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SUSTAINABLE LIVELIHOOD STRATEGIES OF SMALL-SCALE INLAND FISHERS: AN ASSET-BASED ANALYSIS FROM THE KLAWING RIVER, CENTRAL JAVA

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ABSTRACT

Small-scale inland fishers depend on river ecosystems for income, food, and livelihoods, yet their sustainability is threatened by ecological degradation and economic uncertainty. This study analysed livelihood sustainability of small-scale inland fishers in the Klawing River, Central Java, by examining livelihood assets, vulnerability exposure, and adaptive strategies across river zones. Conducted from March to August 2025 in five villages, the study applied a descriptive quantitative approach with qualitative support using the Sustainable Livelihood Framework (SLF). Data were collected through observations, semi-structured interviews, and structured questionnaires involving 31 fishers selected purposively. Livelihood sustainability was assessed using the Sustainable Livelihood Index (SLI), an equal-weighted composite index of five capitals: human, natural, physical, financial, and social. Each capital was operationalized into measurable indicators and scored using a three-level ordinal scale, where higher scores indicated more favorable conditions. Results showed moderate livelihood sustainability, with an SLI score of 2.12. Social capital was the strongest asset (2.42), followed by physical capital (2.32), human capital (2.13), natural capital (1.88), and financial capital (1.85). The Kruskal-Wallis's test showed no significant difference in overall SLI among zones ($p = 0.527$), but social capital differed significantly ($p = 0.002$), with the downstream zone scoring highest. Main vulnerabilities included declining fish stocks, floods, pollution, sedimentation, habitat degradation, limited capital access, and seasonal income fluctuations. Fishers adapted through livelihood diversification, fishing-ground mobility, gear adjustment, seasonal adaptation, and family/community networks. This study highlights the need for asset-based, zone-specific inland fisheries management integrating habitat restoration, financial strengthening, and social capital development.

Keywords: Asset-Based Analysis; Adaptive Strategies; Klawing River Fisheries; Small-Scale Inland Fishers; Sustainable Livelihood

INTRODUCTION

Small-scale fisheries constitute an important livelihood system because they provide food, income, employment, and a source of protein for communities, particularly in developing countries with a high dependence on fisheries resources (Allison & Ellis, 2001; FAO, 2020). Globally, the fisheries and aquaculture sector employs approximately 59.5 million people, with about 85% of fishers and fish farmers located in Asia (FAO, 2020). In Indonesia, small-scale fisheries are characterized by considerable diversity in terms of fleet size, fishing gear, fishing grounds, market orientation, and household involvement in fishing activities (Halim *et al*., 2019). According to Law No. 7 of 2016, small-scale fishers are defined as fishers who conduct fishing activities to meet their daily subsistence needs, either without a vessel or using fishing vessels of up to 10 gross tons (GT). Despite their important role, small-scale fishing households are often vulnerable due to uncertain catches, limited capital, low educational attainment, environmental change, increasing operational costs, overfishing pressure, and limited access to alternative employment opportunities (Béné & Friend, 2011; Cinner *et al*., 2018; Saksono *et al*., 2023). Similar conditions were reported by Suadi *et al*. (2022), who showed that environmental change and unpredictable weather can reduce fish catches and fishers' income, thereby requiring fishing households to develop ecological, economic, and social adaptation strategies.

In riverine small-scale fisheries, livelihood vulnerability is not only reflected in low income, but also in fishers' limited access to productive assets, unstable catches, ecological risks, and the capacity of households to adjust their livelihood strategies (Béné, 2003; Nissa *et al*., 2019). From the perspective of the Sustainable Livelihood Framework (SLF), river fishers' livelihoods can be considered sustainable when households are able to maintain or enhance their assets, cope with floods, declining fish stocks, seasonal income fluctuations, and other shocks, while avoiding further degradation of the river ecosystem on which they depend (Scoones, 1998; DFID, 1999). In this context, human capital refers to fishing experience, health, and local ecological knowledge in reading river

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conditions; natural capital reflects fish availability, habitat quality, water flow, and access to fishing grounds; physical capital includes fishing gear, boats, and market access; financial capital relates to income stability, savings, and access to credit; while social capital is reflected in fisher networks, trust, group participation, and collective action. These assets interact in shaping the adaptive capacity of river fishing households, so livelihood sustainability needs to be analyzed through the balance among livelihood capitals rather than only through catch volume or income (Allison & Ellis, 2001; Ellis & Freeman, 2005).

Livelihood diversification is one of the key strategies for small-scale fishers because fishing households generally do not depend on a single source of income (Ellis, 1998). Livelihood diversification is a process through which households build a portfolio of economic and social activities to sustain their lives, reduce risks, and improve livelihood security (Ellis, 1998). In fishing communities, diversification may take the form of non-fishing employment, agriculture, small-scale trading, services, labor migration, or the use of family networks as household economic support systems (Gordon & Pulis, 2010). This strategy is important because fishing households frequently face seasonal fluctuations, price changes, declining fish stocks, damage to fishing gear, and uncertainty in accessing fishing grounds (Béné & Friend, 2011; Fabinyi *et al*., 2022). Thus, fishers' adaptive capacity is determined not only by their ability to catch fish, but also by their ability to combine various livelihood assets, move across fishing grounds, adjust fishing time and gear, and utilize social networks to sustain income and household resilience (Dharmawan *et al*., 2016; Manlosa *et al*., 2019).

Studies on small-scale fishers' livelihoods have generally focused more on coastal and marine areas, as shown in the works of Nissa *et al*. (2019), Halim *et al*. (2019), Fabinyi *et al*. (2022), Suadi *et al*. (2022), and Saksono *et al*. (2023). In contrast, studies on inland fishers, particularly riverine fishers, remain relatively limited within fisheries livelihood research. Rivers are important socio-ecological ecosystems because they function as fish habitats, sources of local food, economic spaces for rural communities, and livelihood bases for small-scale fishing households (Funge-Smith & Bennett, 2019). River ecosystems are also vulnerable to pollution, sedimentation, flooding, habitat fragmentation, dam construction, land-use change, and declining fish diversity (Tickner *et al*., 2020). These pressures may reduce fisheries productivity, limit fishers' access to fishing grounds, and increase the vulnerability of households that depend on river resources. Therefore, the SLF approach is relevant for analyzing the relationships between natural resource quality, access to productive assets, local institutions, and household adaptation strategies in response to socio-ecological change (Garcia *et al*., 2008; Hahn *et al*., 2009).

The Klawing River in Purbalingga Regency, Central Java, is one of the inland water ecosystems that plays an important role as a habitat for native fish species and as a livelihood source for small-scale fishers. However, the Klawing River is also facing ecological pressures. Gunara and Rukayah (2019) reported that water quality in the upstream section of the Klawing River remains relatively good, whereas the middle and downstream sections have declined due to liquid waste, solid waste, erosion potential, and the continued occurrence of destructive fishing practices using poison and electrofishing. The study also recorded 23 fish species in the Klawing River, consisting of 16 native species and 7 introduced species, indicating that the river has important biodiversity while also facing anthropogenic pressures (Gunara & Rukayah, 2019). Saprudin *et al*. (2022) further recorded 707 fish individuals comprising 23 species and 12 families in the middle section of the Klawing River, with Cyprinidae as the dominant family. These findings confirm that the Klawing River has significant fish resource potential for supporting fishers' livelihoods, yet its sustainability depends heavily on habitat quality, exploitation pressure, local management capacity, and the ability of fishing households to develop adaptive livelihood strategies.

