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Mismanagement Issues in Sustaining Capture Fisheries in Lake Batur

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ABSTRACT

Lake Batur holds significant aquatic value and has been prioritized nationally for developing Indonesia's aquaculture operations and economic growth. This initiative has transformed traditional fisheries into industrial aquaculture, significantly impacting both the ecological and socioeconomic status of the lake area. The catch per trip and income of fishermen in 2022 decreased by 7% and 11% compared to the previous five years, respectively. Through diverse research methods including surveys, field observations, and in-depth interviews, we identified several key findings that highlight the necessity for implementing appropriate regulations to improve Lake Batur's management practices. These findings include: (i) declining performance of current fisheries, (ii) concerns about the long-term sustainability of aquaculture, and (iii) inadequate management approaches. Therefore, policies should prioritize preserving sustainable fisheries industries to support local socioeconomic well-being while safeguarding the lake's ecological integrity. Recommendations include setting limits on catch rates and revising spatial zoning to maximize resource utilization. Additionally, supporting policies should enable some fishermen to transition away from fishing activities, thus easing pressure on the lake's natural resources. The findings of this research provide broader implications, emphasizing the crucial importance of thoroughly considering all technical and social impacts of any policy to achieve an effective balance between economic growth and ecological sustainability.

1. INTRODUCTION

Lake Batur in Bali has the coordinates of 115º22'42.3" - 115º25'33.0" East Longitude and 8°13'24.0" - 8°17'13.3" South Latitude at an elevation of 1,050 meters [1, 2], spans an area of 16.05 km² with a depth ranging between 60 and 70 meters [3] and a catchment area of 105.35 km^2 [4]. The lake contributes social, economic, and cultural significance to the local community [5]. It is a primary water source for agriculture, plantations, tourism, and fisheries [6]. Fisheries began in the 1990s [7], exploiting the 380–660 kg/ha/year potential [8], targeting Nile tilapia (*Oreochromis niloticus*) and Mozambique tilapia (*Oreochromis mossambicus*) [9-11].

Despite the initial success, recent reports have highlighted a significant decline in fish catches, dropping below the lake's maximum capacity [3], which has raised concerns about the sustainability of fishing activities. The introduction of the national Aquaculture Minapolitan program [12] was aimed at promoting integrated fishery systems and enterprises. This program was characterized by expedited development projects focusing on productive fishing and fish-processing activities [13], and included components such as infrastructure advancement, skill development, marketing facilitation, and input subsidies [12]. The program initially led to an increase in aquaculture area to 8.11 hectares in 2010, with a production of 189.15 tons [14-16]. However, the expansion of aquaculture has resulted in several challenges, including the proliferation of aquaculture cages and deterioration in water quality, which has adversely affected local fisheries [17].

In response, policymakers have intervened by capping the aquaculture area to 10 percent of the lake's surface in Bangli Regency [14] and initiating restoration efforts by the central government [18, 19]. Despite these measures, the lake continues to face pressing issues that compromise both its ecological health and the sustainability of local fisheries.

This study is essential as it seeks to analyze the current trend of capture fisheries production in Lake Batur, assess the sustainability of ongoing fishery activities in Lake Batur, and propose relevant policy recommendations. By providing a comprehensive evaluation of these aspects, the study addresses critical gaps in the existing literature and contributes novel insights into the challenges faced by Lake Batur. Specifically, it highlights the need for adaptive management strategies that balance economic development with ecological preservation. This research offers a holistic approach to understanding and guiding the sustainable management of Lake Batur, which is crucial for ensuring the long-term well-being of both the local community and the lake's intricate ecological systems.

2. MATERIAL AND METHODS

2.1 General methodological approach

This study utilized a multi-faceted methodological framework to gather and analyze data related to Lake Batur's fisheries and aquaculture practices. It integrated three primary data collection methods: surveys, field observations, and in-depth interviews, each designed to address specific aspects of the study.: surveys, field observations, and in-depth interviews, each designed to address specific aspects of the study. The data was then carefully analyzed using several different methods: (a) descriptive statistical approaches [20], (b) multidimensional scaling [21, 22], and (c) interpretative descriptive [23]. Regression analysis [24] was utilized to analyze the current trend of fisheries performance at the research site, and multi-dimensional scaling was adopted to assess its sustainability prospects; meanwhile, interpretive descriptive was used to review the management options available. Data from this study were collected in Abang, Buahan, Kedisan, Songan, and Tarunyan (Figure 1). They were villages that substantially contributed to the fishing activities and exploitation of fish resources in Lake Batur.

