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Population dynamics of the yellowstripe scad (*Selaroides leptolepis* Cuvier, 1833) and Indian mackerel (*Rastrelliger kanagurta* Cuvier, 1816) in the Wondama Bay Water, Indonesia

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Abstract. The Wondama Bay water is located within the Cendrawasih Bay National Park and is potential for fishery resources, including pelagic fish such as yellowstripe scad (*Selaroides leptolepis* Cuvier, 1833) and Indian mackerel (*Rastrelliger kanagurta* Cuvier, 1816). Yet, information about the population dynamics of these species in the region is unknown until today. Meanwhile, the fishing activities have been quite intensive and include the dominant catches over the last ten years by traditional fishermen fishing using liftnets. Therefore, this study aims to determine some of specific characteristics of the population dynamics and fish utilization status of scad and mackerel in the waters of the Wondama Bay. Data used in this study were taken from direct observation of catch of liftnet fishery. The data then were analysed by using FISAT II to estimate the growth parameters, mortality rates, and yield per recruitment. The results showed that yellowstripe scad has the positive allometric growth, while Indian mackerel followed isometric growth. Models of fish growth were $L(t) = 22 (1 - e^{-3.0(t-0.05)})$ for yellowstripe scad and $L(t) = 27.8 (1 - e^{-4.0(t-0.04)})$ for Indian mackerel. The natural mortality (M) of 4.19 year⁻¹, fishing mortality (F) of 5.01 year⁻¹, and total mortality (Z) of 9.20 year⁻¹ were for yellowstripe scad, and M of 4.74 year⁻¹, F of 2.52 year⁻¹ and Z of 7.26 year⁻¹ were for Indian mackerel. Based on the mortality rates, estimated exploitation rate for the yellowstripe scad was 54 % and the Indian mackerel was 35 %. To increase the production of catch without increasing fishing effort (fishing mortality) can be done by increasing the size of fish caught or the L_c/L_∞ should be greater than 0.5.

1. Introduction

The present study focuses on the yellowstripe scad (*Selaroides leptolepis* Cuvier, 1833) and Indian mackerel (*Rastrelliger kanagurta* Cuvier, 1816) that live in coastal waters of the Wondama Bay. The bay is within conservation areas of the Cendrawasih Bay National Park (CBNP). Both fishes belong to small pelagic fish that have value in supporting ecological function of coastal ecosystem. In addition, both fishes are considered economically important and consumed by most communities in Wondama. Yellowstripe scads are caught in coastal waters and live in schooling up to 50 m depth [1] and Indian mackerel schoolings are found in water up to 90 m depth [2]. Nowadays, high demand and high prices of these species encourage increased catch [3]. Data from 2008 to 2012 showed that yellowstripe scad and Indian mackerel were at the top five of fish species contributing to fish production in Wondama [4].



Utilization of fishery resources in the CBNP often leads to conflict between fishermen from outside the region and local fishermen [5]. A fishing technology approach in fisheries management in the CBNP has emphasized [6]. Based on the above facts, research on the dynamics of population becomes very important, especially from the aspects of growth, mortality, and exploitation rates of the yellowstripe scad and Indian mackerel species.

Both fishes are the dominant catch of liftnet fishery in the waters of the Wondama Bay operated by small scale fishery. Fishing with liftnets used light aids to draw fish gathered on the net. Because of the nature's attraction of the fish on light [7], it makes the fish very susceptible for being caught by the liftnet fishing gears. In addition, since the selectivity of the liftnets is low, because it used very small mesh size of net (minnow net), it makes almost every size of the fish caught by the liftnet. Consequently, young cohort fish will be caught.

Fishing on young fish or fish with size less than the first maturity size will lead to a decrease in population productivity to reproduce a new generation and reduce recruitment supply for fisheries. This may lead to disruption of the population's ability to maintain its sustainability. In addition, yellowstripe scad and Indian mackerel populations are important part of the fish communities that support the ecosystem in the Wondama Bay waters. The existence of the fish populations is important to maintain a trophic balance of food which will further maintain the balance of the ecosystem.

Concerning the declining population of small pelagic fish resources in off the Cendrawasih Bay National Park area, and efforts to obtain data on fisheries resources, study on the dynamics of the pelagic fish populations was proposed. Such study is crucial in the context of sustainable fisheries resource management [8], particularly for the management of catch size and optimum level of fishing effort.

