Size composition and length-weight relationships of the Yellowfin Tuna (*Thunnus albacares*) in Bone Bay

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Abstract. The size composition, length-weight relationship, and condition factor of Thunnus albacares were examined in Bone Bay. Sampling was conducted at two stations, i.e., Station I at Cimpu in Luwu Regency and Station II at Lonrae in Bone Regency between July 2018 and June 2019. 10246 and 2651 yellowfin tunas were captured in Station I and Station II, respectively. Measurement of the fork length ranged between 20 cm and 192 cm with an average length of $81,257 \pm 33,456$ cm in Station I, and between 26 to 162 cm with an average length of 95,479 cm in Station II. The weight measurement ranged between 0,35 and 99,21 kg with an average of 14,539 kg in Station I, and between 0,46 and 97,35 kg with an average of 26,978 kg in Station II. Calculation of the relationship was based on the formula $W= 5,5^{-5}FL^{2,7454}$ ($R^2 = 0,963$) in Station I, and $W=4,1^{-5}FL^{2,9103}$ ($R^2 = 0,761$) in Station II. The values of condition factor at Station I and Station II were 2,1395 and 3,4374, respectively. It is quite evident that the growth pattern of the yellowfin tunas at Bone Bay was negatively allometric, indicating that the length increased faster than the weight.

1 Introduction

Yellowfin tuna (*Thunnus albacares*) is of utmost economic importance and extensive international trade in several countries, and, hence, one of the most frequently caught of any fish species in several countries. Yellowfin tuna is ubiquitous across the Indian Ocean, the Pacific Ocean and Atlantic Ocean. Its spatial distribution in Indonesia includes the bodies of water in the Indian Ocean (West Sumatera, southern part of Java, Bali and Nusa Tenggara), Makassar Strait, Bone Bay, Flores Sea, Tomini Bay, Sulawesi Sea, Arafura Sea, Banda Sea, the waters around Maluku and Pacific Ocean [1].

Indonesian waters within the tropical regions are favorable zones for tuna fishing[2] . Fisheries Management Area of the Republic of Indonesia (Wilayah Pengelolaan Perikanan Negara Republik Indonesia or WPPN RI) for the fishing grounds of yellowfin tuna consists of Makassar Strait, Bone Bay, and Flores Sea. Bone Bay is set administratively in the regions of South Sulawesi and Southeast Sulawesi that stretches from south to north.

Modern fisheries have begun keeping serious track of the utilization of yellowfin tuna resources in the waters of Bay Bone for decades. One of the fishermen was interviewed in

the research site at Cimpu Village of Luwu Regency (Uwwa Indo), who was known to engage in fishing operations of tuna using handline fishing since he was 15 years old. Catch tendencies and levels of yellowfin tuna in the waters of Bay Bone have generally fluctuated in the recent years. The use of Fish Aggregation Devices (FDAs) in pole and line, handline, and purse seine fisheries are common among the local fishing communities to make yellowfin tuna more accessible to fishing boats.

The length-weight relationship of fish is a critical measurement in describing the key biological aspects of fish stocks which settles down to a mathematical model to conduct growth pattern analysis that estimates the weight of the observed species on the basis of length measurement and vice versa[3]. Carrying out empirical length-weight analysis serves several purposes, i.e., to allow conversion of the growth-in-length equation to growth-in-weight equation, to estimate biomass based on the distribution of fish length-frequency distributions, to evaluate fish condition factors, and to show comparisons of life histories and morphological features of similar species in different locations [3]. The information of the length-weight relationship that represents important biological attributes of a species is key to the fishery resource management [4]. Growth may vary according to energy availability after other functions are maximized. Energy availability is subject to spatial and temporal changes depending on the environmental condition and food availability.[5]

A number of biometric relationships for tuna species have been extensively found in a wide body of studies to predict the conditions of fishery resources in a given geographical area for the purpose of either temporary or continual monitoring. For that purpose, the compiled data for this study represents Bone Bay-wide effort to pool length-weight data of yellowfin tuna (*T. albacares)*.

2 Material and Method

2.1 Length-weight relationship

Length-weight relationships were based on the sampling of yellowfin tuna (*Thunnus albacares*) catch by the fishermen across the waters in Bone Bay from July 2018 to June 2019. The categories that the research site fit into were adjusted to a range of potential catch areas and landings of the observed species in the Bay. Sampling was conducted at two locations of fishing base i.e., Cimpu Village in Luwu Regency which represents species catch on the northern side of Bay Bone and Lonrae Village in Bone Regency which represents the southern part of the catch area. Length-weight measurements were obtained and recorded at the landing stations each fishing trip, normally every 6-8 days.

