JIPK. Volume 13 No 2. November 2021
Sinta 2 (Decree No: 10/E/KPT/2018)
e-ISSN:2528-0759; p-ISSN:2085-5842
DOI=10.20473/jipk.v13i2.27465
Available online at https://e-journal.unair.ac.id/JIPK/index

JIPK
(JURNAL ILMIAH PERIKANAN DAN KELAUTAN)
Scientific Journal of Fisheries and Marine

Short Communication

Estimation of Fishing Mortality Rate and Exploitation Status of Yellowstrip Scad (*Selaroides leptolepis*) in Tomini Bay using Von Bertalanffy Growth Model Approach

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OPEN ACCESS

ARTICLE INFO

Received: June 12, 2021
Accepted: August 02, 2021
Published: September 28, 2021

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Keywords:

FiSAT
Gorontalo
Growth
Selar
Selaroides
Tomini Bay
WPP 715

Abstract

Comprehensive data is required for implementing sustainable fisheries management. Population dynamic and stock assessment aspects of *Selaroides leptolepis* species in Tomini Bay have not been entirely reported.This study aimed to determine the fishing mortality rate and exploitation status of *S. leptolepis* in Tomini Bay by calculating Von Bertalanffy growth model parameters (L_∞, K, t_0) then plotting them into Pauly's empirical equation. The sampling was conducted monthly from April to September 2020 at Gorontalo City Fishing Port. Samples were collected randomly from five commercial fishing vessels shortly after the fishermen landed their catch at the fishing port. All fish samples were confirmed to be obtained by the fishermen from Tomini waters. The growth parameters of the samples were analyzed using FiSAT II based on Von Bertalanffy mathematical model. While the mortality and exploitation values were calculated manually using Pauly's equation. The study showed that the growth parameter values of *S. leptolepis* in Tomini Bay were 245.47 mm, 0.49/year, and -3.04/year for males, while 227.80 mm, 0.63/year, and -2.72/year for females separately for L_∞, K, and t_0. The total, natural, and fishing mortality rates were 3.06/year, 0.61/year, and 2.45/year for males and 0.99/year, 0.74/year, and 0.25/year for females. The analysis results showed that the female's natural mortality (M) was higher than the male. In contrast, the fishing mortality (F) and total mortality (Z) of male fish exceed the female. The exploitation value of males (E=0.80) was greater than that of females (E=0.26).

Cite this as: Pasisingi, N., Kasim, F., & Moo, Z. A. (2021). Estimation of Fishing Mortality Rate and Exploitation Status of Yellowstrip Scad (*Selaroides leptolepis*) in Tomini Bay using Von Bertalanffy Growth Model Approach. *Jurnal Ilmiah Perikanan dan Kelautan*, 13(2):288-296. http://doi.org/10.20473/jipk.v13i2.27465

1. Introduction

The Directorate General of Capture Fisheries, Ministry of Marine Affairs, and Fisheries of the Republic of Indonesia has set the direction of fish resource management policies for the year 2020-2024, one of which is based on the Fisheries Management Area of Indonesia Republic/WPPNRI (Yunanda, 2020). Tomini Bay is a part of WPPNRI 715 according to Regulation of the Minister of Marine Affairs and Fisheries of the Republic of Indonesia Number 18/Permen-Kp/2014 concerning the State Fisheries Management Area of the Republic of Indonesia. As the largest bay in Indonesia with an area of approximately 6,000,000 hectares (Pramudji, 2018), the development of Tomini Bay has the potential to be adequately optimized to improve community welfare as it has the wealth and uniqueness of marine and fishery resources (Fauzan, 2011).

