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SOME ASPECTS OF THE ECOLOGY OF FRESHWATER ALGAE IN THE DENSU RIVER AND TWO TRIBUTARIES IN SOUTHERN GHANA

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Abstract

Studies on the composition and abundance of the phytoplankton in River Densu and two of its tributaries, Rivers Adeiso and Nsakir were carried out at ten sampling sites, including seven from different regions of the river basin namely Afuaman, Akwadum, Densuso, Manhean, Machigeni, Nsawam and Weija, as well as Adeisoand Pokuase. Sampling was done monthly at each sampling site from January to December, 2006. Physical and chemical parameters of river water were studied. The parameters of the river water varied with the sampling sites and the time of the year. Water samples for phytoplankton identification and enumeration were collected at each sampling site. Physico-chemical conditions of the river were assessed during sample collection or in the laboratory. Correlation analysis showed that there was a positive correlation between algal genera and the measured physical and chemical parameters of the river water.

Key Words: Ecology, Freshwater, Algae, Densu, Tributaries

Introduction

Ecologically, the algae occur in all types of habitats where they are major primary organic producers and therefore a fundamental part of the food chain especially in most aquatic environments, with a profound influence on life on earth. The major freshwater bodies have characteristic features that would influence their algal flora.

Rivers provide habitats which are very different from those of ponds and lakes because they are subject to changes along their course as well as complication from seasonal changes. The problems of maintaining a floating population in a river are enormous since the products of divisions are continuously being transported downstream. Thus, it would seem that a true phytoplanktonic community maintaining itself by active reproduction of the cells is only possible in rivers under conditions of reduced flow. Indeed, Rzóska *et al*. (1955) observed that the phytoplankton of River Nile is reduced considerably during flood periods of fast water flow.
Eaton (1965) recorded in River Niger, planktonic algae of about 1000 algal cells per ml at the time of lowest river level in July. The number continually declined as the water level rose. The fall in algal numbers was attributed mainly to the dilution of the river by an increasing volume of plankton-poor water entering from its tributaries.

The hydrology and phytoplankton of River Sokoto, also in Nigeria, which had been studied earlier in 1956 and 1957 by Holden (1960), were influenced by the water level during the flood period from April to October.

Phytoplankton production in River Oshun lying between Ibadan and Ile-Ife cities in Nigeria showed a good positive correlation with dissolved nutrients, conductivity and water transparency, and an inverse relationship with water level and current velocity (Egborge, 1974). Iltis (1982, 1984) found that the numbers of planktonic algae on Rivers Bagoe, Comoe and Leraba in the north of Cote d'Ivoire had lower mean algal numbers of 27.8, 33.9 and 15.5 per ml, respectively, with a tropical transitional flood regime. The annual peaks were dominated by euglenophytes and chlorophytes. Rivers Maraoue, N'zi and White Buandana in central Cote d'Ivoire with an attenuated equatorial transitional flood regime, studied together with the northern rivers in 1977 had higher mean algal numbers of 351.6, 138.2 and 216.0 per ml, respectively. The lowest densities were recorded over the flood period from September to December and the cyanophytes and chrysophytes generally formed an insignificant proportion of the phytoplankton.

Biswas (1968) also observed two peak phytoplankton populations in the Black Volta in February and April 1964. The February peak was dominated by centric diatom *Aulacoseira granulata* and the April peak by the diatom *Synedra acus*. However, the populations of *Synedra acus* as dominant species were eventually replaced by *Anabaena aphanizomenoides* by the third week of May 1964.

Biswas (1968) found the diatoms and chlorophytes to be the most diverse groups of the Black Volta, and recorded 35 taxa each for these two groups. Of the remainder, there were seven taxa of cyanophytes, two each of cryptophytes and dinoflagellates and one euglenophyte taxon, making 82 taxa in all. Egborge (1974) reported 60 taxa for River Oshun with diatoms as the most diverse group with 31 taxa, followed by chlorophytes with 20 taxa, then five cyanophytes and lastly a single dinoflagellate taxon. According to Livingstone (1963), the dominance of the diatoms in West African rivers is perhaps due to the presence of silica as the most abundant oxide.