The empirical analysis of length-weight relationships fits into a cubic equation that holds the weight of a fish is usually closely proportional to the cube of its length [6] (Effendie, 2002), [7]i.e.:

$$W = \mathbf{aL^b} \tag{1}$$

or

$$\log W = \mathbf{\log a} + \mathbf{b \log L} \tag{2}$$

where:
W   = individual weight (gram)
L   = fork length (cm)
a   = intercept (the value at the intersection between the regression line and y-axis)
b   = regression coefficient (the slope of the fitted line)

The equation was calculated to express the growth pattern of the yellowfin tuna population represented by the resulting b value.

The following criteria address the standard measure of the specific growth pattern of yellowfin tuna:

1. b = 3 indicates an isometric pattern of growth, that is, the length increase equals the weight gain.
2. b > 3 indicates positive allometric growth, where the weight gain is faster than the length increment.
3. b < 3 indicates negative allometric growth, where length increase is faster than added weight.

To measure the observed b value from 3, the t-test was run with a corresponding confidence interval of 95% [8].

2.2 Condition Factor

The variation in the factor condition of yellowfin tuna caught in the waters of Bone Bay with respect to monthly sample grouping was calculated using the relative condition (Kn). The calculation of factor condition compares the average weight of monthly sampling with the predicted weight from length-weight relationship using the following equation [9] :

$$Kn = \frac{Wm}{Wp} \qquad (3)$$

Where
Kn   = condition factor
Wm   = the average monthly weight
Wp   = the general weight prediction from the average length

3 Result and Discussion

3.1 Result

Samples were taken and recorded from July to December 2018 and March to June 2019. Sampling was not conducted between January and February as no fishing operations were carried out during the peak of western monsoon. At Station II, samples were collected from June to November 2018 and February to June 2019. Sampling did not proceed from December 2018 to January 2019 given the impact of western monsoon.

The characteristics of the recorded samples are presented in Table 1. The recorded samples were 10.258 and 2.651 individuals of yellowfin tuna at Station I and Station II, respectively. The abundance of the samples was at its peak in September 2018.

The average fork length of the samples at Station I ranged between 64,45 cm and 116.54 cm. The relatively minimum size of fork length of the fish was captured in August 2018, and the maximum was captured in March 2019. At Station II, the average fork length ranged between 80.04 cm and 108,03 cm, with the minimum length captured in July 2018 and the maximum captured in November 2018.

Table 1 is also indicative of the range of the sample weight at both Stations, i.e., 7.00 kg – 31,23 kg at Station I and 11.40 kg – 37.15 kg at Station II. At Station, I, the lowest and the highest weight were captured in August 2018 and June 2019, respectively. At Station II, the lowest and the highest weight was captured in September 2018 and June 2019, respectively.

No	M	Number of Samples	Mean Length	Maximum Fork Length	Minimum Fork Length	Mean Weight	Maximum Weight	Minimum Weight
1	J	142	69.79	179	38.8	8.25	83.00	1.31

2	A	1554	64.45	170	35.0	7.00	90.23	1.01
3	S	2722	70.24	167.	37	8.70	90.67	1.00
4	O	1184	71.18	161	20	10.03	85.72	0.35
5	N	1070	74.46	165	26	10.5	81.11	0,46
6	D	486	77,86	186	29	12.77	81,91	0,5
7	J	-	-	-	-	-	-	-
8	F	-	-	-	-	-	-	-
9	M	647	116.54	153	81	29.15	70,23	9.09
10	A	375	78.39	174	24	18.15	85.89	0,46
11	M	988	101.70	188.00	24	24.20	99.21	0.46
1 2	J	1090	113.86	192.00	61	31.23	95.40	3.15
Total		10258						

Table 1a. The Characteristics of the Identified Yellowfin Tuna (*Thunnus albacares*) (Luwu)

Table 2b. The Characteristics of the Identified Yellowfin Tuna (*Thunnus albacares*) (Bone)

