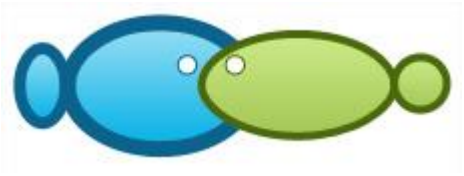

Population dynamic indicator of the yellowfin tuna *Thunnus albacares* and its stock condition in the Banda Sea, Indonesia

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Abstract. The purpose of this study was to estimate population parameters (size structure, age, growth, mortality rate, the eligible catch size, yield per relative recruitment) and the assessment of the condition of the yellowfin tuna (*Thunnus albacares*) stock on handline fishing that operated from the southern coast of Seram Island in the Banda Sea during November 2015 - October 2016. As many as 4.829 fish samples were obtained by the distribution of fork length 25-178 cm which was dominated by medium-large size group with the total of catching 71% and L_c = 94.54 cm. The utilization pattern of the Fish Aggregating Device (FADs) and seasonal (weather) changes affect the fish size distribution. The estimation of growth parameters of von Bertalanffy using the method of ELEFAN-I showed coefficient of growth rate (K) 0.31 year^{-1}, asymptotic fork length (L_∞) of 215 cm, age at length zero (t_o) -0.311 year, longevity (t_{max}) 9.37 year, total of mortality rate (Z) 1.47 year^{-1}, natural mortality rate (M) 0.49 year^{-1}, fishing mortality (F) 0.98 year^{-1}, and exploitation rate (E) of 0.67 year^{-1}. A recent relative yield per recruit (Y/R) was greater than the optimal Y/R. By the method of Sperman-Karber could be obtained the size of first stage mature gonads (L_{50}) 115.2 cm and percentage of eligible catch size was 30.6%. The condition of *T. albacares* fishery resources in the Banda Sea waters is still in the good category. However, several population parameters passed through the optimal limit. It required an implementation of restrained fishery management with the prudential principle.
Key Words: population parameters, exploitation, growth, fishing management, handline fishing.

Introduction. Yellowfin tuna (*Thunnus albacares*) is one of the predominant commodities with high demand of the world market. This cosmopolitan species in Indonesia is abundant and has no life cycle limit in certain sea includes coast area, territorial sea, and Exclusive Economic Zone (ZEE). Indonesia as archipelago state is supported with the sea interaction and peculiar geographical condition where an ample marine biodiversity and fishing zone is. Because of these benefits, Indonesia becomes one of the candidates of 'Coral Triangle Tuna' as a part of *T. albacares* migration cycle, breeding ground, and nursery ground (Bailey et al 2012).

The Banda Sea is included in the Indonesian Fishery Management Area (WPP RI-714) and makes an important contribution to fishery production in Indonesia including tuna species. Maluku Province with the largest contribution of tuna fisheries in the Banda Sea amounted to 438,148 tons, representing 8.29% of the total national fishery production (MMAF 2015). The excessive exploitation of *T. albacares* in Banda Sea was initiated before World War II by Japanese tuna ship that was implemented by the Banda Sea agreement on 1968-1980 (Marten et al 1982). This exploitation is still occurring dominated by modest fishermen using handline.

The issue of production dwindling and alteration of the stock condition of *T. albacares* in global turned into a serious issue (Allen et al 2010; Joseph et al 2010); the dynamic of *T. albacares* suffered fully-exploited status (Akbar et al 2014), a decrease of production 12% (Budhiman 2015), an inflated frequency of fishing at early stage growth phase and mature gonad fish (Damora & Baihaqi 2013; Ningsih et al 2015; Chodrijah

2015). Several studies reported about the population dynamic of *T. albacares* using various estimation methods in several areas that indicated the effect of exploitation compulsion on the change of fish stock abundance in Indian Ocean (Somvanshi et al 2003; Rohit et al 2012; Nurdin et al 2016) and Pacific Ocean (Lehodey & Leroy 1999; Zhu et al 2011; Kantun & Amir 2013).

The study of *T. albacares* population dynamic has not been intensively done yet. An appraisal of *T. albacares* population was beneficial to do for ensuring the condition of resources in a certain area. Analyzing population dynamic employed a length frequency data from the catches of hand line-using fishermen in the Banda Sea. This information was useful for stakeholders as an effective plan of fishery management. An uncontrolled and massive *T. albacares* catching could generate a menace for the sustainability of fishery resource and economic depletion.

The aim of this study was to estimate the parameter of population dynamic including size structure, age, growth, mortality rate, eligible size catch, yield per relative recruitment, and *T. albacares* resource status in the Banda Sea. This information was expected being used as the basis of sustainable fishery management.

