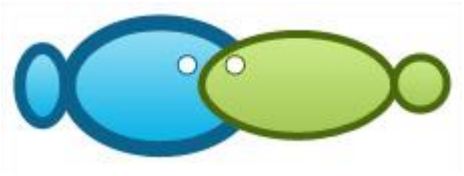

Potential catch and fisheries resource utilization rate of yellowfin tuna (*Thunnus albacares*) in Seram Sea, Indonesia

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Abstract. Tuna is one of Indonesia's main export commodities whose utilization level varies in each water. Large pelagic fish are spread in almost all areas of Indonesian fisheries management. The high exploitation of *Thunnus albacares* fisheries in Seram Sea can reduce production. This study aims to analyze the Catch per Unit Effort (CPUE), MSY and utilization rate of *T. albacares* in the Seram Sea, based on the landed catches. By determining the mean catch, it is expected better maintain the catch in the future. CPUE trend decreased between 2015 and 2020 by an annual average decrement of 1,795 tons trip^{-1}, while the Maximum Sustainable Yield (MSY) was of 10,672 tons year^{-1}, and the optimum effort value (F_{opt}) was of 47 trips year^{-1}. The utilization rate is still below the MSY with an average of 524,428 kg per year and the cultivation level has exceeded the F_{opt} with an average of 281.5 trips per year. Based on this result, it is necessary to take measures to protect the catch.
Key Words: CPUE, over fishing, MSY, optimum effort.

Introduction. Tunas are widely distributed throughout the world. Generally they live in temperate to tropical waters between about 45° North and South of the equator and are broadly classified into coastal, neritic and oceanic species. They are grouped taxonomically in the family Scrombridae, which consists of about 50 species and forms the third largest product in the international seafood trade with almost 10% of the total trade in value terms (FAO 2008). Indonesia's marine fishery potential resources reach about 6.4 million tons of fish year^{-1} (Khaliqi 2019). Yellowfin tuna (*Thunnus albacares*) is one of the important species for the fishing industry in Indonesia (Jatmiko et al 2016) and one of the major exporting fishery commodities for Indonesia (Buana et al 2018; Iranawati et al 2016). Large pelagic fish are scattered in almost all fisheries management areas, where the level of utilization varies between waters (Talib 2017). *T. albacares* is a large pelagic fish particularly targeted by local fishermen in the Indonesian waters (Hasyim et al 2019).

The Banda Sea is included in the Indonesian Fishery Management Area of Repulic Indonesia (FMA-RI 714) and makes an important contribution to the fishery production in Indonesia, including tuna species (Haruna et al 2018). Tuna exploitation in the Banda Sea was started when the Indonesian government gave access to the Japanese fleet under the bilateral cooperation of the Banda Sea Agreement (BSA), between 1975 and 1980. Several studies were conducted afterward in revealing the magnitude of tuna resources in the Banda Sea (Satrioajie et al 2018). The migration area of *T. albacares* spans from the center of the Pacific Ocean to the Banda Sea (Arrizabalaga et al 2015;

Matsumoto et al 2016; Wang et al 2016). Increased fishing can decrease the production (Burhanis et al 2020). Therefore, the Ministry of Maritime Affairs and Fisheries (MMAF), through the regulation (Permen KP) No. 4 of 2015, issued a policy on the fishing prohibition in several areas in FMA-RI 714 to limit fish resources exploitation (MMAF 2020).

Increasing demand causes intensive fishing. Consequently, a production decrease can be observed in all fishing grounds in Indonesia, potentiallyaffecting the reproductive pattern of yellowfin tuna (Kantun et al 2018). Management policies of *T. albacares* need to be applied to maintain sustainability and control its utilization bydefining and respecting the optimum utilization rate, where the exploitation activities can be continued without threatening the sustainability of the *T. albacares* resources (Genti et al 2016). Throughout the year, *T. albacares* has been exploited in Seram Sea using various types of fishing technology such as the pole and line, and the purse seine (Mallawa et al 2014; Nugraha et al 2020). Pole and line tuna fisheries are widely believed to have low bycatch rates, although these have rarely been quantified (Miller et al 2017). The optimal and profitable exploitation of fish resource should be in accordance with the principles of responsible and sustainable use. For an optimum level of exploitation, the potential of fish resources in the waters can be used to recommend the amount of fishing effort that may be carried out by capture fisheries (Hiariey et al 2019). Currently, in Seram Sea, the exploitation level of *T. albacares* passed theMSY level (Waileruny et al 2014). The *T. albacares* potential can be predicted by analyzing the catch and effort (Soukotta et al 2017).