Amuzu (1976) found appreciable levels of dissolved oxygen in River Densu while Kpekata and Biney (1979) reported a pH range of 6.9 to 7.7 and conductivity values ranging from 360 to 2300 μScm^{-1}.

River Densu forms part of the coastal river basins and is one of the most important water sources for the Eastern and Greater Accra Regions of Ghana. This River has been studied in this investigation to provide its much needed pertinent information on the identification and enumeration of the phytoplankton population at 7 stations along the river and 2 tributaries over a year.

Materials and Methods

Study site

(a) River Densu

This river takes its source from the Atewa range of hills at an altitude of 0.64 km above mean sea level, lying between Latitudes 6º 04'N and 6º 10'N, and between Longitudes 0º 40' W and 0º 03'W, near Kibi, in the Akim Abuakwa District of the Eastern Region of Ghana. It flows in a south-easterly direction till it reaches Mangoase, where it changes course and flows generally southwards till it enters the Gulf of Guinea, covering a distance of 116 km (Fig. 1).The sampling sites and their localities are Adeiso, Akwadum, Ashalaja, Densuso, and Nsawam in the Moist Semi-Decidous Forest; and Afuaman, Machigeni, Manhean, Pokuase and Weija in the Coastal Savanna Zone as shown in Fig 1.

