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Sustainability Assessment of Octopus (*Octopus cyanea*) Fisheries in Wakatobi National Park Using EAFM Indicators

Israwaty Ode[1], Eko Sri Wiyono[2]*, Agnes Puspitasari Sudarmo[3], Wa Ode Nur Asma La Dia[4]

[1]Management of Fisheries Study Program, Open University, Indonesia 15437, Tangerang, Indonesia
[2]Department of Fisheries Resources Utilization, Faculty of Fisheries and Marine Sciences, IPB University, 16680 Bogor, Indonesia
[3]Management of Fisheries Study Program, Open University, Indonesia 15437, Tangerang, Indonesia
[4]Marine and Fisheries Community Academy, 93795 Wakatobi, Indonesia

*Corresponding Author: eko-psp@apps.ipb.ac.id

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ABSTRACT

This study utilized the Ecosystem Approach to Fisheries Management (EAFM) to assess the sustainability of octopus (*Octopus cyanea*) fisheries in Wakatobi National Park, Indonesia. A comprehensive evaluation of the six fundamental EAFM domains was conducted, encompassing octopus resources, habitat and ecosystem, fishing technology, economics, society, and institutions. The data were collected through field surveys, stakeholder interviews, and secondary sources, and analyzed using a scoring system based on established EAFM indicators. The findings suggest that multiple domains, encompassing resource status, habitat conditions, and fishing gear selectivity, fall within the good to very good categories. This observation reflects environmentally friendly practices and stable resource use. Local fishers primarily employ *pissi kuitta* (octopus lures), a method of fishing that is selective and non-destructive, thereby contributing to the ecological sustainability of the fishery. The social domain exhibited similarly high performance, propelled by robust stakeholder involvement and the incorporation of indigenous ecological knowledge. However, the economic domain revealed significant challenges, with low household income and limited financial resilience despite stable asset ownership. Furthermore, the investigation revealed deficiencies in governance, particularly concerning the legality of vessels and the absence of certification among fishers. The composite assessment places the fishery in a moderately sustainable status. The fishery has strong ecological and social foundations, but economic and institutional gaps require targeted policy intervention. It is imperative to fortify economic resilience and institutional capacity to guarantee the long-term viability of octopus fisheries within this designated marine protected area.

INTRODUCTION

Indonesia, a global leader in marine resource production, has a pivotal role in the international octopus trade. This species is a high-value fishery commodity that is both

domestically and internationally marketed. In the context of global fisheries, octopus is considered the third most significant commodity after fish and shrimp **(Mulyani *et al.*,, 2023)**. The Wakatobi Regency is among the regions designated as a National Park **(**Wakatobi National Park/WNP**)** by the Ministry of Forestry through Decree No. 765/KPTS.II/2002 issued in 2002. Wakatobi is renowned on a global scale for its remarkably diverse marine biota, which includes octopuses. In 2022, octopus production in Wakatobi reached 503.15 tons, valued at approximately IDR 15.09 billion. A significant proportion of the total production, amounting to 77%, emanated from the South Wangi-Wangi, Kaledupa, and Wangi-Wangi subdistricts **(Marine Affairs and Fisheries Services, 2023)**. The octopus fishery in Wakatobi is predominantly operated by traditional fishers who utilize environmentally friendly fishing gear, including spears and artificial lures. Notwithstanding its substantial economic potential, the fishery is confronted with critical challenges, most notably a persistent decline in productivity over time. A comprehensive analysis of data collected by the Wakatobi National Park Authority in 2024 revealed substantial monthly variations in octopus catch volume. The highest recorded yield was observed in March, with a total of ~13,500 kilograms, while the lowest was documented in August, with a value of less than 2,000 kilograms.

Concurrently, production data from the fish processing unit, Padalleang Samma Processing Unit, demonstrated a substantial decline, from 17,000 kilograms in 2022 to 4,500 kilograms in 2023. Furthermore, local fishermen have reported a marked decrease in the average size of captured octopuses. This decline may be attributed to several factors, including climate change **(Gimenez, 2019)**, overfishing **(Fall & Asiedu, 2024)**, and the lack of sustainable fisheries management practices. A multitude of studies have demonstrated that environmental variables, particularly water temperature, have a substantial impact on octopus growth and body size **(Herwig *et al.*, 2012)**.

