Research Article

Impact of Marine Pollution and Climatic Factors on Artisanal Fish Capture in Nigeria

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Abstract | Fishery resources are renewable, however, only when put to sustainable use. Plastic pollution has been fingered as a cause of dwindling ocean health across states in Nigeria whereas the vagaries of climate change are also detrimental to sustainability of the aquatic ecosystem. Declining fish stock over the years is of stern concern, having strong implications not only on the livelihoods of millions of agents along the value chain but as well on future nutritional security of the populace and perhaps economic development. Despite potential threats that plastic poses to ocean ecosystem, there is still limited research in Nigeria to ascertain the extent and magnitude of the challenge. This study was therefore carried out to unfold how plastic pollution, alongside climatic variables, has affected artisanal fish output in Nigeria. We analysed the effect of marine pollution and selected climatic variables on artisanal fish capture in Nigeria over 1980-2019. Analytical tools employed include unit root test, co-integration, and the error correction mechanism. We found that the sea surface temperature, wind speed, current year marine litter plastic waste, and magnitude of marine litter plastic wastes from the previous year negatively influenced the artisanal fish capture quantity in the period under review ($p<0.05$). We conclude that climate change and marine plastic pollution are major issues with negative impacts on artisanal fish capture in Nigeria. We recommend the need to draw up strategies towards cleaner aquatic environment through the improvement of waste disposal system in Nigeria alongside concerted ocean clean-up exercises. Policies towards ban of single-use plastics, accountability of manufacturers using plastic packaging, job creation in wastes aggregation, and deepening the attractiveness of the upcycling node in the waste value chain were also recommended. Given the potential of climate variables to lower artisanal fish capture, it becomes critical to target efforts at confronting climate change.

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Introduction

Empirical evidence exists (Allen ., 2017; ECESA Plus, 2017) on the decline in fish stock available in the oceans over the years given the lowering quantities of capture fish despite the exploitation using more sophisticated tools. This has implications on food security for the populace and on livelihoods

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of artisanal fisher-folks and other actors along the fish value chain. Various climatic variables have been documented as affecting breeding, survival, and distribution of fish hence demonstrating the negative impact that the changing climate tends to have on the ecosystem (Bertolo and Magnan, 2006; Wetzel, 2001; Lan ., 2012; Søndergaard and Jeppesen, 2007). Most of the available research has been limited to how climate change impact fish at various developmental stages and their availability in the ocean. However, the changing lifestyle of many people across the world now raises the additional concern of marine pollution. The current trend in urbanization globally has seen a rise in the proportion of the population who resort to convenience and out-of-home foods which are mostly packaged in plastics. Despite the knowledge of many in appropriate disposal of plastic wastes, much of the wastes continue to find their way into the oceans. This situation is more common in the Global south as not many countries in the region have put sanctions in place for pollution nor bans on single-use plastics. The resultant effect of this is a deterioration in the water quality.

This study hypothesizes that the quality of water in which the ocean biodiversity exists also has implications on their sustainability. Perhaps, the quality of the ocean may be said to be directly related to the level of pollution of such waters. Key among water pollutants is the plastic which is largely non-biodegradable hence leaving significant and long-lasting footprints on the ecosystem. Plastic pollution has been fingered as a cause of dwindling ocean health across states in Nigeria. With a coastline of about 853km which can accommodate over six million small-scale artisanal fishers and support the livelihoods of additional 24 million agents along the value chain (Nwafili and Gao, 2007), Nigeria still has a profound gap in fish demand-supply. This has strong implications on import bills and foreign exchange given that the gap is inherently being filled through fish importation. Failing to tackle marine pollution in Nigeria has the potential of jeopardizing not just the livelihoods of over 30 million Nigerians but also food and nutrition security of the nation. With the rising urbanization and industrialization in Nigeria, marine pollution will worsen if drastic actions are not taken to curtail the menace.

Albeit the recyclability of plastic, it has continued to suffer gross neglect in most African countries. The effect is visible on the environment, both on lands and in marines with marine litter becoming a major and growing global pollution concern. Some recent studies suggest that the quantity of litters on certain beaches will exceed the current levels 250 times over in about one decade. Globally, over 6 billion tons of plastics have been produced. Out of these quantity, an estimated 10% will be deposited long-term in the world's oceans (Regional Plan for the Marine Litter Management in the Mediterranean, 2013; Kako ., 2014; Deudero and Alomar, 2015; Wang ., 2015; Wichels ., 2017; Acampora, ., 2016; Dussud ., 2017; Babayemi ., 2018).

