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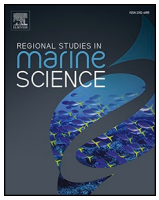

Artisanal fishery and their relationship with mangrove extent, rainfall, and sea surface temperature in the Niger Delta Region

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ABSTRACT

Mangroves are a crucial habitat in tropical coastal ecosystems, providing essential nursery grounds for numerous fish and crustacean species. Mangrove degradation and loss negatively affect species across different stages of their life cycle, with significant implications for artisanal fisheries that depend on these habitats. In the Niger Delta Region (NDR), empirical studies quantitatively assessing the relationship between mangrove extent and artisanal fish landings remain limited, and official fisheries data are frequently incomplete or misreported, making reliable assessment challenging. This study investigated changes in artisanal fish landings, mangrove extent, rainfall, and sea surface temperature (SST) across four mangrove-fringed states (Akwa Ibom, Bayelsa, Delta, and Rivers) in the NDR over three time periods (1988, 2000, and 2013). To improve data reliability, artisanal fisheries landing data were re-estimated using the 'catch reconstruction' approach to account for misreporting and data gaps in official records. Also, the 'catch reconstruction' allowed for the number of fisherfolk engaged in full-time and part-time fishing across the NDR to be estimated for the first time ever. Descriptive analysis revealed a non-linear relationship between artisanal fisheries landings and mangrove coverage across the four states. Fish landings did not increase proportionally with mangrove extent, suggesting that additional environmental and anthropogenic factors including fishing pressure and population growth play an important role in determining fisheries production. Higher rainfall generally coincided with increased landings, particularly in 2013, indicating a positive association with fisheries productivity. In contrast, SST showed little variation relative to landings across the three time periods, suggesting a weak direct relationship with fisheries production. When fitted to a multiple regression model, mangrove coverage and SST in 2000 were the most significant variables in explaining variation in landings, accounting for approximately 96% of the variation for that period. Akwa Ibom state was the largest contributor to artisanal landings in the NDR, accounting for 32% of total landings in 1988 and 48% in both 2000 and 2013, despite having the lowest mangrove coverage among the four states. Fisherfolk estimates revealed that the number of fishermen and total landings across the NDR more than doubled between 1988 and 2013, strongly reflecting the influence of population growth on fisheries production in the region. This study presents the first quantitative assessment of the mangrove-fisheries relationship in the NDR and the wider Gulf of Guinea, as well as the first reliable estimates of artisanal fisher numbers for the region, providing a basis for integrated fisheries management that combines mangrove conservation, climate-informed planning, and regulation of fishing pressure in the Niger Delta.

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1. Introduction

Tropical coastal ecosystems, such as mangroves, seagrass beds, and coral reefs (Ogden and Gladfelter, 1983; Birkeland and Orosenbauqh, 1985; Norman and Wolanski, 2001), are crucial for artisanal fisheries (Allison and Ellis, 2001; Oliveira Júnior et al., 2016), generating up to 25% of the world's fisheries production (Tuda, 2018). They are rich in biodiversity, with approximately one-third of all fish species residing in these habitats (Moberg and Rönnbäck, 2003). These ecosystems also provide a range of ecosystem services, such as food and fisheries, and natural resources like oil and gas deposits, which can support high population densities in the coastal tropics, enhancing the livelihoods and well-being of the local communities (Ronnback, 1999; Moberg and Folke, 1999).

Mangroves, in particular, protect coastal areas from climate-related hazards like storm surges, floods, erosion, tsunamis, and cyclones (Guannel et al., 2016; Narayan et al., 2016; Ellison, 2015, Sarathchandra., et al. 2018), and also act as powerful carbon sinks, promoting nutrient cycling, filtering pollutants, enhancing water quality (Chaudhuri et al., 2019; Twilley and Day, 1999; Blasco et al., 1996; Nor and Obbard, 2014; Donato et al., 2011; Wong et al., 1997), and serving as foraging and nursery grounds for various commercially important fish and crustacean species (Saenger et al., 2013a; Kenyon et al., 2004; Manson et al., 2005b; Faunce and Serafy, 2006). They provide shelter to juveniles and sub-adults and ultimately contribute to adult fish populations (Grimmel et al., 2020;Ronnback, 1999; Ogbeibu & Oribhabor, 2023). Nevertheless, this valuable ecosystem is being lost and degraded at an alarming rate (Friess et al., 2020), mainly due to land use changes, pollution, overfishing, unsustainable aquaculture, and climate change (FAO, 2017; Nababa et al., 2020 Onyena and Sam, 2020; Duke, 2016), leading to an estimated global loss of ~30–50% over the past 50 years (Alongi, 2002; FAO, 2007; Duke et al., 2007a; Thomas et al., 2017 Goldberg et al., 2020).

It is expected that a change in the extent of mangroves or their health will negatively impact commercial fishery captures (Onrizal et al., 2020; Zabbey et al., 2010; Manson et al., 2005a; Primavera, 2005; Ohimain, 2016). However, this assumption may be challenged by the impacts of human activities, leading to ecological imbalance (Ronnback et al., 2007; Ermgassen et al., 2020; Tuda, 2018; Vergara-Solana et al., 2023; Ogbonna, 2001; Sharpe and Hendry, 2009; Katikiro and Macusi, 2012; Olaoye and Ojebiyi, 2018; Belhabib et al., 2016). Commercial fisheries, especially those near the shore, have been reported to be closely linked to mangroves (Manson et al., 2005a; Hutchison et al., 2015; Diele et al., 2010; Beitl, 2014; Macintosh, 1982; Walters et al., 2008).

Except for snapper fish (single species), studies by Aburto-Oropeza et al. (2008) and Carrasquilla-Henao et al. (2013) have demonstrated a strong positive correlation between both single species and aggregated catches of commercially important fisheries (fish and shellfish) in the artisanal/small-scale sector with mangrove coverage in the Gulf of California, Mexico. Similarly, with the exception of Kenyon et al. (2004), there have been several studies on crustaceans, such as prawn landings (species-based and aggregated landings) and shrimp (penaeus-mangrove-dependent and aggregated landings) (Pauly and Ingles, 1988; Barbier and Strand, 1998), which were positively correlated with mangrove coverage in Malaysia, Australia, Indonesia, Mexico, Southeast Asia, and the Philippines. There is a lack of studies in the Atlantic–Caribbean and Eastern Pacific regions due to data paucity issues with developing countries (Carrasquilla-Henao and Juanes, 2017; Oliveira Júnior et al., 2016) particularly, Nigeria (Amire, 1999; Etim et al., 2015). The relationship between mangroves and environmental factors is crucial for their efficient management, conservation, and sustainable use.

However, tropical coastal artisanal fishing faces challenges that threaten its future sustainability due to the dispersed nature of the fishery and the limited resources available for comprehensive management (Batista et al., 2014; Béné, 2006,; Silas et al., 2020). Data on artisanal fisheries are often not reported by fisheries ministries departments and agencies (MDAs) because they are mainly concerned with commercial sectors (Zeller et al., 2006; Parsram, 2010). As a result, artisanal fisheries data are often inaccurate or under-reported, and information is under-represented in official statistics and national estimates (Rawlinson et al., 1995; Federal Department of Fisheries – FDF, 2008; Gillett and Lightfoot, 2002).

In Nigeria, as in numerous other developing nations, the data related to artisanal fisheries are plagued by inaccuracies and inconsistencies (Etim et al., 2015; Zeller and Pauly, 2007; Jacquet et al., 2010). The catch statistics and fishing capacity figures provided by the Federal Department of Fisheries (FDF) have been challenged by various studies (e.g., Anon, 1988; Ssentongo et al., 1986), leading to the perception that the country's artisanal fishery data is unreliable due to being non-specific, incomplete, inaccurate, or unreported. Coastal fishing villages in the NDR are remote and politically unstable, making it difficult to collect landing data for artisanal fisheries.

Given the data limitations, researchers have advocated for data limited approaches to evaluate tropical coastal fisheries (Apel et al., 2013; Fujita et al., 2014; Honey et al., 2010). Zeller et al. (2006) developed the 'catch re-construction' approach which has been successfully applied in many studies (e.g. Jacquet et al., 2010; Simmons et al., 2016). The failure to assess the extent of mangroves and tropical fisheries has a negative impact on the achievement of several Sustainable Development Goals notably, SDGs 2, zero hunger; 8 economic growth; and 14 climate action (Alms et al., 2022; Sharma et al., 2021).

Studies related to mangrove-fisheries linkages in Nigeria have focused on the importance of mangroves to fisheries, including their contribution to ecosystem services and the impact of removing mangroves on declining fisheries catch and species composition (Zabbey et al., 2010; Numbere, 2014; Okonkwo et al., 2015; Adeyemo et al., 2009; Ohimain, 2016; Onyena and Sam, 2020; Osuji et al., 2010; Moffat and Linden, 1995; Ukoli, 2005). Several environmental factors, including SST (Magnuson and DeStasio, 1997; Van der Sleen et al., 2022; Townhill et al., 2023; Innes-Gold et al., 2024), rainfall, river flows (Loneragan, 1999; Vance et al., 1985; Marques et al., 2021; Ngodigha, 2023; Chilton et al., 2021), pH (Loneragan et al., 2005; Lam et al., 2020), salinity (Carrasquilla-Henao et al., 2019, Carrasquilla-Henao et al., 2022), and turbidity (Matveev, Steven, 2014; Marley et al., 2020), have been identified as major factors affecting the composition and productivity of fisheries species in coastal ecosystems. These factors are often used in regression models to better understand variation and predict landings, rather than relying on a single variable (Teixeira et al., 2014; Sundermeyer et al., 2005) such as mangrove extent. Pauly and Ingles (1986) and Loneragan et al. (2005) analyzed various environmental factors and found that latitude and shallow waters have a significant impact on prawn production in the Philippines and Western Pennisular Malaysia, respectively. However, many studies have only included mangrove extent as a dependent variable in their assessments of the mangrove-fisheries link (Aburto-Oropeza et al., 2008; Chong et al., 1994; Staples et al., 1985; Paw and Chua, 1991).

There are no studies in the previous literature assessing mangrove-fisheries relationship in Nigeria. This study aims to answer whether there is a relationship between artisanal fishery landings and mangrove extent, changes in mangrove coverage over time, rainfall, and SST in the Niger Delta Wetlands in Nigeria. This was possible by:

- Re-estimating artisanal fisheries landings and number of fisherfolks using the data-limited approaches to provide a better representation of data;
- Quantifying mangrove extents for the states in the NDR over three time periods (1988, 2000, and 2013);
- Assessing the relationship between artisanal fisheries and mangrove extent, rainfall, and SST in the NDR over the same period.

States contribution to artisanal fishing production to the NDR over

the three time periods have also been analysed. Additionally, we estimated and analysed the number of fisher-folks engaged in artisanal fishing activities together with catch landings in the NDR over time in attempts to assess changes in fishing capacity in the region because there are no information on fleets or vessels and fishing effort.

2. Methods

2.1. Study area

The study area (Fig. 1) covers 36,000 km^2, consisting of four administrative states (Akwa Ibom, Bayelsa, Delta, and Rivers), with a 470 km^2 coastline (NBS, 2018). The Niger Delta is a flat alluvial plain located in Nigeria on the Gulf of Guinea (Fig. 1), with an important water inflow from the Niger and Benue rivers (Abam, 2001). It features a 210,900 km^2 Exclusive Economic Zone and is considered a biodiversity hotspot with three Ramsar Wetlands of International Importance (World Resources Institute, 1992). The ecosystem provides numerous ecosystem services, including fisheries, to more than 33 million inhabitants (NBS, 2018). Over 80% of fish production in Nigeria comes from the artisanal fishery sector, with over five million people depending on it as their primary means of livelihood (FAO, 2018; Udoh, 2016). However, the mangroves of the Niger Delta are among the most degraded, least conserved and protected areas in the world. Additionally, industrial operators and artisanal fishers exploit fish stocks unsustainably under ineffective regulatory regimes(Zabbey et al., 2019).