This phenomenon poses a significant threat to the sustainability of octopus populations and the economic prosperity of coastal communities. Confronted with these challenges, the implementation of comprehensive ecosystem-based management strategies is imperative. The Ecosystem Approach to Fisheries Management (EAFM) provides a relevant framework for ensuring the sustainability of octopus resources. The primary objective of EAFM is to achieve a balance between ecological health and social and economic objectives. This objective is realized through the integration of assessments across six fundamental domains: fish resources, habitats and ecosystems, fishing technology, economic aspects, social aspects, and institutional dimensions. For this reason, a decision was made to conduct a sustainability assessment of the octopus (*Octopus cyanea*) fishery. The ecosystem approach to fisheries management (EAFM) was implemented in Wakatobi National Park, Indonesia, to assess the environmental impact of the fishery. The objective of this study was to assess the sustainability of the octopus fishery in Wakatobi National Park, Indonesia.

METHODS

Research location

This study was conducted in Wakatobi National Park, located in Southeast Sulawesi, Indonesia, with a particular emphasis on two primary islands: The following islands are of particular interest: Wangi-Wangi Island (Mola Village) and Kapota Island, including North Kapota, Kabita, and Kabita Togo. The selection of the site was based on the high level of octopus (*Octopus cyanea*) fishing activity and the significant involvement of coastal communities in the utilization of marine resources through both traditional and modern practices. The two sites are located within the Wakatobi National Park, making them particularly relevant for the application of the Ecosystem Approach to Fisheries Management (EAFM).

Data collection

The data collection period spanned from July to November 2024, adhering to the data requirements stipulated by the National Working Group on EAFM **(NWG EAFM, 2014)**. Primary data were obtained through direct field surveys, in-depth interviews, and stakeholder consultations. A total of 45 octopus fishers were interviewed as the main respondents. Respondent selection employed a purposive sampling technique, targeting active fishers who have engaged in octopus fishing for at least the past two years and who depend primarily on this fishery as their main source of livelihood. This approach ensured the inclusion of participants with substantial local ecological knowledge relevant to EAFM indicators. Key stakeholders included local octopus fishers, Wakatobi National Park authorities, the Fish, Animal, and Plant Quarantine Agency (Wakatobi site), and non-governmental organizations such as WWF-Indonesia, Yayasan Konservasi Alam Nasional (YKAN), Komunitas Nelayan Wangi-Wangi (KOMANANGI), and Masyarakat Hukum Adat (MHA). Secondary data were collected from government institutions, official reports, and literature sources to complement the primary findings. The present study concentrated on the institutional, social, and economic domains of the EAFM framework.

Data analysis

The assessment of EAFM indicators in this study employed a flag modeling technique integrated with a Multi-Criteria Analysis (MCA) approach. The analytical procedure was executed in accordance with the following sequence of stages:

a) Identification and definition of the criteria for each indicator.
b) Establishment of reference values (thresholds) for each indicator.
c) Assignment of performance scores based on an ordinal Likert scale (1 = low/poor performance [red], 2 = moderate [yellow], 3 = good/high performance [green]).

d) Calculation of the indicator value using the formula (Indicator Value = Weight × Score Index).
e) Aggregation of the indicator values to obtain a composite index for each domain using the formula: The formula for calculating the normalized indicator value (Nki) is as follows:
$N_{ki} = C_{at\text{-}i} / C_{at\text{-}max} \times 100$
f) In this formula, $C_{at\text{-}i}$ denotes the total score of indicators in domain i, and $C_{at\text{-}max}$ signifies the maximum possible score in that domain.

