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Biometric and biochemical characteristics of glass eels (*Anguilla* spp.) collected from Cimandiri Estuary, Sukabumi Regency, Indonesia

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Abstract. *Glass eel viability determines the success of cultivation and governs recruitment variability, as seeds in aquaculture are recruited to its population. This study aimed to examine the quality of glass eels by using biometric measurements coupled with proximate content. Glass eels were collected monthly using lift-net fishing gear in the Cimandiry Estuary from December 2020 to April 2021. Biometric aspects were examined for length, weight, eye diameter, heart, and liver, whereas proximate analysis was run on proteins, fats, carbohydrates, and ash. The results showed that length and weight steadily increased between months, although the condition factor was indifferent. Eye diameter and mouth opening confirmed the vision of diurnal predatory fish. The heart and liver have demonstrated metabolic capability, and fast-swimming fish favor migratory catadromous fish. Proximate content demonstrated insignificant fluctuations between months and did not confirm the biometric development of the glass eel. However, the glass eels in April were the largest in size, which might be the best for aquaculture and survival in the recruitment process.*

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INTRODUCTION

Globally, there are 22 taxa of freshwater eel species and subspecies belonging to the genus *Anguilla*, which is widely distributed in the Indo-Pacific, Atlantic, and Oceania regions (Inoue et al. 2010), then Arai (2016) reported 16 species and sub-species. Nine species were reported inhabiting Indonesian waters, namely *Anguilla bicolor bicolor, A. marmorata, A. nebulosa nebulosa, A. celebensis, A. ancentralis, A. borneensis, A. bicolor pacifica, A. obscura,* and *A. megastoma* (Sugeha et al. 2008). In southern Java estuaries, the entering glass eels, a biological term for non-pigmented anguillids larvae, are caught to be cultured for economic benefits (Setyono et al. 2018). Based on morphological and genetic examination, *A. bicolor bicolor* and *A. marmorata* are the two dominant species in the Cimandiri River and Estuary, where the former contributes more than 85 percent of the total (Affandi 2005; Fahmi and Hirnawati 2010; Hakim et al. 2015). The estuary of the Cimandiri River is an important site for glass eel collection in the Sukabumi Regency, West Java Province, where the abundance of glass eels is the highest compared to other adjacent estuaries. The FAO reported that the individual number of glass eels collected from this estuary was 14,473,738, or 78% of the total (Triyanto et al. 2020). This condition may be caused by the morphology of the estuary and the channel dimensions of the Cimandiri River protruding approximately 5 km from the mouth, suggesting that a higher larval abundance is facilitated by a stronger tidal flux, especially during high tide (Hakim et al. 2015), as well as better access for fishing.

Fish larval viability depends on broodstock quality (Ciji et al. 2022), so it determines the offspring survival rate as aquaculture seeds (Iglesias and Fuentes 2014); similarly, it affects the year-class strength of its wild population (Bergenius et al. 2002). Glass eels that encounter the Cimandiri Estuary are partly caught to meet the needs of eel culture seeds, whereas the rest probably become recruits, increasing the individual number and biomass of its natural population. Through biometric examination, Wildan et al. (2020) recently confirmed a good agreement between biometric aspects and environmental conditions and feeding habits in the cultured elver, that is, the pigmented glass eel. This study assessed glass eel viability through biometric and biochemical performance in its natural habitat. Parameters, including length, weight, and internal organs of glass eels, are linked to the nutritional content to predict the behavior and habitat conditions of glass eels.

MATERIALS AND METHODS

Study Site and Glass Eels Collection

The study area is located in the Cimandiri Estuary, which is quite close to the connecting estuary that empties into Palabuhanratu Bay, facing the Indian Ocean (Figure 1). Glass eels were collected monthly during the western monsoon period, coinciding with their appearance in the estuary between December 2020 and April 2021. Sampling was performed between midnight and dawn (01.00 AM to 04.00 AM) on the dates of the new moon period, according to the Hijri Calendar. Monthly sampling led to the assumption that the eels collected were of the same age, but there were monthly gaps in spawning time from one sampling interval to another. Glass eels were collected using lift-net-like fishing gear locally named *sirib*. The gear is a mesh fine net (0.5 mm), squared in a 1.5 m^2 wooden frame, and diagonally connected by a curved wooden stick that functions as a grip during operation. The harvest was removed into a plastic bag filled with approximately 1/4 of its volume of water, oxygenated, closed, and transported to the Laboratory Biomacro at IPB University, Bogor, Indonesia.

