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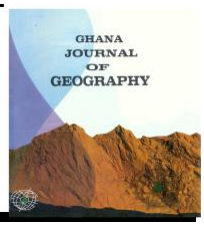

Assessing the Socio-Economic and Ecological Impacts of Fishing Intensity in Bagamoyo, Tanzania: A Community-Based Perspective.

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abstract

Small-scale fisheries along the Tanzanian coast are increasingly shaped by rising fishing intensity, with far-reaching ecological and socio-economic consequences for coastal livelihoods. While national policies promote sustainable and community-based fisheries management, less is known about how the artisanal fishers themselves perceive fishing intensity, how this awareness relates to observed ecological change, and whether it translates into meaningful socio-economic and behavioural responses. Addressing this gap, this study applies the social-ecological systems (SES) framework to examine the relationships between fishers' awareness of fishing intensity, the perceived ecological impacts, income outcomes, and adaptive strategies in Bagamoyo District, Tanzania. A cross-sectional survey was conducted with 357 artisanal fishers across four coastal wards (Dunda, Zinga, Kaole, and Mlingotini), selected from official fisher registers. Data were analysed using descriptive statistics, analysis of variance, Pearson correlations, binary logistic regression, and chi-square tests to assess how awareness of fishing intensity relates to ecological observations, fishing income, and adaptation behaviours. The results show that awareness of fishing intensity was high (74%), with most of the respondents reporting declining fish stocks (90%) and a substantial proportion noting the disappearance of multiple species (35%). Binary logistic regression identified years of fishing experience (OR=1.13, p=0.004), species loss (OR=1.92, p=0.003), and education level (OR=1.36, p=0.039) as significant predictors of awareness. ANOVA revealed significant income differences by awareness ($F=6.34$, $p=0.014$), while correlations showed negative links between income and species loss ($r=-0.32$, $p<0.05$). Chi-square tests linked awareness to gear substitution ($\chi^2=5.12$, $p=0.024$) and reduced effort ($\chi^2=6.34$, $p=0.012$), but not alternative livelihoods ($\chi^2=2.01$, $p=0.156$). These findings reveal a key social–ecological paradox: despite the widespread awareness of ecological decline, adaptive capacity remains constrained, and fishing intensity persists. By empirically linking ecological perceptions, income dynamics, and behavioural responses, the study demonstrates how awareness functions as a critical but insufficient mediator within a constrained SES. The study contributes novel micro-level evidence from an under-studied East African context and highlights the need for fisheries policies that move beyond awareness-raising to address structural barriers, including limited livelihood alternatives, education, and institutional support, in order to enhance socio-ecological resilience in small-scale fisheries.

1. Introduction

Small-scale and artisanal fisheries play a critical role in global food systems, livelihoods, and coastal economies. Worldwide, fisheries provide direct employment to more than 58 million people, the majority of whom operate in small-scale or artisanal contexts, particularly in developing regions (FAO, 2020). Beyond employment, fisheries contribute substantially to food and nutritional security, supplying over three billion people with at least 20% of their animal protein intake. In many coastal societies, fishing is not merely an economic activity, but a deeply embedded social and cultural practice that shapes identities, local knowledge systems, and community cohesion.

Despite their importance, small-scale fisheries are increasingly under pressure from intensified exploitation of marine resources. One of the most widely recognised drivers of fisheries decline is fishing intensity, which refers to the level of pressure exerted on fish stocks through fishing activities (FAO, 2020).

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Fishing intensity encompasses multiple interrelated dimensions, including the number of active fishers, frequency and duration of fishing trips, gear types and efficiency, and the spatial concentration of effort (FAO, 2020; Andriesse et al., 2022). When fishing intensity exceeds the regenerative capacity of marine ecosystems, it leads to overfishing, declining catch per unit effort, biodiversity loss, and habitat degradation. At the global scale, these impacts are evident in the increasing proportion of overfished stocks, now estimated at approximately 35% of assessed fisheries (FAO, 2020).

The challenge of rising fishing intensity is particularly pronounced in the Global South, where high dependence on natural resources intersects with the limited livelihood alternatives and weak regulatory enforcement. Although in Africa, fisheries support more than 12 million livelihoods directly and indirectly, the sector faces mounting pressures from overexploitation, population growth, illegal, unreported and unregulated (IUU) fishing, and environmental change (AU-IBAR, 2021; Weigel et al., 2018). In many African contexts, intensified fishing effort emerges not only from technological change, but also, from the increasing numbers of fishers competing for declining resources under open-access or weakly governed systems. This dynamic often produces a feedback loop in which declining

catches prompt greater effort, further accelerating ecological degradation (Moshy & Bryceson, 2016; Salehe et al., 2020).

Along the East African coast, pressures on fisheries are further amplified by rapid coastal population growth, expanding tourism and port development, and climate-related stressors such as rising sea surface temperatures and changing oceanographic conditions. Countries bordering the Western Indian Ocean, including Kenya, Tanzania, and Mozambique, have reported persistent declines in catch per unit effort, shrinking fish sizes, and localised species disappearance, all of which are indicative of escalating fishing intensity (Nyangoko et al., 2022; Aura et al., 2024). In this region, artisanal fisheries dominate coastal production and rely heavily on nearshore ecosystems such as coral reefs, seagrass beds, and mangroves, which are particularly sensitive to sustained and concentrated fishing pressure (Rehren et al., 2022).