Table 1. Indicator score index

Score	Description	Color
1 – 1.5	Poor	
1.6- 2.5	Medium	
2.6 - 3	Good	

Table 2. Composite index classification and flag model visualizasion

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

RESULTS AND DISCUSSIONS

To assess the sustainability of octopus fisheries, the Ecosystem Approach to Fisheries Management (EAFM) was applied. This approach is expected to provide a relevant framework for ensuring the sustainability of octopus resources. The primary objective of EAFM is to achieve a balance between ecological health and social and economic objectives. For the purpose of managing octopus fisheries, an assessment was conducted across six primary domains: fish resources, habitat and ecosystem, fishing technology, economic aspects, social aspects, and institutional dimensions.

Resource domains

The octopus resource domain functions as a key indicator in assessing the sustainability status of *Octopus cyanea* stocks exploited in the Wakatobi National Park. This evaluation incorporates six-attribute indicators. In addition to data collected from field observations and secondary sources, interviews were also conducted with local fishers to obtain supporting information on CPUE, octopus size trends, octopus catch

trends, Juvenile octopus caught, range collaps, and ETP. The results of the interviews are presented in Fig. (1), while the analysis of the six attributes used to evaluate the sustainability of octopus resource management is shown in Table (3).

The good application of management using the EAFM approach in the octopus resource aspect is demonstrated by two attributes, namely the "catch's species composition" and "range of collapse". This indicates high selectivity and minimal bycatch of non-target species. Moreover, the resource range collapse indicator also obtained a good score, signifying that the octopus fishing grounds have remained relatively stable. This stability is presumably due to the limited operational range of small-scale fishing vessels (<1 GT), which inherently restricts spatial expansion and minimizes the risk of overexploitation in distant fishing areas. Consequently, there has been no substantial shift in the distribution of the target species, and the fishermen's fishing grounds have remained fixed. However, several attributes require attention, namely CPUE, octopus size trend, juvenile octopus caught, and ETP species. The CPUE is an attribute related to fleet characteristics (fishing effort) associated with the number of catches obtained and can serve as an indicator of fish abundance in the water **(Sala *et al.*, 2025)**.

The CPUE indicator shows a downward trend in catch numbers that remains within an acceptable threshold (<25% per year). This reflects increased fishing pressure that has not yet reached critical levels. The decline in CPUE may also reflect limited access of local fishers to modern fishing technology and weak institutional capacity in managing fishing effort, which in turn affects household income and the ability to adopt sustainable fishing practices. Strengthening fisher cooperatives, improving data collection systems, and supporting community-based monitoring could enhance the accuracy of effort control and resource sustainability. The range of weight of the octopuses was determined to be 300-1.100 grams, based on a sample size of 350 individuals (n = 350). This finding indicates that the majority of the captured specimens have reached the minimum legal size stipulated by relevant legislation. The observed size stability can be attributed to the implementation of locally managed area closure systems (temporal spatial closures). Nevertheless, ensuring compliance with size limits requires better institutional enforcement and fisher awareness programs to prevent premature harvesting and maintain recruitment sustainability.

The proportion of juvenile (yuwana) octopus in the catch ranged between 30–60%, indicating partial recruitment overfishing but with the majority of individuals still above the maturity threshold. This condition highlights the need for adaptive management strategies such as rotational closures, seasonal bans during peak spawning, and the introduction of small-scale fisher certification schemes that encourage responsible harvest practices. The ETP (Endangered, Threatened, and Protected) species indicator suggests that octopus fishing activities in the area pose negligible risk to vulnerable or protected marine fauna. To maintain this condition under increasing fishing

and tourism pressures, policy measures should integrate climate adaptation strategies such as ecosystem-based zoning and vessel legality verification to strengthen the resilience of both the fishery and the dependent coastal communities.

