Integration of ecosystem approach in *Loligo spp.* resource management in Tomini Bay

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Abstract. This study examines the management status of squid (*Loligo spp.*) fisheries in Tomini Bay using the Ecosystem Approach to Fisheries Management (EAFM) and Flag model. The analysis results indicate a decline in the squid population, as reflected in the decreasing Catch Per Unit Effort (CPUE) trend from 2019 to 2023. Major factors influencing this condition include increased fishing pressure, low selectivity of fishing gear, and habitat degradation due to destructive fishing practices and pollution. The socioeconomic conditions of local fishermen are also assessed as low, with incomes below the regional minimum wage and limited asset ownership. Fishing conflicts frequently arise between fishermen and authorities, and institutional synergy in fisheries management is considered suboptimal. Recommendations include implementing selective fishing gear, ecosystem rehabilitation, improving fishermen's welfare, and developing an ecosystem-based fisheries management plan involving stakeholders.
Key Words: *Loligo spp.*, CPUE, Tomini Bay, EAFM, fisheries management.

Introduction. Tomini Bay is the largest bay in Indonesia, and of course, there are great opportunities and potential ecosystems, especially in the field of fishing. One of the marine commodities with the highest number of catches is squid (*Loligo spp.*). *Loligo spp.* is an integral part of the marine ecosystem in Tomini Bay (Hamzah 1997). An ecosystem approach emphasizes the importance of maintaining a balanced *Loligo spp.* population in the context of the entire food chain and ecological interactions with other species. *Loligo spp.* can act as prey for different predators such as fish, seabirds, and marine mammals. The ecosystem approach considers the impact of *Loligo spp.* management on other species populations and vice versa, considering the effects of changes in other species populations on *Loligo spp.*

Squid (*Loligo spp.*) is one of the resources with important economic value that ranks third, after fish and shrimp in Indonesia. Squid (*Loligo spp.*) fishing in Indonesia is carried out using various fishing gears, namely bang, beach seine, began tancap, banana boat, trap, and purse seine (Antika et al 2014). The high fishing activity may cause a decline in their ecosystem's squid population (*Loligo spp.*). Therefore, a study of the Integration of the Ecosystem is needed to support the sustainable management of squid (*Loligo spp.*) resources and the creation of sustainable and environmentally friendly fishing.

The need to maintain squid (*Loligo spp.*) resources is to maintain the potential of squid to be utilized optimally so that there is no overfishing. Therefore, it is necessary to analyze population dynamics, including analysis of growth parameters and exploitation rate or utilization rate of Tomini Bay waters. This information is expected to be the basis for establishing appropriate management strategies so that utilization does not lead to overfishing. The purpose of this study is to assess the balance of the Tomini Bay ecosystem and the role of *Loligo spp.* in it, including its impact on the food chain and overall ecosystem structure, and to analyze the sustainability of squid species using the analysis of opportunities and challenges of squid fisheries management.

The problem that is the focus of this research is that the increasing fishing activities without considering the stock will be feared, which can disrupt the sustainability of squid resources (*Loligo spp.*). Therefore, a resource management effort is needed to maintain the sustainability of squid resources.

Squids live in groups or solitary (Goldman et al 1975), this is related to their migration pattern by making diurnal movements in groups, close to the bottom of the water during the day, and will spread out at night (De Araujo & Gasalla 2017). Squids are phototaxispositive (attracted to light) (Mulyawan et al 2015). Therefore, they are often caught using light aids (Jackson et al 1997).

Approaching *Loligo spp.* resource management in Tomini Bay through an ecosystem approach requires a holistic understanding of the interactions between the ecosystem's biological, environmental, and human components.

The ecosystem approach to *Loligo spp.* resource management in Tomini Bay involves analyzing the interactions between *Loligo spp.* species and their environment. In this approach, factors such as water quality, temperature, and other biodiversity are considered variables that affect *Loligo spp.* populations and environmental quality. This can help improve efficiency and productivity in *Loligo spp.* resource management and influence *Loligo spp.* populations and environmental quality.

Materials and Method

Location. This research was conducted along the waters of Tomini Bay, Gorontalo, and then continued at the Laboratory of the Faculty of Marine and Fisheries Technology, Gorontalo State University, Gorontalo.

Research method. This research was conducted through a survey based on descriptive methods (Najamudin et al 2015). Data collection techniques were carried out by direct observation in the field as well as interviews, active participation, and filling in structured questionnaires. Research whose main sources of data and information are obtained from respondents as research samples using questionnaires as data collection instruments is research using survey methods. Primary data were obtained by conducting surveys, direct observation, and through interviews. The selected respondents were determined using purposive sampling, based on the researcher's consideration that the selected fishermen are experienced fishermen in the related fisheries for at least 10 years. The fishermen must be located and catch squid in the Tomini Bay area, namely Gorontalo Province (Boalemo Regency, Pohuwato Regency, Bone Bolango Regency, and Gorontalo Regency), North Sulawesi Province (South Bolaang Mongondow) and Central Sulawesi Province (Parigi Moutong Regency). The number of respondents taken from each district amounted to 100 respondents. Data collection techniques were carried out by direct observation in the field as well as interviews, active participation, and filling in structured questionnaires. The data collection process was implemented using a comprehensive and multifaceted approach to ensure the reliability and validity of the findings. This process involved four primary methods: direct field observations, in-depth interviews, active participation, and the administration of structured questionnaires (Purba et al 2024). Each technique was strategically chosen to complement one another and provide a holistic understanding of the research problem.

Data analysis. The additional analysis methods used consist of two, namely, Ecosystem Approach to Fisheries Management (EAFM) Analysis and Flag Modeling Analysis (Ministry of Marine Affairs and Fisheries of the Republic of Indonesia 2014b; Ministry of Marine Affairs and Fisheries of the Republic of Indonesia 2014c). In addition, descriptive analysis was conducted on the construction of fishing gear and aids, as well as the process of squid fishing, describing the types of fishing gear used at squid fishing sites and analyzing the length of squid caught, which started in the month of April-September 2024.

