

Size structure and growth parameters of striped eel catfish (*Plotosus lineatus*) in Kolono Bay, Southeast Sulawesi, Indonesia

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Abstract. Striped eel catfish, *Plotosus lineatus* is one of the important fish resources in Kolono Bay waters, Southeast Sulawesi, Indonesia. The exploitation of this fish species in Kolono Bay is currently at an alarming rate, signaling immediate sustainable capture management and stock assessment efforts. These management efforts need baseline information on the dynamic population of the species, including its size structure and growth parameters which are currently unavailable for the Kolono Bay region. Therefore, this study investigated the structure size and growth parameters of striped eel catfish in Kolono Bay, Southeast Sulawesi, Indonesia. The research has been conducted in Kolono Bay from April to August 2019. The fish were collected using bottom gillnets with mesh sizes of $\frac{3}{4}$, $1\frac{1}{4}$, $1\frac{3}{4}$, and 2 inches. The growth parameters of the striped eel catfish population were calculated using the Von Bertalanffy equation within the ELEFAN I module of the FISAT II software package. The total number of fish collected were 616 fish ranging from 50 to 254 mm in total length and 1.02-123.40 g in weight. The striped eel catfish populations in Kolono Bay had two cohorts and were dominated by juveniles (62.01%). The length-weight correlation of male-female showed a positive allometric growth pattern. The female population was in better condition than the male population. The equation growth, based on Von Bertalanffy, was $L_t = 251.89\{1 - e^{-0.27(t+0.02)}\}$. The maximum total length reached 251.89 mm when the striped eel catfish was about 2.4 years old.

Key Words: Kolono Bay, nursery ground, *Plotosus lineatus*, positive allometric.

Introduction. Striped eel catfish, *Plotosus lineatus* of the family Plotosidae, known as 'lele laut' or 'sembilang' in Indonesia, is one of the target species by small-scale fishermen (Ball & Rao 1984; Jumiati et al 2017; Muhajirah et al 2018). As an important fishery resource, the fish is traditionally and nationally traded across the Indonesian region and serves as an important source of protein for many coastal communities. Striped eel catfish contains highly essential amino acid nutrients for human health (Manikandarajan et al 2014) such as monounsaturated fatty acid (MUFA), 1.37%; polyunsaturated fatty acids (PUFAs ω -6), 18.0%; PUFA ω -3, 32.0% (Osman et al 2001; Sahena et al 2009); and other PUFAs, 34.0%. These essential amino acids have important roles and usages in pharmaceutical products, food additives, food supplements, and antioxidants (Ray et al 2014). Eel catfish meat also contains carbonate 3.26 mg g^{-1} , protein 14.69 mg g^{-1} , and fat 1.48 mg g^{-1} (Suganthi et al 2015).

In Southeast Sulawesi's waters, striped eel catfish have been exploited by fishermen for decades. However, the current high level of exploitation fueled by an increasing demand has reduced its wild fish population. Several fish species also experienced similar cases in Southeast Sulawesi such as ornate threadfin bream *Nemipterus hexodon* (Asriyana & Sjafei 2012), sulfur goatfish, *Upeneus sulphureus* (Asriyana & Irawati 2018), twobloch ponyfish *Nuclepoma blochii* (Asriyana et al 2018), rivulated parrotfish-*Scarus rivulatus* (Aswady et al 2019; Dayuman et al 2019) and eel catfish in various regions (Mijkherjee et al 2002; Hossain & Alam 2015). Such a condition requires proper resource management strategies to ecologically and economically maintain the population of the fish. These efforts need prerequisite information on the

dynamic population of the species including its size structure and growth parameters for effective management of the fish as an aquatic resource.

Currently available literature and research are limited regarding striped eel catfish, especially for information of its habitat and distribution (Gomon 1984; Unsworth et al 2007), food (Gomon 1984; Lee et al 2012), reproductive biology (Sinha 1981; Khan et al 2002; Fatah & Asyari 2011; Usman et al 2012), and the length-weight correlation (Harteman 2015; Ya et al 2015). This study tried to fill these gaps of knowledge by investigating the size structure and growth parameters of striped eel catfish in Kolono Bay, Southeast Sulawesi, Indonesia. The results from this study serve as important baseline information in managing striped eel catfish resources in Kolono Bay.

