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Sustainable Eel (Anguilla spp) Management through the Application of Freshwater Ecosystem Management Policy in Sukabumi Regency

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A B S T R A C T

Sukabumi Regency, rich in environmental and eel resources, faces challenges such as declining fish biodiversity, habitat degradation, and invasive species. This study used field surveys and descriptive data analysis to identify key issues in eel fisheries, including: a) low income for eel fishermen; b) limited market volume for eels; c) inadequate implementation of eel cultivation practices; d) lack of designated eel conservation areas; and e) declining eel habitat quality. To address these issues, the study proposes a sustainable eel fisheries plan with policies focused on: a) improving the eel supply chain; b) establishing and managing conservation areas; c) integrating watershed management; and d) promoting economic development for small-scale eel fishing communities.

1. INTRODUCTION

The Sukabumi Regency Government has recently enacted Regional Regulation Number 1 of 2023 on Fisheries Management. This regional policy directs fisheries management to ensure optimal, efficient, effective, and sustainable management of fishery resources to enhance the welfare of the local community. In line with this policy direction, one of the strategic plans for fisheries management in Sukabumi Regency that is being proposed is the management plan for freshwater eel (Anguilla spp.). Sukabumi Regency is known to have a high potential for freshwater eel resources and is currently one of the primary

suppliers of eel seeds, particularly the Indonesian shortfin eel (A. bicolor), for eel farming in Indonesia.

The urgency of developing a sustainable eel fisheries management plan in Sukabumi Regency aligns with the central government's policy through the Ministry of Marine Affairs and Fisheries, which has established the National Freshwater Eel Fisheries Management Plan based on Ministerial Decree Number 118 of 2021 on Eel Fisheries Management. The aim of this research is to develop and implement integrated policies and programs by all stakeholders, guided by this regulation, to achieve optimal benefits that could potentially drive economic growth, improve community welfare in the region, and enhance sustainability by ensuring the conservation of eel resources in Indonesia.

The Ecosystem Approach to Fisheries (EAF) is a fisheries management approach designed to meet some of the biodiversity conservation community's aspirations, including the intention to reduce the impacts of fishing to sustainable levels. This approach is used to ensure that the planning, development, and management of fisheries are carried out in a way that meets the diverse needs and requirements of communities without compromising the ability of future generations to benefit from the various goods and services provided by ecosystems.

The application of the ecosystem approach to fisheries is consistent with the framework for analyzing institutional development adapted into a sustainable livelihoods approach (Ostrom, 1999; Ruud, 2004; Allison & Horemans, 2006) (Figure 1). In several developing and developed countries, this approach has proven useful for understanding the management and development of fisheries in coastal, lake, and floodplain ecosystems.

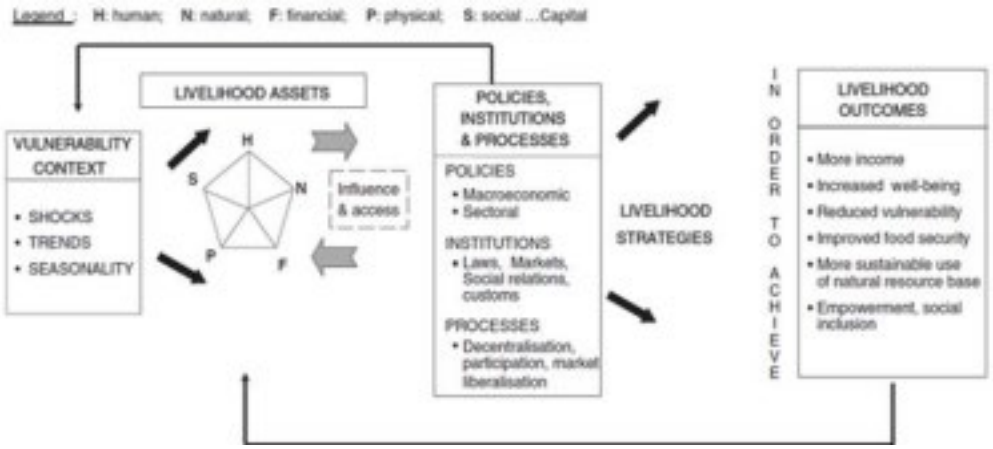

Figure 1: Framework for Analyzing Institutional Development of Fisheries Management Based on an Ecosystem Approach.

