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Assessment of climate change knowledge and ecosystem health on blue economy livelihoods in selected Niger Delta States, Nigeria

Adeyinka Richard Aroyehun[1], Michael Ige Ediabai Edaba[2] and Mercy Sor-Aniabari Joshua[3]

[1]Department of Agricultural Economics and Farm Management, Lagos State University of Science and Technology, Nigeria
[2]Department of Agricultural Economics and Extension, University of Africa, Toru-Orua, Nigeria
[3]Department of Public Health, University of Port Harcourt, Nigeria

ABSTRACT

This study investigated the determinants of climate change knowledge (CCKnw), environmental resilience (EnvRes), and participation in the blue economy among rural fishing households in selected coastal and riverine communities of Bayelsa and Rivers States in the Niger Delta region of Nigeria. Data were collected from 240 households using a multi-stage sampling technique, and the analysis employed descriptive statistics, correlation, Ordinary Least Squares (OLS), binary logit, and multinomial logit models. Results revealed moderate awareness of climate change but limited access to infrastructure, education, and financial resources, which constrained sustainable engagement in blue economy activities. The correlation and OLS analyses indicated that education, cooperative membership, government initiatives, and access to credit positively influenced EnvRes. The logit model identified government programs and trust in research institutions as key predictors of CCKnw, underscoring the importance of institutional trust and policy support in shaping adaptive responses. The multinomial model further showed that education level, age, gender, marital status, blue economy occupation, and perceptions of government policy significantly influenced household resilience. Major challenges included limited access to finance (89%), inadequate infrastructure (87%), and environmental pollution (85%). The study concludes that strengthening institutional frameworks, improving access to credit and education, and promoting gender-inclusive governance are critical to enhancing the sustainability of the blue economy and climate resilience. Policy recommendations emphasize integrated coastal management, institutional capacity building, and stronger collaboration between research and policy actors to advance equitable, climate-smart marine development in the region.

KEY WORDS

Blue economy; Climate knowledge; Environmental resilience; Logit model; MNL

ARTICLE HISTORY

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Introduction

Coastal and marine resources are the basis of livelihoods, food security and cultural identity for millions of people around the world [1]. The blue economy which implies the sustainable use of ocean and coastal resources for economic growth, improved livelihoods and ecosystem health is becoming increasingly important in policy and research [2,3]. The recent views consider blue economy activities as sources of sustainable economic growth, employment and welfare while emphasizing the need to conserve the ocean and coastal ecosystem health [4]. Indeed, the blue economy concept highlights social inclusion and ecosystem integrity as requirements for long-term coastal development and resilience [3,5].

Coastal areas in Africa are vital for national economies, but climate change is increasingly affecting them and threatening progress toward sustainability goals [6]. Increasingly, coastal erosion, saltwater intrusion, flooding, rising sea levels, increasing sea surface temperatures and habitat degradation threaten livelihoods, infrastructure and food security across West African coasts [4,7]. Moreover, continuing anthropogenic pressures, overextraction of resources, pollution and climate variability accelerate the degradation of ecosystems, thereby compromising the resilience of coastal communities that are heavily dependent on natural resources. The increasing degradation of ecosystem health is a threat not only to the ecological balance but also to jobs, household incomes and food systems, especially in developing countries where dependence on natural capital is high [8]. Hence, it has become increasingly important to evaluate ecosystem conditions along with climate knowledge to understand the long-term sustainability of blue economy livelihoods.

These global phenomena are painfully manifest in the Niger Delta region of Nigeria. The area is dominated by large mangrove forest, estuaries and fishing settlements and is still one of the most vulnerable deltaic environments in the world [6]. Sea level rise, oil spills and extreme weather events have degraded the ecological foundation on which rural livelihoods are based [9,10]. Studies have shown that communities in Bayelsa, Delta and Rivers States already face declining fish catches, loss of arable land and displacement from flooding and shoreline retreat [7,11].

Poverty, weak institutions and limited climate information continue to hinder household adaptive capacity [12]. Rural households respond through livelihood diversification and migration but adaptation is constrained by weak tenure systems and institutional support [13]. Coastal degradation has been documented in many studies, but few have integrated multiple climate dimensions with sustainable blue economy livelihoods [14]. Although there is a growing body of literature on coastal vulnerability in the Niger Delta, there has been limited effort in integrating climate change within the sustainable blue economy

***Correspondence:** Dr. Michael Ige Ediabai Edaba, Department of Agricultural Economics and Farm Management, Lagos State University of Science and Technology, Nigeria. e-mail: michaeledaba@yahoo.com

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frameworks [3,5]. Closing this gap is key to progressing Nigeria's blue economy agenda and building resilience.

The study is based on the interaction of CCKnw, environmental conditions, institutional support and socio-economic characteristics in influencing the sustainability of blue economy livelihoods among coastal households in the Niger Delta. The framework assumes that climate-related stressors like water pollution, ecosystem deterioration, flooding and climate variability, influence livelihood outcomes directly and indirectly through adaptive responses of households. Socioeconomic variables like age, education, occupation, access to credit and membership of a cooperative are expected to influence the ability of individuals to adapt to environmental change. Institutional factors, such as extension services, government support, and conflict resolution mechanisms, could further enhance or constrain resilience. Thus, Blue Economy Sustainability (BES) is regarded as an outcome of interaction of environmental, institutional and human-capital factors. Studies have shown that stronger institutions, access to information and adaptive capacity greatly enhance livelihood resilience in climate-vulnerable coastal communities [5,15].

The study is based on the Sustainable Livelihoods Framework (SLF) developed by the Department for International Development [16]. The theory explains how households use available assets, human, social, natural, physical and financial capital to pursue livelihood strategies in conditions of vulnerability and environmental uncertainty. The framework demonstrates that institutional structures, policies and external shocks impact the adaptive capacity of households and access to livelihood assets. Climate change impacts on coastal communities may restrict access to natural capital due to ecosystem degradation and pollution, and weak institutions limit adaptation options. So, the SLF provides an appropriate basis to understand the role of climate knowledge, institutional support and socioeconomic factors on BES in the Niger Delta. Other applications of the framework have shown that the main determinants of livelihood resilience are adaptive capacity and access to supportive institutions [15,17].

Materials and Methods

Study area

The broader geographical context of this study is the Niger Delta region of Nigeria, which comprises nine coastal states, known for their extensive mangrove ecosystems, rich aquatic biodiversity and significant contributions to the country's Blue Economy. However, the empirical survey was conducted only in selected coastal and riverine fishing communities in Bayelsa and Rivers states which were selected because they are among the core coastal states of the Niger Delta with extensive fisheries, aquaculture, marine transportation and other blue economy activities. These states have ecological, socio-economic and environmental features that make them appropriate for the study of CCKnw, ecosystem health and blue economy livelihoods. However, the findings of this study are confined to selected communities in Bayelsa and Rivers States and should not be generalized to the entire Niger Delta region.

The study area is characterized by extensive mangrove forest, estuaries, creeks and active fishing communities, which contribute significantly to the blue economy of Nigeria through fisheries, aquaculture, marine transportation and coastal trade. Despite their economic importance, these communities face serious environmental challenges such as oil pollution, degradation of the ecosystem, flooding, coastal erosion and rising sea levels, which continue to threaten livelihoods, the health of the ecosystem and the sustainable use of natural resources.