Despite potential threats that plastic poses to the ocean ecosystem, there is still very limited research that has been carried out in Nigeria to ascertain the extent and magnitude of the issues at hand. Several nations have continued to embark on marine debris and ocean clean-up activities. Nigeria has, however, participated poorly in such cleanup mandates. Very sparse effort has been targeted in that direction, mostly coming from communal activities and Non-Governmental Organizations. For instance, limited data exist on Nigeria marine debris made available by Ocean Conservancy, USA given the low level of participation in clean up exercise whereas, the Nigerian Institute for Oceanography and Marine Research (founded in 1975) does not even have such relevant database.

Research gap, therefore, exists in investigating marine pollution in Nigeria, which needs to be bridged. Perhaps the low level of involvement of stakeholders in pursuant to healthier oceans may be attributed to lack of evidence-based research on the effect of plastic pollution on ocean biodiversity, carrying out this study will rectify such. Because on-going global biodiversity losses, including in marine environments, and the faster than projected climate change, is creating a more uncertain world (Quentin ., 2023), it becomes important to investigate how to urgently tackle the challenges.

This study was therefore designed to analyse the effect of marine pollution and some selected climatic variables on artisanal fish capture in Nigeria in the period 1980-2019. This study is novel in that the authors have not found previous studies on how plastic pollution, alongside climatic variables, has affected artisanal fish output in Nigeria. Although there is a strand of literature regarding resilience-based management on marine capture fishery such as the work of (Quentin ., 2023), the research is focused more on review than empirical research.

Our research's incremental contribution to literature thus lies in our approach which infuses plastic pollution into the vagaries of climate change to gain a better understanding of how they holistically impact on artisanal fish capture in Nigeria over time. This approach is particularly important in the context of developing countries because the issue of plastic solution is more alarming in the region than in the Global north where research interest may be more attuned to climate change impacts rather than marine plastic pollution.

The study is justified by the dwindling fish stock in the ocean as documented in literature coupled with the fish demand-supply gap attributable to increasing population in Nigeria. The pressure on the oceans to meet a significant percentage of fish demand in Nigeria has continued through the use of more sophisticated fishing methods and over-exploitation of the ocean yet inadequate attention is being paid to ocean sustainability issues. Gaining insight into how plastic pollution and selected climatic variables have impacted artisanal fish capture in Nigeria over the years will drive policy implications that will not only transform the fishery sub-sector in Nigeria but also enhance food and nutrition security in the Nation.

Materials and Methods

Study area

This study was carried out in Nigeria which lies between longitudes 2°49'E and 14°37'E and latitudes 4°16'N and 13°52'N. Nigeria is situated on the coast of West Africa, bordered by the Gulf of Guinea and Bight of Benin in the south. The country shares land borders with the Republique du Benin westwards, Chad and Cameroon eastwards, and Niger northwards. Nigeria also shares maritime borders with Ghana, Equatorial Guinea, and São Tomé and Príncipe (Nations Online Project, 2019). There has been a very rapid growth in Nigerian population, with the statistics showing 88.9 million people in 1991, 140 million in 2006 and over 193 million as at 2017 (NPC, 2017).

Nigeria is richly endowed with huge quantities and diversity of marine and inland fisheries resources which has flourished the fishery subsector. With a country area of about 923,770 km^2, shelf area of 216,325 km^2, coastal length of 853 km, and inland water area of about 13,000 km^2 (FAOSTAT, 2017), Nigeria has huge resources to support fish production. Nigeria has an impressive network of inland waters such as flood plains, rivers, man-made and natural lakes and reservoirs (Shimang, 2005; Chilaka ., 2014). Fish production in Nigeria may be mainly categorized into three main sources: aquaculture (fish farm), artisanal (lakes, inland rivers, coastal and brackish water), and industrial fishing (Otubusin, 2011).

It has been documented in literature that Nigeria inland water fishery resource is the richest in terms of fish diversity in West African sub-region, having more than 311 species (Idodo-Umeh, 2003; Powell, 1993; Olaosebikan and Raji, 1998). About 85% of domestic fish production is accounted for by artisanal fishing activities, despite the exploitative fishing activities that goes on in many water bodies across the country (Adekoya and Miller, 2004). According to the Fishery Committee for West Central Gulf of Guinea (2016), there is about 3.32 million metric tonnes demand for fish in Nigeria considering the 2014 population estimate of 180m. Whereas, the level of domestic production of fish from Artisanal, Aquaculture, and Industrial fisheries for that year was about 1.1 million metric tonnes. Fishery was stated to contribute 0.48% to Agricultural GDP while Agriculture contributed 20.24% to the GDP in that same year. The study is conducted on Nigeria because Artisanal fish farming is an age-long occupation that provides livelihood for millions of people in the country and their activities are being hampered on an ongoing basis for various reasons such as water pollution and changing climate.