2. Materials and Methods

2.1. Site and sample collection

This study conducted in the Wondama Bay of the (CBNP) Indonesia (figure 1). Data collection was carried out from March to April 2016. Samples of yellowstripe scad (*Selaroides leptolepis* Cuvier, 1833) and Indian mackerel (*Rastrelliger kanagurta* Cuvier, 1816) were taken from liftnet fishermen. Yellowstripe scad and Indian mackerel were bycatch of the liftnet, since the fishing targets of the liftnet in Wondama were anchovies. There were 116 individuals of yellowstripe scad and 261 individuals of Indian mackerel sampled during the survey. The fish samples were then measured their total body length (L) and weight (W). L and W of the samples were measured to the nearest centimeter (cm) and gram (g).

2.2. Length-weight relationship

The length-weight relationship was analyzed by fitting function $W = aL^b$ to length (L) and weight (W) data [9]. Regression coefficients a and b were obtained by using least square methods by firstly transforming the function into logarithmic form, $\log W = \log a + b \log L$. Statistical test was done to examine whether b value is close to 3.0 or not by using t-test, as shown in formula (1) below. If b is close to 3, it means that the species shows isometric growth. When b significantly larger or less than 3, it indicates allometric growth [9].

$$t = \left(\frac{SD_y}{SD_x} \right) \left(\frac{|b-3|}{\sqrt{1-r^2}} \right) (\sqrt{n-2}) \quad (1)$$

2.3. Growth model

Model growth of fish species was estimated by using von Bertalanffy growth function (VBGF) as follows:

$$L(t) = L_{\infty} (1 - e^{-k(t-t_0)}) \quad (2)$$

where: $L(t)$ is the fish length at age t ; L_{∞} is asymptotic length; K is growth coefficient; t denotes the age of fish and t_0 is hypothetical age at which a fish would have zero length. The age t_0 was estimated by using Pauly's formula [10]:

$$\text{Log}(-t_0) = -0.3922 - 0.2752 \text{Log} L_{\infty} - 1.038 \text{Log} K \quad (3)$$

The estimated ages at each fish length were calculated by using derivation of VBGF [11] namely:

$$t = t_0 \frac{1}{K} \cdot \text{Ln} \frac{(1-Lt)}{L_{\infty}} \quad (4)$$

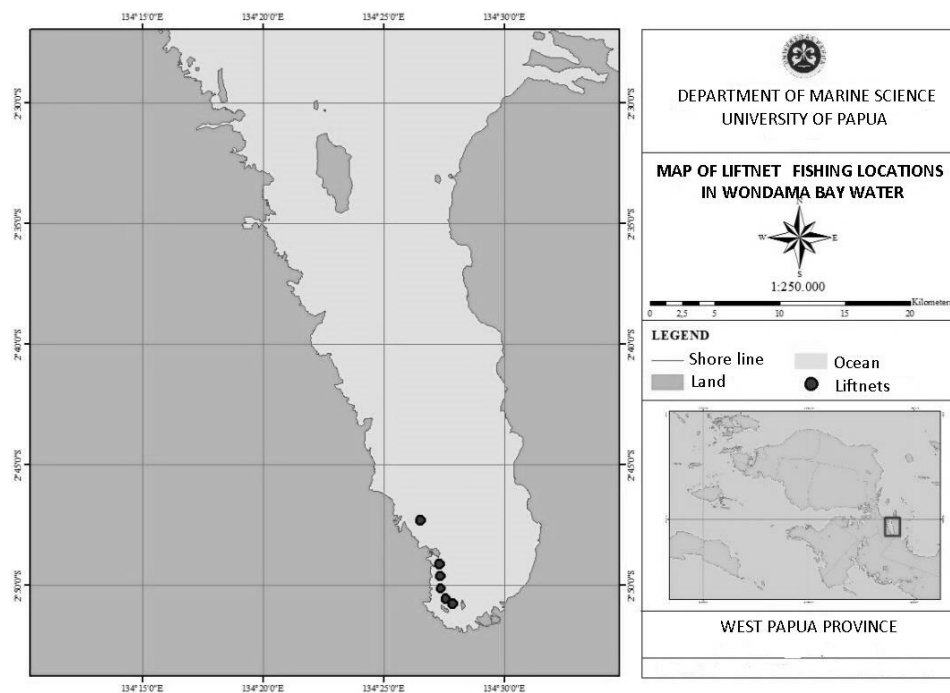


Figure 1. Map of study area in the Wondama Bay.

