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New Perspective of Java Eel Conservation: Case Study in Cilacap Riverine and Coastal Area, Central Java, Indonesia

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ABSTRACT

The case study on a new perspective of Java eel conservation was conducted to address the declining trend of eel capture fisheries in general inland waters of Cilacap in Indonesia from 2017 to 2021 and investigate the perception of fishermen from 2018 to 2022. Site visits and interviews with fishermen and eel collectors were conducted. Results show that there is a similar trend of decreasing eels (i.e., *Anguilla bicolor bicolor* and *Anguilla marmorata*[s1]) in catches from 2018 to 2022, where the catch of glass eels up to the consumption size in the Citandui Watershed and Serayu decreased by 72% and 82%, respectively. The presence of the river barriers, i.e., the Manganti and Gerak Serayu dams, decreases in water discharge over the years and the failure of elvers to migrate upstream has contributed to the decline. The distribution of glass eel and elver in other rivers and along its irrigation channels indicates that the eels escape for their migration upstream. The decrees of the Minister of Marine Affairs and Fisheries of the Republic of Indonesia, issued in 2020 and 2021, have provided limited protection and conservation of eels (*Anguilla* spp.) and imposed quotas for the use of limited protected fish species in order to maintain the sustainability of the eel population. The role of watersheds with forest areas in supplying water to the river throughout the year needs to be concerned. Suggested solutions to improve the population and conservation of eels include controlling and limiting the pattern of yellow to silver eel catches, creating fishways or fish ladders on the walls of both dams as well as reforestation the lost forests in the watershed area.

INTRODUCTION

An ecological problem is causing significant damage to both the environment and its living organisms. Deforestation is causing a decline in water resources, particularly in river watersheds, leading to adverse effects on the living organisms in the river. This condition is wreaking havoc on diadromous species that rely on the continuity of the river's water flow for their migration cycle (**Taufiq-Spj *et al*., 2022**). At the beginning stages of catadromous migration, glass eels are naturally drawn to the flow of rivers, migrating counter-current from low estuaries to upstream rivers (**Trancart *et al*., 2014; Taufiq-Spj *et al*., 2021**). This newly glass eel stage will enter the estuary area towards the river flow by using the "imprint magnetic direction of tidal current" (**Cressi *et al*., 2019**). While, the elver stage and the pencil size will continue to swim upstream until they find a suitable environment for growth. Therefore, the continuity of the river flow is important for the survival of this catadromous species. This flow continuity depends mainly on the catchment area of rainwater in the watershed, where forest area is the main factor.

In terms of eel conservation, there are some declining populations of Anguilla sp. around the world. **Aalto *et al.* (2016)** reported that the fisheries yield of the European eel (*Anguilla anguilla*) has been declining in population along eight countries of the Mediterranean coastal lagoons. Other important species are also facing declining populations, such as *A. rostrata* (**Gress *et al*., 2008; Chang *et al*., 2020; Feng *et al*., 2022**) *Anguilla japonica* **(Chang *et al.* 2018)**; *A. marmorata* (**Lee *et al*., 2018; Pangerang *et al*., 2018**) as well as *A. nebulosa nebulosa* (**Lukas *et al*., 2022**). Other species such as *A. b. bicolor, A. bengalensis, A. australis, A. borneensis, A. celebesensis, A. ancentralis, A. b. pacifica, A. interioris, A. megastoma, A. labiata, A. mossambica* and other Anguillid species also need to be taken into consideration **(Aoyama, 2009; Fahmi & Hirnawati, 2010; Minegishi *et al*., 2012; Fahmi *et al*., 2013; Castonguay & Durif, 2016; Taufiq-Spj *et al*., 2021)**. In addition, due to their wide-spread migration cycle, the importance of catadromous species can act as surrogate species for the conservation of freshwater biodiversity **(Itakura *et al*., 2020**).

Since the genus Anguilla was announced in Appendix II of CITES (2017), the Indonesian Minister of Marine Affairs and Fisheries has issued some regulations, starting with the Decree of the Minister of Marine Affairs and Fisheries (MMAF) of the Republic of Indonesia No. 80 of 2020 concerning the limited protection and conservation of eels *Anguilla* spp. (**Decree of MMAF-RI No. 80, 2020**), followed by the **Decree of MMAF No. 118** (2021) concerning the Eel Fisheries Management Plan. The most recent **Decree of MMAF No. 12 (2022)** concerning the collection of quotas for the use of limited protected fish species in order to maintain the sustainability of the eel population was based on the National Provisions and Fish Species in Appendix II of the Convention on International Trade in Endangered Species (CITES) of Wild Fauna and Flora.