Previous studies have examined the bioecological and management aspects of the Klawing River, including fish diversity and longitudinal distribution (Suryaningsih *et al*., 2018), ichthyofauna in the downstream section (Pramono *et al*., 2018), water quality, native and introduced species, pollution sources, and fishing practices (Gunara & Rukayah, 2019), fish diversity in the middle section of the river (Saprudin *et al*., 2022), and local wisdom in fisheries resource management (Salsabila *et al*., 2025). However, studies that specifically analyze the livelihood sustainability of small-scale inland fishers through livelihood asset structures, vulnerability exposure, and adaptive strategies across the upstream, midstream, and downstream zones of the Klawing River remain limited. This research gap is important because ecological pressures in river systems not only affect fish communities, but also determine fishers' access to resources, income stability, adaptation choices, and household livelihood sustainability. Therefore, this study aims to analyze the structure and sustainability level of small-scale fishers' livelihoods in the Klawing River, Central Java, by assessing five livelihood assets, socio-ecological vulnerability exposure, and adaptive strategies across the upstream, midstream, and downstream zones. The findings are expected to provide empirical contributions to the development of sustainable livelihood studies in riverine fisheries and to serve as a basis for adaptive, asset-based inland fisheries management that is sensitive to socio-ecological differences across river zones.

RESEARCH METHODS

Research Time and Location

This study was conducted from March to August 2025 in five villages located along the Klawing River, Purbalingga Regency, Central Java Province, Indonesia. The study sites included Palumbungan and Banjarsari Villages in Bobotsari Subdistrict, Karangturi Village in Mrebet Subdistrict, Bojongsari Village in Bojongsari Subdistrict, and Kedungbenda Village in Kemangkon Subdistrict. These five villages represent the ecological zonation of the Klawing River, namely the upstream zone, represented by Palumbungan and Banjarsari; the midstream zone, represented by Karangturi and Bojongsari; and the downstream zone, represented by Kedungbenda. This zonation allows for a comparative analysis of variations in resource conditions, adaptive strategies, and livelihood capital across river sections. The study sites were selected based on the presence of small-scale fishing activities conducted by inland fishers along the Klawing River. A map of the study area, showing the spatial zoning (upstream in green, middle in yellow, and downstream in red), is presented in Figure 1.

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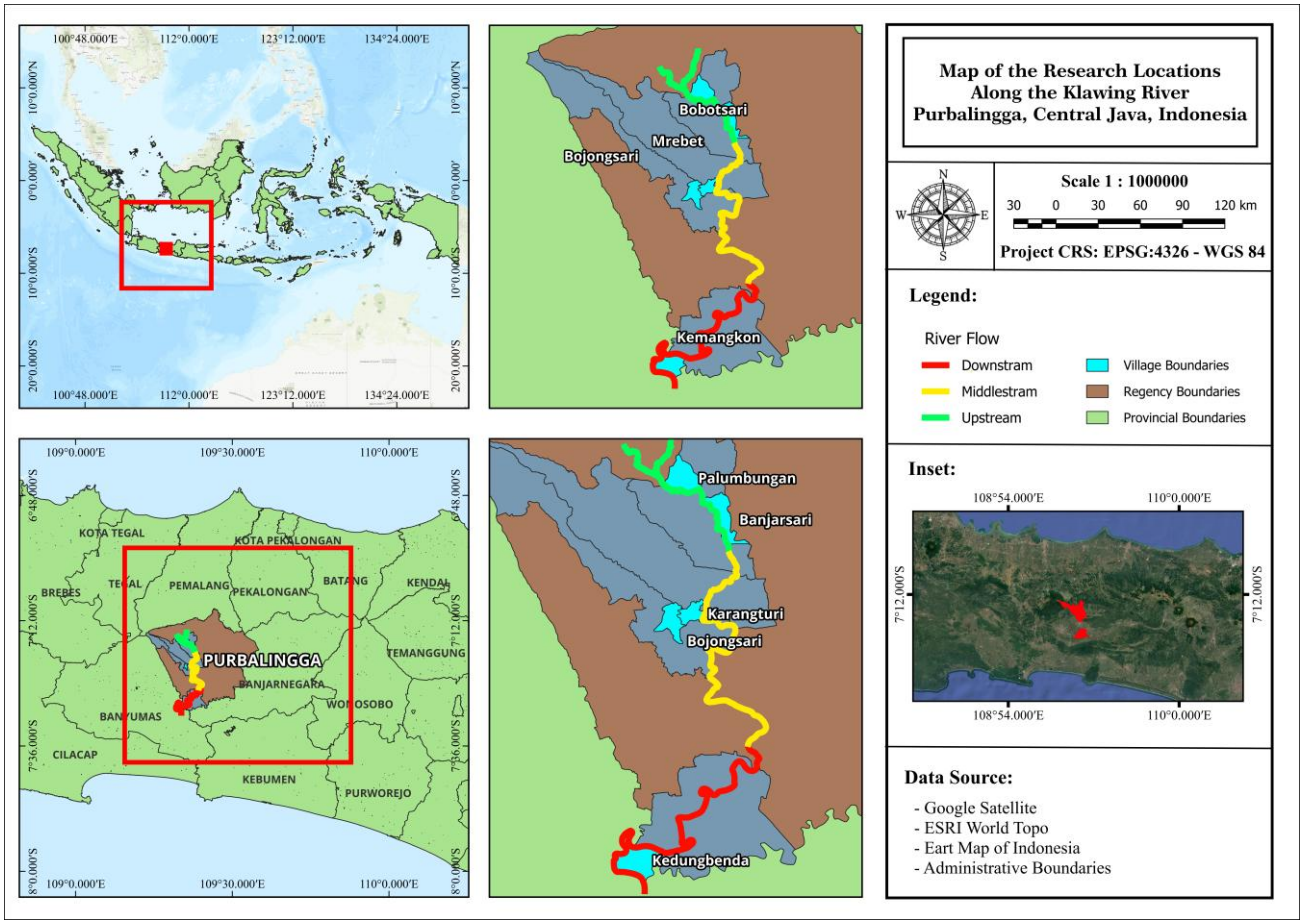


Figure 1. Research Location Along The Klawing River, Central Java

Research Approach and Data Collection Techniques

This study employed a quantitative descriptive approach supported by qualitative analysis based on the SLF developed by DFID (1999) and Scoones (1998). This framework was used to analyse the relationships among livelihood assets, adaptive strategies, and the sustainability level of fishers' livelihoods. Since the SLF is primarily conceptual, this study adopted an asset-based livelihood scoring approach, as applied in empirical studies on small-scale fisheries (Allison & Ellis, 2001; Hahn *et al*., 2009; Islam *et al*., 2014). The descriptive approach was then used to systematically examine livelihood assets, adaptive strategies, and the interrelationships among components within the livelihood structure of small-scale inland fishers.

Primary data were collected through field observations, semi-structured interviews using an interview guide, and structured questionnaires developed based on the five livelihood capitals of the SLF, namely human, natural, physical, financial, and social capital (DFID, 1999; Scoones, 1998). Field observations were conducted to examine the physical conditions of the study area and fishing activities, while in-depth interviews were carried out with fishers and community figures involved in fisheries-related activities along the Klawing River. Prior to respondent selection, preliminary field mapping was conducted with village officials, fisher-group representatives, and local key informants to identify active small-scale inland fishers in the selected villages. Since no official administrative database specifically recorded the number of active small-scale inland fishers in the study area, the accessible fisher population was identified through field listing and verification with local informants. Based on preliminary field mapping, 31 eligible fishers were identified and included as respondents: 12 from the upstream, 13 from the midstream, and 6 from the downstream zones. These respondents represented nearly the entire accessible population of active small-scale inland fishers in the selected Klawing River villages; therefore, the sampling approach was treated as a local census or saturation sampling rather than a conventional small sample. The relatively small number of downstream respondents reflects the actual field condition, as river fishing in this area is a minority livelihood practiced by only a limited number of active fishers. Respondents were included based on the following criteria: (1) active small-scale inland fishers; (2) fishers using traditional or small-scale fishing gears; (3) fishers conducting fishing activities in the Klawing River; and (4) fishers who depended on Klawing River fisheries resources as one of their main livelihood sources. The *Kruskal-Wallis's* test was used only as a supporting non-parametric analysis to compare zone-based livelihood patterns, not to make broad statistical generalizations beyond the study area.

