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Population Dynamic of Two-Tone Goatfish (*Upeneus guttatus* Day, 1868) in the Waters of Polewali Mandar, West Sulawesi, Indonesia

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ABSTRACT

Upeneus guttatus is one of the demersal fish resources used as a bait fish and is favored for human consumption. Its taste liking has gained a high popularity among the people in Polewali Mandar. Unfortunately, the high demand for *Upeneus guttatus* has resulted in an uncontrolled exploitation. In addition, the continuous fishing activities can impact the availability and stock of resources. Other than *Upeneus sulphureus* and *Upeneus moluccensis*, information on the population dynamics of *Upeneus guttatus* species has never been addressed, especially in Polewali Mandar. Therefore, this research aimed to determine the population dynamics of *Upeneus guttatus* caught in Polewali Mandar waters to support as basic data for sustainable fisheries management. Sampling was conducted from August to October 2023 in Polewali Mandar waters, West Sulawesi. During the study, 1134 two-tone goatfish were obtained, consisting of 989 males and 145 females. The recruitment pattern of the two-tone goatfish showed three age groups in August and September and two age groups in October. The predicted L∞ value was 193mm with a K-value of 0.51 per year. The total mortality rate of the two-tone goatfish was 3.48 per year. The exploitation rate was recorded with a value of 0.80, indicating the overfishing of the species under study. Thus, aligned with managing the sustainable developmental goals, efforts exerted by the community and local government should prioritize the availability of the *Upeneus guttatus* via preventing the over exploitation recorded at the study site.

INTRODUCTION

The two-tone goatfish (*Upeneus guttatus* Day, 1868) is a species from the Mullidae family. **Genisa (2003)** stated that this fish is known as the goatfish or jackfruit seeds and is referred to as the beard fish. In particular, the fish is known as the lamotu fish in Polewali Mandar. It is a species with a high abundance in the waters of Polewali Mandar. In addition to being sold fresh for human consumption, the goatfish is also available in the form of processed salted dried fish. It is widely used as fishing bait for the tuna fish and plays an ecological role in the food chain **(Vahabnezhad *et al.*, 2020)**. The fishing gear employed by fishermen to catch the goatfish includes gill net, mini trawlers, and danish seine net **(Kembaren & Ernawati, 2011)**. The goatfish exhibits a schooling nature that is not too large, typically inhabiting nearshore areas with a range that is not too far away. This trait renders it accessible to fishermen **(Azizah *et al.*, 2019)**.

The goatfish represents an ecologically and economically significant demersal fish resource, as evidenced by **Abdullah *et al*. (2015)**. It is a popular catch among the local community, serving as a primary source of protein for consumption. The continual harvesting of the goatfish may result in a reduction in the availability and a shift in the composition of the goatfish population in the waters. This is evidenced by the results of the goatfish production in Polewali Mandar, which fluctuates based on data from fish auction site for Polewali Mandar catch production. In 2015 to 2016, the number of catches increased, while a decrease was recorded from 2016 to 2020 **(Marine & Fisheries Departement of Polewali Mandar, 2023)**. **Iswara *et al.* (2014)** attributed the decline in fish stocks in nature to the environmentally unsustainable nature of fishing activities. The fish caught are dominated by gonadal mature fish, which results in recruitment overfishing. Conversely, when dominated by small fish, this results in growth overfishing. The overexploitation of gonadally mature goatfish causes disruption to the reproductive cycle reducing the quantity of recruitment, while the overexploitation of small fish causes the availability of broodstock to decrease due to the limitation of young fish reaching gonadal maturity. **Sarumaha *et al.* (2016)** argued that, if the quantity of recruitment and availability of fish stocks were reduced, then the goatfish resource would not be able to withstand higher fishing intensity.

The continual fishing of the goatfish without the implementation of effective management strategies may result in a decline in the population. Overfishing can result in the depletion of fish stocks and the deterioration of habitat conditions **(Putera & Setyobudi, 2019)**. It is imperative to conduct research on the population dynamics of the goatfish, particularly in the waters of Polewali Mandar in order to provide a foundation for the effective management of this species. Research on the goatfish has never been done in West Sulawesi, especially in Polewali Mandar, thus this research is considered necessary. The objective of this study aimed to analyze the population dynamics of the goatfish, *Upeneus guttatus*, including size structure parameters, age groups, growth, mortality and exploitation rates in the Polewali Mandar waters. The findings will serve as the basis for resource management, enabling the utilization of the fish to be carried out optimally and sustainably in accordance with the urgency of SDGs 14.