Contrarily, as eels are one of the most nutritious non-starchy foods and famous protein sources, Indonesia was ranked as the number one eel-exporting country in the world. In 2020, Indonesia was able to supply 25% of the world's frozen eel, with a value of up to $13,239,000, and its live eel export was ranked the 14th in the world (**Widyaningrum, 2021**). In fact, the biodiversity of Indonesian eels is also the most varied of Anguillid eels around the world (**Taufiq-Spj *et al*., 2020, 2021**). There are at least eight Anguillid species of Indonesian eels reported in the study of **Fahmi *et al.*** (**2013**) from the 18 species of world known Anguillid eels (**Tomiyama & Hibya, 1977; Leander *et al*., 2012; Minegishi *et al*., 2012; Kottelat, 2013; Taufiq-Spj *et al*., 2022**). Therefore, this study aimed to evaluate the current status of eels in the Cilacap District, especially in terms of yearly catches and their environmental cues in order to carry out an evaluation of the status of this species and its conservation.

MATERIALS AND METHODS

The Study Area

A survey was conducted from 2018 to 2023 in Cilacap in the southern Central Java, covering riverine and estuarine areas (Fig. 1). The study involved site visits and interviews with 47 fishermen and 7 eel collectors in 12 subdistricts of Cilacap Regency. Site visits were made to seven subdistricts, including Patimuan, Kedungreja, Wanareja, Dayeuhluhur, Majenang, Kawunganten, and Kampung Laut to represent the inland fisheries of Citandui, Ciberem, Cimeneng, Grugu/Beling Rivers and the saline water fisheries of Segoro Anakan lagoon. Site visits were also conducted to five subdistricts, including Sampang, Kroya, Maos, Adipala, and Nusawungu to represent inland fisheries of Serayu, Sodong, Gatel, Ijo Rivers and the saline water fisheries at Sodong and Serayu river-mouths. Additionally, site visits were paid to Manganti Weir at Citandui and Gerak Weir at Serayu River (Fig. 1) to observe the mechanism of eel movement.

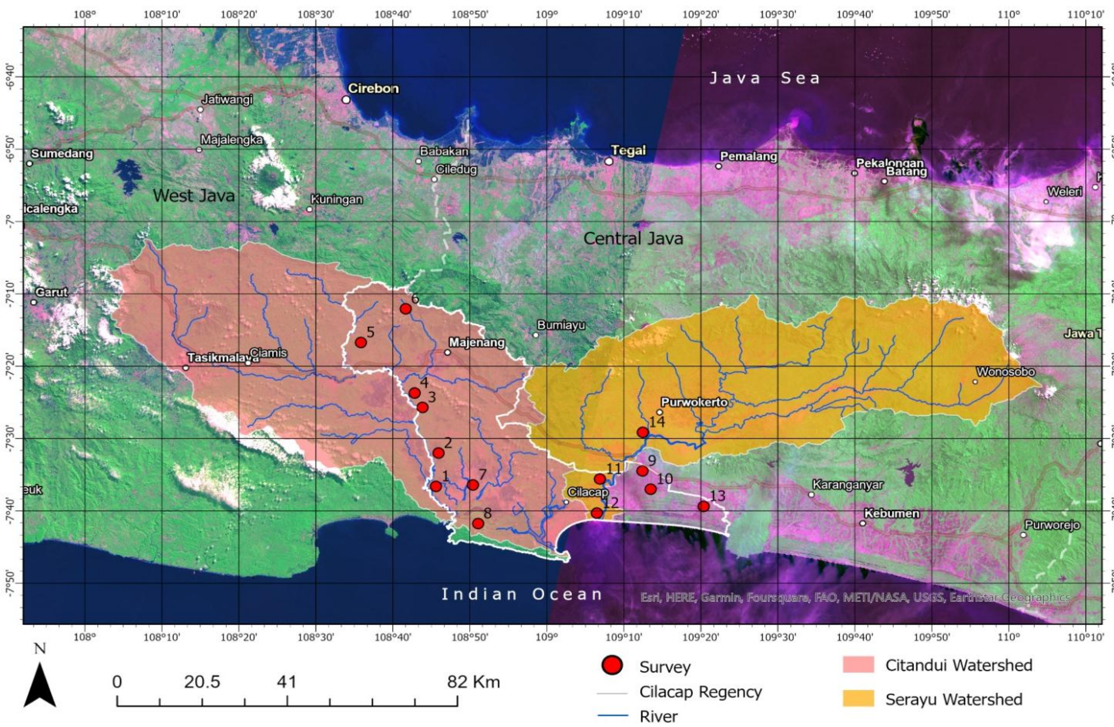

Fig. 1. Map of the study area in the River Basin of the subdistricts; namely, 1. Patimuan, 2. Kedungreja, 3. Manganti Weir of Citandui, 4. Wanareja, 5. Dayehluhur, 6. Majenang, 7. Kawunganten, and 8. Kampung Laut, representing the Citandui watershed (charm-pink), and 9. Sampang, 10. Kroya, 11. Maos, 12. Adipala, 13. Nusawungu, and 14. Gerak Weir of Serayu, representing the Serayu watershed (yellowish) in Cilacap Regency (in white border), Central Java.