In this study, small-scale fishers refer to individuals who use fishing vessels of no more than 10 gross tons (GT) and catch fish to meet their daily household needs, as defined in Law No. 7/2016 on the Protection and Empowerment of Fishers, Fish Farmers, and Salt Farmers. Purposive sampling was considered appropriate because the study did not aim to generalize statistically to all inland fishers, but to obtain relevant and

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contextual information from respondents who met specific research criteria (Patton, 2015). The sample size was considered adequate for descriptive quantitative analysis supported by qualitative interpretation because sample adequacy in qualitative and mixed-method research is determined by the richness, relevance, and saturation of information rather than solely by population proportion (Guest *et al*., 2006; Malterud *et al*., 2016). Secondary data were obtained from the Food Security and Fisheries Office of Purbalingga Regency, the Environmental Office of Purbalingga Regency, Statistics Indonesia, village documents, and relevant scientific literature.

Measurement of Livelihood Assets and Data Analysis

The measurement of livelihood assets in this study was based on the SLF (Scoones, 1998; DFID, 1999) which consists of five main components: human capital, natural capital, physical capital, financial capital, and social capital. Each capital was operationalized into a set of measurable indicators relevant to the context of small-scale inland fishers in the Klawing River. Each indicator was assessed using a three-point ordinal scale, namely 1 (low), 2 (moderate), and 3 (high). To clarify the measurement procedure, each livelihood capital was translated into specific indicators and operational measures. The scoring criteria were developed to reflect the relative condition of each indicator in supporting livelihood sustainability, where higher scores indicate more favorable livelihood conditions. The operationalization of each variable is presented in Table 2. The scoring approach was applied to convert qualitative data obtained from interviews and field observations into composite quantitative values without disregarding the contextual meaning of the socio-ecological conditions being examined. This approach was used because composite index methods allow multidimensional social, economic, and environmental indicators to be standardized, scored, and aggregated systematically to assess livelihood vulnerability or sustainability (Sullivan & Meigh, 2005; OECD, 2008; Hahn *et al*., 2009). The index for each livelihood capital was calculated using the simple average of all its constituent indicators, as expressed in the following formula:

$$CI = \frac{\sum Xi}{n} \quad \text{.....(1)}$$

Description : CI = Capital Index; Xi = Score of the i-th indicator; n = Number of indicators within each livelihood capital

$$HC = \frac{H1+H2+H3+H4+H5}{5} \quad \text{.....(2)}$$

$$NC = \frac{N1+N2+N3+N4+N5}{5} \quad \text{.....(3)}$$

$$PC = \frac{P1+P2+P3+P4+P5}{5} \quad \text{.....(4)}$$

$$FC = \frac{F1+F2+F3+F4+F5}{5} \quad \text{.....(5)}$$

$$SC = \frac{S1+S2+S3+S4+S5}{5} \quad \text{.....(6)}$$

Furthermore, the overall level of livelihood sustainability was calculated using the SLI, which was obtained from the average value of the five livelihood capitals, as expressed in the following formula:

$$SLI = \frac{(HC+NC+PC+FC+SC)}{5} \quad \text{.....(7)}$$

Description: SLI = Sustainable Livelihood Index; *HC* = Human Capital; *NC* = Natural Capital; *PC* = Physical Capital; *FC* = Financial Capital; *SC* = Social Capital

This study applied equal weighting, as commonly used in composite livelihood index analysis (Hahn *et al*., 2009; OECD, 2008), because the SLF treats human, natural, physical, financial, and social capital as interrelated components, and no empirical basis was available to assign different weights to each capital. This approach provided a transparent and neutral basis for constructing the Sustainable Livelihood Index (SLI), while the relative importance of each capital was interpreted contextually across upstream, midstream, and downstream zones. Since SLF indicators are formative and multidimensional, Cronbach's alpha was not applied to the combined indicators because these indicators were not intended to measure a single latent construct, but to represent different livelihood assets. Instead, indicator validity and suitability were ensured through content validity by aligning each indicator with the SLF, relevant literature, field observations, and the socio-ecological context of small-scale inland fishers in the Klawing River. Indicator retention was based on theoretical relevance, operational clarity, and contextual suitability. Data analysis included indicator scoring, capital index calculation, SLI calculation, livelihood asset balance assessment, and analysis of adaptive strategies based on Scoones' (1998) classification. The SLI level classification is presented in Table 1.

Table 1. Classification of SLI Level

SLI Value	Interpretation
1.00 – 1.66	Low
1.67 – 2.33	Moderate
2.34 – 3.00	High

Source: Equal interval approach based on the range of the composite index values, adapted from Hahn *et al*. (2009)

The classification of livelihood sustainability levels in Table 1. was determined based on the SLI, calculated as the average score of the five livelihood capitals. An index value of 1.00–1.66 was categorized as low sustainability, 1.67–2.33 as moderate sustainability, and 2.34–3.00 as high sustainability. This classification is relative and is intended to describe the comparative strength of livelihood assets rather than to serve as an absolute measure of sustainability. The interpretation also considers the balance among livelihood capitals, as Scoones (1998) emphasizes that sustainability is determined by the capacity of a livelihood system to maintain and enhance its assets while coping with stresses and shocks. This equal-weighted composite index approach is commonly applied in empirical livelihood analysis (Hahn *et al*., 2009; Allison & Ellis, 2001).

As shown in Table 2, the scores obtained from each indicator were averaged to produce the capital index for human, natural, physical, financial, and social capital. This procedure enabled qualitative information from interviews and field observations to be transformed into comparable quantitative values while retaining the socio-ecological context of small-scale inland fishers in the Klawing River. The characteristics of the research respondents are presented in Table 3.

Statistical Analysis

To strengthen the comparison among river zones, a non-parametric statistical analysis was performed because the livelihood indicators were measured using an ordinal scoring scale and the number of respondents differed across zones. The Kruskal-Wallis test was used to examine differences in

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livelihood capital scores and the SLI among upstream, midstream, and downstream zones. When significant differences were found, a post-hoc Mann-Whitney U test with Bonferroni-adjusted p-values was applied to identify differences between pairs of zones. Statistical significance was determined at $p < 0.05$. This analysis was used to support the interpretation of zone-based differences and to avoid relying solely on descriptive comparisons (Table 4).

