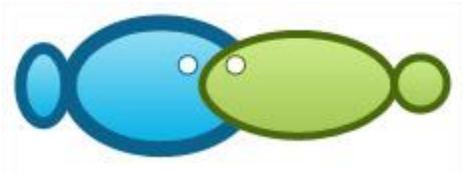

Population parameters and exploitation rate of Indian mackerel (*Rastrelliger kanagurta*) on the Java's North Coast

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Abstract. Indian mackerel, *Rastrelliger kanagurta,* is one of the small pelagic fishes living in the coastal waters (neritic). Its distribution in Indonesia includes the whole coastal regions in the country. *R. kanagurta* is the leading commodity in Indonesia's commercial fisheries, and is one of the purse seine main catch. The present study assessed the population parameters and the exploitation rate of *R. kanagurta* on the northern coast of Java. The survey method was employed in this study. Fish samples were collected from four different locations, including Fish Auction Place (TPI) of Tegal Coastal Fishing Port (PPP), Pekalongan Archipelagic Fishing Port (PPNP), Juwana Pati Coastal Fishing Port (PPP), and Tasik Agung Rembang Coastal Fishing Port (PPP). The results showed that the *R. kanagurta* caught during the study had a total length ranging between 100 and 245 mm. The recruitment peak occurred from March to September. The length–weight relationship of the *R. kanagurta* was obtained following the equation $W = 0.000004 * L^{3.19}$, with a positive allometric growth pattern. The *R. kanagurta* followed the von Bertalanffy growth equation, where the fish length at age t (Lt) was 289.47 $(1\text{-}exp^{-0,45(t-0,147112)})$, with the growth performance index (ϕ) of 4.5764. The total mortality rate (Z) of *R. kanagurta* was 1.74 $year^{-1}$, fishing mortality (F) was of 1.17 $year^{-1}$ and natural mortality (M) was 0.56 $year^{-1}$ (relatively low). The exploitation rate (E) was 0.67, exceeding the optimum level and indicating overfishing. It is assumed that in such cases the size of the caught fishes was dominated by immature fish.
Key Words: gonad maturity, growth, length-weight relationship, mortality, recruitment.

Introduction. The exploitation rate of small pelagic fisheries resources in the Java Sea coast fluctuates along with the development of capture fisheries management. A logistic result in 2011 shows that the exploitation level (E) was at 1.49 (MMAF 2011). In 2016, the exploitation rate declined incisively and the E value was 0.59 (MMAF 2016), and in 2017 it decreased to E=0.38 (MMAF 2017). The study conducted by Khatami et al (2019) reports a different result, showing that only six small pelagic fishes (bigeye scad, rainbow sardine, short mackerel, yellowstripe scad, yellowtail scad, and sardinella) caught in the northern coast of Java have suffered overfishing.

Indian mackerel, *Rastrelliger kanagurta,* is one of the small pelagic fishes living in the coastal waters (neritic) of Indonesia, with the largest concentrations on the coast of Natuna, West Sumatra, Java Sea, in the Strait of Malacca, Muna-Buton, Arafuru Sea and in South Sulawesi (Utami et al 2014). *R. kanagurta* is the leading species of the Indonesia's commercial fisheries, and is one of the purse seine main catch.

Several studies have been conducted on the biology, population dynamics, stock analysis and the exploitation rate of *R. kanagurta*, including the research conducted by Mehanna (2001), Mustafa & Ali (2003), Abdussamad et al (2010), Amin et al (2015), Arrafi (2016), Sonodihardjo & Yahya (2015), Hariati et al (2015), Koolkalya et al (2017) and Zamroni & Ernawati (2019). However, only Zamroni & Ernawati (2019) conducted a research in the Java Sea. In general, these studies infer that the exploitation rate of the *R. kanagurta* has exceeded the optimum level (E>0.5). This research was intended to evaluate the stock condition and the exploitation rate of *R. kanagurta* on the northern coast of Java.

Material and Method. The survey method was applied in this study. Fish samples were collected from four different locations, including Fish Auction Place (TPI) of Tegal Coastal Fishing Port (PPP), Pekalongan Archipelagic Fishing Port (PPNP), Juwana Pati Coastal Fishing Port (PPP) and Tasikagung Rembang Coastal Fishing Port (PPP). The sampling was conducted from August to November 2020.

