Coral fisheries management using an ecosystem approach in the domain of fishing techniques at the Pasiran fish landing base

Abel Muammar Mesha[1], *Alvi* Rahmah[1,2*], *Imelda* Agustina[1,2], and *Ayu* Sriwulanda[1]

[1]Department of Fisheries Resources Utilization, Faculty of Marine and Fisheries, Syiah Kuala University, Banda Aceh, 23111, Indonesia
[2]Marine and Fisheries Research Center, Universitas Syiah Kuala, Darussalam, Banda Aceh.

Abstract. Sabang City has significant potential in coral reef fisheries, which are among its key commodities with high economic and ecological value. However, its management faces several challenges, including seasonal dependency of fishermen, fishing practices targeting fish below their gonadal maturity level, repeated exploitation of the same fishing grounds, and the use of traditional poisons. This study aims to evaluate ecosystem-based coral reef fisheries management within the fishing gear domain at the Fish Landing Site (TPI) Pasiran, Sabang City. The research was conducted from July 1 to July 30, 2024, at the Fish Landing Site (TPI) Pasiran, Sukakarya District, Sabang City. Data collection utilized primary methods (interviews and questionnaires) and secondary methods (reports from related institutions and previous studies). The sampling technique used was a census method with a total of 10 respondents. Data analysis employed ordinal Likert scale scores (1, 2, and 3) for each indicator, followed by the calculation of index values, composite scores, and descriptive analysis. The results show that coral reef fisheries management at TPI Pasiran falls under the "good" category with a composite score of 78. However, certain aspects, such as crew certification ownership and fishing capacity and effort, require further attention to enhance fisheries sustainability.

1 Introduction

Sabang City is a city located on Weh Island which is part of Aceh Province and is located at the westernmost tip of Indonesia. Based on its geographical position surrounded by the Indian Ocean, Bay of Bengal, Strait of Malacca and ZEE, Sabang has quite large potential for fish resources [30]. Reef fish are one of the leading commodities in Sabang City. Reef fish that are the main commodities on Weh Island include Grouper, Red Snapper, Parrot fish, Yellowtail/banana fish, and Giant Trevally [9].

Sukakarya District has several fish landing bases (TPI), one of which is TPI Pasiran. Based on the characteristics during observation, the coral fish fishermen in Pasiran fish landing bases are included in small-scale fisheries. Small-scale fishermen generally use low-tech equipment, operate near the coast and have limited capital investment [17]. This is also

* Corresponding author: alvi_rahmah@usk.ac.id

in accordance with what was conveyed by FAO [11}, that the characteristics of small-scale fisheries are having small investment capital, small boat facilities, the fishing operation area is not too far, and the catch is for consumption needs. On the other hand, the amount of fisheries production in Sukakarya District increased from 2,618 tons in 2022 to 3,986 tons in 2023, of which 3,919 tons came from marine fisheries and 67.26 tons from public waters [16]. Increasing production without good management can reduce fish stocks [8]. Therefore, an approach is needed that balances socio-economic and ecosystem objectives.

FAO introduced the concept of management with a comprehensive approach called fisheries management with an ecosystem approach (Ecosystem Approach to Fisheries Management/EAFM). EAFM is a method that combines climate, habitat, ecological, social and economic factors into fisheries operations [12]. Ecosystem-based fisheries management in the EAFM concept covers several domains, including fishing techniques, which are important for fisheries sustainability. Fishing activities can put pressure on aquatic stocks and ecosystems [18], so *holistic* management is needed that is able to balance ecosystem aspects.

Previous research related to coral fisheries management in Sabang City concluded that the Sabang City Government is able to manage coral fisheries by involving traditional institutions such as Panglima Laot [33]. However, fishermen's dependence on the season causes the catch to be excessive in certain seasons so that it is not optimal and the habit of catching fish without considering the size or maturity level of the gonads threatens the sustainability of coral fish stocks. In addition, in determining fishing areas, the majority of fishermen only rely on their instincts and personal experience. This causes the catch to be less than optimal. Reef fisheries in Pasiran play a crucial ecological role as a habitat for marine biodiversity and a source of livelihood for coastal communities. Coral reefs support marine ecosystems by providing spawning grounds and species protection while also meeting the economic and nutritional needs of local populations. This study addresses gaps in previous research that have not comprehensively examined aspects such as fishing techniques, aiming to provide more accurate recommendations for sustainable fisheries management in Pasiran. In this case, a research study is needed on ecosystem-based coral fisheries management in the domain of fishing techniques.