Table 2. Operationalization of Livelihood Asset Variables and Scoring Criteria

Livelihood capital	Indicator	Operational measure	Score 1: Low	Score 2: Moderate	Score 3: High	Data source
Human Capital	Age structure	Productive age of fishers	A score for those aged >55 years	A score for those aged 36-55 years	A score for those aged 15–35 years	Questionnaire
	Education level	Highest formal education attained	No formal/elementary education	Junior high school	Senior high school or higher	Questionnaire
	Fishing experience	Years of experience as a fisher	Less than 5 years	5–10 years	More than 10 years	Interview, questionnaire
	Health status	Frequency of illness within the past year	Frequent illness affecting fishing activities	Occasional illness	Rarely/no illness	Interview, questionnaire
	Adaptive capacity	Ability to determine fishing seasons and fishing grounds	Limited knowledge; depends on others	Able to identify some seasonal and fishing-ground patterns	Able to determine seasons, water conditions, and fishing grounds independently	Interview, observation
Natural Capital	Fishing ground access	Distance and mobility to fishing areas	Limited access and low mobility	Moderate access to nearby fishing grounds	High mobility across river sections/tributaries	Interview, observation
	Resource trends	Perceived change in fish stocks	Strong decline in fish abundance	Moderate decline or fluctuating condition	Stable or improving fish abundance	Interview
	Fish size trends	Changes in fish size over the past five years	Fish size has become smaller	Fish size is relatively stable	Fish size has increased or remains favourable	Interview
	Catch diversity	Number of dominant fish species caught	1–2 dominant species	3–4 dominant species	More than 4 dominant species	Interview, observation
	Ecological pressure	Dams, pollution, floods, sedimentation, and other stressors	High ecological pressure from multiple stressors	Moderate ecological pressure	Low ecological pressure	Interview, observation
Physical Capital	Fishing gear ownership	Availability and type of fishing equipment	No/very limited gear or dependent on borrowed gear	Owns basic fishing gear	Owns several types of fishing gear and/or boat	Questionnaire, observation
	Gear adequacy	Quantity and condition of fishing equipment	Insufficient or mostly damaged gear	Adequate but limited gear	Adequate and functional gear	Interview, observation
	Gear durability	Frequency of gear replacement	Gear frequently damaged/replaced in less than 6 months	Gear lasts 6–12 months	Gear lasts more than 1 year	Interview
	Market access	Distance and access to collectors/markets	Difficult access or only one buyer	Moderate access to collectors/local buyers	Easy access to several buyers or markets	Interview
	Other productive assets	Ownership of motorbike, livestock, boat, or	No productive assets	Owns one productive asset	Owns several productive assets	Questionnaire

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Livelihood capital	Indicator	Operational measure	Score 1: Low	Score 2: Moderate	Score 3: High	Data source
		other productive assets				
Financial Capital	Income stability	Seasonal variation in fishing income	Highly unstable income	Moderately fluctuating income	Relatively stable income	Interview, questionnaire
	Income level	Average monthly household income	Less than IDR 1,000,000	IDR 1,000,000–2,999,999	IDR 3,000,000 or more	Questionnaire
	Income diversification	Engagement in secondary occupations	No secondary occupation	Occasional secondary occupation	Regular/multiple secondary occupations	Interview, questionnaire
	Savings condition	Availability and trend of savings	No savings or declining savings	Irregular or unchanged savings	Available and increasing savings	Interview, questionnaire
	Access to capital and credit	Formal and informal financial sources	No access to credit/capital	Limited informal access	Access to formal or group-based credit/capital	Interview
Social Capital	Group membership	Participation in fisher/angler/community groups	Not a member or inactive	Member but rarely active	Active group member	Interview, questionnaire
	Trust in groups	Degree of trust in fisher groups/local institutions	Low trust	Moderate trust	High trust	Interview
	Conflict frequency	Number of conflicts over fishing grounds/gears	Frequent conflicts	Occasional conflicts	Rare or no conflicts	Interview
	Collective participation	Involvement in fisheries management and monitoring	No participation	Occasional participation	Active participation	Interview, observation
	Social networks	Intensity of social interaction and mutual cooperation	Weak/rare interaction	Moderate interaction	Strong interaction and mutual cooperation	Interview

Table 3. Characteristics of Respondents at Klawing River

No	Charac-teristic	Category	Upstream		Midstream		Downstream	
			Number of People	(%)	Number of People	(%)	Number of People	(%)
1	Gender	Male	12	100.0	13	100.0	6	100.0
		Female	0	0.0	0	0.0	0	0.0
		Total	12	100.0	13	100.0	6	100.0
2	Position	Crew fishers	4	33.3	4	30.8	2	33.3
		Boat owners	8	66.7	9	69.2	4	66.7
		Total	12	100.0	13	100.0	6	100.0
3	Age Range	≤ 30 years	2	16.7	1	7.7	1	16.7
		31 -40 years	5	41.7	4	30.8	1	16.7
		41 -50 years	3	25.0	2	15.4	3	50.0
		≥ 51 years	2	16.7	6	46.2	1	16.7
		Total	12	100.0	13	100.0	6	100.0
4	Last Education	No Formal Education	0	0.0	3	23.1	1	16.7
		Elementary school	5	41.7	6	46.2	3	50.0
		Junior high school	5	41.7	3	23.1	2	33.3
		High school	2	16.7	1	7.7	0	0.0
		Associate/Bachelor/Graduate's degree	0	0.0	0	0.0	0	0.0
		Total	12	100.0	13	100.0	6	100.0
5	Income	IDR <1,000,000	0	0.0	3	23.1	0	0.0

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No	Charac-teristic	Category	Upstream		Midstream		Downstream	
			Number of People	(%)	Number of People	(%)	Number of People	(%)
	Range	IDR 1,000,000 - 2,999,999	9	75.0	8	61.5	3	50.0
		IDR 3,000,000 - 4,999,999	2	16.7	1	7.7	3	50.0
		IDR 5,000,000 - 9,999,999	1	8.3	1	7.7	0	0.0
		IDR 10,000,000 - 20,000,000	0	0.0	0	0.0	0	0.0
		Total	12	100.0	13	100.0	6	100.0

RESULT AND DISCUSSION

Respondent Characteristics

The characteristics of the 31 small-scale inland fisher respondents along the Klawing River show several important socio-economic patterns that help explain the livelihood asset structure of the study area (see Table 3). Fishing activities were entirely dominated by male respondents, indicating that riverine fishing remains a gendered livelihood activity in which men act as the main actors in fishing operations. Most respondents were boat owners rather than crew fishers, suggesting that although fishing is conducted on a small scale, many households still possess basic productive assets to support fishing activities. This condition is relevant to the relatively strong physical capital observed in the livelihood asset analysis.

In terms of age, all respondents were within the productive-age category of 15–64 years old based on the BPS (2022) classification. This indicates that Klawing River fishers still have sufficient labour capacity to conduct fishing activities and respond to livelihood pressures. However, the age composition differed among zones. The upstream area was dominated by younger productive fishers, while the midstream area had a relatively older age structure, and the downstream area was dominated by middle-aged fishers. This pattern suggests that fishing experience and local ecological knowledge remain important assets, particularly in interpreting seasonal changes, river conditions, and fishing-ground selection.

Educational attainment among respondents was generally low, with most fishers having completed only elementary or junior high school, while very few had reached senior high school and none had higher education. This condition indicates that formal human capital remains limited and may constrain access to innovation, administrative programs, financial institutions, and alternative livelihood opportunities. Nevertheless, low formal education does not necessarily indicate low adaptive capacity, because fishers' practical knowledge is largely developed through long fishing experience, local ecological understanding, and informal learning within fishing communities.

The income profile of respondents also indicates that small-scale inland fishers along the Klawing River remain economically vulnerable. Most respondents earned within the lower income range, particularly between IDR 1,000,000 and IDR 2,999,999 per month, while only a small proportion earned higher income. The midstream area showed stronger signs of economic vulnerability due to the presence of respondents earning less than IDR 1,000,000 per month, whereas downstream fishers had slightly higher income variation but still faced financial limitations. Overall, these characteristics suggest that Klawing River fishers are supported by productive labor capacity, basic fishing assets, and accumulated experience, but their livelihoods remain constrained by low formal education, limited household income, and restricted financial capacity. This socio-economic profile provides an important basis for understanding why human and physical capital are relatively moderate, while financial capital remains one of the weakest livelihood assets.