MATERIALS AND METHODS

Period and location

The research was conducted over a three-month period from August to October 2023. Sampling of the goatfish, *Upeneus guttatus*, was conducted on a monthly basis in the Polewali Mandar waters, East Binuang, Polewali Mandar Regency, West Sulawesi (Fig. 1).

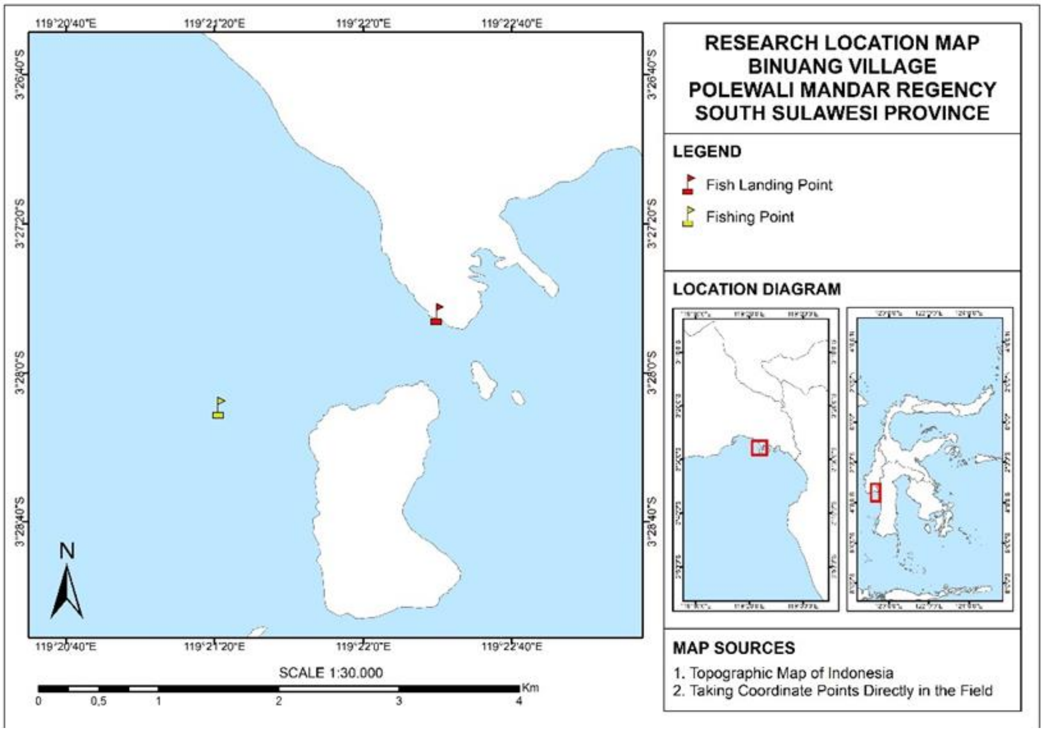

Fig. 1. Research location map

Sampling and handling of samples

Samples of the two-tone goatfish were obtained from the catch of fishermen using fishing nets with a mesh size of 0.3cm. The captured two-tone goatfish were placed in a cool box containing ice cubes. Afterward, samples of two-tone goatfish were transported to the Fisheries Biology Laboratory for further measurement and analysis. The total length of the fish was measured from the oral cavity to the tail tip using a ruler with an accuracy of 0.1mm. The fish was then dissected using a scalpel and observed for gonads to determine the sex of the fish.

Data analysis

The length frequency data of the goatfish were tabulated in class intervals based on length over a three-month observation period. The determination of the length structure of the fish catch was based on the total length data of the goatfish caught in the waters of Polewali Mandar.

The age group of the fish was estimated using the length of the fish distributed across length frequency classes, as proposed by **Battacarya (1974)** and **Sparre and Venema (1999)**. The determination of a normal distribution to estimate age groups was conducted using the FISAT II method.

The growth rate associated with fish length was determined using the von Bertalanffy growth equation **(Sparre & Venema, 1999)**, expressed by the following formula:

$$Lt = L\infty\ [1\text{-}e\text{-}K(t\text{-}t_0]$$

Where, Lt = the length of fish at age t (cm); L∞ = the asymptote length of fish (cm) K = Growth rate coefficient (per year); t_0= the theoretical age of fish when length equals zero (years), and t = the age of fish (years).