Data sources and data analysis procedure

This study utilized time series data spanning over 1980 to 2019. Secondary data used were sourced from various organizations including Food and Agriculture Organization Fishery and Aquaculture Statistics, Fishery Committee for the West Central Gulf of Guinea, United Nations ComTrade database, Harmonized system codes Foreign Trade Online, Our World in Data, and Nigerian Meteorological Agency. These data are publicly available on the website of the organizations and hence the data were directly retrieved from the various websites.

The data collected were analyzed with econometric tools, including the unit root test, co-integration test, and the error correction model. Using Augmented Dickey-Fuller Unit root test (Dickey and Fuller, 1979), the time-series data were first checked for the presence of unit root. This is a preliminary investigation carried out to unravel the level of integration of the variables being modeled. A unit root indicates that a variable is affected by random shocks and tends to return to its mean over time, suggesting a lack of long-term trend or stability. Stationary time series data is crucial for accurate modeling and forecasting in statistical analysis which is why it serves as a foundational step in our analysis in this study.

To analyse the effect of marine pollution and some selected climatic variables on artisanal fish capture in Nigeria in the period 1980-2019, the error correction approach was employed. This objective was achieved by testing, firstly, for cointegration such as to identify the determining factors of artisanal fish capture in the long run. Our choice of these econometric models is driven by our aim in this study which is basically to understand the possible correlations or relationships among the time-series variables we modeled, in the long term.

There are various methods for testing co-integration, for instance the Engel and Granger (1987), and the Johansen and Juselius (1990) methods among others. Our research utilized the two-stage Engel and Granger (1987) approach. This test is the same as Dickey Fuller (DF) or Augmented Dickey Fuller (ADF) unit root test on the regression residuals obtained from the co-integrating regression.

Fuller (1976) posited that a stationary series is one that has its variance and mean being constant over time with the value of the covariance between two time periods and not on the actual time at which the covariance is captured. Assuming non-stationarity in series X_t:

$$X_t = \alpha + \beta X_{t-1} + e_t \ldots..(v)$$

Where α is a constant drift, β= 1, and e_t is the error term. Most economic series do exhibit non-stationary stochastic process that takes on the form shown in Equation v. Assuming the error term e_t has mean of zero, a variance that is constant and covariance of zero, then X_t is regarded as a random walk and is integrated of order I(1). The series X_t is integrated as it is the sum of its base value X_0 and the difference in X from the first to the tth period. If X_t is non-stationary, β is equal to 1 and is said to have unit root (Engle and Granger, 1987).

In this study, ADF tests was used to examine stationarity of the variables which are required to be non-stationary at levels and stationary after first differencing in order to qualify them for cointegration test. The next step involve testing for cointegration in which ordinary least squares estimations of the variables to assess for preliminary significant relationship among the variables. This was to enable one understand if the variables are co-integrated suggesting the existence of a long-term equilibrium relationship. The residuals of an OLS regression must be stationary.

Following established results from the unit root test done using ADF method, the test for cointegration was carried out on the variables and this entails regressing the artisanal fish capture on marine pollution and the selected climatic variables. According to Ayinde . (2015), the cointegration analysis is to be performed after ascertaining the order of integration of each of the variables. This helps to examine if the time series of the variables exhibit a stationary process of a linear combination y = f(x). Co-integration implies the data from a linear combination of two or more variables may be stationary despite non stationarity of those variables singly (Engle and Granger, 1987). The presence of cointegration suggests that there is the existence of long-run relationship between the exogenous and endogenous variables (Ayinde ., 2015).

Cointegration is said to exist if the individual regressor exhibit non-stationarity and the hypothesis of unit root is rejected for the residual of the error term of the linear combination. It should be noted that all these tests are valid provided that the variables' order of integration is one i.e. I (1). As cointegration is found to be present among the variables modelled, the next step involved estimating Error Correction Model (ECM) in order to be able to capture the short-run equilibrium effects respectively on the dependent variables.

ECM estimations were used to specify the variables that were statistically significant in influencing artisanal fish capture in the short run and also to quantify the impact of these variables. Following the Engle-Granger representation theorem, a valid error correction model exists for variables that are discovered to be co-integrated. The deviation found in the long-term equilibrium can be gradually corrected through various partial adjustments in the short-term period.

