Population dynamics of the eel (*Anguilla marmorata*) in Southeast Sulawesi waters, Indonesia

[1]Utama K. Pangerang, [1]La Sara, [2]Usman Rianse, [1]Andi I. Nur

[1] Department of Aquatic Resources Management, Faculty of Fisheries and Marine Science, Halu Oleo University, Kendari 93232, Southeast Sulawesi, Indonesia; [2] Faculty of Agricultural, Halu Oleo University, Kendari 93232, Southeast Sulawesi, Indonesia. Corresponding author: La Sara, lasara_unhalu@yahoo.com

Abstract. The eel (*Anguilla marmorata*) has been exploited since years due to its high demand of consumers either locally or internationally, while its population parameters and habitats studies were very rare conducted. The present study of the eel population was conducted in Lasolo and Lalindu rivers using catches data collected by fishermen from August 2015 to July 2016. This study analyzed some population parameters according to length data. Analysis of class length, growth and mortality used the Bhattacharya method, von Bertalanffy model and Pauly empirical equation, respectively which incorporated in the FiSAT II program. The eels length caught ranged between 24.0 and 160.0 cm. Three classes of average length were found namely 68.35 cm, 94.56 cm and 153.93 cm, respectively. The eel growth patterns were different according to seasons. During November 2015-July 2016 followed negative allometric growth pattern (b = 1.977-2.644), while during August-October 2015 was positive allometric growth pattern (b = 3.477) ($p < 0.05$). Growth parameters of von Bertalanffy were found $L\infty$ = 185.86 cm and K = 0.51 per year, while theoretical age (t_0) was 0.048. It was noted that total mortality (Z) was 1.90, while natural mortality (M) and fishing mortality (F) were 0.66 and 1.24, respectively. It leads to find exploitation rate (E) of 0.653 and suggests that the eel population status has been over exploitation.
Key Words: eel, growth parameters, fishing mortality, natural mortality.

Introduction. The freshwater eels are exotic animals which still lay away of mystery up to present. Scientific studies on their biological and ecologycal aspects and stock assessment in the tropical regions are scarce compared to scientific studies on the eels in the temperate regions which were conducted since decades and covered a wide range of their biological aspects, environment, stock assessment, recruitment patterns and others (Arai 2014a). The eel fishery in Indonesia is an important sector due to its high protein content and contribution to the fishermen income and the government's revenue. Its distribution covers wide range regions from Sumatera, Java and Sulawesi. It had been exploited for local demand consumption and commercial trade particularly to fulfill very high global market demands (Affandi 2005).

The eel constitute one of important fishery resources in the open waters of Southeast Sulawesi, but its ecology and population potential are not well known. However, its population has been exploited since years using uncontrolled fishing gears due to high economics value demand of consumers. Fishing effort of the eels is still categorized as small scale fishery and limited in Lasolo, Lalindu and Konaweha rivers of Southeast Sulawesi.

There were studies which had been conducted on tropical eels in several regions, particularly in Sulawesi waters, such as study on Leptocephaly biodiversity in the sea waters of the central Indonesia (Wouthuyzen et al 2005), glass eel *Anguilla marmorata* in the northern Sulawesi (Poigar river estuary), western Sulawesi (Palu river estuary), and Central Sulawesi (Poso river estuary) (Sugeha & Arai 2010), and population dynamics of tropical eels in Malunda river of West Sulawesi (Amir et al 2009). Study on the eels around Southeast Sulawesi waters is scarce and limited to identification on eels potential, size composition and feeding habits (Fekri 2011; Pangerang et al 2012; Kasendri 2013; Mulyani 2013), while study on its population parameters and bioecology were neglected. The present study was focused on population dynamics of the eels in Lasolo and Lalindu rivers to find out several population parameters such length-weight relationship, growth pattern, and mortality rate in order to be used for its population and habitat management.

Material and Method

Sampling method. The sampling locations in Lasolo and Lalindu rivers were divided into three areas representing the eels fishing area (Figure 1). The characteristics of the first location were water depth of 370-487 cm, current velocity of 0.52-1.04 m second^{-1}, TSS of 0.036-0.145 mg L^{-1}; the characteristics of the second location were water depth of 37-80 cm, current velocity of 0.86-1.37 m second^{-1}, TSS of 0.031-0.199 mg L^{-1}; and the characteristics of the third location were water depth of 400-600 cm, current velocity of 1.06-1.54 m second^{-1}, TSS of 0.037-0.104 mg L^{-1}. The total eel samples of 156 individuals were collected from fishermen catches from those locations using electric fishing, longlines and traps which was based on seasonal changes of dry season months of August-October 2015 (n = 35 inividuals), inter monsoon of November 2015-January 2016 (n = 40 individuals), rainy season of February-April 2016 (n = 35 individuals), and inter monsoon of May-July 2016 (n = 46 individuals). All samples of the eels were measured their total length from terminal mouth up to the caudal tip using a ruler to the nearest 1 mm and weighed their total weight using a balance to the nearest 1 g (Muryanto & Sumarno 2013).

