# Visualization of Landing Data and Analysis of Length-Weight Relationship of Tuna Species in Benoa Fishing Port, Indonesia

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## Introduction

Indonesia is the world's largest archipelago country which consists of more than 17,500 islands with the combined length of coastline around 104,000 km. As a tropical county located between the Pacific Ocean and the Indian Ocean, Indonesia's waters consist of a highly varied ecosystem which produces high biodiversity and productivity of fish resources. The mix between warm and temperate sea surface temperature (SST) make Indonesia's waters suitable as an area for spawning ground especially for highly migratory fish such as tuna, billfish, and shark. With this condition, Indonesia is considered as one of the biggest producers of marine capture fisheries and is producing a significant portion of the world's fish catches, especially for tuna species (FAO 2010).

To ensure sustainability of the fisheries, the Ministry of Marine Affairs and Fisheries (MMAF) Republic of Indonesia have implemented several management strategies. These strategies included unique vessel identifier, mandatory vessel monitoring system (VMS), limitation on fishing days, onboard observer program, implementing quota system, closing the fishing area, implementation of catch documentation scheme. However, these options are expensive and not straightforward. Alternatively, the traditional input in fisheries management and policy such as fisheries landing data is preferable.

Fisheries landing data or catch data is one of several parameters that highly crucial for fisheries management policy. It refers to the total amount of fish taken out from the sea. It could measure the impact of fishing activity on fish population and food chains because it delineates the removal rates of individual species and biomass from an ecosystem (Duggan and Kochen 2016). This data is needed to evaluate the status of fish resources as well as to manage the fisheries in Indonesia.

In Indonesia, catch data is recorded once the fishing vessel unloads their catch in fishing port (landing site). The weight of landings is frequently less than the weight of catch because gills and guts are thrown overboard if fish are cleaned (handled) at sea; and some of a vessel's catch may be eaten by the crew, used for bait or discarded overboard. Nevertheless, the weight data can provide evidence of how well the stocks are performing in response to fishing activity.

In response to delineates the landing data, here we visualized the landing data from Benoa fishing port where the data was collected in 2016. This landing data was derived from tuna longline fishing vessel which registered to the Indian Ocean Tuna Commission (IOTC). The data only consist of big pelagic fishes including tuna, billfish, and shark. In addition to the data visualization, we also analyze the length-weight relationship of several Tuna species. This analysis is based on the length frequency data that recorded randomly by the enumerators in this fishing port.

## Visualization of Landing Data

Total production big pelagic fishes caught by the tuna longline fishing vessel in Benoa fishing port at 2016 was 3136.946 tonnes. These catches including Albacore tuna (ALB), Bigeye tuna (BET), Black marlin (BLM), Blue marlin (BUM), Black escolar (LEC), Stripped marlin (MLS), Southern bluefin tuna (SBT), Swordfish (SWO), Wahoo (WAH), and Yellowfin tuna (YFT). The composition of catches landed by tuna longline fishing vessel in Benoa fishing on 2016 can be seen in Figure 1 below.

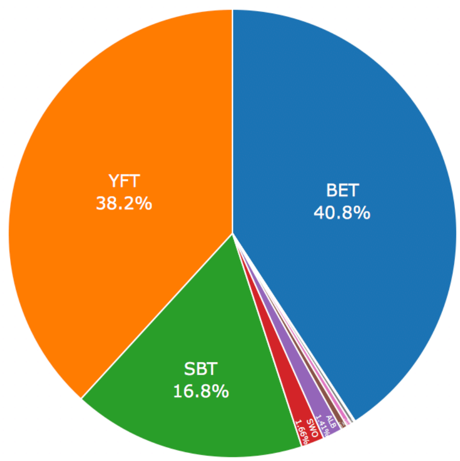


**Figure 1.** Total production by species

As we can see on the Figure 1, there are three species of fishes which dominated the total catches landed in this fishing port. Among these species, Bigeye tuna shared about 40.8% of the total catches followed by Yellowfin tuna and Southern bluefin tuna respectively at 38.2% and 16.8%. The detail of total catches by species is presented in Table 1 below.