The Linear regression model used to analyse the effect of marine pollution and some selected climatic variables on artisanal fish capture in Nigeria in the period under review is specified in Equation vi. We include the contemporaneous and lagged climatic variables and littered marine plastic wastes in the model.

$$L\_AFC_i = \beta_0 + \beta_1 L\_WS_i + \beta_2 L\_WS_{i-1} + \beta_3 L\_SST_i + \beta_4 L\_SST_{i-1} + \beta_5 L\_RF_i + \beta_6 L\_RF_{i-1} + \beta_7 L\_LPW_i + \beta_8 L\_LPW_{i-1} + \varepsilon_i \quad \ldots..(vi)$$

Where; i=1, 2…, 39

The findings from the cointegration test indicated that cointegration is present which implies that at least one variable in the model responds to deviations from the long-run relationship. The short-run relationship was modeled as:

$$\Delta L\_AFC_i = \delta_0 + \delta_1 \Delta L\_WS_{it} + \delta_2 \Delta L\_WS_{it-1} + \delta_3 \Delta L\_SST_{it} + \delta_4 \Delta L\_SST_{it-1} + \delta_5 \Delta L\_RF_{it} + \delta_6 \Delta L\_RF_{it-1} + \delta_7 \Delta L\_LPW_{it} + \delta_8 \Delta L\_LPW_{it-1} + \delta_9 \Delta L\_AFC_{it-1} + \delta_{10} ECM_{it-1} + \tau_i \quad \ldots\ldots(vii)$$

With: *L_AFC*= Artisanal fish capture (metric tonnes), *L_WS*= Wind speed (m/sec), *L_SST*= Sea surface temperature (°C), *L_RF* = Rainfall (mm), *L_LPW*= Littered plastic waste in marine (metric tonnes), εi = stochastic error term, εi ~ IID (0, σ2), ECM_{it-1} is the error correction term and τi is the error term from the static regression Equation v. The ECM_{it-1} may be interpreted as the adjustment mechanism of artisanal fish capture as a response to the changes in the exogenous variables modeled in the study.

Results and Discussion

We make a graphical presentation of the trend in the variables included in our model over the period 1980-2019 which is under review in this study. As shown in Figure 1, the artisanal fish capture has been on the increase over the period reviewed. This may be largely attributed to the intensification of fishery activities in the study area. In addition, the promotion of more innovative fishing technologies and tools have also resulted in higher exploitation of fishery resources accounting for the increase in fish capture that can be observed.

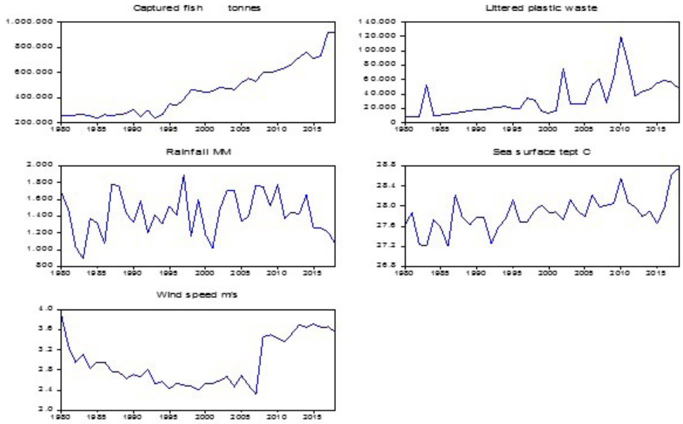

Figure 1: *Impact of marine pollution.*

From the panel containing the littered plastic wastes in Figure 1, it can be seen that littered plastic waste has been on the increase over the years. In the early to mid-1980s, it can be observed that littered plastic wastes were at the lowest. This period coincides with the era of War Against Indiscipline in Nigeria which was a mass mobilization programme with one of its aims targeted at correcting social maladjustment, characterized by environmental cleanup in the nation.

According to Stock (1988), the fifth phase of the War Against Indiscipline (WAI) was tagged Environmental Sanitation and this was launched in Kano on the 29th day of July 1985 by the then Chief of Staff, Supreme Headquarters, Major-General Idiagbon. The Chief of Staff announced a one-million-naira prize award for the cleanest capital city in Nigeria. This resulted in frantic sanitary activities across state capitals. Most states implemented sanitation task forces and hired additional sanitation workers for cleanup exercises, while businesses and government offices were directed to close on designated clean-up days. In order to add credence to the process, mobile sanitation courts that were established to prosecute offenders on the go became more vibrant. By the end of August 1985, numerous permanent piles of rubbish had been evacuated and non-functional drains unclogged. Most of these activities were accomplished by community self-help groups, aided by workers from the offices and factories.

Between the mid-80s and 90s, it can be observed that littered plastic wastes gradually creeped up until 1997 when a surge was recorded. Beyond 1997 till date the narratives of littered plastic wastes has changed with major and more frequent upward volatilities.