Data analysis. The relationship between body wet weight and total length was analyzed using equation: $W = aL^b$ (Sparre & Venema 1998; Liu et al 2011). This equation can be linearized using logarithmic transformation:

$$LogW = Loga + bLogL$$

where W = body wet weight, L = total length, a and b = constants.

Size class separation analysis of the eels was based on length size using the Bhattacarya method namely producing norm curve which figuring some cohorts of length frequency distribution which was analyzed using the FiSAT II program (Gayanilo et al 1996).

Estimated growth parameter used was the von Bertalanffy equation (Tesch 2003; Simon 2007; Liu et al 2011), namely:

$$L_t = L_0\left(1 - e^{K(t-to)}\right)$$

where L_t = length at age t, L∞= asymptotic length, K = growth coefficient, t = age in year, t_0 = time at pre-hatch. Estimated "t_0"was computed using the Pauly empirical equation (Pauly 1983), namely:

$$Log(-t_0) = -0.3922 - 0.2752(\log[L\infty) - 1.038(LogK)]$$

The growth parameters were analyzed using the FiSAT II program (Sparre & Vanema 1998). Estimated natural mortality (M) was analyzed using empirical equation (Pauly 1983), while estimated total mortality (Z) was analyzed using catch curve converted to the length developed by Pauly (1983):

$$Ln\frac{C(L1,L2)}{\Delta t(L1,L2)} = C - Z * t\frac{(L1+L2)}{2}$$

This equation was simplified to be:

$$\ln\left(\frac{N_i}{\Delta t_i}\right) = a + b\,.\,t_i$$

where: N_i = the number of eels at length class i, Δt_i = time needed of eels at width class i, Z = total mortality of eels, a and b = regression constants (b = -Z), and t = age. Total mortality rate (Z) was analyzed using: $F = Z\text{-}M$. Based on these equations, exploitation rate was analyzed as the following (Pauly 1983):

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

when E > 0.5 means high exploitation rate (over fishing), E = 0.5 means optimum exploitation rate (E_{opt}), and E < 0.5 means low exploitation rate (under fishing).

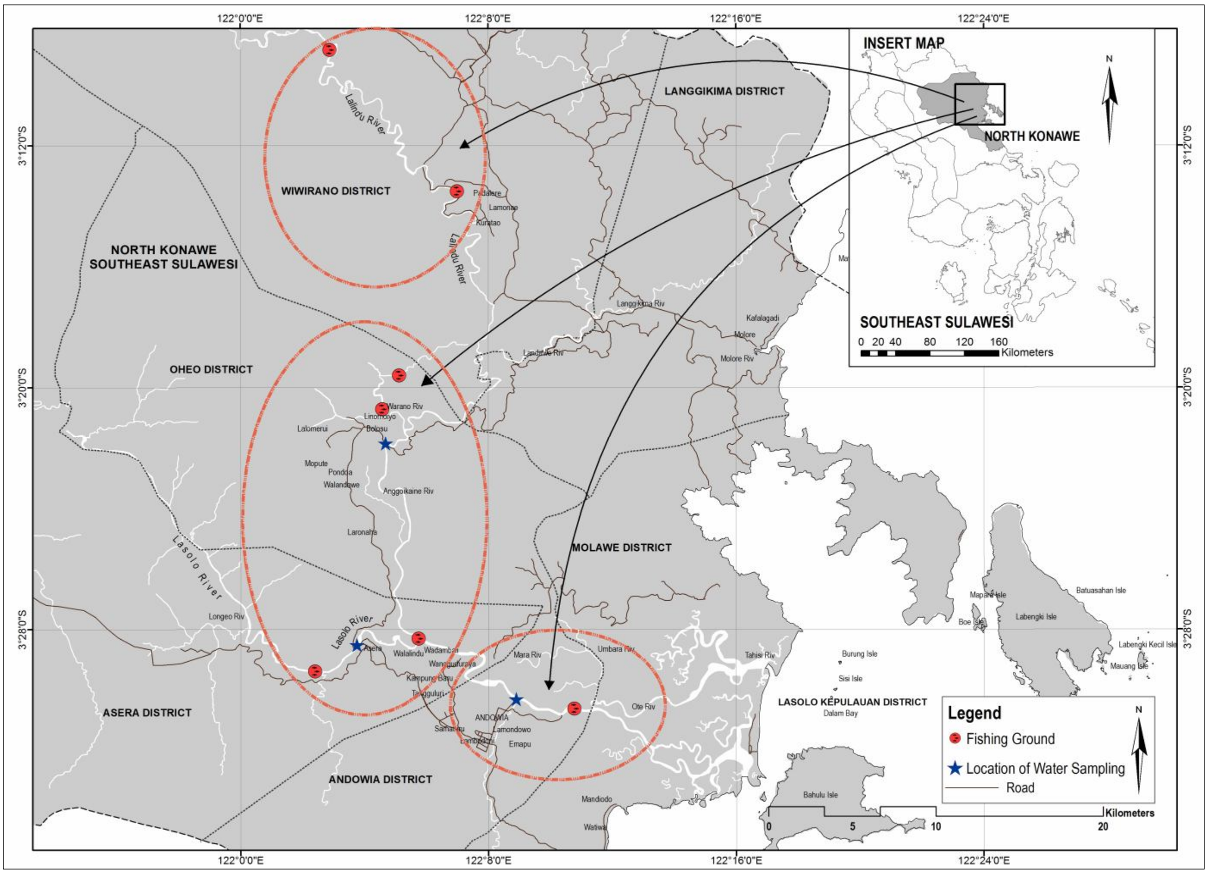

Figure 1. Map of sampling eels in Lasolo and Lalindu rivers of Southeast Sulawesi, Indonesia.

