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BIOMETRIC CHARACTERISTICS AND STRESS LEVELS OF GLASS EEL (*Anguilla* sp.) IN THE SOUTHERN ESTUARIES OF SUKABUMI, WEST JAVA

KARAKTER BIOMETRIK DAN FISIOLOGIS BENIH IKAN SIDAT (*Anguilla* sp.) DI MUARA SELATAN SUKABUMI, JAWA BARAT

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ABSTRACT

Palabuhanratu Bay is the terminating flow for some rivers, i.e. the Cimandiri River, Ciletuh River, Cikaso River, and Cibuni River, where the estuary is the entry route for glass eels (*Anguilla* spp.) or fish seeds from sea waters to these estuaries. Different rivers have different water quality conditions that may imply differences in the quality and quantity of eels entering the estuary. This research aims to determine locations with superior seeds, and seeds with low quality based on studying biometric characteristics and stress levels of eel seeds in several estuaries in the south of Sukabumi, West Java. The information gathered is subject to determining the highly recommended use of glass eels as seeds in eel aquaculture, as well as determining the area where habitat rehabilitation and conservation. The research was carried out in four locations, namely the Cimandiri, Ciletuh, Cibuni, and Cikaso River Estuaries, from December 2021 to January 2022, the peak time for eel seed migration. The parameters observed include water physics and chemistry, biometrics, and blood glucose. The research results show that each location has different physical and chemical water parameter values but has relatively the same stress level. The best biometric value of eel fish seeds was found in eel seeds originating from the Cimandiri River, while the lowest one was at the mouth of the Cibuni River. Therefore, eels that are suitable for cultivation activities come from the Cimandiri River Estuary, while the eel location that needs conservation is the Cibuni River Estuary.

Keywords: biometrics, eel, estuary, glass eel, Sukabumi

ABSTRAK

Teluk Palabuhan Ratu merupakan tempat bertemunya beberapa muara sungai, antara lain Sungai Cimandiri, Sungai Ciletuh, Sungai Cikaso, dan Sungai Cibuni, yang merupakan jalur masuknya *glass eel* atau benih ikan sidat (*Anguilla* spp.) dari perairan laut ke muara-muara tersebut. Sungai yang berbeda memiliki kondisi kualitas air yang berbeda. Kondisi kualitas air yang berbeda ini akan menyebabkan adanya perbedaan kualitas dan kuantitas benih ikan sidat yang masuk ke muara tersebut. Tujuan penelitian ini adalah untuk menentukan lokasi yang memiliki benih unggul dan benih yang mutunya rendah berdasarkan karakteristik biometrik dan tingkat stres benih sidat di beberapa muara di selatan Sukabumi, Jawa Barat. Informasi yang diperoleh akan dijadikan dasar dalam menetapkan lokasi yang memiliki potensi benih sidat unggul dan menetapkan lokasi yang perlu dikonservasi dan rehabilitasi. Penelitian dilakukan di empat lokasi yaitu Muara Sungai Cimandiri, Ciletuh, Cibuni, dan Cikaso, dari bulan Desember 2021-Januari 2022 waktu tersebut merupakan waktu puncak ruaya benih sidat. Parameter yang diamati meliputi fisika dan kimia air, biometrik, dan glukosa darah. Hasil penelitian menunjukkan bahwa setiap lokasi memiliki nilai parameter fisika dan kimia air yang berbeda-beda, akan tetapi memiliki tingkat stres yang relatif sama. Nilai biometrik benih ikan sidat terbaik terdapat pada benih sidat yang berasal dari Muara Sungai Cimandiri, sedangkan benih yang mutunya rendah adalah benih yang ditangkap di Muara Sungai Cibuni. Oleh sebab itu, sidat yang cocok untuk kegiatan budidaya berasal dari Muara Sungai Cimandiri, sedangkan lokasi sidat yang perlu di konservasi adalan Muara Sungai Cibuni.