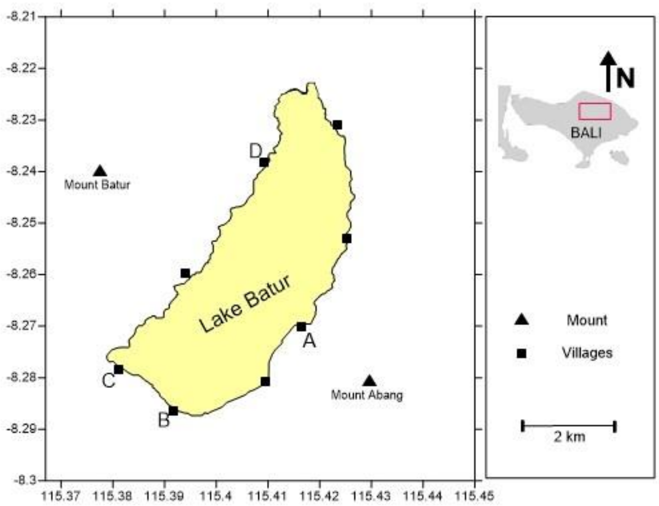


Figure 1. Research location
A. Abang; B. Buahan; C. Kedisan; D. Songan

2.2 Data collection

2.2.1 Surveys

Surveys were conducted across five villages—Abang, Buahan, Kedisan, Songan, and Tarunyan—each significantly contributing to fishing activities in Lake Batur. A structured questionnaire was developed to gather quantitative data on various aspects of fisheries and aquaculture practices. The sample size consisted of 69 fishers, selected through purposive sampling to ensure representation across different fishing activities and demographic profiles. The questionnaire collected data on fishing practices, income, gear used, and perceptions of aquaculture impacts.

2.2.2 Field observations

Field observations were carried out to complement survey data and provide context-specific insights. Observations focused on fishing operations, aquaculture cage management, and water quality conditions. Data were recorded systematically using field notebooks and digital recording tools. The observation period spanned six months to capture seasonal variations and operational practices.

2.2.3 In-depth interviews

In-depth interviews were conducted with key stakeholders, including local fishermen, aquaculture operators, and policymakers. A purposive sampling technique was employed to select 20 interviewees based on their expertise and involvement in Lake Batur's fisheries and aquaculture sectors. Interviews were semi-structured, allowing for flexibility in exploring topics related to fishery management, policy impacts, and sustainability concerns. Interviews were recorded, transcribed, and coded for thematic analysis.

2.3 Analysis

2.3.1 Current performance trend analysis

In this section, we performed a descriptive analysis in which the mean values of relevant variables were calculated and compared. Then, we applied simple linear regression to see whether there were changes in these mean values due to changes in years, such as changes in catches. Finally, using the following multiple linear models [25], we identified what factors affected fishermen's income:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_k X_k + \varepsilon \quad (1)$$

Following this model, fishermen's income, $\hat{Y}$, was predicted following this equation:

$$\hat{Y} = b_0 + b_1 X_1 + b_2 X_2 + \cdots + b_6 X_6 \quad (2)$$

where,

$\hat{Y}$ = fishermen's income
X_1 = mesh size
X_2 = gillnet ownership
X_3 = trip length
X_4 = trip frequency
X_5 = catch per trip
X_6 = fish price

The simultaneous testing was done with the F-test, while each multiple regression coefficient was tested using the t-test [26-28].

2.3.2 Sustainability analysis

The method applied in this study was Multi-Dimensional Scaling following the Rapfish methodology [22]. Figure 2 shows a graphical representation of the adopted analytical framework with 5 (five) dimensions to be evaluated: (A) Ecology, (B) Technology, (C) Economy, (D) Social, (E)

Ethics.

Each of these dimensions consisted of multiple properties. Scores for these attributes were generated through expert respondent interviews, and these scores were then entered into the Rapfish software to calculate the ordination values for each dimension. Rapfish ordinations enable the visualization of index values for each dimension, which can be represented in a multi-dimensional index kite or spider diagram, as illustrated by the example labelled (1) in Figure 2. Furthermore, alongside the ordinations, the research yielded data about leverage factors for each dimension. These factors indicate that even minor interventions on them can substantially alter the index level for the respective dimension.

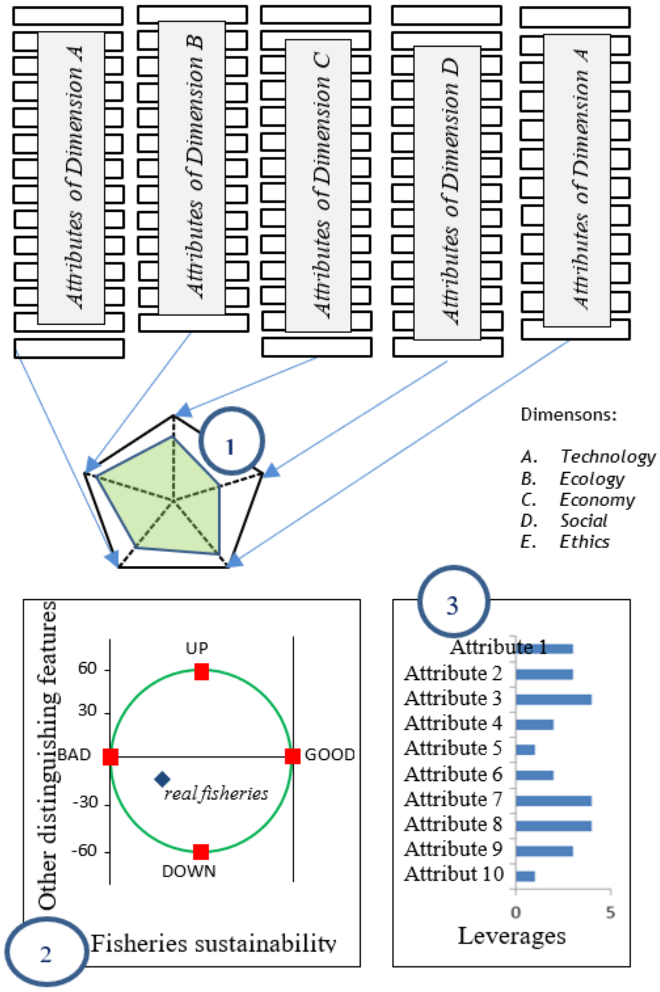


Figure 2. Multidimensional scaling framework using the Rapfish method

1, 2 and 3 represent inter-dimension sustainability, ordination of dimensions, and attribute leveraging, respectively.

