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Survey of the physical characteristics of the upper reaches of New Calaber River, Niger Delta, Nigeria

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Abstract

One of the priority research projects of the Nigerian Institute for Oceanography and Marine Research (NIOMR) is broodstock development and mass propagation of silver catfish, Chrysichthys nigrodigitatus of which the broodstock is naturally abundant in New Calabar River. Selected physical characteristics and water physico-chemical parameters of the upper reach of the New Calabar River at Aluu were investigated. The highest depth value of 9.20 m was recorded in the middle of the river. The width of the river measured during spring high tide and low tide were 174 m and 110 m respectively. The cross-sectional area and average flow velocity of the river were 797.13 m² and 0.374 m/s respectively. The discharge of the river was computed as 298.13m³/s. The river water was acidic most of the period (Hydrogen ion concentration, pH: 5.12 to 7.43), with low total alkalinity values (4.00 to 12.00 mgCaCO₃/L) and low total hardness values (11.5 to 51.2 mgCaCO₃/L) which indicate that the river water is black and soft. There was significant ($p \leq 0.05$) seasonal variation in temperature (23.1 to 31.7°C), Secchi transparency (9.30 to 19.00 cm), total hardness (11.5 to 51.2 mgCaCO₃/L), dissolved oxygen (5.20 to 7.50 mg/L) and dissolved oxygen deficit (0.02 to 2.95mg/L). These results are useful for several stake holders who use the river as a sink for trade wastes, as source of water for fish farming, as source of broodstocks of Chrysichthys nigrodigitatus, as raw water for water treatment plants, and as means of transportation of industrial materials.

Keywords: New Calabar River, physical characteristics and physico-chemical features, seasonal variation.

Introduction

One of the priority research projects of the Nigerian Institute for Oceanography and Marine Research (NIOMR) is broodstock development and mass propagation of silver catfish, *Chrysichthys nigrodigitatus*. This is aimed at diversification of cultivable fish species in the Nigerian aquaculture industry. Research work on broodstock development and mass propagation of silver catfish, *Chrysichthys nigrodigitatus*, began in the 1980s (Ezenwa, 1981), however a breakthrough is yet to be achieved. The upper reach of the New Calabar River at Aluu is known to be naturally abundant in broodstocks of *Chrysichthys nigrodigitatus*. The New Calabar River is one of the most stressed rivers in the Niger Delta river system. This is because the river is of great economic importance to several stakeholders who use it either as receiving water for discharge of point and non-point trade wastes or as means of transportation of industrial materials. Several oil wells, flow stations, oil pipelines, oil servicing companies, food processing companies, agricultural farms, hydraulic sand mining sites, fish farms, etc are located within the catchment area of the river. Prominent users of the river water include William Brothers at Choba, Agbada oil flow station at Mbodo, African regional aquaculture Centre (ARAC) at Omuihuechi, Aluu to mention but a few. The New Calabar River is also dynamically connected to the Bonny river which is another highly stressed river in the Niger Delta river system (Dublin–Green, 1990). The work carried out by Erondu and Chindah (1991) concentrated mainly on the physico-chemical features and phytoplankton of the river. No work has been carried out on the physical characteristics of the river such as depth, cross-sectional area, flow velocity, and discharge of the river. It is believed that a proper understanding of the natural habitat of *Chrysichthys nigrodigitatus* will assist in its successful mass propagation. The importance of data on physical characteristics of the upper reach of New Calabar River at Aluu which is a natural spawning ground of *Chrysichthys nigrodigitatus* cannot, therefore, be overstressed.

The objectives of this study therefore, are to:

i. Provide baseline data on selected physical characteristics of the upper reach of New Calabar River at Aluu, and
ii. Provide updated data on selected water quality parameters of the upper reach of the river.

