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Sustainable Management Strategy of Tuna (*Thunnus* sp.) in FMA 573 Malang Regency East Java Indonesia

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ABSTRACT

Tuna (*Thunnus* sp.) is one of the main fishery commodities with high economic value and a significant export market, particularly to the United States, Japan, and the European Union. This study aimed to formulate a primary strategy for the sustainable management of tuna (*Thunnus* sp.) in Fisheries Management Area (FMA) 573, Malang Regency, East Java, Indonesia. The research used a quantitative methodology. Primary data were collected from seven experts representing key stakeholders: one representative from the Ministry of Maritime Affairs and Fisheries (Directorate General of Capture Fisheries), one from the Indonesian Tuna Association, one from the East Java Provincial Fisheries Service, one from the Malang Regency Fisheries Service, one tuna fishing entrepreneur, one academic specializing in capture fisheries, and one representative from the fishermen's association. The study identified the top strategic priorities for sustainable tuna management in FMA 573. The highest priority is implementing a quota system (measured fisheries), with a priority score of 0.36274. This is followed by the strategy of adopting AI applications and environmentally friendly fishing technologies (0.32077), capacity building and strengthening fishermen's institutions (0.20497), and finally, law enforcement to combat Illegal, Unreported, and Unregulated (IUU) fishing, which received the lowest priority score of 0.11152.

INTRODUCTION

Indonesia is one of the largest tuna producers in the world, with waters rich in fisheries resources **(FAO, 2021)**. Indonesia plays an important role in global tuna fisheries and has committed to improving its fisheries management. Based on data from the Central Statistics Agency (BPS), the value of Indonesian tuna exports in 2023 reached $927.13 million or equivalent to IDR 15.2 trillion. Fisheries Management Area (FMA) 573, which covers the waters around Malang Regency, East Java and the South coast of Java, has great potential in supporting the tuna fishing industry, both for domestic and export markets **(KKP, 2022)**. However, uncontrolled exploitation can threaten the sustainability of tuna resources. According to the International Union for Conservation of Nature **(IUCN, 2023)**, several tuna species have been categorized as threatened due to overfishing pressure. Therefore, sustainable management of tuna fisheries is a necessity to maintain a balance between economic utilization and conservation of marine ecosystems **(Bailey *et al.*, 2018)**.

Despite its great potential, tuna fisheries in Indonesia still face serious challenges, including overfishing, the use of destructive fishing gear, illegal, unreported, and unregulated fishing, where the lack of effective regulation has led to a decline in tuna stocks in several regions **(MMAF, 2021)**. Data from **KKP (2023)** show that some tuna species are under high exploitation pressure, especially *Thunnus albacares* and *Thunnus obesus*. In addition, competition in international trade also requires Indonesia to improve sustainability standards in order to compete in the global market, considering that several export destination countries such as the European Union and the United States have implemented strict provisions related to the sustainability of fishery products **(Ward *et al.*, 2019)**. The imbalance between exploitation and conservation is a crucial issue that needs to be addressed through better management strategies **(Fahrudin *et al.*, 2020)**. Some research results highlight the importance of comprehensive management. For instance, **Wiryawan *et al.* (2020)** showed that seasonal and annual patterns of tuna abundance are influenced by sea surface temperature and chlorophyll-a, which are associated with upwelling and El Niño events. **Hsu *et al.* (2021)** discussed challenges in identifying potential fishing grounds due to rapid changes in the marine environment. **Pons *et al.* (2023)** noted that the use of fishing aids such as FADs can also have negative impacts, including overfishing and increased bycatch. **Hermawan *et al.* (2021a)** examined the sustainability and feasibility of tuna fishing around Buhung Pitue Island, Indonesia, while **Hermawan *et al.* (2021b)** explored a socio-economic production model based on tuna fishing in the same region. All of these studies contribute to the formulation of sustainable fisheries management. As emphasized by **Yusuf *et al.* (2024)**, sustainable management is a primary goal in the utilization of marine resources and plays a key role in driving national economic growth through the blue economy sector. The importance of sustainable tuna fisheries management is not only related to the

