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Pelagic Phytoplankton Succession Pattern in a Tropical Freshwater Reservoir (Aiba Reservoir, Iwo, Osun, Nigeria)

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ABSTRACT

Fortnight phytoplankton sampling of Aiba Reservoir was carried out between March 2004 and February 2005 to determine phytoplankton succession pattern. Five major phytoplankton groups identified show two similar ordered directional repeated sequences of abundance peak patterns during an annual cycle; each began with a peak in Cyanophyceae abundance followed in order by peak abundances of Dinophyceae, Chlorophyceae, Bacillariophyceae and Euglenophyceae. The first succession pattern occurred between late April and mid-September (early rainy season) while the second occurred between early September and early February (late rainy season – dry season). A brief dry spell (August break) during the rainy season is a major factor determining this biannual pattern.

Keywords: Aiba Reservoir, annual cycle, pelagic, phytoplankton, succession pattern

INTRODUCTION

Phytoplankton refers to photoautotrophic microscopic plants having little or no resistance to currents and living free-floating or suspended in open or pelagic waters (Boney 1989; APHA 1992; Gupta and Gupta 2006). Phytoplankton responds quickly to environmental changes because of their short life cycle, and is subject to ecological succession (Zębek 2009). The sequential appearance of algal taxa in plankton environments is termed phytoplankton succession (Lewis 1986). Seasonal succession is regarded as the change in dominant species of phytoplankton from season to season (Khenari *et al.* 2010). It can also be regarded as a series of episodes initiated by abrupt changes in abiotic factors (Lewis 1978). All phytoplankton decrease and increase in abundance over the course of a year and the periods of increase for a particular species correspond with the coincidence of certain favourable conditions which define the central portion of the niche for the species (Lewis 1977; Xiao *et al.* 2011). Light and temperature have also been reported to be strong drivers of phytoplankton growth (Khenari *et al.* 2010; Domingues *et al.* 2011; Xiao *et al.* 2011). Changes in phytoplankton abundance can occur as organisms modify their environment either by biologically driven change (autogenic succession) through nutrient uptake or as a direct result of drastic abiotic influences (allogenic succession) such as mixing (Lewis 1986). Annual patterns of phytoplankton seasonality are usually either dominated by hydrological features (water input-output) or by hydrographic ones (water column structure and circulation) (Talling 1986; Matveev and Matveeva 2005; Adon *et al.* 2011; Xiao *et al.* 2011). Succession rate is quantitatively related to absolute rate of change in resource supply and to grazing rate (Lewis 1977). Stability in plankton taxa abundances and plankton taxonomic composition to ecosystem resilience is attributed to strong fluctuations in reservoir water level, and to other potential anthropogenic impacts (Matveev and Matveeva 2005). Although seasonal analyses are the usual approach in temporal variation of plankton, Padovesi-Fonseca *et al.* (2002) opined that monthly sampling is not sufficient to obtain a realistic picture of population dynamics of plankton as well as their importance in the ecosystem because sampling frequency has great influence on investigation of population dynamics of tropical water bodies. The seasonal physico-chemistry of Aiba Reservoir has been documented (Atobatele and Ugwumba 2008). This study reports the annual cycle successional pattern of the phytoplanktonic groups of Aiba Reservoir, Iwo.

MATERIALS AND METHODS

Aiba Reservoir, located in Iwo city in the southwestern part of Nigeria, lies between longitude 004° 11' to 004° 13' and latitude 07° 38' to 07° 39' of the Equator. Aiba Reservoir is the second oldest impoundment of the Osun River Basin and came into full operation officially on June 1, 1957. It is approximately 1.91 billion cubic meters storage dam supplied freshwater from a catchment area of 54.39 km^2. The dam is 11.58 m high and 455.2 m long. The reservoir has a mean depth of 0.75 m. The dry season extends from November to March while the rainy season is from April to October. However, during the rainy season in the month of August, there is the occurrence of a short dry season spell. The average monthly rainfall for July is about 254 mm and as low as 25.4 mm in December or January (Alamu 1992). The mean Secchi disc transparency ranged from 0.97 m during the dry season to 0.90 m during the rainy season (Ayodele and Adeniyi 2006). Phytoplankton sampling was carried out fortnightly from March 2004 to February 2005 between 900 and 1100 a.m. Phytoplankton samples were collected with plankton net (mesh size of 80 µm and mouth diameter of 22 cm). The plankton net was submerged about 70 cm below the water surface from a canoe and dragged horizontally at low speed for 5 min along the pelagic region of the reservoir. The net was lifted out and the content of the plankton bottle attached to the end of the plankton net was preserved immediately in 5% buffered formalin. In the laboratory, the preserved phytoplankton samples were allowed to settle first and withdrawn using a pipette into 25 ml. A drop of the agitated sample was added to a Neubaeur improved heamocytometer using a bulb micropipette. The organisms were identified and the total number of organisms per milliliter for each sample was determined by simple calculation. The phytoplankton species identified were grouped into five major phytoplankton taxa using the following guides: Prescott (1954), Needham and Needham (1969), Whitford and Schumacher (1973), Compere (1974, 1975a, 1975b), Okusanmi and Adu (1992), APHA

