PLANKTON ECOLOGICAL AMPLITUDE: A USEFUL TOOL IN OIL SPILL MONITORING IN A BRACKISH MANGROVE ECOSYSTEM

ISSN: 2141 – 3290

ESSIEN[1], J. P., IKPE[1], D.I, UDOINYANG[2], E. P. AND UBOM[3], R. M.

[1]*Department of Microbiology, University of Uyo*

[2]*Department of Zoology, University of Uyo*

[3]*Department of Botany and Ecological Studies, University of Uyo*

ABSTRACT: Based on spatial variation in tidal mud salinity, the direct gradient analysis procedures were adopted to establish plankton ecological amplitude of epipellic microalgae along salinity gradients in Qua Iboe Estuary mangrove swamp. Variations in mud salinities were established and this affected the incidence and productivity of the microalgae. In the dry season, all the microalgae species but *Closterium* (a Centric diatom) and *Oscillatoria* (a cyanobacterium) species encountered in the tidal mud flats showed statistically significant negative correlations with salinity, while most microalgal species excluding *Oscillatoria* and *Closterium* species were positively correlated with the same factor during the wet season. Four Ecological Groups of micro-algae were established in the dry season month of December as against two Ecological Groups in the wet season month of July. However no microalgae species was found to occur on the highest values of mud salinity and there were overlapping range of occurrences and ecological optima for most species along the gradients. This research has shown that rather than embark on broad biomass stock analysis during oil spills, emphasize should be directed on microalgae ecological optima to ascertain the abundance and productivity of specific planktons and their response to spillage at a period.

INTRODUCTION

Tidal mud flats with high salt content are found in the mouth of estuaries inundated by tropical tide water (Ukpong, 1991 and 1995, Essien and Ubom, 2003). Several studies have therefore attempted to correlate salinity to the productivity of mangrove ecosystem (Good, 1972, Davies, 1772 & 1995, Lugo and Snedaker 1974 and Ukpong 1991). Walsh (1974) however reported that such correlations often fail to identify directly the differences in primary production of macrophytes due to overlapping responses of species to salinity, more so as mangrove swamps vary in terms of tidal and freshwater imports, duration of dry spells and concentration of soluble salts in the water and soil (Citron *et al*., 1978 and Chapman, 1997). Similar observations have been reported by Ubom and Essien (2003) on the epipsammic microalgae and, Essien and Ubom (2003) on the epipellic microalgae communities of the Qua Iboe Estuary. In both studies the predominance of *Actinoptychus undulatus,* a fresh water Centric diatom in a brackish sandy beach and mixohaline tidal mud flats of the estuary was revealed.

In this study, the pattern of microalgae species productivity and distribution of microalgae along salinity gradients of the tidal mud flats found in the mangrove swamps of the ever wet estuarine environment were investigated. Direct gradient analysis using the factor gradient approaches of Whittaker (1978) in which species are assigned to ecological groups according to their modalities on a factor gradient was adopted. Waring and Major (1964) and Ubom (1998) stated that ecological optimum is the point at which maximum population density of a species occur along a selected gradient. The distribution of the species was based on relative dominance (relative density) because it represents an important measure of species performance or productivity.

METHODOLOGY

Study Area

Figure 1 shows the mangrove swamp of the Qua Iboe Estuary. Although the swamp experience regular tidal inundations, there are fluctuations in salinity between the rainy and relatively drier months. Tidal amplitude is low, the mean being 2.01m at spring tides and 1.07m at neap tides (Ukpong, 1991). Microalgae species represented in the tidal mud flat (epipelic habitat) of the mangrove swamp include *Amphora ovalis, Campylodis cibrosus, Cymbella lanceolata, Navicula radiosa, N. rhynocephala, Pleurosigma* sp*, Stephandiscus* sp*, Pinnularia viridis, Tabellaria* sp*, Actinoptychus undulatus, Closterium* sp*, Oscillatoria nigroviridis,* and *Nodularia spumigena,* (Essien and Ubom, 2003).

Sampling Procedure

Sampling was carried out in 20 locations along the coastal tidal mud flats during the dry season month of December and wet season month of July in the year 2002. Sediments were taken through short suction cores from the upper 5cm of the intertidal mud flats of the Estuary. The sediment core were homogenized and dispensed into clean 500ml capacity beakers containing 50ml of physiological saline to avoid desiccation. Samples meant for analysis of salinity were not treated with physiological saline.

