% 2 = medium 50–75% 3 = high <50%	15
Compliance of vessel function and size with legal documentation	Alignment of vessel ownership and legal documents (e.g., vessel certificate, operating permit)	1 = low >50% of samples non-compliant 2 = medium 30–50% non-compliant 3 = high <30% non-compliant	10

(Kementerian Kelautan dan Perikanan, 2014)

Data analysis was conducted using a multi-criteria analysis (MCA) approach, in which a set of criteria was developed through the construction of a composite index. This index was used to determine the status of each domain, and the overall score reflected the condition of fisheries management in the study area (El Fajri et al., 2021). The assessment applied a Likert scale scoring system (values 1, 2, and 3), adjusted to the current conditions for each criterion within the indicators of every domain (Gazali et al., 2017). The assessment of scores are presented ini Table 3.

Table 3. Assessment of scores

Score Range	Description	Flag Model
1	Poor	
2	Moderate	
3	Good	

(Kementerian Kelautan dan Perikanan, 2014)

Each indicator was assigned a weight coefficient, reflecting its relative priority within the domain. After scoring, the assigned weight was multiplied by the score value. The sum of these products for each indicator represented the aggregate index score for the respective domain. The classification and visualization of the flag model are represented in Table 4.

Table 4. Classification of indices and visualization of the flag model

Range	Description	Description in EAFM
100-125		Poor
126-150		Fair
151-200		Moderate
201-250		Good
251-300		Very Good

(Kementerian Kelautan dan Perikanan, 2014)

3. Results and Discussion

3.1 Existing conditions od the terubuk sanctuary area

The Terubuk Sanctuary Area was established in response to the decline of the terubuk fish (*Tenualosa macrura*), which has been subject to overexploitation since the 1970s (Lubis et al., 2016). This decline has been attributed to intensive fishing activity, particularly during the spawning migration, as well as habitat degradation caused by pollution and sedimentation in the Bengkalis Strait. As a conservation measure, the terubuk fish was designated as a species under limited protection through decrees issued by the Ministry of Marine Affairs and Fisheries in 2011 and 2016. In addition, the Bengkalis Regency Government established the Terubuk Sanctuary Area under Bengkalis Regent Regulation No. 15 of 2010, which was later reinforced by Riau Governor Regulation No. 8 of 2012. The sanctuary covers three regencies, such as Bengkalis, Kepulauan Meranti, and Siak, with a total area of 40,741.8 hectares (Efizon et al., 2015).

As a conservation zone, the Terubuk Sanctuary Area aims to maintain ecosystem balance and ensure the sustainability of fishery resources. According to Government Regulation No. 60 of 2007, the area may still be utilized sustainably if ecosystem integrity is preserved. Beyond terubuk, the sanctuary is rich in other valuable fishery resources, including Spanish mackerel (*Scomberomorus* sp.), fourfinger threadfin (*Eleutheronema tetradactylum*), Bombay duck (*Harpadon nehereus*), largehead hairtail (*Trichiurus lepturus*), and ilisha (*Ilisha elongata*), which serve as key commodities for coastal communities. While the sanctuary plays an important role in sustaining fishery stocks, it also necessitates the adoption of more selective fishing techniques to prevent adverse impacts on the aquatic ecosystem. Fisheries utilization within the area is regulated through various measures, including the prohibition of terubuk fishing during the spawning season. The terubuk migration cycle occurs during the new moon and full moon phases from August to November, with migration routes spanning the Malacca Strait, Bengkalis Strait, Siak River Estuary, and Lalang Strait (Syahrian & Rahmat, 2023). In addition to formal regulations, local wisdom also plays a role through the *Semah Terubuk* tradition, which has been practiced since the rule of Datuk Laksamana Raja di Laut IV in 1927. This tradition emphasizes the prohibition of catching terubuk during spawning to safeguard its population (Syahrian & Rahmat, 2023).