To obtain the estimated length of the fish asymptote (L_∞) and the growth rate coefficient (K), data analysis was conducted using the response surface analysis tool in ELEFAN I, part of the FISAT II program. This involved entering the highest score obtained from the table determining the values of L∞ and K, separately. The theoretical age when the length of the fish is equal to zero (t_0) was estimated using the empirical formula of **Pauly (1983)**, as follows:

$$\log(-t_0) = -\ 0.3922 - 0.2752\ (\log L_\infty) - 1.038\ (\log K)$$

Where, L∞ = the asymptote length of the fish (cm); K = the growth rate coefficient (per year), and T_0 = the theoretical age of the fish when the fish length equals zero (years).

Mortality and exploitation rate

Total mortality (Z) was conducted using the length converted catch curve method in the FISAT II program **(Pauly, 1983)**:

$$\text{In}\ (C(L1\text{-}L2))/(\Delta t(L1\text{-}L2)) = C\text{-}Z{*}t\ ((L1\text{-}L2))/2$$

The above equation is estimated through a simple linear regression equation $y = b_0 + b_{1x}$ with y = In (C(L1-L2))/(Δt(L1-L2)) as ordinate. X = C-Z*t ((L1-L2))/2as abscissa, and Z = -b.

The natural mortality rate (M) was calculated using the empirical equation of **Pauly (1983)**, which employs average water temperature data. The following formula was employed:

$$\log(M) = -0.0066 - 0.279 \log L\infty + 0.6543 \log K + 0.4634 \log T.$$

Where, M = the natural mortality rate (per year); L_∞= the asymptote length of fish (mm); K = the growth coefficient (year), and T = the average annual temperature of the water.

Fishing mortality rate was calculated as follows:

$$F = Z - M$$

Where, Z is the total mortality rate, and M is the natural mortality rate.

The exploitation rate (E) was determined via comparing the fishing mortality rate (F) with the total mortality rate (Z) **(Pauly 1984)**:

$$E=F/Z$$

Where, F = the fishing mortality (per year); Z = the total mortality rate (per year), and M = natural mortality (per year).

The yield per recruitment (Y/R) can be calculated using Beverton and Holt's equation. Here's how to calculate it:

1. Yield per recruitment (Y/R):

YR=E·UMK\frac{Y}{R} = E \cdot \frac{UM}{K}RY=E·KUM

where:

- **EEE = Exploitation rate**
- **L′L'L′ = Smallest length limit of fully caught fish (millimeters)**
- **MMM = Natural mortality rate (per year)**
- **KKK = Growth rate coefficient (per year)**
- **L∞L_{\infty}L∞ = Asymptote length of fish (millimeters)**
- **FFF = Fishing mortality value**
- **ZZZ = Total mortality**

Explanation of components:

- **Exploitation rate (E): The proportion of the fish population that is removed by fishing.**
- **UM: It represents the yield per recruit at a given exploitation rate.**
- **K: The growth rate coefficient which describes how quickly the fish grows.**
- **L∞: The maximum length the fish can reach.**
- **F: Fishing mortality rate.**
- **Z: Total mortality rate, which is the sum of natural and fishing mortality rates.**

Yield per recruitment was calculated using Beverton and Holt's equation as follows:

$$Y/R' = E.\ U^{M/K}\left(1 - \frac{3U}{1+m} + \frac{3U^2}{1+2m} - \frac{U^3}{1+3m}\right)$$

Where:

$$u = 1 - \frac{L'}{L\infty}$$

$$E = \frac{F}{z}$$

$$m = \frac{1 - E}{\frac{M}{K}}$$

It should be noted that: E =exploitation rate; L' = smallest length limit of fully caught fish (millimeters); M = natural mortality rate (per year); K = growth rate coefficient (per year); L_∞ = asymptote length of fish (millimeters); F = fishing mortality value, and Z = total mortality.

RESULTS AND DISCUSSION

Size structure

Length observation of goatfish is useful to determine the size composition. The number of samples for measuring fish length was 1134 fish with a length range of 90-172mm. Size structure distribution is related to several factors such as food, water quality, age, and sex **(Prayitno *et al.*, 2020)**. The length range of the goatfish is shown in Fig. (2).

