CENTRE FOR BEHAVIOUR & WELLNESS ADVOCACY

Publisher: Centre for Behaviour and Wellness Advocacy, Ghana
Co-publisher: Cherkas Global University, USA
Has been issued since 2014
ISSN 2410-4981. E-ISSN 2508-1055
2025. 12(3): 243-263

DOI: 10.13187/jare.2025.3.243

Journal homepage:
http://kadint.net/our-journal.html

Sustainability of Artisanal Fishing in Nigeria: Implications for Food Security

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Abstract

The growing demand for artisanal fish as a source of protein is overstretching the fish-catching sector, threatening its sustainability. This study examines the food security implications of the nexus between artisanal fishery catch and sustainable fishing in Osun State, Nigeria. With a structured questionnaire, primary data were collected from 150 artisanal fishers in Osun State and analysed using Seemingly Unrelated and binary logistic regressions. The results reveal that catfish and tilapia are the most harvested fish species by artisanal fishers, who are more food-secure. Fishing experience and gender significantly influence sustainability indicators, while food security is influenced by social, environmental, and catfish harvesting. Artisanal fishers should improve their sustainability efforts to ensure food security. The Federal Ministry of Agriculture, through its Department of Fisheries and Aquaculture, should educate and encourage artisanal fishers to diversify their fishing activities to address the negative environmental impacts of continuous fishing and to improve their economic well-being.

Keywords: Artisanal Fish species catch, Sustainable fishing, food security, Nigeria.

1. Introduction

Sustainability has garnered significant research attention globally, particularly in agriculture (Adomako et al., 2023; Hermundsdottir, Aspelund, 2022). The United Nations Sustainable Development Goals (SDGs) emphasise the need for policy interventions to address socio-economic challenges such as food insecurity, poverty, and hunger (United Nations, 2015). Sustainability, characterised by a balance between environment, equity and economy, aims to foster thriving, resilient communities (UCLA Sustainability Charter, 2016). Implementing sustainable practices enhances energy efficiency and environmental improvement (Liu et al., 2020) and organisational competitiveness (Yao et al., 2011).

Recent FAO assessments and the State of the World Fisheries Report reaffirm that small-scale fisheries are indispensable to local diets and livelihoods (Thanh, 2021). These reports emphasise governance models that conserve fish stocks, while ensuring access for vulnerable populations. The Kunming-Montreal Global Biodiversity Framework (GBF) (Convention on Biological Diversity [CBD], 2022) and IPBES syntheses sharpen this debate, urging a shift from

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Received: 01 March 2025 Revised: 11 July 2025, 20 October 2025 Accepted: 25 October 2025
Published: 30 December 2025

"conserve versus feed" to "conserve and feed." The GBF's ambitious 30x30 conservation target shows the scale of environmental commitments, yet scholars warn that spatial protection without social safeguards risks imposing disproportionate burdens on the poorest communities.

Emerging literature on trade-off analytics offers pathways out of these zero-sum dilemmas. Systems and spatial trade-off models demonstrate how ecological, nutritional, and economic objectives can be balanced. For example, aligning seasonal closures with local production cycles, protecting critical habitats while supporting alternative livelihoods, or investing in aquaculture where wild stocks are under stress. Central to these approaches is the integration of local knowledge with spatially explicit conservation and food-system modelling (Von et al., 2024), thereby ensuring that biodiversity targets do not unintentionally undermine dietary security for populations dependent on artisanal fisheries (Nuer et al., 2024).

In Nigeria, fishing is a critical economic activity, contributing 1.09 % to the national Gross Domestic Product (GDP) in 2020 (Odioko, Becer, 2022). The country ranks second in African fish production, with an estimated 1,477,651 individuals employed across the fisheries value chain (Posthumus et al., 2018). Artisanal fishing, characterised by small-scale operations using simple equipment (Martins, Carneiro, 2021), is labour-intensive, capital-limited, and often conducted in remote areas with poor infrastructure (Omorinkoba et al., 2011). Key species harvested include finfish (catfish, tilapia) and shellfish (molluscs, shrimps) (Kareem et al., 2013).

Artisanal fishing significantly influences livelihoods, nutrition, and local economies (Harper et al., 2013). However, the sustainability of this sector faces threats from overfishing (Sumaila, Tai, 2020), destructive methods (Amos, Peter, 2018), climate change (Bryndum-Buchholz et al., 2021), inadequate regulation (Egesi, 2016), and limited community awareness (Amos, Peter, 2018). Preserving fish populations is now an urgent necessity due to global environmental degradation (Munang et al., 2011). While sustainability and food security exhibit a bidirectional relationship (Singh et al., 2024), the sustainability of artisanal fisheries and its impact on food security remains a concern. Understanding the link between sustainable fish catch and food security is crucial for developing effective management strategies.

This study explores the relationship between artisanal fish species catch and sustainable fishing practices in Osun State, Nigeria, recognising their direct and indirect effects on food security. By examining this nexus, the research aims to unravel the human and ecological factors shaping fisheries' dynamics and sustainable practices. This research contributes to SDGs 3, 8, 9, 12, 14, and 17, promoting health, economic growth, innovation, responsible consumption, life below water, and partnerships.

2. Methods and materials

Research Philosophy

The study is rooted in the positivist research philosophy. The study's choice of positivism is based on the assumption that reality is objective, observable, and measurable through systematic inquiry. Positivism emphasises empirical evidence, statistical testing, and causal explanation (Ali, 2024; William, 2024), making it well-suited to investigating the relationships among artisanal fish species catch, sustainability practices, and food security in Osun State, Nigeria. Within this paradigm, knowledge is generated by formulating hypotheses, collecting quantifiable data, and applying rigorous statistical models to validate or refute assumptions (Bibi et al., 2022). The use of structured questionnaires, Seemingly Unrelated Regression (SUR), and binary logistic regression reflects a commitment to objectivity and generalisability. These methods enable the study to identify significant associations among socio-economic characteristics, sustainability practices, and food security outcomes while minimising researcher bias. The positivist stance also underpins the study's cross-sectional design and its reliance on representative sampling techniques. By employing Yamane's formula to determine sample size and stratified random sampling for respondent selection, the research ensures replicability and statistical validity.

Research Design

This study employed a descriptive-analytical cross-sectional survey design to investigate the relationship between artisanal fish species catch, sustainable fishing practices, and food security outcomes among artisanal fishers in Osun State, Nigeria. A cross-sectional design was deemed appropriate as it enables the collection of quantitative data from a defined population at a single point in time, providing a robust snapshot of current practices, demographic characteristics, and livelihood outcomes. Such a design is widely recognised in sustainability and food systems research for its efficiency in identifying associations and explanatory factors without the time and resource intensiveness of longitudinal studies. Additionally, the cross-sectional design enabled the simultaneous examination of multiple relationships while controlling for demographic and socio-economic variables (Omega et al., 2025).