2.2. Data

2.2.1. Mangrove land cover estimates per state in NDR

Mangrove (healthy mangrove and degraded) information for three time points (1988, 2000, and 2013) were derived from Nababa et al. (2020). These are for four states (Akwa Ibom, Bayelsa, Delta, and Rivers; Fig. 2) in the NDR which corresponds to the fisheries landing data. Boundary shapefiles for the four states were obtained from OpenStreetMap, provided by Geofabrik (GmbH and Contributors, 2018), then used to delineate mangrove coverage (M+DM), and extract data for the four states for three time periods. The operation was undertaken using the 'Spatial Analyst' tool within the ArcGIS 10.7 environment (ESRI, 2020). For information about the data sources and methodologies used in producing the mangrove cover data used in this study, refer to Nababa et al. (2020).

2.2.2. Artisanal fishery data

The choice of data was guided by the availability of fishery information in the NDR and its linkages to mangrove systems. The artisanal fishery in the study region comprises commercial fish and crustaceans, which are strongly linked to mangroves (Aburto-Oropeza et al., 2008; Carrasquilla-Henao et al., 2013; Manson et al., 2005a). The relationships among commercial fish, shellfish, and crustaceans notably (penaeid shrimps and prawns) and mangroves are well documented in the literature (Saenger et al., 2013b; Islam and Haque, 2004; Islam and Wahab, 2005; Naamin, 1977; Alonso-Perez et al., 2003; Barbier and Strand, 1998; Aburto-Oropeza et al., 2008; Chong et al., 1990). Artisanal fishing also plays an important role in sustaining livelihoods in the NDR and supporting food security in Nigeria (Ben-Yami, 2001).

Annual artisanal fishery landing data and fisherfolk information for the four mangrove-fringed states of the NDR were collected from secondary sources, primarily the Federal Department of Fisheries (FDF), and complemented with grey and peer-reviewed literature (Ekpo and Essien-Ibok, 2013; Amire, 1999). In this study, 'artisanal fishery landings time series' refers to annual records of fish and crustaceans brought ashore and reported by Ministries, Departments and Agencies (MDAs) in official government documents over several decades. These annual records were collected for the four states for the period 1988–2013 from the FDF (3rd, 4th, and 5th editions), with the exception of Akwa Ibom state for 1988, where data were missing.Although annual landings data spanning several decades were collected, results are presented for only three time points (1988, 2000, and 2013). This is because the study required corresponding mangrove cover maps to link fisheries data to mangrove extent, and maps were only available for these three years due to difficulties in obtaining cloud-free satellite imagery for intervening periods. The catch reconstruction and analysis were therefore aligned to these three time points.

Missing landing data for Akwa Ibom state for 1988 were complemented using data reported by Ekpo and Essien-Ibok (2013), who documented artisanal fisheries landings for the state between 1978 and 1987. These were comparable to FDF records for Akwa Ibom for other years and were used to interpolate the missing 1988 value. Data on the number of fishermen engaged in artisanal fishing across the three time

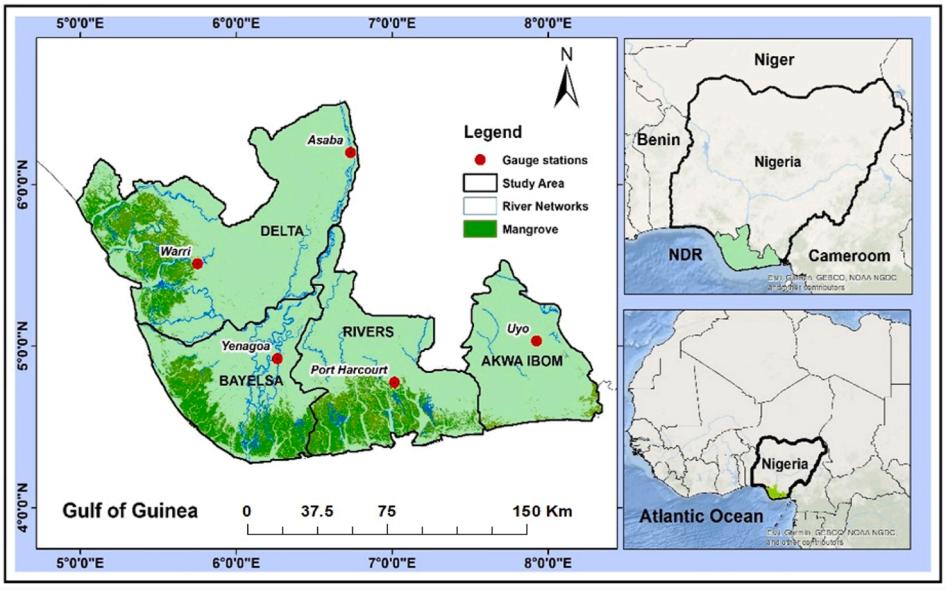

Fig. 1. (a) West Africa and (b) Nigeria (c) Delineation of the Niger River Delta (comprising of Akwa Ibom, Bayelsa, Delta, and Rivers and their gauge stations, and major river channels), and its location within (b).

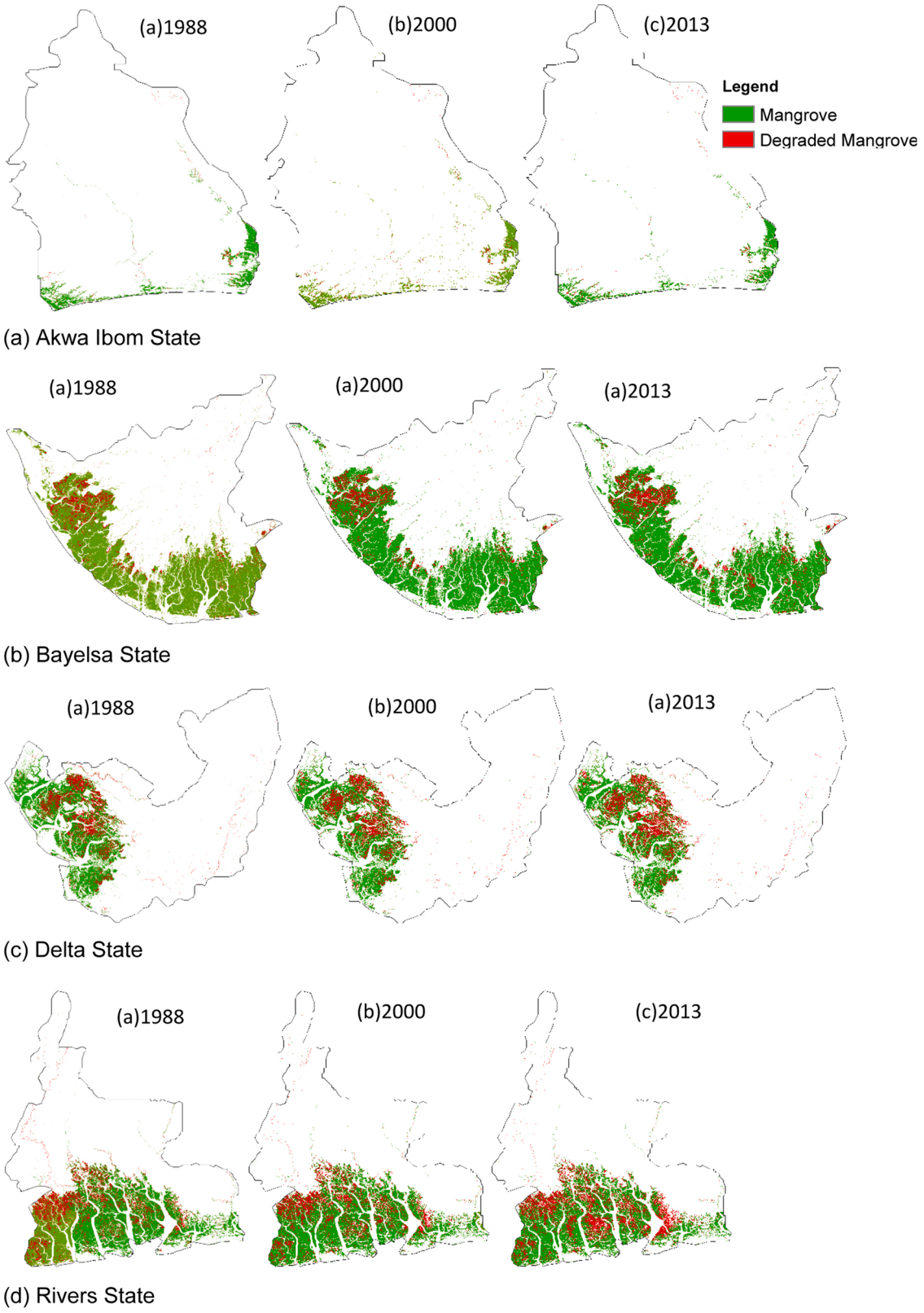

Fig. 2. Mangrove coverage in the NDR: (a) Akwa Ibom; (b) Bayelsa; (c) Delta; and (d) River state over three time epoch.

periods were also obtained from the FDF; however, these were available only as regional estimates for 1988 and national estimates for later periods. These data, used in conjunction with the approach developed by Amire (1999), enabled the re-estimation of fisherfolk numbers for the NDR at the three time points. Further details on the data and methods used are provided in the data analysis section.

2.2.3. Artisanal fishery of the NDR

Artisanal fishery landings published in the Fisheries Statistics of Nigeria were not defined by species, but rather by aggregated catches of multiple species grouped into different states for the inland and coastal areas of the country. The fishery is multi-species with more than 199 species of finfish and shellfish belonging to 78 families in brackish/marine waters and ~40–50 species in freshwater exploited by artisanal fishermen in the coastal and marine environment of Nigeria (Nwosu et al., 2016), which are largely mangrove-related (Udoh, 2016). Several studies have reported common species composition of the artisanal fishery of the coastal marine environment of Nigeria (i.e. predominantly the NDR) to comprise of commercially important fishes and crustaceans: estuarine catfish (*Chrysichthys nigrodigitatus*), the bonga *shad (Ethmalosa fimbriata)*, croakers *(Pseudotolithus spp.)*, shawa *(sardinella spp),* the estuarine prawn (*Nematopalaemon hastatus*; known as crayfish in Nigerian markets), the southern pink shrimp (*Penaeus notialis*) and freshwater prawns of the genus *Macrobrachium*, and black tiger prawn (*Penaeus monodon*) (Aderounmu, 1986; Moses et al., 2002; Oketoki, 2015; Sylvanus and Gao, 2007; Daniel and Monsi, 2019; Abowei and Hart, 2008; Sikoki and Otobotekere, 1999; Amire, 1999; Olaoye and Ojebiyi, 2018; Ben-Yami, 2001; Moses, 2000; Adebola, 2017). Based on the above findings, it is concluded that afore-mentioned species are the dominant composition of the aggregated multi-species landings for the study area (Schneider, 1990; Nwosu et al., 2016). Moreover, more than 70% of the fish caught in the coastal zone of the country are directly or indirectly mangrove-related (Udoh, 2016).

Artisanal fisherfolks in the NDR use motorized canoes, dug-out wooden canoes/paddled (small, medium, and large) such as the Ghanaian 'purse seine'; beach seines and utilize multi-gear mainly: gill nets, beaches, cast nets, hooks, hooks-and-lines, and a variety of traps to target the aforementioned species. Motorized canoes sometimes trawl further away from the 5 nautical miles non-trawling zone and use small-sized meshes, such as small eyed-nets, to capture large commercially important fisheries in brackish waters, and sometimes landings are recorded. Landings from canoes and other tools from different sites were recorded in each state on a monthly basis. The data were collected, compiled, and analyzed by FDF data scientists to produce annual summaries of combined artisanal landings for each state (not species-based) and other fishery information (sometimes fishery by species, revenues, number of vessels, etc.) at the national level (Federal Department of Fisheries – FDF, 2008). This annual fishery information is presented in tables and charts and published as the 'Fisheries Statistics of Nigeria' in different editions by the Federal Ministry of Agriculture and Rural Development of Nigeria. The artisanal fishery in the NDR is largely based on mangrove-associated fish species because the region is entirely fringed by extensive mangrove forests.