This study discusses the estimation of *T. albacares* catch and effort at maximum sustainable yield (MSY), based on the catch per unit effort (CPUE) and on the pole and line production in Seram sea, during the period from 2015 to 2020. The Schaefer model surplus production method can be used to describe the relationship between catch and effort (Sparre & Venema 1998). This research is to see the level of exploitation and population of *T. albacares* in the Seram Sea so that it can be used as policy input in managing *T. albacares* resources in the area.

Material and Method. This research was conducted from May 18th to July 12th, 2021, by observing the fishery resources of *T. albacares* in the Seram Sea. Figure 1 shows a map of the fishing ground and research locations.

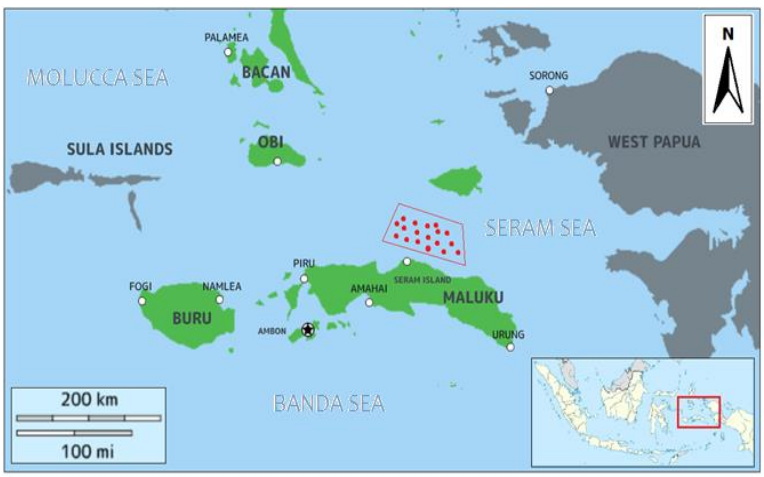

Figure 1. Map of sampling sites (MMAF 2020).

Tools and materials used include pole and liner, cameras, stationery, fishing logs and a list of questionnaires. Primary data collection is done by the direct observation method. Observations were made to obtain technical data on the operation of fishing gear, and data of the composition and number of catches. The primary data in this study is data from *T. albacares* from pole and line catches in the Seram Sea, collected from 2015 to 2020, and also from commercial fisheries, by participating in fishing activities using pole and liner, operating in the Seram Sea. 33 fishing boats were surveyed over 6 years.

Secondary data is data collected from various existing sources. The secondary data used in this study are 2015 to 2020 time series of the *T. albacares* total catch and effort in the FMA-RI 715, obtained from the Marine and Fishery Resources Supervisory Vessel Compliance (PSDKP) Report.

The Catch Per Unit Effort (CPUE) calculation is used to determine the abundance and utilization rate (Gulland 2009). In this study, the model used to estimate the potential size of marine fisheries is the surplus production method which is used to determine the catch MSY, utilization rate, and effort of *T. albacares*. The formula used is as follows (Rahmawati et al 2013):

$$CPUE\text{-}t = Catch\text{-}t / Effort\text{-}t$$

Where:
CPUE-t - year-to-date fish catch per unit of effort;
Catch-t - year-to-date fish catch;
Effort-t - year-to-date effort;

To get the optimum fishing effort to reach MSY, the Schaefer equation is used (Al Hasim et al 2020):

$$F_{opt} = -a / 2b$$

Where:
F_{opt} - number of trips representing the optimal fishing effort to reach MSY;
a - line intercept;
b - slope.

The potential of *T. albacares* as resource can be estimated by analyzing the catch and effort. According to Sparre & Venema (1998), the relationship between catch and effort can use the Schaefer model for the production surplus.

The steps for data processing are:

1. Plotting the value of the effort (F) against the ratio (C/F) and predicting the value of the intercept (a) and the value of the slope (b), with linear regression.
2. Calculating the estimation of sustainable production (CMSY) and optimum effort (EMSY).

The optimal fishing effort level at which the MSY is be achieved can be calculated using the formula (Al Hasim et al 2020):

$$MSY = -a^2 / 4b$$

Where:
MSY - maximum sustainable catch;
a - line intercept;
b - slope.

Results and Discussion. Pole and line is one of the dominant fishing gear used by fishermen to catch fish in Indonesia (Jansen & Sumarauw 2016). The operation of pole and lines can be said is environmentally friendly, because the catch of pole and lines is more selective, of high quality, and does not harm consumers. Pole and lines operations also do not damage habitat and do not endanger fishermen during fishing operations.