Referring to this methodological approach, an assessment and mapping of the suitability of each site for the implementation of warehouse receipt systems was conducted, taking into consideration various dimensions and factors. The data utilized in this part were obtained by performing a comprehensive assessment of relevant documents and conducting interviews with expert resource individuals using a structured questionnaire.

2.3.3 Relevant policy options

In this section, the qualitative descriptive methodological approach [29, 30] was adopted to examine issues based on factual evidence obtained through three specific techniques: (i) observation, (ii) interviews, and (iii) review of relevant documents. The snowball sampling technique [31] was employed to identify and recruit individuals with relevant expertise and knowledge. Interviews followed the participants to gather insights and explanations about Lake Batur's various aspects, encompassing natural and human-related phenomena. This was conducted carefully, especially towards the operations' attributes, excellence, and interconnectedness.

The interview structure utilized in this study incorporated elements discussed by Hennink et al. [29] and Nassaji [30]. These elements encompassed the construction of social reality and cultural meaning, interactive processes, related events, authenticity, and the integration of theory and data. Implementing these elements was situational and contextual, with full involvement from the researchers.

The final step in this section involved synthesizing the facts, information, and knowledge acquired in the preceding steps to discern indications of pertinent policy alternatives [31-33]. The results of the interviews were crosschecked and validated by several methods, including field observations, document checks, expert consultations, and discussions among team members. The resulting output comprised a range of alternatives to tackle issues that will be considered during the decision-making process and developing solutions for public policy.

3. RESULT

3.1 Current performance trend analysis

Data was gathered through interviews conducted with a total of 69 participants to evaluate the efficacy of the Lake Batur fisheries to evaluate the effectiveness of the Lake Batur fisheries. The respondents' characteristics are outlined in Tables 1-6.

Table 1. Age distribution of respondents in the Batur area

Age (year)	Number	Percentages
< 30	4	5.80
> 50	8	11.59
30 - 40	40	57.97
41 - 50	17	24.64
Total	69	100.00

Table 2. The educational achievement of respondents in the Batur area

Education	Number	Percentages
Elementary school	58	84.06
Junior high	10	14.50
High school	1	1.44
Total	69	100.00

Table 3. Distance of respondents' home to the Batur Lake

Distance	Number	Percentages
Near (< 1 Km)	58	84.06
Moderate (1 - 2 Km)	8	11.59
Far (> 2 Km)	3	4.35
Total	69	100

Table 4. Length of residence in the Lake Batur

Length of Residence	Number	Percentages
Up to 10 years	2	2.90
More than 10 years	67	97.10

Table 5. Respondents' village of residence in the Batur Lake

Village	Number	Percentages
Abang Village	7	10.14
Buahan Village	26	37.68
Kedisan Village	5	7.25
Songan Village	18	26.09
Tarunyan Village	13	18.84
Total	69	100.00

Table 6. The central location of fishing in the Batur Lake

Fishing Location	Number	Percentages
Abang Batudinding	1	1.45
Songan	66	1.45

The information provided by the respondents allowed us to track the progress and efficiency of aquaculture in Lake Batur. In this situation, the profits from fishing activities served as a metric or scale. To do this, we first noticed the general trend by examining the average values and trends of pertinent deciding independent variables, considering the previously indicated technique.

Of the six variables we hypothesized determining income, our data showed that two remained unchanged from 2009 to 2022. The two variables were (i) trip length and (ii) trip frequency. Our survey found an average trip length value of 6.1 hours per day and an average trip frequency of 21 times monthly.

The following data presents the statistical results of the four remaining variables, illustrating their annual fluctuations. The study examines four variables, namely: (i) mesh size, (ii) gillnet ownership, (iii) catch per trip, and (iv) fish pricing.

The initial aspect to consider is *mesh size*. The variable in question has an upward trend based on the yearly average data, with measurements rising from 2.67 inches in 2009 to 3.90 inches in 2022 (refer to Table 7).

Table 7. Mesh size used by fishers in the Batur Lake

Year	Mesh Size (inch)		
	Mean	Min	Max
2009-2022	3.18	1.00	4.00
2022	3.90	2.00	4.00
2021	3.87	2.00	4.00
2020	3.84	2.00	4.00
2019	3.77	2.00	4.00
2018	3.55	2.00	4.00
2017	3.11	1.00	4.00
2016	3.01	1.00	4.00
2015	2.91	1.00	4.00
2014	2.87	1.00	4.00
2013	2.84	1.00	4.00
2012	2.75	1.00	4.00
2011	2.70	1.00	4.00
2010	2.68	1.00	4.00
2009	2.67	1.00	4.00

Upon analysis, the mean values shown in Table 7 yielded a regression model denoted as Mesh size = -222.07 + 0.11176 Year + Error. The R-square value associated with this model was determined to be 89.96%. The average mesh size exhibits a statistically significant rise over time.

