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Status of Sustainability Management of Tuna Fisheries Using An Ecosystem Approach In Morotai Island District, Indonesia

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ABSTRACT

Tuna is an economically important fish in Indonesia, particularly in Morotai Island Regency, where it is a leading commodity. Since 2017, local governments have focused on managing tuna fisheries. However, over time, and particularly due to the impact of the COVID-19 pandemic, tuna fisheries management has not been optimal. This highlights the need for a new management model to maximize the production of this valuable resource. The proposed management model emphasizes responsible and sustainable fisheries management, specifically through the ecosystem approach to fisheries management (EAFM). This research aimed to assess the sustainability status of tuna fisheries based on EAFM criteria in Morotai Island Regency. Data collection for this study involved gathering information for each criterion across the six EAFM domains, using both primary and secondary data. Primary data were collected through direct surveys at the research site, in-depth interviews with respondents, and focus group discussions. The respondents included fishermen, business owners, and stakeholders. Secondary data were sourced from relevant agencies. The sustainability status of ecosystem-based tuna fisheries was analyzed using the six EAFM criteria and assessed using the flag model. The findings indicate that the sustainability of tuna fisheries in Morotai Island Regency, based on EAFM criteria, falls within a medium to very good range. The implementation of EAFM can be effective while maintaining the status of fish resources, fishing technology, and economic factors. Additionally, there is potential to enhance criteria related to habitat and ecosystems, as well as social and institutional domains.

INTRODUCTION

Tuna is an economically important fish in Indonesia, as evidenced by an export volume of 195,759,299 kilograms in 2022, making it the second-largest exported fish after shrimp **(Mursit *et al.*, 2022)**. According to the National Stock Assessment Commission, the potential for tuna fisheries in Indonesia is extensive, although the utilization level in some areas is still low **(Lintang *et al.*, 2012)**. In Indonesia, tuna fisheries are dominated by small-scale fishing using hand lines **(Kasim *et al*., 2024)**. Regions that make tuna a management focus must make many preparations **(Firdaus, 2018; Kantun, 2018)**. Tuna management cannot be equated with managing other fish resources because tuna is an export commodity that requires extra handling **(Supriatna *et al*., 2014; Ratu *et al*., 2019)**. Morotai Island Regency is a Regency in North Maluku Province that was only expanded in 2009 to an area of 2,314.90km^2. Its geographical location, surrounded by the Halmahera Sea, Sulawesi Sea, and the Pacific Ocean, and 89% of villages which are coastal villages, cements Morotai Island Regency as a maritime district in the eastern region of Indonesia **(Central Statistics Agency for North Maluku, 2022)**. The capture fisheries potential of Morotai Island Regency is 61,980 tonnes/year, consisting of large pelagic fish, small pelagic fish, and demersal fish. In 2021, fisheries production reached only 4,716 tons per year, highlighting a significant opportunity for the optimal and integrated utilization of superior fish commodities **(Central Statistics Agency for Morotai Island Regency, 2022)**.

Tuna is the leading commodity of Morotai Island Regency **(Sofiati, 2016)**. In 2021, total the yellowfin tuna production reached 2,612 tons **(Central Statistics Agency for Morotai Island Regency, 2022)**. Regional governments have been focusing on tuna management since 2017. According to **Sofiati and Alwi (2019)**, tuna fisheries management strategies include: 1) applying an integrated management model for tuna utilization; 2) opening up market opportunities by establishing business channels with investors from outside Morotai Island; and 3) achieving good management through the fishermen's cooperative program. However, over time and especially due to the impact of the COVID-19 pandemic, tuna fisheries management has not been optimal. As a result, a new management model is needed to maximize the production of this valuable resource.