The target for pole and line catches is large pelagic fish such as tuna (*Thunnus* sp.) and skipjack tuna (*Katsuwonus pelamis*). In addition, several bycatch were also obtained such as dolphin fish (*Coryphaena hippurus*) (Arrizabalaga et al 2015) and mackerel (*Euthynnus affinis*) (Sepri et al 2020). Thunnus albacares catches in FMA-RI 715by fishing vessels, from 2015 to 2020, were compiled from PSDKP Report, showing an overall decrease of the annual production, starting from 2016 (Figure 2).

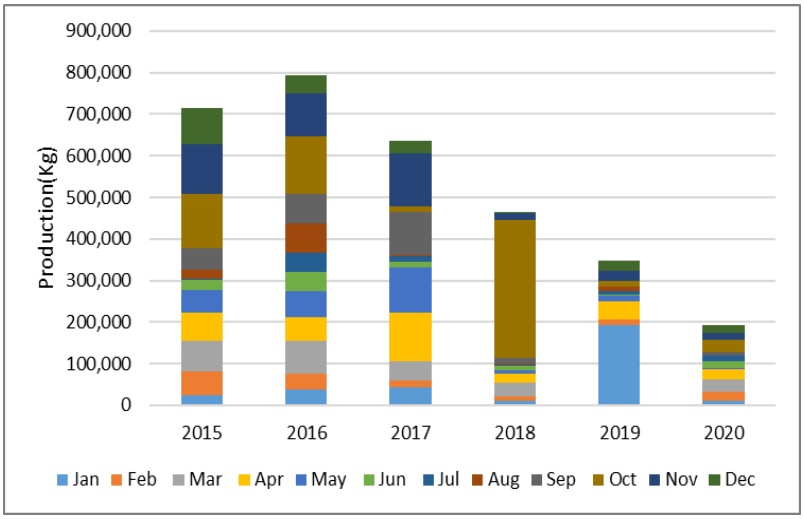

Figure 2. Production of *Thunnus albacares* (2015 -2020).

The production of *T. albacares* in the Seram Sea was obtained from 33 vessels, but because the time of data collection was not constant, the catch data differed from month to month, as shown in Figure 2. The decreasing annual production trend of *T. albacares* since 2016 is detailed in Table 1 below:

Table 1

Catches, effort and CPUE

Year	*Catches (tons)*	*Effort (trip)*	*CPUE (tons trip^{-1})*
2015	713,394	296	2,410
2016	792,636	370	2,142
2017	634,976	298	2,131
2018	465,591	288	1,617
2019	347,887	281	1,238
2020	192,083	156	1,231
	Total		10,769
	Average		1,795

Figure 3 and Figure 4 below are graphic representations of the data from Table 1.

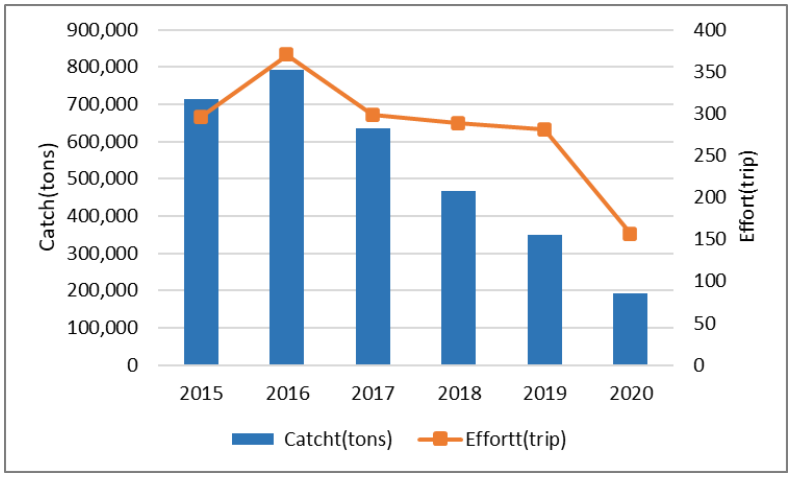

Figure 3. Comparison of catch,effort and CPUE of *Thunnus albacares* (2015-2020).