Analysis of ecosystem approach to fisheries management (EAFM). The EAFM technique was used to analyze the sustainability level of squid fisheries in the seas of Tomini Bay. Through integrated, comprehensive, and sustainable fisheries management, EAFM aims to balance socioeconomic goals while accounting for knowledge, information, and uncertainties regarding biotic and abiotic components and human interactions in aquatic ecosystems (FAO 2003). Stakeholder participation in the management process and evaluation of various goals are essential components of EAF (Purcell et al 2014).

Flag modeling analysis. Flag modeling analysis is a multi-attribute analysis that looks at symptoms or performance as indicators of overall aquatic ecosystem problems (Tallis & Polasky 2009). In substance, the evaluation of EAFM indicators is a multi-criteria method that results in a composite index indicating the level of performance of fisheries management in line with EAFM principles (Adrianto et al 2005). Flag modeling technique is conducted using the multi-criteria analysis (MCA) approach, in which a set of criteria is built as the basis for the analysis of the status of fisheries management areas from the ecosystem approach in fisheries management (EAFM) through the development of a composite index with the following steps (Budiarto et al 2015):

1. Defining criteria for each indicator within the 6 EAFM domain. The sixth domain, namely the Fish Resources Domain, Habitat and Ecosystem Domain, Fishing Technology Domain, Social Domain, Economic Domain, and Institutional Domain;
2. Assigning a score to each indicator's keratan;
3. EAFM at each point location in the study using a Likert scale based on ordinal 1, 2, and 3;
4. Mentioning weight for each indicator;
5. Establishing a composite index for every point of score.

Table 1

Composite index value classification and flag model visualization for EAFM assessment

No	*Score*	*Composite value*	*Flag model*	*Description of colors*
1	1	1 – 33.30	(red)	Poor
2	2	33.40 – 66.70	(yellow)	Moderate
3	3	66.80 - 100	(green)	Good

Modification from Ministry of Marine Affairs and Fisheries of the Republic of Indonesia 2014b.

The aggregate attribute value is then scaled from 1 to 100. The aggregate with a value of 100 is defined as the highest aggregate or the best condition in the region, whilst lesser values are considered as the least/worst conditions in the area. The previously mentioned aggregate scores are divided into three categories. These three categories indicate three degrees of status in an area's EAFM domain and are given in the form of a flag model.

The ratings varied from 1 to 3 depending on the conditions. They were based on a modified version of the Ministry of Marine Affairs and Fisheries' EAFM (Ecological Approach to Fisheries Management) (Ministry of Marine Affairs and Fisheries 2012). Poor ratings indicate the least advantageous conditions for sustainability management, whereas high scores indicate the most ideal settings (Pitcher & Preikshot 2001). This data collection aims to find fish lengths for length frequency analysis (Ministry of Marine Affairs and Fisheries of the Republic of Indonesia 2014b).

Results. Research on *Loligo spp.* resource management in Tomini Bay through an ecosystem approach aims to evaluate population conditions, utilization, and sustainable management strategies. The survey results showed that the *Loligo spp.* population in Tomini Bay is highly diverse. In this context, *Loligo spp.* contributes to the dynamics of the aquatic ecosystem, which also affects other species in the food chain. According to (Rumagia et al 2023), good management requires the active participation of various stakeholders in decision-making and transparency in the management process. This is in line with the findings of (Malik & Kristiana 2021), which emphasize the importance of integrating ecological, social, and institutional aspects in fisheries management.

Local fishermen use *Loligo spp.* resources in Tomini Bay using various fishing gear. The dominant fishing gear for *Loligo spp.* in the waters of Tomini Bay Gorontalo, according to data obtained from the Gorontalo Provincial Maritime and Fisheries Office in the range of 2022 to 2024 as of June, is squid angling in Bone Bolango and Gorontalo districts and circle gill net fishing gear in Boalemo district. Other tools that can catch *Loligo spp.* are begun boats in the North Gorontalo district and sister in the Bone Bolango district. The boats used are smaller than 5 GT.

Fish resources domain

CPUE (catch per unit effort). To calculate CPUE from Teluk Tomini Bay, we have used a formula that combines the capture (catch) with the effort (effort), however, before doing CPUE calculations, we had to first standardize the catcher. Based on data from the production of squid of Tomini Bay using more than one type of catcher, namely Sesser, Squid Fishing Rod, and Circle Gill Net. Standardization of fishing gear needs to be done to determine the number of standard trips and CPUE values.

Table 2
Trends in Squid Fisheries Production, Growth, Effort, and Catch Per Unit Effort (CPUE), 2018–2023

Indicator	*2018*	*2019*	*2020*	*2021*	*2022*	*2023*
Production (Kg)	4,390,784	4,795,429	4,525,666	4,255,903	3,986,140	3,716,377
Growth		8%	- 6%	- 6%	- 7%	- 7%
Effort (trip)	215,870	220,128	224,386	228,644	209,389	218,350
CPUE	20.34	21.78	20.17	18.61	19.04	17.02

Based on the results of interviews and time series, data obtained in the field reveal a consistent decline in production and CPUE, accompanied by fluctuating growth rates and increasing fishing efforts in some years. Production peaked in 2019 at 4,795,429 kg, with an 8% growth compared to the previous year. However, it steadily decreased thereafter, reaching its lowest point in 2023 at 3,716,377 kg, with negative growth rates (-7%) recorded for the last three years. Similarly, the CPUE values dropped from 20.34 in 2018 to 17.02 in 2023, indicating declining efficiency in fishing activities despite high effort levels. The effort, measured in fishing trips, increased from 215,870 trips in 2018 to a peak of 228,644 trips in 2021 before slightly declining to 218,350 trips in 2023.

The negative trends in production and CPUE, coupled with increasing effort, suggest potential overexploitation of squid resources or environmental changes impacting their availability. These indicators underscore the need for adopting sustainable fisheries management practices aligned with the Ecosystem Approach to Fisheries Management (EAFM) (Listiani et al 2013).

