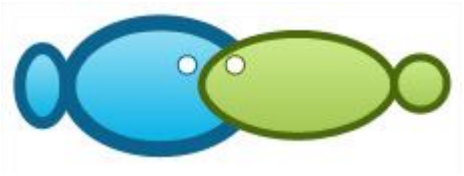

Growth and mortality parameters of yellowfin tuna (*Thunnus albacares*) in Palabuhanratu waters, west Java (eastern Indian Ocean)

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Abstract. Growth and mortality parameters were estimated for the yellowfin tuna (*Thunnus albacares* - Bonnaterre, 1788). A total of 2,906 individuals were sampled from the types of small scale commercial vessel units operating five fishing gears (troll line, hand line, floating line, vertical line and kite line) around fish aggregating devices (FADs) in the Palabuhanratu waters (eastern Indian Ocean) from April to December 2015. The aims of this study were to estimate the growth and mortality rate. The data were analyzed by using FiSAT II. The von Bertalanffy growth parameters were estimated at L_∞ = 178 cm fork length (cmFL), k= 0.47 year^{-1}, and t_0 = -0.213 year. The total mortality rate (Z) estimated was 1,27 year^{-1}, with the natural mortality rate (M) and fishing mortality rate (F) of 0.66 year^{-1} and 0.61 year^{-1} respectively. The exploitation rate (E) was estimated to be 0.48. This condition indicates that exploitation of the yellowfin tuna is still in good condition and it is necessary to manage the fishing pressure on the stock to prevent the probability of overfishing events.
Key Words: overfishing, tuna fishing, fishing management, commercial fishing.

Introduction. Fisheries resources are a common property where the exploitation can be used by more than one individual at the same time (open access). Tuna resource utilization from year to year tends to increase. While impact in long-term, will affect to the continuity of fish stock. Therefore, a management concept for controlling the sustainable yield is needed.

ISSF technical report (2012) states that global catches for tuna; albacore, bigeye, bluefin, yellowfin and skipjack in year 2010 amount to 4.34 million tons, decrease 4% from 2009. Tuna catches from 1950 tend to increase steadily since the early 2000s. Yellowfin and bigeye tuna stock in Indonesia waters is estimated in fully exploited condition and overfished in some areas (Langley et al 2009a; IOTC 2010; WCPFC 2010; Harley et al 2011).

The increase in catch production and the development of fishing effort has led to the decline of the size of resources. If the size were narrowed, the number of chance for tuna to spawn will be reduced, and this will inflict the recruitment of overfishing.

Management of fisheries resources should be based on the precautionary approach principle, for the protection of resources and environmental conservation. The implementation of the precautionary approach is an alternative to the provisions of United Nations Convention on the Law of the Sea (UNCLOS) in 1982 that requires the results of the best scientific evidence available for the management and conservation of fish resources.

The aims of this study are to estimate the growth and mortality rate of yellowfin tuna. These factors have an affect on population dynamics, thought to predict the pattern of population growth and as basic data in fisheries management.

Material and Method. Yellowfin tuna (*Thunnus albacares*) samples were collected monthly from April to December (2015) at major landing sites on the Palabuhanratu fishing port (Figure 1) in west Java from small scale commercial vessel units which operating five fishing gears (troll line, hand line, vertical line, vertical long line and kite line) around fish aggregating devices (FADs) in the Palabuhanratu waters (eastern Indian ocean) from April to December 2015. The length (fork length) has been measured by scientific operators thus taken into account all size groups caught.

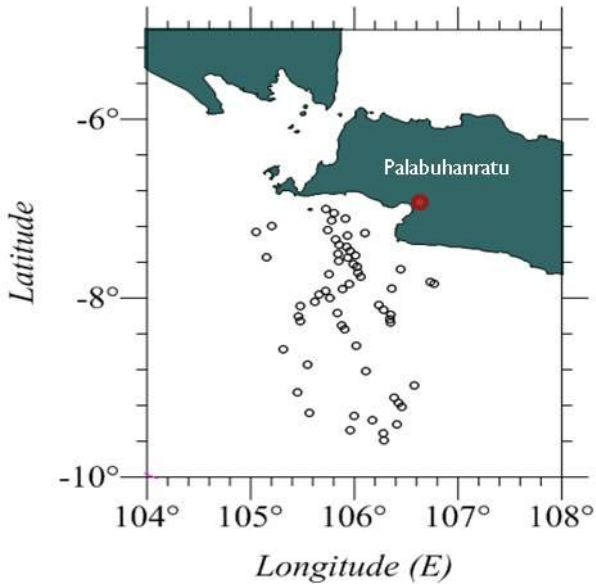

Figure 1. Palabuhanratu landing site, circle indicates the fishing ground (FADs).