Kata kunci: biometrik, *glass eel*, muara, sidat, Sukabumi

INTRODUCTION

Palabuhan Ratu Bay is a meeting place for several river estuaries, including the Cimandiri River, Ciletuh River, Cikaso River, and Cibuni River (Setiawan and Triyanto 2012). These rivers are the entry routes for glass eels or eel seeds (Anguilla spp.) from sea waters to fresh waters (Triyanto et al. 2019; Suhendar et al. 2016; Annida et al. 2022). The Cimandiri River, Ciletuh River, Cikaso River, and Cibuni River have estuaries with varying dimensions and depths, so the water quality conditions will be different. Different water quality conditions will cause differences in the quality and quantity of eel seeds (Triyanto *et al.* 2019).

Ell restocking and cultivation activities require seeds that are in prime condition, therefore, information regarding river estuary habitats that are suitable for the living needs of glass eels is very important. The information regarding less-than-optimal eel seed habitats, on the other hand, is required as a basis for habitat rehabilitation so that eel seeds that live in the rehabilitated habitat become quality seeds (Krismono and Kartamihardja 2012).

Efforts to determine whether the condition of the estuary habitat is prime or not can be made by analyzing water quality, while determining whether the condition of eel seeds is prime or not can be done using the biometric parameter analysis approach and stress levels (Wildan *et al.* 2020; Kamal *et al.* 2023). Biometric parameters will provide an overview of the eel's body, whether it has good growth or not; in contrast, the stress level described by blood glucose parameters will provide an overview of whether the fish seeds live in a suitable habitat or not (Wildan *et al.* 2020). Therefore, it is necessary to conduct a study related to habitat conditions, biometric characteristics, and stress levels of eel seeds (*Anguilla* spp.) in several river estuaries in southern Sukabumi to determine the quality of eels at each location.

METHODS

Time and location

This research was conducted from December 2021 to January 2022. The research was conducted at several river estuaries in the southern region of Sukabumi, namely at the Cimandiri, Ciletuh, Cibuni, and Cikaso River Estuaries (Figure 1).

Data collection methods

Measurement of aquatic habitat quality

Water quality data, including water physics and chemistry, were collected at each research location. Water quality data collection was carried out with 3 replications. Water physics and chemistry data were obtained by measuring directly in the waters according to the data collection location in-situ (temperature (°C) using a thermometer, turbidity (NTU) using a turbidity meter, TDS (mg/l) using a TDS meter, salinity (PPT) using a refractometer, pH using a pH meter, and oxygen (mg/l) using a DO meter) and ex-situ for laboratory tests (TSS (mg/l) using a TSS meter, conductivity (µs/cm) using a conductivity meter, alkalinity (mg/l $CaCO_3$) using titration, COD (mg/l) using the open reflux method, and ammonia (mg/l) using the phenate method). Analysis of water physics and chemistry followed the APHA method (2012).

Biometrics of glass eel

Biometric characters are one of the bases for evaluating the biological potential performance of a type of aquatic biota. The eel seed samples used for biometric analysis amounted to 30 from each location. The biometric parameter analysis carried out included condition factors, relative eye diameter (ESr), mouth opening width (WMO), relative mouth opening width (WMOr), relative intestine length (ILr), relative heart weight (HWr), and relative liver weight (LWr) (Table 1).

Blood glucose measurement

Blood glucose measurement aims to determine the stress level of fish living in their environment. Blood glucose samples of glass eels were obtained from 30 glass eels that were ground and added with an anticoagulant as much as the amount of blood (1:1) so that body fluid was obtained which was used as a blood glucose sample. After that, the sample was analyzed using a glucose kit brand GCU glucose kit. Blood glucose analysis was carried out according to the method of Wedemeyer and Yasutake (1977).