When compared to other studies on squid fisheries under the EAFM framework, similar challenges are evident. For example, research by Pitcher et al (2001) and Adrianto et al (2005) emphasizes the importance of multi-criteria evaluation techniques, such as CPUE and growth rate indicators, to assess the sustainability of fisheries. Studies on squid fisheries in the South China Sea (Wang et al 2021) also report declining CPUE values due to overfishing and environmental degradation, underscoring the critical need for adaptive management strategies. Moreover, the application of flag modeling and other EAFM tools has effectively highlighted overexploitation risks and guided management decisions.

The observed trends in this data align with broader findings in squid fisheries research, highlighting the importance of maintaining a balance between fishing efforts and stock sustainability. Effective implementation of EAFM, including the use of composite indices, stakeholder engagement, and adaptive regulatory measures, is essential to mitigate overfishing and ensure the long-term viability of squid resources. CPUE patterns suggest that this trend of decline may indicate a negative direction in the fish population or even suggest a tendency to overfish.

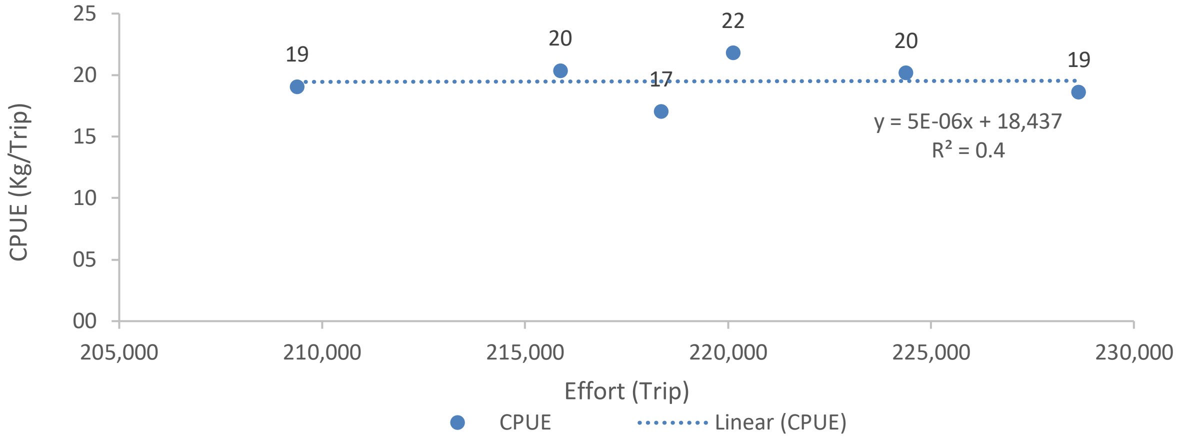

Figure 1. Effort and CPUE relationship chart in Tomini Bay 2018 to 2023.

The graph above depicts the link between Catch Per Unit Effort (CPUE) in kg/trip and Effort (number of trips) on a particular scale. This graph has a linear equation.

$$y=0.000005x+18{,}437$$

with R2 = 0.4.

The following is an equation-based analysis:

Linear equation interpretation. Slope (gradient) 0.000005x: This little gradient suggests that the association between CPUE values and Effort (number of trips) is quite weak. For example, the CPUE number only rises by 0.000005 kg/trip for every unit increase in effort. The nearly horizontal slope, in this case, suggests that an increase in effort does not much impact the catch per unit of effort (CPUE).

The intercept is 18,437 (y-axis cutoff). This shows the anticipated CPUE of around 18,437 kg/trip when Effort is zero. This intercept, however, is more of a marker for the linear line's location on the graph because zero effort is nearly impossible.

Determination coefficient (R2=0.4). According to the R2 value of 0.4, the linear model can explain only 40% of the fluctuation in CPUE data. This suggests that Effort is not the only factor influencing CPUE or that the linear model may not adequately capture the connection due to the large data volatility.

Visual evaluation of data fluctuation in graphs. The graph's data points, which range from the lowest at 17.0 kg/trip to the greatest at about 21.8 kg/trip, demonstrate a notable fluctuation in CPUE. This suggests that CPUE and changes in effort are inconsistent. Put another way, a higher effort does not necessarily translate into a higher catch.

Flattening Trend Line: The catch per unit of effort was comparatively constant and even tended to decline at higher effort points, as shown by this nearly horizontal linear trend line.

Implications and effects on resource management. These findings demonstrate that a rise in CPUE is not necessarily correlated with an increase in effort. Overfishing or near-optimal fishing capacity, when increasing effort only slightly increases catch, may cause this. Operational Efficiency: These findings imply that extra work or travel could not be efficient in terms of efficiency because they do not significantly raise CPUE. It's possible that better management techniques, such as better catch areas or timing, will increase CPUE outcomes more effectively than merely raising effort.

The computation of potential and optimal fishing effort does not need to be repeated if the coefficient value (b) is positive since this suggests that more fishing effort may still be used to increase the catch.

Trends in fish size. Data collection is based on the findings of interviews with fishermen with over ten years (research Sample) of experience and is done at regular intervals for five months. There may have been overfishing in the water region from year to year if the target fish's capture size decreased, as shown by a value of 1, which shows that the trend in fish size is decreasing. The Raw CPUE value indicator, which also indicates overfishing activities in these areas, is directly tied to this issue. Morphometric information in the form of standard length (SL) or fish length units (TL) in centimeters is needed for this indication (Doyle et al 2017).

Composition of species. Determining the species composition index serves the dual function of identifying the species of fish and non-fish that are the target of capture and those that are not or non-target (bycatch). The percentage of fish in the observed region is calculated based on the number of fish caught using fishing gear (Jereb & Roper 2013). According to Figure 2, the catch species composition indicator has a score of 1. This shows that the target species (squid) accounts for a larger percentage of the capture (>30%). The composition of squid caught with squid fishing gear displayed a larger proportion of target and non-target species, with an average of 4%, according to data from the Gorontalo Provincial Fisheries Service. Criterion 1 indicates this. According to this indication, fishing gear must be more selective when the target fish composition is low to optimize the catch of the squid, the goal species.

