

# Growth, mortality and exploitation rate of *Pampus argenteus*, *Parastromateus niger* and *Scomberomorus commerson* in Sebatik Waters, Indonesia

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**Abstract.** Salim G, Handayani KR, Indarjo A, Ransangan J, Atieqah N. 2020. Growth, mortality and exploitation rate of *Pampus argenteus*, *Parastromateus niger* and *Scomberomorus commerson* in Sebatik Waters, Indonesia. *Biodiversitas* 21: 5363-5372. The economic revenue of the local government of the Indonesian Sebatik Island relies much on the exploitation of its rich marine biodiversity. One of the important economic activities is the capture fisheries of commercially important fishes such as the white pomfret (*Pampus argenteus*) and black pomfret (*Parastromateus niger*), and mackerel fish (*Scomberomorus commerson*). The current study aims to estimate the growth, condition factor, and exploitation rate of the fish species for developing sustainable fishery management. Fish samplings were conducted in the Sebatik Waters, Nunukan District, North Kalimantan Province, Indonesia from June to July 2020. The fish were caught using gillnet at daytime (pomfrets) and nighttime (mackerel), respectively. Then, 82, 73, and 83 specimens of white pomfret, black pomfret, and mackerel were randomly selected for the length-weight relationship, condition factor, and exploitation rate analysis, respectively. The results revealed that the size distribution of the white pomfret population in the coastal waters of Sebatik Island ranged from 220.0 to 351.0 mm, black pomfret ranged from 231.0 to 362.0 mm and mackerel, ranged from 242.0 to 432.0 mm. All the fish species exhibited negative allometric ( $b < 3$ ) weight and length relationship with moderate to strong correlation. About 50% and 53.42% of the white pomfrets and black pomfrets were characterized by thin body shape. However, 49.40% of the mackerels were characterized by fat body shape. The asymptotic length ( $L_{\infty}$ ) for white pomfrets was recorded at 359.133 mm; k value of 0.0427 mm/year with r-value of 0.9918 and the  $t_0$  value of 1.11/year. For black pomfret, the  $L_{\infty}$  was estimated at 370.22 mm; k value of 0.043 mm/year with r-value at 0.9919 and the  $t_0$  value of 1.104/year. For mackerel, the  $L_{\infty}$  value was estimated at 492.724 mm, k-value of 0.0246 mm/year with r-value of 0.9634, and the  $t_0$  value of 1.322/year. The total mortality, fishing mortality and natural mortality (Z, F, and N, respectively) and exploitation rate (E) for white fish were recorded at 113.76%, 80.58%, 33.18%, and 70.83%, respectively. For black pomfret, it recorded 113.15% (Z), 79.97% (F), 32.75% (N) and 70.67% (E). For mackerel, it recorded 109.87% (Z), 66.29% (F), 43.58% (N) and 60.33% (E). The high exploitation rate (>50%) and fishing mortality (>60%) of all the fish species analyzed in this study indicate that there is a sign of overfishing to these fish resources in the coastal waters of Sebatik island. Hence, sustainable fishing management is timely needed to prevent depletion of these important fishery resources. Such management can include fishing restrictions for small-sized and first mature fish, close fishing season, and strict requirement for fishing permits.

**Keywords:** Fisheries management, overfishing, population, population depletion

## INTRODUCTION

Nunukan District is one of the districts located in the northern region of North Kalimantan Province, Indonesia. It is directly adjacent to Sabah, Malaysian Borneo and subdivided into several districts. Sari and Sujarwoto (2019) stated that the area of Nunukan District consists of 19 sub-districts in 2019. Nunukan District has one outer island, Sebatik Island. Sebatik Island is one of the 92 outermost small islands located in the North Kalimantan Province which directly adjacent to neighboring countries, namely Malaysia and Philippines. Sebatik Island is divided into two, the northern and the southern Sebatik Island. The northern part has belonged to Malaysia whereas the

southern part-owns by the Nunukan District, Indonesia. In term of area, the Malaysian Sebatik Island covers 187.23 km<sup>2</sup> while the Indonesian Sebatik Island has a coverage 246.61 km<sup>2</sup> (Pemerintah Kabupaten Nunukan, 2002).

The economic potential of the Indonesian Sebatik Island relies on its rich marine resources. Capture fishery is the main economic activity of the community on that island. This activity contributed about 302,356.58 tons of fish to the Nunukan District in 2016 (BPS Kabupaten Nunukan, 2017). Major part of this production is exported to neighboring countries, particularly Malaysia. The main targets of this capture fishery in Sebatik Island are the white pomfret (*Pampus argenteus*) and black pomfret (*Parastromateus niger*). However, other bycatches such as

grouper (*Epinephelus* spp), trevally fish (*Caranx* spp), red snapper (*Lutjanus* spp), sea catfish (*Arius thalassinus*), and mackerel (*Rastreliger* sp.) (Khaerudin, 2006) are also quite significant. Many of the targets species are demersal fish (e.g. white pomfret and black pomfret) which often live and feed on at the bottom of the water or in the water column near the coast to the depth of 100 m (Prihatiningsih et al. 2015; Hikmawansyah et al. 2019; Nugraeni et al. 2019). In addition to demersal fish, mackerel (*Scomberomorus commerson*), a large pelagic fish belonging to the Scombridae family (Randall, 1995) is also targeted for gill net fishing in the island.