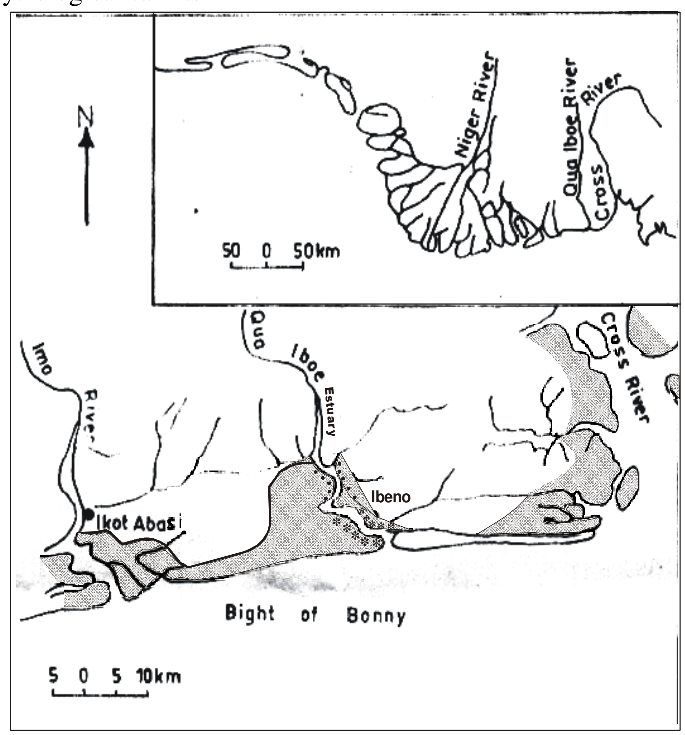

Fig. 1 Mangrove swamps of the coastal region of Southeastern Nigeria showing the sampling locations at the upper (▪) and lower (*) reaches of Qua Iboe Estuary

Determination of Salinity of Mudflat

Percentage salinity for each samples was determined from silver thiourea (AgTU) extracts and $AgNO_3$ (0.1M) titration (Essien *et al.*, 2005 & 2006) using potassium chromate as indicator and calculated as total water soluble salts (chlorides + sulphates)

Estimation of Microalgae Biomass and Ecological Optima

The density of microalgae was determined in preserved tidal mud samples. To preserve the mud samples, 2.0ml o 3.7% fomaldehyde was added, followed by the addition of three drops of

Lugols solution and left to stand for 30 minutes, which allowed the plankter to settle. The concentrated phytoplanktonic samples were examined under a compound microscope. The procedure have been previously used by Opute (1990 and 1991), Yakubu *et al*., (1998), Ubom and Essein (2003), Essien and Ubom (2003) and Essien and Antai (2004).

The microalgae observed were identified using the illustrations of freshwater (Han, 1978, Woodhead and Tweed, 1960, Carmichael, 1981) and marine water (Cassie, 1961; Moore, 1981a and 1981b) phytoplankta. The number of the phytoplankta per location was estimated using a 1.0ml counting chamber filled with the concentrated phytoplanktonic sample and examined under a compound microscope equipped with a haemocytometer. The densities of the microalgae were calculated using the formula:

$D = m/a$ x 1000 (Cochran, 1963; Essien and Ubom 2003)

where; D = density of each species per hectare, a = areas of mud sampled (5 cm x 5 cm), m = number of individual species under the microscope

Based on the distribution potentials of the species, their ecological status was elucidated following the environmental gradients of salinity. The species variables were converted to a range of 0 – 100 and subjectively grouped into gradient classes (Wikum and Wali, 1974). Using relative dominance values ecological modalities of the species were established along appropriate gradient.

RESULTS AND DISCUSSION

A summary of the results of salinity analysis of the tidal mud samples is presented in Table 1. The observed variations in the mud salinity may be attributed to distance from coast and tidal influence and freshwater inputs. The epipellic tidal mud flats of Qua Iboe Estuary habour diverse species of microalgae. Majority of the isolates encountered were Pinnate diatom including *Amphora ovalis*, *Campylodis cibrosus Cymbella lanceolata, Pleurosigma* sp*, Stephandiscus* sp*, Navicula radiosa, N. rhynocephala, Pinnularia viridis and Tabellaria* sp. Only two Centric diatoms, namely *Actinoptychus undulatus* and *Closterium* species; and two Cyanobacteria species namely *Oscillatoria* sp and *Nodularia spumigena* were isolated from the estuary. However *Nodularia spumigena* was not selected for the salinity gradient study because it occurred in less than 4% of the mud samples analysed, in both the dry (Table 2) and wet season samples (Table 3) Similarly *Amphora ovalis* and *Campylodis cibrosus*, were not selected because they occurred in only one sample (less than 4%) out of the 20 mud samples analyzed during the wet season. The occurrence of all the isolates but *Closterium* sp listed above, in the epipellic habitats have previously been reported by Essien and Ubom (2003)