Materials and Methods

Research site. The research was conducted in Kolono Bay, Southeast Sulawesi from April to August 2019. The bay is located between latitudes of 4°20'35"-4°27'30" S and longitudes of 122°39'55"-122°47'49" E (Figure 1). Three sampling stations were purposively placed to geographically represent the distribution of the striped eel catfish populations in Kolono Bay. Station I was located close to the river mouth on the upper bay and adjacent to mangrove and coral reef ecosystems. Station II was adjacent to mangrove, seagrass, and coral reef ecosystems in the middle of the bay. Station III was positioned near the mouth of the bay but still close to mangrove and coral reef ecosystems.

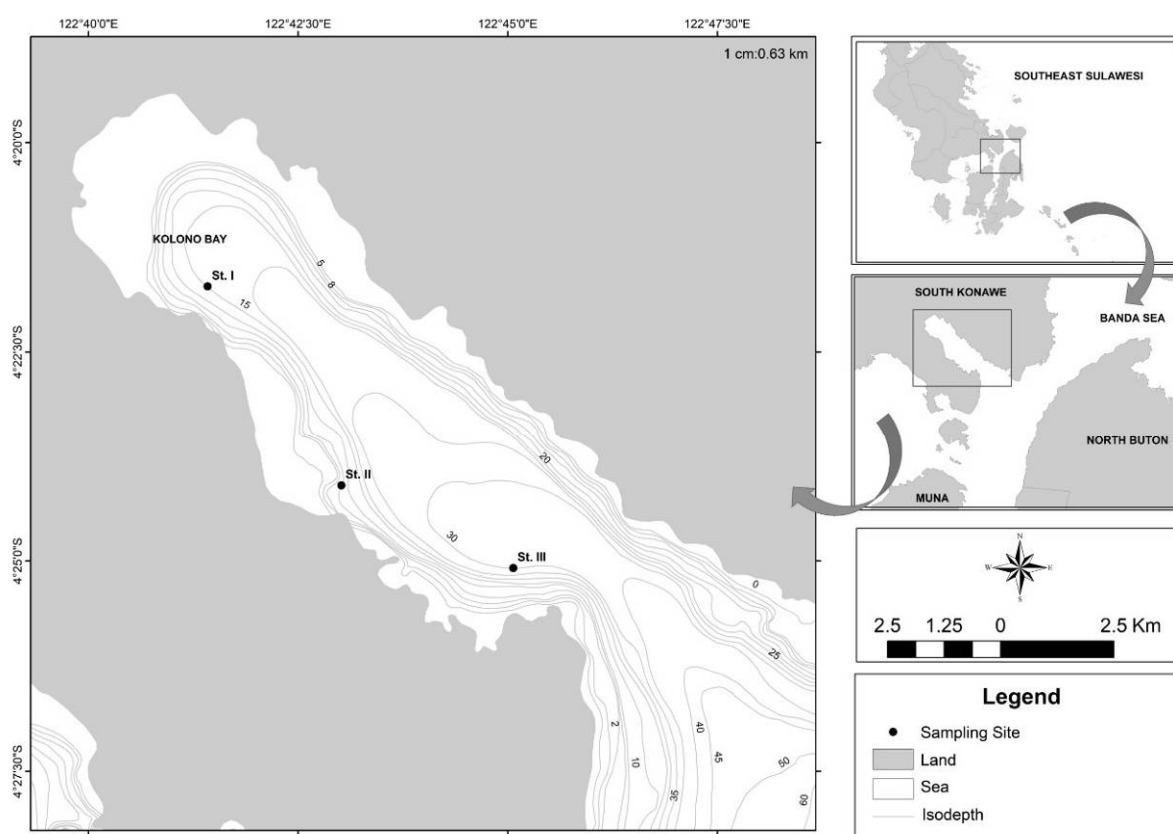


Figure 1. Location of Kolono Bay and sampling area.