2.2.4. Rainfall and sea surface temperature data

Monthly rainfall data for five stations in four states in the NDR were obtained from Nigerian Meteorological Agency for periods between 1988 and 2013. The five stations comprised two stations in Delta state (Warri and Asaba), one in Rivers state (Port Harcourt), one in Akwa Ibom state (Uyo), and one in Bayelsa state (Yenagoa). Monthly SST data for the four states were obtained from the European Space Agency Climate Change Initiative for the same period (Merchant et al., 2019). Annual rainfall and SST data estimates were calculated by averaging the monthly means for the four states for the years: 1988, 2000 and 2013 and used as explanatory variables, together with mangrove estimates in the regression models.

The SST data was simply obtained by specifying the coordinates and using four data points for each of the states. The co-ordinates were approximated to values 0.05 ° to provide the finest information: a resolution 1 km × 1 km (the ATSR imagery at nadir view) and 18 km × 2.5 km (maximum footprint of AVHRR global based on spatial footprint of the thermal infra-red TIR observations). The SST data are based on global estimates and are available between 1981 and 2016. They are derived using 4×10^{12} satellite measurements of TIR radiance from two satellite sensors:11 Advanced Very High-Resolution Radiometers (AVHRRs) and three Along-Track Scanning Radiometers (ATSRs), and follows a comprehensive processing, ensuring consistent, high-quality SST estimates suitable for climate applications (Merchant et al., 2019). The data processing involved calibrating, geo-locating, and harmonizing satellite radiance data, followed by probabilistic pixel classification to identify valid SST pixels. The skin SST was retrieved from thermal radiances, then adjusted to estimate daily and monthly mean SST at a depth comparable to in situ measurements. Additionally, uncertainty estimates were derived for each retrieval. More information about the data processing approaches for the SST data can found in Merchant et al. (2019).

2.3. Data analysis

2.3.1. Re-estimation of artisanal fishery data

To address the anomalies in artisanal fisheries time series data, this study followed the 'catch re-construction' approach developed by Zeller et al. (2006) and Zeller et al. (2007). This approach allows for interpolation and informed assumptions where fisheries data are incomplete or absent, and is particularly suited to correcting the common misinterpretation of 'no data' as zero catch, a frequent issue in poorly documented fisheries. The reconstruction followed six steps: (1) identifying and collecting existing records of fisheries landings, number of fishermen, and fishing effort; (2) searching the literature for missing data across catch sectors, time periods, species, and gear types not covered in 1; (3) consulting local experts and relevant ministries, departments, and agencies (MDAs) to fill remaining data gaps in 2; (4) establishing data anchor points in time for missing records; (5) interpolating landing estimates between anchor points; and (6) combining reported landings data in 1 with interpolated data from step (5) to produce total landings and fishermen estimates.

This approach was applied to re-estimate missing artisanal fishery landings and the number of fishermen in the NDR for three-time periods:1988, 2000, and 2013. These years were selected because they correspond to the periods for which mangrove maps were available; cloud-free satellite imageries could not be obtained for intervening years.

Annual landing data for the four mangrove-based states of the study area (Akwa Ibom, Bayelsa, Delta, and Rivers) were collected from the FDF for the period 1988–2013. Data for 2000 and 2013 were used directly, as they were complete. However, data for 1988 presented two challenges: landing records for Akwa Ibom state were missing entirely, and landings for Bayelsa and Rivers states, and for Delta and Edo states, were reported as aggregated figures, likely because some of these states did not exist as separate administrative units before 1988.

To address missing 1988 data for Akwa Ibom, annual landing time series reported by Ekpo and Essien-Ibok (2013) for the period 1978–1987 were used alongside FDF records from 1989 onwards, and simple interpolation was applied to estimate the 1988 value. To disaggregate the combined Bayelsa / Rivers and Delta / Edo landing figures, the average percentage of changes in the annual landing time series data of each state derived from Fisheries Statistics of Nigeria covering 2007–2015 were used to re-estimate individual state landings for 1988. Total NDR landings for each time point were then calculated by summing the landings of the four states (Table 1). The raw landing time series that was obtained from the FDF and from peer reviewed literature is provided in S2 and Table S1 in the Supplementary Material.

To re-estimate the number of artisanal fishermen for three time points, the study the followed the approach by Amire (1999). A productivity rate of 0.95 tonnes per man-year was applied to the 1988 landings of Akwa Ibom and Delta states to estimate the number of full-time fishermen, with part-time fishers estimated as 20% of that figure. For the same period for Bayelsa and Rivers states (then River state), full-time and part-time fishermen counts were obtained directly

Table 1
summarises artisanal fishery landings of states in the NDR and their contribution in tons and % to total landings in the entire region over three time points.

	1988		2000		2013	
States	**FL (Tons)**	In (%)	**FL (Tons)**	In (%)	**FL (Tons)**	In (%)
AkwaIbom	37377	32.00	87586	48.00	153740	48.00
Bayelsa	13018	11.18	16282	9.11	42815	13.50
Delta	39665	34.05	26038	14.57	40747	12.85
Rivers	26431	22.00	48845	27.33	79810	25.17
NDR	116491	100.00	178751	100.00	317112	100.00

Note: FL=Fish Landings

from the FDF. The same productivity rate was then applied to total NDR landings for 2000 and 2013 to produce regional estimates of full-time and part-time fisherfolk for those periods. For more information on the estimation approach see S3 in the Supplementary material.

2.3.2. Relationship between landings, mangroves, rainfall and sea surface temperature

The relationships between artisanal fishery landings and mangrove coverage, rainfall, and SST for each state across the three time points were first examined using descriptive analysis. To further investigate these relationships, multiple regression analysis was conducted using a stepwise method in SPSS version 25 (Ghani and Ahmad, 2010).

Prior to the step-wise approach, all variables including mangrove coverage, rainfall, and SST were checked for multi-collinearity. Variables with high correlation coefficients (R^2) were selected and fitted to the multiple regression model. The significance of relationships, both for individual variables and combinations of variables within the multiple regression model, was determined at a 95% confidence interval ($p \leq 0.05$).

3. Results

3.1. Rainfall

The mean annual rainfall of the four mangrove-states in the NDR exceeded 2400 mm over the three time periods of the study except, for Delta state in 2000 (2170.4 mm), 2013 (2207.4 mm) and Rivers state in 2013 (2259.6 mm). The highest mean rainfall estimated was recorded for Akwa Ibom state in 2013, with mean rainfall well exceeding 4000 mm, and almost double the mean rainfall recorded for Delta state in 2000 (Fig. 4). For the NDR as a whole (i.e. four states), except in 2000 (2441.5 mm), the mean annual rainfall well exceeded 2500 mm in other time points, with the highest value recorded in 2013 (2980.4 mm) (Fig. 4). The coefficient of variation for mean annual rainfall was less than 9% for the time points.

3.2. Sea surface temperature

The mean annual SST for the four states was higher than 28°C across the three time periods. However, in Akwa Ibom and Rivers states in 2000, and Bayelsa state in 2013, the mean annual SST was relatively lower, ranging between 25.5°C and 26.1°C. The highest mean annual SST recorded was for Bayelsa state in 1988 (30.8°C; Fig. 5). For the NDR as a whole, the mean annual SST was above 27°C across the three time periods, with the highest value also recorded in 1988 (Fig. 5).

3.3. Mangroves extent in the Niger Delta region

Table 2 shows the estimates of mangrove coverage in the four states over the three epochs from the land cover classification map of the entire NDR in Nababa et al. (2020). From the results, Bayelsa state has the largest mangrove coverage among all the states for all periods: 3355 km^2 in 1988, 3333 km^2 in 2000, and 3301 km^2 in 2013 (Fig. 6). Similarly, the Delta state has the second largest mangrove: 2810 km^2 in 1988, 2758 km^2 in 2000, and 2720 km^2 in 2013. However, Akwa Ibom state recorded the lowest mangrove cover for all periods: 236 km^2 in 1988, 241 km^2 in 2000, and 225 km^2 in 2013. The results also shows a continues decline in mangrove coverage in all states for all the three dates except for Akwa Ibom state, where mangrove coverage recorded a gain in the first interval (between 1988 and 2000). The state with the largest decline in mangrove coverage (4.66%) was Akwa Ibom between 1988 and 2013. The second state is rivers (3.56%), followed by the delta state (2.85%), and then Bayelsa state (1.61%). In the Akwa Ibom state, the results demonstrate an interesting dynamic of mangrove coverage, with gains of 2.12% between 1988 and 2000 and a notable decline of 6.64% between 2000 and 2013, the highest among the four states over the study period. The results also showed that the total mangrove coverage in the NDR as a whole remained relatively stable, with a decline of 1.11% between 1988 and 2000, 1.17% between 2000 and 2013, and 2.69% between 1988 and 2013 (Fig. 6).

3.4. Variation of artisanal fishery landing between states in the NDR

In both 2000 and 2013, landings in Akwa Ibom state almost doubled compared to those of the second highest state (Rivers), at 1.8 times and 1.9 times higher respectively (Fig. 7 and Table 1). In the earliest period (1988), landings in Akwa Ibom state were also higher than those in Rivers state, by approximately a quarter (0.4 times). Akwa Ibom state contributed 48% of total landings in both 2000 and 2013, and 32% in 1988. The second highest contributor, Rivers state, accounted for 22% in 1988, 27% in 2000, and approximately 25% in 2013. In the earliest period, Delta state contributed 34% of total NDR landings. However, the contributions of Delta state in the remaining time periods, and of Bayelsa state across all three time periods, were less than 15% (Fig. 7 and Table 1).

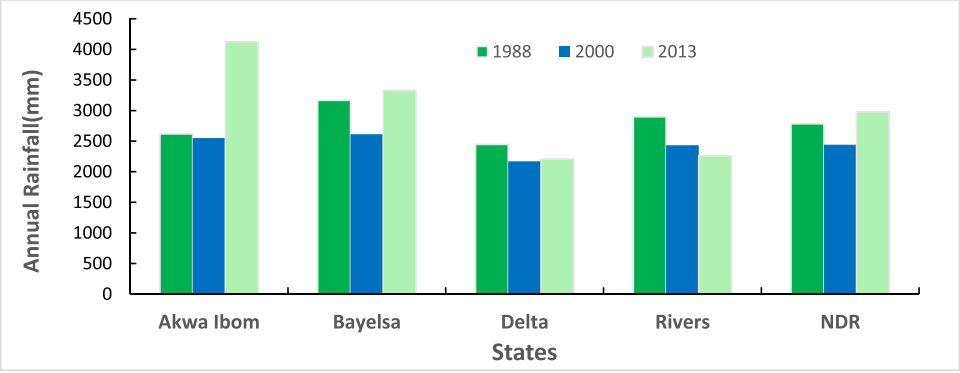

Fig. 4. Mean annual rainfall in the four states.

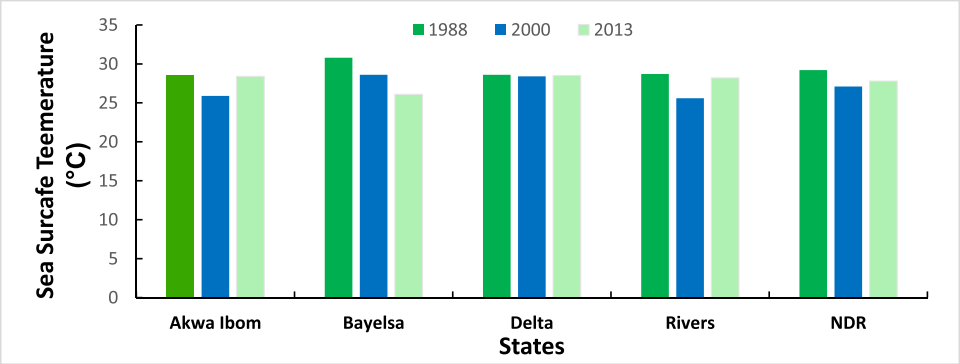

Fig. 5. Mean annual SST in four states of the NDR and in the NDR as a unit.

Table 2
Mangrove estimates of four states in the NDR for three periods in Km^2. M: Mangrove; D: Degraded Mangrove; and Total Mangrove M + DM.