The model introduced is responsible and sustainable fisheries management, specifically the ecosystem approach to fisheries management (EAFM) **(Fletcher, 2008; NWG EAFM, 2014; Juan-Jorda *et al.*, 2019)**. EAFM has been implemented in several regions across Indonesia, including the fisheries management in the West Kei Islands, small pelagic fisheries in the waters of West Aceh, as well as in the waters of Raja Ampat and Aru Island **(Mulyana, 2018; Gazali, 2019; Abrahamsz *et al.*, 2023)**.

It is essential to implement the ecosystem approach to fisheries management as a management reference toward sustainable Indonesian fisheries for the welfare of society **(FAO, 2003; Cotter *et al*., 2009; Muffley *et al*., 2021)**. EAFM is based on six domains, namely: 1) fish resources, 2) habitat, and ecosystem, 3) fishing techniques, 4) social, 5) economic, and 6) institutional **(NWG EAFM, 2014)**. Evaluating the criteria from these six domains can describe the sustainability status of tuna fisheries in Morotai Island Regency. Understanding the status of tuna fisheries management in Morotai Island Regency can make it easier for local governments to plan related policies **(Makino *et al*., 2009; Sunoko & Huang, 2014; Obregon *et al*., 2021)**.

Based on the explanation above, this research aimed to determine the sustainability status of tuna fisheries based on EAFM criteria in Morotai Island Regency.

MATERIALS AND METHODS

1. Research location

The research was conducted in Morotai Island Regency, North Maluku Province. The study locations included the North Maluku Province Maritime and Fisheries Service, the Morotai Island Regency Maritime and Fisheries Service, the Morotai Integrated Marine Fisheries Center (SKPT), and fish landing sites in tuna-centered villages (Daeo, Sangowo, and Bere-Bere). Additionally, the research covered the Tuna Pacific Cooperative, the Tuna Najwa Cooperative, CV Charlie Morotai Cemerlang, and the Indonesia Fisheries and Community Foundation (MDPI). A map of the research locations is shown in Fig. (1).

