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ESTIMATION OF YELLOWFIN TUNA PRODUCTION LANDED IN BENOA PORT WITH WEIGHT-WEIGHT, LENGTH-WEIGHT RELATIONSHIPS AND CONDITION FACTOR APPROACHES

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ABSTRACT

Yellowfin tuna (*Thunnus albacares*) is one of the important catch for the fishing industry in Indonesia. Length-weight relationship study is one of important tools to support fisheries management. However it could not be done to yellowfin tuna landed in Benoa port since they are in the form of gilled-gutted condition. The objectives of this study are to determine the relationship between gilled-gutted weight (*GW*) and whole weight (*WW*), to calculate length weight relationship between fork length (*FL*) and estimated whole weight (*WW*) and to assess the relative condition factor (K_n) of yellowfin tuna in Eastern Indian Ocean. Data were collected from three landing sites *i.e.* Malang, East Java; Benoa, Bali and Kupang, East Nusa Tenggara from January 2013 to February 2014. Linear regression analysis applied to test the significance baseline between weight-weight relationships and log transformed length weight relationship. Relative condition factor (K_n) used to identify fish condition among length groups and months. The results showed a significant positive linear relationships between whole weight (*WW*) and gilled-gutted weight (*GW*) of *T. albacares* ($p<0.001$). There was a significant positive linier relationships between log transformed fork length and log transformed whole weight of *T. albacares* ($p<0.001$). Relative condition factor (K_n) showed declining pattern along with length increase and varied among months. The findings from this study provide data for management of yellowfin tuna stock and population.

Keywords: **Weight-weight relationships; length-weight relationships; condition factor; yellowfin tuna; Eastern Indian Ocean**

INTRODUCTION

Tuna is one of important export commodity in Indonesia with total production reaches 1.352.802 tons from 2005 to 2012. Yellowfin tuna is the highest percentage with 72% from total big tuna group production, followed by bigeye tuna (21%), albacore (6%) and southern bluefin tuna (1%) (DGCF, 2015). Yellowfin tuna (*Thunnus albacares*) is highly migratory species with distribution in trophic and temperate water. This species can be found in Atlantic, Hindian and Pacific Ocean (Collette & Nauen, 1983). In Indonesia, the distribution of this species spreading from west and south Sumatera; south of Java, Bali and Nusa Tenggara; Banda and Sulawesi Sea; and west of Papuan waters (Uktolseja *et al.*, 1991).

Length-weight relationship study is one of an important tool to support fisheries management. This information can estimate the average weight from known fish length which can then be used to estimate the biomass of fish population (Froese, 2006). Furthermore, length-weight relationships and condition factor studies were applied to support stock assessment of population (Ricker, 1979) and also valuable to understand the life history including reproduction aspect and general health of the species (Pauly, 1993).

One of the important tuna landing site in Indonesia is located in Benoaport, Bali. Different with albacore that landed in whole condition in this port, three other species of tuna were processed onboard (removing gill and stomach content) and landed in gilled-gutted condition. This process performed to maintain the quality of the fish for export destination. However, this procedure affects the loss of fish weight due to gill and gutted removal. The objectives of this study are

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to determine the weight-weight relationship between gilled-gutted weight (GW) and whole weight (WW), to calculate length weight relationship between fork length (FL) and whole weight (WW) and to assess the relative condition factor(K_n) of yellowfin tuna in Eastern Indian Ocean. The finding of this study be able to become data base for the estimation of yellowfin tuna production. Moreover, the results from this study can be used to determine the quota for yellowfin tuna in the Regional Fisheries Management Organization (RFMO).

MATERIALS AND METHODS

Data Collection

Yellowfin tuna data were collected from three landing sites i.e. Malang, East Java; Benoa, Bali and Kupang, East Nusa Tenggara (Figure 1). For weight-weight relationships study, the fish samples gained from August 2013 to February 2014 in Malang, East Java and Kupang, East Nusa Tenggara. The fork length (FL) of fish was measured (±1 cm), weighing whole weight (WW) and gilled-gutted weight (± 0.01 kg) with a digital balance. The yellowfin tuna from these sites were caught by handline fishing. For length-weight relationships and condition factor study, other fish samples were measured monthly by enumerator from January to December 2013 in Benoa, Bali. The fork length (FL) of fish was measured (±1 cm), weighing gilled-gutted weight (± 1 kg) with a regular balance. The yellowfin tuna from this site was caught by longline fishing.