Correlation between microalgae species and mud salinity for the dry and wet seasons are shown in Table 2 and 3 respectively. Only species and with frequency occurrence of 4% and above in the samples are included. All the microalgae species except *Closterium* and *Oscillatoria* species are negatively correlated with mud salinity at statistically significant levels (P = 0.01), during the dry season.

The research findings indicate that epipellic microalge species are facultative or salt tolerant on the basis of morphological and physiological adaptations. The level of adaptation varies between genera and even between species of the same genus. Species which are highly correlated with salinity e.g *Navicula radiosa* (r = -0.68), *Amphora ovalis* (r = -0.60) *Pinnularia viridis* (r= -0.58) and *Navicula rhynocephala* (r = -0.57) are the most tolerant and frequently found microalgae in the epipellic habitat, while species with lower levels of correlation e.g *Actinoptychus undulatus* (r = -0.04), *Cymbella lanceolata* (r = -0.43) *Pleurosigma* sp. (r = -0.44) and *Tabellaria* sp. (r = -044) occur most frequently in the epipellic habitat but in somewhat less saline niches. The most restricted microalgae in the saline mud habitat during the dry season were *Closterium* (r = 0.30) and *Oscillatoria* (r = 0.84) species.

Table 1: Ranges, mean and SD for percentage salinity in tidal mud flats during the dry (December 2002) and wet (July, 2002) seasons.

Sample Location	December (Dry Season) Range	Mean	±SD	July (Wet Season) Range	Mean	±SD
Lower ranches						
1	4.5 – 6.2	5.33	0.85	2.8 – 3.2	2.96	0.20
2	5.0 – 6.1	5.53	0.55	2.9 – 3.4	3.10	0.26
3	4.3 – 6.9	5.23	1.44	2.6 – 3.3	3.02	0.29
4	3.8 – 6.2	4.83	1.23	2.7 – 3.1	2.86	0.20
5	4.6 – 6.9	5.93	1.19	2.7 – 4.1	3.53	0.74
6	3.8 – 5.8	4.60	1.05	2.5 – 3.1	2.83	0.30
7	3.6 – 5.8	4.36	1.24	2.7 – 3.0	2.86	0.15
8	3.4 – 4.6	3.93	0.61	2.9 – 3.8	3.16	0.55
9	3.7 – 6.3	4.70	1.40	2.8 – 4.5	3.60	0.85
10	5.4 – 6.8	5.90	0.78	2.5 – 2.7	2.60	0.10
Upper reaches						
11	4.7 – 6.8	5.60	1.08	1.8 – 3.2	2.70	0.78
12	3.8 – 6.3	4.70	1.38	2.2 – 3.1	2.66	0.45
13	4.8 – 6.2	5.56	0.70	1.8 – 2.1	1.96	0.15
14	3.6 – 4.5	3.96	0.47	2.2 – 3.6	2.73	0.76
15	3.6 – 3.9	3.76	0.15	2.7 – 3.2	2.90	0.26
16	4.3 – 4.7	4.53	0.20	1.9 – 2.4	2.13	0.25
17	3.9 – 4.2	4.03	0.15	1.0 – 2.8	1.70	0.96
18	3.6 – 3.9	3.76	0.15	1.5 – 2.8	2.56	0.97
19	2.9 – 3.6	3.16	0.38	2.8 – 3.2	2.80	0.40
20	3.2 – 3.6	3.43	0.20	1.8 – 3.2	2.56	0.70

Values are derived from 3 determinations.

However, during the wet season *Cymbella lanceolata* (r = 0.63), *Stephandiscus* sp (r = 0.54) and *Navicula radiosa* (r = 0.49) are positively correlated with salinity at statistically significant levels (P = 0.01). Other such as *Pleurosigma* sp., (r = 0.43) and *Actinoptychus undulatus* (r = 0.42) also correlated positively but at less significant level (P = 0.05). These indicate that the productivity of some microalage species particularly the Pinnate diatoms such as *Navicula radiosa, Cymbella lanceolata,* and *Stephandiscus* are more restricted in the epipellic habitat during the wet season, whose diluting influence seem to promote the existence of *Oscillatoria* sp (r = -0.11) and *Closterium* sp (r = -0.41) in the microhabitat.