The livelihoods framework integrates assets and activities and illustrates the interactions between them (Figure 1). Ultimately, this framework will be effective if fishing households can maintain or improve their living standards concerning welfare and income or other human development goals, reduce their vulnerability to shocks and external trends, and

ensure that their activities are aligned with the sustainability of the fish resources they manage

2. RESEARCH METHODS

The method used in this research involves direct observation (field survey) at the research site, focusing on social factors, community activities, and the surrounding environmental conditions. The data sources include both primary and secondary data. Primary data are facts collected and measured during the field survey by visiting the research area to conduct direct observations, measure water quality, and interview residents. Physical-chemical characteristics of the water measured on-site include temperature, water clarity, water flow, pH, and dissolved oxygen. In-depth interviews were conducted with local communities and relevant agencies to explore various aspects, including historical background, community interactions (utilization) with water bodies, local knowledge about eel fishing (glass eels and adult eels), eel farming, economic benefits, challenges, opportunities, and their perceptions of eel management and future development.

Supporting document data were obtained from various sources, including previous reports and research such as the FAO PPLH Report (2017); BOPTN LPDP IPB Research Activities (2021); LIPI Research Activities (2018-2020); BRIN Research Activities (2021-2022); Strategic Plan of the Sukabumi Regency Fisheries Office for 2021 – 2026; Freshwater Eel Management Plan Documents, National Eel Conservation Action Plan, and FMARI-IW Documents. Catch data were collected by the Sukabumi Regency Fisheries Office and publications, including journals and peer-reviewed reports. The collected data were analyzed descriptively. The data are presented in tables and graphs to explain the research findings. The analyses conducted include stock availability of eels, water quality conditions of eel habitats, the demand for eel seeds for aquaculture, market analysis, development of processed eel products, and analysis of eel resource management regulations in accordance with existing regulations from the Ministry of Marine Affairs and Fisheries (KKP).

3. RESULTS & DISCUSSION

Freshwater eels (*Anguilla spp*.) are catadromous fish that migrate to grow in freshwater and return to the sea to spawn (Tesch, 1977; Tesch, 2003). Tesch (1977) and Mochioka (2003) describe that eel larvae live in the sea, are broad, transparent, and known as leptocephali. Leptocephali exist as plankton carried by ocean currents towards coastal areas (Bru et al.,2009). Leptocephali undergo metamorphosis into transparent eel larvae called glass eels (Figure 2.a). Glass eels then migrate back to freshwater through river estuaries, where they grow and develop into adult eels in freshwater habitats such as rivers

and lakes. Figure 2.b illustrates the entire life cycle of freshwater eels, which consists of three phases: oceanic, estuarine, and river (Tsukamoto and Arai 2001; Tzeng et al., 2003).

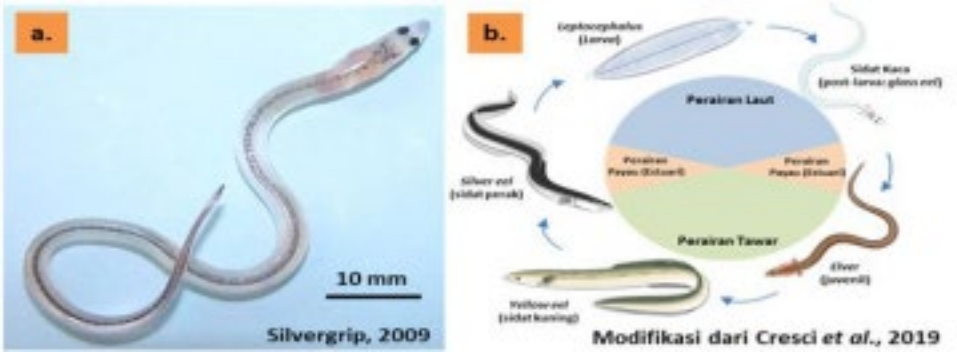

Figure 2. Freshwater Eels (Anguilla spp.). a. Glass Eel Stage/Phase. b. Life Cycle of Freshwater Eels. Source: Silvergrip, 2009 and Modified from Cresci et al., 2019

