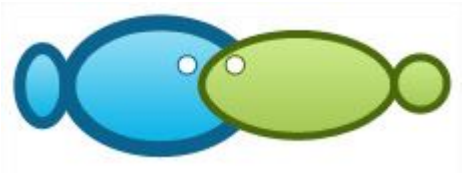

Size structure and population dynamics of Indo-Pacific king mackerel (*Scomberomorus guttatus*) in Kepulauan Riau's water, Indonesia

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Abstract. Indo-Pacific king mackerel (*Scomberomorus guttatus*) is one of the important species in the Kepulauan Riau water. The fishing is mostly done by traditional boats under 10 grosstones. The excessive and continuous fishing without any control would endanger the sustainability of king mackerel fisheries. This research was conducted in 2014 to 2017 in Kepulauan Riau waters. The objective of this research was to analyze the size structure variations and the population dynamics parameters, such as growth rate, mortality rate, exploitation rate, and the recruitment patterns of king mackerel. Sample size of king mackerel was taken randomly from drift gillnet catches. Population dynamics parameters are estimated by using FISAT II program. The size structure ranges from 11 to 75 cm, the dominant mode values in the range of 49-51 cm and 37-39 cm. From Von Bertalanffy growth parameters, there were length infinity (L∞) of 77.7 cm and growth rates from 2014-2017, 0.37; 0.50; 0.52; and 0.61 per year respectively. Mortality also varies each year, as fishing mortality rates change every year, due to impact of fishing efforts. Changes in fishing mortality also affect the exploitation rate. The exploitation rate from 2014-2017 has exceeded the optimum level of 0.5 per year. Peak recruitment occurred in June to August, the average took place in July. The exploitation rate of king mackerel should be controlled as much as possible until the value is below the optimum rate. One of the main management options that can be done is by setting the number of fishing effort and setting the gillnet meshsize.
Key Words: Indo-Pacific king mackerel, length frequency distribution, exploitation rate, Kepulauan Riau waters.

Introduction. Indo-Pacific king mackerel (*Scomberomorus guttatus*) is one of Scombridae species found in Indonesian waters. It spreads throughout the coastal areas and islands in Indonesia and migrates closer to the beach than the narrow-barred Spanish mackerel (*Scomberomorus commerson*). This habitate is in the waters which is not too clean and its salinity is low (Collette & Nauen 1983).

There are a lot of Indo-Pacific king mackerels, tohok - the local name, caught in Kepulauan Riau waters. This king mackerel is caught in a large quantity with fishing equipment called gillnet. The production of Indo-Pacific king mackerel in the Indonesian Fisheries Management Area (IFMA) 711 in 2014, reached 21,168 ton or around 58% from the total production of natioanl Indo-Pacific king mackerel (MMAF 2016). This shows that the production of Indo-Pacific king mackerel in IFMA 711 is higher than that in other areas. The production of Indo-Pacific king mackerel fluctuated as shown in the data of 2005. However, the production rose significantly in 2014 (MMAF 2016).

The fishing of king mackerel in Kepulauan Riau waters is done in a small boat, < 10 GT (gross tons). The result of the catching from fishermen is then sold to the fish collectors, *tangkahan* – local name. *Tangkahan* is a landing place owned by an individual. Tangkahan is an integrated port where there is a cold storage, a workshop, a dock as a place to unload the fish from fishermen, and then the preparation of export takes place. Next they export it to Singapore and Malaysia. The location of fish and fishermen landing in Kepulauan Riau spreads throughout the coastal areas and small islands. The landing

has been done in *tangkahan* so far Indo-Pacific king mackerel is one of the prominent export commodities. Moreover, this is very popular in Malaysia and Singapore.