Livelihood Asset Structure of Klawing River Small-Scale Fishers

Based on Table 5, the livelihood asset structure of small-scale inland fishers along the Klawing River indicates a moderate level of sustainability, with an average asset score of 2.12. This suggests that fishers' livelihoods remain functional as a socio-ecological system, although they are not yet fully resilient. This asset-based interpretation is consistent with Allison and Ellis (2001), who argue that livelihood analysis in small-scale fisheries should consider the interaction among human, natural, physical, financial, and social capital, since household strategies are shaped not only by fishing yields but also by asset access and adaptive capacity. Social capital was the strongest asset, with a score of 2.42, mainly supported by collective participation, group membership, and social networks. This finding aligns with Stacey *et al*. (2021), who emphasize that institutional strengthening and social networks are critical for sustaining small-scale fisheries livelihoods. Physical capital was also relatively strong, with a score of 2.32, particularly through market access and ownership of productive assets, while human capital scored 2.13, reflecting fishers' adaptive capacity to determine fishing seasons and fishing grounds, as described by Halim *et al*. (2019).

Spatially, the upstream zone showed the most balanced livelihood asset structure, with human capital at 2.22, natural capital at 1.95, physical capital at 2.37, financial capital at 2.05, and social capital at 2.23. This indicates that upstream fishers are still supported by fishing experience, health conditions, livelihood diversification, and relatively better financial access. In contrast, the midstream and downstream zones showed weaker natural and financial capital. Natural capital in the midstream and downstream zones was particularly low, as reflected in resource trend scores of 1.31 and 1.17, respectively. These low scores indicate perceived declines in fish abundance

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and suggest that fishers' vulnerability is closely linked to ecological degradation. In the midstream area, strong physical capital (2.37) and social capital (2.42) were not sufficient to compensate for declining natural capital (1.83) and financial capital (1.80). Meanwhile, the downstream zone had the highest social capital score (2.80), but the lowest financial capital score (1.53), indicating that strong collective networks have not fully offset economic vulnerability related to unstable income, limited savings, and restricted access to capital.

The weak natural capital in the Klawing River should be understood not only as declining fish availability from fishers' perceptions, but also as a reflection of biological and ecological pressures on riverine fish habitats. The low scores for fish size trends (1.19), resource trends (1.42), and ecological pressure (1.52) suggest that fish stocks, fish size, and habitat quality have declined. In the midstream and downstream zones, river regulation structures, dam-related flow alteration, sand mining, sedimentation, and pollution may disrupt longitudinal river connectivity, modify flow regimes, reduce access to spawning and nursery habitats, and alter riverbed morphology. Such disturbances can affect fish migration, recruitment success, feeding areas, and community structure, thereby reducing fish abundance and catch stability. This supports the argument that freshwater ecosystems are highly vulnerable to cumulative pressures such as habitat degradation, pollution, disrupted river connectivity, exploitation, and changes in flow regimes (Tickner *et al*., 2020). Sand mining may further increase turbidity, disturb benthic substrates, reduce habitat complexity, and affect ecological processes that support fish reproduction and growth (Koehnken *et al*., 2020).

Across river zones, vulnerability patterns differ according to dominant ecological and socio-economic pressures. Upstream fishers are mainly exposed to seasonal flooding, sedimentation, waste accumulation, and occasional destructive fishing practices. Midstream fishers face declining fish stocks, competition among gear users, conflicts between net fishers and anglers, fishing gear damage, and limited access to capital. Downstream fishers experience stronger pressures from dam construction, sand mining, flooding, sedimentation, habitat degradation, boat and gear maintenance costs, and dependence on seasonal income. These patterns indicate that livelihood vulnerability increases when ecological degradation intersects with weak financial capacity and limited adaptive resources. This condition reflects a socio-ecological trap, in which resource pressure, limited economic alternatives, and weak livelihood assets reinforce household vulnerability (Cinner, 2011; Villasante *et al*., 2022). Therefore, strengthening livelihood sustainability in the Klawing River should prioritize restoration of natural capital, protection of river habitats, improvement of financial access, and strengthening of local institutions.

Table 4. *Kruskal-Wallis* Test of Livelihood Capital Differences Among River Zones

Livelihood variable	Upstream Mean ± SD	Midstream Mean ± SD	Downstream Mean ± SD	*Kruskal-Wallis H*	*p-value*	Interpretation
Human Capital	2.22 ± 0.45	2.06 ± 0.35	2.10 ± 0.24	2.220	0.330	Not significant
Natural Capital	1.95 ± 0.30	1.83 ± 0.18	1.87 ± 0.21	0.873	0.646	Not significant
Physical Capital	2.37 ± 0.32	2.37 ± 0.28	2.13 ± 0.27	3.217	0.200	Not significant
Financial Capital	2.05 ± 0.50	1.80 ± 0.31	1.53 ± 0.37	5.456	0.065	Not significant, but shows a declining tendency
Social Capital	2.23 ± 0.27	2.42 ± 0.34	2.80 ± 0.13	12.791	0.002	Significant
SLI	2.16 ± 0.20	2.10 ± 0.11	2.09 ± 0.07	1.280	0.527	Not significant

Note: Post-hoc Mann-Whitney U tests with Bonferroni-adjusted p-values were conducted only for variables with significant Kruskal-Wallis results. For social capital, downstream fishers had significantly higher scores than upstream fishers (p = 0.004) and midstream fishers (p = 0.033), while the difference between upstream and midstream fishers was not significant (p = 0.282)

Table 5. Sustainable Livelihood Index by Indicators and Operational Measures Across Klawing River

Indicator	Operational Measure	Up Stream ± SD	Mid Stream ± SD	Down Stream ± SD	All Areas Mean ± SD
1. Human Capital		2.22 ± 0.45	2.06 ± 0.35	2.10 ± 0.24	2.13 ± 0.37
Age Structure	Proportion of productive age population	2.08 ± 0.67	1.85 ± 0.69	2.00 ± 0.63	1.97 ± 0.66
Education Level	Highest level of formal education attained	1.67 ± 0.78	1.38 ± 0.65	1.33 ± 0.52	1.48 ± 0.68
Fishing Experience	Years of experience as a fisher	2.08 ± 0.79	2.54 ± 0.66	2.50 ± 0.55	2.35 ± 0.71
Health Status	Frequency of illness within the past year	2.58 ± 0.67	1.62 ± 0.77	1.83 ± 0.75	2.03 ± 0.84
Adaptive Capacity	Determine fishing seasons and fishing grounds	2.67 ± 0.49	2.92 ± 0.28	2.83 ± 0.41	2.81 ± 0.40
2. Natural Capital		1.95 ± 0.30	1.83 ± 0.18	1.87 ± 0.21	1.88 ± 0.24

