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Biological aspect approach in sustainable management of coral catshark *Atelomycterus marmoratus* (Anonymous [Bennett], 1830) in Bali Strait, Indonesia

TRI DJOKO LELONO[1,♥], GATUT BINTORO[1], LEDHAYANE IKA HARLYAN[1], ARIEF SETYANTO[1], MIHROBI KHALWATU RIHMI[1], DIDIK RUDIANTO[2]

[1]Department of Fisheries and Marine Resource Utilization, Faculty of Fisheries and Marine Science, Universitas Brawijaya. Jl. Veteran No.16, Malang 65145, East Java, Indonesia. Tel./Fax.: +62-341-557837, ♥email: t.djoko@ub.ac.id
[2]Fishery Instructor Blitar District. Blitar 66133, East Java, Indonesia

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Abstract. *Lelono TD, Bintoro G, Harlyan LI, Setyanto A, Rihmi MK, Rudianto D. 2023. Biological aspect approach in sustainable management of coral catshark* Atelomycterus marmoratus *(Anonymous [Bennett], 1830) in Bali Strait, Indonesia. Biodiversitas 24: 5873-5882.* Coral catshark (*Atelomycterus marmoratus*) is a shark species that thrives in many coral reefs. The study aimed to evaluate the biological aspects of *A. marmoratus* and their type of growth curve for a time series to support their sustainability. Sampling was performed from August 23rd, 2019, to March 31st, 2020. The morphological analysis was performed by recording or photographing to reduce possible errors. Then, the length-weight relationship, sex ratio, length at first captured and matured, and spawning ratio were evaluated. The present study demonstrated that the coral catshark captured in the cohort that produces two cohorts only happens in February. The sex ratio is 41.6% male and 48.4% female, which is considered healthy, whereas the remaining percentage is so severely damaged that its gender cannot be determined. The FISAT-II software analysis results in a von Bertalanffy growth formula of $Lt = 76.21 (1-e^{-2.01(t+0.0596)})$ with t max = 1.49/ year and L max = 77.39 cm. They grow steadily or tend to slow down after they reach the age of 1.5 years, with an asymptotic length of 77.39 cm. The L_c value (67.5 cm) is more significant than their L_m value (53 cm), indicating that their sustainability is highly possible to maintain because only fish that have passed the spawning stage are captivated. The spawning potential rate (SPR) is 35%, with M = 0.66, E = 1.85, and F = 0.78. These results indicate that the exploitation rate of coral catshark is moderate because 20% < SPR < 40%. In conclusion, the *A. marmoratus* length-weight relationship is categorized as negative allometric, where the length grows faster than the weight.

Keywords: Growth rate, Length Weight Relationship, Length at First Capture (L_c), Length at First Mature (L_m), Spawning Potential Ratio (SPR)

Abbreviations: Length at First Capture (L_c); Length at First Mature (L_m); Spawning Potential Ratio (SPR)

INTRODUCTION

The sustainability of the fisheries world depends on appropriate managerial strategies and the availability of information such as bio-ecological factors, the status of the population (the genetic structure of the population), connectivity, size, and species dynamics. Information about the biological parameters of species is the main requirement for developing and implementing sustainable fisheries management strategies (Heupel et al. 2018; Hasan et al. 2021a; Hasan et al. 2023). Thus, the biological characteristics of coral sharks require a detailed explanation, which includes their growth rate, length at first maturity (L_m), length-weight relationship, length at first capture (L_c), and spawning potential ratio (SPR) to sharks, stingrays, and chimeras are members of the Chondrichthyans. Overfishing threatens over a third of the three species, which are megafaunal lineages phylogenetically varied and ecologically essential in coral reefs. These three fish have distinct life histories that render them highly vulnerable to anthropogenic pressures such as overfishing, habitat loss, and increased shark fisheries due to global warming, which can jeopardize their long-term viability and support their sustainable management. Exploited oceanic species, biological information, and population dynamics are the basic requirements to evaluate the species' resilience against exploitation to determine the optimum catching strategy and help determine its alternative management (Fogarty and Siskey 2018; Hasan and Islam 2020; Hasan and Widodo 2020b; Hasan et al. 2021b).