Growth. Growth parameters (K) and length infinity (L∞) were estimated using the ELEFAN I module of FiSAT-II software (Gayanilo et al 2005). Estimation of the theoretical age parameter (t_0) was determined by empirical equation proposed by (Pauly 1983):

$$Log(-t_0) = -0.392 – 0.275LogL\infty - 1.038K$$

The age data was analyzed using the von Bertalanffy growth function:

$$Lt = L_\infty (1 – e^{-K(t-to)})$$

where:
Lt = length at age t (fork length)
L_∞ = asymptotic length
K = coefficient of growth
t_0 = theoretical age at zero length

Longevity or maximal age (t_{max}) of *T. albacares* was estimated using the equation proposed by Pauly (1984):

$$t_{max} = t_0 + 0\ 2.996 / k$$

The length based growth performance index (ϕ) using the equation proposed Pauly & Munro (1984):

$$\phi = Log\ K + 2 * Log\ L_\infty$$

Mortality and exploitation rate. The value of total mortality (Z) was obtained from length converted catch curve on FISAT II software (Gayanilo et al 2005), while natural mortality (M) was calculated by Pauly's empirical equation (Pauly 1983):

$$Log\ (M) = -0{,}0066 – 0{,}279\ Log\ L_\infty + 0{,}6543\ Log\ K + 0{,}4634\ Log\ T$$

Where:
T = the mean annual temperature (28 °C).
Fishing mortality (F) and exploitation rate (E) were calculated by Pauly's formula (Pauly 1983):

$$F = Z - M \text{ and } E = F/Z$$

Results and Discussion

Growth. The growth parameters estimated by ELEFAN I module FISAT-II and the performance index (ϕ) were as follow: L_∞ = 178 cm (fork length), k = 0.47 year^{-1}, t_0 = -0.213 and ϕ = 4.17 respectively. The value of L_∞ was higher than the maximum observed fork length of 160 cm. The goodness of fit index (Rn) was 0.273. (Figure 2).

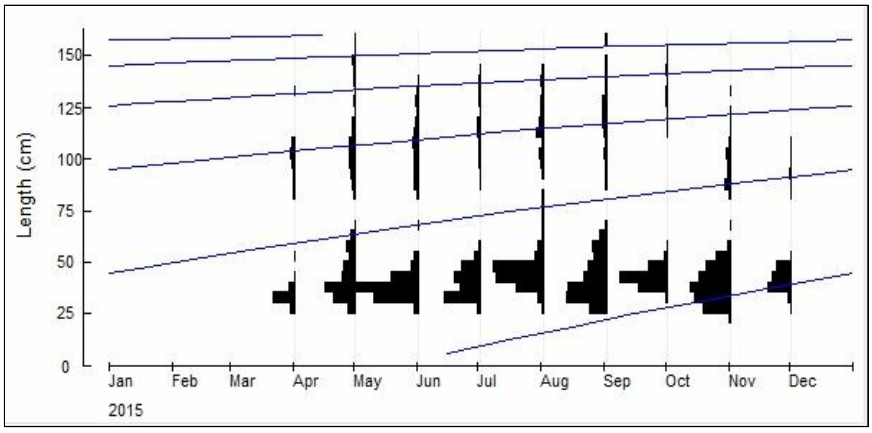

Figure 2. Von Bertalanffy growth plot of *Thunnus albacares* in Palabuhanratu waters, west Jawa, Indian Ocean.

The theoretical age at zero length (t_0) of the von Bertalanffy model was estimated at -0.213 year, with longevity (t_{max}) 6,2 year and the growth performance index (ϕ) of 4.17. The Von Bertalanffy growth equation was driven as: $Lt = 178*[1-EXP^{(-0.47*(t-(-0.21323))}]$. (Figure 3).