From the correlations obtained, three groups of species relationship to salinity were apparent; (a) negative relationships of microalgae (true marine or brackish water microalgae, Pinnate diatoms) to salinity, (b) negative relationships of freshwater non-marine/brackish water microlagae (Centric diatoms) to salinity and (c) positive relationships of the dominant freshwater microalgae to salinity particularly, during the wet season. The first group occurs on the most consistent saline substrates of the tidal mud flats, while latter two groups are associated with freshwater inputs and tidal influence. These two groups represent species of very wide ecological amplitudes. The group limits of microalgae in gradients classes are shown in Figure 2. The distribution of the species along gradients gave information on the ecological optimum and amplitude for each species.

Table 2: Ranges, means and SD for abundance of selected microalgae species (frequency ≥ 4.0%) and the abundance - moment correlations between these values and mud salinity during the dry season of December

Abundance **Microalgae species**	Order	Range	Mean ±SD	Correlation Coefficient (r)
Amphora ovalis	Pennales	2 - 26	13 ± 9.5	-0.60
Campylodis cibrosus	Pennales	1 – 18	9 ± 5	-0.48
Cymbella lanceolata	Pennales	2 – 34	12 ± 6	-0.43
Navicula radiosa	Pennales	2 - 22	11 ± 7	-0.98
N. rhynocephala	Pennales	1 – 21	9 ± 7	-0.57
Pleurosigma sp	Pennales	1 – 27	9 ± 4	-0.44
Stephandiscus sp	Pennales	1 – 31	16 ± 9	-0.55
Pinnularia viridis	Pennales	2 – 17	7 ± 5	-0.58
Tabellaria sp	Pennales	1 – 41	12 ± 7	-0.44
Actinoptychus undulates	Centrales	10 – 50	20 ± 12	-0.09
Closterium sp	Centrales	3 – 41	18 ± 10	0.30
Oscillatoria sp	Blue-Green	1 – 16	5 ± 2	0.84

Table 3: Ranges, means and SD for selected microalgae species (frequency ≥ 4.0%) and abundance – moment correlations between these values and mud salinity during the wet season month of July.

Abundance Microalgae species	Order	Range	Mean ±SD	Correlation Coefficient (r)
Cymbella lanceolata	Pennales	1 – 15	3 ± 2	0.63
Navicula radiosa	Pennales	1 – 18	1 ± 0.9	0.49
N. rhyrocephala	Pennales	1 – 3	1 ± 0.9	
Pleurosigma sp	Pennales	1 – 14	4 ± 2	0.43
Stephandiscus sp	Pennales	1 – 8	3 ± 2	0.54
Tabellaria sp	Pennales	1 – 13	4 ± 1	0.14
Actinoptychus undulates	Centrales	5 – 26	10 ± 4	0.42
Closterium *sp*	Centrales	1 – 23	10 ± 5	-0.41
Oscillatoria sp	Blue-Green	1 – 9	4 ± 2	-0.11

As previously reported by Essien et al. (2005), the results of the present study show that the brackish water microalgae (the Pinnate diatoms) and associes (Centric diatoms and Blue-Green microalgae) share a niche attribute of tolerance for changing salinities. However each species also has special niche relationship to a particular range of the factor in both seasons. In the dry season samples, *Navicula rhynocephala, Amphora ovalis, Cymbella lanceolata, Tabellaria* sp., *Pleurosigma* sp. and *Stephandiscus* sp belong to Ecological Group 1 (species of similar occurrence but with wider amplitude than those occurring almost, exclusively under the most limiting condition of the factor). All the species under this group have similar occurrences under the most limiting conditions of salinity. They were abundant at a range of 5.53% to 5.90% with an ecological optimum on a salinity value of 5.65%. *Campylodis cibrosus, Actinoptychus undulatus* and *Closterium* species belong to Ecological Group 2 (species found at the midpoint of the factor gradient) since their dominance is restricted to the mid-point of the gradient, with ecological optimum on a salinity value of 3.9%. *Navicula radiosa* and *Pinnularia viridis* belong to Ecological Group 3 (species which dominate where the factor in consideration is in plentiful supply) since they dominate where salt concentrations appear to be in plentiful supply, they occur within a salinity range of 4.5% to 4.7 with an optimum of 4.6%.