sustainability of fish resources but also has an impact on the economy and welfare of coastal communities **(Sugiyono *et al*., 2022)**. The fisheries sector has become a major focus of global socio-economic activity **(Lu *et al*., 2015)**. Coastal and marine ecosystems play an important role in building the global economy, especially in maritime countries that benefit significantly from trade in marine products **(Day *et al*., 2015; Laffoley, 2019)**. Therefore, protecting this resource is very important. Tuna fisheries sector represents one of the sectors that absorbs a large number of workers and is a source of income for traditional fishers and large-scale fishing industries **(Amri *et al*., 2021)**. On the other hand, the sustainability of tuna fisheries is also closely related to Indonesia's commitments in international agreements such as Regional Fisheries Management Organizations (RFMOs) and Sustainable Development Goals **(**SDGs**) (UNDP, 2023)**. Therefore, the formulation of appropriate management strategies will provide long-term ecosystem, economic, and social benefits **(Zainuddin *et al*., 2020)**. To maintain sustainability, scientific evidence-based management is required. Some suggested solutions include seasonal closure of fishing areas **(Wiryawan *et al*., 2020)**, use of suitable habitat models to predict potential fishing grounds **(Hsu *et al*., 2021)**, as well as the implementation of management tools such as discard bans, restrictions on active FADs, and full data transparency **(Pons *et al*., 2023)**. With proper management, Indonesia can maximize the economic benefits of tuna fisheries while preserving its marine resources.

This research offers a new approach in the strategy of sustainable management of tuna fisheries in FMA 573 by considering ecological, social, economic, technological and institutional aspects holistically as the research conducted in this study by **Setyawan and Nuraini (2021)**. Through expert-based data analysis with a hierarchical analysis approach, this research is expected to provide scientific-based recommendations that can be applied in sustainable fisheries management policies **(Hidayat *et al*., 2023)**, especially in the management of tuna fish in FMA 573 Malang District. This research also contributes to the development of an expert-based sustainable management model that can serve as a reference for other fisheries areas in Indonesia, such as research conducted by the Ministry of Fisheries **(Sari *et al*., 2022)** and **Rahmawati *et al*. (2023)**. Thus, the results of this study are expected to be a foothold in efforts to maintain the sustainability of tuna fisheries management in Indonesia in general, and especially sustainable tuna fisheries management in FMA 573 Malang Regency.

MATERIALS AND METHODS

Time and location of research

The research was conducted from June to December 2024 in Fisheries Management Area (FMA) 573 Malang Regency, East Java Indonesia. The location was chosen because Malang Regency, precisely in Sindang Biru, is one of the landing centers for tuna caught

in Indian Ocean waters, especially in FMA 573. In the research location there is a Coastal Fishing Port (CFP) Pondokdadap Sendang Biru which is one of the largest fish landing ports in Malang, East Java, especially Tuna Tongkol Cakalang (TTC) **(Mawarida *et al.*, 2022)**. Visually, the research location is depicted in Fig (1).