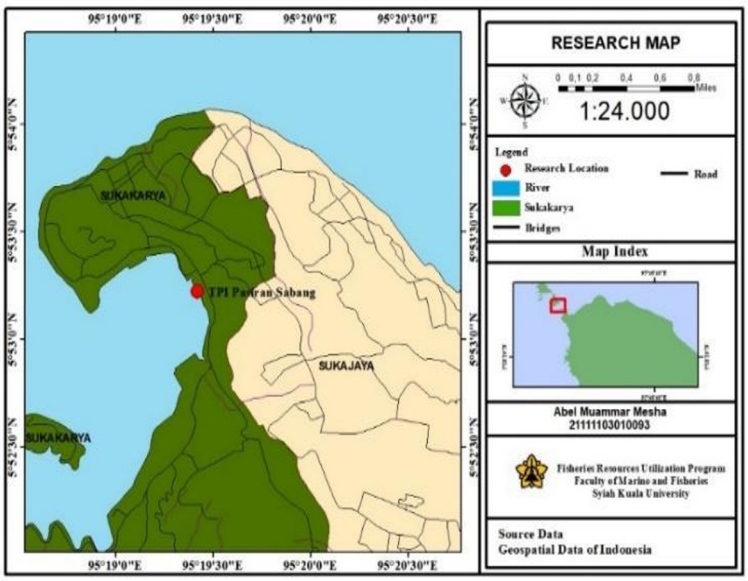

Fig. 1. Research site.

2 Materials and methods

2.1 Time and place of study

This study was carried out from July 1, 2024, to July 31, 2024, at the Pasiran Fish Landing Base (TPI) in Sukakarya District, Sabang City. The research site is illustrated in Fig. 1 below:

2.2 Data analysis and assessment of fishing technique indicators

This study focuses on analyzing the Fishing Techniques Domain. Each indicator is evaluated using a straightforward assessment system, employing a Likert ordinal scale with scores of 1, 2, and 3, aligned with the criteria for each indicator. A higher score reflects better performance [8]. The analysis involves evaluating the indicators within the fishing techniques domain, with collected and processed data used to address the research objectives. Data processing techniques were applied to the assessed indicators and analyzed using a simple composite analysis method. The EAFM indicator assessment results were presented using a flag model.

Tabel 1. Criteria and weighting of EAFM fishing technique domain.

Indicator	Criteria	Weight
1. Destructive or illegal fishing methods	1 = frequency of violation >10 cases per year 2 = frequency of violation 5-10 cases per year 3 = frequency of violation <5 cases per year	30
2. Modification of fishing gear and fishing aids	1 = more than 50% of the target species size <Lm 2 = 25-50% of the target species size <Lm 3 = <25% of the target species size <Lm	25
3. Fishing capacity and fishing efforts	1 = Fishing capacity ratio < 1 2 = Fishing capacity ratio = 1 3 = Fishing capacity ratio > 1	15
4. Fishing selectivity	1 = low (> 75%); 2 = moderate (50-75%); 3 = high (less than 50%) use of non-selective fishing gear)	15
5. Suitability of fishing vessel function and size with legal documents	1 = low compliance (more than 50% of samples do not comply with legal documents) 2 = moderate compliance (30-50% of samples do not comply with legal documents) 3 = high compliance (less than 30%) of samples do not comply with legal documents	10
6. Crew certification in accordance with regulations	1 = Certificate ownership <50% 2 = Certificate ownership 50-75% 3 = Certificate ownership >75%	5

2.3 Composite index and value assessment

The index value is obtained by multiplying the score value by the weight of each indicator. The index value calculation uses the following formula:

$$Cat\text{-}I = Sat\text{-}I \times 100 \times Wat\text{-}I \quad (1)$$

Description:
Cat-i = Index value of attribute/indicator i
Sat-i = Score of attribute/indicator i
Wat-i = Weight of attribute/indicator i

The weight distribution for each indicator is determined based on the degree of influence (level of importance) of the indicator in the domain. Indicators that have a direct influence or a large influence in the domain, then the indicator also has a large weight. The total index value obtained is then analyzed using a simple composite analysis based on the arithmetic mean. Composite value calculations are carried out using the following formula:

$$NK = (Cat\text{-}i/\ cat\text{-}max) \times 100 \quad (2)$$

Description:
NK = Composite value to-i
Cat-I = Total index value of all attributes/indicators
Cat-max = Maximum total index value

The results of the composite value will be displayed in the form of a flag model according to Table 2.