Data collection

Additional data were collected from from previous studies and fisheries statistics issued by the local governments of Cilacap (capture fisheries). In order to confirm the statistical data released by the local government, an interview was conducted to explore the different catch production between 2018 and 2022. This interview was conducted using a focused group discussion method so that differences in perception could be concluded at that time, with the minimum and maximum values of the catch results. The eels caught were categorized into six commercial-size classes, based on their individual weights. These were i.e., glass eels (<1 g), elvers (1-5 g), small pencils (6-15 g), big pencils (16-50 g), fingerlings (51-150 g), and consumption sizes (>150 g) (Rohman, Pers.com., 2018.).

Furthermore, the consumption sizes with a weight between 150 & 1,000g were categorized as yellow eels, while those between 1,000 & 2,000 g were classified as silver eels (based on the study conducted by **Rahmawati *et al.* (2022**). Due to the fishermen having their own local names for the eels caught (i.e., *pelus* and *sidat*) as well as the official fish nomenclature from the yearly statistical data of Cilacap District, some of the eels caught were confirmed by morphometric identification i.e. anno dorsal ratio (A/D %, **Taufiq-Spj *et al.*, 2021**) to ensure and define the species.

In order to evaluate the environmental conditions, the forestry of the Citandui and Serayu watershed was evaluated between 2010 and 2020 in terms of declining forest area. Yearly sedimentation velocity in Segoro Anakan lagoon (impounding seawater, Fig. (1 No. 8) was counted using sedimentation data published by **Hakiki *et al.* (2021)** and the data from the Fisheries Department of Cilacap (unpublished data). A distribution map of eel at every stage development was based on the place where they were found or caught by fishermen. Henceforth, the eel stage development, movement, distribution and yearly production can be described based on environmental cues.

RESULTS

1. Inland eel fisheries production

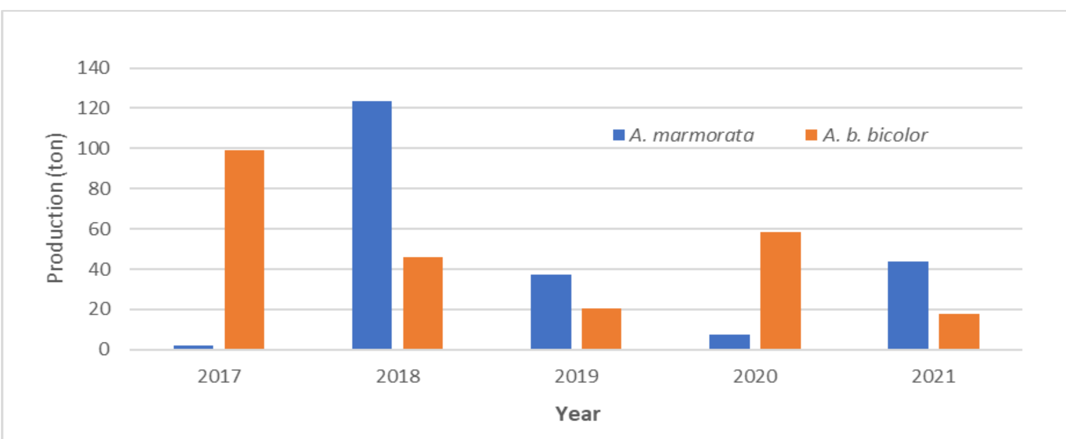

Fig. 2. Inland eel fisheries production from 2017 to 2021 in Cilacap Regency

A general description of eel production in Cilacap District is shown in Fig. (2). It shows that the eel production trend tended to decline from 2017 to 2021. Fishers who have caught fish known as "pelus" and "sidat" have been confirmed by morphometry with anno dorsal ratios (A/D) of 14.2 - 17.2% and 0.2 - 3.6%, which correspond to the species *Anguilla marmorata* and *A. bicolor bicolor* (**Watanabe *et al.*, 2008**), respectively. There are unstable catch productions, especially for *A. marmorata*, where the catch of this species produced only 1.81 tons in 2017 and then increased steeply to reach 123.71 tons in 2018 before declining again in 2019 and 2020. Another species of *A. b. bicolor* faced a consistent decline from 2017 to 2021 (Fig. 2).