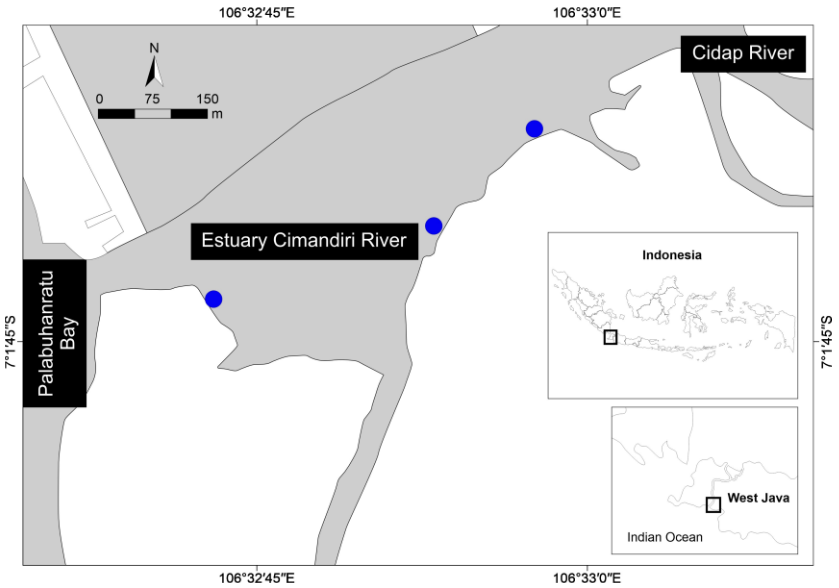


Figure 1 Partial map of Cimandiri Estuary showing the sites for glass eels collection (blue circles), modified from Triyanto et al. (2021)

Biometric Assessment and Proximate Analysis

Biometric assessment was performed on 30 glass eels each month. The measurements were conducted using a Dino lite AM 2111, digital calipers 6" NB60EDC6, and measuring the cups shown by the corresponding units (Table 1). The results of glass eel biometrics were verified by proximate analysis to compare their nutritional contents, including proteins, fats, nitrogen-free extracts, crude fibers, and ash (Wijayanti and Susilo 2018). The results were compared between collection months to explore the variability of the Cimandiri Estuary habitat.

Table 1 Biometric parameters measures on glass eels (*Anguilla* spp.)

Parameter	Unit	Description
Total length	mm	Measured from the tip of the snout to the tip of the longer lobe of caudal fin
Body weight	g	Amount of the whole body of each glass eel
Body volume	ml	Measured by the increase of surface level of the liquid
Gut length	mm	Measured from the posterior of the stomach to the the anus
Eye diameter	mm	The vertical distance of glass eels' eyeball
Maxilla length	mm	Measured as the length along the upper jaw
Head length	mm	Measured as the distance from the snout to the edge of operculum
Heart weight	g	Amount of heart of each glass eel
Liver weight	g	Amount of liver pf each glass eel

Data Analysis

In fishing biology, condition factor (K) has been used as an indicator of fish health linked to food availability and feeding activity of certain species. Glass eels' condition factor (K) was estimated after the L-W relationship (Effendie 2002), formulated as:

$$\mathrm{K} = \frac{100W}{L^3}$$

Where:
W = weight (g)
L = length (mm)

Examination of eye and mouth morphometrics was following Ward-Campbell and Beamish (2005) to calculate:

$$\text{Relative Eye Diameter (RED)} = \frac{Eye\ diameter}{Head\ length}\ x\ 100,$$

$$\text{Mouth Opening (MO)} = \sqrt{\text{length of the upper jaw (mm)}}$$

$$\text{Relative Mouth Opening (RMO)} = \frac{Mouth\ opening}{Head\ length} x\ 100$$

