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The significance of community-based management in the structure and sustainability of the fisheries in Cross River Estuary, Nigeria

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Abstract. *Antigha AA, Armah AK, Nyarko E. 2021. The significance of community-based management in the structure and sustainability of the fisheries in Cross River Estuary, Nigeria. Indo Pac J Ocean Life 5: 29-41.* Given the unsustainable fishing practices in the Cross River estuary, this study examined its fisheries' structure and sustainability. Water quality and fish health in the research area were evaluated by analyzing the water's physicochemical parameters. Surface measurements included pH, DO, turbidity, salinity, alkalinity, phosphate, and nitrate levels. In addition, researchers looked into the exploitation rates, fish sizes, and socioeconomic elements in the estuary's multispecies gillnet fishery to ascertain its susceptibility to human and environmental influences. The turbidity of the water in the area varied significantly between the study sites, with values ranging from 21.8 to 52.2 NTU (normalized turbidity units) at Esuk Anansa, 30.3 NTU at Esuk Okon, and 21.8 NTU at Esuk Anantigha. Nevertheless, fish could tolerate the water quality during the research period. Sampled monthly catches averaged 21.2 kilograms in weight (range 15.3 kg to 27.0 kg). CPUE averaged 7.1 kg per vessel per journey. *Pseudotolithus elongatus* made up 56.69% of the catch by weight, followed by *Ethmalosa fimbriata* at 30.28% and *Chrysichthys nigrodigitatus* at 7.53%. The study found that certain fish species are in danger because of unsustainable fishing practices that result in the taking of predominantly small fish (less than 15 cm in length). To update knowledge on socioeconomic indices, fishing equipment, and prime captures of the fishes in the area and to propose management methods for the fisheries and environment, the socioeconomic situation of artisanal fishermen, traders, and mangrove loggers in the estuary were determined. The study suggests implementing a community-based coastal resource management strategy for the long-term health of the region's fisheries and ecology.

Keywords: Fishing, health status, physicochemical, water

INTRODUCTION

Compared to other ecosystems, such as forests, grasslands, or agricultural land, estuaries are among the most fertile on Earth. As a result, unique ecosystems of plants and animals suited for living at the sea's edge thrive in the tidal, protected waters of estuaries. Shallow open seas, freshwater and salt marshes, swamps, sandy beaches, mud and sand flats, rocky coasts, oyster reefs, mangrove forests, river deltas, tidal pools, and seagrasses can all be found in and around estuaries (USEPA 1998).

Since estuarine ecosystems are subject to constant or periodic external forcing (such as tides, storms, and river discharges), they will be significantly impacted by human-induced climate change. It is often physically variable, sometimes to the extreme (for example, exposed to high or low salinity, temperature, oxygen, or moisture) (Officer 1976; Kennedy 1984; Hobbie 2000; Valiela 2006). As a critical transition zone with steep gradients in energy and physicochemical qualities at the interface of land and sea, they are naturally a focal point of influences from both landward and seaward sides. During periods of global upheaval, they serve as a focal point for the stresses that human activity and climate change place on the world's oceans and continents. As a result, ecosystem services and economic potential can be severely diminished for any creature or activity dependent on estuarine stability (Jennerjahn and Mitchell 2013).

Estuaries have been recognized for a long time as crucial locations for fish because of the multiple functions they serve: as nurseries, migration corridors, feeding grounds, and shelter areas (Mc. Lusky and Elliot 2004; Rezai et al. 2011; Tumiran et al. 2011; Hossain et al. 2012; Zaleha et al. 2013; Rahim et al. 2014; Saifullah et al. 2014; Paturej et al. 2017; Eugenia et al. 2019; Aiman et al. 2020). Furthermore, to ensure their safety and long-term maintenance, it's essential to have a firm grasp on the ecosystem process (i.e., the operation of these transitional environments) (Franco et al. 2008). Fish are a sustainable aquatic resource. Advantages include reversing a downward trend toward overexploitation by employing prudent management and techniques. In addition, the stock's renewability idea facilitates the fish population's dynamics. Therefore, studying population dynamics in fisheries is gaining popularity as a valuable resource for conservation and management (Mosepele 2000).

Many types of fish and crustaceans are considered estuary dependent due to the crucial role estuaries play in their life cycles (Potter et al. 1990; Holt and Miller 2011). Consequently, there has been a lot of focus on the need to conserve estuarine ecosystems as nurseries to ensure the survival of critical fisheries since many of the bigger marine species that use estuaries as nursery regions are of economic and recreational importance (Elliot et al. 1990; Pomfret et al. 1991).

Restoring the ecological services of damaged tropical estuaries has received little attention (Twiley et al. 1996). While efforts to improve water quality through pollution control have received much attention, restoring habitats like mangroves received very little effort. However, managing and conserving tropical estuaries are becoming challenging as devastation proceeds and fisheries yields decline. Several nations have already launched pilot programs to examine the viability of mangrove reforestation (Blaber et al. 2000). Protecting tropical estuaries is crucial because little rehabilitation effort has been made.

Humans have become an integral element of the ecology of the Cross River estuary due to its frequent closeness to population centers, biological diversity, high fisheries productivity, and recreational value (Oribhabor et al. 2013). Indiscriminate mangrove harvesting, garbage disposal, multi-faceted pollution, and unsustainable fishing practices are all human-caused factors degrading the estuary's ecosystem.

The study aims to analyze the fisheries' framework so that adequate measures may be taken to protect the estuary's aquatic life in the long run. The objectives are (i) to precisely evaluate the quality of the water in the cross-river estuary and the condition of the fish that live there by examining the water's physicochemical characteristics; (ii) to determine the diversity of fish species, the frequency with which they are caught, and the effects of human and environmental variables on their populations; (iii) to evaluate the catch sizes and exploitation rates of target species in the estuary.

MATERIALS AND METHODS

Survey of the study area

Before starting data collecting, a preliminary reconnaissance survey was conducted. The GPS coordinates of each research site in Nigeria's Cross River Estuary have been recorded. In addition, social, environmental, and economic problems were discovered through on-the-ground observational walks and boat cruises.

Description of the study area

Southeastern Nigeria is home to the estuary of the Cross River. Located between 04º10′ and 05º10′ north latitude and 08015 and 08035 east longitude, this Cross River State coastal region is adjacent to Cameroon. Also, it includes a portion of Akwa Ibom State and Rivers State to the east of the Niger Delta. The estuary has the distinction of being the largest in the entire Gulf of Guinea. The estuary serves as a meeting place for three major rivers that flow south to the Atlantic Ocean. Countries like Nigeria and Cameroon share this estuary (Nwosu et al. 2005). Its origin can be traced back to the Cameroun Mountains. As it makes its way westward into Nigeria, it winds through the country's high rainforests until finally emptying into the Atlantic. Mangrove forest replaces other types of flora in the lower brackish parts of the river (Ama-Abasi 2002).

Climate and vegetation

The climate of the research area is characterized by a long wet season from April to October and a dry season from November to March. The mean yearly rainfall is roughly 2,000 mm. During the wet season, around August/September, there is a prolonged drought known as the August drought. The harmattan is a period of extreme cold, dryness, and dust that often occurs between December and January. The average temperature is 22°C during the wet season and 35°C during the dry season, and the average relative humidity is above 60% year-round, approaching 90% during the wet season (Akpan 1993). The hydrodynamic circumstances change the salinity of the coastal waters and flood the floodplain, which affects both marine and freshwater fisheries in the area (Moses 1990). *Rhizophora racemosa, Rhizophora mangle, Rhizophora harrissonii, Languncularia racemosa,* and *Avicennia marina (africana)* are the five kinds of mangroves found in the region, together with the invasive exotic nipa palm (*Nypa fruticans*). Plankton, crustaceans, molluscs, fin fishes, reptiles, birds, and mammals are some of the many species that call this region home (Nwosu 2005).

Locations of study

The research was conducted in the Cross River estuary in Nigeria, namely on the Bakassi Peninsula and in the Calabar South Local Government Area. Because of the abundance of fish landings in the region, these spots were chosen.

A peninsula in the Gulf of Guinea, Bakassi is a place. The estuaries of the Cross River (near Calabar) and the Rio del Ray (to the east) form its boundaries. The peninsula is located at 04°25′N 05°10′W (or longitudes 08°20′E and 09°08′E). Area-wise, it's about 665 km^2, and its islands are all low and covered in mangroves. Bakassi is estimated to have a population of between 150,000 and 300,000. The warm east-flowing Guinea current (known as Aya Efiat in Efik) meets the chilly north-flowing Benguela current in Bakassi, located at the easternmost point of the Gulf of Guinea (called Aya Ubenekang in Efik). Submarine shoals rich in fish, shrimp, and a wide variety of other marine species are formed due to the interaction between these two ocean currents, and enormous, foamy breakers ceaselessly advance toward the shore. Because of this, the waters around Bakassi are teeming with fish. The primary economic activity is fishing (Gill et al. 2003). Coordinates for the Calabar South LGA are latitudes 04° 95' and 05° 15'N and longitudes 08° 32' and 08° 45'E. In addition, Anantigha is home to its administrative hub. As of the 2006 Census, its population was 191,630, and its land area was 264 square kilometers. Most of the locals make their living off the sea and the mangrove forests.

