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Salinity, Dissolved Oxygen, pH and Surface Water Temperature Conditions in Nkoro River, Niger Delta, Nigeria

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Abstract: Salinity, dissolved oxygen, pH and surface water temperature conditions in Nkoro River, in the Niger Delta area of Nigeria was studied for a period of one year (January – December 2008). The response of estuarine fishes to changes in salinity, dissolved oxygen, pH and surface water temperature conditions does not only enhance our biological understanding of estuarine fish, but contributes to the understanding of the potential effects of anthropogenic impacts on estuarine fish species. Dissolved oxygen meter of the model: OxyGuard Handy MK II was used in measuring dissolved oxygen and temperature. pH was measured using pH meter (model: Hanna Instrument model No. H1 8915 ATC) while salinity was measured using salinometer, model: New S-100.for each of the parameters. The probe end of the meter was dipped into the river while the value at the pointer of the scale was read off and recorded. The measurements were taken while inside the canoe along Nkontoru – Job Ama, which is part of the Nkoro river system. Dissolved oxygen (DO) was measured in milligrams per litre (mg/I); temperature in ºC (degrees centigrade); and salinity was in parts per thousand (ppt or $\%_o$). Salinity values ranged from 5‰ (September) to 17‰ (February and March). Dissolved Oxygen values ranged from 6mg/l(January, April, July and October) to 10mg/l (September). PH values ranged from 6.1(August) to 8.5(November) and Temperature values ranged from 24 0 ºC (July) to 32 0 ºC (March). Salinity values ranged from 12.8±0.30(‰) (station 4) to 13.3±0.10(‰) (station 3). Dissolved Oxygen values ranged from 3.2±0.1 (mg/l)(station 3) to 7.3±0.16 mg/l(station 1). pH values ranged from 7.3±0.17 (station 1) to7.7±0.14(station 3) and Temperature values ranged from27.3±0.24(station 1) to33.7±0.21(station 3). There was no significant difference in salinity and pH between stations, but dissolved oxygen, and temperature showed significant differences between stations ($P \le 0.05$). The results of the correlation matrix analysis showed significant correlation between the variables at different stations. The association between the environmental variables in the Nkoro river was generally similar because the water at the stations was seemingly from the same source, Atlantic Ocean through Bonny River. Positive association was observed indicating functional similarity. The varying magnitude of the relationship between the water variables in lower Bonny River of Niger Delta was attributed to micro habit differences.

Key words: Dissolved oxygen, Nigeria, Niger Delta, Nkoro River, pH, salinity and temperature

INTRODUCTION

The conservation of biodiversity and management of aquatic environments in particular has become a major concern in recent years. The linear nature of most estuaries, and their high degree of linkage with freshwater and marine ecosystems, makes estuarine habitats highly vulnerable to external perturbations . It was noted more than a decade ago that anthropogenic activities could lead to the periodic or permanent elimination of estuarine-dependent fish species from individual estuarine systems (Cyrus, 1991; Kennish, 2002).

Such activities include practices that result in siltation (extremely high turbidity levels) and construction of impoundments in the catchments, which result in freshwater abstraction (salinity extremes and hyper saline conditions). Since the adults of many estuarine-dependent species are exploited commercially, the preservation of estuarine habitats is critical for the maintenance of many marine fisheries. Therefore, knowledge of the response of estuarine fishes to changes in environmental conditions will not only enhance our biological understanding of estuarine fish, but will contribute to our understanding of the potential effects of anthropogenic impacts on estuarine fish species.

Salinity has been viewed as one of the most important variables influencing the utilization of organisms in estuaries (Marshall and Elliot, 1998). Spotted grunters are euryhaline and have been found to tolerate salinities from 0 to 90 (Whitfield *et al.*, 1981). In this study, spotted grunters were located in a wide range of salinities (ranging from 0 to 36). The variation in the mean salinity between the first and second periods can be ascribed to the large proportion of fish located in the freshwater upper reaches of the estuary during the initial stages of the second period.

Temperature has been identified as the primary abiotic factor controlling key physiological, biochemical and life history processes of fish (Beitinger and Fitzpatrick, 1979), and has been found to influence the utilization of estuaries by fishes worldwide (Morin *et al*., 1992; Thiel *et al*., 1995). Generally, fish have a thermal preference that optimizes physiological processes. Spotted grunter were however located in a wide range of temperatures during both periods. The large variation in water temperature, between and within both periods, was due to the large tidal fluctuation in the estuary, with cold incoming seawater and warm outgoing freshwater.

