SOME ASPECTS OF THE ECOLOGY OF SUSPENDED ALGAE IN TOUR PONDS IN ZARIA (NIGERIA) DURING THE DRY SEASON

BY

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D E C L A R A T I O N

I declare that this work is wholly the author's and has not been part of any presentation for any other qualification.

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THESIS APPROVAL

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DEDICATION

This thesis is dedicated

to

My beloved husband - Finnian Osakpanmwan,

and children -

Caleb Ikpomwosa; Daniel Osazee and Gideon Aisosa.

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ABSTRACT

The ecology of suspended algae in four ponds were investigated during the dry season (November 1986 - March 1987). Two of the ponds, (the Stabilization ponds) received mainly raw sewage influent from the University halls of residence while the other two receive mainly underground water.

Samples collected at monthly intervals were analysed for suspended algal taxa and standing crops and physico-chemical properties which included, temperature, pH, transparency, conductivity, magnesium, potassium, sodium, calcium, dissolved oxygen, Biochemical oxygen demand, dissolved iron, phosphate phosphorus, nitrate nitrogen, silica and alkalinity ponds were compared on the bases of these properties. Physico-chemical properties varied from month to month. There was a general in increase in the concentration of cations possibly due to evaporative concentration. The Kubanni pond had the least concentration of ions generally, though it had the highest level of silica. The Stabilization ponds had the highest concentration of phosphate-phosphorus and nitrate-nitrogen.

The lists of constituent members of suspended algal communities present in the samples are presented along with their abundance, frequency, distribution and biomass. The distribution of algal taxa in the ponds reflects the state of physico-chemical properties and organic enrichment.

On the basis of the magnitude of total biomass of major algal groups, the ponds were compared. The Chlorophyta were the predominant algal group in the By Pass pond, while the Cyanophyta were predominant in the Stabilization ponds. The Bacillariophyta (diatoms) predominated in the Kubanni pond.

The strikingly higher biomass of suspended algae in the Stabilization ponds, portray a higher trophic (organic enrichment) level than the other ponds. The Kubanni pond had the least algale biomass.

Pearson's correlation coefficients of relationship between physico-chemical properties and algal biomass in the ponds are presented and discussed.

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CHAPTER ONE

1.11 INTRODUCTION

The term 'ecology' which is now taken to mean the study of inter-relationships between organisms, or between organisms and their environment was first used in a scientific way by Haeckel (1870). An organisms environment embraces the physical, chemical and biological variables of the habitat.

Freshwater systems are self sustaining ecosystems. They are categorised into two: lotic (running) and lentic (standing) waters. Sometimes these are not readily separable because many running waters have standing water in their system whilst most standing waters receive several running water systems and empty their waters via a single running outflow (Maitland, 1978). The composition of freshwaters is dependent on the geology and nature of the basin of the catchment area.

Algae are normal inhabitants of surface waters. They grow suspended (phytoplankton) or attached to other objects in the water (periphyton) such as stones (epilithon), sand or mud (epipsammon) or other plants (epiphyton). They are primary producers and constitute the base of the food pyramid on which other forms of aquatic life depend. Bowker and Deny (1976) showed that algal communities contribute much to the food chain and production of herbivorous fish in Nyumba ya Mungu reservoir, Tanzania. Fish (1955) andFryer (1961) reported consumption of phytoplankton by Tilapia in Lake Victoria. It shows then that the role of algae

in the development of communities can not be over-emphasized.

Since algae constitute part of a chain of aquatic life, whatever alters the number and kinds of algae, affects all the other organisms including fish. Factors affecting development of algae in an aquatic system are the system's size, shape, depth, amount of shore-lines, character of the bottom, physiography and soils of the water shed, amount and rate of precipitation sunlight and quality of water. Hence the state of a given community results from the actions of these complex environmental physico-chemical factors on the organism which have their own biological rythm and also exert mutual influence on each other (Kawecka, 1980). Fresh-waters among other aquatic systems, offer a distinct advantage in the integration of community inter-relationships in that they provide a relatively simplified ecosystem when considered as individual units.

Studies of community structure have been useful in recognizing how different ecosystems are organized (May, 1976) and have provided insight into the complexities of aquatic communities (Patrick, 1971).