The following are the three locations at which the research was conducted:

Station 1: Esuk Anansa lies in the town of Ikang, between latitudes 04° 47' and 05º 20'N and longitude 08° 30′ and 08° 42' E. Calabar, the state capital, is around 5 km away, and Station 2 (Esuk Okon) is about 1 km away from the town. In this station, the high population density has led to widespread deforestation, littering, and surface runoff pollution caused by residential wastes, especially during the wet season. Palm trees (*Elaeis guineensis*), bamboo (*Bambusa africana*), plantain and banana (*Musa* spp.), and mangroves (*R. racemosa*, *R. mangle*, and *A. africana*) compose the majority of the local flora. Okra (*Abelmoschus esculentus*), Water Leaf (*Talinum triangulare*), Fluted Pumpkin (*Telfairia occidentalis*), and Maize (*Zea mays*) are the most common crops grown in the riparian zones. Silty sediments describe the biotope or beach at this location.

Station 2: Esuk Okon is situated between latitudes 04º 49′ and 05° 22' N and longitudes 08° 33 ′ and 08° 40' E, on the outskirts of Ikang in the Bakassi Local Government Area of Cross River State, Nigeria. Calabar Municipality, the state capital of Cross River State, is around 6 kilometers from the settlement. About 200 households call this area home; most are fishermen, but the area lacks essential services and infrastructure, such as a hospital, school, access road, power, hotels, and a market. These conveniences are unavailable in the village itself. Therefore, residents must travel to Ikang, the nearest central town, only approximately 1 km away. The predominant plants and crops at this location are similar to those at station 1. In addition, the beach at this location is characterized by muddy sediment composed of silt.

Station 3: Esuk Anantigha is situated between latitudes 04° 55′ and 05° 10'N and longitudes 08° 22′ and 08° 34'E, in the southern section of the capital of Cross River State (Calabar South). With a higher population density than Station 1, this station has seen widespread deforestation, erosion, flooding, and widespread pollution from sources as diverse as human waste and urban and agricultural runoff during the rainy season. Flora, fauna, and farmed crops are similar to those at the other stations, except for a higher concentration of nipper palms and a smattering of fish and poultry farms. Mangrove wood is a home fuel used for fish smoking, cooking, baking, and construction, and this station is the primary landing site/market for this product. This biotope is distinguished by its muddy substrate and bank root structure (Figure 1).

Research design and sampling methods

Either primary or secondary data were used in the analysis. Taking water samples once a month at each site and analyzing them in a lab was the primary source of information. pH, dissolved oxygen (DO), turbidity, salinity, alkalinity, phosphate (PO_4- P), and nitrate (NO_3- N) were among the water quality characteristics tested for in the study. In addition, in-situ measurements of water temperature and turbidity were taken. Water samples were taken monthly from each station at a distance of 100 meters from the beach and at a depth of 1 meter using one-liter polyethylene bottles that had been washed, rinsed, and dried in a laboratory. Samples of water were kept cold in a cooler containing ice chips. The Institute of Oceanography at the University of Calabar in Nigeria tested the water and wastewater using the American Public Health Association's (APHA) standard technique (APHA 2005).

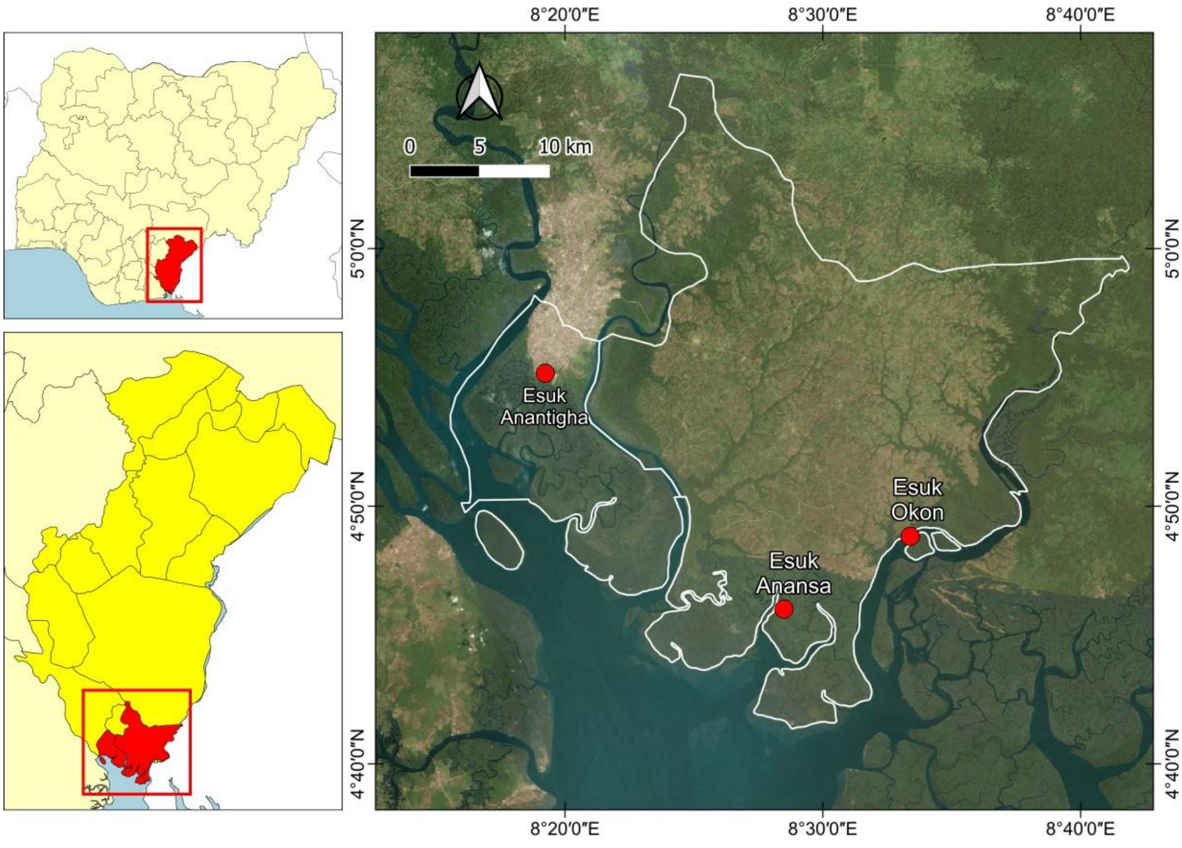

Figure 1. Map of the study area showing the three stations of Esuk Anansa, Esuk Okon Esuk Anantigha of Cross River State, Nigeria

The landings of multispecies artisanal gillnet fishing in the study area were evaluated during the study. Traditional methods were used to measure the length of 1,814 fish within 0.1 cm, from the point of snout to the tip of the caudal fin. The arriving boats were chosen randomly to reduce the potential for bias. It was accomplished by taking daily boat samples at each location. In addition, once a month, at various landing days during flow tide, samples were taken from each station (landing periods). Near-surface and near-bottom gillnets of around 100 m in length and of stretched mesh size range from 2.9 cm to 5.0 cm (average 3.8 cm) were the most common fishing gears in the area. These were used to catch bonga (*E. fimbriata*) and demersal fish, respectively (Holzlohner et al. 2007). Other methods included artificial shelters, basket traps, and fish fences in addition to the traditional hook-and-line way.

One hundred forty-two respondents from the three study sites provided socioeconomic data. There were 70 responses from fishermen, mangrove loggers, fish processors/ traders, and farmers, 50 from Esuk Anantsa, and 22 from Esuk Okon. A census of each station's inhabitants was used to compile this data. Most people live in Esuk Anantigha, although there are also many people in Esuk Anansa. Rainfall data was received from the Department of Meteorology of the Nigerian Airport Authority in Calabar, Cross River State. A map of the research region was obtained from the Geography and Regional Planning Department of the University of Calabar, Nigeria.