Sharks, stingrays, and chimeras are members of the Chondrichthyans. Overfishing threatens over a third of the three species, which are megafaunal lineages phylogenetically varied and ecologically essential in coral reefs. These three fish have distinct life histories that render them highly vulnerable to anthropogenic pressures such as overfishing, habitat loss, and increased shark fisheries due to global warming, which can jeopardize their long-term viability (Last et al. 2016; Rahayu et al. 2020; Dulvy et al. 2021; Ebert et al. 2021; Wannell 2021). Human activity contributes significantly by providing direct economic advantages that come from the fisheries and tourism industries, becoming a crucial food source in many parts of the world, and playing a substantial ecological role in aquatic ecosystems (Anna and Saputra 2017; Awruch 2018; Hall 2021). On the other hand, sharks are among the most vulnerable vertebrates facing anthropogenic stressors such as overfishing (Worm et al. 2013; Queiroz et al. 2019; Albano et al. 2021). Furthermore, sharks are top predators and critical species, which can have a significant effect on the ecology, food web, and dynamics of coral reefs and oceanic pelagic (Sofyan et al. 2020; Díaz-Delgado et al. 2021). According to DNA barcoding analysis of shark fin in marine fisheries caught in Indonesian waters, there are two major concerning issues, which are (1) the rarity of reef sharks that supposedly dominate the Indonesian coastal ecosystem and (2) the marine fishing system that leads to shark extinction (Sembiring et al. 2015).

The abundance of sharks living in the coral reefs is encouraged by top-down processes (predation and competition) and bottom-up approaches (such as recruitment and disturbance). Therefore, the alteration of trophic structure can only be linked to one of these processes if both are quantified simultaneously (Conversi et al. 2015). According to food analysis, reef sharks generally are mesopredators with the highest trophic rank and are almost identical to big piscivore (Roff et al. 2016).

The genus *Atelomycterus* Garman, 1913, consists of three recent species, *A. fasciatus* Compagno & Stevens, 1993, *A. macleayi* Whitley, 1939, and *A. marmoratus* Bennett 1830 (Compagno 1999; Bor et al. 2003) Coral catshark (*A. marmoratus*) is a member of Scyliorhinidae (Carcharhiniformes family). The genus member of Atelomycterus consists of five species: Banded Catshark *Atelomycterus fasciatus* (from northwest Australia) (White 2015), Australian Marbled Catshark *Atelomycterus macleayi* (Card 2019) Catshark *A. marmoratus* (from north Australia), West Indo-Pacific (White 2003; Bernal and Lowe 2015) and Balinese Catshark *Atelomycterus baliensis* (from Indonesia) (White 2007).

Atelomycterus marmoratus can be distinguished from other species in the same genus by its coloration, which is dominated by dark brown dots and marks in the shape of the saddle, light grey and white dots on the head, body, and fins, bold white stripes through the gills, and a long and narrow clasper (Fahmi and White 2015). *Atelomycterus marmoratus* has a most comprehensive geographic range and can thus be found in the whole area of the West Indo-Pacific (India, Pakistan, all the way to Vietnam, the Philippines, and New Guinea) (Fahmi and White 2015). *Atelomycterus marmoratus* is a little-known on-shore species that lives in coral reef cracks and crevices. Fishing boats occasionally catch them on coral reefs, and they are utilized fresh and dried, salted for food, or processed for fishmeal and oil (Maran et al. 2022). Sharks have a high vulnerability but low fecundity, a high trophic rank, and a lack of biological information. Thus, this research aims to observe its stock status based on biological aspects to give useful advice on managing sustainable marine fisheries for coral cat sharks.

MATERIALS AND METHODS

Study scope

This research began on August 23rd, 2019 - March 31st, 2020, at Coastal Fisheries Harbour (CFH) of Muncar, Banyuwangi District, East Java, Indonesia (Figure 1).

Procedures

The method applied in this research is direct observation once fishing boats pull over to Muncar Harbour. The fishing location and other relevant information are obtained by interviewing the fishermen on the spot while caught sharks are named. The identification process is conducted by taking their pictures and giving them a tag, followed by observing their characteristics, including their body shape, coloration, fin shape, mouth shape, and head shape. The identification process is performed according to the book Sharks and Rays Borneo and The Identification Guide to Sharks, Rays, and Skates of the Southeast Asian Region (Last et al. 2010; White et al. 2011; Ali et al. 2017). The next step is measuring their morphometry, including the length (standard, forked, total, and claspers), weight, sex, and maturity level.