No	M	Number of Samples	Mean Length	Maximum Fork Length	Minimum Fork Length	Mean Weight	Maximum Weight	Minimum Weight
1	J	166	80.04	153	26	13.28	68	0.46
2	A	157	97.17	159	82	15.79	10	15.79
3	S	145	80.10	125	45	11.40	35	0.98
4	O	178	106.88	160	89	22.71	73	11
5	N	132	108.03	162	92	23.22	85	14
6	D	-	-	-	-	-	-	-
7	J	-	-	-	-	-	-	-
8	F	51	83.20	115	83.2	27.64	54.69	13.67
9	M	238	81.59	135	63	23.44	68.64	8.80
10	A	395	96.83	144	49	30.53	89.87	8,36
11	M	817	96.67	150	64	30.87	150	8,69
1 2	J	372	104.35	155	72	37.15	93.06	10.03
Total		5302						

The result of the length-weight relationship analysis of yellowfin tuna captured in the waters of Bay Bone can be observed using the equation $W = aL^b$ at both Stations. At Station I, the resulting parameter a = 0,000055, b = 2.7454 and coefficient of correlation or r^2 = 0.963. At Station II, the resulting a = 0,000041, b = 2.9103, and r^2 = 0.76. The regression graphs of the length-weight relationships are shown in Figure 1.
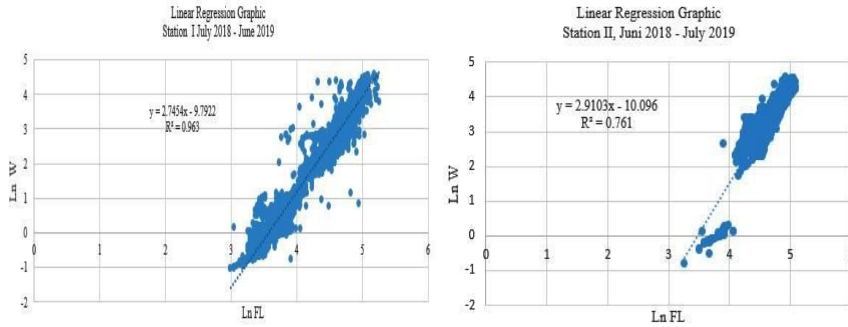
Fig. 1. Linear Regression Graphs of Yellowfin Tuna Captured in the Waters of Bone Bay

Table 1. Regression of the Length-Weight Relationships of Yellowfin Tuna at Both Stations from July 2018 to June 2019

Month	Length-Weight Relationship		Growth Pattern	
	Luwu	Bone	Luwu	Bone
July	$W=9,1305^{-05}FL^{2,6269}$ $(R^2=0,9799)$	$W=7,8342^{-06}FL^{3,1732}$ $(R^2=0,9828)$	Negative Allometric	Positive Allometric
August	$W=5,4533^{-05}FL^{2,7401}$ $(R^2=0,9523)$	$W=9,5021^{-06}FL^{3,1104}$ $(R^2=0,8633)$	Negative Allometric	Positive Allometric
September	$W=7,7758L^{2,6532}$ $(R^2=0,9446)$	$W=4,4660^{-06}FL^{3,3226}$ $(R^2=0,8633)$	Negative Allometric	Positive Allometric
October	$W=7,6538^{-05}FL^{2,6648}$ $(R^2=0,9728)$	$W=1,1829^{-05}FL^{2,9966}$ $(R^2=0,9716)$	Negative Allometric	Negative Allometric
November	$W=8,4758^{05}FL^{2,6514}$ $(R^2=0,9760)$	$W=1,7628^{-05}FL^{2,9996}$ $(R^2=0,9647)$	Negative Allometric	Negative Allometric
December	$W=2,2657^{-05}FL^{2,9647}$ $(R^2=0,9656)$	-	Negative Allometric	-
January	-	-		
February	-	$W=0,0008FL^{2,3453}$ $(R^2=0,9156)$		Negative Allometric
March	$W=1,2547^{-05}FL^{3,0722}$	$W=0,0012FL^{1.8313}$ $(R^2=0,0242)$	Positive Allometric	Negative Allometric
April	$W=0,00019FL^{2,4993}$ $(R^2=0,9514)$	$W=0,0014FL^{2,1772}$ $(R^2=0,8765)$	Negative Allometric	Negative Allometric
May	$W=5.7761^{-05}FL^{2,7464}$ $(R^2=0,9671)$	$W=3,8187^{-05}FL^{2,9605}$ $(R^2=0,9605)$	Negative Allometric	Negative Allometric
June	$W=2,3418^{-05}FL^{2,9458}$ $(R^2=0,9596$	$W=0,0001FL^{2,7057}$ $(R^2=0,9469)$	Negative Allometric	Negative Allometric
Total	$W=5.5885^{-05}FL^{2.7454}$	$W=4,1244^{05}FL^{2,9103}$		