Although the mean water temperature at which spotted grunter were located was 23 ºC in the first and 20 ºC in the second period, the thermal preference of 0+ juveniles under culture conditions was found to be between 24 and 25 ºC (Deacon and Hecht, 1995). Lower temperatures are likely to reduce metabolism and growth. The very low sea temperatures may account for the noticeable peak position observed certain estuary during this period. The upper reaches may have provided a thermal refuge and caused the fish to move to this region where they maintained position for an extended period. This suggests that fishes may use movement in response to temperature variations within the estuary environment (Clark, 1996).

Dissolved oxygen is vital to aquatic life, as it is needed to keep organisms alive. Coastal waters typically require a minimum of 4.0 mg/l and also do better with 5.0 mg/l of oxygen to provide for optimum ecosystem function and highest carrying capacity (UNESCO/WHO, 1978). Main source of oxygen is aquatic plants also provide atmosphere, but much during photosynthesis, oxygen may fall to unhealthy levels if water is polluted. Example if sewage and other wastes (e.g. from food processing) with high Biological Oxygen Demand (BOD) are discharged into the sea (Clark, 1996).

Dissolved oxygen depletion could suppress respiration, cause death of fish, depress feeding or affect embryonic development and hatching success due to oxygen starvation (Clark, 1996). This could lead to reproductive failure, stock-recruitment failure at the population level or changes in the composition, abundance and diversity of species at the community level. Index of water pollution is the decrease of oxygen level measured by Dissolved Oxygen (DO) levels. Oxygen is removed from the water as organic matter decays.

The degree of pollution depends on the material, the physical nature, chemical nature of the material discharged, water depth and hydrographic conditions (Cairns, 1992). Polluted water can reduce productivity and biodiversity and could contribute to stock decline or lack of fish in some areas (Clark, 1996). Pollution has negative impact on the quality of fish that reaches the consumer. Water pollution brings external cost to society in general (Burrows, 1979).

The livable pH range is from 5.5 to 10 (Moyle, 1993). A low pH can result in death as well as a variety of more subtle effects. Values less than 6 can result in a marked decrease in some fish oogenesis, egg fertility or growth of fry, or egg hatchability and growth (Matthews, 1998). Matthews (1998) also discovered that in spite of the possible stress of water with a low pH, most fish failed to discriminate between the ranges of 5.5 to 10. The most productive waters, however, are those that are slightly alkaline (pH 8) (Moyle, 1993).

The Nkoro River is one of the economically important and rich in biodiversity rivers in the Niger Delta region of Nigeria providing breeding ground for a variety of fish species. Numerous activities such as oil exploration and production and agricultural activities takes place in the river. A study of some key physical and chemical characteristics from the river is essential for the effective management of Nkoro River fishery and other similar water bodies.

MATERIALS AND METHODS

Study Area: The Nkoro River is a distributory of the Andoni River in the Niger Delta area of Nigeria. The Nkoro River lies between latitudes 4º 28′ to 4º 45′ N and longitudes 7º 45′E. The Niger Delta is one of the world largest wetlands covering an area of approximately 70,000 km^2. The area is economicaly important and rich in biodiversity. Numerous activities such as oil exploration and production and agricultural activities go on in the region. Most of Nigeria's oil and gas reserves and production, which account for over 80% federal government's revenue, is located within the Niger Delta region.

The Red and white mangroves (*Rhizonhora* and *Avicenia* spp) mangrove swamps and flood plains border the river and its numerous creeks; and these are well exposed at low tides.

The physical and chemical characteristics monitored included temperature, pH, dissolved Oxygen and salinity. Dissolved oxygen meter of the model: OxyGuard Handy MK II was used in measuring dissolved oxygen and temperature. pH was measured using pH meter (model: Hanna Instrument model No. H1 8915 ATC) while salinity was measured using salinometer, model: New S-100. for each of the parameters. The probe end of the meter was dipped into the river while the value at the pointer of the scale was read off and recorded. The measurements were taken while inside the canoe along Nkontoru – Job Ama. Which is part of the Nkoro river system. Dissolved Oxygen (DO) was measured in milligrams per litre (mg/I); temperature in ºC (degrees centigrade); and salinity was in parts per thousand (ppt or $\%_o$).