Fish collection. Fish samples were collected using bottom gillnets made from nylon monofilament with mesh sizes of $\frac{3}{4}$, $1\frac{1}{4}$, $1\frac{3}{4}$, 2, and 3 inches. The length of each gillnet was 80 m. The sampling was carried out every month in the three stations for five months. The net was set under the water surface down to 1.5 to 3 m deep during low tide and lifted at the highest level of high tide. Trapped fish were collected and identified following the sampling procedures of Allen (1999), Carpenter & Niem (1999), Kuitert &

Tonozuka (2001), and Froese & Pauly (2019). All samples were kept in cool boxes for further analysis in the laboratory. In the laboratory, fish samples were measured for their total length (TL), which is the length of the fish from the tip of its nose to the end of the longer lobe of its caudal fin using a scale with an accuracy of 1 cm fish gauge. The weight was determined using a scale with an accuracy of 0.1 g. The samples of male and female fish were separated based on gonad morphology due to the absence of striped eel catfish secondary sexual characteristics (Heo et al 2007).

Data analysis. Fish size was determined based on the length-frequency analysis using the Bhattacharya method in the FISAT II program package (Gayanilo et al 2005). The length-weight relationships (LWRs) were calculated using the equation of Le Cren (1951), Tesch (1971), Ricker (1975), Froese (2006), Asriyana (2015), and Oladipo et al (2018):

$$W = a L^b$$

where W is the weight of fish (g); L is the total length of fish (mm); a, b are constants. To test whether the value of b = 3 or not, the statistical t-test was used. The value of b ≠ 3 means that the fish has an allometric growth pattern, whereas if b = 3 means the fish growth pattern is isometric (Sokal & Rohlf 1995). The Excel Microsoft Office v.10 was used in the analysis of the length-weight relationship.

The ponderal index (K) or condition factor was calculated based on the growth pattern of the length-weight relationship. If the growth pattern was isometric, then the ponderal index was calculated using equation 2 below (Hile 1936):

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

If the growth pattern was allometric, then the relative ponderal index was calculated following equation 3 (Hile 1936):

$$K_n = \frac{W}{a L^b}$$

where K_n is the relative ponderal index; W is the weight of fish (g); L is the total length of fish (mm); a, b is constant from length-weight relationship. The differences in the ponderal index values among times of sampling were determined using the non-parametric statistic Kruskal-Wallis with significance at 0.05 (Sokal & Rohlf 1995) in SPSS software ver. 16.0.

The growth of striped eel catfish was determined by the Von Bertalanffy equation (Sparre & Venema 1998):

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

where L_t is the length of fish at time t; L_{∞} is maximum length; k is coefficient of growth rate; t_0 is the theoretical age when $L = 0$; t is the time when length = L_t .

The growth parameters (K and L_{∞}) were analyzed using ELEFAN I (Electronic Length Frequency Analysis) program in the FISAT II program package (Gayanilo et al 2005), and the growth parameter t_0 was calculated by employing Pauly's empirical formula (Sparre & Venema 1998) as follows :

$$\text{Log}_{10}(-t_0) = -0.3922 - 0.2752 \text{Log}_{10} L_{\infty} - 1.038 \text{Log}_{10} K$$

Results

Size structure. The total number of striped eel catfish caught during the study was 616 individuals consisting of 501 males and 115 females. The length and weight of male fish ranged 50.00-254.00 mm and 1.02-123.4 g, respectively. The length and weight of female fish ranged 68.0-232.0 mm and 1.77-79.3 g, respectively. The fish were categorized into ten size groups (Figure 2). The group size of 70.0-89.99 mm was more dominant (62.01%) than the other groups, especially during the month of August for both males (287 individuals) and females (85 individuals). The fish size grouping based on the Bhattacharya method showed that the striped eel catfish population in Kolono Bay was divided into two size groups or cohorts (Table 1).