Most investigations of aquatic algal communities in Africa generally, and Nigeria in particular have been limited to large bodies of water. Those on rivers include the works of Brook and Rzoska (1954), Biswas (1968), Egborge (1974), Karim and Saeed (1978), El-Ayouti and Ibrahim (1980) and Sinada and Karim (1984). The orks on lakes include Biswas (1972a, b & c) Adeniji

(1973), Vareschi (1982), Hancock (1979), Hecky and Kling (1986), Kalff (1986), Talling and Talling (1986) while those on reservoirs include Coche (1974), Imevbore (1967), Anyam (1980), Khan and Ejike (1984a and b). In Zaria, the studies available, with respect to freshwater bodies, are those of Adegbenro (1970), Akaahemba (1976), Ndaman (1978), Anyam (1980) Etuk (1984), Abba (1985) and Sule (1985). There is no comprehensive study of algal communities in Zaria ponds.

1.12 Research Objectives

The objectives of this research work are to determine and to compare:

(i) the physico-chemical factors of four selected ponds;

(ii) the occurrence, distribution, and biomass and biomass of suspended algae in the four ponds;

(iii) the relationships between physico-chemical properties and suspended algae in the ponds;

(iv) the level of organic pollution in the ponds, using Biomass and the distribution of "indicator species" as indices.

Also to present a species list in contribution towards a check-list of algae in Zaria ponds.

1.13 Justification

Algae are major food producers of aquatic environments and are fundamental in the food chains which support the fauna of these ecosystems. They also contribute to the production of oxygen which is vital for metabolic and chemical reactions within the system. Certain algae are involved in biological purification

of organically polluted waters(Palmer, 1980). Some are used as pollution indicators, because they are able to flourish in polluted waters even when other species succumb (Palmer, 1980). Therefore a knowledge of their occurrence, distribution and the physico-chemical factors that govern their lives, will give an insight into the complex interations they are involved in. An attempt is therefore made in this investigation, to study these aspects of algal ecology in the aquatic ecosystem, and also to use the occurrence and distribution of pollution'indicator species' to assess the trophic status of the selected ponds.

During the rainy season, the rapid influx of rain water into aquatic systems causes dilution of nutrients (Imevbore 1965, Imevbore and Adegoke 1970, Henderson 1973). Though in situations where such run-offs are loaded with nutrients, rather than dilute, they may increase the nutrient load in the receiving water body (Beadle 1974). Contrarily, the dry season is absolutely free from rainfall and its characteristic low humidity results in high evaporation rate, causing concentration of nutrients in aquatic systems (Green, 1974). The differences between these two seasons are more pronounced in the northern part than in the southern part of Nigeria. Water retention time is higher during the dry season than during the rainy season (Biswas, 1966). This provides enough time for growth of aquatic organism (other conditions being favourable). During the peak of the dry season dust-haze reduces insolation and visibility to less than a $\frac{1}{4}$ km. There are however spells of bright sunny weather (Mortimore, 1970). Hence organisms requiring sunlight could obtain an appreciable exposure to solar radiation.

In addition to the foregone, there is a paucity of information relating to freshwater ecology of suspended algae in Zaria ponds and lack of a comprehensive checklist of the algal flora of Zaria in particular and Nigeria in general. This lack of information on the Zaria algae motivated this study, with a view of contributing to the existing body of knowledge in these respects.

1.14 Research Hypothesis

If there is variation in physico-chemical factors between the ponds then the distribution of the different algal taxa will vary accordingly.

2.1 LITERATURE REVIEW

The ecology of suspended algae is one of the most intensively studied areas of limnology, and many more investigations in this diverse field have been conducted in recent times. (Wetzel, 1964).

In Africa, an appreciable number of investigations on the ecology of freshwater algae, have dealt with the seasonality aspect. The first assessment of phytoplankton seasonality stems from collections made in 1899 by the Fulleburn expedition to Lake Nyasa, and later Lake Malawi. The samples of phytoplankton were analysed quantitatively by Schmidle (1902) who graded the abundance of component species and combined results from various northern stations in his table of seasonality. Although not strictly quantitative, at least one of its features - the marked abundance of the main planktonic diatom, a Melosira sp during the coolest season - was to be of significance in later work (Talling, 1986).

In South Africa, Schuurman (1932) followed plankton periodicity during 1926 - 1928 in a small artificial lake at Johannesburg. Abdin (1948a,b&c) likewise studied seasonal changes in the phytoplankton of the Aswan reservoir (1942-1944) and the Nile near Cairo (1941-1942). Both studies were limited by the use of nets for sampling (net sampling is selective, some important taxa are missed as they may pass through the meshes). Abdin (1948a) (following Pearsall) expressed the results only in terms of relative (percentage) representation of species.