Study Area

The study was a cross-sectional survey design carried out in three (3) zones in Osun State, Nigeria. Osun State is nestled in the southwestern part of Nigeria and boasts a landscape enriched with freshwater bodies: rivers, lakes, and ponds, which have nurtured artisanal fishing traditions for generations (Adelekan, Fregene, 2015). The State is located at longitude 4.5199593 and latitude 7.5628964. It shares boundaries with Ekiti and Ondo states to the east, Kwara state to the north and Ogun and Oyo states to the south and west, respectively. It experiences tropical savannah climatic conditions, with an average temperature of 64 °F and 596 inches of rainfall (Onyekuru, Marchant, 2014). The abundance of freshwater bodies and the predominance of artisanal fisheries influenced the choice of the State for the study.

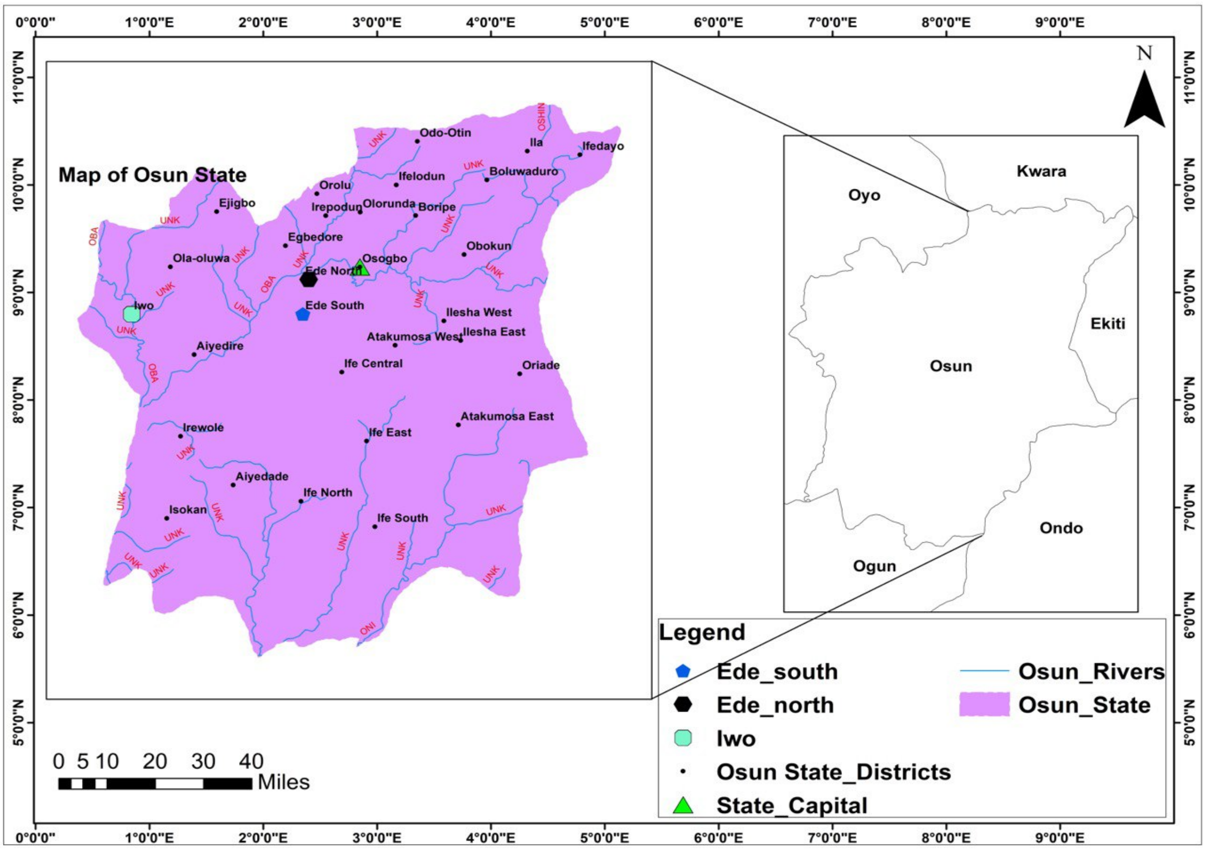

Fig. 1. Map of Osun State, Nigeria
Source: Simwa (2018)

Sampling Procedure and Sample Size

A sample size of 150 artisanal fishers was determined from a total population of 240 artisanal fishers using Yamane's (1969) formula, with a confidence interval of 95 % (Margin of error 5 %). The study population was obtained from the local fisher extension officers of the zones. To ensure methodological rigour, explicit eligibility criteria were used to define the sample. Respondents included were artisanal fishers who: (i) had been actively engaged in fishing for at least the past two years, and (ii) relied on fishing as their primary or significant source of livelihood. Excluded were part-time fishers, fish processors not directly involved in fishing, and individuals under the legal working age of 18. These criteria ensured that the sample reflected active artisanal fishing households and improved the reliability and replicability of the study.

Furthermore, a multistage sampling technique was used to collect data from the respondents. In the first stage, Osun State was stratified into three strata by local government: Iwo, Osogbo, and Ede South, based on the existing Agricultural Extension zonation prepared by the Extension Department in the area. In stage two, simple random sampling was used to select one community from each of the three (3) zones, given the homogeneity of artisanal fishers across the zones. Finally, simple random sampling was used to select 50 artisanal fishers from each of the three communities (Ede, Iwo, and Osogbo), for a total of 150.

Data Collection

Data collection was conducted through structured questionnaires administered by five trained research assistants from the University of Ibadan who spoke Yoruba. To enhance the accuracy and reliability of responses, the questionnaire was pre-tested in Ede North Local Government Area (Oja Timi), and necessary adjustments were made. Data collection occurred between April and June, 2020. Data collection was conducted face-to-face in Yoruba. Ultimately, 129 completed questionnaires were retrieved, representing a response rate of 86 %. The survey instrument gathered information on demographic characteristics, fishing practices, species harvested, sustainability practices, and food security. Food security status was measured using the Household Food Insecurity Access Scale (HFIAS), developed by the Food and Nutrition Technical Assistance (FANTA) Project. This internationally validated tool captures the multidimensional nature of food insecurity by assessing household-level access, availability, and adequacy of food. Household Food Insecurity Access Scale comprises nine occurrence questions with frequency-of-occurrence responses coded as rarely (1), sometimes (2), or often (3). Scores are summed to give a continuous index ranging from 0 (food secure) to 27 (severely food insecure). Households are then classified into four categories: food secure, and food insecure, comprising mildly food insecure, moderately food insecure, and severely food insecure.

Sustainability was measured in terms of environmental, social, and economic. Environmental sustainability had eleven (11) indicators, economic sustainability (10) and social sustainability (10), which were obtained from the literature. Sustainable fishing practices were measured on a 10-point Likert scale from 1 (very slowly) to 10 (very highly), with 0 = not applicable/can't tell.

Table 1. Reliability Test Results

Subscale	Number of questions	Cronbach's Alpha Value	Cronbach's Alpha Value based on standardised items
Food security	9	0.931	0.930
Social Sustainability	10	0.840	0.840
Economic Sustainability	10	0.610	0.733
Environmental Sustainability	11	0.793	0.835

The reliability test revealed that the Cronbach's alpha value for the food security and sustainability indicator met the minimum threshold of 0.70 proposed by Van Schoor (2010), as shown in Table 1. Thus, the constructs are appropriate to measure food security and sustainability.

