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# Morphometrics, Meristics and Fecundity Data from Areolate Grouper (Epinephelus Areolatus Forsskål, 1775) from the National Conservation Area of Pulau Pieh

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***Abstract***

*The Agency for National Marine Protected Area (LKKPN) has the main task of managing marine conservation areas in the western part of Indonesia. The Management Plan for the Pieh Island National Conservation Area (PINCA) has the main objective of maintaining and improving the quality of biodiversity by protecting and preserving fish resources and important ecosystems. Key resources include all coral species in the reefs, turtles and particularly economically important fish species such as grouper. For a balanced management of the grouper fish stocks, data about growth and reproduction are needed. In this paper we reported for the first time population data about Epinephelus areolatus from western Sumatra. The length distribution shows that the grouper population is dominated by individuals in the growth phase towards adulthood. The formula for the length-weight relationship was estimated with W = 0.00928 L 3.08992. From 115 groupers 87 specimens were females with Gonad Maturity Levels (GML) of I (22%), II (22%), III (32%) and IV (24%). The Gonad Maturity Index (GMI) peaked with 1.9 at GML IV, indicating fully mature gonads, ready to spawn. Female fish have larger gonad sizes than male fish. Overall, those data show that waters of Pieh Island and surroundings provide good environmental conditions for the growth of Epinephelus areolatus. Meristic data might indicate morphological uniformity in the grouper population.*

**Keywords:** Fish Population, MPA, Biodiversity, Resources Management, Indonesia

## Introduction

The Agency for National Marine Protected Area (LKKPN) is one of the Technical Implementation Units of the Directorate General of Marine Spatial Management of the Ministry of Marine Affairs and Fisheries. The Pekanbaru LKKPN has the main task of managing marine conservation areas in the western part of Indonesia that have been determined by the government. According to LKKPN (2021, 2022) the Pieh Island National Conservation Area and Surrounding Seas (39,920 ha; legal document No. 56/KEPDJPRL/2023) is located in West Sumatra Province, west of the administrative areas of Padang City in the Padang Pariaman Regency.

The Management Plan for the Pieh Island National Conservation Area (now called PINCA) for 2022-2042, has the main objective of maintaining and improving the quality of biodiversity by protecting and preserving fish resources and important ecosystems in the waters to ensure the sustainability of their ecological functions, realizing the utilization of fish resources and their ecosystems and environmental services in a sustainable manner, in order to improve the welfare of the community around the conservation area. The potential biological resources that are targeted for conservation in the PINCA are all coral species in the reefs, turtles and particularly economically important fish species such as grouper.

Groupers belong to the families of Serranidae and Epinephelidae with preference to live in coral reef ecosystems. Groupers feed

on zooplankton, small fish, shrimp and other small organisms. Therefore, the abundance of groupers is greatly influenced by the presence of food. This again is influenced by several environmental condition parameters such as chlorophyll-a produced by phytoplankton, which is the source of nutrition for zooplankton, as well as sea surface temperature which affects dissolved oxygen in the waters and directly affects the survival of zooplankton and fish [1].

The areolate grouper (Epinephelus areolatus) lives in tropical and subtropical waters and is known as a demersal fish, which lives on the seabed in coral reef habitats and sandy areas. This grouper can reach sizes between 18 and 300 cm with a lateral line that ends just before the caudal fin. Some groupers are protogynous hermaphrodites, which are born as females then turn into males [2]. Epinephelus areolatus has an elongated body shape with a superior mouth position. The body is dark brown to yellowish on the lower part of the head and body. There are yellowish brown spots arranged tightly on the head, body and fins. The caudal fin is upright with a curve at the top and bottom of the caudal fin (emarginate) [2].

Ecologically, Epinephelus areolatus are carnivorous or predatory fish. In addition, economically grouper is a preferred target for fishermen. Their fishing method also greatly affects the sustainability of the ecosystem, especially fishing that is not environmentally friendly. Therefore, the presence or absence of grouper species is a good indicator of the level of anthropogenic disturbance. Data from groupers on morphometrics, meristics and gonad maturity can be used in management and supervision efforts, particularly as an indicator for the presence or absence of key species. As there are hardly any data on groupers in West Sumatran waters available, particularly on one of the key species, the aims and objectives concentrate on Epinephelus areolatus. The overall aim of this study is to assess stock parameters, and develop potential recommendations for management of this species.