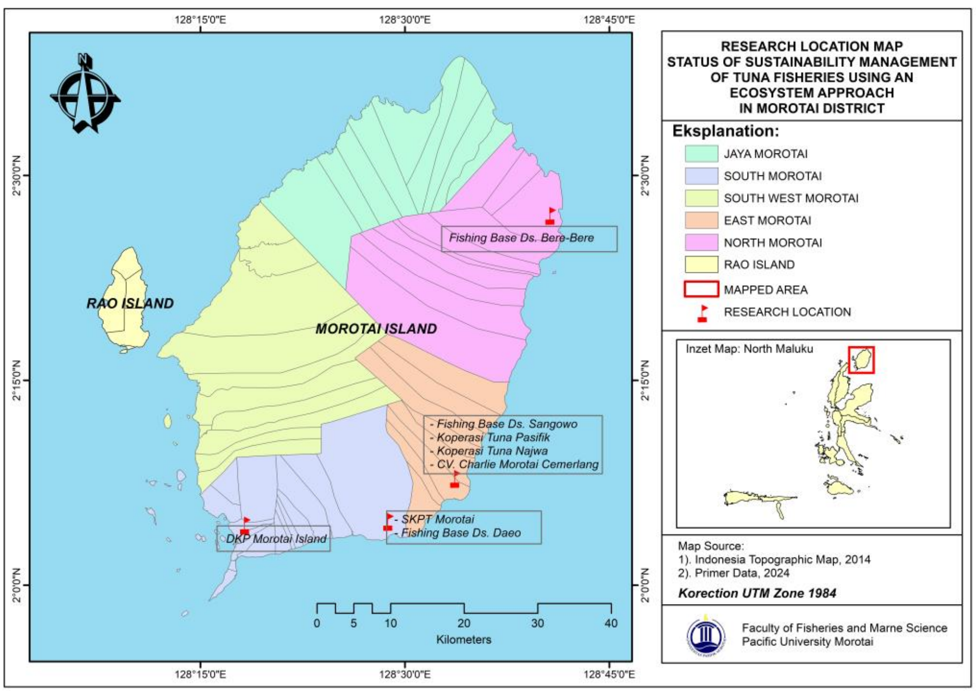

Fig. 1. Research location

2. Tools and materials

The tools and materials used in this research included questionnaire sheets, satellite images, recorders, digital cameras, snorkels, and self-contained underwater breathing apparatus (SCUBA). Other equipment included turbidity meters, salinometers, refractometers, dissolved oxygen (DO) meters, current meters, pH meters, thermometers, sediment traps, plastic ropes, 1m x 1m quadrants, GPS/Spot track devices, roller meters, and laptops with Microsoft Excel for data tabulation. ARGIS 10.5 software was used for creating maps of the research locations and fishing grounds. Additionally, digital scales were used for weighing specimens. Juvenile fish and endemic species were identified using guidelines from Fishbase.

3. Data collection

Data collection in this research followed the data requirements outlined in **NWG EAFM (2014)** for each criterion across the six EAFM domains. The data gathered included both primary and secondary sources. Primary data were collected through direct surveys in the research locations, in-depth interviews with respondents, and focus group discussions. The respondents included fishermen, business owners, and various stakeholders. Secondary data were obtained from relevant agencies. The sustainability status of ecosystem-based tuna fisheries was analyzed using the six EAFM domain criteria.

4. Data analysis

Data analysis for EAFM indicator assessment use the flag modeling technique through a multi-criteria analysis (MCA) approach. According to **Adrianto *et al*. (2005)**, MCA is an analysis of the diversity of fisheries management areas, consisting of criteria for assessing the EAFM approach through developing a composite index. The analysis stages for calculating the composite index **(Adrianto *et al.*, 2005; NWG EAFM, 2014)** were as follows:

1. Determining the criteria for each indicator in each EAFM domain.
2. Setting reference points (value limits) for each indicator.
3. Assigning scores to each indicator (i) using the Likert scale (ordinal-based: 1, 2, 3) based on the performance of each indicator. A score of 1 represents the lowest value, indicating poor or low conditions (red), while a score of 3 represents the highest value, indicating good or high conditions (green) (Table 1). The value for each indicator is calculated using the formula:
   Indicator value = weight × score index
4. Calculating the composite (total) value of all indicators. The composite value of each domain is then used to determine the flag model. The calculation for the composite value is as follows:
   Nk-i = (Cat-i / Cat-max) × 100
   Where:
   - **Cat-i** = Total EAFM value for indicator i in the domain
   - **Cat-max** = Maximum value in domain i
5. Classifying the 6 EAFM domain values using the flag model, as shown in Table (2).

Table 1. Indicator score index

Score	Description	Color
1	Low/Poor	
2	Medium	
3	High/Good	

Table 2. Composite index clasification and flag model visualisation

Range	Flag Model	Description Aplication of EAFM
1-20		Very Bad
21-40		Bad
41-60		Medium
61-80		Good
81-100		Very Good

RESULTS

1. Current conditions of tuna fisheries

Tuna fisheries in Morotai Island Regency have received significant attention from the local government. Morotai's strategic geographic location, bordered by three Fisheries Management Areas (FMAs) 715, 716, and 717, and serving as a key tuna migration route, provides a prime opportunity to exploit this valuable resource. Tuna fishing activities are carried out by fishermen in the South Morotai, East Morotai, and North Morotai districts. According to the **Central Statistics Agency for Morotai Island Regency (2022)**, the number of fishing gears in these districts was 687 in South Morotai, 616 in East Morotai, and 353 in North Morotai. The fishing method predominantly used is handline, with fishing fleets ranging from 1.5 to 5 GT. Fishing operations follow a one-day system, with an average fishing time of 8 to 19 hours.