Data Processing and Analysis

Data collected from the structured questionnaires were first screened for completeness and consistency before analysis. Data entry and cleaning were performed using Stata 15.0 statistical software. Continuous variables such as age, education, household size, and fishing experience were summarised using means and standard deviations, while categorical variables were summarised using frequencies and percentages. The econometric analysis employed two main techniques: the SUR and the binary logistic regression. Model validity and robustness were confirmed using diagnostic tests. For the SUR, the Breusch-Pagan test of independence confirmed significant cross-equation correlations, justifying the use of the system estimator. For the logistic regression, model adequacy was verified through the Wald chi-square test, log-likelihood statistics, and the Hosmer-Lemeshow goodness-of-fit test. Statistical significance was considered at the 5 % level ($p < 0.05$).

For the SUR, sustainability indicators (economic, social, and environmental) were modelled as interdependent response variables, with demographic characteristics and fish species type serving as predictors. The choice of SUR was motivated by the likelihood of correlated error terms across sustainability dimensions, making single-equation models less efficient. Before estimation, multicollinearity among predictors was checked, while model fit was confirmed using the Hosmer-Lemeshow test. This operationalisation ensured that the results presented in the findings section are directly derived from the specified equations, thereby enhancing reproducibility and transparency.

Model Specification

The SUR was used to analyse the factors affecting the sustainability practice of artisanal fishers in the study area**.** The SUR model follows Mokumako (2023), in which stacked general linear models serve as the backbone of the SUR framework, which is limited by its stochastic specification and by the linear relationships between response variables and covariates (Taylor, McGuire, 2005). Model specifications in Zellner's SUR framework are organised into blocks, which are systems of m > 1 equations, and T observations each (Peremans, Stefan, 2018), indicating the i^{th} cell in the matrix as:

$$y_i = X_i\beta_i + \varepsilon_i \qquad i = 1, \dots, m \tag{1}$$

Where y_i and ε_i are T-dimensional vectors, X_i is $T \times K_i$ and βi is a K_i-dimensional vector. Stacking all m equations gives:

$$\begin{bmatrix} y_1 \\ y_2 \\ \vdots \\ y_m \end{bmatrix} = \begin{bmatrix} X_1 & 0 & \cdots & 0 \\ 0 & X_2 & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & X_m \end{bmatrix} \begin{bmatrix} \beta_1 \\ \beta_2 \\ \vdots \\ \beta_m \end{bmatrix} + \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \vdots \\ \varepsilon_m \end{bmatrix}$$

Which compact to be written as: $y = X\beta + \varepsilon$ (2)

Where, y = a vector of the observed values of the response variable, X = a vector of predictor variables, β = a K-dimensional vector of the regression parameters, and $K = \sum_{i=1}^{m} K_i$. ε = constitutes its error term. For the mT X 1 vector of stacked disturbances, the assumptions are that $E\ (\varepsilon_j) = 0$, and cov $E(\varepsilon_i \varepsilon_j) = \sigma_{ij} I_T$, where T represents T X T an identity matrix. According to these presumptions, the T disturbances in each of the m equations are independent, with a mean of zero and a variance of one (Baltagi, 2008).

In this study, the dependent variables in the SUR framework were the three sustainability dimensions of artisanal fishing: environmental, economic, and social. Each of these dimensions was measured as a continuous variable derived from composite indices reflecting fishers' practices and perceptions (Table 1). The decision to model these three sustainability outcomes simultaneously rather than independently rests on both conceptual and statistical grounds. Conceptually, the three sustainability dimensions are inherently interlinked: for instance, adopting environmentally friendly fishing practices may reduce immediate income but enhance long-term ecological stability, while socially cohesive practices can reinforce both economic and ecological outcomes. Statistically, the disturbance terms across the three equations are likely to be correlated, since unobserved factors such as institutional capacity, cultural norms, or climatic variability can simultaneously influence all dimensions of sustainability. The SUR framework is therefore appropriate, as it not only improves efficiency by accounting for contemporaneous correlation among error terms but also allows for the identification of cross-effects between sustainability dimensions. This approach is consistent with Zellner's (1962) original formulation, in which seemingly unrelated outcomes are best analysed jointly to capture shared influences and reduce bias in parameter estimates. In this context, treating environmental, economic, and social sustainability as a system of equations ensures a more holistic and rigorous evaluation of artisanal fishers' sustainability practices.

Binary logistic regression was used to analyse the effect of artisanal fish species catches on sustainable fishing and food security. Although food security can indeed be conceptualised along a spectrum, from mild to severe insecurity, this study employed a binary logistic regression model for both methodological and contextual reasons. The Household Food Insecurity Access Scale (HFIAS) data were reclassified into two categories: food secure and food insecure, consistent with widely used approaches in food security research (Azam et al., 2022; Dwomoh et al., 2023; Worku et al., 2022), where the emphasis is on identifying whether households cross the threshold into insecurity rather than the intensity of that insecurity. This binary operationalisation aligns with the study's core policy objective of distinguishing artisanal fishers who are food secure from those who are not, thereby simplifying the translation of findings into actionable interventions. While multinomial or ordered models may capture nuance, the binary approach provides sharper, policy-relevant insights without compromising statistical reliability. Additionally, it allows us to estimate the probability of artisanal fishers being food secure or otherwise. The dependent variable, food security, was categorised into 1 = food secure, and 0 = food insecure. The general form of the logistic function is given as;

$$p(x) = \frac{1}{1+e^{-(B_0+B_1 x)}} \quad (3)$$

Where $ß_0$ is the intercept and $ß_1$ is the slope of the log odds as a function of x. Due to the logit transformation linking the dependent variable to the independent variables, the logit link will be of the form; Logit (p_i) = log $(\frac{p_i}{1-p_i})$ (4)

Where, Logit (p_i) = the odd of the event occurring, p_i= the probability that the event will occur, and 1- p_i= the probability of the event not occurring.