Materials and Methods

- **Description of the Study Area**: The New Calabar River is located on the eastern flank of the Niger Delta River System. It lies between longitudes 4°30′ and 5°00′ N and latitudes 6° 30′ and 7° 00′ E. It took its rise from Elele-Alimini where it is acidic, fresh and non-tidal (Erondu and Chindah, 1991) (Figure 1). At Aluu, it is joined by a smaller tributary river, which took its rise at Isiokpo. It is a black water type (RPI, 1985; Ubong and Gobo, 2001) and empties into some creeks and lagoon bordering the Atlantic Ocean. At Aluu, the sampling area for this study, the river is fresh and tidal, whereas at a little distance down stream (Choba and Ogbogoro) it is brackish (Figure 1). The study area is inundated by tidal waters during floodtides. The climate is tropical with dry season during November to March and rainy season during April to October. The vegetation is thick rain, swamp forest with gentle sloping topography. The tidal nature of the river is indicative of well mixed, unsteady floodtide and ebbtide flows. The New Calabar River basin experiences an annual rainfall of 254 mm (Erondu and Chindah, 1991).

Fig. 1: Map of New Calabar River showing location of Aluu as study area

- **Measurement of the physical characteristics of the river**: Selected physical characteristics of the New Calabar River at Aluu were measured at the mouth of the earth canal supplying the tidal fish farm of African Regional Aquaculture Centre, Aluu, Rivers State.

  i. **Width of river.** The width of the river measured from bank to bank at the monitoring station was measured with a tape.

  ii. **Depth of river.** The depth of the river at the monitoring station was obtained using the method of anchor sounding. First a bench mark was established straight across the river and the crests of the river were identified at both banks of the river. The width of the river (straight path) was measured with tape and divided into even numbered strips of same width. The water level at the first ordinate at both banks was noted. At each point marking the ordinate the anchor was lowered until it hits the river bed. The depth of the river at that ordinate was marked on the lowering rope with a labeled ribbon. The procedure was followed for the remaining ordinates. The water level mark on the first ordinate was checked against the initial water level. Increase in water level was added to the initial value. All data obtained were plotted graphically as shown in figure 2.

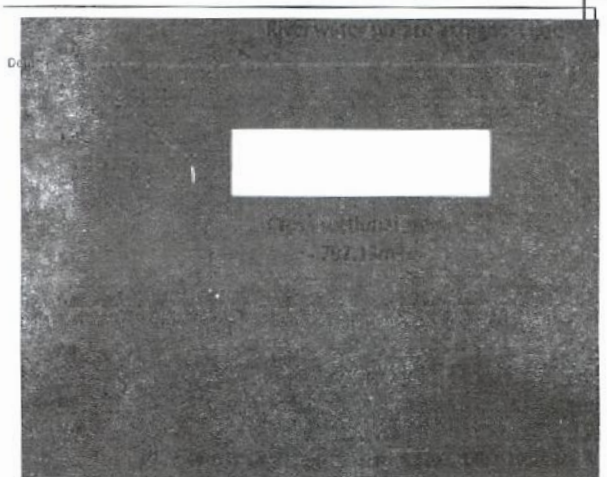

Fig. 2: Width and depth profile of new Calabar River at Aluu.

  iii. **Cross-sectional area.** The cross-sectional area of the river at the monitoring station (Figure 2) was computed using the Simpson's 1/3 formula:

$A\ (m^2) = S/3\ [(F+L) + 4E + 2R]$

Where: S = width of the strip, F = First strip, L = Last strip, E = Even-numbered strip, R = Remaining odd-numbered strip.

  iv. **The river flow velocity.** The river's ebbtide and floodtide flow velocities at the monitoring station was determined using the float method as described by dela Cruz (1983).The average flow velocity of the river was obtained by multiplying the velocity values with a factor of 0.85.

  v. **Discharge of the river.** The discharge of the river at the monitoring station was computed as the product of cross-sectional area and the average flow velocity.

- **Associated fisheries resources:** Survey of the fisheries resources of the river at Aluu was also carried out using non-return valve traps, paying visits to nearby Choba market, in addition to information gathered from personal communication with the local fishermen who dive into the river to retrieve pipe-trap set at the river bed.

