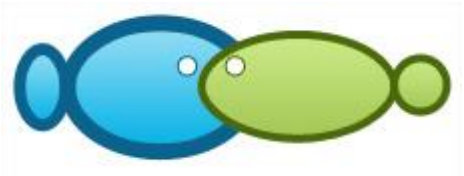

Evaluation of fishery resources status and fishing techniques of *Scarus* sp. fisheries in Karimunjawa Island, Indonesia

[1]Trisnani D. Hapsari, [1]Faik Kurohman, [1]Abdul K. Mudzakir, [1]Yunitania Simanjuntak, [2]Pranata C. P. Putra

[1] Department of Capture Fisheries, Faculty of Fisheries and Marine Sciences, Diponegoro University, Tembalang, Semarang, Central Java, Indonesia; [2] Environmental Science Study Program, Postgraduate School, Universitas Brawijaya, Malang, Indonesia. Corresponding author: T. D. Hapsari, trisnanihapsari@live.undip.ac.id

Abstract. Parrotfish (*Scarus* sp.) is a coral reef fish which has high economic value. The increasing market demand for *Scarus* sp. has led to an increasing pressure on fishing. *Scarus* sp. fish are caught using spearfishing gear. Uncontrolled exploitation activities can disrupt fish resources. The purpose of this study was to determine the status of *Scarus* sp.'s management and resource utilization related to the given resource domain and fishing techniques, based on the Ecosystem Approach to Fisheries Management (EAFM) method. Data collection was carried out through field observations and interviews with 35 spearfishing fishermen in Karimunjawa Island, between May-June 2024. The results of the study indicated that the status of *Scarus* sp. fisheries was in the good or moderate category, given the resource domain and fishing techniques, showing a composite value of 64.23 with an indicator score of 2.08. Although the assessment, based on the resource domain and fishing techniques, shows that the sustainability status of parrotfish fisheries management and resource utilization are close to optimal, these can be improved through regulating fishing seasons, conducting socialization of information on stock conditions and sizes of fish caught. These can be achieved by controlling parrotfish fishing activities and conducting collaborative supervision and community participation.

Key Words: EAFM, parrotfish, spear, Karimunjawa Island.

Introduction. Karimunjawa Islands has a land area of 111,625 ha, of which 104,592 ha being ocean (Ismanto et al 2019). The sea area that exceeds the land makes the potential of the fisheries and marine sector in Karimunjawa considerably large. As one of the archipelagos with 25 islands with 4 permanently inhabited islands (BPS-Statistics Jepara Regency 2024), most of the Karimunjawa Islands population works as fishermen. Karimunjawa fishermen have a main catch target in the form of coral reef fish (Ramadhan & Apriliani 2016; Yuliana et al 2019).

Parrotfish (*Scarus* sp.) is one of the coral reef fish demanded by consumers, especially in the Karimunjawa Islands and can be found at collectors and Karimunjawa markets. Based on Lestari et al (2017), *Scarus* sp. is in great demand because of its delicious taste and affordable price, and can even be used as a diversification of processed salted fish and dried fish for souvenirs for tourists. Based on interviews with collectors, it is known that the parrotfish sold reaches an average of 220-300 kg per day. The demand for parrotfish during the holiday season is higher than outside the tourist season, putting pressure on fishing intensity. *Scarus* sp. fishing is conducted by spearfishing equipment operated at 5 m to 25 m depth. Fishing activities will certainly reduce the number of fish populations and will affect environmental conditions, especially coral reefs (Patanda et al 2021). The reduction in the parrotfish population can cause uncontrolled algae growth, which will disrupt reef growth; coral reef ecosystems are also habitats for certain fish species. Based on research conducted by Perry et al (2015), it is known that parrotfish produce >85% of the 5.7 kg m^{-2} $year^{-2}$ of sandy sediment located on coral reef flats.

Based on the results of study conducted in Karimunjawa, the stock status of herbivorous fish, especially parrotfish in the *Scarus niger* species, is in a fully exploited condition, *Chlorurus sordidusis* is in an under exploited condition, while the utilization status of parrotfish (*Bolbometopon muricatumis*) is in an over exploited condition (Pangestu 2021). If parrotfish fishing is carried out continuously, it is feared that it will affect the sustainability of the surrounding ecosystem habitat.

Parrotfish fisheries management in the Karimunjawa Islands is an activity that must be carried out to achieve sustainable fisheries. Managing parrotfish fisheries in the Karimunjawa Islands is essential to achieving sustainable fisheries. Ecosystem Approach to Fisheries Management (EAFM) is an integrated fisheries management approach, which can be used as a monitoring and evaluation tool regarding the implementation of the ecosystem-based management principles (Hiew 2012). This study aimed to analyze the conditions of parrotfish (*Scarus* sp.) management and resources utilization in the Karimunjawa Waters, Jepara Regency, related to the resource domain and fishing techniques, and based on the EAFM indicators method. The results of this study are expected to provide information and considerations for managing parrotfish fisheries in the Karimunjawa Islands Waters.

Material and Method

Study location and time of research. This study was conducted in the period May - June 2024, in the Karimunjawa Islands, Karimunjawa Subdistrict, Jepara Regency (Figure 1).

