Status of mackerel scad (*Decapterus* sp.) resource based on Ecosystem Approach (EA) at PPS Kutaraja, Banda Aceh

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Abstract. The Kutaraja Ocean Fishery Port (PPS) is the largest port serving as the center of fisheries in Aceh Province, with a potential and diverse fishery, including the mackerel scad (*Decapterus* sp.). The fluctuation of the mackerel scad population on an annual basis, which raises concerns about the sustainability of the stock. Therefore, a structured management effort is required, employing an Ecosystem Approach to Fisheries Management (EAFM) to address this problem. The study aimed to assess the management status of mackerel scad resources based on PPS Kutaraja. The research was carried out from February to April 2023. Data collection was carried out through direct observation and interviews with 73 respondents. Data analysis for each indicator was performed using a multi-criteria approach with composite index assessment and flag model visualization. The research results indicate a 20% annual decline in the CPUE trend, a relatively consistent fish size trend, a 4% proportion of juvenile fish caught, a catch composition dominated by target species at 77%. Based on these EAFM indicators, the management status of mackerel scad resources in PPS Kutaraja falls under the 'good' category.

1 Introductionnn

The location of Kutaraja Ocean Fishing Port (PPS) is in WPP 571 (Malacca Strait and Andaman Sea) and WPP 572 (Western Indian Ocean and Sunda Strait) [1]. It is the largest port serving as the center of fisheries in Aceh Province. The fish landed at PPS Kutaraja are potential marine fisheries products, especially for small and large pelagic fish such as tuna, mackerel tuna, skipjack tuna, and mackerel scad. The fishermen at PPS Kutaraja use purse seines and handlines to catch mackerel scad. Mackerel scad is the focus of this research because their catch production fluctuates, while other potential fish did not experience significant fluctuations. In addition, at PPS Kutaraja, research related to mackerel tuna fish

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resources has been carried out by Salmarika et al. [2], and research related to skipjack tuna fish resources has also been carried out by Sari et al. [3].

Annual variations occur in the production of mackerel scad catches. In 2019, the production of purse seine catches reached 4,952,976 kg/year; in 2020, it decreased to 4,105,500 kg/year; and in 2021, it increased again to 4,711,464 kg/year. Whereas in hand line fishing gear in 2019, the catch production reached 692,076 kg/year, in 2020 it decreased to 554,176 kg/year and increased again in 2021 to reach 689,724 kg/year [4]. The amount of mackerel scad production has fluctuated over the past 3 years. Therefore, it is necessary to assess mackerel scad management at PPS Kutaraja to know the sustainability of mackerel scad stocks.

FAO [5] developed a concept of fisheries management through a holistic approach known as fisheries management with an ecosystem approach (Ecosystem Approach to Fisheries Management/ EAFM). This approach aims to manage fisheries sustainably by ensuring a balance between ecosystem health (ecosystem well-being), actor welfare (human well-being), and harmonious governance [6]. There are six domains for implementing EAFM, one of which is the fish resources domain [7]. Therefore, with the increasing number of fishing fleets and mackerel scad fluctuating every year, it is necessary to research the assessment of mackerel scad fisheries management with EAFM in the fish resource domain in Kutaraja PPS. This study aims to assess the management status and formulate recommendations for the management of mackerel scad resources based on PPS Kutaraja.

2 Materials and Methods

2.1 Location and time research

This research was conducted from February to April 2023. The research location is located in the Kutaraja Fishing Port (PPS), Lampulo Village, Banda Aceh, Aceh.

2.2 Data collection methods

The data used in this research are primary and secondary. The primary data used consisted of the size and length of the fish, the proportion of juvenile mackerel scad, the species composition of the catch, as well as the results of interviews from questionnaires that were directly observed in the field. The interview is face-to-face between interviews with the fishermen as respondent, and the activity is carried out orally [8]. The data utilized for the fish length indicator came from direct measurements of landed mackerel scad fish using a tape measure (cm) and the accidental sampling method, specifically the landing technique for mackerel scad fish. According to Masyhuri and Zainuddin [9], the accidental sampling technique involves selecting a sample of the population based on chance encounters made by researchers in the field. The sampling technique was chosen because of the uncertainty of the number of fish populations and the ease of obtaining samples. The total fish samples measured were 1.211 fish. Meanwhile, the number of respondents to the questionnaire was determined using the Slovin formula [10] as follows:

$$n = \frac{N}{1 + Ne^2}$$

Where:

n : Sample size

N : Population size

e : The percentage of inaccuracy due to sampling errors that can still be tolerated or desired