Material and Method. This study was conducted during November 2015 - October 2016 in the fishing area of Banda Sea (Figure 1). Appraisal of population dynamic parameters in this study is based on lengthy frequency data. Samples was obtained weekly in several interim fish landing sites in Central Maluku that successfully caught using handline and ship capacity <5 GT.

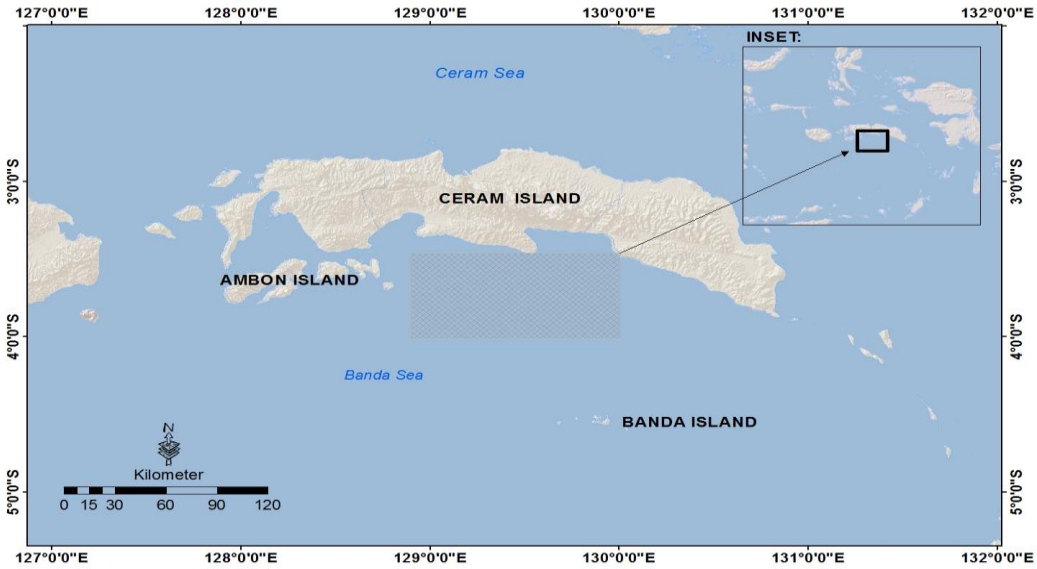

Figure 1. Research sites in the Banda Sea, Indonesia.

The collected data were recorded on 4,829 individuals of *T. albacares*. The growth parameter of von Bertalanffy was assumed with using ELEFAN-1 module of FiSAT-II software which was completely developed by Gayanilo et al (2005) in a way of projecting several possibilities of the combination of growth parameter of von Bertalanffy (L_∞ and K). The growth parameter of t_o was calculated through Pauly's (1983) equations: Log (t_0) = -0.3922 – 0.2752 (log L_∞) – 1.038 (log K). The age data was analyzed by the equation: Lt = L_∞ (1- $e^{-K(t-to)}$) where: Lt = length at age t (fork length); $L_{\infty=}$ asymptotic length (cm); K = a coefficient of growth rate (year); t_0 = theoretical age at zero length. The estimation of maximum age or Longevity (t_{max}) was analyzed using the equation: t_{max} = 3/K+to (Pauly 1983).

Natural mortality rate (M) was assumed by Pauly's (1983) empirical equations: Log M = 0.0066 - 0.279 log L_∞ + 0.6543 log K + 0.4634 log T as noted M = natural mortality rate/year, $L_{\infty=}$ asimtot length (cm), K = a coefficient of growth rate (year), T =

average of water surface temperature = 29^0C; Fishing mortality (F) and exploitation rate (E) were calculated by Pauly's formula: F=Z-M and E= F/Z.

The size estimation of the first-time ripe gonad utilized Sperman-Karber's method (Udupa 1986) that used two characteristics of gonad ripeness, such as immature gonad (gonad stages I and II) and mature gonads (gonad stages III, IV, and V). The average fish size estimation of first-time gonad ripe used the group of mature gonads (Itano 2001) and analyzed referred to Spare et al (1989).

Each indicator assigned different heaviness according to its urgency; each indicator is divided into sub-indicators with different values. Furthermore, multiplication of indicator heaviness and value of the indicator is obtained (Table 1). The percentage criteria of condition stock value were calculated using the equations of Mallawa et al (2015): Stock condition = {(ΣHeaviness x value/full value)}x 100%; where the full value is 55. The stock condition used references, such as:

- Stock condition ≥85–100% - very good;
- Stock condition <85–65% - good;
- Stock condition <65% - low.

