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THE STATUS AND ENVIRONMENTAL IMPACTS OF BIOTURBATION ON THE COASTAL ZONE OF QUA IBOE RIVER ESTUARY, NIGERIA.

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ABSTRACT
This research assessed the status of the coastal zone of Qua Iboe River Estuary, Akwa Ibom State, Nigeria; and evaluated the environmental impacts of bioturbation on the resource use and abundance. Quantitative and semi qualitative data collection tools were used. A computer database and statistical programme were used to analyze the date in order to identify the areas of resource use and conflict. Tarballs, beach oil, drift oil, plastics bags, empty cans and scrap metals were all of frequent occurrences (10% - 37%); with plastic bags recording the highest frequency of occurrence (29% - 37%). Human impacts such as overfishing, oil prospecting and production, gas flaring, traffic in motorized river crafts, sewage input, effluents from highway construction as well as waste disposals were identified. The main abundance and magnitude of the resource use and impact range between 0[for mammals] and 22[for fin fish]. Significant [p<0.01] correlations were obtained between biological resources and impacts considering data from the inter-tidal and sub-littoral zones. The implications of the above on coastal zone management are imminent.

Keywords: *Environmental impacts, Bioturbation, coastal zone, Nigeria*

INTRODUCTION
The coastal zone is a dynamic area surrounding the interphase between the land and sea and encompasses shoreline environments as well as adjacent coastal and marine waters with frequently changing biological, chemical and geological attributes (Hayden *et. al*., 1979; Awosika 1992, and Akpan 2002). It encompasses shoreline environments as well as adjacent coastal and marine waters, including the interphase where terrestrial and marine factors interact. The coastal zone typically includes coastal plains, river deltas, wetlands, lagoons, beaches and dunes, mangroves, reefs and other coastal features (Post and Lundin, 1996), so also the splash zone, the high intertidal zone, the low intertidal zone and the low tide zone. These zones are very sensitive to human perturbations. The operational area within the continental shelf for coastal artisanal fishery is 2258km^3 with a depth of 15m (Moses, 1980). A greater part of this area has been degraded through anthropogenic influences including oil prospecting and production resulting in oil spills, gas flaring discharge of untreated effluents, deforestation, highway development, sewage inputs, unregulated handling of petroleum products, heavy traffic in motorized river crafts and unorthodox methods of fishing. The estuarine bottom is generally of mixed deposit of sand and mud with abundant silt, rich organic effluents transported by the river thereby making it one of the richest fishing zones in Nigeria. The Qua Iboe River estuary is of immense scientific interest for several reasons notably because it contains rich fisheries and other renewable resources of national significance. It is rich in enormous oil reserves whose exploitation has resulted in resource use conflicts; the area is prone to frequent oil spills.

The coastal zone of Qua Iboe River Estuary experiences tremendous human perturbation through such activities as solid waste disposal, pollution and modification of coastline through construction activities, sand-filling and dredging. Other activities include deforestation, soil erosion and habitat destruction due to urbanization, over-exploitation of fishery resources through unorthodox and destructive fishing methods, dumping of sewage effluents, oil spills, municipal runoff and oil-related activities including gas flaring. The objective of the study was to investigate the status and the various human activities that impact the coastal zone of Qua Iboe Rivers Estuary, east of the Niger Delta and their relative magnitude on the biota.

MATERIALS AND METHODS
Study Area
The study area covered the Qua Iboe River estuary coastal zone including the coastline and stretching about 10 kilometers along the shoreline which border the Atlantic Ocean and sand beaches from Cross River Estuary to Qua Iboe River Estuary and beyond.

The Qua Iboe River coastline is characterized by brackish water with thick mangrove swamp forests on tidal mudflats and sandy beaches. The exotic nipa palm (*Nypa fruticans*) is fast replacing the indigenous mangrove forests at various locations by its aggressive growth and advancement. Two locations with anthropogenic disturbance were chosen in the estuary to evaluate the effect of bioturbation on the coastal zone of the estuary. The fishing settlements/locations are Ibeno and Upenekang on Qua Iboe River estuary Qua Iboe River is located between 7^{o}30′ - 8^{o} 20′ W; 4^{o}30′ - 5^{o}30′N. Parallel investigation was also carried out at locations/fishing settlements with minimal human influence for comparison at the upstream segment of Qua Iboe River.

