Egyptian Journal of Aquatic Biology & Fisheries
Zoology Department, Faculty of Science,
Ain Shams University, Cairo, Egypt.
ISSN 1110 – 6131
Vol. 25(5): 419 – 432 (2021)
www.ejabf.journals.ekb.eg

Population dynamics analysis of the yellowstrip scad (*Selaroides leptolepis,* Cuvier 1833) in the waters of Ternate Island

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ARTICLE INFO

Article History:
Received: July 5, 2021
Accepted: Aug. 29, 2021
Online: Oct. 16, 2021

Keywords:
Yellowstrip scad,
Population parameters,
Exploitation,
Acid solvent,
Mortality,
SPR

ABSTRACT

The purpose of this study was to review the parameters of the population dynamics of the yellowstrip scad (*Selaroides leptolepis*) for consideration in sustainable management from October 2020 to March 2021. Yellowstrip scad samples were collected using purse seine, gill net, and hand line fishing gears and then analyzed for population parameters to meet the study objectives. The parameters of the yellowstrip scad population in Ternate Island waters were relatively stable, with a maximum length value of 33.49 cm, growth coefficient of 0.99 per year, fishing mortality of 0.42, natural mortality of 1.71, exploitation rate of 0.2, and SPR 4 of 2%, and a recruitment value of 1.9% Y/R and 56.8% B/R. Whereas,these findings indicate that increased fishing effort is required until the exploitation value reaches 0.4 for optimal and sustainable management.

INTRODUCTION

The intensity of catching pelagic fish in the waters of Ternate Island is high, as evidenced by the results of an analysis of the exploitation level of yellowstrip scad fish in 2018, which reached 0.55 exceeding the optimum level of utilization (**Tangke *et al*., 2018; Lekahena *et al*., 2021**). If this condition persists, it will undoubtedly put pressure on fish resources, resulting in reduced stock or the extinction of the yellowstrip scad population in Ternate Island waters. To avoid this, management attempts to ensure the sustainability of fish resources, particularly the type of yellowstrip scad fish (Fig. 1) are highly required.

Fishery management activities aim to conserve fish resources in a fishing area by restricting fishing activities to the closure of fishing areas in the event of excessive pressure on the fish population, which is based on stock studies and population parameter estimates. The goal of population parameter estimation is to investigate the fundamental changes that occur in a population, such as age group, maximum length, growth rate, mortality rate, and exploitation rate in order to apply rational and generally quantitative fisheries resource management principles (**Lelono *et al*., 2018**)

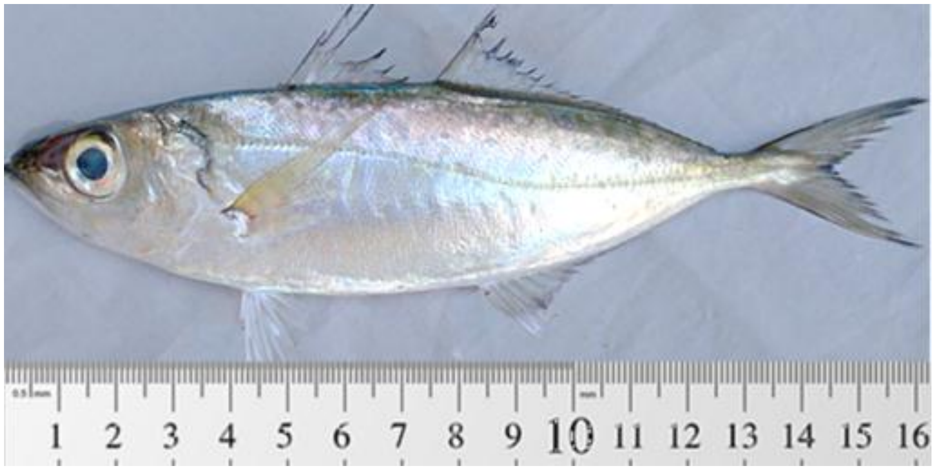


Fig. 1. Yellowstrip scad (*Selaroides leptolepis*)

Tangke (2014) stated that knowledge of population parameters is important because it provides information about the number and size of fish that fishermen can catch each year in order to maintain resource sustainability. The primary goal of population parameter research is to provide information and/or recommendations for management purposes, such as optimal exploitation of fish resources, inputs and outputs for fisheries (**Kartamihardja, 2015)**.