2.4. Mortality and exploitation rates

Total mortality rate (Z) of fish consists of natural mortality (M) and fishing mortality (F). The total mortality rate was estimated by using Beverton-Holt method which was based on the length frequency of data distribution [11], in which Z and L follow functional relationship:

$$Z = K \cdot \frac{(L_{\infty} - L)}{(L - L_c)} \quad (5)$$

where Z = total mortality, L_{∞} = asymptotic length, K = growth coefficient, L = mean length of the fish (cm), L_c = length of fish caught (cm).

Estimation of natural mortality used empirical equation of Pauly [12] as shown in equation (6).

$$\text{Log} M = -0.0066 - 0.279 \text{log} (L_{\infty}) + 0.6543 \text{log} (K) + 0.4634 \text{log} (T) \quad (6)$$

where M = natural mortality, L_{∞} = asymptotic length, K = growth coefficient, T = Mean sea surface temperature ($^{\circ}\text{C}$). The equation shows a positive relationship between natural mortality, growth parameters, and sea surface water (SST). We used mean SST of 31°C as suggested by [13] for water surface temperature in CBNP.

When Z and M are known, then fishing mortality rate (F) can be estimated by using formula $F = Z - M$. Furthermore, the exploitation rate (E) can also be estimated since E is the ratio of fishing mortality (F) and total mortality (Z) [14]. The optimal exploitation rate of fish stocks occurs when F equals M [15]. Thus, when E larger than 0.5, it indicates that the fish stock is experiencing overexploitation.

2.5. Relative yield-per-recruit (Y/R)

Relative yield-per-recruit (Y/R) was estimated by using formula [16] :

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

where

$$U = 1 - (L_c/L_\infty)$$

$$m = K/Z$$

L_c = Length at fish caught

E = Exploitation rate

The analyses of data for estimating growth parameters, mortality rates and yield per recruitmet were done by using FAO-ICLARM Stock Assessment Tools II (FISAT II) [16].

2.5.1. A subsection. The paragraph text follows on from the subsection heading but should not be in italic.

3. Results and Discussion

3.1. Length frequency distribution of yellowstripe scad and Indian mackerel

Frequency distribution of yellowstripe scad and Indian mackerel caught in the Wondama Bay is shown in figure 2. Length of yellowstripe scad spreaded between the range of 10 and 24 cm, whereas the Indian mackerel ranged between 15 and 26 cm.

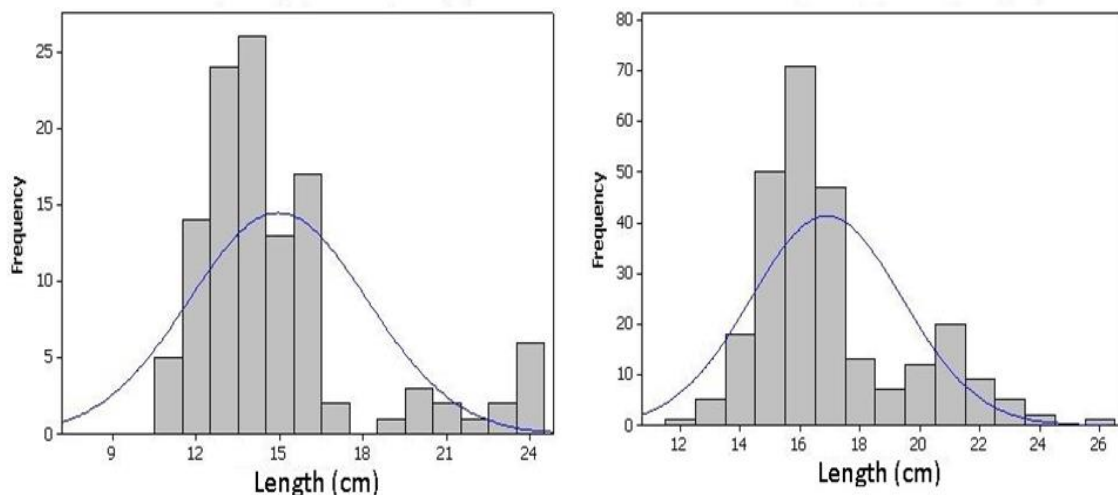


Figure 2. Size composition of yellowstripe scad (left) and Indian mackerel (right) in the Wondama Bay.