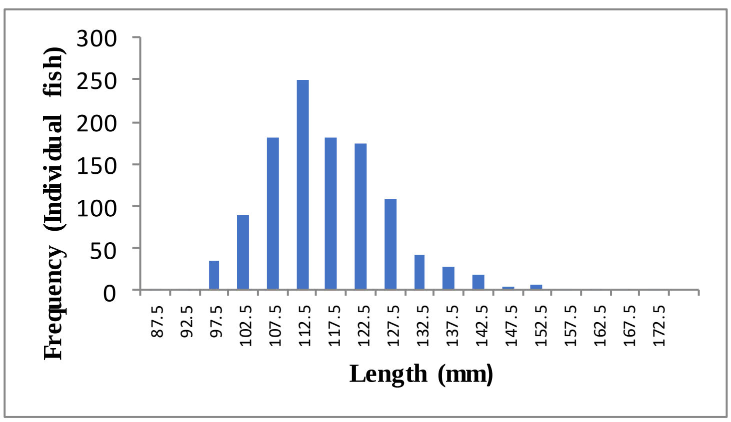

Fig. 2. Size structure of the total length of *Upeneus guttatus* (Day, 1868) in the Polewali Mandar waters

The mode of total length for goatfish was concentrated within the 112.5mm length class, with a total of 251 fish (Fig. 2). In a previous study by **Abdullah *et al.* (2015)**, it was found that in Kendal waters, the length of the goatfish was in the range of 105-193mm. The most commonly found goatfish recorded a length of 123-131mm. Research conducted by **Triana (2011)** in the waters of Jakarta Bay revealed that the dominant goatfish caught with length ranges of 120-127mm were 90. **Motomura *et al.* (2012)** found that in the Japanese waters, the length of goatfish was in the range of 57.8-

139.5mm. Moreover, **Iswara *et al*. (2014)** found that in the waters of Pemalang Regency, the length of goatfish was in the size range of 77-172mm. Furthermore, **Ernawati and Sumiono (2006)** found that in the waters of Makassar Strait the length of goatfish was in the size range of 55-165mm, with the highest frequency at the size of 105mm. A comparison of the frequency distribution of the most caught goatfish with the results of research in the waters of Sunda Strait, Jakarta Bay, Pemalang Regency waters, and Semarang waters revealed that the fish caught in Polewali Mandar waters have a smaller size. Conversely, when compared to the results of research in the Makassar Strait, two-tone goatfish caught in Polewali Mandar waters had a larger size. The observed differences in the length of fish caught may be indicative of differences in age and spawning season, which are likely to be related to habitat conditions.

Age group

A frequency distribution analysis is necessary to ascertain the distribution of fish abundance in waters based on size structure. Additionally, the results of frequency distribution analysis can describe the distribution pattern of age groups in a population (**Yonvitner & Fahmi 2012)**. The number of fish in each class present in the waters at a given time is monitored annually. The number of fish missing from the waters due to human exploitation, fishing, or natural mortality can be quantified by combining the age of the fish and the composition of the population. This information can be used to assess the success or failure of fish reproduction in a given year **(Effendie, 2002)**. The results of the analysis of the number, range, and age group of male and female *Upeneus guttatus* (Day, 1868) are presented in Table (1).

Table 1. Cohort analysis of *Upeneus guttatus* (Day, 1868) in Polewali Mandar waters

Observation time (month)	Age group	Average length (mm)	Standard deviation	Populations (fish individual)	Separation index
August	1	119	9.21	334	n.a
	2	141	4.63	30	2.11
	3	150	6.79	11	1.97
September	1	112	8.24	353	n.a
	2	123	7.18	64	1.93
	3	128	11.1	14	1.8
October	1	111	6.35	316	n.a
	2	118	7.86	60	1.88

In August and September, there were three size groups each, meaning there were three age groups, while in October there were two size groups, indicating the presence of two age groups (Table 1 & Fig.3). The age groups of the goatfish obtained in previous studies can be found in Table (2).