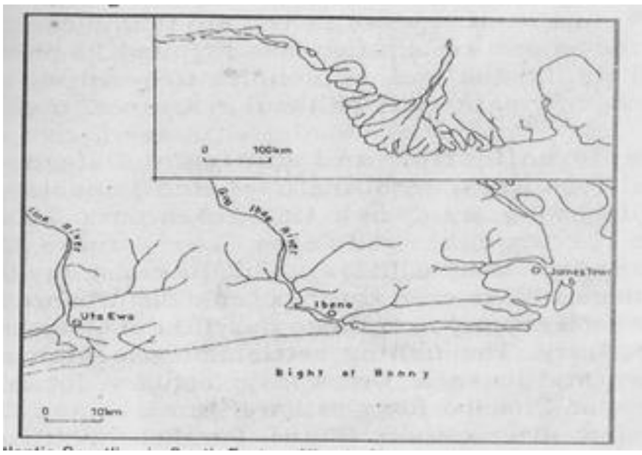

Figure 1: The Study Area

Sample Collection and Analysis: Data on the biological resources, their uses and impacts were recorded for two years (March 2018 to February, 2020) comprising the coastline of Qua Iboe River Estuary (QIRE).
Sample collection and observations were made in 500m × 500m quadrants bisecting the beaches and covering both the inter-tidal and immediate sub-tidal zones (Price, 1990). The abundance of the biological resource and the uses/impacts were estimated and recorded both quantitatively and semi-quantitatively. The biological attributes (both flora and fauna) together with the resource uses/impacts were scored using a ranked 0-6 scale (Price, 1990).

Impacts and resource uses were also scored but the scores represented the estimated relative magnitude depicted by a ranked scale of 0 to 6; 0 representing no impact while greatest impact was represented by 6. Estimates of abundance of biological resources (flora and fauna) were scored based on estimates of areal (m^2) for flora and estimated number of individuals for fauna within each quadrat of 250, 000m^2 (500m × 500m) (price, 1990).
Some of the biological attributes such as mangrove trees, nipa palm that could be observed outside the quadrat were also recorded as either present or absent but not included in the data. A number of oceanographic parameters such as salinity and tidal range were recorded at each site. In addition, observations and measurements were also made on coastal topography, substrate and habitat types and anthropogenic disturbances. Some water quality parameters such as pH, water temperature, turbidity, Total Suspended Solids (TDS), conductivity, total alkalinity, water hardness, Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Nitrated Nitrogen ($NO^{3-}N$) and Phosphate-Phosphorus ($PO^{4-}P$) were analyzed following methods described in APHA (1989). Numerical estimation was made on fish catches (fin and shell fish) from the artisanal fishers and their fish landings (Table 1).

Table 1: Biological resources, resource uses/impacts and the abundance scale for fauna evaluated in the coastal zone of south – eastern Nigeria (modified from Price, 1990).

Biological resources		Resource uses / impacts
Fauna	Flora	
Fin fishes	Mangroves	Fishing
Shell fishes	Algae	Sea traffic
Birds	Halophytes	Construction
Aufwuchs	Nipa palm	Oil prospecting / production
Macroinvertebrates		Effluent discharges / sewage
Mammals		Dredging pollution Drift wood / CPOM

Abundance scale Areal extent (m2) (flora) number of individuals
(Fauna) (Range)

0	0
1	1-9
2	10-99
3	100-999
4	1000-9999
5	10,000-99,999
6	100,000+

Cluster analysis was used to compare and separate the different sites according to the various biological resource data and the data on resource use/impacts. This type of analysis was used as recommended by Price (1990) because it is a useful interpretive tool, although not a statistical test. The Dissimilarity Index (DI) was calculated using the formula given by Levandowsky (1972) as follows:

$$DI = 1 - \sum_{i=1}^{S} (\min X_{1i} \,.\, X_{2i}) / \sum_{i=1}^{S} (\min x_{1i} \, X_{2i})$$

Where X_{1i} . X_{2i} = values of relative abundance of ith taxon in two respective communities (1 and 2), S = total number of species.
The Bray-Curtis (1957) similarity index was also calculated followed by a simple hierarchical clustering of sites using the arithmetically-determined centroid (Sneath and Curtis, 1973; Vanden Hoek *et. al*. (1975). Data collected were analysed using computer software (Apple Works). Spearman's rank correlation coefficient (Rs) was calculated to establish significant relationships between some hydrological and oceanographic factors. Shannon's index of general diversity was also analyzed for the biological variables at each location using the designation:

$$H = \Sigma (ni / N) \log_2 (ni / N)$$

Where H = diversity index ni = number of individuals of each species,
N = total number of individuals of all species.