Table 1

Analysis of stock condition specification

Indicator	*Heaviness*	*Value*	*Heaviness x Value*
Size Structure			
Dominant small fish		1	
Small – medium	2.00	3	10
medium - large		5	
Number of age groups			
<three age groups		1	
Three-five age groups	2.00	3	10
>five age groups		5	
The rate of catch mortality			
Value of F> 2.0		1	
Value of F 1.0–2.0	2.00	3	10
Value of F< 1.0		5	
The rate of exploitation			
Value of E > 1.0		1	
Value of E > 0.5 - < 1.0	1.00	3	5
Value of E< 0.5		5	
The rate of population growth			
Value of K < 0.5 per year		1	
Value of K ≥ 0.5–0.75 per year	1.00	3	5
Value of K > 0.75 per year		5	
The percentage of eligible catch size			
< 30%		1	
30 - < 50%	2.00	3	10
≥ 50%		5	
Yield per Recruitment			
Y/R now> Y/R optimal		1	
Y/R now = Y/R optimal	1.00	3	5
Y/R now< Y/R optimal		5	
Full value (Total)			55

Source: Mallawa et al (2015) modified.

Results

The distribution of length frequency. The size of *T. albacares* catching during the annual period was distributed in a range of 25-178 cm with a mean length of 94.0 cm (Figure 2).

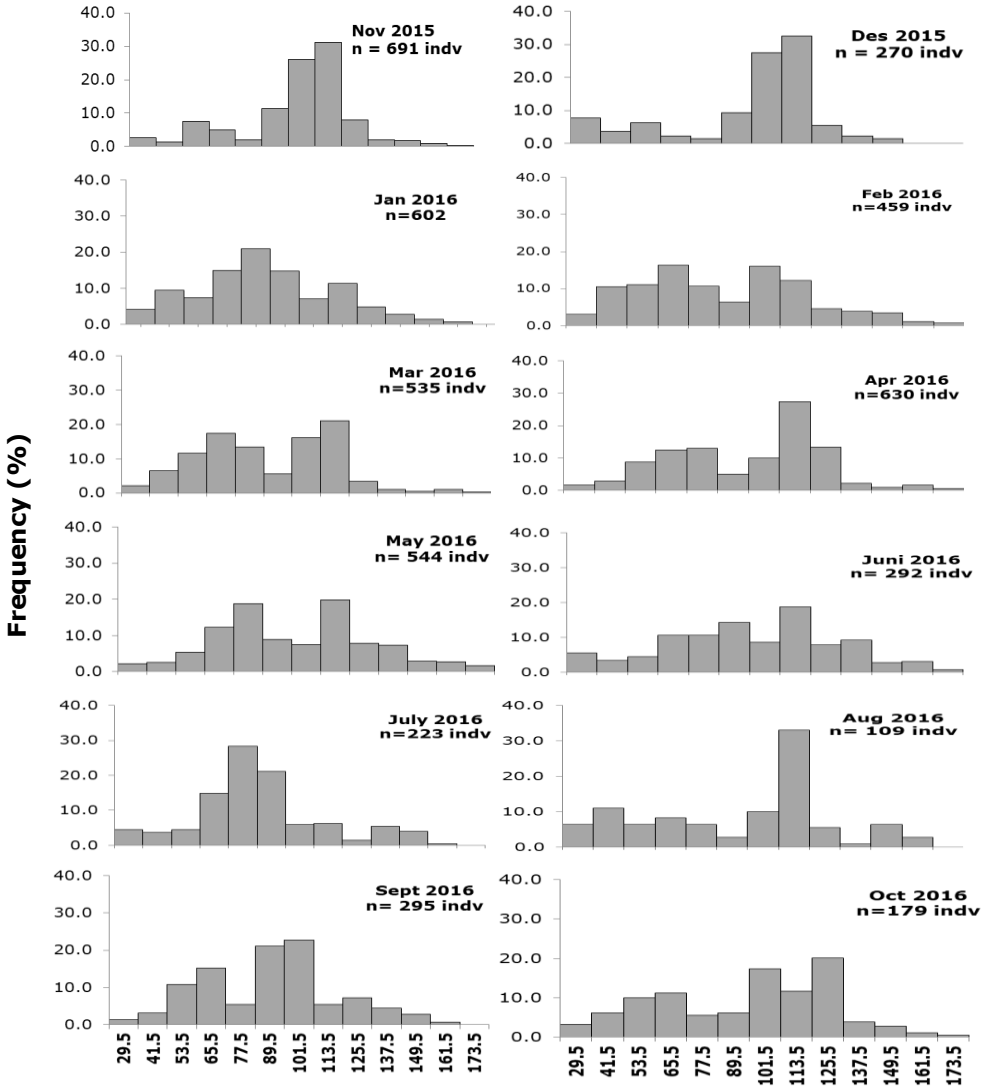

Figure 2. The *Thunnus albacares* fork length frequency distribution, of the catch in the Banda Sea.