Based on the processed research data, the catch per unit effort (CPUE) for tuna shows fluctuations, but with an overall increasing trend, as shown in Table (3) and Fig. (2). The highest CPUE value occurred in 2023, at 5.45, while the lowest was in 2022, at 4.30. The decline in tuna catches in 2022 was primarily due to reduced fishing efforts. Fishing hours dropped from 947 hours in 2021 to 688 hours in 2022. The higher CPUE values are influenced by fishing effort; generally, greater fishing effort leads to higher catch rates.

Table 3. Catch, effort, and CPUE values

No	Year	Catch (kg)	Effort (hour)	CPUE
1	2018	14864.3	3234	4.60
2	2019	23178.9	4924	4.71
3	2020	14898	2971	5.01
4	2021	4611	947	4.87
5	2022	2961	688	4.30
6	2023	33100.1	6073	5.45
	Average	15602.22	3139.5	4.82

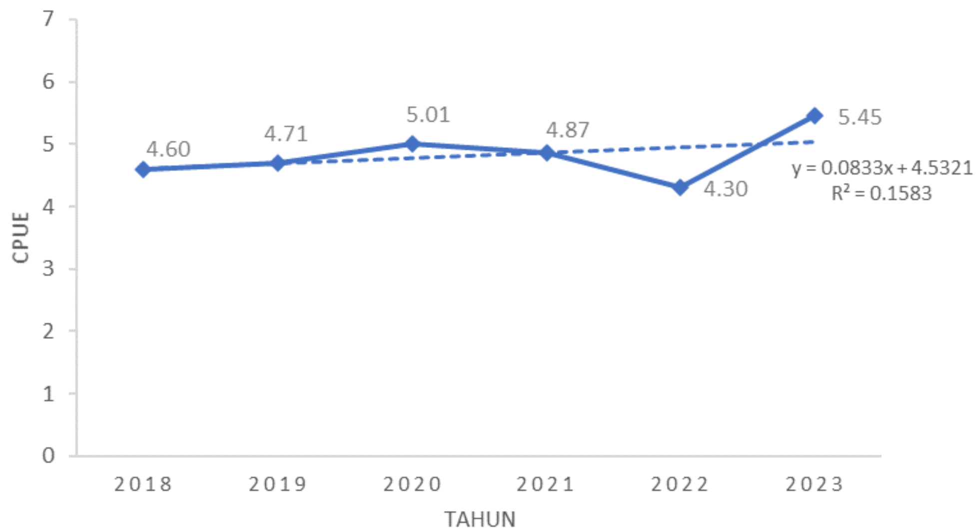

Fig. 2. CPUE trendline of tuna fishing

2. Status of sustainability of tuna fisheries based on an ecosystem approach

Sustainable fisheries management requires a balance between ecological, social, economic, institutional, and policy aspects **(Charles, 2001)**. EAFM is a form of implementing sustainable management, which can provide an overview of the sustainable status of fish resources by assessing each indicator. The indicator assessment score consists of 1-3, representing each indicator's condition as bad, moderate, and good using the flag model depicted in Table (2). The assessment of indicators for the 6 EAFM domains in tuna fisheries in Morotai Island Regency can be seen in Tables (4, 5, 6, 7, 8, 9).

Table 4. Analysis results and flag model of the fish resource domain

No	Indicator	Score	Flag
1	Raw CPUE	3.00	Good
2	Fish size trend	2.00	Medium
3	Proportion of wild fish caught	3.00	Good
4	Species composition of the catch	3.00	Good
5	'Range Collapse' of fish resources	3.00	Good
6	ETP species	3.00	Good

Table 5. Analysis results and flag model of the habitat and ecosystem domain

No	Indicator	Scor	Flag
1	Water quality	1.70	Medium
2	Status of seagrass ecosystem	1.00	Poor
3	Status of mangrove ecosystem	1.00	Poor
4	Status of coral reef ecosystem	1.50	Poor
5	Unique/specialized habitats	2.00	Medium
6	Climate change on water and habitat conditions	2.00	Medium