The Kepulauan Riau waters are directly adjacent to the waters of neighbouring countries; Singapore and Malaysia. Therefore, the availability of scientific data about the fishery in Kepulauan Riau is very important. The research about Indo-Pacific king mackerel in Indonesia is still rare. Thus, this research is significantly important to find out the level of king mackerel fishing activity in the Kepulauan Riau waters. Some parameters of population dynamics are necessary to be known, especially for the population of fish that is being exploited. The aim of this research is to analyze the size structure variations and the population dynamics parameters, such as growth rate, mortality rate, exploitation rate, and the recruitment patterns of Indo-Pacific king mackerel. From the results of this study is expected to understand the status of this fish explotation in the waters of the Riau Islands, and then the results can be considered for the management of sustainable fisheries resources.

Material and Method. The data of king mackerel length size are gathered from the fish collector and fish manager from Kepulauan Riau waters. The Kepulauan Riau waters include the waters of Tanjung Pinang, Sugi waters, Moro waters, Durian Island waters, and other small islands. The length data of king mackerel were collected from 2014 to 2017. The location of this research can be seen in Figure 1.

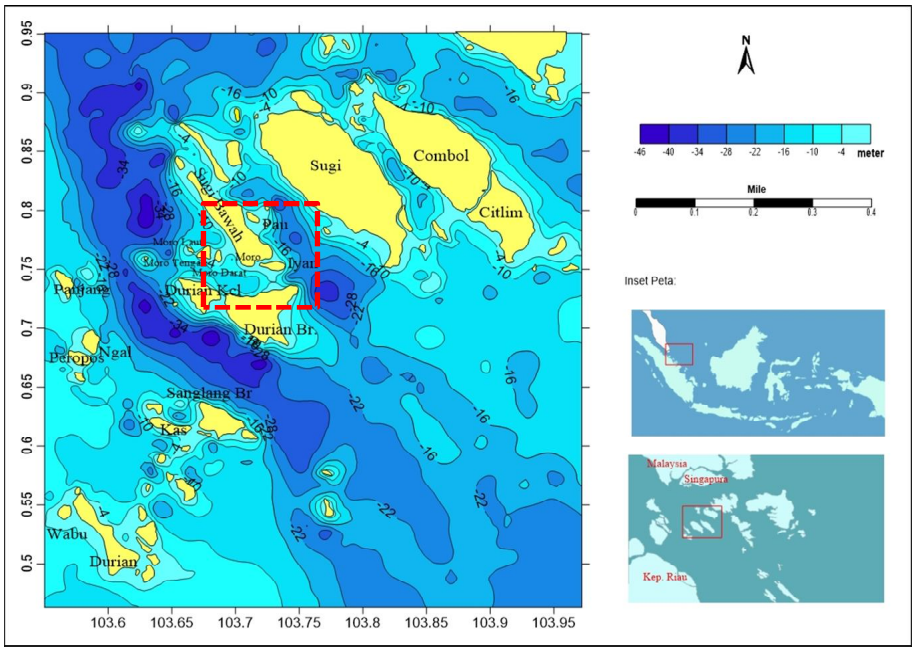

Figure 1. Research location of Indo-Pacific king mackerel in Kepulauan Riau waters (red box).

Size structure. Length sample of fish are collected monthly. The measured length used in this analysis is the fork length. The length frequency distribution was created with 3 cm class interval. Size structures are observed to see the fishing gear selectivity, the size of dominant fish caught, and growth.

Growth estimation. Some parameters of king mackerel population is estimated with *Electronic Length Frequency Analysis* (ELEFAN) and FISAT software (Gayanilo et al 1996). The asymptotic size and the value of growth constants are measured by using ELEFAN I (Pauly & David 1981). The growth of the fish is calculated with the formula of Von Bertalanffy (Beverton & Holt 1956) as follows:

$$Lt = L\infty\ (1\text{-}e^{-K(t-t0)})$$

Value estimation t_o (the age of 0 year based on the equation of Pauly et al (1984) is:

$$Log\ (-t_o) = 0.3922 - 0.2752\ Log\ (L_\infty) - 1.038\ Log\ (K)$$

in which: Lt = the length at t years old; L∞ = asymptotic length (infinity); K = parameter describing the speed achieved L∞; t_0 = theoretical age when the length size of the fish is zero.