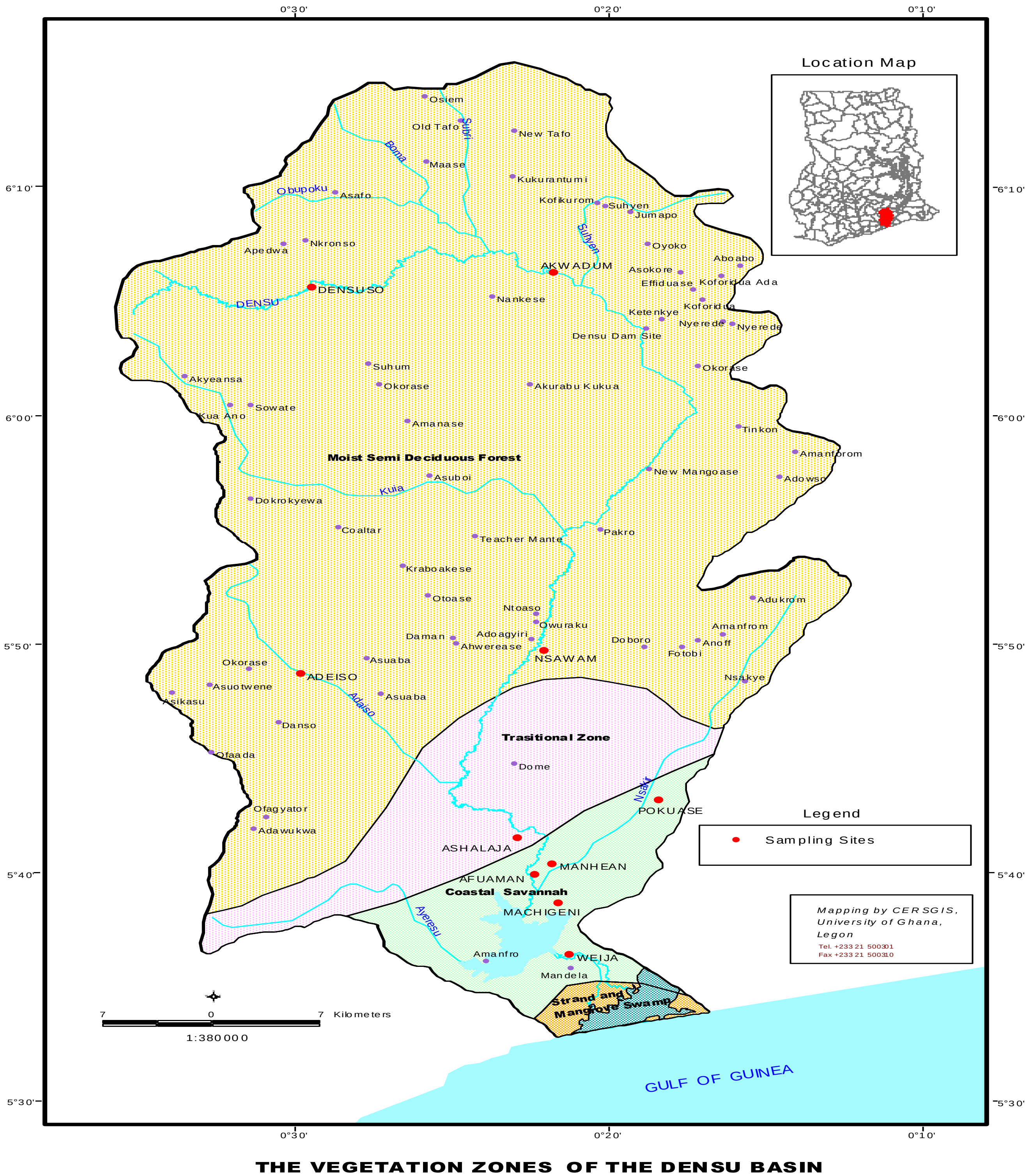

Fig. 1 Map of the Densu River and two tributaries showing the sampling sites

b) Studies on the Phytoplankton

Members of the alga groups, Bacillariophyta, Chlorophyta and Cyanophyta of ten sites,eight along the course of River Densu situated in 2 different ecological zones, and two tributaries, Rivers Adeiso and Nsakir, were studied (Fig. 1).

(i) Collection and Preservation of Phytoplankton samples

Water samples from the photic zone for phytoplankton assessment were collected at each indicated site of the Densu River and the tributaries monthly, for 24 months from January 2010 to December 2012. Where the water was relatively shallow, the sample was taken from just off the bottom to the surface. About 1 ml of Acid-Lugol's solution (Lugol's iodine) was added to each 30 ml water sample from each site at the time of collection (Prescott, 1970). The samples were then transported to the laboratory for later identification and enumeration of algae.

(ii) Enumeration and Identification of Phytoplankton species

The phytoplankton was enumerated using 25 ml of each of the iodized samples, following the procedure of Biswas (1966). Phytoplankton density measured as numbers of individuals per ml was estimated by counting individuals whether single cells, colonies or filaments in a counting cell, after about an hour of sedimentation. Identification of the species of planktonic flora was done according to the works of Huber-Pestalozzi (1938) for Cyanophyta, Kramer and Lange-Bertalot (1988) for Bacillariophyta and those of Ettl (1983) and Ettl and Gartner (1988) for Chlorophyta.

(c) Studies and on the river chemistry and physical factors

All determinations were done following established pertinent methods (APHA, AWWA, and WEF (1995); UNESCO/WHO, 1978; WHO, 1987)

Results

Mean monthly Temperature and pH of the water of Rivers Densu and the tributaries, River Adeiso (Adeiso) and River Nsakir (Pokuase) over a 12 months period (January to December 2009) is shown in Fig 2. Mean monthly concentrations of Ammonia, Nitrate and Phosphate (mg l^{-1}) of the water of River Densu and the Tributaries River Adeiso (Adeiso) and River Nsakir (Pokuase) over a 12 month sampling period is shown in Table 1. Similarly, mean monthly concentrations of Silica (mg l^{-1}) of the water of River Densu and the tributaries Adeiso (Adeiso) and Nsakir (Pokuase) over a sampling period is shown in Fig 3.