The study of fish population dynamics is an important tool in effective management **(Hoeng & Gruber, 1990)**, and it can provide inputto support decisions regarding the sustainable management of fish stock and resource populations, as well as serve as a biological indicator to determine the status of fish populations. The success of good fishery management is heavily reliant on estimating the condition of the fish population by examining the dynamics population of exploited fish resources, which are influenced by parameters such as growth, recruitment, mortality, exploitation rate, and analysis of spawning potential ratios. Therefore, The purpose of this study was to review the parameters of the population dynamics of the yellowstrip scad in the waters of Ternate Island for consideration in sustainable management.

MATERIALS AND METHODS

Yellowstrip scad samples were collected from fishermen using purse seine, gill net and hand line fishing gears in the waters of Ternate Island (Fig. 2), with the number of samples measured at 2,045 fish and sampling time per week for 6 months beginning in October 2020 and ending in March 2021.

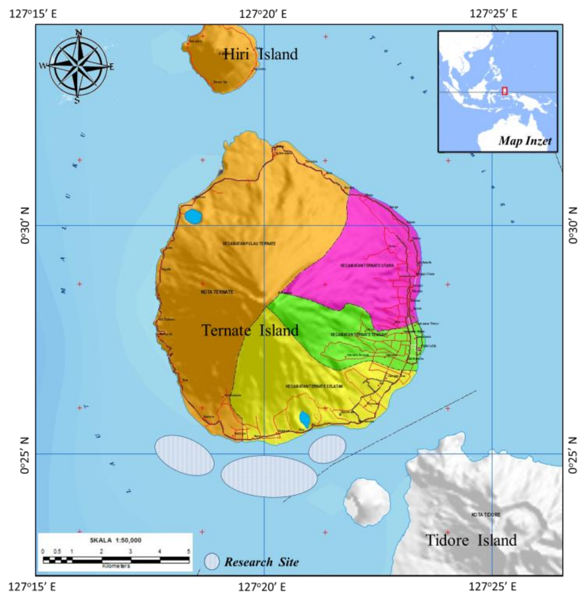


Fig. 2. Research locations (Ternate Island waters)

Data from the measurement of 2045 yellowstrip scad were then analyzed for population parameters with data analysis including: the growth pattern of the yellowstrip scad, estimated by the von Bertalanffy growth model (**Sparre &Venema, 1999**) as in Equation 1.

$$L_t = L_\infty\left[1 - e^{-K(t-t_0)}\right] \quad \text{...(1)}$$

where : *Lt* is the total length of the fish at age *t*, *L*∞ is asymptotic length of the fish, *K* is the growth coeficient and t_0 is the theoretical age when the fish length is zero.

Asymptotic length (*L*∞) and growth rate (*K*) were estimated by the ELEFAN method FISAT II **(Mildenberger *et al*., 2017)**. The value of t_0 (age at length 0) is estimated based on the formula of **Pauly (1983)** following Equation 2.

$$\text{Log}(-t_0) = (-0.3922) - 0.2752 \log L\infty - 1.038 \log K \quad \text{……………..(2)}$$

The natural mortality (M) can be estimated using **Pauly's (1984)** empirical formula as in Equation 3.

$$M = \exp(-0.0152 - 0.279 \ln L\infty + 0.6543 \ln K + 0.4634 \ln T) \quad \text{… (3)}$$

Natural mortality (M) was estimated using the Pauly's M Equation method in FISAT II software, and total mortality (Z) was estimated using the Length convertedcatch curve method (**Pauly, 1983**). Furthermore, from determining the total mortality rate (Z) and natural mortality rate (M), the fishing mortality rate was calculated using Equation 4.

$$F = Z - M \quad \ldots (4)$$

The exploitation rate or analytical utilization rate (E) were calculated by the formula proposed by **Gulland (1971)** in the study of **Pauly (1983)** as in Equation 5.

$$E = \frac{F}{Z} \quad \ldots (5)$$

If: E > 0.5, the exploitation rate is high (overfishing); E < 0.5, low exploitation rate (underfishing); and E = 0.5, optimal utilization **(Sparre and Venema, 1999)**.

Afterwards , the yield per recruitment was analyzed using Baverton and Holt equation **(Sparre and Venema, 1999)** as in Equation 6.

$$\frac{Y}{R} = \left(1 - \frac{3U}{1+m} + \frac{3U^2}{1+2m} + \frac{U^2}{1+3m}\right), \text{ where } U = 1 - \frac{L'}{L_\infty} \text{ dan } m = \frac{1-E}{M/K} \quad \ldots (6)$$

Where : M = natural mortality (per year); L' = the smallest limit of the length of the fish caught (cm); $L\infty$ = asymptote length (cm); and K = coefficient of growth rate (per month).

