Sustainability assessment of Devis' anchovy (*Encrasicholina devisi* (Whitley, 1940)) (Clupeiformes: Engraulidae) fisheries based on biology aspects, Kutai Kartanegara, Indonesia

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Abstract. The Code of Conduct for Responsibility Fisheries (CCRF) is required to study biological aspects such as the length and weight of the catch caught by stick held dip net (bouke-ami) fishing gear than can also be used as reference in the framework of fisheries management. The purpose of this study was to determine the status of utilization of Devis' anchovy (Encrasicholina devisi (Whitley, 1940)) resource. A total of 9,392 individuals were sampled from the types of small scale commercial vessel bouke ami units operating around Kutai Kartanegara waters from January to December 2017. The data were analyzed by using FiSAT II. The results showed that the frequency distribution mode of the total length ranged from 68 to 74 mm. The value of Lc50% (51.56 mm) < ½ L∞ (65.1 mm) indicated that the size is still small or not feasible to catch. The Devis' anchovy has positive allometric growth. The growth analysis shows that anchovies in this area can grow until 122.0 mm (Lmax). The Von Bertalanffy equation is 130.2(1-e{-1.3(t-(-0.081)}). The status of the rate of exploitation was underfishing. The natural mortality rate is greater than the mortality rate due to capture.

Key Words: growth, mortality, Devis' anchovy, exploitation rate, growth coefficient.

Introduction. Anchovy (*Engraulidae*) catch production in the world has decreased day by day (Whitehead et al 1988; Froese & Pauly 2019). This condition has impact on the sustainability of fish resources (Pauly et al 2014) which requires a collaboration among all countries to reach sustainable fisheries (Kosamu 2015). From 2005 to 2014 the average fish production of Engraulidae family in the world reached 7,845,566 tons, while the production of fish reached 5,646,233 tons in 2015 and 4,496,960 tons in 2016 (FAO 2018). In European waters, anchovies live in the Atlantic Ocean, Black Sea and Mediterranean Sea (Whitehead et al 1988) and have become the subject of various ecological studies (Guidetti et al 2013), reproduction (Uriarte et al 2012; Manzo et al 2013), fisheries (La Mesa et al 2009) and their relationship with zooplankton (Simbolon et al 2010; Kaswadji et al 1995). Production of anchovy in 2016 in Indonesia was 2,608,445 tons. In East Kalimantan Province, the production of anchovy was 67,448 tons and in Kutai Kartanegara Regency, the production was 4,345 tons (MMAF 2019). The utilization of environmentally friendly fishing gear was recommended for sustainability of the fisheries business (Daly 1991; Costanza 1991; Hawken 1993; Berg & Janssen 2005; Blignaut et al 2014).

There has been few research on Devis' anchovy in these waters, and therefore this strengthens the reason of conducting this present research besides the things mentioned earlier as an initial step in preserving the sustainability of fish resources. In addition, this species lives in a strategic position in transferring energy from plankton to large predators (Cury et al 2000) and has a main role in the ecosystem that represents a fundamental relationship between the production of plankton and predators of upper trophic levels (Palomera et al 2007; Coll et al 2009; Qendouci et al 2018). The study of biological parameters includes the size of the catch, growth pattern, feasible capture size and mortality rate which are considered to be essential to maintain fish stocks as a part of ecological subunits and the main foundation for biological fish stocks (Biswas 1993; Haddon 2011; Aghajanpour et al 2016). The purpose of this study is to estimate the growth, length-at-first capture, mortality rate, exploitation rate and growth coefficient of Devis' anchovy. These factors have an effect on population dynamics, thought to predict the pattern of population growth and as basic data in fisheries management (Nurdin et al 2016).

Material and Method

Time and research site. This research was conducted from January to December 2017 in Coast Fishery Port (CFP) Samboja Kuala, precisely at the geographical position of 1°.1'22.22"S and 117°.6'58.85"E in Kutai Kartanegara Regency, East Kalimantan Province, Indonesia. The bouke ami (stick held dip net) operated by the Samboja Kuala fishermen was located in the waters of Makassar Strait and it belongs to the Fisheries Management Area 713 (FMA 713) (Figure 1).