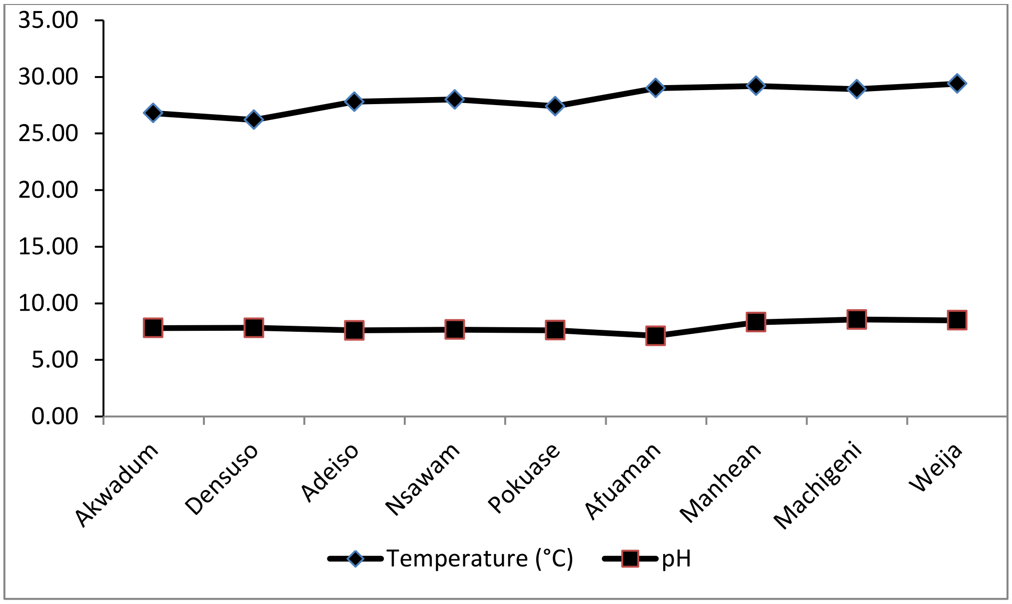

Fig. 2: Mean monthly Temperature and pH of the water of Rivers Densu and the tributaries, River Adeiso (Adeiso) and River Nsakir (Pokuase) over a 12 months period

Table 1: Mean monthly concentrations of Ammonia, Nitrate and Phosphate (mg l^{-1}) of the water of River Densu and the tributaries River Adeiso (Adeiso) and River Nsakir (Pokuase) over a 12 month sampling period

	Sampling Station									
Nutrient	Akwa-dum	Den-suso	Adei-so	Nsa-wam	Poku-ase	Afua-man	Asha-laja	Manh-ean	Machi geni	Wei-Ja
AMMONIA	0.40	0.43	0.46	0.39	0.51	0.38	0.48	0.64	0.55	0.69
NITRATE	0.43	0.49	0.59	0.58	0.51	0.66	0.53	0.82	0.71	0.87
PHOSPHATE	0.38	0.36	0.35	0.27	0.29	0.28	0.33	0.43	0.53	0.53

