Population dynamics of Indo-Pacific king mackerel (*Scomberomorus guttatus*) in Pangandaran, West Java, Indonesia

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Abstract. Indo-Pacific king mackerel (*Scomberomorus guttatus*) is one of Scombridae species that can be found in Pangandaran. *S. guttatus* production was reached almost half (45.62%) out of total large-pelagic-fish production in Pangandaran in 2018. The excessive fishing would jeopardize the sustainbility of *S. guttatus*, thus, a stock assessment and proper management is needed urgently. The objective of this study is to estimate the population dynamic of *S. guttatus* in Pangandaran by focusing on the growth parameter, mortality rate, exploitation rate, and length-at-first-capture. These factors are the basic data for fisheries management. The reasearch was conducted from August to September 2018 in Pangandaran waters. Data sampling for *S. guttatus* was using stratified random sampling method and the asymptotic length (L_∞) of *S. guttatus* was found at 735 mm with growth coefficient (K) of 0.87 year^{-1} and theoretical age (t0) of -0.46 years. The total mortality (Z), natural mortality (M), fishing mortality (F), and exploitation rate (E) of *S. guttatus* were 2.01 year^{-1}; 0.53 year^{-1}; 1.48 years^{-1}; and 0.73 year^{-1}, respectively. The mortality of *S. guttatus* in Pangandaran was dominated by fishing activities. The length-at-first-capture (Lc) of *S. guttatus* was found at 374 mm TL and 52.25% of samples were indicated an overfishing. Size and quantity of catch should be controlled with one of the management options by regulating the number of fishing efforts and the management of fishing gear (gill net) mesh size.

Key Words: growth parameters, length-at-first-capture, mortality, Pangandaran, *Scomberomorus guttatus*.

Introduction. Pangandaran is one of the fish landing centers in West Java, Indonesia. Capture fisheries is recognized as one of the major sectors that contribute to the local economy at the coastal area around Pangandaran (Nurhayati 2013).

Indo-Pacific king mackerel (*Scomberomorus guttatus*) is one of Scombridae species which can be found in Pangandaran. *S. guttatus* with its production rate reaching 45.62% out of the total large-pelagic-fish production in Pangandaran from 2015 to 2018 (DMAFFS 2018). Thus, *S. guttatus* has been recorded as the most large-pelagic-fish commodity caught in Pangandaran. The production also increased in parallel with the increase of market demand for *S. guttatus*. Therefore, fishers have been trying to improve their catchability to maximize revenue. This way would just result in the increase of fishing efforts for catching *S. guttatus* in Pangandaran.

Fisheries resources utilization regime known as common resources and open access for everyone triggers the excessive exploitation (Fauzi 2010). Overfishing will hamper the sustainability of this species as overfishing is a term or status given to a fishing area where a natural fish stock has been over-fished. Overfishing occurs when the fishing rate has exceeded the ability of a fish stock to recover naturally (Atmaja et al 2011). This will also affect the ecological equilibrium as well as economy as well as social aspects.

Fishery resource management is increasingly needed due to the increase of fish utilization. If there was no management involved in the fish utilization it will result in the depletion of a fish stock. The main purpose of a stock assessment is to prepare an estimation for fishing rate and efforts of a population with precautionary impacts of

various management policies (Widodo & Suadi 2008). The aim of this study is to estimate the growth, mortality rate, and length-at-first-capture of *S. guttatus* in Pangandaran, West Java, Indonesia.

Material and Method

Study site and sampling method. This study was conducted in Pangandaran, West Java, Indonesia (Figure 1). Fish samples were collected from fishers at a fish landing site in Cikidang, Pangandaran and collected once a month for 2 months (August 2018 to September 2018).

The samples of *S. guttatus* were collected from gillnetter fishers with fishing vessel < 5 gross tonnage (GT) in Pangandaran. Furthermore, samples collection stratified were randomly taken from five piles. Each pile contained small, medium and large in body size. All samples were calculated and measured for their total length (TL) using millimeter block with 1 mm of accuracy furthermore, the individual wet-sample was weighted using a digital scale with 0.1 g of accuracy (Digital scale manufacturer: *Seasiant India* MS-K07 Portable 3kg 0.1g Drip Coffee Scale with Timer Electronic).