According to data from PPS Kutaraja, the population of purse seine captains is 269 people [4]. Then a sample of 73 people was taken with a data accuracy rate of 90% and an error margin of 10% because the total population is less than 1000 populations. Then secondary data is needed to determine the CPUE trend indicators, namely mackerel scad production and purse seining efforts from 2017–2021 obtained directly from relevant agencies, such as data from the Regional Technical Implementation Unit (UPTD) and the Department of Marine and Fisheries of Aceh Province (DKP Aceh).

2.3 Data analysis

2.3.1 Identify EAFM Indicators

1. Raw Catch Per Unit Effort (CPUE)

Catch Per Unit Effort (CPUE) is defined as the fish catch rate per year which is obtained using time series data. CPUE trend indicator according to Gulland (1983) in Febriani et al. [11] can be calculated using the following formula:

$$\text{CPUE} = \frac{Catch}{Effort}$$

Where:
CPUE : Number of catches per unit of fishing effort (kg/trip)
Catch : Catch/production (kg)
Effort : Attempt to capture (trip)

2. Fish Size Trends

The size of the mackerel scad in this study was carried out by measuring the fork length (FL) because it was feared that the morphology of the fish's fins was not in good condition and intact which resulted in not being able to measure the total length (TL). The results of mackerel scad measurements are included in the class interval. Sturges' rule (1962) is referred to in Leone et al. [13] explains that determining the number of classes is calculated using the following equation:

$$K = 1 + 3.3 \text{ Log } n$$

Where:
K : Number of classes
N : Number of samples

Then determine the class interval using the following equation:

$$P = R/K$$

Where:
P : Class gap
R : Range (highest fish length – lowest fish length)

3. Proportion of Juveniles Fish Caught

According to the NWG EAFM Module [7], the proportion of juvenile fish is calculated in the following way:

$$Pcy = Cyi/Ctot \times 100$$

Where:
Pcy : Proportion of juveniles caught (%)
Cyi : Yuwana caught (ind)
Ctot: Total catch (ind)

4. Species Composition of the Catch
Analysis of species composition aims to see comparisons between target and non- target fish catches [14]. The species composition of the catch is calculated using the following equation:

$$Pi = ni/N \times 100\%$$

Where:
Pi : Proportion of catch of the i species (%)
ni : Total Catch of fish species I (kg)
N : Total number of catches (Kg)

5. Range Collapse of Fish Resources
The determination of range collapse can be seen based on the condition of the fishing area. The easiest indicator in determining range collapse is to see if there are any indications that it is becoming more difficult to find fishing grounds by interviewing fishermen.

6. ETP (Endangered, Threatened, and Protected) species
Observation of ETP (Endangered, Threatened, and Protected) species was carried out by directly observing the catches of fishermen in the field and collecting data from fishermen who were interviewed as respondents.

2.3.2 EAFM Indicators Assessment

The assessment of indicators was analyzed using a multi-criteria analysis (MCA) approach with the development of a composite index using a Likert scale score (based on ordinal 1, 2, and 3). The following are the stages of the assessment:
1. Determine the criteria for each fish resource domain indicator, its seen in Table 1

Table 1. Criteria and Weight of Fish Resources Domain Indicators in EAFM

Number	**Indicator**	**Description**	**Criteria**	**Weight**
1.	Raw CPUE	the number of fish caught by an amount of effort	1 = CPUE decreased sharply (average decrease >25% per year) 2 = CPUE decreased slightly (average <25% per year) 3 = CPUE stable or increasing	40
2.	Fish size trend	Change in fish size	1 = The size of the fish is getting smaller 2 = Relatively fixed fish size 3 = Fish size increased	20
3	The proportion of juvenile	Percentage of fish caught before reaching maturity	1 = A lot (> 60%) 2 = Many (30 -60%) 3 = Few (<30%)	15