Results

Body weight-length relationship. The relationship between body wet weight and length of eels showed high and positive correlation (r > 0.9), while growth patterns followed seasonal changes. The positive allometric growth pattern was found during August-October 2015, while other seasons followed the negative allometric growth patterns (Table 1).

Table 1

Body weight and length relationship of the eels in the Lasolo and Lalindu rivers of Southeast Sulawesi, Indonesia

Period	*N*	*a*	*b*	R^2	*Remark*
August-October 2015 (dry season)	35	0.001	3.477	0.947	Positive allometric
November 2015-January 2016 (inter monsoon)	40	0.269	1.977	0.875	Negative allometric
February-April 2016 (rainy season)	35	0.105	2.168	0.844	Negative allometric
May-July 2016 (inter monsoon)	46	0.011	2.664	0.733	Negative allometric

Note: n = number of samples; R^2 = determination coefficient; a and b = constants.

Size class. The size structure of the eel populations could be evaluated through length frequency distribution. The Bhattacharya method may be used to separate composite distribution into normal distribution (Sparre & Venema 1998). The Bhattacharya method may consist of several normal distributions which represent cohort of length size from the whole length distributions. The analysis of the eels length frequency distribution taken from Lasolo and Lalindu rivers formed three cohorts (Figure 2) as shown by their respective mean length ($\overline{x}$) and separation-index (I) (Table 2).

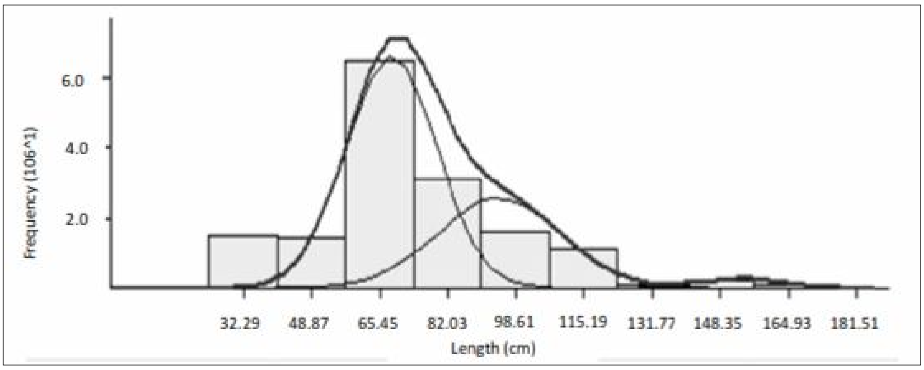

Figure 2. Cohort curve of the eels taken from Lasolo and Lalindu rivers of Southeast Sulawesi, Indonesia.

Table 2
Mean length, deviation standard of and index separation (I) of the eels taken from Lasolo and Lalindu rivers of Southeast Sulawesi, Indonesia

No.	*Population samples (n)*	*Mean length (cm) ($\overline{x}$)*	*Standard deviation (sd)*	*Separation index (I)*
1	110	68.35	10.993	-
2	59	94.58	15.14	2.01
3	4	152.93	9.53	4.73

The eels observed during the entire study (August 2015-July 2016) consisted of 2 cohorts (Figure 3) based on their growth stages namely yellow stage (mature) of 20-60 cm body length and silver stage (gonad maturity) of > 60 cm body length (Tesch 2003; Husnah et al 2008; Widyasari 2013).

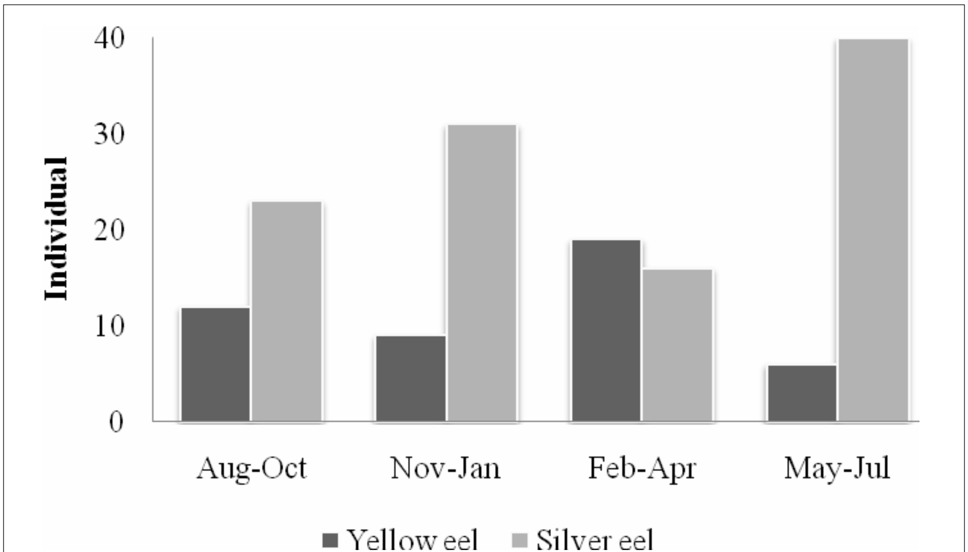

Figure 3. Distribution of the eel size based on the growth stages and periods of fishing at the Lasolo and Lalindu rivers of Southeast Sulawesi, Indonesia.