The second is *gillnet ownership*. The annual average data for this variable shows a decrease from 3 units/person in 2009 to 2 units/person in 2022 (see Table 8).

Table 8. Gillnet ownership from the fishers in the Batur Lake

Year	Gillnet Ownership (unit/person)		
	Mean	Min	Max
2009-2022	2.5238 ≈ 3	2.00	12.00
2022	2.2319 ≈ 2	2.00	7.00
2021	2.2609 ≈ 2	2.00	7.00
2020	2.2609 ≈ 2	2.00	7.00
2019	2.2609 ≈ 2	2.00	7.00
2018	2.3043 ≈ 2	2.00	7.00
2017	2.3913 ≈ 2	2.00	9.00
2016	2.4783 ≈ 2	2.00	9.00
2015	2.6812 ≈ 3	2.00	9.00
2014	2.6377 ≈ 3	2.00	12.00
2013	2.6667 ≈ 3	2.00	12.00
2012	2.7536 ≈ 3	2.00	12.00
2011	2.7681 ≈ 3	2.00	12.00
2010	2.8116 ≈ 3	2.00	12.00
2009	2.8261 ≈ 3	2.00	12.00

Gillnet ownership was relatively high in 2009-2015, averaging three units/person, but dropped to an average of 2 units/person in the following years. Meanwhile, the range of ownership is narrowed. From 2009 to 2014, ownership ranged from 2 to 12 units/ person; from 2015 to 2017, it ranged from 2 to 9 units/person; and in the following periods it ranged from 2 to 7 units/person.

The regression model we obtained for this variable is $Gillnet\ ownership = 111.2727 - 0.05396\ Year + Error$. This equation has a very high coefficient of determination, 93.91%. The slope was -0.05396 with an error probability of 1.18×10^{-8}, meaning that the predicted value of gillnet ownership per fisherman is significantly influenced by the variable 'Year.'

The third is *catch per trip*. The annual average data for this variable shows a decrease from 3.5580 kg/trip in 2009 to 2.6087 kg/trip in 2022 (refer to Table 9).

Table 9. Catch per trip for fisheries in the Batur Lake

Year	Catch per Trip (kg/trip)		
	Mean	Min	Max
2009-2022	3.0218	1.00	16.0
2022	2.6087	1.00	6.50
2021	2.6377	1.00	8.50
2020	2.7362	1.00	6.50
2019	2.7609	2.50	6.50
2018	2.8768	2.50	6.50
2017	2.7971	1.00	6.50
2016	2.9319	1.00	8.50
2015	3.0580	1.00	11.50
2014	3.1232	1.00	13.50
2013	3.1522	1.00	13.50
2012	3.2464	1.00	11.00
2011	3.3188	1.00	11.00
2010	3.5000	1.00	16.00
2009	3.5580	1.00	16.00

Every year, the average catch on each trip dropped. A statistically significant regression of Catch per trip=148.9773-

0.07242Year_Error demonstrates this. The regression's F-statistics were 378.64, with a 1.92×10-10 significance level. The slope t-statistics had a significance of 1.92×10^{-10} and was -19.4586.

Table 10. Price of fish from the Batur Lake

Year	Price (IDR Thousand / kg of Fish)		
	Mean	Min	Max
2009-2022	19.4689	15.00	35.50
2022	25.3478	15.00	35.50
2021	25.3478	15.00	35.50
2020	25.3478	15.00	35.50
2019	25.3478	15.00	35.50
2018	24.7391	15.00	25.50
2017	21.7391	15.00	25.50
2016	17.2826	15.00	25.50
2015	15.4565	15.00	25.50
2014	15.7609	15.00	25.50
2013	15.1522	15.00	25.50
2012	15.1522	15.00	25.50
2011	15.2971	15.00	35.50
2010	15.2971	15.00	35.50
2009	15.2971	15.00	35.50

Fourth is *fish pricing*. The data shows that between 2009 and 2022, the average price of fish grew from Rp 15.2971 per kg to Rp 25.3478 (see Table 10).

Statistically, there is a notable and meaningful growth as indicated by the regression equation: $Price\ (thousand) = -2065.743 + 1.0346Year + Error$. The regression's F statistics were 16.926, with a significant relationship between the variables 0.001436. Moreover, the t-statistic test yielded a value of 4.114105, indicating a statistically significant result with a significance level of 0.001436.

The dependent variable under consideration is *income*. The annual average data for this variable shows a slight increase, from IDR thousand 1115.0580 / person/ month in 2009 to IDR thousand 1355.9783 / person/ month in 2022 (see Table 11). Fishers' income is also influenced by the price of fish, where the price of Tilapia has increased. The price of Tilapia in 2022 is 25.3 thousand (IDR), which is higher than the average of the last fourteen years (2009-2022), which is only 19.5 thousand (IDR). In addition, the income of fishermen has also decreased, where the average income of fishermen is currently 1,356 million rupiahs (2022), 7% less than the previous five years (2018).