Sampling. The chosen sampling vessel is a boat with mini purse seine, and the Java Sea is chosen as the fishing area (WPPNRI 712). The number of sampling vessel units is adjusted with the number of landing boats every day. If there are less than 5 vessels landed, then one sampling vessel is chosen. If there are 5–10 vessels, then 2 sampling vessels are chosen and so forth, following the multiples of 5, as suggested by Potier & Nurhakim (1995).

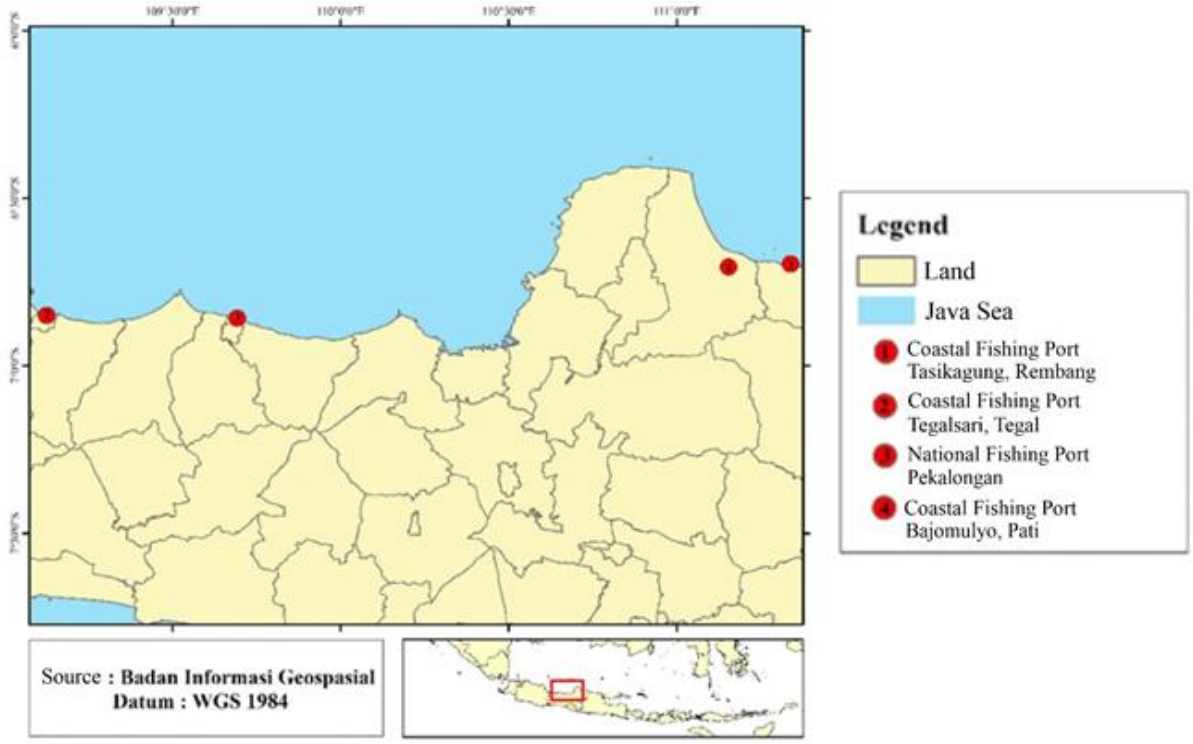

Figure 1. Sampling locations.

Data collection. The primary data collected include the sex, the total length (using 1 mm precision ruler), the weight (using 1 g accuracy scale), the gonad maturity rate and the mesh size (inch).