	1988			2000			2013		
States	**M**	**DM**	**M+DM**	**M**	**DM**	**M+DM**	**M**	**DM**	**M+DM**
Akwa Ibom	222	13	236	223	18	241	209	16	225
Bayelsa	2953	402	3355	2874	459	3333	2769	532	3301
Delta	2155	655	2810	2032	726	2758	1903	817	2720
Rivers	1634	390	2024	1549	452	2001	1326	626	1952

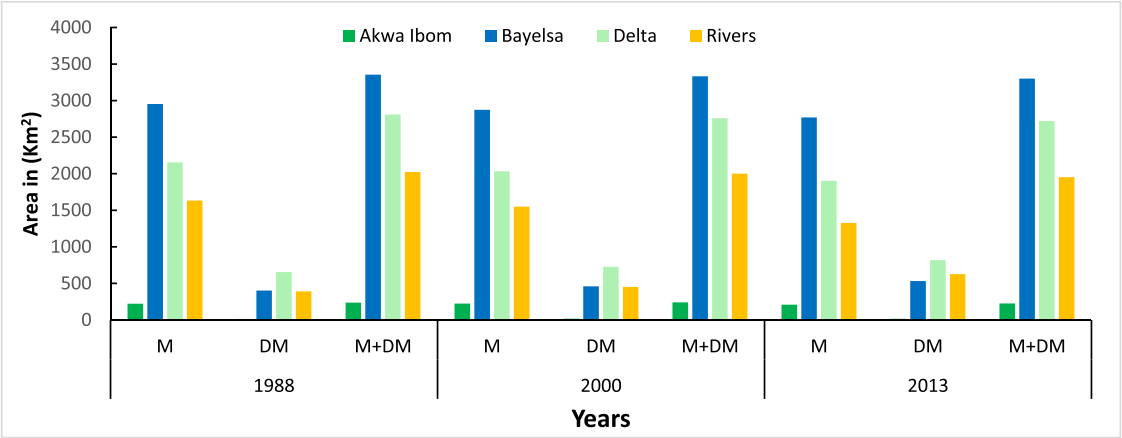

Fig. 6. Mangrove coverage for per state in the NDR over the three periods in Km^2. M: Mangrove; DM: Degraded Mangrove.

Across the four states and the NDR as a whole, mangrove extent showed little change over the study period; however, landings increased steadily in parallel (Fig. 8). Notably, in Akwa Ibom and Rivers states, where the largest mangrove losses occurred between 2000 and 2013, landings increased by approximately 76% and 63% respectively by 2013. In contrast, Delta state experienced comparatively lower mangrove loss between 1988 and 2000, at approximately 65% less loss than the other states. Interestingly, a slight increase in mangrove coverage of 2% in Akwa Ibom state during the first interval did not produce a comparable increase in landings by 2000, unlike the pattern observed in Akwa Ibom and Rivers states during the second interval, where the greatest mangrove losses coincided with the largest increases in landings. Between 1988 and 2013, landings increased by over 200% in all states except Delta state, where the increase was considerably lower at 2.73% (Fig. 8)

3.5. Re-estimations of landings and number of artisanal fishermen in the Niger Delta Region

The 'catch re-construction' approach devised by Zeller et al. (2006), was used to re-estimate all the landings in the earliest period (1988) present in Table 1. Also, the approach enabled estimation of the number of fishermen engaged in full-time and part-time fishing activities across the NDR as a whole, providing an assessment of the region's fishing capacity. More specifically, the approach by Amire (1999) was applied to total landings data for the three time points to estimate the number of fisherfolk for the NDR as a whole. Consequently, in 1988, 130 302 full time and 26 065 part-time fishermen accounted for 116 491 tonnes of landings in the NDR. By 2000, this increased to 188,159 full-time and 37,631 part-time fishermen, corresponding to 178,751 tonnes of landings. By 2013, the number of both full-time and part-time fishermen had almost doubled, reaching 333,802 and 66,760 respectively, with total landings of 317,112 tonnes (Fig. 6).

3.6. Relationships between mean annual artisanal fisheries landings, mangroves, rainfall, and SST

The relationship between sea surface temperature (SST) and fish landings across the four states (Akwa Ibom, Bayelsa, Delta, and Rivers) for 1988, 2000, and 2013 shows relatively little variation in SST

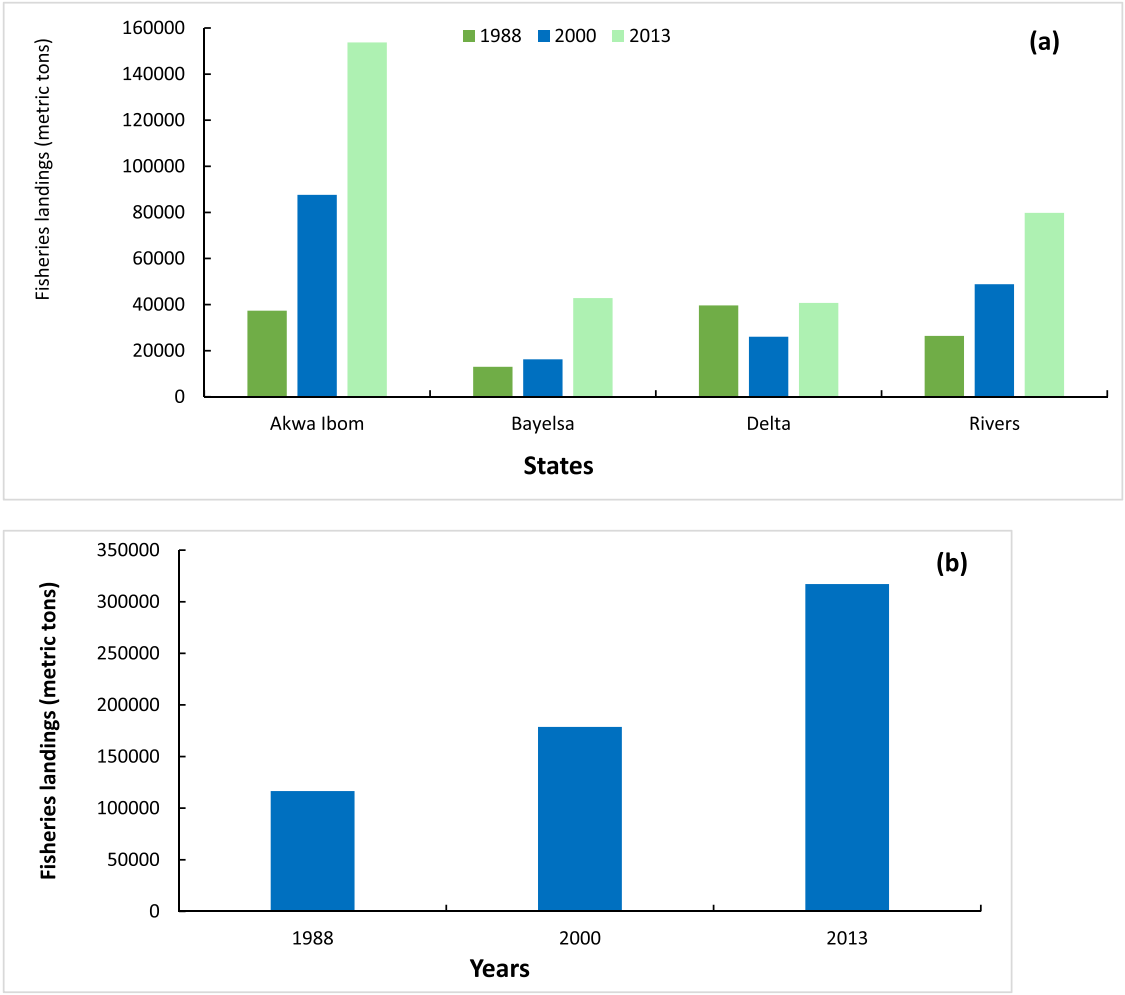

Fig. 7. Landings for in four states (a) and For the NDR (b).

compared to pronounced fluctuations in fish landings, indicating a weak direct relationship between SST and fisheries production (Fig. 9a). In contrast, annual rainfall and fish landings across the four states show that higher rainfall levels generally coincide with increased fish landings, particularly in 2013, suggesting a positive association between rainfall and fisheries productivity (Fig. 9b). The relationship between mangrove area and fish landings across the four states for the same periods shows that fish landings do not increase proportionally with mangrove extent, indicating a complex, non-linear relationship that is likely influenced by additional environmental and anthropogenic factors (Fig. 9c)

Table 4 shows the outputs of the stepwise approach when multiple variables were fitted into the multi-regression models. The stepwise multiple regression results predicted a strong positive correlation when multiple variables, including landings with rainfall and SST in 1988, landings with mangroves and SST in 2000, and landings with mangroves and rainfall in 2013, were fitted to the model (Table 4). The only statistically significant correlation is in the 2000s, accounting for ~96% of the variation in total landings. In 1988 and 2013, the multiple regression model accounted for ~91% and ~ 87% of the variation in the total landings, respectively (Table 4). With the exception of 1988, mangroves were included with SST and rainfall in 2000 and 2013, respectively, and fitted to the model, indicating a positive influence on catches in the NDR.

4. Discussion

Reliable estimates of mangrove coverage, fisheries landing data, and fishing capacity are necessary to examine the relationship between mangroves and fisheries in tropical coastal areas. However, obtaining accurate data can be problematic due to the diverse nature of artisanal fishing and the resulting spatial bias in landing data. This study demonstrates that the 'catch reconstruction' approach, combined with descriptive and regression analysis can enable the assessment of the relationship between mangroves, fisheries landings, and environmental factors such as rainfall and sea surface temperature. Additionally, the approach allows for the examination of states landings contribution to the national total and the estimation of the number of fishermen engaged in full-time and part-time artisanal fishing, which is a key variable in fishing capacity.

4.1. Is there a relationship between artisanal fishery landings and mangrove extent, changes in mangrove coverage over time, rainfall, and SST in the NDR?

Artisanal fisheries in tropical areas typically face challenges in obtaining data, including catch landing, information on fishing efforts, fisherfolk demographics, and socio-demographic and cultural factors (Batista et al., 2014; Tuda, 2018; Béné, 2006; Parsram, 2010). This study, the first of its kind in Nigeria and the Gulf of Guinea, aimed to quantitatively assess the relationship between artisanal fisheries and mangrove coverage, rainfall, and SST in the NDR. The study also

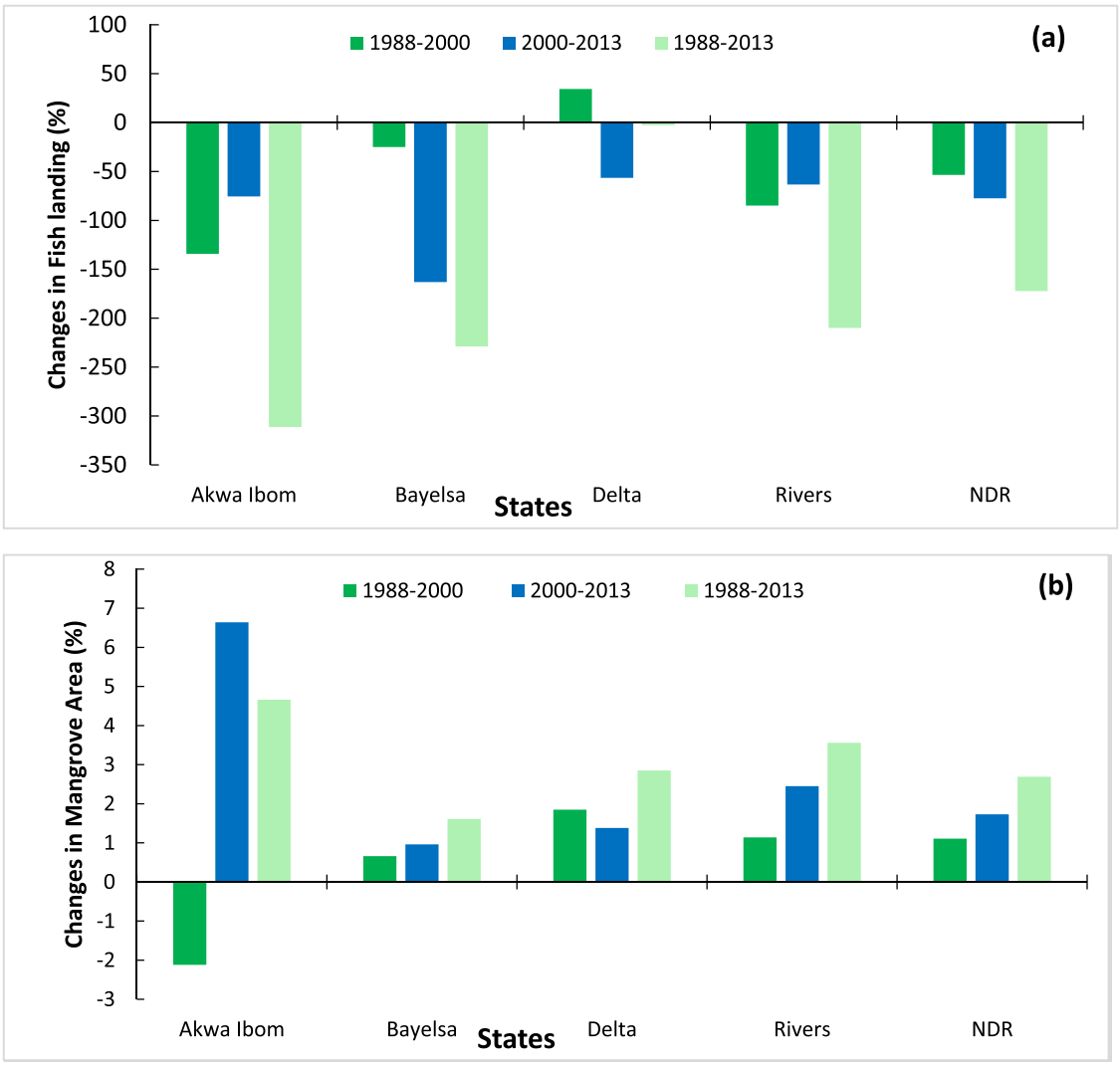

Fig. 8. Changes (%) in fisheries landings (a) and Changes (%) in mangrove are for four states in the NDR (b).