From an economic viewpoint, pomfrets are highly demanded fish and have attractive prices. For example, the price for white (*P. argenteus*) is around Rp. 150,000.00/kg or USD10.18/kg while black pomfret fish (*Ps. niger*) is slightly lower at Rp. 100,000/kg or USD6.79/kg (Prihatiningsih et al. 2015). Mackerel (*S. commerson*) also has a good price at Rp. 60,000/kg or USD4.07/kg (Noegroho et al. 2018). Generally, frozen pomfret fish are exported to China, Korea, Japan, Malaysia (Nugraeni et al. 2019), Singapore and Thailand. Black pomfret (*Ps. niger*) is also quite expensive at Rp. 140,000/kg but this fish is rarely caught in the Indonesian Sebatik Island. Because of high demand and attractive prices, these fish resources often became the target for unsustainable fishing activity. Hence, sustainable management of these fishery resources is needed.

Unlike in Kuwait (Morgan et al. 1985), China (Shu and Qiu 2005), Bangladesh (Mustafa 1993; Mustafa 1999), Iran (Alit 2001; Mohamed et al. 2008; Narges et al. 2011; Hashemi et al. 2012, Iraq (Nukpi 1996; Salari 1996; Parsamanesh et al. 2003; Mohamadi et al. 2005), Korea (Lee and Kim 1992), Tarakan Waters (Prihatiningsih et al. 2015; Laga et al. 2017), Oman Sea (Parsa et al. 2017), In Pangandaran Waters (Hikmawansyah et al. 2019), in Paloh Waters in West Kalimantan (Damora et al. 2018), the

growth characteristics of pomfret fish in the Indonesian Sebatik Island are yet to be studied.

Therefore, the present study was conducted to analyze the levels of fish mortalities, exploitations, and growth characteristics of white pomfret (*P. argenteus*), black pomfret fish (*Ps. niger*), and mackerel (*S. commerson*) in the coastal waters of Sebatik Island, North Kalimantan, Indonesia.

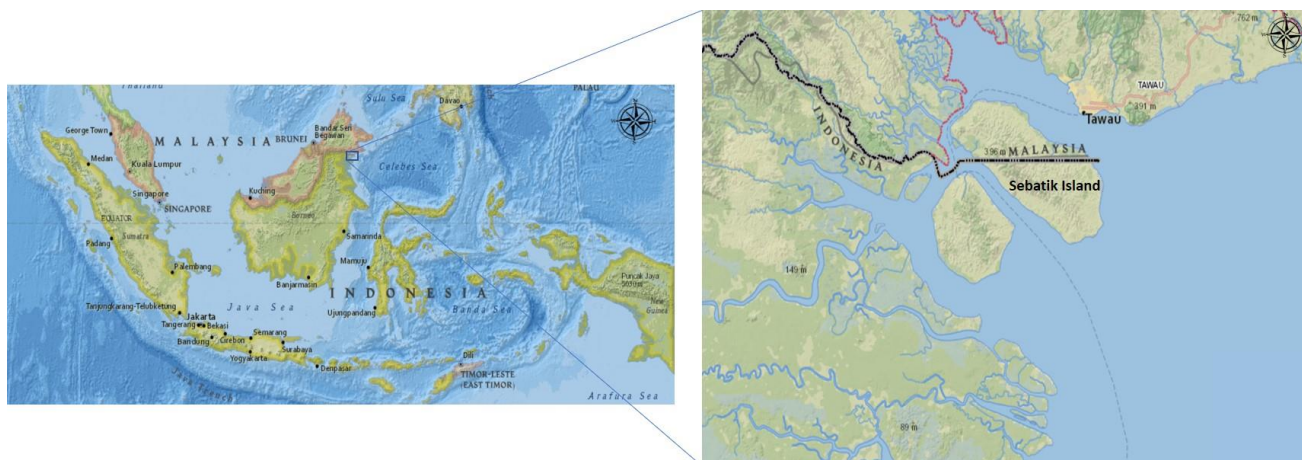
## MATERIALS AND METHODS

### Sampling site

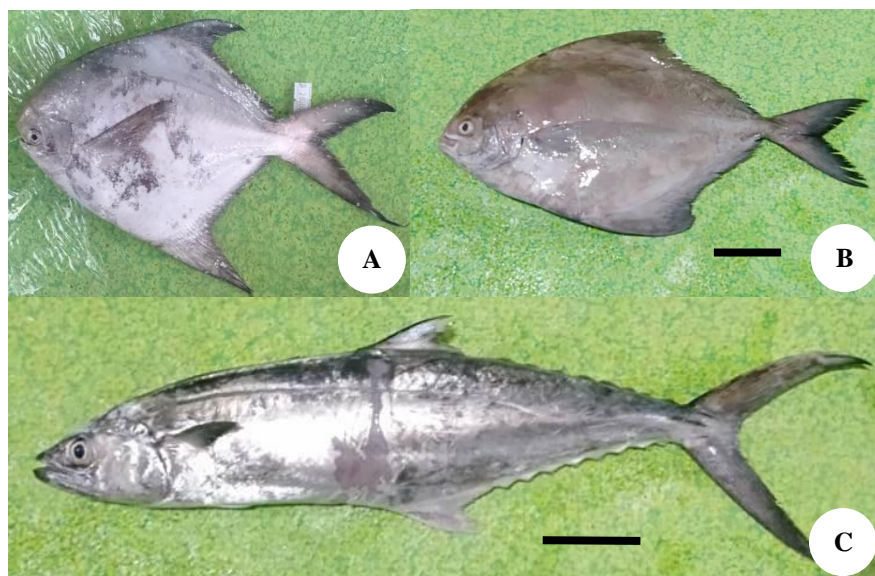
This study analyzed fish specimens of three different species, namely white pomfret, black pomfret, and mackerel which were obtained from fishermen's catch in the Sebatik Waters, Nunukan District, North Kalimantan Province, Indonesia. Samplings were conducted 4 times (June 13<sup>th</sup>, June 26<sup>th</sup>, July 17<sup>th</sup>, and July 30<sup>th</sup>) during the 2 months sampling period starting June 2020 to July 2020 following the purposive sampling method following Prasetyo et al. (2020). The samplings were done at the two predetermined fishing grounds around the Indonesian Sebatik Island using gillnets (Figure 1). The two fishing grounds are the waters within Tanjung Harapan to Batulamampu (4°9'23"N; 117°57'55"E) and the waters within Taiwan River to Cape Aru (4°2'64"N; 117°64'48"E). The samplings for pomfrets were done during daytime whereas samplings for mackerels were carried out at night.

