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Full Length Research Paper

Diversity and Distribution of Phytoplankton in Ndop Wetland, Cameroon

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Phytoplankton is very sensitive to nutrient changes. Very little work has been carried out on the effect of these changes on the phytoplankton community in the Ndop wetland. Four paddy-field sites were studied to evaluate the effect of some abiotic factors on their occurrence and abundance of phytoplankton. Water samples were collected from the paddy-fields sites following age gradient 34, 32, and 5 years old fields. Potassium, sodium, nitrate-nitrogen, phosphate-phosphorus, conductivity and pH were the factors that contributed to phytoplankton diversity and density. There was a positive significant correlation between pH and potassium ($r = 0.99$, $P \leq 0.01$), and pH and sodium ($r = 0.977$, $P \leq 0.05$). A negative correlation ($r = -0.992$, $P \leq 0.01$) was observed between pH and evenness. Eight divisions of phytoplankton were recorded: Chlorophyta (26.42%), Bacillariophyta (20.76%), Pyrrhophyta (20.76%), Cyanophyta (15.09%), Chrysophyta (1.87%), Xanthophyta (3.77%), Rhodophyta (1.87%), and Euglenophyta (7.55%). The most abundant species included *Microcystis aeruginosa, Anacystis* sp., *Chlorococcus disperses* and *Peridinum* sp. These may be used as bioindicator of the water quality. Diversity index increased with increase in the age of paddy-fields sites. 43% of the species indicated eutrophic status, 16.9% mesotrophic, and 20.8% oligotrophic. Eutrophic species were more in the older paddy sites while the young paddy sites had more oligotrophic species.

Key words: Phytoplankton, diversity, abundance, pollution, Ndop wetland.

INTRODUCTION

Wetlands are dynamic ecosystems, continually undergoing natural changes due to infilling with sediments and nutrient subsidence and a rise in water levels during heavy floods. They sustain all life forms and perform some useful functions in the maintenance of overall balance of nature. Rapid urbanization, burgeoning human population and their various activities have contributed to the decline of the quality and quantity of wetlands. Hence, it is imperative to focus on preservation of these endangered habitats to achieve ecological sustainability. In the Philippines, around 67% of the mangrove has been lost over the last 60 years or so, whilst in Senegal, 90% of the protected flood plains were expected to be lost by the early turn of this century(Dugan, 1990). Intensive farming practices cause changes in wetland soils, hydrology, and vegetation condition and dynamics. The main anthropogenic factors that have contributed to wetland changes are: change in area (habitat loss), change in water regime, change in water quality, unsustainable exploitation of wetland resources, and interaction of alien species (Piyankarage et al., 2004).

The Ndop wetland, like other wetlands, constitutes a vital ecosystem necessary for the subsistence of life at all forms. They host considerable biological diversity including endemic species, making them fall among the most productive life supporting systems in the world (WWF, 1999). This wetland ecosystem is the most widely utilized plain in the North West Region of Cameroon. The main staple crops grown in the area are *Zea mays* (maize), *Oryza sativa* (rice) and *Phaseolus vulgaris* (beans). It is for this reason that the Upper Nun Valley Development Authority (UNVDA) was instituted in the region in 1970 as the main custodian of the wetland

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ecosystem (UNVDA, 1982). The natural hydrological regime of the wetland has resulted to the occurrence of many floodplain lakes, which are supplied with water from their own catchment area. According to Junk et al. (1989) and Moss and Balls (1989), flood pulses are a very important environmental parameter in floodplain lakes, and these pulses determine the abundance and species composition of the biota.

Phytoplankton is an important primary producer, since it is the basis of the whole food chain in open waters. Sinha and Srivastava (1991) and Muhammad et al. (2005) reported that the maximum production of phytoplankton is obtained when the physico-chemical factors are at optimum level. Species composition of phytoplankton community is an efficient bio-indicator for water quality (Peerapornpisal et al., 2004). The Bacillariophyta (diatoms), Chlorophyta (green algae), and Cyanophyta (blue green) make up the three major groups of algae in fresh water ecosystems. Water quality or nutrient changes will affect the algal ecological distribution (Moss, 1995; Kelly, 1998). However, many authors have used floating algae (phytoplankton) as biological indicators for lenthic lakes or reservoirs (Wu, 1993; Michael and Paerl 1994; Chang et al., 1995), but in Cameroon little or no studies have been done, using algae, or phytoplankton as bio-indicator. No study has been carried out either to assess if there are any changes both in the biota or the phytoplankton species community since the insertion of the different paddy-field sites. The objectives of the present study is to: determine the abundance and diversity of phytoplankton in the floodplain following age gradient of different paddy-field sites, monitor water quality, and establish the status of pollution using bio-indicator species.