examined the contribution of the four mangrove states to artisanal fisheries in the NDR and estimated the number of fishermen engaged in artisanal fishing in the region.

The relationships observed in Fig. 9a–c demonstrate that fish landings in the Niger Delta are influenced by interacting environmental processes rather than a single controlling factor. Each variable influences fisheries production through different ecological pathways. Fig. 9a indicates a weak relationship between sea surface temperature (SST) and fish landings. Although SST is known to affect fish metabolism, distribution, and productivity, its influence is often most evident when temperature changes exceed species' physiological thresholds (Van der Sleen et al., 2022). The relatively narrow SST range observed across the study area likely remains within the tolerance limits of most tropical marine species, reducing its direct impact on interannual fish landing variability. Similar studies show that where SST variability is moderate, fishing effort and habitat conditions tend to outweigh thermal effects in determining catch levels (Innes-Gold et al., 2024).

In contrast, Fig. 9b shows a clearer positive association between rainfall and fish landings. Rainfall plays a critical role in Niger Delta estuarine systems by controlling freshwater inflow, nutrient delivery, sediment transport, and habitat connectivity (Chilton et al., 2021). Increased rainfall enhances land-to-sea nutrient fluxes, stimulating primary productivity and supporting higher trophic levels, including fish (Yi et al., 2023). Previous studies in the Niger Delta have reported improved fish productivity during periods of high rainfall and flooding due to expanded feeding and breeding habitats (Ngodigha, 2023). This explains the coincidence of peak rainfall and exceptionally high fish landings observed in 2013.

Fig. 9c reveals a complex and non-linear relationship between mangrove area and fish landings. Mangroves are widely recognised as critical nursery and refuge habitats that enhance fish recruitment and long-term stock sustainability (Ogbeibu & Oribhabor, 2023; Faunce and Serafy, 2006). However, fish landings do not scale directly with mangrove extent, as landings also depend on fishing effort, access, gear efficiency, and post-harvest infrastructure (Teixeira et al., 2014; Batista et al., 2014., Silas et al., 2020). In the Niger Delta, extensive mangrove degradation from oil pollution and deforestation has reduced habitat quality in some areas, potentially weakening the expected positive relationship between mangrove cover and fisheries output (Ohimain, 2016; Ogbeibu & Oribhabor, 2023). Consequently, high fish landings in states with limited mangrove cover may reflect intensified fishing activity as shown in Akwa Ibom State. Although, this study uses aggregated landings, the findings are comparable to those of single species studies conducted in the Joseph Bonaparte Gulf in Northwest Australia (Kenyon et al., 2004) and the Gulf of California in Mexico (Carrasquilla-Henao et al., 2013), both of which found no significant relationship between mangrove extent and commercial fish species

The non-linear relationship between fisheries landings and

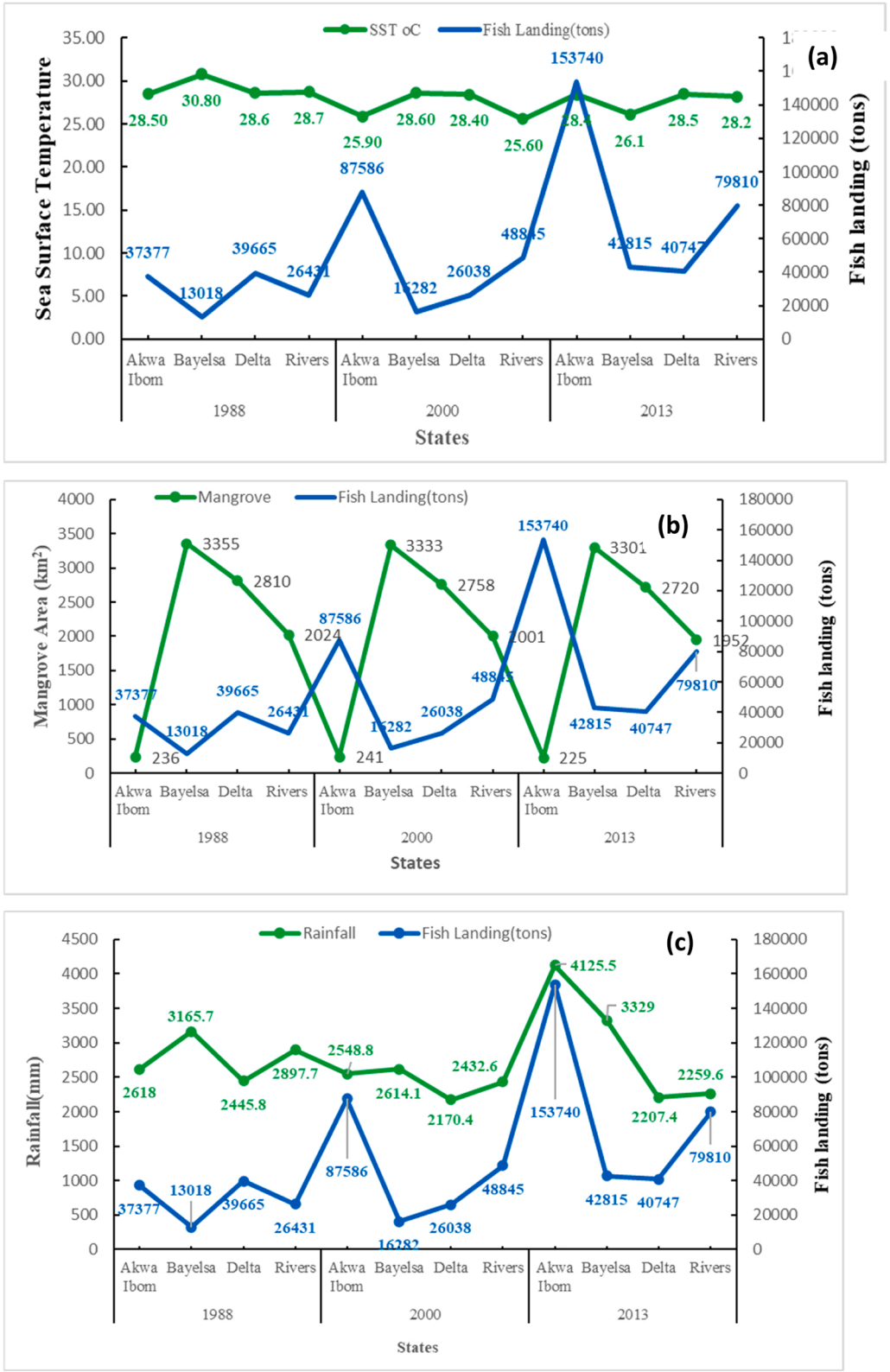

Fig. 9. Relationship between Landings and mangroves in (a), landings and rainfall in (b), and landings and SST in (c) between 1988 and 2013.

mangrove extent in the NDR is likely attributable to overfishing, supported by data from fisherfolk during the study period (Adebola, 2017; Ogbonna, 2001; Moses, 2000). Also, the study period coincided with increased mechanized and motorized artisanal fishing and intense fishing along the Nigerian coastal waters (Tuda, 2018), resulting in a significant increase in fisheries landings alongside declining mangrove and increased degradation (Table 1 & 2). Additionally, Nigeria's population nearly doubled between 1988 and 2013, growing from approximately 90 million to 177 million, which contributed to a more than two-fold increase in fisherfolk in the region and a three-fold increase in Fish landings in the NDR (Fig. 8a & b). Furthermore, reduced tension in the region following the Federal Government's granting of Amnesty in

Table 4
Coefficient of determination (R2) and significance levels (*) for stepwise multiple regressions between mean annual landings with Rainfall + SST, Mangroves+ SST, and Mangroves + Rainfall over the three time points.

Years	Variables	R	P-value
1988	Rainfall + SST	0.99	ns
2000	Mangroves+ SST	0.99	*
2013	Mangroves + Rainfall	0.98	ns

Levels of significance: *** p- value < 0.001 (highly significant); ** p- value < 0.01 (very significant); *p -value < 0.05 (significant), ^{ns} p -value ≥ 0.05 (not significant).

2009 led to increased migration and greater fishing opportunities for local communities, as observed at the latest time point.

The multiple regression analysis revealed strong positive correlations between fish landings and several environmental variables: landings with rainfall and SST in 1988, landings with mangroves and SST in 2000, and landings with mangroves and rainfall in 2013 (Table 4). The strongest relationship was observed in 2000, where the model accounted for approximately 96% of the variation in total landings (Table 4). This may be attributed to the combined effect of consistently high rainfall across the region, a favourable temperature range (25–31°C), and relative stability in mangrove coverage, which reached its peak during this period (Staples et al., 1985; Kuenzer et al., 2014; Nababa et al., 2020).

Akwa Ibom state is the largest contributor to artisanal fisheries landings in the NDR, with particular emphasis on shellfish such as southern pink shrimp and crayfish (Ekpo and Essien-Ibok, 2013). The state has 218 fishing villages across 11 local government areas, and its high population density (774.2 persons/km^2) likely contributed to its high number of fisherfolk and large catch volumes, despite having the lowest mangrove coverage and the highest percentage of mangrove loss among the four states (Table 1 and Fig. 8). Notably, its artisanal fisheries landings along a coastline of only 134 km are approximately 7.5 times greater than the average annual aggregated landings in the Gulf of California (11,600 tonnes; Aburto-Oropeza et al., 2008), which extends approximately 4000 km.

The relationship between artisanal fisheries landings and mangrove coverage in the Niger Delta is complex and inconsistent across states. Despite Rivers state experiencing the second largest area of mangrove loss (2.45%) and a substantial area of degraded mangrove (174 km^2) between 2000 and 2013, fish landings in the state increased by 63%. In contrast, Delta state recorded a decrease in landings of 34% despite experiencing less mangrove loss and retaining higher mangrove coverage than both Akwa Ibom and Rivers states. This difference may partly reflect higher mangrove diversity in Akwa Ibom and Rivers states (Sarathchandra et al., 2018), or the shared border between the two states, which may facilitate fisherfolk movement and influence landings across state boundaries. Rivers state also has the second highest population density in the NDR (659.4 persons/km^2), which likely contributes to higher fishing effort and catch volumes. Delta state, by contrast, has the lowest population density (320 persons/km^2) and the largest extent of degraded mangroves among the four states (Table 2). The prevalence of oil spills and gas incidents in the area may further explain the reduced fish landings recorded there (Kadafa, 2012; Balogun, 2015; Duke, 2016).