3.1. Coastal Water Ecosystem

The river basins in Sukabumi Regency, which flow into the Indian Ocean, are crucial habitats for the migration of freshwater eels to complete their life cycle (Arfrianto 2014; Hakim, 2015; Haryono & Wahyu Dewantoro, 2016; Hidayat, 2014; Putra, 2016; Sriati,1998; Vamellia, 2014). Figure 3 shows the river basins that flow into Palabuhanratu Bay, including Cibareno, Citepus, Cimandiri, and part of Ciletuh. The other segment of Ciletuh joins the Cikaso and Cibuni rivers, flowing into the southern part of the Java Sea through Palabuhanratu Bay.

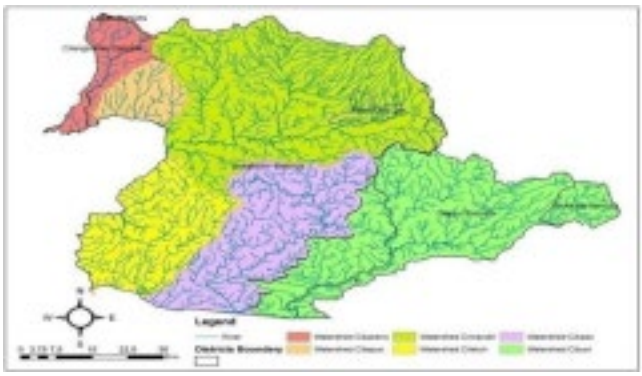

Figure 3: River basins in Sukabumi Regency as freshwater eel habitats during their catadromous migration

The oceanographic conditions of the southern Java coast include high waves that can exceed three meters and deep marine bathymetry. The seasonal monsoon currents consist of four periods: the eastern monsoon (May-August), the western monsoon (November-February), the eastern transition (March-April), and the western transition (September-October) (Wyrtki, 1961). These conditions significantly affect water conditions, such as

increased turbidity during the eastern monsoon and changes in salinity during the western monsoon

3.2. Freshwater Ecosystem

The land slope conditions of river basins in Sukabumi Regency vary from gentle to steep. Generally, these rivers are classified as Type C. The primary morphology of Type C rivers includes low-relief channels, gentle slopes, moderate sinuosity, low channel banks, high depth-to-width ratios, and well-developed floodplains, which are preferred habitats for eels due to their marshy nature (Jacoby et al., 2014). The flow is also relatively calm, supporting higher natural primary productivity compared to other river types. The characteristic morphology of Type C rivers includes coastal swamps. According to Noor and Rahman (2015), coastal swamps are wetland ecosystems primarily influenced by tidal effects from adjacent rivers/sea. As part of the estuarine ecosystem, coastal swamps play an important ecological role, providing shelter, feeding grounds, spawning sites, and breeding areas for aquatic animals. Estuarine areas are also home to migrating biota, including diadromous and amphidromous species (McDowall, 2008).

One of the coastal swamps in Sukabumi Regency is the estuary of the Cimandiri and Cikaso Rivers (Trieyanto et al., 2019). It is estimated that the area of coastal swamp land in Sukabumi Regency is around 269 hectares, with most of it being used for agricultural purposes (BPS Sukabumi Regency, 2018). Other rivers in the Cibareno and Citepus basins are classified as Type Aa+ rivers, which flow rapidly (Naiman, 1998), indicating that these river basins have lower productivity. Sedimentation occurs only in the estuaries and coastal waters around the estuaries. There are few or no meanders or floodplains in these rivers, which are preferred environments for adult eels.

3.3. Changes In FreshwaterEel Habitat Characteristics

Anthropogenic activities have affected freshwater eel habitat conditions from 1998 to 2018 (Table 1). Land cover change analysis shows that over the past 20 years (1998-2018), forest and highland areas in the river basins of Sukabumi Regency have been converted to agricultural land. Dryland agricultural areas, particularly mixed gardens, have been

permanently transformed into agricultural lands (rice fields, rubber, and oil palm), vacant lands, and developed areas.