Mortality. The natural mortality rate (M) is estimated with the application of empirical model from Pauly (1980):

$$\text{Log (M)} = -0.066 - 0.279 * \text{Log } (L\infty) + 0.6543*\text{Log (K)} + 0.4634 * \text{Log (T)}$$

The total mortality coefficient (Z) is obtained from the length converted catch curve (Pauly 1983), whose calculation is computerized with FISAT package program (Gayanilo et al 1996). The rate of fishing mortality (F) is estimated with the equation:

$$F = Z-M$$

Exploitation rate. The exploitation rate (E) is calculated with the Pauly equation (1983); that is:

$$E = F/Z = F/ (F+M)$$

In the equations for mortality and exploitation rate, M = mortality rate; E = exploitation rate; Z = total mortality; F = fishing mortality; T = average water temperature.

The pattern of recruitment is estimated with the program of FISAT in the part of *recruitment pattern*, with the data input L∞, K, and t_0 (Gayanilo et al 1996). From the pattern of recruitment formed, the time when the peak recruitment happens can be estimated, and the season of spawning can be presumed as well.

Result and Discussion. All samples obtained ranged from 11 to 75 cm, with mode of 49-51 cm. The change of mode movement from month to month is not very clear. This represents the selectivity of gillnet fishing gear. Of the mode values it has been shown that the dominant fish size is large fish. This is very good in order to prevent the occurrence of recruitment overfishing. Size structure variation is presented in Figure 2.

Population dynamic parameters. Result from length frequency data analysis using ELEFAN I in FISAT showed that the length infinity (L∞) of Indo-Pacific king mackerel was 77.7 cm. The growth rate (K) was varies between years with both parameters (L∞ and K) can be seen in Table 1.

Table 1

The length infinity and growth rate of Indo-Pacific king mackerel

Year	*L∞ (cm)*	*K/year*	t_0
2014	77.71	0.37	-0.043
2015	75.25	0.50	-0.060
2016	68.25	0.62	-0.064
2017	77.60	0.61	-0.073

Therefore, the relationship between the length and age could be described as seen in Figure 3.