Research Design

A cross-sectional survey design was adopted for this study. This approach enabled the collection of primary data from respondents at a specific point in time and facilitated the analysis of relationships between socio-economic, environmental, and institutional variables influencing climate change awareness and participation in blue economy activities.

Population and sampling procedure

The study population consisted of rural fishing households located in selected coastal and riverine communities within the Niger Delta. A multistage sampling technique was used to select respondents.

In the first stage, two states were randomly selected from the region. Subsequently, three Local Government Areas (LGAs) with strong dependence on fisheries were purposively chosen from each state, resulting in a total of six LGAs. In the third stage, four fishing communities were randomly selected from each LGA, giving a total of 24 communities.

Finally, ten fishing households were selected from each community with the assistance of community leaders, resulting in a total sample size of 240 households.

The sample size was determined from a population of 5,708 using Kothari's formula, ensuring representativeness at a 95% confidence level, with a probability level of 0.5 and a margin of error of 6.19% [18]. This method was considered appropriate due to its reliability and suitability for studies requiring statistical precision.

$$n = \frac{Z^2 pqN}{e^2(N-1)+Z^2pq} \quad (1)$$

Where Z = 1.96; p = 0.5; q = 0.5; N = 5704; e = 0.0619; n = sample size.

$$n = \frac{1.96^2 * 0.5 * 0.5 * 5704}{0.0619^2(5708-1)+1.96^2 * 0.5 * 0.5}$$

$$n = \frac{0.9604 + 5704}{0.003834(5707)+0.9604} = \frac{5704.96}{22.84} = 249.78$$

Therefore, the study sampled 250 fishing households, although only 240 responses were found to be consistent and valid for collation and analysis, as shown in Table 1. Although the estimated minimum sample size was approximately 250 households, equal allocation of 10 households across the 24 selected fishing communities produced a final planned sample of 240 households.

Table 1. Summary sampling procedure for climate change knowledge and ecosystem health on blue economy livelihood.

State	LGA	Community	Population	Persons
Bayelsa	Nembe	Ogbolomabiri	242	10
		Oluasiri	251	10

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		Sabatoru	229	10
		Agbakabiriyai	237	10
	Brass	Twon-Brass	273	10
		Akasa	242	10
		Sangana	222	10
		Okpoma	237	10
	Ogbia	Ayama	202	10
		Akipelai	209	10
		Emakalakala	245	10
		Oloibiri	211	10
Rivers	Bonny	Bonny	239	10
		Finima	264	10
		Kuruma	220	10
		Opukiri	235	10
	Andoni	Okuru	241	10
		Uyeada	252	10
		Asarama	224	10
		Amansa	231	10
	Okrika	Okrika	259	10
		IKalio	242	10
		Isaka	234	10
		Abam-Ama	267	10
2	6	24	5704	10

Source: Field Survey, 2025.

Data collection

The research gathered primary data through a well-tested questionnaire designed to capture a range of information, including socio-demographic details, access to credit, cooperative membership, extension services, government programmes, environmental challenges, and knowledge about climate change. The questionnaire also featured sections that addressed perceived obstacles to fully leveraging blue economy opportunities. To ensure accuracy in data collection, the Kobocollect tool was utilized.

Analytical techniques

The data were analyzed using descriptive and inferential statistical methods. Descriptive statistics such as means, frequencies and percentages were used to summarize the socio-economic characteristics of respondents and main constraints to participation in blue economy activities. Correlation analysis was used to examine relationships between continuous variables. Moreover, OLS regression was used to examine the influence of socio-economic factors on the income from blue economy activities and on EnvRes.

Individual and institutional factors were used in a Binary Logit model to evaluate determinants of CCKnw. Further, a MNL model was employed to analyze the factors affecting the differences in EnvRes and livelihood diversification among households. Overall significance of the estimated models was analyzed by Analysis of Variance (ANOVA). The Variance Inflation Factor (VIF) and Tolerance statistics were used to test for the presence of multicollinearity among explanatory variables.

Cronbach's Alpha was used to test the reliability of the measurement scales. Values greater than 0.70 suggest acceptable internal consistency. All statistical analyses were conducted using SPSS.

Cronbach's Alpha is expressed as follows:

$$\alpha = \frac{K}{K-1}\left(1 - \frac{\sum_{i=1}^{k}\sigma_i^2}{\sigma_t^2}\right) \qquad (2)$$

Where;

α = Cronbach's Alpha

K = Number of items

σ_i^2 = Variance of item i

σ_t^2 =Variance of the total score

$$\alpha = \frac{8}{8-1}\left(1 - \frac{19.675}{100.00}\right) = \frac{6.426}{7} = 0.918$$

In this study, a Cronbach's Alpha value of 0.918 was obtained, which shows a strong level of internal consistency and reliability for the measurement tool used. This means that the items on the scale are well-connected as a group and effectively measure the same concept.

Institutional Support was measured by a composite index of four institutional indicators namely; access to credit, membership of cooperative societies, access to extension services and perceived government support. Since these indicators are complementary dimensions of institutional support, they were aggregated using an unweighted arithmetic mean, giving equal importance to each component. Binary variables (access to credit, cooperative membership, and government support) were coded as 1 = favorable response, and 0 = otherwise. The extension service variable was first normalized to a 0-1 scale, as it was originally measured on a four-point frequency scale. The Institutional Support Index (ISI) was thus calculated as:

$$\mathrm{ISI} = \frac{\mathrm{Cred}+\mathrm{MemCoop}+\mathrm{ExtSer}_{std}+(1-\mathrm{GovSupport})}{4} \qquad (3)$$

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Since, PrGovt = Poor Government Support (1 = Yes, 0 = No)
GovSupport = 1 – PrGovt

The greater the index value, the stronger the institutional support available to fishing households, and vice versa. Equal weighting was used because there was no empirical or theoretical basis to assign differential weights to the individual indicators, a procedure commonly applied in composite index construction in socio-economic and livelihood studies [19].

Model specification

The OLS regression model was used to explore the socioeconomic and institutional factors that affect the sustainability of the blue economy among rural households in Nigeria's Niger Delta Region. The model can be expressed in the following functional form:

$$lnBES_i = f\left(lnCA_{i,} lnSC_{i,} lnIS_i, lnAge_i, lnMarStat_i, lnEduYr_i, lnBEOccup_i, \mu_i\right) \quad (4)$$

The explicit linear form of the equation is given as:

$$lnBES_i = \beta_0 + \beta_1 lnCA_i + \beta_2 lnSC_i + \beta_3 lnIS_i + \beta_4 lnAge_i + \beta_5 lnMarStat_i + \beta_6 lnEduYr_i + \beta_7 lnBEOccup_i + \mu_i \quad (5)$$

Where:

lnBES = Natural log of blue economy Sustainability Index (dependent variable)
lnCAi = Natural log of Climate Adaptation Index (comprises ecosystem, knowledge of climate change, water pollution awareness, and environmental resilience)
lnSCi = Natural log of Social Capital Index (comprises conflict resolution and illegal fishing practices)
lnISi = Natural log of Institutional Support Index (comprises access to credit, cooperative membership, extension services, and poor government support)
lnAge = Natural log of the age of the household head
lnMarStati = Natural log of marital status (coded as a categorical variable)
lnEduYri = Natural log of years of education
lnBEOccupi = Natural log of blue economy occupation type (coded as a categorical variable)
μi = Error term assumed to be normally distributed with zero mean and constant variance.
β1,...,β7 = are the coefficients measuring the marginal effect of each explanatory variable on BES.