## Materials and Methods

This research was conducted for 4 months, namely from September 6th - December 21st 2024, by taking fish samples from three auction locations, only concentrating on fishermen who frequently operate in the conservation area. Three fishermen at each auction location were identified, who caught fish in PINCA using the handline method. The boat they use is a 7 x 1.2 m boat with 15 HP engine. Each boat captain was accompanied by one crew member. Each time they caught fish, they used two fishing gears. The total number of fishing gears used by the three fishermen is six. Sampling was carried out at three locations, where fishermen land fish taken from Pieh Island waters, namely Padang City Purus Beach, Muaro Padang and near Gunung Padang. Measurements and observations of morphometrics, meristics and gonad maturity determinations were made from 115 specimens. The length-weight relationship was determined according to the following equation [3]:

$$W = a \; x \; L^b,$$

where W = Weight (g), L = Length (cm), $a$ = intercept (intersection of the length-weight relationship curve with the y-axis), and b = estimated length-weight relationship coefficient. To determine whether fish growth is isometric or allometric, we tested whether the value of b 86 = 3 or b ≠ 3 (Nurdin et al., 2012; Chodrijah and Faizah 2019). The total length of the fish was measured from the leading edge of the snout to the last edge of the tail fin, by using a measuring board with an accuracy of ±1 cm. The total weight of the groupers was measured using a digital scale with an accuracy of ±0.1 g. The length frequency distribution was obtained by determining the number of class intervals, class widths, class midpoints and frequencies of each class [4]. Then the length frequency distribution was constructed in a LF- Plot according to Restiangsih and Noegoho (2017). orsal fin ray count data were collected from each individual. Parameters recorded include both the number of hard fin rays and the number of soft fin rays. Sex ratio (SR) was calculated using the following equation [5]:

$$SR = \frac{A}{B} x \; 100\%,$$

where A = Number of male or female, and B = Total number of fish.

The Gonad Maturity Level (GML) was determined visually/ macroscopically based on the morphological characteristics of the female and male fish following Zamroni et al., (2019). Fish were dissected and gonads were weighed (Harnic Digital Scale Model HL-3750, precision ±1g). The Gonad Maturity Index (GMI) was calculated by comparing the gonad weight with the total body weight of the fish, multiplied by 100%, using the following formula [3, 6]:

$$GMI = \frac{B_g}{\overline{B_t}} x \; 100\%,$$

where GMI = Gonad Maturity Index, Bg = Weight of fish gonad (g), Bt = Weight of fish body with gonad (g)

### Ethical Statement

The care and use of experimental animals complied with The Constitution of the Republic of Indonesia animal welfare laws, guidelines and policies as approved by Head of The Agency for National Marine Protected Area (LKKPN) with the permit reference number B.345/LKKPN/KP.120/III/2025.

## Results

### Morphometrics and Length Frequency Distribution

The total number of grouper (Epinephelus areolatus) was 115 from three fish auction locations, where fish from Pieh waters is landed. The length frequency distribution is shown in Figure 1.

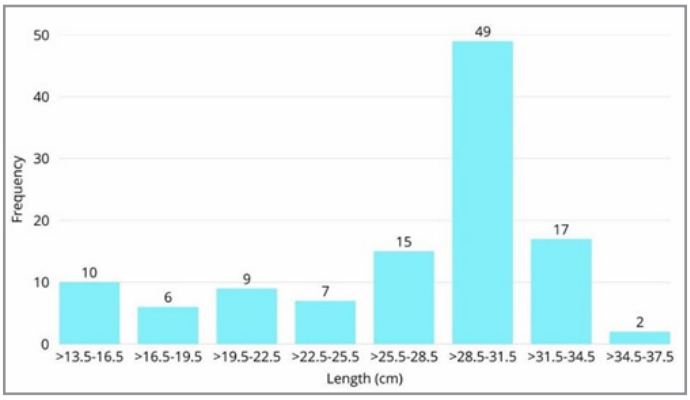


**Figure 1:** Length frequency distribution of grouper (Epinephelus areolatus) from the conservation area, n = 115.

The average length of all 115 grouper (mean ± SD) was 27.2 ± 5.64 cm with a range of 13.5- 37.5 cm. The most frequently caught length was in the range of 28.5-31.5 cm (n = 49) and the least caught size was in the range of 34.5-37.5 cm (n = 2). Length frequency distribution, classintervals, and class mean values, were determined according to Kartini et al., (2017).