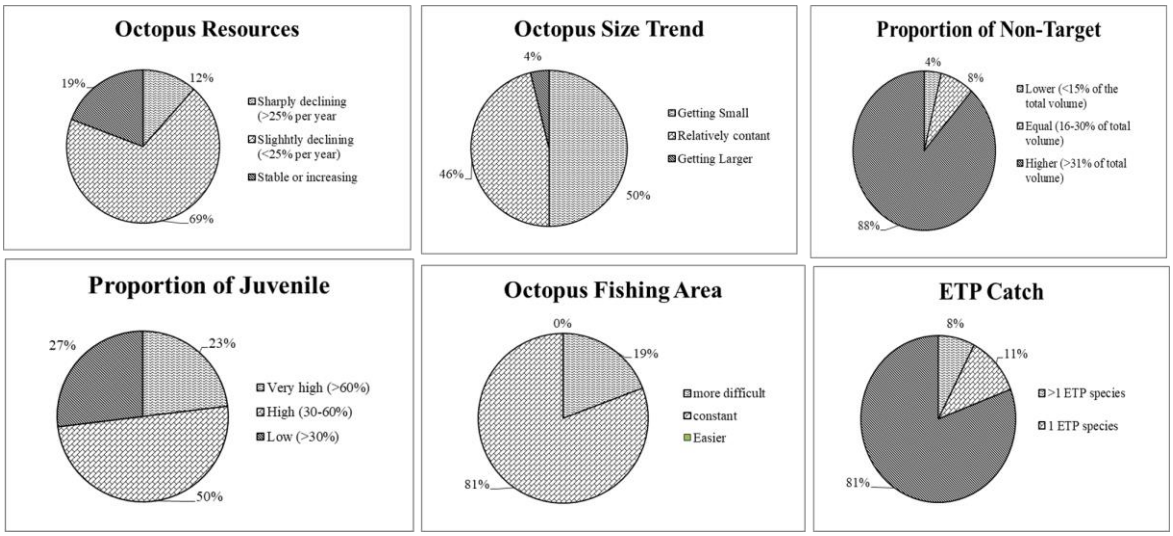

Fig. 1. Fishers' interview on the octopus resource domain

Table 3. Analysis result and flag model of octopus resource domain

No	Indicator	Score	Flag
1	CPUE	2.00	**Medium**
2	Octopus size trend	2.00	**Medium**
3	Juvenile octopus caught	2.00	**Medium**
4	The catch's species composition	3.00	**Good**
5	Range collapse of octopus resources	3.00	**Good**
6	ETP spesies	2.50	**Medium**

Habitat and ecosystem domains

Habitat and ecosystem components are fundamental to the sustainability of octopus populations, as they provide spawning grounds, shelter, and feeding areas. Water quality in Wakatobi is classified as good, with physicochemical parameters that comply with established environmental standards. Seagrass beds and mangrove ecosystems are in good condition (score 3), characterized by high biodiversity, broad coverage, and optimal ecological function. Coral reefs are in moderate condition, with live coral cover ranging between 25–50%. These habitats are managed collaboratively by the government, local communities, and non-governmental organizations (score 3), aligning with an ecosystem-based management approach. However, the state of impact indicator scored only 1 due to climate-related pressures such as coral bleaching, while the state of knowledge indicator received a score of 2. This suggests that although habitat conditions remain generally

favorable, adaptive capacity to respond to climate stressors remains limited. Climate change impacts particularly rising sea temperatures and increased bleaching frequency can reduce the productivity of coral reef and seagrass ecosystems, which serve as key habitats for octopuses and their prey. Therefore, strengthening climate adaptation strategies is critical to ensure long-term ecological and fishery sustainability. Practical actions may include developing early-warning systems for coral bleaching, rehabilitating seagrass and mangrove habitats as blue carbon ecosystems, and enhancing coastal community resilience through climate-adaptive fisher certification programs and area-based management schemes. Moreover, improved institutional coordination among stakeholders and the integration of scientific data with local ecological knowledge are essential to reinforce the social ecological resilience of Wakatobi's coastal ecosystems. In summary, while the current habitat conditions are generally supportive of octopus population sustainability, mainstreaming climate adaptation and strengthening local governance frameworks are key strategies for maintaining ecosystem balance and ensuring the long-term sustainability of the octopus fishery.