In Tanzania, fisheries constitute a vital component of coastal livelihoods and consequently,a the national economy. The sector contributes approximately 1.8% to national GDP and directly employs over 200,000 fishers, while indirectly supporting millions more through processing, trade, and transport (Robertson et al., 2018). To address sustainability concerns, the government has introduced policy and legal instruments such as the Fisheries Act of 2003 and the National Fisheries Policy of 2015, which emphasise conservation, co-management, and community participation (United Republic of Tanzania, 2003; Ministry of Livestock and Fisheries Development, 2015). Nevertheless, the empirical evidence available indicates that fishing intensity in nearshore artisanal fisheries has continued to rise. Long-term data reveal substantial declines in fish landings per fisher and per vessel, with estimates suggesting reductions of nearly 50% between 1984 and 2016 (Shalli et al., 2020). Coastal areas such as Bagamoyo, Zanzibar, and the Rufiji Delta have become hotspots of fishing pressure, characterised by increasing effort, intensified competition, and declining returns (Rehren et al., 2022; Ishengoma, 2023).

While national and regional studies have documented ecological decline and governance challenges, comparatively less attention has been paid to how fishing communities themselves perceive fishing intensity and how this awareness shapes socio-economic outcomes and behavioural responses. Existing research in Tanzania often treats overfishing as a biophysical or institutional problem, focusing on stock assessments, governance arrangements, or policy design, with limited integration of fishers' perceptions, income dynamics, and adaptive behaviour (Robertson et al., 2018; Ishengoma, 2023). Consequently, a critical gap remains in understanding the micro-level feedbacks within fisheries systems, specifically how fishers' awareness of fishing intensity, as a form of social-ecological knowledge, mediates livelihood outcomes and adaptation strategies in contexts where economic and institutional options are constrained.

This gap is particularly important when viewed through the lens of social-ecological systems (SES) theory. The SES framework conceptualises fisheries as complex, interconnected systems in which ecological processes, human behaviour, and governance arrangements co-evolve through feedback loops (Berkes et al., 2003; Ostrom, 2009). Within this framework, fishers' perceptions and awareness are central components of the "actors" subsystem, shaping how ecological signals such as declining stocks or species loss are interpreted and acted upon. However, SES scholarship also cautions that awareness alone does not guarantee sustainable outcomes. Where governance systems are weak and alternative livelihoods are limited, increased awareness may coexist with continued or intensified fishing effort, reinforcing maladaptive feedback loops (Rohe et al., 2017; Ishengoma, 2023).

The Bagamoyo District, located along Tanzania's central coast, provides a particularly suitable setting for examining these dynamics. The district has a long history of artisanal fishing and remains highly dependent on nearshore marine resources for livelihoods and food security. Empirical studies and local accounts indicate declining catches despite increased effort, suggesting that fishing intensity has exceeded sustainable thresholds in nearshore waters (Robertson et al., 2018; Rehren et al., 2022). However, systematic empirical analysis linking fishers' awareness of fishing intensity to the perceived ecological change, income outcomes, and adaptive strategies at the community level remains limited.

Against this background, this study adopts a community-based perspective to examine fishing intensity in Bagamoyo District using an explicit SES framework. Rather than treating fishing intensity solely as an ecological or regulatory problem, the study also focuses on how artisanal fishers understand and experience it, how this awareness relates to observed ecological change, and whether it translates into measurable socio-economic outcomes and adaptive behaviour. By empirically linking these dimensions, the study aims to generate micro-level insights that inform community-based fisheries management and contribute to broader debates on small-scale fisheries sustainability in Tanzania and comparable contexts.

2. Literature Review and Theoretical Framework

2.1 Fishing Intensity and Small-Scale Fisheries

Fishing intensity has become a central concept in fisheries science and governance, particularly in the context of small-scale fisheries in the Global South. Broadly, fishing intensity refers to the magnitude of fishing pressure exerted on aquatic resources, shaped by factors such as the number of active fishers, frequency and duration of fishing trips, gear type and efficiency, spatial concentration of fishing activities, and cumulative effort over time (FAO, 2020; Andriesse et al., 2022). High fishing intensity is not inherently problematic; rather, it becomes unsustainable when fishing pressure exceeds the regenerative capacity of fish stocks and associated ecosystems.

Empirical studies across tropical fisheries consistently link increased fishing intensity to declining catch per unit effort, reduced fish sizes, and loss of species diversity (Rehren et al., 2022; Robertson et al., 2018). In small-scale fisheries, intensified effort is often a response to declining catches rather than a cause alone, creating a feedback loop in which fishers increase effort to maintain incomes, thereby accelerating ecological degradation (Moshy & Bryceson, 2016; Salehe et al., 2020). This dynamic is particularly evident in the contexts where alternative livelihoods are limited and access to fisheries remains weakly regulated.

In Africa, fishing intensity is shaped by population growth, poverty, and governance constraints. AU-IBAR (2021) notes that African fisheries are characterised by high dependence on natural resources and limited adaptive capacity, making communities especially vulnerable to overexploitation. Studies from West and Southern Africa show that even where community-based or co-management structures exist, enforcement challenges and livelihood pressures often undermine sustainability outcomes (Weigel et al., 2018; Owusu-Achiaw & Osei-Owusu, 2023).