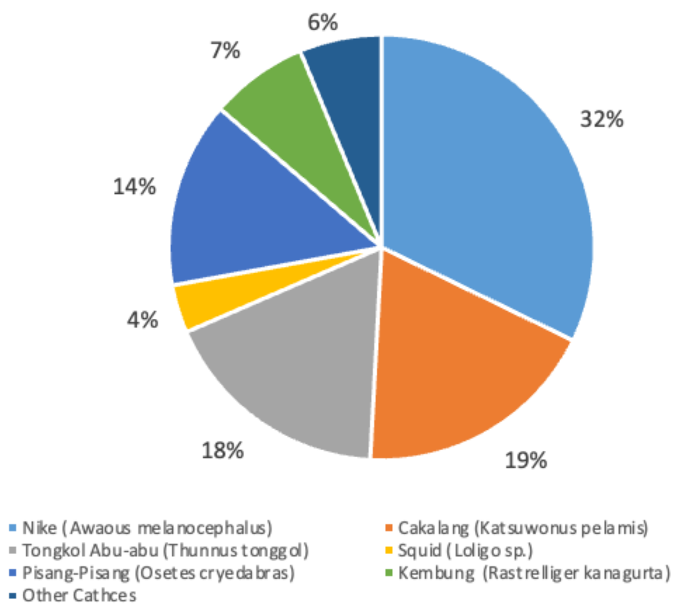

Figure 2. Diagram of Squid catches with a circle gill net.

Endangered, threatened, and protected species. The Endangered Species, Threatened Species, and Protected Species (ESP) indicator assesses the impact on ETP species caused by fishing operations with certain gears in an area. ETP species are obtained from field data and some fishermen with 10 years of fishing experience (respondents) removing the ETP species, this indicator scores 2 with a value of 100. Based on the results of this evaluation, squid fishing using circle nets should be improved to be more sustainable. information related to ETP species should continue to be provided to fishermen and coastal communities.

Range collapse fish resources. The range collapse of fish resources has a score of 1. The findings indicate that the four fishermen's layer fishing spots are becoming farther apart. Due to a spatial "shrinkage" of the biomass of the fish population in question, the findings of the indicator score obtained suggest that fish resources in the Palabuhanratu water region are undergoing range collapse by becoming more "difficult" to capture. Given the difficulties of acquiring catches in the fishing ground area at the initial point, which forces fishermen to search for fish in distant areas, catch per effort (CPUE) is the unit used for the indicator of range collapse of fish resources.

Table 3

Assessment of fish resources domain

No	*Domain*	*Actual value*	*Flag model and score*
1	Catch per unit effort	Slight decrease (<25%)	1
2	Trends of fish size	Decreasing	1
3	Composition of species	Less target proportion	1
4	Endangered species, threatened species, and protected species	Caught but released	2
5	Range collapse fish resources	Difficult to obtain the target	1

Habitat and ecosystem domain. The EAFM method of fishery management heavily relies on the analysis of habitat and ecosystem variables. The diversity, output, and quantity of other resources are all influenced by habitat, which is intimately linked to their existence. The recruitment process and the availability of food will promote fisheries production to enhance the welfare of coastal populations when habitat conditions are favorable. The effectiveness of fisheries management will be determined by several indicators, including water quality, the state of the mangrove ecosystem, unique or special habitats (spawning ground, nursery ground, feeding ground, and upwelling), climate change, and water and habitat conditions.

Water quality. The first indicator of water quality is waste or the degree of pollution around the waterways, with Tomini Bay classified as low-contaminated (Pramudji et al 2019). Based on the pollution index of many physicochemical characteristics of Tomini Bay waters, the results suggest that the waters are rated as excellent to mildly contaminated. Tomini Bay's water quality, as measured by the pollution indicator, is included in criteria number 1 (Ministry of Marine Affairs and Fisheries of the Republic of Indonesia 2014a). The water quality parameters measured were Temperature, pH, salinity, Dissolved Oxygen, Ammonium nitrogen, Nitrate, and Orthophosphate for 3 months, namely June, July, and August. The sampling procedure is based on the standard method (APHA 1998). Existing water quality data will then be analyzed using the STORET method (Ministry of Environment 2004). The pollution level in Tomini Bay from June to August was poor with a total score of -48. This data is also supported by previous research that Gorontalo Bay or Tomini Bay had an average pollution index score of 4.74; this demonstrates that the quality state of Gorontalo Bay from June to July 2017 was classed as mildly contaminated (Kadim & Pasisingi, 2018). The analysis of water quality parameters at Tomini Bay reveals that the environmental conditions remain stable. The temperature recorded was 29.36^{0}C, the pH level was 7, the dissolved oxygen (DO) was 6.69 mg L^{-1}, the salinity was 32.9 ppt, the current was 0.01 m sec^{-1}, and the clarity was 5 meters. These findings are consistent with the results reported in the study by (Djunaidi et al 2014). However, other studies reveal that Gorontalo Bay received an overall score of -39. This demonstrates that Gorontalo Bay's quality status from May to July is classed as a bad category, which is minimally contaminated (Kadim et al 2017).

Status of Tomini Bay ecosystem. Growth patterns generally rely on an organism's biological and physiological parameters, including food availability and gonad development. Additionally, environmental elements like waves and currents have an impact on the growth patterns (length and weight values) of aquatic organisms like fish and squid. According to the type of water these fish species live in and how active their movement is, fish that live in calm waters typically have large length and weight values, while fish that live in fast-current waters typically have low length and weight values. Active swimming fish will also exhibit relatively low length and weight values compared to passive swimming fish. In addition, seeing firsthand the condition of the Tomini Bay waters is very beautiful with a high level of view, so the status of the marine ecosystem gets a score of 1.