For the heart and liver organs, the relative heart weight (RHW) and the relative liver weight (RLW) were calculated by dividing the weight of the organ by the body weight times by 100 (Dekić et al. 2016). The results of the proximate analysis were calculated (Wijayanti and Susilo 2018), as follows:

$$\text{Nitrogen content (\%)} = \frac{(\mathrm{B}-\mathrm{A})\ \mathrm{x}\ \mathrm{C}\ \mathrm{x}\ 14.007\ \mathrm{x}\ 100}{\mathrm{D}}$$

$$\text{Protein content (\%)} = \text{Nitrogen content (\%) x FK}$$

Where:
A = HCl volume for blank titration (ml)
B = HCl volume for sample titration (ml)
C = normality level of HCL used (N)
D = sample weight (mg)
FK = conversion Factor (6.25 for fishery products)

$$\text{Fat content (\%)} = \frac{W3-W2}{W1} \text{ x } 100$$

Where:
W1 = sample weight (g)
W2 = Fat flask without fat (g)
W3 = Fat flask with fat (g)

$$\text{Ash content (\%)} = \frac{\text{Ash weight}}{\text{Dried sample weight}} \text{ x } 100$$

The average value of each data was compared and tested at a 5% confidence level ($\alpha < 0.05$) (Fowler and Cohen 1997). The whole calculation and statistical tests were performed using software Excel 2010 for Windows.

RESULTS AND DISCUSSION

Length, Weight, and Condition Factor

The length and weight of the glass eels showed a steady increase over the research periods. The average values for both parameters have incremented from December 2020 to April 2021 (Figure 2). However, a significant different was only found when comparing between the initial and final months ($\alpha < 0.05$). Based on length-weight relationship, the growth pattern of glass eel was isometric (b = 3), from which the condition factor K ranged between 0.0650–0.0813. Figure 3 demonstrated K values improving respectively but in April 2001. A significant difference was found between December 2020 and March 2021 ($\alpha < 0.05$).

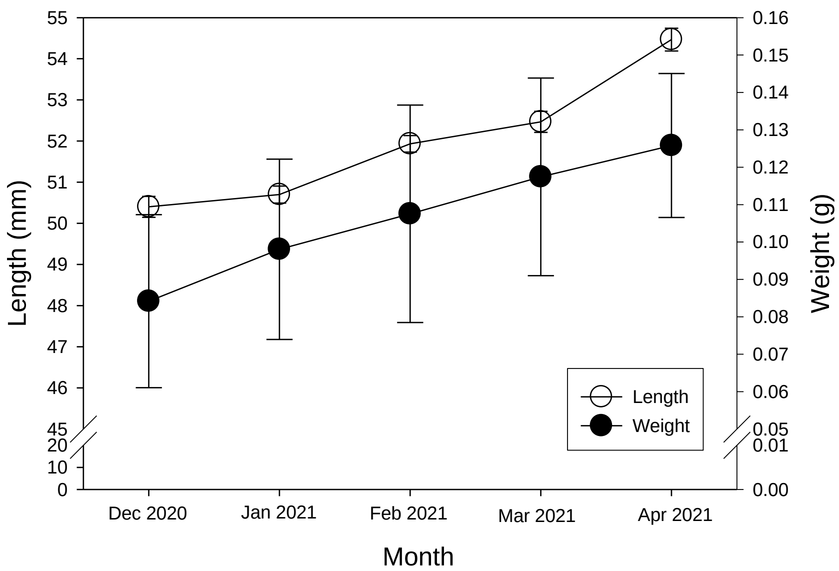


Figure 2 Length and weight variability in the glass eels (*Anguilla* spp.) collected during the study period in Cimandiri Estuary, Sukabumi