Table 11. Income of respondents from Batur area

Year	Income (IDR Thousand/Person/Month)		
	Mean	Min	Max
2009-2022	1181.3064	120.00	6720.00
2022	1355.9783	459.00	2983.50
2021	1369.2826	459.00	3901.50
2020	1406.3870	487.50	2983.50
2019	1428.5978	487.50	3213.00
2018	1446.5326	487.50	4641.00
2017	1201.5543	331.50	2730.00
2016	1012.5652	195.00	3812.25
2015	999.2065	120.00	4620.00
2014	1036.4783	120.00	5670.00
2013	998.5761	120.00	5670.00
2012	1023.6087	120.00	4620.00
2011	1045.0580	120.00	4620.00
2010	1099.4058	120.00	6720.00
2009	1115.0580	120.00	6720.00

The independent variables above were used to analyze factors that affect fishermen's monthly income. In this analysis, we employed multilinear regression analyses with X1 for mesh size, X2 for gillnet ownership, X3 for trip length, X4 for trip frequency, X5 for catch per trip, and X6 for fish price. The regression model yielded the following equation: Income (per month) = 2399.573 + 30.408 × mesh size + 89.654 × gillnet ownership + 19.492 × trip duration + 293.683 × catch per trip + 51.761 × fish price. An ANOVA demonstrated that these independent variables substantially impacted fishermen's income.

3.2 Sustainability analysis

According to Rapfish multidimensional scaling analysis, all dimensions were indexed low, indicating complex fisheries challenges. The kite diagram in Figure 3 demonstrates that the Ecology Dimension has the most significant index value, but even at that point, it is still below 55, which is below the excellent rating threshold. Consequently, significant modifications are needed for sustainable lake aquaculture.

The following is the result of further exploration of the attributes of each dimension, which is processed using leverage analysis to provide an initial indicator of what should be enhanced in this context. The outcomes demonstrate which attributes were deemed leverage attributes for each dimension.

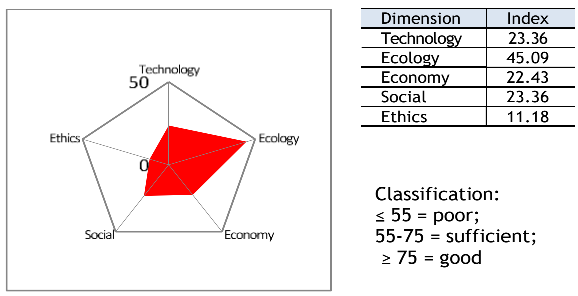


Figure 3. Rapfish multi-dimensional scaling of the five dimensions

3.2.1 Ecology dimension

Figure 4 displays Rapfish ordination and leverage analysis for the Ecological Dimension. This dimension has an ordination value of 45.09, classifying it as 'poor.' Thus, the following features were determined to be leverage attributes within this dimension: (i) range collapse, (ii) fish size attained, and (iii) migratory range.

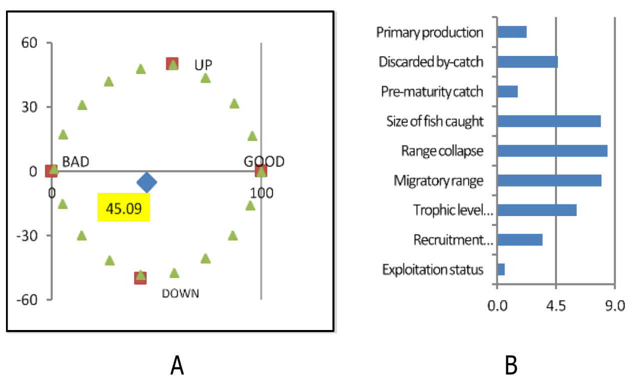
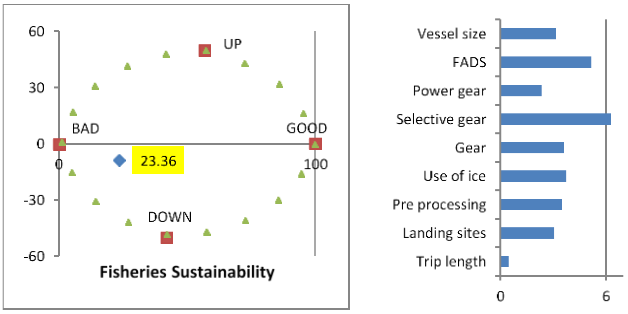


Figure 4. Rapfish ecological dimension. Ordination (A) and Leverage analysis (B)

3.2.2 Technology dimension

Figure 5 displays Rapfish ordination and leverage analysis for the Technology Dimension. The ordination value of 23.36 indicates that the technological sustainability of Danau Batur fisheries is 'poor.' Therefore, two leverage attributes were determined in this dimension, namely (i) the use of selective gear and (ii) the deployment of fish aggregating devices (FADs).