Table 6. Analysis results and flag model of the fishing technology domain

No	Indicator	Scor	Flag
1	Destructive fishing	3.00	Good
2	Modification of fishing gear and fishing aids	2.00	Medium
3	Fishery capacity and fishing effort	3.00	Good
4	Fishing selectivity	3.00	Good
5	Conformity of function and size of fishing vessels with legal documents	2.00	Medium
6	Certification of fishing vessel crew in accordance with regulations	1.00	Poor

Table 7. Analysis results and flag model of the social domain

No	Indicator	Scor	Flag
1	Stakeholder participation	2.00	Medium
2	Fisheries conflict	1.00	Poor
3	Utilisation of local knowledge in fish resource management	2.00	Medium

Table 8. Analysis results and flag model of economic domain

No	Indicator	Scor	Flag
1	Asset Ownership	3.00	Good
2	Fishery household income (RTP)	3.00	Good
3	Saving ratio	1.00	Poor

Table 9. Analysis results and flag model of institutional domain

No	Indicator	Scor	Flag
1	Adherence to responsible fisheries principles	3.00	Good
2	Completeness of rules of the game in fisheries management	1.80	Medium
3	Decision-making mechanism	1.50	Poor
4	Fisheries management plan	1.00	Poor
5	Level of synergy of fisheries management policies and institutions	2.50	Good
6	Capacity of stakeholders	2.00	Medium

The results show that the 6 EAFM domains of tuna fisheries in Morotai Island Regency have varying scores and flag models. The fish resource domain in Table (4) has the highest score with a dominant green flag model, which means it is good. Meanwhile, the domain conditions that need critical attention are the habitat, ecosystem, and social. Based on Table (5) for the habitat and ecosystem domain, there are three red flag models and three yellow flag models of the six indicators. Table (7) shows the social domain: the three indicators, one red flag, and two yellow flags. The results shown in Tables (6, 8, 9) show that there are indicators that need to be improved in each domain.

The sustainability of each EAFM domain is determined by looking at the results of the composite value analysis for each domain. The composite value for tuna fisheries in Morotai Island Regency is presented in Fig. (3). Fig. (3) shows that the composite value is in the range of 51.17-88.33. The lowest composite value is in the ecosystem and habitat domain, while the highest is in the fish resources domain.

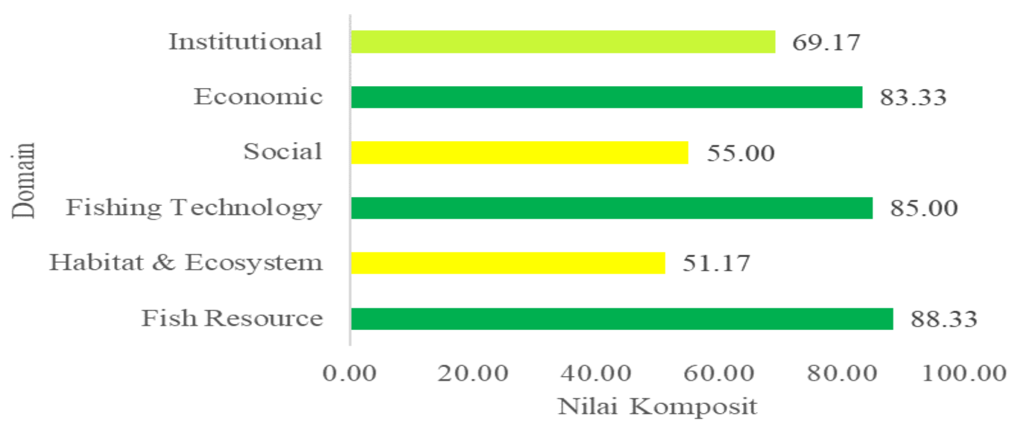

Fig. 3. Sustainability status of tuna fisheries in Morotai Island District

Fig. (3) shows the sustainability status of the various domains based on the flag model. In the fish resources, fishing technology, and economic domains, the sustainability status is rated as "very good" in the application of EAFM. The governance domain has a sustainability status of "good" in EAFM implementation. The habitat, ecosystem, and social domains show a moderate sustainability status in implementing EAFM.