The inland fishery eel production above (Fig. 2) is obtained from various regions and from various types of waters in Cilacap District. As seen in Fig. (3), river water types highly contribute to eel production compared to puddles (wetlands) and swamps. In 2017, the biggest catches of *A. b. bicolor* were found in rivers (68 tons), followed by wetlands (32 tons), and no eels were found in swamps. The biggest catches of *A. marmorata* started to be obtained in 2018, especially in river areas (67 tons), followed by wetlands (56 tons); during this year, no eels were found in swamp waters (Fig. 3).

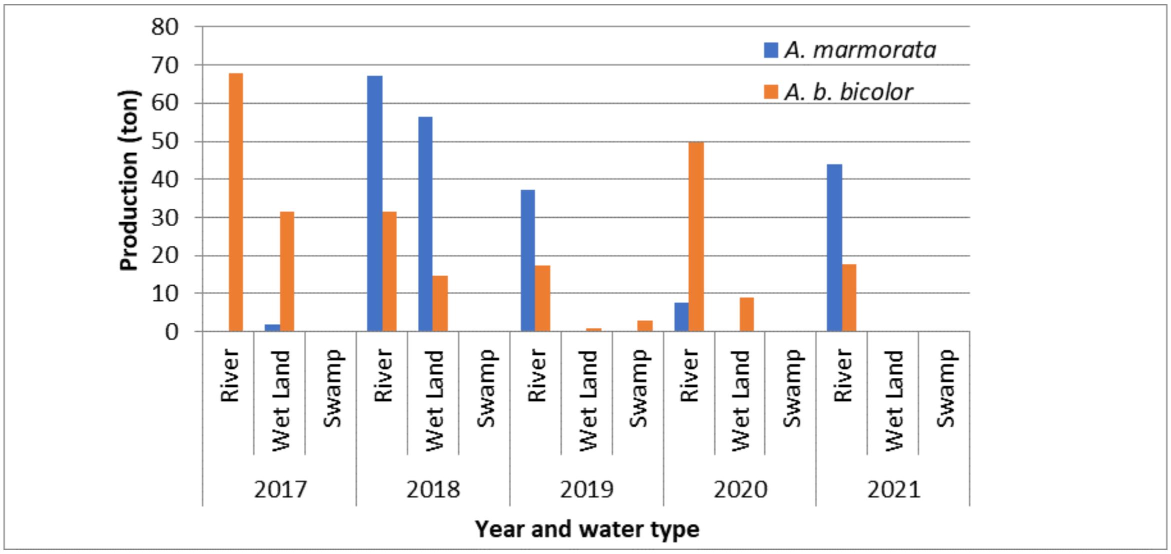

Fig. 3. Eel production based on the region and water type along inland public waters of Cilacap District during 2017–2021

2. Fishermen's perceptions of eel capture

The eel capture perception showed a decline between 2018 and 2022. Generally, the range of eel catches in the Citandui watershed was much bigger than that recorded in the Serayu watershed during 2018 and 2022. The biggest eel catches along the Citandui watershed were found in Patimuan subdistrict (5 to 35 kg eel per fishing trip in 2018), followed by Kedungreja, Wanareja, Dayeuhluhur, Majenang, and the smallest was found in Kampung Laut subdistrict (3 to 5kg). Even though the eels caught along the Serayu watershed were much smaller in Sampang, Adipala and Nusawungu, eel fishing in Maos was as big as that in Patimuan of Citandui watershed (Table 1).

Table 1. Eel capture range in one trip fishing (kg) of eel caught by fisherman in 2018 and 2022

Watershed (WS)	Subdistrict	2018		2022		Eel size	[3] Declining proximation
		Min	Max	Min	Max		
Citanduy	Dayeuhluhur	2	11	2	6	Consumption	-45%
	Wanareja	3	15	0	5	Consumption	-67%
	Majenang	0	12	3	5	Consumption	-58%
	Kedungreja	5	25	0	5	Cons. & Fingerling	-80%
	Patimuan	5	35	0	5	Consumption, Pencil & Glass Eel	-86%
	[1] Kampung Laut	3	5	1	3	Consumption, Fingerling & Glass Eel	-40%
Serayu	Sampang	0	0.5	0	0.8	Pencil & Elver	+60%
	Maos	6	35	0	4	Consumption, Fingerling & Pencil	-89%
	Adipala	0	4	0	2	Glass Eel, Elver & Pencil	-50%
	[2] Nusawungu	0.5	1	0.3	0.5	Glass Eel, Elver & Pencil	-50%
Average Citanduy WS		3.00	17.17	1.00	4.83		-72%
Average Serayu WS		1.63	10.13	0.08	1.83		-82%