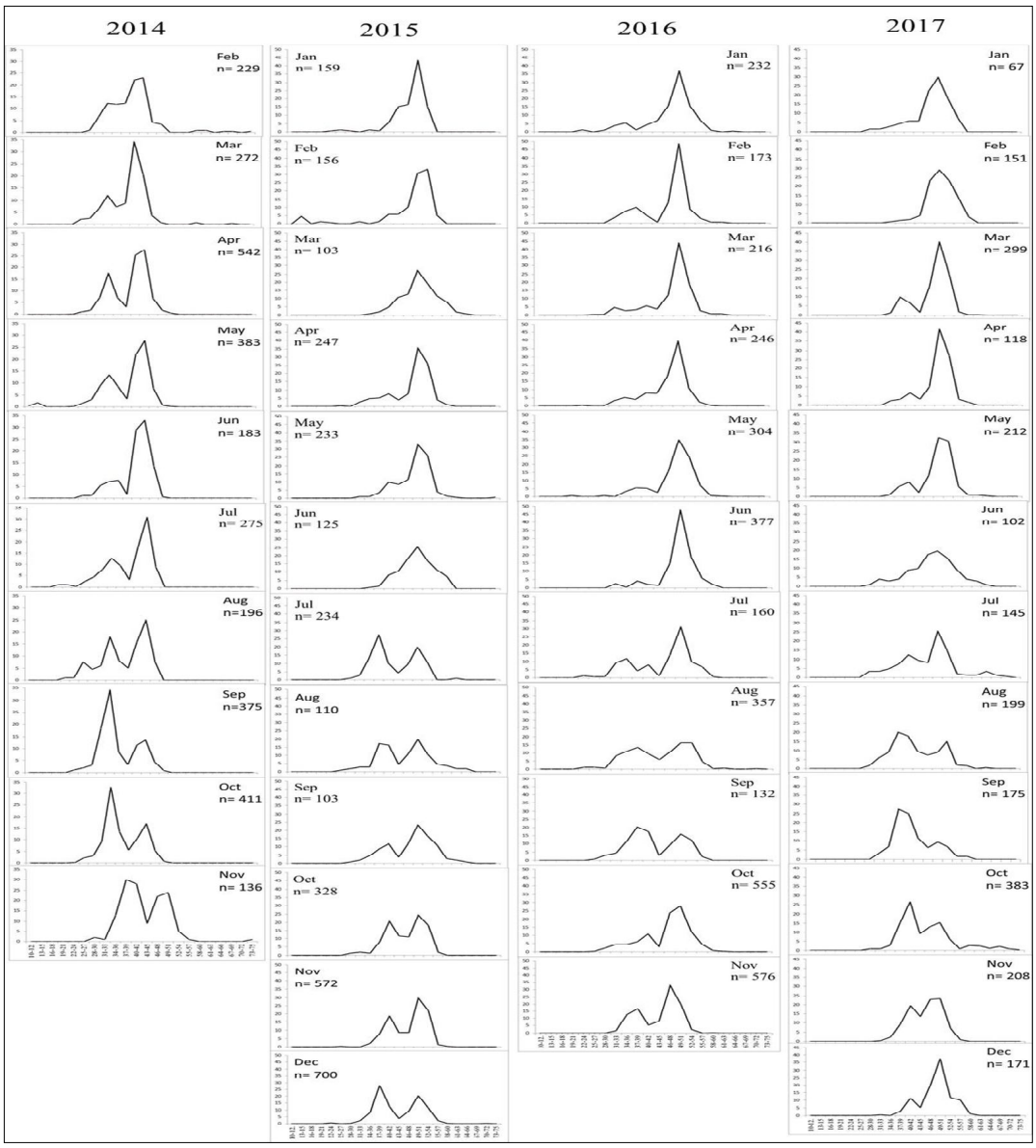

Figure 2. Size structure variations of Indo-Pacific king mackerel in Kepulauan Riau waters, 2014 to 2017.

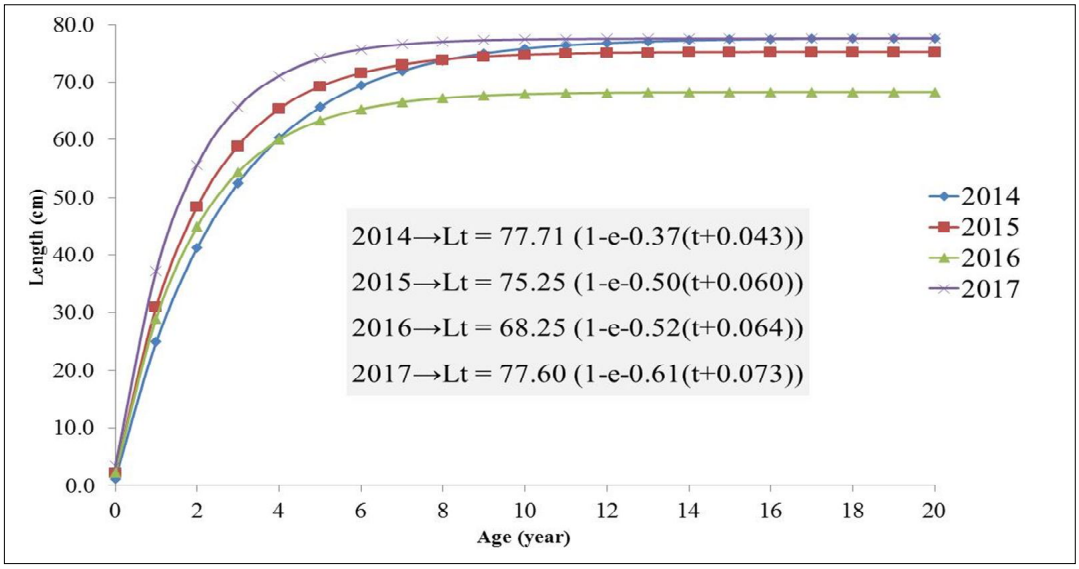

Figure 3. Growth curve of Indo-Pacific king mackerel.