MATERIALS AND METHODS

Description of study area

The Ndop wetland is found in the Ngoketunjia Division and has about 13000 ha of wetland out of 15000 ha in the Nun Valley, drained by 7 rivers (Ngwa, 2005). The Ndop wetland has a surface area of 1,152 km^2 and a population of about 160,000 inhabitants. It is located between latitude 4°48′ N and 6°10′ N and longitude 10°15′ E and 10°40′ E (Figure 1). The mean annual temperature range is 27 to 33°C. Rainfall begins from mid-March and lasts until mid-November with the mean annual rainfall range of 330 to 2000 mm (SNEC Ndop, 2007). The rock types are basically igneous and basaltic. The area is characterized by a rich species population of fauna and flora (Kometa, 2006).

Sample collection and handling

Two sets of water samples were collected in 500 ml Teflon bottles, at a depth of 5 cm, from April to November, 2008 in four paddy field sites based on their age of construction. These sites include 1975 (34 years old), 1977 (32 years old), 1988 (22 years old) and 2004 (five years old). A set of the samples was used for chemical analysis and the other for biological analysis. For easy identification, three drops of Lugol's solution was added to the water samples used for biological analysis. In each collection, the two sets of samples were transported in a cooler packed with ice blocks (to stop further biological activities) to the laboratory for analysis.

Physical and chemical qualities of water at sampling sites

The following physico-chemical parameters were recorded on site; temperature (T) in °C, conductivity and pH (Nguetsop et al., 2007) using a Tracer pocket tester field conductivity meter, model pH/TDS/salts. Other physicochemical parameters (NH_4^+, Ca^{2+}, Mg^{2+}, K^+, Na^+, NO_3^-, PO_4^{3-}) were analysed in the University of Dschang Soil and Environmental laboratory using standard methods (APHA, 2005).

Phytoplankton assessment

Identification and counting of phytoplankton species were done by use of a binocular light microscope (Olympus CH20), at a magnification of 1000× (oil emersion). Slides for qualitative and quantitative analyses were prepared (in triplicate) and whole count method was employed, using Sedgwick rafter Counting Chamber to determine their density. Identification of phytoplankton species followed relevant text books and articles (Bourelly, 1957; Bourelly and Manguim, 1952; Compere, 1977; Lltis, 1980; Krammer and Lange-Bertalot, 1986, 1988, 1991, 2002; Gasse, 1980, 1986; Nguetsop, 1990; Nwankwo and Onyema, 2003; Nwankwo et al., 2003; John et al., 2005; Nguetsop et al., 2007; Bellinger and Siegee, 2010).

Statistical analysis

The effect of physicochemical parameters, diversity and abundance of phytoplankton on the different sites was determined using multivariate analysis (Principal Component Analyses, PCA), to rank the many factors under investigation based on their magnitude of interactions.

The density of the most abundant species (cells/l) was calculated from the formula:

$$Density = {}^{Xn}/_{M}\, x\ 44\mu l$$

Where: Xn = number of individuals in species X; M = number of drops observed under the microscope. A drop of sample taken up by the micropipette = 44 µl (Moser et al., 2004).

Trophic class of the different paddy field sites were calculated using Stockner (1972). This was calculated using the Euglenophycean index (Bellinger and Siegee, 2010).

The Species Richness Index (d) according to Margalef (1958) was used to evaluate the community structure. The following equation was applied and results were recorded to two decimal places:

$$D = (S - 1)/Log_e N$$

Where: D = Species richness index; S = Number of species in a population; N = Total number of individuals in S species.