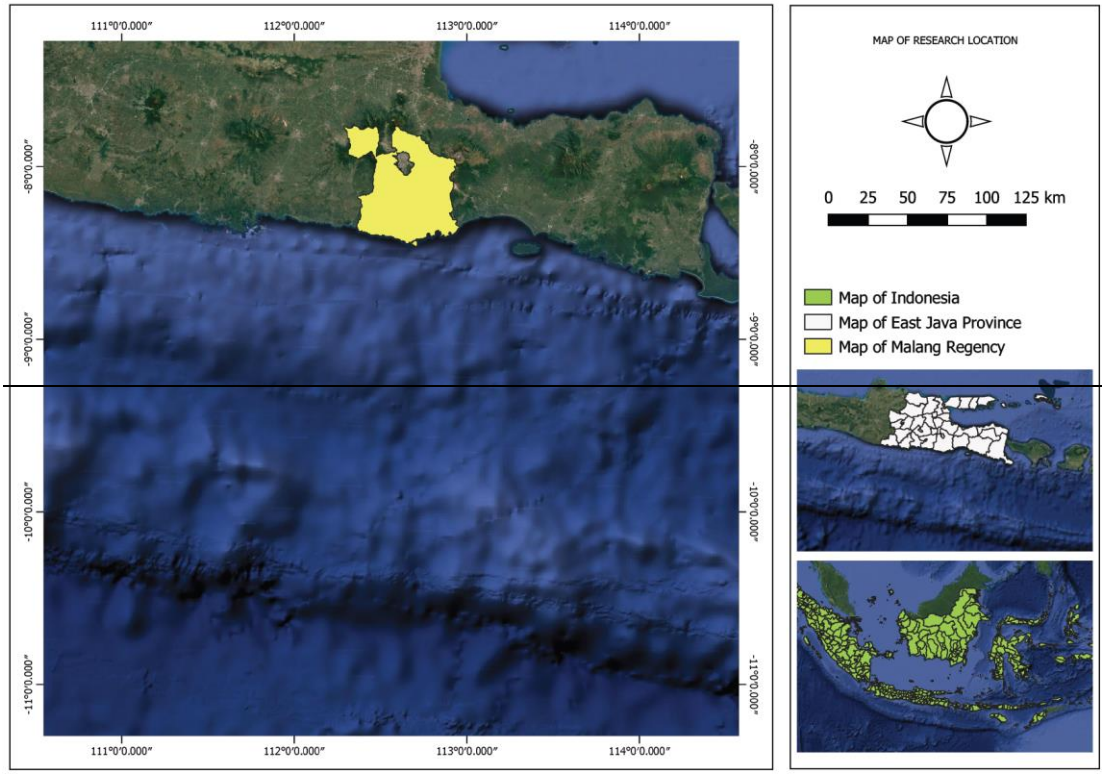

Fig. 1. Map of research location

Data type and sources

The types of data used in the research are primary data and secondary data. Primary data are information collected directly by researchers in accordance with their research objectives **(Cheong *et al.*, 2023)**. Secondary data are pre-existing information collected for other purposes, but is needed and will be used by researchers to answer their research objectives **(Martin-Melon *et al.*, 2023)**. Primary data in the study are in the form of data on answers to a number of questions asked through a questionnaire. The answers came from experts totaling 7 people. According to **Yusuf *et al.* (2021)**, the criteria for experts/experts include; 1) expertise or expertise based on knowledge at the academic or research level (academics), 2) expertise or expertise based on position, namely as a decision maker, such as; ministries, agencies, and 3) expertise or expertise based on specialization, such as professionals and others. The number of experts as many as 7 people is in accordance with the study of **Hora (2004)**, who stated that the ideal and

proportional number of experts or has high precision is 3 to 6 or 7 people. While the type of secondary data in the study is data in the form of theory or literature and research publication data related to tuna fish management in Indonesia.

Data collection

The data collection methods carried out in the study are the desktop method (desk study) and the survey method using questionnaires. The desktop method is used to collect secondary data which includes research results, as well as laws and regulations related to sustainable tuna management in Indonesia in general, and especially tuna management in the waters of FMA 573 Malang Regency, East Java. Desktop study, also known as the desk study or desk research method, is the collection of data from existing (secondary) sources, such as published study results, reports, and statistics **(Arikunto, 2006)**. This method is considered a low-cost technique compared to field research, since its main costs involve only the researcher's time, communication costs, and directories. This perspective coincides with that of **Bungin (2008)**, who noted that desk studies offer advantages in terms of cost efficiency and accessibility. However, it is essential to maintain the quality and relevance of the data sources used by ensuring they are reliable and up to date in order to obtain valid and dependable results.

Meanwhile, the survey method was employed to collect primary data in the form of responses from seven experts regarding their evaluations of criteria and alternative strategies for sustainable tuna management in FMA 573, Malang Regency, East Java. The survey method is a research approach used to gather information from a group of respondents through questionnaires, as explained by **Creswell (2014)**. It is particularly effective for obtaining opinions, perspectives, experiences, or preferences from a broader population, and the results can be analyzed to identify specific patterns or trends, as noted by **Moleong (2010)**. Surveys can be conducted either online or offline, with or without the direct involvement of researchers or enumerators.

Data Analysis

Data analysis is a crucial step in extracting meaningful insights from large and complex datasets. It involves examining, processing, and interpreting the data to uncover trends, patterns, and valuable information that can inform decision-making, as outlined by **Miles *et al.* (2014)**.

This study used the Analytic Hierarchy Process (AHP) as the method for data analysis. AHP is a robust and widely recognized multi-criteria decision-making (MCDM) method that incorporates mathematics and psychology to address complex decision scenarios, as described by **Pant *et al.* (2022)**. AHP involves the development of a pairwise comparison matrix to calculate the local priorities of alternatives or criteria.