According to Holzlohner et al. (2007), fish were sampled by weighing every fish caught in a single boat expedition. The capture rate was calculated by adding the weight of all fish taken from each boat on each trip and expressing it as kilograms per boat. During the study period, six boats were sampled at each station, with one being sampled every month for six months. Overall, 18 boats were sampled from a total of 149 at each location. Esuk Anantigha has the most boats (62), followed by Esuk Okon (34) and Esuk Anansa (53) in terms of overall numbers. Because of storage limitations, we only sorted the total catch from each boat sample for the three most common fish in the area: *Pseudotolithus elongatus* (West African croaker), *Ethmalosa fimbriata* (Bonga), and *Chrysichthys nigrodigitatus* (estuarine catfish). It is because fishermen focused on catching these species to meet consumer demand. Due to their low commercial value, a few additional species caught in the landings were considered by-catches.

The following formula was utilized to get the catch per unit effort:

$$\text{CPUE} = \frac{Catch\ per\ Trip}{Effort} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

CPUE, or catch per unit effort, is the average catch divided by the average effort during the study period.

Once the monthly totals were tallied, the relative abundance of each species was calculated as a percentage of the month's total landings by weight, as shown below:

$$\textbf{Percentage Weight}\ (\%) = \frac{Species\ weight}{Total\ Weight} \times 100 \quad \ldots\ldots\ldots(2)$$

Sokal and Rohlf (1981) and Cochran (1977) used biostatistics to determine the mean length, variance, and standard deviation.

The following equation determined the mean length of each sample:

$$\times = [x(1) + x(2) + \cdots + x(n)] = \frac{1}{n} * \sum_{i=1}^{n} x(i) \quad \ldots\ldots\ (1)$$

Where: n = sample of a particular fish species caught from one boat and

x(i) = length of fish no i., and I = 1,2,…….,n.

The variance, which is the variability about the mean value, is given by the following equation:

$$S^2 = \frac{1}{n-1} * [(x(1) - \times)^2 + (x(2) - \times)^2 + \cdots + (x(n) - \times)^2] = \frac{1}{n-1} * \sum_{i-1}^{n} [x(i) - \times]^2 \quad \ldots\ldots\ldots\ldots(2)$$

Thus the variance, S^2, is the sum of squares deviation from the mean divided by the number minus one.

$$S^2 = \frac{1}{n-1} * [\sum_{i=1}^{n} x(i)^2 - \frac{1}{n} * |\sum_{i=1}^{n} x(i)]^2 \quad \ldots\ldots(3)$$

The square root of the variance is the standard deviation. The relative standard deviation or coefficient of the mean is the standard deviation divided by the mean, i.e.

$$\frac{S}{X} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (4)$$

The growth parameters L∞ (asymptotic length) and K (stress factor) of the species were examined with the FISAT II software package. The total mortality Z was calculated as follows:

$$Z = F + M \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(5)$$

Where F = fishing mortality and M = Natural mortality. The exploitation rate (E) was calculated as follows:

$$E = \frac{F}{Z} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(6)$$

Data sources

Focused group discussions (a semi-structured discussion with groups of fishermen, mangrove loggers, and traders to identify their impression of the environment), questionnaires, water samples for physicochemical parameter analysis, and the catch composition of gillnet fisheries in the research locations were utilized to obtain data from the field between December 2014 and May 2015. The Calabar, Nigerian Airport Authority (NAA.)

Meteorology Department provided precipitation totals for the study period. Knowledge gained from prior research was also incorporated.

The questionnaire included both open-ended questions, which provided respondents with the freedom to share their thoughts and feelings, and closed-ended questions, from which respondents could choose among a set of pre-coded replies designed to reduce the possibility of respondent bias. The questionnaire covered six distinct topics: respondent demographics, traditional fisheries management, other estuarine resources management, ethnicity, social life, and local government. Discussions with fishermen and women, shellfish harvesters, mangrove loggers, fish, and shellfish processors, and traders preceded the distribution of questionnaires. In addition, the stations' focal groups met twice before surveys were distributed.

Data analysis

Water samples were analyzed physicochemically following the procedures outlined in the American Physical Health Association (APHA 2005). The growth parameters were examined using the FISAT II fish statistics software package. The fish samples' catch per effort, catch composition, and length frequency was analyzed using pertinent statistics, including mean, variance, and standard deviation. The fish catch per unit effort and the water's physicochemical properties were statistically tested using a simple Analysis of Variance (ANOVA). Descriptive statistics were used to evaluate the questionnaire data (Statistical Package for Social Science software). There were also tables, charts, graphs, and pictures used.

RESULTS AND DISCUSSION

Physicochemical characteristics of water in the study area

Mean values for surface temperature, pH, dissolved oxygen, turbidity, salinity, alkalinity, and nutrients (PO_4-P and NO_3-N) are displayed in Table 1 for the research locations and time. The temperature of the water did not follow any discernible pattern. Across the board, average surface temperatures were between 29.25°C and 29.50°C. In this case, hydrogen ions (pH) concentration varied from 6.25 to 6.47. 5.15 mg/L is the average dissolved oxygen concentration. From 5.20 to 5.90 mg/L, that was the range. From December 2014 to January 2015, dissolved oxygen levels increased. Salinity averaged 7.65 ppt, and turbidity ranged from 21.80 to 52.50 NTU across all sites. Average phosphate and nitrate levels were between 0.0016 and 0.0048 Mg/L and 0.0023 and 0.0048 Mg/L, respectively, throughout the three stations of Anansa, Okon, and Anantigha, with alkalinity averaging 35.0 Mg/L. At all the stations, phosphate and nitrate concentrations rose over the study's drier months, but at Anantigha, they peaked in April, just as the wet season was beginning. The former was between 0.016 and 0.048 mg/L, whereas the latter was between 0.023 and 0.048 mg/L.

Catch assessment

The catch-per-effort of the multispecies gillnet fishery in the research areas is shown in Table 2. Anansa had 161.90 kg, Okon had 88.20 kilograms, and Anantigha had 131.00 kg of total landings throughout the research period (range from 88.20 kg to 161.90 kg). Sampled monthly landings (CPUE) had a mean weight of 21.20 kg/boat/trip (range 15.33 kg to 27.00 kg).

Pseudotolithus elongatus constituted 56.69%, by weight, of the total catch in the study areas, followed by *E. fimbriata* (30.28%), *C. nigrodigitatus* (7.53%), and other fishes (5.5%) (Figure 2). In addition, *Ilisha africana, Pseudotolithus typhus, Scomberomorus tritor, Liza falcipinnis, Caranx hippos, Polydactylus quadrifilis, Cynoglossus senegalensis, Arius parkii, Sphyraena sphyraena,* and *Schilbe mystus* were also discovered. Together, the bonga (*E. fimbriata*), the estuary catfish (*C. nigrodigitatus*), and the bobo croaker (*P. elongatus*) made up 94.50% of the total haul. The *P. elongatus* was found to be present in the catch every month, with the highest numbers being caught in January and April (82.29% and 85.34%, respectively). As with the other species, *E. fimbriata* was spotted from December to May, with the highest occurrence rates in February (37.32%) and March (74.57%). While *C. nigrodigitatus* was present throughout the research, it was most abundant in February and April, making up 15.86% and 8.56%, respectively.

Table 1. Physicochemical characteristics of water in the study area (Mean±S.D)

Location	Temp. (°C)	pH	DO. (mg/L)	Turbidity (NTU)	Salinity (ppt)	Alkalinity (mg/L)	$PO4^{-}P$ (mg/L)	$NO3^{-}N$ (mg/L)
Anansa	29.5±0.2	6.25±0.2	5.90±0.3	52.20±1.2	10.63±0.8	36.25±0.25	0.0016±0.002	0.0048±0.003
Okon	29.7±0.1	6.47±0.2	5.80±0.5	30.33±0.7	7.65±1.5	35.00±1.25	0.0048±0005	0.0023±0.002
Anantigha	29.25±0.25	6.27±0.3	5.15±0.4	21.80±2.2	10.20±0.6	42.50±1.0	0.0018±0.001	0.0046±0.003

Table 2. Monthly distribution of the CPUE (kg/boat/trip) for the study locations

Location	Dec.2014	Jan.2015	Feb.2015	Mar.2015	Apr.2015	May2015
Anansa	20.50	26.50	37.30	34.00	22.40	21.20
Okon	10.30	12.20	16.20	15.70	18.30	15.50
Anantigha	15.20	18.40	27.50	25.20	24.60	20.10
Mean	15.33	19.03	27.00	24.97	21.77	18.93

Figure 3. Gear composition of the artisanal fishery for the study area

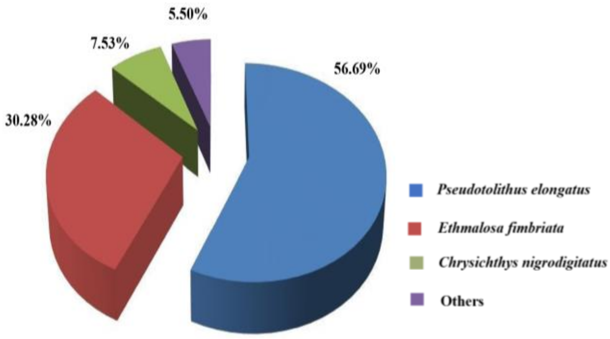

Figure 2. Catch composition (%) by weight of the gillnet fishery for the study period

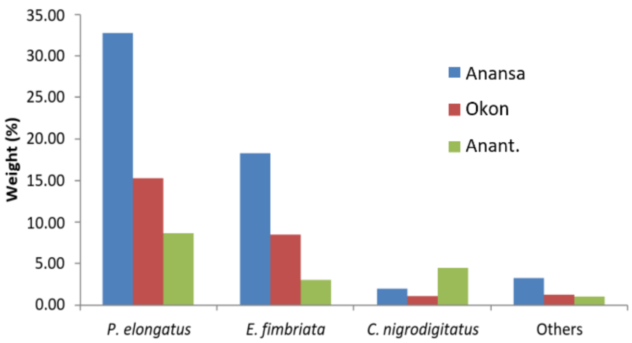

Figure 4. Catch composition (%) by weight for the study locations

Although some species were present throughout the period, others made a more noticeable impact in January and March. In December 2014, the value of the catch was at its lowest. In February 2015, the total catch averaged 127.00 kg, while the highest value was 81.0 kg.

