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# Assessing fishery management models in the Kampar River, Riau Province, Indonesia, using Ecosystem Approach to Fisheries Management (EAFM) tool

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**Abstract.** *Prianto E, Jhonnerie R, Oktorini Y, Adriman, Fajri NE. 2024. Assessing fishery management models in the Kampar River, Riau Province, Indonesia, using Ecosystem Approach to Fisheries Management (EAFM) tool. Biodiversitas 25: 4581-4592.* The Kampar River's high fish diversity dramatically benefits the local community. However, overfishing threatens the river's fishery resources. Urgent and concerted management efforts, including local wisdom implementation, are crucial to address this pressing issue. Law Number 45 of 2009 concerning fisheries mandates sustainable fishery resource management, primarily through an ecosystem-based approach. From January to June 2024, researchers conducted a study in the Kampar River area to assess the status of ecosystem-based fishery resource management across several management models. The research combined qualitative and quantitative methods, using purposive sampling to select 5-10 participants from each village. Following guidelines from the Directorate of Fish Resources, the study developed indicators for each domain and converted them into composite indicators using the 'flag modeling' technique. Data analysis showed that the Lubuk Larangan management model achieved the highest ecosystem-based fishery resource status, scoring 13,374 points (green), indicating optimal implementation of sustainable fisheries management principles. This success necessitates the development of strategic plans to maintain or enhance existing domain conditions and indicators. The individual auction system, communal auction system, and government regulations scored 13,168, 13,120, and 10,899 points respectively (yellow), signifying partial implementation of sustainable fisheries principles.

**Keywords:** Ecosystem approach, fishery management models

## INTRODUCTION

River and swamp ecosystems, with their distinct and ever-changing features influenced by annual seasonal floods, are not mere bodies of water (Hasan et al. 2022). These ecosystems serve as spawning and nursery grounds for various fish species, provide rearing areas with abundant invertebrates for food, offer protection from extreme temperature changes and currents, shelter prey fish (Cooke et al. 2016) and habitat of many native species (Valen et al. 2020). Inland fisheries, with their strategic functions, serve as a protein source for inland populations, maintain genetic diversity, and provide livelihoods for local inhabitants (Suuronen and Batley 2014; Béné et al. 2015; Prianto et al. 2015; Lynch et al. 2016; Nuruhwati and Rizal 2019). Despite this indisputable importance, due to lack of reliable data, inland fisheries have never been part of any high profile global fisheries assessment (Hasan and Islam 2020). In addition, the current challenges in inland fisheries management are habitat fragmentation (reservoir construction), pollution (from domestic, industry, factory and mining), and invasive fish species (Prianto et al. 2015). Moreover, although inland fisheries are very important for the community, they still consider their role unimportant because the proportion of fish produced could be much higher (Bartley et al. 2015; Hasan et al. 2022) and their value in terms of food and nutritional security is often neglected mainly due to the principal focus on marine fisheries management (Funge-Smith and Bennett 2019). The significance of inland fisheries is not limited to local communities; it extends to supporting national development. These fisheries significantly contribute to livelihoods, food security (McIntyre et al. 2016; FAO, Duke University and WorldFish 2023), and genetic diversity (Insani et al. 2022; Nurjirana and Keith 2022). Almost the majority (90%) of fish utilization in inland waters is carried out by developing countries. The number of workers in inland fisheries (fish catching and processing) worldwide reaches around 61 million people (Bartley et al. 2015). According to Strieder Philippsen et al. (2018), through an ecosystem modeling approach (Ecopath with Ecosim), the impact of small-scale fisheries on the structure and function of tropical ecosystems can be adequately studied.

In Riau Province, approximately 20,000 individuals rely on fishing as their primary or secondary occupation (CBS Kampar 2020). The inland waters of Riau Province, with their diverse fish species, represent valuable genetic resources for human use (Fauzi et al. 2021). Among these,

the Kampar River stands out for its rich diversity of fish resources and substantial potential. The Kampar River, one of the largest rivers in Riau Province, serves as a year-round fishing ground for local communities. Based on the inland fisheries management area the Kampar River is located in the Inland Fisheries Management Area of the Republic of Indonesia (IFMA RI) 438. The Kampar River stretches from west to east through two regencies, namely Kampar and Pelalawan Regencies, with a length of ± 413.5 km and an average width of 143 m. The Kampar River stretches from west to east through several sub-districts, namely District XIII Koto Kampar, Bangkinang, West Bangkinang, Bangkinang Seberang, Kampar, East Kampar, Rumbio Jaya, North Kampar, Siak Hulu, Kampar Kiri (CBS Kampar 2020), Langgam, Pangkalan Kerinci, Pelalawan and Teluk Meranti. Its abundant fish production provides an accessible and affordable source of animal protein, playing a crucial role in maintaining food security for rural populations. The river also hosts protected species such as the clown knife fish (*Chitala hypselonotus* (Bleeker, 1851)) and bronze featherback (*Notopterus notopterus* (Pallas, 1769)), as designated by the Decree of the Minister of Marine Affairs and Fisheries of the Indonesia Republic Number 1 of 2021. Regrettably, over the past decade, fishery production in the Kampar River has significantly declined due to intensive fishing activities (Kottelat and Whitten 1993; Kottelat 2013).

Rights-based Fisheries Management (RBFM), offers a potential solution to these overfishing concerns. In Indonesia, indigenous communities often implement RBFM through local wisdom practices. Along the Kampar River, several villages employ local wisdom instruments such as Lubuk Larangan and 'auction systems' (known as Sistem Pajak) for fisheries resource management. The auction system authorizes community groups to utilize fish resources in designated areas for one-year periods (IFRCS and FAO 2023; Prianto et al. 2023). This system comprises individual and communal auction systems. Lubuk Larangan in the river where fish lay eggs are areas where fishing restrictions apply for specified periods. However, not all villages along the Kampar River implement these local wisdom practices, with some adhering solely to existing government regulations.