RESULTS AND DISCUSSION

Magnitude of wastes / Resource Use

Considerable quantity of organic and inorganic wastes (solid, semi-solid and particulates) generated by anthropogenic disturbances and activities were identified within the beaches and coastal waters. These include; plastic bags mainly from disused packaged water bags (locally called "pure water" bags), waste oil, beach oil, drift oil, tar balls, empty cans of various dimensions, scrap metals, woody debris, waste papers, discarded fabric materials, discarded fishing nets and floats and domestic wastes. These were all of frequent occurrence. Wastes from construction activities, mechanic workshops including scrap metals were dominant at QIRE which experiences remarkable site-specific encroachment and environmental disturbances from oil related activities. The mean, modal abundance and magnitude of the different wastes/uses/impacts are presented in Table 2.

Table 2: Organic and inorganic waste, uses, impacts on coastal resources and their magnitudes at Qua Iboe River estuary. Values recorded are ranges for the Qua Iboe River Estuary.

Wastes	Sources	Impacts / Uses scale	Range of Occurrence (%)	Range of abundance /magnitude mean (0 – 6) Mean	Mode
Tar balls	Oil spills	Stains beaches, reduce estuarine biodiversity and aesthetic value.	10–15%	2.5–3.5	2–4
Plastic bags	Domestic uses / tourists	Litters the estuarine coastline, reduces aesthetic value of coastline / water.	29–37%	1.5–3.4	2–4
Waste oil/ Drift oil	Discarded lubricants from automobile / engines/ workshops	Stains beaches, forms thin film on estuarine water, reduces aesthetic value/ biodiversity	14–26	0.8–2.4	1–2
Empty cans, scrap Metals, tyres/tubes	Discarded domestic beverages /industrial appliances / tools; disused tyres / tubes, automobile, motor bike and bicycle parts; engine boat parts.	Visible solid waste impeding movement/ navigation; reduce aesthetic value; serve as hide-out/micro-habitat for crabs/ other intertidal organisms.	0–18	0–0.5	0
Textile, fabric, leather materials	Discarded domestic textile, fabric materials,shoes.	Visible solid waste, nasty, unsightly, smelly reduces aesthetic value.	0–19	0–0.5	0
Discarded footwears, abandoned boats, ships wreckage wood logs, timbers,	Disused boat / ship, timber from lumbering.	Blocks channels, impedes navigation.	0–26	0–0.8	0
Fishing nets, floats, Netting materials, valved traps, longline	Disused fishing materials, nets for mending.	Reduces aesthetic value.	0–16	0–06	0
Dead/ Decaying Fish, Fish remnants scales, fins, entrails	Spoilt fish, remnants of processed fish. Odour, reduction in aesthetic value.	Messy, unsightly, emits offensive and putrefying odour.	2–23	0–0.8	0
Driftwood, CPOM, Woody debris, twigs	Remnants of fire wood, parts of disused boats, sticks, paddles; dislodge littoral zone vegetation, disused building materials.	Hinders navigation, reduction in aesthetic value	16–35	0.5–2.5	0-3
Inorganic particulates	Erosion, surface runoff, automobile /machinery moment.	Increases turbidity. Siltation of coastal area / lagoons.	0–4	0–0.1	0

CPOM = Coarse particulate organic matter.

Anthropogenic inputs of petroleum hydrocarbon in the coastal soil, sediments and water in the study area has been identified to come from a variety of sources including occasional oil spills (Olagbende *et al.* 1999), storm water runoff from city highways, car parks, mechanic workshops, fuel stations and spills from careless handling of petroleum products (Akpan and Ufodike, 1995). Other sources include automobile combustion, atmospheric deposition particularly from gas flaring, industrial enterprises and the expanding offshore oil exploration and production (Enyenihi, *et. al*.1987). Tar balls are a regular occurrence on the estuarine beaches (Akpan and Ufodike, 1995), distributed and dispersed by tidal currents and strong waves from the sea (Antia, 1985, 1987).