Within East Africa, intensified fishing effort has been documented across coastal and inland systems, driven by rising numbers of artisanal fishers, expanding markets, and climate-induced ecological change (Nyangoko et al., 2022; Thoya et al., 2022). In Tanzania, long-term declines in landings and increasing competition over nearshore fishing grounds point to persistent high fishing intensity despite policy reforms aimed at sustainability (Shalli et al., 2019; Ishengoma, 2023). However, much of the literature focuses on the ecological outcomes or governance structures, with less attention on how fishing communities themselves perceive fishing intensity and translate the awareness into behavioural change.

2.2 Community Perceptions, Awareness, and Adaptive Responses

A growing body of research has emphasised the importance of local perceptions and knowledge in understanding fisheries dynamics. Fishers' observations of declining stocks, disappearing species, and changing marine conditions often align closely with scientific assessments, particularly in data-poor contexts (Moshy & Bryceson, 2016; Rehren et al., 2022). Such perceptions shape decision-making at the household and community level, influencing choices related to gear use, fishing effort, and livelihood strategies.

Studies in Tanzanian coastal communities reveal high awareness of ecological decline but limited capacity to adapt in transformative ways, such as shifting to alternative livelihoods (Salehe et al., 2020; Imbwae et al., 2023). Instead, adaptations tend to be incremental changing gear, fishing longer hours, or travelling farther offshore which may reduce short-term risk but intensify long-term ecological pressure. Similar patterns have been observed in Bagamoyo and Zanzibar, where livelihood diversification remains constrained by limited capital, skills, and institutional support (Mwaipopo & Ndaluka, 2023; Rehren et al., 2022).

These findings point to a critical gap in the literature in the sense that while awareness of fishing intensity and ecological change is often high, the pathways through which awareness translates into behavioural adaptation remain poorly theorised and empirically tested. Addressing this gap requires

an analytical framework capable of capturing the interactions between ecological conditions, socio-economic variables, institutions, and human behaviour.

2.3 Socio-Economic Outcomes and Adaptive Responses

Fishing intensity has direct and indirect implications on the socio-economic well-being of small-scale fishing communities. Declining fish stocks and species loss are commonly associated with reduced incomes, increased income variability, and heightened livelihood insecurity (AU-IBAR, 2021; Imbwae et al., 2023). In response, fishers often adopt short-term coping strategies aimed at sustaining livelihoods under conditions of ecological stress.

Empirical studies across East Africa show that adaptive responses tend to be incremental rather than transformative. Common strategies include changing fishing gear, increasing fishing frequency or duration, travelling farther offshore, or targeting different species (Salehe et al., 2020; Rehren et al., 2022). While such strategies may temporarily stabilise income, they frequently increase the overall fishing pressure and contribute to long-term ecological decline.

Livelihood diversification into non-fishing activities is widely promoted as a pathway to reducing fishing intensity. However, evidence from Tanzania suggests that diversification remains limited in practice due to barriers such as the lack of capital, skills, education, and market access (Mwaipopo & Ndaluka, 2023; Thoya et al., 2022). As a result, even fishers who are aware of fishing intensity and ecological decline often remain locked into fishing as their primary livelihood, reinforcing dependence on degraded resources.

2.4 The Social-Ecological Systems (SES) Framework

The Social-Ecological Systems (SES) framework provides a robust theoretical lens for analysing fisheries as complex, interdependent systems rather than isolated ecological or social components. Developed and formalised by Ostrom (2009) and further elaborated by Berkes et al. (2003), the SES framework conceptualises resource systems as comprising interconnected subsystems, including resource units (e.g., fish stocks), resource systems (e.g., coastal marine ecosystems), actors (e.g., fishers and households), and governance systems (e.g., policies, norms, and institutions).

A core premise of the SES framework is that sustainability outcomes emerge from interactions among these subsystems, shaped by feedback loops, learning processes, and adaptive behaviour. In fisheries, this means that ecological decline cannot be fully understood without considering how fishers respond to changing conditions, how institutions regulate access and use, and how socio-economic constraints influence decision-making (Berkes et al., 2003; Ostrom, 2009).

The SES framework has been widely applied in fisheries research to examine community-based management, adaptive governance, and resilience (Campos-Silva & Peres, 2016; Ensor et al., 2018). Empirical studies demonstrate that systems with strong local participation, knowledge integration, and institutional fit are more likely to achieve ecological recovery and livelihood resilience (Campos-Silva et al., 2018; Eriksson et al., 2016). However, other studies caution that community-based arrangements alone are insufficient where structural inequalities, market pressures, and weak state support persist (Rohe et al., 2017; Ishengoma, 2023).

In the Tanzanian context, the SES framework has been used implicitly in studies examining co-management, climate adaptation, and mangrove-based fisheries, though often without explicit theorisation (Nyangoko et al., 2022; Brodie et al., 2024). This has limited its analytical power in explaining why awareness and participation do not always lead to sustainable outcomes.