Table 4. Analysis result and flag model of the habitat and ecosystem domain

No	Indicator	Score	Flag
1	Water quality	3.00	**Good**
2	Status of seagrass ecosystem	3.00	**Good**
3	Status of mangrove ecosystem	3.00	**Good**
4	Status of coral reef ecosystem	2.00	**Medium**
5	Unique/specialized habitats	3.00	**Good**
6	Climate change on water and habitat conditions	2.00	**Medium**

Fishing technology domains

The evaluation of the octopus fishing technology domain reveals a predominant use of pissi kuitta (octopus fishing lures) (Fig. 2), a selective and non-destructive fishing method that aligns with sustainability principles. This approach yields a good score (3) for the indicator on destructive fishing practices, as it minimizes habitat damage and bycatch. The capture capacity ratio also scores 3, indicating that fishing activities are maintained within sustainable limits, without signs of overcapacity or overfishing. As noted by **Azis *et al.* (2022)**, a ratio value below 1 suggests potential overcapacity that could lead to resource depletion. Nevertheless, the legality of fishing vessels received a poor score (1), largely because most of the operating boats are small-scale units (<5 GT) without formal registration or licensing. This condition reflects broader institutional weaknesses particularly limited access to administrative services and low awareness of regulatory compliance among local fishers. Furthermore, all octopus fishers in Wakatobi lack formal

competency certification for fishing crews. This is primarily because most of them are traditional fishers who use simple gear and acquire their fishing skills through generational transfer. As a result, the certification indicator also received a low score (1), as the ownership rate of competency certificates was below 50%. These findings are consistent with **Azis *et al.* (2022)**, who reported that octopus fisheries in Tarupa Island are dominated by small-scale fishers operating vessels under 5 GT without formal fishing competency certificates. These institutional deficiencies often correlate with low household income and limited livelihood diversification, which discourage fishers from engaging in formalization or certification processes. To address these challenges, targeted policy interventions are necessary. Strengthening vessel registration systems through simplified procedures and mobile administrative services can enhance compliance among small-scale fishers. Implementing certification and training programs for fishing crews would improve technical competence, safety, and accountability. Additionally, integrating these measures with climate adaptation strategies such as promoting gear innovation and resource diversification would further enhance resilience and sustainability within the octopus fishery sector in Wakatobi.

Fig. 2. Fishing gear modification

Table 5. Analysis result and flag model of the fishing technology domain

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

Social domains

The assessment of the social domain encompasses three key factors: the utilization of local knowledge in octopus resource management, fisheries conflict, and stakeholder participation. The incorporation of indigenous knowledge is of paramount importance in optimizing the efficacy of octopus resource management. Local fishers employ traditional ecological knowledge, including the identification of octopus habitats and the comprehension of their migratory patterns, thereby directly contributing to sustainable fishing practices. This finding aligns with the conclusions of **Dudayev *et al.* (2023)**, who underscored the significance of incorporating local knowledge and participatory governance in marine resource management to enhance conservation outcomes, particularly in the context of preserving coral reef ecosystems and biodiversity. According to the findings of the study, the frequency of fisheries conflicts was reported to be relatively low, with an estimated annual incidence of 2-5 incidents. These estimates were derived from data collected through interviews. These conflicts primarily pertain to the competition over access to octopus fishing grounds. Conflict resolution efforts entail active involvement from fishers and traditional legal institutions, with government support manifesting through the implementation of spatial zoning regulations in designated octopus fishing areas. The enforcement of these zoning policies is expected to minimize conflict and ensure the long-term sustainability of octopus resources. Furthermore, the involvement of relevant stakeholders has been demonstrated to exert a substantial positive influence on the management of octopus fisheries. The active participation of a diverse array of stakeholders, including fishers, customary leaders, and government representatives, in the formulation and implementation of fisheries management policies is a critical factor in attaining a high social sustainability status. The social domain indicators yielded a composite score of 88.89, which falls within the "very good" category in the application of the Ecosystem Approach to Fisheries Management (EAFM). The assessment of the three indicators yielded a perfect score of 3 for stakeholder participation, indicating full support for this component. These findings are consistent with those reported by **Dwihastuty *et al.* (2023)**, whose study also achieved an excellent rating with a composite score of 100.