Particular habitats or species. Unique/special habitats that have significant ecological and economic value are referred to as unique or special habitats and, as such, require special monitoring attention. Coral reefs that host small fish and shrimp as a food source for squid in Tomini Bay consist of 30 genera from 14 families, with 17.47% of surviving corals, especially on small islands in Parigi Muorong District and along the coastline of Ampana City, Tanjung Api, coral reefs in the Tomini Bay area have suffered significant damage (Yapanto et al 2023). Apart from the existing regulations, human activities in using fish resources that are food for squid with the use of bombs are the cause of damage to this ecosystem. Another thing is the increasing industrialization of squid in Gorontalo, making squid in the status of overfishing. Squids only breed once in a lifetime. Unfortunately, regulations governing the amount of squid utilization in the WP751 area of Indonesia already exist, but the follow-up is still lacking. Therefore, this indication has a score of 2.

Climate change impact. Tomini Bay, one of Indonesia's most important marine areas, is directly impacted by climate change, mainly due to monsoon wind patterns and the Indian Ocean Dipole (IOD) phenomenon (Fadziellaa et al 2020). Here are some specific impacts on squid populations in Tomini Bay:

Temperature Changes in Tomini Bay: The average water temperature in Tomini Bay ranges from 29 to 30°C. However, rising seawater temperatures due to climate change may affect squid metabolic rates and their ideal habitat (Pecl & Jackson 2008). Rising seawater temperatures can affect squid physiology, including growth, reproduction, and metabolism. Higher temperatures accelerate squid growth but can reduce their body size at sexual maturity. In addition, extreme temperatures can reduce squid larval survival. Higher temperatures can force squid to move to deeper or colder waters, reducing catch productivity (Pecl & Jackson 2008).

Decrease in Dissolved Oxygen: Studies show that DO in Tomini Bay is at a level of 5.8 ppm, which is still considered viable. However, climate change may cause water stratification, reducing oxygen in the lower layers. This may limit the living space of squid, especially in the juvenile phase (Banteng 2022).

Monsoon Patterns and IOD: Monsoon wind patterns dominate the annual cycle in Tomini Bay and are affected by the IOD. This phenomenon can affect upwelling patterns and nutrient distribution, impacting the abundance of plankton as a food source for squid (Arkhipkin & Middleton 2009). When negative IOD occurs, increased rainfall can increase inland runoff, leading to eutrophication and potential hypoxia in coastal areas. Fisheries Productivity: Under climate change conditions, squid populations in Tomini Bay may experience greater ecological pressure. Decreases in primary productivity and other ecosystem disturbances could reduce squid stocks available to fishers. Thus, this indicator has a value of three based on the findings of the evaluation of the effects of climate change on the water and habitat conditions in Tomini Bay.

Table 4

Habitat and ecosystem domain

No	*Domain*	*Actual value*	*Flag model and score*
1	Water quality	Polluted	1
2	Status of Tomini Bay ecosystem	Decreasing	1
3	Particular habitats or species	Moderate specialised habitats are known but not well managede	2
4	Climate change impact	Known impacts of climate change	3

Fishing technology domain

***Methods* of *destructive fishing*.** Destructive fishing practices in Tomini Bay were given a score of three in the evaluation. This is because fishing violations do not always occur around Tomini Bay. Interviews with Gorontalo Police and Lanal in the Tomini Bay Coastal Area, as well as Fisheries Supervisors at the Gorontalo PSDKP Supervisory Unit, provided information that between 21 and 22 fishing technique violations occur annually in the Tomini Bay area. However, squid fishers in Tomini Bay use ecologically acceptable fishing practices. All fishers use squid lines, trawls, and circular gill nets to collect squid (Olii et al 2022). Fishers also use fishing aids, such as stones attached to the fishing line, to use stones being to speed up the fall of the line. Fishermen in Tomini Bay apply environmentally friendly fishing practices, as evidenced by a score of three on the indicator of harmful or illegal fishing methods. The almost non-existent number of offenses demonstrates this.

***Fishing aids and equipment modification*.** The indicator for fishing aids and gear modification has a score of 3. This score number shows that fishing aids and equipment have not been altered. It is determined that there is no alteration of fishing aids or gear based on the findings of interviews with Gorontalo PSDKP Fisheries Supervisors, fisheries officials, and fishermen with over ten years of experience, as well as observations of nets and fishing gear. The only squid fishing gear fisherman utilize is lengthening their fishing ropes and using stones as tools. This is because, about its home, which tends to be near the bottom, the squid that was grabbed is moving deeper.

***Fishing capacity*.** While fully operational, the greatest quantity of fish that a single vessel or fleet can produce in each time frame (year) is known as fishing capacity. According to observations and interviews, the capacity for squid fishing varies year, although it is generally growing.

Table 5

The ratio value of the fishing capacity of squid

Year	Seser		Squid fishing rod		Circle gill net		Average
	Fishing capacity (kg)	Ratio	Fishing capacity (kg)	Ratio	Fishing capacity (kg)	Ratio	
2018	24,705	0.92	379,025	0.30	2,147,823	0.98	
2019	31,039	1.15	1,131,268	0.89	2,082,946	0.95	
2020	26,709	0.99	1,234,000	0.97	2,147,823	0.98	
2021	25,637	0.95	1,199,756	0.95	2,110,392	0.96	
2022	25,526	0.95	1,165,512	0.92	2,201,293	1.00	
2023	26,930	1.00	1,268,244	1.00	2,191,284	1.00	
Average		0.99		0.84		0.98	0.94

The table presents the annual fishing capacity and ratio values (R) for three fishing gear types—Seser, Squid Fishing Rod, and Circle Gill Net—from 2018 to 2023. The ratio value is calculated by comparing the fishing capacity of each year to that of the baseline year (the previous year). Higher ratio values (R) indicate better fishing efficiency and capacity, directly influencing the indicator score (Airlangga et al 2018).