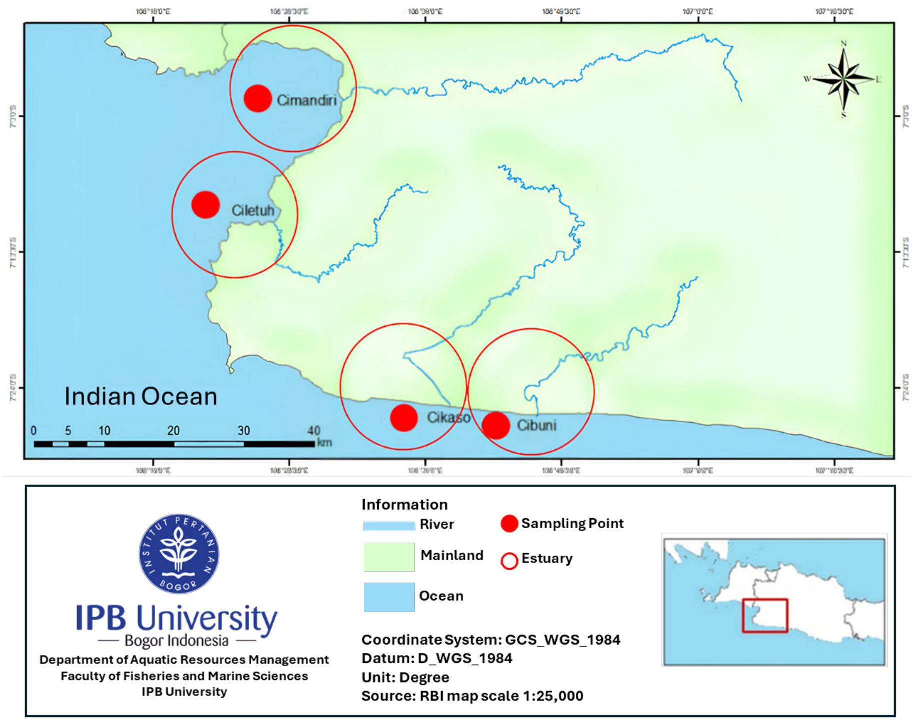

Figure 1. Location of research on taking eel seeds in the southern river estuary of Sukabumi Regency.

Table 1. Biometric parameters observed in glass eels.

Parameters	Formulas	Descriptions	
Condition factor (K)	$K = (1000W)/L^3$	W L	: Weight (g) : Total length (cm)
Relative eye size (ESr (%))	$ESr = (ED/HH) \times 100$	ED HH	: Eye diameter (mm) : Head height (mm)
Width of mouth opening (WMO)	$WMO = UJL\sqrt{2}$	UJL	: Upper jaw length (mm)
Relative width of mouth opening (WMOr (%))	$WMOr = (WMO/HH) \times 100$	WMO HH	: Mouth opening width (mm) : Head height (mm)
Relative intestine length (ILr (%))	$ILr = (IL/BL) \times 100$	IL BL	: Intestine length (mm) : Body length (mm)
Relative heart weight (HWr (%))	$HWr = (HW/BW) \times 100$	HW BW	: Heart weight (g) : Body weight (g)
Relative liver weight (LWr (%))	$LWr = (LW/BW) \times 100$	LW BW	: Liver weight (g) : Body weight (g)

Data analysis

Biometric parameters

Biometric parameters provide an overview of the quality of glass eels. Biometric parameters that provide an overview of the growth of glass eels are condition factors, relative intestine length, relative heart weight, and relative liver weight, while biometric parameters that provide an overview of living habits include relative eye diameter and mouth opening width. All biometric data of glass eels were analyzed according to Table 1.

Anova test

Biometric parameter data and stress levels of glass eel seeds were analyzed statistically using a completely randomized design (CRD) analysis of variance (ANOVA) processed with SPSS (Statistical Product and Service Solutions) and Excel 2021 for Windows. Then the data was further analyzed using the Tukey test with the aim of determining the differences between the mean values of the variables (Steel and Torrie 1991).

Decision-making matrix

Determination of glass eel habitats that have prime quality and glass eel habitats that need rehabilitation and conservation is done using a matrix. The matrix columns are research locations (Cimandiri, Ciletuh, Cibuni, and Cikaso River Estuaries), while the matrix rows are biometric parameters (weight = 60 with details of condition factors, relative heart weight, and relative liver weight, each 20 points) and blood glucose (weight = 40). The matrix is made by giving a score to each parameter (1 to 5). Details of the scores for biometric parameters and blood glucose are presented in Table 2. The location with the highest value is the location that produces prime quality glass eels, while the location with the lowest value is the location that has poor seed quality, so rehabilitation is needed.

RESULTS AND DISCUSSION

Results

Condition of river estuary

The results of the analysis of physical and chemical parameters of waters in the natural habitat of glass eels provide information on the condition of physical and chemical parameters of the habitat of glass eels compared to the needs according to their stage. Data from the analysis of the physical and chemical parameters of water are presented in Table 3.