***Table 1.*** *Total production by species*

| Species | Total production [ton] |
|---|---|
| ALB | 44.142 |
| BET | 1279.459 |
| BLM | 1.676 |
| BUM | 7.664 |
| LEC | 14.421 |
| MLS | 0.830 |
| SBT | 527.114 |
| SWO | 52.195 |
| WAH | 10.948 |
| YFT | 1198.497 |
| Total | 3136.946 |

Tuna and billfish are high-speed swimmers and long-distance migrators(Westneat and Wainwright 2001). As they swimming all the time searching for food, the migration pattern is determined by their spawning cycle and the food availability. In addition, the sea surface temperature (SST) also determine the migratory timing (Dufour et al. 2010). Moreover, these fishes are searching for food up to the temperate water area, then back to the tropical area for reproduction purpose. This condition led to the seasonal change in fishing activities. Although the fishing time is open all year round, there are some patterns regarding high season and low season in catching the fish. Figure 2 illustrates the landing pattern as it represents the monthly production in Benoa fishing port.

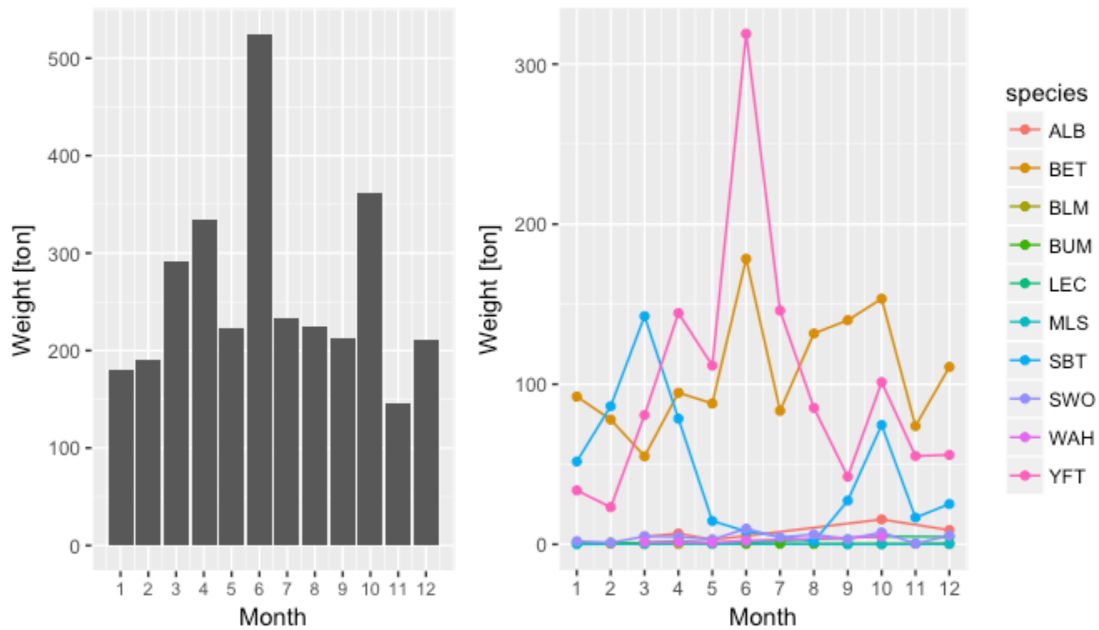


**Figure 2.** Monthly production

As we can see in Figure 2, there are at least three peak seasons in 2016 where one of them is way higher than the others. The month of June is the highest landing in Benoa fishing port in 2016, followed by October and April respectively. Yellowfin tuna and Bigeye tuna is the driver that makes June is the highest landing of the year. This condition is caused by the similarity of the habitat among this two species. In term of vertical distribution, they both distributed in the mesopelagic water column (Goujon and Majkowski 2000), where horizontally, they spread in tropical and sub-tropical oceanic (IOTC 2017).

Explicitly, the distribution of weight for each species is presented in Figure 3. In this figure, we can see the clusterization of weight of the species landed in this fishing site which is presented as yellow dots. Meanwhile, the range of weight is presented by the straight blue line and dots.