Spawning Potential Ratio (SPR) was analyzed using the method of **Prince *et al.* (2014)** as in Equation 7, 8 and 9. The formula is as follows:

$$SPR = \frac{\sum_{t=0}^{t} EPt}{\sum_{t=0}^{tmax} Ept} \quad \ldots (7)$$

$$EP_t = (N_{t-1}^{e} - M) f_t \quad \ldots (8)$$

Where : EPt = reproduction output at age t, Nt = the number of individuals at time t with N_0 is 1000, M = Natural mortality, dan f_t = average fecundity.

If the ft value was not available, then the EPt value could be obtained by the equation 9:

$$EP_t = (N_t * W_t * m_t) \quad \ldots (9)$$

Where : Wt = fish weight at age t, and mt = the average size of mature fish gonads.

Spawning Potential Ratio (SPR) was estimated using lengthbased-spawning potential ratio (LB-SPR) software developed by **Hordyk *et al*. (2014)** accessed online at http://barefootecologist.com.au/lbspr. It was supported with the criteria of **Walters and**

Martell (2004); where SPR > 40% (underexploited); 20% SPR 40% (moderate); and SPR 20% (over exploited).

RESULTS AND DISCUSSION

Age Group

Traditional ~~scale~~ fishermen use purse seines, gill nets, and hand line fishing gear to catch yellowstripe scad in Ternate Island's waters. Fig. (3) shows the results of 2,045 measurements recorded in the period from October 2020 till March 2021. Recorded data show that the length of the yellowstripe scad is in the range of 5.65 - 31.82 cm and the average length is 18.5 cm, with a normal curve that describes the number of the monthly cohorts of the frequency distribution of yellowstripe scad during the research using the Bhattacarya method.

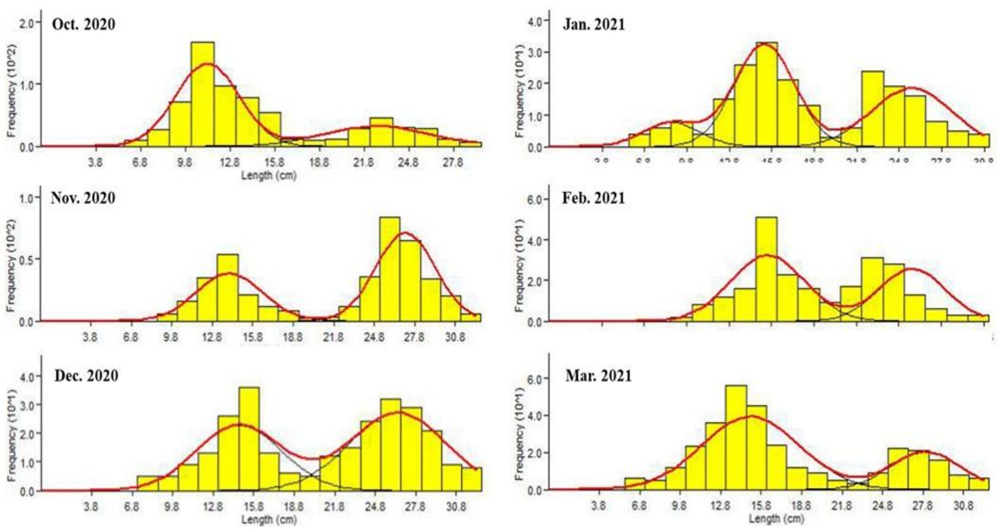


Fig. 3. Yellowstripe scad length frequency and monthly cohort in the of Ternate waters during October 2020 - March 2021.

Fig. (3) shows the size distribution of yellowstripe scad caught from October 2020 to March 2021 with two age groups on average, having January 2021 with 3 age groups as an exception. In October 2020, the fish size group recorded a length of 22.63 ± 3.5 cm, but it witnessed a change in November and December 2020 with values of 27.05 ± 2.2 cm and 26.43 ± 3.6 cm, respectively. In the period extending from January to March 2021, the length values were 25.63 ± 2.8 cm, 25.71 ± 2.3 cm, and 27.92 ± 2.6 cm respectively. The presence of a shift in the age group from October 2020 to March 2021 in Fig. (3) indicates a change in the length of the fish caught each time a research sample was collected.