According to the division of the size, the group which obtained the dominant catches was in the medium size category (72-107 cm) of 36.50% and was generally caught in the Fish Aggregating Device (FAD) region (Figure 3). *T. albacares* caught in dolphin-associated schools are generally large fish but the caught sizes vary. The frequency distribution of sizes based on quarter group separations did not differ significantly. However, according to the season the abundance of *T. albacares* sizes for fishing lines where the size of the quarter is grouped there is an increase in the proportion in the middle class of 101.5 cm to 125.5 cm in September-November which is considered the beginning of fishing season and March-May in the middle class 113.5 cm and 125.5 cm are considered as fishing season II (Figure 4). According to the frequency composition of length size, the fishermen catch showed result was in a range of medium until big size.

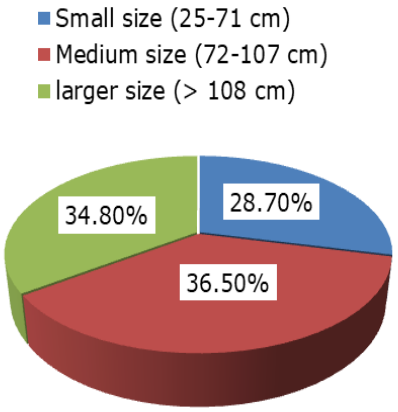

Figure 3. Size distribution *Thunnus albacares* by three different size groups in the Banda Sea.

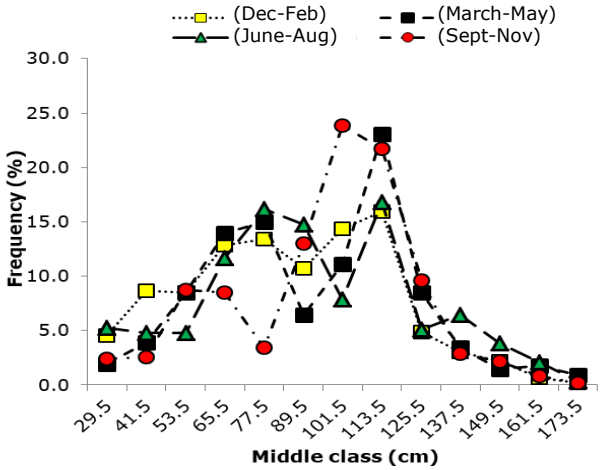

Figure 4. The size distribution *Thunnus albacares* by quarter in percentage of each size class in the Banda Sea.

Growth. According to the equations of growth parameter of von Bertalanffy assumed by ELEFAN-I it was acquired the coefficient of growth rate (K) = 0.31/year, asymptotic length (L_∞) = 215 cm, an age of fish theatrically was zero (t_o) = -0.311 so that the growth curve combined was L_t = 215 [1-exp$^{-0.311(t)}$]. The *T. albacares* population in the Banda Sea built seven age groups (Figure 5). Response Surface R_n (Goodness of fit index) = 0.266 so that the growth curve combined was L_t = 215 [1-exp-0.311(t)] (Figure 5). The firstly caught size (L_c) was 94.54 cm on age (t_c) 1.6 year^{-1}.

The estimation of maximum age was analyzed using the equation: t_{max} = 3/K+to (Pauly 1983), resulting 9.37 year. The average of growth level in the age group of 0.5-6 year was 22.8 cm/year (2.07 cm/month). With the growth level of 4.0 cm/month, the estimation of fish length on the juvenile group was 47.84-71.84 cm. Then, a sub-adult group from age of 1-2 year with the growth level of 3.2 cm/month was 71.84-110 cm and an adult group from age of 2-6 year with the growth level 1.55 cm/month was 110.89-184.61 cm.

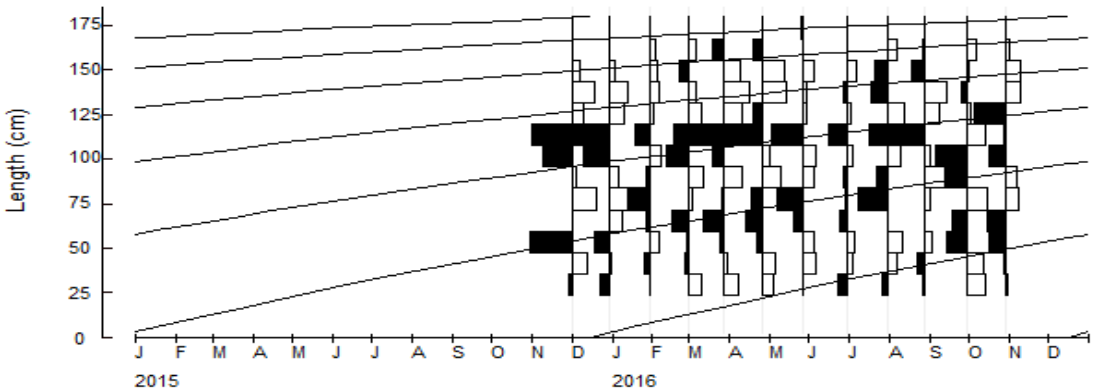

Figure 5. The growth graph of *Thunnus albacares* in the Banda Sea.