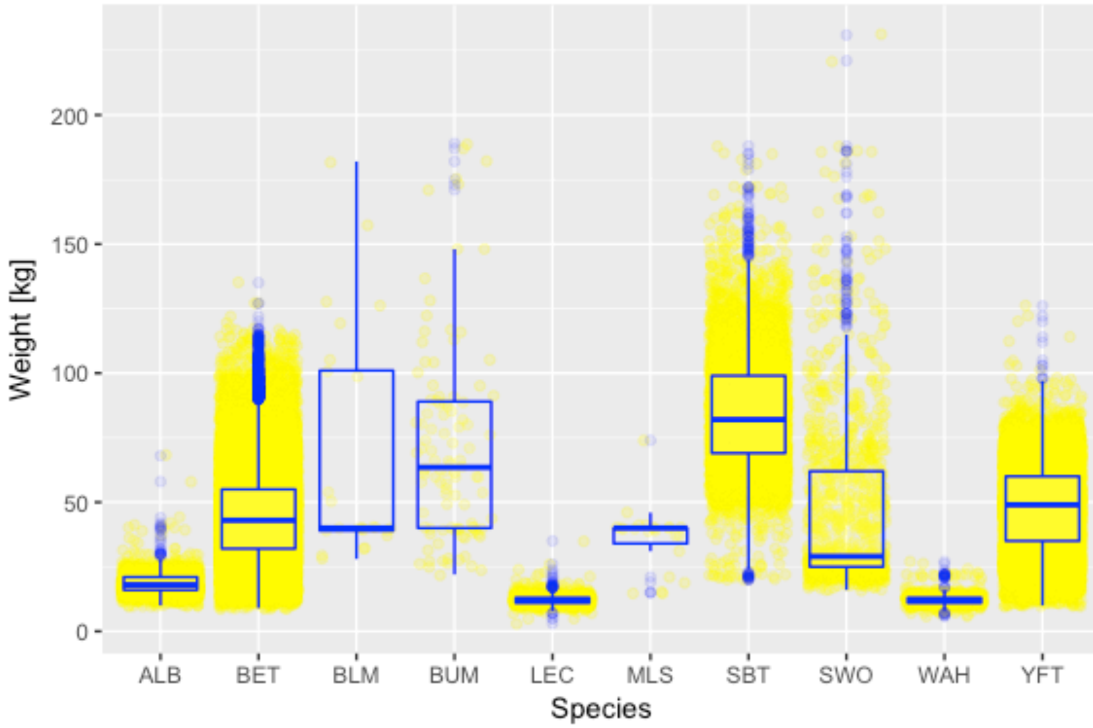


**Figure 3.** Weight distribution by species

## Length-Weight Relationship of Tuna Species

Based on the data visualization in the above, tuna species such as Bigeye tuna, Yellowfin tuna, and Southern bluefin tuna dominated the total catches landed in Benoa fishing port in the year 2016. With this condition, the analysis of length-weight relationship will be attempted only on these three species. The minimum requirement to run this analysis is the measurement of length (L) and weight (W) of individual fish at the time of capture (Table 2.). Any other information about individual fish, such as date, month, year of capture, gears, etc. can also be recorded.

***Table 2.*** *Data requirement for L-W analysis*

| month | day | year | species | weight | length | handling | weight_ton |
|---|---|---|---|---|---|---|---|
| 1 | 5 | 2016 | BET | 34 | 117 | GGT | 0.034 |
| 1 | 5 | 2016 | SWO | 74 | 132 | HDD | 0.074 |
| 1 | 5 | 2016 | SBT | 92 | 168 | GGT | 0.092 |
| 1 | 5 | 2016 | BET | 36 | 124 | GGT | 0.036 |
| 1 | 5 | 2016 | SBT | 87 | 157 | GGT | 0.087 |
| 1 | 5 | 2016 | YFT | 22 | 106 | GGT | 0.022 |
| 1 | 5 | 2016 | BET | 69 | 148 | GGT | 0.069 |

The type of length measurement performed by the enumerator of this data is fork length (FL) measurement (Figure 4.). This type of measurement is the requirement for measuring tuna species (IOTC 2013). Fork length is the length from the most anterior point to the anterior notch in the fork of the tail.