Shannon-Weaver diversity (H) and Sorenson's indices

Shannon Weaver diversity index of phytoplankton species within

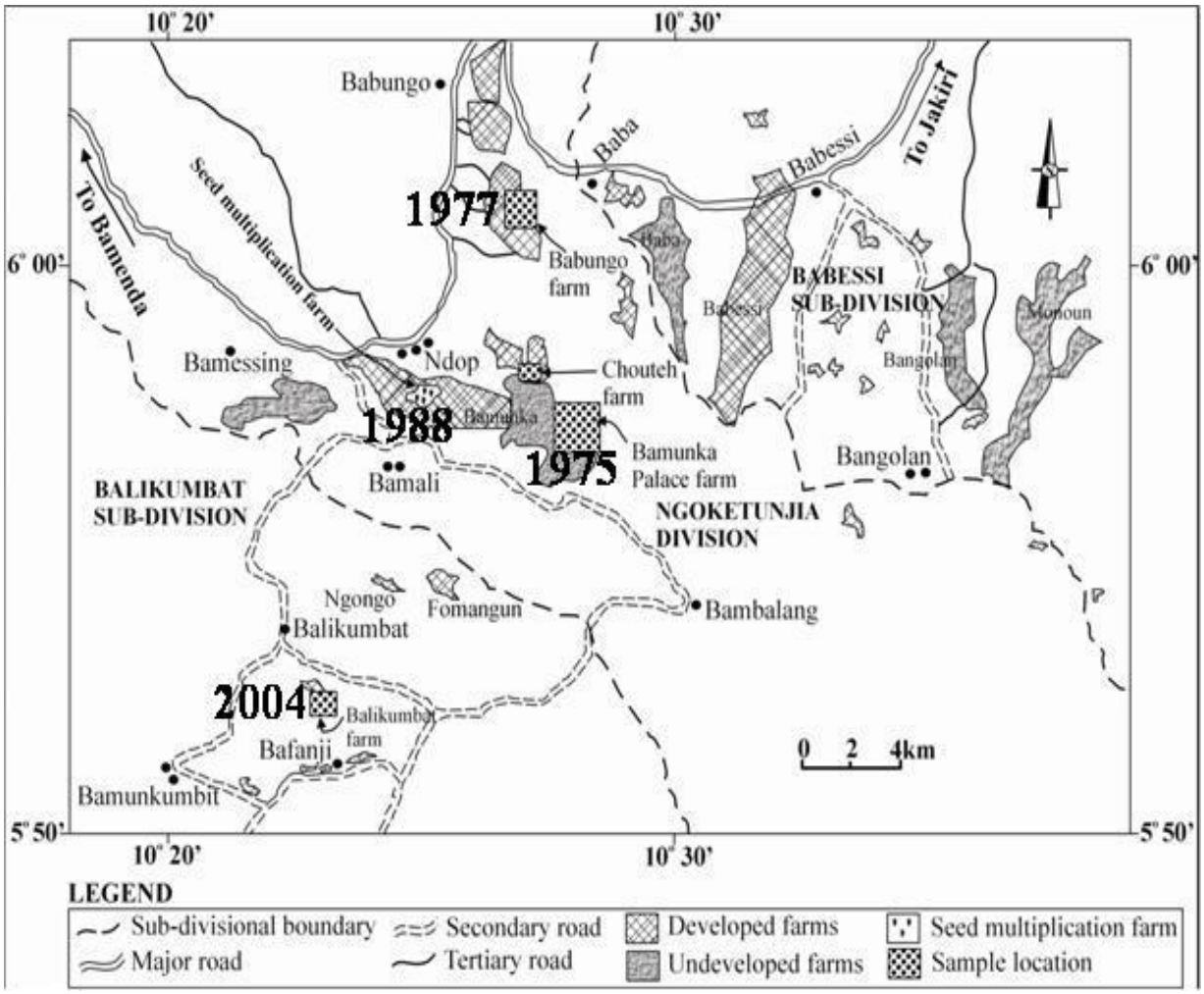

Figure 1. Selected sampling sites.

the different sites was determined using:

$$H^1 = \sum(p_i)(\log_n P_i)$$ (Magaurran, 1988)

Where: H^1 = Index of species diversity (information content of sample, bits or individuals); p_i = Proportion of total sample belonging to i^{th} species, and i = Number of species.

Sorensen's similarity index

Modified Sorensen (1948) was used to show species similarity in the different sites in terms of species distribution. It is expressed as:

$$Cn = 2a/(2a + b + c)$$

Where: C_n = Sorensen's similarity coefficient; a, b, c = number of individuals per sites.

The effect of some physico-chemical parameters, diversity and abundance of phytoplankton on the different sites was determined using a multivariate analysis (Principal Component Analyses, PCA). Pearson Correlation was conducted to find out the physico-chemical factors that significantly affect species richness and diversity.

RESULTS

Water quality analyses

The pH of the water from the recent farms (constructed in 2004) was very acidic (2.71), while the 1988 farms were the most basic (pH = 7.44). The conductivity of the water ranged from 938 to 1570 µS/cm. Nitrate levels ranged from 136.40 to 365.8 mg/L for the different rice fields. Phosphate levels ranged from 509.77 to 12322.78 mg/L for paddy-fields. Total nitrogen (Tot N) ranged from 30.8 to 82.6 mg/L for the different paddy field sites. Potassium ranged from 2.22 to 17.02 mg/L for paddy-fields and 1.29 to 4.44 mg/L. Sodium ranged from 3.05 to 11.1 mg/L for paddy-fields (Table 1).

A multivariate correlation analysis was carried out to determine the influence of the various physicochemical

Table 1. Summaries of Physico-chemical parameters of the water of different paddy-fields sites.

Parameters measured	Paddy field sites			
	2004 site	1888 site	1977 site	1975 site
pH	2.71	7.44	2.80	3.26
Conductivity	1370	938	1905	1570
NO_3^-	136.40	328.60	365.8	195.30
PO_4^{3-}	509.77	1232.55	1602.5	721.29
N/P*	0.32	0.33	0.28	0.33
Tot. N	30.80	74.200	82.60	44.10
K	3.85	17.02	2.22	5.45
Na	4.10	11.11	3.56	3.05

*N/P ratio was obtained by summing up the nitrate and total nitrogen over the amount of phosphate.

Table 2. Multivariate correlation analysis showing the Eigen distribution analysis of the covariance matrix for the phytoplankton in the different paddy field sites in Ndop wetland, Cameroon.