Number	Indicator	Description	Criteria	Weight
4.	Species composition of the catch	Comparison of target and non-target fish species	1 = Lower proportion of target fish (<15% of total volume) 2 = The proportion of target fish is the same as non-target 3 = Larger proportion of target fish (>31% of total volume)	10
5.	Range collapse	The fishing location is getting farther away	1 = Fishing ground is getting very far depending on the species 2= Fishing ground further away, according to the target species	10
			3= Fishing grounds are relatively fixed in distance depending on the target species	
6.	ETP species	Species whose populations are decreasing and whose existence is threatened with extinction so it needs to be protected	1 = There are ETP individuals caught but not released 2 = Caught but released 3 = No ETP individuals caught	5

Source: NWG EAFM Module (2014)

2. Provide a score for each indicator (based on ordinal 1,2,3)
3. Determine the weight of each indicator
4. Calculate the index value for each indicator. According to NWG EAFM Module [7], the indicator index value can be calculated using the following formula:

$$Cat\text{-}i = Sat\text{-}i \times Wat\text{-}i$$

Where:
Cat-i : EAFM total value of one indicator in the domain
Sat-i : The score of the I attribute/indicator
Wat-i : Weight of the I attribute/indicator
5. Develop a composite index for each indicator. According to NWG EAFM Module [7], the composite value can be calculated using the following formula:

$$\text{NK-i} = \frac{Cat-i}{Cat-max} \times 100$$

Where:
NK-i : Composite value to i
Cat-i : The total value of all the i indicators
Cat-max: The maximum value of all the i indicators

Furthermore, the composite values obtained were visualized using the flag model which is presented in Table 2. This model describes the condition of mackerel scad resource management in the categories of bad, not good, medium, good, and very good.

Table 2. Composite Index Value Classification and Flag Model Visualization

Composite Score Value	Model Flag	Description
1-20		Bad
21-40		Not good
41-60		Medium
61-80		Good
81-90		Very good

Source: NWG EAFM Module (2014)

3 Result and Discussions

3.1 EAFM fish resource management status

a. Raw Catch Per Unit Effort (CPUE)
Before carrying out CPUE calculations, it is necessary to standardize fishing gear. This is because each fishing gear has a different ability to catch mackerel scad. Mackerel scad landed at Kutaraja PPS are caught using two types of fishing gear, namely purse seines and hand lines. Therefore, standardization of fishing gear needs to be done to determine the number of standard trips so that the CPUE value can be determined. CPUE values for each fishing gear can be seen in Table 3 below.

Table 3. CPUE of scads from purse seines and handlines

Year	Purse seines			Handlines		
	Total Production (kg)	*Effort* (trip)	CPUE (kg/trip)	Total Production (kg)	*Effort* (trip)	CPUE (kg/trip)
2017	3.474.548	3.038	1.143.69	355.460	1.124	316.24
2018	4.696.748	2.883	1.629.11	599.872	1.119	536.07
2019	4.952.976	2.321	2.133.98	692.076	1.131	611.91
2020	4.105.500	2.344	1.751.49	554.176	1.244	445.47
2021	4.711.464	2.312	2.037.83	689.724	1.471	468.88
Amount	21.941.236	12.898	8.696	2.891.308	6.089	2.378
Average	4.388.247	2.579	1.739	578.262	1.218	476

Source: PPS Kutaraja (2021)

Based on the calculation of the CPUE value of the two fishing gears, the purse seine gear has the highest CPUE value. In the standardization of fishing gear, the calculation of the Fishing Power Index (FPI) value is carried out, which begins with determining the standard fishing gear. Based on the mackerel scad data that has the greatest productivity value is the purse seine fishing gear so it becomes a standard fishing gear that has an FPI value equal to one, while the FPI value of other fishing gear is obtained from the CPUE value of other fishing gear divided by the CPUE value of the fishing gear used as the standard.

The next step is to calculate the standard trip with the formula: FPI of the i-year purse seine x effort of the i year of the purse seine, FPI of the i year of hand-line fishing x of the i year of hand-line fishing. After knowing the number of standard efforts, the CPUE value is recalculated using the catch formula divided by the value of the new fishing effort or standard trip. The results obtained can be seen in Table 4 below.