Table 2. Flag model with criteria.

Composite score value	Flag model	Description
1-20		Bad
21-40		Not Good
41-60		Moderate
61-80		Good
81-100		Very Good

The aggregate score is classified into five group categories, with each category representing the increasing impact of the reviewed EAFM domain [6].

3 Results and discussion

Data collected through structured interviews using questionnaires, along with information obtained from literature and agency reports, yielded the following scores for the indicators: 1) Destructive and/or illegal fishing methods received a score of 3 and were categorized with a green flag model; 2) Modification of fishing gear and fishing aids received a score of 2 and were assigned a yellow flag model; 3) Fishing capacity and fishing effort were scored at 1, corresponding to a red flag model; 4) Selectivity of fishing gear achieved a score of 3, falling under the green flag model; 5) Compliance with the function and size of fishing vessels using illegal documents was scored at 3 and categorized with a yellow flag model; and 6) Certification of fishing vessel crews according to regulations received a score of 1, marked with a red flag model.

Tabel 3. Fishing Technique Domain Analysis of Fisherman.

Criteria	1*	2*	3*	4*	5*	6*	Total
Result	1 cases per year	30%	< 1	less than 50%	< 30%	Certificate Ownership <50%	
Score	3	2	1	3	3	1	
Weight	30	25	15	15	10	5	
Index Score	9000	5000	1500	4500	3000	500	23500

Note :
*1.) Destructive or illegal fishing methods; 2.) Modification of fishing equipment and fishing aids; 3). Fishing capacity and fishing effort; 4.) Fishing Selectivity; 5.) Suitability of fishing vessel function and size with legal documents, and 6.) Crew certification in accordance with regulations.

3.1 Indicator specificatios

3.1.1 Indicator of destructive or illegal fishing methods

According to the 2019 Decree of the Minister of Marine Affairs and Fisheries, destructive fishing refers to activities involving materials, tools, or methods that harm fish resources and the environment, such as explosives, toxic substances, and electrofishing. Destructive fishing methods is a key or "killer indicators" due to their high sensitivity to aquatic ecosystem damage [15]. An assessment based on secondary data from the Department of Marine Affairs and Fisheries in Sabang City recorded one case of violation in TPI Pasiran in 2021, involving the use of a compressor in the waters of Gampong Lhok Pasiran, Kuta Timu District. This resulted in the indicator scoring 3, with a violation frequency of fewer than five cases per year.

The use of compressors is prohibited in all Fisheries Management Areas of the Republic of Indonesia (WPPNRI) under Law No. 45 of 2009. While compressors are often used as breathing aids to extend diving time and expand fishing areas [26], they pose serious health risks to fishers, such as decompression sickness [4], nosebleeds, ear pain, headaches, and physical fatigue [6] Furthermore, compressors are frequently employed in destructive fishing practices, such as poisoning fish with potassium, spreading toxins, or fish bombing [5]. An interview with coral fishers in TPI Pasiran revealed the use of traditional poisons, such as extracts from the tuba jenu root (*Derris elliptica*), for fishing. This substance has the potential to be environmentally friendly when applied at the appropriate concentration [24]. This claim is supported by findings that tuba jenu extract decomposes within 2-3 days when exposed to sunlight, mixed with water, or settled into the soil, leaving no permanent residues in the waters [17].

Destructive fishing methods, such as the use of compressors and hazardous chemicals, significantly impact the sustainability of fisheries and marine ecosystems. However, fishers in TPI Pasiran have shown awareness in preserving the ecosystem, as indicated by the absence of reported use of destructive tools such as explosives or potassium. Nonetheless, regular monitoring remains essential to ensure sustainable fisheries practices in the region.

3.1.2 Indicator of modification of fishing equipment and fishing aids

Gear modifications that do not comply with regulations directly impact the sustainability of reef fish resources. Sampling was conducted using a purposive approach, selecting the most dominant reef fish species caught during a single fishing trip. The length at maturity (Lm) values of the catch were analyzed using data from FishBase. Out of 40 measured fish, 32.5%

were found to be below gonadal maturity. Based on this result, the indicator received a score of 2, as 25-50% of the target species caught were smaller than their Lm size.