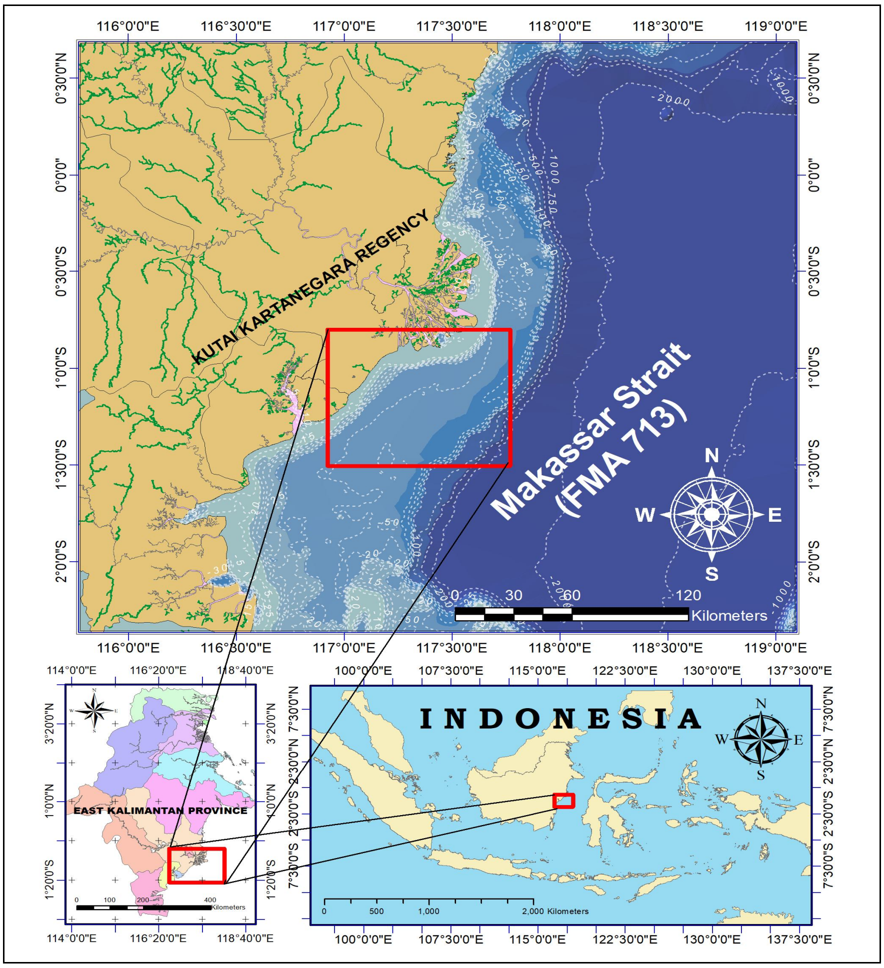

Figure 1. Map of research site.

Sampling methods. As many as 9,392 Devis' anchovy (*E. devisi*) (Froese & Pauly 2019) samples were collected during the 12 months of the study by bouke-ami fishing gears. All samples were stored in cool boxes in low temperature and transported to laboratory for further analysis. Anchovy samples were identified down to species level following Carpenter & Niem (1998). The total length (TL) of *E. devisi* has been measured by scientific operators thus taken into account all size groups caught was measured by caliper (accuracy of 0.01 mm) started from the tip of mouth to the fork end (TL), while the total weight per individuals was weighed by pocket scales max capacity 200 g (accuracy 0.01 g), type IL-200P made in Idealife Home Innovations Manufacture China.

Data analysis. The variables observed consisted of TL (mm) and body weight (grams). The data were analyzed using a simple FISAT or FAO-ICLARM Stock Assessment software because they only required the long frequency data (Mancera & Mendo 1996; Amin et al 2001; Jagadis & Rajagopal 2007; Panda et al 2011; Chakraborty et al 2014; Hariyadi et al 2017).