Driftwood, CPOM and woody debris are important wastes in the estuarine beaches and water transported from upstream of the river including allochthonous inputs from the thick riparian vegetation and forested catchment through surface runoff. Large quantity of suspended solids and organic debris from earth moving equipment during highway construction, debris and silt inflow from runoff and inorganic particles are known to cause clogging and abrasion in fish gills; these materials also smother and cover the spawning grounds of fish (Sikoki and Kolo, 1993). In addition, they silt up the waterways, increase turbidity and impede navigation.
The plastic bags and other plastic containers, disused tyre tubes and rubbers which are non-degradable wastes including aluminum cans, battery containers, steel products and other metal alloys were also abundant and tend to persist in the coastal environment. Input of large proportion of agricultural wastes from agricultural land drainage carried from runoff or leached into aquatic systems cause eutrophication (Morgan: 1972; Moss *et al.*, 1980 and Godfrey, 1982).

The encroachment of urbanization, and rapid development is threatening to convert the estuarine basin from unique ecologically productive ecosystems into sub-urban sprawl in the QIRE where there is a large industrial area owned and operated by an oil company with other services and subsidiary companies. The process of filling, piling and reclamation of large expanses of estuarine swamps and coastal areas has extended the coastal towns causing loss of rich fishing grounds and ecologically valuable wetlands (Hudson, 1979).

Biological resources/impacts
The occurrence and abundance of key biological resources in the Qua Iboe River estuary as well as the major uses and impacts are presented in Table 3 including the potential impacts. Qua Iboe River estuary has a rich assemblage of fish species with high diversity and species richness with mean percentage occurrence of 32% determined from landings by the fishers (Ekpo and Essien-Ibok (2013). Anthropogenic and environmental impacts on fishing include overfishing, habitat degradation through oil pollution and continuous droning of engines from river crafts. There is a likelihood that the water body has been exploited above the maximum sustainable yield (MSY) as evidenced by declining yields and reduction in fish sizes. Shelled fishes were also abundant but most showed evidences of impact with empty shells. The dissimilarity index values for the biological resources at the river estuary ranged between 1.02 and 1.45 in the perturbed and control area indicating unidentical communities.

Table 3: Biological resources from the coastal waters and intertidal community of the Qua Iboe River estuary and uses / impacts.

Biological Resource	Occurrence (%)	Abundance /Magnitude		Resource Use	Human Impacts
		Mean	Mode		
Fin fish	22.0	0.7	0	Artisanal fishing, human consumption	Overfishing, habitat Degradation
Shell fish	15.60	1.4	0	Artisanal fishing, human consumption	Overfishing, habitat Degradation
Other invertebrates	11.90	0.4	0	–	Destruction/ degradation of habitat
Algae/Aufw uchs	14.70	3.2	1	Fire wood Construction	Over exploitation deforestation/degradation/
Mangroves	10.27	2.1	2	–	Destruction of habitat
Birds	4	0.2	0	Game hunting	Gas flaring interference with food chain/food wed.
Grasses	21.5	0.5	0	Grazing by cattle	Bush burning destruction of habitat.
Halophytes	30.4	1.2	0	–	Destruction of habitat
Mammals*	0	0	0	Tourist/game hunting	Game hunting, destruction of habitat.

Associations between environmental variations:
The correlation between the oceanographic parameters such as salinity and other physico-chemical factors (TDS, conductivity, water hardness and total alkalinity) were strongly positive and significant indicating a direct relationship between them. The relationship between salinity and pH, was insignificant. The correlation between shell fish abundance and salinity (rs = 0.669, $p < 0.01$) was positive and significant indicating that salinity is implicated as a strong environmental variable for its abundance. However, when the data were separated into dry and wet seasons, the correlation in the wet season was negative and insignificant indicating that declining salinity probably accounted for increase in abundance. The association between other macroinvertebrate groups and salinity was negative and significant (rs = - 0.49, p<0.05). The correlation between fish abundance and some impacts such as construction, beach oil, driftwood and other forms of pollution were significant but these are considered indirect rather than real, and may be explained by the fact that several of the uses/impacts are strongly inter-connected.

CONCLUSION
This study has successfully assessed the status of the Qua Iboe River Estuary, Akwa Ibom State, Nigeria. It has also evaluated the environmental impacts of bioturbation on the resource use abundance of the ecosystem, following quantitative and semi-quantitative data collection tools used. Tar balls, beach oil, drift oil, plastic bags, empty cans and scrap metals frequently occurred. Human activities were also identified. Mean abundance of resources was lowest in mammals and highest in fin fish. Significant (p<0.01) correlations were obtained. It can be concluded that this ecosystem is significantly impacted by waste and anthropogenic activities such that the aquatic life may be threatened.

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