Mortality and exploitation rate. The estimation of the natural mortality (M) was 0.49 year^{-1} and fishing mortality (F) = 0.98 year^{-1}. Taking Z = 1.47 into account, an exploitation level (E) of 0.67 year^{-1} was obtained for *T. albacares* in the Banda Sea (Figure 6). The estimation of exploitation rate (E) showed that this indicator was on the far side of optimum. It could be assumed that the sustainable optimum exploitation value was equivalent to 0.5 year^{-1} (Gulland 1971).

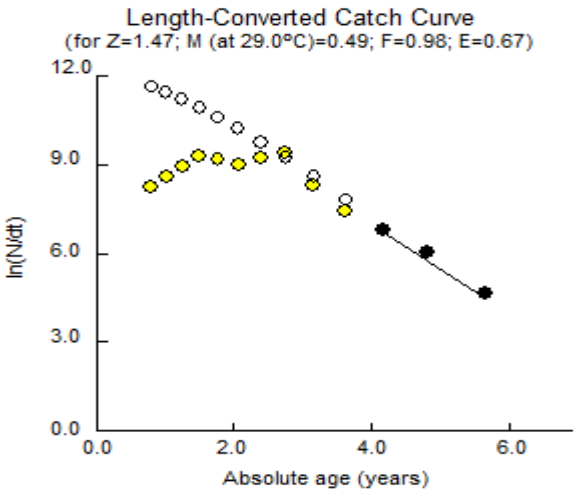

Figure 6. The curve of *Thunnus albacares* catch in the Banda Sea.

Length at first maturity (L_{50}). Length at first maturity is used as a minimum limit in the utilization of fish resources. The observation of 629 female gonad samples included gonad stages III-V distributed in a range of 69-178 cm. In the present study, the length at first maturity (L_{50}) for *T. albacares* females in the Banda Sea was estimated at 115.2 cm fork length (Figure 7).

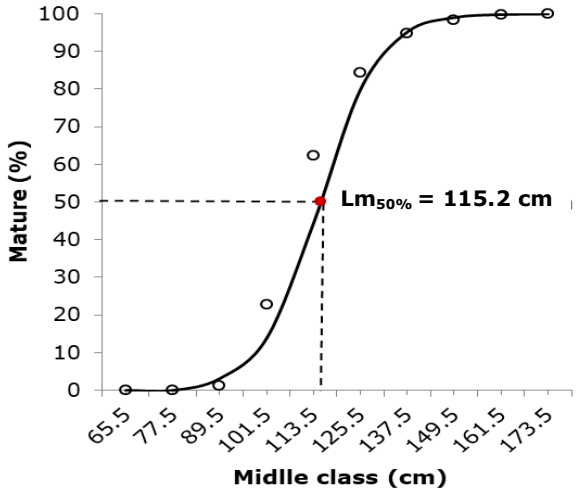

Figure 7. The Logistic curve of the estimation of the length at first maturity of *T. albacares* in the Banda Sea.

Yield per recruitment. The relative yield per unit (Y/R) and the relative biomass per recruit (B/R) that derived from the equations of L_c/L_∞ = 0.44 and M/K = 1.58, where the recent exploitation rate (E = 0.67) had been exceeded the optimum exploitation rate (E_{max} = 0.65) (Figure 8). The relative biomass level per recruit on the value of optimum exploitation was 76.2% and the exploitation level decreased as many as 2.9%. This study showed that the population was slightly decreased so that it needed an attentive exploration. If the exploitation rate could be reduced, it would guarantee the *T. albacares* reproduction in the Banda Sea.

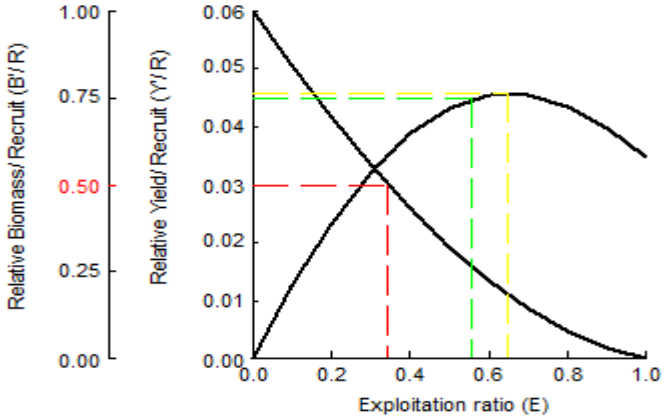

Figure 8. The curve of yield per recruitment of *Thunnus albacares* in the Banda Sea.