Fishing activities in Tomini Bay are greatly supported by abundant fishery resources (Muzakir and Suparman, 2016) and their diversity (Mustika *et al*., 2021). Furthermore, *S.leptolepis,* also known as yellowstrip scad (Fuad *et al*., 2020; Jaafar *et al*., 2020) or selar kuning (Hestiana *et al*., 2019; Ferse and Glaser, 2021), is a dominant species caught from Tomini Waters. The species is also categorized as an economically important marine fish (Genisa, 1999). Although the *S. leptolepis* fishing in Tomini Bay is established all years, optimizing data collection on the fish production and fishing efforts for monitoring the resources exploitation status purposes is still not optimal. Hence, the matter is potentially threatening the stability of the fishes in nature. An integrated data are required to implement sustainable fisheries resources management.

Von Bertalanffy mathematical model has been applied widely to plot growth for numerous biota (Lee *et al*., 2020), such as in fishes (Ogle and Isermann, 2017; Du Pontavice *et al*., 2018; Harris *et al*., 2018; Vahabnezhad *et al*., 2020; Wang *et al*., 2021), mollusks (López-Rocha *et al*., 2018; Ford *et al*., 2020; Prato *et al*., 2020) , sea turtle (Ramirez *et al*., 2021), and poultry (Mata-Estrada *et al*., 2020; Del Norte-Campos *et al*., 2021). It even started to be attempted in several study areas (Fernandes *et al*., 2020), including Covid-19 outbreak (Brahma *et al*., 2021). It indicates that Von Bertalanffy Growth Function is a tool that is still demonstrative to be used.

The aquatic ecology conditions and fish biology information must be provided comprehensively to support the sustainability of fish production. Research on the reproductive biology of *S. leptolepis* in Tomini Bay has been carried out (Pasisingi *et al*., 2020; Pasisingi *et al*., 2021). However, the other population dynamic and stock assessment aspects of the species in Tomini Bay, particularly the Von Bertalanffy Growth Function and the exploitation of the resources, have not been entirely reported. By providing such data, it will assist stakeholders in assessing and controlling to what extent the exploitation status of *S. leptolepis* occurs in Tomini Bay.

Therefore, this study aims to determine the fishing mortality rate and exploitation status of *S. leptolepis* in Tomini Bay by calculating Von Bertalanffy growth model parameters (L_∞, K, t_0) then plotting them into Pauly's empirical equation. The information will provide supporting data for the proper aquatic resource management implementation purpose.

2. Materials and Methods

2.1 Area and Sampling Technique

Samples were collected by commercial fishing vessels from Gorontalo City fishing port, the northern part of Tomini Bay, Indonesia. Additionally, the fishing area was confirmed to be located in Tomini Bay (Figure 1). Monthly sampling was conducted from April to September 2020. Total samples of 1500 fish were gathered randomly from fishers catch using purse seines with the least mess size of 0.25. All fish samples were collected shortly after the fishermen landed their catch at the fishing port. The total length and the fish body weight were measured using a ruler (1 mm accuracy) and a digital scale (nearest = 0.01 gram). Further, sex separation was carried out by dissecting and directly observing the gonad samples.

2.1.1 Data analysis

a. Growth parameters

The mathematical model of individual growth, Von Bertalanffy, explains fish length (L) as a function of fish age (t) is as follows (Sparre and Venema, 1999):

$$Lt = L\infty\ (1- e^{-K(t-to)})$$

Through a series of algebraic manipulations of the Von Bertalanffy equation, the linear equation for the Ford-Walford plot method (Sparre and Venema, 1999) is presented below:

