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

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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 ecological 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 individuals), 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:

\[
\text{Log} W = \text{Log} a + b \text{Log} L
\]

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 Bhattacharya 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:

\[
L_t = L_{\infty}(1 - e^{K(t-t_0)})
\]

where \(L_t =\) length at age \(t\), \(L_{\infty} =\) 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:

\[
\text{Log} (t_0) = -0.3922 - 0.2752(\text{Log}[L_{\infty}] - 1.038(\text{Log} t))
\]

The growth parameters were analyzed using the FISAT II program (Sparre & Venema 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):

\[
\ln \frac{C(L_1, L_2)}{\Delta t(L_1, L_2)} = C - Z \times t \left(\frac{(L_1 + L_2)}{2}\right)
\]

This equation was simplified to be:

\[
\ln \left(\frac{N_i}{\Delta t_i}\right) = a + b \cdot t_i
\]

where: \(N_i = \) the number of eels at length class \(i\), \(\Delta t_i =\) 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: \(F = Z \cdot M\). Based on these equations, exploitation rate was analyzed as the following (Pauly 1983):
when \( E \) > 0.5 means high exploitation rate (over fishing), \( E = 0.5 \) means optimum exploitation rate (\( E_{\text{opt}} \)), 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.](image)

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

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 ($\bar{X}$) and separation-index ($I$) (Table 2).

![Figure 2. Cohort curve of the eels taken from Lasolo and Lalindu rivers of Southeast Sulawesi, Indonesia.](image)

<table>
<thead>
<tr>
<th>No.</th>
<th>Population samples (n)</th>
<th>Mean length (cm) ($\bar{X}$)</th>
<th>Standard deviation (sd)</th>
<th>Separation index ($I$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>110</td>
<td>68.35</td>
<td>10.993</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>59</td>
<td>94.58</td>
<td>15.14</td>
<td>2.01</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>152.93</td>
<td>9.53</td>
<td>4.73</td>
</tr>
</tbody>
</table>

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.](image)
**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).

![Growth equation](image)

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.

![Catch curve](image)

Figure 5. Catch curve linearized of the eels taken from Lasolo and Lalindu rivers of Southeast Sulawesi, Indonesia.
Estimation of mortality and exploitation rate of the eels in Lasolo and Lalindu rivers of Southeast Sulawesi, Indonesia

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Value (per year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total mortality (Z)</td>
<td>1.90</td>
</tr>
<tr>
<td>Natural mortality (M)</td>
<td>0.66</td>
</tr>
<tr>
<td>Fishing mortality (F)</td>
<td>1.24</td>
</tr>
<tr>
<td>Exploitation rate (E)</td>
<td>0.65</td>
</tr>
</tbody>
</table>

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 prey 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% zoa of crab, 0.35-100% insecta, 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.** Analysys 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

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

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∞) of the eels was 185.86 cm, while growth coefficient (K) and theoretical age at length is zero (t0) were 0.51 per year and 0.048, respectively (Figure 4), which are relatively high compared 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°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∞ 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 due to sex differences and environmental condition. Sex differences are generally easy to be known of their growth due to sex differences and environmental condition. Sex differences are generally easy to be known of their growth due to sex differences and environmental condition. Sex differences are generally easy to be known of their growth due to sex differences and environmental condition.

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

**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°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 yellow 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).

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