These findings suggest that the degradation of smaller mangrove areas can have a greater impact on fish landings than equivalent degradation in larger areas, as smaller mangrove patches are often more accessible and more important to local communities for subsistence fishing. Our findings in this study, underscore the need for integrated fisheries management in the NDR that combines targeted mangrove habitat conservation, climate-informed planning, and effective regulation of fishing pressure to ensure the long-term sustainability of artisanal fisheries in the Niger Delta.

4.2. How reliable are the sources of data and the re-estimation approach?

With the exception of annual artisanal fisheries catch and fishermen data, all other data used in this study are considered relatively reliable due to the methods used in their estimation. The diverse nature of the artisanal fisheries, including multi-species, multi-gear operation, and mobility of fisherfolks are the primary sources of bias in official records. These factors make it difficult to identify species, estimate landings accurately, and compare indices such as catch per unit effort (CPUE), tasks typically carried out by a limited number of field officers. As a result, landings are often reported in aggregate, errors in reporting are common, and zero catch is sometimes recorded consistently over time. Furthermore, states have been known to inflate production figures reported to the FDF in order to appear as the highest producers (Etim et al., 2015). Additionally, final fisheries production figures published by the FDF are typically higher than those provided by individual states, partly due to bureaucratic inefficiencies within MDAs in data collection. Nevertheless, these official data remain the primary source used to assess local and national fisheries status and trends. The over-representation of total catches, however, risks erroneous interpretation of the fisheries status in the NDR, with serious implications for the sustainability and ecosystem-based management of the fishery.

Official data on artisanal fisheries production in the NDR and other regions of the country, published in Fisheries Statistics of Nigeria by the FDF are inconsistent, and information on fishing capacity is fragmentary (FDF, 2007; Etim et al., 2015). Artisanal fisheries landings for the NDR for 1988 and the number of fishermen across the three time points were therefore re-estimated in this study, with the exception of landing data for later periods, which were used directly. Results indicate that Akwa Ibom, Bayelsa, Delta, and Rivers states had total landings of 37,377 t, 13,018 t, 39,665 t, and 26,431 t respectively in 1988 (Table 1). To the best of our knowledge, no existing studies have re-estimated fisheries catches for the NDR, particularly for the artisanal sector. The landings for Akwa Ibom and Delta states for 1988 were estimated using a standard reconstruction approach based on anchor points sourced from peer-reviewed (Ekpo and Essien-Ibok, 2013) and grey literature (Amire, 1999), moderated by conservative assumptions and interpolated for missing data years (Zeller et al., 2006).

Similarly, no studies estimating the number of fisherfolks specifically for the NDR or revising national estimates to be representative of the region were identified in the literature. A national estimate of approximately 666,320 fisherfolk for the year 2000 has been reported for what is referred to as the NCW, presumably the NDR (Tuda, 2018). In contrast, this study estimates 188,159 full-time and 37,631 part-time fishermen for the same period, a difference of more than three-fold for full-time fishermen alone. This study acknowledges that fisheries statistics can be subject to alteration, leading to over-reporting and misleading information, which in turn risks overvaluing the economic and social contributions of the fishery sector, with significant implications for sustainability and management.

To validate the reliability of the re-estimation approach, particularly for missing 1988 landing data for Akwa Ibom state, interpolation was carried out for the years 1991 and 2000 for the same state. The interpolated values compared favourably with official estimates reported in the Fisheries Statistics of Nigeria, providing confidence in the reliability of the interpolation carried out (See S2 and Table S1 in the Supplementary Material). Whilst, some of the estimates may not be statistically rigorous, the conservative approach adopted is considered more defensible than for example, the national fisherfolk estimates presented as representative of the NDR by Tuda (2018)

The inherent challenges associated with artisanal fisheries data collection remain a significant limitation of this study. The tendency to report zero catch for problematic periods, and the absence of regional or local fishermen estimates in official figures, constrained the analysis. Nevertheless, the finest available data from official sources, peer-reviewed literature, and grey literature were utilised, and a

conservative reconstruction approach was applied throughout. Fisheries-independent surveys are critical for improving the reliability of stock assessments and recruitment indicators (Saenger et al., 2013a; Loneragan et al., 2005). Such surveys were previously conducted in Nigeria's coastal waters on an annual basis (Amire, 1999) and should be reinstated to monitor the status of artisanal fisheries in the NDR. Increased sampling efforts are particularly, recommended for Akwa Ibom state, given its importance as the country's primary producer of crayfish (estuarine prawn) and its significance to artisanal fisheries, and shellfish production more broadly (Ekpo and Essien-Ibok, 2013)

5. Conclusion

Artisanal fisheries catch data are notoriously characterised by data paucity, with official figures frequently over-reported or incomplete. For the first time, this study disentangles the relationship between artisanal fisheries landings and mangrove extent, rainfall, and SST across three time periods by incorporating catch reconstruction, descriptive, and regression analysis. A non-linear relationship was found between landings and mangrove coverage, with rainfall positively associated with increased landings. Akwa Ibom was the largest contributor to NDR landings across all three time points, despite having the lowest mangrove coverage. Additionally, for the first time ever, fisherfolk numbers engaged in full-time and part-time artisanal fishing in the NDR were reliably estimated, with results suggesting that landings are strongly influenced by population growth. This study presents the first quantitative assessment of mangrove-fisheries links in the NDR and Gulf of Guinea, with practical importance for integrated fisheries management combining habitat conservation, climate-informed planning, and regulation of fishing pressure.

CRediT authorship contribution statement

Nababa Iliya: Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Olalekan Adekola:** Writing – review & editing, Supervision, Resources, Project administration, Methodology, Conceptualization. **Nwachukwu Joseph:** Writing – review & editing, Conceptualization. **Gina Cavan:** Writing – review & editing, Supervision. **Elias Symeonakis:** Writing – review & editing, Supervision, Project administration. **Kuta Abdullahi:** Writing – review & editing, Visualization, Validation, Software.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.rsma.2026.105071.

Data availability

It is contained in the supplementary materials and data sources were referenced accordingly in the manuscript

References

Abam, T., 2001. Regional hydrological research perspectives in the Niger Delta. Hydrol. Sci. J. 46 (1), 13–25.
Abowei, J., Hart, A., 2008. Artisanal fisheries characteristics of the fresh water reaches of lower Nun River, Niger Delta, Nigeria. J. Appl. Sci. Environ. Manag. 12 (1), 5–11.
Aburto-Oropeza, O., Ezcurra, E., Danemann, G., Valdez, V., Murray, J., Sala, E., 2008. Mangroves in the Gulf of California increase fishery yields. Proc. Natl. Acad. Sci. USA 105 (30), 10456–10459.
Adebola, T.M., 2017. Investigating Anthropogenic Impacts on Nigerian coastal Waters using Ecosystem Modeling Approaches. George Mason University.
Aderounmu, A. (1986) 'Small-scale fisheries development in Nigeria: Status, prospects, constraints/recommended solutions.' *3rd Annual conference of the fisheries society of Nigeria* (FISON). Maiduguri, Nigeria pp. 30–39.
Adeyemo, O.K., Ubiogoro, O.E., Adedeji, O.B., 2009. Oil exploitation, fisheries resources and sustainable livelihood in the Niger delta, Nigeria. Nat. Faune 24 (1), 56–88.
Allison, E.H., Ellis, F., 2001. The livelihoods approach and management of small-scale fisheries. Mar. Policy 25 (5), 377–388.
Alms, V., Romagnoni, G., Wolff, M., 2022. Exploration of fisheries management policies in the Gulf of Nicoya (Costa Rica) using ecosystem modelling. Ocean Coast. Manag.
Alongi, D.M., 2002. Present state and future of the world's mangrove forests. Environ. Conserv. 29 (3), 331–349.
Alonso-Perez, R. F. Ruiz-Luna, J. Turner, C.A. Berlanga-Robes, G. Michelson-Jacob (2003) Land cover changes and impacts of shrimp aquaculture on the landscape in the Ceuta coastal lagoon system, Sinaloa, Mexico : Ocean and Coastal Management, 46 (2003), pp. 583-600.
Amire, A.V. (1999) *Monitoring, measurement and assessment of fishing capacity: the Nigerian experience*. FAO fisheries technical paper. Measuring capacity in fisheries. No 445. FAO, Rome, Italy.
Anon. (1988) *Fishing industry–Annual report, Nigeria*. 12: Department of State, Message Reference Number A-9, U.S.
Apel, A., Fujita, R., Karr, K., 2013. Science-based management of data-limited fisheries: a supplement to the catch share design manual. Environ. Def. Fund. 27.
Balogun, T.F., 2015. Mapping impacts of crude oil theft and illegal refineries on mangrove of the Niger Delta of Nigeria with remote sensing technology. Mediterr. J. Soc. Sci. 6 (3), pp. 150-150.
Barbier, E.B., Strand, I., 1998. Valuing mangrove-fishery linkages - a case study of Campeche, Mexico. Environ. & Resour. Econ. 12 (2), 151–166.
Batista, V.S., Fabre, N.N., Malhado, A.C.M., Ladle, R.J., 2014. Tropical artisanal coastal fisheries: challenges and future directions. Rev. Fish. Sci. Aquac. 22 (1), 1–15.
Batista, V.S., Fabre, N.N., Malhado, A.C.M., Ladle, R.J., 2014. Tropical artisanal coastal fisheries: challenges and future directions. Rev. Fish. Sci. Aquac. 22 (1), 1–15.
Beitl, C.M., 2014. Navigating over space and time: fishing effort allocation and the development of customary norms in an open-access mangrove estuary in ecuador. Hum. Ecol. 42 (3), 395–411.
Belhabib, D., Lam, V.W., Cheung, W.W., 2016. Overview of West African fisheries under climate change: impacts, vulnerabilities and adaptive responses of the artisanal and industrial sectors. Mar. Policy 71, 15–28.
Béné, C., 2006. Small-scale fisheries: assessing their contribution to rural livelihoods in developing countries. FAO Fish. Circ. 1008, 46.
Ben-Yami, M., 2001. Integration of traditional institutions and people's participation in an artisanal fisheries development project in south-eastern Nigeria. Underst. Cult. Fish. Communities A Key Fish. Manag. Food Secur. 401.
Birkeland, C. and Orosenbauqh, D. (1985) 'Ecological Interactions between Tropical Coastal Ecosystems. UNEP Regional Seas Reports and Studies No. 73.' *UNEP Regional Seas Reports and Studies*.
Blasco, F., Saenger, P., Janodet, E., 1996. Mangroves as indicators of coastal change. Catena 27 (3-4), 167–178.
Carrasquilla-Henao, M., Ban, N., Rueda, M., Juanes, F., 2019. The mangrove-fishery relationship: a local ecological knowledge perspective. Mar. Policy 108, 103656.
Carrasquilla-Henao, M., Juanes, F., 2017. Mangroves enhance local fisheries catches: a global meta-analysis. Fish Fish. 18 (1), 79–93.
Carrasquilla-Henao, M., Ocampo, H.A.G., Gonzalez, A.L., Quiroz, G.R., 2013. Mangrove forest and artisanal fishery in the southern part of the Gulf of California, Mexico. Ocean Coast. Manag. 83, 75–80.
Carrasquilla-Henao, M., Rueda, M., Juanes, F., 2022. Fish habitat use in a Caribbean mangrove lagoon system. Estuar. Coast. Shelf Sci. 278, 108090.

Chaudhuri, P., Chaudhuri, S., Ghosh, R., 2019. The role of mangroves in coastal and estuarine sedimentary accretion in Southeast Asia. Sediment. Process. Ex. Asia Turk. Niger. Lond. UK 89–112.

Chilton, D., Hamilton, D.P., Nagelkerken, I., Cook, P., Hipsey, M.R., Reid, R., Sheaves, M., Waltham, N.J., Brookes, J., 2021. Environmental flow requirements of estuaries: providing resilience to current and future climate and direct anthropogenic changes. Front. Environ. Sci. 9, 764218. https://doi.org/10.3389/fenvs.2021.764218.

Chong, V.C., Sasekumar, A., Atmadja, W.S. and Low, J.K.Y. (1994) *Status of mangrove prawn fisheries in the ASEAN countries*. Third ASEAN-Australia Symposium on Living Coastal Resources, Townsville (1), pp. 147-156.