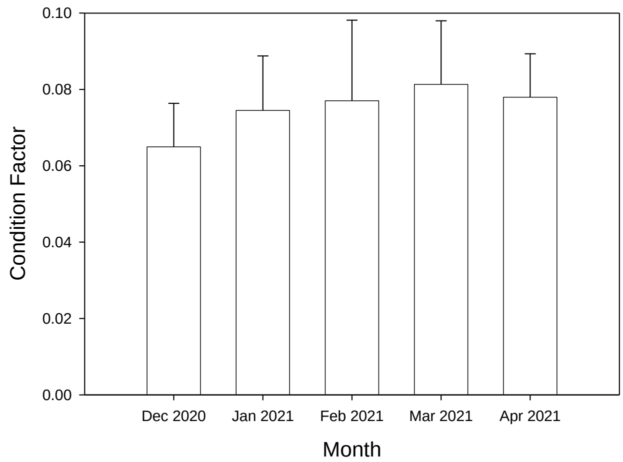


Figure 3 Condition factor (K) of the glass eels (*Anguilla* spp.) collected during the study period in Cimandiri Estuary, Sukabumi

Estimation of the condition factor in fish is used to estimate the growth pattern (Froese 2006) linked to fish well-being, fitness, and habitat quality (Jisr et al. 2018). These two aspects showed relatively good agreement, of which an increase in glass eels' size coincided with the increasing condition factor, with a little exception in April 2021. A high condition factor value describes good eel growth and stable environmental conditions (Kardin et al. 2016). The temperature might be driven the growth performance in glass eels in the study area. Recently, based on 21 yrs satellite data from the year 1997–2018, Nababan et al. (2022) have confirmed an increase in surface temperature in Palabuhanratu Bay from December – February and March – June throughout the year. Laboratory experiments conducted in sub-tropical (Seo et al. 2013; Blakeslee et al. 2018) and in tropical (Fekri et al. 2018) confirmed warmer temperatures resulted in a higher growth rate of glass eels.

Eye and Mouth Morphometric

The absolute and relative dimensions of eye diameter were all similar but in February 2021, being the smallest in diameter size ($\alpha < 0.05$). Though the absolute pattern was comparable with the relative ones, the difference between month comparison was insignificant (Figure 4, upper panel). By mouth dimension, the variation in both absolute and relative patterns was similar to the eye, and none of them was different over the sampling periods (Figure 4, lower panel). The eyes and mouth of the fish reflect the fish feeding activity. In response to light conditions linked to relative eye diameter, fish are grouped into diurnal and nocturnal animals (Fujaya 2004; Anissya 2014). To the former, Tanaka et al. (1981) investigated this mouth dimension on the Nile tilapia ranging from 29–34%, and the latter was from Hossain et al. (1999) on the African catfish between 20–26%.

Glass eels with 27–42% in the range are, therefore, categorized as diurnal fish, those that actively feed during the day. In comparison to the larger stadia, this species shifts its feeding strategy from diurnal to nocturnal. In this context, Sembiring et al. (2015) pointed out that the early life stage of freshwater eels requires better light-based vision to explore natural food availability. The dimension of the mouth as a digestive tract organ describes the maximum swallowable size of food that fits inside a fish's mouth (Ward-Campbell and Beamish 2005) and the morphology of the digestive tracts (Affandi et al. 2005). By relative mouth opening, glass eels are classified as predatory fish whose dimension values show a wider range in relative mouth opening compared to the greasy grouper, a predatory fish, reported by Chen (1979), that is 83–253% to 81–114%.