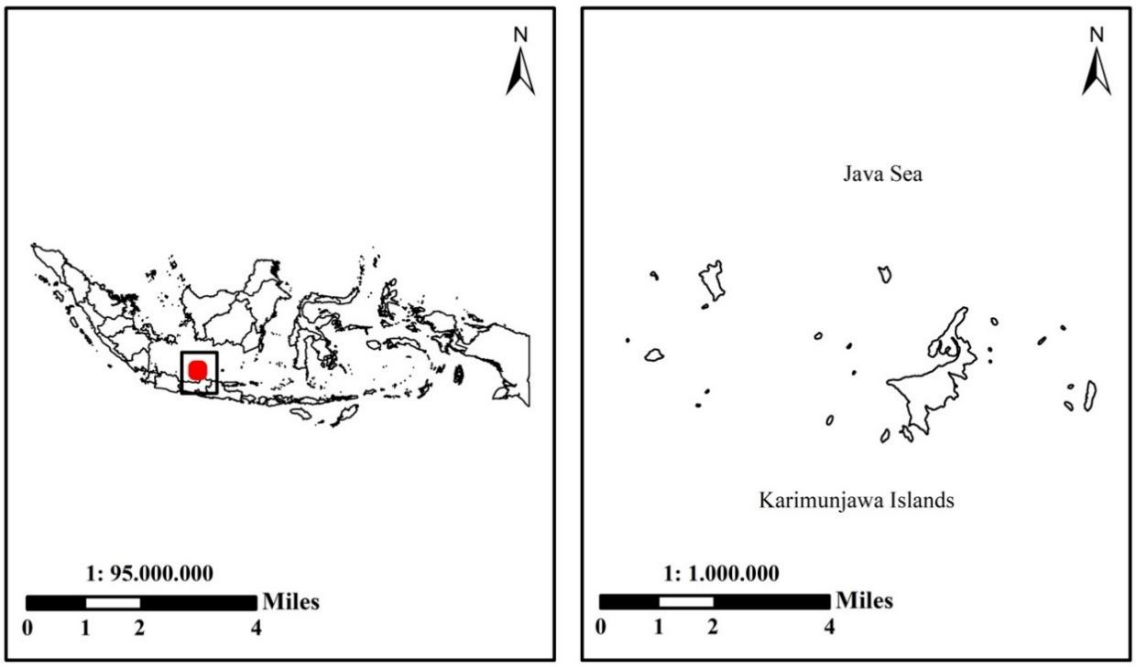

Figure 1. Karimunjawa Island map.

Data collection. Primary data were obtained directly from measuring the length of parrotfish and spearfishing fishermen in Karimunjawa Waters as respondents through interviews using structured questionnaires. The number of respondents in this study was 35 spearfishing fishermen in Karimunjawa Waters. The method used in collecting samples in this study was the snowball sampling, by determining one spearfishing fisherman to be the first respondent. Then, the first respondent will indicate which spear fisherman who can be the next respondent. The data collection methods used in the study were observation, interview, literature study and documentation methods. The data analysis method used in this study used the EAFM assessment in the resource domain and the fishing technique domain.

Resource domain analysis

Exploitation rate indicator. The total mortality value (Z) was estimated using the length-converted catch curve method in FiSAT II, accessed through the Mortality Estimation module, with the steady-state sample option by entering the growth parameter values. The growth parameters (L∞ and K) obtained from the ELEFAN I method were input into the FiSAT II program. The annual natural mortality coefficient (M) is calculated using the empirical formula (Pauly 1980):

$$\text{Log } (M) = -0.0066 - 0.279 \text{ Log}(L\infty) + 0.6543 \text{ Log}(K) + 0.4634 \text{ Log}(T)$$

Where:
L∞ - the asymptotic length;
K - the growth coefficient;
T - the average water temperature (°C) at research location.

In this study, the estimation of fishing mortality (F) is formulated as follows (Gulland 1987):

$$F = Z - M$$

Where:
F - the capture mortality;
Z - the total mortality;
M - the natural mortality.

In accordance with Sparre & Venema (1999), the exploitation rate is determined by comparing fishing mortality (F) to total mortality (Z) using the following formula:

$$E = F/Z$$

Where:
E - the exploitation rate;
F - the capture mortality;
Z - the total mortality.

An exploitation rate value E>0.5 indicates overfishing; an exploitation rate E<0.5 indicates underfishing, while an exploitation rate value E=0.5 indicates optimal utilization (Sparre & Venema 1999).

Fish size trend indicator. Based on Permathasari et al (2021) and Oktary et al (2024), for measuring the frequency trend of fish size the following formula can be used:

$$K = 1+3.3 \log N$$

$$C = W/K$$

Where:
K - the number of class (to calculate interval class value);
N - the number of samples;
C - the class hose;
W - the hose length (maximum length-minimum length).

Indicator of the proportion of young fish (juvenile) caught. The proportion of parrotfish in the juvenile category is sought by calculating the number of juvenile fish caught divided by the total number of fish caught from spearfishing gear. The formula for calculating the proportion of juvenile parrotfish is as follows (Froese et al 2018):

$$Pcy\ (\%) = (Cyi/Ctot) \times 100$$

Where:
Pcy - the proportion of juvenile parrotfish caught (%);
Cyi - the young parrotfish (juvenile) caught (kg);
Ctot - the total overall catch (kg).

Species composition indicators. Species composition is the ratio between the number of parrotfish species and the number of individuals of all species caught. The volume of catch by species was calculated based on the formula proposed by Krebs (1989) as follows:

$$Ks\ (\%) = (ni/N) \times 100$$

Where:
Ks - the species composition (%);
ni - the number of parrotfish caught;
N - the number of individuals of all fish species caught.

Range collapse indicator of fish resources. Range collapse is a reduction in the area or spatial space of a marine ecosystem which is usually inhabited by a particular fish stock (National Working Group EAFM 2014; Bergstrom et al 2021). Knowing the occurrence of range collapse is done by interviewing fishermen about the condition of fishing grounds in the last 5 years. The most available indicator in determining range collapse is the difficulty in finding fishing locations (Hapsari et al 2021).

Indicators of ETP (Endangered, Threatened, and Protected) species caught. In order to identify the ETP species caught, direct observation of the fishermen's catches was carried out and data was collected from the fishermen interviewed as respondents.

Fishing technique analysis
Indicators of illegal and destructive fishing. In determining illegal and destructive fishing, interviews were conducted with spearfishing respondents about fishing activities, the location of fishing areas, fishing gear operation, and observing fishing techniques carried out, in order to determine whether there are stages that conflict with applicable provisions, such as fishing gear operating methods that can damage the ecosystem.

Modification indicators for fishing gear and fishing aids. In spearfishing activities, fishers use a fishing aid in the form of a compressor. According to the Regulation No. 18 Year 2021 (Ministry of Marine Affairs and Fisheries 2021) regarding Placement of Fishing Gears and Fishing Supporting Gears in Fishery Management Areas of the Republic of Indonesia and High Seas as well as Fishing Andon Management, the use of compressors in fishing activities involving diving is generally prohibited due to the risks it poses to diver safety and its potential to harm fishery resources (overfishing and habitat destruction). In order to find out the modification of fishing gear and fishing aids, direct observation was conducted on the results of parrotfish catches. The data taken consisted of primary data in the form of fish length measurement results.

Indicators of fishing selectivity. In determining the level of fishing selectivity, direct observation is carried out on the composition and results of parrotfish catches. The high or low selectivity of fishing is analyzed by looking at the type of fishing gear used according to the existing list of fishing gear selectivity classifications and calculating the number of main catches compared to bycatch. The more selective the fishing gear, the smaller the threat of ecosystem damages (He et al 2021).

EAFM assessment analysis. The assessment of each indicator refers to the NWG EAFM Module (2014), the assessment of the status of each indicator uses an ordinal Likert score of 1, 2, 3 which is in accordance with the assessment criteria for each indicator and is described in Table 1.