Near-surface gillnets for bonga were around 100 meters long, and their stretched mesh sizes ranged from 2.9 to 5.0 cm; near-bottom drift nets for demersal fish were 4.0 to 6.6 cm. In addition, there were other methods, such as hook and line, and various traps like brush traps, basket pots, artificial shelters, basket traps, fish fences, and drums (Figure 3).

The species distribution of the fish caught in each of the three locations is displayed in Figure 4. The *P. elongatus* was found at a prevalence of 32.75% in Esuk Anansa, 15.32% in Esuk Okon, and 8.62% in Esuk Anantigha. The Esuk Anansa, Esuk Okon, and Esuk Anantigha percentages were 18.60%, 8.50%, and 2.98% for *E. fimbriata* and 1.98%, 1.05%, and 4.50% for *C. nigrodigitatus*. Esuk Anansa had 3.25%, Esuk Okon 1.23%, and Anantigha 1.02% of various species. The *P. elongatus* made up the majority of the catch composition (56.69%), followed by *E. fimbriata* Esuk (30.28%), and *C. nigrodigitatus* had the lowest percentage (7.53%), with respective catch compositions of 2.03% at Anansa, 2.03% at Esuk Okon, and 5.5% at Anantigha. At only 5.50% across the board, the miscellaneous fishes were most common in the Anansa and Okon regions. Most people landed at Esuk Anansa (56.28%), next at Esuk Okon (26.1%), and finally at Esuk Anantigha (17.1%).

Exploitation rates and sizes of fish

During the study period, more than 80% of the captured fish were in the growth stages. According to data on fish length distributions, the average size of *P. elongatus* was 14.30±2.45 cm, the average size of *E. fimbriata* was 10.47±1.58 cm, and the average size of *C. nigrodigitatus* was 17.7±3.23 cm. Length distributions of the three most-caught fish species revealed that the captures were dominated by smaller fish (Appendix V). The average length of the 1,009 fish in the sample was between 10.5 and 19.5 cm. Fewer than 10% of the fishes surveyed were in the 20-25 cm total length range, and this size range was the most common. However, few huge adult fish were captured; most were mature females carrying eggs. With a total length of 53.2 cm, *C. nigrodigitatus* was the longest fish caught and landed. Although there is a statistically significant variation in CPUE between sites, the monthly average showed no statistical significance in the simple ANOVA test (Appendix VII and VIII).

The results of the growth indices of the target species for this study were L∞ = 26.78cm, K = 0.32yr^{-1}, M =1.80, Z = 2.72, F = 1.83, E = 0.67 for *P. elongatus*. L∞ =17.33cm, K = 0.63yr^{-1}, M = 1.57, Z = 2.75, F = 1.18, E = 0.43 for *E. fimbriata* and L∞ = 25.70cm, K = 0.46yr^{-1}, M = 1.15, Z = 3.78, F = 2.60, E = 0.69 for *C. nigrodigitatus*, at mean temperature 29.48°C (Table 3).

Socioeconomic information

To better understand the health of local fisheries, 142 surveys were sent to local fishermen, fish processors, and mangrove fellers. As a result, a total of 109 people (or 76.8% of the sample population) were discovered to be fishermen; 9 people (or 6.3% of the sample population) were engaged in fish processing; and 24 people (or 16.9% of the sample population) were involved in mangrove felling. In addition, 82% of those surveyed were also engaged in farming or commerce for their own subsistence.

The male population numbered 107 (75.35% of the total), while the female population numbered 35 (24.65%). Moreover, 44 people (31.0% of the total) said they were 31-35 years old, and another 33 (23.2%) said they were 26-30 years old. Twenty-one (21.8%) of the respondents fell in the 36-40 age range, and twenty-two (15.5%) were in the 41-45 age range.

Ten (7.0%) respondents were between 46 and 50 years old, whereas only two (1.4%) were between 51 and 55 years old. There were 108 married respondents (76.9%), twenty-five single respondents (17.6%), and nine divorcees (6.3%). Among the respondents, 93 (68.4%) were based in estuaries, followed by 29 (21.3%) in freshwater, eight (5.6%) in the ocean, and six (4.4%) in lagoons. Respondents' usage of gillnets as their primary fishing gear indicates that this is the method of choice. Among the respondents, 55.2% (79) relied on gillnet fishermen, 14.0% (20) on hook-and-line fishermen, and 7.0% (10) on fishing traps.

Sixty-three respondents (44.4%) highly disagreed with the availability of records of catch and fishing excursions, forty-eight (33.8%) disagreed, twenty-four (16.9%) agreed, and seven (4.9%) strongly agreed. Town/village councils received the most votes (52.9%), followed by chiefs (37.2%), and then chief fishermen (2.1%). 75 (52.8%) people strongly disagreed that enforcement was efficient, 43 (33.1%) people disagreed, 15 (10.6%) people were neutral, and 3 (5%) people were in agreement about the efficiency of the enforcement of the rules and regulations in the area. It was said that Chief Fishermen, Traders Associations, and Municipal Governments all played roles in the administration of fisheries. Of those polled, 46% strongly disagreed that fisheries management was effective, 41% disagreed, 13% somewhat disagreed, 3% barely disagreed, and 3% only agreed. Eighty-six (74.8%) of those surveyed agreed that certain fish species were deficient in their most recent landings. In comparison, twenty-nine (25.2%) found themselves unable to draw any firm conclusions either way. Refuse disposal was ranked as the top environmental issue in the study area by 33 respondents (23.2%), followed by poor sanitation with 29 (20.4%), erosion at 21 (14.8%), deforestation at 19 (13.4%), inadequate environmental management at 17 (12.0%), inadequate drainage at 15 (10.6%), and flood at only 8 (5.6%).

While 88 respondents (62%) had access to social infrastructure like roads, hotels, schools, drinkable water, power, and hospitals, 54 respondents (38%) did not. About 41.5% of respondents reported using mangrove wood for food preparation, whereas 19.7% made palm oil, 18.3% made bread, 16.1% constructed homes, and 6.3% prepared fish. Eighty-five people (60.7%) identified as Ibibios, thirty-five as Efiks, and twenty as belonging to another ethnic group. There were 140 respondents (99.3% response rate); 89 of them (62.7%) said they believed conflicts existed in the area, and 53 (37.3%) said they did not.

According to everyone who chimed in, the town council, in conjunction with the local government council, runs things. Most respondents agreed that a community-based approach to coastal management was important better to oversee the region's fisheries and other coastal resources. Eighty-three percent of those polled were in favor of implementing CBCRM, while just sixteen percent were neutral.

Discussion

Physicochemical characteristics of the study area

Water quality examination results from all three sites in the research region showed consistent physicochemical characteristics, except turbidity, across the board. Nonetheless, measurements showed that the average surface temperature of the water was 29.48±0.20, with a range of 28°C to 30°C. The situation here is similar to that of other African bodies of water (Akpan 1999). Mustapha (2008) reports a little temperature discrepancy, possibly due to a timing gap between the two readings. There are statistically significant changes in water quality between the study sites, as indicated by a P-value less than the 0.05 confidence limit.