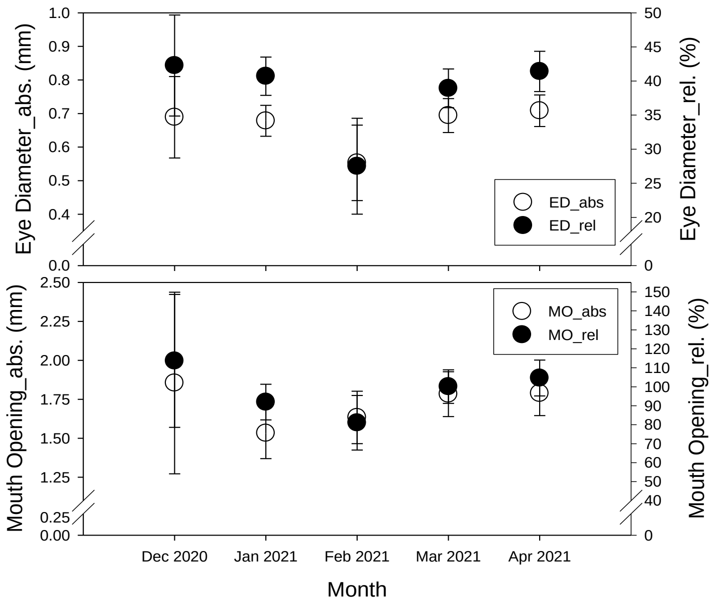


Figure 4 Absolute and relative values of eye and mouth dimensions of glass eels (*Anguilla* spp.) collected during the study period in Cimandiri Estuary, Sukabumi

Heart and Liver

Figure 5 (upper panel) shows a relatively stable heart weight and consistent decrease in relative heart weight (RHW). Correspondingly, the decrease in RHW was in good agreement with the decrease in body weight during the sampling period (see Figure 2). The RHW values were significantly lower in the last two months of research periods compared to December 2020 ($\alpha < 0.05$). On the contrary, the difference in the absolute and relative weight of the liver was subtle, of which there were two clusters of liver dimensions showing February to April were significantly higher compared two December – January (Figure 5, lower panel).

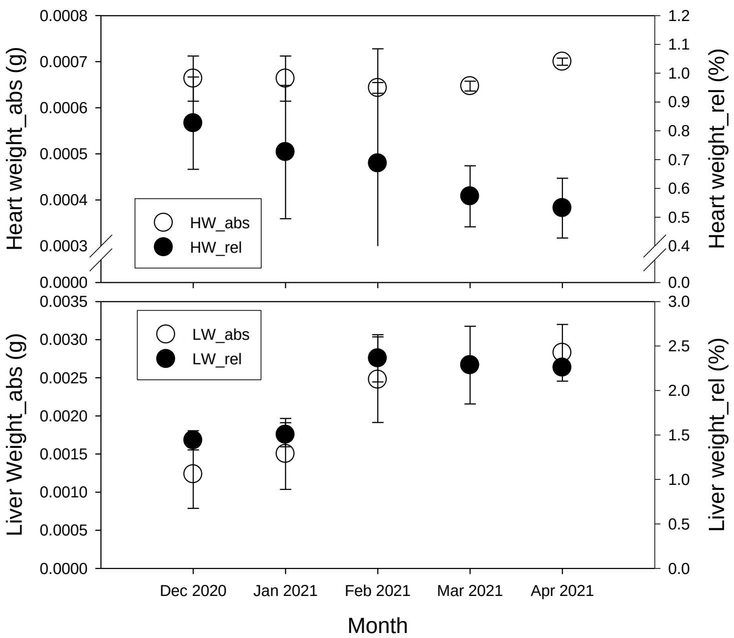


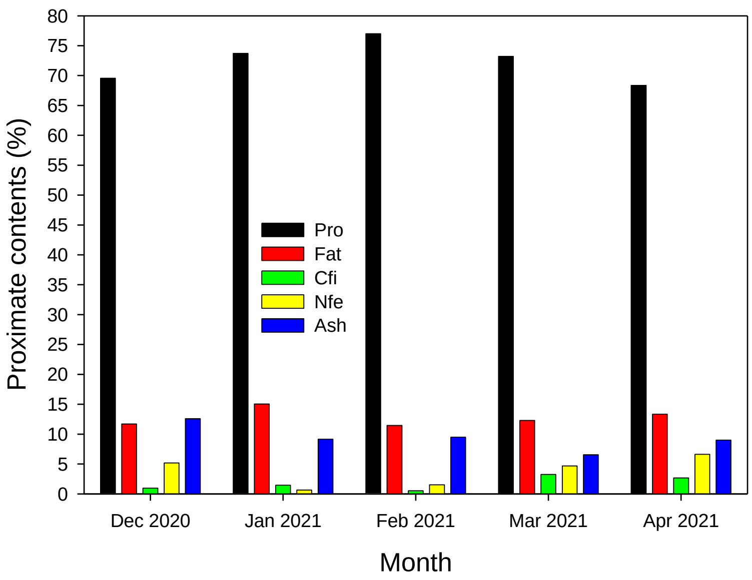
Figure 5 Absolute and relative weight of heart and liver of glass eels (*Anguilla* spp.) collected during the study period in Cimandiri Estuary, Sukabumi