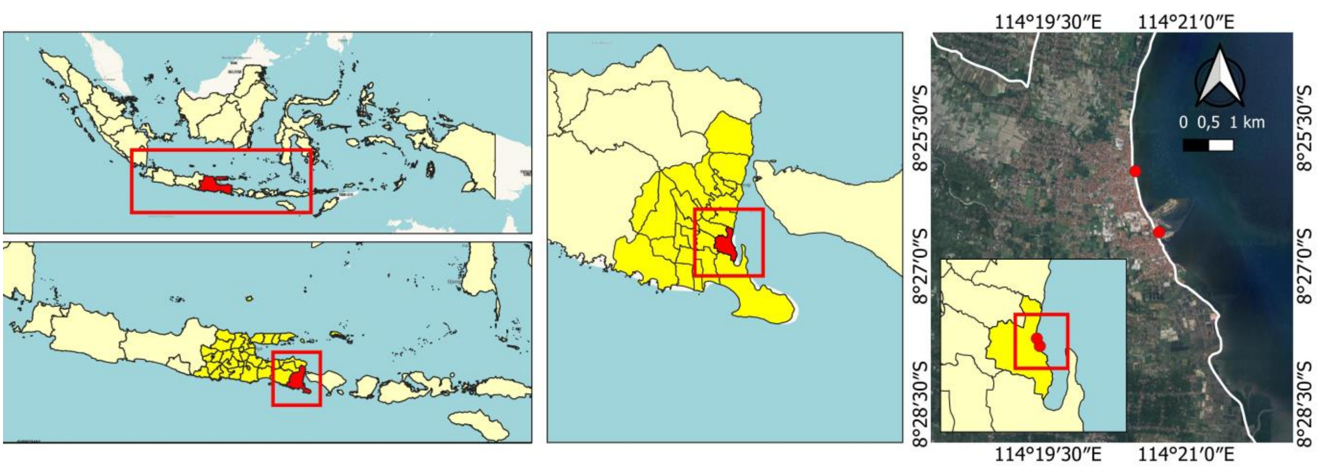

Figure 1. Sampling site at Muncar Harbor, Banyuwangi District, East Java, Indonesia

Morphological analysis

The required morphological data are obtained by recording or photographing all the shark species to minimize any possible errors along the identification process due to their high degree of similarity in their physical appearance (Oktaviyani et al. 2019).

Analysis of length-weight relationship

The mathematical equation used to describe the length-weight relationships (LWR) is W= a x $(TL)^b$, where W is the total weight (g), TL is the full length (cm), and a and b are the coefficients of regression (Jisr et al. 2018). Coefficients of regression (a and b) and r2 (coefficient of determination) are estimated using the least-square fitting method applied to the logarithm-transformed length-weight relationships (LWR) LWR expression log W = log a + b log TL (Jisr et al. 2018). To find out whether b is allometric or isometric, statistical t-test analysis is performed with the formula and hypothesis as follows:

$$t_{count} = \left| \frac{(3-b)}{(Sb)} \right|$$

H0 = Count> T table; the value of b = 3 (isometric)
H1 = Table> T_{count}; the value of b ≠ 3 (allometric)

Sex ratio

The determination of the sex ratio is analyzed using the following equation by (Shin et al. 2023).

$$SR = \frac{\sum M}{\sum F}$$

Where:
SR : sex ratio
∑M : number of male fish
∑F : number of female fish

Determination of sex balance analysis is carried out using the chi-square test (Young 2017; Hermawan et al. 2023) as follows:

$$X^2 = \frac{\sum(Oi - ei)^2}{ei}$$

Where:
X^2 : *chi-square*
Oi : number of observed frequencies
Ei : number of expected frequencies

If the analysis result shows the value of X^2count < X^2table (0.005), H_0 is accepted. This result means no significant difference in the sex ratio between males and females and vice versa.

Comparative gender analysis

The ratio between the total number of male and female sharks is calculated using the formula as follows:

$$GR = \frac{Nfi}{Nmi}$$

Where:
GR : Gender Ratio
Nfi : The Number of individual females
Nmi : number of male individuals

The sex comparison test has been carried out using the Chi-Square test with a 95% confidence interval, namely:

$$X^2 = \mathcal{E}$$

Where:
X^2 : Chi-Square
Fo : frequency observed
Fn : The expected frequency

Test the table within the 95% confidence interval (n-1) with the following hypothesis:

H0 = There is no significant difference between the number of male and female shark

H1 = There is a significant difference between the number of male and female shark

If X^2 counts < from the X^2 table, H0 is accepted, and H1 is rejected, and vice versa.

Analysis of sexual maturity level

The level of sexual maturity in male sharks is primarily determined by the state of the clasper, which is affected by the liming process. The liming process makes the clasper longer and harder. The smaller size of the clasper indicates shark sexual immaturity. It is essential to know the level of sexual maturity to determine the spawning season and period. The length of sexual maturity in the same species varies widely and does not have to be the same.