[1] Data taken in 2019 and 2023, [2] data taken in 2018 and 2023, [3] Declining proximation counted from maximum value

3. Stopping elver migration at the weirs

The Manganti Weir of Citandui in Sidareja-Cilacap was completed in 1987, while the Gerak Weir of Serayu in Kebasen-Banyumas was completed in 1996. Up to 2015, elvers were still found around both dams, especially around the drainage and overflow channels (Weir technician, pers.com 2018). During the dry season until 2017, there were still fishermen catching elvers that failed to climb through the leaking water flow on the dam walls. However, from 2018 to 2022, elvers were still found at the Manganti Dam, while at the Gerak Dam, they haven’t been seen since 2018. Fig. (4) shows the mechanism of elver migration during the dry season, which failed to climb up the dam wall through the leaking water at both dams.

Fig. 4. Eels migrating upstream stopping at either the Manganti Weir of Citandui River (on the left) or the Gerak Weir (on the right) of the Serayu River

4. Eel distribution map and its stages of development

Eel movements depend apparently on the fresh water flow. Glass eels were found in the estuaries of Platar Agung (-7°.69 S, 108°.79 E) and Majingklak (-7°.67 S, 108°.8 E) around Segoro Anakan lagoon, while elvers were found at the Cise'el estuary (7°.6 S, 108°.74 E) and Manganti Weir (-7°.45 S, 108°.72 E) along Citandui River (Fig. 5– left). Meanwhile, the yellow eel was found upstream of the Manganti Weir Bojongsari Kedung (-7°.45 S, 108°.72 E), and then seven points of yellow eel fishing grounds were found along the Meluwung swamp of Wanarejo, Dayeuhluhur and the subdistrict of Majenang – Cilacap (Fig. 5 – right).

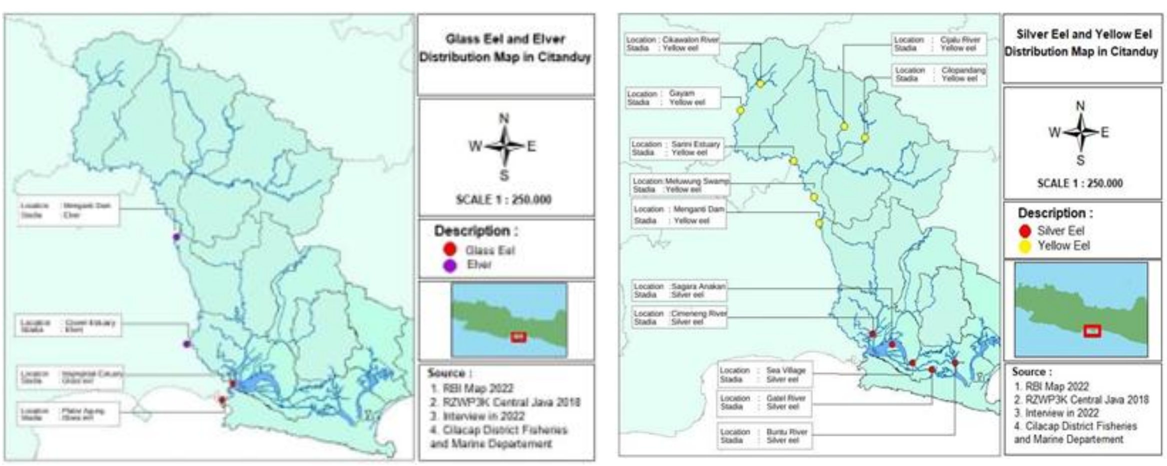

Fig. 5. Distribution maps of glass eel and elver (on the left) and yellow and silver eel (on the right) found along the Citadui watershed and Segoro Anakan lagoon of the Cilacap District in Central Java, Indonesia

For the eel distribution performance along the Citandui watershed (Fig. 5), the yellow eel was found in the Serayu River, especially in the Maos/Kesugihan subdistrict (-7°.59’ S, 109°.14’ E; -7°.60’ S, 109°.14’ E; -7°.60’ S, 109°.13’ E) (Fig. 6- left). While the glass eel was only found at the Sodong estuary of the Adipala Subdistrict-Cilacap (-7°.69’ S, 109°.16’ E), elvers were found in the riverine of Doplang at Adipala (-7°.66’ S, 109°.19’ E). Elvers were also found in five points of irrigation canals; namely, Mernek, Sidasari, Sampang, Karang Jati and Buntu (Fig. 6, right).