2.5 Operationalising the SES Framework in this Study

This study explicitly operationalises the SES framework to analyse fishing intensity in Bagamoyo District. Fishing intensity is conceptualised as an emergent outcome of interactions between the resource system (nearshore marine ecosystems), actors (artisanal fishers differentiated by experience, education, and income), and the governance context (co-management arrangements and regulatory frameworks).

Within this framework, fishers' awareness of fishing intensity is treated as a key element of the "actors" subsystem, representing social-ecological knowledge derived from long-term engagement with the resource system. Observed ecological changes, such as declining stocks and species loss, correspond to feedback signals from the resource system. The socio-economic outcomes, reflect the material consequences of these interactions, and particularly fishing income, while adaptation strategies (gear changes, effort reduction, and livelihood diversification) represent behavioural responses within the system.

By statistically examining the relationships between awareness, ecological perceptions, income dynamics, and adaptive behaviour, the study moves beyond descriptive accounts of decline to analyse how feedbacks within the SES shape fishing intensity at the micro level. In doing so, it contributes to fisheries literature by demonstrating how awareness functions as a mediating variable between ecological change and human response, while also highlighting the limits of individual adaptation in the absence of supportive institutional and economic conditions. This integrated approach strengthens understanding of why fishing intensity persists in small-scale fisheries despite high awareness and policy interventions, particularly in the Tanzanian coastal context.

3. Methodology

3.1 Study Design

This was a cross-sectional descriptive study employing a quantitative methodology to investigate the socio-economic and ecological effects of fishing intensity in Bagamoyo District, Tanzania. The design was chosen to capture a snapshot of community perceptions, fishing practices, income patterns, and adaptation strategies related to fishing intensity. Primary data were collected through a structured questionnaire administered to artisanal fishers in the selected coastal wards. The study adopted a socio-ecological systems framework (Ostrom, 2009; Berkes et al., 2003) to conceptualise the interactions between human activities and marine ecosystems, with awareness of fishing intensity as the central variable influencing adaptive behaviours.

3.2 Study Area and Population

The study was conducted in Bagamoyo District, located in Tanzania's Pwani (Coast) Region, eastern Tanzania. Geographically, the district lies between latitude 6°00' and 7°00' South and longitude 38°30' and 39°05' East, bordering the Indian Ocean to the east, Kibaha District to the south, and Pangani District (Tanga Region) to the north. Bagamoyo was selected purposively as the study area due to its status as a historical and contemporary hub for small-scale fisheries, which serve as a primary livelihood for the coastal communities. According to the 2022 Tanzania Population and Housing Census, the district has 58,360 households, with a significant proportion engaged in artisanal fishing (National Bureau of Statistics [NBS], 2023). The area is representative of broader coastal challenges in Tanzania, including declining fish stocks (e.g., prawns, rabbitfish, parrotfish, emperors, snappers, sea cucumbers, and mollusks) attributed to overexploitation, habitat degradation, and climate change, as documented in regional studies (Rehren et al., 2022; Robertson et al., 2018). This makes Bagamoyo an ideal site for examining micro-level socio-ecological dynamics, unlike other coastal districts where fishing intensity may be less pronounced or data less accessible.

The target population comprised artisanal fishers residing and operating in Bagamoyo's coastal wards. Four wards - Dunda, Zinga, Kaole, and Mlingotini were selected purposively as they represent hotspots for fishing activities, with proximity to rich fishing grounds, established landing sites, and a mix of traditional villages and semi-urban settlements (see Figure 1). This selection ensured coverage of diverse fishing contexts while focusing on areas with reported ecological stress.

3.3 Sampling Frame and Techniques

The sampling process was conducted in two stages: selection of study areas (wards) and selection of respondents (fishers). As noted, wards were chosen purposively based on their fishing intensity and accessibility. Within these wards, the sampling frame consisted of lists of registered artisanal fishers obtained from Ward Executive Officers (WEOs) and local Beach Management Units (BMUs), estimating a total accessible population (N) of approximately 5,000 fishers across the four wards, derived from district fisheries records and census data (NBS, 2023; Robertson et al., 2018).