Given; p_i= Pr(Y=1|$X = x_i$), the outcome variables are written in the form;

$$\Pr(Y_i=y|X = x_i)= \begin{cases} p_i & if\ y = 1 \\ 1 - p_i & if\ y=0 \end{cases}$$

y = 1, indicates the artisanal fisher is food secure and y = 0 implies the artisanal fisher is food insecure (sometimes, rare and often). Then the logistic model is written as;

$$\text{Logit}(p_i) = \log\left(\frac{p_i}{1-p_i}\right) = ß_0 + ß_1 X_1 + \ldots + ß_n X_n + e \quad (5)$$

Where X_1... X_n = Independent Variables and e = Error term

The odds are captured as;

$$\frac{p_i}{1-p_i} = \exp(ß_0 + ß_1 X_1 + \ldots + ß_n X_n + e) \quad (6)$$

The dependent variables used and their aprior expectation are captured in Table 2 as:

Table 2. Variables and A Priori Expectations

Variables	**Definition and Measure**	**A Priori Expectations**
Food Security	Food security status of respondents. Dummy; 1 = food secure, and 0 = food insecure	
Environmental Sustainability	Perceived practices that protect the environment; Continuous variable	+
Economic Sustainability	Perceived practices that promote resource growth and the well-being of respondents; Continuous variable	+
Social Sustainability	Perceived practices that protect and promote societal well-being and interaction; Continuous variable	+

Variables	Definition and Measure	A Priori Expectations
Catfish (catch type)	Fishes that belong to the order Siluriformes. Dummy; 1-yes 0-no	+
Carp (catch type)	Fishes that belong to the family Cyprinidae. Dummy; 1-yes 0-no	+
Tilapia (catch type)	Fishes that belong to the family Cichlidae. Dummy; 1-yes 0-no	+
Others (catch type)	Other families of fishes other than the stated. Dummy; 1-yes 0-no	+
Marital Status	Relationship status of respondents. Dummy; 1-married, 0-otherwise	+/-
Sex	Biological makeup of respondents. Dummy; 1-Male, 0-otherwise	+/-
Age	Years at last birthday. Measured in years	+
Education	Years of schooling. Measured in Years	+
Status in household	Position in the household. Dummy; 1-Head, 0-otherwise	+
Fishing Experience	Years of being an artisanal fisher. Measured in years	+
Reason for fishing	Motivation for being an artisanal fisher. Dummy; 1-Income, 0-otherwise	+
Access to credit	Ability to obtain credit from a financial institution for artisanal fishing activities. Dummy; 1-yes, 0-otherwise	+
Household size	The number of individuals who live under a roof. Number of people under a roof	-
Fishing type	The nature of artisanal fishing carried out. Dummy; 1-Migratory, 0-otherwise	+/-

Source: Computed from Field Survey (2020)

In this study, continuous variables such as age, years of education, fishing experience, household size, and sustainability indices were analysed in their natural measurement scales. Standardisation or transformation was not applied, as the objective was to preserve the interpretability of coefficients in terms of the original units, which is essential for policy relevance.

The effect sizes (η^2) as reported in Table 3 were interpreted using conventional benchmarks recommended in the social and behavioral sciences (Cohen, 1988; Richardson, 2011). Specifically, values between 0.01 and 0.05 were considered small, values between 0.06 and 0.13 were considered moderate, and values greater than 0.13 were considered large. These thresholds provide a standardised way to evaluate the magnitude of association between fish species caught and food security status, beyond mere statistical significance.

Ethical Considerations

This study was reviewed and approved by the Institutional Review Board of the University of Ibadan, Nigeria, in line with national ethical guidelines and the principles of the Declaration of Helsinki. All respondents were fully informed about the objectives of the research, their right to decline or withdraw at any time, and the voluntary nature of participation. Verbal informed consent was obtained before administering the questionnaires. To protect confidentiality and anonymity, no identifying information was recorded, and all responses were treated with strict confidentiality for research purposes only. Given that fieldwork occurred during the COVID-19 pandemic (2020), all research activities adhered to Nigeria Centre for Disease Control (NCDC) and World Health Organization (WHO) COVID-19 safety protocols. These included the use of face masks, physical distancing, hand sanitisation, and minimising group interactions during data collection to ensure the safety of both respondents and research assistants.

3. Results

Demographic Characteristics of Respondents

Table 3 presents the summary statistics of the demographic characteristics of the respondents. It indicates that the majority of the artisanal fishers sampled are male (71.9 %), a common feature in many fishing communities globally. The majority 77 % of the fishers are married, as marriage is often seen as a stabilising factor in fishing communities. Also, the vast majority of respondents fish for income (89.4 %), indicating the economic reliance on fishing as the main livelihood. Again, a considerable portion of respondents engage in migratory fishing (57.9 %), a practice that allows fishers to follow seasonal fishing stocks and optimise catch. This type of fishing is often associated with higher risks but can yield better income, compared to stationary fishing. The low access to credit (19 %) is a serious barrier for fishers and may affect their livelihood. The high percentage of those without credit access suggests limited financial inclusion, which can stifle progress.

Table 3. Summary Statistics of Demographic Characteristics of Respondents

Variable	**Category**	**Frequency (n = 129)**	**Percentage**
Sex	Male	91	70.54
	Female	38	29.46
Marital status	Married	97	75.19
	Otherwise	32	24.81
Status in household	Head	92	71.32
	Otherwise	37	28.68
Reason for fishing	Income	110	85.27
	Otherwise	19	14.73
Fishing type	Migratory	73	56.59
	Otherwise	56	43.41
Access to credit	Yes	30	23.26
	No	99	76.74
Continuous Variables		**Mean**	**SD**
Age		36.97	13.51
Education		10.65	3.59
Fishing Experience		15.27	9.31
Household Size		6.61	3.07

Source: Computed from Field Survey (2020)

Also, the average age of respondents is 37 years, suggesting that the population engaged in artisanal fishing is relatively young. Furthermore, the average artisanal fisher spends 11 years schooling and 15 years fishing, indicating that the fishers have extensive experience in fishing. Household size averaging 7 members is common in rural and fishing communities.

Fish Species caught by Artisanal Fishers and food security status

Table 4 shows that the artisanal fishers' food security status is different depending on the kind of fish they catch. Compared to other types of fish caught, artisanal fishers who specialise in harvesting African catfish, silver catfish, and Tilapia guineansis are more likely to be food secure. The ability of artisanal fishers to catch in-demand fish varieties contributes to increased income, allowing them to purchase a diverse range of food products.

The effect size demonstrates that the proportion of variance in food security explained by the type of fish caught varies by size. Significant variables, such as Heterobranchus longifilis (Sampa), Ctenopharygodon idella (Grass carp), and Tilapia guineensis, had moderate effects on food security.

Sustainability Practices of Artisanal Fishers

Table 5 shows the economic sustainability practices of artisanal fishers. The mean score for the economic sustainability questions posed to artisanal fishers was 7.26 (SD-2.55), as shown in Table 4. This suggests that the majority of artisanal fishermen prioritise economic sustainability in their operations. Most of the fishers were aware of the economic aspects of their work, thereby actively engaging in practices to promote sustainability.

Table 4. Test of Fish Species caught by Artisanal Fishers and food security status

Type of fish Caught	Fish Caught	Food Security Status		t-value	p-value	Eta-square	Effect Size
	Yes (%)	No	Yes				
Catfish							
Heterobranchus bidorsalis (African catfish)	96.6	47	82	0.237	0.813	0.003	Small
Chrysicthys nigrodigitatus (silver catfish)	91.7	53	76	0.941	0.356	0.016	Small
Clarias gariepinus (North African catfish)	86.3	61	69	0.887	0.380	0.019	Small
Heterobranchus longifilis (Sampa)	50.0	67	63	2.337	0.027*	0.082	Moderate
Carp							
Ctenopharygodon idella (Grass carp)	22.6	69	61	3.338	0.003*	0.114	Moderate
Cyprinus carpio (common carp)	50.0	67	62	2.041	0.050	0.066	Moderate
Tilapia							
Tilapia guineansis	69.0	58	71	4.916	0.000*	0.098	Moderate
Mullet (Mugil cephalus)	8.0	69	60	0.549	0.588	0.023	Small
Tilapia zillii	62.5	66	64	1.444	0.159	0.046	Small
Others							
Heterotis niloticus	43.3	69	61	0.273	0.787	0.010	Small
Oreochromis niloticus (Nile Tilapia)	89.6	63	67	1.664	0.103	0.026	Small

Source: Computed from Field Survey, 2020; *$p < 0.05$ Effect Size: 0.01-0.05-Small 0.06-0.13-Moderate > 0.13-Large; n = 129

Table 5 presents the social sustainability practices of artisanal fishermen. It shows that the average score for artisanal fishers' social sustainability index is high (Mean-7.34, SD-2.10). This suggests that artisanal fishers actively participate in activities that promote social sustainability in their fishing operations.