Figure 1. Research location of Indo-Pacific king mackerel in Pangandaran.

Estimates of growth parameters. Results from growth coefficient (K), asymptotic length (L_∞), and theoretical age (t_0) were tested to estimate the von Bertalanffy's growth model (Sparre & Venema 1998) with the following formula:

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

where: L_t is the length at age t (mm), L_∞ is the asymptotic length (mm), K is the growth coefficient ($year^{-1}$) and t_0 is the theoretical age (year).

L_∞ and K were calculated using electronic length frequency analysis (ELEFAN) I model which was provided by the FAO-ICLARM Stock Assessment Tools (FiSAT) II (Gayanilo et al 2005), while the t_0 was determined based on Pauly's (1983) formula as follows:

$$\log(-t_0) = 0.3922 - 0.2752 \log L_\infty - 1.0380 \log K$$

Results from K and L_∞ obtained were then used to calculate the Growth Performance Index (Φ') using the Pauly formula (Pauly & Munro 1984):

$$\Phi' = \log K + 2 \log L_\infty$$

Mortality and exploitation rate estimations. Total mortality (Z) was predicted using Length-Converted Catch Curve provided from FiSAT II (Gayanilo et al 2005) and the natural mortality (M) was estimated by the empirical relationship equation (Pauly 1980):

$$\ln M = -0.0152 - 0.279 \ln L_\infty + 0.6543 \ln K + 0.463 \ln T$$

where: M is natural mortality (year^{-1}) and T is annual average habitat temperature (°C).

According to Pauly (1983), the fish mortality rate with schooling behavior such as mackerel is 20% lower than that of others. Therefore, the mortality rate of mackerel should be multiplied by 0.8. Z and M were further used to estimate fishing mortality (F) with relationship (Pauly 1983):

$$F = Z - M$$

where: F is fishing mortality (year^{-1}) and Z is total mortality (year^{-1}), and M is natural mortality.

Based on M, F, and Z value, the exploitation rate (E) was calculated by formula (Pauly 1983):

$$E = \frac{F}{F + M} = \frac{F}{Z}$$

Length-at-first-capture estimation. Length-at-first-capture estimation was calculated from a relationship between length distribution and the number of captured fish, based on the Beverton & Holt (1957) method:

$$S_L = \frac{1}{1 + \exp(S_1 - S_2 L)}$$

$$L_c = -\frac{S_1}{S_2}$$

where: S_L is the estimated value, L is median of interval class (mm), S_1 is intercept, S_2 is slope, and Lc is length-at-first-capture (mm).

Results

Size composition. A total of 356 of *S. guttatus* samples were observed during the study, with approximately 161 of samples in August and 195 of samples in September, respectively. TL ranged between 205 and 885 mm TL. The *S. guttatus* samples were found at 205-596 mm TL in August while between 260 and 685 mm TL in September (Figure 2).

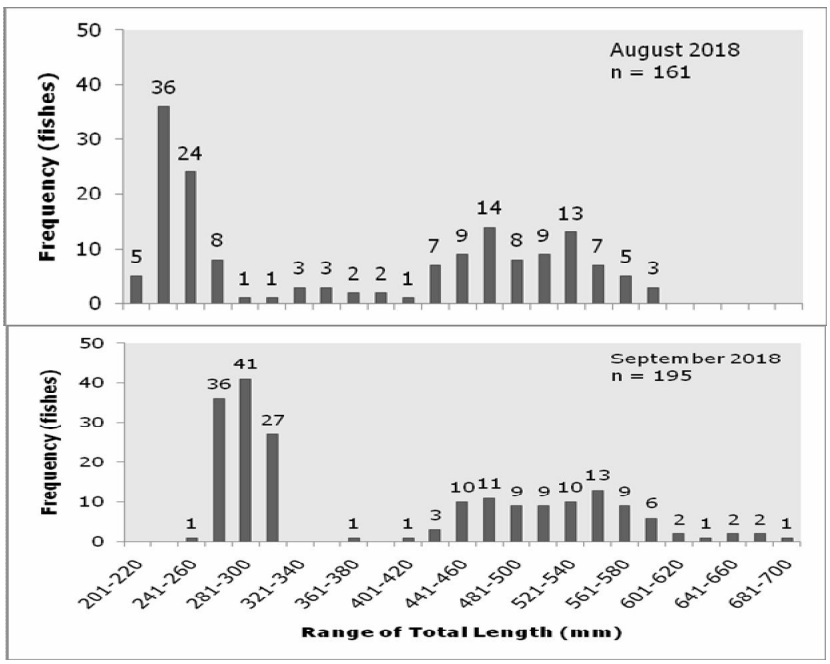

Figure 2. Size structure of *S. guttatus* in Pangandaran (August to September 2018).