The physical and chemical parameters of the waters based on Table 3 show that there are differences in values at each location for each parameter. In general, based on the water quality data presented, it can be seen that the condition of the Cimandiri River is the most suitable location for the life of eels (glass eels) compared to the other three rivers. This can be seen from the water quality parameters, which are generally within the optimal range of glass eels.

Blood glucose

Blood glucose is an indicator of stress in fish. High blood glucose levels in fish indicate that the fish is experiencing stress. The detailed blood glucose data of glass eels based on the results of this study are presented in Figure 2.

The blood glucose value of glass eels based on Figure 2, it can be seen that the range of glucose values in this study ranges from 53-67 mg/dL. Statistically, the difference in location did not have a significant effect on blood glucose values ($p > 0.05$). The lowest blood glucose value was possessed by glass eel from the Cibuni River Estuary with a value of 53 mg/dL, while the highest blood glucose value came from the Ciletuh River Estuary with a value of 67 mg/dL.

Biometric data of glass eels

The results of the biometric data analysis used to determine superior glass eels include condition factors, relative eye diameter (EDr), mouth opening width (MOW), relative mouth opening width (MOWr), relative intestine length (ILr), relative heart weight (HWr), and relative liver weight (LWr). Biometric data of eel seeds are presented in Table 4.

Biometric data based on Table 4 shows significant variation between glass eels in various river locations, with the Cimandiri River as the best location. Glass eels in the Cimandiri River have the highest average length of 5.04 cm, the largest weight of 0.08 g, and a better condition factor of 0.0649, indicating more optimal health. In addition, the weight of the heart and liver is also higher than in other locations, indicating better organ proportions. Meanwhile, the Ciletuh and Cibuni Rivers show lower characteristics, especially in heart and liver weight. Thus, the Cimandiri River shows the best potential for the sustainability and health of the fish population.

Decision-making matrix

Determination of prime *glass eel* habitat and habitat that needs rehabilitation and conservation is done using a decision-making matrix. The location with the best value is the location that produces prime eel seeds, while locations with low value need conservation. The decision-making matrix is presented in Table 5.

Table 2. Details of biometric scores and blood glucose of glass eels.

Scores	Parameters			
	Biometric Glass Eels			Blood Glucose
	K	HWr	LWr	
1	0.0612<x≤0.0619	0.9916<x≤1.0451%	1.3124<x≤1.3358 %	120-130 mg dl^{-1}
2	0.0619<x≤0.0626	0.9382<x≤0.9916 %	1.3358<x≤1.3592 %	110-120 mg dl^{-1}
3	0.0626<x≤0.0634	0.8848<x≤0.9382 %	1.3592<x≤1.3826 %	100-110 mg dl^{-1}
4	0.06342<x≤0.0641	0.8314<x≤0.8848 %	1.3826<x≤1.4060 %	90-100 mg dl^{-1}
5	0.0641<x≤0.0649	0.7780<x≤0.8314 %	1.4060<x≤1.4294 %	40-90 mg dl^{-1}

Table 3. Physical and chemical parameters of waters in the southern river estuary of Sukabumi.

Parameters	Units	Locations				Water Quality Standards *	Glass Eels Living Needs
		Cimandiri	Ciletuh	Cibuni	Cikaso		
Physics							
Temperature	°C	27.35±0.07	26.70±0.14	28.94±0.09	28.25±0.07	Deviation 3°C	28-30[1]
Turbidity	NTU	28.015±0.9	108.84±0.23	282.06±0.08	37.51±0.11	-	≤25[2]
TSS	mg/l	77.5±2.12	73±1.41	408±1.41	85.5±2.12	≤50	≤25[2]
TDS	mg/l	358±5.66	1,181±7.07	663.5±4.95	571±7.07	≤1,000	≤1,000[3]
Conductivity	µs/cm	730±1.41	2,349±1.41	1,377.5±3.54	1,170.5±2.12	-	500-2,000[8]
Chemistry							
Dissolved Oxygen	mg/l	4.39±0.13	5.28±0.25	5.77±0.1	5.16±0.08	≥4	>5[4]
pH	-	6.70±0.01	6.98±0.01	6.91±0.05	6.68±0.14	6-9	7.0-8.5[5]
Salinity	ppt	0±0	0±0	0±0	0±0	-	0.5-15[6]
Alkalinity	mg/l	96.85±0.07	33.25±0.64	42.5±3.54	62.5±3.54	-	57-68[7]
COD	mg/l	89.025±0.01	26.205±0.15	89.595±0.01	89.52±0.69	≤100	≤100[9]
Ammonia	mg/l	0.473±0.01	0.289±0.003	0.0875±0.001	0.07±0.001	≤0.5	<0.01[10]