$$L(t+\Delta t) = a + b * Lt$$

Description:
$a = L\infty\ (1-b)$
$b = \exp\ (-K * \Delta t)$

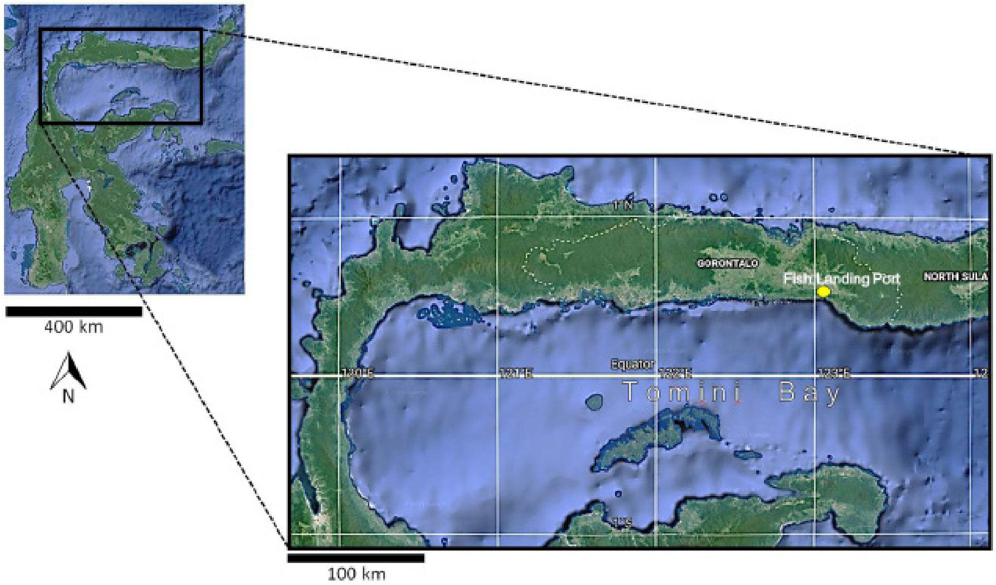

Figure 1. The fishing area and the fish landing port of *S. leptolepis* in Tomini Bay

Table 1. Summary of the Von Bertalanffy growth parameters estimated for *S. leptolepis* in several Indonesia areas

No	Areas	Sex	L_∞ (TL, mm)	K (per year)	t_0 (year)	References
1	Tomini Bay, Gorontalo, Indonesia	male	245.47	0.49	-3.04	This research
		female	227.80	0.63	-2.72	
2	Wolo Waters, Kolaka, Indonesia	male + female	173.80	0.97	-0.10	(Rasyid *et al*., 2019)
3	North Costal of Java, Indonesia	male + female	168.50	1.44	-0.41	(Khatami *et al*., 2019)
4	South Ternate Island Waters, Indonesia	male + female	227.80	0.28	-0.64	(Tangke *et al*., 2018)
5	Malacca Strait, Medan, Indonesia	male + female	181.65	1.10	-	(Tambun *et al*., 2018)
6	Wondama Bay, Cendrawasih Bay, Indonesia	male + female	220.00	3.00	-0.05	(Sala *et al*., 2018)
7	Bintan Island Waters, Riau, Indonesia	male + female	180.00	1.20	-	(Sudradjat, 2006)

Table 2. Mortality and Exploitation Rates of *S. leptolepis* in Tomini Bay

Parameters	Male	Female
M (per year)	0,61	0,74
F (per year)	2,45	0,25
Z (per year)	3,06	0,99
E	0,8	0,26

Description: M = natural mortality, F = fishing morality, Z = total mortality, E = exploitation

The asymptotic length (L_∞) and growth rate coefficient (K) were calculated using the ELEFAN I program in the FiSAT (FAO ICLARM Stock Assessment Tools) II program package. Furthermore, the estimation of the theoretical age value (t_0) was applied using the following empirical formula of Pauly (1979) (Sparre and Venema, 1999):

$$\log(-t_o) = -0.3922 - 0.2752 \log L_\infty - 1.0380 \log K$$

Description:
L_t = length of fish at age t (mm)
L_∞ = the asymptotic length of the fish (mm)
K = Von Bertalanffy growth rate coefficient
t_0 = theoretical fish age at 0 mm length

The graphs of growth and mode shift were visualized using Microsoft Excel and FiSAT II programs, correspondingly.