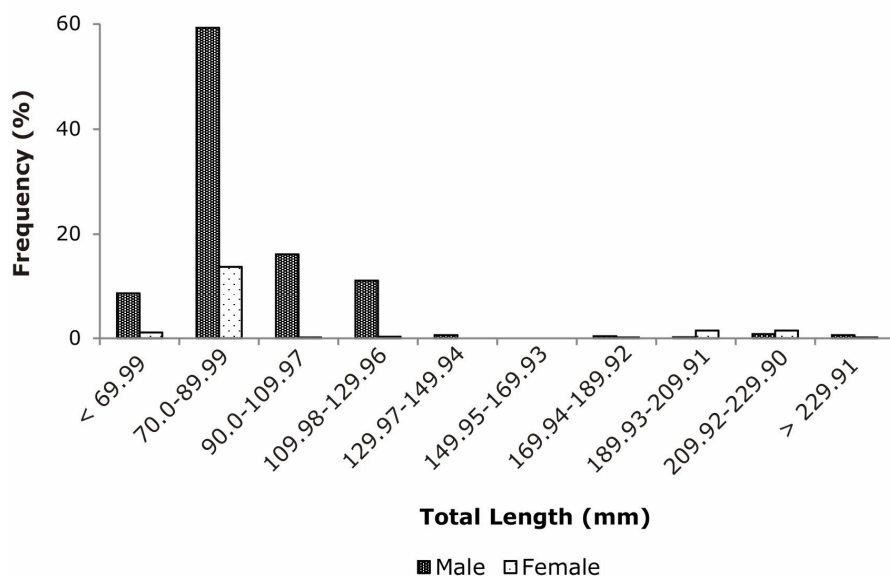


Figure 2. Distribution of striped eel catfish size in Kolono Bay.

Table 1

The group of striped eel catfish size in Kolono Bay

Cohort	Length (mm)	Computed mean (mm)	SD	Population estimate (individual)	Percentage (%)
I	50.00-129.90	80.86	10.88	557	95
II	169.90-249.90	211.52	18.31	32	5

SD = standard deviation.

Length-weight relationship. The length-weight relationship of striped eel catfish is shown in Figure 3. Based on the verification of 'b' values using the t-test, the striped eel catfish male and female had $b \geq 3$ (positive allometric growth pattern). The length-weight relationships of the male and female of striped eel catfish can be represented in the linear regression equations of $W = 2.10^{-6}TL^{3.23}$ and $W = 3.10^{-6}TL^{3.13}$, respectively.

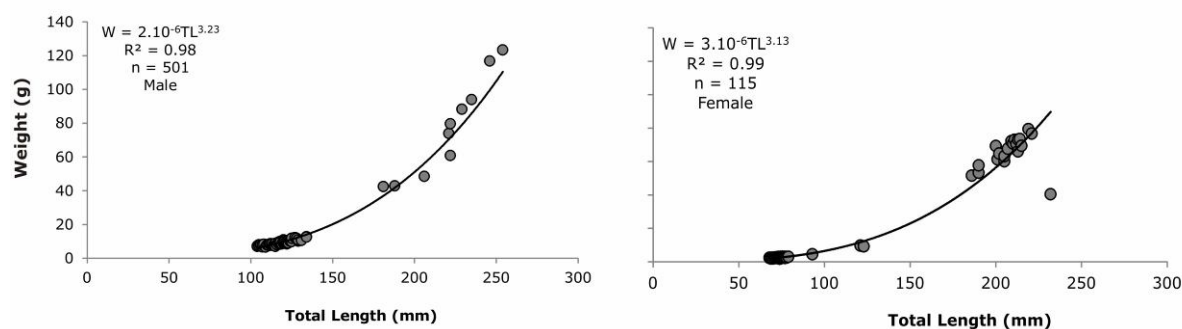


Figure 3. Length-weight relationship of striped eel catfish in Kolono Bay.

The ponderal index of striped eel catfish male and female relatively fluctuated during the observation period with the highest value found in July ($K = 1.29$ and $K = 1.27$, respectively) and the lowest in April ($K = 0.80$ and $K = 0.89$, respectively). The ponderal index values based on the sampling times showed significant differences (Kruskal-Wallis test) at the 95% confidence level ($p < 0.05$; $\alpha = 5\%$), as shown in Figure 4.