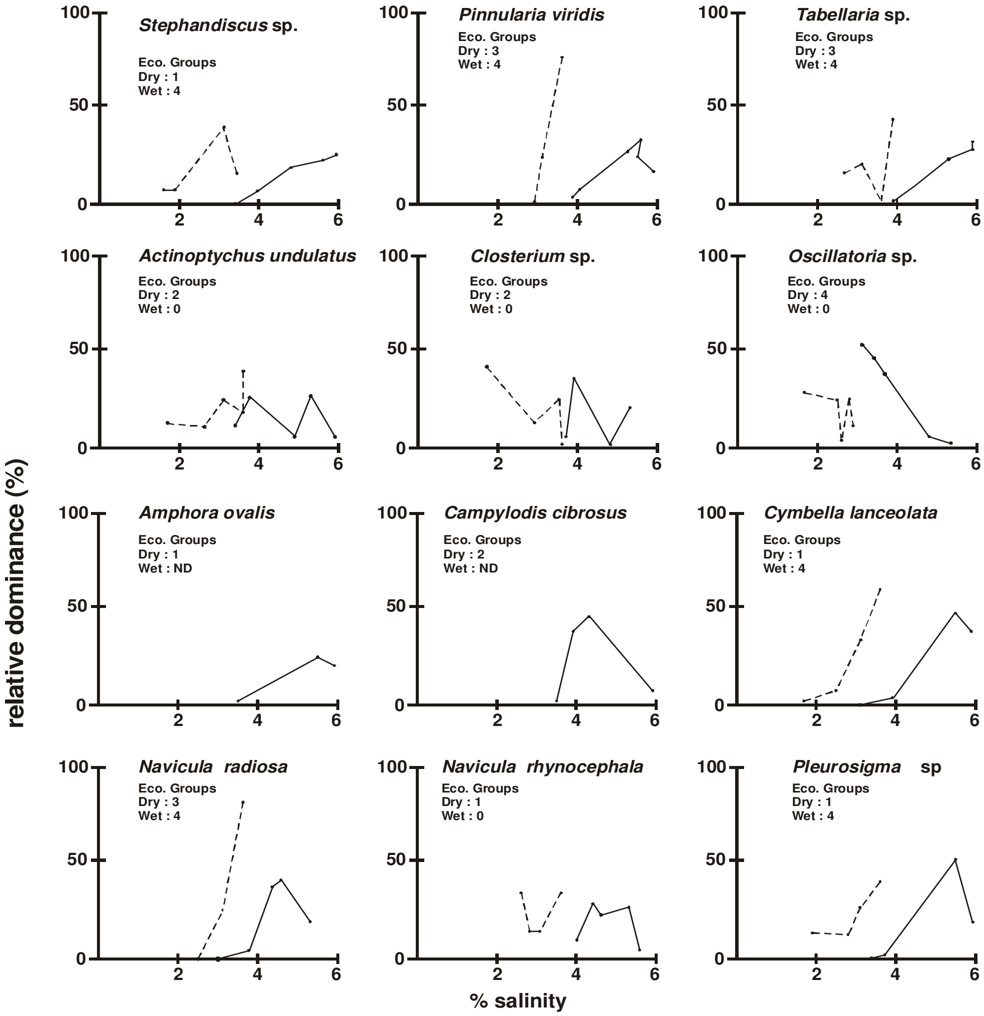

Fig. 2 Variation in the performance of epipellic microalogae species along salinity gradients in mangrove swamp of the Qua Iboe Estuary

------ = performance during the rainy season month of July
—— = performance during the dry season month of December
ND = not detected

CONCLUSION AND RECOMMENDATION

The results of the present study show that the brackish water microalgae (the Pinnate diatoms) and associes (Centric diatoms and Blue-Green microalgae) share a niche attribute of tolerance for changing salinities. However each species also has special niche relationship to a particular range of the factor in both seasons. The study has revealed niche specification over seasons, which is vital in biomass stock monitoring during oil spill impact assessment. The research has shown that rather than embark on broad biomass stock analysis during oil spills, emphasize should be directed on microalgae ecological optima to ascertain the abundance and productivity of specific planktons and their response to spillage at a period.