Instead of previous dependence on nets, iodine sedimentation was first used to concentrate cells about 1949 - 51 by Fish (1952, 1957) and Gayral (1954). The former used Utermohl inverted microscope to follow population changes in Lake Victoria as early as 1950.

After 1950, available methods for measuring relevant environmental variables were more widely applied in studies of algal ecology (Talling, 1986). In this respect, physical measurements (e.g temperature, transparency etc) were generally in advance of chemical ones (e.g of algal nutrients). Therefore, possibility for interpretation was advanced by chemical assessments of crop composition (e.g Prowse and Talling, 1958; Viner, 1977).

Quantitative studies of algal population in relation to environmental changes includes the work of Hart and Hart (1977) in Lake Sibaya. In the Aswan Reservoir Abdin (1948c) found that that phytoplankton was subject to wash-out during the flood season. Blue green algae were remarkably sparse, but a variety of green algae (e.g Volvox species, Pediastrum species) were well represented. The information obtained here and at Cairo (Abdin 1948a,b) on seasonal changes in nutrients (nitrates, phosphates, silicon and alkalinity) was apparently the first for any study of phytoplankton seasonality in Africa (Talling, 1986).

Biswas (1969), 1972) recognized the Dry and Wet seasons as periods of most general changes in environmental conditions

influenced by water through-put and disturbance of water layers by harmattan wind. In her studies of two small reservoirs in Kenya that were strongly influenced by increased run-off during the wetter seasons, Lind (1968) points out that the nutrient status of run-off water could be very variable, according to the type of catchment area and that for this reason alone both positive and negative effects on algal growth were possible. In a small reservoir of very low nutrient status in Malawi, the generally low development of phytoplankton was found by Moss ('970) to be related to the small retention time. During the drier season however, retention was apparently long enough to allow an appreciable population of Chlamydomonas species. to develop

In Nigeria (West Africa), the published studies on algal ecology are as follows. Mills (1932) gave a description of some diatoms from the mangrove swamps of Warri. Imevbore (1965) prepared a preliminary check-list of the planktonic organisms of Eleiyele reservoir. He described the hydrology and planktonic algae (Imevbore 1968) of the Eleiyele Reservoir in Western Nigeria. Khan and Ejike (1984a and b) presented some aspects of the limnology and ecology of plankton in Jos Plateau Water Reservoir, Anyam (1980) compared the water chemistry and plankton density of two man-made lakes near Zaria.

In terms of suspended algal ecology, the pond ecosystem is one that has been rather neglected. Most studies have been

concentrated on larger bodies of water such as lakes and reservoirs, as indicated above. There are very few studies that have considered the ecology of suspended algae in ponds in Zaria for example. Akaahemba (1976) surveyed fresh-water algae in the pools around the Lebanon club, and in Samaru stream near Zaria. He observed a limited range of algae in the pools; Chlorophyta and Chrysophyta were the only groups represented. He attributed this to the nutrient status of the water. Oedogonium sp and Ankistrodesmus sp were well distributed but restricted to the Lebanon club pools. Some ponds in Zaria City and the Samaru stream, were investigated for algae, by Ndaman (1978). He observed that the algal communities in both Zaria City ponds and Samaru stream were similar. Navicula spp were found to be common at the pollution outfall, where concentration of nutrients is high. The algae identified were very few. Another survey of algae in polluted waters in Zaria was conducted by Sule (1985). The selected sites were a stagnant pond (the By-Pass Pond), Samaru stream and a gutter. The aim was to survey the algae and relate them to the physico-chemical properties prevailing in these ecosystems. The stagnant pond had the highest number of algal taxa (50). Scenedermus and Navicula were found to be common. The stagnant pond was alkaline but had the lowest conductivity values. This was attributed to the pond receiving underground water while the stream and gutter received domestic wastes with high salt content which gave rise to high conductivity. Phosphate values for the stagnant pond were also the least. The alkaline nature of the stagnant pond, was stated as the reason

for sustaining a more prolific growth of algae. The Palmers index (Palmer, 1980) for pollution determination was applied to the three aquatic systems. The stagnant pond was rated least polluted. These studies of aquatic systems in Zaria have dealt mainly with determining algal taxa present in samples, paying very little attention to physico-chemical properties and variation in the standing crop of algae present in these aquatic systems. Moreover identifications of algae have been done to generic level only, thereby giving a shallow insight into the nature of the composition and distribution of algae in these investigated aquatic systems.