Table 1. Changes in land cover in river basins related to eel habitats in Sukabumi Regency for the period 1998-2018.

No	Land Cover	1998		2008		2013		2018	
		Ha	%	Ha)	%	Ha	%	Ha	%
1	Forest	99 884.41	18,38	93 415.31	17,19	94 408.46	17.38	95 212.43	17.52
2	Shrubland	216 091.41	39.77	198 309.46	36,50	184 541.52	33.96	156 613.68	28.82
3	Mixed Landscaping	75 971.59	13.98	81 406.24	14,98	45 742.57	8.42	55 839.24	10.28
4	Rubber Plantation	22 196.63	4.09	22 291.13	4,10	28 743.89	5.29	34 032.06	6.26
5	Oil Palm Plantation	30 677.76	5.65	17 843.37	3,28	22 280.63	4.10	33 704.98	6.20
6	Rice Field	32 862.39	6.05	59 715.57	10,99	82 333.06	15.15	90 596.88	16.67
7	Highland	48 891.73	9.00	48 529.27	8,93	49 293.63	9.07	29 670.67	5.46
8	Vacant Land	11 852.08	2.18	9 583.62	1,76	20 083.28	3.70	28 822.58	5.30
9	Developed Land	4 402.15	0.81	11 935.29	2,20	15 728.27	2.89	18 679.60	3.44
10	Water Body	517.78	0.10	318.67	0,06	192.61	0.04	175.80	0.03
	Total	543 347.92	100.00	543347,92	100,00	543 347.92	100.00	543 347.92	100.00

Source: Data Processing (2019)

In addition to land use changes, mining activities also threaten the sustainability of eels in Sukabumi Regency. Figure 4 shows the distribution of mining business permits in Sukabumi Regency, indicating that the local government has legally granted these activities across all river basins. The negative impacts of mining include increased turbidity and the danger of heavy metals such as mercury and cyanide, which are harmful to living organisms in the aquatic system.

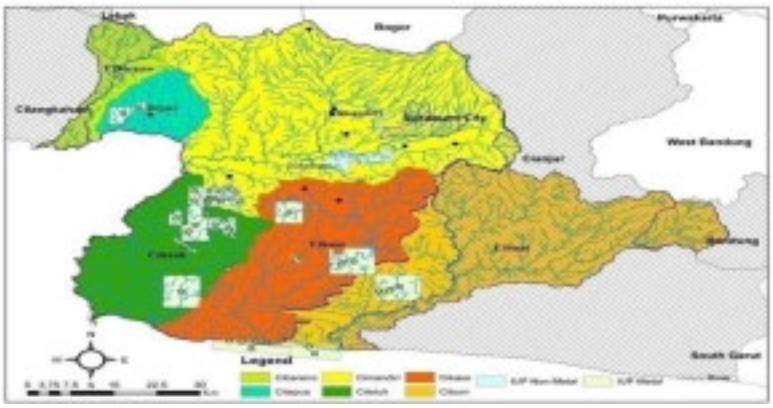

Figure 4. Distribution of mining permits along river basins overlapping with freshwater eel habitats in Sukabumi Regency
Source: Data Processing (2019)

River water pollution sources include solid waste from domestic, industrial, and agricultural activities, comprising plastic, fabric, and wood waste. The composition of waste reflects the activities occurring in the river basin. Increased population and diverse human activities significantly impact environmental quality. In the Cimandiri River, which traverses more residential and industrial areas compared to the Cibuni River, the dominant waste composition comes from domestic and industrial sources. Conversely, in the Cibuni

River, which passes through more plantation and agricultural areas, the waste composition is predominantly wood residues.