Table 1

Criteria and weighting of resource domain and fishing technique indicators in EAFM

Indicator	*Criteria*	*Data source*	*Weight*
A. Fish resources domain			
Exploitation rate	1=E 5, the exploitation rate exceeds the limit (over fishing) 2=0.5=E, optimal condition 3=E<0.5, under fishing	Observation of parrotfish size, comparison of secondary data from Pangestu's study (2021) and primary data on the level of parrotfish exploitation).	40
Parrotfish size trends	1=trend of the average size of fish caught getting smaller 2=relative size trend remains constant 3=trend of increasing size	Observations (sampling) of parrotfish and secondary data are a comparison of the results of primary data with the results of Pangestu's (2021) study on the length interval of fish sizes.	20
Juvenile parrotfish caught	1=abundant (>60%) 2=many (30-60%) 3=little (<30%)	Sampling to see the proportion of parrotfish based on size.	15
Species composition of the catch	1=target proportion is greater (>31% of total volume) 2=proportion of targets is the same as non-targets (16-30% of total volume) 3=target proportion is less (<15% of total volume)	Direct observation and interviews for see the comparison between target and non-target fish catches.	10
"Range Collapse" resource	1=increasingly difficult, depending on target species 2=relatively constant, depending on target species 3=easier, depending on target species	Interviews with fishermen to see if there have been any changes in the location of fishing grounds, changes in the size and quantity of parrotfish catches or diversity of catch.	10
ETP species	1=there are ETP individuals caught but not released 2=there are ETP individuals caught but released 3=no ETP individuals	Directly observing the fishermen's catch in the field and collecting data from fishermen who were interviewed as respondents.	5
B. Fishing technique domain			
Illegal and destructive fishing of parrotfish	1=intentional violation 2=unintentional violation 3=no rule violations occurred	Interviews with respondents who have information about parrotfish fishing activities that are not in accordance with regulations; reports from spearfishing fishermen or the community during interviews.	40
Modification of fishing gear	1=>50% of target species size <Lm 2=25-50% of target species size <Lm 3=<25% target species size <Lm	Observation and interview of spearfishing respondents to determine whether the use of fishing gear is appropriate or not with its selectivity.	35
Capture selectivity	1=high (<50%) use of non-selective fishing gear 2=moderate (50-75%) use of non-selective fishing gear 3=low (>75%) use of non-selective fishing gear	Fishermen interviews and observations to determine the composition and size of the catch from each type of parrotfish fishing gear.	

Source: NWG-EAFM 2014 (modified).

The assessment of the indicator domain was analyzed using the multi criteria analysis (MCA) approach. The MCA approach is a series of criteria built as a basis for performance analysis through the development of a composite index for each indicator in each domain (Budiarto et al 2015; Türegün 2022; Dean 2022). The stages of developing a composite index are determining indicators in each domain, adjusting indicator criteria, determining indicator weights, and summing up indicator index values. Determination of the criteria value of each indicator is obtained through Likert-scale scoring based on ordinals 1, 2, 3 (NWG EAFM 2014). The limits of the score values in this study can be seen in Table 2.

Table 2

EAFM indicator score value limits

Value limit		*Description*	*Color*
Lower limit	*Upper limit*		
1	1.5	Low/Poor	
1.51	2.5	Moderate	
2.51	3	High/Good	

Source: NWG-EAFM 2014.

The weight value is determined based on the amount of contribution or level of importance. The score value and weight value of each indicator will be calculated to obtain the index value. The equation for calculating the index value of the indicator is as follows (NWG EAFM 2014):

$$I_i = S_i \times 100 \times W_i$$

Where:
I_i - the index value of the i^{th} indicator;
S_i - the score value of i^{-th} indicator;
W_i - the weight of the i^{th} indicator.

The next step is to determine the composite score value for each EAFM domain using the following equation, according to NWG-EAFM (2014):

$$NK_i\ (\%) = \frac{Cat-i}{Cat-max} \times 100$$

Where:
NKi - the composite value in the i^{-th} domain;
Cat_i - the total index value of all indicators in the i^{th} domain;
Cat_{max} - the maximum value in the i^{-th} domain.

The composite values obtained will be visualized using the flag model as illustrated in Table 3.

Table 3

EAFM domain composite value limits

Value limit		*Description*	*Color*
Lower limit	*Upper limit*		
1.00	20.00	Bad	
20.01	40.00	Inadequate	
40.01	60.00	Medium	
60.01	80.00	Good	
80.01	100.00	Very well	

Source: NWG EAFM 2014.

The success of parrotfish fisheries management is largely determined by management actions. The management actions recommended in this study are based on the results of the evaluation of the status of fisheries management using EAFM indicators. The decisional approach can be described as follows:

1. Determining the objectives of parrotfish fisheries management based on EAFM indicators;
2. Determining the reference point for each EAFM indicator;
3. Determining tactical steps to achieve a sustainable parrotfish management strategy based on indicators that may suggest the necessary improvement programs in accordance with the EAFM-based fisheries management module.

Results

Evaluation of the status of EAFM management and utilization in each domain

Fish resource domain. Based on NWG EAFM (2014), the status of fish resource management can be measured by EAFM indicators, i.e.: (1) exploitation rate; (2) fish size trends; (3) proportion of juveniles caught; (4) catch composition; (5) range collapse and (6) ETP species. The results of the EAFM assessment in the fish resource domain can be seen in Table 4.

Table 4

Results of the assessment of fish resources domain in Karimunjawa waters

No	*Indicator*	*Score*	*Weight (%)*	*Density**	*Index value*
1	Exploitation rate	1	40	10	400
2	Fish size trends	2	20	8	320
3	Proportion (juvenile) captured	2	15	8	240
4	Composition of the catch	1	10	4	80
5	"Range collapse" of fish resources	2	10	7	140
6	ETP species	3	5	8	15
	Total	1.83	100		1,155
			Maximum domain value		2,490
			Domain composite value		46.39

*Density represents the number of possible connections among indicators in the EAFM framework. With all indicators, each indicator can be connected to a maximum of eight others (n–1 rule), resulting in a maximum of 36 undirected connections in total. In this assessment, density is used to describe the degree of connectivity among indicators, where a higher density indicates stronger interdependence and greater influence of the indicators on ecosystem or management dynamics.