The length frequency distribution of female grouper (n = 87) showed an average length (mean ± SD) of 25.9 ± 5.81 cm, with a range of 13.5-37.5 cm (Figure 2 A). The most frequently caught length was in the range of 28.5-31.5 cm (n= 37), the least caught size is in the range of 16.5- 19.5. No fish was caught in the range of 34.5-37.5 cm.

Length frequency distribution of male groupers (n = 28) showed an average length (mean ± SD) of 30.9 ± 2.65 cm with a range of 25.5-37.5 cm (Figure 2 B). The most frequently caught length was in the range of 28.5-31.5 cm (n= 12). The least caught size was in the range of 34.5- 37.5 cm (n = 2). No fish was caught in the range of 22.5-25.5 and above. The overall length frequency distribution showed that males tend to be larger than females, with an average lengthof 30.9 ± 2.65 cm. Most male groupers were in the length range of 28.5-31.5 cm.

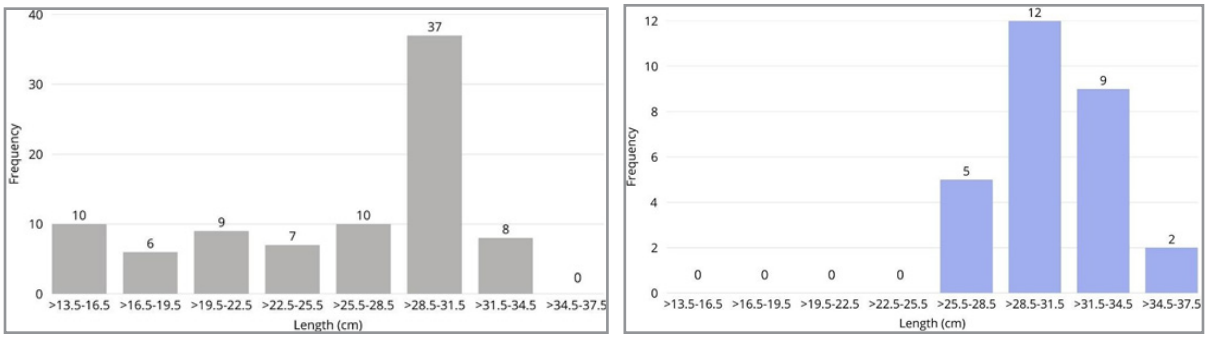


**Figure 2:** Length frequency distribution of female (A) and male (B) grouper (Epinephelus areolatus).

The length-weight relationship of all 115 grouper clearly showed that fish display an isometric growth pattern, where the growth coefficient b equals 3 (Figure 3). This value indicated that the growth of both weight and length increased proportionally (balanced). The length–weight relationship of the grouper revealed an exponent value (b) of 3.08992, with a correlation coefficient (r) of 0.999382 and a coefficient of determination ($R^2$) of 0.98772.

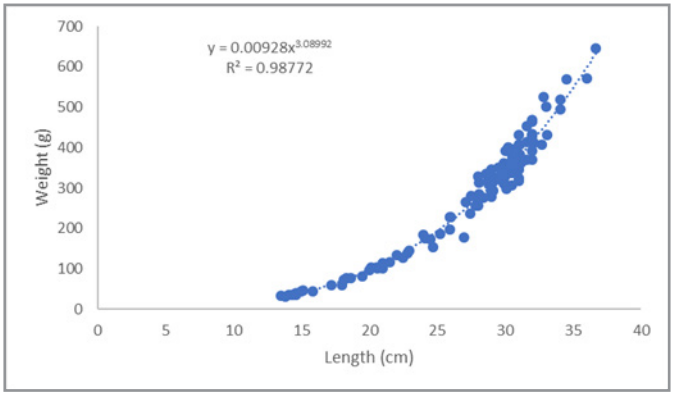


**Figure 3:** Length-Weight Relationship of Grouper (Epinephelus areolatus) from 115 samples.

Fin Ray Count, Sex Distribution and Gonad Maturity

The number of hard and soft dorsal fin rays of groupers was the main morphological characteristic for the identification of this species. The frequency of dorsal fin ray size had a peak distribution at a value of XI,16, namely 46 fish, while some 30 specimens displayed a value of XI,17. All other values, such asX.15

and X.17, had a much lower frequency, with 1 and 2 fish only (Figure 4).