Recent studies highlight that such community-based conservation traditions contribute significantly to co-management success in small-scale fisheries (Lister, 2025). The presence of local customary rules in tandem with government regulation exemplifies the EAFM principle of participatory and adaptive governance. This dual governance mechanism helps foster socio-ecological resilience by aligning conservation goals with community livelihoods (Staples et al., 2014).

Conservation efforts for terubuk have also generated positive impacts on the broader ecosystem and associated species, including Spanish mackerel. Through habitat protection and resource utilization regulations, the aquatic ecosystem of the Bengkalis Strait has remained relatively preserved, enabling the sustainable exploitation of other fishery resources by local fishers. The substantial fishery potential within this area is significant for regional economic development and the welfare of coastal communities, thereby necessitating sustainable planning, management, and utilization of resources.

In the context of fisheries management, planning and management that integrate ecosystem considerations alongside the application of knowledge and technology are essential for enhancing both community livelihoods and long-term resource availability. The concept of management based on the Ecosystem Approach to Fisheries Management (EAFM), particularly in the domain of fishing techniques, is applied by considering environmentally friendly fishing practices, gear and auxiliary device modification, fishery capacity and effort, gear selectivity, and vessel compliance with applicable legal documentation.

3.2 Assessment of indicators in the fishing technique domain

During the study, two species of Spanish mackerel were caught by fishers from Buruk Bakul Village: Indo-Pacific king mackerel (*Scomberomorus guttatus*) and narrow-barred Spanish mackerel (*Scomberomorus commersonii*). The catch of Spanish mackerel by these fishers is influenced by several factors, including seasonal variations, fishing gear types, and the availability of fish stocks. Fishers from Buruk Bakul Village, who operate within the Terubuk Sanctuary Area, generally use relatively uniform fishing gear. The majority employ gill nets—locally known as *jaring tangsi*—as their primary gear for catching Spanish mackerel. Mesh sizes vary among fishers. Based on interviews, they reported that mesh sizes ranging from 2 to 4 inches can improve catch selectivity, although this may reduce the overall volume of fish landed.

Fishing patterns among local fishers are strongly shaped by seasonal dynamics. During the study, two seasons commonly recognized by Spanish mackerel fishers in Buruk Bakul Village were identified: the northeast monsoon (*musim utara*) and the southeast monsoon (*musim tenggara*). The northeast monsoon is characterized by higher waves, with winds blowing southward from the South China Sea and the Pacific Ocean. This season typically occurs from November to April, during which cloudy conditions and frequent rainfall prevail. Under these circumstances, fish tend to move farther offshore, leading to a decline in production as fishers face greater challenges in catching fish. Conversely, the southeast monsoon, lasting from May to October, is regarded by fishers as a period of abundance. During this season, winds blow from the southeast—from the Indian Ocean and Australia northward—resulting in clear weather and relatively calm seas. These favorable conditions enhance fish availability in coastal waters and encourage increased fishing activity (Lukum et al., 2023). This aligns with peak fishing seasons for Spanish mackerel occur between March–May and October–December, with recruitment typically observed in April. The two species of Spanish mackerel identified are shown ini Figure 2.