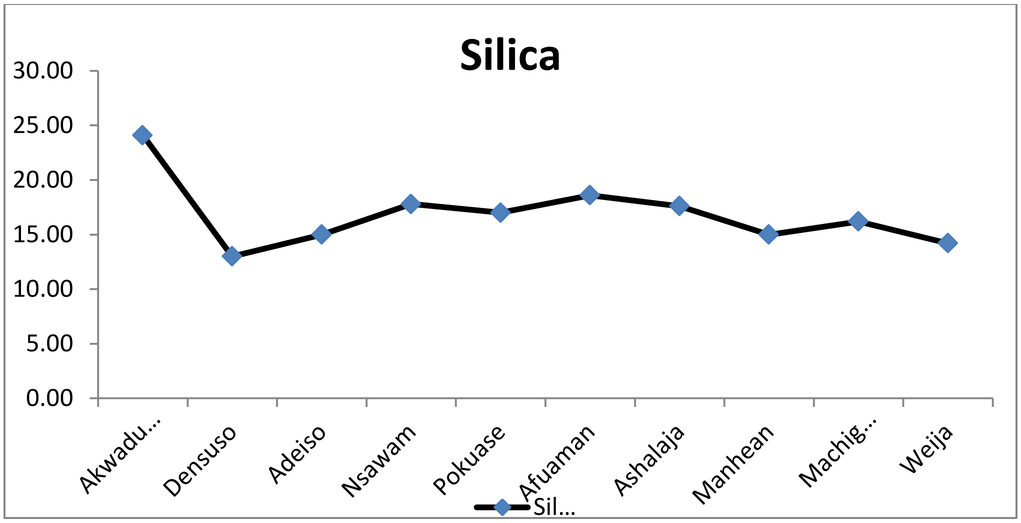

Fig.3: Mean monthly concentrations of Silica (mg l^{-1}) of the water of River Densu and the tributaries Adeiso (Adeiso) and Nsakir (Pokuase) over a sampling period

The pH ranged from 7.21 to 8.57. The ranges of the concentrations of the principal nutrients, in mg l^{-1}, were Ammonia, 0.38 - 0.0.69; Nitrate, 0.43 - 0.87; Phosphate, 0.27- 0.53. Silica concentrations at the ten sampling stations ranged from 13.0 to 24.1 mg l^{-1} (Table 2). The data in Table 2 illustrates the total phytoplankton cell numbers at the ten sampling sites in one year, from January to December.

Table 2: Total Phytoplankton cells per milllitre of the water of River Densu and the tributaries River Adeiso and River Nsakir over 12 months

Month and Taxon	**SAMPLING SITE**									
	Akwa-dum	Den-suso	Adei-so	Nsa-wam	Poku-ase	Afua-man	Asha-laja	Manh-ean	Machi-Geni	Wei-Ja
JANUARY										
Bacillariophyta	63	4	4	8	17	3	4	505	161	270
Chlorophyta	4	17	2	9	6	8	13	746	598	627
Cyanophyta	9	7	10	11	7	5	4	6132	8276	7657
FEBRUARY										
Bacillariophyta	23	3	37	4	8	7	84	101	91	56
Chlorophyta	9	11	12	27	13	12	9	618	473	141
Cyanophyta	4	5	51	12	4	6	5	3206	3937	5702
MARCH										
Bacillariophyta	36	5	9	5	3	4	4	273	76	51
Chlorophyta	9	11	6	12	10	8	6	342	536	182
Cyanophyta	7	3	2	4	3	15	9	3573	3591	4728
APRIL										

Bacillariophyta	40	14	12	17	14	18	7	291	76	234
Chlorophyta	13	4	17	16	15	5	22	559	536	271
Cyanophyta	7	3	4	8	4	6	17	8283	4022	5413
MAY										
Bacillariophyta	12	20	3	21	21	27	6	334	241	225
Chlorophyta	8	9	12	5	1	7	7	564	680	830
Cyanophyta	8	7	7	8	9	6	7	374	3612	4162
JUNE										
Bacillariophyta	40	10	3	5	3	1	3	70	136	148
Chlorophyta	12	8	5	9	11	7	16	168	427	658
Cyanophyta	1	3	9	5	5	5	10	92	1599	3173
JULY										
Bacillariophyta	27	10	20	3	5	10	8	491	705	857
Chlorophyta	28	2	7	5	4	3	3	1688	1803	1937
Cyanophyta	12	6	4	7	3	5	14	2510	3365	3995
AUGUST										
Bacillariophyta	19	7	7	9	3	8	6	55	146	59
Chlorophyta	14	12	9	11	11	6	8	1826	373	394
Cyanophyta	5	4	5	4	8	6	3	2055	1236	751
SEPTEMBER										
Bacillariophyta	22	8	10	11	19	45	11	57	74	92
Chlorophyta	17	1	8	8	11	12	22	315	368	222
Cyanophyta	15	5	5	16	5	42	10	1292	3848	3071
OCTOBER										
Bacillariophyta	33	11	35	9	4	4	4	73	112	69
Chlorophyta	13	10	7	6	9	3	8	189	258	252
Cyanophyta	12	18	7	17	5	10	4	2371	4297	4311
NOVEMBER										
Bacillariophyta	40	17	6	12	5	7	10	601	258	696
Chlorophyta	17	11	7	24	8	12	8	194	272	302
Cyanophyta	12	7	13	5	9	17	22	2491	2935	1528
DECEMBER										
Bacillariophyta	40	5	6	17	4	9	11	534	397	331
Chlorophyta	14	8	22	37	20	15	21	2138	971	543
Cyanophyta	8	9	18	15	16	10	34	1806	2491	1214