The sex distribution of Epinephelus areolatus showed that 24% of the population were male and 76% were female with a total of 28 and 87 fish, respectively (ratio 1: 3.11 males: females). The gonad maturity levels varied from TKG I to TKG V (Table 1).

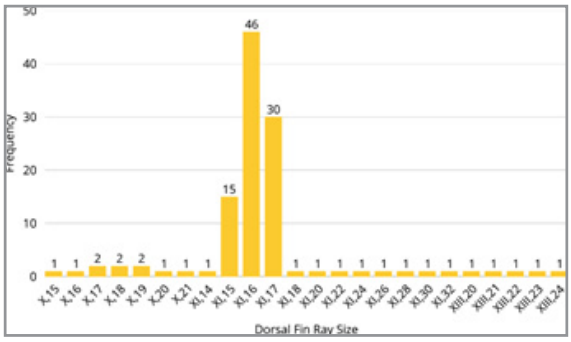


**Figure 4:** Frequency of dorsal fin rays of Grouper (Epinephelus areolatus).

**Table 1:** Total Gonad Maturity Level (GML) of 115 Grouper (Epinephelus areolatus)

| Gonad Maturity Level | All Gonad Maturity | Female Gonad Maturity | Male Gonad Maturity |
|---|---|---|---|
| I | 17% | 22% | 0% |
| II | 17% | 33% | 0% |
| III | 24% | 32% | 18% |
| IV | 32% | 24% | 39% |
| V | 10% | 0% | 43% |

There were 19 specimens classified as GML I (17%) considered immature, while another 19 specimens were classified as GML II (17%), considered beginning maturity. GML III was found in 28 fish (24%), considered as half mature, GML IV in 37 fish (32%), considered fully mature and finally GML V in 12 fish (10%), which means gonads after spawning. Average GMI value of male and female grouper ranged from 0.033 in GML I to 1.903 in GML IV (Figure 5).

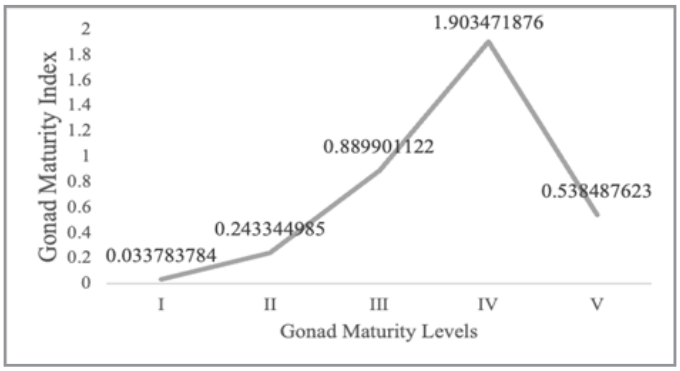


**Figure 5:** Gonad Maturity Index of 115 Grouper from five different Gonad Maturity Levels (GML) (Epinephelus areolatus).

## Discussion

This paper addresses for the first time detailed morphometric, meristic and fecundity data from an economically important grouper species from within a national conservation area. These population data are useful for a potential management of local fishery resources, particularly the area of the Pieh Island National Conservation Area PINCA. The length frequency distribution shows that the grouper population in the Pieh Island Marine Conservation Area is highly dominated by adult individuals (28.5 - 31.5 cm, n = 49 fish), while groupers caught in Kambing Island were only between 26.0-29.9 cm [7].

All data were obtained from fisheries catches, where fishermen confirmed, that they were fishing in the waters of the PINCA. Provided that the fishing effort is evenly distributed and not highly selective, we could draw the conclusion that the structure of the fishery catch represents the fish population structure at PINCA. The population shows a dominance of medium-sized individuals, which may reflect suitable environmental conditions for grouper growth during the sampling period. This phase is important, because medium sized groupers are in the stage approaching gonad maturity, so the potential for future reproduction is quite large. Only two individuals were recorded in the largest size class (34.5–37.5 cm). While larger groupers are generally more susceptible to capture due to their higher market value, the present study was based on a relatively short sampling period and fisheries-dependent data. Therefore, no definitive conclusions can be drawn regarding the influence of fishing pressure on body size structure in the Pieh Island Marine Protected Area. Long-term monitoring and comparisons with

historical data would be required to assess temporal trends and potential fishing impacts.