a b

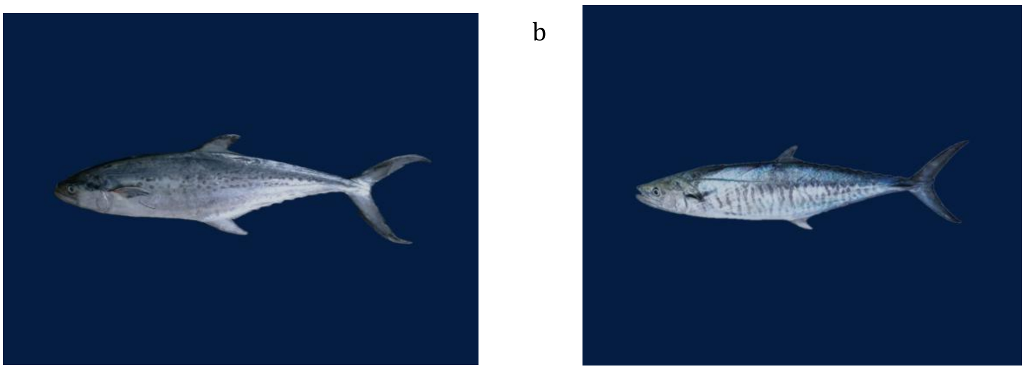

Fig. 2. (a) Indo-Pacific King Mackerel (*Scomberomorus guttatus*); (b) Narrow-barred Spanish Mackerel (*Scomberomorus commersonii*)

For the indicator of fishing methods and gear modification, no fishing gears destructive to the ecosystem were identified. According to the Ministry of National Development Planning/*Badan Perencanaan Pembangunan Nasional* (BAPPENAS), destructive fishing practices conducted by certain individuals generally involve the use of explosives (fish bombs) and toxic substances to capture fish, both of which cause ecosystem degradation and the mortality of various fish species and sizes. Meanwhile, illegal fishing refers to activities conducted in violation of applicable regulations. Examples include fishing in restricted zones, using prohibited fishing gears, and fishing without official permits from the fisheries authority. Such practices may result in a decline of fish stocks, ecosystem damage, and reduced income for both fishers and the state.

In practice, Spanish mackerel fishers from Buruk Bakul Village generally employ gill nets, locally known as *jaring tangsi*, as their primary fishing gear. The mesh sizes used vary among fishers but commonly range from 2 to 4 inches. This mesh size is considered effective for targeting larger fish while reducing the capture of juveniles. Based on surveys and data collection with fishers and village authorities, a single fisheries-related conflict had occurred in the past, triggered using *belat* fishing gear. *Belat* is commonly used in coastal areas and consists of nets mounted on wooden stakes. The conflict arose because fishers perceived this gear as harmful, given its relatively small mesh size that could potentially capture juvenile fish. The issue was resolved peacefully at the village office.

In fishing practices, gear modification is generally intended to improve catch performance. This may involve altering gear size or design beyond the Length at Maturity (Lm). Lm refers to the minimum body length at which fish reach gonadal maturity. Fishing gear modifications exceeding Lm thresholds may capture immature fish, thereby reducing reproductive opportunities.

Although no population dynamics study has yet been conducted for Spanish mackerel in the Terubuk Fishery Reserve. Furthermore, the first maturity length of Spanish mackerel is 45.12 cm, while the length at first capture is 37 cm. Discussions with fishers and village authorities revealed that Spanish mackerel fishers in Buruk Bakul Village do not modify their gears to increase catches. The most common modification involves layering several gill nets to improve net durability. However, such modifications do not significantly affect gear selectivity, as mesh size remains unchanged and only fish of certain sizes are retained. Fishers also reported that the size of Spanish mackerel captured is relatively consistent, ranging from 40 to 50 cm.

Fishing capacity is defined as the potential fishery input used to generate output in the form of catch, measured by fishing units or the production of other gears (Olii et al., 2007). It generally reflects the ability of a fishery system to produce a maximum sustainable yield without depleting natural resources. Fishing effort, on the other hand, refers to activities carried out to harvest fish in the waters, encompassing methods and gears employed, number of vessels, and trips. Based on catch data of Spanish mackerel in 2023 and 2024, fishing capacity in the Terubuk Fishery Reserve is presented in the following Table 5.

Table 5. Fisheries effort and capacity

Year	Number of Fishers	Number of Vessels	Number of Trips	Production (kg)	Fishing Capacity
2023	10	10	8	3,032	242,560
2024	10	10	8	3,800	304,00
Fishing Capacity					0.79

Based on Table 5, Spanish mackerel production increased from 2023. This rise in fishing intensity may have implications for the sustainability of fishery resources. A capture capacity value of less than 1 indicates that Spanish mackerel utilization in this region has not yet reached its maximum potential, which may affect fishers' economic outcomes. The small capacity of fishing boats in Buruk Bakul Village indicates that the traditional fishers in this area still operate on a small scale. A similar finding was reported in the study by Ninef et al. (2019), which stated that most traditional fishers are small-scale operators.