Variable	PC1	PC2	PC3
Eigenvalue	4.3110	3.5393	0.1497
Proportion	0.539	0.442	0.019
Cumulative	0.539	0.981	1.000
pH	0.478	0.061	-0.128
Conductivity	-0.375	-0.321	-0.447
NO_3^-	0.253	-0.450	-0.186
PO_4^{3-}	0.182	-0.492	-0.061
N/P	0.172	0.475	-0.706
Total N	0.253	-0.450	-0.186
K	0.466	0.129	-0.174
Na	0.472	0.057	0.426

parameters on the diversity and distribution of phytoplankton in the different paddy sites. Principal component (PC) 1 explains 53.9% of the overall variance and PC 2 44.2% contributing 98.1% in the paddy field sites (Table 2). In the paddy-field sites, pH, potassium, sodium, nitrate-nitrogen, phosphate-phosphorus and conductivity were the factors that contributed to phytoplankton diversity and density. There was a positive significant correlation between pH and potassium ($r = 0.99$, $P \leq 0.01$), and pH and sodium ($r = 0.977$, $P \leq 0.05$). A negative correlation ($r = -0.992$, $P \leq 0.01$) was observed between pH and evenness (Table 3).

Phytoplankton

53 species belonging to 26 families were identified in the different paddy field sites. Chlorophyta was the most common class with the most abundant number of species 26.42% followed by bacillariophyta and dinophyta (20.76%) which are more frequent as the paddy-fields grow older (Figure 2). The most abundant families were the Dinophyceae and Nitzschiaceae, while the least abundant was the Ulotrichaceae, Podolampaceae and Cladophoraceae. The most abundant species were *Microcystis aeruginosa* (in the 1975 site), *Anacystis* sp. (in the 1977 site), *Chlorococcus dispersus* (in the 1988 site), and *Peridinum* sp. (in the 2004 site). In the 1975 site, the least abundant species were *Thalasslosira ritscherii, Trachelomonas syndeyesis,* and *Ceratum* sp. In the 1977 site, *Pyrocystis* sp*., Cladophora* sp., and *Coscinodiscus lacustrisnin* were the least abundant while *Placodem desmid,* and *Histioneis remora* (in the 1988 site), and *Spirogyra longata, Euglena* sp. and *Ulothrix* sp. (in the 2004 site) were the least abundant species in those sites. The most frequent species were *Nitzschia seriata*, *Chlorella* sp. and *Cyclotella menghirians,* present in the 1975 and 1977 sites. *Euglena* sp. was more frequent in the 1977 and 2004 sites, and *Peridium* sp. is present in the 1988 and 2004 sites. The least frequent species were *Ulothrix* sp. and *Podolampas* sp. which were present only in the 2004 site (Table 4).

Phytoplankton as bio-indicator for water quality in the Ndop wetland plain

The phytoplankton species community indicated oligotrophic to eutrophic status, as paddy-field sites increased with age. Species which indicated oligotrophic status were mostly *Cosmarium* sp., *Crythropsis pavillardi* and *Pinnularia* sp. These were mostly found in the 2004 and 1988 paddy-field sites while species indicating mesotrophic status (*Cyclotella meneghirians, Anacystis* sp. and *Surirella ovalis*) were predominant in the 1988 and 1977 paddy-field sites. As the paddy- field sites increased in age, the species move from mesotrophic to eutrophic. Species which indicated eutrophic status included *Microcystis aeruginosa, Chlorococcus disperses, Nitzschia seriata* and *Chlorella* sp.

Table 3. Pearson correlation co-efficient matrix between water quality parameters and species richness indices.

Parameter	H'	D (Margalef)	EXP H'	Hmax	Evenness	pH	Conductivity	NO_3^-	PO_4^{3-}	N/P	Tot. N	K
D (Margalef)	0.218	1										
EXP H'	0.998**	0.234	1									
Hmax	0.536	0.932*	0.557	1								
Evenness	0.513	-0.716	0.489	-0.449	1							
pH	-0.471	0.758	-0.454	0.486	-0.992**	1						
Conductivity	0.694	-0.402	0.653	-0.155	0.895	-0.832	1					
NO_3^-	0.052	0.524	0.005	0.366	-0.309	0.429	0.115	1				
PO_4^{3-}	0.106	0.390	0.051	0.261	-0.145	0.271	0.269	0.985**	1			
N/P	-0.206	0.355	-0.140	0.338	-0.569	0.469	-0.769	-0.550	-0.686	1		
Tot. N	0.052	0.524	0.005	0.366	-0.309	0.429	0.115	1.000**	0.985**	-0.550	1	
K	-0.482	0.738	-0.457	0.481	-0.999**	0.991**	-0.888	0.308	0.142	0.580	0.308	1
Na	-0.641	0.608	-0.629	0.290	-0.972*	0.977*	-0.856	0.413	0.268	0.400	0.413	0.964*

*. Correlation is significant at the 0.05 level; **. Correlation is significant at the 0.01 level.