Epinephelus areolatus is a protogynous hermaphrodite, meaning that this fish starts out as a female and will change into a male when it reaches a certain size or age. Fish that have slow growth, long life span and protogynous hermaphrodites have a higher risk of overfishing and a higher threat of extinction due to a high exploitation pressure [8]. Several researchers stated that grouper populations in Indonesia have experienced a population decline due to increasing fishing pressure (Tuya et al., 2006) [9]. This increase in fishing pressure is a result of an ever-increasing market demand and high economic value [10]. The length frequency distribution of female Epinephelus areolatus shows that most female grouper are in the 28.5-31.5 cm size range, which is just before reaching the critical size for sex change. This size is their active phase in reproduction as females [8]. The absence of female grouper in the 34.5-37.5 cm length range likely indicates that most fish of that size have undergone sex change to males. This is in accordance with the protogynous hermaphrodite pattern, which shows that larger female individuals tend to transform into males after reaching a certain size.

In Epinephelus areolatus, males tend to be larger than females, with an average total length of 30.9 cm. Most male individuals fall within the length range of 28.5–31.5 cm, suggesting that the process of sex reversal from female to male likely begins around this size. The limited number of large male fish (above 35.5 cm) may be attributed to several factors: (1) large males are more actively involved in reproductive activities, making them more susceptible to predation and environmental stress; (2) large groupers are often preferentially targeted by fisheries due to their higher economic value, leading to a decline in the number of large males in the wild; and (3) large males may experience higher mortality rates as a result of dominance competition or unfavorable environmental conditions.

The isometric growth pattern probably reflects environmental conditions that support the growth of grouper in PINCA and the surrounding sea. The availability of food and good habitat conditions allow grouper fish to achieve optimal growth. In tropical areas, food availability could be more important than water temperature, because the temperature in tropical areas is within the optimum range for growth [11]. Our data are well in line with observations of Nuraini with groupers from Berau waters,East Kalimantan Province. A potential difference in growth pattern can occur due to differences in environmental factors. According to Ongkers et al., factors influencing growth patterns are habitat, gender and stages of growth achieved (larvae, juveniles and mature gonad fish) and availability of prey.

In our study we achieved a correlation coefficient (r) of 0.99 and a determination coefficient (R2) of 0.98772 for the length-weight relationship. In the study of Adaka et al., about Sunu grouper (P. leopardus) and Tiger grouper (E. fuscoguttatus) “only” values of 0.90 and 0.94 were achieved. Our analysis of frequency of dorsal fin count values for Epinephelus areolatus in the Pieh Island National Conservation Area and the surrounding sea, yielded a dominant dorsal fin count of XI.16 (n = 46), while counts of X.15 and X.7 were only found for two specimens each. This corresponds well with the study by Heemstra and Randall, who conclude that this value could indicate genetic stability and morphological uniformity in the population. A low frequency would indicate that this combination is rare, and individuals with these characteristics have different genetic variations or come from smaller population groups.

Main factors that affect the shape and arrangement of grouper meristics are differences in age and sex, as well as differences in temperature, light, dissolved oxygen, free carbon dioxide and ammonia. Meristic traits can change due to habitat selection or resource management pressure [12-14]. Meristic characters are not only influenced by salinity, pH and temperature, but are also influenced by genetic factors. These genetic changes or variations can also be caused by lifestyle, environment and species-specific factors. Kusumanigrum et al., stated that genetic changes are also important for the long-term survival of a species and can also guarantee the strength and ability of a species to adapt to environmental changes. Differences in meristic characters can indicate the stability of the population of a particular species [15].

To find out whether the grouper population is in an ideal condition to maintain its sustainability with the assumption that one male grouper will at least spawn the eggs of one female grouper, it is necessary to look at the sex ratio. According to Chodrijah and Budiarti this aspect can be used as an indicator for ideal population conditions. A relatively equal ratio between males and females is essential to ensure optimal breeding potential and long-term population stability [16]. The ideal sex ratio condition is generally supported by good environmental and habitat conditions for the survival of the organism [17].

We found a sex ratio of 1: 3.11, which shows that the grouper population is not balanced, but dominated by females. The occurrence of deviations from ideal conditions is usually caused by differences in growth, so that it affects both the difference in the natural death rate of male and female fish, as well as different behavior in schools, environmental conditions, and fishing factors. However, according to Saputra et al., this fish population is still ideal. In grouper populations in general, the dominance of female grouper is due to being protogynous hermaphrodites, where most grouper start life as females and will change into males as they grow and mature. Those changes in grouper sex are influenced by size, age and species. For example, mud grouper undergoes a sex change from female to male after reaching a body length of 66-72 cm [18].