The first survey conducted from August 2013 to February 2014 collected 79 samples with fork length ranged 26-68 cm, whole weight (WW) ranged 0.32-6.40 kg and gilled-gutted weight (GW) ranged 0.27-5.80 kg. The second survey covered a period of 12 consecutive months from January to December 2013. A total of 7,254 measured samples of *T. albacares* were examined with fork lengths (FL) ranging from 77 to 180 cm and gilled-gutted weight (GW) ranged 8-103 kg (Table 1).

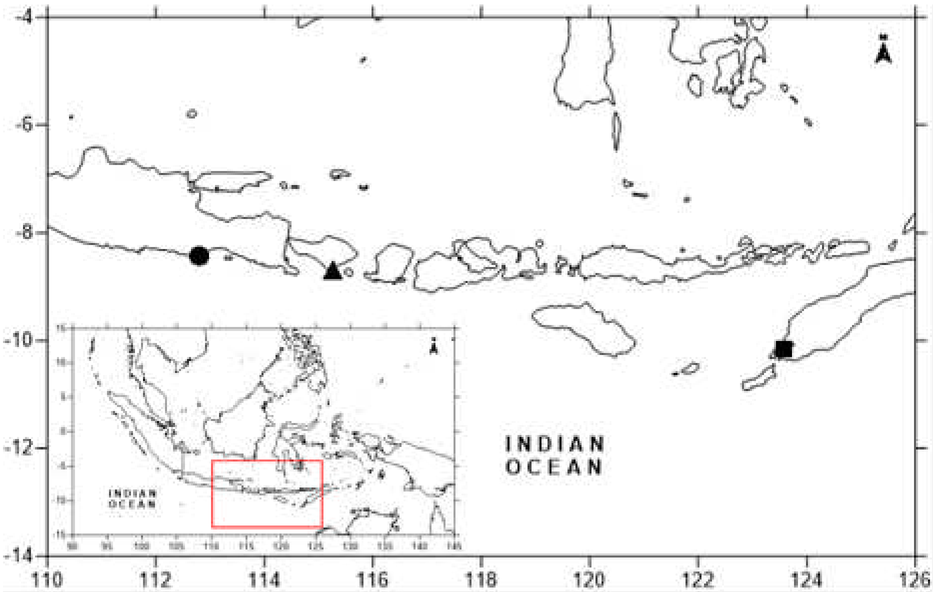

Figure 1. Sampling site in Malang, East Java (circular), Benoa, Bali (triangle) and Kupang, East Nusa Tenggara (square).

Table 1. The summary of descriptive statistics of *T. albacares* samples.

Survey	*N*	*Fork length (cm)*		*Whole weight (kg)*		*Gilled-gutted weight (kg)*	
		Range	*Mean ± SE*	*Range*	*Mean ± SE*	*Range*	*Mean ± SE*
I	79	26-68	41.73±1.05	0.32-6.40	1.51±0.11	0.27-5.80	1.33±0.10
II	7254	77-180	132.53±0.20	-	-	8-103	43.21±0.19

Data Analysis

Relationships between whole weight (WW) and gilled-gutted weight (GW) was analyzed using linear regression model $Y = a + b\,X$, where a is intercept and b is slope.Linear regression analysis performed to determine the amount of deviation in Y variable explained by X variable. Test for linear regression was conducted to examine the significance between two variables (Barnett, 2003). This relationship was used to convert from gilled-gutted weight data into estimated whole weight data to generate length-weight relationships.

The relationships between the length and estimated whole weight of a fish calculated using equation, $W = aL^b$. Where W is body weight (kg), L is fork length (cm), a is a coefficient related to body form and b is an exponent indicating fish growth (Ricker, 1979).