Thus, a more detailed study of at least a few ponds is necessary to give more insight into physico-chemical properties distribution of algae and the relationship between these two sets of variables and to contribute towards a check-list of algae in Zaria aquatic systems.

Physico-chemical properties.

Literature show that there is a connection between the development of algae and the amount of certain mineral substances in the water, a connection based on the fact that an appreciable change is registered in the amount of these substances at times of maximum plankton growth. A clear case of this kind is the relation between abundance of diatoms and the silica content of the water. The diatom maxima follow the maxima in the silica content of the water because the utilization

of this substance by diatoms caused a corresponding decrease in the silica content (Moss, 1981; Sommer and Stabel 1983). Pearsall (1932), as a result of his detailed studies of some English lakes, reported that diatoms were more abundant in silted lakes than in rocky lakes. The silted lakes have more silica in solution than the rocky lakes because more silt in suspension offers greater opportunity for disolution of silica and hence more of this substance will tend to be present in the waters. Green (1975) explained that values of calcium and magnesium decreased during period of high phytoplankton density probably as a result of biological deposition during photosynthesis. Low and undetectable levels of nitrate and phosphate in lakes have been associated with high rate of algal growth (Prowse and Talling; 1958, Bishai 1962; Woodson and Gore 1968; Beadle 1974). Moss (1981) attributed the reduction in phytoplankton during spring to nitrogen depletion. Einsele (1944) found that phosphate added to water disappeared in a few days having been taken up by algae. Moss (1981) reported an increase in phytoplankton density, following an in-flow of phosphorus rich gull excreta from the catchment into the Hickling broad, Norwich.

Alkaline ponds have been found to support more luxuriant growth of algae than acidic ponds (Woodson and Gore 1968).

High dissolved oxygen has been attributed to high phytoplankton activity (Talling, 1957b; Prowse and Talling 1958; Schmidle 1969). Temperature has been shown by Holand (1932) to influence the frequency of diatoms. An increase in density of algae have been shown to occur

with increased illumination (Egborge 1974, Jewson and Taylor 1978). In their studies of the East African Lakes Worthington and Ricardo (1936) observed a relationship between PH and distribution of phytoplankton. Holdway et al. (1978) explained that large volume of algae lead to fast removal of free carbondioxide for photosynthesis thereby causing an increase in pH. On the other hand, the decomposition process has been shown to lower PH, because as decomposition progresses, more carbondioxide results (Talling 1957a).

Plankton distribution has also been found to correlate with values of parameters such as secchi disc transparency, nitrogen and phosphorus concentrations (Tiren, 1974).

Suspended algae

Algae have been sampled for different reasons and for various purposes over a very long period. Originally only a few real plankton algae could be studied and described, due to poor microscopical equipment, but during the nineteenth century, revolutionary advances in microscopy resulted in descriptions of most of the algal genera known at that time (Willen, 1979). The actual sampling of suspended algae is a simple task, but the careful analyses which are necessary, make comprehensive studies very time consuming (Willen, 1979). Evaluation of the number of individuals is appropriate for studies considering population dynamics, diversity and structure of ecosystems (Vollenweider (1974).

Algae populations differ greatly in size, and for this reason cell number does not give a true picture of the actual biomass, therefore the number of individuals of each species must be multiplied by the average cell volume (Vollenweider, 1974). Volume is calculated using the geometric shape that best suits the shape of the species (Kristiansen 1964; Kovala and Larrance 1966; Vollenweider, 1974; Gorham et al. 1974). This gives a fairly good assessment of biomass (standing crop). Before counting can be effectively done, suspended algae must be concentrated. Gorham et al. (1974) used the *sedimentation technique for algae concentration.* He viewed at X100 magnification. They expressed abundance of algae as individuals (colonies or filaments) per ml. Priddle and Happeywood (1983) also used this method in expressing abundance. Both fresh and fixed materials have been used for analyses of algae (Kristiansen 1964).

The knowledge of special ecological demands of individual organisms and groups have led to the use of phytoplankton as indicating the trophic status or quality of the waters (Willen, 1979; Palmer, 1980). Biomass values can be used as basis of a *classification into different trophic levels.* Ranberg (1976) related biomasses of Swedish lakes with their nutrient content. The occurrence of one or several indicator species (without any detailed quantitative analyses) have been used by Kolwitz and Marsson in the saprobic system of classification of aquatic systems (Willen, 1979).