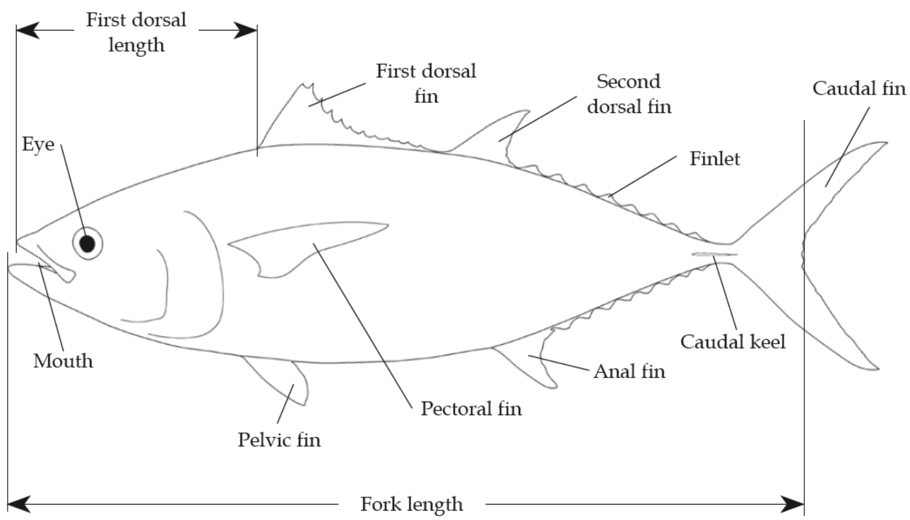


**Figure 4.** Fork length measurement for tuna species (IOTC 2013)

It is essential to understand that the relationship between length and weight of individual fish is not linear (Froese 2006). Please see Figure 5 as an example. It is because of length is a linear measure and weight is related to volume. However, the variability of weight increases as the length of the fish increases. This condition led to misassumption of using the simple linear regression on this analysis. In fact, at least a two-parameter power function should be used to model the length-weight relationship. Specifically, the most common model that can be used is

$$W = aL^b$$

where $a$ and $b$ are constants. The length-weight model can be transformed to a linear model by taking the natural logarithms of both sides and simplifying,

Thus, we could derive $y = log(W)$, $x = log(L)$, slope=b, and intercept=log(a).