Table 1: *Summary of the augmented dickey-fuller unit root tests.*

		Level		First differencing	
Variable description	**Variable Name**	**t stat.**	**Prob.**	**t stat.**	**Prob.**
Wind speed	L_WS	-0.521602	0.4841	-7.312496	0.0000
Sea surface Temp.	L_SST	0.490864	0.8167	-8.346346	0.0000
Rain fall	L_RF	-0.960522	0.2949	-9.087716	0.0000
Littered Plastic Waste	L_LPW	-1.531248	0.1164	-7.548499	0.0000
Artisanal Fish Capture	L_AFC	2.783411	0.9982	-6.029597	0.0000

It is important to mention that the trend observed in the littered plastic waste may not all be attributed to the end of the WAI programme in Nigeria but as well to the rising population and changing lifestyle resulting in the generation of more waste in the environment, albeit with inadequate plan as to how these will be catered for.

The panel on Figure 1 depicting rainfall and sea surface temperature can be seen to follow a similar pattern. The graph shows that both variables have indeed been highly variable over the years, emphasizing the tropical issue surrounding the changing climate in Nigeria as the case is global. The high levels of unpredictability shown in the graphs calls for adaptive and broader approaches towards tackling the challenge of climate change.

As depicted on the Windspeed panel on Figure 1, there was a sudden rise in windspeed in 2008 and the variable has continued to be in that range with very slight but continuous increase since then. The windspeed, which has been fingered as a menace to timing of breeding, spawning, and survival of fish (Bertolo and Magnan, 2006; Wetzel, 2001; Søndergaard and Jeppesen, 2007), may therefore be a variable of interest in artisanal fisheries. An important perspective to this may be around the question of deforestation in the communities considering the impact that the existence or non-existence of trees may have on the speed of wind which in turn has attendant effects on fisheries activities.

Unit root test

In ascertaining the stationarity and integration order of the time series data for the variables modeled in this study, the Augmented Dickey-Fuller unit root test was carried out on the modeled variables and the results are as provided in Table 1. The unit root test result showed that all the modeled variables were not stationary at level however, these became stationary after the first differencing suggesting that they are integrated of order one i.e. I (1) and are hence qualified for the test for co-integration.

Cointegration tests

The result of the Engel-Granger test for cointegration is as presented in Table 2. Our test statistic of -6.301 is smaller than the critical values at the 1%, 5%, and 10% levels. Therefore, we cannot accept the null hypothesis of no cointegration having found evidence in support of the existence of cointegration among the variables included in our model.

Table 2: *Result of Engel-granger test for cointegration.*

			N (1st step) = 38 N (test) = 37	
	Test statistic	**1% Critical value**	**5% Critical value**	**10% Critical value**
Z(t)	-6.301	-5.582	-4.804	-4.425

Critical values from MacKinnon (1990, 2010).

The existence of cointegration in the model hence confirms the need for the error correction model in this study.

The result of the OLS regression carried out to gain insight into the long-run relationship that exists among the modeled variables is as presented in Table 3. The validity tests carried out on the model indicated that the model was of a good fit based on the R-squared value of 0.8336 suggesting that the variables included in the model explains up to 83.36% of the dependent variable. The Durbin-Watson statistic of 1.89 which is close to 2 indicates there is no issue of autocorrelation. There is likewise no issue of multicollinearity in the model as none of the variance inflation factors exceeded 10 as shown in Table 3. There was no challenge of heteroscedasticity with the white test statistic of 39.1534 with p-value of 0.4595 making us accept the null hypothesis that heteroscedasticity is not present in our model at 5%

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significance level.

Table 3: *OLS model showing estimates of the effect of plastic pollution on artisanal fish capture in Nigeria (1980-2019).*

Variable	Coefficient	Std. Error	t-ratio	p-value
Const.	-43.822***	13.772	-3.182	0.0035
L_SST	-0.8703**	0.3681	-0.2365	0.0250
L_SST_{t-1}	-0.7791*	0.3945	-0.1975	0.0479
L_RF_{t}	0.335	0.210	1.594	0.1218
L_RF_{t-1}	0.016	0.227	0.0683	0.9460
L_WS	-0.827**	0.443	-1.866	0.0422
L_WS_{t-1}	-0.399	0.404	-0.989	0.3309
L_LPW	-0.204***	0.064	-3.194	0.0034
L_LPW_{t-1}	-0.165**	0.071	-2.307	0.0284
Mean dependent var	12.95284	S.D. dependent var	0.424210	
Sum squared resid	1.107720	S.E. of regression	0.195441	
R-squared	0.833633	Adjusted R-squared	0.787739	
F(8, 29)	18.16417	P-value (F)	2.28e-09	
Log-likelihood	13.25070	Akaike criterion	-8.501402	
Schwarz criterion	6.236873	Hannan-Quinn	-3.257636	
Rho	0.937405	Durbin-Watson	1.894754	