Daniel, U., Monsi, B., 2019. Characteristics of artisanal fisheries in the upper reaches of Bonny Estuary, Niger Delta, Nigeria. MOJ Eco Environ. Sci. 4 (6), 263–266.

Diele, K., Araujo, A. d R., Glaser, M. and Salzmann, U. (2010) 'Artisanal fishery of the mangrove crab Ucides cordatus (Ucididae) and first steps toward a successful co-management in Bragança, North Brazil.' *In Mangrove dynamics and management in north Brazil*. Vol 211, pp. 287-297.

Donato, D.C., Kauffman, J.B., Murdiyarso, D., Kurnianto, S., Stidham, M., Kanninen, M., 2011. Mangroves among the most carbon-rich forests in the tropics. Nat. Geosci. 4 (5), 293–297.

Duke, N.C., 2016. Oil spill impacts on mangroves: recommendations for operational planning and action based on a global review. Mar. Pollut. Bull. 109 (2), 700–715.

Duke, N.C., Meynecke, J.-O., Dittmann, S., Ellison, A.M., Anger, K., Berger, U., Cannicci, S., Diele, K., et al., 2007a. A world without mangroves? Science 317 (5834), 41–42.

Ekpo, I.E., Essien-Ibok, M.A., 2013. Development, prospects and challenges of artisanal fisheries in Akwa Ibom State, Nigeria.' *International Journal of Environmental Science*. Manag. Eng. Res. 2 (3), 69–86.

Ellison, J.C., 2015. Vulnerability assessment of mangroves to climate change and sea-level rise impacts. Wetl. Ecol. Manag. 23 (2), 115–137.

Ermgassen, P., Mukherjee, N., Worthington, T.A., Acosta, A., Araujo, A.R.D., Beitl, C.M., Castellanos-Galindo, G.A., Cunha-Lignon, M., et al., 2020. Fishers who rely on mangroves: Modelling and mapping the global intensity of mangrove-associated fisheries. Estuar. Coast. Shelf Sci. 248 (2021), 107159.

Etim, L., Belhabib, D., Pauly, D., 2015. An overview of the Nigerian marine fisheries and a re-evaluation of its catch data for the years 1950–2010. Fish. Cent. Work. Pap. Ser. 68.

FAO. (2007) *The world's mangroves 1980-2005*. FAO Forestry Paper: 153, Rome.

FAO. (2017) *Fisheries and Aquaculture:Fishery and Aquaculture Country Profile, the Federal republic of Nigeria*. Rome, Italy.

Faunce, C.H., Serafy, J.E., 2006. Mangroves as fish habitat: 50 years of field studies. Mar. Ecol. Prog. Ser. 318, 1–18.

Federal Department of Fisheries – FDF (2008): Fisheries statistics of Nigeria. Fourth edition, 1995-2007, Nigeria,48pp.

Friess, D.A., Yando, E.S., Abuchahla, G.M.O., Adams, J.B., Cannicci, S., Canty, S.W.J., Wee, A.K.S., 2020. Mangroves give cause for conservation optimism, for now. Curr. Biol. 30 (4), R153–R154.

Fujita, R., Thornhill, D.J., Karr, K., Cooper, C.H., Dee, L.E., 2014. Assessing and managing data-limited ornamental fisheries in coral reefs. Fish Fish. 15 (4), 661–675.

Ghani, I.M.M. and Ahmad, S. (2010) 'Stepwise Multiple Regression Method to Forecast Fish Landing.' *International Conference on Mathematics Education Research 2010 - Icmer 2010*, 8 pp. 549-554.

Gillett, R. & Lightfoot, C. 2002, *The contribution of fisheries to the economies of Pacific Island countries*, Asian Development Bank, PO Box 789, 0980 Manila, Philippines.

GmbH, G. and Contributors, O. (2018) 'Open Street map of Nigeria.' [Online]. [Accessed on online Accessed 20th June 2020] ⟨https://download.geofabrik.de/africa/nigeria.html⟩.

Goldberg, L., Lagomasino, D., Thomas, N., Fatoyinbo, T., 2020. Global declines in human-driven mangrove loss. Glob. Change Biol. 26 (10), 5844–5855.

Grimmel, H.M.V., Bullock, R.W., Dedman, S.L., Guttridge, T.L., Bond, M.E., 2020. Assessment of faunal communities and habitat use within a shallow water system using non-invasive BRUVs methodology. Aquac. Fish.

Guannel, G., A, K., Ruggie, P., Verutes, G., 2016. The power of three: coral reefs, seagrasses and mangroves protect coastal regions and increase their resilience. PLoS ONE 11 (7), e0158094.

Honey, K.T., Moxley, J.H., Fujita, R.M., 2010. From rags to fishes: data-poor methods for fishery managers. Manag. Data-Poor Fish. Case Stud. Models Solut. 1 (978), 159–184.

Hutchison, J., Ermgassen, P.Z., Spalding, M., 2015. The current state of knowledge on mangrove fishery values. Mangroves Fish. Habitat 83, 3–15.

Innes-Gold, A.A., Carvalho, P., McManus, L.C., Correa-Garcia, S., Marcoux, S.D., Oleson, K.L.L., Stokes, K., Madin, E.M.P., 2024. Modeling the interactive effects of sea surface temperature, fishing effort and spatial closures on reef fish populations. Theor. Ecol. 17, 289–300. https://doi.org/10.1007/s12080-024-00591-7.

Islam, M.S., Haque, M., 2004. The mangrove-based coastal and nearshore fisheries of Bangladesh: ecology, exploitation and management. Rev. Fish. Biol. Fish. 14 (2), 153–180.

Islam, M.S., Wahab, M.A., 2005. A review on the present status and management of mangrove wetland habitat resources in Bangladesh with emphasis on mangrove fisheries and aquaculture. Hydrobiologia 542, 165–190.

Jacquet, J., Fox, H., Motta, H., Ngusaru, A., Zeller, D., 2010. Few data but many fish: marine small-scale fisheries catches for Mozambique and Tanzania. Afr. J. Mar. Sci. 32 (2), 197–206.

Kadafa, A.A., 2012. Oil exploration and spillage in the Niger Delta of Nigeria. Civ. Environ. Res. 2 (3), 38–51.

Katikiro, R.E., Macusi, E.D., 2012. Impacts of climate change on West African fisheries and its implications on food production. J. Environ. Sci. Manag. 15 (2), 83–95.

Kenyon, R., Loneragan, N., Manson, F., Vance, D., Venables, W., 2004. Allopatric distribution of juvenile red-legged banana prawns (Penaeus indicus H. Milne Edwards, 1837) and juvenile white banana prawns (Penaeus merguiensis De Man, 1888), and inferred extensive migration, in the Joseph Bonaparte Gulf, northwest Australia. J. Exp. Mar. Biol. Ecol. 309 (1), 79–108.

Kuenzer, C., van Beijma, S., Gessner, U., Dech, S., 2014. Land surface dynamics and environmental challenges of the Niger Delta, Africa: Remote sensing-based analyses spanning three decades (1986-2013). Applied Geography 53, 354–368.

Lam, V.W., Allison, E.H., Allison, E.H., Bell, J.D., Bell, J.D., Blythe, J.L., Cheung, W.W., Frölicher, T.L., Frölicher, T.L., Gasalla, M.A., Sumaila, U.R., 2020. Climate change, tropical fisheries and prospects for sustainable development. Nat. Rev. Earth Environ. 1, 440–454.

Loneragan, N.R., 1999. River flows and estuarine ecosystems: implications for coastal fisheries from a review and a case study of the Logan River, southeast Queensland. Aust. J. Ecol. 24 (4), 431–440.

Loneragan, N.R., Adnan, N.A., Connolly, R.M., Manson, F.J., 2005. Prawn landings and their relationship with the extent of mangroves and shallow waters in western peninsular Malaysia. Estuar. Coast. Shelf Sci. 63 (1-2), 187–200.

Macintosh, D., 1982. Fisheries and aquaculture significance of mangrove swamps, with special reference to the Indo-West Pacific region. Recent Adv. Aquac. 4–85.

Magnuson, J., DeStasio, B., 1997. Thermal niche of fishes and global warming. In: Wood, C.M., McDonald, D.G. (Eds.), Implications for freshwater and marine fish, 61. Cambridge University Press, Cambridge, pp. 377–408.

Manson, F.J., Loneragan, N.R., Harch, B.D., Skilleter, G.A., Williams, L., 2005b. A broad-scale analysis of links between coastal fisheries production and mangrove extent: a case-study for northeastern Australia. Fish. Res. 74 (1-3), 69–85.

Manson, F.J., Loneragan, N.R., Skilleter, G.A., Phinn, S.R., 2005a. An evaluation of the evidence for linkages between mangroves and fisheries: a synthesis of the literature and identification of research directions. Oceanogr. Mar. Biol. Annu. Rev. 43 (43), 483–513.

Marley, G.S., Deacon, A.E., Phillip, D.A., Lawrence, A.J., 2020. Mangrove or mudflat: prioritising fish habitat for conservation in a turbid tropical estuary. Estuar. Coast. Shelf Sci. 240, 106788.

Marques, J.M.L., Cruz, R., Feitosa, C.V., 2021. Dynamics of artisanal fisheries performed with hook-and-line gear under different management regimes inBrazil. OceanCoastManag 200, 105403.

Matveev, V.F., Steven, A.D.L., 2014. The effects of salinity, turbidity and flow on fish biomass estimated acoustically in two tidal rivers. Mar. Freshw. Res. 65, 267–274. https://doi.org/10.1071/MF12266.

Merchant, C.J., Embury, O., Bulgin, C.E., Block, T., Corlett, G.K., Fiedler, E., Good, S.A., Mittaz, J., et al., 2019. Satellite-based time-series of sea-surface temperature since 1981 for climate applications. Sci. Data 6 (1), 223.

Moberg, F., Folke, C., 1999. Ecological goods and services of coral reef ecosystems. Ecol. Econ. 29 (2), 215–233.

Moberg, F., Rönnbäck, P., 2003. Ecosystem services of the tropical seascape: interactions, substitutions and restoration. Ocean Coast. Manag. 46 (1-2), 27–46.

Moffat, D., Linden, O., 1995. Perception and reality: assessing priorities for sustainable development in the Niger River Delta. Ambio 24 (7-8), 527–538.

Moses, B.S., 2000. A review of artisanal marine and brackishwater fisheries of south-eastern Nigeria. Fish. Res. 47 (1), 81–92.

Moses, B.S., Udoidiong, O.M., Okon, A.O., 2002. A statistical survey of the artisanal fisheries of south-eastern Nigeria and the influence of hydroclimatic factors on catch and resource productivity. Fish. Res. 57 (3), 267–278.

Naamin, N., 1977. Relationship between tidal forests (mangroves) and commercial shrimp production in Indonesia. Mar. Res. Indones. 18, 81–86.

Nababa, I.I., Symeonakis, E., Koukoulas, S., Higginbottom, T.P., Cavan, G., Marsden, S., 2020. Land cover dynamics and mangrove degradation in the Niger Delta region. Remote Sens. 12 (21), 3619.

Narayan, S., Beck, M.W., Reguero, B.G., Losada, I.J., van Wesenbeeck, B., Pontee, N., Sanchirico, J.N., Ingram, J.C., 2016. The effectiveness, costs and coastal protection benefits of natural and nature-based defences. Plos One 11 (5), e0154735.

NBS. (2018) National Population projection. Abuja, Nigeria. (NBS Report) Alonso-Perez, R. F. Ruiz-Luna, J. Turner, C.A. Berlanga-Robes, G. Michelson-Jacob (2003) Land cover changes and impacts of shrimp aquaculture on the landscape in the Ceuta coastal lagoon system, Sinaloa, Mexico : Ocean and Coastal Management, 46 (2003), pp. 583-600.

Ngodigha, S.A., 2023. Fish diversity in extreme flood in Epie Creek, Bayelsa State, Niger Delta. Formosa J. Sci. Technol. 2 (7), 1779–1788.

Nor, N.H.M., Obbard, J.P., 2014. Microplastics in Singapore's coastal mangrove ecosystems. Mar. Pollut. Bull. 79 (1-2), 278–283.

Norman, D., Wolanski, E., 2001. Muddy coastal waters and depleted mangrove coastlines–depleted seagrass and coral reefs. Oceanogr. Process. Coral reefs Phys. Biol. Links. Gt. Barrier Reef. 77–91.