Log transformed length and log transformed weight were plotted in order to examine the significance between these two variables. Values of the exponent b provide information on fish growth. When b=3, increase in weight is isometric. When the value of b is other than 3, weight increase is allometric, (positive allometric if b>3, negative allometric if b<3). The null hypothesis of the isometric growth (H_0: b=3) was tested using t-test (Morey *et al.*, 2003).

To detect seasonal variations in the condition of the fish, relative condition factors *(K_n)* were calculated from monthly samples. The conditional factors can be calculated by comparing the mean weight of fish in a sample with the predicted weight of fish from a generalized length-weight relationship using equation (King, 2007):

$$Kn = \frac{W_m}{W_p}$$

Where:

K_n = relative condition factor
W_m = monthly of mean weight
W_p = general predicted weight of fish from the same mean length

RESULTS AND DISCUSSION

Results

Whole Weight (WW) and Gilled-gutted Weight (GW) Relationship

There was a significant positive linear relationships between whole weight (WW) and gilled-gutted weight (GW) of *T. albacares* ($F_{1,77}$ = 80,383.60, p< 0.001, R^2 = 0.999). As gilled-gutted weight increases, the whole weight of *T. albacares* increases. Gilled-gutted weight explained 99% variation in the whole weight of *T. albacares* with equation WW = 1.1167 GW + 0.0266 (Figure 2).

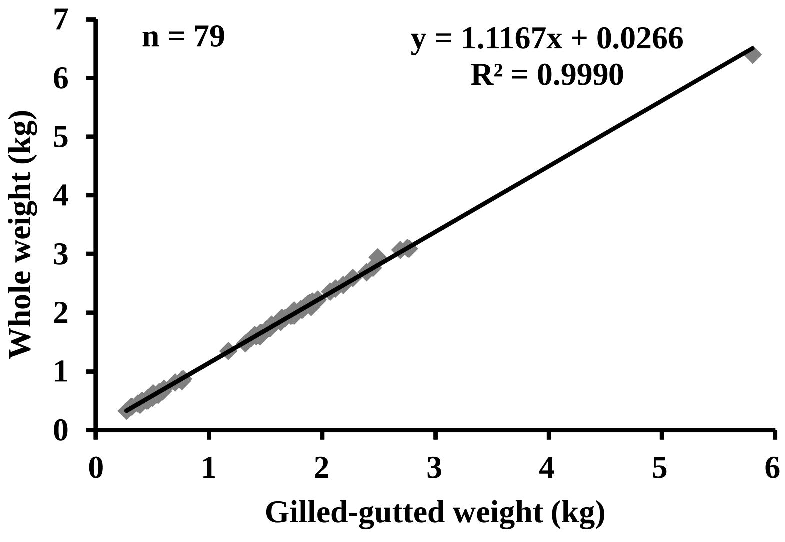

Figure 2. Weight-weight relationships between gilled-gutted weight (GW) and whole weight (WW) of *T. albacares* in Eastern Indian Ocean.

Length and Estimated Whole Weight (WW) Relationship

Monthly descriptive statistics and estimated parameters of length-weight relationships for *T. albacares* were shown in Table 1. Growth pattern of *T. albacares* showed that positive allometric growth occurred in January, March, April, October and December. Whereas the isometric growth appeared in February, May, June, July, August, September and November. Overall, the growth pattern of *T. albacares* in Eastern Indian Ocean is isometric (Table 2).

Length-weight analysis showed the equation W = 0.00002 $L^{3.0294}$ with coefficient determination (R^2) 0.9635. Fork length explained 96% variation in the weight of *T. albacares* (Figure 3).

Table 2. Monthly growth pattern of yellowfin tuna caught in Indian Ocean southern of Java, Bali and Nusa Tenggara