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Indicator	Operational Measure	Up Stream ± SD	Mid Stream ± SD	Down Stream ± SD	All Areas Mean ± SD
Fishing Ground Access	Distance and mobility to fishing areas	2.50 ± 0.52	2.46 ± 0.52	2.67 ± 0.52	2.52 ± 0.51
Resource Trends	Perceived decline in fish stocks	1.67 ± 0.65	1.31 ± 0.48	1.17 ± 0.41	1.42 ± 0.56
Fish Size Trends	Changes in fish size over the past five years	1.33 ± 0.49	1.08 ± 0.28	1.17 ± 0.41	1.19 ± 0.40
Catch Diversity	Number of dominant fish species caught	2.58 ± 0.51	2.85 ± 0.38	3.00 ± 0.00	2.77 ± 0.43
Ecological Pressure	Dams, pollution, floods, and other stressors	1.67 ± 0.78	1.46 ± 0.52	1.33 ± 0.52	1.52 ± 0.63
3. Physical Capital		2.37 ± 0.32	2.37 ± 0.28	2.13 ± 0.27	2.32 ± 0.30
Fishing Gear Ownership	Availability and type of fishing equipment	1.92 ± 0.90	2.00 ± 0.71	1.67 ± 0.82	1.90 ± 0.79
Gear Adequacy	Quantity and condition of fishing equipment	2.08 ± 0.67	2.15 ± 0.55	2.00 ± 0.89	2.10 ± 0.65
Gear Durability	Frequency of gear replacement	2.25 ± 0.62	1.92 ± 0.76	1.33 ± 0.52	1.94 ± 0.73
Market Access	Distance to collectors/markets	2.67 ± 0.49	2.77 ± 0.44	2.67 ± 0.52	2.71 ± 0.46
Other Productive Assets	Ownership assets	2.92 ± 0.29	3.00 ± 0.00	3.00 ± 0.00	2.97 ± 0.18
4. Financial Capital		2.05 ± 0.50	1.80 ± 0.31	1.53 ± 0.37	1.85 ± 0.43
Income Stability	Seasonal variation in income	2.08 ± 0.67	1.77 ± 0.73	1.33 ± 0.52	1.81 ± 0.70
Income Level	Average monthly income	1.92 ± 0.51	1.62 ± 0.77	1.83 ± 0.41	1.77 ± 0.62
Income Diversification	Engagement in secondary occupations	2.25 ± 0.62	2.23 ± 0.44	1.67 ± 0.82	2.13 ± 0.62
Savings Condition	Availability and trend of savings	1.83 ± 0.94	1.85 ± 0.90	1.33 ± 0.52	1.74 ± 0.86
Access to Capital	Formal and informal financial sources	2.17 ± 0.94	1.54 ± 0.66	1.50 ± 0.55	1.77 ± 0.80
5. Social Capital		2.23 ± 0.27	2.42 ± 0.34	2.80 ± 0.13	2.42 ± 0.34
Group Membership	Level of participation (active/inactive)	2.00 ± 0.60	2.62 ± 0.65	3.00 ± 0.00	2.45 ± 0.68
Trust in Groups	Degree of trust among group members	1.92 ± 0.67	2.23 ± 0.60	2.67 ± 0.52	2.19 ± 0.65
Conflict Frequency (reverse-scored)	Number of conflicts within the community	2.58 ± 0.51	1.77 ± 0.60	2.83 ± 0.41	2.29 ± 0.69
Collective Participation	Involvement in fisheries management and monitoring	2.58 ± 0.51	2.85 ± 0.38	3.00 ± 0.00	2.77 ± 0.43
Social Networks	Intensity of social interaction and mutual cooperation	2.08 ± 0.79	2.62 ± 0.65	2.50 ± 0.55	2.39 ± 0.72

Livelihood Sustainability of Small-Scale Fishers

Based on Figure 2, the livelihood asset structure of small-scale fishers along the Klawing River indicates a moderate level of livelihood sustainability, with the strongest assets ranked as follows: Social Capital (2.42), Physical Capital (2.32), Human Capital (2.13), Natural Capital (1.88), and Financial Capital (1.85). This pattern suggests that fishers' livelihoods are supported more by social networks, productive assets, market access, fishing experience, and adaptive knowledge than by the quality of natural resources and financial capacity. Among the three river zones, the upstream zone shows the most balanced livelihood asset structure, as indicated by relatively even scores across human capital (2.22), natural capital (1.95), physical capital (2.37), financial capital (2.05), and social capital (2.23). This balance implies that upstream fishers have relatively better livelihood stability because no single asset is extremely weak. Human capital also remains relatively stable across the upstream, midstream, and downstream areas, indicating that fishers' experience and ability to interpret fishing seasons and fishing grounds are fairly evenly distributed, although formal education levels remain low. This finding is consistent with Salsabila *et al*. (2025), who reported that Klawing River fishers apply local wisdom, such as pranata mangsa, in determining fishing seasons. Similarly, Silas *et al*. (2020) emphasized that the adaptive capacity of small-scale fishers is largely shaped by experience, the ability to respond to fluctuating catches, and

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strategies for coping with environmental change. However, the downstream zone can be considered the most vulnerable livelihood area because it has the lowest financial capital score (1.53), relatively lower physical capital (2.13), and weak natural capital (1.87), despite having the highest social capital score (2.80). This indicates that downstream fishers face stronger economic vulnerability, particularly in terms of income instability, limited savings, restricted access to capital, and higher maintenance needs for boats and fishing gear.

Natural capital also remains one of the weakest assets across the Klawing River, particularly in the midstream and downstream zones, reflecting increasing pressure on fish stocks, fish size, and river ecological conditions.This condition is relevant to McIntyre *et al*. (2016), who emphasized that river fisheries are essential for food security and livelihoods, yet highly vulnerable when river ecosystems experience degradation. Zieritz *et al*. (2024) also explained that tropical freshwater ecosystems face strong pressures from habitat alteration, pollution, exploitation, and weak conservation governance. In the Klawing River context, the high social capital in the downstream zone suggests that group participation, trust, collective involvement, and social networks may function as compensatory adaptive mechanisms for fishers facing weak financial and natural capital.

The management implications of these findings differ across river zones. In the upstream zone, management should focus on maintaining the relatively balanced livelihood asset structure through river habitat protection, prevention of destructive fishing practices, and support for livelihood diversification. In the midstream zone, priority should be given to reducing ecological pressures such as pollution, sedimentation, sand mining impacts, and conflicts among river users. In the downstream zone, management should prioritize financial strengthening, access to capital, support for fishing gear and boat maintenance, habitat restoration, and the use of strong social capital as an entry point for collective adaptation. This is important because Finkbeiner (2015) showed that diversification of fishing locations, strategies, and livelihood sources can enhance fishers' resilience, while Roscher *et al*. (2022) emphasized that livelihood diversification can reduce vulnerability, although its effectiveness depends strongly on the local social-ecological context. Thus, the Klawing River case reveals a distinctive pattern: social and physical capital relatively support fishers' livelihoods, whereas natural and financial capital remain the main constraints to livelihood sustainability. Therefore, strengthening small-scale inland fishers' livelihoods should not only focus on increasing fish production, but also on restoring river habitats, improving financial access, strengthening fisher groups, and developing zone-specific livelihood strategies that do not increase pressure on fish resource.

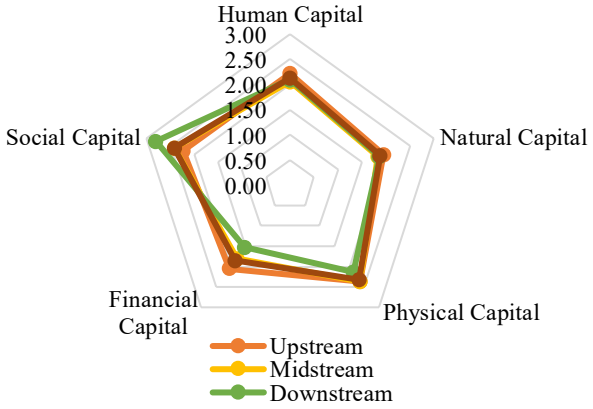


Figure 2. Livelihood Pentagon Assets

Vulnerability Exposure and Adaptive Strategies

Vulnerability exposure and adaptive strategies of small-scale fishers along the Klawing River vary across the upstream, midstream, and downstream zones. These variations are influenced by differences in river biophysical characteristics, ecological pressures, resource-use patterns, and the socio-economic conditions of fishing households. The major vulnerability factors include seasonal flooding, fluctuating river discharge, sedimentation, pollution, declining fish abundance, habitat degradation, limited access to capital, and conflicts related to fishing-ground use. To cope with these pressures, fishers adopt several adaptive strategies, including livelihood diversification, shifting fishing grounds, adjusting fishing gear and fishing time, and relying on family and community networks, as summarized in Table 6.