Both length curves tended to skew to the left, which showed that more portions of fish caught were at small sizes (young fish). On average, the length of yellowstripe scad is 14 cm and Indian mackerel is

16.88 cm, as shown in table 1. Fishbase (fishbase.org) records the length at first maturity (L_m) for the yellowstripe scad is 11.9 cm and for the Indian mackerel is 19.9 cm. Based on these data, the scads captured by using liftnets in the Wondama Bay were generally larger than L_m or have been in spawning ages. On the other hand, most the Indian mackerel taken using liftnets in the Wondama Bay waters were at the sizes less than L_m or immature fish.

Table 1. Mean length and weight of yellowstripe Indian scad and mackerel in the Wondama Bay

No	Type	Length (cm) Average and Standard deviation (n)
1	Yellowstripe scad	14.90 ± 3.20 (116)
2	Indian mackerel	16.88 ± 2.519 (261)

3.2. Length-Weight Relationship of yellowstripe scad and Indian mackerel

The length-weight relationship (LWR) of yellowstripe scad caught in the Wondama Bay followed the equation $W = 0.003L^{3.41}$ with the coefficient of determination between length and weight (R^2) of 0.91. The LWR for Indian mackerel followed the equation $W = 0.009L^{3.02}$ with R^2 is 0.74. The relationship curves, which is in logarithmic form of L and W, is shown in figure 3.

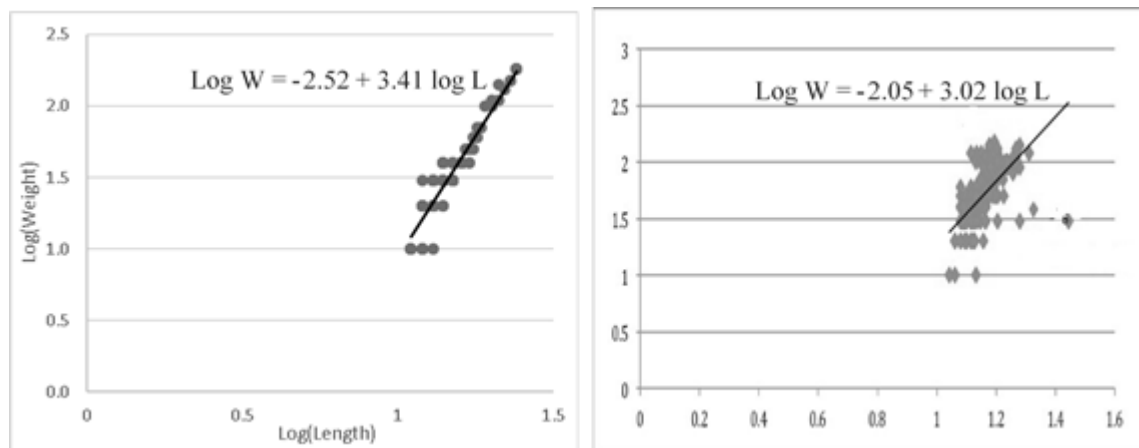


Figure 3. Length-weight relationship of yellowstripe scad (left) and Indian mackerel (right) in the Wondama Bay.

The above-mentioned pattern of growth-length relationship shows a regression coefficient (b) for yellowstripe scad is 3.41 (greater than 3) which means having a positive allometric growth pattern, or growth of weight faster than growth of length. This is in contrast to the growth pattern of yellowstripe scads in some places in Indonesia that shows negative allometric and isometric growth pattern [17]. The relationship pattern of Indian mackerel exhibit that b coefficient is 3.02, indicating that the fish had an isometric growth pattern, which means growth of length is proportionally to growth of weight. This growth pattern is different from that found in the waters of the Bay of Bengal, has a negative allometric growth pattern [18], and also different from that found in the western Indonesian waters [2] that tends to be allometrically positive pattern [9] found several things that affect the difference in rates of weight growth and length growth, including differences in habitat, time, season, size, and growth phases (i.e. at the beginning of the growth phase tends to increase in the length faster than other dimensions).