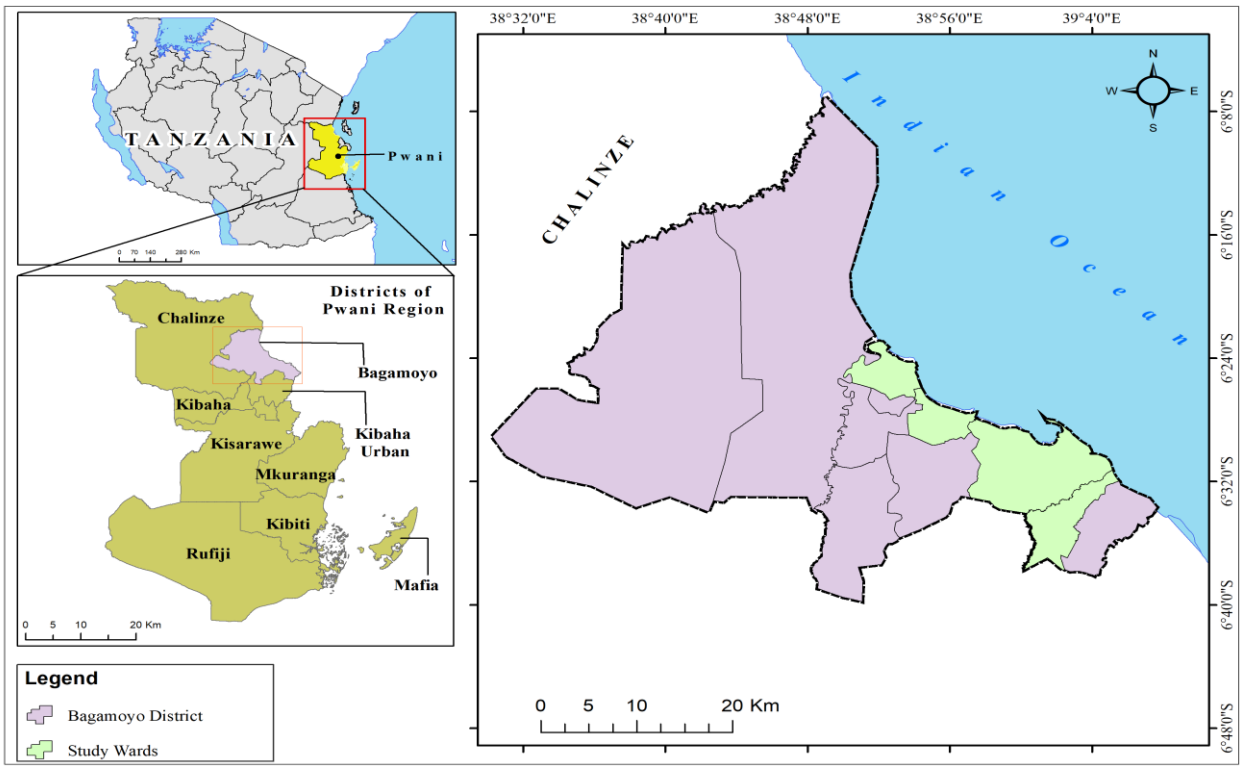

Figure 1: Location of the Study Area – Bagamoyo District, Tanzania

A statistically valid sample size was calculated using Cochran's formula for large populations:

$$n_0 = \frac{Z^2 \cdot p \cdot (1-p)}{e^2}$$

Where:

n_0 = sample size required

Z = standard score at the desired level of confidence (1.96 at the 95% level of confidence)

p = estimated proportion of the population (take to be 0.5 to give maximum variability)

e = margin of error (taken to be 0.05 or 5%)

$$n_0 = \frac{(1.96)^2 \cdot 0.5 \cdot (1-0.5)}{(0.05)^2} = \frac{3.8416 \cdot 0.25}{0.0025} = \frac{0.9604}{0.0025} = 384.16$$

The first calculated sample size was about 384 participants. However, since the study focused on a specific population (artisanal fishers in Bagamoyo's coastal wards), the total accessible population was relatively smaller than the general population figure used in Cochran's original formula. Hence, the Finite Population Correction (FPC) was applied to the sample size in order to mirror the real fishing population within the sampled wards. In this way, this study was represented by 357 artisanal fishers. This was deemed statistically adequate and logistically feasible and hence reliable analysis with a manageable scope of fieldwork.

3.4 Data Collection and Measurement of Variables

Primary data were collected through face-to-face interviews using a structured questionnaire administered by trained enumerators. The questionnaire comprised five main sections: socio-demographic characteristics, awareness of fishing intensity, perceived ecological impacts, socio-economic outcomes, and adaptation strategies.

i. Awareness of fishing intensity was measured using a binary question: *"Are you aware that fishing intensity (defined as increasing fishing pressure on fish stocks through fishing activities) is increasing in Bagamoyo waters?"* (Yes/No).

ii. Perceived ecological impacts included:

   a. *Reduction in fish stocks*, measured as a binary response (Yes/No).

   b. *Species loss*, measured by asking respondents to report the number of fish species they no longer commonly observe in their fishing areas. Responses were categorised into none, 1-2 species, or three or more species.

iii. Socio-economic outcomes focused on *monthly fishing income*, self-reported in Tanzanian Shillings as an average over the previous year to account for seasonal variation.

iv. Fishing experience was measured as the number of years the respondent had been actively engaged in fishing and treated as a continuous variable.

v. Education level was recorded as an ordinal variable (no formal education, primary, secondary, post-secondary).

vi. Adaptation strategies were measured using binary responses (Yes/No) for actions such as changing fishing gear, reducing fishing effort, and engaging in alternative livelihoods.

Data collection was conducted during the peak fishing season to capture periods of maximum fishing effort and income dependence, which are most relevant for assessing fishing intensity. While this approach allowed the study to focus on high-pressure conditions, it may over-represent peak-season income and effort levels. This limitation is acknowledged in the interpretation of results.

The questionnaire was pilot-tested with 30 non-sampled fishers from a neighbouring ward, leading to minor revisions for clarity. Reliability testing of multi-item perception measures produced a Cronbach's alpha of 0.82, indicating good internal consistency.