RESULTS

The results for the monthly physical and chemical characteristics in Nkoro River are shown in Table 1. Salinity values ranged from 5‰ (September) to 17‰ (February and March). Dissolved Oxygen values ranged

Table1: Monthly mean physical and chemical characteristics in Nkoro River

Month	Salinity (‰)	DO (mg/l)	pH	Temp (oºC)
Jan	15	6	7.5	28
Feb	17	7	7.2	27
Mar	17	8	7.0	32
April	15	6	6.8	27
May	15	9	8.0	25
June	14	8	7.6	25
July	13	6	7.1	24
Aug	16	7	6.1	27
Sep	5	10	7.5	26
Oct	10	6	7.2	28
Nov	9	8	8.5	29
Dec	12	7	7.0	30

Table 2: Physical and chemical parameters for various stations

Stations	1	2	3	4
Salinity(‰)	$13.2\pm0.^{12a}$	13.2 ± 0.11^{a}13.	3 ± 0.10^{a}	12.8 ± 0.30^{a}
D O (mg/l)	7.3 ± 0.16^{a}	6.7 ± 0.13^{a}	3.2 ± 0.1	$4.5.3\pm0.11^{ab}$
pH	7.3 ± 0.17^{a}	7.6 ± 0.21^{a}	7.7 ± 0.14^{a}	7.4 ± 0.23^{a}
Temp(oºC)	27.3±0.24a	27.5 ± 0.31^{a}	33.7 ± 0.21^{b}	27.4 ± 0.33^{a}

Means with different superscripts are significantly different.

from 6mg/l(January, April, July and October) to 10mg/l (September). PH values ranged from 6.1(August) to 8.5 (November) and Temperature values ranged from 24 0ºC (July) to 32 0ºC (March).

Table 2 shows the physical and chemical characteristics for various stations. Salinity values ranged from 12.8±0.30(‰) (station 4) to 13.3±0.10(‰) (station 3). Dissolved Oxygen values ranged from 3.2±0.1 (mg/l)(station 3) to 7.3±0.16 mg/l(station 1). pH values ranged from 7.3±0.17 (station 1) to7.7±0.14(station 3) and Temperature values ranged from27.3±0.24(station 1) to33.7±0.21(station 3). There was no significant difference in salinity and pH between stations, but dissolved oxygen, and temperature showed significant differences between stations ($P \le 0.05$).

DISCUSSION

The salinity values ranging from 12.8±0.30(station 4) to 13.30±0.10‰ (station 3), showed gradual increase of salinity values from the upstream stations to downstream stations along the creek. This trend could be attributed to effluent water discharges from several industrial establishments, slaughterhouse operations and domestic activities that are prevalent along the upstream area of the creek. Higher salinity value (11.67±0.517‰) recorded during the dry season (November to March) than the wet season (6.98±0.701‰) April to October also compared favorably the report by Payne (1976).

The months of April to October in West Africa usually coincide with the rainy season when high volumes of freshwater are discharged into coastal or estuarine waters that lower or dilute the water. Similarly, McLusky (1989) reported that rainfall could cause dilution of estuaries and hence cause reduction in salinity, while heat generated by sunlight in dry season months would cause evaporation of the surface water making it saltier and hence more saline.

From the rainfall data available the month of April and June were rainy months therefore the high salinity values recorded in them may be attributed to factors such as days of sampling, time of sampling and nature of effluents discharged to the sampling stations before or during the sampling. The results of the study showed that salinity of the study area generally alternated between Oligohaline (0-5‰) and mesohaline (5-18‰).

The dissolved oxygen values were higher at the upstream sampling stations than the downstream stations with the highest of 9.6mg/l observed in station 3 and the lowest 0.4mg/l in station 6. Similar trend was also reported by Hart and Zabbey (2005) for Woji Creek. Davies *et al.* (2008) also made similar report for the Trans-Amadi (Woji) creek, Port Harcourt. They attributed it to the effects of higher temperature and abattoir wastes. There was no significant ($P<0.05$) difference in the variation between the dry and wet seasons in the area. This is contrary to results of (Plimmer, 1978; McNeely *et al.*, 1979) who reported that at high temperature, which is usually observed in dry season, the solubility of oxygen decreases while at lower temperature (wet season) it increases. Davies *et al.* (2008) also reported lowered dissolved oxygen (4.48mg/l) in wet season than dry season (5.14mg/l) and attributed it to be due to reduced photoperiod and photosynthetic activities of aquatic plants.