Aspects of fish population dynamics. Length at first capture (L_c)

The value of L_c is extracted from the length-frequency data, which results from the calculation of the highest mode middle value of the frequency of the middle-value class. Analysis of length frequency distribution was done using the normal distribution approach. The length at first capture (L_c) value can be calculated using the formula (Lelono et al. 2021a):

$$y' = ln\, ln\, Fc\, (x + dL) - ln\, ln\, Fc(x)$$

Where Fc (x) is a normal distribution curve that has the following equation:

$$Fc = \frac{n.dL}{s\sqrt{\pi}} \times \left[\frac{-(x-x)^2}{2s^2} \right]$$

Where:
Fc : Calculated frequency
N : Total of observations
dL : Class interval
s : Standard deviation
ẋ : Average count
π : 3,14

Aspects of fish population dynamics. Length at first mature (L_m)

L_m is the body length where 50% of individuals of both sexes have reached sexual maturity at least once (Perez-Palafox et al. 2022). L_m analysis is carried out using a logistic curve equipped with non-linear smallest quadrat regression as follows:

$$P = \frac{1}{1+e^{-(a+bLm)}}$$

and

$$Lm = -\frac{a}{b}$$

Where:

P : proportion of adult fish
a : intercept
b : slope of the maturity curve
L_m : size of 50% adult fish

Aspects of fish population dynamics. Spawning Potential Ratio (SPR)

SPR is defined as the ratio of total reproduction production on the balance for mortality rate in particular catch divided by reproduction production if not caught (Hordyk et al. 2015a). This metric is usually known as static SPR or equilibrium (Hordyk et al. 2015b). It represents the expected equilibrium SPR if the stock is maintained without time limitation on the mortality rate of a particular catch and constant recruitment.

The required parameters in SPR analysis are natural mortality (M), coefficient of growth (K), asymptomatic length (L_y), and length at first maturity (L_m) (Yonvitner et al. 2021). The analysis is carried out using the length-based spawning potential ratio (LB-SPR) method, which requires an input of the frequency of length distribution. SPR analysis was carried out using the formula as follows:

$$R = \frac{\sum(1-\tilde{L}_x)^{(M/k[(F/M)+1]}\tilde{L}_x^b}{\sum(1-\tilde{L}_x)^{(M/k}\tilde{L}_x^b} \quad \text{For: } xm\ \ddot{y}\ x\ \ddot{y}\ 1$$

Where:

Lx : total length
M : natural mortality rate
k : coefficient of growth
F : captive mortality rate
b : exponent (usually close to 3)

Aspects of fish population dynamics. Growth rate

The growth rate is estimated by the Von Bertalanffy formula and performed by FISAT-II software with Length Frequency Analysis (ELEFAN-II) (Damora et al. 2021) as follows:

$$L_t = L_\infty (1 - e^{-k(t-t_0)})$$

Where:

L_t : length of the fish at age year t (cm)
L_∞ : possible maximum length of fish
t_0 : theoretical age of fish at zero length
k : growth coefficient
e : natural number; e = 2.71

Determination of t_0 is performed using the following equation (Pauly 1980)

$$\log(-t_0) = -0,3922 – 0,2752(\log L_\infty) – 1,038(\log K)$$

Maximum age (Tmaks, in a year) is calculated using inverse VBGF (Pauly 1980) and making the model as $T_{maks} \approx 3/K$ as follows:

$$\text{Log}(M) = -0.0152 - 0.279 \log(L_\infty) + 0.6543 \log(K) + 0.463 \log(T)$$

Where:

$L\infty$: asymptotic total length (as estimated by allometric relationship TL–CL, where CL : $CL\infty$),
K : coefficient of growth
T : average annual temperature of the habitat of catched fish

RESULTS AND DISCUSSION

Distribution of length frequency

The *A. marmoratus* has a unique color pattern with greyish to brownish in the dorsal body and white spots outlined in black from head to tail. *Atelomycterus marmoratus* could reach a maximum length of up to 700 mm (Oktaviyani et al. 2019). During eight months of data collection, data of length frequency is successfully obtained. Based on the Bhatacharya approach (Bhattacharya 1967), only *A. marmoratus* sharks that were captured in October gained two cohorts, while sharks captured in the other months gained only 1 cohort (estimated length around 43,5-67,5 cm with cohort peak at 55,5 cm (Figure 3).

Length-weight relationship

Analysis of the length-weight relationship reveals the coefficient of determination (R^2) value as 0.7699 and the W value as $9E\text{-}06L^{2.7412}$ (Figure 4). This result implies that the growth pattern of *A. marmoratus* during this research is categorized as negative allometric with a T value as 2.579144 > Ttab 1.970659, b value as 2.741, and r square value as 0.769. In conclusion, the fish's body length affects its body weight by 76%.