Data analysis. The collected data were analyzed as follows:

1) The correlation and regression of the total length and weight relationship were analyzed and presented in a curve diagram. The equation of the length-weight relationship (Effendie 1997): W = a Lb, where: W-weight (g); L-total length (mm); a-intercept; b-slope.
2) Growth parameters von Bertalanffy (K, L_∞, t_o), were estimated using the ELEFAN I method. Growth von Bertalanffy formula is: Lt = L_∞ ($1-e^{-K(t-t0)}$), where: Lt-length at age t, von Bertalanffy growth curve index; L_∞-infinity length; t-age; t_0-age at length of fish null.
3) The total mortality rate (Z) was estimated using the length-converted catch curve method (Sparre & Venema 1998; Gayanilo et al 2005). The natural mortality rate (M) was estimated using the empirical equation (Richter & Evanof 1976):

$$M = \frac{1.521}{(T_{m50})^{0.720}} - 0.155$$

4) The new recruit pattern was analyzed using ELEFAN I (Gayanilo et al 2005).
5) The size at first gonad maturity and the size at first capture were analyzed using the standard logistics method from Spearman-Karber.
6) The exploitation rate (E) was obtained using the formula E=F/Z. The exploitation rate reached an optimum level if F=M, or E=0.5.

Results and Discussion

The recruitment structure and pattern of R. kanagurta. The *R. kanagurta* caught during the study have a total length of 100–245 mm. An overview of the size structure of *R. kanagurta* caught during the study (August-October) is presented in Figure 2.

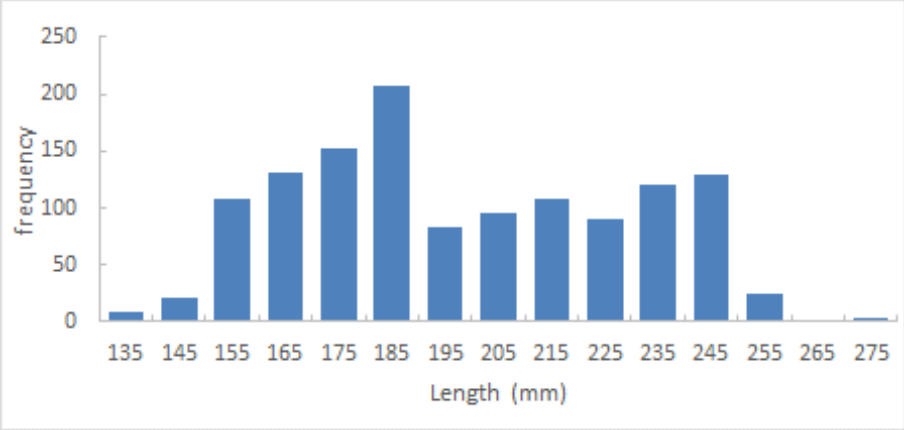

Figure 2. Histogram of the length of *Rastrelliger kanagurta* during the study.

Figure 2 shows that the total length mode of the *R. kanagurta* caught during the study has two cohorts, 185 and 245 mm, respectively. It indicates that the stock of *R. kanagurta* on the Java's North Coast originated in the two stock groups. Based on the analysis of recruitment patterns, it can be inferred that the recruitment of *R. kanagurta* occurs from March to September (Figure 3).

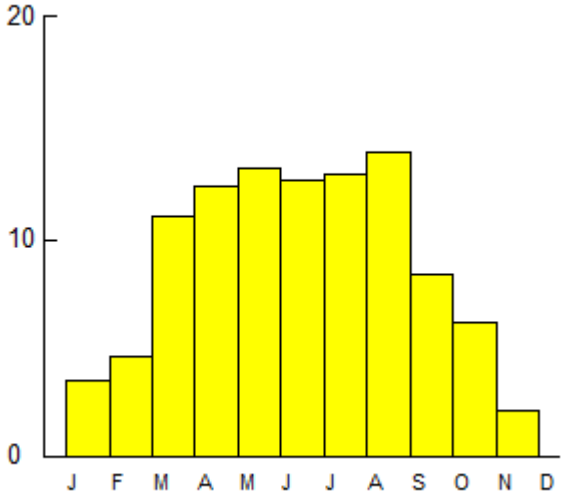

Figure 3. Histogram of *Rastrelliger kanagurta* recruitment pattern.