- **Measurement of water quality parameters:** Selected water quality parameters of New Calabar river were also measured at the mouth of the earth canal supplying African Regional Aquaculture Centre tidal fish farm at Aluu, Rivers State for 17 months. Surface water samples were collected every two months during high tide and the samples were immediately taken to the laboratory for analysis. Surface water temperature (°C) was measured using a mercury-in-glass thermometer; transparency was measured in-situ using a weighted white Secchi disc of 12 cm diameter (Boyd and Lichtkoppler, 1979) and dissolved oxygen (DO) was measured using Winkler's method (Boyd 1979; APHA, 1995). Dissolved oxygen deficits (DOD) values were computed by subtracting the DO values from the saturated DO value at measured temperature values. The hydrogen ion concentration (pH) was determined with

a glass electrode pH meter (model 191) while total hardness was measured using EDTA titration (Boyd, 1979). Rainfall data for the period was obtained from International Institute of Tropical Agriculture (IITA), Onne, Rivers State (Figure 4).

- **Statistical Analyses:** Data generated in this study were subjected, where necessary, to descriptive statistical analyses such as range, mean, standard deviation, visual correlation.

Results

Table 1: Range and mean values of water physico-chemical parameters of New Calabar River at Aluu.

Surface water temperature	23.10 – 31.70°c (25.99 ± 1.89°c)
Secchi transparency	9.30 – 19.00cm (13.65 ± 2.73cm)
DO	5.20 – 7.70 mg/L (6.27 ± 0.61mg/L)
DOD	0.05 – 2.65mg/L (1.72 ± 0.74mg/L)
pH	5.12 – 7.43 (6.34 ± 0.48)
Total Hardness	11.80 – 51.2mg$CaCO_3$/L (19.67 ± 11.96) mg$CaCO_3$/L
Total Alkalinity	4.00 – 12.00 mg$CaCO_3$/L (8.00 ± 1.63) mg$CaCO_3$/L
Chloride	12.00 - 16.00 mg/L (11.32 ± 1.63) mg/L

Physical characteristics of the river

- **Width:** The width of the river measured during spring high tide was 174 m while the width recorded during the low tide was 110 m.
- **Depth:** The depth profile of the New Calabar River at Aluu measured at the monitoring station is presented in Figure 2. The highest value of 9.20m was recorded at the middle of the river.
- **Cross-sectional area:** The cross-sectional area of the river measured at the monitoring station was 797.13 m^2 while the average river flow velocity was 0.374 m/s.
- **Discharge:** The discharge of the river was therefore computed as 298.13m^3/s.

Associated fisheries resources

The most important and common fish species found in the river at Aluu were silver catfish, *Chrysichthys nigrodigitatus*, *Clarias gariepinus, Heterobranchus longifilis, Oreochromis niloticus, and Macrobrachium* sp, among others.

Water Quality Parameters

Results of the water phyisico-chemical parameters are presented in Table 1 and Figure 3. Values of the water quality parameters measured indicated seasonal variation (Figures 3 and 4). The mean surface water temperature for the study period varied from 23.10 and 31.70OC. The lowest value of 23.10°C was recorded in December which is usually dry season and harmattan period. Dry season temperature values ranged from 23.10 to 30.20°C with a mean of 26.10 ± 1.76°C. The records for rainy season ranged from 23.80 to 31.70°C with a mean of 25.93 ± 2.00°C. Secchi disc readings (transparency) for study period ranged from 9.30 to 19.00 cm. The mean Secchi disc readings for the period was 13.65 + 2.73 cm. Secchi disc readings for dry season ranged from 11.00 to 19.00 cm with a mean of 15.45 ± 2.65 cm while the rainy season records varied from 9.30 to 17.00 cm with a mean of 12.44 + 2.10cm. Values recorded during rainy season were generally lower compared to the dry season values. Data on dissolved oxygen for the period are presented also in Figure 3. It ranged from 5.20 to 7.70 mg/L. The mean DO value for the period was 6.27 ± 0.61 mg/L. The dry season values ranged from 5.20 to 7.69 mg/L with a mean of 6.31 ± 0.64 mg/L while that of rainy season varied from 5.30 to 7.50 mg/L with a mean of 6.24 ± 0.61mg/L. The dissolved oxygen deficit (DOD) values ranged from 0.02 to 2.95 mg/L. The mean dissolved oxygen deficit (DOD) values ranged from 1.72 ± 0.74 mg/L. The values for dry season ranged from 0.05 to 2.65 mg/L with mean of 1.64 + 0.67mg/L while that of rainy season ranged from 0.02 to 2.95 mg/L with a mean of 1.78 ± 0.79 mg/L. The lowest value of 0.02 mg/L was recorded in April. Data on hydrogen ion concentration (pH) indicated that the New Calabar River was slightly acidic throughout the study period. The pH values recorded for the study period ranged from 5.12 to 7.43 with a mean of 6.34 ± 0.48. Dry season values ranged from 6.12 to 7.43 with a mean value of 6.69 ± 0.44 while the rainy season values ranged from 5.12 to 6.88 with a mean of 6.12 ± 0.35. The values of total alkalinity ranged from 4.00 to 12.00 mg CaCO3/L, with a mean of 8.00 ± 1.63 mg CaCO3/L. The mean total hardness for the period ranged from 11.80 to 51.20 mg CaCO3/L. Values for dry season varied from 11.80 to 50.60 mg CaCO3/L, while that of rainy season ranged from 12.50 to 51.20 mg CaCO3/L. The peak values (50.60mgCaCO3/L and 51.20mgCaCO3) were recorded in March and April respectively. Chloride values ranged from 12.00 to 16.00 mg/L with a mean of 11.33 ± 1.63mg/L. Rainfall data varied between 0.82 and 42.3 cm with the lowest value