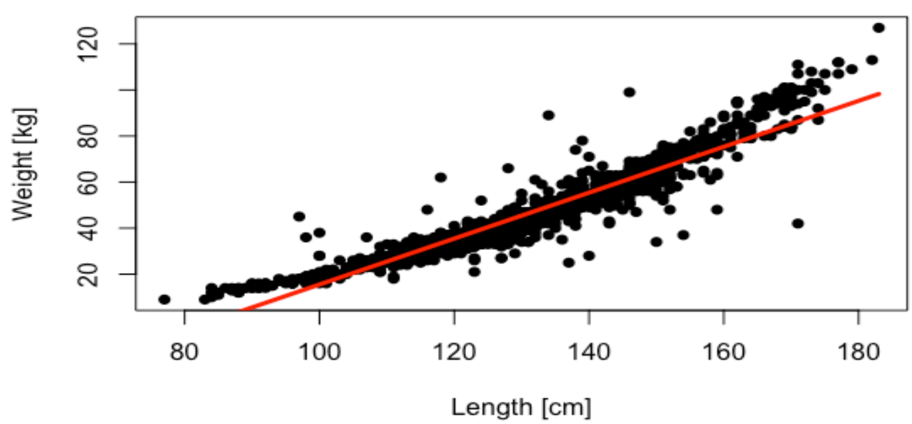


**Figure 5.** Length and weight of Bigeye tuna

## Fitting the data to model

### Bigeye tuna

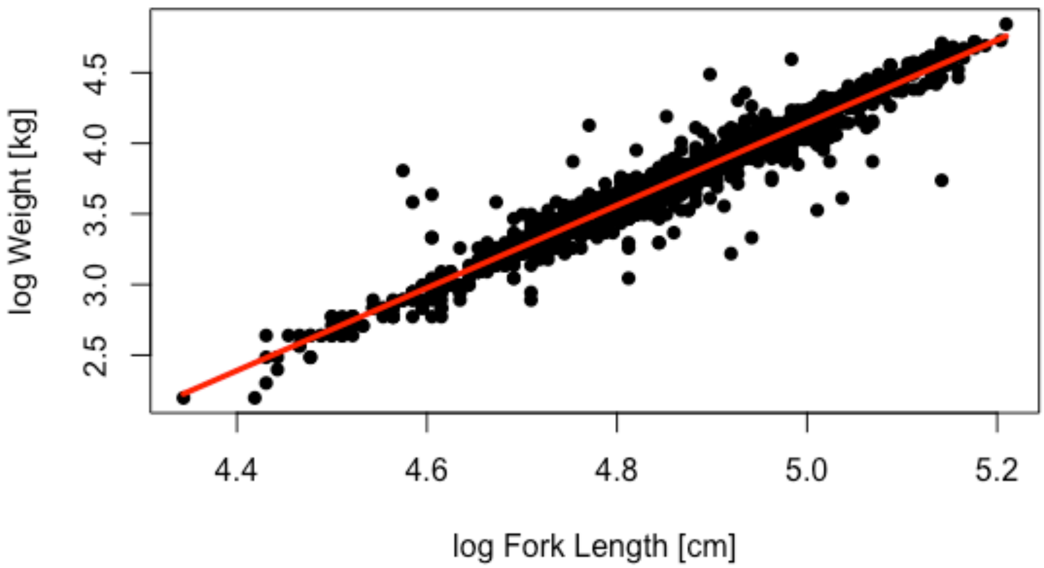


**Figure 6.** Natural log transformed fork length and weight of Bigeye tuna

```
##
## Call:
## lm(formula = logW ~ logL, data = bigeye)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.82268 -0.04177  0.00322  0.04511  0.90519
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept) -10.48394    0.08815  -118.9   <2e-16 ***
## logL          2.92596    0.01815   161.2   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.1021 on 1594 degrees of freedom
## Multiple R-squared:  0.9422, Adjusted R-squared:  0.9422
## F-statistic: 2.6e+04 on 1 and 1594 DF,  p-value: < 2.2e-16
```

Based on Figure 6 and the summary in the above, we can see that the model shows a tight fit to the transformed data ($R^2 = 0.94$) with the possible exception only of a few individuals. The equation of the best-fit line is $log(W) = -10.48 + 2.92x log(L)$ on the transformed scale and W =$0.000028L^{2.92}$ on the original scale.

### Yellowfin tuna

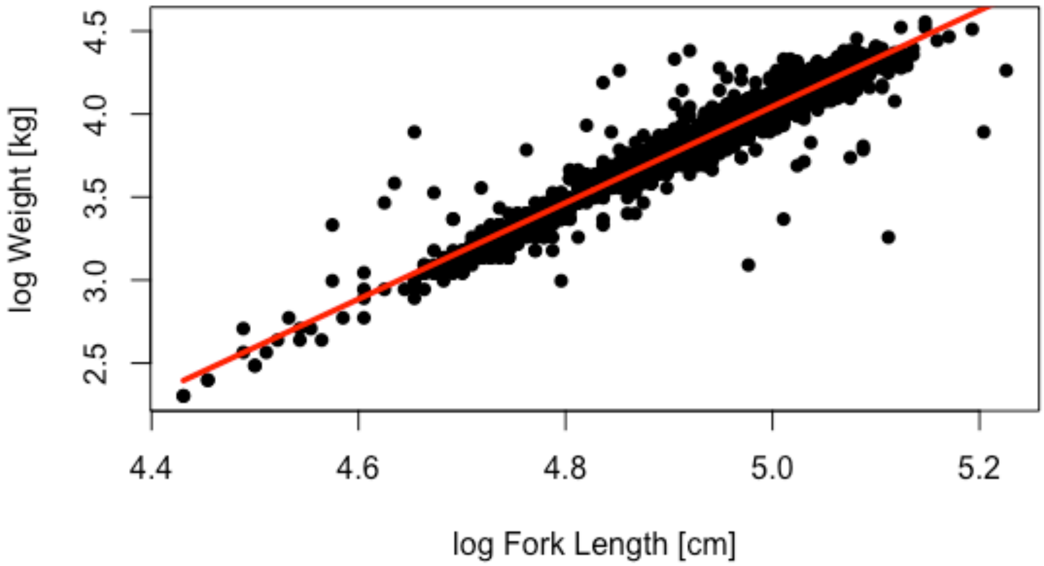


**Figure 7.** Natural log transformed fork length and weight of Yellowfin tuna

```
##
## Call:
## lm(formula = logW ~ logL, data = yellowfin)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -1.11117 -0.04607  0.00468  0.04088  0.84988
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept) -10.44489    0.08688  -120.2   <2e-16 ***
## logL          2.89793    0.01758   164.8   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.09387 on 2132 degrees of freedom
## Multiple R-squared:  0.9272, Adjusted R-squared:  0.9272
## F-statistic: 2.716e+04 on 1 and 2132 DF,  p-value: < 2.2e-16
```

Similarly, based on the summary and Figure 7, it is seen that the model exhibits a tight fit to the transformed data ($R^2 = 0.92$). The equation of the best-fit line is $log(W) = -10.44 + 2.89x log(L)$ on the transformed scale and in the original equation become $W = 0.000029L^{2.89}$.