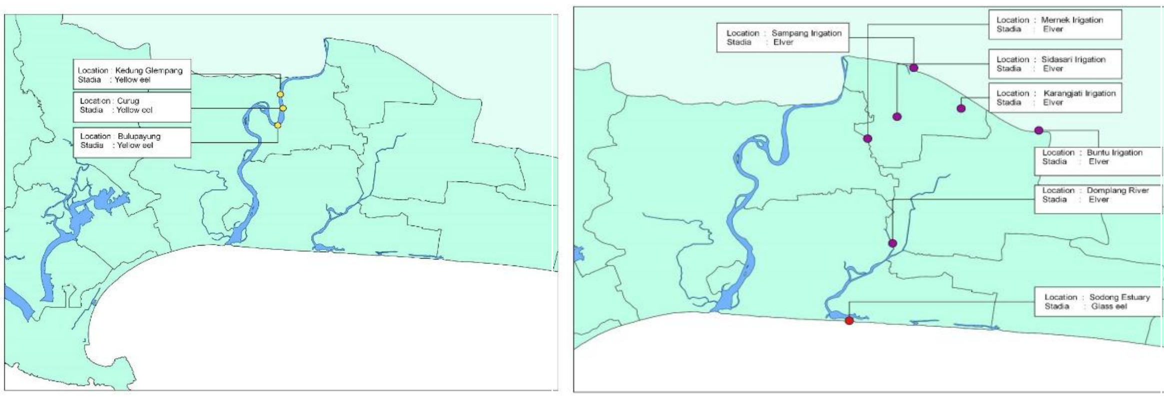

Fig. 6. Distribution map of yellow eel (left), glass eel and elver (right) along the Serayu watershed (Serayu and Sodong Rivers).

5. Forestry area along Citandui & Serayu watershed

The total area of Citandui and Serayu watersheds released by the Ministry of Public Works and Housing in 2015 (unpublished data) are 447,285.90 and 372,536.90 Ha, respectively. The digitized forest map of the Citandui River basin in 2010 was 219,253.15 Ha; while in 2020, it was 213,966.25 Ha. The forest area of the Serayu River basin in 2010 was 204,813.52 Ha, and in 2020 it decreased to 198,584.35 Ha (Table 2 & Fig. 1).

Table 2. The loss of forestry area along the Citandui and Serayu watersheds from 2010 to 2020

No	Watershed	WS Area (Ha)	Area of forestry in watershed (Ha)			Loss of forest (Ha) during 10 years
			2010	2015	2020	
1	Citandui	447285,9	219253,15	214,178.90	213966,25	5,286,90
2	Serayu	372536,9	204813,52	200,999,24	198584,35	6,229.17

The development of the decrease in the area of Segoro Anakan lagoon varies by year. In 1984, the lagoon had an area of 2,906 ha; while in 1985, there was a decrease of 0.45% to 2,893 ha. The largest decrease of 33.3% occurred between 2002 and 2003. However, between 2003 and 2005, there was an increase of 19.5%. Overall, between 1984 and 2014, there was an annual decrease of 2.8% for 30 years of sedimentation (Table 3), with a total reduction in the sea water area of the lagoon of 2,406 ha or 82.8% of the original area of the lagoon.

Table 3. The decreasing area of the Segoro Anakan lagoon during 1984 to 2003(1), 1984/2005 – 2014(2)

Year	**1984**		**1985**		**1986**		**1989**		**1991**
Lagoon area (Ha)	2906		2893		2811		2298		2019
Yearly area decline (%)		0,45		2,8		6,1		6,1	
Year	**1991**		**1992**		**1994**		**1995**		**1998**
Lagoon Area (Ha)	2019		1800		1575		1400		1250
Yearly area decline (%)		10,8		6,3		11,1		3,6	
Year	**1998**		**2000**		**2001**		**2002**		**2003**
Lagoon area (Ha)	1250		1200		1126		900		600
Yearly area decline (%)		2,0		6,2		20,1		33,3	
Year	**2003**		**2005**		**2008**		**2014**		**1984**
Lagoon area (Ha)	600		834		750		500		2906
Yearly area decline (%)		-19,5		3,4		5,6		2,8	

(1) **Hakiki *et al.* (2021)** data from 1984 to 2003.
(2) Data compilation from various reports on the management of Segoro Anakan Lagoon by the Fisheries Department of Cilacap Regency (unpublished data).