Table 4. Calculation Results for Total Catch, Standard Effort, and CPUEs

Year	Total Production (kg)	Standard Effort (trip)	CPUEs (kg/trip)
2017	3.474.548	3.038	1.143.69
2018	4.696.748	2.883	1.629.11
2019	4.952.976	2.321	2.133.98
2020	4.105.500	2.344	1.751.49
2021	4.711.464	2.312	2.037.83
Amount	21.941.236	12.898	8.696
Average	4.388.247	2.579	1.739

Source: PPS Kutaraja (2021)

Based on the research results, it can be seen that the CPUE trend of mackerel scad based on PPS Kutaraja has decreased by 20% per year. However, this is different from research conducted by Wahyudi [15] in the northern waters of Sumenep Regency, where the CPUE trend for mackerel scad is stable or increases slightly so the score given is 3. Based on data for the last 5 years from PPP Pasongsongan, namely 2017-2021. The lowest CPUE value is in 2018 and the highest is in 2021. The declining trend of CPUE is an indication of a decrease in stock availability from fish resources [2]. According to Nugraha et al. [16] that the decreasing trend of CPUE indicates that the utilization of fish resources is already high.

b. Fish Size Trends

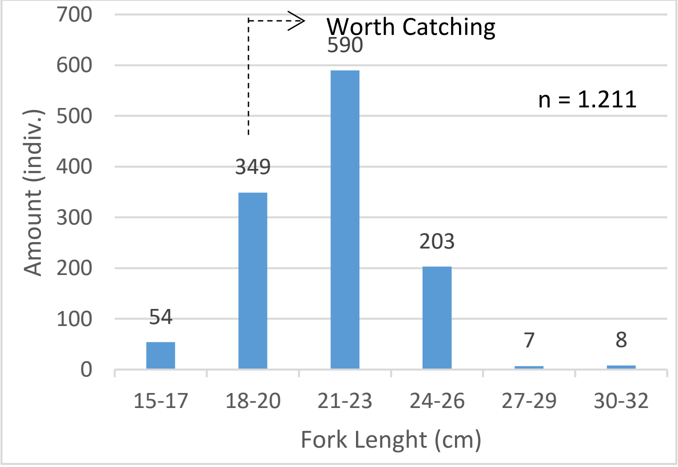

Fig. 1. Frequency distribution of maackerel scad

Based on measurements, the mackerel scad in this study had a size distribution of 15-35 cm FL with a dominant size of 21-25 cm FL. This size is almost the same as the size found in Hariati's research [17] in the waters of Banda Aceh, the fork length of the mackerel scad measures between 16-32 cm with a mode of 28,5 cm. While in the waters west of North Sumatra the size is between 16-26 cm with a mode of 20,5 and 23,5 cm. The length distribution of mackerel scad caught by purse seines shows various lengths. Iksan and Irham [18] stated that mackerel scad caught from the waters of the Maluku Sea ranged in size from 21,1-31,1 cm with a dominant size of 24,1-25 cm. Fadila et al. [19] stated that the mackerel scad that landed at Kendari PPS had a length distribution of 18,2-29,8 cm with a dominant size of 21-22,4 cm.

The difference in the length distribution of mackerel scad is influenced by several factors, namely related to the operation of purse seine fishing where variations in the length of the day of operation will affect the wider fishing area. This can result in the size of the fish caught being more diverse. In addition, it is also influenced by environmental conditions, abundance and availability of food, temperature, and light in each different water [20]. This is in line with Sasmito et al. [21] that the aquatic environment is very limited by the abundance of food. The abundance of food is an important factor in the waters that will affect the growth of fish.