Law Number 31 of 2004 concerning Fisheries, as amended by Law Number 45 of 2009, mandates sustainable fishery resource management efforts. Subsequent regulations, including the Minister of Marine Affairs and Fisheries Regulation No. 22 of 2021 and No. 9 of 2020, further delineate these management guidelines. Developing effective management plans requires an assessment of the status of fishery resource management through Ecosystem Approach to Fisheries Management (EAFM). EAFM as balancing socio-economic objectives while considering human interactions within aquatic ecosystems (Kolding and Zwieten 2014). However, according Fulton et al. (2014) that the ecosystem approach is a central goal in fisheries management, but there needs to be more consensus on the strategies required to achieve it. Then, Ditya et al. (2022) stated the concept of EAFM in inland fisheries has been considered a useful tool to provide a holistic framework in the fisheries management planning process. An Ecosystem Approach to Fisheries (EAF) could encourage sustainable management of inland fisheries by addressing both human and ecological aspects (Suuronen and Bartley 2014; Anderson et al. 2015). This study aimed to assessing the status of ecosystem-based fisheries resource management on several fisheries resource management models in the Kampar River, Riau Province.

## MATERIALS AND METHODS

### Study area

This study focused on the Kampar River in Riau Province, Indonesia, from January to June 2024 (Figure 1). The research sampled villages using local wisdom and government regulations for managing fish resources. These include Tambak Village and Muara Sako Village, which apply an individual auction system; Lubuk Siam and Tanjung Balam, which use a communal auction system; Kuntu, Teluk Paman, and Siberuang, which practice lubuk larangan; and Mentulik and Tanjung Alai, which follow government regulation (Table 1).

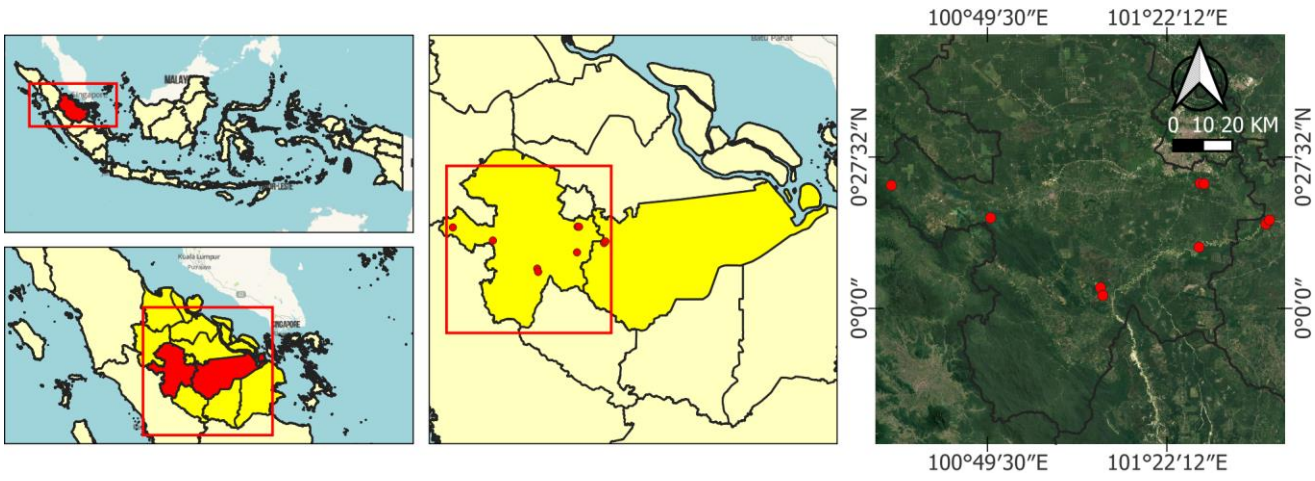


**Figure 1.** Map of the study site location in Kampar River of Kampar and Pelalawan districts, Riau Province, Indonesia

**Table 1.** The site location, coordinates and remarks in Kampar River of Kampar and Pelalawan districts, Riau Province, Indonesia

| Site location | Coordinates | Remarks |
|---|---|---|
| Tambak Village | 0° 15' 22.73" N, 101° 40' 15.68" E | Individual auction system |
| Muara Sako Village | 0° 16' 5.99" N, 101° 40' 54.17" E | Individual auction system |
| Lubuk Siam Village | 0° 22' 44.82" N, 101° 28' 17.74" E | Communal auction system |
| Tanjung Balam Village | 0° 22' 40.36" N, 101° 28' 58.13" E | Communal auction system |
| Kuntu Village | 0° 3' 48.69" N, 101° 10' 5.57" E | Lubuk larangan |
| Teluk Paman Village | 0° 2' 21.37" N, 101° 10' 31.23" E | Lubuk larangan |
| Siberuang Village | 0° 22' 23.48" N, 100° 31' 59.15" E | Lubuk larangan |
| Mentulik | 0° 11' 9.15" N, 101° 28' 3.83" E | Government regulation |
| Tanjung Alai | 0°16'28.6"N 100°50'04.8"E | Government regulation |

**How to determine sample size**

Each phenomenon is broken down into problem components, variables, and indicators to conduct measurements. Each variable receives scoring according to related information categories. These scoring enable quantitative mathematical calculations, producing generally applicable conclusions within parameters. Quantitative research obtains data by sampling representative portions of the population. The sample group undergoes special treatment, typically through interviews, questionnaires, or experiments. Statistical processing of the results yields numerical research outcomes. This study uses purposive sampling, where researchers deliberately select respondents based on specific criteria or considerations. Qualitative data as descriptive information about observable human behavior in spoken or written words. Qualitative data falls into three categories: observation results, discussion outcomes, and written materials. This study's combination of quantitative and qualitative approaches allows for a comprehensive analysis of fishery resource management practices in the Kampar River area.