Length at first capture (L_c)

The data shows the highest fish total length is 67.5 cm, and the lowest is 43.5 cm (Figure 5). Linear regression analysis shows the value of intercept (a) is 5.526, x variable (b) is -0.096, Fsig is 0.002, and r square value is 0.970. This result implies that the independent variable affects the dependent variable by 97%. Lc Value obtained by this analysis is 57.18, which is the length of *A. marmoratus* at first capture.

Figure 2. Coral catshark, *Atelomycterus marmoratus,* in the waters of Bali Straits, Indonesia

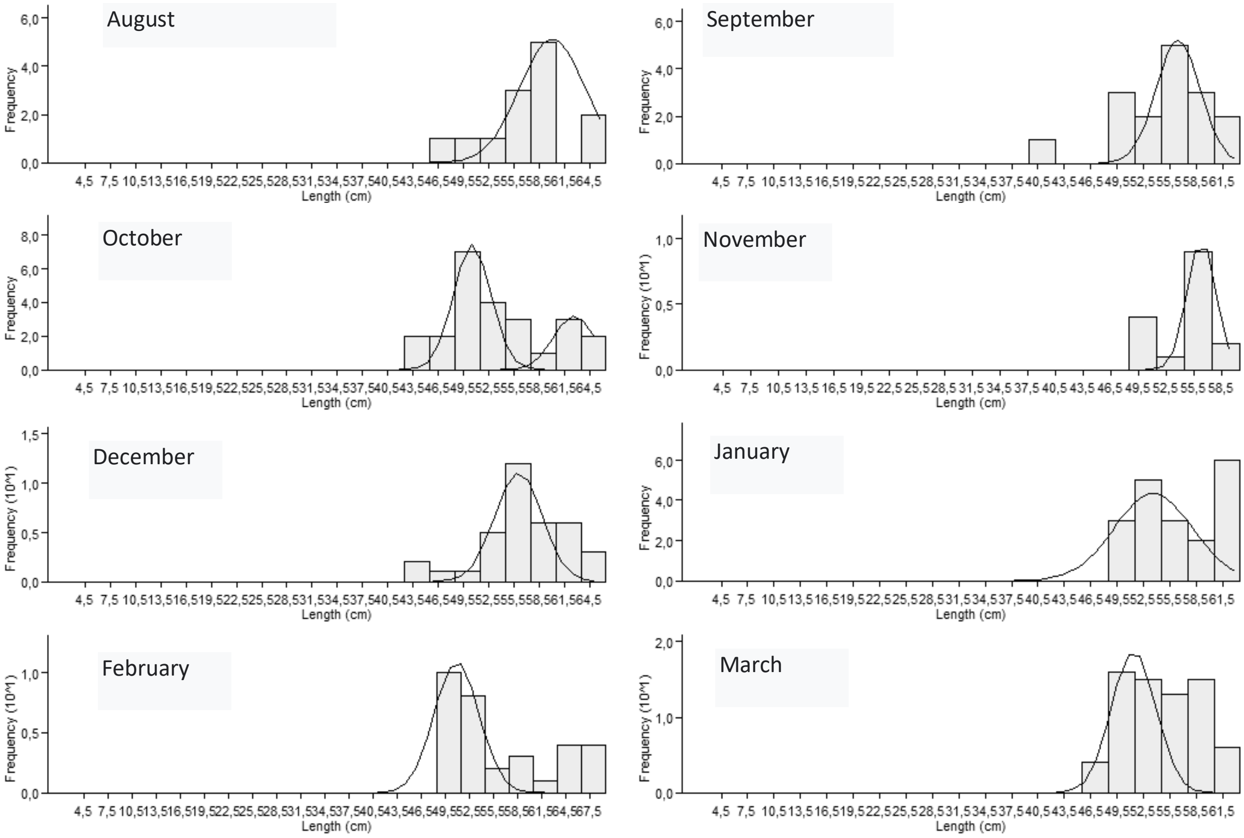

Figure 3. Distribution of length frequency of *Atelomycterus marmoratus*

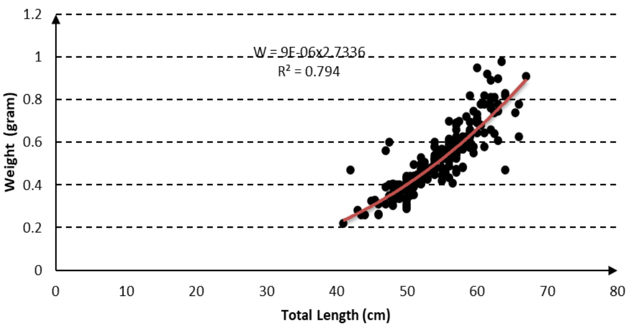

Figure 4. The curve of the length-weight relationship

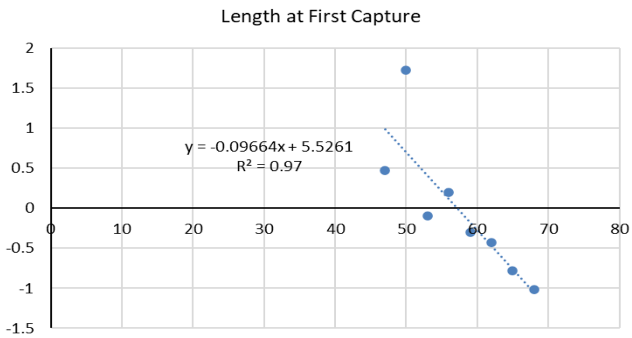

Figure 5. Length at first capture

Sex ratio

Sex ratio analysis can act as a balance indicator between male and female *A. marmoratus*. The sex ratio analysis of 225 *A. marmoratus* shows a male : female ratio of 1:1.16 or 41.6%:48.4%. The entire sex ratio of *A. marmoratus* could not achieve 100% due to numerous fish that were landed being severely damaged, and it was also unable to determine if the fish was male or female.

Length at first mature (L_m)

The total number of *A. marmoratus* whose clasper maturity can be observed is 105, with a total mature clasper of as many as 63 fish. The total length of *A. marmoratus* measured directly on the field ranged from 43 to 66 cm. According to the analysis, the value of intercept (a) is 3.418, x variable (b) is -0.064, r is 0.064, F_{sig} is 0.326, and R square is 0.137. Thus, the L_m of *A. marmoratus* is 53 cm (the size when *A. marmoratus* spawns for the first time).