The results of the fishing technique domain assessment obtained a composite value of 46.39 and an average indicator score of 1.83 in the moderate category (yellow). The exploitation rate indicator has a score of 1 (red). The exploitation rate value gets a value of 0.66 indicating that the exploitation level has experienced overfishing. According to Rithauddin et al (2023), the assumptions on the assessment criteria in determining the exploitation rate value are: E>0.5 means overfishing, E<0.5 means underfishing and E=0.5 is optimal. The exploitation rate value must be optimal with an exploitation value (E) of 0.5 year^{-1}. The exploitation rate value that gets a low score is due to the fishing mortality value being greater than the natural mortality value and causing a decline in parrotfish stocks and can trigger overfishing (Ben-Hasan et al 2021; Maunder et al 2023). As stated by to Clovis & Simon (2024), overfishing can occur if the decrease in fish biomass due to fishing activities is greater than the increase in biomass resulting from the growth process.

The fish size trend indicator has a score of 2 (yellow); the fish size trend is measured to see whether the size of the parrotfish caught is suitable for catching with the size of the parrotfish entering adult size or not yet adult. The size of juvenile parrotfish ranges 5-15 cm (Sievers et al 2020; Eggertsen et al 2020). Based on the results of the study, the

smallest size of parrotfish caught by fishermen was 18 cm and the largest size was 59.9 cm with the size of parrotfish most often caught in the interval of 26.4-30.5 cm.

The Lm (length at first maturity) value of parrotfish ranges from 17 cm to 27.9 cm (Taylor & Choat 2014; Roos et al 2016; Mansyur et al 2021; Pangestu 2021). The size of parrotfish when the sex change occurs "female to male" is in the range of 17.6-24.1 cm (Yanti et al 2023). This shows that the parrotfish that are most often caught have passed the gonad maturity phase and have experienced a sex change from female to male (when the fish have experienced the spawning phase). Parrotfish that have reached their Lm value are more dominant at 82% with a length interval of 26.4-30.5 cm. The size of the parrotfish in this study was smaller than the size of the fish in a study by Pangestu (2021), which observed that the size of the parrotfish caught by fishermen was in the range of 27-32 cm, where 98% of the parrotfish were said to be suitable for catching with an Lm value of 27.9 cm. Based on the results of the interview, it was found that 51% of fishermen stated that the size of the parrotfish obtained was relatively constant. The majority of fishermen who catch parrotfish that have entered the adult phase can maintain the sustainability of the parrotfish ecosystem and coral ecosystem (Roos et al 2020). According to Patanda et al (2021), in maintaining the sustainability of parrotfish resources, fishermen's awareness and knowledge are needed to catch fish that have passed the spawning phase or those caught have laid eggs at least once so that they can maintain the sustainability of fish resources and their habitat (Bezerra et al 2021; Rasekhi et al 2023).

The indicator of juvenile fish proportion has a score of 2 (yellow). This is based on direct measurements of 404 parrotfish samples, which indicate that the average parrotfish caught by fishermen with spearfishing are suitable for catching. Parrotfish's (*Scarus rivulatus*), larval phase has a length of 1-2 cm, their juvenile phase has a length of 5-15 cm and their adult phase has a length of 18.5-24.7 cm (Froese & Pauly 2022; Aswady et al 2019). The first mature gonad size (Lm) of parrotfish is in the range of 17-27.9 cm. The size of parrotfish that is included in the category of being suitable for catching is known by comparing the Lm value of parrotfish with the size of the fish when undergoing sex change with a size range of 18.5-24.7 cm. The size of parrotfish ranging 18.0 - 22.1 cm corresponds to fish not yet suitable for catching, with a percentage of 17.8%, while parrotfish caught with a size ranging 22.2-59.9 cm belong to a category suitable for catching and has passed the juvenile period, with a percentage of 82%. The parrotfish studied were mostly caught at adult size and had passed the gonad maturity phase. Good fishing practice is respected when 90% of the catch has reproduced.

The catch composition indicator is at a score of 3 (green), based on observations of spearfishing fishermen. The catch is composed by: 17% parrotfish (catch target), 55% yellowtail and 28% other bycatch (*Epinephelus* sp., *Siganus* sp., *Caranx* sp., *Lutjanus* sp.). Yellowtail fish dominates the catch the population of yellowtail fish is greater than parrotfish in the coral area habitats. Parrotfish's transition from the larval to juvenile phase takes 2-4 weeks, from juvenile to adult parrotfish phase it takes 3-5 years, then entering into the female to male sex change phase takes a matter of months to a year, depending on the age of the fish, population density and carrying capacity of the habitat environment (Moore 2022). This phase makes parrotfish quite long in adult growth or the catchable size phase (Shantz & Burkepile 2020), therefore fishermen understand that, if they continue to capture the species, it will affect the coral community ecosystem. The existence of herbivorous fish in coral reef ecosystems plays an important role in maintaining coral communities (McClanahan & Muthiga 2020; Molina-Hernández & Álvarez-Filip 2024; Herbig et al 2024).

Range collapse is a phenomenon that occurs when fish stocks experience overfishing due to continuous exploitation activities, becoming increasingly depleted, making it difficult for fishermen to determine fishing locations (Putra et al 2024,2025; Hapsari et al 2021; Gough et al 2020). The range collapse indicator has a score of 2 (yellow), based on the results of interviews with spearfishing fishermen, showing that the fishing locations used by spearfishing fishermen are relatively fixed, depending on the target species to be caught. The distance to the catching zones ranges 1-2 km. 63% of spearfishing fishermen stated that the fishing area is relatively fixed and 37% of them stated that the fishing area is increasingly difficult to rapidly locate, since fishermen

compete in finding fishing locations and the population stock at the location has begun to decline. Range collapse of fish resources can occur if fish stocks experience overfishing due to continuous exploitation activities which result in fish stocks becoming depleted and it is difficult for fishermen to determine fishing locations (Britten & Worm 2021; Link 2021). The selection of fishing areas that are increasingly far away is carried out by fishermen because the presence of fish is very difficult to find in fishing areas that are often visited by fishermen. Sose et al (2022) in their research stated that the selection of fishing area locations is influenced by the availability of fish resources themselves.

ETP species refer to species that are legally protected due to their vulnerable conservation status and high risk of extinction (Hapsari et al 2021; Aprilla et al 2024). The ETP species indicator scored 3 (green). The results of interviews with spearfishing fishermen showed that during their time at sea they had never caught any specimen classified as rare and protected species. Fishermen said that during the fishing process, sometimes several ETP species were accidentally caught, such as the napoleon species (*Cheilinus undulatus*). Fishermen also said that the average number of ETP species caught was no more than 2. However, in recent years, the spearfishing fishermen interviewed have never intentionally caught protected fish, because fishermen already have an understanding and awareness of the regulations regarding the prohibition on fishing these ETP species.