### Data collection

Throughout the sampling period, 82, 73, and 83 individuals of white pomfret, black pomfret, and mackerel (Figure 2) were randomly selected from the fishermen catches for analyses. Then, the total length and total weight of each fish specimen were measured by using the measuring tape and electric balance, respectively. After that, the length sizes were distributed into 10 size classes.



**Figure 1.** Study site in map of Indonesia (left); Sebatik Island (right)



**Figure 2.** Specimens collected from fishermen operating in the coastal water of Sebatik Island, Indonesia. A. white pomfret (*P. argenteus*); B. Black pomfret (*Ps. niger*); C. Mackerel (*S. commerson*). Bar = 5 cm

## Data analysis

### Length-weight relationship

The length-weight relationship was calculated by the allometric growth formula as used by Ricker (1973) as follows:

$$W = aL^b$$

Where, W: stands for weight; L: length; a: is a constant; b: the exponent.

The equation was transformed into a logarithmic as suggested by Le Cren (1951) and expressed as:

$$\text{Log } W = \text{Log } a + b \text{ Log } L;$$

Where, a: constant being initial growth; b: growth coefficient. The values 'a' and 'b' were determined empirically.

### Condition factor and Relative condition factor

Condition factor of Ponderal index (K) each fish species were also determined by using the following formula:

$$K = 10^5 \times \frac{W}{L^3}$$

Where, K: condition factor; W: mean weight of fish (g); L: mean length of fish (mm); the number  $10^5$  is the factor to bring the Ponderal index (K) near to unity (Walker and Carlander 1970).

Relative condition factor 'Kn' introduced by Le Cren (1951) was estimated by the following formula:

$$Kn = \frac{W}{\hat{W}}$$

Where, W: actual weight of fish (g);  $\hat{W}$ : expected weight of fish in gram (g). The  $\hat{W}$  was estimated from the logarithmic transformed of the allometric growth formula:

$$\text{Log } W = \text{Log } a + b \text{ Log } L$$

The condition index was then compared with the index suggested by Firdaus and Salim (2011), Salim (2013, 2015), Firdaus et al. (2018, 2020), and Indarjo et al. (2020).

### Estimation of absolute growth using Von Bertalanffy's Model

Absolute growth of the fish species was measured by using the Von Bertalanffy growth function (Sparre and Venema 1998) as follows:

$$L(t) = L_{\infty} (1 - e^{-k(t-t_0)})$$

Where, L (t): length of fish at age t (unit of time);  $L_{\infty}$ : the maximum length of fish (length asymptotic); K: fish growth coefficient (per unit time);  $t_0$ : fish theoretical age at zero length.

The variable age structure was estimated using the mode class shift method associated with the Von Bertalanffy growth function (Sparre and Venema 1998) as follows:

$$(\Delta L / \Delta t) = (L_2 - L_1) / (t_2 - t_1)$$

$$L(t) = (L_2 + L_1)$$

Where,  $\Delta L / \Delta t$ : relative growth of fish;  $\Delta L$ : fish length;  $\Delta t$ : time difference for taking fish samples; L (t): average length of the mode.

The linear equation,  $Y = a + bx$  of the age structure was established by plotting the values of L (t) and  $(\Delta L / \Delta t)$ .

Where,  $a = (\sum y/n) - (b (\sum x/n))$ ;  $b = (n \sum (xy) - (\sum x)(\sum y)) / (n \sum x^2 - (\sum x)^2)$

The average length value of the long mode uses the linear regression equation method to calculate the asymptotic length ( $L_\infty$ ) of the fish, namely  $-a/b$ , while the growth coefficient (K) is  $-b$ . The theoretical age of fish when the length is equal to zero was estimated separately using the empirical equation (Sparre and Venema 1998):

$$\text{Log}_{10} (-t_0) = -0.3922 - 0.275 \text{Log}_{10} L_\infty - 1.038 \text{Log}_{10} K$$

Where,  $L_\infty$ : asymptotic length of fish (mm); K: fish growth rate coefficient;  $t_0$ : theoretical age of fish at length equal to zero (year).

#### Estimation of mortality and exploitation level

The natural mortality (M) of the fish species was estimated using Pauly's empirical formula (Pauly 1984):

$$\text{Log}_{10} M = -0.0066 - 0.279 \text{log}_{10} L_\infty + 0.6543 \text{log}_{10} K + 0.4634 \text{log}_{10} T$$

Where, M: natural mortality;  $L_\infty$ : asymptotic length; K: growth coefficient; T: average surface temperature of the water.