Table 6. Analysis result and flag model of the social domain

No	Indicator	Score	Flag
1	Stakeholder participation	3.00	**Good**
2	Fisheries conflict	2.00	**Medium**
3	Utilisation of local knowledge in fish resource management	3.00	**Good**

Economic domains

The assessment of the economic domain is comprised of three key indicators: asset ownership, household income from fisheries, and the savings ratio. The economic domain aims to assess the level of welfare and economic resilience of fishing households, particularly octopus fishers in Wangi-Wangi Island. This assessment comprises three main indicators: asset ownership, household income, and savings ratio. The asset ownership indicator evaluates the ability of fishers to accumulate productive assets derived from octopus fishing activities. The results show that this indicator obtained the highest score, classified as medium (score 2), reflecting relative stability in asset possession among fishers. Approximately 94% of respondents reported that their asset values remained constant or showed no significant increase over the past year (Fig. 3). This suggests that while most fishers own basic assets such as boats and fishing gear, asset growth remains limited, indicating that their economic resilience has not yet improved substantially. The household income indicator reflects the total income of octopus fishers, with the Regional Minimum Wage (UMR) of Wakatobi Regency IDR 2,885,964 used as the economic adequacy benchmark. Survey results revealed that 81% of respondents earn below the UMR, while only 19% earn equal to or above the threshold. This low-income level demonstrates limited catch productivity and significant seasonal fluctuations. Interview results show that octopus fishing activities are influenced by three distinct fishing seasons peak, moderate, and low. During the peak season (August–November) (Fig. 4), catch volumes are relatively high, whereas during the moderate and low seasons, production declines sharply, resulting in reduced household income. This seasonal pattern corresponds with previous ecological findings, which indicate that habitat conditions and seasonal changes directly affect fishing productivity.

The savings ratio indicator recorded the lowest score, categorized as poor (score 1). About 88% of respondents reported having no savings because their income is primarily used for daily needs and operational costs. This highlights a high level of economic vulnerability, as most fishers lack financial reserves to cope with income fluctuations or adverse weather conditions that limit fishing activities. Overall, the economic domain is categorized as poor, with an average composite score of 44.44. Although asset ownership remains relatively stable, it is not translated to improved income or savings capacity. This finding indicates that asset ownership alone does not necessarily equate to better financial well-being or economic resilience. Similar findings were reported by **Aprilla *et al.* (2023)** in Simeulue Timur District, where less than 50% of fishers had adequate asset ownership. **Meidiana and Marhaeni (2019)** also emphasized that while asset ownership positively affects fisher income, the relationship is not significant without the support of other factors such as market access and price stability.

A comparison with other regions reveals that octopus fishers in Wakatobi earn relatively less, with average monthly incomes below those reported in North Minahasa Regency (IDR 2,920,654–5,203,200), Banggai Laut Regency (IDR 1,500,000–3,000,000), and Sikka Regency (IDR 2,301,910–3,054,469). This disparity suggests that despite the abundance of octopus resources in Wakatobi, they have not yet provided optimal economic benefits to local fishers. Therefore, targeted management strategies are needed beyond resource sustainability to strengthen the economic and social dimensions of the fishery through improved market access, financial management training, and income diversification programs.