Growth parameters. Results from the analysis of TL distribution for *S. guttatus* were used to calculate the von Bertalanffy growth curve (Figure 3). Based on the analysis, from 2 (two) months of samples collection we found that the *S. guttatus* asymptotic length (L_∞) were 735 mm with the growth coefficient (K) of 0.87 year^{-1} and the theoretical age (t_0) of -0.46 years. Based on these results, the von Bertalanffy equation for *S. guttatus* can be written as follows:

$$Lt = 735\left[1-e^{-0.87(t+0.46)}\right]$$

L_∞ and K results then can be used to calculate the growth performance index (Φ′) and from the analysis, Φ′ of *S. guttatus* was found at 5.67.

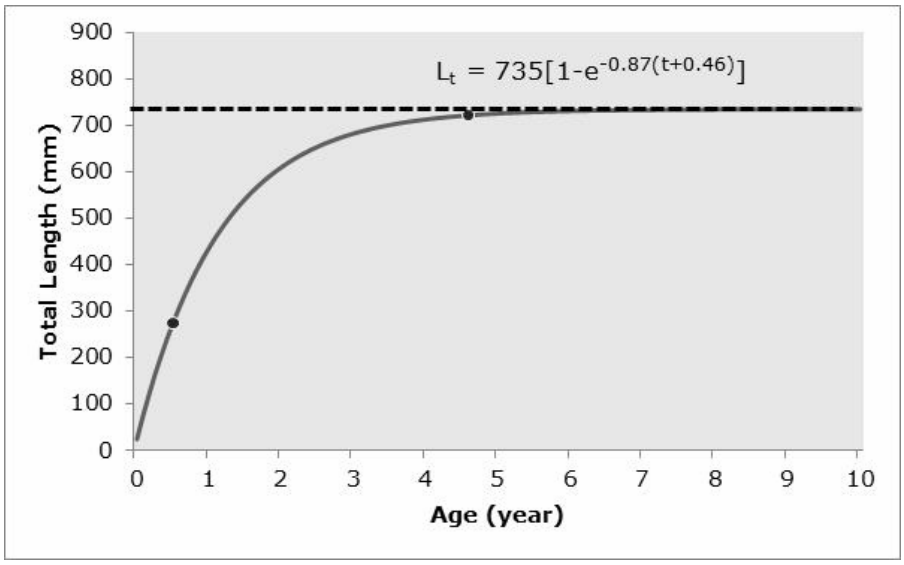

Figure 3. von Bertalanffy growth curve of *S. guttatus* in Pangandaran.

Mortality and exploitation rate. Total mortality rate (Z) of *S. guttatus* in Pangandaran water was found at 2.01 year^{-1} with the natural mortality (M) of 0.53 year^{-1} at an annual average habitat temperature approximately 28°C. The fishing mortality (F) was found at 1.48 year^{-1} and the exploitation rate (E) was obtained by dividing the F by Z and resulting in E = 0.73 year^{-1}.

Length-at-first-capture. From the analysis, *S. guttatus* length-at-first-capture (Lc) was 374 mm TL as shown in Figure 4.