b. Mortality and exploitation rates

The mortality rate determination requires input data for the value of L_∞ and K from the Von Bertalanffy mathematical equation and the Ford-Walford method. The total mortality rate was analyzed through the catch curve approach, which is linearized based on the length converted catch curve analysis using the FiSAT II program following the equation of Beverton & Holt (1986) (Sparre and Venema, 1999):

$$Z = (K (L_\infty - \bar{L}) / (L_\infty - \hat{L})$$

The natural mortality rate is calculated based on Pauly's empirical equation for estimation of natural mortality is (Pauly, 1984):

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

The fishing mortality (F) was calculated as follow:

$$F = Z - M$$

Description:
Z = total mortality rate (per year)
M = natural mortality rate (per year)
F = fishing mortality rate (per year)
K = growth rate coefficient (per year)
L_∞ = asymptotic length (mm)
L = average length of fish caught (mm)
L_c = lower limit of most catch length class interval (mm)
T = mean annual water surface temperature (27°C)

Exploitation (E) was obtained by dividing the fishing mortality and the total mortality (Pauly, 1984) as follow:

$$E = F / Z$$

3. Results and Discussion

3.1 Length Frequency Distribution

The data showed that the length of the fish ranges from 95 mm to 222 mm. The total length of *S. leptolepis* caught in Tomini Bay during this study was slightly different from the same species found in Wondama Bay with a range from 100 to 240 mm (Sala *et al.*, 2018) and also the *S. leptolepis* size at the Bintan waters fishing areas ranging of 102-215 mm (Septiyawati *et al.*, 2020). The size of the males and females caught were not much different (p-value > 0.05). However, the male was dominated by 164.30 –175.85 mm, while the female was dominated by 196.84-206.92 mm in total length. The shortest body length is in the class range of 95-106.55 mm for the male and 96-106.08 mm for the female (Figure 2).

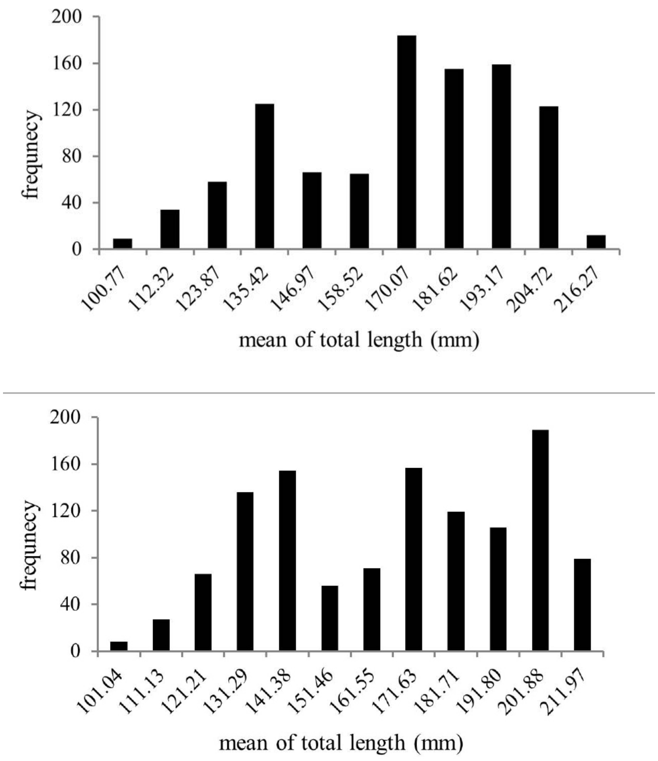

Figure 2. Length-frequency distribution of *S. leptolepis* (a) male and (b) female caught from Tomini Bay, Indonesia

3.2 Von Bertalanffy Growth Parameters

Values of the growth parameters estimating in this research are asymptotic length (L_∞), growth rate coefficient (K), and theoretical age (t_0). The higher the growth rate of the fish, the faster the fish will reach asymptotic length or maximum length. In other words,