The binary logit model for CCKnw was expressed as:

$$ln\left(\frac{P_i}{1-P_i}\right) = \beta_0 + \beta_1 BEInc + \beta_2 Cred + \beta_3 MemCoop + \beta_4 ExtSer + \beta_5 PrGovt + \beta_6 ConflRes + \beta_7 IllegPra + \beta_8 Age + \beta_9 Gender + \beta_{10} MarStat + \beta_{11} EduYr + \beta_{12} BEOccup + \mu_i \quad (6)$$

Where:

Pi = Probability of having adequate CCKnw.
1-p_i = probability of not having adequate CCKnw.
BEInc = Blue economy income (₦/month)
Cred = Access to credit (1 = Yes, 0 = No)
MemCoop = Membership in cooperative society (1 = Yes, 0 = No)
ExtSer = Access to extension/advisory services (1 = Never, 2 = Occasionally (less than 3 times a year), 3 = Often (3–6 times a year), 4 = Regularly (more than 6 times a year))
PrGovt = Poor government support/policy gaps (1 = Yes, 0 = No)
ConfRes = Level of conflict resolution effectiveness (1 = Yes, 0 = No)
IllegPra = Exposure to illegal fishing practices (1 = Yes, 0 = No)
Age = Age of fishers/household (years)

Gender = Sex of fishers/household (1 = Male, 0 = Female)
MarStat = Marital status (1= Single, 2 = Married, 3 = Widow/Widower, 4 = Divorced)
EduYr = Years of formal education
BEOccup = Pri mary blue economy occupation (fishing, aquaculture, Coastal trade, transport)

The MNL model was applied to examine the factors influencing the capacity of rural households to adapt to environmental changes within the context of blue economy activities. The dependent variable, EnvRes, was categorized into five ordered levels: very low, low, neutral, high, and very high. The "very low" resilience category was specified as the reference (baseline) category against which the log-odds of membership in the remaining resilience categories (low, neutral, high, and very high) were estimated. This specification allows the estimated coefficients to be interpreted relative to households exhibiting very low EnvRes. The outcome variable comprised five categories: Very Low (reference category), Low, Neutral, High, and Very High. The MNL model estimated four sets of coefficients corresponding to the non-reference categories, each interpreted relative to the baseline (Very Low EnvRes).

Mathematically, the model is specified as [20]:

$$P(Y_i = j) = \frac{e^{\beta_j X_i}}{\sum_{k=0}^{J} e^{\beta_k X_i}}, J = 1,2,3, \ldots, J \quad (7)$$

Where:

$P(Y_i = j)$ = Probability that household i falls into category j of environmental resilience
X_i = Vector of explanatory variables
β_j = Vector of coefficients associated with each category j
J = number of outcome categories.

The options *Js* (representing the dependent variables) are as follows: 1 = Very High, 2 = High, 3 = Neutral, 4 = Low, and 5 = Very Low. The baseline category was set as very low resilience to facilitate interpretation of the log-odds relative to households with low EnvRes.

The MNL model can be estimated with a set of coefficients $\beta^{(1)}$, $\beta^{(2)}$, $\beta^{(3)}$, $\beta^{(4)}$, and $\beta^{(5)}$.

$$\Pr(Z = 1) = \frac{e^{x\beta(1)}}{e^{x\beta(1)}\, e^{x\beta(2)}\, e^{x\beta(3)}\, e^{x\beta(4)}} \quad (8)$$

$$\Pr(Z = 2) = \frac{e^{x\beta(2)}}{e^{x\beta(1)}\, e^{x\beta(2)}\, e^{x\beta(3)}\, e^{x\beta(4)}} \quad (9)$$

$$\Pr(Z = 3) = \frac{e^{x\beta(3)}}{e^{x\beta(1)}\, e^{x\beta(2)}\, e^{x\beta(3)}\, e^{x\beta(4)}} \quad (10)$$

$$\Pr(Z = 4) = \frac{e^{x\beta(4)}}{e^{x\beta(1)}\, e^{x\beta(2)}\, e^{x\beta(3)}\, e^{x\beta(4)}} \quad (11)$$

$$\Pr(Z = 5) = \frac{e^{x\beta(5)}}{e^{x\beta(1)}\, e^{x\beta(2)}\, e^{x\beta(3)}\, e^{x\beta(4)}} \quad (12)$$

The model was estimated using the following empirical form:

$$ln\left(\frac{P(Y_i=J)}{P(Y_i=0)}\right) = \beta_0 + \beta_1 Cred + \beta_2 MemCoop + \beta_3 ExtSer + \beta_4 PrGovt + \beta_5 ConfRes + \beta_6 IllegPra + \beta_7 Age + \beta_8 Gender + \beta_9 MarStat + \beta_{10} EduYr + \beta_{11} BEOccup + \mu_i \quad (13)$$

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Where:
Cred = Access to credit (1 = Yes, 0 = No)
MemCoop = Membership in cooperative society (1 = Yes, 0 = No)
ExtSer = Access to extension/advisory services (1 = Never, 2 = Occasionally (less than 3 times a year), 3 = Often (3–6 times a year), 4 = Regularly (more than 6 times a year))
PrGovt = Poor government support/policy gaps (1 = Yes, 0 = No)
ConfRes = Level of conflict resolution effectiveness (1 = Yes, 0 = No)
IllegPra = Exposure to illegal fishing practices (1 = Yes, 0 = No)
Age = Age of fishers/household (years)
Gender = Sex of fishers/household (1 = Male, 0 = Female)
MarStat = Marital status (1= Single, 2 = Married, 3 = Widow/Widower, 4 = Divorced)
EduYr = Years of formal education
BEOccup = Primary blue economy occupation (fishing, aquaculture, Coastal trade, transport)

Results and Discussion

Table 2. Socioeconomic and environmental characteristics of the fishers.

Variables	Minimum	Maximum	Mean	Std. Deviation
BEInc	10000	1000000	143502.50	130601.519
Ecosys	0	1	0.90	0.301
CCknw	0	1	0.82	0.384
Watpol	0	1	0.85	0.362
EnvRes	1	5	2.90	1.068
Cred	0	1	0.20	0.398
MemCoop	0	1	0.25	0.434
ExtSer	1	4	1.35	0.662
PrGovt	0	1	0.87	0.336
ConfRes	0	1	0.64	0.482
IllegPra	0	1	0.74	0.439
Age	24	66	41.72	8.891
Gender	0	1	0.68	0.469
MarStat	1	3	1.80	0.503
EduYr	4	38	11.70	7.057
BEOccup	1	4	2.06	1.263

Source: Field Survey, 2025

The results in Table 2 shows the socioeconomic and environmental characteristics of fishers in the rural coastal communities of the sampled States. The results show salient patterns on livelihoods, environmental conditions, institutional support and demographic characteristics that affect participation in blue economy activities.

Average annual income from blue economy activities was ₦143,502.50 with wide variation among respondents (SD = 130,601.52). Such a low-income level suggests that a great number of fishers are employed in vulnerable livelihood systems, despite being strongly dependent on coastal and marine resources. The sources of income instability among artisanal fishing households have been identified as declining fish stocks, environmental degradation, weak market access and inadequate support services. Similar observations have been reported by Belhabib et al. that small-scale fisheries in West Africa generally generate insufficient income to support household welfare because of ecological and institutional challenges [21, 22].