A B

Figure 5. Rapfish technology dimension. Ordination (A) and Leverage analysis (B)

3.2.3 Social dimension

Figure 6 displays the Rapfish ordination and leverage analysis for the Social Dimension. This dimension's 23.36 ordination falls into the 'poor' category. Thus, two leverage attributes are found within this dimension: (i) conflict status and (ii) fishing income.

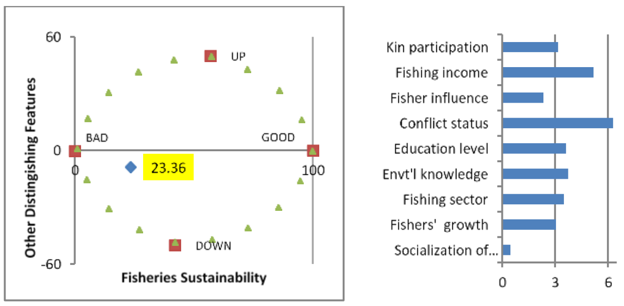


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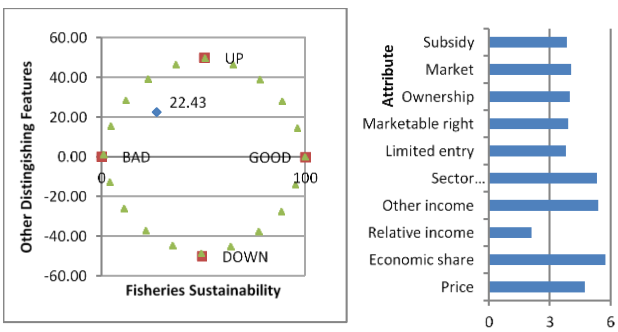
Figure 6. Rapfish social dimension. Ordination (A) and Leverage analysis (B)

3.2.4 Economy dimension



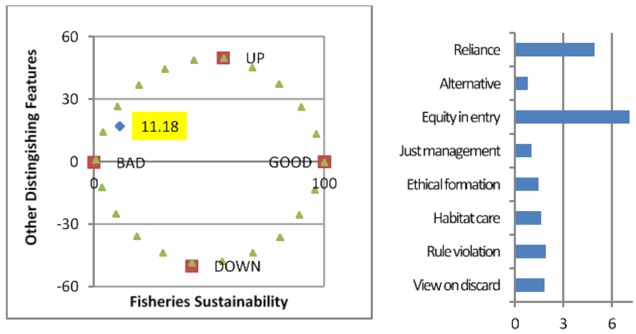
A B

Figure 7. Rapfish economy dimension. Ordination (A) and Leverage analysis (B)

Figure 7 displays the Rapfish ordination and leverage analysis for the Economy Dimension. The ordination of 22.43 is categorized as 'poor'. Within this dimension, three leverage attributes were identified: (i) economic share, (ii) other income, and (iii) sector employment.

3.2.5 Ethical dimension

Figure 8 displays the Rapfish ordination and leverage analysis for the Ethics Dimension. This dimension's index of 11.18 falls within the 'deficient' category, indicating that the institutional sustainability of Danau Batur fisheries is low. Within this dimension, two leverage attributes were identified: (i) equity in entry and (ii) reliance.



A B

Figure 8. Rapfish ethics dimension. Ordination (A) and Leverage analysis (B)

3.2.6 Policy options to consider

Our extensive discussions with local experts suggested a relationship between Lake Batur's poor aquaculture and socioeconomic issues with mismanagement. While our previous analysis indicated several leverage attributes, which gave hints about which aspects should be prioritized in addressing existing problems, we will return to this section to develop potential policy options corresponding to our leverage analysis and social affairs results. As mentioned in the literatures [34, 35], leverage attributes can be defined as those that exhibit high sensitivity to slight variations, resulting in significant effects on the sustainability index. In our study, specific leverage attributes have been identified as necessary, namely: (i) gear selectivity, (ii) range collapse, (iii) size of fish caught, (iv) economic share, (v) other income, and (vi) sector employment, (vii) reliance, (vii) conflict status and (ix) fishing income. To expand on this, we investigated additional pertinent facts that apply to the local community.

First, we must consider how the Batur people view their lake now. Our fieldwork found that community people were anxious about the lake's future, with many citing aquaculture difficulties and their effects. Aquaculture gave the Batur inhabitants hope for healthier food and better living conditions. The change was beneficial to a minority. They are lakeside onion farmers with substantial capital support. Thus, the aquaculture programs are now doubted.

Fishermen who still work on the lake expressed a more negative impression. Some of them had no farmland to cultivate crops. They found the lake without living things. Capture fisheries on the lake were their livelihood before and after the aquaculture program. They started with simple gillnet fisheries. However, they have now been marginalized.

Enhancing the well-being of these fishermen would pose significant challenges. Furthermore, the absence of land ownership and poor human capital development, as seen by their socioeconomic attributes (as presented in Table 1 to Table 11), will undoubtedly impede these efforts. With such restrictions, individuals can only work as farm laborers. Two obstacles prevented their villages from benefiting from the new aquaculture program: (1) land tenure, customs-related entry barriers, and (2) capital. According to Batur tradition, families residing directly on the lake's shoreline have exclusive claims to the waters bordering the lake's shore (Figure 9). They can use water up to 'one adult throw' from the lake's maximum tide.