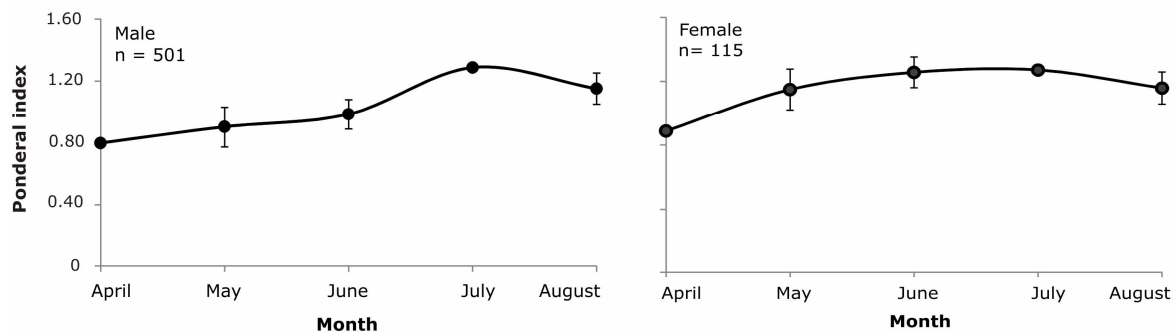


Figure 4. Ponderal index of striped eel catfish in Kolono Bay.

Growth parameters. The growth parameters, including growth coefficient (K), maximum length (L_{∞}), and theoretical age were 0.27 per year, 251.89 mm, and 0.02 year, respectively. The growth model of striped eel catfish based on the Von Bertalanffy equation is provided in Figure 5. Striped eel catfish in Kolono Bay had a maximum length of 251.89 mm achieved at 28 months with a growth rate of 0.27 per year.

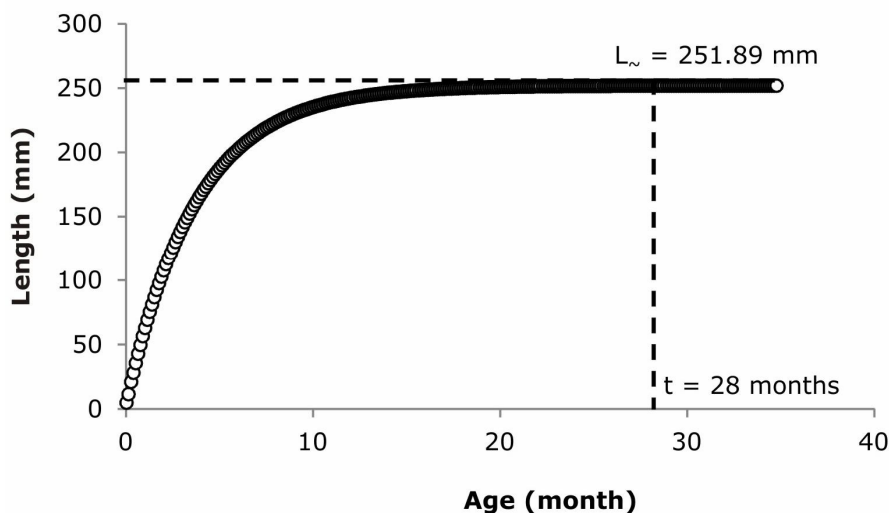


Figure 5. Growth curve of striped eel catfish in Kolono Bay.

Discussion. The average length of striped eel catfish caught in the waters of Kolono Bay was relatively shorter compared to some other locations (Table 2) and dominated by juveniles (Figure 2). The juveniles of striped eel catfish in Kolono Bay were predominantly found in the tidal area, similarly reported by Taylor & Gomon (1986) and Kuitert & Tono-zuka (2001) in Indonesia. The juveniles of striped eel catfish were generally found in estuary, tidal and open coastline areas in an aggregated dense formation consisting of 50 to 100 individuals.