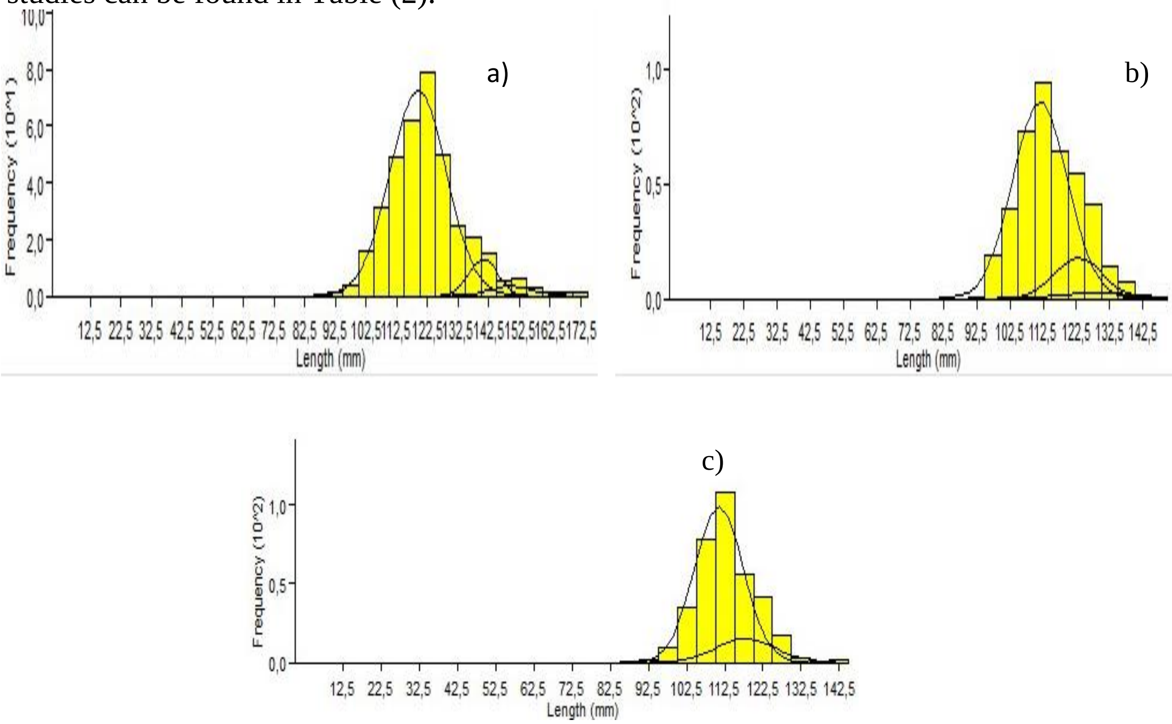

Fig. 3. Histogram curves of length frequency distribution and age group determination of *Upeneus guttatus* during: a) August, b) September and c) October

Table 2. Age group *Upeneus guttatus* in several waters

Type species	Location	Age group	Population	Information	Reference
Upeneus sulphureus	Strait Sunda	2 2	105 105	Male Female	Azizah *et al.* 2019
Upeneus Sulphureus	Tuban waters , East Java	2	-	Combined	Dewi, 2019
Upeneus asimetricus	Tambelan Island Waters	2	380	Combined	Yonvitner, 2012
Upeneus guttatus	Polewali Mandar Waters	3	375	Combined	This research

The discrepancy in the number of cohorts caught in the waters is believed to be attributable to the recruitment of new individuals from the catch of the goatfish that occurred in previous months, resulting in a cohort of catches being observed in the following month. Another potential contributing factor is the environment, as evidenced by the stock analysis conducted by **Mallawa *et al.* (2017)**, which indicates that obtaining three age groups from an exploited population suggests that the stock is already under stress. Age group formation for *Upeneus guttatus* was a maximum of three groups, thus there was no repetition in the following month. Therefore, these data are considered representative of the results of the analysis throughout the year. The present study demonstrates that the second age group constitutes the majority of research samples. It is postulated that the second age group represents the juvenile fish group.

Growth

The estimation of growth parameters was conducted using the von Bertalanffy growth formula method via Fisat II software. The value of the growth rate (K) of the goatfish was found to be 0.51 per year, indicating that the value of the growth rate of the goatfish is greater than 0.5. This implies that the growth of the goatfish is relatively fast. This is consistent with the findings of **Sparre and Venema (1999)**, who posited that a value of k < 0.5 indicates slow growth or a prolonged timeframe to reach maximum length. Conversely, a value of K > 0.5 is indicative of fast growth. The growth rate at an early age is faster than it is at a later age, and it will slow down due to the distribution of energy for the reproductive process in adult fish. This result is in accordance with the findings of **Vishnupriya *et al*. (2024)**. The growth curves of male and female goatfish are presented in Fig. (4).