**Data collection**

The research team meticulously designed the sampling process to ensure comprehensive primary and secondary data collection. Researchers gathered over a month of primary data, including interview responses and questionnaire results. They conducted structured interviews using questionnaires as a vital part of this process. The researchers employed purposive sampling to select 5-10 respondents per village, including ninik mamak (traditional leaders), village heads, District Fisheries Service officials, youth leaders, and fishermen. They sourced secondary data from publications and documentation of relevant agencies such as the Kampar and Pelalawan District Fisheries Services, sub-district offices, the Central Bureau of Statistics (CBS), universities, and other institutions. This diverse range of sources ensured a thorough and well-rounded research process, instilling confidence in the reliability of the findings.

**Data analysis**

The research utilized an indicator development model based on the Directorate of Fish Resource Management's (2022) indicators (Table 2). This model incorporates the DPSIR (Drivers-Pressures-State-Impact-Response) cycle (Turner 2000). The 'flag modeling' technique, a significant part of the analysis, converts partial indicators from each domain into composite indicators. This technique employs a Multi-Criteria Analysis (MCA) approach, constructing a set of criteria to analyze fisheries management area performance from an Ecosystem Approach to Fisheries Management (EAFM) perspective through composite index development (Adrianto et al. 2005).

Data analysis each domain's indicators undergo ranking, weighting, and scoring. The weighting process prioritizes issues within the domain. Scoring compares each indicator's current condition to its ideal state. Weight values (br) range from 1-100, with the total weight in each domain equaling 100. Indicator criteria values (nk) utilize a likelihood scale based on a Likert scale of 1-3: 1 indicates a poor value, 2 indicates a moderate value, and 3 indicates a good value. The composite indicator value calculation follows the formula provided by the Directorate of Fish Resource Management (2022):

$$CI = br \times nr \times nk$$

Where: CI: Indicator composite; nr(1...,n): Indicator/domain nth ranking value; br: Indicator weight value (1-100); nk: Indicator criteria value (1-3)

$$CA = \frac{CD_1 + CD_2 + CD_3 + CD_4 + CD_5 + CD_6 + CD_7}{7}$$

Where: CA: Aggregate value of all EAFM domains; CD1: Composite value of environment domain; CD2: Composite value of fishing technology domain; CD3: Composite value of the social domain; CD4: Composite value of the economic domain; CD5: Composite value of fish resources domain; CD6: Composite value of governance domain; CD7: Composite value of stakeholders' domain

The composite value of each indicator's weighting and scoring results shows each domain's condition (Table 3).

The aggregate value of all domains indicates the fisheries management status at the study location (Table 4). The smallest composite value across domains highlights the magnitude of problems in fisheries resource management, requiring priority in management efforts. Management steps focus on identifying the main issues with high-weight values. This approach ensures management efforts target specific needs.

**Table 2.** Domains and indicators are using in the research

| | Domain | | | | | | |
|---|---|---|---|---|---|---|---|
| | **Environment** | **Fishing gear technology** | **Social** | **Economic** | **Fish Resources** | **Governance** | **Stakeholders** |
| **Indikator** | Water level fluctuations | Fishing gears | Society participation | Asset ownership | Fish production trends | Compliance with sustainable fisheries principles | Synergy of cross-sector policies/ programs/ activities |
| | Pollution | Fishing method | Fisheries conflict | Proportion of income | Changes in the size of fish caught | Completeness of legal regulations | Stakeholder capacity |
| | Riparian vegetation | Selectivity and capacity of fishing gear | Local agreement | Proportion of expenditure | The proportion of juvenile/broodstock fish caught not for cultivation | Local wisdom | Local Government Policy Orientation |
| | No fishing area | Fishing gear productivity | Role of leader | Economic dependency | Composition of the catch | Decision-making mechanism | Local-scale fisheries management institutions |
| | Environmental modification | Placement of fishing gear | Proportion of education | Fishermen's livelihood performance | The presence of introduced and invasive species | Ecosystem-based fisheries management policy | |
| | Sedimentation | | Experience as a fisherman | | | | |
| | Important habitats | | | | | | |

Sources: Directorate of Fish Resource Management (2022)

**Table 3.** Criteria for determining management conditions for each domain based on the range of Composite Indicator (CI) values

| | | | |
|---|---|---|---|
| Status flag of Environment Domain | 500 | 833 | Poor |
| | 834 | 1,168 | Moderate |
| | 1.169 | 1.500 | Good |
| Status flag of Fishing Technology Domain | 367 | 611 | Poor |
| | 612 | 857 | Moderate |
| | 858 | 1,100 | Good |
| Status flag of Social Domain | 433 | 722 | Poor |
| | 723 | 1.012 | Moderate |
| | 1,013 | 1,300 | Good |
| Status flag of Economic Domain | 367 | 611 | Poor |
| | 612 | 857 | Moderate |
| | 858 | 1,100 | Good |
| Status flag of Fish Resources Domain | 367 | 611 | Poor |
| | 612 | 857 | Moderate |
| | 858 | 1,100 | Good |
| Status flag of Governance Domain | 367 | 611 | Poor |
| | 612 | 857 | Moderate |
| | 858 | 1,100 | Good |
| Status flag of Stakeholders Domain | 300 | 500 | Poor |
| | 501 | 701 | Moderate |
| | 702 | 900 | Good |