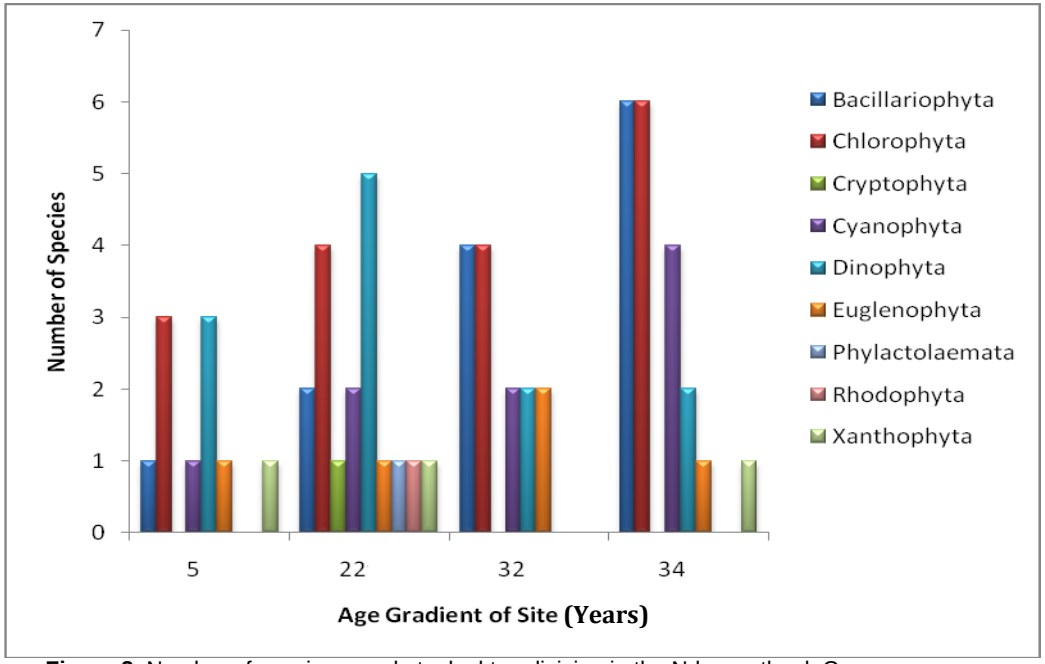

Figure 2. Number of species per phytoplankton division in the Ndop wetland, Cameroon.

Table 4. Abundance of phytoplankton in the different paddy-field sites.

No	Species names	Phyllum	Family	Species abundance in the different age gradients				Total	RD (%)	Status
				5 year old site	22 years old site	32 years old site	34 years old site			
1	*Anabaena* sp.	Cyanophyta	Nostaceae	0	0	0	10	10	6.25	Meso
2	*Anacystis* sp.	Cyanophyta	Cyanophyceae	0	0	6	0	6	3.75	Eutro
3	*Caloneisbacillum*	Bacillariophyta	Caloneiceae	0	0	0	5	5	3.13	Oligo
4	*Ceratiumsp*	Pyrrophyta/Dinophyta	Gymnodiniaceae	0	0	0	1	1	0.63	Meso
5	*Chlamydomonas* sp.	Chlorophyta	Chlamydomonadaceae	0	0	0	4	4	2.50	Eutro
6	*Chlorella* sp.	Chlorophyta	Chlorellaceae	0	0	2	5	7	4.38	Eutro
7	*Chlorococcus dispersus*	Cyanophyta	Chlorococcaceae	0	5	0	5	10	6.25	Eutro
8	*Chytriodinium affine*	Pyrrophyta/Dinophyta	Chytriodiniaceae	0	1	0	0	1	0.63	Meso
9	*Cladophora glomerata*	Chlorophyta	Cladophoraceae	0	0	1	0	1	0.63	Eutro
10	*Clastidium* sp.	Cyanophyta	Clastidiaceae	0	1	0	0	1	0.64	Meso
11	*Closteriopsis longissima*	Chlorophyta	Oocystaceae	1	0	0	0	1	0.64	Meso
12	*Coscinodiscus lacustris*	Bacillariophyta	Coscinoiscaceae	0	0	1	0	1	0.63	Oligo
13	*Cosmarium* sp.	Chlorophyta	Desmidiaceae	0	1	0	0	1	0.63	Oligo
14	*Cosmarium* sp.	Chlorophyta	Desmidiceae	0	2	0	3	5	3.13	Oligo
15	*Crythropsis pavillardi*	Cyanophyta	Conjugaceae	2	0	0	0	2	1.27	Oligo
16	*Cyclotella meneghirians*	Bacillariophyta	Thalassiosiraceae	0	0	3	4	7	4.38	Meso
17	*Dactylococcopsis acicularis*	Cyanophyta	Chrococcaceae	0	0	2	0	2	1.25	Eutro
18	*Dinophysis* sp.	Pyrrophyta/Dinophyta	Dinophyceae	0	1	0	0	1	0.63	Eutro
19	*Euglena* sp.	Euglenophyta	Euglenaceae	1	0	2	0	3	1.88	Eutro
20	*Euglena spingyra*	Euglenophyta	Euglenaceae	0	2	0	0	2	1.27	Eutro
21	*Gloeocystis gigas*	Xanthophyta	Xanthophyceae	0	0	0	2	2	1.25	Meso
22	*Gyrosigma acuminatus*	Pyrrophyta/Dinophyta	Dinophyceae	0	0	0	1	1	0.63	Oligo
23	*Histioneis remora*	Pyrrophyta/Dinophyta	Dinophysiaceae	0	1	0	0	1	0.63	NC
24	*Lemaneasp*	Rhodophyta	Rhodophyceae	0	2	0	0	2	1.25	NC
25	*Microcystis aeruginosa*	Cyanophyta	Cyanophyceae	0	0	0	15	15	9.38	Eutro
26	*Monoraphidium setforme*	Chlorophyta	Monostromataceae	0	0	3	0	3	1.88	Eutro
27	*Mougeotia* sp.	Chlorophyta	Zygnemataceae	0	0	0	2	2	1.25	NC
28	*Nitzschia acuminata*	Bacillariophyta	Nitzschiaceae	0	4	0	0	4	2.50	Eutro
29	*Nitzschia deticatissina*	Bacillariophyta	Nitzschiaceae	0	0	0	2	2	1.25	Eutro
30	*Nitzschia seriata*	Bacillariophyta	Nitzschiaceae	0	0	4	6	10	6.25	Eutro
31	*Oscillatoria* sp.	Cyanophyta	Oscillatoriaceae	0	0	0	2	2	1.25	Eutro
32	*Dinobryon divergens*	Chrysophyta	Chrysophyceae	0	2	0	0	2	1.25	Oligo
33	*Peridiniopsis* sp.	Pyrrophyta/Dinophyta	Dinophyceae	2	3	0	0	5	3.18	Eutro