Growth parameters. The result of growth parameters analysis of von Bertalanffy on the eels taken from Lasolo and Lalindu rivers showed $L\infty$ = 185.86 cm and K = 0.51, while parameter of t_0 (age of the eel at length = 0) using the Pauly's equation was t_0 = 0.048 (Figure 4).

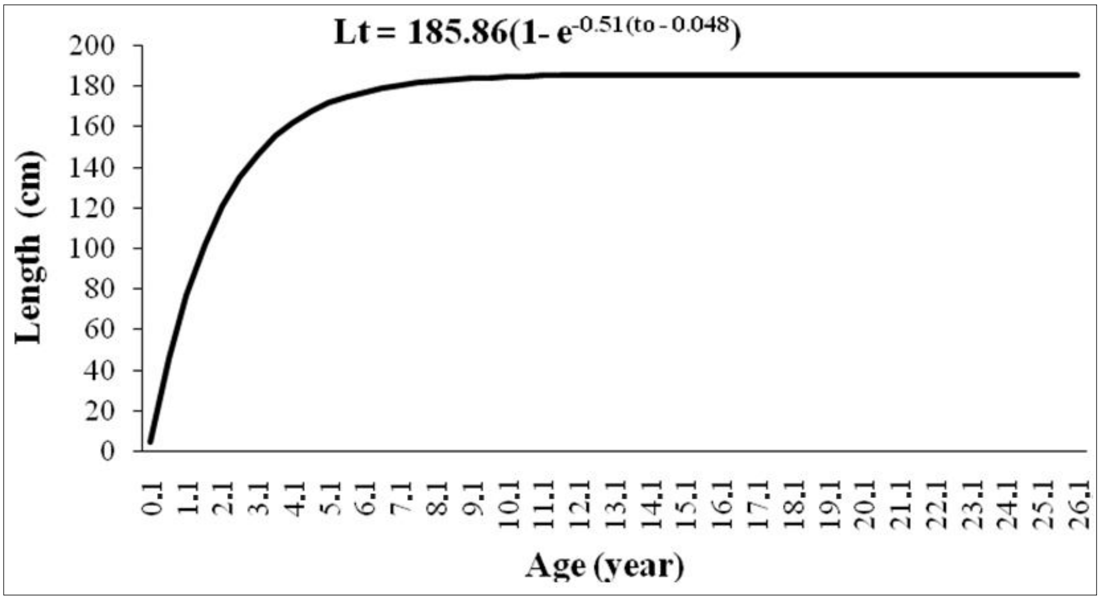

Figure 4. The growth equation of von Bertalanffy of the eels taken from Lasolo and Lalindu rivers of Southeast Sulawesi, Indonesia.

Mortality and exploitation rates. The mortality is a process which may affect population sizes. The mortality consists of natural mortality and fishing mortality (Sparre & Venema 1998). The total mortality can be estimated from catch curve linearized (Figure 5) using length frequency data. The estimation of total mortality (Z), natural mortality (M), fishing mortality (F) and exploitation rate (E) is presented in Table 4.

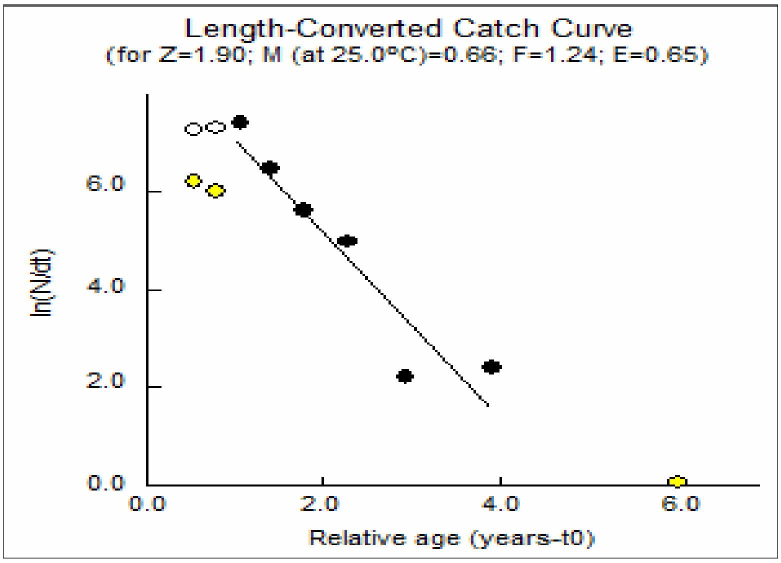

Figure 5. Catch curve linearized of the eels taken from Lasolo and Lalindu rivers of Southeast Sulawesi, Indonesia.