Table 5. Sustainability Practices of Artisanal Fishers

Economic Sustainability	Mean	SD	Interpretation
Economic gains when employing sustainable fishing practices are not convincing	6.18	3.72	Moderate
Sustainable fishing can improve income	8.42	2.18	High
Net fishing income may decrease when a fisherfolk implements sustainable fishing practices	4.35	3.61	Moderate
There may be insufficient labour for the workload required in sustainable fishing	4.65	3.32	Moderate
The primary goal of fishing should be to maximise the catch, efficiency, and profitability of their fishing	8.32	2.00	High
Fish caught will increase only if there is a reduction in mesh	6.12	3.82	Moderate

Economic Sustainability	**Mean**	**SD**	**Interpretation**
size			
Practicing sustainable fishing leads to employment	8.29	2.34	High
Sustainable fishing leads to value for money	8.70	1.40	High
Sustainable fishing makes fish catch profitable	8.76	1.65	High
Sustainable fishing will lead to economic growth	8.83	1.41	High
Composite	**7.26**	**2.55**	**High**
Social Sustainability			
Sustainable fish catch should produce an adequate food supply to feed the world population	7.71	2.36	High
Adoption of sustainable fishing practices will be easier for fisherfolks who have both cropped and livestock enterprises	7.91	2.75	High
Sustainable fishing practices would work well on any water body	7.46	2.74	High
Sustainable fishing practices may require additional management beyond conventional practices	8.22	2.09	High
Fishersfolks in sustainable fishing lives more in harmony with nature	8.11	2.18	High
Practicing sustainable fishing promotes health and education of workforce and local fishing community	8.36	2.30	High
Practicing sustainable fishing promote positive image of the local fishing community	8.56	1.96	High
Non-sustainable fishing is a serious threat to my health and the health of future generation	8.42	2.31	High
Sustainable fish product is healthier for consumption	8.65	2.30	High
Sustainable fishing is a source of healing, inner peace and inspiration	8.41	2.47	High
Composite	**7.34**	**2.10**	**High**
Environment Sustainability			
The best way to control overfishing is to use sustainable fishing methods	8.58	2.33	High
Recommended fishing methods for sustainable fishing have potential for more fish health challenges	7.62	3.30	High
An advantage of sustainable fishing practices is reduction in the use of chemical in fishing	8.75	2.48	High
Sustainable fishing practices help protect the environment and natural resources	8.91	2.09	High
Application of fish aggregating devices is not necessary in sustainable fishing	7.36	3.23	High
Sustainable fishing can reduce fish loss and by catch	8.45	2.43	High
Environmental balance is one basis for sustainable fishing practices	8.78	1.94	High
Sustainable fishing makes the most efficient use of sustainable fishing method to preserve fish and other natural resources	8.66	2.38	High
I often return unwanted and under size fish back into the river	5.90	4.07	Moderate
If you realised your fishing method is harmful to the environment, will you stop fish catch	7.51	3.56	High
I am actively involved in political and social actions to protect the natural environment	6.67	3.94	Moderate
Composite	**8.72**	**3.18**	**High**

Source: Computed from Field Survey (2020); n=129 1-3.99 (Low), 4-6.99 (Moderate) and 7-10 (High)

Furthermore, Table 5 shows the environmental sustainability practices of artisanal fishermen. It shows that artisanal fishers have a high mean score of 8.72. (SD-3.18) for practicing environmental sustainability. The high mean score indicates that, on average, artisanal fishers prioritise environmental sustainability in their fishing practices, and recognise the importance of environmental protection for the long-term viability of their livelihoods and ecosystems.

Correlation of Sustainability Indicators

Table 6 shows the correlations between sustainability indicators. The findings indicate that there is a strong positive correlation among the various sustainability indicators. The strong positive correlation indicates that the sustainability indicators are closely related and tend to move together. This implies that improvements or deterioration in one aspect of sustainability are likely to be reflected in others. The interlinked relationships among the sustainability indicators underscore the need to use the SUR rather than other regression forms.

Table 6. Correlation of Sustainability Indicators

Sustainability Indicators	**1**	**2**	**3**
Economic	1		
Social	0.531*	1	
Environmental	0.525*	0.700*	1

* $p < 0.05$

Factors Influencing Sustainability Practices

The SUR results for the factors influencing artisanal fishers' sustainability practices are presented in Table 7. It shows that gender influences how fishers prioritise and act on various aspects of sustainability. Environmental sustainability often takes a back seat to the priorities of male fishers, who seem more concerned with economic and, to a lesser degree, social sustainability.

Table 7. SUR results of factors Influencing Sustainability Practices

Variables	**Environmental**		**Economic**		**Social**	
	Coef.	**Std. Err**	**Coef.**	**Std. Err**	**Coef.**	**Std. Err**
Sustainability						
Environmental			17.138*	6.480	1.138*	0.231
Economic	4.822	5.297			-0.444	0.227
Social	2.306	4.671	-20.291*	5.705		
Fish Species Type						
Catfish	10.258	8.060	5.774	7.575	-0.136	0.298
Carp	-48.621	25.042	6.639	24.680	1.285	0.848
Tilapia	9.362	8.109	10.236	7.594	0.200	0.291
Others	30.759*	10.531	-18.304	10.116	-1.098*	0.469
Demographics						
Marital Status	-5.519	7.884	-3.074	7.352	0.312	0.362
Gender	-31.097*	8.476	21.906*	7.727	1.373*	0.362
Age	0.002	0.236	0.532*	0.234	0.008	0.010
Education	0.131	0.894	1.827*	0.741	0.026	0.033
Status in household	-7.888	6.186	6.589	6.314	0.272	0.255
Fishing Experience	1.965*	0.448	-1.080*	0.453	-0.075*	0.022
Reason for fishing	-10.459	9.658	-4.176	8.971	0.308	0.344
Access to credit	47.352*	11.864	15.120	14.399	-0.551	0.559
Model Specification						

Variables	Environmental		Economic		Social	
Observation	129		129		129	
Parameters	14		14		14	
RMSE	14.524		12.819		0.552	
R-Square	0.995		0.993		0.997	
F-stat	286.22		186.80		528.39	
P-value	0.000		0.000		0.000	

Source: Computed from Field Survey (2020); *p < 0.05; n = 129

The results also reveal that newer fishermen are more likely to participate in sustainability practices related to economics and society. In contrast, more seasoned fishermen are more likely to practice environmental sustainability. This outcome emphasises the complex relationship between fishers' experiences and their adoption of sustainable practices. While more seasoned fishermen emphasise environmental sustainability as they gain life experience, new fishermen may be more concerned with social and economic sustainability as they build their careers and provide for their families.