Total mortality (Z) of the fish species was estimated using the Beverton and Holt's Z-equation (Sparre and Venema 1998; Sparre and Venema 1998):

$$Z = K \cdot \left[ \frac{L_\infty - \bar{L}}{\bar{L} - L'} \right]$$

Fishing mortality (F) of the fish was calculated by subtracting total mortality (Z) with natural mortality (M) as follows:

$$F = Z - M$$

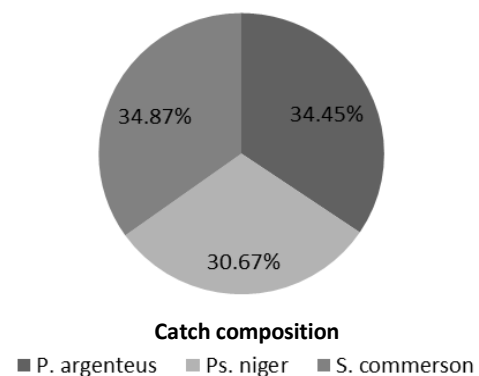
According to Pauly (1984), rate of exploitation (E) is ratio of fishing mortality (F) and total mortality (Z), and can be written as:

$$E = \frac{F}{F + M} = \frac{F}{Z}$$

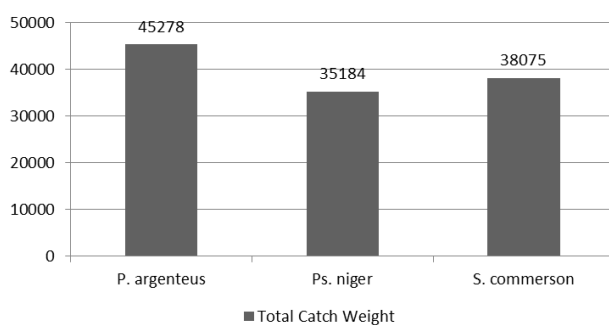
## RESULTS AND DISCUSSION

### Size structure

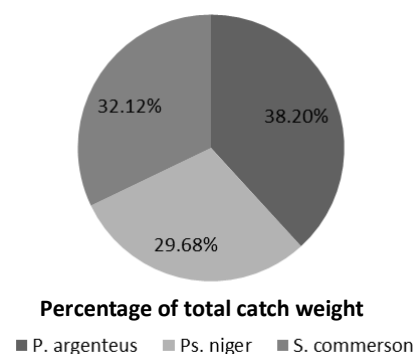
During the 2 months survey, it was noted that fishermen operating in the coastal waters of the Indonesian region of Sebatik Island were recorded able to capture 45,278 tons (38.2%) of white pomfret, 35,184 tons (29.68%) of black pomfret and 38,075 tons (32.12%) of mackerel (Figure 3). Out of these catches, 82 specimens of white pomfret (34.45%), 73 specimens of black pomfret (30.67%) and 83 specimens (34.87%) of mackerel were randomly collected (Figure 4) for size (length) distribution analysis, growth characteristics, estimation of fish mortalities and level of exploitation. The results indicated that the length distribution of the three fish species was narrow and concentrated within the 260 to 341 mm (Figure 5).



**Figure 4.** Percentage of fish specimens used for growth, mortalities and level of exploitation rate analyses

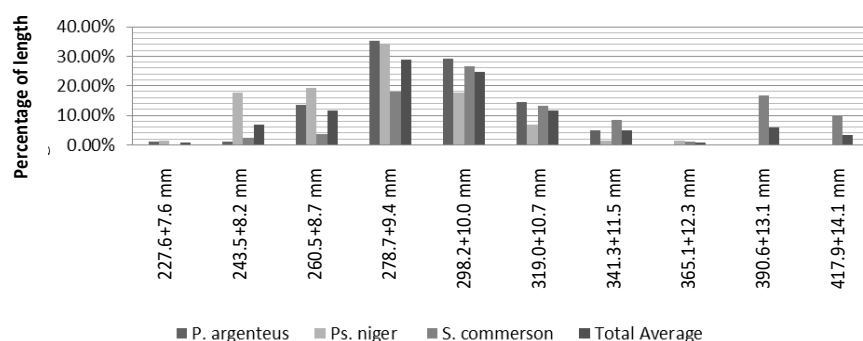


**A**

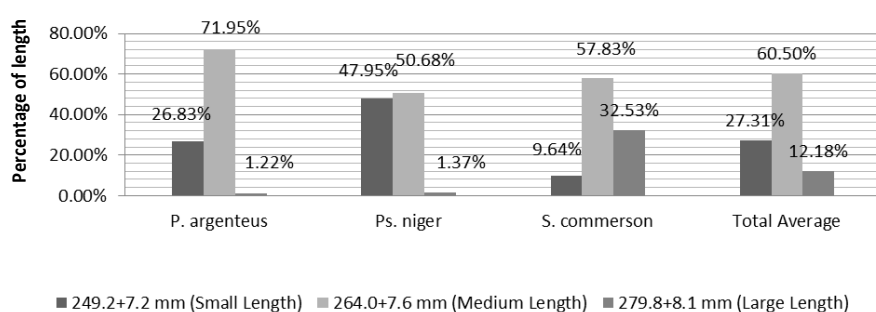


**B**

**Figure 3** Total catch weight (A) and percentage of total catch weight (B) of each fish species caught in the coastal waters of the Indonesian region of Sebatik Island during the two months sampling period



**Figure 5.** Percentage of length distribution of fish specimens (*P. argenteus*, *Ps. niger* and *S. commerson*) occurring in the coastal waters of the Indonesian region of Sebatik Island during sampling period