Month	*N*	*Fork length (cm)*		*Whole weight (kg)*		*Parameters*			*Growth pattern*
		Range	*Mean±SE*	*Range*	*Mean±SE*	*a*	*b*	*R^2*	
Jan	672	79-176	127.29±0.74	10-106	44.88±0.76	0.00001	3.0892	0.9774	Positive allometric
Feb	336	77-165	124.06±0.94	10-90	39.78±0.94	0.00002	3.0295	0.9605	Isometric
Mar	292	85-165	125.85±0.96	12-98	41.41±1.04	0.00001	3.1056	0.9642	Positive allometric
Apr	462	87-171	126.77±0.73	15-103	42.33±0.79	0.00001	3.1221	0.9545	Positive allometric
May	980	89-174	136.21±0.50	12-95	51.57±0.55	0.00002	3.0459	0.9696	Isometric
Jun	958	91-171	134.95±0.52	17-93	50.11±0.57	0.00002	3.0261	0.9614	Isometric
Jul	1337	81-172	136.13±0.46	11-90	50.95±0.47	0.00002	2.9555	0.9469	Isometric
Aug	257	94-162	133.42±0.89	13-86	46.27±0.89	0.00002	2.9565	0.9576	Isometric
Sep	328	81-165	128.67±0.73	10-88	43.98±0.74	0.00002	2.9985	0.9389	Isometric
Oct	369	80-180	129.98±1.05	9-115	48.14±1.08	0.000009	3.1779	0.9664	Positive allometric
Nov	600	80-169	133.63±0.82	10-102	50.41±0.81	0.00002	3.0217	0.9793	Isometric
Dec	663	85-173	134.88±0.62	11-105	51.38±0.66	0.00001	3.0700	0.9693	Positive allometric
All	7254	77-180	132.53±0.20	9-115	48.30±0.21	0.00002	3.0294	0.9635	Isometric

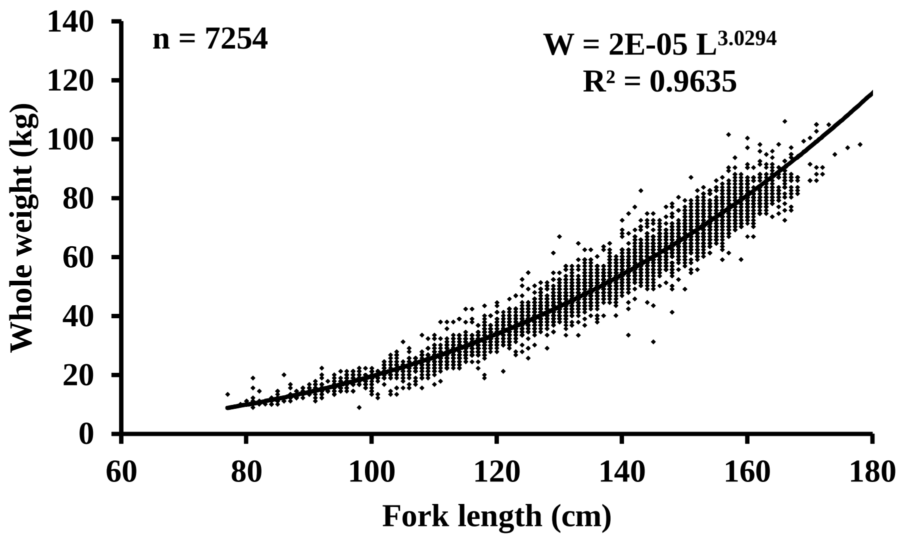

Figure 3. Length-weight relationships between fork length (FL) and whole weight (WW) of *T. albacares* in Eastern Indian Ocean. Whole weight data were estimated from weight-weight relationship.

Relative Condition Factor (K_n)

The relative condition factor (K_n) has been calculated for each 5 cm length groups. Generally, the relative condition factor (K_n) decreased along with the increasing of fork length. The highest value with 1.04 occurred at length group 80 cm then decreased significantly up to 0.83 at length group 110 cm. There has been slightly increased at length group 115 cm and tend to steady until length group 160 cm then decline drastically to 0.75 at length group 180 cm (Figure 4).

Monthly relative condition factor (K_n) of *T. albacares* showed fluctuated during the year. The highest relative condition factor (K_n) occurred in March with 0.89 and the lowest appeared in August with 0.82 (Figure 5).