Economic sustainability appears to be the most important form of sustainability to older fishers, according to the positive relationship. It seems that older fishers are more focused on tactics and activities such as making the most efficient use of their available resources to help them financially in the fishing business. Environmental sustainability, as opposed to other types, is more common among artisanal fishers who have access to financing. When fishermen have access to credit, they can invest in environmentally friendly practices like sustainable fishing, equipment upgrades, and habitat restoration.

The result further shows that low-educated fishers prioritise economic sustainability over other types of sustainability. This shows that educational opportunities have a substantial impact on fishermen's perspectives, understanding, and actions concerning economic decision-making in the fishing industry. More educated fisherfolk may be less concerned about the long-term viability of the industry than those with less education, because they may have other options for making a living besides fishing.

Table 8 shows the follow-up test of the SUR. The low correlational values detected indicate that the dataset contains no highly correlated variables. This suggests that the regression model's independent variables are not redundant or highly interrelated, which is required for accurate regression coefficient estimates. The absence of multicollinearity improves the model's interpretability and reduces the likelihood of inflated standard errors or unstable parameter estimates.

Table 8. Correlation matrix of residuals of sustainability

	1	2	3
Environmental	1		
Economic	0.206	1	
Social	0.448	0.149	1

Breusch-Pagan test of independence: chi2(3) = 4.774, Pr= 0.189

The Breusch-Pagan test of independence was used to test for heteroskedasticity in the study, and the results show that there is no heteroskedasticity (p-value greater than 0.05). This implies that the variance of the errors in the regression model remains constant across different levels of the independent variables. The absence of heteroskedasticity ensures that the regression coefficients' standard errors are unbiased and consistent, allowing for valid statistical inference. The absence of multicollinearity and heteroskedasticity improves the reliability and validity of the regression model. These tests ensure that the model meets the key assumptions of classical linear regression, thereby increasing confidence in the model's robustness and the accuracy of its conclusions.

Food Insecurity Among Artisanal Fishers

Figure 2 depicts respondents' responses to food insecurity scale constructs. The result indicates that 43 % of respondents were food secure, while 57 % experienced various levels of food insecurity. This finding suggests that factors such as limited access to food resources, insufficient income, and a lack of social support play a significant role in household food insecurity.

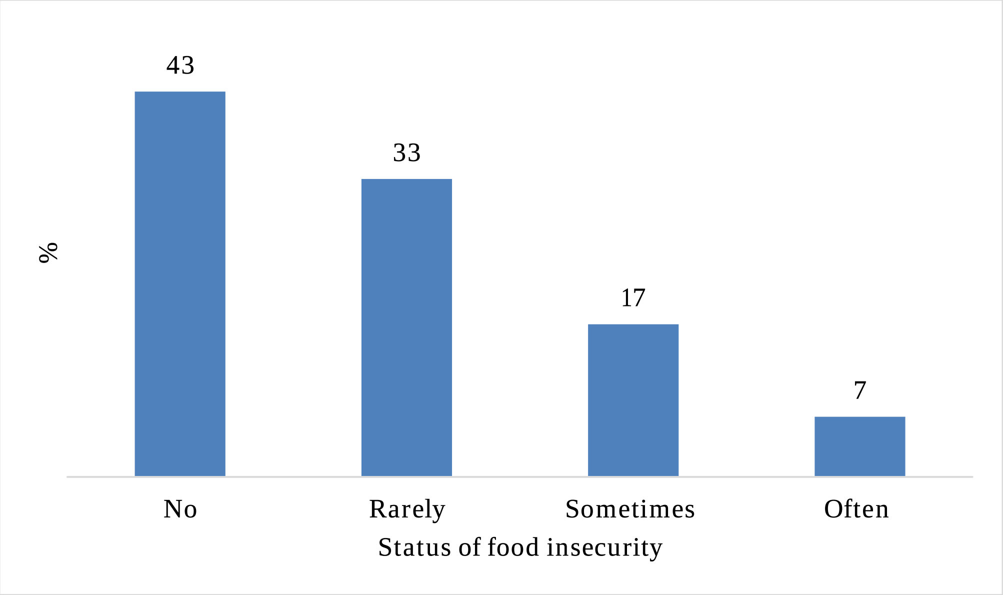

Fig. 2. Occurrence of food insecurity among Artisanal fishers

Effect Of Fish Species Catches and Sustainable Fishing on Food Security

Table 9 presents the binary logistic regression results on the effect of artisanal fish species catch and sustainable fishing on food security. The model's significance, combined with the goodness-of-fit assessment, provides evidence that the logistic regression model is valid in predicting food security. Beyond the Hosmer–Lemeshow test, the sensitivity-specificity classification plot (Figure 3) demonstrates that the logistic regression model has reasonable discriminative ability. At probability thresholds between 0.65 and 0.75, both sensitivity and specificity exceed 0.75, suggesting the model effectively balances the identification of food-secure and food-insecure artisanal fishers. This strengthens the evidence that the model is both well-calibrated and practically useful for policy targeting.

Artisanal fishers who prioritise social sustainability practices benefit from improved food security. According to the marginal effect of social sustainability, artisanal fishers who participate in social sustainability activities improve their food security status by an average of 1.9 %.

Table 9. Effect of fish species catches and sustainable fishing on food security

Food Security	**Odd Ratio**	**Std. Err**	**dy/dx**	**Std. Err**
Sustainability				
Economic	0.937	0.043	-0.007	0.005
Social	1.185*	0.093	0.019*	0.007
Environmental	0.908	0.055	-0.011*	0.005
Fish Species				
Catfish	34.214*	42.452	0.387*	0.085
Tilapia	0.235	0.249	-0.159	0.150
Demographics				
Household size	0.942	0.268	-0.007	0.030
Education	1.213*	0.115	0.021	0.013
Credit	0.389	0.549	-0.104	0.177
Fishing Experience	1.024	0.049	0.003	0.005
Fishing type	0.732	1.002	-0.034	0.152
Model Specification				

Food Security	**Odd Ratio**	**Std. Err**	**dy/dx**	**Std. Err**
Observations	129			
Wald chi2(10)	20.46			
Prob>chi2	0.0252			
Log pseudolikelihood	-11.165			
Hosmer-Lemeshow chi2(8)	4.23			
Prob>chi2	0.836			

Source: Computed from Field Survey (2020); *$p < 0.05$; $n = 129$

In contrast, environmental sustainability practices have a negative impact on artisanal fishers' food security status. The marginal effect suggests that engaging in environmental sustainability activities is less likely to result in a 1.1 % decrease in food security status. This reflects trade-offs or challenges associated with implementing environmental conservation measures, such as fishing practice restrictions or changes in fishing locations, which may have an impact on artisanal fishers' food availability or livelihood opportunities.