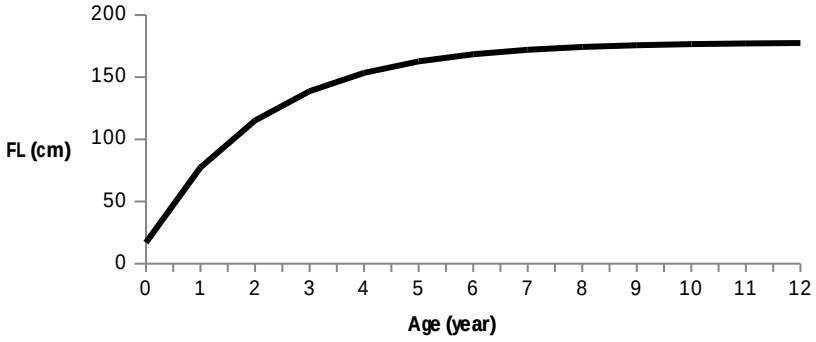

Figure 3. Estimated growth curve of *Thunnus albacares* exploited in Palabuhanratu waters west Jawa, Indian Ocean.

Yellowfin tuna is a pelagic and epipelagic fish, associated with floating objects (Gooding & Magnuson 1967; Hunter & Mitchell 1967), spread in the tropics and subtropics ocean waters (Collette & Nauen 1983). According to Langley et al (2009b) in Indian Ocean the sizes ranged of *T. albacares* caught from 30 to 180 cm (fork length). The maximum age of *T. albacares* is less than 10 years, reach sexual maturity at an early age (2-5 years) and can grow to a maximum size of 180-200 cm (ICCAT 2011, ISSF 2012, IOTC 2012).

The observation of growth parameters in this study showed that the *T. albacares* in Palabuhanratu has L_∞ = 178 cm FL, K = 0.47 year^{-1}, t_0 = -0.213 and ϕ = 4.17

respectively. The growth parameters in this study are close to the result from other sites where the asymptotic length (L_∞) ranged from 151 to 233 cm FL, growth rate (K) ranged from 0.3 to 0.88 per year, theoretical age at zero length ($t_{0)}$ ranged from -0.70 to 0.19 and growth performance index (ϕ) ranged from 4.0 to 4.21. In a document of the threatened species IUCN redlist on habitat and ecology in the Indian Ocean, *T. albacares* life stated at least 7 years (Romanov & Korotkova 1988). In this study the longevity (t_{max}) is 6.2 years close to the result from other sites ranged from 6.5 to 10.1 years (Table 1).

Table 1

Estimation of *Thunnus albacares* growth parameters reported from other sites

Data type	*K*	*L∞*	t_0	t_{max}	ϕ	*Location*	*Source*
LF	0.47	178.0	-0.213	6.2	4.17	Palabuhanratu waters	Present study
O	0.67	165.07	-0.489	-	-	Indian ocean	Emmanuelle et al (2015)
LF	0.45	183.3	-0.184	6.5	4.21	Oman sea	Kaymaram et al (2014)
LF	0.51	233	-0.184	-	-	Banda sea	Damora & Baihaqi (2013)
LF	0.33	192.5	-0.705	8.4	4.14	Makassar strait	Kantun & Amir (2013)
O	0.88	151.8	-0.446	-	-	Indian ocean	Dortel et al (2013)
LF	0.39	173.3	-0.099	7.6	4.07	Andaman & Nicobar waters	Kar et al (2012)
LF	0.30	197.42	-0.116	10.1	4.0	East cost of India	Rohit et al (2012)
LF	0.52	175.9	0.19	-	4.21	Eastern & central pacific ocean	Zhu et al (2011)

LF - length frequency, O - otolith.

The results showed that *T. albacares* growth rates (K) were slow, did not reach the value of one (Sparre & Venema 1998). These conditions provide a warning that the resources utilization should be precautionary approach for sustainable. In addition, the asymptotic length, the growth rate as well as the age at which the change in growth occurs depend on environmental conditions, food availability and the intrinsic characteristics of fish, which likely to vary from one fish to another (Emmanuelle et al 2015; Sparre & Venema 1998). The differences in growth parameters can also caused by the time differences, size composition of the fish, fishing methods, fishing gear and fishing areas.

Mortality and exploitation rate. Natural mortality (M) was calculated at 0.66 $year^{-1}$ and fishing mortality (F) at 0.61 $year^{-1}$. Taking Z= 1.27 into account, an exploitation level (E) of 0.48 $year^{-1}$ was obtained for *T. albacares* in the Palabuhanratu waters (Figure 4), which seem to be lower than the expected optimum level of exploitation (E = 0.50). The reliability of the estimated M was ascertained using the M/K ratio because this ratio reported to be within the range of 1.12-2.50 for most species (Beverton & Holt 1957, in Zhu et al 2011). The value of M/K ratio in this study was 1.22.