Table 4
Estimation of mortality and exploitation rate of the eels in Lasolo and Lalindu rivers of Southeast Sulawesi, Indonesia

Parameters	*Value (per year)*
Total mortality (Z)	1.90
Natural mortality (M)	0.66
Fishing mortality (F)	1.24
Exploitation rate (E)	0.65

Discussion

Body weight-length relationship. It was found that the smallest body length of the eels from all samples taken was found during August-October 2015 (dry season), while the largest one was found during February-April 2016 (rainy season) (Table 1). The regression coefficient (b) of weight-length relationship of the eels differed according to the seasons. Despite during dry season all the eels have small body length, but its weight-length relationship still has high coefficient (b). The eels taken seem relatively fat. It is due to the eels can easily hunt its natural food as source of its energy because water depth of the rivers is relatively shallow during dry season. Tesch (2003) revealed that seasonal diet patterns of tropical eels was significantly different from temperate ones. During summer season, the eels consume more food items compare to winter season. The eels diet rely on prey population found in their habitat. The density of those preys is very much affected by water column depth and its yearly cycle. A study of the eels diet in several rivers of Poso, Central Sulawesi showed that several types of natural diet in the gut content of eels had preponderance index of 1.70-20.19% plant materials, 8.59-100% crabs, 0.71-54.37% shrimp, 10.41-28.85% snail, 0.71-3.21% gastropod, 0.95-12.82% fish, 0-0.30% zoea of crab, 0.35-100% insects, and 2.33-6.41% crustacean (Muryanto & Sumarno 2013). Another study on food habit of eels in Lasolo river showed the preponderance index of 38.23% shrimp juveniles, 23.75% crabs, 19.58% plankton, 9.28% shrimp debris, and 9.16% unidentified materials (Pangerang et al 2012). In a recent observation in the same location shows that fresh water shrimps and crabs have dense population which constitute natural diet of the eels (Pangerang et al 2017).

Several studies on the eels (Table 5) had been showed that growth patterns differ according to the regions and seasons (Shiao et al 2003; Piria et al 2014). The relationship between body weight-length of the eels (*A. anguilla*) at four rivers of Croatia during the periods of 2004-2007 showed negative allometric growth pattern ($b < 3$) (Piria et al 2014). Other studies on *A. marmorata* and *A. japonica* at two rivers of Taiwan showed positive allometric growth pattern (Shiao et al 2003).

Size class. Analisys of fish cohort can be shown by index separation (I). The index separation (I) is a quantity index to separate the possibility of close two components of mean body length of the eels. If the index separation is less than two ($I < 2$) there is no possibility for a separation between two size classes (cohort) due to “big coincide” of those size classes (Sparre & Venema 1998). The index separation (I) of the present study was 2.01 and 4.73. Those indexes imply that size classes (cohorts) of the eels found perform only two cohorts where mean length of 68.3 cm and 94.6 cm (Table 2) coincide to be one cohort with $I = 2.01$ (Table 2), while other mean length of 152.9 performs another cohort (Figure 2) with $I = 4.73$.

The eel length varies according to the habitat condition and sex. The length of the silver eel of Europe eels (*A. anguilla*) caught from several habitats ranged between 35 and 46 cm. The male eels of short fin (*A. australis*) of New Zealand may reach maximum of 60 cm. It had been caught the eels of 130 cm in Switzerland lake. The female European eels may reach 150 cm. The *A. dieffenbachii* has maximum length of 180 cm with fresh body weight of 24 kg. It was reported that the female eels from South Africa ranged between 8 and 23 kg with maximum length of 180 cm (Tesch 2003).

Table 5

Coefficient of regression and correlation of relationship between body weight-length of different species of the eels from several regions

Region	*n*	*Species*	*TL range (cm)*	*a*	*b*	*r*	*Growth pattern*	*Source*
Cetina river	36	*A. anguilla*	24.0-42.0	0.0081	2.6637	0.652	Negative allometric	Piria et al (2014)
Riverbanks river	21	*A. anguilla*	18.0-61.5	0.0050	2.8155	0.849	Negative allometric	Piria et al (2014)
Jadro river	151	*A. anguilla*	18.0-70.0	0.0066	2.7240	0.911	Negative allometric	Piria et al (2014)
Zrnovnica river	171	*A. anguilla*	13.0-63.0	0.0106	2.5957	0.899	Negative allometric	Piria et al (2014)
Taiwan	78	*A. japonica*	27.2-50.2	< 0.001	3.5	-	Positive allometric	Shiao et al (2003)
Taiwan	105	*A. marmorata*	33.7-60.3	< 0.001	3.2	-	Positive allometric	Shiao et al (2003)
Lasolo and Lalindu river	156	*A. marmorata*	24.0-160.0	0.060	2.2770	0.858	Negative allometric	Present study

Note: n = number of samples; TL = total length; r = regression coefficient; a and b = constants.