Information:
* PPRI (2021)
[1] Affandi and Suhenda (2003)
[2] Beveridge (1996)
[3] Boyd (1990)
[4] Colt (2006)
[5] Timmons and Ebeling (2007)
[6] Arai (2016)
[7] Lukas *et al.* (2017)
[8] Boyd and Tucker (1998)
[9] Knösche (1994)
[10] Wahyuningsih and Gitarama (2020)

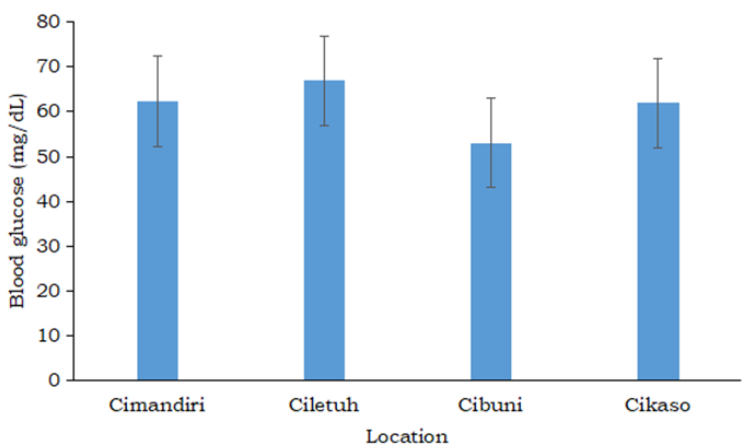

Figure 2. Blood glucose of glass eels in the southern estuary of Sukabumi.

Table 4. Biometric data of eel seeds in the southern river estuary of Sukabumi.

Biometric Parameters	Unit	Locations			
		Cimandiri River	Ciletuh River	Cibuni River	Cikaso River
Length	cm	5.04±0.25[a]	4,94±0,03[a]	4,83±0,31[a]	4,89±0,07[a]
Weight	g	0.08±0.02[a]	0,07±0,002[a]	0,07±0,01[a]	0,07±0,004[a]
K	-	0.0649±0.0114[a]	0,0648±0,0004[a]	0,0612±0,0072[a]	0,0641±0,0010[a]
HW	g	0,0007±0,00004[a]	0,0006±0,00002[ab]	0,0007±0,00002[a]	0,0006±0,00005[ab]
HWr	%	0,8263±0,1602	0,7780±0,0234	1,0451±0,3865	0,8080±0,0490
LW	g	0,0012±0,0004	0,0010±0,0004	0,0009±0,0003	0,0010±0,0008
LWr	%	1,4294±0,1127	1,3959±0,0117	1,3124±0,1932	1,3814±0,0245
WMO	mm	1,85±0,5	1,78±0,14	1,86±0,23	1,80±0,10
WMOr	%	113,6±35	100,1±8,8	109,2±16,9	121,4±3,1
ES	mm	0,68±0,12	0,69±0,05	0,70±0,04	0,63±0,1
ESr	%	42,2±7,4	38,9±2,8	41,4±2,9	42,7±4,3

Description: a, b = notation of further test results bnt

Table 5. Decision-making matrix for determining eel seed locations.