Table 3. Growth parameters and exploitation rates of target species

Species	L∞ (cm)	K (yr^{-1})	Z	Z/K	M	F	E
P. elongatus	26.78	0.32	2.72	2.34	0.89	1.83	0.67
E. fimbriata	17.33	0.63	2.75	2.14	1.57	1.18	0.43
C. nigrodigitatus	25.70	0.46	3.78	1.35	1.15	2.60	0.69

According to Boyd (1979), the pH range of 6.25 to 6.47 is suitable for the survival of fish and shellfish in estuaries. According to Akpan et al. (2002), unpolluted tropical rivers often have a pH between 5 and 6.75. Geological and biochemical factors (shales and sandstones) and humus materials from swamps and streams within the river basin may account for the mildly acidic condition of the water during the study, as described by Akpan et al. (1999). pH dropped in March and April. It could be because of the entry and exit of salt water in the estuary during the rainy season. Karikari et al. (2006) found a similar pattern in Ghana's Korle lagoon. Consistent with our findings and those of Akintola et al. (2011) in Badagry Creek, Nigeria, Michael (1992) found that the pH of surface water varies during the day. According to Nyam, insufficient environmental nutrition levels could explain the study's low pH (1998). According to Akpan (2004), varying pH levels are caused by a combination of water's evaporation and transpiration and biological activity.

The minor temperature rise in April may be caused by the action of prevailing air masses (Akpan, 2004) as the rain gets closer. The study found that as temperature and precipitation rose, so did the pH of the water. The findings of Adebisi's (1981) investigation along the upper Ogun River in Nigeria are consistent with this.

Dissolved oxygen values varied from 5.15 to 5.90 mg/L, with a mean value of 5.62±0.75 mg/L. Although this can support fish grow in a reservoir, Boyd suggests it may slow their development (1979). The higher the salinity, the lower the dissolved oxygen (DO) content. Contrarily, Michael (1992) reported that warm-water organisms could live for extended periods with only 2–3 mg/L of dissolved oxygen. During the dry part of the research, DO levels were greater (December and January). Consonant with the findings of Akpan et al. (1999). March and April had the lowest oxygen readings across the board (Ezenwa 1981). Respiration and photosynthesis are dynamic processes that may explain the variations in oxygen content. Moses's (1979) reported range of DO levels for the Cross River is within the range seen in this study. Flowing water allows atmospheric oxygen to diffuse and combine with the water, which could explain why the DO level is somewhat higher at Esuk Okon. For the Qua Iboe River, this finding agrees with the results of Akpan (1993). When oxygen is used up in the decomposition of organic matter (leaf litter), this causes a decrease in the available oxygen (King and Ekeh 1990).

On the other hand, Kemdirim and Ejike (1992) contended that increased photosynthetic activity of phytoplankton causes dissolved oxygen concentrations to rise during dry seasons. The wetter months of March and April saw a more comprehensive range of turbidity, from 21.80 to 52.20 NTU, with a mean value of 34.78±21.87. It could result from erosional deposits caused by runoff from the increasing rainfall.

Esuk Anansa (with a turbidity of 52.20 NTU) was the most turbid location in the research region, while Esuk Anantigha was the least turbid. Possible causes include the dispersal of agricultural and human wastes to the area and the suspension of detritus and silt from mangrove exploitation due to the concentration of mangrove logging activities in the swamp. Evaporation crystallization due to sea salt intrusion may also contribute to the local turbidity. Although Akpan (1991) claimed the same, his studies on Uyo's water bodies in 2004 revealed an increase in turbidity alongside an equivalent rise in precipitation, so the two findings contradict one another. After observing the increase in turbidity in the Umtata River (South Africa), Fatoki et al. (2001) concluded that runoff from settlements during the summer rains was a significant contributor. Fish are rarely directly affected by solid particles in suspension. But they could harm fish populations (Boyd 1979). Kausch (1990) claims that most estuaries have photic depths of less than 1 m and are characterized by significant turbidity.

Moses (1979) and Lowenberg and Kunzel (1992) all reported salinities that were lower than the range found (1999). Possible explanations include shifts in the tidal and seasonal conditions during the research. The salinity peaked in the winter months, from December to February, when rainfall was at its lowest. Saltier than usual water is present during high tide because ocean water has made its way inland. Since Akpan et al. (1999) limited their sample to low tides, they could avoid the confounding effects of seawater intrusion, resulting in usually lower salinity levels in their study compared to reports from the Cross River. The salinity of estuaries is regulated primarily by inflows and outflows of fresh water (Cronin et al. 1962). With a salinity between 7.0 and 8.0 ppt, Esuk Okon exhibits substantial salt and fresh water mixing and may be categorized as a mid-estuary according to Fairbridge's (1980) classification scheme. Throughout the research, the alkalinity levels at the three stations were remarkably consistent. According to the United States Department of Agriculture's Soil Conservation Service (1975), the phosphate levels were below the threshold of 0.01 to 0.03 mg/L for phosphorous typically observed in uncontaminated streams. The presence of phosphorus and nitrate facilitates plant blooms and the eutrophication of lakes and streams. Phosphate enters the estuary through various sources, including industrial waste, surface runoff, the decomposition of organic matter at the river's bottom, and the accumulation of detergent. The deposition of nutrients by agricultural runoff in the area has been linked to eutrophication, nutrient enrichment, productivity, degradation, and sedimentation in the research areas. From October to January, the phosphate concentration in Tapi estuary, India's surface water, was observed by George et al. (2012) as being between 0.001 mg/L and 0.822 mg/L. They mentioned that the phosphate in the Tapi estuary could be mainly due to home and industrial effluents emitted from Surat city. It backs up the conclusion drawn from the current investigation into the estuary of the Cross River. Michael (1992) reported that over ten mg/L nitrate is safe, but water may have harmful chemicals and contamination from industrial and agricultural sources; the range and mean of nitrate recorded in the present study were below this level. Location1, Anansa (0.048 mg/L), and Location3, Anantigha (0.046 mg/L) may have greater nitrate concentrations since they are urban centers with concomitant local industrial and agricultural activity.

Generally speaking, Jaji et al. (2007) found that nitrate levels in untreated natural water were relatively low.

It indicates that no significant water pollution occurred throughout the time of the study. According to Mustapha and Omotosho (2005), the nitrate content in Nigeria's Moro Lake is the highest at 22.4 mg/L, whereas Kolo (1996) found that Shiroro Lake's value was only 0.5 mg/L. Nitrate concentrations in this investigation were within the safe range established by the Federal Ministry of Environment and the World Health Organization. There is likely a high quantity of nitrate because fertilizers wash off surrounding farms. The most excellent oxidized form of nitrogen, nitrate, is one of the most prominent water pollution indicators. While studying nitrogen levels in the Tapi estuary, India, George et al. (2012) found a fluctuation from 16 mg/L to 1.43 mg/L between June and December.

Catch composition, exploitation rates, and sizes of fish

Holzlohner et al. (2007), two previous researchers of the Cross River estuary, reported fish species identical to those found in the current study. This study confirms the importance of the marine near-shore area as a nursery location for a diverse assemblage of fishes, as noted by Bassey (1988) and Holzlohner et al. (2007), and finds that *P. elongatus, Ethmalosa fimbriata,* and *C. nigrodigitatus* were the most important species in the catch (Nunoo et al. 2007). Bassey (1988) found that these species accounted for 80.1% of the catch by weight, Holzlohner et al. (2007) found that they accounted for 92.1%, and the current study found that they accounted for 94.5%. Throughout the recent study, from December 2014 to May 2015, *P. elongatus* was consistently observed in the captures. From January through April, with peak abundance in March, *E. fimbriata* was widely distributed throughout the region.

Monthly catch averages of 21.2 kg/boat/trip and mean CPUE of 7.1 kg/boat/trip in the current study are comparable to 36.2 kg/boat/trip and 6.2 kg/boat/trip, respectively, as reported by Holzlohner et al. (2007). Although the prior study spanned an entire year and sampled more areas than this study, which investigated only three locations in six months, the results also indicate declining fisheries. Bassey (1988) states the average CPUE was 4.9 kg/boat/trip. The adult population of E. fimbriata, according to research by Ama-Abasi et al. (2004) on the species' migration pattern and life cycle, remains in coastal waters all year round for feeding and spawning activities, making them susceptible to near-shore purse seine fishing.

However, *C. nigrodigitatus* dominated the freshwater area of Anantigha, while *P. elongatus* and *E. fimbriata* dominated the captures in the Anansa and Okon areas, which are closer to the marine water of the ocean. *C. nigrodigitatus*, according to Moses (1979), lives in brackish water, small and large freshwater bodies in Africa, while *P. elongatus* and *E. fimbriata* were reported by Holzlohner et al. (2007) as marine species. Esuk Anansa boasts the largest catches. As a result of the deposition of detritus from mangrove exploitation and other nutrients from runoff of adjacent agricultural activities, the water may be extremely murky. Throughout the research period, a sparse population of *C. nigrodigitatus* persisted. Rates of capture were lowest in December and April. The *P. elongatus* and *E. fimbriata*, along with various other marine species, leave the estuary at the start of the wet season, which begins in April (Ama-Abasi et al. 2004). Most of the fish collected in the current study were relatively small, highlighting the importance of implementing sustainable fishing practices such as standardizing fishing net mesh sizes and developing a community-based coastal resource management system. Holzlohner et al. (2007) and Ama-Abasi and Uduakobong (2014) in the Cross River estuary, and Ngodigha et al. (2015) in the River Nun estuary in Bayelsa state, Niger Delta, Nigeria, all reported findings similar to these.