The first catch caught by the bouke ami were measured using the standard logistic curve (Saputra 2009). To calculate the estimation of growth parameters (L_∞ and K), ELEFAN 1 method in the FISAT II software was used (Pauly 1987; Gayanilo et al 2005). Growth parameters consisted of coefficient of growth (K), infinity length ($L\infty$) and theoretical age of fish (t_0) estimated by the Von Bertalanffy growth model (Sparre & Venema 1998). The length-at-first-capture was calculated by the formula $L_\infty = L_{max} / 0.95$ (Pauly 1984), where $L\infty$ (asymptotic length), Lmax (maximal length) and 0.95 (constant). The relationship between length and weight was performed by the length-weight correlation analysis based on $W = a\ L^b$ formula (Effendie 2002; Fafioye & Oluajo 2005; Kalayci et al 2007), where: W = total weight of fish; b = allometric coefficient; a = constant; L = total length in milimeters. The constant (a) and the allometric coefficient (b) were calculated by the least squares method based on the logarithmic form of equation as recommended by Froese (2006). Total mortality (Z) was estimated by the catch curve method which was converted into length (Pauly 1984; Sparre & Venema 1998). The natural mortality value (M) was obtained based on Pauly's empirical formula: $\text{Log } M = -0.0066 – 0.279 \text{ Log } L_\infty + 0.6453 \text{ Log } K + 0.4634 \text{ Log } T$ (Pauly 1984) based on the average temperature of Makassar Strait waters (FMA 713) around 29.7^{o}C (Labania et al 2017). Fishing mortality (F) and exploitation rate (E) were calculated by Pauly's formula $F = Z – M$, where total mortality rate (Z), natural mortality rate (M), and the rate of exploitation (E) = F / Z, where E = 0.5 indicated that the value is optimum (E_{opt}). We assumed that exploitation is optimum if the results were balanced (Gulland 1983; Pauly 1983).

Results and Discussion. Five species of anchovy were identified in these waters i.e *Encrasicholina devisi* (Whitley, 1940), *Stolephorus insularis* (Hardenberg, 1933), *Stolephorus indicus* (van Hasselt, 1823), *Encrasicholina heteroloba* (Ruppell, 1837) and *Stolephorus commersonii* (Lacepede, 1803). However, *E. devisi* was the only species taken as a sample. A total of 9,392 individuals fish taken from each different month were selected as the samples. Anchovy size 68-74 mm was mostly found in this area (2,799 individuals with weight ranging from 1.57 to 2.91 g (Figure 2).

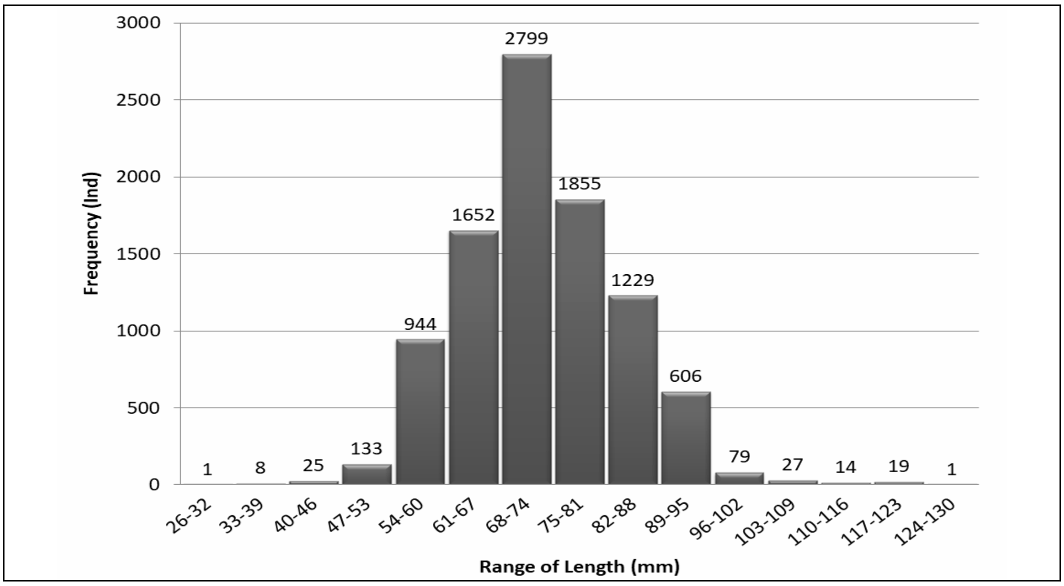

Figure 2. Range of length-frequency.

Devis' anchovies sample have length between 26 and 130 mm with an average length of 70.0 mm and an average weight of 3.97 g. Maximum anchovy population in size 68-74 mm was caught in October-November (Figure 3). The smallest Devis anchovy's weight was 0.04 g and the heaviest one was 19.47 g.