The table analyzes fishing capacity and its associated ratio values (R) for different fishing gear types used in squid fishing from 2018 to 2023. The ratio values are calculated based on the principle that higher ratios reflect better fishing capacity efficiency and performance over time. The results show that the Seser and Circle Gill Net gear types maintain relatively stable and efficient fishing capacities, with average R values of 0.99 and 0.98, respectively. In contrast, the Squid Fishing Rod exhibits more variability, with a lower average R-value of 0.84. The overall average ratio value across all gear types is 0.94, which is less than the threshold of 1. Consequently, the fishing capacity indicator score is determined to be 1, as per the assessment methodology. This score highlights the need for further improvements in fishing capacity efficiency to support sustainable fisheries management

For Seser gear, the fishing capacity shows fluctuations over the years, ranging from 24,705 in 2018 to 26,930 in 2023, with the highest capacity recorded in 2019 at 31,039. The corresponding ratio values for Seser remain consistently close to 1, with an average of 0.99, suggesting stable and efficient fishing operations for this gear type. This indicates that the Seser gear maintains its fishing capacity over time without significant declines or inefficiencies.

The Squid Fishing Rod demonstrates a significant increase in fishing capacity, from 379,025 in 2018 to 1,262,844 in 2023. However, the ratio values for this gear type show greater variability, with an average of 0.84. This lower ratio reflects less consistent performance and indicates that the Squid Fishing Rod's efficiency varies more widely than the other gear types. The variability might be due to environmental factors, changes in squid stock availability, or operational challenges.

The fishing capacity for the Circle Gill Net remains relatively stable, ranging from 2,147,823 in 2018 to 2,191,284 in 2023. The ratio values for this gear type are consistently high, averaging 0.98, which indicates stable and efficient performance. This stability reflects the effectiveness of the Circle Gill Net in maintaining consistent fishing capacity over time, making it one of the most reliable gear types among the three. The study's results (Yuliana & Nurhasanah 2019) show that the use of appropriate techniques in the operation of fishing gear can significantly increase the catch.

When averaged across all gear types, the overall ratio value (R) is 0.94, which is below the threshold value of 1. As per the scoring methodology, this average ratio value translates to a score of 1 for the fishing capacity indicator. This outcome suggests that the fishing capacity across the observed gear types is not fully optimized and requires improvement to achieve better sustainability. Specifically, the variability in Squid Fishing Rod performance and slight inefficiencies in Seser gear contribute to the overall reduction in the ratio.

In conclusion, while some gear types, such as the Circle Gill Net, demonstrate consistent and efficient fishing capacity, others, like the Squid Fishing Rod, exhibit variability that affects the overall sustainability score. The findings highlight the need for targeted management interventions to enhance fishing efficiency and capacity, particularly for low-performing gear types. These improvements are essential to support sustainable fisheries practices and ensure the long-term viability of squid stocks.

Selectivity of capture*.* Fishing activity related to the catch’s quantity, timing, and variety is known as fishing selectivity. This indicator's objective is to calculate the proportion of fishing gear use that is categorized as non-selective and its estimated effect on the sustainability of fish resources in a certain water region. The fishing selectivity indicator has a score of 3. This suggests that fishermen in Tomini Bay primarily employ eco-friendly fishing gear when harvesting squid. In Tomini Bay, fishing lines are used by the majority of squid fishermen to capture squid. Snares and circular nets are two other fishing tools that may be used for squid fishing in addition to longlines. However, the primary goal of capture is not squid species in these three gears.

The research was conducted using the types of fishing gear. Namely, the boat began and skidded, angling squid fishing rod operated by MT 0005. Data collected during 2023, with the catching of *Loligo spp.* using boating began fishing gear, reached 743,976 kg less than the catch using squid angling squid fishing gear with MT 0005 ship type, reaching 791,265 kg. These results indicate that the squid angling method effectively catches *Loligo spp.* in Boalemo District.

Compliance of fishing vessels' size and function with legal documents. The indicator of fishing vessels' size and function compatibility with legal papers has a score value of 3, indicating that the vessel with current documentation is very suitable. A comparison between the legal papers held and the actual activities of the function and dimensions of the vessel size in conducting fishing operations determines whether the size and function of fishing boats are appropriate for legal documents. This indicator was selected because it might be considered unlawful fishing and would indirectly jeopardize the sustainability of fish resources if the license granted differs from the actual activity.

Table 6

Fishing technology domain

No	*Domain*	*Actual Value*	*Flag model and score*
1	Methods of destructive fishing	Offence frequency <5 cases per year	3
2	Fishing aids and equipment Modification	<25% species targer size <Lm	3
3	Fishing capacity	capture capacity ratio <1	1
4	Selectivity of capture	High (less than 50% use of non-selective fishing gear)	3
5	Compliance of fishing vessels' size and function with legal document	High suitability	3

Social domain

Participation of stakeholders. Stakeholder engagement is demonstrated by the effective management of fish resources. Stakeholder involvement in Tomini Bay is extremely strong, as indicated by the stakeholder participation indicator's score of 3. The goal of measuring stakeholder involvement is to determine how involved current stakeholders are in all aspects of managing and using fish resources. Through planning documents, local Supervisory Community Groups (Pokmaswas), academics, fisheries entrepreneurs and fishermen, the Gorontalo Provincial Maritime Affairs and Fisheries Office, the Gorontalo Fishery Port and Auction administration, the Gorontalo PSDKP Supervisory Unit, Polair, and the Tominin Bay Regional Maritime Affairs and Fisheries Office are among the stakeholders.

Conflict in fisheries. The score for the fisheries conflict indicator is 2. In Tomini Bay, disputes overfishing arise both between fishermen and the government as well as amongst fishermen themselves. The competition for cargo boats and catchment regions leads to disputes amongst fishermen. Misunderstandings between the government and fishermen about the management of fish resources are the root cause of conflicts between the two groups. Abuse of authority over fishermen's rights can also lead to conflicts. This indicates that disputes over the use of fish resources arise two to five times a year. Conflicts typically arise because of the growing quantity of fishing rods and other fishing gear, as well as fishing regions where FADs are present.