Small-scale fisheries in TPI Pasiran primarily target reef fish species, including yellowtail fusilier (*Caesio cuning*), long-barbel goatfish (*Parupeneus macronemus*), cardinal soldierfish (*Myripristis murdjan*), and tomato hind (*Cephalopholis sonnerati*). Based on field observations, a total of 40 fish specimens were measured, comprising 16 yellowtail fusiliers, 11 long-barbel goatfish, 7 cardinal soldierfish, and 6 tomato hinds. The results of the check can be seen in the figure below.

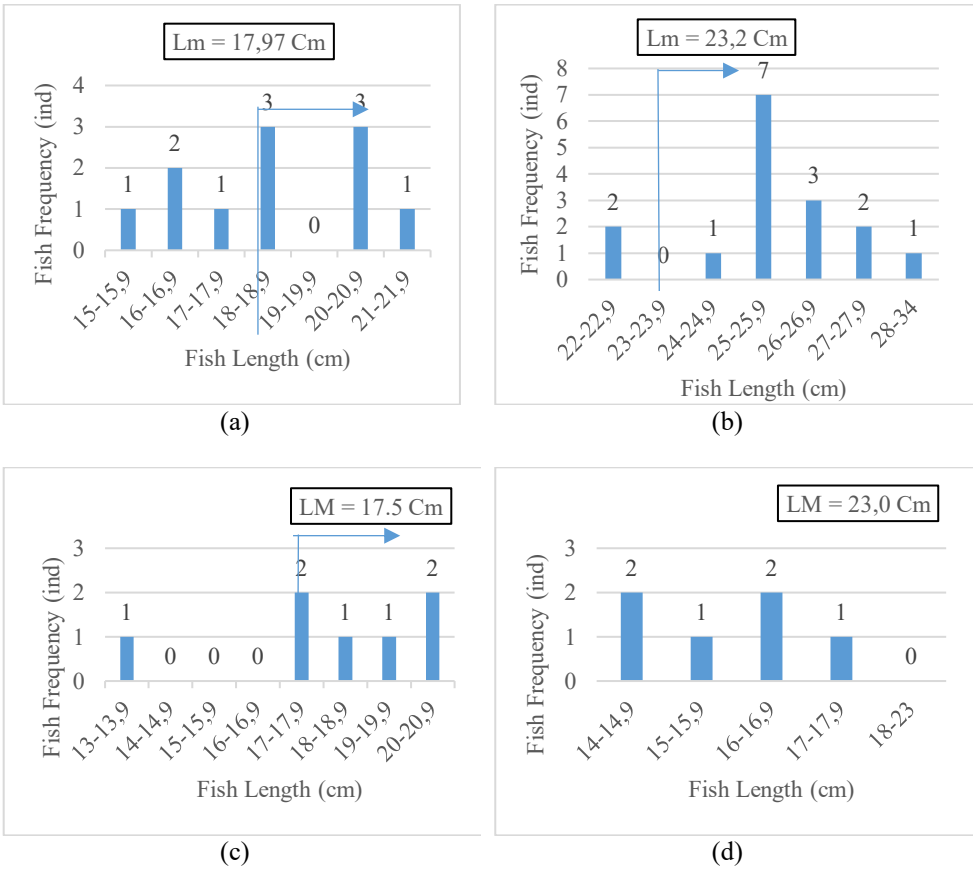

Fig. 2. Distribution of catch size based on Lm (Length of Maturity) a) long-barbel goatfish (*P. macronemus*); b) yellowtail fusilier (*C. cuning*); c) cardinal soldierfish (*M. murdjan*); d) tomato hind (*C. sonnerati*).

The data obtained indicate that most of the fish species caught by the reef fishers in TPI Pasiran have reached their gonadal maturity sizes. Long-barbel goatfish (*P. macronemus*), for example, are known to reach gonadal maturity at a size of 12.3 [18]. The measurements of this species showed that the captured fish met this size criterion. Similarly, yellowtail fusilier (*Caesio cuning*) exhibited average lengths exceeding the gonadal maturity threshold of 22.92 cm, indicating a healthy size distribution within the population [28]. Cardinal soldierfish (*M. murdjan*) were likewise found to have reached their gonadal maturity size of 17.5 cm, as noted in FishBase. In contrast, the tomato hind (*C. sonnerati*) specimens caught by fishers in TPI Pasiran were all below their gonadal maturity size. According to the Aceh

Fisheries Data and Information Center, this species reaches gonadal maturity at a size of 26.68 cm. The capture of tomato hinds below their maturity size suggests a potential issue with the fishing methods or gear used in the area. The percentage of total fish caught based on catchability is presented in the form of a pie chart as in the following image.