Length-weight relationship of R. kanagurta during the study. From the analysis result of the length-weight relationship of *R. kanagurta*, the following equation variables were obtained: a (intercept)=0.000004; b (slope)=3.19. Therefore, the equation of Length and weight relationship can be written as: $W=0.000004*L^{3.19}$. The curve of the weight and length relationship of *R. kanagurta* is presented in Figure 4. The test results

show that *R. kanagurta* has a positive allometric growth. It means that the weight growth is faster than the length growth. The condition factor (K) of *R. kanagurta* on the northern coast of Java, as shown by the results of this study, is 1.1.

The b coefficient of *R. kanagurta* on the west Aceh coast is 2.625 and 3.449, with the condition factor ranging between 0.9176 and 1.4509 (Arrafi et al 2016). Amin et al (2015) obtained a positive allometric growth at b=3.2135, on the coast of the Gulf of Suez, Egypt. However, several other studies obtained a negative allometric growth. Based on the data of the fishing landed in PPI Sangeh, Manokwari, Randongkir et al (2018) obtained an allometric growth with the value of b=2.032 (short mackerel) and b=1.84 (*R. kanagurta*). A research conducted by Rahman & Hafzath (2012) in the Kuantan coastal obtained a negative allometric to isometric growth pattern. On the other hand, Hulkoti et al (2013) obtained a positive allometric growth pattern, both for the *R. kanagurta* and short mackerel, on the Mengalore India coast. A negative allometric growth pattern was obtained on the Palaw coast and in the surrounding area, in Taninthayi, Myanmar, with b=2.79 (Aye & Tint 2020).

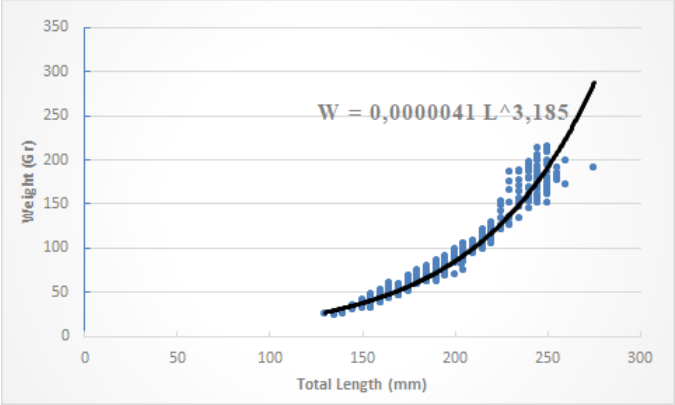

Figure 4. The curve of weight-length relationship of *Rastrelliger kanagurta* during the study.

The R. kanagurta length at the first capture (Lc) and the length at the first gonad maturity (Lm). The total length at the first capture of *R. kanagurta* using a purse seine was of 187 mm (Figure 5).

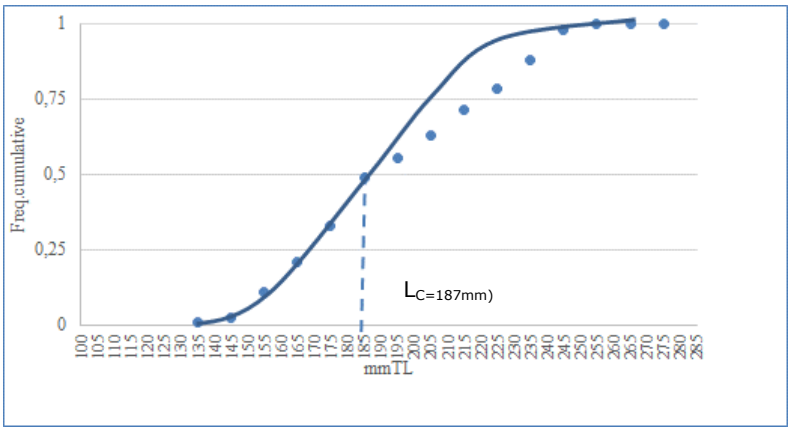

Figure 5. The length at Lc 50% of the *Rastrelliger kanagurta* during the study.