(0.82cm) recorded in February while the maximum value (42.3 cm) was recorded in October (Figure 4).

Discussion

- **Physical characteristics of New Calabar River:** The width of the New Calabar River at Aluu has been quite stable despite anthropogenic activities such hydraulic sand dredging. This is from personal observation spanning over twenty five years. This is attributed to highly cohesive soil formation along the river course whose texture ranges from clay to silt clay loam (Leton and Uzukwu, 2011), and the gradually varied nature of the ebbtide and floodtide flow velocities of the river. As a result the river banks have not been experiencing serious riparian erosion and are expected to remain so in the future. The depth of the river varied from bank to bank with the highest value (9.2 m) in the middle of the river. This is expected since the river has been under periodic hydraulic sand dredging. The depth range of the river bed where pipe traps (in which *Chrysichthys nigrodigitatus* brood stocks breed) are set is 2.5 to 3.0 m. This depth range may be physiologically important in the successful artificial propagation of the fish and also suggests that rather than diving into the river to catch the fish a safer method of trapping the fish should be designed. The value of the cross-sectional area of the river (797.13 m^2) measured at the monitoring station together with the average river flow velocity value (0.374 m/s) was important in the computation of the discharge of the river. The discharge of the river (298.13m^3/s) even with low average flow velocity (0.374 m/s^2) shows that the river is important in the Niger Delta river system, and therefore deserves all the attention it receives. These data are new and therefore invaluable in understanding the behavior of the river at the monitoring station and indeed other monitoring stations along the river course.

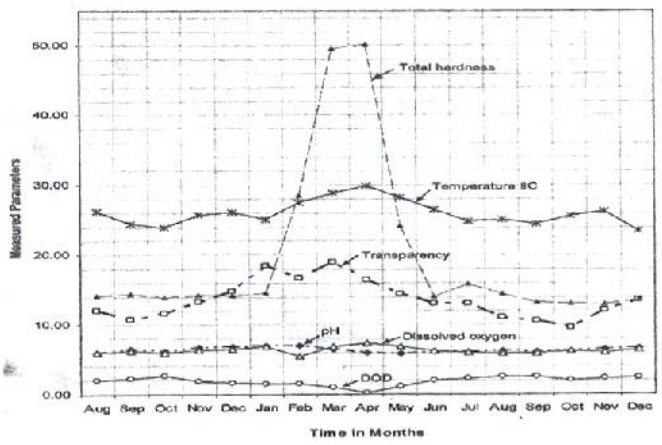

Fig. 4: Rainfall data from IITA, Onne.

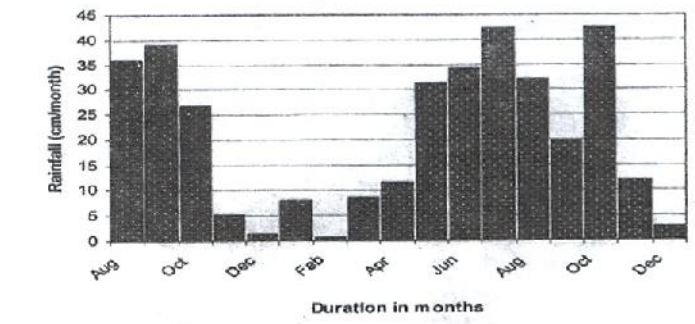

Fig. 3: Mean values of water physico-chemical parameters of New Calabar River.