Comparison of mortality and exploitation rates from several studies in other sites with varying values is indicated in Table 2. The estimation of natural mortality (M) ranged from 0.48 to 0.68 $year^{-1}$, fishing mortality (F) ranged from 0.23 to 1.79 $year^{-1}$, total mortality (Z) ranged from 0.71 to 2.40 $year^{-1}$ and an exploitation level (E) ranged from 0.32 to 0.77 $year^{-1}$.

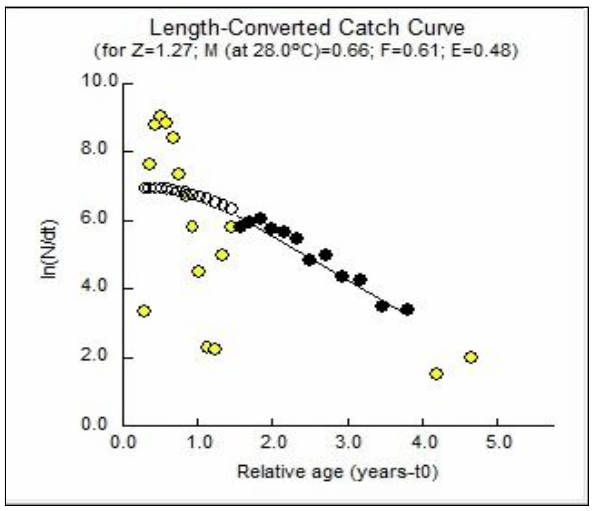

Figure 4. Length-converted catch curve of Thunnus albacares in Palabuhanratu waters, west Jawa, Indian Ocean.

Table 2

Estimation of mortality and exploitation reported from other sites

M	*F*	*Z*	*E*	*Location*	*Sources*
0.66	0.61	1.27	0.48	Palabuhanratu	Present study
0.48	1.56	2.04	0.76	Oman sea	Kaymaram et al (2014)
0.68	1.79	2.40	0.74	Banda sea	Damora & Baihaqi (2013)
0.55	1.69	2.21	0.77	Makassar passage	Kantun & Amir (2013)
0.48	0.23	0.71	0.32	East Cost of India	Rohit et al (2012)
0.65	0.91	1.56	0.46	Eastern & Central Pacific Ocean	Zhu et al (2011)

In general, the results showed that the value of natural mortality (M) was higher than the fishing mortality (F) and the exploitation rate (E) less than 0.5 (0.48 year^{-1}), this indicates that the exploitation rate in this area is still in good condition and sustainable. Gulland (1971) and Pauly (1983) suggested that in a stock with optimum exploitation when fishing mortality is equal to natural mortality (F = M), where the highest value of exploitation rate (E) at 0.5. The differences of exploitation rate in any sites due to different levels of fishing effort. The high value of exploitation rate (above 0.5) indicates that there has over exploited.

According IOTC (2015), the *T. albacares* stock in Indian Ocean is determined to be overfished and subjected to overfishing. The low level of biomass stock in 2014 is consistent with the long-term decline in the primary stock abundance indices and recent trends are attributable to increase of catch levels. Total catch has continued to increase assessment to be more pessimistic where in 2012 assessment due to the increase in catches and the changes in assessment assumptions regarding the recruitment processes.

Further more according to the IOTC (2015), the substantial increase in longline, gillnet, handline and purse seine effort and associated catches in recent years has substantially increased the pressure on the Indian Ocean stock as a whole, with recent fishing mortality exceeding the MSY-related levels. The current assessment estimates that the biomass stock is below the level that will support the MSY and current levels of catch.

The recruitment overfishing caused by the increase of fishing pressure upon undersize fish (juvenile) led to the decline of the size of resources. If the size were narrowed, the number of chance for tuna to spawn will be reduced. This condition needs a correct management concept for controlling the yield. Fisheries are supposed to be managed for sustainability. Therefore controls are needed to maintenance the sustainable

fisheries resources for future. Research and data collection are important to provide the necessary base on knowledge.

Conclusions. The results of the present study show that the growth parameters (L_∞, k, t_0) and the performance index (ϕ) were as follow: L_∞ = 178 cm (fork length), k = 0.47 $year^{-1}$, t_0 = -0.213 and ϕ = 4.17 respectively. Natural mortality (M) was calculated at 0.66 $year^{-1}$, fishing mortality (F) at 0.61 $year^{-1}$, Z= 1.27 $year^{-1}$ with exploitation level (E) of 0.48 $year^{-1}$. These data indicates that the *T. albacares* exploitation in this area is still in good condition.

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