Based on this study, the length at the first gonad maturity of *R. kanagurta* was Lm=218 mm. Kasmi et al (2017) obtained in the Takalar, South Sulawesi coast, a length of 211.8 mm at first gonad maturity (Lm), for the short mackerel and 213 mm for the *R. kanagurta*. The FAO Fishbase has mentioned that the length at first gonad maturity (Lm) of the Indian mackerel is of 199 mm. In addition, Zamroni & Ernawati (2019) obtained the Lm of 229.5 mm total length (TL), on the local coast. Arrafi et al (2016) also obtained

the Lm of 195.8 mm TL in the western coast of Aceh, whereas Zaki et al (2016) obtained the Lm at 257 mm TL (*R. brachysoma*) and 252 mm TL (*R. kanagurta*) in the coastal waters of Mahout, Oman Sultanate. Based on the abovementioned descriptions, it can be inferred that the size at the first gonad maturity is almost similar in the Takalar coast, South Sulawesi (Kasmi et al 2017), smaller in the West of Aceh, but much larger on the Mahout coast, Oman.

It was mentioned that the length at first capture (Lc) of *R. kanagurta* is 187 mm TL, smaller than the Lm (218 mm TL). Similar results (Lc<Lm) were obtained by Zamroni et al (2019) in the Bitung coastal region, and Bintoro et al (2019), in the Madura Strait, East Java, due to a mesh size of the purse seine of one inch (25.4 mm), based on the MMAF Ministerial Decree No. 59/2020 regarding the fishing route and fishing gears, which causes many small/immature fish catches, before the spawning, leading to overfishing.

Growth parameters. From the analysis results, the estimated values of *R. kanagurta* growth parameters were L_∞=289.47 mm, K=0.45 and t_o=0.147112. Based on these values, the von Bertalanffy growth equation was Lt=289.47 $(1\text{-}exp^{-0.45(t-0.147112)})$ (Figure 6). The obtained growth performance index (ϕ) was 4.5764.

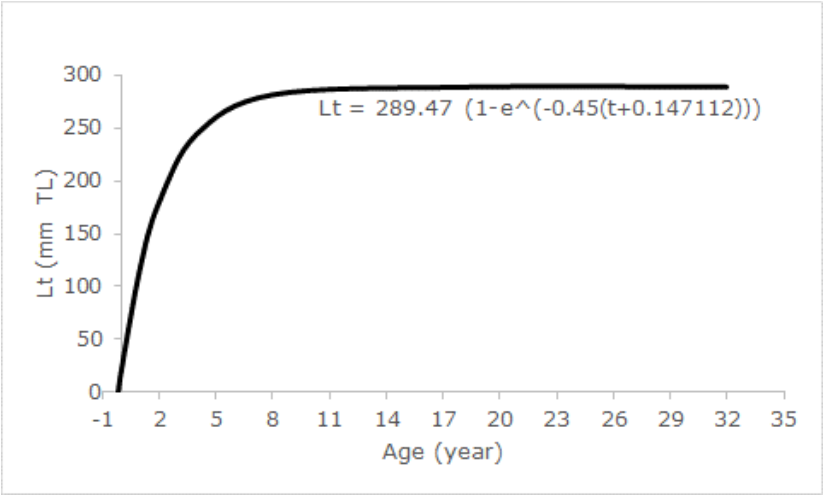

Figure 6. The von Bertalanffy growth curve of *Rastrelliger kanagurta*.

The research conducted by Hariati et al (2015) on the Strait of Malacca coast obtained a smaller L_∞ value, of 272 mm TL, with a higher K value, of 0.73. Meanwhile, Muastafa & Ali (2003) obtained a value of L_∞=274 mm TL and K=0.90 on the Bay of Bengal coast. Arrafi et al (2016), in their research on the West of Aceh coast, obtained the value of L_∞= 273 mm, K=0.56 and t_0=-0.526 $year^{-1}$. Tangke (2014) also obtained a slightly smaller L_∞ value, of 284.6 mm, with a higher K value of 0.71 and t_0=-0.24, in the Coastal region of Ternate Island, North Maluku Province. Faizah et al (2017) obtained the value of L_∞= 273 mm, with a K value of 0.8, in the coastal region of North Kwandang Gorontalo. Oktaviani et al (2019) obtained the L_∞ value of 284 mm, with a K value of 0.97 in the coastal region of Mayalibit Bay, Raja Ampat, Papua. These L_∞ values are smaller, with higher K values than those of the present study.