Overfishing of *P. elongatus* in the Cross River estuary was reported by Nwosu et al. (2010), who found an exploitation ratio of 0.79. The current study found that *P. elongatus* and *C. nigrodigitatus* had exploitation rates of 0.67 and 0.69, respectively, whereas *E. fimbriata's* rate was 0.43. Possible causes include the time frame, time of year, and geographical location of the samples used. However, the study recommends implementing management restrictions, including seasonal closures during peak spawning, to better the estuary's fishery. In addition, the mangrove ecosystem, which is essential to the system's productivity, should also be carefully managed and conserved.

Overfishing has put a strain on the Cross River's fishery, with the exploitation rate calculated by Ajang et al. (2011) coming in at 0.81 per year. It necessitates controls on fishing hours, gear types, mesh sizes, and restrictions on the amount of work put into fishing. However, Holzlohner et al. found that a lack of comprehensive effort data hinders the management of estuarine fisheries resources (2004). The amount of time and energy expended while fishing also matters greatly. In turn, it allows for determining an abundance index (Holden and Ritts 1974). Tracking fish populations' biomass spectra requires constant observation or at least a systematic study of the fishery's catch structure. Actions to preserve fish stocks can be implemented in response to sudden structural shifts, such as the disappearance or proliferation of species due to fishing, habitat disturbance, pollution load, or natural disasters (Holzlohner et al. 2007).

Socioeconomics

Fishing was found to be the most common occupation among the study's settlers, followed by mangrove logging, subsistence cultivation, and commerce. The primary focus of this research is on the importance of implementing a sustainable management plan to increase the efficiency of fisheries and restore near-shore fish-producing habitats with the involvement of community groups. The requirement to promote technology that fishers might apply with minimal support services should direct the work of the community organization. Sea ranching, aquaculture, and limiting damaging fishing techniques are all examples of such initiatives. Researchers have found that unsustainable fishing practices and the loss of coastal ecosystems, notably mangrove forests, are strongly linked to declining fishery production in the estuary. The widespread public has become more aware of the vital service activities of this ecosystem in sustaining fishing harvests due to direct observations of highland deforestation and the elimination of mangrove forests.

According to Alcala (1998), a crucial part of current CBCRM programs worldwide is creating marine reserves, parts of the marine environment that are protected from various forms of exploitation. Nearly all CBCRM projects have a provision for creating marine reserves to facilitate environmental and resource recovery (such as mangroves and coral reefs) (e.g., fishery). Marine reserves could be used in the management of coral fisheries to preserve critical stock biomass, for instance, to guarantee a recruitment supply via larval dispersal to fished regions and maintain enhanced fish yields to areas adjacent to reserves via the movement of adult fish. Stakeholder communities would likely see the creation of reserves as part of CBCRM in the research region favorably, if not rationally. Sustainable management of the fisheries in the area under investigation is necessary because they have the potential to underpin efforts to increase economic activity, reduce poverty, and increase the availability of animal protein for Nigeria's massive population. However, as Pinkerton and Weinstein (1995) outlined, the absence of community organization and competence for carrying out fundamental management responsibilities is a crucial obstacle to the formation of CBCRM in the Cross River estuary.

Approaches for community-based coastal resource management

Weak management structures are to blame for the pervasive disorganization of the study areas' communities and their inability to perform even the most fundamental management tasks. Traditional community institutions are so weak as to be non-functional, even in remote, rural villages like Esuk Okon and Ine Abasi, where the lure of modern commercialism is absent. As a result, the villagers, predominantly fishermen, do not understand the connection between declining fisheries and mangrove destruction and have forgotten how to work together. Therefore, organizations that serve several purposes in these communities, including fisheries management, must be established.

Elements common to community-based coastal resource management include social preparation and community organizing; environmental education and capacity building; resource management plans, including protective management; support activities for livelihood and financial resources mobilization; research and monitoring; and networking activities. Social preparation, community organizing, and environmental education are generally given priority and great importance in the early stages of project implementation. The effort and duration dedicated by project implementers to these efforts vary from project to project. It is because, via these activities, a community can recognize its own needs and the challenges it must address to improve the socioeconomic well-being of the people with the participation of all its members.

Successful community organizing leads to establishing citizen groups capable of conceiving and carrying out local improvement initiatives. In the beginning stages of CBCRM, environmental education is also crucial. They must persuade the locals that safeguarding and controlling their own resources is in their best interest. Community members must be shown the need to maintain ecological balance for continued maritime productivity. The economic benefits of tropical ecosystems like coral reefs and mangroves for coral reef fish production and mangrove values should also be communicated to the resource's beneficiaries (Alcala 1998).

At least one other organization, typically a university or non-governmental organization (NGO), must be involved in implementing the CBCRM strategy. Development is catalyzed by partner organizations' initiative, direction, technical expertise, and finance. Partner agencies act as co-managers of projects during the partnership period. Still, because CBCRM's ultimate goal is to give local communities the tools to safeguard and manage their resources, those agencies must leave the sites of completed projects after a set period has passed. Timelines for various CBCRM activities typically range from 2-3 years but can go as high as 4-5 years (Alcala 1998). It is, however, not uncommon for partner groups to keep ties to organized communities even after the original partners have withdrawn.

About 20 programs and projects dealing with fisheries or coastal resources have been implemented throughout the last 20 years (the 1970s-1990s). These programs and projects range from highly participatory to community-based (Alcala 1998). There are projects on a small scale that affect one town, and projects on a much larger scale affect the entire country.

Government and non-profit organizations contribute financially. Even though most of the smaller CBCRM projects have been started by universities or NGOs, they have always been carried out in conjunction with municipal agencies. For example, among the several community-based initiatives at Carbin Reef Marine Reserve in Sagay, Negros Occidental, only one was managed by a town mayor.

Thus, a successful community-based project may be characterized by the following features: the formation of one or more functional community organizations; the creation of a community-protected marine reserve; the development of sustainable economic activities based on coastal (fishery) resources; the establishment of connections with relevant government and international agencies and non-governmental organizations; and the implementation of a capacity-building program. Even though not all community-based projects have been successful, the most successful ones have been community-based Alcala (1998). However, due to its dependence on a wide range of uncontrollable social elements, the CBCRM strategy carries an inherent risk of failure.

Further, a legislative framework and the development of community-based organizational and technical capacities are necessary for effective CBCRM. Governments and multilateral agencies alike have realized the importance of community and partner groups in managing and protecting coastal ecosystems and fisheries. As a result, CBCRM has gained popularity as a solution to the problem of exhaustion of open-access resources like fisheries. However, it is impossible to establish legal ownership of these resources using appropriate tenurial instruments, as with most land resources. In an open-access system, only possession or actual usage confers legal title.

It is held accountable for the unrestricted use of fishing resources. One benefit of the CBCRM is that it gives those with a stake in helping the feeling of ownership and rightful access that these individuals may otherwise lack. For example, suppose coastal fisheries and other coastal resources are to be effectively protected and managed. In that case, local coastal people must be acknowledged and given authority over their management on a day-to-day basis (Alcala 1998).

Sustainability of CBCRM projects

The question of sustainability is one of many in CBCRM, but it is one of the most pressing. Because of their restricted area of jurisdiction, limited research ability, budget limits, and the dominance of parochial interests in local politics, it is believed that local governments and communities typically cannot appropriately manage coastal ecosystems. These restrictions make it difficult, if not impossible, for management initiatives to get off the ground and remain viable over time. One of the main reasons specific initiatives have failed is local officials' narrow or even self-serving motives (Alcala 1998). Although there are constraints on research capacity and local jurisdiction, these problems are not intractable. The good news is that these obstacles have been addressed through training, capacity building, and networking with NGOs and academic institutions, leading to relatively successful projects. The constraint of the budget is of primary importance.

While, it often takes communities four to five years to establish sustainable organizations capable of creating and implementing development plans, partner organizations that launch CBCRM programs are typically only prepared to financially support these projects for two to three years. Providing communities with sustainable livelihood options likewise takes around the same time.

Interestingly, it takes only four years for plankton-feeding fish to migrate from coral reef reserves to fishing regions (whereas it takes eight to ten years for carnivores to do the same). Partner organizations concerned with showing the impact of protected areas on local fish food supplies should look to these timelines as essential references. Convincing individuals of the importance of community resource management is best done by "tangible gains in a project," as stated by Newkirk and Rivera (1996).