Growth rate

According to data analysis using FISAT-II software, an equation of $Lt = 76.21\ (1\text{-}e^{-2.01(t+0.0596)})$ is obtained with the t_{max} is 1.49/year, and the L_{max} is 77.39 cm (Figure 6). The growth curves illustrate the growth of *A. marmoratus* is extremely rapid at 0-1.5 years old and starts to slow down after 1.5 with an asymptotic length of 77.39 cm.

Mortality rate

The mortality rate is analyzed using FISAT-II software through a length-converted catch curve sub-program. The result shows the hypothetical value of the total mortality rate (Z) is 8.17/ year. On the other hand, the natural mortality rate (M) is analyzed using the Pauly equation (1983). The result shows L∞ = 76.21 cm, K = 2.01/ year, and T = 28°C, resulting in an M value as big as 2.28/ year with a captive mortality rate (F) = 5.89/ year (Figure 7).

Spawning Potential Ratio (SPR)

The analysis of 105 male *A. marmoratus* with a body length of 41-66 cm using FISAT-II software is conducted to obtain K and L∞ values. The next step is analyzing the value of natural mortality rate (M), captive mortality (F), exploitation rate (E), and total mortality (Z) (Figure 8). The results show the value of L∞ = 75.58 cm, K = 0,32, Z = 1.44, M = 0.66, E = 1.85, F = 0.78, and, finally, SPR = 35%.