Numbere, A., 2014. Impact of hydrocarbon pollution on the mangrove ecosystem of the Niger River Delta, Nigeria. Saint Louis University, Saint Louis, Missouri.

Nwosu, F.M., Dixon, B., Holzlöhner, S., 2016. Mapping the artisanal fisheries within Cross River and Qua Iboe estuaries of the Niger Delta, Nigeria, using a Geographic Information System. GIS/Spat. Anal. Fish. Aquat. Sci. 6, 235–248.

Ogbeibu, A.E., Oribhabor, B.J., 2023. The Niger Delta mangrove ecosystem and its conservation challenges. Mangrove Biology, Ecosystem, and Conservation. IntechOpen. https://doi.org/10.5772/intechopen.112543.

Ogbonna, J., 2001. Nigeria. Reducing the impact of tropical shrimp trawling fisheries on the living marine resources through the adoption of environmentally friendly techniques and practices in Nigeria. FAO Fish. Circ. 974, 188–215.

Ogden, J.C. and Gladfelter, E.H. (1983) *Coral reefs, seagrass beds, and mangroves: their interaction in the coastal zones of the Caribbean: report of a workshop held at West Indies Laboratory, St. Croix, US Virgin Islands, May, 1982*. Unesco. IOCARIBE. Fairleigh Dickinson University.

Ohimain, E.I., 2016. Mangroves of the Niger Delta: their importance, threats, and possible restoration. Wetl. Sci. & Pract. 33 (1), 1–12.

Oketoki, T., 2015. Survey on phytoplankton biomass and water parameters in the habitats of invasive tigers shrimps (Penaeus monodon) in Nigeria. Fish. Aquac. J. 6 (4), 1000145.

Okonkwo, C.N.P., Kumar, L., Taylor, S., 2015. The Niger Delta wetland ecosystem: What threatens it and why should we protect it? Afr. J. Environ. Sci. Technol. 9 (5), 451–463.

Olaoye, O.J., Ojebiyi, W.G., 2018. Marine fisheries in Nigeria: A review. Marine Ecology-Biotic and Abiotic Interactions. IntechOpen, London, UK. ⟨https://www.intechopen.com/chapters/59865⟩ [Online] [Accessed on 23 November 2020].

Oliveira Júnior, J.G.C., Silva, L.P., Malhado, A.C., Batista, V.S., Fabré, N.N., Ladle, R.J., 2016. Artisanal fisheries research: a need for globalization? PloS One 11 (3), e0150689.

Onrizal, O., Ahmad, A., Thoha, A., 2020. The Correlation Between Mangroves and Coastal Aquatic Biota, 1542. IOP Publishing.

Onyena, A.P., Sam, K., 2020. A review of the threat of oil exploitation to mangrove ecosystem: Insights from Niger Delta, Nigeria. Glob. Ecol. Conserv. 22, e00961.

Osuji, L.C., Erondu, E.S., Ogali, R.E., 2010. Upstream petroleum degradation of mangroves and intertidal shores: The Niger Delta experience. Chem. Biodivers. 7 (1), 116–128.

Parsram, K., 2010. People, issues, and networks in Small-scale fisheries in the Eastern Caribbean. Proc. 62nd Gulf Caribb. Fish. Inst. 62, 128–136.

Pauly, D. and Ingles, J. (1988) 'The relationship between shrimp yields and intertidal vegetation (mangrove) areas: a reassessment'. In {C}A. Yanez-Arancibia and D. Pauly{C}, editors. IOC/FAO Workshop on Recruitment in Tropical Coastal Demersal Communities. *UNESCO Intergovernmental Oceanographic Commission Workshop Report Supplement* 44, 277– 283.

Pauly D, Ingles J (1986) The relationship between shrimp yields and intertidal (mangrove) areas: A reassessment. In: IOC/ FAO workshop on recruitment in tropcial coastal demersal communities, pp 227–284. IOC, UNESCO, Paris.

Paw, J.N., Chua, T.-E., 1991. Assessment of the ecological and economic impact of mangrove conversion in Southeast Asia. *Towards an integrated management of tropical coastal resources*. ICLARM Conf. Proc. 22, 201–212.

Primavera, J.H., 2005. Mangroves, fishponds, and the quest for sustainability. Science 310 (5745), 57–59.

Rawlinson, N.J.F., Milton, D.A., Blaber, S.J.M., Sesewa, A., Sharma, S.P., 1995. A survey of the subsistence nd artisanal fisheries in rural areas of Viti Levu, Fiji. ACIAR Monogr. No 35, 138.

Ronnback, P., 1999. The ecological basis for economic value of seafood production supported by mangrove ecosystems. Ecol. Econ. 29 (2), 235–252.

Ronnback, P., Crona, B., Ingwall, L., 2007. The return of ecosystem goods and services in replanted mangrove forests: perspectives from local communities in Kenya. Environmental Conservation 34 (4), 313–324.

Saenger, P., Gartside, D., Funge-Smith, S., 2013a. Review of mangrove and seagrass ecosystems and their linkage to fisheries and fisheries management. Food Agric. Organ. U. Nations Reg. Off. Asia Pac.

Sarathchandra, C., Kambach, S., Ariyarathna, S.C., Xu, J., Harrison, R.D., Wickramasinghe, S., 2018. Significance of mangrove biodiversity conservation in fishery production and living conditions of coastal communities in Sri Lanka. Diversity 10 (20), 1–12.

Schneider, W. (1990). FAO species identification sheets for fishery purposes-Field guide to the commercial marine resources of the GULF of Guinea. Food and Agricultural organization of the United Nations, Rome.

Sharma, H.B., Vanapalli, K.R., Samal, B., Cheela, V.R.S., Dubey, B.K., Bhattacharya, J., 2021. Circular economy approach in solid waste management system to achieve UN-SDGs: solutions for post-COVID recovery. Sci. Total Environ. 800.

Sharpe, D.M.T., Hendry, A.P., 2009. Life history change in commercially exploited fish stocks: an analysis of trends across studies. Evolut. Appl. 2 (3), 260–275.

Sikoki, F., Otobotekere, A.T., 1999. Fisheries. The Land People of Bayelsa State Central Niger Delta, Port Harcourt, Nigeria. Onyoma Research Publications, pp. 301–319.

Silas, M.O., Mageleka, S.S., Polke, P., Skold, M., Lingborg, R., Torre-Castra, M., Gullstom, M., 2020. Adaptive capacity and coping strategies of small-scale coastal fisheries to declining fish catches: Insights from Tanzanian communities. Environ. Sci. Policy 108, 67–76.

Simmons, G., Bremner, G., Whittaker, H., Clarke, P., Teh, L., Zylich, K., Zeller, D., Pauly, D. (2016) 'Reconstruction of marine fisheries catches for New Zealand (1950-2010).' [Online] [Accessed on on 17 July 2020]⟨http://www.seaaroundus.org/doc/PageContent/OtherWPContent/Simmons+et+al+2016+-+NZ+Catch+Reconstruction+-+May+11.pdf⟩.

Ssentongo, G.W., Ukpe, E.T. and Ajayi, T.O. (1986) 'Marine fishery resources of Nigeria: a review of exploited fish stocks.' CECAF/ECAF Series 86/40. FAO, Rome, 73pp.

Staples, D., Vance, D., Heales, D., 1985. Habitat requirements of juvenile penaeid prawns and their relationship to offshore fisheries, 2. National Prawn Seminar, Cleveland, Qld.

Sundermeyer, M.A., Rothschild, B.J., Robinson, A.R., 2005. Using commercial landings data to identify environmental correlates with distributions of fish stocks. Fish. Oceanogr. 14 (1), 47–63.

Sylvanus, A.N., Gao, T., 2007. Structure and dynamics of fisheries in Nigeria. J. Ocean Univ. China 6 (3), 281–291.

Teixeira, C.M., Gamito, R., Leitao, F., Cabral, H.N., Erzini, K., Costa, M.J., 2014. Trends in landings of fish species potentially affected by climate change in Portuguese fisheries. Reg. Environ. Change 14 (2), 657–669.

Thomas, N., Lucas, R., Bunting, P., Hardy, A., Rosenqvist, A., Simard, M., 2017. Distribution and drivers of global mangrove forest change, 1996–2010. PloS One 12 (6), e0179302.

Townhill, B.L., Couce, E., Tinker, J., Kay, S., Pinnegar, J.K., 2023. Climate change projections of commercial fish distribution and suitable habitat around north western Europe. Fish Fish.

Tuda, P.M., 2018. Assessing the state and impacts of the artisanal reef fisheries and their management implications in Kenyan south coast. Universität Bremen.

Twilley, R.R. and Day, J. (1999) 'The productivity and nutrient cycling of mangrove ecosystem.' *Ecosistemas de manglar en América Tropical. Instituto de Ecología, AC México, UICN/ORMA, Costa Rica, NOAA/NMFS, Silver Spring MD, EUA*. pp. 127-151.

Udoh, J.P., 2016. Sustainable nondestructive mangrove-friendly; aquaculture in Nigeria II: models, best practices; and policy frame work; best practices and Policy Frame work. AACL Bioflux 9 (1), 151–173.

Ukoli, M. (2005) 'Environmental factors in the management of the oil and gas industry in Nigeria.' *[Online] [Accessed on December February 2019]://www. warmofloor. co. uk/pages/environmenta lpdf.*

Van der Sleen, P., Zuidema, P.A., Morrongiello, J.R., Ong, J.J.L., Rykaczewski, R.R., Sydeman, W.J., Di Lorenzo, E., Black, B.A., 2022. Interannual temperature variability is a principal driver of low-frequency fluctuations in marine fish populations. Commun. Biol. 5, 28. https://doi.org/10.1038/s42003-021-02960-.

Vance, D., Staples, D., Kerr, J., 1985. Factors affecting year-to-year variation in the catch of banana prawns (Penaeus merguiensis) in the Gulf of Carpentaria, Australia. ICES J. Mar. Sci. 42 (1), 83–97.

Vergara-Solana, F.J., Vargas-López, V.G., Bolaños-Durán, E., Paz-García, D.A., Almendarez-Hernández, L.C., 2023. Bioeconomic analysis of stock rebuilding strategies for the green abalone fishery in Mexico under climate uncertainty. Ocean Coast. Manag. 243, 106759.

Walters, B.B., Ronnback, P., Kovacs, J.M., Crona, B., Hussain, S.A., Badola, R., Primavera, J.H., Barbier, E., et al., 2008. Ethnobiology, socio-economics and management of mangrove forests: a review. Aquat. Bot. 89 (2), 220–236.

Wong, Y.S., Tam, N.F.Y., Lan, C.Y., 1997. Mangrove wetlands as wastewater treatment facility: a field trial. Hydrobiologia 352, 49–59.

World Resources Institute. IUCN—The World Conservation Union. In Global Biodiversity Strategy: Guidelines for Action to Save, Study, and Use Earth's Biotic Wealth Sustainably and Equitably; World Resources Inst: Andrew Steer, DC, USA, 1992.

Yi, Y., Zhao, F., Liu, Q., Song, J., 2023. Runoff from upstream changes the structure and energy flow of food webs in estuaries. Front. Mar. Sci. 10, 1103502. https://doi.org/10.3389/fmars.2023.1103502.

Zabbey, N., Giadom, F.D., Babatunde, B.B., 2019. Nigerian coastal environments. In: Sheppard, C. (Ed.), World Seas: An Environmental Evaluation, Volume 1: Europe, the Americas and West Africa, second ed. Elsevier, UK, pp. 835–854.

Zabbey, N., Hart, A. and Erondu, E. (2010) 'Functional roles of mangroves of the Niger Delta to the coastal communities and national economy.' *In Proceedings of the 25th Annual Conference of the Fisheries Society of Nigeria (FISON)*, Lagos, Nigeria.

Zeller, D., Booth, S., Craig, P., Pauly, D., 2006. Reconstruction of coral reef fisheries catches in American Samoa, 1950–2002. Coral Reefs 25 (1), 144–152.

Zeller, D., Pauly, D., 2007. Reconstruction of marine fisheries catches for key countries and regions (1950-2005). Fish. Cent. Res. Rep. 15 (2), 1198–6727.