The type of fish species targeted by artisanal fishers has a significant impact on food security. Artisanal fishers who primarily fish for catfish have a 38.7 % higher chance of improving their food security than those who target other species. This suggests that certain fish species may have higher nutritional value, greater market demand, or greater resilience to environmental change, resulting in better food security outcomes for artisanal fishers who rely on them as their primary source of income and subsistence.

Years of education were positively associated with food security, with each additional year increasing the odds of being food secure by 21.3 % (OR = 1.213, $p < 0.05$). However, the marginal effect was small (2.1 % points) and not statistically significant. This discrepancy reflects the non-linear transformation from odds to probabilities, whereby increases in education improve the odds of food security but yield only modest changes in the predicted probability given the sample's baseline conditions.

4. Discussion

The demographic characteristics of artisanal fishers reveal a relatively homogenous profile. Quantitatively, 71.9 % of respondents were men, predominantly engaged in direct fishing due to the physical demands of the activity, while women, as supported by qualitative evidence in prior studies, contribute significantly through post-harvest and processing roles (Pickett, Hofmans, 2019; Stacey et al., 2019). Collaborative efforts between spouses are common in small-scale fisheries, reinforcing household resilience (Locke et al., 2017). However, the reliance on fishing as the primary income source (Agbeja et al., 2019) increases economic vulnerability and drives migratory fishing, particularly when local fish stocks decline (Asiedu et al., 2022). Larger household sizes, averaging nearly 7 members in this study, further intensify fishing pressure, creating the risk of overfishing as families strive to sustain livelihoods (Knudsen, 2016). These findings suggest that household dynamics and gendered labour divisions must be explicitly considered in fisheries policies. For example, extension services could design gender-responsive training and provide family-centred livelihood diversification programs to reduce dependence on migratory fishing.

The study revealed that catfish and tilapia are the most commonly caught fish varieties among artisanal fishers. Consistent with Burchi and De Muro (2016) and Iyiola and Jenyo-Oni (2023), the findings suggest a positive relationship between income generation in the fishing sector and food security. However, significant differences in food security were observed only for Heterobranchus longifilis (Sampa), Ctenopharyngodon idella (Grass carp), and Tilapia guineensis, indicating that specific fish species have varying impacts on artisanal fishers' food security. Therefore, the type of fish caught plays a crucial role in determining food security outcomes. Factors such as market demand, cultural preferences, and the ecological characteristics of each fish species can significantly influence their effect on food security (Smith, 2023; Sogbesan, Kwaji, 2018). This indicates the need for policy interventions that encourage the cultivation and conservation of nutritionally and economically strategic species such as catfish and tilapia, while also supporting biodiversity to reduce overreliance on a narrow range of species.

This study examined the sustainability practices of artisanal fishers across economic, social, and environmental dimensions. The observed economic sustainability practices align with the findings of Nunoo et al. (2015) and Begossi (2014), which indicated the critical role of economic sustainability for the survival and prosperity of artisanal fishers. Regarding social sustainability, the study revealed a multifaceted approach that considers health, community image, and the practical challenges of implementing sustainable practices. These findings are consistent with de Lara and Corral (2017), who state that social sustainability in this sector involves participatory planning, local knowledge sharing, and collaborative decision-making. Addressing both intrinsic motivations and external constraints is crucial for promoting socially responsible fishing practices. However, the study also revealed a disparity between artisanal fishers' environmental awareness and their actual practices. While environmental sustainability is valued, it is not consistently reflected in their fishing activities. This divergence suggests a potential area for targeted interventions, such as training and resource provision, to align actions with environmental values. Promoting selective fishing practices and educating fishers on the importance of returning undersized fish can help maintain healthy fish populations.

The SUR analysis underscores the need to address gender disparities and promote gender-inclusive approaches to sustainability initiatives in fisheries management and conservation. This aligns with findings by Meinzen-Dick et al. (2014) and Muallil et al. (2013), who demonstrated gender's significant role in shaping sustainability contributions. Furthermore, the study indicates that fostering intergenerational knowledge sharing can enhance the sustainability of fisheries. This finding is supported by Kelty and Kelty (2011), who found that fishers value natural resources and are concerned about the impacts of development. Experienced fishers, possessing greater insight into market opportunities and risk mitigation, contribute to long-term financial viability. However, Lloret et al. (2018) note that economic pressures, particularly among younger fishers facing limited profitability and alternative job opportunities, can prioritise economic gains over ecosystem sustainability. Education levels also influence fishers' perspectives. Higher education is associated with greater awareness of social and environmental issues, potentially leading to greater prioritisation of sustainability. Therefore, efforts to improve economic sustainability should consider fishers' educational backgrounds and tailor interventions accordingly. Lloret et al. (2018) further emphasise that limited alternative employment options, aligned with fishers' skills and aspirations, reinforce the tendency to prioritise economic needs over long-term sustainability. These findings suggest that policies must be differentiated: youth-targeted programs could emphasise long-term environmental benefits while simultaneously addressing immediate livelihood concerns, and education initiatives should integrate sustainability literacy into both formal and informal training.

Findings indicate that social initiatives, including community engagement, equitable resource distribution, and access to support networks, contribute to improved food security in artisanal fishing communities. This aligns with Lang and Barling (2012), who advocate for the holistic integration of social, environmental, and economic factors for sustainable food security, which extends beyond daily caloric intake to include understanding food origins and production. Renard and Tilman (2021) further emphasise the critical role of government policies and biodiversity-based practices in promoting social sustainability and equitable food security. Supporting these findings, Jennings et al. (2016) highlight the significant role of fish species in daily nutrition and food security. Belton and Thilsted (2014) reinforce this by emphasising the importance of fish species diversity, particularly in regions with diverse food availability, and the cultural preference for indigenous fish species, which bolsters food security. Additionally, small, low-market-value fish from capture fisheries serve as a crucial economic buffer, acting as a "bank in the water" during seasonal cash shortages.

5. Limitation

The study was affected by COVID-19 restrictions, as data collection occurred during the pandemic, which made it impossible to reach all respondents. Also, the data collection process of the study took longer than expected due to the routine of artisanal fishers and the inaccessibility of some settlements in Osun state. Again, the reliance on self-reported data through structured questionnaires may have introduced self-reporting bias, as respondents could overstate or understate their fishing practices, sustainability measures, or household food security status. Also, the study recorded a non-response rate of 14 % (21 out of 150 fishers did not return questionnaires). While the overall response rate was strong, non-response bias remains possible if the views and experiences of non-participants systematically differed from those who completed the survey. Lastly, the sampling frame was drawn from lists provided by extension officers, which may not comprehensively represent all artisanal fishers in the State. This reliance raises the possibility of sampling bias, particularly if certain groups of fishers were inadvertently excluded.