The ecosystem sustainability indicator showed a high mean value (0.90) indicating that most respondents thought that their surrounding ecosystem was relatively stable. This perception is, however, contrasted by the high-water pollution score (0.85) which shows a widespread concern over the deteriorating quality of water. The result suggests that fishers are still possibly reliant on ecosystem services, but environmental stressors such as oil pollution, waste disposal and habitat destruction continue to threaten the sustainability of resources. Similar findings have been reported in studies on environmental degradation in coastal Nigeria, were pollution drastically reduced fisheries productivity and ecosystem resilience [7].

The mean score of the CCKnw index was 0.82, showing that respondents are generally aware of climate-related issues. Increased awareness may be associated with exposure to media campaigns, community sensitisation programmes or past experiences of flooding and environmental shocks. However, there is a lack of correspondence between awareness and effective adaptation behaviour. Previous studies have shown that rural households are aware of climate risks but do not have the financial capacity or institutional support to respond adequately [6].

The environmental responsibility score was 2.90 on average on a five-point scale, indicating a moderate level of commitment to environmental stewardship. This indicates that although fishers are aware of the importance of sustainable use of resources, their practical involvement in conservation activities is still limited. Poverty, short-term livelihood needs and poor enforcement of regulations often limit the capacity for environmental stewardship in coastal communities. Similar results were observed for coastal households with poor environmental protection practices despite their awareness of the ecological decline [5,9].

Institutional indicators have major weaknesses. Both access to credit (0.20) and membership in cooperative societies (0.25) were low, suggesting limited financial inclusion and poor collective organization among fishers. Access to finance is

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limited constraining households to invest in improved fishing technologies, diversify livelihoods or for the adoption of adaptation strategies. Previous studies have noted that lack of financial support remains a significant barrier to resilience and livelihood improvement in climate-vulnerable communities [21].

Similarly, access to extension services recorded a low mean value (1.35), suggesting that the interaction between fishers and advisory services was minimal. Limited extension contact may hinder the spread of information on climate adaptation, sustainable fishing practices and resource management. Institutional support is found to be an important determinant of adaptive capacity of rural populations [15].

Poor Government Support had an average score of 0.87, indicating that the majority (87%) of the respondents felt that the government support and policy interventions were inadequate. These finding highlights significant institutional gaps in the provision of financial assistance, extension services, infrastructure, and effective coastal governance needed to strengthen climate resilience and sustainable blue economy livelihoods. Even where institutional structures existed, respondents generally felt that their implementation and effectiveness were weak. The finding is consistent with previous studies which associate poor government support and weak policy implementation with major constraints in sustainable coastal resource management and climate adaptation [4,15].

Illegal practices have an average score of 0.74, which suggests continued participation in unsustainable resource exploitation. Illegal fishing and poor compliance with environmental regulations can degrade ecosystems faster and reduce long-term productivity. Belhabib et al. expressed similar concerns and stated that illegal and unregulated fishing represents a major threat to the sustainability of fisheries in West Africa [22].

About the demographic characteristics of the respondents, the mean age was 41.72 years, indicating that most fishers are within economically active age groups. The gender distribution (68% male) confirms male dominance in fishing related occupations, a reflection of the traditional gender roles common in coastal communities. Average education was 11.7 years, suggesting moderate literacy levels that could improve information uptake and adaptation capacity. Education has consistently been shown to improve awareness, innovation uptake, and resilience to environmental change [17]. Also, the average blue economy occupation score (2.06) shows a move towards diversification in activities like fishing, aquaculture, processing and coastal trading as households try to hedge against livelihood risks.

In summary, the results indicate that the awareness on climate and environmental issues is relatively high but sustainable blue economy development is still constrained by limited access to finance, weak institutional support and environmental degradation. To grow sustainably, the blue economy requires stronger institutions, better financial inclusion, effective extension systems and environmental governance. These findings provide evidence for the claim that successful blue economy transitions depend not only on resource availability, but also on institutional capacity and community empowerment [5].

Determinants of blue economy sustainability

Table 3. Collinearity statistics.

Variable	Tolerance	VIF
LnCA	0.810	1.235
LnSC	0.867	1.154
LnIS	0.790	1.265
LnAge	0.629	1.590
LnMarStat	0.603	1.658
LnEduYr	0.724	1.382
LnBEOccup	0.751	1.332

Source: Field Survey, 2025.

The figures in Table 3 shows the collinearity statistics for testing the existence of strong relations among the explanatory variables included in the regression model. Tolerance values ranged from 0.603 to 0.867 and VIF values ranged from 1.154 to 1.658. The VIF values are all less than 10, which is the acceptable limit, and the tolerance is greater than 0.1, indicating that there is no serious multicollinearity between the predictors. This indicates that the independent variables contribute unique information to the model and are unlikely to bias the regression estimates.

The study finds that the variables of climate adaptation, social capital, institutional support, age, marital status, education and blue economy occupation can be reliably included in the analysis without creating instability in the coefficient estimates. Thus, the estimated relationships between these variables and sustainability of blue economy are considered robust and appropriate for interpretation. The threshold for diagnosing multicollinearity with a similar value has been widely recommended in the literature of regression analysis [16]. The low VIF values increase the reliability of the model's predictions and estimates of parameters.

Table 4. Regression estimates for determinants of blue economy sustainability.

Variable	Coefficient	Std. Error	T	Sig.
Constant	5.829***	1.425	4.091	0.000
LnCA	0.131	0.344	.382	0.703
LnSC	-0.488**	0.220	-2.222	0.028
LnIS	-0.362*	0.199	-1.815	0.072
LnAge	1.306***	0.367	3.564	0.001
LnMarStat	-0.214	0.241	-.888	0.376
LnEduYr	0.629***	0.116	5.443	0.000
LnBEOccup	-0.094	0.123	-.769	0.443
R Square	0.304			
Adjusted R Square	0.261			
Durbin-Watson	1.761			

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Significance levels: ***p < 0.01; **p < 0.05; * p < 0.10.
Source: Field Survey, 2025

Table 4 presents the regression estimates for factors influencing BES among coastal households in the surveyed coastal states. The model explains a moderate proportion of the variation in sustainability outcomes, with an R^2 of 0.304 and an adjusted R^2 of 0.261. This implies that approximately 26.1% of changes in BES are explained by the included socioeconomic, institutional, and adaptive variables. The Durbin–Watson statistic (1.761) indicates the absence of serious autocorrelation problems, suggesting that the regression estimates are reliable [23,24].

Climate adaptation (LnCA) recorded a positive but statistically insignificant effect on BES ($\beta = 0.131$, $p > 0.05$). This suggests that existing adaptation measures may not yet be sufficient to generate meaningful improvements in sustainability outcomes. Similar findings indicate that adaptation benefits often emerge gradually and depend on institutional capacity and resource availability [25].

Social capital (LnSC) showed a significant negative relationship with sustainability ($\beta = -0.488$, $p < 0.05$). This result implies that participation in informal groups or networks may not necessarily translate into improved sustainability outcomes. Weak cooperative structures, limited access to resources, and dependence on informal support systems may reduce the effectiveness of social capital in promoting resilience. Comparable observations were reported by Berman et al. who emphasized that institutions must be functional and resource-backed before they can strengthen adaptive capacity [15].