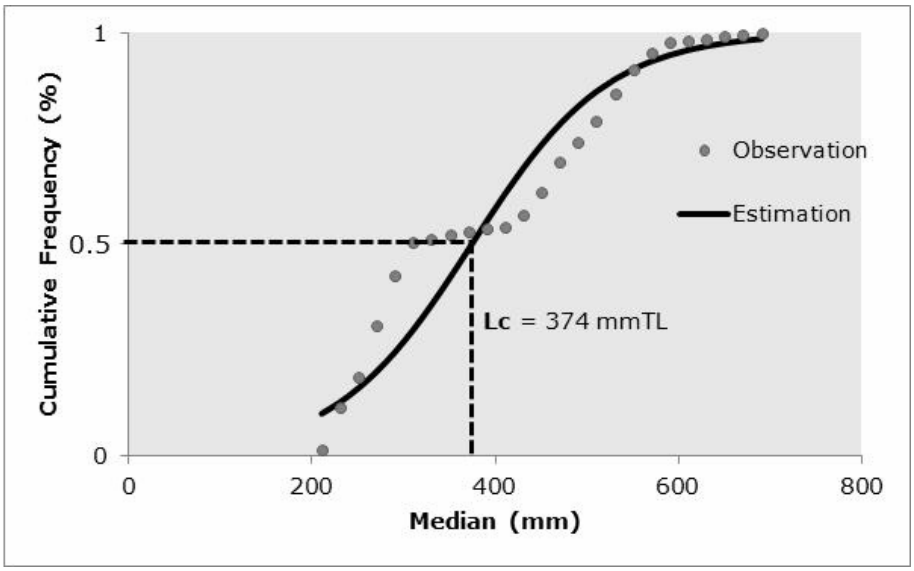

Figure 4. Length-at-first-capture curve of *S. guttatus* in Pangadaran.

Discussion

Growth parameters. This research found that the shortest samples (205 mm TL) were at the age of 4 months and the longest samples (685 mm TL) were found at the age of 37 months (3.08 years) (Figure 2). Maximum age for *S. guttatus* was found at L_∞ 16.33 years (Devaraj 1977). Similar to a research conducted by Sparre & Venema (1998) who founded that the increase of the growth coefficient (K) values was resulting in fast-to-reach the asymptotic length ($L\infty$) and will be closer to perish. Conversely, the smaller the $L\infty$ value, it can indicate that the high-pressure fishing activities have been occurred and will result in a decline in fish populations from year to year (Wujdi et al 2012).

Differences in growth parameters can be due to the environmental factors differences which affect the fish growth (Harahap & Djamali 2005). Besides, the differences in growth parameters can be also influenced by ecological characteristics, population size, and the natural selection (Adams 1980 in Hashemi & Taghavimotlagh 2013). Other possible reasons that may give the disparity to the data are seasonal influences, the duration of sampling and its size distribution as well as classes length variation (Abdussamad et al 2006). Thus, the value of growth parameters for the same species in different locations might differ (Table 1).

Table 1

Growth parameters of *S. guttatus* in several locations

Location	*Length type*	L_∞ *(mm)*	*K* *(year^{-1})*	t_0 *(year)*	*Φ′*	*Source*
Bay of Mannar and Palk, India	TL	1278	0.18007	-0.4654		Devaraj (1981)
Veraval water, India		612.7	1.4	-0.0046	3.721	Ghosh et al (2009)
Bay of Bengal, India	TL	735	0.60		3.5	Rashid et al (2010)
Kepulauan Riau water, Indonesia	FL	777.1 752.5 682.5 776.0	0.37 0.50 0.62 0.61	-0.043 -0.060 -0.064 -0.073		Noegroho et al (2018b)
Pangandaran water, Indonesia	TL	735	0.87	-0.46	5.67	Present study

Note: FL = fork length; TL = total length.

Mortality and exploitation rate. Fishing mortality rates are higher than the natural mortality rates for *S. guttatus* in Pangandaran; that showed that the pressure to the wild stocks came from the fishing activities. According to Pauly (1984) the stock is optimal exploited when the fishing mortality value is equal to the natural mortality value, or in other words the exploitation rate value is equals to 0.5. The exploitation rate that exceeds from their natural-optimum level indicates that *S. guttatus* in Pangandaran is in overexploitation condition.

Total *S. guttatus* production reached 45.62% out of total large-pelagic-fish production in Pangandaran. A research by Mutakin (2001) has found that the maximum sustainable yield (MSY) for *S. guttatus* in Pangandaran was 78.59 tons per year, while in contrast, the annual production for *S. guttatus* in Pangandaran in 2015 (94.02 tons), 2017 (85.58), and 2018 (89.92 tons) has been over its natural MSY. Those findings have shown that the *S. guttatus* exploitation exceeded the natural MSY level and tended to be over-exploited. When the exploitation rates are higher than their optimum value (0.5) it means that the fishing mortality is greater than their natural mortality (Sarasati 2017).