DISCUSSION

The decline in production of eel capture fisheries in general inland waters of Cilacap from 2017 to 2021 (Fig. 2) was initially attributed to declining market demand. However, from discussions with the fishermen, there is a similar trend of decreasing eel catches from 2018 to 2022 (Table 1). *Anguilla bicolor bicolor* consumption size (Table 1) caught in general inland waters of Cilacap is generally in the range between 200 & 1000g. According to **Chai and Arai (2018**), *A. b. bicolor* in the North western Peninsula of Malaysia, with weights of 179- 798g reached gonad maturation stage V. Meanwhile, *A. bicolor* found in the Serayu River Cilacap has reached a gonadosomatic index of 4.37, with a weight of 1,026g (**Rachmawati *et al.*, 2022**). Given these two statements, it seems that the fishermen's catches of *A. b. bicolor* are in yellow approaching to silver eel size stages. The Decree of **MMAF No. 80 (2020)** which only allows for a catch limit of *A. b. bicolor*, with a weight of no more than 2kg provides an opportunity for fishermen to catch eels below that weight. If the data from **Chai and Arai (2018)** and **Rachmawati *et al.* (2022)** are applied, the minister's decision is actually counter-productive to the conservation efforts of this species, especially in Cilacap inland waters.

The catch of *A. marmorata* fluctuates steeply from year to year, with a very low production in 2017, followed by a sharp increase in the following years and a succeeding decrease (Figs. 2, 3). This low production is likely due to the low recruitment of glass eels in two to four years prior, or the massive catches of yellow and silver eels in three to five years prior. The catch of *A. marmorata* of consumption size reaches 0.5- 2kg (Table 1). However, during the dredging of the Mrica reservoir in upstream of the Serayu River in Banjarnegara Regency at the beginning of April 2022, some giant mottled eels were found reaching 5- 15kg. Morphometric measurements of glass eel, elver and pencil size in various Cilacap estuaries in 2019 showed that *A. marmorata* species was only found in 3.7% of the total sample (**Taufiq-Spj *et al.*, 2021**). Since eels generally have the same migration cycle (**Taufiq-Spj *et al.*, 2022**), the fluctuation of increased catch of consumption size reaching silver eel stage will decrease the number of glass eels entering the river and subsequently decreasing the production of this species. **Jacoby *et al.* (2015)** reported that over the last 36 years, recruitment of glass eels and escapement of silver eels from the St. Lawrence River system to the Caribbean Gulf of Mexico and the Mississippi River system has decreased significantly. This condition led to a decline of more than 50% in the population of American eels (*Anguilla rostrata*), placing them in the endangered (EN) category.

Confirmation of the decline in eel catch production (Figs. 2, 3) was then conducted with fishermen in the two rivers. From the fishermen's perception, it was stated that there was a drastic decrease in eel catch by 2022 compared to 2018. They added that the catch of glass eel up to the consumption size in the Citandui Watershed decreased by 72% and Serayu 82% (Table 1). There are several causes for this decline in production. In addition to the causes mentioned above, one of them is the presence of the river barriers, i.e., the Manganti and Gerak Serayu dams (Fig. 4), which are decreasing in water discharge over the years. Since the presence of both dams does not have fish ways or fish ladders, the elvers fail to migrate upstream. The failure of this direct migration will make the eel face various alternative events. The first one is that the elvers look for another way out to continue the migration, whereas the second is predation by carnivorous organisms, and the third is death. In the first alternative possibility, there is evidence that elvers can migrate between rivers through the ocean, but this fact occurs at the yellow eel stages of *Anguilla japonica* (**Kume *et al*., 2021**). Thus, it is possible that elvers who fail to migrate upstream will still look for another small channel or return to a downstream area that is more suitable.

The two weirs (Manganti and Gerak Weir) are intended as a source of irrigation for various areas along the two river basins. Some branch irrigation channels from Citandui (Manganti Weir) that irrigate the fields in Sidareja Subdistrict will be connected to the Ciberem and Cimeneng Rivers (Fig. 5). Meanwhile, branch irrigation channels from Serayu towards Adipala are connected to the Sodong River, and those towards Nusawungu will be connected to the Gatel River (Fig. 6) and then towards the Ijo River, which borders Kebumen Regency. Thus, the spatial distribution of each stage can be seen not only in the two rivers (Citandui and Serayu), but also in other rivers (Ciberem, Cimeneng, Sodong, and Gatel) and along their irrigation channels (Figs. 5, 6). This is possible because elvers are attracted to low salinity and rheotropic, allowing them to swim against the flow (**Trancart *et al*., 2014; Taufiq-Spj *et al*., 2022**). In other words, eels have a magnetic compass, which gives clues to migration triggered by endogenous rhythms at the early stages of life (**Cressi *et al*., 2017**) in addition to a geomagnetic compass, which gives clues to migration triggered by the Earth's magnetic field at the later stages of life (**Katsumi *et al*., 2020**).