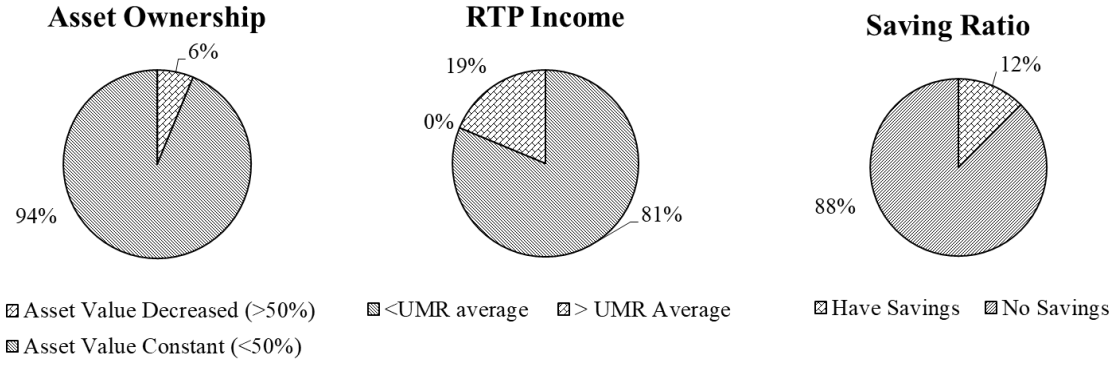

Fig. 3. Fishers' interview on the economic domain

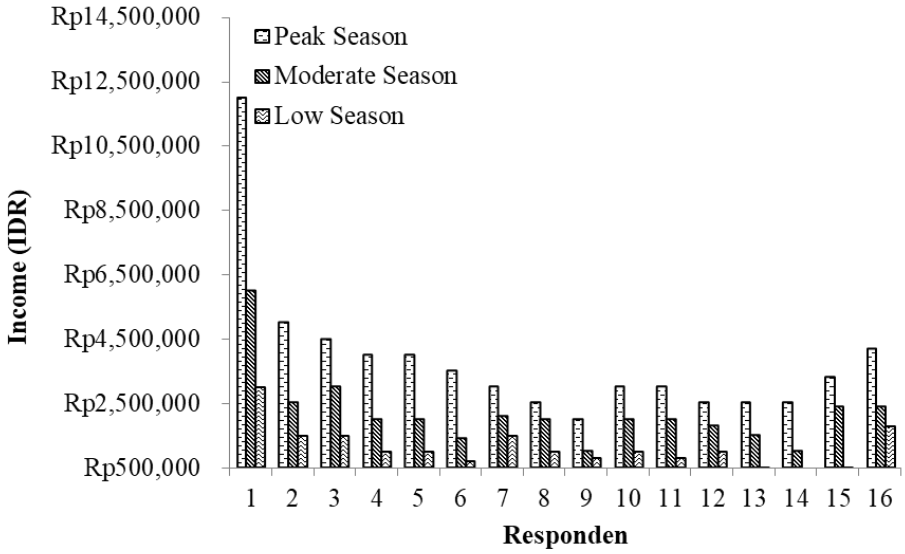

Fig. 4. Income of octopus fishers in different seasons

Table 7. Analysis result and flag model of the economic domain

No	Indicator	Score	Flag
1	Asset ownership	2.00	**Medium**
2	Fishery household income **(**RTP**)**	1.00	**Poor**
3	Saving ratio	1.00	**Poor**

Institutional domains

The assessment of the institutional domain encompasses the level of compliance with responsible fisheries principles, the comprehensiveness of regulatory frameworks, decision-making mechanisms, the existence of fisheries management plans, the degree of policy and institutional synergy in fisheries governance, and stakeholder capacity. The institutional domain showed a generally favorable condition, with an average composite score of 88.89 categorized as "good." This indicates that institutional aspects play a vital role in ensuring sustainable and effective octopus fisheries management in Wakatobi. Four indicators completeness of fisheries regulations, existence of a fisheries management plan, policy and institutional synergy, and stakeholder capacitywere rated "good," reflecting strong institutional support. However, compliance with responsible fisheries principles and decision-making mechanisms were rated "medium" (score 2.00), highlighting the need to enhance regulatory enforcement and participatory governance. Strengthening institutional performance therefore requires not only well-established regulations but also effective implementation through consistent socialization, monitoring, and law enforcement. Integrating local ecological knowledge and promoting adaptive co-management can further improve coordination between local and national institutions, supporting long-term sustainability of octopus fisheries.