Figure 9. Exclusive use rights to lakeshore family

Thus, non-coastal families, especially fisherman families, have little chance of obtaining such rights. They may build cages farther offshore, but most fishermen cannot afford their capital. Aquaculture sites are rarely sold. Lake properties are traditionally only sold to family members.

Another problem for fishermen caused by aquaculture cages is that schooling fish in fishing grounds where they have been catching now move closer to the cages, which are the aquaculture owners' territory. Aquaculture cages attract wild fish to the cage's proximity by providing fish feed residues, persuading fishermen to target these species.

Lake Batur has no fishing restrictions. Anyone can fish or throw nets in all lake waters without a license. Fishermen increasingly avoid cages. The result decreases their space, pushing some to leave the fishery. Naturally, just 10% of fishermen remained. Fishermen should have remained steady under typical circumstances.

People who visited Lake Batur between 20 and 30 years ago have a strong impression of a severe ecological decline. The aquaculture concentration area has clusters of cages, indicating a lack of regulated growth and inequitable space distribution. In contrast, certain areas of the lake exhibit clear signs of impaired environmental functionality. The most prominent illustration is represented by spontaneously proliferating vegetation. Numerous research has substantiated the correlation between human-induced variables and the deterioration of aquatic environments. Wiradana et al. [36] identified a prevailing trend among aquaculture operators: they tend to employ excessive seed density and exceed the maximum feed limit. Meanwhile, Irdhawati Manuruang and Reichelt-Brushett [37] examined garbage disposal behavior as a prominent deterrent factor occurring in the lower regions of the lake. The erosion of the lake bank has resulted in an annual increase of 1,930 tonnes of sediment deposition in the center region of the lake. Irdhawati Manuruang and Reichelt-Brushett [37] reported a significant decrease in the depth of the lake.

Several groups have recognized the urgency to develop effective management strategies. Budiasa et al. [38] suggested restricting lake land utilization for aquaculture at a maximum of 5% of the total area. The development of fisheries has been limited to only 6.28 hectares, leaving a significant portion of 77.07 hectares unutilized. Even though the amount of space being used was still below what was suggested, we surveyed and wrote down what people said about evidence of environmental problems, including those that affected fishermen.

In light of this observation, the local administration initiated a campaign for enhancement, culminating in implementing eco-enzyme treatment in the lake water. Government authorities instructed all government employees and students to prepare a quantity of 25 litres of enzymes each, intending to release them into the lake at a specific time. Our assessment was highly favourable Regarding the commitment and enthusiasm demonstrated towards this movement. Nevertheless, the interviewed individuals were highly sceptical about this endeavour in the Batur community.

This study addresses phenomena commonly perceived as pertaining solely to the natural world while considering alternative perspectives. To be accurate, we must look back to figure out how human activities or management authorities that regulate or drive their activities have damaged the lake's biological function. Food sufficiency, economic improvement, and well-being are crucial but must be addressed with minimal ecological impact. Our interviews suggested that the community would not accept all people. Government extension workers who deliver development programs often struggle. Most aquaculture operators ignore extension worker warnings about limiting cages. However, the community consulted more traditional elders. But they don't know much about formal policymakers' remarks. As a result, many community members are unaware of specific rules, such as having a license, etc. Considering this, encouraging strong collaboration between traditional systems and government regulations is a better option. *'Awig-awig'* is a conventional oral management system highly respected by the community. Through this tradition, government objectives can be communicated to the local community. Thus, older people need to be empowered with government-disseminated information.

It is widely acknowledged that the waters of Lake Batur constitute natural resources that are subject to legal jurisdiction by the state. In line with this perspective, it is generally accepted within the community that the government possesses the authority and responsibility to manage the utilization of the lake while also recognizing that each citizen residing in the lake area is entitled to access it per the state's established system.

4. DISCUSSION

The findings from this study provide critical insights into the challenges and opportunities for managing Lake Batur's fisheries and aquaculture sectors, addressing both the research objectives and the broader context of sustainability outlined in the introduction. Returning to the findings of the leverage analysis, the preceding discourse on the contextual aspects of social affairs has provided us with an understanding of viable policy alternatives that need consideration. Regarding this matter, some leverage attributes offer legitimately reasonable barriers, while others seem to cause substantial difficulties. The inquiry presented to experts concerning "gear selectivity" in the Rapfish questionnaire primarily related to regulations that enable the release of non-recommended catches. In the particular case of Lake Batur, the indicator used to measure its features was the net size. A moderate rating was assigned to this element, indicating that the evaluators perceived the enforcement of net size regulations as adequate for promoting the long-term sustainability of fisheries in the lake.

These findings are consistent with the trend derived through on-site observations, questionnaires, and in-depth interviews. As indicated in Table 7, a discernible trend of mesh size increasing over time suggests an enhancement in gear selectivity. This shows that fishermen comply highly with policymakers' directives about mesh size configurations. The findings from Rapfish's research indicate that 'gear selectivity' is a significant feature. However, the results from the previous observations, surveys, and in-depth interviews suggest that this attribute may be of relatively low value in future management schemes.