Sources: Directorate of Fish Resource Management (2022)

**Table 4.** The Aggregate values of all domains

| | | | |
|---|---|---|---|
| Status Flaf of Inland Fisheries EAFM | 5,646 | 9,410 | Poor |
| | 9,411 | 13,176 | Moderate |
| | 13,177 | 16,939 | Good |

Source: Directorate of Fish Resource Management (2022)

Note: Poor: Fisheries management in the local ecosystem needs to implement sustainable fisheries principles. A strategic plan requires establishing an improvement or enhancement of conditions of existing domains and indicators; Medium: Fisheries management in the local ecosystem implements sustainable principles but not optimally. A strategic plan requires optimizing or enhancing conditions in existing domains and indicators; Good: Fisheries management in the local ecosystem optimally implements sustainable fisheries principles. A strategic plan requires an establishment to maintain or enhance conditions of existing domains and indicators.

## RESULTS AND DISCUSSION

Kampar River is inhabited by various economically important fish utilized by the community as a source of protein and livelihood. Types of economically important fish in the Kampar River include kissing gourami (*Helostoma temminckii* Cuvier, 1829), Malay combtail (*Belontia hasselti* (Cuvier, 1831)), giant Malayan catfish (*Wallago leerii* Bleeker, 1851), long-barbel sheatfish (*Kryptopterus limpok* (*Bleeker, 1852*)), clown knife fish (*C. hypselonotus*) and so on (Figure 2). Fishing serves as a primary or secondary livelihood for communities along the Kampar River. Residents utilize traditional fishing technologies to sustain their lives. However, several communities have implemented diverse fish resource management models to ensure fish resource sustainability, promote equality and justice principles, and generate funds for village development.

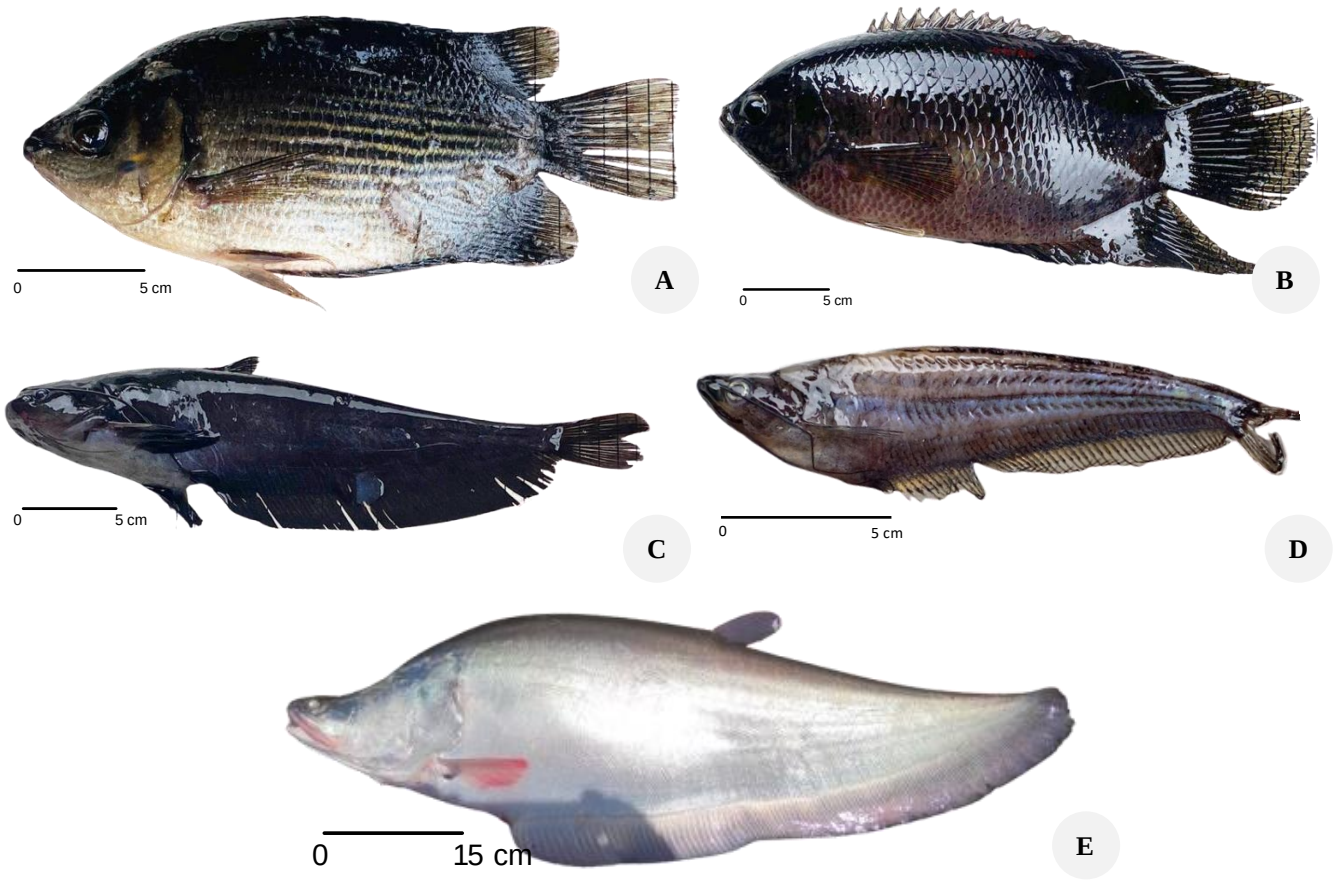


**Figure 2.** Several types of economically important fishes in Kampar River of Kampar and Pelalawan districts, Riau Province, Indonesia. A. Kissing gourami; B. Malay combtail; C. Giant Malayan catfish; D. Long-barbel sheatfish; E. Clown knife fish