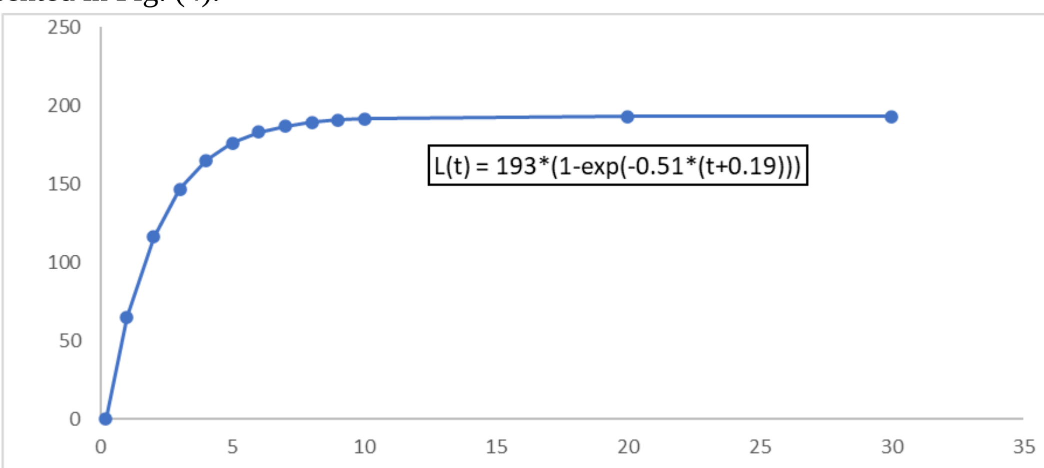

Fig. 4. Growth curves of male and female *Upeneus guttatus* (Day, 1868) in Polewali Mandar waters

The theoretical maximum length of the goatfish (L_∞) is 193mm, the growth coefficient of fish is 0.51 per year, and the theoretical age at which length equals zero for fish is 0.19 per year. The estimated values of the growth parameters (L_∞, K, and t_0) are then entered into the von Bertalanffy equation, which describes the growth of male and female goatfish. The equation is as follows: $L_t = 193*(1-\exp(-0.51*(t+0.19)))$.

The relationship between L∞ and K is that an increase in the value of K will result in a faster rate of growth, which will ultimately lead to the fish reaching L∞ at a faster rate. Consequently, the fish will die at a faster rate. As stated by **Sparre and Venema (1999)**, the higher the growth coefficient value, the faster the time needed to reach its maximum length. Conversely, fish individual with a low coefficient rate takes a long time to reach its maximum length and tends to be long-lived. The growth parameters for each species exhibit disparate values. These discrepancies can be attributed to variations in fish size, the fishing area and season at the time of sampling, and the type of fishing gear employed **(Prihartiningsih *et al.*, 2013)**. **Bakhtiar *et al.* (2013)** additionally elucidated that differential growth rates within the same species across distinct aquatic habitats can be attributed to environmental factors. This phenomenon can be observed in Fig. (3), where a more sloped graph indicates a decreasing growth rate in fish, which ultimately leads to the fish reaching its maximum length. Growth is a complex biological process that is influenced by a number of factors, both internal and external. In the study of **Effendie (2002)**, the internal factors that influence growth are age, parasites, heredity, sex, and disease. The main external factors are food availability and water temperature. The data in the table indicate that the growth parameters of the results of the research conducted are not significantly different from those of previous studies conducted by **Sarumaha (2016)**, **Asriyana and Irawati (2017)**, **Mehanna (2018)**, **Nurulludin *et al*. (2020)** and **Clarito and Suerte (2021)**. The maximum length of the sample fish obtained decreased in comparison with that recorded in the previous studies.

Table 3. Comparison of the goatfish growth parameters from various studies

Reference	Research site	L∞ (mm)	K
Sarumaha, 2016	Sunda Strait	282.25	0.17
Clarito and Suerte, 2021	Visayan Sea, Philippines	206.3	1.4
Mehanna, 2018	Mesir	228.9	0.38
Nurulludin *et al.*, 2020	Malaka Strait	210	0.80
Asriyana dan Irawati, 2017	Kendari Bay	184.42	1.5
This research	Polewali Mandar waters	193	0.51

Mortality and exploitation rate

The estimation of the total mortality rate (Z) of the goatfish was conducted by employing the length-converted catch curve methodology, as implemented in the Fisat II software. This was followed by the input of the values of L∞ and K. The results of the analysis of the mortality coefficient and exploitation rate of the male and female goatfish are presented in Fig. (4).