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Research Note

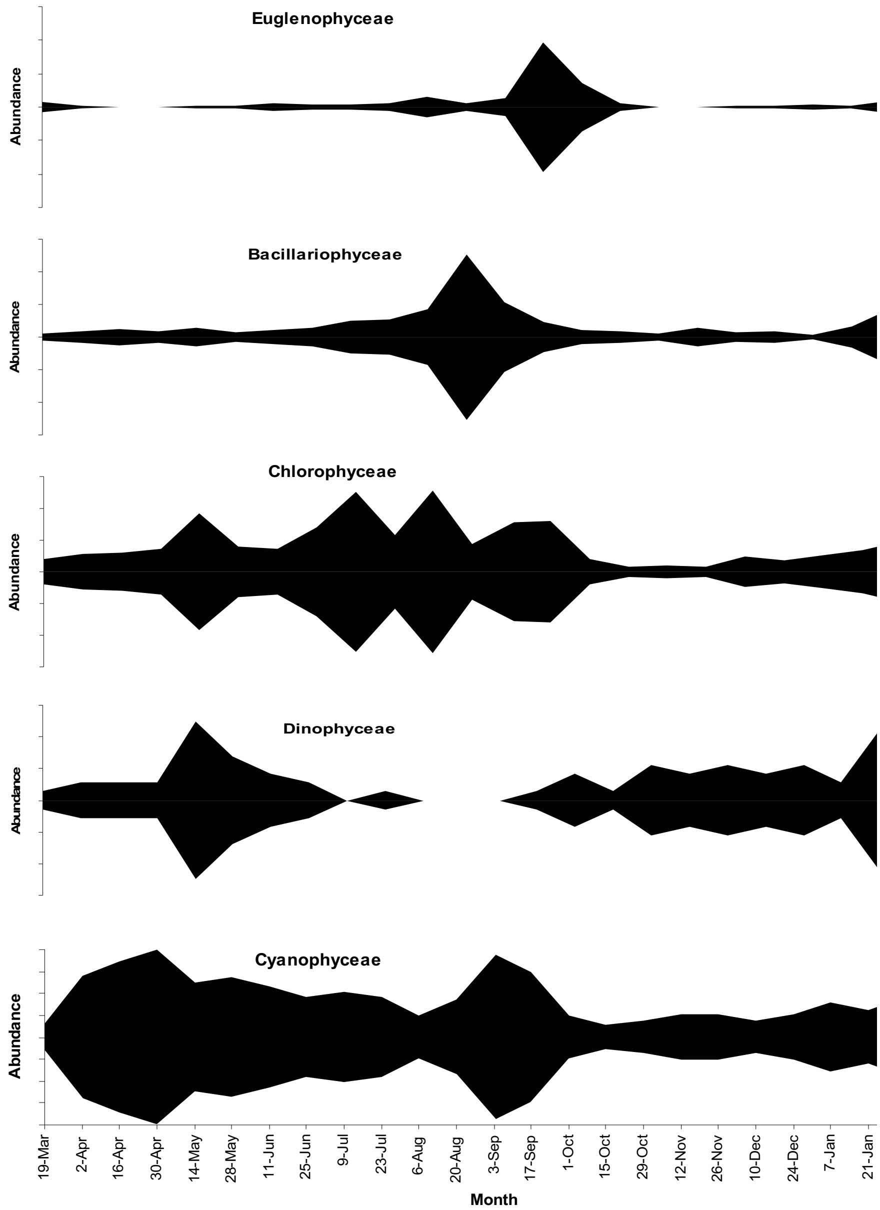

Fig. 1 Succession pattern of the major groups of phytoplankton for Aiba Reservoir from 2004 to 2005. Abundance values are relative.

(1992) and Opute (2000). For filamentous organisms, total filament lengths were divided by the respective mean cell lengths to calculate the cell numbers and all cells of colonial forms were counted (APHA 1992). Therefore, the enumeration method used was total cell count. Spearman rho correlation was carried out to determine significant relationship among phytoplankton groups and between concurrent physico-chemical and zooplankton data using SPSS 14.0 for Windows, Release 14.0.0 (5 Sep. 2005).