Table 4. Contd.

34	*Peridinium* sp.	Pyrrophyta/Dinophyta	Peridiniaceae	5	0	0	0	5	3.18	Eutro
35	*Peroniella planktonia*	Xanthophyta	Xanthophyceae	0	1	0	0	1	0.63	NC
36	*Phaeocystis* sp.	Pyrrophyta/Dinophyta	Phaeocystaceae	0	0	2	0	2	1.25	NC
37	*Pinnularia* sp.	Bacillariophyta	Naviculaceae	2	0	0	0	2	1.27	Oligo
38	*Pleurosigma* sp.	Chlorophyta	Pleurococaceae	0	1	0	0	1	0.63	NC
39	*Plumatella* sp.	Phylactolaemata	Plumatellidaceae	0	2	0	0	2	1.25	NC
40	*Podolampas* sp.	Pyrrophyta/Dinophyta	Dinophyceae	1	0	0	0	1	0.64	NC
41	*Pyrocystis moctilua*	Pyrrophyta/Dinophyta	Pyrocystaceae	0	1	0	0	1	0.63	NC
42	*Pyrocystis lunula*	Pyrrophyta/Dinophyta	Pyrocystaceae	0	0	1	0	1	0.63	NC
43	*Sphaerocystis sp*	Chlorophyta	Chlorophyceae	0	0	1	0	1	0.63	Meso
44	*Spirogyra longata*	Chlorophyta	Conjugaceae	1	0	0	2	3	1.88	Eutro
45	*Staurastrum bieneanum*	Chlorophyta	Desmidiaceae	1	0	0	0	1	0.64	Eutro
46	*Surirellaovalis*	Bacillariophyta	Surirellaceae	0	0	3	0	3	1.88	Meso
47	*Thalassiosir arutula*	Bacillariophyta	Thalassiosiraceae	0	1	0	0	1	0.63	Oligo
48	*Thalassiothrix frauenfeldii*	Bacillariophyta	Thalassionemataceae	0	0	0	2	2	1.25	Oligo
49	*Thalasslosira ritscheri*	Bacillariophyta	Thalassiosiraceae	0	0	0	3	3	1.88	Oligo
50	*Trachelomonas hispida*	Euglenophyta	Euglenaceae	0	0	2	0	2	1.25	Eutro
51	*Trachelomonas syndeyesis*	Euglenophyta	Euglenaceae	0	0	0	1	1	0.63	Eutro
52	*Ulothrix* sp.	Chlorophyta	Ulotrichaceae	1	0	0	0	1	0.64	Eutro
53	*Volvox* sp.	Chlorophyta	Volvocaceae	0	2	0	2	4	2.50	Eutro
	Total			**17**	**33**	**33**	**77**	**160**		

These were mostly found in the 1975 and 1977 sites. In the different paddy fields, 43% of the species identified indicated eutrophic status, 16.9% mesotrophic, 20.8% oligotrophic while 18.9% were unknown. The eutrophic species were more in the older paddy sites meaning that recent paddy–field sites were oligotrophic while older fields were eutrophic (Table 4).