Growth Parameters

The Von Bertalanfy Growth Function (VBGF) curve in Fig. (4) depicts the length frequency and number of yellowstripe scad cohorts sampled from October 2020 to March 2021, where the cohort crossed by the blue line indicates a cohort that is still growing in length, so that fish reaching L growth occurs constantly, as indicated by a blue line that is getting straighter.

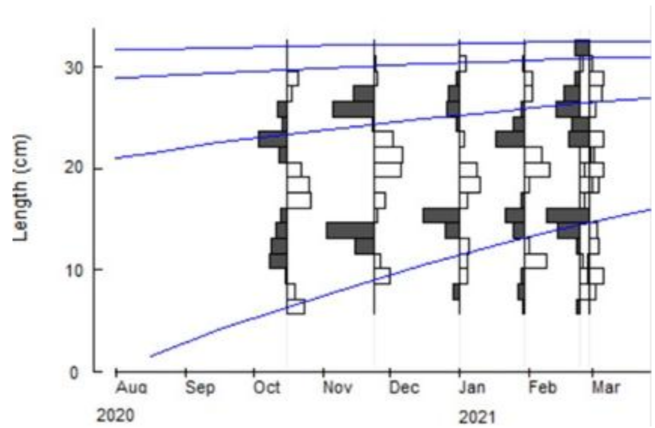


Fig. 4: Von Bertalanfy Growth Function (VBGF) curve of Yellowstripe scad

The analysis of yellowstripe scad growth parameters in the FISAT II program using the ELEFAN I method of scanning of K-values yielded a L_∞ of 33.94 cm and a K value of 0.99/year. The yellowstripe scad is assumed to have a fast growth rate and a short lifespan based on the value of K because it takes a relatively short time to reach its asymptotic length. When compared to studies of the same species conducted in various locations and years, the growth parameter values of the yellowstripe scad in the current study appear to be different (Table 1).

Table 1. Growth of Yellowstripe Scad (*S. leptolepis*) in Several Locations

Researcher/Year	Location	K (per year)	L_∞ (cm)
Damayanti, 2010	Jakarta Bay	0.31	28.298
Kusuma, 2013	Karangantu	0.55	24.550
Sapira & Zulfikar, 2013	Malang Rapat	0.105	33.0
Annisa *et al*., 2015	Malacca Strait	0.87	20.0
Rasyd *et al*., 2019	Wolo waters	0.97	17.383
Tangke *et al*., 2020	Ternate Island Waters	0.28	22.78
This study, 2021	Ternate Island Waters	0.99	33.49

Data presented in Table (1) show that, the growth parameters (L_∞ and K) of yellowstripe scad fish in Ternate Island waters are higher than in some other locations, with the exception of the K value in the *Malang Rapat* area. Moreover, the previous author conducted a study in the same location and in different years recorded different growth parameters for the same species. The difference in the growth parameter is due to environmental factors and exploitation pressures that can affect the maximum growth of yellowstripe scad, a viewpoint which coincides with the perception of **Omar *et al*. (2013)** who attributed the difference in maximum length in some watersto the environmental factors such as fertility. Meanwhile, **Tambun (2017)** concluded that each species of the same fish, though living in different locations, will record a different growth period.

After determining the values of L_∞, K, and t_0, the growth equation was obtained using the VBGF equation, namely: $L_t = 33.49(1 - exp^{-0.99(t-(-0.166))})$, and a yellowstripe scad growth curve was created as shown in Fig. (5). The growth curve in Fig. (5) shows that the yellowstripe scad's length grows rapidly when it is less than 2 months old, then the length begins to slow down when it gets older than 2 months until it reaches its maximum length at 5.7 months. The rapid growth of yellowstripe scad is thought to be due to the condition of Ternate Island's waters, which are fertile and rich in the availability of quite a lot of plankton due to the AIRLINDO process and the increase in water mass (upwelling), where plankton is a food source for small pelagic fish, particularly, yellowstripe scad.