3.5 Data Analysis

Data were coded and analysed using IBM SPSS Statistics (Version 20). Descriptive statistics were used to summarise socio-demographic characteristics, awareness levels, ecological perceptions, and income patterns. Inferential analyses included:

a. Analysis of variance (ANOVA) to test for differences in mean income between fishers who were aware and unaware of fishing intensity.
b. Pearson correlation analysis to examine relationships among income, fishing experience, ecological perceptions, and awareness.
c. Binary logistic regression to identify predictors of awareness of fishing intensity, with years of fishing experience, education level, and species loss as independent variables.
d. Chi-square tests to assess associations between awareness and adaptation strategies.

Statistical assumptions were tested prior to analysis, including normality and homoscedasticity. Significance was assessed at the 5% level ($p < 0.05$).

3.6 Methodological Limitations

The study relied on self-reported income and retrospective ecological observations, which may be subject to recall bias or under-reporting. In addition, the cross-sectional design limits causal inference, meaning that observed relationships should be interpreted as associations rather than direct causal effects. These limitations are addressed in the discussion when interpreting the findings.

4. Results and Discussion

4.1 Community Awareness and Perceptions of Fishing Intensity

Out of the 357 artisanal fishers surveyed, 265 respondents (74%) reported being aware of fishing intensity in Bagamoyo waters, while 92 respondents (26%) reported no such awareness (Table 1). A large majority of respondents (321; 90%) indicated that fish stocks had declined over time. Regarding species disappearance, 177 respondents (50%) reported the loss of one to two species, 126 respondents (35%) reported the disappearance of three or more species, and 54 respondents (15%) reported no observed species loss.

4.2 Socio-Economic Impacts: Income and Fishing Practices

Monthly fishing income varied widely among the respondents. Reported income ranged from TZS 5,000 to TZS 100,000 per month, with a mean monthly income of TZS 28,500. Most of the respondents (161; 45%) reported monthly incomes between TZS 20,001 and 50,000, while 142 respondents (40%) reported earning between TZS 5,000 and 20,000. A smaller proportion (54; 15%) reported incomes above TZS 50,000 (Table 2). Fishing activity was frequent, with respondents reporting an average of 4.5 fishing days per week.

4.3 Income Differences by Fishing Intensity Awareness

Analysis of variance (ANOVA) was conducted to test for differences in mean monthly fishing income between respondents who reported awareness of fishing intensity and those who did not. The results indicate a statistically significant difference in mean income between the two groups ($F = 6.34$, $p = 0.014$). The summary statistics and test results are presented in Table 3.

4.4 Correlations between Key Variables

Pearson correlation analysis was conducted to examine relationships among fishing income, years of fishing experience, reported species disappearance, fishing frequency, and awareness of fishing intensity. Fishing income was negatively correlated with reported species disappearance ($r = -0.32$, $p < 0.05$) and awareness of fishing intensity ($r = -0.25$, $p < 0.05$). Years of fishing experience showed a positive correlation with reported species disappearance ($r = 0.41$, $p < 0.01$) and awareness ($r = 0.19$, $p < 0.05$). Fishing frequency was positively correlated with reported species disappearance ($r = 0.28$, $p < 0.05$). Summary of these results are presented in Table 4.

Table 1: Awareness and Perceptions of Fishing Intensity (n=357)

Variable	Category	Frequency (n)	Percentage (%)
Awareness of Fishing intensity	Yes	265	74
	No	92	26
Observed fish stock decline	Yes	321	90
	No	36	10
Reported disappeared species	1-2 species	177	50
	3+ species	126	35
	None	54	15

Table 2: Monthly Fishing Income Distribution (n=357)

Income Range (TZS / USD)	Frequency (n)	Percentage (%)
5,000–20,000 (2–8)	142	40
20,001–50,000 (8–20)	161	45
50,001–100,000 (20–40)	54	15
Mean: 28,500 (11.40)		

Table 3: ANOVA: Income Differences by Fishing Intensity Awareness (n=357)

Source	SS	df	MS	F	p-value
Between groups	4.2e9	1	4.2e9	6.34	0.014
Within groups	5.8e10	89	6.5e8		
Total	6.2e10	90			

Table 4: Correlation Matrix: Fishing Intensity Indicators (n=357)

Variable	1	2	3	4	5
1. Fishing income	1.00				
2. Years fishing	-0.18	1.00			
3. Disappeared species	-0.32*	0.41**	1.00		
4. Fishing frequency	0.15	0.22	0.28*	1.00	
5. Fishing intensity awareness	-0.25*	0.19	0.37**	0.12	1.00

Table 5: Predictors of Fishing Intensity Awareness (n=357)

Predictor	B	SE	Wald	p-value	Odds Ratio
Years fishing	0.12	0.04	8.21	0.004	1.13
Disappeared species	0.65	0.22	8.76	0.003	1.92
Education level	0.31	0.15	4.28	0.039	1.36
Constant	-2.45	0.98	6.25	0.012	0.09

Table 6: Fishing intensity and Adaptation Strategies (n=357)

Adaptation Strategy	Fishing intensity Aware (n=68)	Not Aware (n=23)	χ^2	p-value
Changed fishing gear	221 (62%)	135 (38%)	5.12	0.024
Reduced fishing effort	311 (87%)	46 (13%)	6.34	0.012
Alternative livelihoods	325 (91%)	32 (9%)	2.01	0.156

(Note: Percentages are within awareness groups for clarity.)