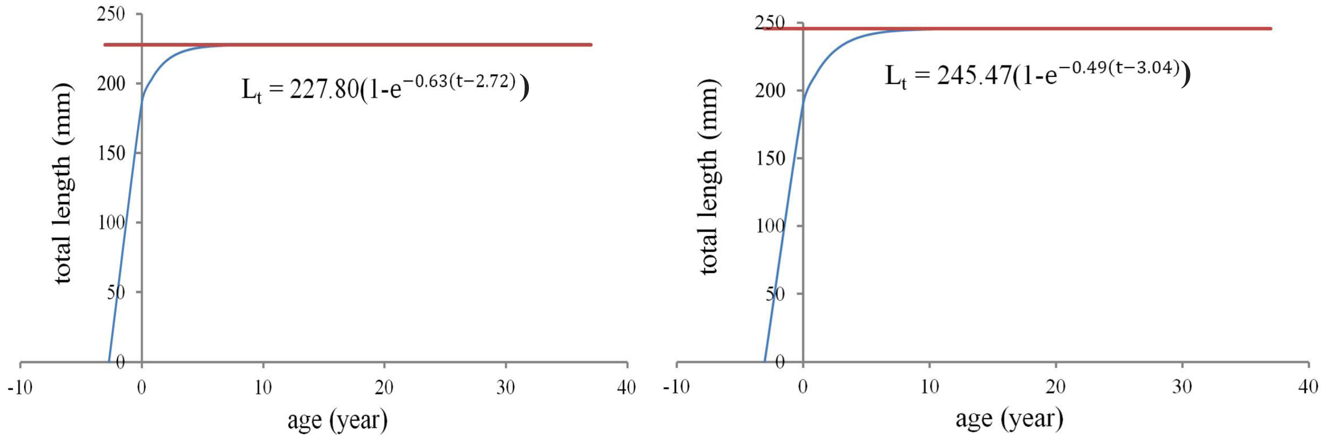

Figure 3. Growth Curve of *S. leptolepis* (a) male and (b) female in Tomini Bay Based on Von Bertalanffy Equation