The Shannon Weaver Diversity Index (DI) and the evenness of different phytoplankton species found in the respective paddy field sites are shown in Table 5. The 1975 sites had the highest DI (2.71), with 21 species and evenness of 0.90, while the 1988 sites had the least DI (2.12), with 15 species and the least evenness (0.73).

Species Richness Index (D) showed the 1977 paddy-field sites as the richest (4.86) followed by 2004 site (4.37), while 1975 paddy site was the least (2.86). The Sorenson's Coefficient of Community Similarity (Table 6) showed that paddy-fields of 1975 and 2004 were similar in phytoplankton species composition (81.6 %) while those in the 1977 and 1988 paddy-fields (71.37%) were also similar in species composition.

DISCUSSION

The occurrence, abundance and diversity of the phytoplankton community in a paddy-field wetland complex are influenced by nutrient concentrations, rainfall patterns, location and the nature of the physical environment. This also tends to affect water quality in the ecosystem. The biota differs greatly with the changes in the physico-chemical conditions in aquatic ecosystems. According to Reid (1961), the successful development and maintenance of a population of organisms depends upon harmonious ecological balance between environmental conditions and tolerance of the organisms to variations in one or more of these conditions. The pH in the study area was more acidic but for the 1988 (22 years old site), it was basic. This could be as a result of the rainfall pattern and the agricultural activities in the area.

Table 5. Phytoplankton diversity indices in the different paddy field sites in Ndop wetland plain, Cameroon.

Sites	Species richness (D)	Species diversity (H')	EXP H'	Hmax	Evenness
1975	2.82	2.71	15.01	2.99	0.90
1977	4.86	2.49	12.10	2.64	0.95
1988	3.72	2.12	8.29	2.89	0.73
2004	4.37	2.12	8.29	2.30	0.92

Table 6. Similarity index between different paddy sites following different gradient [1975 (34 years), 1977 (32 years) and 1988 (22 years)].

Step	Number of clusters	Similarity level	Distance level	Clusters joined	New cluster	Number of observations in new cluster
1	3	28.6334	0.7137	2 3	2	2
2	2	18.4036	0.8160	1 4	1	2
3	1	-6.4696	1.0650	1 2	1	4

Cluster 1: 1975 (34 years), 2004 (05 years); Cluster 2: 1977 (32 years), 1988 (22 years).

Potassium and sodium greatly influenced the alkalinity of the system and this was reflected in the negative correlation between pH and evenness of phytoplankton. This finding is in line with Kensa (2011) who observed that the distribution of phytoplankton decreases with increase in alkalinity. In the study area, the mean annual rainfall patterns have been torrential and undulating within the last ten years which has turn to alter the hydrological net work of the region. The highest $P\text{-}P0_4^{2-}$ and $N\text{-}N0_3^-$ in the 22 years old site may be due to the agricultural activities and the location of the paddy fields. This area is one of the cattle zones in Cameroon, resulting to a high increase in the organic load in the area from cow manure. In the 5 years old fields, the low input is as a result of age or less co-precipitation of phosphate with calcium carbonate, a phenomenon that has often been reported to occur in many fresh water lakes (House, 1990; Heleen et al., 1995; Ibrahim et al., 2009). According to Ibrahim et al. (2009), torrential rains, effect

of deforestation, fertilizer application, herbicides, affect physico-chemical parameters.

The most abundant genera were *Microcystis, Anacystis, Chlorococcus*, and *Peridinum,* which are mostly cyanophyta (blue green algae) which may have the competitive ability and /or resilience taxa competent of producing extracellular substances that inhibit and/or eliminate other algal species (Chindah et al., 2007). It may also be due to the constant addition of nutrient particularly through nitrate and phosphate fertilizers used in the paddy fields. The nutrient levels were generally very high, with nitrate levels ranging between 136.4 to 365.8 mg/L while phosphate ranged between 509.77 to 12.322.78 mg/L. According to Carlson (1977), a wetland is said to be hyper-eutrophic when the phosphate level is above 96 mg/L. This may have been the cause of the high phytoplankton level which has resulted in eutrophication. Oviatt et al. (1989) and Władysława et al. (2007) related abundance of phytoplankton to increase nutrient loads, especially blue green algae. These groups of algae are said to fix nitrogen, causing eutrophication in the wetland plains. Blue-green algae are said to produce toxins that pose a health risk to humans and animals when exposed to them in large quantities (Oben et al., 2006).