Institutional support (LnIS) also exhibited a negative effect ($\beta = -0.362$, $p < 0.10$), suggesting that existing support systems may not adequately promote sustainable blue economy practices. Weak policy implementation, limited coordination, and bureaucratic inefficiencies could reduce institutional effectiveness. Previous studies similarly found that poor governance constrains adaptation and livelihood resilience in vulnerable communities [15].

Age (LnAge) had a significant positive effect on BES ($\beta = 1.306$, $p < 0.01$). This suggests that older respondents are more likely to practice sustainable practices, most likely due to accumulated experience and indigenous ecological knowledge. Education (LnEduYr) was also found to have a positive effect on sustainability ($\beta = 0.629$, $p < 0.01$). This means that higher education increases awareness, decision making and adoption of sustainable practices. Previous studies have identified education as an important driver of resilience and adaptation to environmental change [17,21]. The blue economy occupation and marital status variables were statistically insignificant, implying that the variables had minimal impact on sustainability outcomes in the study area.

Overall, the results show the importance of human capital, especially age and education in enhancing BES. However, the negative effects related to social and institutional factors point to shortcomings in the existing governance and support systems. Therefore, strengthening institutions, improving policy implementation and expanding educational opportunities may be key to sustainable coastal livelihoods in the Niger Delta.

Table 5. ANOVA.

Mode	Sum of Squares	Df	Mean Square	F	Sig.
Regression	21.835	7	3.119	7.046	0.000
Residual	50.024	113	0.443		
Total	71.859	120			

Source: Field Survey, 2025

Table 5 shows the ANOVA test, which looks at the overall significance of the regression model. It assesses whether the independent variables, when taken together, have a statistically significant impact on the dependent variable. Specifically, BES. With an F-statistic of 7.046 and a p-value of 0.000 (which is less than 0.01), it can be confidently stated that the overall regression model was statistically significant at the 1% level.

This indicates that the joint effect of factors such as climate adaptation (lnCA), social capital (lnSC), institutional support (lnIS), age (lnAge), marital status (lnMarStat), years of education (lnEduYr), and blue economy occupation (lnBEOccup) are important in explaining a considerable share of the variation in BES among the sampled coastal communities. This finding strongly suggests that the predictors in the model have a significant collective impact on the dependent variable and it shows that the model was not just a result of random chance [24]. The significant F-ratio also suggests that the estimated regression coefficients were significantly different from zero when considered together, which supports the explanatory power of the model [26]. In short, the ANOVA results confirm the reliability and significance of the regression model statistically. The F-value (7.046, $p < 0.01$) indicates that the combined effect of the selected explanatory variables has a significant impact on BES. This supports the view that the sustainability path of coastal livelihoods is shaped by a combination of socioeconomic, institutional and adaptive factors. It also points to the importance of increasing education, institutional performance and adaptive capacity to achieve a resilient and inclusive blue economy framework in the region.

Determinants of blue economy sustainability

Table 6. Logistic regression determinants of climate change knowledge.

Mode	Sum of Squares	Df	Mean Square	F	Sig.
BEInc	0.000***	0.000	9.235	0.002	1.000
Cred	-0.627	0.690	0.826	0.364	0.534
MemCoop	-0.725	0.721	1.013	0.314	0.484
ExtSer	-0.432	0.378	1.307	0.253	0.649

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PrGovt	3.359***	0.662	25.755	0.000	28.750
ConfRes	2.608***	0.702	13.783	0.000	13.571
IllegPra	0.037	0.647	0.003	0.954	1.038
Age	0.046	0.036	1.599	0.206	1.047
Gender	0.150*	0.553	0.074	0.786	1.162
MarStat	-0.538	0.568	0.896	0.344	0.584
EduYr	0.050	0.043	1.366	0.243	1.052
BEOccup	0.154	0.245	0.392	0.531	1.166
Constant	-2.174	1.458	2.223	0.136	0.114
LR Chi square	114.431				
Prob >chi square	0.000				
Nagelkerke R Square	0.609				

Significance levels: ***p < 0.01; **p < 0.05; * p < 0.10.
Source: Field Survey, 2025

The results of the logistic regression analysis of factors that influence CCKnw of fisher households are shown in Table 6. The Likelihood Ratio Chi-square (LR $\chi 2$ = 114.431, $p < 0.001$) indicates that the model is statistically significant, meaning that the group of explanatory variables together explains the variations in knowledge about climate change. The Nagelkerke R2 value of 0.609 indicates that the model explains about 61% of the variation in climate knowledge, which is a strong explanatory power [20]. "Blue economy income (BEInc) has a positive and significant effect on CCKnw (B = 0.000, p = 0.002). The odds ratio (Exp(B) = 1.000) seems to be small, but it is because of scaling. The Wald statistic is significant and shows that the higher the income, the more access to information and learning opportunities. This result is consistent with Maddison and Deressa et al. who showed that income increases the ability of households to obtain climate-related knowledge, and adapt to changes in the environment [27,28].

Government presence and support (PrGovt) have a very significant and positive impact (B = 3.359, $p < 0.001$) and has anodds ratio of 28.75. This implies that households that receive government programmes are much more likely to have knowledge of climate change than households that do not receive government programmes. This result underscores the need for public policy measures, awareness raising and institutional outreach to improve climate literacy. Similar results were reported [29,30]. Confidence in research institutions (ConfRes) also has a positive and significant influence (B = 2.608, $p < 0.001$; Exp(B) = 13.57). The more trust research organizations have, the more likely households are to be aware of climate change issues. The results are in line with Adzawla et al. and Amadou who highlighted the role of confidence in scientific institutions in the adoption of climate information in rural areas [31,32]. The findings highlight the important role of institutional factors particularly government support and trust in research institutions in the construction of CCKnw. On the other hand, individual socio-economic characteristics such as income, access to credit and education seem to have a relatively weaker impact. This indicates that the attributes at the household level are less effective in improving climate literacy than the concerted policy measures, institutional participation and specific awareness campaigns.

Effect of blue economy activities on household livelihoods and environmental resource sustainability

Table 7. Collinearity statistics.

Variables	Tolerance	VIF
Cred	0.515	1.942
MemCoop	0.482	2.074
ExtSer	0.853	1.172
PrGovt	0.788	1.270
ConfRes	0.502	1.994
IllegPra	0.510	1.962
Age	0.677	1.478
Gender	0.945	1.058
MarStat	0.670	1.491
EduYr	0.858	1.166
BEOccup	0.779	1.284

Source: Field Survey, 2025

The collinearity statistics used to test for the presence of multicollinearity among the independent variables in the regression model are presented in Table 7. This analysis was generally done by two main indicators, namely Tolerance and VIF. Tolerance is the amount of variance in a variable that is not explained by other independent variables. Generally, a tolerance value of less than 0.10 is a sign of high multicollinearity [23]. VIF is a measure of the inflation of the variance of the estimated regression coefficient due to multicollinearity. A cutoff of 10 is generally accepted as indicative of high multicollinearity [24,26]. From the Table, the Tolerance values of all variables are between 0.482 (MemCoop) and 0.945 (Gender). The VIF values of all variables are between 1.058 and 2.074. These values were far below the critical threshold value of 10 and significantly above the lower Tolerance limit of 0.1. Thus, there is no evidence of serious multicollinearity among the explanatory variables. This means that the independent variables were statistically independent and do not bias the regression coefficients. The absence of multicollinearity improves the reliability, precision and interpretability of the estimated regression parameters, and confirms that the regression model offers a strong statistical basis for inference [33]. Thus, the collinearity diagnostics show that there was no multicollinearity problem in this study since all VIF values were less than 2.1 and the tolerance values were above 0.4. This assurance is provided by the statistical robustness of the regression model, where each variable provided unique explanatory insights. Hence, the regression results and their explanations (Tables 6 and 8) were valid, robust and reliable for policy and academic inferences on BES in coastal Nigeria.