The appraisal of stock condition. The appraisal of stock condition indicator that was acquired from several population parameters can be seen in Table 2. Assessment of stock condition indicators obtained from several population parameters can be seen in Table 2. The results show that *T. albacares* resources remain in good condition. However, there are several criteria, such as size structure, number of age groups, and mortality rates below the optimum average, while other criteria are above the optimum average.

Table 2

The appraisal of the *Thunnus albacares* stock condition in the Banda Sea

Indicator	*Heaviness*	*Value*	*Heaviness x Value*
The size structure (small-large)	2	5	10
Number of age groups (>five age groups)	2	5	10
The rate of catch mortality (F < 1.0)	2	5	10
The rate of exploitation (E > 0.5 - < 1.0)	1	3	3
The rate of population growth (K < 0.5/year)	1	1	1
The percentage of eligible catch size (30- <50%)	2	3	6
Yield per recruitment (Y/R now>Y/R) (optimum)	1	1	1
Σ Heaviness x value	-	-	41
Percentage (%)	-	-	74.5
Stock condition		Good	

Discussion. The temporal distribution of *T. albacares* size year-round was prevalent in the Banda Sea from juvenile until adult. This condition was influenced by the Fish Aggregating Device (FAD) utilization and season (weather) change. The catch of *T. albacares* in the Banda Sea was performed year-round and the peak of the catch occured in September-November and March-May. It can be concluded that the Banda Sea is fish migration area and the best place for feeding and spawning ground. The enhancement of the proportion of adult size could be commonly found in the Banda Sea during September-December (Damora & Baihaqi 2013), in the Oman Sea during July-December (Kaymaraman et al 2014) and the spawning activity in Indonesia during December-February (Itano 2000). The augmentation of primary productivity is caused by the mixture of water mass, the alteration of current direction, and upwelling frequently occurred in the Banda Sea (Gordon & Susanto 2001; Sediadi 2004).

The growth rate parameter of *T. albacares* was on the sluggish state. Several research of *T. albacares* in the sub-tropical and tropical area revealed values as K= 0.27-1.88 per year, L_∞ = 148-214 cm, t_o = 0.003-0.400 year Zhue et al (2011), Nurdin et al (2016) reported K= 0.3-0.88 per year, L_∞ = 151.8-233 cm, t_o = 0.099-0.705 year, t_{max} = 6.2-10.1 year, and there were 5-6 clusters. The parameter of the growth rate of these

researches was similar to the other research, which only distinguished in a range of sample size, asymptotic length, and the result of individual sampling (Zhu et al 2011).

The exploitation of *T. albacares* in the Banda Sea had exceeded the optimum exploitation rate of 0.5/year. The catch indicator can be viewed in the recent exploitation rate (E = 0.67) that had exceeded the optimum value (E_{max} = 0.65). In Table 3, it presented the mortality and exploitation rate from the other studies as comparative data. There were natural mortality differences established through the estimation method, observation location, and sensitivity on the growth rate, K, and L_∞ (Kaymaraman et al 2014). The optimum exploitation level was susceptible and uncertainty on M.

Table 3

The study of mortality and exploitation rate in several locations

Source	*Fishing mortality (F)*	*Natural mortality rate (M)*	*total mortality rate (Z)*	*Exploitation rate (E)*	*Location*
Present study	0.98	0.49	1.47	0.67	Banda Sea
Nurdin et al (2016)	0.61	0.66	1.27	0.48	Pelabuhan Ratu
Kaymaram et al (2014)	1.56	0.48	2.04	0.76	Oman Sea
Damora & Baihaqi (2013)	1.79	0.68	2.40	0.75	Banda Sea
Kantun & Amir (2013)	1.69	0.55	2.21	0.77	Strait of Makassar
Rohit et al (2012)	0.23	0.48	0.71	0.32	East Cost of India
Zhu et al (2011)	0.91	0.65	1.56	0.46	Eastern & Central Pacific Ocean

The size at first maturation for *T. albacares* in the Indian Ocean was described by Zhu et al (2008) and IOTC (2009) estimating a value of 100 cm for females and male; according to Itano (2000) in the Western Pacific Ocean the same indicator was reported to be 104 cm. In the Philippine and Indonesia the estimated length at first maturity for females was 104.6 cm (Itano 2001), in the West Pacific 107.7 cm (Sun et al 2003), in the Indian Ocean 87.5 cm (Rohit & Rammohan 2009), and in the Western Pacific Ocean (Bone Bay) 107.9 cm (Kantun & Amir 2016). Eligible catch size was the size of fish which is greater than the length at first maturity (at least has spawned once). The results of the present study obtained that the average size of fork length (FL) is greater than length of the first maturity (L_{50}) (115.2 cm), the percentage of eligible capture size of *T. albacares* is estimated as 30.6%. The variety of size was related to the tools, fish catch method, and the distribution of caught fish size.