Some studies were reported for *A. marmorata* species. It was found out that *A. marmorata* as tropical anguilid could reach a length of 200 cm with body weight of 21 kg (Arai 2014b; Arai & Chino 2018). It was reported that the length of *A. marmorata* found in Oxbow lake flowing from Xindian river of Taiwan in 1991 was 148.4 cm which was estimated 12 years old, while *A. marmorata* found in river of western Guangxi of South China was 180 cm length and body weight of 28 kg which was estimated 17 years old (Leander et al 2012). Furthermore, it was revealed that all the eels living in the fresh water around the world may reach total length of 200 cm (FAO 1983). Those data are comparable with the data in the present study (Table 2). The maximum length of the eel found in the present study is 160 cm with body weight of 12.8 kg.

The biggest length size of the eels found in the present study was lower than that reported before due to high catch intensity. Generally fishermen prefer to catch silver eel stage because of its premium price (Figure 3). The price of eels in local market was around Rp120,000/kg (equal to US$ 10/kg) (Pangerang & Mustafa 2012). It is a threat for the eel population sustainability in Lasolo and Lalindu rivers if fishermen continue catching without applying selective sizes.

Growth parameters. It is found in the present study that growth parameters of length infinity ($L\infty$) of the eels was 185.86 cm, while growth coefficient (K) and theoretical age at length is zero (t_0) were 0.51 per year and 0.048, respectively (Figure 4), which are relatively high compare to other K of the eels from different regions (Table 6). This condition is due to Lasolo and Lalindu rivers are still very limited affected by any human activities so its water quality was still in the optimal range of eels tolerance such as water temperature of 27-28^{o}C, pH of 7.40-7.81, and TSS of 0.012-0.135 mg L^{-1}. The smallest body length of eels found was 24 cm (yellow eel) which was equal to 4 months old, while the biggest body length caught was 160 cm (silver eel) which was equal to 4 years old.

Studies on the eels growth strategies were mainly conducted in the temperate regions (Table 6) (Tzeng et al 2000; Yalcin-Ozdilek et al 2006; Amir et al 2009). Growth parameters of K and $L\infty$ showed that there were variation of those parameters between the eels caught from tropical regions and those from temperate regions. Growth parameters varied according to the stock in a certain species during its life span. The series of cohort in a certain species may differ in their growth due to sex differences and environmental condition. Sex differences are generally easy to be known of their growth rate (Sparre & Venema 1998). There is no homogenous growth parameters for the eels. Sex, water column depth and size population are parameters affecting all those growth parameters of $L\infty$, K and t_0 (Tesch 2003).

Table 6

The eel growth parameters from different locations around the world

Location	*Species*	*Sex*	*L∞ (cm)*	*K (per year)*	*Source*
Asi River, Turkey	*A. anguilla*	-	67.57	0.37	Yalcin et al (2006)
Kaoping River, Taiwan	*A. japonica*	Male	59.43	0.28	Tzeng et al (2000)
		Female	77.79	0.17	
Malunda River of West Sulawesi, Indonesia	*A. marmorata*	-	202.0	0.20	Amir et al (2009)
Lasolo and Lalindu Rivers of Southeast Sulawesi, Indonesia	*A. marmorata*	-	185.86	0.51	Present study

Estimation of mortality and exploitation rates. There are two mortality types in the study on fish populations namely of natural mortality (M) and fishing mortality (F). Estimation of natural mortality in the present study used the Pauly's empirical equation (Sparre & Venema 1998) with a year mean water temperature of 25^{o}C. The estimation of total mortality rate (Z) was derived from catch curve linearized based on length data (Figure 4). It was found that Z of 1.90 per year, M of 0.66 per year, and F of 1.24 per year. This condition shows that eels mortality in the locations was dominated by fishing mortality. Those parameters are relatively similar with the study conducted in Malunda river of West Sulawesi (Amir et al 2009) which showed population parameters of the eels were Z = 1.344 per year, M = 0.366 per year, F = 0.978 per year and estimation of E = 0.728. The rate of mortality of the exploited eels in the Lasolo and Lalindu rivers are mainly due to the use of electrical fishing, while the low values of Z and F in the Malunda river area due to the difference of types of fishing gear and target fish sizes that was relatively small (young eels or yellow eels). Fishing gear used in Malunda river consisted of arrows, fish traps, fishing line and nets that give uncaught eels having a chance to escape. The eels found in the Malunda river were dominated by young eels (yellow eel) while the eels obtained from the Lasolo and Lalindu rivers were dominated by adult eels (silver eel).

The exploitation rate (E) of 0.65 in the present study means that the eel populations at those locations had been over-exploited due to fishing activities done by local fishermen were the whole years round and using electrical fishing. The average total catch of the eels in the location ranged 500-1,000 kg per month. However, there was data of average total catch of the eels during dry season (September) ranged 2,000-3,000 kg (Pangerang & Mustafa 2012). The peak season of fishing activities were in the dry season (August-October) when water depth was shallow ranging from 50 to 100 cm and water transparency of 33-100%. On the contrary, fishing activities during rainy season (February-April) were very rare due to high current velocity of water in the river and very high water turbidity.