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Table 8. Multinomial logit estimates of the determinants of environmental resilience among rural households engaged in blue economy activities.

Variables		B	Std. Error	Wald	Sig.	Exp(B)
	Intercept	-0.825	3.193	0.067	0.796	
	Cred	-1.512	1.169	1.672	0.196	0.22
	MemCoop	1.69	1.162	2.117	0.146	5.421
	ExtSer	-0.431	0.763	0.32	0.572	0.65
	PrGovt	-1.337	0.988	1.832	0.176	0.263
Very High EnvRes	ConfRes	0.027	1.206	0.001	0.982	1.028
	IllegPra	-1.518	1.22	1.549	0.213	0.219
	Age	-0.05	0.057	0.762	0.383	0.951
	Gender	0.65	0.65	0.926	0.492	1.916
	MarStat	3.154***	1.206	6.838	0.009	23.424
	EduYr	0.004	0.066	0.003	0.956	1.004
	BEOccup	-0.934**	0.409	5.213	0.022	0.393
	Intercept	2.265	1.95	1.349	0.245	
	Cred	-0.136	0.942	0.021	0.885	0.873
	MemCoop	0.652	0.886	0.542	0.462	1.92
	ExtSer	0.735	0.461	2.542	0.111	2.086
	PrGovt	2.169***	0.908	5.708	0.017	8.753
High EnvRes	ConfRes	-0.984	0.89	1.223	0.269	0.374
	IllegPra	1.31	1.055	1.54	0.215	3.706
	Age	-0.084**	0.042	3.961	0.047	0.92
	Gender	0.48	0.588	0.665	0.415	1.616
	MarStat	0.027	0.659	0.002	0.968	1.027
	EduYr	0.089**	0.04	4.974	0.026	1.093
	BEOccup	-1.583***	0.297	28.405	0	0.205
	Intercept	2.498	1.713	2.128	0.145	
	Cred	-0.264	0.884	0.089	0.765	0.768
	MemCoop	-0.682	0.812	0.705	0.401	0.506
	ExtSer	0.04	0.442	0.008	0.927	1.041
	PrGovt	1.407*	0.739	3.623	0.057	4.083
Neutral EnvRes	ConfRes	-0.345	0.801	0.185	0.667	0.709
	IllegPra	-0.787	0.864	0.831	0.362	0.455
	Age	0.001	0.033	0.001	0.981	1.001
	Gender	0.46	0.494	0.867	0.352	1.584
	MarStat	0.582	0.54	1.161	0.281	1.79
	EduYr	0.028	0.034	0.682	0.409	1.028
	BEOccup	-1.260***	0.238	28.079	0	0.284
	Intercept	1.111	2.199	0.255	0.613	
	Cred	-0.153	1.222	0.016	0.9	0.858
	MemCoop	-0.934	1.162	0.646	0.422	0.393
	ExtSer	-0.358	0.674	0.282	0.595	0.699
	PrGovt	1.323	0.937	1.996	0.158	3.756
Low EnvRes	ConfRes	-1.341	0.925	2.102	0.147	0.262
	IllegPra	-0.992	0.956	1.075	0.3	0.371
	Age	-0.043	0.041	1.093	0.296	0.958
	Gender	1.330**	0.691	3.7	0.054	3.78

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	MarStat	1.687**	0.751	5.049	0.025	5.404
	EduYr	-0.011	0.046	0.057	0.812	0.989
	BEOccup	-0.913***	0.288	1.046	0.002	0.401
	LR Chi square		173.702			
	Prob >chi square		0			
	Nagelkerke Pesudo R^2		0.55			

Significance levels: ***p < 0.01; **p < 0.05; * p < 0.10.

Source: Field Survey, 2025

Table 8 presents the results of the MNL model estimating the effects of socio-economic and institutional factors on EnvRes among rural households engaged in blue economy activities. EnvRes was classified into five categories (very low, low, neutral, high, and very high), with the very low resilience category specified as the reference (baseline) outcome. Consequently, the estimated coefficients represent the log-odds of belonging to each of the remaining resilience categories relative to households exhibiting very low EnvRes. The model is statistically significant as shown by the Likelihood Ratio Chi-square (χ 2 = 173.702; $p < 0.01$). The Nagelkerke Pseudo R 2 of 0.550 indicates that the variables included in the model explain 55% of the variation in EnvRes. This indicates a good fit of the cross-sectional data [20]. Marital status (B = 3.154, p = 0.009) and main occupation (B = −0.934, p = 0.022) are statistically significant for very high EnvRes category. Married households are more likely to be very highly resilience (Exp(B) = 23.424). This could be due to better household cooperation, shared resources and more adaptive capacity [34,35]. On the other hand, the negative coefficient of primary occupation suggests that people who are less directly involved in natural resource-based activities are less likely to achieve very high resilience. This is consistent with Eakin and Bojórquez-Tapia who highlighted the importance of livelihood diversification in reducing exposure to environmental risks [36].

In the high resilience class, important determinants are perception of government policy (B = 2.169, p = 0.017), age (B = −0.084, p = 0.047), years of education (B = 0.089, p = 0.026), and primary occupation (B = −1.583, p < 0.01). Positive perceptions of government interventions increase the probability of high resilience (Exp(B) = 8.753), showing the importance of institutional trust and effective governance in shaping adaptive behaviour [15,37]. Education also has a positive implication, suggesting that more educated people have better knowledge and skills to respond to environmental changes [17]. Conversely, the negative coefficient of age suggests that younger individuals are more likely to possess a greater adaptive capacity, possibly due to their greater flexibility and openness to innovation [38].

In the neutral resilience sub-category, the primary occupation is the only significant predictor (B = −1.260, p < 0.01), reflecting the role of the type of livelihood in determining resilience outcomes. Households involved in environmentally sensitive sectors (e.g., fisheries and agriculture) are often more exposed to climatic and market risks, which may constrain their adaptive capacity [39,40]. Marital status (B = 1.687, p = 0.025), gender (B = 1.330, p = 0.054) and primary occupation (B = -0.913, p = 0.002) were significant in the low resilience category. This could be the burden of household responsibilities that limits adaptive flexibility, married individuals are more likely to be in this category (Exp(B) = 5.404) [41]. There are also gender differences, with males more likely to be of low resilience (Exp(B) = 3.780). This is contrary to previous studies could be a result of changing social dynamics or differences in decision making roles concerning environmental management [42,43].

The results show that EnvRes is driven by a combination of socio-economic characteristics and institutional factors. Important factors include education, age, gender, marital status, occupation, and perceptions of government policy. Occupation remained consistently important across resilience categories, further highlighting the crucial role of livelihood strategies. We find that the resilience of households increases with the level of diversification of their income sources and decreases with the level of dependence on fragile ecological systems. The findings underscore the need to build human capital and institutional capacity to improve adaptive resilience and promote sustainable blue economy outcomes in the surveyed States, and the entire Niger Delta at large.