3.3. Growth models for yellowstripe scad and Indian mackerel

The curves of length growth models for yellowstripe scad and Indian mackerel are shown in figure 4. The yellowstripe scad and the Indian mackerel have asymptotically long parameters of 22.0 cm and 27.8 cm respectively. Both fish species have large values of growth coefficient (K), i.e. 3.0 for yellowstripe scad and 4.0 for Indian mackerel. The large K values indicates that both fish have very rapid growth to achieve asymptotic length.

The growth parameter values for both fish species are slightly different from those observed in some waters in Indonesia. For yellowstripe scad, $L_{\infty} = 18.9$ cm and $K = 1,1 \text{ year}^{-1}$ are observed in Riau waters and $L_{\infty} = 22$ cm and $K = 1.2 \text{ year}^{-1}$ are found in the Java Sea [19]. For Indian mackerel, $L_{\infty} = 23.9$ cm and $K = 2.76 \text{ year}^{-1}$ are found in Java Sea [20], $L_{\infty} = 25.8$ cm and $K = 1,630 \text{ year}^{-1}$ are observed in Java Sea (Pekalongan) [19]. The species occupying different habitat environments will exhibit different patterns of life history characteristics [21]. So, the differences in growth parameters, particularly the growth coefficient and K of between yellowstripe scad and Indian mackerel might be related to differences in the quality of the aquatic environment, including the availability of food. The Wondama Bay waters possibly has good water conditions and food availability to support the growth of fish.

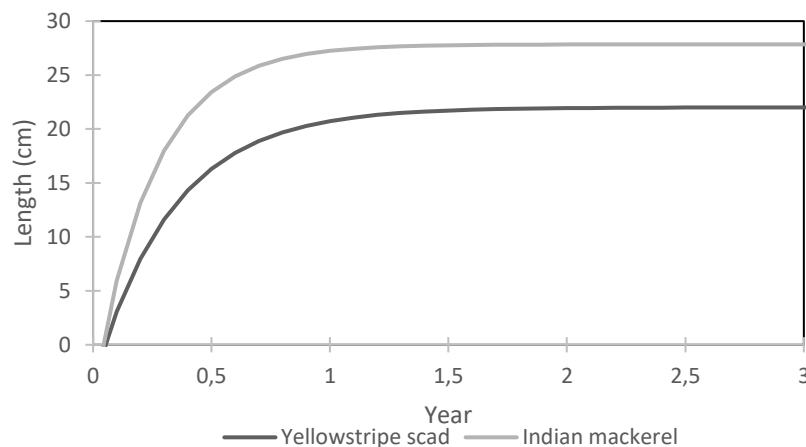


Figure 4. Growth curves of yellowstripe Indian scad and in the Wondama Bay.

3.4. Mortality rate of yeallowstripe scad and Indian mackerel

Mortality rate (Z), natural mortality (M), fishing mortality (F) and rate of exploitation for yellowstripe scad and Indian mackerel in the Wondama Bay can be seen in table 2. Natural mortality of yellowstripe scad is lower than the fishing mortality while natural mortality of Indian mackerel is higher than fishing mortality. The natural mortality rate of yellowstripe scad is higher than that in Tambelan (Riau) with a value of 0.64 [22]. However, the natural mortality rate for Indian mackerel was is similar to that observed in the Java Sea ($M = 4.4$) [20]. The rate of natural mortality of fish is influenced by environmental conditions like SST, and life history of the fish such as fish i.e. growth rate (K). The increase in SST has affected the existence of marine ecosystems (including fish population) especially in the tropic [23]. The average SST in the CBNP is about 31 °C [13] which possibly caused a high natural mortality of fish in that region.

The important thing to note from the table 2 is the value of the rate of exploitation (E), which describes how the portion of biomass resources that have been taken by fishermen. The value of the rate of exploitation of yellowstripe scad is 0.54 and Indian mackerel is 0.35. These values suggested that yellowstripe scad has been exploited exceeded the optimum level. Therefore, action should be given to control fishing activities on this species so that this resource can be sustainable. Different conditions for mackerel, where exploitation rate is 0.35, there are many opportunities to catch this species.