4.5 Predictors of Fishing Intensity Awareness

Binary logistic regression analysis was used to identify factors associated with awareness of fishing intensity. Years of fishing experience, number of disappeared species, and education level were included as independent variables. All three variables were statistically significant predictors of awareness. The odds of being aware increased with years of fishing experience (OR = 1.13, p = 0.004), reported species disappearance (OR = 1.92, p = 0.003), and higher education level (OR = 1.36, p = 0.039). The model explained 28% of the variance in awareness (Nagelkerke R^2 = 0.28). The summary of these results are presented in Table 5.

4.6 Fishing Intensity Awareness and Adaptation Strategies

Chi-square tests were used to examine the associations between awareness of fishing intensity and reported adaptation strategies. A statistically significant association was observed between awareness and changing fishing gear (χ^2 = 5.12, p = 0.024) and between awareness and reducing fishing effort (χ^2 = 6.34, p = 0.012). No statistically significant association was found between awareness and engagement in alternative livelihoods (χ^2 = 2.01, p = 0.156). Results are summarised in Table 6.

5. Discussion

This study examined fishing intensity in Bagamoyo District through a social–ecological systems (SES) perspective, focusing on how fishers' awareness of fishing intensity relates to perceived ecological change, income outcomes, and adaptive behaviour. Rather than treating fishing intensity as a purely ecological or regulatory issue, the findings demonstrate that it is an emergent outcome of interactions between ecological degradation, livelihood dependence, and constrained adaptive capacity. Interpreted through the SES theoretical framework, the results offer insights into why fishing pressure persists despite high levels of awareness and policy emphasis on sustainability (Berkes et al., 2003; Ostrom, 2009).

5.1 Awareness of Fishing Intensity as Social–Ecological Knowledge

The high level of awareness of fishing intensity among artisanal fishers reflects accumulated experiential knowledge developed through long-term interaction with nearshore marine ecosystems. Within the SES framework, this awareness constitutes a form of social–ecological knowledge embedded in the "actors" subsystem, shaped by repeated feedback from the resource system (Berkes et al., 2003; Ostrom, 2009). Reports of declining fish stocks and species disappearance align with findings from other coastal and small-scale fisheries in Tanzania and the wider Western Indian Ocean, where fishers' perceptions have been shown to closely mirror scientific assessments of ecological decline (Moshy & Bryceson, 2016; Rehren et al., 2022).

However, the persistence of high fishing effort despite widespread awareness highlights a central insight from the SES scholarship: awareness is a necessary but insufficient condition for sustainable resource use. Similar patterns have been documented in Tanzanian and East African fisheries, where fishers recognise ecological degradation but continue fishing because of livelihood dependence and limited alternatives (Salehe et al., 2020; Nyangoko et al., 2022). These findings challenge assumptions embedded in some community-based management narratives that increased awareness or participation alone will lead to behavioural transformation.

5.2 Ecological Decline and Feedback Loops in the SES

Perceived declines in fish stocks and the disappearance of species represent negative feedback signals from the resource system, indicating that fishing intensity has exceeded sustainable ecological thresholds. In theory, such feedbacks should prompt adaptive responses that reduce pressure and allow recovery (Ostrom, 2009). In practice, the Bagamoyo case reflects what Berkes et al. (2003) describe as a maladaptive feedback loop, where ecological decline coincides with continued or intensified exploitation.

This pattern mirrors previous findings from other Tanzanian coastal systems, including Zanzibar and the Rufiji Delta, where declining catches prompt fishers to increase effort, change gear, or expand fishing grounds in an attempt to stabilise income (Rehren et al., 2022; Nyangoko et al., 2022). Rather than alleviating pressure, these responses often accelerate ecological degradation. The positive association between years of fishing experience and reported species loss further underscores how long-term engagement with the fishery increases awareness of cumulative ecological change without necessarily enabling exit or collective restraint, particularly under weak governance conditions (Rohe et al., 2017; Ishengoma, 2023).

5.3 Socio-Economic Outcomes and Unequal Adaptive Capacity

The observed negative relationship between fishing income and indicators of ecological decline highlights the material consequences of fishing intensity for artisanal fishers. Declining stocks and species loss translate into lower or more unstable incomes, reinforcing livelihood vulnerability, a pattern widely documented in African small-scale fisheries (AU-IBAR, 2021; Imbwae et al., 2023). Within the SES framework, this illustrates how degradation in the resource system feeds back into the socio-economic outcomes of actors, shaping incentives and behavioural responses.

The finding that fishers who are more aware of fishing intensity exhibit significantly different income outcomes complicates simplistic interpretations of awareness as inherently beneficial. Rather than conferring economic advantage, awareness may be associated with behavioural restraint or selective practices that impose short-term income costs in the absence of compensation or alternative livelihoods. Similar trade-offs have been observed in community-based fisheries elsewhere, where conservation-oriented behaviour can exacerbate short-term economic vulnerability for already marginalised households (Campos-Silva & Peres, 2016; Ensor et al., 2018). These results reinforce the argument that adaptive capacity is unevenly distributed and shaped by structural conditions rather than individual knowledge alone.

5.4 Adaptation Strategies: Incremental Change Rather Than Transformation

The pattern of adaptation observed in Bagamoyo is characterised by incremental rather than transformative change. Awareness of fishing intensity was associated with changes in fishing gear and reductions in fishing effort, consistent with findings from other Tanzanian coastal communities (Salehe et al., 2020; Rehren et al., 2022). These adjustments reflect adaptive behaviour

within the "actors" subsystem, informed by ecological feedbacks and experiential knowledge.