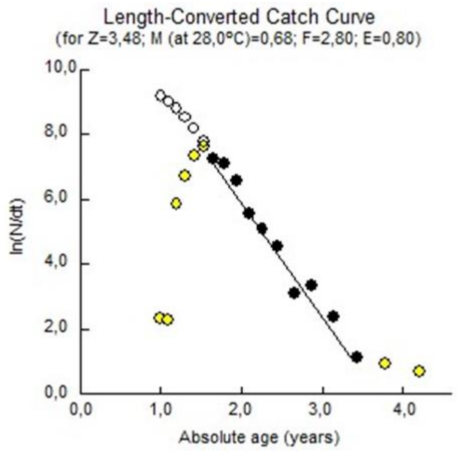

Fig. 5. Length- converted catch curve of *Upeneus guttatus*

For the goatfish, the total mortality (Z) is 3.48 per year, natural mortality (M) is 0.68 per year, and fishing mortality (F) is 2.8 per year. This suggests that the fishing mortality is greater than the natural mortality (Fig. 4). The high capture mortality rate is accompanied by a high exploitation rate, as documented by **Azizah *et al.* (2019)**. The exploitation rate value of 0.80 is greater than 0.5, indicating that the exploitation rate is quite high. As stated by **Gulland (1983)**, an exploitation rate exceeding 0.5 is indicative of an overfishing. This suggests that fishing effort is high, which could result in a reduction in the availability of goatfish stocks in the waters.

The mortality of goatfish in the waters of Polewali Mandar is attributable to fishing mortality (F). The results of this study are consistent with those of previous research conducted by **Sarumaha (2016)** and **Claro and Suerte (2021)** in the Sunda Strait, and **Nurulludin *et al.* (2020)** in the Malacca Strait, which demonstrated that the mortality of the goatfish in these waters is primarily caused by fishing mortality. The mortality of the goatfish in several waters is presented in Table (4).

Table 4. Mortality and exploitation rates of the goatfish in several waters

Reference	Location	M	F	Z	E
Nurulludin *et al*, 2020	Malaka Strait	1.73	2.51	4.24	0.59
Claro & Suerte 2021	Visayan Sea, Philippines	2.47	2.87	5.34	0.54
Sarumaha, 2016	Sunda Strait	0.94	3.4	4.34	0.93
This research	Polewali Mandae waters	0.68	2.80	3.48	0.80

The mortality of fish can vary due to differences in the demand for goatfish, which in turn affects the manner in which fishing activities are conducted. A high fishing mortality rate may also indicate the occurrence of growth overfishing conditions, namely the small number of old fish. This is because young fish do not have sufficient time to grow due to being caught. The high intensity of capture results in a higher mortality rate coefficient **(Fauzi *et al*., 2020)**. The fishing rate may be relatively high due to the density of fishing effort **(Bintoro *et al*., 2020)**. **Lorenzen (2022)** posited that mortality is influenced by extrinsic and intrinsic factors. Extrinsic factors are factors originating from external sources, such as abiotic factors, fishing pressure, competition, and exposure to pathogens. Intrinsic factors are those intrinsic to the organism, including factors such as aging, physiological resilience, response to predators, ability to compete, and immunity to disease. As indicated by **Bahrin *et al.* (2020)**, the fishing pressure on the stock should be reduced until it reaches an optimal condition, resulting in a fishing mortality rate equals to the natural mortality rate.

The exploitation value indicates that the utilization of goatfish has been significantly overexploited, with an E-value of 0.80 per year. **Sparre and Venema (1999)** argued that if the value of E exceeds 0.50, the status of the fishery is classified as overfished. The exploitation rate is classified as overfishing when growth overfishing occurs in conjunction with recruitment overfishing **(Nurulludin & Prihartiningsih, 2014)**. Growth overfishing refers to the capture of young fish that have the potential to become fish stocks before reaching a size suitable for fishing. Recruitment overfishing, on the other hand, is the capture of adult fish with too many exploited stocks, which in turn reduces the reproduction of young fish **(Pauly, 1984)**. The exploitation rate of the goatfish in several waters is presented in Table (3). **Nurulludin *et al.* (2020)** found that the exploitation rate of the goatfish in the Malacca Strait was above the optimum value, which indicated that there had been overfishing of the goatfish in the Malacca Strait. It is hypothesized that the exploitation rate of the goatfish is a consequence of the daily fishing of the goatfish. The fishing mortality rate is influenced by the exploitation rate. The greater the exploitation in an area, the greater the fishing mortality **(Lubis *et al.* 2019).**

Yield per recruitment

The yield per recruitment was estimated using the Beverton and Holt equation **(Sparre & Venema 1999)**, as illustrated in Fig. (6), incorporating the values obtained. The relative yield per recruitment model is one of the non-linear models, also known as the recruitment analysis model, which was developed by **Beverton and Holt (1957)**. Recruitment is defined as the addition of new individuals, either due to the birth process or the process of growth and migration **(Yonvitner & Fahmi, 2012)**. **Pauly (1984)** asserted that this model is more straightforward and practical to employ since it necessitates fewer input values for population parameters than other yield-per-recruitment models.