Before cutting off communities' access to external financial aid, they must make adequate preparations to guarantee that their residents will continue to engage in sustainable livelihood activities. The Apo Island Marine Conservation Project in Central Visayas is a prime example of a successful CBCRM initiative in the Philippines. The initiative kicked out in 1981, and by 1982, a marine reserve (10% of the coral reef area) had been formed, and by 1985 and 1986, community organizing had ramped up. Since 1987, the local community of 500 has been well organized, and with little assistance from the partner agency (Silliman University), they have administered and preserved the reserve. The fishermen say that since the reserve was established, their fish catches outside of the area have increased dramatically. They are pleased with the reserve since it has enhanced their income from fish and tourism.

The research concluded that *P. elongatus, Ethmalosa fimbriata*, and *C. nigrodigitatus* were the most common species caught in the estuary's multispecies gillnet fishing. Using the collected data, we found that the water quality metrics varied considerably. However, fish could survive in the water since it was not too polluted. On the other hand, about 70% of the gear utilized in the research region was a gill net, which also impacted the average size of the fish caught. The study found that most of the fish caught were undersized, and the rate of exploitation constituted a significant threat to the fisheries. Habitat loss occurred due to the indiscriminate harvesting of mangroves for fuel in industries such as oil palm processing, fish processing, cooking, baking, agriculture, and construction. Therefore, there must be pressure for sustainably managed fisheries in the region because they can contribute to efforts to increase economic activity, reduce poverty, and increase the availability of animal feed. The following are some of the suggestions for regional fishery management that emerged from the study.

REFERENCES

Adebisi AA. 1981. The physicochemical hydrology of a tropical seasonal River-Upper Ogun River. Hydobiology 79: 157-165. DOI: 10.1007/BF00006123.

Aiman WM, Yusoff FM, Arshad A, Kamal AHM, Ismail J, Idris MH, Karim NU, Asif AA. 2020. Distribution of zooplankton community in Toli shad (*Tenualosa toli*) habitats, Sarawak, Malaysia. Biodiversitas 21: 4022-4033. DOI: 10.13057/biodiv/d210913.

Ajang RO, Ndome CB, Ekwu A, Uttah E, Iboh CI. 2011. Population dynamics and gillnets selectivity of *Chrysichthys nigrodigitatus* (Lalepede 1803) in lower reaches of the Cross River Estuary, Nigeria. Ethiop J Environ Stud Manag 6: 31- 40. DOI: 10.4314/ejesm.v6i1.4.

Akintola SL, Anetekhai MA, Lawson EO. 2011. Some physicochemical characteristics of Badagry Creek, Nigeria. West Afr J Appl Ecol 18: 95-107. DOI: 10.4314/wajae.v18i1.70313.

Akpan AW. 1993. The effect of hydrological regime on the temperature and salinity profiles of a tropical coastal river (Nigeria). Acta Hydrobiol 35 (4): 275-284.

Akpan AW. 2004. The water quality of some tropical freshwater bodies in Uyo (Nigeria) receiving municipal effluents, slaughter house washings and agricultural land drainage. Environmentalist 24: 49-50. DOI: 10.1023/B:ENVR.0000046346.93401.5c.

Akpan ER, Offem JJ, Nya AE. 2002. Baseline ecological studies of the Great Kwa River, Nigeria 1: Physicochemical studies. Afr J Environ Pollut Health 1: 83-90.

Akpan ER. 1991. Seasonal Variation in Phytoplankton Biomass and Pigments in Relation to Water Quality in the Cross River System. [Dissertation]. University of Calabar, Calabar. [Nigeria]

Akpan ER. 1993. Seasonal cycles of phytoplankton and grazing activity in the Cross River system of southeastern Nigeria. Trop Ecol 34 (2): 143-149.

Akpan ER. 1999. Spatio-seasonal trends of physicochemical characteristics of Cross River Estuary, Nigeria. Prog. Biometeorol 13: 127-131.

Akpan I, Bankole MO, Adesemowo AM. 1999. A rapid plate culture method for screening of amylase-producing micro-organisms. Biotechnol Tech 13 (6): 411-413. DOI: 10.1023/A:1008965808641.

Alcala AC. 1998. Community-based coastal resource management in Philippines: A case study. Ocean Coast Manag 38: 179-186. DOI: 10.1016/S0964-5691(97)00072-0.

Ama-Abasi D, Holzlohner S, Enin UI. 2004. The dynamics of the exploited population of *Ethmalosa fimbriata* (Bowdich, 1825. Clupeidae) in the Cross River Estuary and adjacent Gulf of Guinea. Fisher Res 68: 225-235. DOI: 10.1016/j.fishres.2003.12.002.

Ama-Abasi D, Uduakobong S. 2014. Fecundity, gonadosomatic index and spawning period of *Chrysichthys nigrodigitatus* of the Lower Cross River, Nigeria. J Fisher Aquat Sci 9: 277-280. DOI: 10.3923/jfas.2014.277.280.

Ama-Abasi D. 2002. Aspects of Population Biology of the Bonga, *Ethmalosa* (Bowdich, 125) in the Cross River Estuary, Nigeria. [Dissertation]. University of Calabar, Calabar. [Nigeria]

American Public Health Association (APHA). 2005. Standard Methods for the Examination of Water and Wastewater. 21st Ed., American Water Works Assoc., Water Pollution Control Federation, Virginia.

Bassey BU. 1988. The Catch Structure of the Artisanal Gillnet Fishery of the Lower Cross River. [M.Sc. Thesis]. University of Calabar, Calabar. [Nigeria]

Blaber SJM, Cyrus DP, Albert CVC, Day JW, Elliot M, Fonseca MS, Hoss DE, Orensanz J, Potter IC, Silvert W. 2000. Effects of fishing on the structure and functioning of estuarine and near-shore ecosystems. ICES J Mar Sci 57: 590-602. DOI: 10.1006/jmsc.2000.0723.

Boyd CE. 1979. Water Quality in War Water Fish Ponds. Auburn University Publications, Alabama.

Cochran WG. 1977. Sampling Techniques. (3rd ed.). John Wiley and Sons. Inc., New York.

Cronin LE, Daiber JC, Hulbert EM. 1962. Quantitative seasonal aspects of zooplankton in the Delaware River Estuary. Chesapeake Sci 3: 63-93. DOI: 10.2307/1351221.

Elliot M, O'Reily MG, Taylor CJL. 1990. The Forth estuary: A nursery and overwintering area for North Sea fishes. Hydrobiologia 195: 89-103. DOI: 10.1007/BF00026816.

Eugenia BB, Armah AK, Dankwa HR. 2019. Fish as bioindicators of habitat degradation in coastal lagoons of Ghana. Bonorowo Wetlands 9: 9-26. DOI: 10.13057/bonorowo/w090102.

Ezenwa BIO. 1981. A Study of the Reproductive Biology of the Catfish, *C. nigrodigitatus* (Lacepede), in Nigeria. [Dissertation]. University of Lagos, Lagos. [Nigeria]

Fairbridge RW. 1980. The estuary: Its definition and geodynamic cycle. In: Olausson E, Cato I (eds). Chemistry and Biogeochemistry of Estuaries. Wiley, New York.

Fatoki OS, Muyima NYO, Lujiza N. 2001. Situation analysis of water quality in the Umtata River catchment. Water SA 27: 467-473. DOI: 10.4314/wsa.v27i4.4959.

Franco A, Elliott M, Franzoil P, Torricellil P. 2008. Life strategies of fishes in European estuaries: The functional guild approach. Mar Ecol Progr Ser 354: 219-228. DOI: 10.3354/meps07203.

George B, Nirmal KJI, Kumar RN. 2012. Study on the influence of hydro-chemical parameters on phytoplankton distribution along Tapi estuarine area of Gulf of Khambhat, India. Egypt J Aquat Res 38 (3): 157-170. DOI: 10.1016/j.ejar.2012.12.010.

Gill TD, Dotinga H, Rosenne H, Molenaar EJ, Elferink AG. 2003. Rosenne's the World Court; What it is and how it works. United Nations Publications.

Hobbie JE. 2000. Estuarine Science: A Synthetic Approach to Research and Practice. Island Press, Washington, DC.

Holden MJ, Ritts DFS. 1974. Manual of fisheries science. Part 2. Resource investigation and their application. FAO Fish Tech Pap 115 (1): 214.

Holt AE, Miller WS. 2011. Bioindicators: Using organisms to measure environmental impacts. Nat Educ Knowl 2 (2): 8.

Holzlohner S, Enin UI, Ama-Abasi D, Nwosu FM. 2007. Species composition and catch rates of the gillnet fishery in the central cross river estuary, SE Nigeria. J Afr Trop Zool 2007: 107-112.