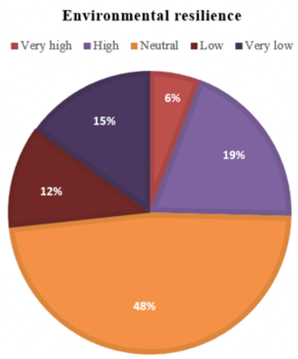

Figure 1. Environmental resilience.

Source: Field Survey, 2025

Figure 1 shows levels of EnvRes among households engaged in blue economy activities in the Niger Delta region. The results indicate that a significant percentage of fishers (48%) have a neutral EnvRes, which means a moderate capacity to adapt and a partial adoption of sustainable practices in their daily lives. This implies that some adaptation measures exist but they are often hampered by lack of institutional support, financial resources and infrastructure problems [17,34]. The good news is that about 19% of fishers indicated a high degree of EnvRes i.e., those households have successfully implemented effective adaptation strategies. These include joining cooperative societies, diversifying income sources, and adopting eco-friendly fishing and aquaculture practices. This is consistent with the work of Allison and Ellis and Bryan et al. who emphasized that diversification of livelihoods and promotion of social cooperation can significantly enhance resilience of coastal communities to environmental challenges [21,44].

By contrast, 15% and 12% of fishers had very low and low resilience respectively. These numbers point to households particularly vulnerable to the negative impacts of environmental degradation, pollution and other common unsustainable fishing practices in Rivers and Bayelsa States. This finding corroborates with the work of Okpara et al. and Ebeku who reported lack of institutional support, low level of environmental awareness and dependence on extractive

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economic activities impede sustainability in the coastal areas [6,45]. Only 6% of fishers reported a very high level of resilience, indicating that a small but growing number of households are able to sustain their livelihoods in the face of changing environmental conditions. These fisher farmers are likely to benefit from extension services, government initiatives, or community-led conservation programs. According to Adeleke and Omitoyin, adaptive capacity and long-term environmental sustainability of Nigeria's blue economy can be greatly enhanced through targeted policy actions, education and institutional participation [46,47]. In summary, the neutral resilience levels suggest that the people in the region were undergoing a transition in environmental adaptation that needs to be reinforced by stronger institutional frameworks, capacity-building programs, and the promotion of environmentally sustainable livelihood practices. This is in line with the view of Oluwatayo and Ojo, who noted that to build resilience in Nigeria's coastal economy, the local knowledge should be integrated with the modern strategies of environmental governance [48].

Table 9. Correlations matrix.

Variable	EnvRes	Cred	MemCoop	ExtSer	PrGovt	ConfRes	IllegPra	Age	Gender	MarStat	EduYr	BEOccup
EnvRes	1											
Cred	0.186**	1										
MemCoop	0.300**	0.661**	1									
ExtSer	0.177**	0.260**	0.258**	1								
PrGovt	-0.119	-0.311**	-0.351**	-0.113	1							
ConfRes	-0.009	-0.130*	-0.125	-0.199**	0.201**	1						
IllegPra	0.05	-0.045	0.033	-0.029	0.198**	0.664**	1					
Age	0.041	0.077	0.073	0.036	0.027	0.109	0.181**	1				
Gender	0.041	-0.016	0.051	-0.045	-0.082	-0.116	-0.084	0.032	1			
MarStat	0.016	0.176**	0.077	0.05	-0.005	-0.111	-0.083	0.499**	-0.099	1		
EduYr	0.051	0.134*	0.104	0.202**	0.086	-0.111	-0.054	-0.064	-0.026	-0.055	1	

** and * Correlation is significant at the 0.01 and o.o5 level (2-tailed) respectively.
Source: Field Survey, 2025

The results of Table 9 give an insight into the relationship between EnvRes and the various socio-economic, institutional and behavioural factors among coastal households in the area. Importantly, there is a positive and significant relationship between EnvRes to access to credit ($r = 0.186$, $p < 0.05$). This implies that households with financial means are more likely to adopt adaptation strategies and address coastal environmental issues. Availability of credit stimulates investment in sustainable aquaculture, mangrove restoration and alternative energy sources. This finding is consistent with Nhemachena and Ozor et al. who found that access to credit significantly increases the adaptive capacity of rural communities by alleviating liquidity constraints [49,50]. We also find a significant positive relationship between membership in cooperatives and EnvRes ($r = 0.300$, $p < 0.01$) indicating that social capital and collective efforts are critical to building resilience. Cooperatives provide a platform for knowledge sharing, resource pooling and group access to financial and technical support for the sustainable use of marine resources. This finding is consistent with the work of Adger and Bryan et al. who emphasize the role of social networks and community institutions in climate adaptation and resource management in developing economies [21,34].

Access to extension services was positively associated with EnvRes ($r = 0.177$, $p < 0.05$), suggesting that technical support and environmental awareness could improve sustainable livelihood practices. This is in line with the findings of Gebrehiwot and van der Veen and Adeleke and Omitoyin that interaction with extension services in agriculture and fisheries enhances the adoption of climate-smart and eco-friendly technologies [13,46,47]. On the other hand, the weak and negative correlation between perceived government presence and EnvRes ($r = -0.119$) implies that households do not perceive government efforts to be effective in addressing coastal environmental issues. This is in agreement with the works of Ebeku and Oluwatayo and Ojo who noted deficit of trust and poor institutional performance in coastal governance and policy implementation in the Niger Delta [45,48]. Additionally, there is a significant negative correlation between EnvRes and blue economy occupations ($r = -0.414$, $p < 0.01$), indicating an increased dependence on extractive or environmentally damaging blue economy activities. This is in line with findings by Okpara et al. that dependence on unsustainable livelihoods may adversely affect the health of the ecosystem and adaptive capacity in coastal Nigeria [6]. This highlights the urgent need for livelihood diversification and ecological restoration programs.

Table 10. Constraints faced by rural households in maximizing benefits from blue economy opportunities.

Constraints	Yes	No	Mean	Std. Dev.
Limited access to finance	213(88.8)	27(11.3)	0.89	0.317
Poor market access	180(75.0)	60(25.0)	0.75	0.434
Lack of modern fishing equipment	215(89.6)	25(10.4)	0.9	0.306

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Inadequate infrastructure (roads, cold storage, electricity)	208(86.7)	32(13.3)	0.87	0.341
Inadequate training and technical knowledge	209(87.1)	31(12.9)	0.87	0.336
Environmental degradation/pollution	216(90.0)	24(10.0)	0.9	0.301
Conflicts over fishing rights	153(63.7)	87(36.3)	0.64	0.482
Climate change impacts (flooding, storms, temperature changes)	197(82.1)	43(17.9)	0.82	0.384
Water pollution	203(84.6)	37(15.4)	0.85	0.362
Illegal fishing practices	178(74.2)	62(25.8)	0.74	0.439
Poor government support/policy gaps	209(87.1)	31(12.9)	0.87	0.336

Source: Field Survey, 2025

Table 10 presents the major socio-economic, infrastructural and environmental constraints to the participation of rural households in blue economy (BE) activities in coastal and riverine communities. The results revealed that the most serious constraints were limited access to finance (88.8%), inadequate fishing equipment (89.6%) and environmental degradation (90.0%) with mean scores of 0.89, 0.90 and 0.90 respectively. The results show that the main barriers to inclusive participation in blue economy projects still relate to financial and infrastructural deficiencies. Also, the key challenges were lack of infrastructure (86.7%) and weak government support or gaps in policy (87.1%). The lack of crucial infrastructure such as cold storage facilities, stable power supply and convenient transport networks hampers the processing, preservation and marketing of fish and other aquatic products, thereby decreasing productivity and income. Limited access to training and technical knowledge (87.1%) similarly constrains the uptake of improved fishing technologies and sustainable resource management practices [30].