Applying local knowledge to the management of fish resources. The purpose of measuring local knowledge use is to determine whether or not local knowledge is applied effectively in squid resource management operations. The efficiency of squid resource management initiatives is determined by how well local knowledge is applied. As a result, the success rate of squid resource management initiatives increases with the effectiveness of local knowledge applications. The indication of using local knowledge to manage squid resources has a score value of one. This finding demonstrates that squid fishermen who use fishing rods and nets lack local expertise, especially an understanding of squid habitat and behavior (Rodhouse & Webb 2014). The only foundation for knowledge is information passed down from generation to generation.

Table 7

Social domain

No	Domain	Actual Value	Flag model and score
1	Participation of Stakeholedrs	100% stakeholder engagement	3
2	Conflict in fisheries	2-5 times/year	2
3	Applying local knowledge to the Management of fish resources	None	1

Economic domain

***Ownership of assets**.* Because it is known from the interview findings that the degree of asset ownership among fisheries families is still low, the asset ownership indicator value is 1. According to several respondents, their assets could not be supported by their producing assets. Their sole assets are privately held homes, property, and technology items they purchase during busy times. This indicator's definition of asset ownership includes productive assets—that is, assets that may be invested in or produced—owned by households in the agriculture and fishing industries.

***Income of the household**.* The fisheries family income indicator has a score of 1. This demonstrates that the revenue of Tomini Bay's squid and net fishermen is less than the Gorontalo Province and Central Sulawesi Province Minimum Wages. The minimum wage in Gorontalo is IDR 3,025,100 (rupiah), in accordance with Governor Decree number 446/32/XI/2023, which stipulates the minimum wage of Gorontalo Province in 2024. Interviews with Tomini Bay's squid and rod and net fishermen revealed that their monthly wages vary from 400,000 Rp during the lean season to 800,000 Rp during the harvest season for crew employment.

Meanwhile, the skipper and boat owner's monthly salary varies from 1,500,000 Rp in the lean season to 2,000,000 Rp in the harvest season. Because fishing rod fishermen's earnings fall short of the minimum wage, they are therefore not seen as having a respectable income.

***Rate of savings**.* The examination of the interviews with fishermen revealed that the amount of money spent by each fisherman varies depending on the season. According to boat owner interviews, 75% of participants are aware that they should preserve a portion of their income, but they often do not do so. Some respondents stated that they had never saved in a bank but had instead used their tools, while 15% of respondents in the captain and crew fisherman group decided to set away the money from squid sales for savings. The savings ratio measures the gap between the income and expenses of households that are fishers. This indicator's value is 1.

Table 8

Economic domain

No	Domain	Actual Value	Flag model and score
1	Ownership of assets	Asset value reduced (by more than 50%)	1
2	Income of the household fisheries	Less than the average minimum wage	1
3	Rate of savings	Less than the loan credit interest	1

Institutional domain

Respect for the principles of responsible fisheries. By examining the degree of regulatory compliance, one may evaluate both positive and negative signs of adherence to the principles of responsible fishing in fisheries management using an ecosystem approach (Sudarmo et al 2016). Relatively few known fisheries management guidelines are broken in the Tomini Bay region. Particularly for longline fishermen, there aren't many known infractions of fisheries management in the Tomini Bay area. The indicator of adherence to the responsible fisheries principles has a score value of 2. This suggests that the concepts of responsible fisheries have not been fully implemented in fisheries management.

According to the findings of observations and interviews with PSDKP staff at Gorontalo Fishing Port and fish auction sites in Tomini Bay, many fishermen still use fishing gear weighing between 10 and 30 GT to land their catch outside PPN Palabuhanratu without an Andon letter, which is considered a document violation.

Completeness of the rules. Rules Law of the Republic of Indonesia No. 45 of 2009 concerning amendments to Law No. 31 of 2004 concerning Fisheries, Regulation of the Minister of Maritime Affairs, and Fisheries Number. 2/PERMEN-KP/2015 on the Prohibition of the Use of Trawls and Seine Nets in the Fisheries Management Area of the Republic of Indonesia, Regulation of the Minister of Maritime Affairs and Fisheries No. 45 of 2015 on SLO (Letter of Operational Feasibility), Minister of Maritime Affairs and Fisheries No. 36 of 2014 on fishermen, and Minister of Maritime Affairs and Fisheries No. 13 of 2012 on catch certification are among the regulations that are applicable in this area of fisheries management and PSDKP No. 10: Regulation of the Director General on Technical Guidelines for Fish Landing Verification. Law enforcement of current regulations has been successful, as evidenced by the completeness indicator of the game rules in fisheries management, which has a score value of 3.

Mechanism for making decisions. Tomini Bay is not centrally regulated, or there is no extension of the policy-implementing arm of the central government, such as from the ministry, so it lacks a program initiative in decision-making. Instead, the Ministry of Fisheries and Maritime Affairs, the Department of Fisheries and Maritime Affairs of Gorontalo Province, Maluku Province, and Central Sulawesi Province handle the management of the fisheries in Tomini Bay. The decision-making mechanism indication has a score value of one, indicating that no mechanism (SOP) has been adopted and is ineffective.

Plan for fishery management (FMP) Teluk Tomini Bay. The Tomini Bay Fisheries Management Plan (FMP) is a necessary operational standard for executing responsible fisheries governance. The fisheries management plan indicator has a score of 1, suggesting that Tomini Bay does not have an FMP.

Degree of cooperation between institutions and policies in fisheries management. The integration of motions and steps between institutions and fisheries management strategies measures the degree of synergy between such institutions and policies (Sudarmo et al 2016). The existence of dialogue or coordination efforts for managing fisheries offenses and resolving disputes at the provincial, district, or regional levels illustrates synergy. The indicator of the degree of synergy between institutions and policies for fisheries management has a score of 2. This demonstrates that although there has been good institutional synergy, there is no sustainability.