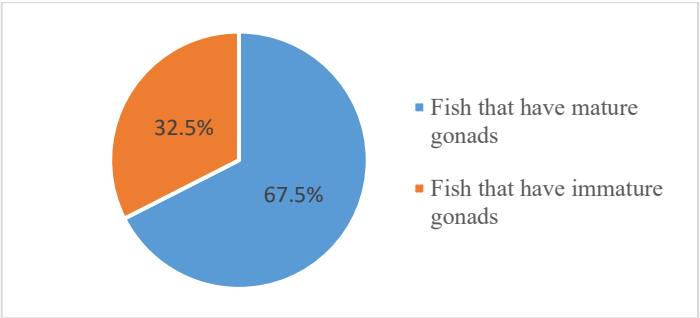

Fig. 3. Percentage of catches.

Interviews result with fishers revealed no significant gear modifications that could have influenced the catch composition. The only reported adjustment involved adding stones to handlines to accelerate the sinking of the hooks. Other fishing gear, such as gillnets and spearguns, showed no evidence of design modifications. This aligns with findings that fishing gear design plays a crucial role in enhancing selectivity, particularly in reducing the capture of immature fish, thereby supporting sustainable fishing practices and the preservation of fish populations [30]. Overall, the majority of fish caught in TPI Pasiran meet the maturity size criteria as documented in FishBase and previous literature. However, the capture of immature tomato hinds underscores the need for greater attention to fishing gear management to support more sustainable small-scale fishing practices in the coral reef ecosystems of the region.

3.1.3 Indicator of fishing capacity and fishing effort

Fishing capacity refers to the maximum potential fish catch that can be achieved within a specific period (year) by a vessel or fleet operating at full capacity without management restrictions. This indicator is calculated using data on total catch, number of vessels, and fishing trips over the past four years (2020–2023). Catch data is derived from annual production records, vessel data from Sabang's fisheries fleet statistics, and trip data estimated through interviews with fishers due to the unavailability of secondary trip data. Based on the data analysis, this indicator scored 1, reflecting low fishing capacity. A ratio below one indicates poor fishing capacity [1], which serves as an important input control in fisheries management. Excessive inputs, such as fishing gear, vessels, or trips, can lead to overcapacity [19]. If this condition persists over time, it can result in overfishing, ultimately threatening the long-term sustainability of fish populations and the health of the ecosystem [23]. The results of the check can be seen in the table below.

Tabel 4. Fishing Capacity Ratio.

Year	Vessel (unit)	Trip/year	Catch/ton	*Fishing Capacity* (Kg/year)	Ratio
2020	607	70	6452	274145480	1.00
2021	640	90	7406.04	426587904	0.64
2022	674	85	8519.21	488065541	0.87
2023	685	75	9043.08	464588235	1.05
Final Ratio					0.89

The low fishing capacity at TPI Pasiran aligns with the increasing number of fishers and fishing gear in Sabang, particularly in Sukakarya District. The rise in fishers and gear affects fishing capacity [20]. However, the local tradition of *pantang meulaot* (refraining from fishing) at TPI Pasiran, which prohibits fishing on specific days such as Fridays, religious holidays, and commemorative events, reflects a community-based management approach [24]. This tradition significantly supports sustainable coastal resource management [32] as it reduces fishing trips on certain days, indirectly providing recovery time for marine ecosystems in TPI Pasiran.

3.1.4 Indicator of fishing Selectivity

Coral reef fishing activities at TPI Pasiran utilize three types of fishing gear: handlines (pancing ulur), gillnets (jaring insang), and spearguns (alat tangkap panah). Based on the classification of selective and non-selective fishing gear by BBPPI Semarang, these gears are identified as highly selective. Consequently, the fishing selectivity indicator received a score of 3, indicating less than 50% use of non-selective fishing gear.