c. Proportion of Juvenile Fish Caught

Based on the results of sample measurements in the study, the size of the mackerel scad landed at PPS Kutaraja was 4% still classified as juvenile fish because the size at first maturity (Lm) for mackerel scad is found in the [22] database, namely at size 17,6 cm. This can be caused by fishing operations carried out around FADs which result in small mackerel scad around FADs being caught too. According to Sudirman and Mallawa [23], FADs are in principle a gathering place for plankton and other small fish, thus inviting large fish to gather in search of food. Wiadnya et al. [24] also stated that FADs can attract juvenile-sized and adult-sized fish in a variety of abundance and diversity. The proportion of juvenile fish caught was also found at several different locations. Research by Sitanggang [25] conducted by PPN Sibolga, North Sumatra with the result that the proportion of juvenile fish caught was 44%, and research by Widodo et al. [26] at PPS Cilacap, Central Java, the proportion of juvenile fish caught was 31,5%.

d. Species composition of the catch

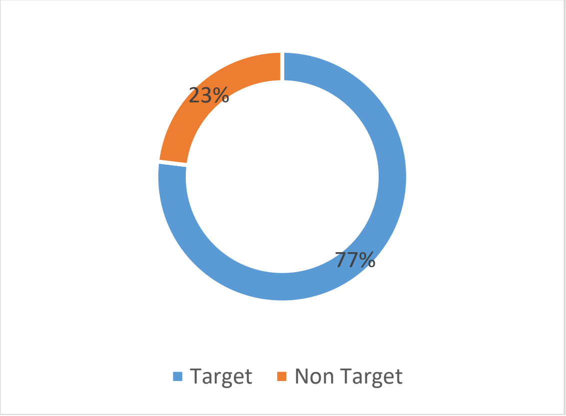

Fig. 2. Species composition of ring seine catches in Kutaraja PPS

The species composition of the catch in this study revealed that the target fish caught by purse seiners dominates compared to the non-target fish. Target fish has a percentage of 77% and non-target fish with a percentage of 23%. Target fish catches include mackerel scad (*Decapterus* sp.), tuna (*Auxis* sp.), skipjack tuna (*Katsuwonus pelamis*), and baby tuna (*Thunnus* sp.). Meanwhile, non-target fish catches include yellowfin tuna (*Thunnus* *albacares)*, coral leubim (*Abalistes stellaris*), siro (*Amblygaster sirm*), setuhuk (*Makaira* sp.), selar (*Selaroides leptolepis*), sunglir (*Elagastis bipinnulatu)*, kwee/rambe (*Caranx ignobilis*), squid (*Loligo* sp.), swordfish (*Xiphias gladius*), and the rat shark (*Alopias pelagicus*). The results of interviews with respondents obtained that 100% of fishermen stated that the species composition of catches at PPS Kutaraja was dominated by target fish. This condition is similar to a study conducted by Putra et al. [27] in Seraya Timur Village, Bali where the species composition of gill net and troll line fishing gear was dominated by target species with percentages of 98% and 90,7%, respectively.

e. Range Collapse of Fish Resources

The fishing areas for fishermen in the Kutaraja PPS include WPP 571 (the Andaman Sea and Malacca Strait) and WPP 572 (the Western Indian Ocean and Sunda Strait). The results of interviews with respondents obtained as many as 99% of fishermen stated that the fishing area was getting farther away. Currently, fishermen have to do fishing activities as far as 50-300 nautical miles from the port. However, this condition is different from research conducted by Arianto et al. [28] in the waters of Ternate Island where the results of interviews obtained 100% of respondents stated that fishing conditions in the last 5 years were not difficult, and the fishing ground is still the waters south of the island of Ternate.

According to Adrianto et al. [29], the cause of the increasing difficulty in finding fishing areas can be caused by the spatial reduction of the biomass of fish stocks as a catch target due to the impact of increasing fishing pressure. The difficulty of finding fishing areas for fishermen is also caused by the ability of fishermen to carry out fishing activities, and the limited information that fishermen have in determining fishing areas. Himelda et al. [30] changes in the catchment area are influenced by the main factor of the nature of the flying fish whose life is straddling. Roaming is the movement of fish due to the need to carry out the reproductive process, the interest in looking for food, and roaming occurs due to changes in the aquatic environment.

f. ETP (Endangered, Threatened, and Protected) species

Based on observations and interviews with fishermen, there are several types of ETP species caught by fishermen, including dolphins (*Delphinus* sp.), turtles (*Chelonia mydas*), and rat sharks (*Alopias pelagicus*). The results of interviews with respondents showed that 47% of the ETP species caught were released and 53% of the ETP species caught were sold/consumed themselves. Based on PERMEN KP RI No. 26/2013 concerning Capture Fisheries Business in WPP-RI stated that several protected species in the form of sharks, sea turtles, and marine mammals including whales or non-fish which are caught accidentally must be carried out as conservation efforts in the form of releasing the caught species if they are still caught alive and handling if the species is caught dead. However, the rat sharks that were caught during fishing activities were not released by fishermen at PPS Kutaraja.