CHAPTER THREE

MATERIALS AND METHODS

3.10 GENERAL DESCRIPTION OF THE INVESTIGATED AREA

3.11 Some Aspects of the Geography and Geology of Zaria

Zaria $11^{o}3'N$, $7^{o}42'E$ is located on a plateau (640.08m) above sea-level in the centre of northern Nigeria and is more than (700 km) from the sea. It possesses a tropical savanna climate with distinct wet and dry seasons. They rainy season lasts seven months from April to October and the dry season lasts five months from November to March.

The Zaria area is on a dissected portion of the Zaria-Kano plains, an extensive peneplain developed on crystalline metamorphic rocks on the Nigerian basement complex. Residual granite inselbergs, the largest of which is Kufena Hill, provide the main relief and there are low quartzite ridges on the west (Mortimore, 1970).

3.12 Type of Soil: Implication for Aquatic Systems

Most of the soil in Zaria contain 30 - 40% of clay and this allows for good moisture retention. The soils are poor and cannot sustain intensive agriculture for long periods without the use of fertilizers (Mortimore, 1970). Fertilizer application to farmlands has its implications on aquatic life. Fertilizers are plant nutrients and are usually added to farmlands in excess of the crop requirements (Anyam, 1980). The excess fertilizers are washed by rain into inland bodies of water either by surface run-offs or through underground seepages (Biggar and Correy, 1969).

Beadle (1974) showed that such run-offs increase the nutrient level of the aquatic system at their destination.

3.13 The Dry Season

The dry season which lasts from late October to March in most years occurs when the dry dusty continental north easterly winds replace the moist south westerlies. In some years the arrival of harmattan wind characteristic of the dry season is very abrupt, it may be experienced before the rains really end. The relative humidity drops from 60 - 65% to between 20 - 25% and dust haze may overcast the sky and reduce visibility to less than a quarter kilometer on some days. However, this dense harmattan dust rarely lasts continuously for more than four or five days even during the peak of the dry season. This season is also characterized by low temperatures especially at night when temperatures may drop below $10^{o}C$ (Mortimore, 1970). The water temperatures at Zaria drops to $18.09^{o}C$ (Anyam, 1980) at this time of the year.

3.14 The Investigated Ponds

Four ponds were selected for this study. Two of the ponds are part of the Ahmadu Bello University Sewage Treatment system, the third is located downstream after the Kubanni Lake. The fourth pond is situated close to a residential area on the Zaria by-pass road. (Plate 1).

3.14.1 The stabilization ponds

The University sewage system consists of a screening tank and three open air stabilization ponds in a set. There are two sets of three ponds each, which work either alternately or simultaneously. Sewage from the residential areas (Hostels) is channelled to a screening tank where grit is removed. From the screening tank, liquid waste, rich in organic matter, is passed into the first stabilization pond where it is retained for two weeks. From here the waste is directed into the second pond and then into the third, each allowed 7 days retention time.

During the retention time biological purification of the organic matter takes place. The water appears green with algal growth (algal bloom) which provides oxygen for aerobic breakdown of the organic matter by bacteria. By the time the water leaves the third stabilization pond, it is considered safe enough to be channelled into the Kubanni stream (Dr Okuofu, Pers. Comm.). The stabilization ponds have a mean depth of about 1.5 m and a surface area of about 10,098 m^2. The shores are bordered by low herbaceous weeds. In this study, water samples were collected from ponds one and three because they represent the initial and final stages of treatment, and should contrast well.

3.14.2 Kubanni pond

The Kubanni stream was dammed in 1973 to form a lake (Kubani lake) which supplies water for domestic use to the University community. After the dam wall downstream, a pond is formed which

is referred to as the Kubanni pond and forms the head of the Kubanni stream after the dam. The pond has a mean depth of about 3 m and a surface area of 2,414 m^2. It is bordered partly by a concrete wall and partly by earth which is overgrown by herbaceous weeds.

The pond has water throughout the year. This is because it is supplied by underground scepages below the dam wall. During the rainy season it has additional supply of water, from the reservoir's spill way and through surface run-offs. The pond water, like that of the main reservoir is turbid throughout the year (Anyam, 1980). The turbidity is probably caused by the particles of ferric compounds resulting from the iron-stones which underlie the soil of the catchment area (Anyam, 1980). Petty fishing and swimming go on in the pond occasionally.

3.14.3 The by-pass pond

The by-pass pond is situated along the Kaduna by-pass highway in Zaria. It is located close to the Kaduna state low-cost Housing Estate near Zaria Hotel. It contains water throughout the year.