**Figure 6.** Percentage of size (length) distribution of the fish specimens (*P. argenteus*, *Ps. niger* and *S. commerson*) caught in the coastal waters of the Indonesian region of Sebatik Island, Indonesia

The white pomfret specimens were distributed within the size classes 220.0–351.0 mm ( $285.5 \pm 65.5$  mm;  $n=82$ ). However, the dominant size class was within the 277.9–291.1 mm ( $284.5 \pm 6.6$  mm) at 30.5%. Small portion (1.22%) of the fish specimens were felt within the 220–241.4 mm and 335–351 mm size class. As for black pomfret, they have distributed within the 231.0–362.0 mm ( $296.5 \pm 65.5$  mm;  $n=73$ ) size classes. Similar to black pomfret, the dominant size was within the 276.5–289.1 mm ( $282.8 \pm 6.3$  mm) at 24.7% but small amount of the black pomfret specimens (1.37%) were categorized within the 330.0–362.0 mm ( $346.4 \pm 15.6$  mm) size classes, respectively. According to Prihatiningsih et al. (2015), the size distribution of white pomfret in Tarakan city ranged from 90–350 mm (average  $179.3 \pm 180$  mm;  $n=1255$ ). According to Parsa et al. (2017), the size distribution of white pomfret (*P. argenteus*) in Iranian Waters ranged between 100 and 320 mm ( $199.7 \pm 1.2$  mm;  $n=1919$ ). Whereas the size distribution of white pomfret in Khuzestan Province (northwest the Persian Gulf) was recorded between 95 and 312 mm (Narges et al. 2011). Mohammadkhani and Shirangi (2013) reported the size distribution of *P. argenteus* in Oman Sea to range from 150 to 350 mm. Hikmawansyah et al. (2019) also reported that the size distribution of white pomfret in Pangandaran Waters to range between 193 and 368 mm. Damora et al.

(2018) reported the size distribution for *P. argenteus* in Paloh Waters, West Kalimantan was from 120 to 450 mm. Thus, the size distribution of the white pomfret in Sebatik island is within the range and agreed to the records obtained elsewhere.

The mackerel fish in Sebatik island ranged from 242.0 to 432.0 mm ( $337.0 \pm 95$  mm;  $n=83$ ). The majority (21.69%) of the fish specimens were felt under the 287.9–305.0 ( $296.5 \pm 8.5$  mm) size class. However, small portion of the fish (2.41%) were in the 256.4–271.6 mm ( $264.0 \pm 7.6$  mm) size class. According to Noegroho et al. (2018), the size distribution of mackerel fish in Kwandang Bay, Sulawesi Sea was recorded to range from 250 and 1380 mm ( $n=5248$ ).

It is obvious in the present study that the size distribution of the three fish species important to fishery sector in Sebatik Island was categorized into three size classes (Figure 6) which are small ( $249.2 \pm 7.2$  mm), medium ( $264.0 \pm 7.6$  mm), and large ( $279.8 \pm 8.1$  mm). However, the dominant size class for white pomfret (71.95%), black pomfret (50.68%), and mackerel (60.5%) was the medium size class. It is also interesting to note that small portion of the white pomfret (1.22%), black pomfret (1.37%), and mackerel (9.64%) were grouped within the large size class category (279 mm), respectively.



**Table 1.** Allometric Growth and correlation

Sample of fish	Allometric growth			
	Number of fish specimens	b	r <sup>2</sup>	r
<i>P. argenteus</i>	82	2.7303	0.2515	0.5015
<i>Ps. niger</i>	73	1.9697	0.197	0.444
<i>S. commerson</i>	83	0.6309	0.262	0.512

### Allometric growth

The present study revealed (Table 1) that the growth of the three fish species was described as negative allometric growth (value  $b < 3$ ), with a strong correlation value for white pomfret ( $r = 0.5015$ ) and mackerel ( $r = 0.512$ ) but moderately for black pomfret ( $r = 0.444$ ). According to Prihatiningsih et al. (2015), the exponential equation of the length-weight relationship of white pomfret in the waters of Tarakan was characterized as allometric negatively ( $b = 2.374$  and  $r = 0.916$ ). This is in agreement to Laga et al (2017) who suggested both male and female pomfrets exhibit negative allometric growth (male  $b = 0.334$ ;  $r = 0.962$  and female  $b = 0.335$ ;  $r = 0.963$ ). Hikmawansyah et al. (2019) also reported negative allometric growth for the white pomfret in Pangandaran Waters ( $b = 2.371$ ;  $r = 0.9332$ ). For mackerel, the result of present study was contrary to the result of Weng et al. (2020) who reported a positive allometric growth with very strong correlation for mackerel fish in Central Taiwan Street ( $b > 3$ ,  $r = 0.754$ ;  $n = 110$ ). The differences in the level of correlation between length and weight in fish could be due to both internal (intrinsic) and external (extrinsic) factors which are generally difficult to control. The internal factors include sex, age, parasites, and diseases whereas the external factors include food (Mommensen 1998) and water temperature (Effendie 2002; Prihatiningsih et al. (2015); Indarjo et al. 2020). However, Ecoutin and Abaret (2005) and Hamid et al. (2015) did suggest that number of samples ( $< 30$  specimens) and sampling procedure can also affect the  $b$  values and length-weight relationships of fish species. In the present study, it is difficult to ascertain if the sampling influenced the  $b$  values and the correlation