REFERENCES

Carmichael, W. W. (1981). *The Water Environment: Algal Toxins and Health.* Plenum Press, New York, pp 161–172

Cassie, V (1961). *Marine Phytoplankton in New Zealand Waters* (Illustrations). De Cruyter

Chapman, V. J. (1976). Mangrove Vegetation. J. Camer Publ. Co. Vaduz

Citron, G., Lugo, A. E., Pool, D. J. and Moris, G. (1978). Mangroves and environments in Puerto Rico and adjacent Islands, *Biotropica,* 10: 110 – 121

Cochran, W. G. (1963). *Sampling Techniques*; 2nd Edition, Wiley Eatern Ltd. New Delhi, 413p

Davies, C. C. (1972) Plankton dynamics in a New Foundland Lake. *Verh Internat Verein Limnology*, 18(1):278–283

Davies CC (1995) *Marine and Freshwater Planktons*. Michigan State University Press, pp 154–394

Essien, J. P., Antai, S. P. and Benson, N. U. (2008).Microalgae biodiversity and biomass status in Qua Iboe Estuary mangrove swamp, Nigeria. *Aquatic Ecology*, 42:71–81

Essien, J. P., Ubom, R. M. and Antai, S. P. (2005) Productivity and distribution of epipelic microalgae along salinity gradients in mangrove swamp of the Qua Iboe Estuary (Nigeria). *Environ. Monitoring Assessment* 121:65–75

Essien, J. P. and Antai, S. P. (2005) Negative effects of oil spill on beach microalgae in Nigeria. *World J. Microbiol Biotechnol*, 24(4):567–573

Essien, J. P., Ubom, R. M. (2003). Epipelic algae profile of the mixohaline mangrove swamp of Qua Iboe River Estuary (Nigeria). *The Environmentalist*, 23(4): 323–238

Han, M. (1978). *Illustration of Freshwater Planktons*. Academic Press, London, 85p

Moore, R. E. (1981a). Toxins and marine blue-green algae.In: Carmichael WW (ed) *The Water Environment: Algal Toxins and Health*. Plenum Press, New York, pp 15–23

Moore, R. E. (1981b). Constituents of blue-green algae. In: Schever P (ed) *Marine Natural Products*, Vol. 4. Academic Press, London, pp 1–52

Opute, F. I (1991) A check list of marine phytoplankton. Nigeria Journal of Botany, 4:227–254

Opute, F. I. (1990) Phytoplankton flora of the Warri-Forcados Estuaries of Southern Nigeria. *Hydrobiologia*, 208:101–109

Ubom, R. M. (1998). Responses of plant species to environmental gradients in Isoberlina woodlands of Northwestern Nigeria, Tropical Ecology, 39 (1): 39 – 54

Ubom, R. M. and Essien, J. P. (2003). Distribution and significance of epipsammic algae in the coastal shore (Ibeno beach) of Qua Iboe River Estuary, Nigeria. *The Environmentalist* 23(2):109–115

Ukpong, I. E. (1995) Vegetation and soil acidity of mangrove swamp in Southeastern Nigeria. *Use Manage*. 11:141– 144

Ukpong, I. E. (1991). The performance and distribution of species along soil salinity gradients of mangrove swamps in South eastern Nigeria. *Vegetation*, 95:63–70

Walsh, G. E. (1974). Mangroves: A review; In: R. Reimond and H. Queen (eds), *Ecology of Halophytes*, Academic Press, New York, pp 51 – 174

Waring, R. H. and Major, K. (1964). Some Vegetation of the California coastal redwood region in relation to gradients of moisture, nutrients, light and temperature, *Ecological Monographs*, 44: 441 – 464

Whittaker, R. H. (1978). Direct gradient analysis, In; R. H. Wittaker (ed), *Ordination of Plant Communities; Handbook of Vegetation Science*. %D. W. Junk, The Hague

Woodhead, N. and Tweed, R. (1960). A second checklist of tropical West African algae (Fresh and Brackish water), *Hydrobiologia,* 15: 225 - 286

Yakubu, A. F., Sikoki, F. D. and Horsefall Jr. M. (1998). An investigation into the physicochemical conditions and planktonic organisms of the lower reaches of the Nun River, Nigeria. *Journal of Applied Sciences and Environmental Management,* 1: 38 – 42

Lugo, A. E. and Snedaker, S. C. (1974). The Ecology of mangroves. *Ann. Rev. Ecol. Sys*., 5: 39 - 64