Table 6. Linkage among Livelihood Capital, Vulnerability Exposure, and Adaptive Strategies of Klawing River Fishers

Case Study Area	Livelihood Capital Condition	Vulnerability Exposure	Capital-Vulnerability Linkage	Adaptive Strategies
Upstream (Palumbungan and Banjarsari, Bobotsari Subdistrict)	• The upstream zone has the most balanced livelihood asset structure, supported by relatively stable human capital, physical capital, and financial capital. However, natural capital remains under pressure due to ecological disturbance	• Seasonal floods, fluctuating water levels, sedimentation from upstream erosion, declining fish abundance, domestic waste pollution, occasional illegal fishing practices, unstable catches, fluctuating seasonal income, limited access to capital, and competition with fishers from neighbouring villages	• The relatively balanced human, physical, and financial capital enables upstream fishers to respond more flexibly to seasonal and ecological pressures. However, declining natural capital weakens catch stability and increases dependence on non-fishing income sources	• Fishers combine fishing with farming, construction work, trading, transportation services, aquaculture, and migrant labor. They also adjust fishing time, move fishing grounds along the Klawing River and tributaries, use multiple fishing gears, share fishing information, participate in restocking programs, conduct informal monitoring of illegal fishing, and rely on family and social networks for economic support

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Case Study Area	Livelihood Capital Condition	Vulnerability Exposure	Capital-Vulnerability Linkage	Adaptive Strategies
Midstream (Karangturi, Mrebet Subdistrict and Bojongsari, Bojongsari Subdistrict)	• The midstream zone is supported by relatively strong physical and social capital, but has weaker natural and financial capital. This indicates that fishers have fishing facilities and social interaction, but face ecological degradation and limited economic resilience	• Seasonal floods, sudden increases in river discharge, extreme weather, decreasing fish stocks, river pollution, sedimentation, dams affecting fish habitats, fluctuating household income, limited capital for fishing gear maintenance, competition between gear users, and conflicts between net fishers and anglers	• Weak natural capital increases exposure to declining fish resources and habitat disturbance, while weak financial capital limits the ability of fishers to maintain or replace fishing gear. Social capital becomes important for reducing conflict and maintaining cooperation among river users	• Fishers engage in alternative occupations such as construction labour, carpentry, sand mining, farming, livestock raising, and small trading. They adjust fishing time, gear types, and fishing locations according to seasonal conditions and fish availability. Social cooperation is developed through information exchange, informal conflict resolution, river clean-ups, and fish restocking activities
Downstream (Kedungbenda, Kemangkon Subdistrict)	• The downstream zone is the most vulnerable area because it has the lowest financial capital, relatively weak natural capital, and lower physical capital. However, it has the highest social capital, which functions as an important compensatory asset	• Frequent floods, strong river currents, unpredictable weather, declining fish abundance associated with dam construction, sand mining activities, habitat degradation in the Klawing and Serayu Rivers, unstable fishing income, limited capital for fishing gear and boat maintenance, competition with anglers and outside fishers, declining effectiveness of fisher groups, and limited access to fisheries extension services	• Weak financial capital limits the ability of downstream fishers to cope with income instability and maintenance costs, while weak natural capital reduces fishing productivity. High social capital helps fishers maintain livelihood resilience through cooperation, group participation, shared information, family support, and collective adaptation	• Fishers operate small wooden paddle boats, move between fishing locations along the Klawing and Serayu Rivers, adjust fishing practices according to water conditions, use cast nets and gillnets with two-person crews, shift fishing grounds to areas with higher fish abundance, combine fishing with agriculture or informal jobs, involve family members in fishing or fish marketing, and sell catches directly to collectors, markets, or local consumers

To provide statistical evidence for the zone-based comparison (Table 4), the Kruskal-Wallis test was applied to the five livelihood capitals and the SLI. The results showed that the overall SLI did not differ significantly among the upstream, midstream, and downstream zones ($H = 1.280$; $p = 0.527$), indicating that livelihood sustainability among small-scale inland fishers along the Klawing River was generally similar and remained within the moderate category across zones. Human capital, natural capital, and physical capital also showed no significant differences. Financial capital was not statistically significant at the 5% level, although it was marginally significant ($H = 5.456$; $p = 0.065$). In practical and economic terms, however, the decline in financial capital from 2.05 in the upstream zone to 1.53 in the downstream zone indicates a meaningful disparity in household economic well-being, reflecting greater downstream vulnerability related to income instability, limited savings, restricted access to capital, and accumulated ecological and operational pressures. In contrast, social capital differed significantly among zones ($H = 12.791$; $p = 0.002$).

The post-hoc Mann-Whitney U test with Bonferroni-adjusted p-values indicated that downstream fishers had significantly higher social capital than upstream fishers ($p = 0.004$) and midstream fishers ($p = 0.033$), while the difference between upstream and midstream fishers was not significant ($p = 0.282$). These results confirm that the main zone-based difference in the livelihood structure of Klawing River fishers lies in social capital, particularly in the downstream zone, where stronger group participation, trust, collective involvement, and social networks may function as compensatory adaptive support in facing higher ecological and economic vulnerability.

Table 6 shows that vulnerability exposure among small-scale fishers along the Klawing River differs across the upstream, midstream, and downstream zones, and these differences are directly shaped by the condition of livelihood capitals in each zone. In the upstream zone, the relatively balanced structure of human, physical, financial, and social capital enables fishers to respond more flexibly to seasonal floods, fluctuating water levels, sedimentation, declining fish abundance, domestic waste pollution, and occasional illegal

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fishing practices. However, pressure on natural capital still weakens catch stability and increases fishers' dependence on non-fishing income sources. As a result, upstream fishers adapt by combining fishing with farming, construction work, trading, transportation services, aquaculture, and migrant labor, while also adjusting fishing time, shifting fishing grounds along the Klawing River and its tributaries, using multiple fishing gears, sharing fishing information, participating in fish restocking programs, and conducting informal monitoring of destructive fishing practices. In the midstream zone, relatively strong physical and social capital supports fishers' capacity to maintain fishing activities, but weak natural and financial capital increases their vulnerability to declining fish stocks, pollution, sedimentation, dam-related habitat disturbance, limited capital for gear maintenance, competition among gear users, and conflicts between net fishers and anglers. Therefore, midstream fishers rely on gear adjustment, livelihood diversification, information exchange, informal conflict resolution, river clean-ups, and restocking activities as adaptive responses. The downstream zone represents the most vulnerable livelihood condition because financial capital is the weakest, while natural and physical capital are also under pressure from frequent floods, strong currents, dam construction, sand mining, habitat degradation, unstable income, and high boat and gear maintenance costs. Nevertheless, the high social capital in this zone functions as a compensatory asset that supports cooperation, group participation, shared information, family involvement, collective adaptation, fishing-ground mobility, and direct marketing to collectors, markets, or local consumers. Thus, the adaptive strategies of Klawing River fishers are not merely general responses to environmental change, but are directly shaped by the strengths and weaknesses of livelihood capitals in each river zone.