The higher mean dissolved oxygen value recorded in the dry season, did not agree with the findings of Egborge (1971), who reported that dissolved oxygen is generally higher in the wet season in the tropics. A possible explanation for the lower mean dissolved oxygen values in the wet season could be the turbidity nature of the water at this period due to inflows from run-offs and decomposition of organic matter in the water. In fact, Braide *et al.* (2004) also had similar results in their study of water quality of Miniweja stream in Eastern Niger Delta, Nigeria.

The spatial distribution of pH ranging from 6.68±0.07 to 7.03±0.05, is characteristics of a tidal brackish water environment as noted by the International Joint Commission (1977) and Ajao and Fagade (2002). The generally lower pH values at the upstream (1 to 3) stations (6.68±0.07 – 6.81±0.05) than at the downstream (4 to 7) stations (6.97±0.07 - 7.03±0.05), may have resulted from decaying of the domestic and industrial waste litter in the upstream area contributing to the acidic nature of the water. However, pH values recorded in this study were well within the preferred pH of 6.5 to 9.0 recommended for optimal fish production (Boyd and Lichktopller, 1979).

The seasonal variation of pH values observed in this study is in agreement with results of previous studies conducted by Dublin-Green (1990) in Bonny River, where the highest pH values were recorded in the dry season and lower values of pH in the late rainy season. Similar trend was reported by Ekeh and Sikoki (2003) in the New

Calabar River and also by Ansa (2005) in Andoni flats of the Niger Delta area. The seasonality in the pH of Okpoka creek water may be due to the influx and decay of debris in the area as well as imbalance level of H^+ ions input from surface run-offs during the rains. This assertion is based on the result of the correlation analyses between pH and other parameters.

In considering the temperature profile of the Okpoka Creek, it is clear that the dissolved oxygen values recorded in this study are lower than the standard values (8.38mg/l and 7.64mg/l) quoted by Boyd and Lichktoppler (1979) at equivalent temperature range of 23ºC to 29ºC. However, since dissolved oxygen concentration are usually low in the morning and rises to a maximum in the afternoon, the concentrations reported in this study show that the creek contains high concentration of dissolved oxygen as the readings were taken in the morning. The range of dissolved oxygen was still within the acceptable limit of aquatic life (McNeely *et al.*, 1979).

The sub-surface water temperature ranges from 27°C to 31°C and the mean values ranged from 28.98±0.23°C to 29.77±0.15°C across the stations observed are considered normal with reference to the location in the Niger Delta, which is described as humid/semi hot equatorial climate (NEDECO, 1961). Alabaster and Lloyd (1980) reported that temperature of natural inland waters in the tropics generally varies between 25°C and 35°C.

This findings agree with earlier reported works in the Niger Delta waters by Chindah *et al*. (1998) who reported temperature ranges of between 26°C and 30.5°C, Zabbey (2002) between 26.3°C and 30.4°C, Braide *et al*. (2004) (26.64 ± 1.18°C and 30.83 ± 1.47°C), Ansa (2005) (25.9°C and 32.4°C); Hart and Zabbey (2005) (25.8°C and 30.4°C), Sikoki and Zabbey (2006) (26°C and 27.8°C), Dibia (2006) (25°C to 27°C) and Jamabo (2008) reported a temperature range between 27°C and 30°C in the Upper Bonny River of Niger Delta . Spatial differences in temperature were statistically significant (P£0.05). The highest mean temperature value of 29.77±0.15°C was recorded in station 5 (Ojimba/Abuloma); indicating that this station heats up faster than the other five stations due to the shallow nature of the depth.

The shallow nature of the area and the absence of any stratification ensure adequate mixing and circulation of surface and bottom waters. Temperature showed significant seasonal variation (P£0.05) as shown. The temperature values are significantly higher in the dry season. A similar trend was reported in the main Bonny River by Dublin-Green (1990) (31.2°C dry season and 27.5°C wet season); Amakiri (2006), (27.6°C wet season; 31.6°C dry season) whereas in the New Calabar, Ekeh and Sikoki, (2003) reported lowest temperature of 25°C in the wet season and 30°C in the dry season, and in Andoni River, Ansa (2005) reported 25.9°C wet season and 32.4°C dry season. Higher temperature values recorded in the dry months are expected since heat from sunlight increases temperature of surface water. Similarly the drop in water temperature in the wet season months is attributable to heavy rainfall experienced during the period.