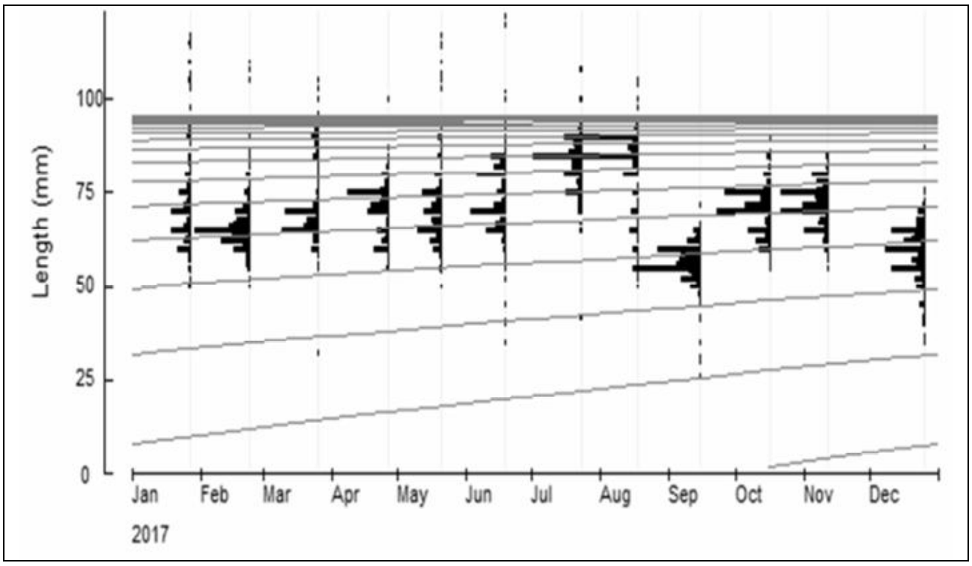

Figure 3. Range of length-frequency in January-December.

An earlier study of Sasmita et al (2018) on the same species in other tropical waters of Brebes Pulolampes showed that the longest size of the species was 91 mm with the weight of 6.5 g. The shortest length was 29.8 mm with a weight of 2 g. The mode size was 62.9 mm and this size belonged to as worthy capture fish in August compared to April and May. In Muara Sungsang waters located in South Sumatera, anchovy's length was between 20 and 120 mm with weight range 1-8 g, the mode was 65-75 mm in length and the standard size for fishing was 61-67 mm in July and September (Fauziyah et al 2016). In Pemalang coast, the range of length was approxiamtely 37-81 mm with weight of 0.35-4.51 g, the standard length for fishing was 57.24 mm (Dewanti et al 2014). In Ambon Bay waters, the range was 10-105 mm in length and the mode was of 72.5-77.5 mm (Ongkers 2008). Generally the maximum length found in European waters i.e. Atlantic Ocean, Black Sea and Mediterranean Sea was 153 mm (Whitehead et al 1988) and in Singapore Strait waters was 190 mm (Tham 1967) and 218 mm (Pauly 1980), respectively.

Growth. The growth, recruitment and length-at-first capture fish were needed as scientific information for management and sustainability of fisheries. The key factor is natural recruitment and natural mortality or fishing pressure (Udoh et al 2017). Growth analysis obtained maximum length (L_{max}) of 122.0 mm, and maximum length prediction (L_∞) of 130.2 mm (Table 1). This result was relatively higher than that from other sites in Indonesia. In Brebes Pulolampes waters, L_∞ was found to be 96.0 mm (Sasmita et al 2018). In Muara Sungsang, L_∞ was at 126.0 mm (Fauziyah et al 2016). In Pemalang Central Java, L_∞ was at 85.26 mm (Dewanti et al 2014). In the waters of Palabuhan Ratu Bay, L_∞ was at 98.0 mm (Utami et al 2018). The difference in L_∞ value was based on different stock and recruitment, fishing area and the number of samples. Our prediction was the anchovy can grow maximum 1.3 years^{-1} (K) and the value of t is -0.081. The Von Bertalanffy equation is $130.2(1\text{-}e^{\{-1.3(t-(-0.081)\}})$ showed in Figure 4 and Table 1.