*White test statistics – TR*2 = 39.1534; p-value= p(chi-square(8) >39.1534) = 0.4595; VIF(j) = 1/(1-R(j)*2); L_SST 6.451; L_SSTt-1 5.624; L_RF 4.806; L_RF t-1 5.242; L_WS 6.485; L_WSt-1 7.322; L_LPW 5.228; L_LPWt-1 8.363.*

The co-integration regression results shown in Table 3 indicates that on the long run, the sea surface temperature, wind speed and litter plastic wastes in the current year were statistically significant at 5% and had a negative influence on the quantity of artisanal fish capture in Nigeria. It was further revealed that one-year lagged sea surface temperature and one-year lagged litter plastic waste also had a negative influence on the quantity of artisanal fish capture in Nigeria. From Table 3, it can be seen that a unit increase in sea surface temperature resulted in 0.8703 unit decrease in the quantity of artisanal fish capture whereas a unit increase in the sea surface temperature in the previous year resulted in 0.7791 unit decrease in the artisanal fish capture.

From the result, it can be seen that a unit increase in wind speed resulted in 0.827 unit decrease in artisanal fish capture in the study area. Litter plastic waste was shown to have a lesser effect that those of the climate variables as the result indicated that a unit increase in litter plastic waste resulted in 0.204-unit decline in the artisanal fish capture. Plastic litter waste can, therefore, be said to have close to about 25% of the effect of either the wind speed or the sea surface temperature. A unit increase in the one-year lagged litter plastic waste was revealed to result in 0.165unit decrease in artisanal fish capture in the long run.

Post estimation was carried out to generate the residuals from the fitted regression and the graphical result is as depicted in Figure 2. This represents the level of the artisanal fish capture as it deviates from its predicted values over time. The residuals generated is required in order to estimate the error correction model.

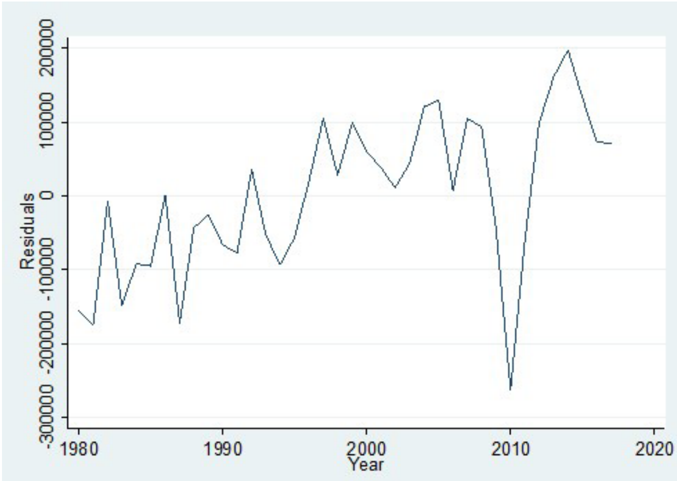

Figure 2: *Impact of marine pollution.*

Table 4 present the error correction model result which shows the relationship among the modeled variables in the short run. The sea surface temperature, wind speed, and litter plastic wastes were statistically significant and had an inverse relationship with artisanal fish capture in the study area. The error correction coefficient for the artisanal fish capture model was indicated to be -0.877. This result indicates that a quick convergence to equilibrium exists in each period with intermediate adjustments captured by the differenced terms. This result, therefore, validates the existence of a stable long-run equilibrium relationship among the time series in the modeled equation.

It may be said that the quantity of artisanal fish capture in the period under study is sensitive to departure from its equilibrium value in the previous period. In the absence of variations in the exogenous variables, the model's deviation from the long-run relation will tend to be corrected by 87.7% increase in the artisanal fish capture by the following year which implies that

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artisanal fish farmers would have resorted to finding better means of exploiting the ocean in order to attain the equilibrium they had. Surprisingly, this study found no statistically significant relationship between temperature and artisanal fish capture neither in the long nor short run. However, the positive signs that were observed in both the co-integrating and error correction models were consistent with apriori expectation and with past studies, for example, Apindi (2010) which found that a positive relationship between rainfall and fish catch.