3.4. Freshwater Eel Fisheries in Sukabumi

In fisheries resource management, there are known restrictions on resource utilization aimed at maintaining sustainability. These restrictions are referred to as Total Allowable Catch (TAC). TAC is a regulation designed to control the level of fishing exploitation, such as through limiting the number of fishing permits, restricting fishing effort (e.g., limiting the number of fishing days, number of fishermen, etc.). According to Law No. 45 of 2009, as amended by Law No. 31 of 2004, Article 7, paragraph (1.c) states that to support fisheries resource management policies, allowable catch limits need to be established in Indonesian waters, and paragraph (1.e) requires determining the potential and allocation of certain fish stocks in Indonesian waters. When setting eel catch quotas, it is important to consider the available eel stocks. Glass eel stocks entering estuarine waters are directly related to adult eel stocks that will later grow and develop in freshwater habitats.

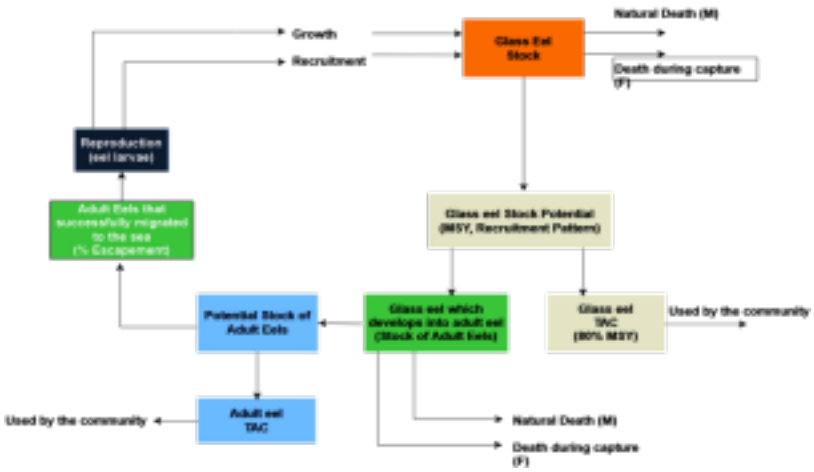

Figure 5. Diagram showing the relationship between glass eel stocks and adult eel stocks in the context of sustainable utilization.

The average eel catch from 2014 to 2019 was 895.60 kg per year, with an actual fishing effort of 1,044 trips per year. The maximum sustainable yield (MSY) for eels based on the Schaefer surplus production model (Sparre & Venema 1999) is 1,208 kg per year, with a sustainable fishing effort (FMSY) of 1,229 trips per year.

In 2018, according to the Sukabumi Regency Fisheries Office data, the number of eel fishers reached 629, with 55 middlemen. The effective number of fishers, in line with the sustainable catch value, needs attention to ensure that each fisher receives a catch commensurate with their effort while also maintaining resource sustainability. Currently, the number of eel fishers needs to be verified. This is related to the low demand for glass eels and their relatively low price, around IDR 250,000 per kilogram. The selling price is

determined by the middlemen, so eel fishing activities are highly influenced by the middlemen's decisions to either continue or cease these activities.

3.5. Consumption Eels (Adult Eels)

Adult eels are captured using fishing rods and wooden traps, with fishing rods being the predominant method. Eel fishers typically fish at night in rivers, specifically in areas known as "leuwi" or riverbeds. In Sukabumi Regency, eel fishers have organized themselves into a special group known as a fishing community. This group is still categorized as a fishing practitioner, particularly in freshwater fisheries.

According to the Indonesian Ministry of Marine Affairs and Fisheries Regulation No. 80/KEPMEN-KP/2020 on the limited protection of eel species, the regulation restricts the capture of all types of eel larvae (*Anguilla spp*.). Efforts to restore eel populations are also being made through adult eel restocking programs conducted by eel farming companies that obtain eel larvae from waters in Sukabumi Regency. However, these efforts have not yet been carried out regularly or at fixed locations.