- **Associated fisheries resources:** The most important and common fish species found in the river at Aluu were silver catfish, *Chrysichthys nigrodigitatus*, *Clarias gariepinus, Heterobranchus longifilis*, *Oreochromis niloticus, and Macrobrachium* sp, among others. However the target species for this study is silver catfish, *Chrysichthys nigrodigitatus,* because of the need to diversify cultivable fish species in the Nigerian aquaculture industry. This study is, therefore, to be seen as part of the larger efforts to realize the objective.
- **Water Quality Parameters:** Records of surface water temperature indicated slight seasonal variation (Figure 3). This was expected. The lowest value of 23.5°C which was obtained during December (dry season) is attributed to the cooling effect of the harmattan which is caused by the south bound cold North-East trade winds (Iloeje, 1980). Transparency varied between the seasons (figure 3). The marked low Secchi transparency values recorded during the rainy season could be attributed to increased clay and silt loading of the river due to sheet erosion of soils within the catchment area of the river by runoff. Heavy influx of silt and clay particles should be discouraged because they do smother fish eggs when settled on the substrate being used as fish spawning ground (Boyd, 1979; Boyd and Lichtkoppler, 1979). Dublin-Green (1990) reported seasonal variation of Secchi transparency readings in the upper reaches of Bonny estuary.

Dissolved oxygen values varied slightly between seasons having higher values in the dry season than rainy season. The higher values obtained during the dry season is attributed to increased photosynthetic activities of phytoplankton due to increased light penetration occasioned by decreased turbidity in dry season.

The seasonal variation in DO deficits (DOD) reflects the trend and degree of pressure exerted on DO by oxidizable contaminants (BOD, COD, and NOD) in the river arising from domestic and trade wastes routinely discharged into the river environment by local population and industries located along the riverbanks. The DOD records are important in the design of waste treatment facilities for effluent BOD discharged into the river.

According to Horsefall and spiff (2001), the pH of natural waters determines the solubility and the also forms of most chemical substances in water. The low pH values recorded in this study is typical of black waters and rivers in the Niger Delta basin (RPI, 1985; Ubong and Gobo, 2001; Erondu and Chindah, 1991; Dublin- Green, 1990). Although pH values appeared to be quite close, a seasonal pattern was however discernable. Lower value of standard deviation in dry season indicated that pH varied more in the dry season than during the rainy season. This trend contrasts the report of Dublin-Green (1990) on the lower Bonny Estuary. This may be attributed to the fact the upper reach of New Calabar river is not as estuarine as the lower Bonny Estuary.

Total hardness showed significant seasonal variations. High values were recorded in peak dry season (March and April), while lower values were recorded in the peak rainy season (October). The decrease in total hardness value in the rainy season is attributable to the dilution effect of rain. The low total hardness values recorded in the New Calabar river system indicate that the river is soft while the mean low pH value (<6.5) and alkalinity value (< 10 mg CaCO3/L) indicate that the river is black water. The observed pattern of rainfall variation is typical of the Niger Delta region of Nigeria (Figure 4), with March being the peak dry season and April being the transition between rainy and dry seasons. Results of the fisheries resources survey indicate that the river is rich in finfish and shell fish resources such as Chrysichthys nigrodigitatus, Macrobrachium sp. These results are invaluable in the development of broodstocks and mass propagation programs of Fisheries Research Institutes and Universities in the Niger Delta Region of Nigeria.

Conclusion

Reliable data on physical characteristics of the upper reach of the New Calabar River at Aluu have been documented. The results of the water physico-chemical features obtained in this study exhibit a seasonal trend and when compared to previous findings indicate that the river has not changed significantly as black water. This is indicative of high buffering capacity of the river which receives substantial runoffs from fertilized agricultural lands in the watershed. These results are invaluable to several stakeholders who use the river for diverse purposes.

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