The graphs of monthly length-weight relationships at both Stations are presented in Figure 2.
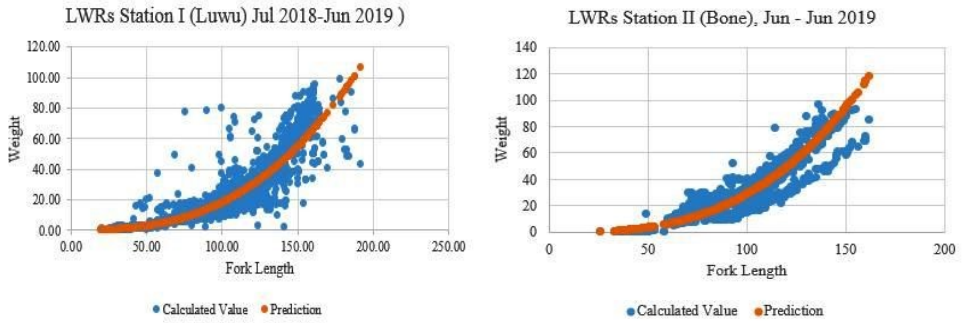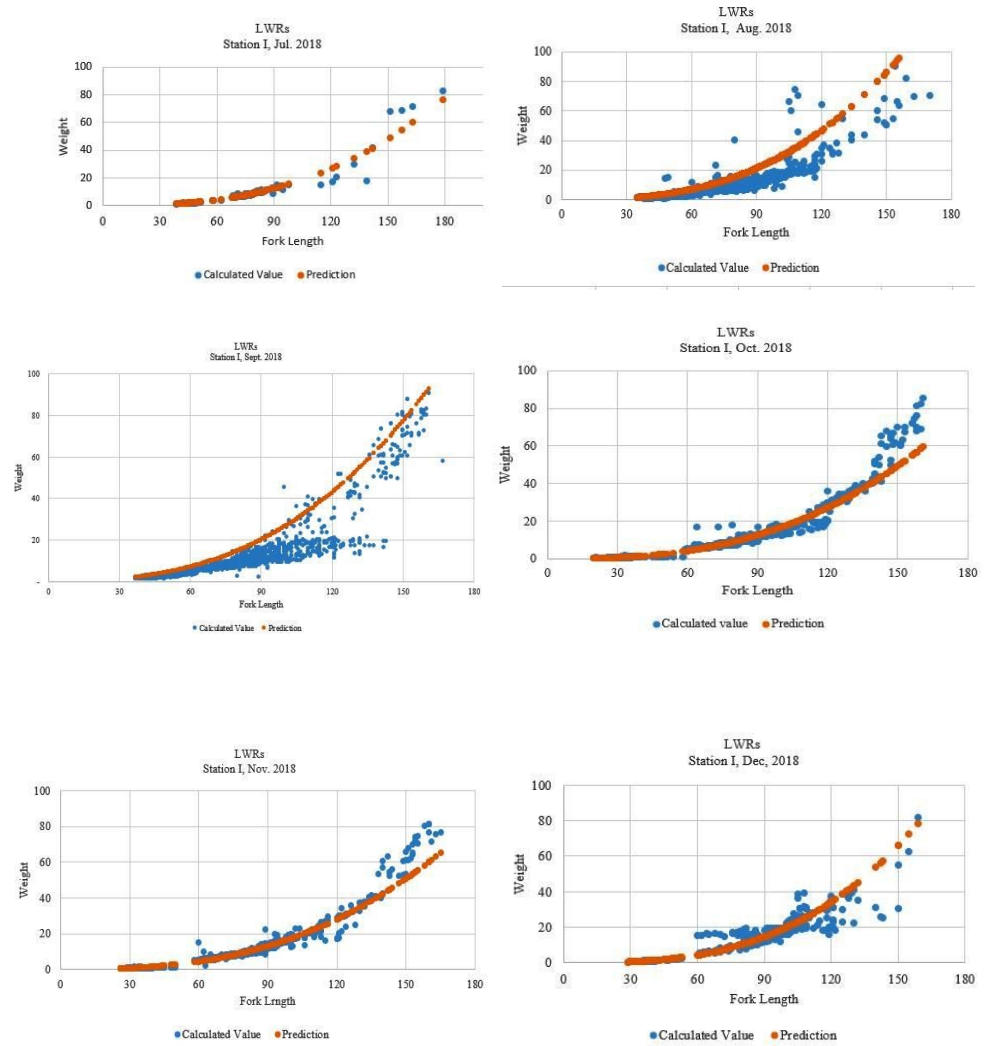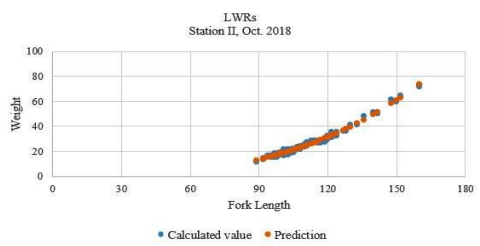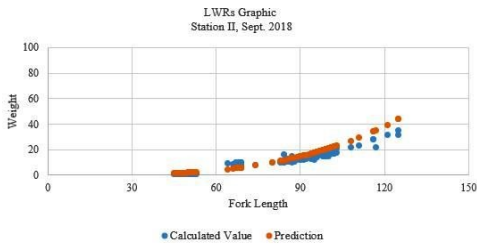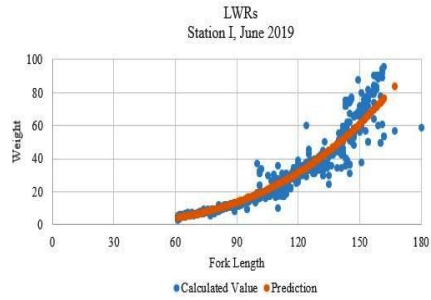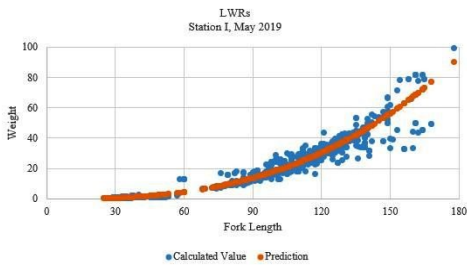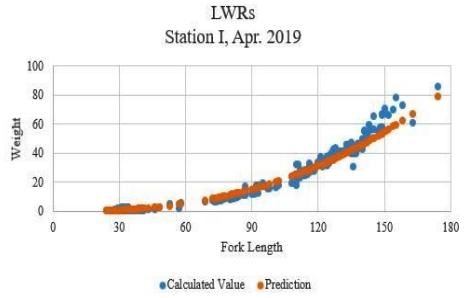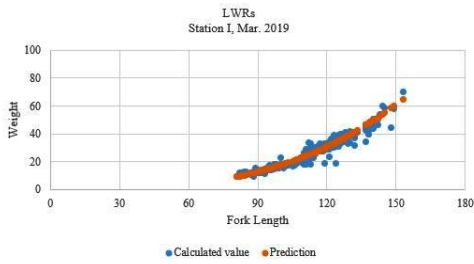
Fig. 2. The Overall Length-Weight Relationships of Yellowfin Tuna at Station I (Luwu) and Station II (Bone)