### Southern bluefin tuna

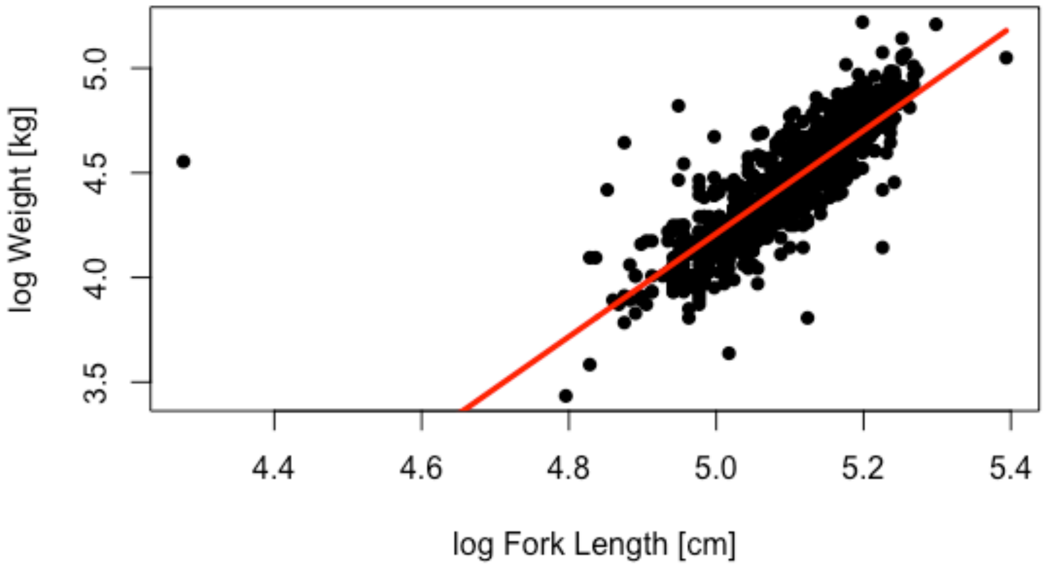


**Figure 8.** Natural log transformed fork length and weight of Southern bluefin tuna

```
##
## Call:
## lm(formula = logW ~ logL, data = bluefin)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.70838 -0.08121 -0.00720  0.07104  2.12585
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept) -8.10600    0.23858  -33.98   <2e-16 ***
## logL         2.46314    0.04672   52.72   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.138 on 1271 degrees of freedom
## Multiple R-squared:  0.6862, Adjusted R-squared:  0.6859
## F-statistic:  2779 on 1 and 1271 DF,  p-value: < 2.2e-16
```

Different from the two previous result, Figure 8 and the summary in the above shown that the model doesn't fit to the transformed data ($R^2 = 0.68$). Based on the $R^2$ value, the model only fit about 68% of the available data. The best-fit line is generated by $log(W) = -8.10 + 2.46xlog(L)$ which is equal to $W = 0.00030L^{2.46}$.

### Results interpretation

The length-weight relationship analysis shows that a value (intercept) from all species is less influential to the analysis than the b value due to very small result: 0.000028 for Bigeye tuna, 0.000029 for Yellowfin tuna, and 0.00030 for Southern bluefin tuna. The b values in this study are less than 3 but higher than 2.4 which means that the growth pattern of tuna species in our study area is negative allometric or the growth in length is faster the growth in shape (Froese 2006). Usually, the b value is varied between 2.5 to 4 (Le Cren 1951). Our result in this analysis corresponds to the result from other studies which most of them are in the negative allometric growth pattern (S.-B. Wang et al. 2002; Uchiyama and Kazama 2003; Zhu et al. 2008; Batista Da Silva and Fonteles-Filho 2011; Parera, Haputhanthri, and Bandaranayake 2013) except study conducted in the Pacific Ocean (Zhu et al. 2008). As the habitat of Bigeye tuna and Yellowfin tuna is mainly in the surface (epipelagic water column) and the sea temperature in Indonesia is relatively the same, the length-weigth relationship within these two species become similar. In contrary, Southern bluefin tuna mostly distributed in subtropical water area where the temperature is lower than in tropical water area makes the growth in weight (b = 2.46) is slower than the other two species.

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