The Chlorophyta (green algae) dominated the flora with 23 genera identified. The second largest, the Bacillariophyta (diatoms) was represented by 22 genera, and the smallest number of 12 genera represented the Cyanophyta (blue-green algae). On the other hand, the diatoms constituted the smallest percentage of the total number of cells, and the blue-greens the largest percentage. The algae were generally very low in numbers at seven out of the ten sampling sites. Some genera of these groups were consistent and were encountered throughout the sampling period. These included the blue-green algae; *Anabaena*, *Anacystis* and *Oscillatoria*, the green algae, *Ankistrodesmus*, *Pediastrum*, *Scenedesmus*, and *Ulothrix*; and the diatoms, *Asterionella*, *Cyclotella*, *Fragilaria*, *Navicula* and *Synedra*. The genera varied with the sampling sites. With regards to the diatoms, temperature, pH, ammonia, phosphate and silicon had p-values of less than 0.05. Table 2 shows that the diatoms constituted the smallest percentage of the total number of cells. That also happened over the period of the investigations.

Discussion

Livingstone (1963) concluded that the dominance of diatoms in West African rivers is due to the presence of silica as the most abundant cation. Silica values recorded for River Densu are similar to those reported by Biswas (1968), Egborge (1971) and Rai (1974) for River Volta, Ghana (18.9 mg l^{-1}), River Oshun Nigeria (10.0 - 26.9mg l^{-1}) and River Bandama, Cote d'Ivoire (11.1mg l^{-1}), respectively. The concentration in River Densu and the two tributaries was, therefore, adequate to support growth of diatoms. There was an initial increase in diatoms from May to July 1986followed by a gradual decline to September 1986 and the population thereafter increased steadily to its maximum in mid-December 1986. The chlorophyta were the second most abundant group, constituting 20 per cent of the phytoplankton population (Egborge, 1974). The population of Desmidiaceae increased from October 1968 to February 1969 when they attained a peak of 320 per 0.1 m^3, followed by a decline in numbers from May 1969. The Cyanophyta virtually disappeared from May to September 1968 and then reappeared in October and attained a peak of 165 per 0.1m^3 in February 1969. The desmids and Cyanophyta combined accounted for less than 10 per cent of the phytoplankton population (Egborge, 1974).

The Cyanophyta genera were dominated by *Anabaena*, *Anacytstis* and *Oscillatoria* and the Cholorophyta by *Ankistrodesmus*, *Spirogyra* and *Ulothrix*. These genera contributed substantially to the high numbers of cells of the blue-greens and greens at Manhean, Machigeni and Weija.

Comparing the sizes of the water body at the different sections of River Densu, it is reasonable to conclude that the large size of the water body at Manhean, Machigeni and Weija, and drastic reduction of unidirectional flow led to sudden increase in the density of the phytoplankton algae. Indeed, Machigeni and Weija collecting points were located in Weija Lake, and Manhean sampling point close to the lake and thereby had more standing water than other parts of the rivers.

The physico-chemical factors of the river may have, individually or collectively, also caused the uneven phytoplankton distribution, bearing in mind that it is often impossible to explain changes in algal abundance on the basis of the actions of a single ecological factor.

The mean temperatures of the water of the tributaries of River Densu – 26.1^{0}C for River Adaiso, 28.3^{0}C for River Doblo, 20.5^{0}C for River Kuia and 27.0^{0}C for River Obopeko determined by Akpabli and Drah (2001) – were almost within the range obtained during this work. The water temperature will be expected to remain favorable for phytoplankton growth throughout the year at all locations. Also, their pH range of 7.12 to 8.57 is ideal for phytoplankton growth. Photosynthetic activity of the high algal cell population might have been responsible for the increased values of pH.