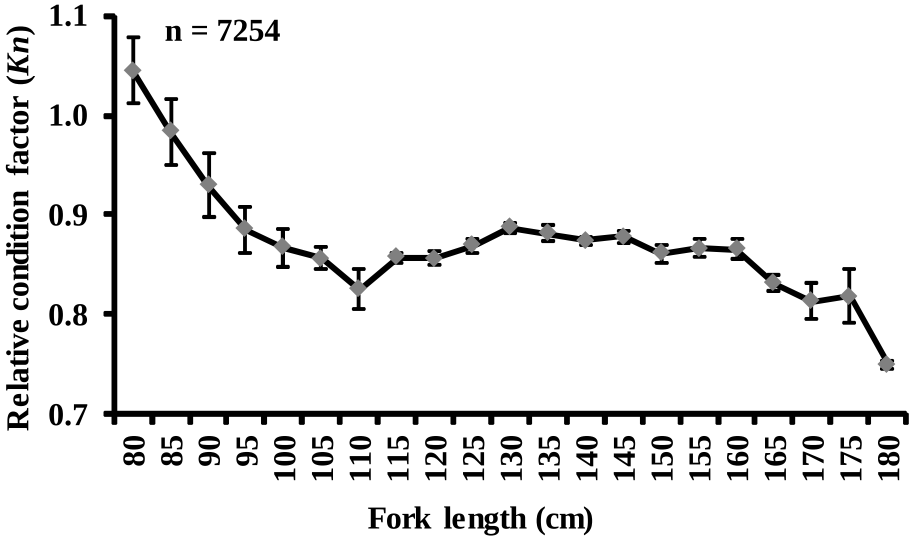

Figure 4. Variation of relative condition factors (mean±SE) of *T. albacares* in Eastern Indian Ocean. Values on fork length are the upper limit of 5 cm length groups.

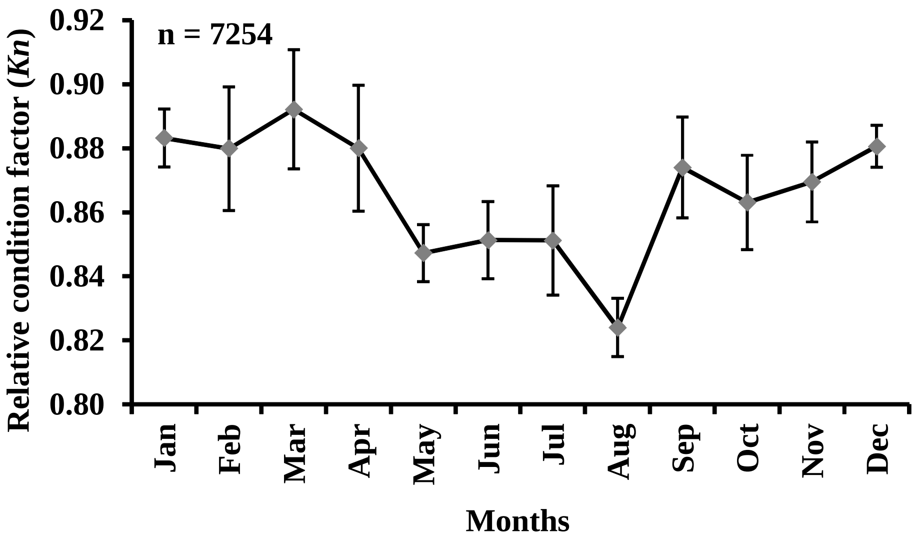

Figure 5. Monthly relative condition factors (mean±SE) of *T. albacares* in Eastern Indian Ocean.

Discussion

Weight-weight relationships and length-weight relationships studies are important for fisheries management, for example in calculating yield and biomass (King, 2007). However, processing fish on board had consequences in the loss weight of the fish. This study showed that additional weight of *T. albacares* landed in Benoa port ranged from 1.2 kg at length class 80 cm to 10.2 kg at length class 180 cm. The additional weight increased along with the increase of length. The increasing length of fish leads the greater on the weight of the fish.