Furthermore, it is crucial to consider the phenomenon known as "range collapse." Examining the prevailing socioeconomic conditions provided insights into the determinants responsible for Lake Batur's substantial decline in fish production. One factor that might be observed is that fishermen sometimes utilize the lake as their last employment opportunity. With their low level of education (see Table 2), it is clear that the fishermen will encounter significant difficulties in changing to alternate occupations to reduce the strain on the lake. Hence, evaluations are urgently needed to focus on enhancing education in the community.

A significant finding from the study is the decline in the catch per trip, fishermen's income, and ownership of fishing gear. Fisher's income is influenced by the price of fish, where the price of Tilapia has increased. The price of Tilapia in 2022 is 25.3 thousand (IDR), which is larger than the average of the last fourteen years (2009-2022), which is only 19.5 thousand (IDR). Nonetheless, the income of fishermen has decreased, where the average income of fishermen is currently 1,356 million rupiahs, 7% less than the previous five years. The average catch per trip in 2022 is 2.6 kg/trip, found to be 11% less than five years earlier and 25% less than ten years earlier. Moreover, there is a decline in the maximum recorded size of Tilapia, with recent measurements showing a reduction from 39 cm in 2011 to 36 cm in 2023 [39]. The trend can be attributed to both natural factors, such as climate change [40] and anthropogenic pressures, including overfishing [41]. The observed decline underscores the urgent need for policies aimed at controlling fishing activities to manage the capture rates and the effect of overfishing. Afterward, three interrelated traits emerge as significant components determining future management policies. They are 'economic share,' 'employment,' and 'reliance.' The initial variable measures the comparative significance of lake fishing within the economic system of the Lake Batur community. The second variable quantifies the proportion of families engaged in fisheries within the statistical data related to settlements surrounding Lake Batur. The third variable pertains to the degree to which members of the community rely on the existence of the lake and its various services for their livelihoods. The present condition of the leverage attributes plays a crucial role in determining the sustainability of fisheries in the lake. Since just a small change or decline in any of these features can significantly affect the likelihood of sustainability. Nevertheless, a transformation in the social context of employment is required in this specific situation. Undoubtedly, it provides significant barriers to the community's limited chances for jobs and low levels of education.

Concerning the following attribute, "conflict status," as we've already said, our field findings suggest that this attribute is essential for prioritizing future management policy actions. This sense of conflict manifests itself both within the community of established fishermen and in the interactions between these fishermen and operators engaged in aquaculture activities. Based on our previous discussion, dealing with the significant issues of overfishing and concurrent utilization of water space is essential. Consequently, future management strategies should incorporate techniques such as implementing catch rate restrictions and establishing specified zones for sustainable utilization of fishing resources.

The final attribute that deserves discussion is the variable of "fishing income." When Rapfish asked resource employees about their "fishing income," they were asked how much of their family's total income came from fishing. The more significant the amount, the greater the likelihood they will continue fishing, putting more pressure on resources. In this case, the pertinent policy involves improving the sustainability of non-fisheries businesses established by specific individuals engaged in fishing activities. Our interviews identified several critical policy recommendations, including offering marketing support, upgrading skills, and improving employment sources and infrastructures.

Examining previous studies, such as those by Suryati and Samuel [39], Audzijonyte et al. [40], and Allan et al. [41] reveals both similarities and differences with our findings. Our study aligns with earlier research that highlights the impact of overfishing and climate change as significant factors affecting fish. Another study also described how climate change has raised the vulnerability of the agricultural industry [42]. However, our study adds depth by focusing on the specific impacts of socioeconomic factors on fisheries management and the need for integrated policy approaches. The alignment with other studies confirms the relevance of our findings, while the unique emphasis on local socioeconomic dynamics provides new insights into managing Lake Batur's fisheries.

To conclude this discussion, we highlight the potential contributions of our study to the field by providing a comprehensive analysis of both technical and social dimensions of fisheries management. Integrating factors such as gear selectivity, socioeconomic conditions, and conflict management into policy recommendations offers a more grounded approach to achieving sustainability in Lake Batur's fisheries.

5. CONCLUSION

This study reports alarming degradation in Lake Batur's fisheries, characterized by reduced ownership of fishing gear, decreased catch per trip, and declining fishermen's income. Rising fish prices appear insufficient to offset the decrease in productivity. Nonetheless, many fishermen remain in the industry despite declining performance, indicating underlying management issues. This phenomenon justifies the need for appropriate and comprehensive policies. The Rapfish analysis reveals critical deficiencies in the sustainability of these fisheries across various dimensions, reflecting broader issues in environmental and socio-economic management.

To address these challenges, future research should focus on evaluating the effectiveness of proposed policy interventions, including the impact of catch rate restrictions and reorganization of utilization zones. Investigating the integration of traditional management practices, such as customary rules (awig-awig), with modern regulations could offer new pathways to sustainability.

Moreover, research needs to consider strategies for facilitating fishermen's transition away from environmentally harmful practices, including enhancing skill development and livelihood options. Long-term studies are also necessary to assess the effectiveness of these policies in improving fisheries management and their broader impacts on the socio-economic well-being of Lake Batur's communities. Implementing these recommendations will not only help restore Lake Batur's ecological balance but also support the sustainable development of the fisheries sector, ensuring its resilience and viability for future generations.

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