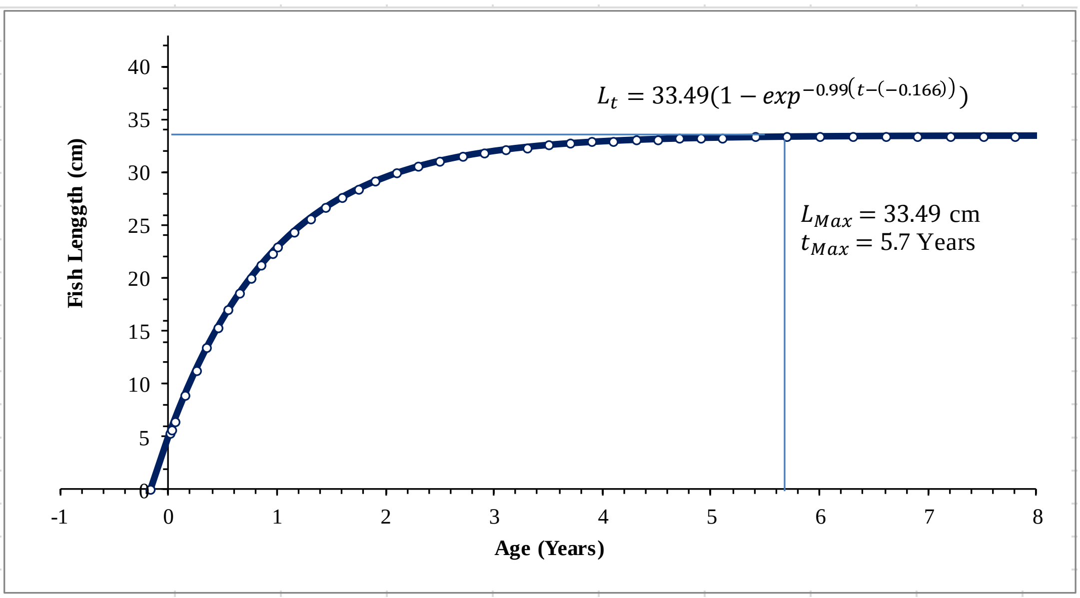


Fig. 5. Graph of Yellowstripe Scad Fish growth rate in the waters of Ternate Island

Mortality and Exploitation Rate

The mortality rate of the yellowstripe scad in Ternate Island waters was estimated using fish length and data of an average water temperature of 27.5°C, with the results of the analysis of the natural mortality (M), fishing mortality (F) total mortality (Z) per year recording values of 1.71, 0.42, and 2.13, respectively (Fig. 6).

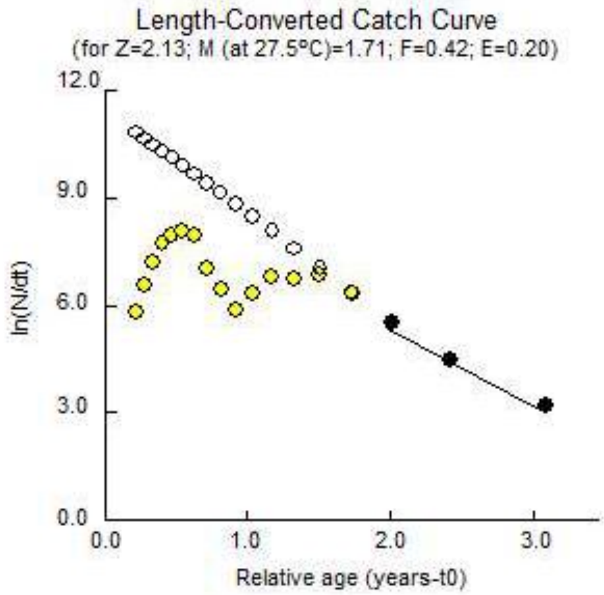


Fig. 6: Linearized catch curve based on fish length composition data

These findings indicate that the natural mortality value is greater than the fishing mortality value, which means that the yellowstripe scad fish resources in Ternate Island's waters are not used to their full potential. The results of the exploitation level analysis using the value of fishing mortality analysis on total mortality show an exploitation value of 0.20 per year. This indicates that the exploitation level of yellowstripe scad in Ternate Island waters is still under fishing and that management efforts to maximize yellowstripe scad utilization are required. According to **Rasyid *et al*. (2019)** and **Maulana (2011)**, fisheries management must be determined through several stages, including the initial stage, when fish production is still below the maximum sustainable yield (MSY). The policy must aimeprimarily at encouraging fishing development. When a fish stock's capacity limit (potential, carrying capacity) is reached, the rate of development of fishing begins to slow, and when the catch value exceeds the MSY threshold, all policies become more restrictive.