Anchovy is a fast-growing species (Guerault & Avrilla 1974; Cendrero et al 1981; Vovovik & Kozlitina 1983; Erkoyuncu & Ozdamar 1989; Campillo 1992; Djabali & Hemida 1992; Ramos & Santos 1999; CGPM 2000; Machias et al 2000; Basilone et al 2004; Samsun et al 2004; Kada et al 2009; Bacha et al 2010; Amponsah et al 2016; Benchikh et al 2018). Our calculation showed that anchovies in Kutai Kartanegara have rapid and linear growth from 0 year to 2 years and then they grew slowly (Figure 4). Based on our results of analysis, fish caught using bouke-ami had an age range between 1 year 4 months to 2 years 3 months. In many studies, generally, rapid and linear growth occured when fish are at 2 years of age and move slowly to 4 years of age in the waters of the east coast of Algeria (Benchikh et al 2018), the west coast of Algeria (Bacha et al 2010), coast of Tunisia (Khemiri et al 2007) and western Mediterranean sea (Morales-Nin & Pertierra 1990), Adriatic coast (Sinovcic 2000). The optimum age of anchovy varies between 2 years (Fage 1911), 5 years (Hemida 1987; Bellido et al 2000), 4.92 years (Benchikh et al 2018), and 5 years (Berné et al 2004).

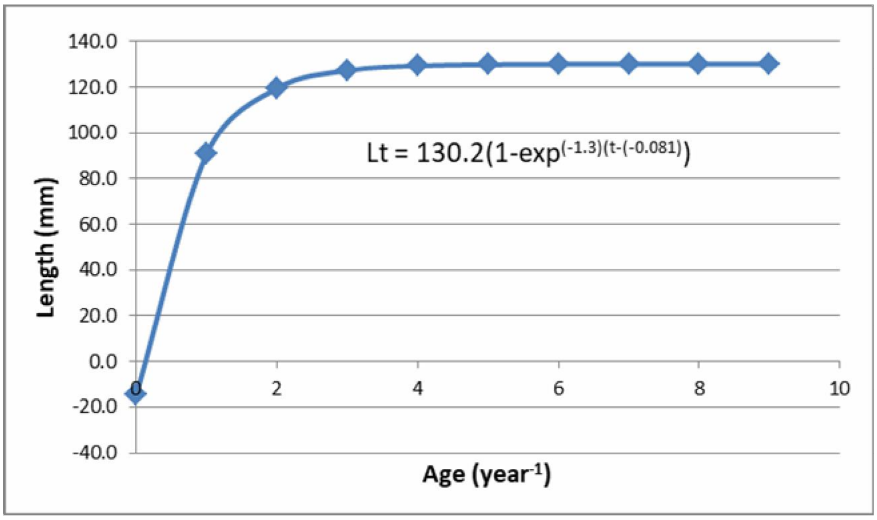

Figure 4. Length-age relationship.

Table 1

The value of maximum length (Lmax), asymptotic length (L∞), growth coefficient (K), fish hypothesis age at a zero length (t0) and length of the fish at the age of –t (Lt)

Parameters	*Value*	*Information*
L_{max} (mm)	122.0	Measurement method, TL (mm)
L_∞ (mm)	130.2	ELEFAN I in FiSAT II
K ($year^{-1}$)	1.3	ELEFAN I in FiSAT II
t_0 (year)	-0.081	Pauly (1984) formula
L_t (mm)	$130.2(1-e^{\{-1.3(t-(-0.081)\}})$	Growth model Von Bertalanffy (1934) equation

Estimated growth and age of fish is the most important information in a species stock assessment model (Haddon 2011), which is not only a distinguishing indicator but also has an important role in the aquatic habitat ecosystem (Walters & Martell 2004). The length of infinity varies due to differences in sampling methods and environmental factors. Variations occur in various waters in certain species due to environmental factors such as dissolved oxygen, salinity, temperature and the other factors that affect metabolism (Jones 1981; King 1995; Aghajanpour et al 2016). Temperature changes affect the values of K and L_∞ so that the water temperature increases. The value of K increases in the logarithmic trend while L_∞ decreases, but this reduction is less than the increase in the value of K (Sparre & Venema 1998). The following L_∞ values and length range mode in several studies in Indonesian waters are presented in Table 2.