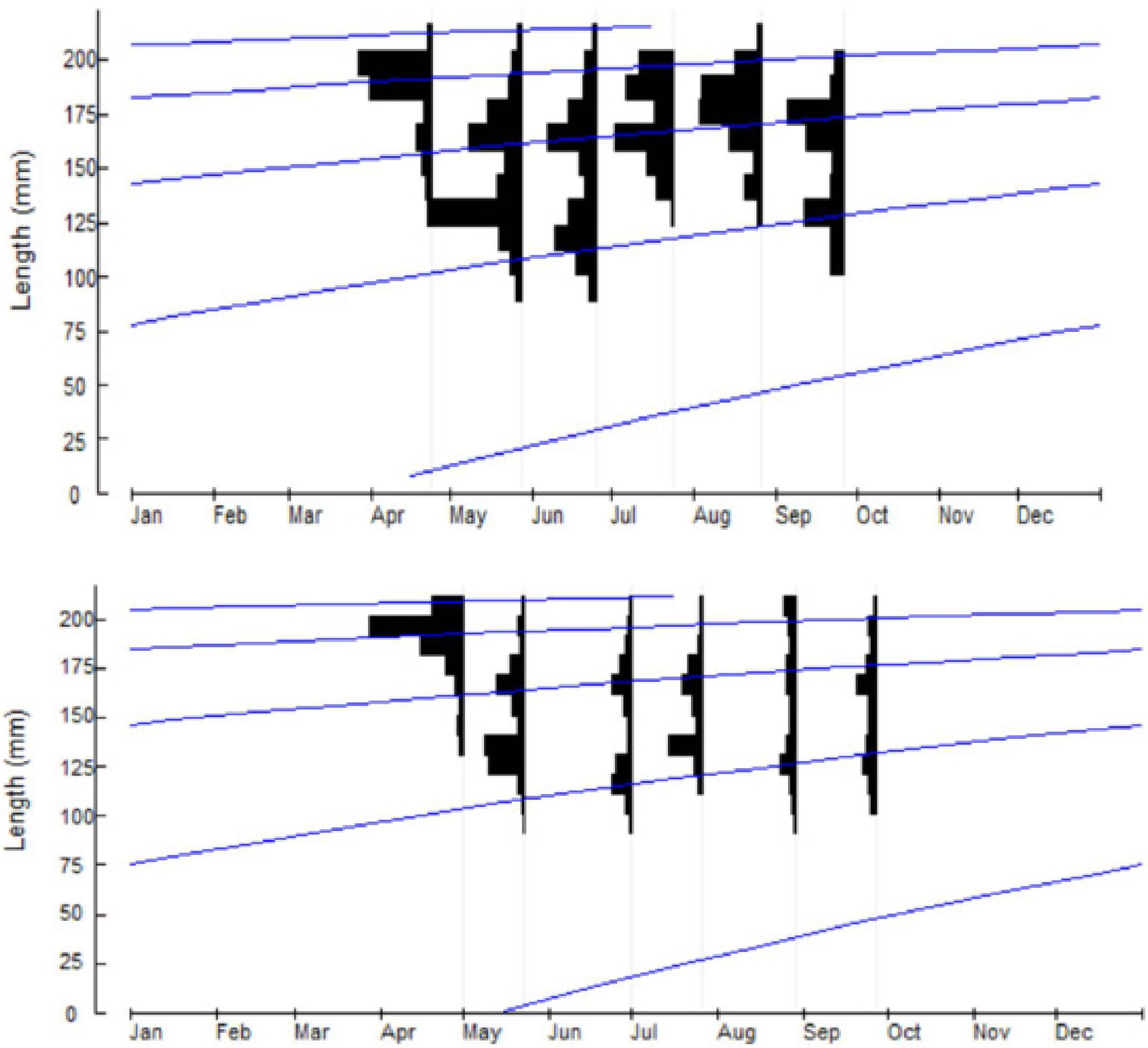

Figure 4. A shift in length size mode of *S. leptolepis* (a) male and (b) female in Tomini Bay using the Bhattacharya ELEFAN I Method

the fish have matured gonads at a relatively younger age if the growth rate is relatively fast. The t_0 value indicates the theoretical age of the fish when the fish is at length 0 mm. A comparison of the growth parameters of *S. leptolepis* fish in various water areas in Indonesia shows a number that is quite varied (Table 1). The different value of some growth parameters indicates environmental stress experienced by the fish. Sudradjat (2006) stated that the difference in asymptotic length in some of these waters might be due to food factors or water eutrophication.

The growth graph of male and female *S. leptolepis* were both plotted following the trend of the Von Bertalanffy equation where the fish growth rate was faster when the fish were young then grew slower when they were getting old until they reached an asymptotic length (Figure 3). However, there is a slight difference in the steepness of the curve where the growth rate of the males is slower than that of females causing the male curve to be relatively sloping than the female. The growth concept is autocatalytic, i.e., growth will run slowly, then it will run fast, then it will run slowly again until it reaches a certain length and growth becomes constant (Effendie, 2002). The growth of old fish will continue although slowly since most of the food absorbed by the body is used in body maintenance and movement (Salim, 2010) especially rabbitfishes write (Siganus javus and not for cell growth.

S. leptolepis fish data in this study showed the occurrence of prolonged growth. It can be seen by shifting the mode to the right and changing the length of the fish for each sampling period. The forward motion analysis of fish length mode for six consecutive months of observation showed that the new cohort emerged in May (Figure 4). It is also supported by Pasisingi *et al.* (2020) hypothesis that *S. leptolepis* spawning season in Tomini Bay occurs in April. Therefore, the following month (May), the fish has been grown and recognized as the new cohort. However, it is necessary to collect annual data to present complete data and visualize the possibility of new cohorts appearing in other months.