According to the Ministry of Marine Affairs and Fisheries of the Republic of Indonesia in 2017, Bengkalis Regency falls within Fisheries Management Area of the Republic of Indonesia/*Wilayah Pengelolaan Perikanan Negara Republik Indonesia* (WPPNRI) 571. This area, which includes the Malacca Strait and the Andaman Sea, has a large pelagic fish utilization rate of 0.52. This figure indicates that 52% of the maximum capacity has been utilized, leaving approximately 48% available for further use. Such utilization, however, must be pursued under sustainable and optimal fisheries practices. Enhancing the utilization of Spanish mackerel resources in the Terubuk Fishery Reserve can be achieved by considering catch per unit effort (CPUE), which reflects fishers' efficiency without exerting excessive pressure on fish stocks.

On the other hand, fishing gear selectivity remains a crucial aspect in capture practices. Selectivity reflects how effectively a gear targets desired fish species while reducing unwanted bycatch. Dewanti et al. (2020) define capture selectivity as the ability of fishing gear to catch certain species and sizes while avoiding or minimizing unwanted bycatch. Data from the Fisheries Agency of Bengkalis Regency regarding gillnet fishers' catches in Buruk Bakul Village are presented in Table 6.

Table 6. Catch data (kg) of gillnet fishers in 2024

Species	Month												Total
	Jan	Feb	Mar	Apr	May	June	July	Ags	Sep	Oct	Nov	Dec	
Lomek	192	192	216	264	312	312	336	289	299	312	360	209	3,293
Indo-Pacific king mackerel	90	90	101	123	146	146	157	134	134	146	169	104	1,540
Narrow-barred Spanish mackerel	129	128	144	176	209	208	224	192	192	209	240	209	2,260
Gemprang	96	128	144	176	209	209	224	192	192	209	240	104	2,123
Pies	128	96	108	132	156	156	169	144	144	156	190	209	1,788
Total (kg) Spanish mackerel													3,800
Grand total													11,114

(Dinas Perikanan Kabupaten Bengkalis, 2024)

The results of the capture selectivity calculation, comparing target catches to bycatch, are shown in Table 7. With only 52% of the total catch comprising Spanish mackerel, while the remainder consists of bycatch, the results suggest that current fishing gears are not fully optimized for targeting species. Although some bycatch species, such as hairtail, fourfinger threadfin, and Bombay duck, have economic value, persistent capture in large quantities risks disrupting aquatic ecosystem balance. The high proportion of bycatch (66%) demonstrates that the gillnets used by fishers in Buruk Bakul Village are not yet fully selective. If not managed properly, this may reduce the efficiency of fishing operations, as bycatch of lower economic value can negatively affect fishers' income (Mollen et al., 2023).

Table 7. Calculation results of capture selectivity

Catch Category	Amount (kg)	Percentage (%)
Grand Total	11,114	100
Target (Spanish mackerel)	3,800	34
Bycatch	7,314	66
Selectivity		52

From a fisheries management perspective, efforts are needed to improve fishing gear selectivity so that fishers can optimize target catches, particularly Spanish mackerel. One potential measure is outreach and training programs for fishers on using more selective mesh sizes, thereby reducing bycatch without sacrificing main catches. Additionally, support from the Fisheries Agency could be directed toward gear improvement programs and incentives for fishers who adopt environmentally friendly fishing methods. Such measures would help maintain resource sustainability in the Terubuk Fishery Reserve while improving the long-term livelihoods of local fishers.