Table 4: *Error Correction model showing estimates of the effect of plastic pollution on artisanal fish capture in Nigeria in the short run (1980-2019).*

	Coefficient	Std. Error	t-ratio	p-value
Const.	-35.2368***	11.1687	-3.155	0.0034
L_SST	-0.978061**	0.290308	-3.369	0.0024
L_SST_{t-1}	-0.494092	0.543567	-0.9090	0.3717
L_RF_{t}	0.0302384	0.550566	0.05492	0.9566
L_RF_{t-1}	0.160518	0.0311062	5.160	0.0561
L_WS	-0.220184**	0.0686397	-3.208	0.0035
L_WS_{t-1}	0.0899332	0.0635417	1.415	0.1688
L_LPW	-0.05054***	0.0118305	-4.400	0.0002
L_LPW_{t-1}	-0.038027**	0.0119979	-3.234	0.0033
L_AFC_{t-1}	0.0280273	0.0138277	2.027	0.0530
ECM_{-1}	-0.876938**	0.0211234	-41.51	0.0401
Mean dependent var	12.95284	S.D. dependent var		0.424210
Sum squared resid	5.47e-22	S.E. of regression		4.50e-12
R-squared	0.71426	Adjusted R-squared		0.65821
Log-likelihood	459.3737	Akaike criterion		-127.3232
Schwarz criterion	-185.734	Hannan-Quinn		-121.0760
Rho	0.912847	Durbin Watson		1.889756

Results of this model is as presented in Table 4 showing the short run, Findings from this study on the relationship between sea surface temperature and artisanal fish capture can be seen to be in tangent with that of findings from past study by Mackenzie and Koster (2004) which was conducted in the Baltic Sea and Black sea in which they found that water temperature variation had a negative effect on catch of fish. This finding is also consistent with that of Apindi (2010) in a study conducted in Kenya to investigate the influence of climatic and non-climatic influences on fishing activities in lake Victoria where the negative relationship was also reported. In fact, Werry . (2018) also reported that Bull shark catch (occurrence) in beach areas is influenced by rainfall and sea surface temperature. However, the research of Tidd . (2023) is worthy of note as the authors provide convincing submission on how temperature anomalies may affect countries differently suggesting that while some countries have enhanced production from an increase in the resource distribution, which alter the structure of the ecosystem, others have had to adapt to the negative impacts of seawater warming.

Similarly, Catch per unit effort was observed to be negatively correlated with Sea surface temperature (Lan ., 2012). The ecology, biology, and geographical extent of fish species is related to the quality and quantity of the water as well as climatic factors such as wind speed and temperature that affect timing of breeding, spawning, and survival of juveniles (Søndergaard and Jeppesen, 2007; Bertolo and Magnan, 2006; Wetzel, 2001). Likewise, a reduction in the level of oxygen can potentially reduce the growth of fish indirectly through reduced food availability resulting from prey mortality (Diaz and Rosenberg, 2008; Garrabou ., 2009; Basset ., 2013).

Findings from this study that wind speed is negatively correlated to artisanal fish capture supports past study by Ogutu-Ohwayo (2003) where it was reported that strong winds have a negative effect and alongside other factors, can drastically change the copiousness, distribution, and availability of fish population. Souza . (2018) stated that winds and rainfall are significant drivers of fish species richness and yields in fishing in the coastal tropical waters. The authors opined that the consistent seasonal changes determined by rainfall and wind direction/intensity are ecological changes that have unavoidable knock-on effects on fisheries yields and even composition of the catch. Our finding is also similar to what was revealed by Pelage . (2023) in a study the authors carried out in Rio Formoso, North-east Brazil where it was shown that extreme weather conditions and the changing nature had a negative impact on yield of small scale fisheries in the communities. The authors further stated that the fisherfolks have perceived threats to their fishing activities which they attributed to global change consequences, including climate change, pollution and conflicts with tourism. As global change accelerates, the activities of these stakeholders are likely to face even greater challenges.

Our results in this study support the hypothesis that littered plastic waste in the ocean have negative effects on the ecosystem, having the tendency to lower fish stock in the water bodies. In a study by Utete . (2018) in Lakes Chivero and Manyame in Zimbabwe, water pollution was one of the factors pinpointed to be causing decline in fish catches. According to Eriksen . (2014), plastics can be found all over the world in the marine environment, with estimates pointing to over 5 trillion plastic debris (over 250,000 tons) floating at sea. A significant amount of such plastic debris are from various continental sources from where they enter the marine environment mainly through rivers (Lebreton ., 2017). Our finding is as well consistent with that of Alava . (2023) in their research carried out in Galápagos Islands where they reported that the widespread marine pollution such as oil spills, persistent organic pollutants, metals, and ocean plastic pollution are linked to concerning changes in the ecophysiology and health of Galápagos species.