The environmental and governance constraints are also strong. Major challenges to the sector development are effects of climate change (82.1%), water pollution (84.6%) and disputes over fishing rights (63.7%). This is consistent with the findings of Allison and Ellis who pointed out the vulnerability of small-scale fishers in developing countries to environmental shocks and institutional weaknesses [44]. The high prevalence of illegal fishing practices (74.2%) also indicates the weak enforcement of marine regulations, confirming the findings of Belhabib about the threat of illegal, unreported and unregulated (IUU) fishing to coastal livelihoods in West Africa [22].

Taken together, these constraints reveal the limited access to finance, poor infrastructure, and weak institutional frameworks that constrain the capacity of Nigeria's coastal communities to fully benefit from the blue economy. Similarly observed that structural barriers, particularly in finance and technology adoption, constrain rural participation in marine-based enterprises [46]. In addition, environmental degradation and climate change continue to decrease the productivity of aquatic resources. Pollution, flooding and the decline of the ecosystem in the Niger Delta have a great impact on the availability of fish and increase the vulnerability of households [7,9,10]. To address these challenges, targeted interventions are required, including improved access to credit, investment in critical infrastructure, expanded technical training and stronger regulatory and governance frameworks. These measures are essential to unlock the full potential of the blue economy and make it sustainable.

Conclusions and Policy Implications

The study highlights the importance of improved environmental conservation efforts, climate education programs, and policies to promote the resilience of blue economy livelihoods in Rivers and Bayelsa States, and the Niger Delta region in general. There is also a need to increase investment in research funding, transport infrastructure, digital data collection technologies, and interdisciplinary research collaborations to enable broader and more comprehensive studies in the region. Such investments would allow future researchers to utilize larger and more geographically diverse samples, use advanced analytical approaches, and generate deeper insights into the complex interactions among climate change, ecosystem health and livelihood sustainability.

The study offers important policy insights. Implementation of the proposed measures could help to meet key Sustainable Development Goals such as poverty reduction, climate action and sustainable use of marine resources. The following policy recommendations are thus proposed.

a) Create a Blue Economy Development Authority (BEDA) to oversee policy implementation, research, and monitoring of marine-based livelihoods. Extension programmes and local governance structures must incorporate climate education and marine conservation. There is also a need to improve the enforcement of environmental laws and governance of marine resources to combat illegal, unreported and unregulated (IUU) fishing activities.

b) Based on the findings of this study, governments, development agencies, and relevant stakeholders should prioritize investments in climate change education, ecosystem restoration, and sustainable blue economy initiatives that strengthen the adaptive capacity of coastal and riverine communities. Policies aimed at reducing environmental degradation, improving access to climate-resilient livelihood opportunities, and promoting community participation in ecosystem management should be intensified. Additionally, increased support for research and data-driven decision-making is essential to enhance understanding of climate-related challenges and to develop effective strategies for sustainable livelihood and ecosystem resilience in the Niger Delta region.

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c) Access to credits is essential for small-scale producers who want to embrace sustainable technologies and diversify their livelihoods. Therefore, blue economy Microfinance Schemes should be developed through public-private partnerships for small-scale fishers, aquaculture farmers and marine processors. Climate-resilient financial products such as microinsurance and low-interest green loans for marine and coastal enterprises should also be developed.

d) Education is a key factor for enhancing adaptation capacity and for responsible resource management. That is why it is important to incorporate blue economy literacy into secondary and tertiary education curricula. Capacity building programmes should also be provided to coastal communities by stakeholders on sustainable fishing, aquaculture and waste management. Partnerships between universities, research institutions and local communities will promote knowledge transfer and innovation.

e) Low infrastructure and technology is hampering productivity and post-harvest efficiency of the blue economy sector. This calls for investment in rural marine infrastructure such as cold chains, landing sites and coastal roads to reduce post-harvest losses. Subsidies and public-private partnerships should also be used to incentivize the use of modern fishing gear and vessels powered by clean energy. Furthermore, supporting ICT-based marine data systems can help climate forecasting and sustainable fisheries management

f) Social networks and cooperative structures play a vital role in sharing knowledge, pooling risks, and improving market access. Stakeholders should focus on strengthening marine and fisherfolk cooperatives to help them gain better access to finance, training, and markets. Encouraging community-based resource management (CBRM) systems will empower local groups to sustainably co-manage marine resources.

g) Pollution and the depletion of resources are serious threats to EnvRes and food security. Governments and other stakeholders need to implement stricter pollution control regulations aimed at oil exploration and industrial waste discharges. Promoting mangrove restoration projects and eco-friendly aquaculture can enhance biodiversity and protect our coastlines. It's also essential to encourage community-based environmental monitoring through citizen science initiatives and local awareness campaigns.

h) Gender gaps in access to knowledge and resources may hinder inclusive growth in the blue economy. Stakeholders need to embed gender-sensitive approaches in the formulation of marine policy and the delivery of extension services. It is important to support women-led marine businesses through grants, cooperatives and educational programs. It will also be useful to set up regional blue economy research and innovation hubs that connect academic institutions with government agencies and local communities. Finally, enhancing the dialogues between policy and science will ensure that research results are integrated into adaptive management and investment priorities. The authors gratefully recognize the invaluable contributions of fisher farmers in the study area, whose collaboration and willingness to contribute their time, experiences, and ideas enabled this research. We are also appreciative of community leaders and agricultural extension workers for facilitating access to rural communities and assisting with data collection. We thank the research assistants who helped with the fieldwork and data processing.

Limitations of the Study

One of the major limitations of this study was the difficulty in data collection across the Niger Delta region. The area is characterized by a complex terrain with large networks of rivers, creeks, lakes and coastal waters, which greatly restricts accessibility to many rural communities. So, contacting respondents was a lot of physical effort, money and time. These limitations hindered the potential for a larger sample size, especially since the study was self-funded with no external financial support. However, rigorous sampling procedures were applied to ensure that the selected respondents were adequate representation of the study population and the findings were reliable and valid.

Another limitation of this study is its geographical scope. Although the Niger Delta region comprises nine states, the empirical survey was carried out only in selected fishing communities in Bayelsa and Rivers States. Hence, the results should be interpreted as not representative of the entire Niger Delta region but representative of the sampled communities. These two states are among the most active coastal zones, offering a suitable context for examining CCKnw, the health of the ecosystem and livelihoods within the blue economy.

Informed Consent

Oral informed consent was obtained from individual participants included in the study.

Ethical Approval

The study was done in conformity with ethical guidelines. Participation was entirely voluntary, and all respondents provided informed consent. The participants' anonymity and confidentiality were ensured, and the data obtained were utilized purely for the study. The ethical guidelines for Human Subjects are followed in the study.

Conflicts of Interests

The authors declare that there are no conflicts of interests.

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Data and Materials Availability

All data associated with this study will be available based on the reasonable request to the corresponding author.

Disclosure Statement

The Authors declare that there is no conflict of interest.

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