Table (2) shows that the natural mortality value (M) of yellowstripe scad in Ternate Island's waters in 2021 is quite high when compared to several locations, including the same location in different years, whereas fishing mortality (F) is quite low, and these two conditions are related to total mortality (Z) and exploitation rate (E).

Based on the analysis of results presented in Table (2), it can be deduced that the level of utilization or activity of catching yellowstripe scad in several locations , including the same location in 2018, is quite high. This caused an elevation in the level of exploitation (E) to a high extent passing the optimum management limit and cused it to be classified as over fishing, when compared to the oblique fishing (in 2021). It is obvious that fishing activity and exploitation of yellowstripe scad in Ternate Island waters is still low or non-existent. According to **Sparre and Venema (1999)**, an exploitation value greater than 0.5 indicates overfishing, whereas, an exploitation value less than 0.5 indicates underfishing, and an exploitation value equal to 0.5 indicates optimal utilization. According to **Tangke *et al*. (2018)**, if fishing activity (F) is high and natural mortality is low, the level of exploitation (E) will be higher. Furthermore, **Rasyid *et al*. (2019)** assessed that, one of the factors contributing to the high level of exploitation is the high rate of fishing, as well as the type and number of fishing gear used.

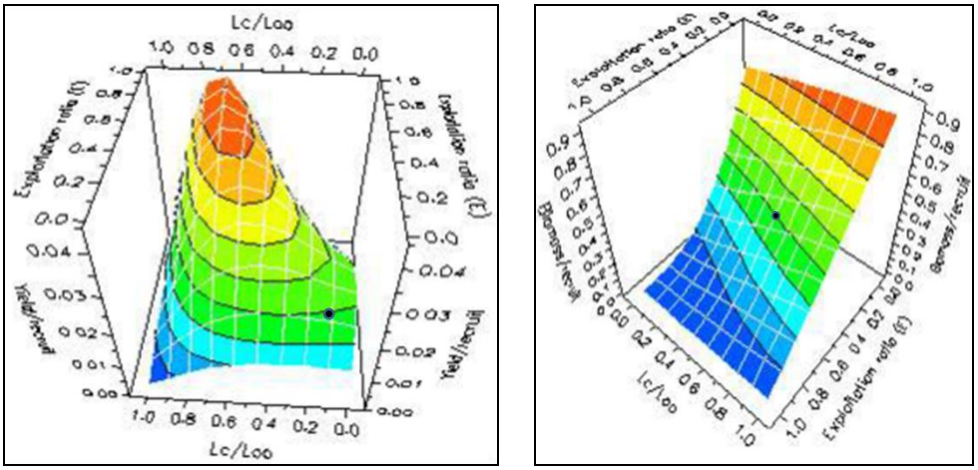
Table 2. Mortality and Exploitation rate of Yellowstripe Scad in Several Locations

Researcher/Year	Location	Z	M	F	E
Damayanti, 2010	Jakarta Bay	2.25	0.007	2.17	0.96
Kusuma, 2013	Karangantu	1.91	0.42	0.48	0.77
Sapira and **Zulfikar, 2013**	Malang Rapat	0.78	0.30	17.383	0.61
Rasyd *et al*., 2019	Malacca Strait	2.65	1.09	1.5	0.59
Tambun, 2017	Wolo waters	4.34	1.20	3.13	0.72
Tangke *et al*., 2018	Ternate Island Waters	1.43	0.64	0.79	0.55
This study, 2021	Ternate Island Waters	2.13	1.71	0.42	0.20

According to the Ternate City Maritime Affairs and Fisheries Service's 2018 Annual Report, the total production of yellowstripe scad fish reached 13.9 tons per year, from 7 purse seine fishing gear units, 12 gill net units, and 153 hand line units, with a total of 15,312 fishing trips. Following the imposition of the restrictions in 2019, the production of yellowstripe scad in 2020 fell to 9.6 tons/year, with 12,168 fishing trips per year, from 5 purse seine units, 10 gill net units, and 156 hand line units. According to **Tahapary (2010)**, the greater the fishing effort and the number of fishing gear in use, the higher the mortality rate of fish due to catching.