3.6. Freshwater Eel Aquaculture

Before the outbreak of the COVID-19 pandemic, there were three eel farming units operating in Sukabumi Regency: two units in Palabuhanratu District and one unit in Cicantayan District. There is a technological difference in aquaculture methods used between the farming units in Palabuhanratu and Cicantayan. The eel farming technology used in Palabuhanratu is the “Japanese Model,” which involves growing eels in shaded concrete ponds (Figure 6) and using specialized eel feed with a success rate of around 70 percent (Pers. Comm., manager, 2020). In contrast, the technology used in the Cicantayan eel farming unit is the “Local Model,” employing earth ponds (Figure 7) with local feed mixed with natural feed (silkworm larvae) and a success rate of about 30 percent (Pers. Comm., Jafar, 2022)

Figure 6. Japanese eel farming technology in Palabuhanratu

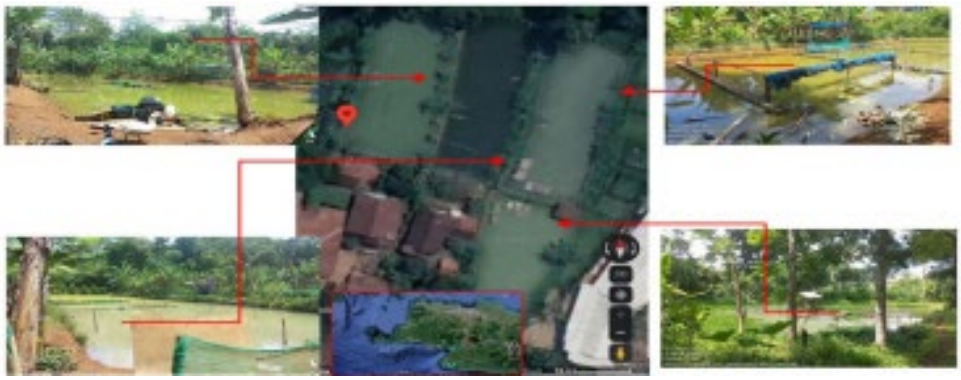

Figure 7. Traditional eel farming technology model in Lembur Sawah Village, Cicantayan District.

Market target is one of the reasons for choosing technology, aside from venture capital. The use of intensive technology following Japanese aquaculture guidelines (Japanese Model) is because the eel farming unit in Palabuhanratu targets the export market. Meanwhile, the eel farming unit in Cicantayan (Local Model) targets the local market in Jakarta and its surroundings.

3.7. Sustainable Freshwater Eel Fisheries Plan

Strategic issues in eel management based on an ecosystem approach include:

1. Lack of Catch Quotas: There is no catch quota for eels based on population data obtained from eel habitats, which is not available regularly in Sukabumi Regency.
2. Low Fishermen Income: Eel fishers have relatively low income and tend to choose this profession when there are no other livelihood options. Additionally, the contribution of women to the household economy of fishermen is still relatively low.
3. Increased Financial Risk: The financial risk in eel farming is increasing due to the need for precise segmentation in eel farming operations.
4. Limited Market Volume: The market for consumption eels is limited. Traditional market targets often require the implementation of Japanese aquaculture SOPs, which require relatively high investment, making it challenging for small-scale eel farming. Global market shocks, such as during the COVID-19 pandemic, further reduce the viability of small-scale eel farming due to increasingly restricted markets.
5. Lack of Conservation Areas: There is no proposal for eel conservation areas that could serve as protection and preservation zones to enrich eel populations in their natural habitats.
6. Declining Habitat Quality: The quality of eel habitats in inland waters tends to decline due to the impact of various activities upstream, midstream, and downstream.
7. Diversification of Eel Products: Develop and diversify processed eel products.

Steps for Addressing Issues: To establish a sustainable eel supply chain, several policy implementation plans need to be carried out, including:

1. Strengthening Population Data and Quota Setting: Improve the system for data collection on sustainable potential populations and establish catch quotas for eels.
2. Regulation and Monitoring: Establish regulations and oversight for the capture of eels (both glass eel and adults).

3. Aquaculture Segmentation: Categorize and segment eel aquaculture practices.

Through these plans and programs, it is hoped that the existing eel supply chain (Figure 8a) can be transformed into a sustainable eel supply chain (Figure 8b).