In figure 2, the length-weight measurements at Station II resulted in a uniform data in distinction to those at Station I. the length-weight relationships in terms of monthly grouping at both Stations are presented in Figure 3.
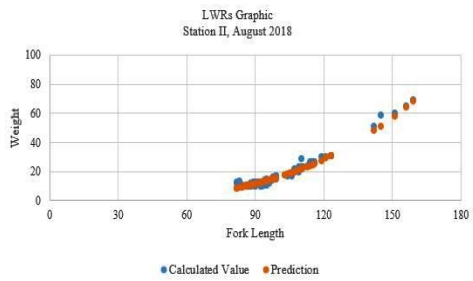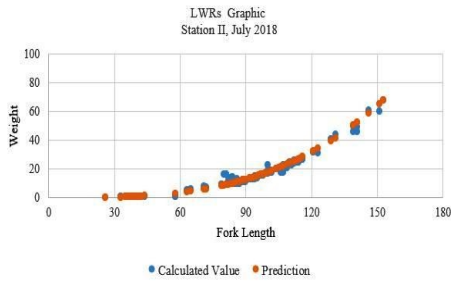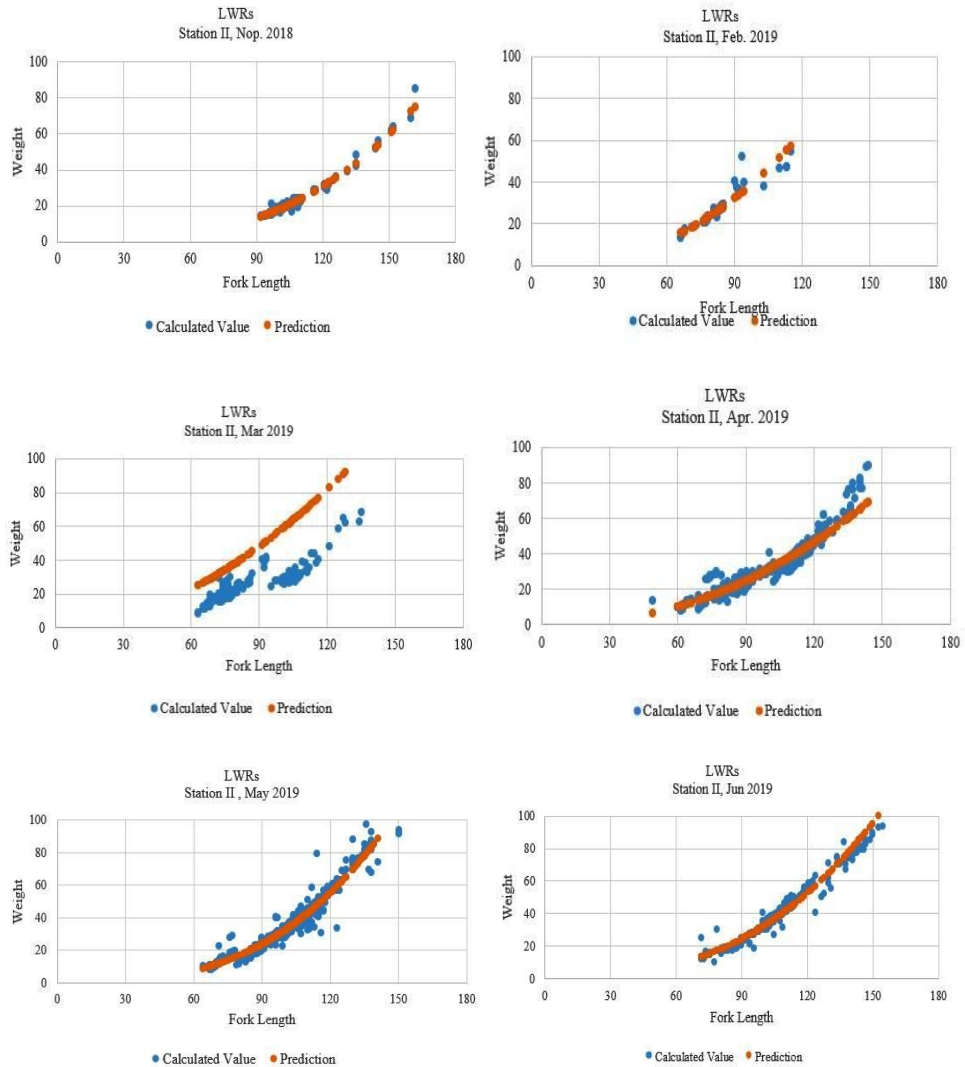
Fig. 3. Monthly Length-Weight Relationships of Yellowfin Tuna at Station I (Luwu) and Station II (Bone)