**Table 5.** Conservation status of several fishes in Kampar River of Kampar and Pelalawan districts, Riau Province, Indonesia

| Species | Scientific name | Conservation status |
|---|---|---|
| Kissing gourami | *Helostoma temminckii* | LC* |
| Malay combtail | *Belontia hasselti* | LC* |
| Giant Malayan Catfish | *Wallago leerii* | LC* |
| Long-barbel Sheatfish | *Kryptopterus limpok* | LC* |
| Clown knife fish | *Chitala hypselonotus* | LC* |

Sources: *the International Union for Conservation of Nature (2024). LC = Least concern

The five types of economically important fish above are native species to the Kampar River with a conservation status based on the International Union for Conservation of Nature (IUCN) in 2024 of Least Concern (LC) (Table 5). However, among the five fish above, Indonesia's clown knife fish (*C. hypselonotus*) has a protected status designated by the Decree of the Minister of Marine Affairs and Fisheries of the Indonesian Republic Number 1 of 2021.

The fisheries resource management models in the Kampar River encompass four main categories: Lubuk Larangan, individual auction systems, communal auction systems, and government regulations. An ecosystem-based fisheries resource status assessment revealed that the Lubuk Larangan model achieved the highest score of 13,374 points (green/good category). The individual auction system, communal auction system, and government regulations scored 13,168, 13,120, and 10,748 points, respectively, all falling within the yellow/medium category (Table 6). These findings suggest that local wisdom-based approaches, particularly the Lubuk Larangan model, demonstrate superior effectiveness in managing fisheries resources sustainably. Implementing such models may balance resource conservation and community needs while contributing to local development initiatives.

Table 6 reveals that the Lubuk Larangan model achieves a green status flag, indicating optimal implementation of sustainable fisheries management principles. This success necessitates the development of strategic plans to maintain or enhance existing domain conditions and indicators. Conversely, the individual auction system, communal auction system, and government regulations models display yellow flags, signifying partial implementation of sustainable fisheries principles. These models require strategic plans to optimize or improve domain conditions and indicators.

**Table 6.** The flag status values in several fish resource management models in Kampar River of Kampar and Pelalawan districts, Riau Province, Indonesia

| Domain | Lubuk Larangan | | | Individual auction system | | | Communal auction system | | | Goverment regulation | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | CI | Br | CA | CI | Br | CA | CI | Br | CA | CI | Br | CA |
| Environment | 1,411 | 7.1 | 10,016 | 1,014 | 7.1 | 7,201 | 943 | 7.1 | 6,694 | 1,143 | 7.1 | 8,114 |
| Fishing technology | 1,100 | 25 | 27,500 | 1,040 | 25 | 26,000 | 900 | 25 | 22,500 | 840 | 25 | 21,000 |
| Social | 1,214 | 14.3 | 17,364 | 1,214 | 14.3 | 17,364 | 1,195 | 14.3 | 17,092 | 1,295 | 14.3 | 18,522 |
| Economic | 427 | 10.7 | 4,565 | 547 | 10.7 | 5,849 | 787 | 10.7 | 8,417 | 493 | 10.7 | 5,279 |
| Fish resources | 927 | 3.6 | 3,336 | 820 | 3.6 | 2,952 | 507 | 3.6 | 1,824 | 567 | 3.6 | 2,040 |
| Governance | 1,065 | 21.4 | 22,785 | 1,065 | 21.4 | 22,785 | 1,065 | 21.4 | 22,785 | 665 | 21.4 | 12,211 |
| Stakeholders | 610 | 17.9 | 10,919 | 560 | 17.9 | 10,024 | 700 | 17.9 | 12,530 | 510 | 17.9 | 9,129 |
| Σ CD:. | 6,753 | | 96,484 | 6,260 | | 92,176 | 6,096 | | 91,842 | 5,419 | | 76,294 |
| Average CD: | 965 | | 13,784 | 894 | | 13,168 | 871 | | 13,120 | 774 | | 10,748 |

Note: CI: Composite Value of Indicator; Br: Weight Value; CA: Aggregate Value of All Domains; CD: Composite Value of Domain

**Table 7.** Indicator scores value on environmental domain

| Domain | Communal auction system | Lubuk Larangan | Individual auction system | Government regulation |
|---|---|---|---|---|
| Water level fluctuations | 3 | 3 | 3 | 2 |
| Pollution | 3 | 3 | 3 | 2 |
| Riparian | 2 | 2 | 2 | 3 |
| No fishing area | 2 | 3 | 1 | 1 |
| Environmental modification | 2 | 3 | 1 | 2 |
| Sedimentation | 3 | 3 | 3 | 2 |
| Important habitats | 3 | 3 | 3 | 3 |

**Table 8.** Indicator scores value on the fishing technology domain

| Domain | Communal auction system | Lubuk Larangan | Individual auction system | Government regulation |
|---|---|---|---|---|
| Fsihing gears | 3 | 3 | 3 | 2 |
| Fishing method | 2 | 3 | 3 | 2 |
| Selectivity and capacity of fishing gear | 3 | 2 | 3 | 2 |
| Fishing gear productivity | 2 | 3 | 3 | 2 |
| Placement of fishing gear | 2 | 3 | 2 | 2 |

Red flags predominantly appear in the economic domain (3 management models) and the fish resource domain (2 management models). The prevalence of red economic domains underscores the critical nature of financial challenges in the Lubuk Larangan, individual auction system, and government regulation, necessitating prioritized attention. The red color in the economic domain in Lubuk Larangan, the individual auction system, and government regulations is caused by non-food expenditures being smaller than food expenditures. It shows that fishermen in the three management models earn low incomes, so they prioritize food needs over non-food needs. Economic dependence comes not only from fisheries but also from non-fisheries businesses such as plantations and agriculture. It shows that fisheries businesses have been unable to meet daily living needs, so they must find other businesses.