Vessel function and size compliance are also important indicators in fishing practices. Vessel suitability refers to how well vessel size matches its purpose and function. Compliance with legal documentation is essential to ensure that vessels operate safely and according to applicable regulations. Required legal documents include registration certificates, operating permits, safety certificates, and other documents issued by maritime authorities, which must accurately reflect the vessel's physical condition and function. Survey results showed that Spanish mackerel fishers from Buruk Bakul Village operating in the Terubuk Fishery Reserve typically use vessels with a capacity of 1.5–2.5 GT. According to fishers, such vessels are adequate for transporting catches in a single trip. However, all 10 surveyed fishers lacked registration certificates and operating permits, as their vessels and gears were not officially registered with fisheries authorities. Furthermore, the vessels were rarely equipped with standard safety equipment, such as life vests. This was corroborated by the Marine and Fisheries Service of Riau Province, which confirmed that no records of vessel or gear registration exist for Buruk Bakul Village fishers. Such conditions highlight existing gaps and challenges in fisheries in the region. These limitations may hinder access to government assistance and complicate the implementation of sustainable fisheries management.

3.3 Management status based on EAFM

The evaluation of Spanish mackerel (*Scomberomorus* sp.) fishing techniques in the Terubuk Sanctuary Area refers to the indicators within the fishing techniques domain established by the Ministry of Marine Affairs and Fisheries/*Kementerian Kelautan dan Perikanan* (KKP) in 2014. Table 8 presents a summary of the assessment of fishing technique indicators based on field observations and interviews with respondents.

Table 8. Evaluation of indicators for Spanish mackerel fishing techniques in the Terubuk sanctuary area

Indicator	Evaluation Result	Flag Model	Category
Destructive fishing methods	No destructive methods were found		Good
Fishing gear modification	Modifications were carried out to strengthen nets rather than to increase catch		Good
Fising capacity and fishing effort	Fishing capacity in this area has a value of 0.79 or < 1		Poor
Selectivity of fishing	Gear selectivity reached only 52%, with bycatch at 66%		Moderate
Suitability of vessel function and size	All fisher respondents reported not having vessel documentation		Poor

The composite assessment yielded a total score of 220, placing the management status in the "good" category (light-green flag). This classification indicates that the current fishing practices in the Terubuk Sanctuary Area are relatively sustainable and that destructive or illegal fishing activities are absent. However, this "good" status should not be interpreted as fully optimal, since several key challenges like particularly low fishing capacity, limited vessel documentation, and moderate gear selectivity still constrain the fishery's long-term sustainability. The "good" category reflects a transitional management phase rather than a fully mature sustainable fishery. As emphasized by Makailipessy & Abrahamsz (2023), fisheries within EAFM frameworks that achieve "good" performance in technical domains often remain vulnerable unless supported by adaptive governance and stakeholder collaboration. In this case, the sustainability of Spanish mackerel fisheries is highly dependent on the ability of local institutions to strengthen compliance, promote environmentally friendly technology adoption, and ensure equitable resource access.

Table 9. Evaluation of the foshing techniques domain

No.	Indicator	Score	Weight	Value
1.	Destructive fishing methods	3	30	90
2.	Fishing gear modification	3	25	75
3.	Fising capacity and fishing effort	1	15	15
4.	Selectivity of fishing	2	15	30
5.	Suitability of vessel function and size	1	10	10
Total				220

The poor score for fishing capacity and effort (score = 1) suggests that resource utilization remains suboptimal and that traditional small-scale fishers in Buruk Bakul Village continue to operate with limited capital, vessel capacity, and technical support. This aligns with findings from Katili et al. (2022), who reported similarly low capacity-effort indices in the Ayau Islands, highlighting the persistence of small-scale operational constraints despite otherwise positive ecological conditions. In both contexts, limited fishing capacity can protect resources in the short term but may also reflect underutilization of potential economic benefits if not paired with mechanisms for controlled expansion and adaptive management. This situation is similar to findings in Pangpang Bay, Banyuwangi, where small-scale capture fisheries, despite low coastal vulnerability, still demonstrate constraints in fishing capacity that restrict both ecological sustainability and livelihoods (Setyaningrum et al., 2025).