RESULTS

A total of 104 taxa belonging to five groups of phytoplankton namely: Cyanophyceae, Chlorophyceae, Bacillariophyceae, Euglenophyceae and Dinophyceae were encountered. Cyanophyceae abundance peaked in late April during the early rainy season followed by Dinophyceae abundance in mid-May while Chlorophyceae recorded two peaks in succession during early July and early August, and was followed by a sharp rise in Bacillariophyceae abundance in late August and of Euglenophyceae in mid-September (**Fig. 1**). A second peak of Cyanophyceae occurred in early September, Dinophyceae, Chlorophyceae and Bacillariophyceae each recorded a second peak abundance in late January and were closely followed by a second peak of Euglenophyceae in early February.

Cyanophyceae showed a significant positive correlation ($P < 0.01$) with Chlorophyceae; Chlorophyceae also recorded a significant positive correlation ($P < 0.01$) with Bacillariophyceae; while Bacillariophyceae recorded a significant negative correlation ($P < 0.05$) with Dinophyceae (**Table 1**). Cyanophyceae recorded a significant positive correlation with pH ($P < 0.01$), conductivity ($P < 0.05$) and dissolved oxygen ($P < 0.05$); while Chlorophyceae showed significant positive correlation only with pH ($P < 0.05$) and conductivity ($P < 0.05$). However, Bacillariophyceae was negatively correlated with water temperature ($P < 0.05$) while Dinophyceae recorded a significant negative correlation with turbidity ($P < 0.05$). All the phytoplankton groups show negative correlation with zooplankton.

DISCUSSION

The phytoplankton groups recorded for Aiba Reservoir are characteristic of tropical African reservoirs (Egborge 1974; Adon *et al.* 2011). Aiba Reservoir recorded two similar succession patterns during an annual cycle; each begins with maxima in Cyanophyceae abundance and ends with maxima in Euglenophyceae abundance. This is in contrast to Zębek (2009) who opined that the annual pattern of succession of dominants in nutrient rich lakes often follows the dinoflagellate to blue green pattern. Soylu and Gönülol (2010) reported that succession starts with R-strategists

Table 1 Two-tailed Spearman's rho for the phytoplankton groups, physico-chemical parameters and zooplankton data of Aiba Reservoir.

Phytoplankton group/ Physicochemical parameters	Cyanophyceae (blue-green algae)	Chlorophyceae (green algae)	Bacillariophyceae (diatoms)	Euglenophyceae (euglenoids)	Dinophyceae (dinoflagellates)
Cyanophyceae (blue-green algae)	1.000				
Chlorophyceae (green algae)	0.513**	1.000			
Bacillariophyceae (diatoms)	0.308	0.658**	1.000		
Euglenophyceae (euglenoids)	-0.102	0.367	0.353	1.000	
Dinophyceae (dinoflagellates)	-0.174	-0.281	-0.479*	-0.271	1.000
Zooplankton	-0.101	-0.063	-0.231	-0.126	-0.293
Water temperature	0.100	-0.178	-0.480*	-0.307	0.231
pH	0.511*	0.472*	-0.011	0.146	-0.160
Conductivity	0.435*	0.482*	0.167	0.171	-0.359
Alkalinity	0.380	0.392	0.012	0.078	-0.234
Dissolved oxygen	0.489*	0.342	0.290	0.109	0.063
Total hardness	-0.363	-0.018	-0.009	-0.016	-0.084
Turbidity	0.156	0.362	0.285	0.119	-0.517*

n = 25 except for turbidity, where n = 18
* = significant at 0.05 level
** = significant at 0.01 level