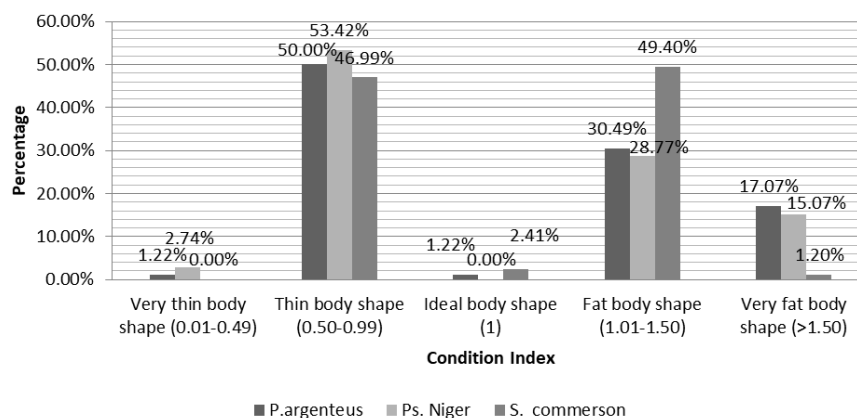
strength between length and weight. In addition, removal of fish specimens via overfishing may also affect this relationship.

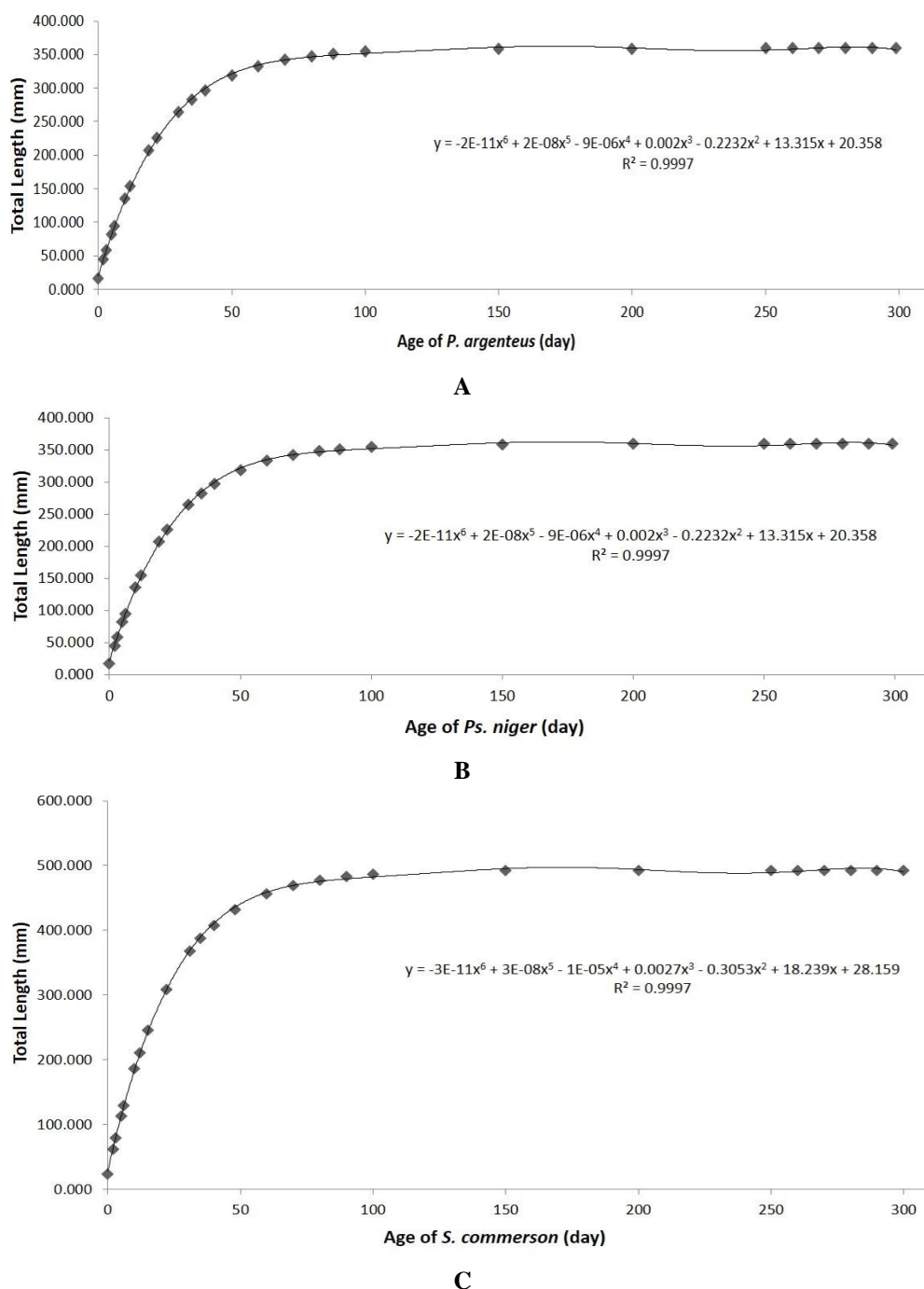
### Condition index

Analysis of condition index of the white pomfret revealed that the fish population consisted of 5 different body shapes namely very thin, thin, proportional, fat and very fat. This shows that the population of white pomfret in the coastal waters of Sebatik Island has a balanced distribution in terms of condition index (body shape). The same observation was noted for black pomfret, except it did not record fish with proportional body shape. As for mackerel, no specimens were noted within the thin body shape category. It also appears that the population of white pomfret (50%) and black pomfret (53.42%) in the coastal waters of Sebatik Island were dominated by fish specimens within the thin body shape category. For mackerel, 49.40% of the population was characterized by very fat (obese) body shape category (Figure 7). The observation on the condition index of white pomfret in waters of Sebatik island was different from Tarakan waters because the fish population in that area was dominated by very fat body shape category. The differences in the condition index of the fish analyzed in this study may be due to the availability of foods in the habitat and differences in gonad development among fish (Gupta et al. 2011).