The moderate selectivity score (~52%) and high bycatch proportion (~66%) show that gears used are not fully optimized for selective catching of the target species. Although gillnets are relatively selective compared with other passive gears, the high proportion of bycatch (66%) remains a concern for ecosystem stability. Studies in Vietnam showed that experimental mixed gillnets (with multiple mesh sizes) caught larger Spanish mackerel while reducing relative bycatch compared to conventional single-mesh nets (Nguyen et al., 2023). These findings suggest gear modification is a viable path to improve selectivity without necessarily sacrificing catch rates. Consequently, improving mesh design and enforcing minimum size limits could enhance both selectivity and ecological resilience in the Bengkalis Strait.

Vessel documentation and safety compliance scored “poor,” reflecting governance and institutional challenges. None of the surveyed fishers possessed official registration certificates or operating permits, which restrict access to government assistance and formalized co-management schemes. Such gaps mirror systemic issues identified by Nissa’ et al. (2023), who noted that weak institutional capacity and informal fleet governance are key barriers to implementing EAFM in Indonesian small-scale fisheries. Strengthening administrative support and providing simplified registration mechanisms could thus improve compliance and eligibility for sustainability incentives.

In the broader EAFM framework, the overall “good” result represents a positive trajectory toward sustainable fisheries governance but also underscores the need for multi-dimensional enhancement. The EAFM emphasizes six interlinked domains, such as fishery resources, habitat and ecosystem, fishing techniques, socio-economic conditions, institutional arrangements, and compliance (Staples et al., 2014). Within this context, the fishing technique domain serves as a crucial operational link between ecological sustainability and socio-economic outcomes. A “good” technical performance score implies that the ecological base remains relatively stable, but without corresponding improvements in institutional and socio-economic domains, sustainability gains may be short-lived.

However, as shown in regional OA studies, resilience must be understood not merely biologically but also socially and institutionally: adaptive capacity, enforcement, compliance, and stakeholder participation are just as important. Without improvements in these areas, even “good” fisheries can drift toward overexploitation especially under pressure from environmental variability or market demands. From a socio-ecological perspective, the findings indicate that the Spanish mackerel fishery in the Terubuk Sanctuary Area demonstrates early signs of resilience the ability to maintain function despite external pressures such as seasonal variability and fluctuating market demand. However, resilience at this stage is largely ecological, not institutional or social. As noted by Biggs et al. (2021), achieving full socio-ecological resilience requires adaptive governance systems capable of learning and responding to feedback from both ecological and human dimensions.

Adaptive management and participatory governance are therefore critical next steps. Local fishers' knowledge, particularly regarding seasonal patterns and gear performance, provides valuable input for co-management initiatives. Engaging fishers through participatory monitoring and adaptive feedback loops, such as those used in small-scale capture fisheries in Pangpang Bay, Banyuwangi Regency, Indonesia (Setyaningrum et al., 2025), could strengthen the legitimacy and responsiveness of the management framework. Moreover, cross-sectoral integration linking fisheries with tourism, ecosystem restoration, and livelihood diversification could enhance adaptive capacity and reduce dependence on a single resource base.

In regional comparison, while the Terubuk Sanctuary Area's score (220) is "good", there are similar open-access studies that show fisheries achieving "good" technical or ecological performance still face major institutional, socio-economic, or governance constraints. For example, in the EAFM assessment in Rote Ndao, the composite index for small-scale fisheries averaged 52.4 (on a scale with maximum ~100), indicating moderate performance overall although technical domains were among the stronger ones (Ninef et al., 2020). Another comparison: small-scale capture fisheries in Pangpang Bay, though in a low coastal vulnerability setting, still struggle with issues of fisher human resources, perceptions, catch sizes and equitable participation. These cases demonstrate that even with good technical/gear practices, sustainability requires strong governance, legal compliance, stakeholder participation, and institutional support. Therefore, while ecological and technical aspects in Terubuk appear solid, comprehensive sustainability demands integrated policy coordination and long-term investment in community-based capacity building.