Although the mechanisms of migration of glass eel to other rivers need to be separately studied (**Bolliet *et al*., 2017**), the distribution of glass eel and elver found in the Sodong River and irrigation channels all seem to be heading towards the weir for further upstream travel to the Serayu River (Fig. 6). This indicates that the migration loop of the eel (**Taufiq-Spj *et al*., 2022**) has been successfully completed, even though they had to pass through other rivers due to the original river being blocked by the dam wall (Fig. 4). However, the yellow eel found in Maos subdistrict (Kedung glempang, Curug, Bulupayung) (Fig. 6-left) might be elver that failed to go upstream and kept searching for suitable locations until they found the curves and bends in the Serayu River. It is possible that the meandering form of the river (Fig. 6**-** left) creates a food-trapping situation for the organisms living in it, thus creating a stable food chain for the eel.

Therefore, the role of watersheds with forest area as a rainwater catchment is important in supplying water to the river throughout the year, even though the area of forests in Citandui and Serayu watersheds (Table 2) has exceeded the 30% requirement specified in legislation **Law No. 41 (1999**). The fact that there was 5,286.9 and 6,229.17 Ha of forestry lost along the Citandui and Serayu watersheds during 2010 & 2020, respectively (Table 2), has affected the downstream environment, especially in terms of high sedimentation rate (Table 3). This presumably causes a decrease in glass eel recruitment (Table 1). The decrease in the area of the Segoro Anakan lagoon is another result of sedimentation from several rivers (Citandui, Ciberem, Cimeneng, Cikonde, Beling, Sapuregel) that flow into the lagoon (Table 3). However, it is expected that the restoration of the lost forests in both watersheds will improve the flow pattern in the dry season, and subsequently improve the recruitment pattern of glass eel. At the Joint Environment and Climate Ministers' Meeting (2022), the G20 has agreed to promote and increase mainstream ecosystem restoration, including land and forest restoration on all types of ecosystems, involving public-private partnerships, into recovery policies and plans. Therefore, it is hoped that the loss of eel population above can be recovered in line with the UN Decade on Ecosystem Restoration 2021–2030, which encompasses protection, conservation, restoration and sustainable land management in the pursuit of fighting climate change and halting biodiversity loss (**G20-Indonesia, 2022**).

In general, the main efforts to improve the population and conservation of eels in Cilacap are to control and limit the pattern of yellow to silver eel catches by reducing the permissible catch weight of eels. This requires a revision of the Ministerial Decree of Fisheries No. 80/2020 considering the ban on catching *A. b. bicolor* with a weight of more than 2 kg to only less than 1kg (**Rachmawati *et al.*, 2022**). Thus, eels with a weight of 150-1000g can be caught. Meanwhile, due to the indication of decreasing population of *A. marmorata* (**Taufiq-Spj *et al.*, 2021**), a ban on catches is needed in Cilacap waters for at least the next 3 years. This is important due to the wide migration pattern of *A.b. bicolor*, which migrates from Java to Sumatra and Madagascar in Africa (**Taufiq-Spj *et al.*, 2022**). In addition to these sites, the distribution of *A. marmorata* was detected in various Indo-Pacific regions (**Lee *et al*., 2018**; **Itakura *et al.*, 2020**). Therefore, eels will play an important role as a species indicator, umbrella, flagship and surrogate species for the conservation of freshwater biodiversity (**Itakura *et al.*, 2020**) in Cilacap waters.

Population improvement and conservation of eels can also be achieved by creating fishways or fish ladders (**Porcher, 2002**) on the walls of both dams (Citandui and Serayu) or irrigation gates from the two weirs. It is hoped that this will facilitate the upstream migration of elver stages and the downstream migration of silver eel stages. Similarly, reforestation of lost forests in the watershed area will improve the flow of water during the dry season, as well as reducing the rate of sedimentation. In addition, it is expected to improve the Segoro Anakan lagoon and Serayu River estuary area.

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CONCLUSION

This study concluded that, the status of eels in Cilacap has declined due to the catch of either yellow or silver eels and the deforestation in the area. The presence of the two dams, Manganti and Gerak has forced glass eel and elver to take an alternative route for their upstream migration. By utilizing the rivers Ciberem, Cimeneng, Sodong and Gatel, which are connected to the irrigation channels of Citandui and Serayu, the eel migration loop is completed. The continuity of the river flow is essential for the survival of the catadromous species and their migration cycle, which is primarily dependent on the catchment area of rainwater in the watershed, adding to the forest area which is the main factor. In 2020 and 2021, the Minister of Marine Affairs and Fisheries of the Republic of Indonesia issued decrees providing limited protection and conservation of eels (*Anguilla* spp.) and imposed quotas for the use of limited protected fish species in order to maintain the sustainability of the eel population. This study demonstrates that, deforestation in the Cilacap Regency of Central Java is having an adverse effect on the environment and its living organisms. Hereafter, to further effectively conserve the catadromous species, the construction of fish ways or fish ladders on both dams and irrigation gates of the two rivers must be immediately achieved.

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