However, the absence of a significant association between awareness and livelihood diversification highlights the limits of individual adaptation within a constrained SES. Diversification into non-fishing livelihoods requires access to capital, education, skills, and markets factors shaped by the broader governance and economic subsystems (Mwaipopo & Ndaluka, 2023; Thoya et al., 2022). Similar constraints have been documented across the Global South, where livelihood diversification is widely promoted in policy, but remains difficult to achieve in practice (Owusu-Achiaw & Osei-Owusu, 2023; Gupta et al., 2022).

From an SES perspective, incremental adaptations may reduce short-term risk but can also perpetuate fishing intensity by keeping households tied to declining resources. Without enabling institutional and economic conditions, such adaptations are unlikely to generate system-level sustainability (Berkes et al., 2003; Ishengoma, 2023).

5.5 Implications for SES-Based Fisheries Governance

Taken together, the findings demonstrate the analytical value of the SES framework in explaining why fishing intensity persists despite high awareness and policy commitments to sustainability. In Bagamoyo, there is a clear mismatch between fishers' ecological knowledge and their capacity to respond in ways that reduce pressure on marine resources. This mismatch reflects weak alignment between the actors, governance system, and livelihood opportunities, a condition that Ostrom (2009) identifies as a key barrier to effective commons governance.

The results suggest that governance approaches focused primarily on awareness-raising or compliance are unlikely to be sufficient. While environmental education remains important, it must be complemented by interventions that address structural constraints, including limited livelihood alternatives, access to credit, skills development, and support for sustainable fishing technologies (AU-IBAR, 2021; Brodie et al., 2024). By empirically linking awareness, ecological perceptions, income dynamics, and adaptation strategies, this study advances fisheries research that often treats these dimensions separately and provides micro-level evidence from an under-studied East African context.

Overall, the Bagamoyo case reinforces broader SES-based arguments that reducing fishing intensity requires integrated, multi-level interventions that address not only behaviour and knowledge, but also the socio-economic and institutional conditions shaping choices available to fishing communities (Berkes et al., 2003; Ostrom, 2009).

6. Conclusion

This study advances understanding of fishing intensity in small-scale fisheries by examining how ecological change, fishers' awareness, socio-economic outcomes, and adaptive behaviour interact within a social–ecological systems (SES) framework. Focusing on Bagamoyo District, the analysis moves beyond descriptive accounts of overfishing and governance challenges to reveal how fishing intensity emerges as a systemic outcome shaped by feedbacks between declining marine resources, livelihood dependence, and constrained adaptive capacity.

A key contribution of the study is the demonstration that high awareness of fishing intensity and ecological decline does not, on its own, translate into reduced fishing pressure or transformative adaptation. While most fishers recognised declining stocks and species loss, awareness operated within a context of limited livelihood alternatives and weak institutional support. Consequently, adaptation remained largely incremental—through gear changes or effort reduction—rather than transformative, such as diversification into alternative livelihoods. This finding reinforces SES-based arguments that knowledge and awareness are necessary but insufficient conditions for sustainability when governance and economic subsystems fail to provide viable options for change (Berkes et al., 2003; Ostrom, 2009).

By statistically linking ecological perceptions, income dynamics, and behavioural responses at the micro level, the study fills an important gap in Tanzanian and East African fisheries research, where these dimensions are often examined in isolation. The observed associations between species loss and declining or unstable incomes underscore how ecological degradation feeds directly into socio-economic vulnerability, reinforcing reliance on fishing and perpetuating fishing intensity. This dynamic reflects a maladaptive feedback loop widely documented in small-scale fisheries under conditions of poverty and weak governance (AU-IBAR, 2021; Ishengoma, 2023).

Theoretically, the study extends the application of the SES framework by operationalising fishers' awareness as a mediating variable between ecological change and human response. This approach highlights the analytical value of local ecological knowledge while also exposing its limits in structurally constrained systems. Awareness, in this context, functions less as a pathway to sustainability and more as an indicator of accumulated ecological loss experienced by fishers over time.

From a policy perspective, the findings suggest that interventions aimed at reducing fishing intensity should move beyond awareness-raising and compliance-focused measures. While environmental education remains important, it must be complemented by structural interventions that expand fishers' adaptive capacity, including access to education and skills training, livelihood diversification opportunities, financial support mechanisms, and stronger institutional backing for sustainable fishing practices. Without addressing these underlying constraints, community-based and co-management initiatives are unlikely to achieve lasting reductions in fishing pressure.

Although the study is limited by its cross-sectional design and reliance on self-reported data, it provides robust empirical evidence from an under-studied coastal context and offers insights that are relevant to small-scale fisheries across the Global South. Future research could build on these findings through longitudinal designs, mixed-method approaches, and comparative studies across coastal regions to further unpack how social–ecological feedbacks evolve over time.

Overall, the study reinforces the central insight of SES scholarship: reducing fishing intensity is not simply a matter of changing individual behaviour, but of reshaping the broader social, economic, and institutional conditions that govern how people interact with marine resources.

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