The water temperature correlated significantly (P<0.001) with the pH and salinity and but has no significant correlation with Dissolved Oxygen. The latter may be due to the increased photosynthetic process during the sampling period in the area as it was daylight. A possible explanation for this trend may be due to the influx allocutions organic and inorganic materials from the surrounding catchments area during the rains. The results also showed that Dissolved oxygen increases as one moves downstream. The dissolved oxygen values observed were significantly different (P<0.05) between stations. This could be attributed to nutrient regeneration from bottom sediments, decomposition and mineralization of microbes downstream as noted by Dibia (2006). He observed that conductivity significantly correlated with temperature, pH and salinity, which agreed with Boyd and Lichktoppler (1979).

The results of the correlation matrix analysis showed significant correlation between the variables at different stations. It is also important to note that the association between the environmental variables in the Nkoro river was generally similar. This is expected as the water at the stations is seemingly from the same source, Atlantic Ocean through Bonny River. The positive association observed also suggests functional similarity. Also, Chindah and Nduaguibe (2003) attributed the varying magnitude of the relationship between the water variables in lower Bonny River of Niger Delta to micro habit differences.

REFERENCES

Ajao, E.A. and S.O. Fagade, 2002. The ecology of *Neritina_glabrata* in Lagos Lagoon, Nigeria. Arch. Hydrobiol., 119(3): 339-350.

Alabaster, J.S. and R. Lloyd, 1980. Water quality criteria for freshwater fish. Butter worth's, London, U.K. pp: 297.

Amakiri, N.E., 2006. Aspects of the biology of *Pseudotolithus elongatus* (Bowdich, 1825) of bonny estuary, Niger Delta, Nigeria, M.Sc. Thesis, Rivers State University of Science and Technology, Nkpolu-Oroworukwo, Port Harcourt, pp: 99.

Ansa, E.J., 2005. Studies of the benthic macrofauna of the Andoni flats in the Niger Delta Area of Nigeria. Ph.D Thesis University of Port Harcourt, Port Harcourt, Nigeria, pp: 242.

Beitinger, T.L. and L.C. Fitzpatrick, 1979. Physiological and ecological correlates of preferred temperature in fish. Am. Zool., 19(1): 319-329.

Boyd, C.E. and F. Lichtkoppler, 1979. Water quality management in fishpond, Research and Dev. Series No.22. International centre for Aquaculture and Agriculture (I.C.A.A.), Experimental station Auburn University, Alabama, pp: 45-47.

Braide, S.A., W.A.L. Izonfuo., P.U. Adiukwu., A.C. Chindah and C.C. Obunwo, 2004. Water Quality of Miniweja stream, A Swamp forest stream receiving non-point source waste discharges in Eastern Niger Delta, Nigeria. Scientia Afr., 3(1): 1-8.

Burrows, P., 1979. The economic theory of pollution control. Oxford: Martin Robertson

Cairns, W.J., 1992. North Sea oil and the environment: Developing oil and gas resources, environmental impacts and responses. (Edited). London: Elsevier Applied Science.

Chindah, A.C., S.A. Braide and C. Obunwo, 1998. The effect of municipal waste discharge on the physico-chemical and phytoplankton in a brackish wetland in Bonny Estuary. Acta Hydrobiol., 40: 9-15.

Chindah, A.C. and U. Nduaguibe, 2003. Effect of tank farm waste water on water quality and periphyton of lower Bonny river, Niger Delta, Nigeria. J. Nigerian Environ. Soc., 1(2): 206-222.

Clark, J.R., 1996. Coastal zone management handbook. London: Lewis Publishers.

Cyrus, D.P., 1991. Fish conservation in South African estuaries: pressures, problems and prospects. South Afr. J. Aqua. Sci., 17: 19-27.

Davies,O. A., A.A.A. Ugwumba and D.S. Abolude, 2008. Physico- chemistry quality of Trans- Amadi (Woji) creek, Port Harcourt, Niger Delta, Nigeria. J. Fish. Int., 3(3): 91- 97.