The implications for long-term sustainability are twofold: first, ecological stability must be reinforced through improved gear selectivity and continued habitat protection. Given the sanctuary's ecological significance, maintaining bycatch levels below 50% and preventing habitat degradation are crucial to preserving trophic balance. Second, socio-institutional strengthening is equally vital. Formalizing vessel documentation, providing training on sustainable gear modification, and introducing financial schemes to support selective technology adoption would ensure both ecological and economic sustainability.

When viewed in a broader context, the management status of the Spanish mackerel fishery in the Terubuk Sanctuary Area (score 220) aligns with several other EAFM-based evaluations conducted in Indonesia and neighboring regions. In Indonesia, for instance, Ninef et al. (2023) reported a similar outcome in Rote Ndao, East Nusa Tenggara, where the ecosystem approach yielded a moderate to good level of performance, particularly in the technical and ecological domains. However, governance and institutional aspects remained weak, mainly due to limited coordination and insufficient documentation of fishing vessels. Comparable challenges were also found in the layur fishery of Palabuhanratu, where fishers' practices were largely sustainable but hindered by inconsistent enforcement and lack of adaptive policy implementation (Rahmani et al., 2022).

International comparisons show similar tendencies. In Taiwan, Kuo et al. (2023) demonstrated that improving fishing gear selectivity significantly enhances both ecological stability and model accuracy in assessing stock sustainability. Their findings support the notion that technical improvements—such as mesh-size adjustments and selective gear use—can produce ecological benefits even without major shifts in fishing effort. Likewise, research in Bangka Belitung, Indonesia, by Rengi et al. (2021) showed that optimizing gillnet mesh size for *Scomberomorus* commerson not only improved selectivity but also reduced bycatch by over 20%, reinforcing the importance of gear-based management interventions.

Taken together, these studies confirm that the "good" category achieved in the Terubuk Sanctuary Area represents a solid ecological foundation but still leaves room for improvement in institutional capacity, documentation, and fisher participation. The consistency of these findings across multiple regions indicates that sustainable fisheries management depends not only on sound technical practices but also on continuous social engagement and adaptive governance. Strengthening local institutions and ensuring compliance through participatory approaches would therefore be essential to maintain and further enhance the sustainability of Spanish mackerel fisheries in the region.

4. Conclusions

Based on the evaluation of indicators within the fishing techniques domain, the management of Spanish mackerel (*Scomberomorus* sp.) resources in the Terubuk Sanctuary Area, Buruk Bakul Village, is classified as "good," with a composite score of 220. This suggests that current fishing activities are generally sustainable and free from destructive practices. However, aspects such as fishing capacity, gear selectivity, and vessel documentation still need improvement to reach full sustainability.

From a policy perspective, future efforts should focus on enhancing fisher capacity, streamlining vessel registration, and promoting the use of selective and eco-friendly fishing gear. Strengthening coordination among local authorities, institutions, and communities through training, incentives, and participatory monitoring is key to maintaining long-term compliance and equitable management.

At the governance level, integrating local knowledge and fisher participation into decision-making will help foster trust and adaptability. Collaborative management mechanisms can link ecological conservation with livelihood security. Viewed through a social–ecological lens, the fishery shows solid ecological resilience but remains limited in social and institutional resilience. Achieving genuine sustainability therefore requires balancing ecological integrity with community empowerment and adaptive governance. Future studies should explore socio-economic and institutional dimensions to build a more holistic understanding of sustainable fisheries management in the Terubuk Sanctuary Area.

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Author Contribution
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Data Availability Statement

The datasets generated and/or analyzed during the current study are not publicly available due to institutional policy but are available from the corresponding author on reasonable request.

Conflicts of Interest

The authors declare no conflict of interest.

Declaration of Generative AI Use

During the preparation of this work, the authors used ChatGPT and Grammarly to assist in improving grammar, clarity, and academic tone of the manuscript. After using this tool, the authors reviewed and edited the content as needed and took full responsibility for the content of the publication.

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