Physiologically, the relative heart weight is an expression of activity level in fish in terms of blood flow rate, metabolic processes, and respiration (Korsmeyer et al. 1997). In the present study, the relative heart weight ranged from 0.53 to 0.83%, which was smaller than the salmon with 1.22% (Smith 1982). The higher the relative heart weight, the higher the heart rate and the stronger the power of pumping blood throughout the body. It is well known that the two are representative of anadromous and catadromous groups, respectively, moving oppositely within their migration pathways. Whether such a difference is in favor of life cycle movement behavior is unknown. However, it is certain of being higher activity in salmon gives an advantage for better ability in pursuing the prey, and at the same time avoiding the predators. By a percentage of 1.22%, the relative heart weight of glass eel is comparable to salmon belonging to fast-swimming fish.

In food digestion, the liver plays a crucial role in maintaining homeostasis through metabolism, nutrient storage, and detoxification (Sari et al. 2016). This organ is the main target of most research dealing with the fish's response to environmental impact. In addition, the liver also secretes bile (Morina et al. 2017). The results of the relative liver weight measurement on glass eel seeds showed that the average liver weight ranged from 1.4–2.3%. This explains that there is an increase in body metabolism, because the higher the relative liver weight value, the higher the metabolic rate. This is in accordance with Yandes et al. (2003), who reported that an increase in the relative weight of the liver indicates an increase in nutrients accumulated in the liver due to increased bile secretion activity, which increases the digestion of fats, proteins, and carbohydrates so that the absorption activity of food substances also increases (Putri et al. 2016).

Proximate Contents

Figure 6 presents the composition of proteins, fats, carbohydrates, and ash content of the glass eels. Proteins ranged between 68–78 % or equal to 7–8 folds of fat between 10–15%. Carbohydrates are comprised of two forms: nitrogen-free extract (Nfe) and carbohydrate fibers (Cfi), of which the two form approximately 3–10% of the total. The remaining ash content ranged from 7 to 13%. The values do not represent individual animals. Instead, five individuals were lumped for a single analysis for the reason the minimum biomass required for the analysis.



Note: Pro=Protein; Fat=Fat; Cfi=Carbohydrate fibers; Nfe=Nitrogen-free extract; Ash=Ash

Figure 6 Month comparison of proximate composition in the glass eels (*Anguilla* spp.) collected during the study period in Cimandiri Estuary, Sukabumi

The proximate contents showed monthly fluctuations in each component, but overall, there were no significant temporal differences. High protein content in fish is very common because fish are known to be a food source that contains lots of protein, which is rich in essential amino acids, including lysine, methionine, cystine, threonine, and tryptophan. However, protein levels vary depending on stadia, age, sex, and environmental conditions. Other substances, including fats, carbohydrates, and ash, may be related to natural behavior linked to energy reserve storage, environmental conditions, and fish digestibility mechanisms (Enes et al. 2009; Islamiyati et al. 2010).

CONCLUSION

The biometric characteristics of the glass eel increased slightly in length and weight between December 2020 and April 2021. Eye dimensions revealed that the glass eel was a diurnal predator. Heart and liver dimensions refer to metabolic capabilities that coincide with fast-swimming fish, which favor a highly catadromous migratory fish. The conditions of the Cimandiri Estuary as the glass eel habitat were assumed to be homogenous, and the nutritional contents of the glass eels were indifferent during the research period. However, based on the biometric measurements during the research period, it might be concluded that because of its largest size, the glass eels in April 2021 were best for aquaculture seeds and might show survival probability as rectuits.

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