Such a large concentration of juveniles within one area indicated that Kolono Bay might serve as a nursery area for the striped eel catfish population. The ideal ecological characteristics of Kolono Bay covered by mangrove vegetation might provide sufficient sources of food as well as protection from predators. Mangrove ecosystem is best known as a productive area suitable for many fish species during their nursery phase (Asriyana & Yuliana 2019). Mangrove ecosystem also serves as a protective area for fish juvenile where the complex formation of mangrove root system provides a safe environment from potential predators. Other studies such as Tongnunui et al (2002), Wang et al (2009), and Asriyana et al (2018) have reported relatively the same findings that the juveniles of striped eel catfish use the mangrove ecosystem as protection, nursery, and grow out area.

Table 2

The lengths range of striped eel catfish in several locations

<i>Species</i>	<i>Sex</i>	<i>Size range TL (mm)</i>	<i>Location</i>	<i>References</i>
<i>P. lineatus</i>	Male	120.0 – 214.0	North Andhra	Vijayakumaran (1997)
	Female	121.0 – 234.0	Pradesh Coast	
<i>P. lineatus</i>	Unsex	152.0 – 177.0	Mediterranean	Golani (2002)
<i>P. lineatus</i>	Mixed	110.0 – 170.0	Visakapatnam	Govindarao et al (2015)
<i>P. lineatus</i>	Unsex	105.0 – 272.0	Arabian Sea coast, Pakistan	Farooq et al (2017)
<i>P. lineatus</i>	Male	97.0 – 250.0	Tanjung Tiram,	Jumiati et al (2017)
	Female	92.0 – 216.0	Indonesia	
<i>P. lineatus</i>	Unsex	100.0 – 252.0	Malatapay,	Froese & Pauly (2019)
			Philippines	
<i>P. lineatus</i>	Unsex	165.0 – 250.0	Palawan,	Froese & Pauly (2019)
			Philippines	
<i>P. lineatus</i>	Male	50.0 – 254.0	Kolono Bay,	This study (2019)
	Female	68.0 – 232.0	Indonesia	

Striped eel catfish in Kolono Bay had two distinctively different size groups (cohorts) (Table 1). This finding means that the waters of Kolono Bay were cohabitated by two different generations of striped eel catfish at relatively the same time. Cohort I was dominated by the juvenile stage (95%) with 80.86 mm of average length, while cohort II was dominated by the mature stage (5%) with 211.52 mm in length. A cohort is a fish generation that grows and undergoes the same processes and considered to have the same ages. This is the aim of population grouping, which is to confirm that there are no mixed populations in estimating fish reproduction, growth, mortality, and recruitment (Asriyana 2015).

The predominance of juveniles observed in August was probably the result of the recruitment from the previous fish cohort. In the Sungsan and Jocheon waters, East of Jeju, Korea, the histological observation and variation of gonado-somatic index (GSI) of this species showed a reproductive cycle consisting of several stages i.e.: spawning stage occurred in June-July for striped eel catfish female; while male of striped eel catfish spent in April-July (Heo et al 2007). Different species from the same genus, gray eel catfish *Plotosus canius* in India coastlines had spawning season from February to August, with a peak of spawning in May and June (Sinha 1981). Based on this study results, the spawning period of striped eel catfish in Kolono Bay occurs before August, which can be associated with the dominant juvenile stage found in August.

Population groups of males and females of striped eel catfish in Kolono Bay were found to be unstable. This was because the male and female size groups do not have all size structures and only juvenile and old stage. This condition was probably related to the life cycle, spawning behavior, and spawning area of eel catfish. The male of the spawning pair constructs a nest under rocks and other large pieces of debris. After spawning, females leave their nest while males protect their eggs (Thresher 1984). This phenomenon was suspected to be the reason for the rarity of the matured size of eel catfish caught in the area. Besides that, Kolono Bay is more suitable as a nursery ground and grow out area and not as a spawning area for striped eel catfish.