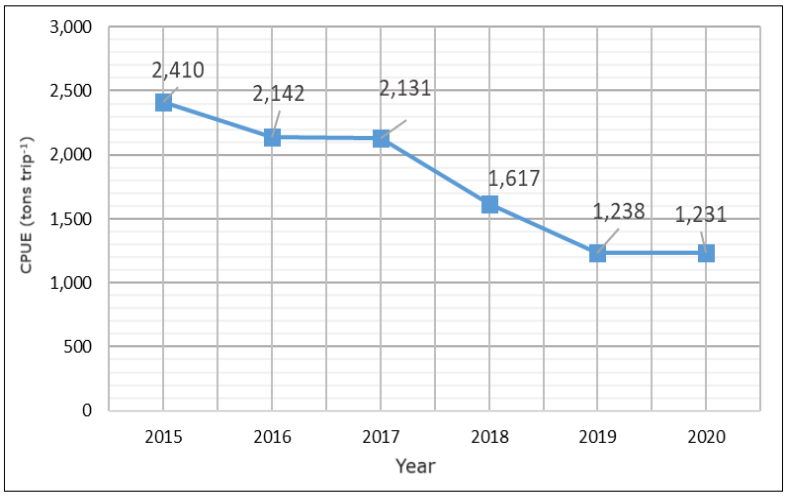

Figure 4. CPUE (tons trip^{-1}) by year (2015 to 2020).

The results show that the average CPUE 1,795 tons a trip (Table 1, Figure 4) indicates that the level of fishing gear productivity (effort) is high (Figure 3). In addition, CPUE was 2,410 tons a trip in 2015, but it can be seen that it continues to decrease by 1,231 tons a trip until 2020. Figure 4 shows the CPUE declining production year by year.

The data obtained is based on catches in the area. The total monthly catch is obtained from the monthly catch made in the fishing area for all vessels that caught that month. Data was obtained for 6 years when fishing activities were carried out. Figure 5 shows the relationship between CPUE and Effort for 6 years.

The relationship between CPUE and Effort results from the equation y = 4.7726x + 451.37, where a = 451.37 and b = 4.7726, suggesting that an additional effort, leading to a fish resource utilization above the MSY value, reduces the fish production (catches) and ship productivity (Figure 5).

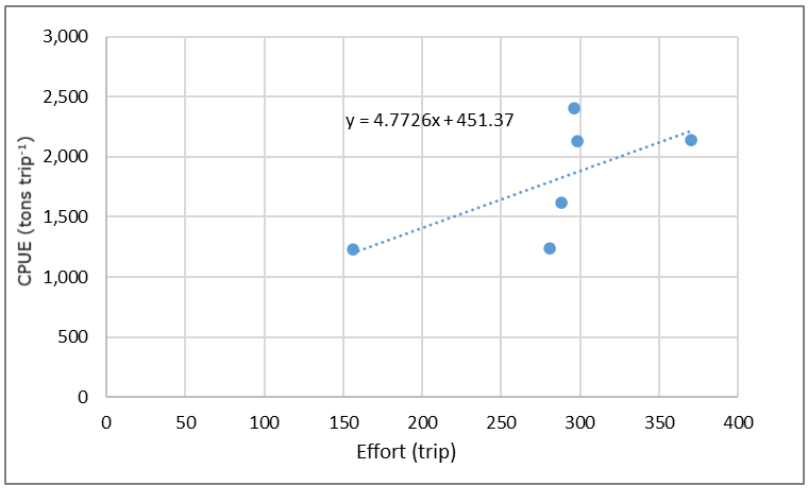

Figure 5. Relationship between CPUE and effort.

Next, F_{opt} and MSY are determined based on the formula:
F_{opt} = -a/2b = -451.37/(2*4.7726) = - 47.2876 ≈ 47

And,
MSY= -a2 /4b = $(-451.37)^2/(4*4.7726)$ = 10,672.1147
≈ 10,672

F_{opt} modulus ($|F_{opt}|$) indicates the number of optimal fishing effort deployed at the MSY.

MSY of Thunnus albacares in Seram Sea. Based on the CPUE data and calculation results as shown in Figure 2, the production of *T. albacares* and CPUE tend to decrease. The study of fish stocks in Indonesian waters provides an estimate of of 1,242,527 tons for the potential fish resources in FMA-RI 715. The potential includes 31,659 tons of large pelagic fish, according to No. 50/KEPMEN-KP/2017 concerning the estimated potential, number of capture permitted, and level of use of fish resources in the FMA-RI 715, while the utilization rate has reached 0.97 (fully exploited) (Tetelepta et al 2019), corresponding to a yellow indicator which means that the fishing effort is mainained under close monitoring.

In order for the fish resources in the waters of FMA-RI 715 to be in a sustainable stage, it is necessary to adjust the according to the optimum effort value (F_{opt}) (Suman et al 2018).