Studies on other anchovy species (Engraulidae family) show that the growth parameters L_∞ (mm) and K ($year^{-1}$) still indicate high growth rates compared to other regions, as reported by Benchikh et al (2018) in waters of Anaba, East Algeria 178.9; 0.6 respectively, Strait of Sicily 186.0; 0.29 respectively (Basilone et al 2004), Middle Ionian Sea, Greece 175.0; 0.51 respectively (Machias et al 2000), Middle-North Adriatic, Croatia 194.0; 0.57 respectively (Sinovcic 2000), Turkish Black Sea 163.6; 0.42 respectively (Samsun et al 2004), Gulf of Cadiz, Spain 186.9; 0.9 and 189.5; 0.9 (Bellido et al 2000), Lagune de Nador, Mediterranean, Morocco 106.8; 0.87 respectively (Kada et al 2009), Mediterranean Morocco Sea, Alboran 188.0; 0.34 respectively (CGPM 2000), Ghana 110.3; 0.58 respectively (Amponsah et al 2016), South Tunisian coast 171.9; 0.36

respectively, North Tunisian coast 191.6; 0.32 respectively (Khemiri et al 2007) and Benisaf, West Algeria 156.1; 0.75 respectively (Bacha et al 2010). The difference in the value of growth parameters mentioned above is due to environmental variations in certain regions (King 1995). In addition, latitude and ecological changes can affect the value of L∞ and K which certainly makes some variations of the growth of a species (Sparre & Venema 1998).

Table 2

Research results of growth parameters in other Indonesian waters

Location	*L_∞ (mm)*	*Modus length range (mm)*	*Sources*
Pulolampes Coast, Brebes, Central Java	96.0	64-70	Sasmita et al (2018)
Muara Sungsang Coast, South Sumatera	126.0	65-75	Fauziyah et al (2016)
Pemalang Regency Coast, Central Java	85.3	57-60	Dewanti et al (2014)
Palabuhanratu Bay, West Java	98.0	48-56	Utami et al (2018)
Ambon Bay, Maluku	121.8	72.5-77.5	Ongkers (2008)
Makassar Strait, Kutai Kartanegara, East Kalimantan	130.2	68-74	Present research on 2019

Length-at-first-capture. The length-at-first capture of fish can be used to help in management efforts, because it can be used to find out whether the catch is feasible or not by comparing $½L_\infty$ (Sparre & Venema 1999). The value of L_∞ is 130.2 mm (Table 3), half of L_∞ 65.1 mm, the average size of the catch $L_{50\%}$ 51.56 mm. The value of $L_{50\%} < ½L_\infty$ indicated that the caught anchovy is still too small or not suitable for capture.

Table 3

Length-at-first-capture

L_{max} (mm)	*L_∞ (mm)*	*½ L_∞ (mm)*	*$L_{50\%}$*
122.0	130.2	65.1	51.56

Length-weight relationship. Exponential linear model had been used for calculating length-weight relationship of anchovy. The relationship analysis between the length and the weight of anchovy has intercept a 0.000007 and a slope b 3.0968. These values completed growth weight equation W = 0.000007L3.0968. Slope value (b) was useful as an indicator of growth model. The calculation of 3.0968 showed that if b > 3 weight growth is faster than length growth (positive allometric) (Figure 5) (Effendie 2002). Variations in values a and b can be determined by several factors including differences in sex and gonadal maturity.

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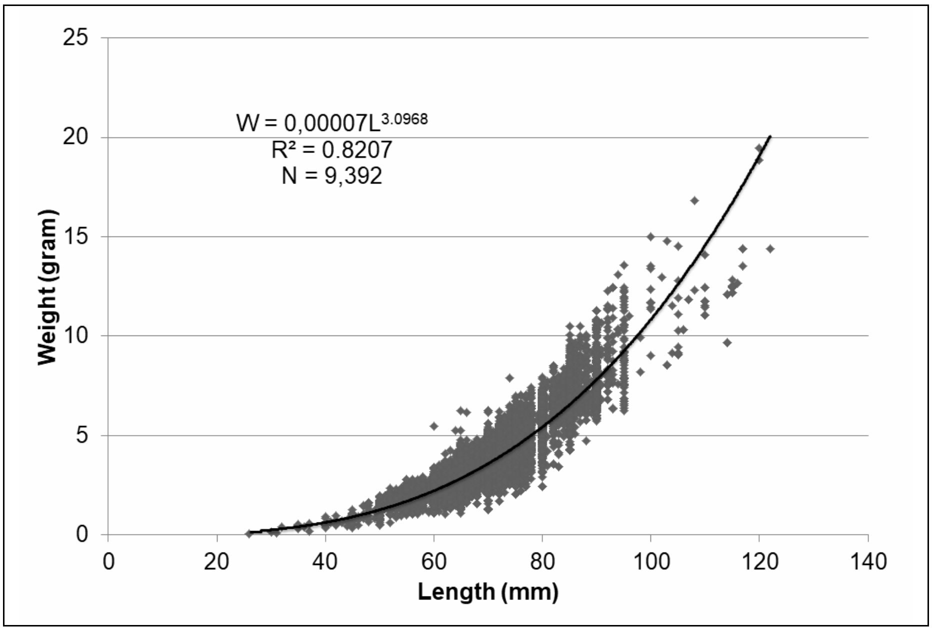

Figure 5. Length-weight relationship.