Length-weight relationship showed that *a* value (*intercept*) is less influential than *b* value (*slope*) to the equation because its value is very small (Table 3). The *a* value in this study is 0.00002, relatively similar to other studies except in Indian Ocean, Sri Lanka waters with *a* value is 0.033 (Perera *et al.*, 2013). The *b* value in this study is 3.029 higher than other studies except in Pacific Ocean with *b* value is 3.244 (Zhu *et al.*, 2010). After *t*-test analysis the result showed that this value is not significantly different (*b*=3), ensuing that growth pattern of *T. albacares* is isometric. It means that growth occurred at the same rate for length and weight of the fish so that its shape is consistent throughout development or in the same dimension as the cube of length (Pauly, 1984). This growth pattern is different with other studies in Atlantic and Indian Ocean where the growth pattern is negative allometric and in Pacific Ocean where the growth pattern is positive allometric (Zhu *et al.*, 2010). The variability of growth pattern of fish can be depend on the food availability, season and environmental conditions (Froese, 2006; Effendie, 2002) and the swimming activity of the fish (Muchlisin *et al.*, 2010).

Table 3. Estimated parameters of length-weight relationships for *T. albacares* from various studies.

Location	*a*	*b*	R^2	Growth pattern	Reference
Pacific Ocean, Taiwan	0.00004	2.854	-	-	Wang *et al.* , 2002
Pacific Ocean, Hawaii	0.00003	2.889	0.975	-	Uchiyama & Kazama, 2003
Atlantic Ocean	0.00002	2.969	0.941	Negative allometric	Zhu *et al.* , 2010
Indian Ocean	0.00002	2.985	0.969	Negative allometric	Zhu *et al.* , 2010
Pacific Ocean	0.000004	3.244	0.945	Positive allometric	Zhu *et al.* , 2010
Indian Ocean, Sri Lanka	0.033	2.848	0.918	-	Perera *et al.* , 2013
Indian Ocean, Indonesia	0.00002	3.029	0.964	Isometric	Present study

Condition factor (K_n) was used to identify the condition of the fish. Study on salmonid fish showed that the higher K_n value showed fish in good condition. On the contrary, the lower K_n value showed poor condition (Barnham & Baxter, 1998). The similar results occured in this study.The relative condition factor (K_n) of *T. albacares* showed high value for small fish and decreased along with the development of fish length. There was steep declining of relative condition factor (K_n) when fish reach 106-110 cm to 0.83. This decreased probably related with the reproduction strategies of yellowfin tuna which reach their length at 50% maturity (L_{50}) at 102 cm (Zudaire *et al.*, 2013), 105 cm (Itano, 2000), 105 cm for male and 110 cm for female (Nootmorn *et al.*, 2005) and 110-115 (Hassani & Stequert, 1991).

Monthly relative condition factor (K_n) showed high value from September to April with the highest value occurred in March with 0.89. On the other hand, it showed low value from May to August with the lowest value happened in August with 0.82. It means that the index of well-being of the fish from September to April was better than the condition of the fish from May to August. The variability of relative condition factor (K_n) among months allegedly due to seasonal variations which may vary with food availability and dietary habit (King, 2007; Saha *et al.*, 2009).

Moreover, monthly condition factor also influenced by environmental condition (Froese, 2006; Effendie, 2002). Indian Ocean waters has distinctive characteristics that its environmental condition had influence from Indian Ocean Dipole-zonal Mode/IODM (Li *et al.*, 2003), El Nino Southern Oscillation/ENSO (Reason *et al.*, 2000) and monsoon (Yang *et al.*, 2007). Monsoon can be categorized into four segments, which are west monsoon (Dec-Feb), transitional season I (Mar-May), east monsoon (Jun-Aug) and transitional season II (Sep-Nov). Monthly condition factor showed that well-being index of yellowfin tuna is better in west monsoon and transitional II. It was allegedly as this season occurred healthy of water fertility that have a positive impact on the availability of abundant food resources (Realino *et al.*, 2010).

CONCLUSION

The strong positive linear relationship between whole weight and gilled-gutted weight resulted from this study indicated that the total weight of yellowfin tuna that landed in Benoa Port can be estimated from gilled-gutted weight (processed weight). Therefore, this finding can be used to determine the quota for yellowfin tuna in Regional Fisheries Management Organizations (RFMO's). The growth in weight and length of yellowfin tuna is proportional to each other with its relative condition factor tend to decrease along with the increasing of length.

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