However, some other studies obtained greater L_∞ value, with a K value that is relatively smaller than or nearly similar to those of the present study. Sonodihardjo & Yahya (2015) in the Pancana coastal, Barru Regency, South Sulawesi obtained a L_∞ of 298.29 mm, with an almost similar K value, of 0.47, and t_o=-0.33 year. Nasution et al (2015) obtained the value of L_∞=368 mm, with K=0.48 and t_0=-0.1707, in the South coast of Java (Indian Ocean), based on the data grounded on the Palabuhanratu Archipelagic Fishing Port (PPN). Mehanna (2001) obtained L_∞=320.4 mm, with K=0.6 (female) and L_∞=294.8 mm, with K=0.66 (male), in the Gulf of Suez, Egypt. Amin et al (2015) also obtained a larger L_∞, of 337.9 mm, with K=0.428 and t_0=-0.868 $year^{-1}$, on the coast of the Gulf of Suez, Egypt. Aye & Tint (2020) obtained L_∞=252 mm, K=1.50

and t_0=-0.109 year, in the coastal region of Palaw in Taninthayi, Myanmar. Abdussalam et al (2010), in their research along the coast of Tuticorin India, obtained a larger L_∞, of 332.8 mm, with a high K value, of 1.634, and a t_0=-0.1707 year^{-1}.

Based on the results of those studies, it can be inferred that the Java Sea's *R. kanagurta*, in the present study, are in the size range of various existing studies in different coastal regions, with a moderate growth curve (K) coefficient.

The mortality rate and exploitation rate of the R. kanagurta. The total mortality rate (Z) of *R. kanagurta* during the study was calculated around 1.74 year^{-1}, while the fishing mortality (F) was 1.17 year^{-1} and the natural mortality rate (M) was 0.56 year^{-1}. Based on the mortality data, the exploitation rate (E) can be calculated by F/Z=0.67 (Figure 7.). The figure shows that the exploitation rate of *R. kanagurta* on the Java's North coast has exceeded the optimum level. The exploitation rate E=0.5 is optimal if F=M.

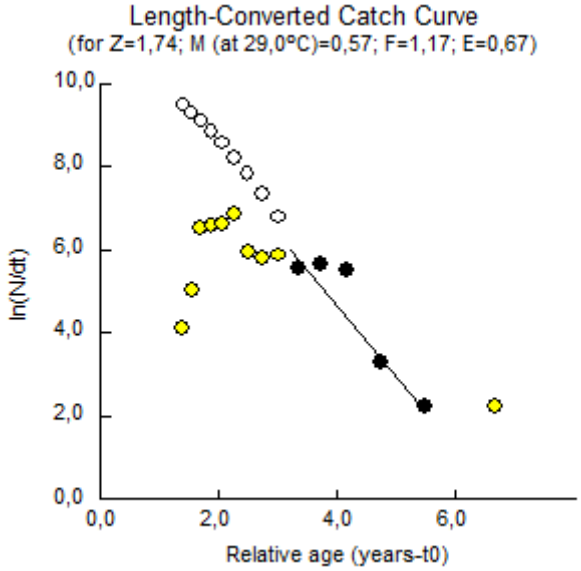

Figure 7. Mortality rate and exploitation rate of the *Rastrelliger kanagurta*.

The results of the present study are almost similar to the mortality rate of *R. kanagurta* in the coastal area of the Gulf of Suez, Egypt, where Mehanna (2001) obtained the Z coefficient at 1.12 year^{-1} (male) and 1.00 year^{-1} (female). The coefficient of F at 0.86 year^{-1} and M at 0.26 year^{-1}. In the same coastal area, Amin et al (2015) reported Z=1.917 year^{-1}, M=0.72 year^{-1} and F=1.197 year^{-1}.