Table 2

The decree number 50/KEPMEN-KP/2017 of the Minister of Marine and Fisheries of the Republic of Indonesia

FMA-RI 715 (Tomini Bay, Maliku Sea, Halmahera Sea, Seram Sea, Berau Bay)		
	Potency (ton)	*Utilization rate*
Small pelagic fish	555,982	0.88
Large pelagic fish	31,659	0.97
Demersal fish	325,080	0.22
Coral fish	310,866	0.34
Shrimp	6,436	0.78
Lobster	846	1.32
Crab	1,386	2.17
Squid	10,272	1.86
Amount	1,242,527	

The current analysis of the Schaefer model, performed on data for Seram Sea, showed that the Maximum Sustainable Yield (MSY) was of 10,672 tons, with an F_{opt} of 47 trip (Figure 6).

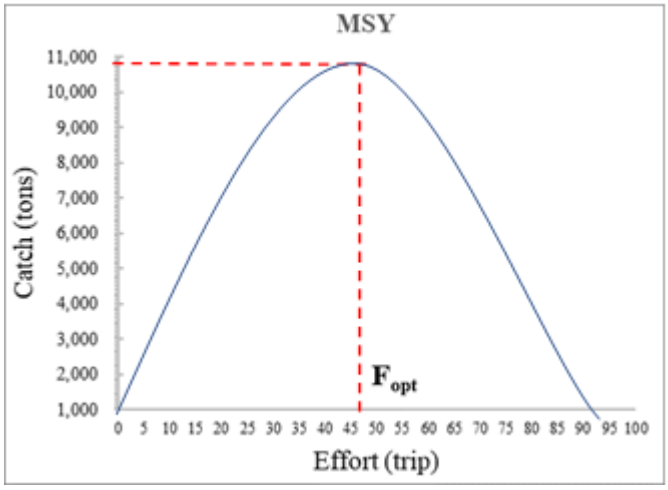

Figure 6. Relation curve between production and effort.

If the MSY is not exceeded but the corresponding optimal fishing effort (F_{opt}, in terms of trips number) of to reach MSY is exceeded, there is a risk of overfishing. Although, for the studied period, Table 3 shows that the production (713,394 kg year^{-1}) is inferior to the MSY (10,672,000 kg year^{-1}), but the actual effort (281.5) is higher than F_{opt} (47), suggesting the necessity of a close monitoring in terms of catches and effort, limiting the fishing vessels capacity or number in the area, in order to prevent overfishing and restore the resources.

Effort and utilization. Table 3 shows that the annual utilization rate (E) for *T. albacares* is less than 1. According to the Minister of marine and fisheries of the republic of Indonesia decree no. 50/KEPMEN-KP/2017, the utilization rate (E) criteria are:
E < 0.5 = Moderately-exploited, fishing effort can be increased;
0.5 > E < 1 = Fully-exploited, fishing effort is maintained under close monitoring;
E > 1 = Over-exploited, indicating that capture effort must be reduced.

Table 3

Effort and utilization rate from 2015 to 2020

Years	*Production (kg year^{-1})*	*Effort (Trip)*	*F_{opt}*	*MSY (tons year^{-1})*	*Utilization Rate (E)*
2015	713,394	296	47	10,672	0.7
2016	792,636	370	47	10,672	0.7
2017	634,976	298	47	10,672	0.6
2018	465,591	288	47	10,672	0.4
2019	348,887	281	47	10,672	0.3
2020	192,083	156	47	10,672	0.2
Total	3,146,567	1,689			
Average	524,428	281.5			

The category of the utilization rate of *T. albacares* during the six years period (2015-2020) passed fromfully exploited to moderately-exploited., while the efforts made have systematically exceeded the F_{opt}. a Additional fishing efforts (by increasing the number of fleets or the vessels capacity), might increase the exploitation, leading to overfishing in the area. This means, in accordance with the MMAF decree number 50/KEPMEN-KP/2017(MMAF 2020), that the capture and utilization of resources must be maintained under a close monitoring, based on a management principle that resources use must comply to the system's natural carrying capacity (Cahyani 2020).

Conclusions. From the results of the study, it can be concluded that autilization rate of *T. albacares* less than 1, suggests a suboptimal state, related to the optimum effort (F_{opt}) of 47 times of and to the MSY of 10,672 tons, in the studied area. On average, production has not exceeded MSY, but the effort made has exceeded F_{opt}, which is a factor in the decline in production. It is therefore possible to further add fishing efforts. To overcome the occurrence of overfishing conditions, it is necessary to manage *T. albacares* fishery resources by adjusting based on the existing utilization levels, through restrictions on fishing areas, selectivity of fishing gear, and restrictions on the number or capacity of fishing vessels.

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

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