Fishing technique domain. Based on the NWG EAFM (2014), the status of fishing technique management can be measured by EAFM indicators, i.e.: (1) illegal and destructive fishing; (2) fishing modification; (3) fishing selectivity. The result of the EAFM assessment in the fishing technique domain is elaborated in Table 5.

Table 5

Results of the assessment of fishing technique domains in Karimunjawa waters

No	*Indicator*	*Score*	*Weight (%)*	*Density*	*Index value*
1	Illegal and destructive fishing	3	40	10	1,200
2	Modification of fishing	2	35	9	630
3	Capture selectivity	2	25	6	300
	Total	2.33	100		2,130
			Maximum domain value		2,595
			Domain composite value		82.08

*Density represents the number of possible connections among indicators in the EAFM framework. With all indicators, each indicator can be connected to a maximum of eight others (n–1 rule), resulting in a maximum of 36 undirected connections in total. In this assessment, density is used to describe the degree of connectivity among indicators, where a higher density indicates stronger interdependence and greater influence of the indicators on ecosystem or management dynamics.

The results of the fishing technique domain assessment obtained a composite value of 82.08 and an average indicator score of 2.33 which is in the moderate category (yellow). Overall, the destructive fishing indicator is at a score of 3 (green), most spearfishing fishermen stated that there was no illegal or destructive parrotfish fishing or the frequency of violations was <5 cases in the past year. Spearfishing gear is selective because the fish that are the target of the catch can be chosen (Hall et al 2022). Non-target catch occurs minimally. Although the spearfishing technique is selective, it still needs to be monitored. Surveillance activities are carried out to address the possibility of increasing violations that may occur related to fishing, such as careless fishing activities that disrupt coral reef habitats or enter core conservation zones where fishing activities are not permitted (Cremers et al 2020; Carneiro & Martins 2022).

The fishing gear modification indicator is at a score of 2 (yellow). Based on interviews with respondents that have been carried out, spearfishing gear is a traditional fishing gear that has not been modified much; currently fishermen still catch manually by diving and looking for catch targets to be shot with arrows, but there are also some spearfishing fishermen who use compressor aids to be able to breathe longer while diving, which is highly discouraged because of the potential danger. Based on measurements of

parrotfish carried out on 404 samples, it can be seen that the range of length of *S. rivulatus* caught is predominantly 26.4-30.5 cm, in proportion of around 34%, with a Lm value of 18 cm, therefore the spearfishing gear can be said to be selective. According to Rossi (2022), fishing efforts can cause degradation of coastal fishing areas due to the high catch of fish sizes that are not suitable for fishing, due to non-selective fishing techniques.

Selectivity indicator of fishing with indicator 2 (yellow) or moderate, where the measurement of selectivity of fishing gear is divided into 2 types, i.e. selective to species diversity and selective to size (Barbosa et al 2021). Based on the diversity of catches caught by spearfishing, 17% are parrotfish, yellowtail fish catches are 55% and other by-catch (*Epinephelus* sp*., Siganus* sp*., Caranx* sp*., Lutjanus* sp*.*) are 28%. Based on the size of the catch, parrotfish are dominated in the size range of 26-30 cm so that the majority of parrotfish catches are included in the category of fish that have entered the adult phase or have entered the Lm value phase of 18 cm for fish sizes that are suitable for catching. Based on Wang et al (2022) and Yulisti et al (2024) selectivity of fishing is related to the applicative nature of environmentally friendly fishing gear. It should be noted that modifications to fishing gear affect sustainable parrotfish management so that parrotfish stocks do not decline (Pereira et al 2021; Callwood 2021). Spearfishing fishermen in Karimunjawa pay close attention to the size of the parrotfish to be caught and pay attention to the catch quota that is caught each time they carry out fishing activities. Spearfishing fishermen are traditional fishermen who use simple fishing gear and the target catch is generally demersal fish living in coral reef and seagrass ecosystems.

The calculation results of the average composite value of the EAFM domain for parrotfish fisheries in Karimunjawa Waters were 64.23 with an indicator score of 2.08. The results of the analysis of the aggregate composite value and the average indicator score for all EAFM domains showed that the management of parrotfish fisheries in Karimunjawa Waters was categorized as good (Table 6). The contribution of the fishing technique domain to the management of parrotfish fisheries in Karimunjawa Waters was categorized as very good. This was mainly because most of the indicators in the fishing technique domain met the reference point value. In addition, it shows that fisheries management, from the perspective of fishing techniques, is good and needs to be maintained. However, improvements in resource domain indicators are a priority.

Table 6

Overall assessment of EAFM domains in parrotfish fisheries in Karimunjawa waters

Domain	*Calculation value*	*Composite value*	*Indicator score*	*Description*
Fish resources	1,155	46.39	1.83	Moderate
Fishing techniques	2,130	82.08	2.33	Very well
Aggregate	1,643	64.23	2.08	Good

Discussion

Improvement plan in the resource domain. The improvement plan for the exploitation rate indicator gets a score of 1 with a red color or "less" level, at its actual value, where the E>0.5 (overfishing), while the E reference point reach the score level 2, (safe limit) is 0.5. The parrotfish size trend indicator, that gets a score of 2 with a yellow color or medium level, at its actual value, is relatively constant; to increase to a score of 3, the length of fish caught should be subject to an increase trend. The proportion of juvenile parrotfish that gets a score of 2, with a yellow or medium color at its actual value, due to a proportion of juvenile parrotfish which is large (30-60%); the reference point to increase to indicator level 3 is a proportion of young and juvenile parrotfish caught <30%. Finally, there is the range collapse of resources that get a score of 2, with a yellow or medium color on its actual value, for relatively stable fishing locations and fish populations, depending on the species; the reference point for increasing to a score level of 3 is the easiness to detect fishing locations and fish populations, depending on the target species.

Management actions taken in the resource domain could increase the actual value to the reference point level by regulating and controlling parrotfish fishing efforts through licensing and data collection of parrotfish fisheries (fishermen, fishing gear, catches, traders, collectors) and periodically educating and raising awareness among fishermen and collectors regarding the minimum size of fish that may be caught and traded and the exploitation status of parrotfish stocks. The next management action or improvement plan that can be taken is to implement an open-close system for fishing areas with the aim of regulating fishing times so that they can provide opportunities for fish that are still juvenile or young parrotfish to grow up, which can also have an impact on the intensity of controlled fishing (Birkenbach et al 2020). In line with research conducted by Owusu & Andriesse (2020) and Cooke (2021), it is necessary to close fishing areas at certain times, then open them at other times for fishermen to catch, which is called the approach of closing the fishing season (close season) or control of the fishing season.