Interviews revealed that most coral fishers at TPI Pasiran primarily use handlines as their main fishing gear. Handlines are widely used by small-scale fishers due to their selectivity for target fish sizes and environmentally friendly [19]. This gear is well-suited for coral reef ecosystems as it allows for the regulation of the minimum size of fish caught through hook size selection [22, 26]. The hook size affects the type and weight of the fish caught, as larger hooks are typically used for capturing bigger fish, while smaller hooks are more suitable for smaller species [17]. Coral fishers at TPI Pasiran use hooks numbered 5, 8, 9, and 10, based on the Japanese numbering system [3]. Hooks numbered 5 and 8 are commonly used for catching groupers, with size 5 being recommended for both groupers and snappers, as they are ideal for ensuring a secure catch while targeting these species [15]. Handlines are known for their high selectivity, making them the dominant fishing gear at TPI Pasiran [30]. They are particularly effective in coral reef ecosystems, as they allow for targeted fishing while minimizing bycatch [35].

Gillnets and spearguns used at TPI Pasiran also adhere to environmentally friendly fishing principles. Gillnets with a mesh size of 2.0 inches, as used by fishers, comply with Ministry Regulation No. 18 of 2021, Chapter V, Article 31, which stipulates a minimum mesh size of ≥2 inches. This demonstrates the fishers' compliance with applicable regulations. Spearguns, on the other hand, are highly selective in terms of fish size and species. Coral fishers at TPI Pasiran target large-sized and high-value fish such as barramundi, red snapper, and grouper. Spearguns are highly selective tools for capturing economically valuable fish, as they allow for precise targeting of specific species. This selectivity has been supported by studies, which emphasize their effectiveness in minimizing bycatch while maximizing the capture of desired fish [10, 20]. Field observations and literature reviews show that small-scale fisheries at TPI Pasiran utilize selective fishing gear, namely handlines, gillnets, and spearguns. Handlines enable target-specific fishing, gillnets

comply with regulated mesh sizes, and spearguns target only large fish. These practices support sustainable fishing and reflect the commitment of small-scale fishers in Pasiran to conserving marine resources.

3.1.5 Indicator of suitability of fishing vessel function and size with legal documents

The majority of fishermen catching coral fish in Pasiran use small boats under 5 GT (gross tonnage), such as traditional non-motorized boats (jukung) and those equipped with outboard motors ranging from 15 to 45 PK engines. These boats have limited fishing capacity, aligning with the characteristics of small-scale fisheries. Compliance between vessel function and size with legal documents is determined by comparing the official documents held by the vessel with its actual operational functions and dimensions. This compliance is crucial for ensuring that fishing activities are conducted within legal frameworks. Secondary data for this study, obtained from the Department of Marine Affairs and Fisheries of Sabang City, included records from Small Ship Registration (Pas Kecil) documents. Among 10 surveyed respondents, 8 vessels possessed the necessary legal documentation, yielding a compliance score of 3, which indicates a high compliance rate with less than 30% non-compliance. This finding suggests that most vessels in Pasiran meet the legal requirements for operation. The results of the check can be seen in the table below.

Tabel 5. Results of matching ship sizes at TPI Pasiran.

No	Vessel Name	Vessel Size			GT	Machine		Information
		L	W	D		Mark	PK/HP	
1.	SKPT Sabang 02	9.60	2.65	1.10	5	Yanmar	35	appropriate
2.	SKPT Sabang 05	9.60	2.65	1.10	5	Yanmar	35	appropriate
3.	Anugerah	7.00	1.60	1.00	1	Dong fen	16	appropriate
4.	Baru Jaya	7.50	1.80	1.10	2	Yanmar	30	appropriate
5.	Putra Laut	7.50	1.80	1.10	2	Yanmar	30	appropriate
6.	Pelita	6.30	1.20	1.00	1	Tian li	26	appropriate
7.	KM. Langguran	6.00	1.20	0.80	1	Tian li	26	appropriate
8.	KM. Mandala	6.00	1.20	0.80	1	Yanmar	26	appropriate

The Pas Kecil certificate plays a vital role in small-scale fisheries. It serves as proof of vessel ownership, nationality, sailing permits, and a guarantee for business credit. Additionally, it facilitates vessel registration and minimizes risks during operations. Pas Kecil is specifically intended for vessels under 7 GT, commonly used by small-scale fishers, emphasizing its importance in regulating these fisheries [22].

Compliance between a vessel's legal documentation and its actual usage is critical [33]. A low level of compliance may indicate illegal fishing practices, as misaligned licenses and vessel activities are considered illegal fishing [27]. Therefore, the high compliance level observed among coral fishers in TPI Pasiran indicates that most vessels operate legally. This not only supports sustainable fishing practices but also reduces the occurrence of illegal fishing in Sabang waters.