### Von Bertalanffy's growth

From Von Bertalanffy's growth model, the maximum length and the average growth rate of the three fish species were successfully estimated (Figure 8). It was estimated that the white pomfret can grow to maximum length of  $L_{\infty}$  359.133 mm with a growth rate ( $k$ ) of 0.0427mm/year with a correlation value of 0.9918 and a value ( $t_0$ ) of 1.11/year. Black pomfret fish obtained an  $L_{\infty}$  growth of 370.22 mm with a growth speed ( $k$ ) of 0.043 mm/year with a correlation value of 0.9919 and a value ( $t_0$ ) of 1.104/year. Mackerel fish obtained an  $L_{\infty}$  growth of 492,724 mm with a growth speed ( $k$ ) of 0.0246 mm/year with a correlation value of 0.9634 and a value ( $t_0$ ) = 1.322/year.

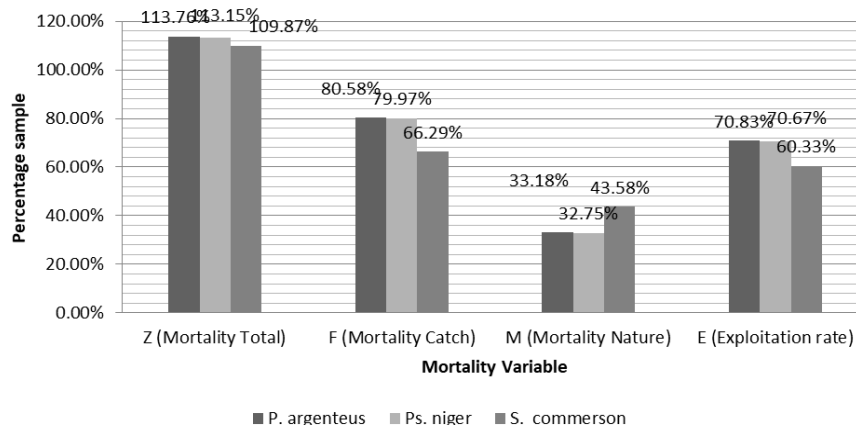
**Figure 7.** Percentage of fish specimens according to index condition



**Figure 8.** Von Bertalanffy growth models. A. *P. argenteus*; B. *Ps. niger*; C. *S. commerson*

Narges et al. (2011) estimated the  $L_{\infty}$  of *P. argenteus* in the northern Persian Gulf to be 339 mm. According to Prihatiningsih et al. (2015), the white pomfret (*P. argenteus*) in Tarakan waters exhibited a growth coefficient ( $k$ ) = 0.052 mm/year;  $L_{\infty}$  growth of 372.8 mm, and the value ( $t_0$ ) = 0.07/year. Parsa et al (2017) calculated the maximum length ( $L_{\infty}$ ) of white pomfret in Java sea to be = 325.5 mm, ( $t_0$ ) = 0.54/year, the  $k$  value was 0.3/year. According to Hikmawansyah et al. (2019), the growth of white pomfret in Pangandaran waters characterized by asymptotic length ( $L_{\infty}$ ) of 530.4 mm with a growth

coefficient ( $K$ ) value equal to 0.026mm/year. According to Damora et al. (2018), the *P. argenteus* from In Paloh Waters, West Kalimantan exhibited maximum length of  $L_{\infty}$  = 462 mm, ( $t_0$ ) = 0.88/year, the  $k$  value was 0.53/year. According to Ballagh et al. (2006), maximum length ( $L_{\infty}$ ) of mackerel fish originating from the east coast of Queensland, Australia, was estimated to be 1047 mm (male) and 1248 mm (female) with a growth rate ( $k$ ) of 0.075mm/year (male) and 0.051 mm/year (female) with a value ( $t_0$ ) of -0.18/year (male) and 0.39/year (female).



**Figure 9.** Percentage of total mortality, fishing mortality, natural mortality and exploitation rate of *P. argenteus*, *Ps. niger*, and *C. commerson* in the coastal waters of the Indonesian region of Sebatik Island, Indonesia

According to Lessa and Duarte-Neto (2004); Damora and Wagiyo (2012); Damora and Baihaqi (2013) the  $L_{\infty}$  and  $k$  values are highly dependent on data, including age and growth. The variations in  $L_{\infty}$  and  $K$  values (Pauly 1984) in various fishing grounds of white pomfret could be due to the differences in ecology, fish physiological conditions, feeding variability, fishing pressure, and sampling methods (Azis et al. 1992; Biswas 1993; Taghavi Motlagh et al. 2010; Prihatiningsih et al. 2015). This is in accordance with the opinion of Sparre and Venema (1998) whereby they explained that the differences in  $K$  values can also be caused by aquatic environmental conditions. In addition, Widodo (1988) and Ecoutin and Abaret (2005) suggested that the difference in the value of growth parameters is also influenced by the composition of the fish specimens due to variations in method used. If a lot of young fish are caught, the growth coefficient is high and if the older fish are caught, the growth coefficient is low (Widodo 1988). Rumondang (2016) noted that fish can still experience growth (e.g. length) even though the environmental conditions are unfavorable.