such as filamentous blue-green algae, with high surface to volume ratio followed by C-strategists such as small green algae characterised by fast nutrient absorption, assimilation and replication ratios. Cyanophyceae reached peak abundance in late April during the early rainy season probably due to a quick and early response to nutrient inflow; this is supported by the significant positive correlation of Cyanophyceae with pH, conductivity and dissolved oxygen. Blue-green dominance suggests high trophic status of water bodies (Zębek 2009; Rychtecký and Znachor 2011). Antenucci *et al.* (2005) reported a dramatic reduction in dominant cyanophyte species abundance as a result of increased artificial mixing (and reduced light availability). This agrees with Domingues *et al.* (2011) that cyanobacteria are the only phytoplankton group acclimated to low light conditions. However, blue-green algae have been reported to increase when nutrient depletion is pronounced and light availability is high (Lewis 1977, 1986). Dinophyceae peaked in mid-May while Chlorophyceae recorded two peaks in succession during early July and early August suggesting a period of freshness of the reservoir water when it was adequately diluted, that is during the peak rainy season. However, Tan *et al.* (2009) reported the dominance of cyanophytes after an initial dominance of chlorophytes in Lake Taihu, China. Increased water transparency and maximum stratification are reported to favour the development of green algae and dinoflagellates respectively (Silva *et al.* 2009; Zębek 2009). Egborge (1974) reported the dominance of motile green algae and dinoflagellates during transition of River Oshun from conditions of free flow to impoundment, and this may be the reason for the significant negative correlation between Dinophyceae and turbidity. Talling (1986) attributed this to the subsequent depletion of nitrate-nitrogen. Dinoflagellates can, however, thrive under conditions of extreme nutrient poverty because of their nutritional flexibility and motility (Lewis 1978; Grahame 1987). This supports the significant negative correlation between Bacillariophyceae and Dinophyceae. In a water body (Southern Black Sea) dominated by diatoms and dinoflagellates, the declines in diatom is reported to have been followed by increases in dinoflagellates (Türkoglu and Koray 2002). The phytoplankton in a polymictic tropical eutrophic reservoir in Brazil is reported to be dominated by competitive exclusion (between Cyanophyceae and Bacillariophyceae) and disturbance (Calijuri *et al.* 2002). The sharp rise in Bacillariophyceae abundance in late August (at the onset of late rains after the dry spell referred to as August break) occurred at a period when the reservoir experienced the greatest turbulence and increase in nutrient input. High nutrient enrichment, turbulence and low light availability favour increased diatom production (Lewis 1977, 1986; Farahani *et al.* 2006; Soylu *et al.* 2007; Khuantrairong and Traichaiyaporn 2008; Silva *et al.* 2009). This is probably due to vertical mixing of the water column and the onset of late rains reduces water temperature. This is supported by the significant negative correlation between Bacillariophyceae and water temperature. This period of increasing nutrient enrichment must have triggered the second peak of Cyanophyceae in early September and of Euglenophyceae in mid-September. Dinophyceae, Chlorophyceae and Bacillariophyceae each recorded a second peak abundance in late January and were closely followed by a second peak of Euglenophyceae in early February. This may be as a result of breakdown in stratification during the Harmattan period, which brings about vertical mixing of the water column and consequent nutrient enrichment during the dry season.

Apart from disturbance and trophic status of freshwaters, herbivory is also regarded as an important factor regulating the main sequence of phytoplankton succession (Morabito *et al.* (2002). The negative correlation between the phytoplankton groups and zooplankton suggests that grazing pressure of zooplankton is not significant enough to drive phytoplankton succession. Experimental evidence showing the inability of zooplankton to shape and control phytoplankton communities in tropical systems have been reported (Pagano 2008, Rückert and Giani 2008). This was attributed to the high phytoplankton production, absence of selectivity by the microcrustaceans on the algal species (Rückert and Giani 2008), and to inefficient feeding by dominant zooplankton (Pagano 2008), resulting in a weak phytoplankton-zooplankton relationship.

Short succession cycles have been reported to depend on coastal upwelling events (Silva *et al.* 2009); nutrient loads (Chan *et al.* 2002; Xiao *et al.* 2011) and light (Ariyadej *et al.* 2004; Domingues *et al.* 2011; Xiao *et al.* 2011) are dominant factors producing phytoplankton peaks in freshwaters. Vertical migration and recruitment of cyanophyte inocula as a result of increased water column has also been reported to lead to abundant cyanophyte population in the pelagic region of freshwaters. Although Lewis (1978) opined that the analysis of growth pulses and growth correlations in the major classes of phytoplankton provides evidence that the niche space is divided temporally on the basis of nutrients and light availability and use; morphological variation, mode of reproduction, temperature sensitivity, hydrology, hydrography, retention time, artificial drawdown, climatic forcing, overfishing, anthropogenic pollution and invasive species influence succession of phytoplankton (Talling 1986; Matveev and Matveeva 2005; Tundisi *et al.* 2008; Litchman and Klausmeier 2008; Khenari *et al.* 2010; Xiao *et al.* 2011). According to Litchman and Klausmeier (2008) several mechanistic pairwise trade-offs between these traits are thought to shape phytoplankton seasonal succession. Similar to report for Adzopé Reservoir, Côte d'Ivoire (Adon *et al.* 2011), the data for Aiba Reservoir suggests that hydrologic factors (e.g. rainfall and inflow from the catchment area) play dominant role followed by hydrographic factors (e.g. breakdown in stratification) in determining the pattern of phytoplankton succession.

CONCLUSION

Aiba Reservoir, therefore, seems to show two similar succession patterns during an annual cycle; each begins with a peak in Cyanophyceae abundance and ends with a peak in Euglenophyceae abundance. The first succession pattern occurred between late April and mid-September while the second occurred between early September and early February. Hydrological and hydrographical factors play significant roles in structuring phytoplankton succession pattern.

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