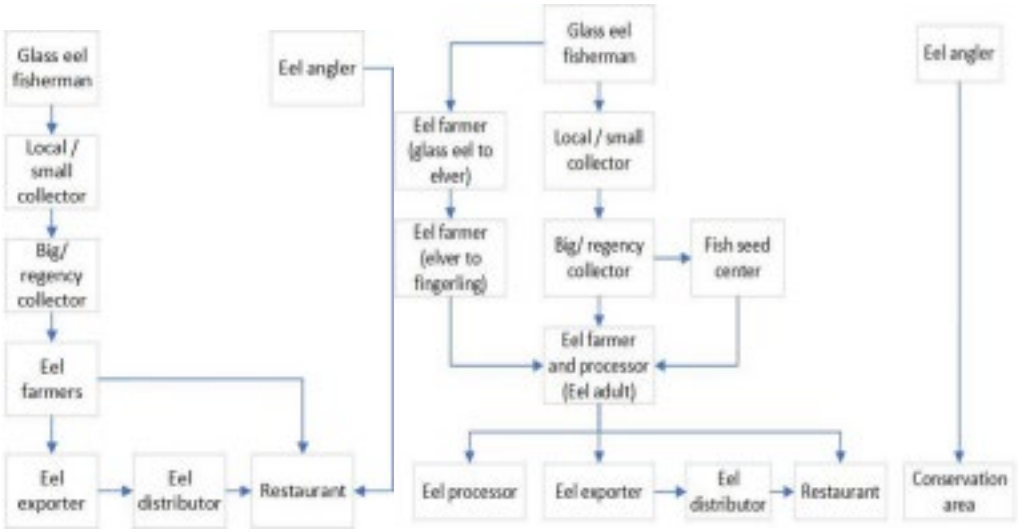

Figure 8: Eel Fishery Supply Chain. a. Current. b. Future

3.8. Determination and Management of Freshwater Eel Conservation Areas

Establishing freshwater conservation areas in Sukabumi Regency can be a strategic step given the limited area of existing conservation zones and the fact that the distribution of the fish species mentioned largely inhabits areas outside the designated protected zones. Besides the unique habitat and fish resources present, priority locations are where community management institutions or organizations have been established, allowing for integration between capture fisheries, aquaculture activities, and conservation efforts. The proposed locations also involve activities where the Sukabumi Regency Fisheries Service coordinates with other technical agencies, particularly those related to environmental affairs, forestry, and tourism. In this context, biodiversity aligns with economic development concerns.

Sustainable eel fisheries management is based on an ecosystem approach. Therefore, an integrated policy involving cross-sectoral stakeholders, both government and other relevant parties, is needed. Considering the type of natural resources to be managed—freshwater ecosystems—such policies are encompassed in river basin management policies, particularly for rivers and other freshwater areas identified as having high conservation value as eel habitats. These policies can be realized through the implementation of several plans, including:

1. Maintenance and restoration of eel habitats in the upper watershed ecosystems
2. Development and maintenance of infrastructure to reduce negative impacts from other sectors on the sustainable eel fishery supply chain
3. Rehabilitation of coastal wetlands as eel and elver fish sources and as eel conservation based tourism destinations
4. Designation and management of eel aquaculture areas

Increasing the income and welfare of eel fishermen and small-scale eel farmers requires support from various parties. This plan can be translated into community empowerment programs and increased participation from private stakeholders concerned with improving the implementation of Environmental, Social, and Governance (ESG) principles in their

business models. Several ESG elements related to and supporting the implementation of the Sukabumi Regency eel fishery master plan include:

1. Waste management to reduce pollution
2. Effective risk management in environmental risk management
3. Organizational involvement in community development

ESG-based companies tend to be more resilient during crises and can create long-term value and profitability. Regarding financing companies, ESG implementation can be linked to: • Credit/financing that supports MSMEs as well as financing to empower women and groups of fishermen and eel farmers whose livelihoods depend on the utilization of freshwater ecosystem services (SDGs goals one, five, and eight)

1. Green sukuk (green bonds) as a financing instrument to support "green" projects or businesses contributing to climate change mitigation and adaptation programs and SDGs (goals eleven, thirteen, fourteen, and fifteen).

4. CONCLUSION & SUGGESTION

Sukabumi Regency has high environmental wealth and eel resource potential; however, its utilization needs improvement. The Freshwater Eel Fisheries Management Plan, with an ecosystem approach, aims to achieve sustainable eel fisheries over the next ten years in the Sukabumi Regency region.

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