Improvement plans in the fishing techniques domain. The improvement plan in the domain of fishing techniques addresses two main aspects: (i) modification of fishing gear, and (ii) fishing selectivity. Regarding fishing gear modification, the current performance corresponds to an indicator level 2, which is in the yellow (moderate) category. This evaluation arises because a relatively high proportion of the catch—between 25 and 50% of the individuals of the target species—are captured below the length at first maturity (Lm). Such a situation indicates that a substantial portion of the stock is being harvested before reaching reproductive capacity. The reference point for achieving a higher performance, namely indicator level 3, requires a significant reduction in the proportion of immature individuals caught. Specifically, the proportion of individuals smaller than Lm should be reduced to less than 25% of the total catch.

With respect to fishing selectivity, the indicator value is also currently at level 2 (yellow or moderate). This is explained by the fact that the selectivity of the fishing gears in use remains within a moderate range, estimated at 50–75%. This level of selectivity suggests that the fishing gears employed are not yet highly efficient in targeting only the mature segment of the population. To progress toward indicator level 3, an improvement in gear performance is required. In practical terms, this would involve increasing the selectivity of fishing gears so that more than 75% of the catch consists of individuals above Lm, thereby ensuring a greater contribution to the reproductive potential of the stock.

Management actions or improvement plans require increasing supervision. Supervision of non-selective parrotfish fishing methods is very important, so that violations do not occur. In line with research conducted by Glaviano et al (2022) monitoring activities are carried out to detect violations that may occur related to modifications to fishing gear and fishing aids as well as operating methods that may not meet environmental friendliness standards, in particular the capture of parrotfish that are not yet of a catchable size.

Conclusions. The condition of management and resource utilization of parrotfish spearfishing fisheries in Karimunjawa Waters, was analyzed through EAFM and each domain was assessed. The fish resource domain obtained a composite value of 46.39 and an indicator score of 1.83, corresponding to a moderate status. The fishing technique domain obtained a composite value of 82.08 and an indicator score of 2.33, corresponding to a very good status. The assessment of the condition of each domain for parrotfish fisheries in Karimunjawa Waters obtained an average composite value of 64.23, with an indicator score of 2.08, indicating an aggregate value in the good or moderate category, which indicates that the management and resource utilization in parrotfish fisheries, given the resource and fishing technique domains, are in maximum condition. Improvement actions are needed on the fishing gear modification indicators and the fishing selectivity indicators. Efforts should be deployed to initiate parrotfish fisheries management planning by disseminating the results of parrotfish biota monitoring, regulating environmentally friendly parrotfish catches and providing regular awareness education for business actors in the parrotfish business network.

Acknowledgement. The research team would like to acknowledge the Faculty of Fisheries and Marine Sciences, Universitas Diponegoro, for funding this research (fiscal year 2024).

Conflict of interests. The authors declare that there is no conflict of interest.

References

Aprilla R. M., Rosnita R., Miswar E., Agustina I., Rahmah A., 2024 Status of mackerel scad (*Decapterus* sp.) resource based on Ecosystem Approach (EA) at PPS Kutaraja, Banda Aceh. BIO Web of Conferences 87:03014.

Aswady T. U., Asriyana, Halili, 2019 [Sex ratio and size of the first mature gonads of parrotfish (*Scarus rivulatus* Valenciennes, 1840) in the waters of Tanjung Tiram Village, North Moramo District, South Konawe Regency]. Jurnal Manajemen Sumber Daya Perairan 4(2):183-190. [in Indonesian]

Barbosa M. C., Luiz, O. J., Cordeiro C. A., Giglio V. J., Ferreira C. E., 2021 Fish and spearfisher traits contributing to catch composition. Fisheries Research 241:105988.

Ben-Hasan A., Walters C., Hordyk A., Christensen V., Al-Husaini M., 2021 Alleviating growth and recruitment overfishing through simple management changes: insights from an overexploited long-lived fish. Marine and Coastal Fisheries 13(2):87-98.

Bergstrom D. M., Wienecke B. C., Van den Hoff J., Hughes L., Lindenmayer D. B., Ainsworth T. D., Shaw J. D., 2021 Combating ecosystem collapse from the tropics to the Antarctic. Global Change Biology 27(9):1692-1703.

Bezerra I. M., Hostim-Silva M., Teixeira J. L.S., Hackradt C. W., Félix-Hackradt F. C., Schiavetti A., 2021 Spatial and temporal patterns of spawning aggregations of fish from the *Epinephelidae* and *Lutjanidae* families: An analysis by the local ecological knowledge of fishermen in the Tropical Southwestern Atlantic. Fisheries Research 239:105937.

Birkenbach A. M., Cojocaru A. L., Asche F., Guttormsen A. G., Smith M. D., 2020 Seasonal harvest patterns in multispecies fisheries. Environmental and Resource Economics 75:631-655.

Britten G. L., Duarte C. M., Worm B., 2021 Recovery of assessed global fish stocks remains uncertain. Proceedings of the National Academy of Sciences 118(31):e2108532118.

Budiarto A., Adrianto L., Kamal M., 2015 [The status of crab fishery management (*Portunus pelagicus*) with an ecosystem approach in the Java Sea (WPPNRI 712)]. Jurnal Kebijakan Perikanan Indonesia 7(1):9-24. [in Indonesian]

Callwood K. A., 2021 Examining the development of a parrotfish fishery in The Bahamas: Social considerations & management implications. Global Ecology and Conservation 28:e01677.

Carneiro M., Martins R., 2022 Destructive fishing practices and their impact on the marine ecosystem. In: Life below water. Cham, Springer International Publishing, pp. 295-304.

Clovis H. I. A., Simon A. M., 2024 Understanding overfishing: a literature review. Asian Journal of Fisheries and Aquatic Research 26(1):61-71.

Cooke S. J., Venturelli P., Twardek W. M., Lennox R. J., Brownscombe J. W., Skov C., Danylchuk A. J., 2021 Technological innovations in the recreational fishing sector: implications for fisheries management and policy. Reviews in Fish Biology and Fisheries 31:253-288.

Cremers K., Wright G., Rochette J., 2020 Strengthening monitoring, control and surveillance of human activities in marine areas beyond national jurisdiction: challenges and opportunities for an international legally binding instrument. Marine Policy 122:103976.