On the other hand, some researchers obtained a significantly higher mortality rate. In the coastal waters of Ternate Island, North Maluku Province, Tangke (2014) obtained Z=3.19 year^{-1}, M=1.47 year^{-1} and F=1.72 year^{-1}. Sonodihardjo & Yahya (2015), in the Pancana coastal area, Barru Regency, obtained Z=3.25 year^{-1}, M=0.51 year^{-1}, and F=2.73 year^{-1}. The research conducted by Hariati et al (2015) in the Strait of Malacca obtained Z=4.38 year^{-1}, F=3.17 year^{-1} and M=1.21 year^{-1}. On the other hand, Mustafa & Ali (2003), in their research on the Bay of Bengal coast, India, obtained Z=4.92 year^{-1}, M=1.71 year^{-1} and F=3.21 year^{-1}. Meanwhile, Zamroni & Ernawati (2019) obtained Z=5.48 year^{-1}, M=2.02 year^{-1} and F=3.46 year^{-1}, in their research on the Java's North Coast. Abdussamad et al (2010) also obtained Z=6.04 year^{-1}, M=2.52 year^{-1} and F=3.52 year^{-1} on their research along the coast of Tuticorin Kerala, India. Koolkalya et al (2017) obtained Z=6.09 year^{-1}, M=2.70 year^{-1} and F=3.39 year^{-1}, on the eastern coast of the Gulf of Thailand. Faizah et al (2017) obtained Z=2.72 year^{-1}, M=1.29 year^{-1} and F=1.43 year^{-1}, on the northern coast of Gorontalo.

Based on the results of the present study and of other related studies in different coastal regions, the fishing mortality rate of the *R. kanagurta* in Java Sea is relatively low and the mortality rate due to fishing (F) is higher than the natural mortality (M). Faizah

et al (2017), in their study, obtained the exploitation rate E=0.53 on the northern coast of Gorontalo. From the analysis results, the obtained exploitation rate was E=0.67. The value indicates that the exploitation of *R. kanagurta* on the North coast of Java has exceeded the optimum level. Many other coastal regions, both in Indonesia and outside of Indonesia, have also exploitation rates exceeding the optimum level. Zamroni & Ernawati (2019), on the Java's North Coast, obtain E=0.63. Tangke (2014) found that the exploitation rate (E) of the coastal waters of Ternate Island, North Maluku Province was 0.54. Sonodihardjo & Yahya (2015) obtained an exploitation rate (E) of 0.84 in the Pancana coastal, Barru Regency, South Sulawesi. Hariati et al (2015), in the Strait of Malacca, obtained the exploitation rate of 0.72. Mehanna (2001) obtained the exploitation rate of 0.77, in the coastal areas of the Gulf of Suez, Egypt, while Amin et al (2015) reported E=0.62, in the same coastal area. Mustafa & Ali (2003) obtained E=0.652, in the Bay of Bengal coastal area, India, while Abdussamad et al (2010) obtained E=0.58, along the Tuticorin coast, Kerala India. Koolkalya et al (2017) also obtained E=0.56 on the eastern coast of the Gulf of Thailand.

Based on the present study and other related studies, it can be inferred that the exploitation rate of *R. kanagurta* has exceeded the optimum level, in general. This condition indicates that the management should be more careful in the exploitation of the *R. kanagurta* resources. According to the above mentioned analysis of the length of captured fishes, overfishing occurred due to small/immature fish at first capture is or fish still having to undergo their gonad maturity.

Conclusions. The *R. kanagurta* caught during the study have a total length ranging from 100-245 mm. The recruitment peak occurred from March to September. The length–weight relationship of the *R. kanagurta* was obtained following the equation $W=0.000004*L^{3.19}$, with a positive allometric growth pattern. *R. kanagurta* followed the von Bertalanffy growth equation $Lt=289.47\ (1-exp^{-0,45(t-0,147112)})$, with a growth performance index (ϕ) of 4.5764. The total mortality rate (Z) of *R. kanagurta* is of 1.74 $year^{-1}$, the fishing mortality (F) is of 1.17 $year^{-1}$ and the natural mortality (M) is of 0.56 $year^{-1}$ (relatively low). The exploitation rate (E) has exceeded the optimum level, indicating overfishing, presumably due to the size of the captured fish, dominated by small/immature specimens.

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Conflict of interest. The authors declare no conflict of interest.

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