Parameters	Locations											
	Cimandiri River Estuary			Ciletuh River Estuary			Cibuni River Estuary			Cikaso River Estuary		
	W	**S**	**V**	**W**	**S**	**V**	**W**	**S**	**V**	**W**	**S**	**V**
Biometrics												
K	20	5	**100**	20	5	**100**	20	1	**20**	20	4	**80**
HWr	20	5	**100**	20	5	**100**	20	1	**20**	20	5	**100**
LWr	20	5	**100**	20	4	**80**	20	1	**20**	20	3	**60**
Blood glucose	40	5	**200**	40	5	**200**	40	5	**200**	40	5	**200**
Total			**500**			**480**			**260**			**440**

Description: W = Weight, S = Score, V = Value

Decision-making matrix based on Table 5, it is known that the total value of the matrix ranges from 260-500 points. The location with the highest value is at the Cimandiri River Estuary (500), while the location with the lowest value is at the Cibuni River Estuary (260). The Cimandiri River Estuary has the best blood glucose and biometric values compared to other locations. The Ciletuh River Estuary has the second lowest value because it has a lower relative liver and heart weight. The Cibuni River Estuary is the location with the lowest matrix value due to the blood glucose and biometrics it has.

Discussion

The physical and chemical parameters of water provide an overview of the habitat conditions of eel seed. The results of the analysis of physical and chemical parameter measurements show that in general the physical and chemical parameters at each location still support the life of glass eel, except for the dissolved oxygen and ammonia parameters at the Cimandiri River Estuary and ammonia at the Ciletuh River Estuary. The high ammonia value is due to the large amount of organic material found in the waters due to household waste disposal. This is in accordance with the research of Zaini *et al.* (2022), which found that the density of waste in the Cimandiri River Estuary was 231.75 items/m^2 (bright moon) and 524.75 items/m^2 (dark moon). The high level of waste causes oxygen in the waters to be relatively low because it causes oxygen diffusion to be suboptimal, and bacteria require large amounts of oxygen to decompose organic material (Wildan *et al.* 2021). In addition to water quality, it is necessary to observe biometric data and eel stress levels to determine the prime quality of glass eel seeds that need to be conserved.

According to Nasichah *et al.* (2016), blood glucose in the fish body is the main source of energy and a source of fuel supply and essential substrates for the metabolism set, especially the brain set. Normal blood glucose levels in fish contain 40-90 mg/dL. Increased glucose levels can be influenced by other factors such as water quality and the environment. This is supported by Nasichah *et al.* (2016), who argue that stress is a physiological response from the body that occurs when animals try to maintain homeostasis in the body, stress that occurs in fish is one of them due to poor environmental conditions. Higher blood glucose levels indicate increased stress levels due to poor environmental influences. At very high-stress levels, a rapid increase in blood glucose concentrations persists at high levels and is followed by fish death.

The results showed that the range of glucose values in this study ranged from 53-77 mg/dL and did not differ significantly between locations. The highest blood glucose value came from the Ciletuh River estuary with a value of 67 mg/dL, while the lowest blood glucose value was found in eel seeds from the Cibuni River estuary with a value of 53 mg/dL. The glucose value in this study was still in normal condition because it was still in the range of 40-90 mg/dL (Reichenbach-Klinke and Landol 1973). Eels are a species that are strong against changes in various water conditions such as temperature, pH, and salinity. This allows eels to migrate or move to river estuaries to grow to adulthood and return to the deep sea for reproduction (Tsukamoto and Kuroki 2014).

One of the biometric parameters is the length and weight of glass eel seeds (*Anguilla bicolor bicolor*). The results showed that there was no significant difference at each research location. The length and weight of eel seeds ranged from 4.8-5 cm and 0.07-0.08 g. The difference in weight values can be caused by several factors, such as water quality conditions, feed availability, and the genetics of the fish seeds (Wildan *et al.* 2020).

Condition Factor is one of the parameters that can describe the habitat conditions of eel seeds, a high K value indicates that the eel has sufficient food so that it has high growth (Wildan *et al.* 2020). The results showed that glass eels from the Cimandiri River Estuary had the highest K value with a value of 0.0650, while those with the lowest value were in the Cibuni River Estuary with a value of 0.0613. This is in accordance with the research of Astuti and Rahul (2023) on *Anguilla marmorata* with a higher K value conducted in the Cimandiri River Estuary with an average K value of 1.081 because it used silver eel stage eels. Efforts to determine the cause of the low K value require observation of the biometric and physiological parameters of the eel seed body.