Yield per Recruitment (Y/R) and Biomass per Recruitment (B/R) analysis

In the Beverton and Holt model, the yield per recruit is a function of the age composition of the fish being exploited. The Y/R value was 0.019, indicating that 1.9 percent of yellowstripe scad entered the waters and were caught by fishermen. The intersection point in the Y/R graph is shaded green, indicating that utilization is still low or underfished (Fig. 7a). While the B/R value indicates the relative biomass per recruit, the results of the B/R analysis yield a value of 0.568, indicating that 56.8 percent of the remaining fish biomass enters the water. The intersection point of the B/R graph (Fig. 7b) is green, indicating that the biomass of yellowstripe scad fish in the waters of Ternate in its multigear management is still in excellent condition.



(a) (b)

Fig. 7: Spin Plot Graph Y/R (a) and B/R (b) of Yellowstripe Scad

Spawning Potential Ratio (SPR)

The Spawning Potential Ratio (SPR) was used to estimate the utilization status of yellowstripe scad in Ternate Island's waters. The spawning potential ratio is a relative reproductive index used to determine stock conditions in exploited fisheries, as a biological reference point to determine the status of exploitation between selectivity, size of fish caught, and size of adult fish caught (**Prince *et al.*, 2014**). Table (3) shows the results of the analysis of the Spawning Potential Ratio (SPR) which is estimated based on the value of the ratio of the natural mortality rate to growth (M/K) which is 1.9, asymptotic length (L_∞) is 33.49 cm, length when 50% of the gonads mature fish population (SL_{50}) is 11.5 cm, and the length when 95% of the population of gonadal mature fish (SL_{95}) is 18.98 cm.

Table 3. SPR Value of Selaroides leptolepis (Cuvier 1833) Caught in Ternate Island Waters.

Spesies	SPR (%)	SL_{50}	SL_{95}	F/M	MK	L_∞
***Selar Kuning (S. leptolepis,* Cuvier 1833)**	42	11.05	18.98	0.25	1.9	33.49

Table (3) reveals that the F/M value is 0.25 or less than 1(0.25 < 1;indicating that mortality from fishing activities is less than natural mortality. This is a consideration that there should be more optimal utilization by increasing the number of fleets or fishing trips to catch yellowstripe scad fish resources in the Ternate Island Waters.

Furthermore, The SPR visualization (Fig. 8) shows that the management status of the yellowstripe scad **(S. leptolepis, Cuvier 1833)** is in the underexploited category (green color), where the same thing is also shown at a low level of exploitation (E = 0.2).

Thus, this condition serves as information material for fishermen and related parties, particularly, policymakers in the management of yellowstripe scad fish.

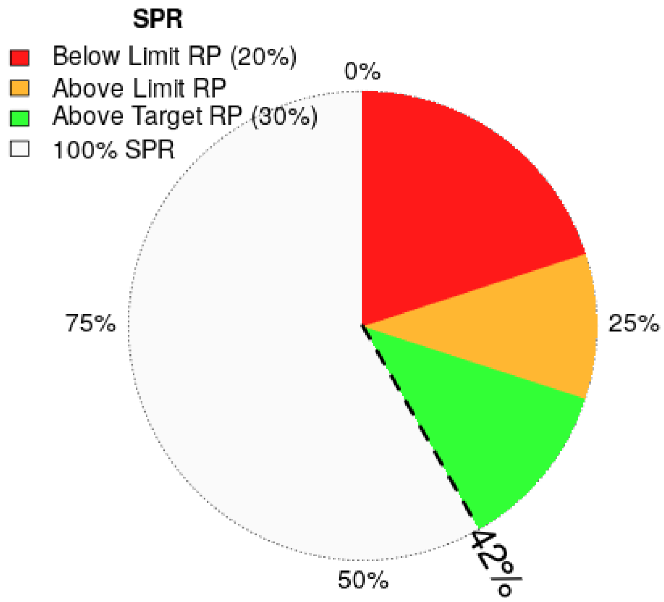


Fig. 8 SPR value of yellowstripe scad fish (S. leptolepis, Cuvier 1833) in Ternate Island water

CONCLUSION

The parameter condition of the yellowstripe scad (*Selaroides leptolepis*) population in Ternate Island waters is still relatively stable, with a maximum length of 33.49 cm in 5.7 months and a growth coefficient of 0.99 cm/month, with natural mortality (1.71) higher than capture mortality (0.42). The exploitation rate remains low, namely (E) 0.2, while the SPR remains high (42%), and the Y/R and B/R values are 1.9% and 56.8%, respectively, implying that more increased fishing efforts are required to maximize the utilization of fish potential. Scad fish yellowstripes until the value of E reaches the maximum number (0.5).

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