In this study, the fish growth was observed as instantaneous growth analyzed from the correlation of the total length and weight. Growth patterns of both males and females were a positive allometric type. Striped eel catfish have a disproportionate weight increase to growth length. This means that the fish have a faster weight gain compared to length gain ($b > 3$). The condition is arguably related to the dominant of striped eel catfish caught during the study.

The family of Plotosidae does not always have an allometric growth pattern, as reported by some researchers from different study locations (Table 3). Growth pattern differentiation in the family of Plotosidae relates to the variation of the coefficient b

values obtained from the length-weight relationship. Variation in the *b* value was related to size distribution and the number of samples as well as ontogenetic development (Türkmen et al 2002), habitat and health of fish (Zhu et al 2008), food availability, gonadal development, and spawning period (Yilmaz & Polat 2009; Asriyana & Irawati 2017).

Table 3

Growth pattern of Family Plotosidae in several locations

<i>Species</i>	<i>b value</i>	<i>r</i> ²	<i>Location</i>	<i>References</i>
<i>P. lineatus</i>				Vijayakumaran (1997)
Male	Positive allometric (3.35)	0.99	North	
Female	Positive allometric (3.43)	0.99	Andhra Pradesh Coast	
<i>P. canius</i>	Isometric (3.00)	0.96	Banyuasin Estuary, Indonesia	Fatah & Asyari (2011)
<i>P. canius</i>				Dewanti et al (2013)
Male	Negative allometric (2.62)	0.94	Krobokan	
Female	Negative allometric (2.69)	0.82	Semarang, Indonesia	
<i>P. canius</i>	Negative allometric (0.34)	0.97	Center Kalimantan Estuary, Indonesia	Harteman (2015)
<i>P. lineatus</i>	Negative allometric (2.76)	0.87	Estuary, Malaysia	Ya et al (2015)
<i>P. lineatus</i>				Jumiati et al (2017)
Male	Positive allometric (3.29)	0.84	Tanjung Tiram, Indonesia	
Female	Negative allometric (2.85)	0.93		
<i>P. lineatus</i>	Negative allometric (2.68)	0.78	Palawan, Philippines	Froese & Pauly (2019)
<i>P. lineatus</i>	Negative allometric (2.95)	0.97	Malatapay, Philippines	Froese & Pauly (2019)
<i>P. lineatus</i>				This study (2019)
Male	Positive allometric (3.23)	0.98	Kolono Bay, Indonesia	
Female	Positive allometric (3.13)	0.99		

One of the growth condition parameters is the ponderal index, an index that represents fish fatness or the accumulation of fat and gonadal development if viewed from fish nutritional adequacy (Le Cren 1951). The ponderal index can also point out the relative condition of a fish population of interest in comparison to the overall fish population (Bolger & Connolly 1989). The ponderal index of striped eel catfish in Kolono Bay fluctuated with the highest value was observed in July (Figure 4). The coincidence of the highest value of the ponderal index and the observed domination of juveniles in the same month (August) leads to a strong indication that the spawning season of striped eel catfish in Kolono Bay most likely occur in July. This indication can be logically explained by the fact that the increased of the ponderal index in July means that the fish are filling their gonads with sperms/eggs and reaching the gonads' maximum volume before spawning season and decrease in volume after spawning season (August). The decrease of the ponderal index value was suspectedly caused by energy utilization during spawning in the form of reproductive activities, including releasing eggs and sperms. Other studies for different fish species reported similar evidence such as for *Engraulis encrasicolus* (Millán 1999); *Upeneus moluccensis* (Sjafei & Susilawati 2001); *Trachurus mediterraneus* (Tzikas et al 2009); and *Sardinella atricauda* (Asriyana 2015). This

condition happened because the main energy source was used to gonad development and spawning (Lizama & Ambrósio 2002). Interestingly, Figure 4 markedly shows that the average ponderal index of male eel catfish was smaller than females. This indicates that the female population in this study was in better condition than the male population.

The variation of ponderal index values is related to the spawning season of striped eel catfish. The fluctuation of food availability both in terms of quality and quantity determined the variation value, as had also been reported by previous researchers (Encina & Granado-Lorencio 1997; Ribeiro et al 2004; Lalèyè 2006; Asriyana 2015). Furthermore, it was related to a differentiation between the sizes and ages of fish (Encina & Granado-Lorencio 1997).