Based on the results of interviews, PPS Kutaraja fishermen also stated that they had caught turtles and dolphins but were released. This is similar to research Putra et al. [27] which stated that there were accidentally caught endangered (EN) species, namely the green turtle (*Chelonia mydas*) and dolphins (*Delphinus* sp.). The cause of the capture of this ETP species was that the species was accidentally trapped when fishermen used gill nets. If this condition occurs, fishermen will try to free the ETP species in the fishing gear used.

3.2 EAFM Assessment

This assessment illustrates that the status of the mackerel scad fishery resource in Kutaraja PPS is in good condition, where the visualization of the flag model is light green. This condition still has the potential to decrease if efforts to improve and implement policies are not implemented in management. Care needs to be taken in terms of its utilization so that these conditions can be improved and its sustainability maintained, bearing in mind that the results of the assessment of each indicator in the fish resources domain still have indicators with poor and moderate status. An assessment of the status of the fish resource domain for mackerel scad fisheries with an ecosystem approach has also been carried out by Puansalaing et al. [31] in the waters of the Sulawesi Sea, North Sulawesi with a composite value of 56,67. This value is in the range of 41-60 which is classified as a moderate criterion marked by a visualization of a yellow flag model. The results of the assessment of each indicator can be seen in Table 5 below.

Table 5. Analysis of EAFM Indicator Assessment with the Flag Model

Number	Indicator	Score	Weight	Value
1	Raw CPUE	2	40	80
2	Fish size trend	2	20	40
3	The proportion of juvenile	3	15	45
4	Species composition of the catch	3	10	30
5	*Range collapse*	2	10	20
6	ETP species	1	5	5
Composite value				73.33

Based on the current condition of mackerel scad resources in Kutaraja PPS, the recommended management is to control fishing efforts. Controlling fishing efforts can be done by setting fishing gear, location, and time as well as setting limits on fishing quotas [32]. Umamah et al. [33] also suggest that regulation of fishing efforts can be carried out by regulating ships, fishing gear, or the number of fishermen participating in fishing activities. Reducing fishing efforts aims to increase the efficiency of purse seine fishing so that it is expected to increase CPUE per year [34].

The next management recommendation is to closely monitor fishing activities, which are related to the use of selective fishing gear and environmentally friendly fishing methods. This is important so that the target and size of the catch are still by the rules. Then, regulate the distance of illegal FADs by KP Regulation Number 26, 2014, namely not less than 10 nautical miles so as not to hurt fish migration. Nurdin et al. [35] state that the impact of installing FADs that are too close causes damage to the migration patterns of fish that migrate far away, thereby disrupting the balance of the ecosystem. The last recommendation is related to ETP species caught, it is necessary to educate fishing communities regarding ETP species and their handling along with conservation efforts that can be carried out.

4 Conclusions

Based on research that has been carried out at PPS Kutaraja, it can be concluded that The status of mackerel scad resource management based on an ecosystem approach in the domain of fish resources in Kutaraja PPS is included in the 'good' category, meaning that caution is still needed in its utilization. From several indicator values, there are management actions that need to be improved so that this condition can be maintained for the better. Recommendations for the management of mackerel scad resources based on an ecosystem approach in Kutaraja PPS that can be suggested include controlling purse seine fishing efforts by regulating the number of vessels, fishing gear, time, and area of fishing as well as limiting fishing quotas; strict supervision of fishing activities, related to the use of selective fishing gear and environmentally friendly fishing methods; controlling the distance between FADs for purse seine fishermen where the installation distance between FADs is not less than 10 nautical miles; as well as providing education to fishing communities regarding ETP species and their handling and conservation efforts that can be carried out.

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