However, despite its strengths, the method has been subject to some criticism, particularly concerning assumptions like the independence of criteria, as mentioned by **Xiao *et al.* (2024)**.

Nevertheless, AHP remains a highly valuable tool across diverse decision-making contexts. Researchers continue to refine and enhance the method to improve its precision and reliability, as noted by **Chen and Huang (2023)** and **Huang and Chen (2023)**. The flexibility and applicability of AHP make it particularly effective in situations involving multiple conflicting criteria **(Khan & Ali, 2020)**.

AHP has been applied in a wide range of domains, including monitoring structural bridge health **(Darban *et al.*, 2021)**, mapping forest fire risk **(Lamat *et al.*, 2021)**, evaluating slum relocation sites **(Elghazouly *et al.*, 2023)**, and selecting collaborative robots **(Sivalingam & Subramaniam, 2024**). In each case, AHP helps prioritize criteria and alternatives through expert judgment and pairwise comparison.

While AHP is a powerful and versatile decision-making tool, its effectiveness depends on the complexity of the problem and the decision context. In certain situations, hybrid or alternative methods may offer more suitable solutions, as noted by **Jagtap and Karande (2023)** and **Zakeri *et al.* (2023)**.

The following presents the structure/hierarchy of the sustainable management strategy for tuna (*Thunnus* sp.) in FMA 573, Malang Regency, East Java, Indonesia.

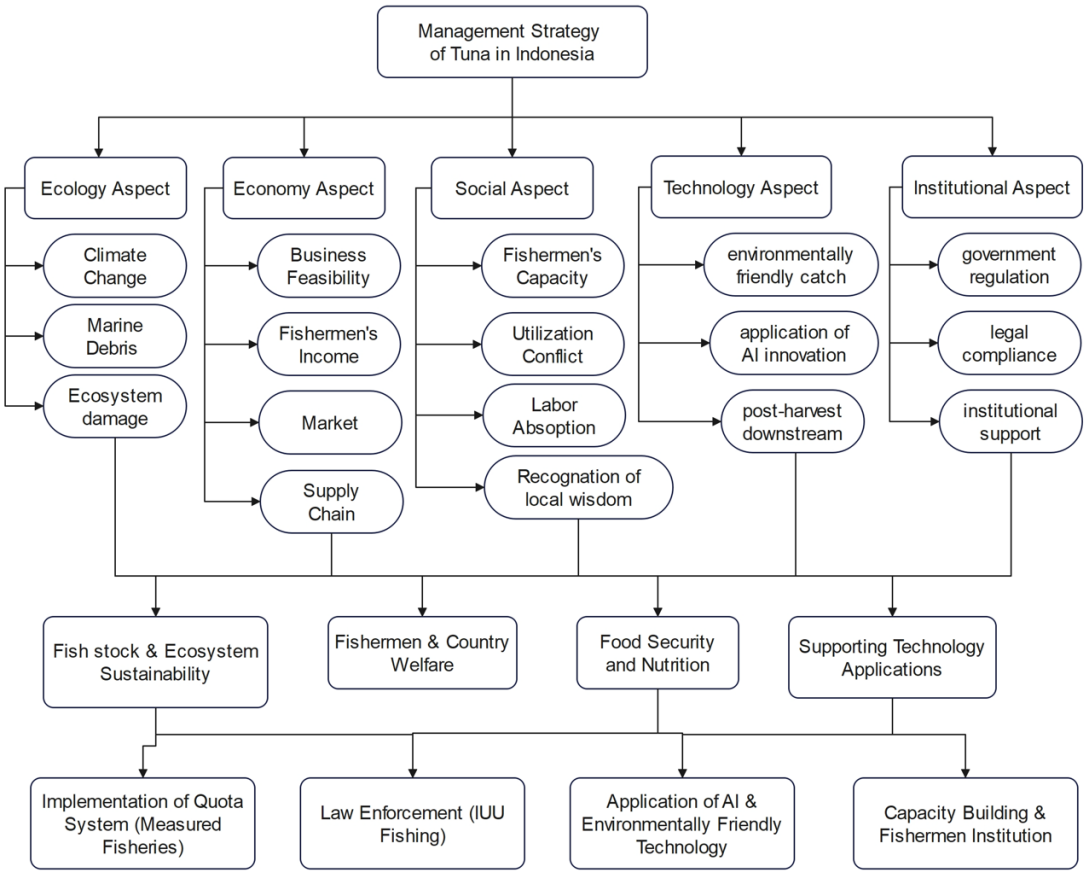

Fig. 2. Hierarchy of sustainable management strategy of tuna (*Thunnus sp.*) at FMA 573 Malang Regency, East Java, Indonesia