The higher exploitation rate shows that fishing mortality is getting bigger (Ernawati & Kamal 2010). Therefore, it is necessary to impose restrictions on fishing efforts so that the stocks of *S. guttatus* in Pangandaran water remain sustainable. According to Mutakin (2001), the optimal fishing effort to catch *S. guttatus* in Pangandaran water is 5,178 trips annually. Lesson learned from other researchers

showed that there are differences between mortality and exploitation rates for *S. guttatus* (Table 2).

Table 2

Mortality and exploitation rate of *S. guttatus* in several locations

Location	*M* ($year^{-1}$)	*F* ($year^{-1}$)	*Z* ($year^{-1}$)	*E* ($year^{-1}$)	*Source*
Veraval water, India	1.79	2.92	4.71	0.62	Ghosh et al (2009)
Bay of Bengal, India	1.00	0.80	1.80	0.50	Rashid et al (2010)
Dumai water, Malaka strait, Indonesia	-	-	0.62	0.22	Wagiyo et al (2016)
Kepulauan Riau water, Indonesia	0.54	1.39	1.93	0.67	Noegroho et al (2018b)
Pangandaran water, Indonesia	0.53	5.25	5.79	0.91	Present study

Length-at-first-capture. Obviously, using environmental unfriendly fishing gears could result in overfishing and in direct impact on both natural recruitment and growth of a fish stock. A research by Sarasati (2017) suggested that growth overfishing is a condition when fish juveniles have been caught before reaching their ideal size, in the other word, the caught fish has not yet reached the Lc size. The length-at-first-capture (Lc) of *S. guttatus* was found at 374 mm TL and 52.25% of samples were indicated an overfishing.

Moreover, this situation is unlikely to change in the future. This research found a recruitment overfishing as the length-at-first-capture for *S. guttatus* were smaller (374 mm TL) than its natural length-at-first-mature (423 mm TL) (Restiangsih et al 2016). In order to maintain their sustainability, the length-at-first capture must be bigger than its length-at-first-mature (Lc > Lm). On the contrary to the natural condition, when the length-at-first-capture is smaller than their natural length-first-at-mature (Lc < Lm), it indicates that the caught does not leave any opportunity for *S. gullatus* to produce new individuals (recruitment).

Regulation is urgently needed to prevent the growth of overfishing and recruitment overfishing condition. Based on the field observation, small samples (less than 374 mm TL) were caught by gill net with 2-3 inches of mesh size. Fishers around Pangandaran are suggested to change their gill net with more than 3 inches of mesh size to catch *S. guttatus*, so that juveniles get the opportunity to grow and reproduce naturally. For comparison, in Table 3 are some reported data regarding the Lc and Lm of *S. guttatus* in several locations.

Table 3

Length-at-first-catch of *S. guttatus* in several locations

Location	*Lc (mm)*	*Lm (mm)*	*Source*
Gulf of Mannar and Palk Bay, India	-	400 TL	Devaraj (1987)
Veraval water, India	201.5 FL	-	Ghosh et al (2009)
Cilacap water, Indonesia	327 FL	423 FL	Restiangsih et al 2016)
Kepulauan Riau water, Indonesia	-	474 FL	Noegroho et al (2018a)
Pangandaran water, Indonesia	374 TL	-	Present study

Note: FL = fork length; TL = total length.

Conclusions. The asymptotic length (L_∞) of *S. guttatus* was 735 mm with growth coefficient (K) of 0.87 $year^{-1}$ and theoretical age (t0) was -0.46 years. The total mortality (Z), natural mortality (M), fishing mortality (F), and exploitation rate (E) of *S. guttatus* were 2.01 $year^{-1}$; 0.53 $year^{-1}$; 1.48 $year^{-1}$; and 0.73 $year^{-1}$, respectively. The mortality rate of *S. guttatus* in Pangandaran was dominated by fishing activities. *S. guttatus*

length-at-first-capture (Lc) were 374 mm TL (52.25% of total samples), which indicates a growth overfishing. This research suggests that to reduce overfishing, fishing effort regulation and mesh size management must be immediately introduced.

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