**Environmental domain**

In the environmental domain, the Lubuk Larangan model attains a green flag (1,411 points), while the individual auction system, communal auction system, and government regulation models receive yellow flags. The green status indicates a well-preserved local fish resource environment, whereas yellow signifies a relatively good condition. The Lubuk Larangan model's green flag results from most indicators in this domain scoring 3 (green), with only the comparable plants indicator scoring 2 (yellow). Current research locations show the degradation of comparable plants due to plantation and agricultural land expansion. The individual auction system scores 1 for two indicators: fishing prohibition areas and environmental modification (Table 7). These findings highlight the varying effectiveness of different management models in maintaining environmental quality and suggest areas for targeted improvement in each system.

**Fishing technology domain**

In the fishing technology domain, management models show varying performance. While three management models achieve green status, indicating optimal performance, the model based on government regulations receives a yellow flag, scoring 840 points. This yellow status results from all indicators in this model scoring 2 out

of 3 possible points (Table 8). The use of prohibited, highly productive fishing gear persists in some villages under government regulation. For instance, fishers in Tanjung Alai continue to use lift nets (calls Bagan), while those in Mentulik employ Belat (a type of fish trap). Despite their high yield, these practices pose risks to the sustainability of fish populations and overall ecosystem health. The continued use of such gear highlights the challenges in enforcing fishing regulations and the need for more effective management strategies. According to government regulations, the types of fishing gear prohibited are only poison and electric fishing, according to applicable laws and regulations. In contrast, Bagan and Belat are not prohibited in their use. For this reason, Bagan and Belat can be found in several villages that implement government regulations. Unlike the Lubuk Larangan system, the individual auction system, and the communal auction system, Bagan and Belat cannot be used because they have a mesh size of <0.5 inches. This causes small fish to be caught, which impacts the decline in fish resources. The community is aware that even though Bagan and Belat are not prohibited in laws and regulations, they are aware that both fishing gear can disrupt the life cycle of fish.

**Social domain**

The social domain presents a complex picture across all fisheries resource management models. While these models receive green flags overall, indicating generally positive performance, a closer examination of individual indicators reveals some concerns. Notably, the indicator for education proportion scores 1 (red) in most management models, except the government regulations-based model (Table 9). This low score reflects the educational landscape in the Kampar River area, where over 60% of the population has only primary education (elementary to junior high school). Such a high percentage of fishers with limited formal education suggests potential challenges in adopting new fishing practices, understanding complex regulations, or engaging with more technical aspects of sustainable fisheries management. This educational gap may impact the long-term effectiveness of fisheries management strategies and highlight an area for potential intervention and improvement.

**Economic domain**

The economic domain presents significant challenges across various fisheries management models in the Kampar River area. Red flags appear in the Lubuk Larangan model, individual auction systems, and government regulation-based models, indicating severe economic concerns. In the Lubuk Larangan model, the economic domain receives a low score due to several factors (Table 10). The proportion of income from capture fisheries is low (less than 50%), with family economies relying on fisheries and non-fisheries activities. Less than 30% of the local community works primarily as fishermen. Most residents in Lubuk Larangan areas consider fishing a secondary occupation, relying mainly on gardening or farming for their livelihoods. Fishing activities are often seasonal, as most rivers remain closed year-round. Fishermen must travel 1-2 hours to reach suitable fishing locations, discouraging full-time fishing.

The individual auction system also faces economic challenges, primarily due to the proportion of expenditure and economic dependence. In Tambak Village and Muara Sako Village, community expenditure leans towards non-food needs, reflecting changing lifestyle demands. The decline in fish catches has led many residents to shift their economic dependence toward plantation and agricultural businesses.

**Table 9.** Indicators score value on social domain

| Domain | Communal auction system | Lubuk Larangan | Individual auction system | Government regulation |
|---|---|---|---|---|
| Society participation | 3 | 3 | 3 | 3 |
| Fisheries conflict | 2 | 3 | 3 | 3 |
| Local agreement | 3 | 3 | 3 | 3 |
| Role of leader | 3 | 3 | 3 | 2 |
| Proportion of education | 1 | 1 | 1 | 3 |
| Experience as a fisherman | 3 | 3 | 3 | 3 |

**Table 10.** Indicator score values on the economic domain

| Domain | Communal auction system | Lubuk Larangan | Individual auction system | Government regulation |
|---|---|---|---|---|
| Asset ownership | 1 | 2 | 3 | 3 |
| Proportion of income | 3 | 1 | 2 | 2 |
| Proportion of expenditure | 2 | 3 | 1 | 3 |
| Economic dependency | 2 | 1 | 1 | 1 |
| Fishermen's livelihood performance | 2 | 1 | 2 | 1 |

The government regulation-based model shows the most severe issues, with red flags in three domains: economic, fish resources, and governance. In the economic domain, two indicators score poorly: economic dependence and fishermen's livelihood performance. In Tanjung Alai and Mentulik Villages, 30-50% of income comes from non-fishery sources. Less than 30% of residents in these villages work as fishermen, with many having transitioned to farming or plantation work. The fish resource domain receives a red flag due to the decreasing average size of fish caught, indicating potential overfishing or ecosystem changes.

These economic challenges across different management models indicated the need for comprehensive strategies to support sustainable livelihoods in the Kampar River area. Diversification of income sources, improvement of fishing practices, and targeted economic development initiatives may be necessary to address these issues effectively.