RESULTS AND DISCUSSION

Priority management goals

Prioritizing goals is a key approach to achieving global sustainability objectives and enabling effective strategic planning, as emphasized by **Nath and Muhuri (2023)**. According to **Asadikia *et al.* (2024)**, prioritizing the Sustainable Development Goals (SDGs) facilitates efficient resource allocation, addresses urgent needs, enhances policy coherence, and allows for measurable impact assessment.

There are notable differences in prioritization preferences between academics and government officials. Academics tend to prioritize SDGs based on interlinkages and performance metrics, while government officials focus more on alignment with national agendas and relevance to policy. Additionally, academics often prefer prioritization at the

target level, whereas government officials favor indicator-level prioritization. Nonetheless, both groups generally prefer national-scale priorities over global or regional scales, as further noted by **Asadikia *et al.* (2024)**.

For these reasons, setting clear priorities is essential for effective decision-making and optimal resource allocation.

The objectives of sustainable management of tuna (*Thunnus* sp.) in FMA 573, Malang Regency, East Java, Indonesia, are generally formulated into four main goals:

1. Sustainability of fish stocks and ecosystems
2. Improving the welfare (income) of fishermen and the nation
3. Enhancing the use of technological applications
4. Meeting food and nutritional needs

In detail, the results of the prioritization analysis **(**AHP**)** are described in Fig. (3).

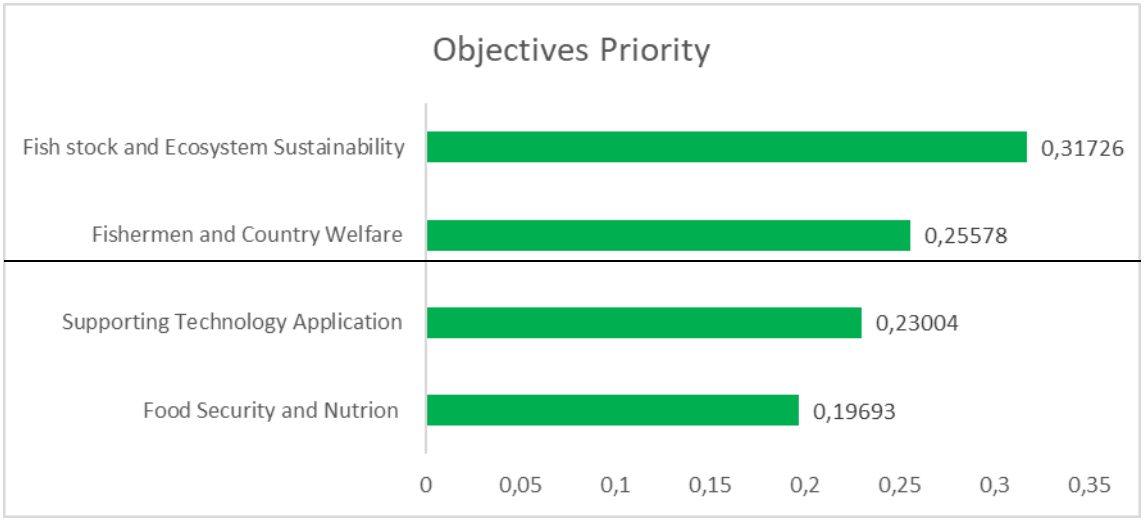

Fig. 3. Priority of sustainable management goals of tuna in Indonesia

The results of the AHP analysis regarding the prioritization of objectives in the sustainable management strategy of tuna (*Thunnus* sp.) in WPP FMA 573, Malang Regency, East Java, Indonesia, indicate that the top priority is the sustainability of fish stocks and ecosystems, with a priority score of 31.73%. This objective is a critical component of sustainable fisheries management, particularly in the context of tuna (*Thunnus* sp.) utilization in this region.