Result from length catch curve analysis, based on length frequency data, showed that mortality rate for this fish varies widely, all for natural mortality(M), fishing mortality (F) and total mortality (Z). The exploitation rate (E) also varies between years, along with the changes of fishing mortality and impact from fishing effort. Exploitation rate level in 2014-2017 has exceeded the optimum level of 0.5, therefore it is necessary to take a precautionary approach in exploitation of this fish resources. The mortality and exploitation rates are presented in the Table 2.

Table 2

The mortality and exploitation rates of Indo-Pacific king mackerel

Year	*Z*	*M*	*F*	*E*
2014	2.98	0.58	2.40	0.77
2015	2.18	0.71	1.47	0.62
2016	1.39	0.75	0.64	0.40
2017	1.87	0.81	1.06	0.51

Peak recruitment occurred in June to August, the average took place in July. The percentage of recruitment peaks can be seen in Table 3.

Table 3

Peaks recruitmen of Indo-Pacific king mackerel from 2014 to 2017

Year	*Peak recruitment*	*Percentage*
2014	July	16.5
	August	15
2015	June	19.1
	July	15.8
2016	July	14.1
	August	12.8
2017	July	18.3
	August	20.3

The size structure varies every month with the mode values being almost in the same range of value for each month. The two peaks mode has began to show in June until the end of the year. The existence of two peaks of this mode indicates that there are a number of groups age of fish that began to enter the waters due to recruitment. The size structure of the Indo-Pacific king mackerel also shows the presence of small size fish starting in June, and more in July. The same mode value every month proves that gillnet has a high selectivity. Fish size structures can be used to show the presence of recruitment on a particular month, it can also be used as a basis for managing fishing activities. Fishing activities can be managed by looking at the recruitment time and considering the spawning season of the fish. Fishing ativity can be closed during the recruitment peaks, which is indicated by the presence of small size fish on the size structure. During that time, fishing activity can be stoped temporarily (closed season) or averted to other fishing ground with different target of fish. The length range of Indo-Pacific king mackerel at several locations is presented in Table 4.

The differences in size of captured fish in each location are caused by the differences in net's mesh size, fish size distribution, and different fishing areas. Mode value of the Indo-Pacific mackerel in Kepulauan Riau's waters showed that many adult fish were caught even though some small size fish also caught. Number of small size fish caught can be reduced by enlarging the mesh size and regulating the fishing area. Fishing in the nursery ground (fishing ground close to coastal area) can result in higher catch for small size fish. The Indo-Pacific mackerel also has habitat preferences that are related to its feeding habits, environmental suitability and safety from predators, so that fishing activities should also be regulated taking into consideration some of these matters, especially in multispecies fisheries.

Table 4

Length range of Indo-Pacific king mackerel

Location	*Fishing gear*	*Length type*	*Length range (cm)*	*Mode (cm)*	*Reference*
India	Gillnet	ML	2.5-87	38.5	Krishnamoorthi (1958)
Mannar Bay & Palk	Gillnet	FL	27-72	55.6	Devaraj (1987)
Veraval India	Gillnet	FL	20-59.9	41.4-43.9	Ghosh et al (2009)
Coast Bangladesh	Gillnet	FL	25-70	40.3	Rashid et al (2010)
India	Gillnet	FL	20-60	42.2	Rohit et al (2012)
Cilacap, Indian Ocean	Gillnet	FL	11-66.6	40-43	Restiangsih et al (2016)
Kepulauan Riau Water	Gillnet	FL	11-75	49-51	This research

The length infinity of Indo-Pacific mackerel fish was achieved at the age of fish over 10 years. The average age of 1 and 2 years, each age reached size at 29-37 and 44-55 cm respectively. The maximum length of Indo-Pacific mackerel fish reported by Collette & Nauen (1983) is 76 cm, whereas in the waters of the Riau Islands can reach up to 77.7 cm long. Ghosh et al (2009) in India reported that at ages 1 and 2 years each have lengths of 46.3 and 57.6 respectively; while Rao (1978) in Indian waters reported that ages 1, 2, 3, 4, 5, in each length reached at 33.7; 51.3; 64.1; 73.8; and 81.1 cm respectively. The Indo-Pacific mackerel fish in the waters of Kepulauan Riau has a slow growth rate compared to those reported by Ghosh et al (2009) and Rashid et al (2010), as presented in Table 5. The differences in the values of L∞ and K are due to differences in environmental conditions, variations in length and type of fishing gear used. The analysis results are also determined from the method used and the availability of data.