Information on the level of gonad maturity is needed to determine the size or age of fish when first mature gonads or first spawning occurs and also indicates spawning intensity [19, 17]. The analysis of the total gonad maturity level showed 17%, 17%, 24%, 32% and 10% for the GML levels I to V, respectively. The dominance of specimens in GML III and IV showed that most of the grouper population in the Pieh Island National Conservation Area and the surrounding sea are in a mature condition and ready to spawn.

In Prihartini's research a high percentage of fish are at the peak of spawning even though spawning occurs throughout the year. The availability of fish with different levels of maturity also indicates a continuous recruitment process, which is important for maintaining population stability. If we compare GML of female

and male individuals separately (Table 2), the picture changes. While the females show 22%, 22%, 32%, 24% and 0% for GML I-V, males are only present in three GML groups, with 0%, 0%, 18%, 39% and 43% for GML I-V. This shows that most of the female individuals were ready to spawn. After females reach the mature stage IV and successfully spawn they change sex, which might explain why there are no individuals in the post-spawning phase (GML V).

The majority of male groupers are in GML IV (39%) and V (43%), which shows that most of the male fish are fully mature, and some have passed the spawning phase. The absence of males in TKG I and II indicates that all identified male individuals come from the transformation process of mature females. The role of males in protogynous hermaphrodite populations is very important, because they originate from females that have undergone sex change. This process ensures the balance of sex ratios and reproductive success in the populations.

Gonad development is influenced by several factors including environmental factors and hormones [4]. The dominant environmental factors influencing gonad development are temperature, food, in addition to light periods and seasons [20]. The gonad maturity index GMI, a measure of gonad activity, is generally lower for males than for females at the same level of gonad maturity, because the weight of the female fish gonad is greater than the weight of the male fish gonad [21].

By monitoring changes in GMI based on time, the size of the fish at spawning time can bedetermined, as well as quantitative changes in gonads [22]. The average GMI value of male and female groupers in the Pieh Island National Conservation Area and surrounding seas was identified with 0.033, 0.243, 0.889, 1.903 and 0.538, respectively for the GML levels of I to V. For GML I and II the GMI value was relatively low, which shows that the gonads are still in the early stages of development, where not much energy is allocated to gamete production. The GMI value was significantly higher at GML III, reaching 0.889.

This indicates that gonads were entering the maturation phase and there was an increase in reproductive activity. The peak occurred at GML IV, with a value reaching 1.903. This phase indicates that the gonads were fully mature, ready to spawn. In this phase, the fish allocate most of their energy to reproduction. After spawning, the GMI value dropped again to 0.534. This indicates that the spawning process was completed, and the gonads begun to regress. In Effendie's research (2002) the GMI in male fish is smaller than in female fish, because the weight of the females' gonads is greater due to the deposition of egg yolk in each individual egg [23-25].

## Conclusions

Meristic analysis of Epinephelus areolatus revealed a high degree of morphological uniformity within the population. The presence of mature individuals and balanced growth parameters likely indicated that the Pieh Island Marine Protected Area provided suitable environmental conditions to support a productive fish stock. These findings provide important baseline data for future monitoring and management efforts, while long-term studies and genetic analyses are required to further assess population dynamics and sustainability of Epinephelus areolatus and other reef fish resources in the region. Based on the findings of this study, several management measures are recommended to ensure the sustainable conservation of Epinephelus areolatus populations within the Pieh Island National Marine Conservation Area. Continuous population monitoring should be implemented to assess changes in size distribution, sex ratio, and gonadal maturity over time, thereby evaluating the effectiveness of ongoing conservation efforts. Protecting critical habitats, particularly spawning and nursery grounds, is essential to maintain reproductive success and natural recruitment [26-30].

Regulating fishing practices through the establishment of minimum catch sizes and seasonal closures during peak spawning periods is recommended to prevent overexploitation of immature individuals. Furthermore, enhancing local community participation and awareness in marine resource management through education and capacity-building programs should strengthen collaborative conservation initiatives. Future studies focusing on genetic variation, growth dynamics, and stock assessment of Epinephelus areolatus are recommended to provide a stronger scientific basis for adaptive management and long-term sustainability of reef fish populations in the region [31-35].

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