In the upstream zone, represented by Palumbungan and Banjarsari Villages, most interviewed fishers had more than 10–30 years of fishing experience, indicating that human capital is strongly supported by accumulated local ecological knowledge. However, fishing activities still relied on traditional gears such as cast nets and hook-and-line, with mesh sizes of approximately 1–2 inches and without motorized boats. During the peak fishing season, average catches ranged from 2–5 kg/trip, dominated by nilem (*Osteochilus vittatus*) and brek (*Barbonymus balleroides*), whereas during the lean season catches declined to approximately 0.5–2 kg/trip. Fishers reported that sudden floods and fluctuations in river discharge frequently forced them to temporarily stop fishing for safety reasons. This indicates that hydrological variability is a key source of vulnerability in the upstream section of the Klawing River, even though fishers have relatively balanced livelihood assets. Changes in river discharge, sedimentation, and seasonal flooding may influence fish community structure and inland fisheries productivity (Tickner *et al*., 2020). In addition, several respondents stated that the average size of fish caught had declined over the past five years, suggesting pressure on natural capital due to intensive fishing, ecological disturbance, and habitat alteration. This pattern is consistent with Fluet-Chouinard *et al*. (2022), who emphasized that changes in freshwater ecosystems can affect fish availability and the sustainability of inland fisheries. Therefore, upstream fishers' adaptation reflects the interaction between relatively strong human and physical capital and weakening natural capital, which encourages fishing-ground mobility, seasonal adjustment, gear diversification, livelihood diversification, and the use of family and community networks to maintain household resilience.

In the midstream zone of the Klawing River, represented by Karangturi and Bojongsari Villages, river fisheries exhibited more complex dynamics due to higher anthropogenic pressures compared with the upstream area. Most fishers in this zone relied on a combination of fishing gears, including cast nets, gillnets, hook-and-line, and traditional traps (*wuwu*), with average mesh sizes of 1–2.5 inches and cast-net lengths of approximately 3–5 meters. During the peak season, average catches ranged from 3–10 kg/day, dominated by nilem (*Osteochilus vittatus*), baceman/baung (*Hemibagrus nemurus*), brek (*Barbonymus balleroides*), and wader (*Puntius binotatus*), while during the lean season catches declined to approximately 0.5–3 kg/day. River water quality in this zone was reported to change frequently, particularly after heavy rainfall, due to the transport of domestic waste and sediment from upstream areas. In addition, sand mining activities at several points along the river were reported to alter riverbed structure, potentially degrading fish habitats. Koehnken *et al*. (2020) stated that sand mining activities may cause aquatic habitat degradation, increase water turbidity, and reduce the reproductive success of riverine fish. Another ecological pressure identified in this study was the increasing number of fishers and recreational anglers at several locations in the midstream Klawing River, resulting in competition over aquatic space between gillnet fishers and anglers. Similar conflicts over space and resource use have also been observed in various inland waters in Indonesia, particularly in open-access river systems (Bennett *et al*., 2021).

In the downstream zone of the Klawing River, represented by Kedungbenda Village, fishers faced relatively higher ecological pressures than those in the upstream and midstream zones. Most fishers in this area used small wooden boats of approximately 4–5 meters in length, operated manually with paddles and without engines. Catches during the peak season reached approximately 10–17 kg/day, but declined to around 1–5 kg/day during the lean season. Fishers also reported that the construction of the Kalibacin Dam, around 2016, altered river flow patterns and affected the presence of several fish species. Before the dam was built, species such as mangut fish, river shrimp, and several migratory fish were more frequently found in the downstream area; however, these species are now rarely encountered. Previous studies have shown that dam construction can reduce fish diversity by obstructing fish migration, reducing river habitat connectivity, and altering aquatic ecosystem dynamics (Barbarossa *et al*., 2021). In addition, downstream fishers reported an increasing occurrence of introduced species such as mujair (*Oreochromis mossambicus*), Nile tilapia (*Oreochromis niloticus*), and suckermouth catfish (*Hypostomus plecostomus*), although native fish species still dominated the catches. The presence of introduced species in river ecosystems may affect fish community structure through resource competition and food-web alteration (Dina *et al*., 2022).

In response to ecological pressures and catch uncertainty, fishers along the Klawing River developed various livelihood adaptation strategies to maintain household economic sustainability. Most fishers did not depend solely on fishing activities but also engaged in other occupations, including agricultural labor, construction work, small-scale trading, sand mining, carpentry, and catfish aquaculture. In the upstream and midstream areas, for example, several fishers worked as construction laborers or traders to supplement household

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income. Such livelihood diversification is a common adaptive strategy among small-scale fishing households to reduce economic risks caused by fluctuating catches and environmental variability (Allison & Ellis, 2001). In addition to occupational diversification, fishers also adapted their fishing practices by shifting fishing grounds, adjusting fishing times according to seasonal and current conditions, and sharing information on fish locations among fellow fishers. This information-sharing practice indicates the presence of strong social networks within riverine fishing communities, functioning as a collective adaptation mechanism in response to ecosystem change. Berkes (2015) and Cinner *et al*. (2018) showed that local social networks and community-based management practices can enhance the resilience of small-scale fishing communities in facing environmental change and resource pressure. Overall, the findings indicate that livelihood strategies among Klawing River fishers emerged as adaptive responses to unequal livelihood asset distribution, particularly the weakness of natural and financial capital, while social capital functioned as a compensatory mechanism for maintaining household resilience.

This study has several limitations. First, the number of respondents was relatively small because the study focused on active small-scale inland fishers who met specific criteria in selected river zones. Therefore, the findings should be interpreted as a contextual representation of livelihood conditions in the Klawing River rather than as a statistical generalization to all inland fishers. Second, several indicators, particularly resource trends, fish size trends, ecological pressure, income stability, and adaptive strategies, were partly based on fishers' perceptions and field interviews. Future studies should combine livelihood assessment with longitudinal catch data, water quality monitoring, and ecological indicators to provide a more comprehensive understanding of the relationship between river ecosystem change and livelihood sustainability.

CONCLUSION

This study demonstrates that the livelihood sustainability of small-scale inland fishers in the Klawing River is shaped not only by the availability of fishery resources, but also by the interaction among livelihood assets, vulnerability exposure, and adaptive strategies across river zones. By applying the Sustainable Livelihood Framework to a riverine fisheries context, this study contributes to the limited body of empirical research on inland small-scale fishers, which has received less attention than coastal and marine fisheries. The findings show that the upstream zone has the most balanced livelihood asset structure, while the downstream zone represents the most vulnerable livelihood condition due to weak financial capital, pressure on natural resources, and higher dependence on adaptive social mechanisms.

The main scientific contribution of this study lies in demonstrating that social capital can function as a compensatory asset in vulnerable riverine fishing communities. Although the downstream fishers face greater ecological and economic pressures, their stronger group participation, trust, collective action, and social networks support adaptive responses such as fishing-ground mobility, household livelihood diversification, direct marketing, and family-based economic support. However, this study also shows that strong social capital alone cannot fully overcome weak natural and financial capital. Therefore, livelihood sustainability in inland fisheries should be understood as a dynamic relationship between ecological conditions, household economic capacity, and collective adaptive capacity.

These findings imply that inland fisheries management should move beyond production-oriented interventions and adopt an asset-based, zone-specific approach. In the upstream zone, management should maintain the relatively balanced livelihood assets through habitat protection and control of destructive fishing practices. In the midstream zone, management should focus on reducing ecological pressures, managing conflicts among river users, and supporting fishing gear maintenance. In the downstream zone, priority should be given to improving financial access, restoring habitats affected by dams and sand mining, strengthening fisher institutions, and using social capital as an entry point for collective adaptation. Thus, the sustainability of small-scale inland fishers in the Klawing River depends on the simultaneous restoration of natural capital, strengthening of financial capacity, and institutionalization of social capital within adaptive river fisheries management.

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