Phosphate concentrations along River Densu and the two tributaries also ranged from 0.2 mg l^{-1} 0.5 mg l^{-1} and lower than concentrations of 1.04, 0.6 and 1.185 mg l^{-1} recorded for River Bandama, Cote d' Ivoire (Rai, 1974), River Black Volta, Ghana (Biswas, 1968) and River Niger, Kainji, area, Nigeria (Imevbore and Visser, 1969), respectively. Rivers Densu, Adaiso and Nsakir therefore had sufficient amounts of nitrogen and phosphorus to support phytoplankton growth. On the basis of the concentrations of nitrate and phosphate encountered in Rivers Adaiso and Nsakir at Adeiso and Pokuase, it appears that the tributaries of River Densu do not unduly enrich it.

It is reasonable to expect changes in the concentrations of these nutrients from time to time. The use of different amounts of fertilizers in the catchment area and the oxidation of ammonia will affect the nitrogen and phosphate levels. So the nitrogen supplied to River Densu will partially be derived from fertilizers and that produced by nitrogen-fixing systems in the soil. The four tributaries studied by Akpabli and Drah (2001) showed very high concentrations of phosphate with an average of 3.76 mg l^{-1}. River Kuia and Obopeko registered the highest levels of 6.40 and 6.39 mg l^{-1}, respectively. Their nitrate levels were lower than those of phosphate. The nitrate concentrations of Rivers Adaiso, Doblo, Kuia and Obopeko were 0.14, 0.30, 0.57 and 1.32 mg l^{-1}, respectively. They acquired their nitrate and phosphate loads from agricultural run-offs from the numerous commercial farms along their banks.

Many algae utilize ammonia nitrogen and its presence in River Densu and its two tributaries is valuable. In fact, Moss (1973) in an experimental study, demonstrated that many freshwater algae including *Cosmarium botrytis*, *Haemotococcus droebakensis*, *Pandorina morum Pediastrum duplex*, and *Volvox aureus* grew at the same rate in nitrate and ammonium media. In exceptional cases, some, for example, *Chlamydomonas reinhardii* and *Euglena gracilis* which used ammonium for growth did not grow at all in the nitrate medium.

The Machigeni and Weija sampling sites, located in the Weija Lake, provided quite a different habitat which explains the relatively high concentrations of nutrients. The lake is inhabited by numerous flowering plants and ferns. Decomposition of parts or entire dead plants of the aquatic vegetation will contribute substantial nutrients to the water. Furthermore, the report of Gaudet (1974) that standing macrophytes excrete organic matter into the water can be of consideration.It was not possible during this investigation to analyse the water for all the ions often included in studies of this sort for lack of the requisite chemicals for this extended work.

It can be suggested that factors which control the occurrence of freshwater free-floating algae generally occur in the Weija Lake where the Machigeni and Weija sampling sites were located. One very significant ecological observation of the present investigations was the distribution of the phytoplankton population along the River Densu. Table 3 provides the data to show how the course of the river was demarcated into two very contrasting sections, viz., Akwadum to Ashalaja with very low mean monthly phytoplankton populations and Manhean with very high populations. The massive population of the phytoplankton recorded at Manhean, Machigeni and Weija is a source of feed for fish which is naturally, supplemented by the abundant organic matter of the macrophytes. Indeed, Manhean and Machigeni are important fishing landing sites for the thriving *Tilapia* fishing industry of the inhabitants of the villages in the vicinity of the three sampling sites.

Conclusion

This paper is mainly about the population density and productivity of phytoplankton in River Densu and the tributaries, Rivers Adaiso and Nsakir, as well as the factors that determine the rise and fall of the population. The study has shown that seasonal occurrence is not determined by a single factor, and it was, thus difficult to evaluate the effects of each environmental factor separately. As more knowledge on the physical, chemical and biological factors accumulates, it will be possible to understand the combined effects of the numerous factors. Those aspects which could not be covered in the present studies could be considered for future investigations.

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