Achieving sustainability of fish stocks and ecosystems requires an integrated approach that considers multiple dimensions. This includes habitat protection, ecosystem-based management, the incorporation of local knowledge, and the implementation of

effective monitoring and stock assessment systems. These approaches help strike a balance between the sustainable use of marine resources and the long-term conservation of ecosystems, ensuring that tuna (*Thunnus* sp.) resources can be maintained for future generations.

The urgency of maintaining fish stocks and ecosystem sustainability is underscored by evidence from several studies. For example, **Fahrudin *et al.* (2020)** reported that tuna stocks in some Indonesian fishing grounds are experiencing a significant decline due to uncontrolled fishing pressure, despite the presence of catch quota regulations. Similarly, **Bailey *et al.* (2018)** emphasized the importance of ecosystem-based management, highlighting that considering the interactions between tuna species and their surrounding ecosystems can lead to improved fisheries productivity.

Furthermore, **Ward *et al.* (2019)** argued that tuna-producing countries such as Indonesia must enhance the sustainability standards of their fishery products to remain competitive in the international market. Countries like Japan, the European Union, and the United States have implemented strict import regulations requiring that fishery products meet defined sustainability criteria. Thus, Indonesia must adopt more rigorous measures to maintain its tuna stocks, especially within FMA 573, to continue meeting global market demands.

In addition, **Hidayat *et al.* (2023)** provided evidence that with the adoption of stricter policies and effective sustainable management practices, tuna stocks can recover, supporting both ecological balance and the economic sustainability of the fishery.

Management strategy priorities

Strategy can be defined as a coordinated plan of actions developed to achieve specific goals under given conditions, while considering the limitations of existing resources, as defined by **Porter (1996)**. In the context of natural resource management, **Harrison and Jaffe (2004)** stated that strategies aim to balance short-term exploitation with long-term sustainability.

Further, **Schlager and Ostrom (1992)** emphasized that sustainable management requires decision-makers to account for the dynamic interactions between social, economic, and ecological systems when crafting strategies to preserve natural resources. In alignment with this, **Caddy and Mahon (1995)** argued that fisheries management strategies must integrate both ecological and economic principles to ensure the longevity of fish stocks. They advocated for an ecosystem-based approach combined with flexible regulatory mechanisms to address the ever-changing environmental and social conditions affecting the fishing industry.

The following are the results of the AHP analysis on the priority strategies for sustainable management of tuna (*Thunnus* sp.) in FMA 573, Malang Regency, East Java, Indonesia.