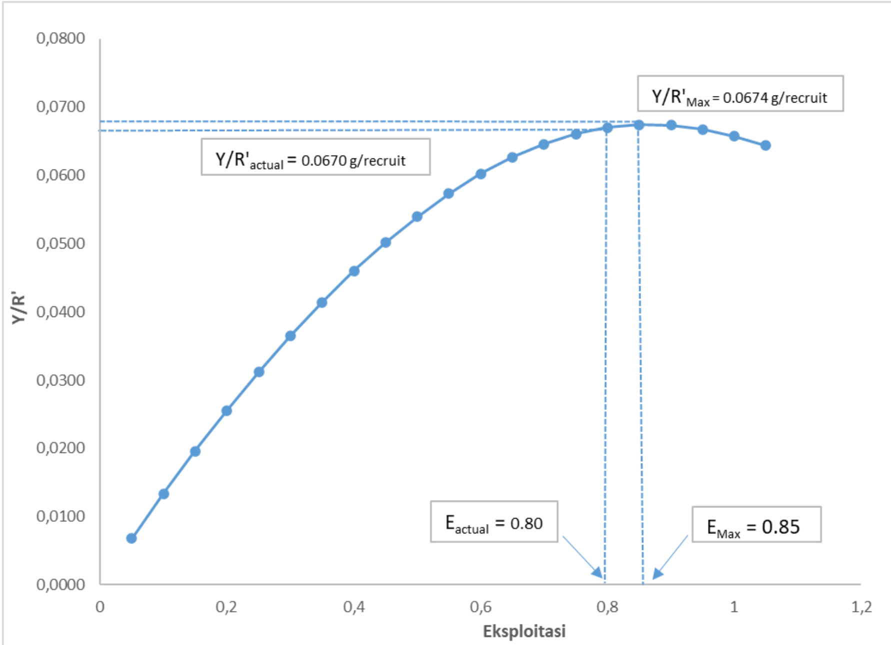

Fig. 6. Yield per recruitment of the goatfish *Upeneus guttatus* in Polewali Mandar waters

The estimated maximum Y/R for the goatfish is 0.07 gram per recruit, which can be taken as a catch with an exploitation rate of 0.85 per year. The research results show that the recruitment process for the turmeric fish is not optimal because the Y/R' optimum value (0.80) obtained is smaller than the maximum Y/R' value (0.85), thus it is estimated that the recruitment process is not optimal. It is thought that the non-optimal recruitment process obtained from this research could be caused by the number of the male and female turmeric fish being significantly different. It is known that in this study, there were 989 male goatfish and 145 female fish. This could be the cause of a non-optimal recruitment process. In some species, recruitment can take the form of migration from designated breeding areas **(Nurulludin *et al.*, 2020)**. **Clarito and Suerte (2021)** found that for stocks of *Upeneus sulphureus* in Visayan waters, Philippines, which had been overexploited, the E_{max} value was greater (0.63) than the optimum exploitation rate (E∗) of 0.50.

In general, returns per recruit tend to increase with the exploitation, as noted by **Akter *et al*. (2020)**. **King (1995)** stated that exploited species will have an impact on reducing adult fish so that adult fish are caught by fishing activities before they can be produced. Continuous fishing operations will cause the stock of goatfish to decrease in the waters, and it is even predicted that they will become extinct if not managed properly. Management alternatives need to be implemented regarding the regulation and supervision of the number of goatfish fishing, fishing area limits, and the size of the fish caught.

CONCLUSION

The total length of the goatfish is predominantly in the middle class of 112.5mm, with 251 individuals, which is shorter compared to previous research. There are three age groups of the goatfish observed in August and September, and two age groups in October. The estimated L∞ value is 193mm with a K-value of 0.51. The fishing mortality rate (F) is 2.80, and the exploitation rate (E) is 0.80, indicating an overexploitation. The catch consists mainly of small fish, which suggests growth overfishing.

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