**Fish resources domain**

The fish resources domain received red flags in the communal auction system and government regulations models. In the communal auction system, declining fish catch production trends and fish size changes led to the red flag. Government regulations earned a red flag solely due to changes in fish size caught, with both indicators scoring 1 (Table 11). Researchers observed changes in fish size caught in both the communal auction system and government regulations areas. Field observations revealed a general decrease in fish size compared to several years ago. Fishermen's use of smaller nets compared to previous years evidences this trend. The reduction in fish size and catch production indicates the potential overexploitation of fish resources in these management systems. These findings suggest a need for more stringent conservation measures and sustainable fishing practices. Implementing such measures could prevent further depletion of fish populations and ensure long-term resource viability in the Kampar River ecosystem.

**Governance domain**

Yellow flags in the governance domain appear exclusively in management models based on government regulations. This classification results from low scores in local wisdom and ecosystem-based fisheries management policy indicators, both receiving a score of 1 (Table 12). Mentulik and Tanjung Alai Villages continue to manage fisheries resources according to local and central government regulations without incorporating local wisdom practices. The ecosystem-based fisheries management policy indicator is absent across all four management models, resulting in a score of 1 for each. This consistently low score highlights a significant gap in policy implementation across the different management approaches in the Kampar River area. These findings pointed out the need for integrating local wisdom and ecosystem-based management policies into existing regulatory frameworks. Policymakers and local authorities should consider developing and implementing comprehensive ecosystem-based fisheries management policies to enhance the sustainability and effectiveness of resource management in the region.

**Stakeholder domain**

All management models received yellow flags for the stakeholder domain, indicating partial implementation of sustainable fisheries principles but requiring further optimization (Table 13).

**Table 11.** Indicator score values on the fish resources domain

| Domain | Communal auction system | Lubuk Larangan | Individual auction system | Government regulation |
|---|---|---|---|---|
| Fish capture production trends | 1 | 1 | 1 | 2 |
| Changes in the size of fish caught | 1 | 2 | 2 | 1 |
| Proportion of juvenile/broodstock fish caught not for cultivation | 2 | 2 | 2 | 2 |
| Composition of the catch | 2 | 3 | 3 | 2 |
| The presence of introduced and invasive species | 2 | 2 | 2 | 2 |

**Table 12.** Indicators score value on the governance domain

| Domain | Communal auction system | Lubuk Larangan | Individual auction system | Government regulation |
|---|---|---|---|---|
| Compliance with sustainable fisheries principles | 3 | 3 | 3 | 2 |
| Completeness of legal regulations | 3 | 2 | 3 | 2 |
| Local wisdom | 3 | 3 | 3 | 1 |
| Decision making mechanism | 3 | 3 | 3 | 2 |
| Ecosystem-based fisheries management policy | 1 | 1 | 1 | 1 |

**Table 13.** Indicator score values on the stakeholder domain

| Domain | Communal auction system | Lubuk Larangan | Individual auction system | Government regulation |
|---|---|---|---|---|
| Synergy of cross-sector policies/programs/activities | 2 | 2 | 2 | 2 |
| Stakeholder capacity | 2 | 2 | 3 | 3 |
| Local government policy orientation | 3 | 3 | 3 | 2 |
| Local scale fisheries management institutions | 3 | 2 | 1 | 3 |

Interviews with stakeholders from the tourism, public works, and fisheries sectors in these villages reveal the execution of their respective work programs. However, these programs only partially support fish resource conservation efforts. This finding indicated a gap between sector-specific initiatives and comprehensive fish resource conservation programs. Stakeholders across various sectors must align their work programs more closely with conservation goals. Improving cross-sector collaboration and integrating conservation objectives into diverse work programs could enhance the overall effectiveness of fisheries management in the Kampar River area. Local authorities should consider developing integrated strategies to achieve optimal stakeholder involvement, encouraging all sectors to contribute actively to fish resource conservation. This approach could foster a more holistic and effective management system for the Kampar River's fisheries resources.

**Discussion**

The Lubuk Larangan get a green flag indicating that fisheries management in the Lubuk Larangan has implemented the principles of sustainable fisheries management optimally. Hence, a strategic plan needs to be established to maintain or improve the conditions of the existing domains and indicators (Directorate of Fish Resource Management 2022). In terms of its management system, Lubuk Larangan prioritize the protection and preservation system of fish resources based on local wisdom. Implementing Lubuk Larangan, where village communities are prohibited from fishing for a certain period (1-2 years), will allow the fish that live in the Lubuk Larangan to growth up. If people catch fish illegally in Lubuk Larangan, the people who catch the fish will be given customary sanctions. This system is quite effective in maintaining the sustainability of fish resources (Prianto et al. 2024).

The economic domain is a domain that needs greater attention because almost all management models get a red flag except for government regulations. The red color is because of the people's economy in the Kampar River; most of their lives are not in the fisheries sector. Most of the fishing communities in the Kampar River depend not only on fishing but also on plantations and agriculture. This change in livelihood is due to the decline in fish resources in the Kampar River, so fishermen's income cannot meet their daily needs. According to Purwoko et al. (2020), the status of fish resource utilization in the Kampar River is at the red level (overfishing). This condition has caused many fishermen to change professions and become farmers, gardeners, or traders.

In addition to the economic domain, the fish resource domain also needs more attention because the management model with a communal auction system based on government regulations gets a red flag. Almost all research locations currently have a downward trend in fisheries production. In Lubuk Siam and Tanjung Balam Villages (applying a communal auction system), the trend in fish catch production has decreased in recent years. This can be seen from interviews with fishermen in Lubuk Siam and Tanjung Balam Villages. In 2013, the average catch of fishermen using nets could reach $\pm$ 15 kg/day, while in 2023, it was only $\pm$ 3 kg/day. The decline in fishermen's catches was due to the rare occurrence of seasonal floods every year in the Kampar Kanan River and the decrease in the quality of the aquatic environment. The decline in catches was also caused by almost all oxbow lakes being covered by aquatic plants, thus inhibiting the development and growth of fish. When viewed from the irregular seasonal flood cycle in the Kampar River, the stock of fish resources in the river has decreased. This is because fish recruitment in rivers and flooded swamps depends on seasonal flooding every year (Prianto et al. 2015).