Stakeholder ability. Stakeholder capacity is generally existent and operational (the acquired expertise is in line with their work tasks). Stakeholders may originate from the community, universities, NGOs, commercial sector, or government bureaucracy. However, they have not yet established their capability. The score of the stakeholder capacity indicator is 2.

Table 9

Institutional domain

No	Domain	Actual Value	Flag model and score
1	Respect for the principles of responsible fisheries	2-4 times a breach of the law occurs	2
2	Completeness of the rules	Availability of fisheries regulation	2
3	Mechanism for making decisions	There is a decision but it is not implemented	1
4	Plan for fishery management (FMP) Teluk Tomini Bay	No fisheries management plan yet	1
5	Degree of cooperation between Institutions and policies in fisheries management	Inter-agency communication does not support each other	2
6	Stakeholder ability	exists but is not utilised	2

Table 10

The value of each EAFM domain

No	Domain	Calculation	Maximum limit	Domain value	Flag model and score
1	Fish resources	1902	6120	31.08	1
2	Habitat and Ecosystem	4102	8238	49.79	2
3	Fishing technology	5439	6130	88.73	3
4	Social	5948	8549	69.58	3
5	Economic	2493	6429	38.78	1
6	Institutional	6029	8320	72.46	3
	Average	4266	7298	58	2

Management status of Squid*.* Based on research data, the management status of squid resources in Tomini Bay has been analyzed through an Ecosystem Approach to Fisheries Management (EAFM) and Flag model, integrating social, economic, and ecosystem aspects of fisheries.

The following are the main findings of this research, highlighting the current state and challenges in squid fisheries management.

Population conditions and Squid resource utilization*.* Research shows that the *Loligo spp.* population in Tomini Bay exhibits high biodiversity, contributing to the local aquatic ecosystem balance. However, the analysis of Catch Per Unit Effort (CPUE) indicates a declining trend from 21.78 kg/trip in 2019 to 17.02 kg/trip in 2023. This decrease suggests possible high fishing pressure or overfishing in the area, as the increased fishing effort does not correspond to significant catch results, as indicated by the low linear gradient in the CPUE and fishing effort relationship.

Technology and selectivity of fishing gear*.* The dominant fishing gear includes circle gill nets and squid jigging rods. The use of environmentally friendly technology in these fishing methods demonstrates high selectivity in catching squid, though it still poses a bycatch risk. Therefore, improvements in more selective fishing methods are necessary to enhance sustainable practices, especially for fishing gear with high bycatch.

Habitat and ecosystem quality*.* The water quality in Tomini Bay is rated good, with the pollution index averaging in the moderate category. However, the coral reef ecosystem has suffered damage due to human activities, such as the use of explosives. This situation highlights the need for sustainable ecosystem management, including coral reef rehabilitation and the reduction of destructive fishing activities.

***Impact of climate change**.* Tomini Bay is vulnerable to climate change impacts, such as rising sea levels that could increase the frequency of flooding in coastal areas. The influence of climate change on storm patterns and rainfall adds challenges to maintaining the stability of the marine ecosystem and fisheries resources in the region.

***The economic welfare of fishermen**.* In the economic domain, it was found that the income of squid-fishing households remains low, often below the provincial minimum wage. The ownership of productive assets is also limited, indicating fishermen's restricted capacity to increase production independently. Therefore, efforts are needed to raise fishermen's income by developing their capacity and providing access to more efficient fishing technology.

***Social participation and conflict**.* Stakeholder participation, including fishing groups, academics, and government, is rated high in squid resource management. However, conflicts in fisheries still occur, both among fishermen and between fishermen and the government. These conflicts arise from competition for fishing resources and misunderstandings in resource management.

***Institutional support**.* Institutionally, the fisheries management system in Tomini Bay still requires improvement in fisheries management planning, such as the implementation of a Fisheries Management Plan (FMP), which has yet to be applied. Institutional cooperation needs to be enhanced to create synergy in addressing issues and violations in the fisheries sector. Effective institutions will increase adherence to responsible fishing principles and strengthen resource management sustainability.

The current status of squid management in Tomini Bay reveals significant challenges regarding sustainability across ecosystem, social, economic, and institutional aspects. The EAFM and Flag model analysis indicates the need for comprehensive interventions, including the application of selective fishing technology, improvement in fishermen’s income and welfare, and strengthened inter-institutional cooperation. Increased awareness and stakeholder participation are also crucial to promoting more sustainable fisheries resource management.

Conclusions. Based on the comprehensive research on squid resource management in Tomini Bay, here are the conclusions and recommendations derived from the findings. Population and Fishing Effort: The squid population in Tomini Bay, specifically the *Loligo spp.,* has shown a decreasing trend in Catch Per Unit Effort (CPUE), dropping from 21.78 kg/trip in 2019 to 17.02 kg/trip in 2023. This trend suggests a potential overfishing risk, as increased fishing efforts have not led to corresponding increases in catch rates, which may indicate pressure on the squid population. Fishing Technology and Selectivity: The primary fishing gear used includes circle gill nets and squid jigging rods, which show high selectivity for squid and minimal bycatch. However, some gear, like the sesser (a scoop net), has been associated with higher bycatch, suggesting a need for further selectivity enhancements to support sustainability. Environmental and Ecosystem Health: Tomini Bay has stable water quality with moderate pollution levels, but the coral reef ecosystem has suffered significant damage, largely due to destructive fishing practices such as bomb fishing. This ecosystem degradation poses a risk to habitat quality, essential for the squid population and broader biodiversity. Economic Conditions: The economic well-being of local fishermen remains low, as their incomes are below the regional minimum wage. Asset ownership and savings rates are limited, reflecting restricted financial capacity among fisher households. This economic vulnerability highlights the need for supportive policies to improve fisher welfare and economic resilience. Social and Institutional Participation: While stakeholder engagement in squid resource management is high, conflicts within the fishing community and with governmental bodies are frequent. These conflicts often arise from competition for resources and disagreements on resource management practices. Institutional synergy and a formal fisheries management plan (FMP) are lacking, which weakens the governance structure needed for sustainable fisheries.

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