6. Implications of the study

Theoretically, the study contributes to and supports the Sustainable Livelihoods Framework by demonstrating the relationships among livelihood activities, multidimensional sustainability, and food security. Additionally, the findings challenge the often-assumed synergy between environmental sustainability and food security by indicating a potential trade-off between conserving resources and meeting immediate nutritional needs. This observation adds a critical layer to existing sustainability literature and suggests that contextualised trade-off management strategies are necessary. The study also provides empirical evidence relevant to the food systems discourse, demonstrating how localised artisanal practices intersect with macro-level development challenges, including resource degradation, income insecurity, and undernutrition.

From a practical standpoint, the study has notable implications for policymakers, practitioners, and fishers. The findings indicate the need for multisectoral interventions that enhance economic and social sustainability through capacity-building, financial inclusion, and access to social services. In particular, the positive association between species diversification and food security underscores the value of species-specific support programs, especially for high-demand fish species such as catfish and tilapia.

7. Conclusion and Recommendation

Artisanal fisheries in Nigeria provide a crucial protein source, yet escalating demand threatens fish stocks, raising concerns about sustainability and food security. This study examined these dynamics in Osun State and found that Oreochromis niloticus, Chrysichthys nigrodigitatus, and Heterobranchus bidorsalis (Tilapia, Silver catfish, and African catfish, respectively) are the predominant species caught, indicating higher demand for them. Food security among fishers varies significantly based on target species. Those primarily harvesting Tilapia, Silver catfish, and African catfish exhibit higher levels of food security. Furthermore, the adoption of environmental sustainability practices can paradoxically reduce short-term food availability. Such findings indicated a broader sustainability trade-off widely debated in global scholarship: the tension between ensuring immediate food security and conserving ecosystems for future generations.

Internationally, scholars highlight that conservation policies such as fishing restrictions, seasonal bans, or gear regulations, though critical for biodiversity, can constrain livelihoods and exacerbate food insecurity in the short term. Our evidence from Osun State illustrates this dilemma at the local scale. Artisanal fishers face a difficult balancing act: ecological stewardship often entails immediate costs, while prioritising yields can undermine the long-term resilience of fish stocks. This reflects the sustainability trilemma, the need to reconcile ecological integrity, economic viability, and social well-being. However, the study also demonstrates that social sustainability practices such as collective action, community participation, and equitable access to resources can enhance food security outcomes. This aligns with global calls for context-sensitive, win-win solutions, in which food security goals are not pursued in isolation but are integrated with biodiversity conservation and social equity.

By embedding training, finance, and market-based strategies into artisanal fisheries governance, Nigeria can align local realities with global sustainability debates-protecting aquatic ecosystems while safeguarding the food and nutrition security of fishing communities. To operationalise these solutions, the study recommends that: State Ministry of Agriculture and Food Security, through the Department of Fisheries and Aquaculture, should provide training modules for artisanal fishers that combine ecological education with hands-on guidance in selective gear use, stock management, and climate-resilient practices, ensuring that environmental goals do not translate into immediate food insecurity. State Ministries such as Agriculture and Food Security, and the Ministry of Finance should provide credit schemes targeted at sustainable fishing, enabling fishers to invest in modern gear, cold storage, and habitat-friendly technologies. Financial inclusion would reduce the short-term economic costs of adopting conservation measures. Again, the State in dealing with issues of artisanal fishing should consider a multifaceted approach that enhances collaboration between stakeholders such as the Agriculture and Food Security, Ministry of Environment and its parastatals, Nigeria Communication Commission, National Population Commission, Works and Housing, Nigerian Meteorological Agency and Federal Ministry of Finance. Also, the study recommends that the Ministry of Agriculture and Food Security, through the Department of Fisheries and Aquaculture, should encourage Artisanal fishers to diversify their fishing activities to reduce the environmental impact of continuous fishing while improving their economic well-being. Furthermore, the Ministry of Agriculture and Food Security, through the Department of Fisheries, should educate artisanal fishers on the relevance of sustainable fishing and its impact on their society and food security.

8. Declarations

Ethical and informal consent statement

Consent of participating respondents was sought from the University of Ibadan and the extension agent responsible for the zones used for the study.

Consent for Publication

Not Applicable

Availability of data

Data and materials relevant to this manuscript are available upon request.

Conflict of interest statement

The authors declare no conflict of interest

Authors' contributions

S.A. O and S.O. designed and collected the study data. R.K.D and A.T.K.N analysed the data. All authors contributed to writing, reviewing, reading and approval of the manuscript.

Funding

This research received no external funding. However, the author thanks the Centre for Behaviour and Wellness Advocacy, Ghana, for providing financial support through the Institutional Open Access Publication Fund.

Acknowledgements

The study acknowledges the contribution of faculty members from the Department of Aquaculture and Fisheries, University of Ibadan, Nigeria, and the Department of Agricultural Economics and Extension, University of Cape Coast, Ghana, under the Academic Mobility Program.

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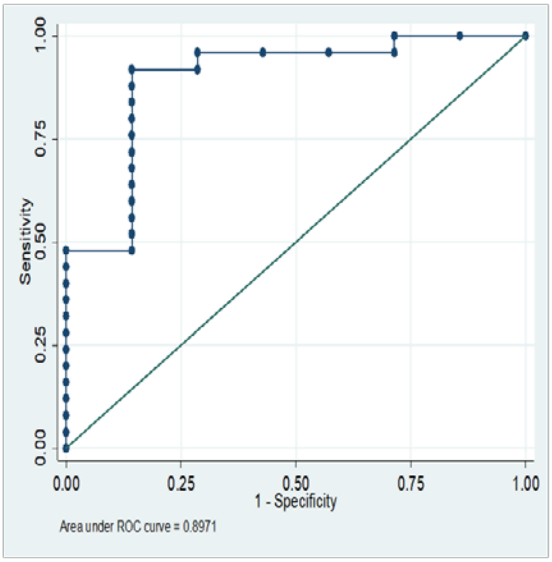
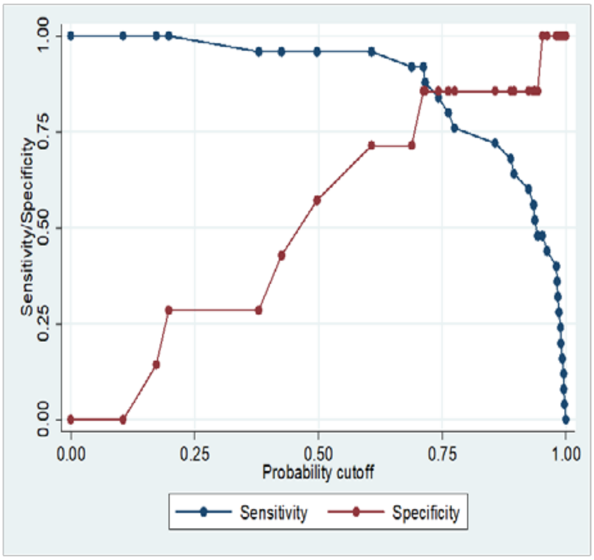
Appendix 1


Sensitivity
0.00
0.25
0.50
0.75
1.00
1 - Specificity
Area under ROC curve = 0.8971


Sensitivity/Specificity
0.00
0.25
0.50
0.75
1.00
Probability cutoff
Sensitivity
Specificity