During its life span to reach a maximum length, each fish undergoes growth variation, which can be represented in varying growth coefficient. The growth coefficient shows how fast a fish or a fish population reaches the maximum length. The growth coefficient of a fish population might temporally and spatially vary even though they belong in the same fish species. Based on the calculated growth parameters, the eel catfish could reach a maximum length (L_{∞} = 251.89 mm TL) within 28 months (2.4 years) with a growth rate of 0.27 per year. This finding is somewhat different to that of other studies where fish species belonged to the family Plotosidae have variation in growth characteristics (Table 4). For example, Vijayakumaran (1997) reported that striped eel catfish reached the maximum length (L_{∞} = 243.73 mm TL) at 2.19 years old which was slightly similar. However, Thresher (1984) reported that the same fish species reached the maximum length at seven years old. *C. macrocephalus* (Family Plotosidae) in Australia waters reached the maximum length (L_{∞} = 760 mm TL) at 13 years old (Kailola et al 1993). The age variations to reach maximum length are influenced by species, habitat conditions, and fish growth coefficient.

Table 4

Population parameter of family Plotosidae in various locations

<i>Species</i>	L_{∞} (TL mm)	K (years ⁻¹)	t_0 (years)	<i>Location</i>	<i>References</i>
<i>Plotosus angularis</i>	280.40	0.45	-	Tamioka Bay, Amakusa, Kyushu	Kikuchi (1966)
<i>P. angularis</i>	270.00	0.45	-	Ago bay, Japan	Kajikawa (1973)
<i>Tandanus tandanus</i>	596.00	0.34	-	Gwydir River, northwest of Sydney	Davis (1977)
<i>Cnidoglanis macrocephalus</i>	917.00	0.20	-0.11	Swan estuary, Australia	Nel et al (1985)
<i>T. tandanus</i>	1,100	0.10	-	Australia	Meunier et al (1994)
<i>P. lineatus</i>	243.73	1.37	0.0085	North Andhra Pradesh Coast	Vijayakumaran (1997)
<i>P. lineatus</i>	251.89	0.27	-0.02	Kolono Bay, Indonesia	This study (2019)

"-" = no data records.

Conclusions. The populations of striped eel catfish in Kolono Bay were characterized by positive allometric growth patterns and dominated by juveniles. This study also concludes that the spawning season of eel catfish in these waters occurs in July based on the high ponderal index in July and the dominant juvenile population in August. This condition clearly suggests that Kolono Bay is used as a nursery ground by striped eel catfish in the region. Based on the study's findings, we highly recommend the formal establishment of

Kolono Bay as the nursery ground for striped eel catfish to maintain a healthy stock of the fish population and ensure its sustainable use as a fisheries resource.

Acknowledgments. The authors wish to acknowledge the financial support provided by the Ministry of Research and Higher Education of Republic of Indonesia through the National Competitive Research Grant 2019 (Contract no. 171/SP2H/LT/DRPM/2019 and no. 511F/UN29.20/PPM/2019) for the project entitled "Sustainable management design of eel catfish fishery towards food resilience in Southeast Sulawesi". We thank the undergraduate students of the Faculty of Fisheries and Marine Sciences, Halu Oleo University who helped fish collection in the field and fish preparation in the laboratory; and the Faculty of Fisheries and Marine Science, Halu Oleo University for providing access to equipment and facilities to undertake this study. We offer our sincere gratitude to Hatim Albasri, Ph.D. from the Center for Fisheries Research, the Indonesian Ministry of Marine Affairs and Fisheries for academic writing counseling to this study.

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Received: 30 September 2019. Accepted: 16 December 2019. Published online: 13 February 2020.

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How to cite this article:

Asriyana A., Halili H., Irawati N., 2020 Size structure and growth parameters of striped eel catfish (*Plotosus lineatus*) in Kolono Bay, Southeast Sulawesi, Indonesia. AACL Bioflux 13(1):268-279.