The biometric parameter that describes the metabolism of the fish body is the relative heart weight because the heart acts as a blood pump containing nutrients and oxygen for the metabolic process (Korsmeyer *et al.* 1997; Wildan *et al.* 2020). The relative heart weight values in this study ranged from 0.77 to 1.04%, respectively. The highest relative heart weight value was found at the Cibuni River Estuary (1.04%), followed by the Cimandiri River Estuary (0.82%), the Cikaso River Estuary (0.80%), and the Ciletuh River Estuary (0.77%). The relative heart weight value illustrates the lower growth of the eel seeds to pump blood throughout the body. This is because at the glass eel stage, the eel migrates (Tesch 1977; Tesch 2003). The results of Smith's (1982) study, related to salmon, found that the relative heart weight value of salmon was 1.22% and was classified as a fast-swimming fish and migrated. The biometric parameters that describe metabolism and environmental conditions are the liver weight of a glass eel.

The liver is an organ related to nutrition because the size of the fish liver is relatively correlated with nutritional status (Caruso *et al.* 2012). The liver weight and relative liver weight values in this study ranged from 0.0010-0.0012 g and 1.31-1.42%, respectively. The highest liver weight value was found in glass eel from the Cimandiri River Estuary (0.0012 g), while the highest relative liver weight value was found in the Cimandiri River Estuary (1.42%). These results explain that the glass eel has sufficient food, this is in accordance with the results of the study by Robisalmi *et al.* (2021), which found that fasted fish will have an HSI value of <1% and fish that have sufficient food will have an HIS value of >1%. The LWr value in this study also explains that the glass eel in each location in this study has sufficient food needs. The relative liver weight value in this study also correlates with the RNA/DNA ratio. This means that it is related to the rate of protein synthesis. Genten *et al.* (2009) stated that the liver has a very important role in protein synthesis, nutrient assimilation, and maintenance of body metabolism, including protein, fat, carbohydrate, and vitamin metabolism. Thus, high growth and relative increase in liver weight indicate that all processes in the liver are running well.

Mouth opening width and eye diameter are biometric parameters that provide information related to the size of the feed eaten and the time the fish are actively moving (Wildan *et al.* 2020). The relative opening width and relative eye diameter values in this study were 100-121% and 38.92-42.73%, respectively. These results provide information that glass eels forage as predatory fish and do so during the day (diurnal) (Chen 1979; Tanaka *et al.* 1981; Sembiring *et al.* 2015). This is suspected because glass eel is still in the growth phase, whose life activities still require light, in contrast to adult eel which are known to be nocturnal (Sembiring *et al.* 2015).

The results of the decision-making matrix analysis determined that the river estuary that produces superior eel seeds and a location that is worthy of conservation is the Cimandiri River Estuary. This is because eel seeds in the Cimandiri River Estuary have high biometric values and blood glucose values that are still within normal limits, so the use of eel seeds from the Cimandiri River Estuary is suitable for eel cultivation activities. In addition to biometric values and blood glucose, glass eels from the River Estuary have the potential to be used in cultivation activities due to their high abundance (Kearney *et al.* 2011). The Cimandiri River Estuary has the potential for glass eel, however, the condition of the eel waters based on this study has several parameters that have lower values (oxygen and ammonia) than other locations but are still in accordance with the needs of glass eel.

Low oxygen and high ammonia condition in the Cimandiri River Estuary are caused by human activities such as the construction of a PLTU and the extraction of sand materials by local residents (Haryono *et al.* 2011). Therefore, the Cimandiri tributaries need to be conserved to maintain their good condition. The forms of conservation that can be carried out include habitat restoration, land use regulation, water resource management, determination of protected areas, making eel fishing regulations, monitoring and researching water quality, and education and socialization related to the Cimandiri River Estuary as an eel habitat (Lake 2001; Allan 2004; Poff and Zimmerman 2010; Roberts and Hawkins 2000; Pauly and Zeller 2016; Allan and Castillo 2007).

CONCLUSION

Glass eels that had superior quality based on biometric data and stress levels were seeds caught at the Cimandiri River Estuary, while glass eels with low quality were seeds caught at the Cibuni River Estuary.

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