The allometric positive growth pattern was confirmed by similar studies in Pemalang waters (Dewanti et al 2014) and the coast of Karachi, Pakistan (Musarratulain et al 2015). The length-weight relationship was used by fisheries researchers to convert length-weight equations into an assessment of growth in stock models (Ozaydin & Taskavak 2006), estimation of biomass (Dulcic & Kraljevic 1996; Moutopoulos & Stergiou 2002), fish conditions (Petrakis & Stergiou 1995), comparing habitat differences (Treer et al 2000). The length-weight data are needed (Cherif et al 2007; Froese 2006) to estimate potential vulnerability and over-exploitation (Ma et al 2010).

Mortality. The result showed that the rate of exploitation of Devis' anchovy still was below the limit of exploitation rate, around 40% year^{-1} of existing stocks. Our result was lower than the other results of similar study in Ambon Bay with the exploitation rate 53% year^{-1}. This means that the rate of exploitation is higher (Ongkers 2008). Our analysis also showed that natural mortality rate was 2.75 individual year^{-1} which was higher than mortality due to capture pressure, 1.84 individual year^{-1} (Table 4). These results confirmed that mortality rate was mostly related to the high population of predators of anchovy, competitors and or environmental/habitat conditions.

Table 4

Value of total mortality (Z), natural mortality (M) and fishing pressure (F) on different regions of the world

Study location	*Z (year^{-1})*	*M (year^{-1})*	*F (year^{-1})*	*Sources*
Coast of Kutai Kartanegara, Makassar Strait, Indonesia	4.59	2.75	1.84	Present research on 2019
Gulf of Annaba, East Algeria	2.31	0.56	1.75	Benchikh et al (2018)
Ghana	3.40	1.59	1.81	Amponsah et al (2016)
Algeria Center	2.63	0.61	2.02	Fedja & Bouaziz (2015)
Black Sea, Turkey	2.84	0.66	2.18	Saglam & Saglam (2013)
Black Sea, Turkey	1.44	0.49	0.95	Samsun et al (2004)
Black Sea, Turkey	1.6	0.46	1.44	Samsun et al (2004)
Ambon Bay, Indonesia	5.78	2.73	3.05	Ongkers (2008)
Ambon Bay, Indonesia	10.73	2.64	8.09	Pattikawa & Ongkers (2002)

When we compared between studies conducted in Indonesia and those of the world, Kutai Kartanegara was the only site which showed the natural mortality rate (M) higher than mortality rate due to fishing pressure (F). This phenomenon seemed natural because of the fact that natural death is mostly caused by predator-prey relationship around 90% and the aging process with the estimation around 10% (Niamimandi et al 2003). The catch mortality rate was caused by fishing activities which was strongly influenced by the type of fishing gear, the intensity of fishing, the power or strength of the vessel engine used for fishing and it also related to fish size, fish behavior and habitat conditions (Saputra 2009).

Conclusions. Our results confirmed the status of the rate of exploitation that is found below exploitation limit, while the natural mortality rate was greater than the mortality rate due to fishing activity. The total length of Devis' anchovy ranged from 68 to 74 mm. The distribution mode of the total length of anchovies caught ranging from 68 to 74 mm was caught in October and November. The value of L_∞ was 130.2 mm, half of L_∞ 65.1 mm, the size of fish first caught $Lc_{50\%}$ 51.56 mm. Based on the result of $Lc_{50\%} < ½L_\infty$, it could be indicated that the fish caught is still too small or not worth catching. The equation of the relationship between the length of Devis' anchovy weight and its growth showed positive allometric. Growth parameters indicated the value of L_{max} or the maximum length 122.0 mm. The amount of K was 1.3 $year^{-1}$, and the value of t was -0.081. The Von Bertalanffy equation was $130.2(1\text{-}e^{\{-1.3(t-(-0.081)\}})$.

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