3.1.6 Indicator of crew certification in accordance with regulations

Fisheries crew certification refers to the qualifications required for crew members to work on fishing vessels. The assessment of this indicator is based on the possession of ATKAPIN (Fishing Vessel Engine Expert) and ANKAPIN (Fishing Vessel Nautical Expert) certifications, as outlined in the NWG EAFM guidelines. Interviews revealed that most crew members of coral fishing vessels in TPI Pasiran lack these certifications, as their seafaring

skills are primarily inherited through generations and acquired from personal experience. Vessel captains typically select crew members based on familial relationships, such as relatives or siblings, rather than on professional skills or expertise. According to the EAFM NWG module, this indicator scored 1, as less than 50% of the crew members possess certifications. The results of the check can be seen in the Table 6 below.

Tabel 6. List of ship captains and crew at TPI Pasiran.

No	Skipper	Certificate Type	Number of Crew Member	Information
1.	Syarifudin	SKK	1	Not Certified
2.	Jonny	SKK	1	Not Certified
3.	Leng len	SKK	1	Not Certified
4.	Abdul Muthalib	SKK	0	Not Certified
5.	Burhani	SKK	0	Not Certified
6.	Khairul Anwar	SKK	0	Not Certified
7.	Saiful	SKK	0	Not Certified
8.	Reza Akbar	SKK	1	Not Certified
9.	Syukri Ismail	SKK	1	Not Certified
10.	Jufri	SKK	0	Not Certified

This situation does not align with Government Regulation No. 33 of 2021 concerning Fishing Logbooks, Onboard Monitoring of Fishing and Fish Transport Vessels, Inspection, Testing, and Marking of Fishing Vessels, and Fisheries Crew Governance, which mandates that all fisheries crew members must hold maritime certificates such as BST (Basic Safety Training) and other certifications relevant to small-scale fishing operations.

Certifications serve as a critical competency standard for fishers to support responsible fishing practices [2]. While coral fishers in TPI Pasiran have acquired practical skills through personal experience, certifications remain essential for enhancing their knowledge and skills. In addition to establishing professionalism among fishers, certifications help prevent misuse and fraud related to claimed expertise [3].

3.2 EAFM aggregate assessment at Pasiran fish landing base

The results of scores, weights, and index values for each indicator in the fishing technique domain, after all values are obtained, will be evaluated using composite analysis, flag color, and a description based on the value range results. The fishing technique domain in Pasiran, regarding fisheries management related to the ecosystem, showed positive outcomes, as reflected by a composite value of 78 with a light green flag.

Tabel 7. The results of the calculation of the fishing technique domain scores.

Domain	Composite Score	Flag Model	Description
Fishing Technique	78		Good

The final score obtained from the fishing techniques domain is in the good category with a final score of 75 in the application of EAFM. Ecosystem management is related to fisheries activities, especially in fishing, so it must be supported by every stakeholder and fishing community in order to continue to improve fisheries management more optimally while maintaining and implementing sustainable fishing practices.

4 Conclusion

The composite score of 78 for the fishing technique domain indicates that the management of coral fisheries at the Pasiran fish landing site falls under the "Good" category. However, the assessment also reveals that two indicators remain in a poor status. The indicator for fishing capacity and efforts scored low at 1, highlighting underutilized fishing capacity. Additionally, crew certification obtained a low score of 1, indicating that the majority of crew members lack formal certification as required by regulations. To improve the score for the fishing crew certification indicator, it is necessary to implement training and certification programs for crew members and strengthen regulations related to fishing crew certification by imposing penalties or fines on vessels operating without certified crew, as required by applicable regulations. Meanwhile, the fishing capacity indicator can be enhanced by optimizing the number of fleets and fishing trips. To ensure a comprehensive and accurate EAFM (Ecosystem Approach to Fisheries Management) assessment of coral fisheries management at TPI Pasiran, it is essential to include additional EAFM domains not covered in this study. These domains—habitat and ecosystem, fisheries resources, social, economic, and institutional—are critical as they provide a holistic understanding of fisheries sustainability. Incorporating these aspects ensures that ecological, social, and economic factors are integrated into management strategies, enhancing the overall effectiveness of conservation and resource utilization efforts.

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