It was noted that fishing activities of the eels for export market, particularly to Hong Kong have been exploited since 2000s up to present. Fishing gears used since that times were electrical fishing, hand line and local trap made from bamboo. Due to premium price and export demand, fishermen catch the eels intensively and all sizes. To sustain the eel populations in this regions that several efforts should be implemented, such as managing and maintaining their populations and habitats along the rivers, its migration path way, and spawning ground and nursery ground in the surrounding of the Banda Sea. Management of the eel populations may involve regulation on total allowable catch (TAC), limitation of the eel length size caught, limitation of total fishing gear used, prohibiting the use of illegal fishing gears such as electrical fishing, prohibiting catch of the eels during peak spawning season and in the spawning ground and nursery ground. It is suggested that cultivation of the eels should be developed in the near future. It is purposed to fulfil demand of the eels either in the local and global markets.

Conclusions. The eel sizes caught in Lasolo and Lalindu rivers of Southeast Sulawesi are divided into two phases namely yelow eels and silver eels which is dominated by silver eels. Those eel populations have relatively high growth rate. However, its fishing mortality is high enough due to high fishing intensity compare to other eel population in other regions. There is an alarm that the eel population status is already over exploited as shown its exploitation rate (E) of 0.65. To sustain its populations, management efforts of its habitat and population should be implemented and followed by regulation of maintaining habitats either in the rivers or in the surrounding Banda sea, the use of fishing gears, and total allowable catch (TAC).

Acknowledgements. This manuscript is part of a dissertation of the first author on “Bioecology and Status of the Eel (*Anguilla* sp.) in Lasolo and Lalindu rivers of North Konawe, Southeast Sulawesi, Indonesia”. The first author is a graduate student of Halu Oleo University funded by BPPDN scholarship of Directorate General of Higher Education of Ministry of Research, Technology and Higher Education of Republic of Indonesia. We would like to thank all the eel fishermen in Wanggudu Raya, Andowia and Linomoiyo Villages of North Konawe, Southeast Sulawesi. We also thank Dr. Bahtiar for his valuable time during discussion, Mr. Amadhan Takwir, M.Si for providing Figure 1, and to all undergraduate students of Faculty of Fisheries and Marine Science of Halu Oleo University who involved in the data collection.

References

Affandi R., 2005 [Utilization strategy of eel (*Anguilla* spp) resources in Indonesia]. Jurnal Iktiologi Indonesia 5(2):77-81. [in Indonesian]

Amir F., Mallawa A., Budimawan, Tresnati J., 2009 [Population dynamics of tropical eels (*Anguilla marmorata*) in Malunda waters, West Sulawesi]. Torani (Jurnal Ilmu Kelautan dan Perikanan 19(2):116-121. [in Indonesian]

Arai T., 2014a Do we protect freshwater eels or do we drive them to extinction? Springer Plus 3:534.

Arai T., 2014b Evidence of local short-distance spawning migration of tropical freshwater eels and implications for the evolution of freshwater eel migration. Ecology and Evolution 4(19):3812-3819.

Arai T., Chino N., 2018 Opportunistic migration and habitat use of the giant mottled eel *Anguilla marmorata* (Teleostei: Elopomorpha). Scientific Reports 8:5666.

FAO, 1983 Species identification sheets for fishery purpose; family *Anguillidae* fishing area 51. Volume I. Western Indian Ocean. Rome, 6 pp.

Fekri L., 2011 [Study of food habits of eel (*Anguilla marmorata*) in the Poleang river Bombana regency, Southeast Sulawesi]. BSc thesis, Faculty of Fisheries and Marine Sciences, Halu Oleo University, Kendari, 57 pp. [in Indonesian]

Gayanilo F. C., Spare P., Pauly D., 1996 FAO-ICLARM Stock Assessment Tools (FiSAT) user's guide. FAO computerized information series (Fisheries) No. 6, Rome, FAO, 186 pp.

Husnah, Tjahjo D. W. H., Nastiti A., Oktaviani D., Nasution S. H., Sulistiono, 2008 [Biodiversity status of freshwater fisheries resources in Sulawesi]. Freshwater Fisheries Research Institute, Department of Marine and Fisheries of the Republic of Indonesia, 128 pp. [in Indonesian]

Kasendri A. R., 2013 [Abundance and growth of eels seed (*Anguilla* sp.) in the estuary of Mosolo at Mosolo village of Konawe islands]. BSc thesis, Faculty of Fisheries and Marine Sciences, Halu Oleo University, Kendari, 78 pp. [in Indonesian]

Leander N. J., Shen K. N., Chen R. T., Tzeng W. N., 2012 Species composition and seasonal occurrence of recruiting glass eels (*Anguilla* spp.) in the Hsiukuluan river, eastern Taiwan. Zoological Studies 51(1):59-71.

Liu K. M., Lin C. P., Joung S. J., Wang S. B., 2011 Age and growth estimates of the black sawtail catshark *Galeus sauteri* in northeastern waters of Taiwan. Zoological Studies 50(3):284-295.