Deacon, N and T. Hecht., 1995. Observations on the thermoregulatory behavior of juvenile spotted grunter, Pomadasys commersonnii (Haemulidae: Pisces). J. Appl. Ichthyol., 11(1-2): 100-110.

Dibia, A.E.N., 2006. Effect of biotope difference on aquatic Macrophytes along Mini-Chindah Stream in Port Harcourt, Rivers State M.Sc. Thesis, Rivers State University of Science and Technology, Port Harcourt, Nigeria, pp: 120.

Dublin-Green, C.O., 1990. Seasonal variations in some physico-chemical parameters of the Bonny Estuary, Niger Delta. NIOMR Technical Paper, 59: 21-25.

Egborge, A.B.M., 1971. The chemical hydrology of River Oshun, Western State, Nigeria. Freshwater Biol., 1: 257-271.

Ekeh, I.B. and F.D. Sikoki., 2003. The state and seasonal variability of some physico-chemical parameters in the New Calabar River, Nigeria. Supp ad Acta Hydrobiol., 5: 45-60.

Hart, A.I. and N. Zabbey, 2005. Physico-chemical and benthic fauna of Woji Creek in the Lower Niger Delta, Nigeria Environ. Ecol., 23(2): 361-368.

International Joint Commission, 1977. New and revised specific water quality objectives. Great Lakes Water Quality Board Report, 11:42-59.

Jamabo, N.A., 2008. Ecology of *Tympanotonus fuscatus* (Linnaeus, 1758) in the mangrove swamps of the Upper Bonny River, Niger Delta, Nigeria. PhD. Thesis, Rivers State University. pp: 340.

Kennish, M.J., 2002. Environmental threats and environmental future of estuaries. Environ. Conserv., 29(1): 78-107.

Marshall, S. and M. Elliot, 1998. Environmental influences on the fish assemblage of the Humber estuary, U.K. Estuarine, Coastal Shelf Sci., 46(2): 175-184.

Morin, B., C. Hudon, F.G. Whoriskey, 1992. Environmental influences on seasonal distribution of coastal and estuarine fish assemblages at Wemindji, eastern James Bay. Environ. Biol. Fish., 35(3): 219-229.

Matthews, W., 1998. Patterns in Freshwater Fish Ecology. New York; Kluwer Academic Publishers, pp: 365.

Moyle, P., 1993. Fish; An Enthusiast's Guide. Berkley. University of California Press.

NCM, 2003. Integrating fisheries and environment policies; the Nordic experiences and the CFP. Report prepared for The Nordic Council of Ministers The Fisheries–Environment strategy programme. pp: 196.

Mclusky, D.S., 1989. The Estuarine Ecosystem. 2nd Edn. Chapman and Hall, New York pp: 214.

McNeely, R.N., V.P. Neimanis and L. Dwyer, 1979. Water quality sourcesbook – A guide to water quality parameters. pp: 112 .

NEDECO, 1961. The waters of the Niger Delta. Report of an investigation by NEDECO (Netherlands Engineering consultants). The Hague, pp: 210-228.

Payne, A.I., 1976, The relative abundance and feeding habits of the grey mullet species occurring in an estuary in Sierra Leone, West Africa. Marine Biol., 35: 275-286.

Plimmer, R.J., 1978. Degradation methodology-chemical and physical effects. Procedure of the workshop on microbial degradation, Pensacola Beach Florida, pp: 423-431.

Sikoki, F.D. and N. Zabbey, 2006. Environmental gradients and Benthic community of the middle reaches of Imo River, South-Eastern Nigeria. Environ. Ecol., 24(1): 32-36.

Thiel, R., A. Sepulveda., R. Kafemann and W. Nellen., 1995: Environmental factors as forces structuring the fish community of the Elbe Estuary. J. Fish Biol., 46(1): 47-69.

UNESCO/WHO, 1978. Water quality survey. Studies and reports in hydrology, No. 23. Paris: United Nation Educational Scientific and Cultural Organization and World Health Organization.

Whitfield, A.K., S.J.M. Blaber and D.P. Cyrus, 1981. Salinity ranges of some southern African fish species occurring in estuaries. South Afr. J. Zool., 16: 151-155.

Zabbey, N., 2002. An ecological survey of benthic macroinvertebrates of Woji Creek, off the Bonny River System Rivers State. M.Sc. Thesis, University of Port Harcourt, pp: 102.