Table 8. Analysis result and flag model of the institutional domain

No	Indicator	Score	Flag
1	Adherence to responsible fisheries principles	2.50	**Medium**
2	Completeness of rules of the game in fisheries management	2.60	**Good**
3	Decision-making mechanism	2.00	**Medium**
4	Fisheries management plan	3.00	**Good**
5	Level of synergy of fisheries management policies and institutions	2.00	**Medium**
6	Capacity of stakeholders	3.00	**Good**

The findings of the study suggest that the six EAFM domains evaluated for octopus fisheries in Wakatobi Regency demonstrate disparate scores and flag model classifications. The habitat and ecosystem domain (Table 4), in conjunction with the institutional domain (Table 8), received the highest scores, exhibiting a predominance of green flags, indicative of conducive conditions for the implementation of sustainable management principles. Conversely, domains necessitating augmented scrutiny encompass fishing technology and economic performance. Within the domain of fishing technology (Table 5), three out of six indicators were designated as red flags, while the remaining three indicators were classified as green flags. Concurrently, the economic domain (Table 7) exhibited two indicators that warranted caution and one that necessitated close observation. The sustainability status of each EAFM domain was determined based on composite score analysis. The composite values for the octopus fisheries in Wakatobi Regency are presented in Fig. (5). The analysis indicates that the composite scores range from 48.44 to 90.00. The lowest score was recorded in the economic domain, while the highest composite values were found in the habitat, ecosystem, and institutional domains.

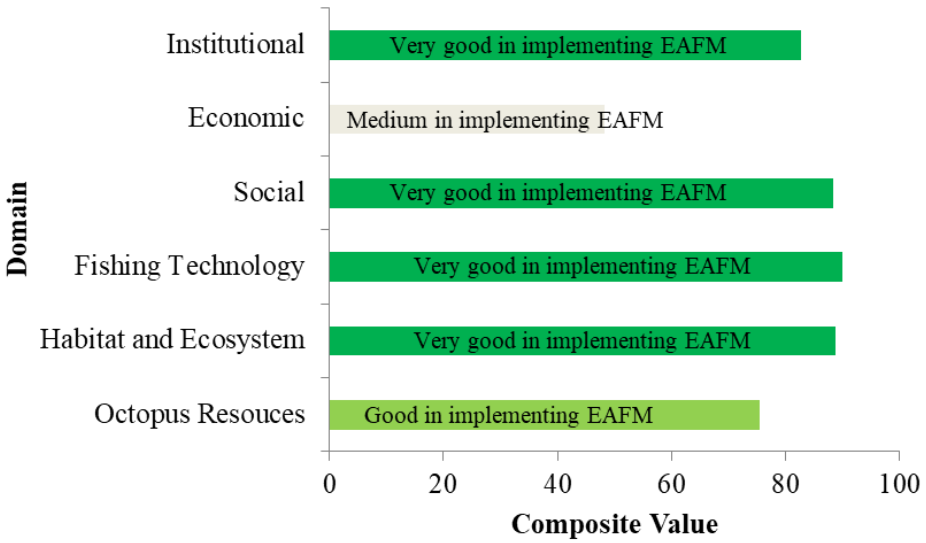

Fig. 5. Sustainability status of octopus (*Octopus cyanea)* fisheries in Wakatobi

The sustainability status across various domains was illustrated by Fig. (1), which employed the flag model approach. The social, institutional, habitat, and ecosystem domains have been demonstrated to exhibit a commendable level of sustainability in the implementation of EAFM principles. The fishing technology domain is classified as "good sustainability." Conversely, the economic domain manifests a moderate degree of sustainability, underscoring the necessity for additional focus and enhancement in its EAFM implementation.

CONCLUSION

A comprehensive sustainability assessment of octopus fisheries in Wakatobi National Park, Indonesia, was conducted, and the results indicated outcomes across EAFM domains ranging from medium to very good. The ecological and social domains demonstrate robust performance, suggesting that community engagement and resource stewardship are effective. Conversely, the economic and institutional domains are characterized by structural vulnerabilities, particularly with regard to fisher income levels, legal compliance, and governance capacity. In order to ensure long-term sustainability, targeted interventions are required to strengthen institutional frameworks, enhance economic resilience among small-scale fishers, and integrate climate adaptation strategies into fisheries management.

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