The assessment of *T. albacares* stock condition was in good condition, which is supported by the topographic characteristic, islands configuration, and the environment of the Banda Sea. However, some population parameters such as exploitation rate (E), and yield per recruit (Y/R) are not yet optimal. An uncontrolled utilization of the resource in the Banda Sea, as the perpetual fishing ground and open access, has implication on the over-fishing and the decrease of fish resource.

Therefore, optimizing its utilization can suppress over-exploitation so as to ensure resource sustainability. A strategic action toward conservation of *T. albacares* resource was the implementation of managed-capture fisheries. The regulation that could be implemented such as, the restriction for the minimum eligible catch size, the prohibition of destructive catch tools use, the limitation of number of permitted ship, and the ban of catch in the certain season (closed seasons) and the closing of catch area in the certain location (closed areas). The implementation was performed with a careful principle and considering the economic and social effect.

Conclusions. The population dynamics parameter of *T. albacares* in Banda Sea waters shows the size structure of 25-178 cm, length of first catch (L_c) 94.54 cm, growth rate

coefficient (K) 0.31 year^{-1}, asymptotic length (L_∞) 215 cm, t_0 = -0.311, longevity (t_{max}) 9.37 years, total mortality (Z) 1.47 years^{-1}, natural mortality (M) 0.49 years^{-1}, fishing mortality (F) 0.98 years^{-1}, the exploitation rate (E) 0.67 years^{-1}, the relative yield per recruit (Y/R) is currently greater than the optimal relative yield per recruit (Y/R), length at first maturity (Lm) of 103.6 cm, and the percentage of decent size of catch is 23.09%. Assessment of stock conditions based on population parameters indicates that *T. albacares* resources are in good condition.

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References

Akbar N., Zamani N. P., Madduppa H. H., 2014 [Genetic diversity of yellowfin tuna (*Thunnus albacares*) from two populations in the Moluccas Sea, Indonesia]. Depik 3(1):65-73. [In Indonesian].

Allen R., Joseph J., Squires D., 2010 Conservation and management of transnational tuna fisheries. First Edition, Blackwell Publishing, 343 p.

Bailey M., Flores J., Pokajam S., Sumaila R. U., 2012 Towards better management of Coral Triangle tuna. Ocean and Coastal Management 63:30-42.

Budhiman A. A., 2015 [Revitalization of pole and line fishery business in capture of skipper fish in East Flores]. Proceedings of the National Symposium on Sustainable Fisheries Management, pp. 5-15, WWF-Indonesia Press, 1269 p. [In Indonesian].

Chodrijah U., 2015 [Relationship of weight length and size structure of yellowfin tuna (*Thunnus albacares*) in Banda Sea waters. Proceedings of the National Symposium on Sustainable Fisheries Management, pp. 341-348, WWF-Indonesia Press, 1269 p. [In Indonesian].

Damora A., Baihaqi, 2013 [Size distribution and population parameters of yellowfin tuna (*Thunnus albacares*) in Banda Sea]. Jurnal BAWAL 5(1):59-65. [In Indonesian].

Gayanilo F. C. Jr., Sparre P., Pauly D., 2005 FAO-ICLARM stock assessment tools II (FiSAT II). Revised version, User's guide, FAO Computerized Information Series (Fisheries), No. 8, FAO Rome, 168 p.

Gordon A. L., Susanto R. D., 2001 Banda Sea surface layer divergence. Ocean Dynamics 52:2-10.

Gulland J. A., 1971 The fish resources of the oceans. FAO Fishing News (Books) Ltd. Surrey, 255 p.

Itano D. G., 2000 The reproductive biology of yellowfin tuna (*Thunnus albacores*) in Hawaiian waters and the western tropical pacific Ocean. Project summary, Pelagic Fisheries Research Program, Joint of Marine and Atmospheric Research, University of Hawaii, SOEST 00-01, JIMAR contribution 00-328, 69 p.

Itano D. G., 2001 The reproductive biology of yellowfin tuna (*Thunnus albacares*) in Hawaiian waters and the Western Tropical Pacific Ocean. Yellowfin Research Group-SCTB 14 Noumea, New Caledonia, 12 p.

Joseph J., Squires D., Bayliff, Groves T., 2010 Addressing the problem of excess fishing capacity in tuna fisheries (Chapter 2). Conservation and Management of Transnational Tuna Fisheries. First Edition, Blackwell Publishing, pp. 11-38.