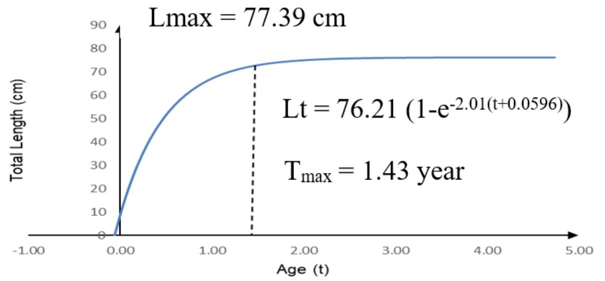

Figure 6. Growth rate

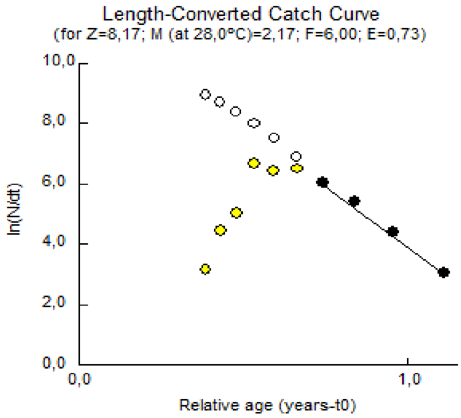

Figure 7. Mortality rate

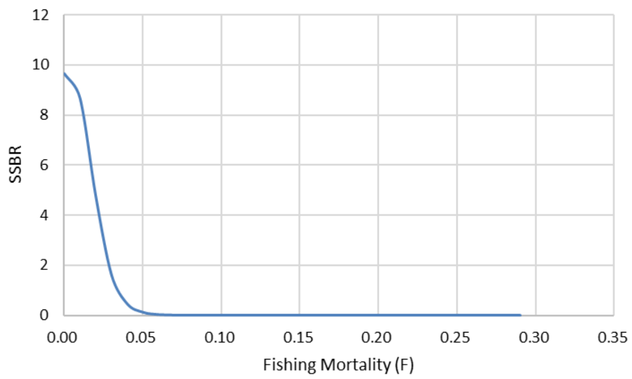

Figure 8. Spawning potential ratio

Discussion

The length frequency distribution analysis is performed to identify the age group (modal group) or the size of a similar age group (cohort). There are two different age groups in February, which might result from different fishing grounds. The length frequency data is the simplest and most affordable, or it could be the only metric for small fisheries suffering from data insufficiency. The average length of captivated *A. marmoratus* was 55.5 cm, typically gained at 2.5 years, depending on the environmental factors. These findings are consistent with a prior study that revealed the average length range of male *A. marmoratus* to be between 25.5 and 57.5 cm (Oktaviyani et al. 2019). Based on our results, the L_c of *A. marmoratus* was 97% influenced by independent variables. This phenomenon might be explained by genetic factors, food availability, sea surface temperature, or fishing pressure in the coral reef community (Oktaviyani et al. 2019; Vergara-Solana et al. 2019). Food availability significantly affects the maximum individual size, while the sea surface temperature might affect the size ratio (Vergara-Solana et al. 2019). Moreover, climate change burdens fisheries more by altering fish schooling, migration patterns, and the vulnerability of fish species (Chen et al. 2021). According to research by Hövel (2010), *A. marmoratus* eggs require approximately 4-6 months to hatch, with a total body length between 10-13 cm. The newly hatched juveniles will grow to 4-5 cm in 3 months (Hövel et al. 2010; Oktaviyani et al. 2019).

The result of the length-weight correlation indicates a negative allometric pattern, which means *A. marmoratus* length grows faster than its weight. A low coefficient b also can be found in *C. falciformis* in the Indian ocean (Lelono et al. 2021b,c; Nurdin et al. 2023). The growth pattern of species may vary between different populations of the same species or in the same population at different times of the year, depending on food availability (Narvaez et al. 2016), quality of water (Tumwesigye et al. 2022), biological factors, and period (Paujiah et al. 2023). This growth pattern might also be affected by sampling (Mehanna and Farouk 2021), which includes the fishing ground, the fish community, the weight of the fish in each observation, the sampling period, or the error caused by the observer or the laboratory equipment. On the other hand, isometric growth patterns, the positive and negative allometric, can be easily observed in the same species in different areas or environments, as been observed in *Diplodus vulgaris* and *Boops boops* (El Samman et al. 2022; Ragheb and Akel 2022). To conclude, various factors such as the reproduction cycle, food availability, and habitats and environments could affect fish growth (Li et al. 2023).

Fishing grounds, fishing equipment, and fishing methods are among the factors that could cause a humble difference in the sex ratio of *A. marmoratus* (male: female, 1:1.16). This research is fairly similar to research on blue sharks (*Prionace glauca*), the most caught shark by the Rawai Tuna fleet, which has a sex ratio of 1:0.91 (male: female) (Zainudin et al. 2017). This implies the healthy state of the sharks when caught. On the other hand, overfishing, as a stressor, could greatly impact the shark population. The impact is probably greater if the fishing ground is also the breeding ground of the sharks. The mean size at first maturity was estimated to be 557 mm for females and 514 mm for males, based on the relationship between the proportion between maturity stage and total length. The ovulation season was estimated to occur from October to March, whereas September to April was the mating season based on monthly variations of gonadosomatic index (GSI) values and the occurrence of egg cases in the uterus (Oktaviyani et al. 2019; Alhajji et al. 2022).

In this research, L_m is smaller than L_c ($L_m < L_c$), which indicates that the first captured *A. marmoratus* had spawned and was feasible to catch. L_m value determination is a critical indicator for maintaining *A. marmoratus* stock management. Thus, their sustainability could be maintained (Oktaviyani et al. 2019). Some previous research has revealed that fishing juvenile fish could be a severe stressor on this precious species and may lead to an extreme decline in its population. Thus, prohibition on fishing juvenile fish may be a massive aid in maintaining their sustainable exploitation in years to come. To avoid overexploitation, some strategies could be implemented, such as increasing the size of fishing rods and nets, prohibiting the use of destructive fishing gear, and collaborating between policymakers, stakeholders, and fishermen to improve marine ecosystems by enhancing biodiversity for the sustainable development of marine resources (Bennett et al. 2018; Napitupulu et al. 2022).