The calculation of factor condition for all samples at Station I (Luwu) and Station II (Bone) resulted in 2,14 and 3,44, respectively. The monthly variation of factor condition at both Stations is presented in Figure 4.
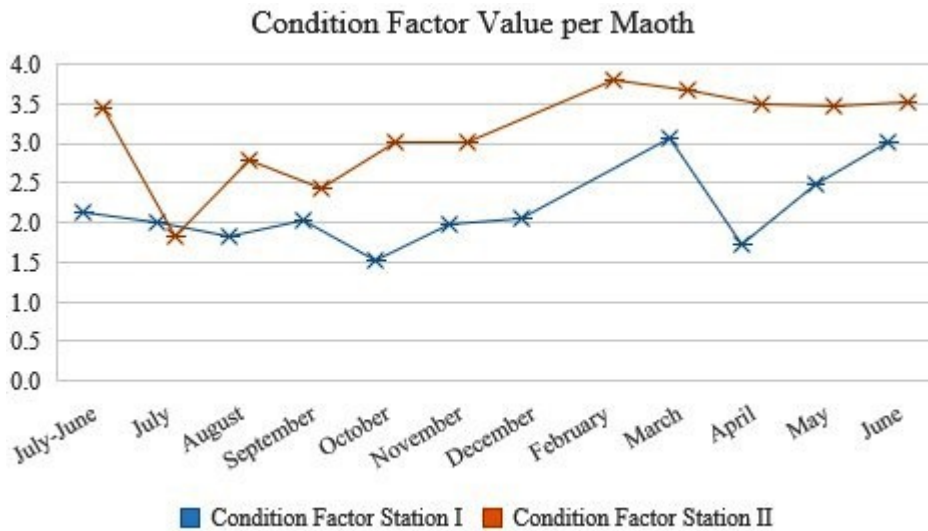
Fig. 4. Monthly Variation of Factor Condition at Station 1 (Luwu) and Station II (Bone)