Mulyani T., 2013 [Food ecology eels seed (*Anguilla sp*) in the estuary of Mosolo River at Mosolo Village Southeast Wawonii Konawe Islands]. BSc thesis, Faculty of Fisheries and Marine Sciences, Halu Oleo University, Kendari, 59 pp. [in Indonesian]

Muryanto T., Sumarno D., 2013 [Observation technique of gastric contents of eel (*Anguilla marmorata*) of catch in Poso waters of Central Sulawesi]. E-Journal. Ministry of Marine and Fisheries of the Republic of Indonesia 11(2):51-56. [in Indonesian]

Pangerang U. K., Mustafa A., 2012 [Conservation of fish eel (*Anguilla* sp.) in the Southeast Sulawesi]. Paper presented on the National Seminar on Maritime Strategy Developing Countries on May 15, 2012, Halu Oleo University, Kendari. [in Indonesian]

Pangerang U. K., Yasidi F., Yusuf S., 2012 [Composition and size of eel (*Anguilla* sp.) in the waters of the Lasolo river, North Konawe, Southeast Sulawesi]. Aqua Hayati Journal 8(2):91-98. [in Indonesian]

Pangerang U. K., Idris M., Yasidi F., Lawelle S. A., 2017 [Study on potential and utilization of eels (*Anguilla* sp.) as economic resource of coastal community in Southeast Sulawesi]. Research and Development Board of Southeast Sulawesi Province, Kendari, 69 pp. [in Indonesian]

Pauly D., 1983 Some simple methods for the asessment of tropical fish stocks. FAO Fisheries Technical Paper, No. 234, 52 pp.

Piria M., Sprem N., Tomljanovic T., Sliskovik M., Mrcelic G. J., Treer T., 2014 Length-weight relationships of European eel (*Anguilla anguilla* L., 1758) from six karst catchments of the Adriatic Basin, Croatia. Croatian Journal of Fisheries 72:32-35.

Shiao J. C., Iizuka Y., Chang C. W., Tzeng W. N., 2003 Disparities in habitat use and migratory behavior between tropical eel *Anguilla marmorata* and temperate eel *A. japonica* in four Taiwanese rivers. Marine Ecology Progress Series 261:233-242.

Simon J., 2007 Age, growth, and condition of European eel (*Anguilla anguilla*) from six lakes in the Havel river system (Germany). ICES Journal of Marine Science 64:1414-1422.

Sparre P., Venema S. C., 1998 Introduction to tropical fish stock assessment. FAO Fisheries Technical Paper, No. 306, 407 pp.

Sugeha H. Y., Arai T., 2010 Contrasting morphology, genetic, and recruitment season of *Anguilla marmorata* glass eels from northern, western, and central Sulawesi Island, Indonesia. Ilmu Kelautan 1:1-19.

Tesch F. W., 2003 The eel (English edition). 3rd edition, Blackwell Science Ltd, Blackwell Publishing Company, 9600 Garsington Road, Oxford, UK, 408 pp.

Tzeng W. N., Han Y. S., He J. T., 2000 The sex ratios and growth strategies of wild and captive Japanese eels, *Anguilla japonica*. International Congress on the Biology of Fish, University of British Columbia, Vancouver, pp. 25-42.

Widyasari R. A. H., 2013 [Integrated design of sustainability of eel (*Anguilla* spp.) fishery industry development in Palabuhanratu, West Java Province]. PhD dissertation, Bogor Agricultural University, Bogor, 217 pp. [in Indonesian]

Wouthuyzen S., Miller M. J., Aoyama J., Minagawa G., Sugeha H. Y., Suharti S. R., Inagaki T., Tsukamoto K., 2005 Biodiversity of *Anguilliform leptocephali* in the Central Indonesian seas. Bulletin of Marine Science 77(2):209-223.

Yalcin-Ozdilek S., Gumus A., Dekker W., 2006 Growth of European eel in a Turkish river at the south-eastern limit of its distribution. Electronic Journal of Ichthyology 2:55-64.

Received: 10 January 2018. Accepted: 20 March 2018. Published online: 30 April 2018.

Authors:

Utama K. Pangerang, Department of Aquatic Resources Management, Faculty of Fisheries and Marine Sciences, Halu Oleo University, the 2nd floor, Kampus Bumi Tridharma, Kendari 93232, Southeast Sulawesi, Indonesia, e-mail: utama48@yahoo.co.id

La Sara, Department of Aquatic Resources Management, Faculty of Fisheries and Marine Sciences, Halu Oleo University, the 2nd floor, Kampus Bumi Tridharma, Kendari 93232, Southeast Sulawesi, Indonesia, e-mail: lasara-unhalu@yahoo.com

Usman Rianse, Faculty of Agricultural, Halu Oleo University, Kendari 93232, Southeast Sulawesi, Indonesia, e-mail: usman.rianse@gmail.com

Andi I. Nur, Department of Aquatic Resources Management, Faculty of Fisheries and Marine Sciences, Halu Oleo University, Kendari 93232, Southeast Sulawesi, Indonesia, e-mail: anima3@gmail.com

How to cite this article:

Pangerang U. K., La Sara, Rianse U., Nur A. I., 2018 Population dynamics of the eel (*Anguilla marmorata*) in Southeast Sulawesi waters, Indonesia. AACL Bioflux 11(2):543-553.