Dean M., 2022 A practical guide to multi-criteria analysis. UCL, London, UK, 85 p.

Eggertsen M., Chacin D. H., Van Lier J., Eggertsen L., Fulton C. J., Wilson S., Berkström C., 2020 Seascape configuration and fine-scale habitat complexity shape parrotfish distribution and function across a coral reef lagoon. Diversity 12(10):391.

Froese R., Winker H., Coro G., Demirel N., Tsikliras A. C., Dimarchopoulou D., Scarcella G., Probst W. N., Dureuil M., Pauly D., 2018 A new approach for estimating stock status from length frequency data. ICES Journal of Marine Science 75(6):2004-2015.
Froese R., Pauly D., 2022 FishBase. World Wide Web electronic publication. www.fishbase.org
Gulland J. A., 1987 Natural mortality and size. Marine Ecology Progress Series 39:197-199.
Glaviano F., Esposito R., Cosmo A. D., Esposito F., Gerevini L., Ria A., Molinara M., Bruschi P., Costantini M., Zupo V., 2022 Management and sustainable exploitation of marine environments through smart monitoring and automation. Journal of Marine Science and Engineering 10(2):297.
Gough C. L., Dewar K. M., Godley B. J., Zafindranosy E., Broderick A. C., 2020 Evidence of overfishing in small-scale fisheries in Madagascar. Frontiers in Marine Science 7:317.
Hall A., Cameron D., Kingsford M., 2022 Prohibiting spearfishing boosts conservation outcomes for partially protected areas. Biological Conservation 272:109662.
Hapsari T. D., Bambang A. N., Ghofar A., Fitri A. D. P., 2021 Resource domain assessment of the mud crab (*Scylla* spp.), based on an ecosystem approach to the fisheries located within the Mojo Mangrove Ecosystem, Pemalang Regency, Central Java, Indonesia. AACL Bioflux 14(4):2134-2148.
He P., Chopin F., Suuronen P., Ferro R. S., Lansley J., 2021 Classification and illustrated definition of fishing gears. FAO Fisheries and Aquaculture Technical Paper No. 672. FAO, Rome, 94 p.
Herbig J. L., Olson J. C., Keller J. A., Grove L. J. W., Shea C. P., Acosta A., 2024 Distribution and abundance of herbivorous reef fishes on a barrier reef system in the Florida Keys and Dry Tortugas, Florida. Bulletin of Marine Science 100(2):211-238.
Hiew K., 2012 Coral triangle initiative: ecosystem approach to fisheries management (EAFM): country position paper – Malaysia. The USAID Coral Triangle Support Partnership. Coral Triangle Initiative on Coral Reefs, Fisheries and Food Security Interim, Jakarta, 62 p.
Ismanto A., Ismunarti D. H., Sugianto D. N., Maisyarah S., Subardjo P., Suryoputro A. A. D., Siagian H., 2019 The potential of ocean current as electrical power sources alternatives in Karimunjawa Islands Indonesia. Advances in Science, Technology and Engineering Systems Journal 4(6):126-133.
Krebs C. J., 1989 Ecological methodology. Harper & Row, New York, USA, 654 p.
Lestari D. P., Bambang A. N., Kurohman F., 2017 [Analysis of factors influencing the price of parrotfish (*Scarus* sp.) in Panggang Island, Thousand Islands, DKI Jakarta]. Journal of Fisheries Resources Utilization Management and Technology 6(4):215-223. [in Indonesian]
Link J. S., 2021 Evidence of ecosystem overfishing in US large marine ecosystems. ICES Journal of Marine Science 78(9):3176-3201.
Mansyur S. A. S., Umar M. T., Yasir I., Yanti A., Rahmani P. Y., Aprianto R., Tresnati J., 2021 Intensive catched parrotfish *Chlorurus bleekeri* (de Beaufort, 1940) in Wallace Line, Makassar Strait, Indonesia. IOP Conference Series: Earth and Environmental Science 860(1):012016.
Maunder M. N., Hamel O. S., Lee H. H., Piner K. R., Cope J. M., Punt A. E., Methot R. D., 2023 A review of estimation methods for natural mortality and their performance in the context of fishery stock assessment. Fisheries Research 257:106489.
McClanahan T. R., Muthiga N. A., 2020 Change in fish and benthic communities in Belizean patch reefs in and outside of a marine reserve, across a parrotfish capture ban. Marine Ecology Progress Series 645:25-40.
Molina-Hernández A., Álvarez-Filip L., 2024 Incorporating parrotfish bioerosion into the herbivory paradigm of coral reef resilience. Conservation Letters 17(6):e13058.
Moore B. R., 2022 Age-based life history of Pacific longnose parrotfish *Hipposcarus longiceps* from New Caledonia. Journal of Fish Biology 100(4):997-1008.
Oktary Q., Zahid A., Susiana S., 2024 [Distribution of size and condition factors of blue crab (*Portunus pelagicus* Linnaeus, 1758) in the waters of Madong Village,