At Station I that represented the northern area (Luwu), the resulting relative condition factor was 1,5246 at its lowest in October 2019 and 3,073 at its peak in March 2019. At Station II representing the southern area (Bone), the relative condition factor stood at 1,84 in July 2018 and peaked at 3,79 in February 2019.

3.2 Discussion

The size compositions of yellowfin tuna captured in the southern part of Bone Bay showed a range of fork lengths between 26 cm and 162 cm with an average of 95,478 cm. This average was higher than those in the northern part i.e., 81.2566 with a range between 20 cm and 192 cm. The present finding exhibits yellowfin tuna specimens with smaller fork length than the previous finding that captured the specimens at the fish landing at Benoa Harbor in Bali with a range of fork length from 77 cm to 180 cm with an average of 132,53 cm. The differences in size may be attributable to the depth of the waters where fishing operates or the range at which fishing gears operate [2].

Table 2 observes the growth patterns of yellowfin tuna fit into the equation $W = 5.5885^{-05}FL^{2.7454}$ in the northern part of Bone Bay and $W = 4,1244^{05}FL^{2,9103}$ in the southern part. The result showed that the growth pattern of yellowfin tuna in the waters of Bone Bay tended to demonstrate negative allometry, that is, the weight had a lower rate than the length. Positive allometry was only identified in March in the northern part of Bay Bone (Station I); the remaining periods (July – December 2018 and April – July 2019) remained negative allometric. In the southern part of Bay Bone (Station II), the only sighting of positive allometry was reported between July and September 2018, with the remaining periods (October – November 2018 and February – June 2019) typically exhibiting negative allometry.

The present findings are similar to those of yellowfin tuna exhibiting an isometric pattern of growth in several waters of the East Coast of India which was formulated in $W = 0,017077 L^{2,976}$. In the Mischief Reef of the South China Sea, the growth pattern of yellowfin tuna was fit in $W = 0,0056 L^{2,548}$ with r2 of 0.9243, indicating negative allometry (b < 3). The length-weight relationship of yellowfin tuna in Andaman and Nicobar Islands was reported based

on the equation $W = 0,00002 L^{2,97}$ with a resulting r^2 of 0,98. Another study in the same site reported that the length-weight measurement resulted in $W = 0.0208^{L2,986}$. In Benoa Harbor, Bali, the length-weight relationship of yellowfin tuna was $W = 3x10^5 L^{2,911}$ (r= 0,967) [10]. A study of yellowfin tuna in Makassar Strait located in Majene observed the length-weight relationship based on sexes, with male species demonstrating $W = 0,000L^{2,596}$ and female species demonstrating $W = 0,0000L^{2,263}$ ($r^2 = 0,944$) [11][12][13][14].