Holzlohner S, Nwosu FM, Enin UI. 2004. Fishing effort statistics of the artisanal fisheries of the Cross River Estuary, Nigeria. Glob J Pure Appl Sci 10 (2): 249-256. DOI: 10.4314/gjpas.v10i2.16390.

Hossain MS, Gopal DN, Sarker S, Rahaman MZ. 2012. Fish diversity and habitat relationship with environmental variables at Meghna River Estuary, Bangladesh. Egypt J Aqua Res 38 (3): 213-226. DOI: 10.1016/j.ejar.2012.12.006.

Jaji MO, Bamgbose O, Odukoya OO, Arowlo TA. 2007. Water quality assessment of Ogun River, South West Nigeria. Environ. Monit Assess 133 (1-3): 447-482. DOI: 10.1007/s10661-006-9602-1.

Jennerjahn TC, Mitchell SB. 2013. Pressures, stresses, shocks and trends in estuarine ecosystems – An introduction and synthesis. Estuar Coast Shelf Sci 130: 1-8. DOI: 10.1016/j.ecss.2013.07.008.

Karikari AY, Asante KA, Biney CA. 2006. Water quality characteristics at the estuary of Korle Lagoon in Ghana. West Afr J Appl Ecol 10: 73-85. DOI: 10.4314/wajae.v10i1.45700.

Kausch H. 1990. Biological processes in estuarine environment. In: Michaelis W (eds). Coastal and Estuarine Studies. Vol. 36. Springer Verlag, Berlin. DOI: 10.1029/CE036p0353.

Kemdirim EC, Ejike C. 1992. The phytoplankton response to artificial enrichment with Nitrates and Phosphates in an upland and lowland reservoir in Plateau State. J Aquat Sci 7: 45-57.

Kennedy VS. 1984. The Estuary as a Filter. Academic Press, Orlando. FL.

King RP, Ekeh IB. 1990. Status and seasonality in the physicochemical hydrology of a Nigerian headwater stream. Acta Hydrobiol 32 (314): 313-378.

Kolo R. 1996. The assessment of physicochemical parameters of Shiroro Lake and its major tributaries. In: Eyo AA (eds). Proc Ann Conf Fisher Nigeria.

Lowenberg U, Kunzel T. 1992. Investigations on the hydrology of the lower Cross River, Nigeria. Mar Res 42 (1): 63-75.

Mc. Lusky DS, Elliott M. 2004. The estuarine Ecosystem: Ecology, Threats and Management. (3rd Ed). Oxford University Press, Oxford.

Micheal KS. 1992. Fish Medicine. W.B Saunders Company, Philadelphia.

Mosepele K. 2000. Preliminary Length Based Stock Assessment of the Main Exploited Stocks of the Okavango Delta fishery. [Mphil. Thesis]. Department of Fisheries & Marine Biology, University of Bergen, Norway. [Norway]

Moses BS. 1979. The Cross River, its ecology and fisheries. In the Proceedings of the International Conference on Kainji Lake and River Basins developments in Africa. Kainji Lake Research Institute, New Bussa, Nigeria.

Moses BS. 1990. The status of artisanal fisheries and fish resources conservation in southeastern Nigeria. Trans Nig Soc Biol Conserv 1: 43-60.

Mustapha M, Omotosho JS. 2005. An assessment of the physicochemical properties of Moro Lake. Afr J Appl Zool Environ Biol 7 (1): 73-77. DOI: 10.4314/ajazeb.v7i1.41151.

Mustapha MK. 2008. Limnology and Fish Assemblages of Oyun Reservoir, Offa, Nigeria. [Dissertation]. University of Ilorin, Ilorin. [Nigeria]

Newkirk GF, Rivera RA. 1996. Synthesis. In: Ferrer EM, dela Cruz LP, Domingo MA (eds). Seeds of Hope. College of Social Work and Community Development, University of the Philippines, Diliman, Quezon City.

Ngodigha SA, Alaoga KJ, Alfred JF. 2015. Aspects of the population dynamics of *Nematopalaemon hastatus* (Aurivillius 1898) in River Nun Estuary, Bayelsa State, Niger Delta, Nigeria. Intl J Curr Res Biosci Plant Biol 2 (4): 161-167.

Nunoo FKE, Hiablie SA, Patu DO. 2007. Trends in fish species diversity found in near-shore marine waters along the coast of Ghana, West Africa. J Ghana Sci Assoc 9: 10-19.

Nwosu FM, Enin UI, Holzlohner S. 2010. Assessment of artisanal fishery impacts on West African croaker, *Pseudotolithus elongatus* in the Cross River Estuary, Nigeria, using length-based models. North Ame J Fisher Manag 30 (4): 860-865. DOI: 10.1577/M10-011.1.

Nwosu FM. 2005. An Overview of Nigeria's mangrove Ecosystem: Problems and Prospects. National Workshop on Coastal and Marine Biodiversity Management. ABGREMO/SU/TCDC/UNDP /UNOPS. Calabar.

Nyam L. 1998. Eco- Environmental Aspects of Integrating Small Scale Aquaculture with Rural Development Programs in Southern Africa. Fisheries Development Series (Sweden). 0280-5375, No .24. National Swedish Board of Fisheries, Goeteborg, Sweden.

Officer CB. 1976. Physical Oceanography of Estuaries and Associated Coastal Waters). Wiley-Interscience, New York.

Oribhabor BJ, Udoidiong OM, Udoh DF, Akpan BE. 2013. Evaluation of the ecological impact of human settlement on the water quality of Lower Cross River, Nigeria. J Ecosyst 2013: 12. DOI: 10.1155/2013/840295.

Paturej E, Gutkowska A, Koszałka J, Bowszys M. 2017. Effect of physicochemical parameters on zooplankton in the Brackish, Coastal

Vistula Lagoon. Oceanol 59 (1): 49-56. DOI: 10.1016/j.oceano.2016.08.001.
Pinkerton E, Weinstein M. 1995. Fisheries that Work. Sustainability Through Community Based Management.
Pomfret JR, Elliott M, O'Reilly MG, Phillips S. 1991. Spatial and temporal patterns in fish communities in two UK North Sea estuaries. In: Elliott M, Ducrotoy JP (eds). Estuaries and Coasts: Spatial and Temporal Inter comparisons. Olson & Olson, Fredensborg, Denmark.
Potter IC, Beckley LE, Whitfield AK, Lenanton RC. 1990. Comparisons between the roles played by estuaries in the life cycles of fishes in temperate Western Australia and Southern Africa. Environ Biol Fish 28: 143-178. DOI: 10.1007/978-94-009-2065-1_9.
Rahim KAA, Tumiran MHL Shabdin M, Esa Y, Husaini ASA. 2014. The Status of Tenualosa toli(Valenciennes, 1847) in the Southwest Coast of Sarawak, Malaysia. Kuroshio Sci 8: 37-42.
Rezai H, Yusoff FM, Othman BHR. 2011. Vertical distribution of zooplankton and copepod community structure in the Straits of Malacca. J Persian Gulf (Mar Sci) 2(3): 17-23.
Saifullah ASM, Abu Hena MK, Idris MH, Halima AR, Johan I. 2014. Seasonal variation of water characteristics in Sibuti River Estuary in Sarawak, Malaysia. Malays J Sci 33 (1): 9-22. DOI: 10.22452/mjs.vol33no1.3.
Sokal RR, Rolf FJ. 1981. Biometry. The Principles and Practice of Statistics in Biological Research. (2nd ed.). Freeman and Company, San Francisco, California.
Tumiran MHB, Rahim KAA, Shabdin ML, Esa Y, Husaini AASA. 2011. Environmental Parameters of "Core Terubok Areas" and the Relationship with Terubok Sarawak Population. International Fisheries Symposium. Universiti Malaysia Terengganu, Kuala Nerus, October 2011.
Twilley RR, Snedaker SC, Yanez-Aranciba A, Medina E. 1996. Biodiversity and ecosystem processes in tropical estuaries: Perspectives from mangrove ecosystems. In: Money H, Cushman H, Medina E (eds). Biodiversity and Ecosystem Function: A Global Perspective. Department of Biology, University of Southwestern Louisiana, Lafayette.
United States Department of Agricultural Soil Conservation Service (USDASCS). 1975. Agricultural waste management. Field Manual, U.S. Printing Office
USEPA. 1998. Estuaries and Your Coastal Watershed. Coastal Watershed Factsheets. E.P.A. 842-F-98-009.
Valiela I. 2006. Global Coastal Change. Blackwell, Malden, MA.
Zaleha K, Abang Jefri AM, Hasimah MS. 2013. Fauna of Porcellidiidae (Copepoda: Harpacticoida) from Sungai Pulai, Malaysia. Malay Nat J 64 (4): 159-167.