Another cause, the rare occurrence of seasonal flooding in the Kampar Kanan River, is due to the construction of the Koto Panjang reservoir in the upstream part of the river, causing obstruction of water distribution from upstream to downstream. Indirectly, this condition causes the recruitment process of river fish to be obstructed. Wu et al. (2019) stated that the construction of dams has an impact on fish resources, including blocking fish migration routes, habitat fragmentation, changes in aquatic ecosystems from lotic to lentic systems, and changes in water flow in the downstream part of the river. These impacts ultimately cause fish production to decline. According Downing et al. (2014) that tropical reservoirs are highly vulnerable systems, strongly dependent on external control (land-use, human-induced hydrological regulations, water retention, water-level fluctuations) and on an array of internal regulatory processes (nutrient recycling, food chain interactions, see below). Being resources with multiple uses, inland aquatic systems are influenced by a wide range of conditions and processes from the surrounding catchment, the immediate riparian zone and within the water body itself. Since fishery dynamics are intricately connected to other supporting services of the lake/ reservoir as well as to fisher communities and their social economies, it is becoming increasingly clear that all those

aspects must be integrated to disentangle drivers and dynamics of change.

The governance domain mostly gets green and yellow flags, but one indicator receives a score of 1, namely the ecosystem-based fisheries management policy. Only now, not all villages in the Kampar River need an ecosystem-based fisheries management policy document. The implementation of EAFM (ecosystem management) in Indonesia, especially in Riau Province, is still a new management approach. However, the local government is currently introducing EAFM to the broader community. Currently most fisheries are controlled in a top–down manner, based on single-species theory, with generally poor management outcomes (Puley and Charles 2022). Then, FAO (2010) stated many fisheries policies and regulations have performed poorly, and in some areas, inland fisheries resources and aquatic environments continue to degrade. Existing policies generally focus on water allocation for irrigation, flood protection, navigation, or hydropower generation and rarely adequately consider fisheries. Current policies and regulations are largely ineffective in maintaining the quantity and quality of water needed for inland fisheries. Weak governance and law enforcement lead to illegal and destructive fishing practices, as evidenced by the high levels of illegal and unreported fishing worldwide (Agnew et al. 2009).

Judging from the four management models applied in the Kampar River, the management model based on government regulations scored low (10,748) compared to other models. Villages that implement government regulations have many shortcomings, one of which is weak law enforcement, resulting in many violations committed by the community. One of the violations that is often encountered is the use of environmentally unfriendly fishing gear. The results of a study by Purwoko et al. (2020) in the rivers of the East Coast of Sumatra (Kampar, Batanghari, and Musi Rivers) obtained information that the average smallest mesh size was 0.5 inches while the maximum mesh size was 3 inches. Using a relatively small mesh size allows young fish that have never spawned to be caught. The shrinking mesh size is because mature fish are rarely caught, so fishermen reduce their mesh size again. The results of interviews with fishermen obtained information on several types of fish that had changed in size, including: paweh (*Osteochilus vittatus* (Valenciennes, 1842)), toman (*Channa micropeltes* (Cuvier, 1831)), catfish (*Clarias batrachus* (Linnaeus, 1758)), papuyu (*Anabas testudineus* (Bloch, 1792)), sepat siam (*Trichopodus pectoralis* Regan, 1910) and tambakan (*Helostoma temminckii* Cuvier, 1829). Yuliana et al. (2019) stated that the condition of fishing technology significantly affects fish resources in the waters. Furthermore, Erisman et al. (2014) stated that the selectivity of fishing gear significantly affects the abundance and biomass of fish. Therefore, it is necessary to regulate fishing gear so that only adult fish are caught.

Capture fisheries yields in Asian lakes and reservoirs reveal remarkable diversity due to differences in the limnology of water bodies, trophic state, basin type and hydrology as well as the intensity of local fisheries and the selective exploitation of the available fish biomass (van Densen and Morris 1999). Previously it was generally believed that tropical reservoirs lacked indigenous lacustrine fish species. It is now well established that inland water bodies produce sizeable populations of Small Indigenous Species (SIS) of Fishes including small pelagics, which often remain unexploited or underexploited, indicating a high potential for increasing fish production in reservoir ecosystems (Amarasinghe et al. 2016; Kolding et al. 2019; Kolding et al. 2023)

In the context of sustainable management, local wisdom is thought to be able to maintain and preserve fishery resources. However, not all local wisdom can play a role in supporting and preserving fishery resources. The use of EAFM in assessing the status of fishery resource management in various fishery management models in the Kampar River shows that only some management models can apply the principles of sustainable fishery management optimally. Of course, the government's concerned about creating the best management model or improving the existing one to make it even better.

Based on the results, it was concluded that the status of fishery management models in the Kampar River through an ecosystem approach shows that the Lubuk Larangan model is in the green category (good category). This means that fisheries management in the local ecosystem optimally implements sustainable fisheries principles. A strategic plan requires an establishment to maintain or enhance conditions of existing domains and indicators. Then, the individual auction system, communal auction system, and government regulations are in the yellow category (medium category). This means fisheries management in the local ecosystem implements sustainable principles but not optimally. A strategic plan requires optimizing or enhancing conditions in existing domains and indicators.

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