One would expect that plastics production will continue to increase in the future and that production levels will possibly double by 2025. Insufficient management of plastic wastes has led to higher contamination of freshwater, estuarine and marine environments (Lusher ., 2017). According to Bennett . (2023), pollution, plastics, climate change, biodiversity loss, ecosystem service degradation, and fisheries declines are producing environmental injustices in the ocean, and threatening the world's ability to achieve the 2030 UN Sustainable Development Goals. These marine environmental justice issues are cumulatively and differentially impacting the well-being of coastal populations across geographies and axes of identity. It is projected that many of these issues will increase in the future. This issue of plastic pollution in the marine environment is hence a major concern especially considering microplastics may inadvertently convey chemicals used in their manufacturing process, as well as environmental contaminants which may be absorbed on to their surfaces in the process of using them and subsequent permanence in the environment (Barbouza ., 2018).

Conclusions and Recommendations

The study concluded that as much as the vagaries of climate change is of critical concern, ocean litter plastic waste is as well a major issue negatively impacting on artisanal fish capture in Nigeria. It therefore becomes important to embrace a holistic approach for a sustainable fishery system in Nigeria. In line with the recommendation of Thomas and Diouf (2023) in a study carried out in Senegal, we also agree that to best guide management measures, it is imperative that policymakers, researchers and stakeholders jointly consider the pressures associated with fishing and climate change in order to support fishing communities and increase their adaptive capacity. This is because fishery resources are renewable, however that only holds in the context of sustainable use. Sustainability on the other hand is hinged on developing adaptive capacity of the stakeholders such that they do not become exploitative in their activities.

Sustainability of the system will require avoiding over-exploitation, optimizing the usage, and supporting the water ecosystem in a manner that enhances their proliferation. This is very important in order to secure the food and nutrition status not only for this generation but for the future. Proper management of plastic waste may be considered to be more under the direct and immediate control of humans than can be said of climate change. This study therefore recommends the need to draw up strategies towards cleaner aquatic environment through the improvement of waste disposal system in Nigeria alongside concerted ocean clean up exercises across the nation. Given the potentials of climate variables to lower artisanal fish capture, it is critical for the nation to contribute their quota in confronting climate change. Considering the endemic nature of plastic pollution in Nigeria, Government should take urgent actions toward implementing policies on the ban of single-use plastic as this will drive down the usage. As a starting point, taxes should be imposed on single-use plastics such that increases the price and hence disincentivize the usage by producers and consumers alike. Other policy directions may entail the introduction of sanctions on the manufacturers whose waste materials are more commonly found across regions. This may force such industries to innovate on changing to more sustainable packaging materials. On the other hand, such private sector entities may begin to invest more on consumer awareness, promotion, and campaigns towards proper waste handling.

The problem of plastic pollution in Nigeria presents an opportunity for the private sector to explore a market niche by investing in the innovation of new products through upcycling. Upcycling involves creatively repurposing by-products, waste materials, or unwanted items into new materials or products with enhanced quality, whether in terms of artistic or environmental value. Policy should also be oriented towards the creation of recycling centers or kiosks which are to be strategically positioned to intercept the poor waste disposals while serving as aggregators for the upcycling business end. To incentivize innovators to get in the plastic wastes value chain, government should be open to giving them grants, subsidies, and tax exemptions such that boosts the attractiveness of the plastic waste value chain.

Limitations of study

The major limitation in this research is the paucity of data and sometimes the inconsistency of the available data from one source to another among the various organizations. This calls for an improvement to the current state of data through deliberate steps by the government and other agencies to collect data given how crucial data is to economic and agricultural planning, among other uses, in any nation. Building on our research, further studies in the future may include more climatic variables as part of the model to gain a robust understanding of how other components of climate change intertwine to impact on the artisanal fisheries industry in Nigeria. Further studies may also look at the impact along the various regions rather than looking at the country on the aggregate. This is because of the diversity in agro-ecology in the country which is accompanied by differing experiences with respect to climate change.

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Novelty Statement

Marine debris especially plastics are problematic as they do not degrade over a long period of time and cause harm to marine life. The current research study was designed to analyze the effect of marine pollution and selected climatic variables on artisanal fish capture in Nigeria. This research area has been largely uninvestigated in Nigeria despite the key roles the fisheries subsector plays in the economy, in food nutrition security and livelihoods sustainability. This research speaks to the need to address the work of vulnerable populations in the subsector that is currently challenged.

Author's Contribution

Ajibade Toyin Benedict: Principal author of the paper, conducted data analysis and prepared draft manuscript.
Yusuf, Mukhtar Abiola: Was part of research conceptualization, preliminary investigation and data gathering
Adebayo Sijuwade Adebukola: Was involved in data cleaning, and review of initial drafts of manuscript
Adeyemi Uswat Temitayo: Reviewed literature and was part of research conceptualization, and manuscript edits
Omotesho Olubunmi Abayomi: Provided oversight functions on the research and finalized the manuscript.
All authors read and approved the final manuscript.

Conflict of interest

The authors have declared no conflict of interest.

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