Diversity increased with age of the paddy field sites. In the 1975 site, bacillariophyta and chlorophyta were the most abundant phytoplankton algal group. This is because they are adapted to a wide range of physico-chemical parameters. Most of the phytoplankton encountered in the study area appeared to be normal inhabitants of natural lakes, ponds, streams and artificial impoundments in the tropics and subtropics (Nwankwo, 1998; Aneni and Hassan, 2003; Olaleye and Adedeji, 2005; Periyanayagi et al., 2007) and typical of flowing rivers dominated by diatoms and Chlorophyceae (Reynolds et al., 1994). Arimoro et al. (2008) reported that in the Orogodo river in Nigeria, phytoplankton was in the order of Bacillariophyceae > Chlorophyceae > Cyanophyceae > Euglenophyceae. Bellinger and Siegee (2010) reported that diatom (bacillariophyta) abundance is a characteristic feature of a eutrophic environment. Kelly (1998), Wackstrom et al. (19 97) and Ajuonu et al. (2011) reported that the qualitative and quantitative dominance of diatoms in an aquatic ecosystem is a major indicator of water quality and environmental condition as they are adapted to a wide range of physico-chemical parameters. In the 2004 sites, the chlorophyta and dinophyta were the most abundant algal groups. This finding agrees with that of most authors who reported that the phytoplankton community in fresh water is mostly

chlorophyta, cyanophyta, diatoms and dinophyta (Sorayya et al., 2011). Similar studies by Adebisi (1981), Ayodele and Ajani (1999) showed that blue algae and green algae dominate most tropical African lakes. Onyema et al. (2006), Davis (1955) and Sverdrup et al. (2003) reported that diatoms and dinoflagellates are important components of photosynthetic organisms and form the basis in the aquatic food chain, with the dinoflagellates being second in importance to the diatoms as basic food producers in the plankton community. The 1975 site was not the richest but the most diverse, followed by the 1977 site. This shows that eutrophication has taken place, reducing the chlorophyta community in favour of the cyanophyta community. This may be as a result of the constant introduction of nutrients in the system during fertilization and also the change in the rainfall patterns.

The preponderance of Chlorophyceace was also observed in the Ikwori Lake, especially during the dry season, which is attributed to bright sunshine, isothermal water column, and extensive catchment area (Adeniyi, 1978). It was also reported that the abundance of phytoplankton increases with increase in transparency, which is normally associated with black flood (dry season), while the high turbidity associated with the white flood (wet season) results in a decrease in its abundance (Adeniyi, 1978). The species similarity between the oldest paddy field sites and the youngest may be due the amount of Phosphate. Low phosphate may be attributed to locking up of phosphate in dense phytoplankton and macrophytic vegetation (Wani and Subla, 1990). During plankton multiplication, automatically phosphate concentration decreases (Moss and Ball, 1989). The blue green algae assimilate phosphate at a faster rate than green algae and accumulate large amount of reserve phosphate for extended growth periods at low phosphate concentration (Lam and Silvester, 1979).

The presence of the blue-green algae, as the most abundant genera, indicates that the water is not potable except after proper treatment. The blue-green algal blooms gave a dark green paint-like appearance in water, which is indicative of eutrophication. The nitrogen and phosphorus levels were higher than normal levels for potable water. According to Williams and Tonnessen (2000), the increased nitrate and phosphorous concentrations have been the drive increasing phytoplankton levels. This is because they are both basic necessities for phytoplankton activities. The two most common consequences of nitrogen and phosphorus saturation of surface waters are eutrophication and acidification (Stoddard, 1994). This high acidity is evident at almost all the paddy sites. McKnight et al. (1994) suggested that acidification of the Green Lake may result in a shift in phytoplankton productivity and community composition.

In the case of the Ndop wetlands, *Thalassiosira* and *Coscinodiscu*s sp. were the least abundant species present, particularly in the older paddy field sites. According to Reynolds (2006), the growth of some species of phytoplankton is unlikely to be constrained by nitrogen availability, unless dissolved inorganic nitrogen concentration falls below 0.1 mg/L. This accounts for the decrease in most species abundance in the 2004 site. The high frequency of some species like *Nitzschia seriata*, *Chlorella* sp., *Cyclotella menghirians, Peridiarium* sp., *Ulothrix* sp*. and Podolampas* sp. (mostly diatom species) indicates nutrient eutrophication. *Microcystis* sp. and *Anacystis* sp. abundance are indicators of water pollution. According to Yasuno et al. (2000) and Bellinger and Siegee (2010), these two species are indicators of eutrophic pollution while *Cosmariun* sp., *Crythropsis pavillardi* and *Pinnularia* sp. are indicators of an oligotrophic environment. This is in agreement with our findings and corresponds to changes in the different paddy-field sites. According to Gerrath (1993) and Sorayya et al. (2011), *Staurastrum*, *Cosmarium, Closterium* and *Pediastrum* (demids species) and some micro-green algae *Scenedesmus; Chlamydomonas* and *Chlorella* are generally common and diverse in oligotrophic lakes and ponds thus are considered as indicator species for oligotrophic systems (Gerrath, 1993). They are highly sensitive to changes in environmental parameters as such are considered as bio-indicators for monitoring water quality (Coesel, 1983, 2001).

Conclusion

The species found indicate the different trophic status of the different paddy-field sites, with the older paddy-field sites being eutrophic while the recent are oligotrophic. The population of the different species was greatly affected by the physico-chemical properties of the wetlands.

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