DISCUSSION

The ecosystem approach to fisheries management is one way to achieve community welfare through the sustainable use of fish resources. **Abdullah *et al.* (2020)** stated that ecosystem-based tuna fisheries management aims to meet human needs in terms of food and social and economic matters while still protecting the structure, diversity, and ecosystem of fish resources. The results of the assessment of all EAFM indicators and domains show that there are opportunities for sustainable management. According to **Mulyana (2018)** and **Makailipessy and Abrahamsz (2023)**, although some domains are not optimal, recommendations for improving fisheries management are needed.

Based on the EAFM indicator analysis results, the fish resources domain has the highest scoring and composite values. Of the six fish resource domain indicators, the trend in fish size must be considered. The study results show that the fish caught have a fixed size. Fish below length maternity (lm) still dominate fishermen's catches. Based on the scoring results in Table (5), the habitat and ecosystem domains are low, with the composite analysis results being in the medium category for applying EAFM. Seagrass, mangrove, and coral reef ecosystems are the primary targets for improving fisheries management. Improved fisheries management is crucial because these three ecosystems are essential and critical habitats for the survival of various juvenile fish and shrimp, as well as for primary aquatic productivity **(Ninef *et al.*, 2019; Abrahamsz *et al.*, 2023)**.

The main obstacle tuna fisheries actors face in the fishing technology domain is the certification of fishing vessel crews. The research results show that not only crew members or crew members have not been certified, but fishing vessels also need permits. Fishing vessel crew certificates are regulated in government regulation 7 of 2000 concerning maritime affairs. **Amin *et al*. (2016)** stated that fishermen's competency certificates are vital in implementing responsible fishing activities. Competency certification also standardizes expertise for the fishing profession **(Katili *et al*., 2022)**.

The low scoring and composite values in the social domain are due to frequent conflicts between tuna fishermen. The results of in-depth interviews with fishermen show that conflicts often occur between local fishermen and migrant fishermen. The cause of the conflict is the one-sided assessment of local fishermen that migrant fishermen have better fishing skills, so migrant fishermen catch more tuna than local fishermen. According to **Natasya *et al*. (2018)**, fighting over fishing grounds and gear is a common problem in fishing communities.

The economic domain score analysis results have less value in the savings ratio indicator because most tuna fishermen in Morotai need to have savings or take out bank loans to sustain their fishing business. **Ahmad *et al*. (2024)** stated that fishermen's income is influenced by the number of fishing trips, catch, market prices and operational costs. This condition has not improved from previous research **(Abdullah *et al.*, 2020)**.

The government's role as a decision and policy maker in tuna fisheries management is vital. **Gazali (2019)** stated that the decision-making mechanism should ideally be built in a system that includes the game's procedures/norms/rules between all stakeholders. The sustainability status of the inertia domain is good in implementing EAFM. However, based on the score calculation, some indicators have low/poor to medium values. Decision-making mechanisms that do not work optimally and the absence of a management plan are problems that must receive special attention to improve the status of EAFM implementation.

Ecosystem-based tuna fisheries management in Morotai Island Regency has an excellent opportunity to be implemented. Abundant fish resource potential, adequate facilities, infrastructure, and government and stakeholder support determine the implementation of EAFM as a management model. Collaboration from various stakeholders can increase the score on indicators from each EAFM domain.

CONCLUSION

This research shows that the sustainability of tuna fisheries based on ecosystem-based management (EAFM) criteria in Morotai Island Regency is at a medium-very good. Ecosystem-based fisheries management (EAFM) can be effectively implemented while maintaining the sustainability of the fish resources, fishing technology, and economic domains. Additionally, the criteria for the habitat and ecosystem, social, and institutional domains can be optimized for greater sustainability.

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