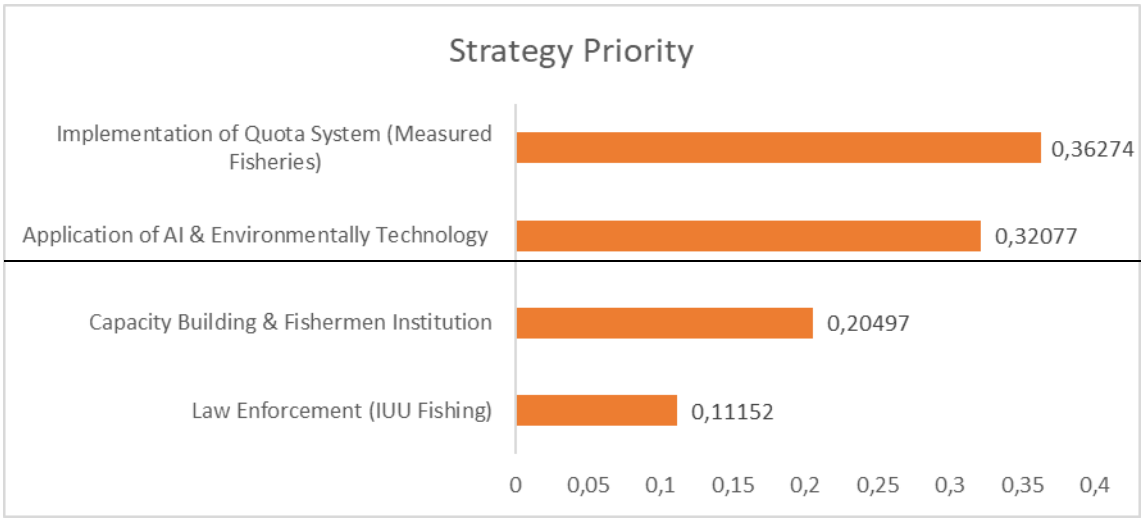

Fig. 4. Priorities of sustainable management strategies of tuna in Indonesia

The results of the AHP analysis indicate that the top-priority strategy for sustainable management of tuna (*Thunnus* sp.) in FMA 573, Malang Regency, East Java, Indonesia, is the implementation of a fishing quota system, also referred to as a measured fishing system. This approach focuses on regulating and limiting the amount of fish that can be harvested based on accurate data and continuous monitoring. The core objective is to ensure that fishing activities are carried out sustainably, preserving fish stocks and preventing their depletion.

FAO (2016), in its guidelines for implementing the ecosystem approach to fisheries, emphasizes the importance of using accurate scientific data and ongoing monitoring to ensure a sustainable fishing system. It also advocates for an ecosystem-based management framework and the implementation of catch quotas as essential components for managing fishery resources sustainably. A catch quota refers to setting a scientifically calculated maximum allowable catch over a specific time period, aimed at preventing overfishing and ensuring fish population stability.

According to **Caddy and Mahon (1995)**, determining catch quotas is a key component in sustainable fisheries management. When carefully planned and supported by scientific data, quota systems can effectively balance ecological sustainability with economic benefits.

Several countries have successfully implemented quota-based systems and achieved notable outcomes:

- Iceland serves as a leading example through its Individual Transferable Quotas (ITQs) system, implemented in 1984. This system allows fishers to hold and trade quotas, fostering efficient resource use. Iceland has used this model to manage

cod and other species, resulting in reduced overfishing and stable cod stocks. Evidence shows that Iceland's cod populations recovered significantly after the implementation of strict quotas **(Arnason, 2005)**.

- Norway also applies a quota system, structured by fish species and fishing areas. A successful example is its halibut fishery, where stocks recovered considerably after the introduction of catch quotas in 1990. Since then, halibut catches have remained stable **(Nielsen & Mathiesen, 2003)**.
- Australia has effectively managed the Southern Bluefin Tuna Fishery in South Australia through a Quota Management System (QMS) using ITQs. Despite intense international market pressure, strict quota enforcement has allowed the bluefin stocks to recover and stabilize **(Ward & Kennelly 2001)**.
- New Zealand has implemented an ITQ system since 1986 to manage various fisheries, including hoki and cod. The system allocates quotas based on stock assessments and has contributed to the recovery of southern hoki stocks, maintaining sustainable catch levels. This approach has also improved both the efficiency and economic sustainability of the fisheries sector **(Grafton & Kompas 2005)**.
- Canada introduced a catch quota system in the early 1990s to manage cod fisheries in the Atlantic region. Despite initial challenges, the quota system helped reduce fishing pressure and protect cod stocks. With close monitoring, the system has proven effective in maintaining fish stock sustainability **(Copes & Charles 2004)**.

These international examples demonstrate that well-designed and strictly enforced quota systems—based on scientific assessments, transparent allocation mechanisms, and robust monitoring—can significantly reduce overfishing, stabilize fish stocks, and support sustainable fisheries economies.

As affirmed by **Grafton *et al.* (2006)**, implementing quota-based fisheries management along with effective data monitoring is a proven way to avoid overexploitation and promote long-term sustainability in the fisheries sector.

Therefore, the implementation of a catch quota system stands out as the most appropriate and effective strategy for sustainable tuna fisheries management in FMA 573, Malang Regency, Indonesia. This approach supports not only the conservation of tuna resources but also the broader goals of economic development for local communities and the nation as a whole.

CONCLUSION

This study concludes that, to realize sustainable tuna fisheries management in FMA 573 Malang Regency, East Java, Indonesia, the main strategy that must be carried out is

the implementation of a fishing quota system (measured fisheries), with the priority of the main objective of management being the sustainability of fish stocks and ecosystems (0.36274). Next is the strategy of AI application and environmentally friendly fishing technology (0.32077) as the second priority, followed by the strategy of capacity building and fishermen institutions (0.20497) as the third priority, and law enforcement strategy **(**IUU Fishing**)** with the lowest priority value of 0.11152 as the fourth priority.

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