Table 2. Model of growth of yellowstripe scad and Indian mackerel in the Wondama Bay.

No	Species	Z (year ⁻¹)	M (year ⁻¹)	F (year ⁻¹)	E (year ⁻¹)
1.	Yellowstripe scad	9.20	4.19	5.01	0.54
2.	Indian mackerel	7.26	4.74	2.52	0.35

3.5. Yield per recruitment

Results of analysis of yield per recruitment (YPR) on yellowstripe scad and Indian mackerel are presented in figure 5. Based on figures, the two fish species have relatively equal values of YPR. For instance, at size $L_c/L_\infty = 0.5$ and $E = 0.5$, Indian mackerel had YPR approximately 0.0456 grams/recruit and yellowstripe scad has YPR of 0.0424 grams/recruit. The YPR values explain the expected yield in every one recruitment of fish [11]. For example, 0.0456 grams/recruit of YPR for Indian mackerel explain that recruitment of one Indian mackerel would give a yield of 0.0456 grams. The amount of yield per recruitment can be improved only when the minimum size of fish allowed to be caught is large (i.e. $L_c / L_\infty > 0.5$) and/or E is greater than 0.5.

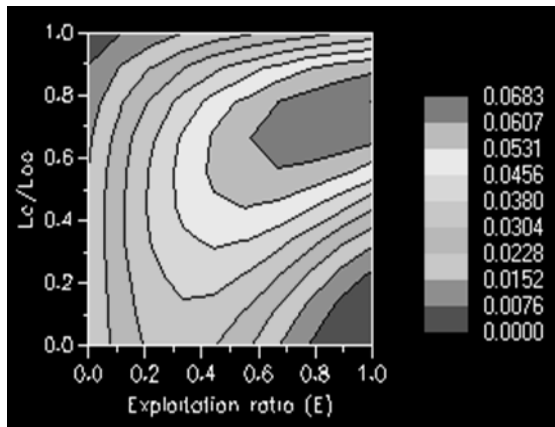


Figure 5. Isopleths of yield per recruitment (gram/recruit) for yellowstripe scad.

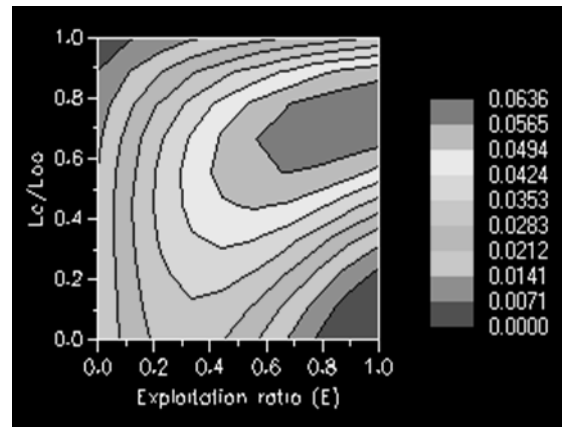


Figure 6. Isopleths of yield per recruitment Indian mackerel.

However, for the purpose of resource conservation of yellowstripe scad and Indian mackerel population, it is suggested to set L_c larger than the minimum length at first maturity of respective species to provide opportunity for the fish to reproduce before being caught. This requires an increase in the selectivity of fishing gears (liftnets) used to catch fish in the Wondama Bay. Also, the management control of fishing effort (e.g increasing the number of liftnets) should be carried out strictly and should not exceed the optimum level of effort.

4. Conclusion

- Yellowstripe scad caught in the Wondama Bay demonstrates a positively allometric growth of body shape, whereas Indian mackerel shows an isometric growth.
- Estimation of life history for yellowstripe scad is 22.0 cm, $K = 3.0 \text{ year}^{-1}$ and $M = 4.19 \text{ year}^{-1}$. For Indian mackerel, L_∞ is 27.8 cm, $K = 4.0 \text{ year}^{-1}$ and $M = 4.74 \text{ year}^{-1}$.
- The exploitation rate for yellowstripe scad is 0.54 and Indian mackerel is 0.35.
- To increase catch, it is suggested that for yellowstripe the size should be larger than L_m , which is larger than 11.9 cm, whereas for Indian mackerel should be larger than 19.9 cm.

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