Tanjungpinang city]. Akuatikisle: Jurnal Akuakultur, Pesisir dan Pulau-Pulau Kecil 8(2):55-61. [in Indonesian]
Owusu V., Andriesse E., 2020 From open access regime to closed fishing season: Lessons from small-scale coastal fisheries in the Western Region of Ghana. Marine Policy 121:104162.
Pangestu H. A., 2021 [Spawning potential ratio approach for estimating the utilization status of parrotfish fisheries in Karimunjawa Waters]. Research report, IPB University, Bogor, 29 p. [in Indonesian]
Patanda M., Rahmani U., Bambang H., 2021 [Resource utilization rate of parrotfish (*Chlorurus strongycephalus*) by potential ratio spawning method in the Waters of Wakatobi National Park]. Jurnal Ilmiah Satya Minabahari 7(1):48-55. [in Indonesian]
Pauly D., 1980 On the interrelationships between natural mortality, growth parameters, and mean environmental temperature in 175 fish stocks. Journal of Marine Science 39(2):175-192.
Pereira P. H. C., Ternes M. L. F., Nunes J. A. C., Giglio V. J., 2021 Overexploitation and behavioral changes of the largest South Atlantic parrotfish (*Scarus trispinosus*): Evidence from fishers' knowledge. Biological Conservation 254:108940.
Permathasari D. P. T., Restu I. W., Pratiwi M. A., 2021 [Cod fisheries management with an ecosystem approach through the assessment of fish resource domain status in the western season landed at Segara Kusamba Beach, Bali]. Jurnal Pengelolaan Perikanan Tropis 5(2):91-99. [in Indonesian]
Perry C. T., Kench P. S., Leary M. J. O., Morgan K. M., 2015 Linking reef ecology to island building: Parrotfish identified as major producers of island-building sediment in the Maldives 6:503–506.
Putra P. C. P., Wahyudi S. T., Sambah A. B., Sartimbul A., 2024 Growth and mortality model of *Caesio cuning* in Karimunjawa National Park, Indonesia. Biodiversitas Journal of Biological Diversity 25:4215-4222.
Putra P. C. P., Wahyudi S. T., Sambah A. B., Sartimbul A., 2025 Determination fishing seasonal of yellowtail (Blonch, 1791): Case study of Karimunjawa Waters, Indonesia. Journal of Fisheries and Marine Research 9(1):80-88.
Ramadhan A., Apriliani T., 2016 [Characteristics of fisheries resources fishing in Karimunjawa]. Buletin Ilmiah Marina Sosial Ekonomi Kelautan dan Perikanan 2(1): 9–17. [in Indonesian]
Rasekhi S., Sharifian A., Shahraki M., Silvano R. A., 2023 Indigenous fishers' knowledge on fish behavior, fishing practices and climatic conditions in a conservation priority coastal ecosystem in the Caspian Sea. Reviews in Fish Biology and Fisheries 33(3):629-648.
Roos N. C., Pennino M. G., de Macedo Lopes P. F., Carvalho A. R., 2016 Multiple management strategies to control selectivity on parrotfishes harvesting. Ocean & Coastal Management 134:20-29.
Roos N. C., Longo G. O., Pennino M. G., Francini-Filho R. B., Carvalho A. R., 2020 Protecting nursery areas without fisheries management is not enough to conserve the most endangered parrotfish of the Atlantic Ocean. Scientific Reports 10(1):19143.
Rossi S., 2022 Fishing and overfishing-sustainable harvest of the Sea. SDG 14: Life below water: A machine-generated overview of recent literature. Cham, Springer International Publishing, pp. 207-325.
Sievers K. T., Abesamis R. A., Bucol A. A., Russ G. R., 2020 Unravelling seascape patterns of cryptic life stages: non-reef habitat use in juvenile parrotfishes. Diversity 12(10):376.
Shantz A. A., Ladd M. C., Burkepile D. E., 2020 Overfishing and the ecological impacts of extirpating large parrotfish from Caribbean coral reefs. Ecological Monographs 90(2):e01403.
Sose M. F., Paulus C. A., Tallo I., 2022 [Capture fisheries management on an ecosystem approach through the domain of fishing techniques in Kakuluk Mesak District, Belu Regency]. Jurnal Bahari Papadak 3(1):156-166. [in Indonesian]
Sparre P., Venema S. C., 1999 Introduction to tropical fish stock assessment. Manual FAO Fisheries Technical Paper. FAO, Rome, 407 p.

Taylor B. M., Choat J. H., 2014 Comparative demography of commercially important parrotfish species from Micronesia. Journal Fish of Biology 84(2):383-402.
Türegün N., 2022 Financial performance evaluation by multi-criteria decision-making techniques. Heliyon 8:e09361.
Wang Z., Tang H., Xu L., Zhang J., 2022 A review on fishing gear in China: Selectivity and application. Aquaculture and Fisheries 7(4):345-358.
Yanti A., Mashar A., Kleinertz S., 2023 Sex changes and gonad maturity of rivulated parrotfish *Scarus rivulatus* (Valenciennes, 1840) from Seribu Islands, Indonesia. Ilmu Kelautan: Indonesian Journal of Marine Sciences 28(2):203-216.
Yuliana E., Nurhasanah, Farida I., 2019 [Analysis of the sustainability of reef fish resources of the caesionidae family in the Karimunjawa National Park Conservation Area]. Jurnal Matematika, Sains, dan Teknologi 20(1):57-67. [in Indonesian]
Yulisti M., Hidayat A. S., Firdausy C. M., Mu'awanah U., Kurniasari N., Nurjati E., 2024 Effects of eco-friendly fishing gears on fishermen's welfare and sustainable fisheries: Lessons learned from Indonesia. Marine Pollution Bulletin 198:115888.
*** BPS-Statistics Jepara Regency, 2024 [Karimunjawa District in figures 2024]. BPS-Statistics Jepara Regency, 144 p. [in Indonesian]
*** Ministry of Marine Affairs and Fisheries, 2021 [Regulation No. 18/2021 concerning the placement of fishing gears and fishing aids]. Jakarta, Indonesia, 117 p. [in Indonesian].
*** NWG-EAFM, National Working Group on Ecosystem Approach to Fisheries Management, 2014 Module of fisheries management indicators using EAFM (Ecosystem Approach to Fisheries Management). Direktorat Sumber Daya Ikan, Kementerian Kelautan dan Perikanan Republik Indonesia, Jakarta, 174 p.

Received: 22 January 2025. Accepted: 26 September 2025. Published online: 19 October 2025.
Authors:
Trisnani Dwi Hapsari, Department of Capture Fisheries, Faculty of Fisheries and Marine Science, Diponegoro University, Tembalang, Prof. Jacub Rais street, Semarang, Central Java, Indonesia, e-mail: trisnanihapsari@live.undip.ac.id
Faik Kurohman, Department of Capture Fisheries, Faculty of Fisheries and Marine Science, Diponegoro University, Tembalang, Prof. Jacub Rais street, Semarang, Central Java, Indonesia, e-mail: faikkurohman@lecturer.undip.ac.id
Abdul Kohar Mudzakir, Department of Capture Fisheries, Faculty of Fisheries and Marine Science, Diponegoro University, Tembalang, Prof. Jacub Rais street, Semarang, Central Java, Indonesia, e-mail: abdulkoharmudzakir@lecturer.undip.ac.id
Yunitania Simanjuntak, Department of Capture Fisheries, Faculty of Fisheries and Marine Science, Diponegoro University, Tembalang, Prof. Jacub Rais street, Semarang, Central Java, Indonesia, e-mail: yunitaniasimanjuntak@gmail.com
Pranata Candra Perdana Putra, Environmental Science Study Program, Postgraduate School, Universitas Brawijaya, Malang, Indonesia, e-mail: pranatacandrapp@student.ub.ac.id

How to cite this article:
Hapsari T. D., Kurohman F., Mudzakir A. K., Simanjuntak Y., Putra P. C. P., 2025 Evaluation of fishery resources status and fishing techniques of *Scarus* sp. fisheries in Karimunjawa Island, Indonesia. AACL Bioflux 18(5):2287-2301.