In contrast, positive allometry was identified in the eastern part of Indian Ocean with a length-weight relationship of $W = 0.00002 L^{3,0294}$ and r2 = 0,9635 [15] . Similar pattern of growth occurred in the western part of Indian Ocean at 1–8˚S / 45–59˚E; 6˚N – 8˚S / 68–75˚E from April to December 2006 and from July to December 2007 with a resulting length-weight relationship of $W = 3.8 \times 10^{-6}L^{3,276}$ and r^2 of 0,94. In the southern part of the Indian Ocean, the reported length-weight relationship was $W = 0.00002 L^{3.0294}$ with r^2 of 0,9365. It is worth noting, however, that monthly measurement results of the growth patterns are subject to temporal variation. Positive allometry is largely recorded in January, March, April, October and December, while negative allometry is predominantly reported in February, May, June, July, August, September and November[15].

The observed estimation of length-weight relationships of fish can differ in the same species dwelling in diverse locations. The difference can also be attributed to diverse study periods given the biological and environmental impact[16].

Positive allometric growth patterns (b> 3) are thought to be related to the spawning season. Where Yellowfin Tuna spawning season in Bone Bay waters occur in February - March, and November – December [16]. Therefore, to maintain the sustainability of fishing activities can be reduced in the spawning season. Limitation on the size of fish that can be caught to give adult fishes to do spawning before being caught.

In terms of the condition factors in Table 3, yellowfin tuna were also observed monthly and exhibited a variation with an average of 2,14 in the northern part of Bone Bay (Station I) and 3,44 in the southern part of Bone Bay (Station II). The variation of Kn was subject to internal and external factors. The internal factors may be associated with sex, age, gonadal maturity rate, fish well-being and food availability [9]. External factors may include food availability and environmental conditions of the waters where the fish thrive in [17] .

4 Conclusion

The empirical report on the species of yellowfin tuna (*Thunnus albacares*) in Bone Bay showed length-weight relationships at a smaller rate than those in other locations. The observed b value was less than 3 (< 3), providing evidence that the overall growth pattern of yellowfin tuna was negative allometric both in the northern part (Station I) and the southern part (Station II). The relative condition factors in Station I and Station II were 2,144 and 3,44, respectively. The findings of these biometric relationships are essential in data processing across all assessments of the fishery resource management for yellowfin tuna, particularly in the bodies of water along Bone Bay.

References

1. A. Wujdi, R. K. Sulistyaningsih, F. Rochman, Research Fisheries Journal **21(2)**, 47-54 (2015)
2. A. Barata, D. Novianto, A. Bahtiar, ILMU Kelaut. Indones. J. Mar. Sci., **16(3)**, 165–170 (2012)
3. S. Kuriakose, ICA- Central Marine Fisheries Research Institute, 215–220 (2014)
4. B. Wahono, L. J. L. Lumingas, Aquatic Science & Management **1 (2)**, 124-132 (2013)

5. M. N. Maunder, P. R. Crone, A. E. Punt, J. L. Valero, B. X. Semmens, Fisheries Research **180**, 1-3 (2016)
6. M. I. Effendie, *Fisheries Biology* (Yayasan Pustaka Nusantara Publishing, Indoensia, 2002)
7. E. D. Le Cren, The Journal Of animal Ecology, *201 - 219* (1951).
8. S. Henley, *Principles and procedure of statistics: A biometrical approach* (Comput. Geosci., 1983.)
9. M. King, *Fisheries biology, assessment and management: Second edition* (Blackwell Publishing, 2007)
10. H. Hartaty, K. Sulistyaningsih, Indonesian Fisheries & Research Journal **20(2)**, 97–103 (2014)
11. M. Yosuva, D. Jeyapragash, V. Manigandan, M. Machendiranathan, A. Saravanakumar, Zoology and Ecology Journal **28(2)**, 1–6 (2018)
12. Mulfisar, Z. A. Muchlisin, I. Dewiyanti, Depik J. **1(1)**, 1-9 (2012)
13. W. Kantun, A. Mallawa, N. L. Rapi, J. Saintek Perikan **9(2)**, 39–48 (2014)
14. C. C. Hsu, H. C. Liu, C. L. Wu, S. T. Huang, H. K. Liao, Fisheries Science **66(3)**, 485-493 (2000)
15. I. Jatmiko, H. Hartaty, B. Nugraha, IOTC 16th *Working Party on Tropical Tuna Bali, Indonesia* (2014)
16. W. Kantun, A. Mallawa, *Biology of Yellowfin Tuna (Thunnus Albacares)*, I (Gadjah Mada University Press, 2016)
17. I. Jatmiko, H. Hartaty, B. Nugraha, Indonesian Fisheries & Reasearch Journal **22(2)**, 77 (2017)