Kantun W., Amir F., 2013 [Age structure, growth pattern and mortality of yellowfin tuna-*Thunnus albacares* (Bonnatere, 1788) in Macassar streat. Jourrnal Balik Diwa 4(1):8-14. [In Indonesian].

Kantun, Amir M. F., 2016 [Biological aspect and composition of line fishing in Bone Bay waters]. Jourrnal Balik Diwa 4(1):8-14. [In Indonesian].

Kaymaram F., Hosseini S. A., Darvishi M., 2014 Estimates of length-based population parameters of yellowfin tuna (*Thunnus albacares*) in the Oman Sea. Turkish Journal of Fisheries and Aquatic Sciences 14:101-111.

Lehoday P., Leroy B., 1999 Age and growth of yellowfin tuna (*Thunnus albacares*) from the western and central Pacific Ocean as indicated by daily growth increments and tagging data. SCTB12 working paper. YFT-2. 12th Standing committee on tuna and billfish.
Mallawa A., Amir F., Musbir, Susianti W., 2015 [Assessment of *Katsuwonus pelamis* conditions in Flores Sea waters, South Sulawesi]. Proceedings of the National Symposium on Marine and Fisheries II, pp. 299-307, Hasanuddin University Press, 513 p. [In Indonesian].
Marten G. G., Matsuda Y., Bardach J., Comitini S., Hardjolukito S., 1982 A goal analysis of alternative tuna fishery arrangements between Indonesia and Japan. Ocean Management 8:125-150.
Ningsih O., Tisera W. L., Pesulima W., Kiuk J. W., Ginzel F. I., 2015 [Preliminary study of reproduction of yellowfin tuna caught In the waters of East Nusa Tenggara]. Proceedings of the National Symposium on Sustainable Fisheries Management, pp 162-167, WWF-Indonesia Press, 1269 p. [In Indonesian].
Nurdin E., Sondita M. F. A., Yusfiandayani R., Baskoro M. S., 2016 Growth and mortality parameters of yellowfin tuna (*Thunnus albacares*) in Palabuhanratu waters, west Java (eastern Indian Ocean). AACL Bioflux 9(3):741-747.
Pauly D., 1983 Some simple methods for the assessment of tropical fish stocks. FAO Fisheries Technical Paper 234, 52 p.
Rohit P., Rammohan K., 2009 Fishery and biological aspects of yellowfin tuna *Thunnus albacares* along Andhra Coast, India. Asian Fisheries Science 22:235-244.
Rohit P., Rao G. S., Rammohan K., 2012 Age, growth and population structure of the yellowfin tuna *Thunnus albacares* (Bonnaterre, 1788) exploited along the east coast of India. Indian Journal of Fisheries 59(1):1-6.
Sediadi S., 2004 [Upwelling effects on the abundance and distribution of phytoplankton in the Banda Sea waters and its surroundings]. Journal Makara Sain 8(2):43-51. [In Indonesian].
Somvanshi V. S., Bhargava A. K., Gulati D. K., Varghese S., Sijo P., Varghese, 2003 Growth parameters estimated for yellowfin tuna occurring in the Indian EEZ. WPTT-03-21. IOTC Proceedings 6:191-193.
Sparre P., Ursin E., Venema S. C., 1989 Introduction to tropical fish stock assessment. Part I., Manual, FAO, Rome, 337 p.
Sun C. L., Su N. J., Yeh S. Z., 2003 Estimation of growth parameters and age composition for yellowfin tuna, *Thunnus albacares*, in the Western Pacific using the length-based MULTIFAN method. SCTB16 Working Paper, Institute of Oceanography, National Taiwan University, Taipei, Taiwan.
Udupa K. S., 1986 Statistical method of estimating the size at first maturity in fishes. Fishbyte 4(2):8-10.
Zhu G., Xu L., Zhou Y., Song L., 2008 Reproductive biology of yellowfin tuna *T. albacares* in the west-central Indian Ocean. Journal of Ocean University of China (English Edition) 7:327-332.
Zhu G., Liuxiong X., Xiaojie D., Wei L., 2011 Growth and mortality rates of yellowfin tuna, *Thunnus albacares* (Perciformes: Scombridae), in the eastern and central Pacific Ocean. Zoologia 28(2):199–206.
*** IOTC, 2009 Report of the Eleventh Session of the IOTC Working Party on the Tropical Tuna. Mombasa, Kenya. FAO Working Party on Tropical Tuna (WPTT-R(E).
*** MMAF, 2015 Analysis of Marine and Fisheries Data 2015. Basic Data Analysis. Statistics and Information Data Center. Ministry of Marine Affairs and Fisheries Republic of Indonesia. http://statistik.kkp.go.id/sidatik-dev/Publikasi/src/analisisdatakkp2015.pdf

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