Based on the Von Bertalanffy growth model analysis using the orthogonal polynomial type 6 model, the growth of white pomfret can be expressed as  $y = -2E-11x^6 + 2E-08x^5 - 9E-06x^4 + 0.0002x^3 - 0.2232x^2 + 13.315x + 20.358$  with  $R^2$  of 0.9997 and the correlation value of 0.9999 (Figure 8.A). The orthogonal polynomial equation model type 6 of the black pomfret is expressed as  $y = -2E-11x^6 + 2E-08x^5 - 9E-06x^4 + 0.002x^3 - 0.2232x^2 + 13.315x + 20.358$  with  $R^2$  of 0.9997 and a correlation value of 0.9999 (8.B). The orthogonal polynomial equation model type 6 of mackerel was  $y = -3E-11x^6 + 3E-08x^5 - 1E-05x^4 + 0.0027x^3 - 0.3053x^2 + 18.239x + 28.159$  with an  $R^2$  of 0.9997 and a correlation value of 0.9999 (8.C). Correlation analysis revealed that the length and average growth of the three fish species analyzed in this study showed very strong correlation value and in agreement with Sarwono (2013).

#### Mortality and exploitation rates

According to Sparre and Venema (1998); Indarjo et al. (2020), mortality rate consists of four components, namely

the total mortality, the catch/fishing mortality, the natural mortality, and the exploitation rate. The results of the analysis of mortality and exploitation rates of the three fish species (white pomfret, black pomfret and mackerel) are presented in Figure 9. It was observed that the white pomfret experienced high total mortality rate (113.76%). This has been contributed by the high fishing mortality (80.58%), natural mortality (33.18%), and exploitation rate (E) of 70.83%. As for black pomfret, it estimated to experience 113.15% total mortality, 79.97% fishing mortality, 32.75% natural mortality, and exploitation rate (E) of 70.67%. Prihatiningsih et al. (2015) recorded total mortality (Z) of white pomfret at 276%, fish mortality (F) of 165%; natural mortality (M) of 111%, and the exploitation rate (E) of 60%. Parsa et al. (2017) also estimated 155%/year total mortality, 75%/year natural mortality, 78%/year fishing mortality, and exploitation rate of 51%. According to Hikmawansyah et al. (2019), the estimated total mortality rate of white pomfret in Pangandaran waters was 60%/year, 364%, 304%, and 84%, respectively. The white pomfret from Paloh waters, West Kalimantan (Damora et al. 2018) also exhibited high total mortality (168%/year), fishing mortality (121%), natural mortality (47%), and exploitation rate of 72%.

Mackerel was estimated to experience 109.87% total mortality, 66.29% catch mortality, 43.58% natural mortality, and 60.33% exploitation rate. Worrisome, the exploitation rate of each fish species was exceeded the 0.5 (50%) threshold which indicates that the fish are overfished. The results of current study differ from the study of Yuliana and Nurhasanah (2017) whereby the recorded exploitation rate of mackerel (*S. commerson*) at Karimunjawa National Park (KNP) to experience low exploitation of 0.29 (under-exploited). This could be that the fish are somehow protected within the part area. Prihatiningsih et al. (2015) reported that the white pomfret population in Tarakan, East Kalimantan to have higher exploitation rate ( $>0.5$ /year) which indicate that the fish is under tremendous fishing pressure hence it was suggested that better policy for fishery management of the white pomfret in this area should be established. Patterson (1992)



reported that even at the exploitation level of 0.5, fishing activity still has the tendency to reduce fish stock abundance. Hence, the author suggested the optimal exploitation level should be maintained at 0.4 in order to prevent stock depletion.

The present study revealed that size distribution of the white pomfret population in Indonesian waters of Sebatik island ranged from 220 to 352.7 mm whereas the black pomfret population ranged from 220.0 to 377.4 mm. For mackerel, it ranged from 235.4 to 432.0 mm. All the three fish species exhibited negative allometric ( $b < 3$ ) weight and length relationship with moderate to strong correlation. About 50% and 53.42% of the white pomfret and black pomfret were characterized by thin body shape. However, 49.40% of mackerel were characterized by fat body shape. The asymptotic length ( $L_{\infty}$ ) for white pomfret was recorded at 359.133 mm; k value of 0.0427 mm/year with r-value of 0.9918 and the  $t_0$  value of 1.11/year. For black pomfret, the  $L_{\infty}$  was estimated at 370.22 mm; k value of 0.043 mm/year with r-value at 0.9919 and the  $t_0$  value of 1.104/year. For mackerel, the  $L_{\infty}$  value was estimated at 492.724 mm, k-value of 0.0246 mm/year with r-value of 0.9634 and the  $t_0$  value of 1.322/year. The mortalities (Z, F and N) and exploitation rate (E) for white pomfret were recorded at 113.76%, 80.58%, 33.18% and 70.83%, respectively. For black pomfret, it recorded 113.15%, 79.97%, 32.75% and 70.67%, respectively. For mackerel, it recorded 109.87%, 66.29%, 43.58% and 60.33%, respectively. The high exploitation rate ( $>50\%$ ) and fishing mortality ( $>60\%$ ) of all the fish species analyzed in this study indicate that there is a sign of overfishing of these fish resources in the coastal waters of Sebatik island. Hence, sustainable fishing management such as fishing restriction to small-sized and first mature fish, close fishing season and strict requirement for fishing permit, is timely needed to prevent depletion of these fishery important species in the coastal waters of Sebatik island.

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