Table 5

Length infinity, growth rate, and theoretical age of king mackerel

Location	*L∞ (cm)*	*K*	*t_0*	*Reference*
India	61.27	1.4	0.0004	Ghosh et al (2009)
Beach of Bangladesh	73.5	0.6		Rashid et al (2010)
India	127.8	0.18	-0.47	Devaraj (1981)
Kepulauan Riau waters	68-77.7	0.37-0.61	-0.043-0.073	Present study

The exploitation rate of king mackerel shows a very high score, whose optimum score is 0.5/year. This indicates that the catch of king mackerel trends to an over exploitation. The fishing mortality shows a very high score. This condition is almost the same as reported by Ghosh et al (2009) in India and Rashid et al (2010) in Bengal Bay (Table 6). The Indo-Pacific mackerel is the main fishing target from gillnet so the catch is dominant. The high value of fishing mortality shows that this fish are under fishing pressure.

This high exploitation rate should be lowered in order to protect the fisheries. The management which should be applied to this situation is by reducing the fishing effort and to close the fishing season. Efforts management can be made by directly reducing the number of effective days of fishing or combining between season closures with effort settings. Fishermen are still allowed to catch fish by changing fishing areas and as compensation, the manager will provide an additional number of fishing days for the fishermen. This regulation can only be done with the fishermen's awareness on sustainable fishing and strict supervision on fishing activities. Supervision systems need to be well designed so that fishermen can fish optimally and the fish resources also can still be sustainable.

Table 6

Estimation of Z, M, F, and E value of king mackerel

Location	*M*	*F*	*Z*	*E*	*Reference*
India	1.79	2.92	4.71	0.62	Ghosh et al (2009)
Beach of Bangladesh	0.99	0.80	1.79	0.45	Rashid et al (2010)
Kepulauan Riau waters	0.71	1.39	2.11	0.58	Present study

The recruitment peak has happened in the same month during 2014-2017, i.e in July. Peak recruitment takes place in a period with a long duration. Rashid et al (2010) reported on the coast of Bangladesh, Bengal Bay that mackerel fish recruitment occurred in two periods; May-July and September-October, while Ghosh et al (2009) reported that in Indian waters recruitment occurred in February-July.

The growth and mortality parameters can provide important guidelines for the management of the Indo-Pacific king mackerel fishery. However, detailed studies of gonadal maturity, reproductive biology and stock status, are also required for sustainable fisheries management. Some options in management including: regulate the amount of catch (quota system), regulate the mesh size, regulate the minimum size to be caught, regulate the fishing effort, open and close of fishing season and the regulate the fishing grounds. Some of these decision in management would require a more in-depth scientific studies. The current management plan shall be established or approved by all fisheries stakeholders, agreements including to establish harvest control rules and strategies. Harvest strategy must be agreed to establish the reference points, both biologically and economically. Reference points should also take into consideration the social factors of society in which the fisheries activities take place. Monitoring and evaluation of the established rules is also very important to be arranged and implemented. The design of fisheries management should be applied with the principle of prudence, so as not to cause problems or conflicts in the future.

Conclusions. The size structure of the Indo-Pacific mackerel fish caught by gillnet is dominated by adult fish, with a 49-51 cm mode. The growth rate of Indo-Pacific mackerel fish in each year always varies depending on the condition of the aquatic environment, while the length of infinity is relatively stable. Mortality and exploitation rates of Indo-Pacific mackerel fish in the waters of the Kepulauan Riau is high, indicating an intense fishing pressure. The rate of exploitation has exceeded its optimal level of 0.5 per year. Recruitment takes place from June to August, with recruitment peaks occurring in July.

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