The growth model is crucial to value the stock used to maintain commercially critical oceanic invertebrate species. This size-based valuation model can illustrate population dynamics better than age-based models, as different growth models are required to analyze the same species in different areas (Flinn and Midway 2021). Fish growth models are needed to predict the outcomes of fisheries, improve production in fish farming, and analyze the dynamics of a fish population. Several models, such as the von Bertalanffy growth model (VBGM), the Gompertz growth model, and the logistic model, have been widely used to describe fish growth (Smart and Grammer 2021). The most studied and commonly applied model of fish growth is the von Bertalanffy model (Smart and Grammer 2021). According to von Bertalanffy's growth model analysis using equation $Lt = 76.21\ (1\text{-}e^{-2.01(t+0.0596)})$, the K value is 2.01. K value indicates that the growth speed of the catsharks is exceptionally rapid in the age of 0-1.5 years, and the speed begins to decline, or becomes steady, after 1.5 years with asymptotic length = 77.39 cm. This condition might be the result of one of the most critical environmental factors that affect fish growth (Kim and Lim 2017; Musa et al. 2020), the metabolism speed and the growth speed (Pistevos et al. 2015), which is best in their juvenile age. The effect on the growth in the initial stage of sexual maturity might have been observed more frequently than in the other live stages (Bello et al. 2015; Jisr et al.; 2018; Oktaviyani et al. 2019).

The survival of an individual in the population is influenced by varied factors in the oceanic ecosystem, such as food scarcity, competition, and predation (Sobocinski et al. 2021). The natural mortality rate (M) of coral catsharks is 2.28/ year, and their captive mortality rate (F) is 5.89/ year. Higher or lower natural mortality rates might be caused by water temperature, salinity, rainfall, and predation.

The M value from SPR analysis is 0.66, the E is 1.85, and the F is 0.78. Thus, the final SPR value is 35%, which means that the exploitation level of *A. marmoratus* is moderate because 20% < SPR < 40%. This result is also indicated by the captive mortality rate (0.78), which is smaller than the natural mortality rate (0.66). A higher captive mortality rate means a higher exploitation rate. The determination of stock status relies on the ability to estimate current stock size, which depends on the reference point of maximum sustainable yield (MSY). The proxy reference point based on SPR has been proven on the uncertainty in the equation of stock-recruitment that was underlying it together with other relevant biological parameters (Legault and Brooks 2013; Anna and Saputra 2017; Scott et al. 2016). SPR is a fraction where a captive mortality rate subtracts a recruit's lifetime reproduction yield (Hordyk et al. 2015a; Fisch and Camp 2022).

Several observations of reef sharks were undertaken in Indonesian territorial seas. Three reef sharks, *Carcharhinus melanopterus*, *Triaenodon obesus*, and *Carcharhinus amblyrhynchos*, representing eight families, were discovered in the South Morotai Waters of North Maluku.

In contrast, in Cenderawasih Bay National Park, SST and SSC parameters are the two most critical characteristics influencing the presence of whale sharks, followed by SSHD, depth (bathymetry), and current parameters. On the other hand, human activities affecting fish and their habitats, such as fishing and tourism, are accountable for declining whale shark populations (Anna and Saputra 2017; Manuhutu et al. 2021). A previous study conducted by Md-Zain et al. (2018a) demonstrated that 88.2% of individuals were found in a local market in Malaysian Borneo where sharks were endangered *(Lamiopsis tephrodes*, *Sphyrna mokarran*, and *Sphyrna lewini*), vulnerable (*Alopias pelagicus* and *Rhynchobatus australiae*), and near threatened (*Carcharhinus limbatus*, *Chiloscyllium griseum*, *Carcharhinus sorrah*, and Carcharhin). Each taxonomic position is given the same morphological character by knowing the evolutionary link between guitarfish, sharks, and rays. As a result, it will be beneficial to identify the species of guitarfish, sharks, and rays before they are consumed from the local fish market (Md-Zain et al. 2018b). While studies on the bigeye thresher shark (*Alopias superciliosus* Lowe, 1841) landed in Palabuhanratu Fishing Port revealed significant changes in population structure between Palabuhanratu, the Atlantic, and the Indian Ocean with an FST ***p-value*** of 0.04420 (Kanedi et al. 2023).

In conclusion, coral catshark (*A. marmoratus*) mostly live in the same age level group. Fishing ground significantly affects their length-weight correlation, indicating that length growth's dominance outweighs growth. The sex ratio indicates the healthy state of the sharks. Thus, the sustainability of *A. marmoratus* is greatly possible to maintain due to selective fishing (only mature fish is caught), high growth rate, and moderate management status.

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