3.3 Mortality Rate and Exploitation

Determination of the rate of exploitation is one factor that needs to be known to determine the condition of fishery resources in assessing fish stocks (King, 1995). The rate of exploitation of fish resources is at the optimum level if the amount of mortality due to fishing is the same as natural mortality (F=M). The decrease in the stocks is caused by two factors, specifically natural mortality and species exploitation in fishing mortality. Natural mortality is affected by various factors, including predation, disease, stress, spawning seasons, age, and food availability. Fishing mortality is a function of fishing effort, including the number and types of fish, the effectiveness of fishing gear, and the duration used to catch fish (King, 1995). The total fish population's mortality rate can be applied to estimate the fish exploitation rate in nature. Information on the rate of exploitation is beneficial in fisheries management as it can predict the effect of fishing on the population (Hartaty and Sulistyaningsih, 2014). The cause of the high level of exploitation is the high level of fishing, the type of fishing gear, and the number of fishing gear operated (Rasyid *et al*., 2019). The greater the fishing effort and the number of fishing gear operating, the higher the fishing mortality.

This study estimates the mortality rate and exploitation of male and female fish separately. The analysis results showed that the female's natural mortality (M) was higher than the male. In contrast, the fishing mortality (F) and total mortality (Z) of male fish exceed the female. The exploitation rate (E) for males is very high compared to females (Table 2). These data revealed that the threat of fishing is more relevant to the male compared to the female. Therefore, these data tend to lead to recommendations for increased fishing to achieve optimum utilization of E=0.5, as demonstrated by Kartini *et al.* (2017) for female fish only.

Meanwhile, specifically for male fish, the value of the exploitation rate is relatively high (E>0.5), indicating overfishing. The difference in exploitation status of males and females of *S. leptolepis* fish in Tomini Bay is considered to occur due to the fish natural sex ratio (male:female) in the waters not balanced as reported by Pasisingi *et al*. (2021) where the female of *S. leptolepis* proportion remaining preponderated over the male. It is necessary to control the rate and number of male fish capture. Consequently, this data needs to be observed attentively. It warns that combining male and female data in calculating and estimating fish exploitation status leads to a decision endangering aquatic resource sustainability. Furthermore, many studies on stock assessment aspects that require data on the sex distinguishing of fish are still conducted by dissecting the samples (Lawadjo *et al*., 2021). Hence, strengthening the sexual dimorphism research of *S. leptolepis* fish, for instance, differences in meristic (Sari, 2018) and morphometric characters (Cabuga *et al*., 2019), may provide information easing the similar study application technically.

4. Conclusion

Based on the Von Bertalanffy growth parameter values (L_{∞}, K, and t_0), which were plotted into Pauly's empirical equation, it was found that the fishing mortality rate and exploitation status of the male (F=2.45; E=0.80) of *S. leptolepis* were much higher than those of female (F=0.25; E=0.26). The male was indicated to be overfished as the exploitation value exceeds the optimum standard for safe fish stock utilization (E>0.50). Therefore, it is necessary to limit the fishing season to re-establish sex ratio stability of the species in Tomini Bay as the fishing ground by prudently considering all stock assessments data comprehensively and integrated through multi-stakeholder engagement.

Acknowledgment

This research is funded by the Institute for Research and Community Service (LPPM), Gorontalo State University (UNG), through the beginner lecturer research (PDP) scheme, contract period 2021. We thank Ahmad Musyali for helping dissect samples and the local fishermen to provide the relevant information during the research.

Authors' Contributions

All authors have discussed the results and contributed to the final form of the manuscript. Each author's involvement as follows, NP; devised the main conceptual ideas, analyzed the data, drafted the manuscript. FK; did a critical revision of the article and proofread the article, ZM; collected samples and proofread the article.

Conflict of Interest

The authors declare that they have no competing interests.

Funding Information

This research was fully funded by the Institute for Research and Community Service (LPPM), Gorontalo State University (UNG), with the Rector decree number 404/P/2021.

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