It has a mean depth of about 2 m during the wet season and a surface area of 1,561 m^2. It has an underground source of water supply. The water table in this area has been shown to be high (Mortimore 1970). It receives surface run-offs during the rainy season and very little sullage (domestic waste water) from the neighbourhood. Although it receives surface run-off water, during

the rainy season, the pond water is clear for most of the time. This is probably because of the absence of iron clay in the catchment area. Most of the shorelines have herbaceous weeds and includes a dense vegetation of Typha australis Schum & Thonn.

The surface of the pond is partially covered by aquatic macrophytes (especially Nymphea lotus linn. and Pistia stratiotes linn). However, by the peak of the dry season, the density of the macrophytes, reduce considerably. Occasionally, cattle visit the pond for watering.

3.2 SAMPLING

Sampling was done at monthly intervals. Prior to sampling days, polyethylene and glass wares were thoroughly washed with either liquid soap or chromic acid, depending on the analysis to be performed. They were then properly rinsed with distilled water and kept dust free. Values for wind run, sunshine hours and relative humidity for the sampling dates were collected from the Institute for Agricultural Research, Weather Station.

All containers were given a final rinse with the pond water before sample collection. Subsurface water samples (as suggested by APHA 1985 for shallow aquatic systems) were collected at about 30 cm depth, and 1 m away from the shores. Kilner glass jars (Approximately 400 ml capacity) were used to collect samples for algal analysis, dark brown glass bottles (250 ml) for pH, dissolved oxygen (DO) and conductivity determinations. Samples for other chemical determinations were collected and stored in polyethylene

jars (400 ml). Standard Biochemical Oxygen Demand (B.O.D) bottles were used to collect water for B.O.D determination. Samples for chemical and algal analyses were collected from the same location to ensure maximum correlation of findings (APHA, 1985). Based on the assumption that algae are uniformly distributed at the subsurface level of the ponds, single samples were collected by dipping the appropriate container into the water by hand, and allowing it to fill to the brim before removal. After filling, the containers were all tightly stoppered to prevent any gaseous exchange with the atmosphere. They were then duly labelled and placed in subdued light in an insulated cold box containing ice block. The samples were then transported to the laboratory within the shortest possible time for further treatment.

3.21 ANALYSES OF PHYSICO-CHEMICAL PROPERTIES

Temperature

At the sites, shade, air and water temperatures were measured in situ with a mercury thermometer.

Transparency

The transparency of the water was estimated using a 30 cm diameter Secchi disc, with alternating black and white quadrants. It was lowered gently into the water and allowed to sink to a depth where it just disappeared from sight and reappeared. The depth at which this occurred was noted.

pH

The pH of water samples from the ponds was determined in the laboratory with a Pye Model 292 Unicam pH meter, pre-warmed for over 30 minutes and pre-calibrated with standard buffer solutions (pH 4.5, 7 and 9).

Conductivity

The conductivity of the samples was measured with a Hofelt Den Hag CDM3 conductivity Meter corrected to 25°C and of cell constant 0.316 = 1 cm. Values were recorded in umhos/cm.

Dissolved Oxygen and Biochemical Oxygen Demand

Dissolved oxygen determination was conducted with a pre-calibrated YSI Dissolved Oxygen Meter Model 57. (See Appendix 21 for the manufacturers procedure for calibration of the dissolved oxygen meter).

Samples for B O D determination were first analysed for dissolved oxygen. Any sample with low D O was agitated vigorously by hand in a large container for about 20 minutes to increase its D.O level. The agitated water sample was returned to the B O D bottle. The new D.O level was then measured and considered as the initial D.O measurement. The B O D bottles were then covered with aluminium foil and kept in a dark incubator (to prevent the algae from photozynthesizing) set at 20°C for

5 days, at the end of which the samples were again analysed for dissolved oxygen. This is considered the final D.O measurement. The difference between the two dissolved oxygen concentration values gave an estimate of the B O D 5 days of the samples (APHA 1985, modified).

Alkalinity

Alkalinity was determined according to the method of Lind (1974), by titrating 100 ml of an unfiltered water sample with standard 0.02 N sulphuric acid using phenolphthalein and Bromocresol green-Methyl red indicators. Colour change was from light blue to light pink.

Total alkilinity was calculated using the formula:

$$\left.\begin{matrix} mgCaCo_3 \text{ per litre} \\ \text{Total alkalinity} \end{matrix}\right\} = \frac{B \times N \times 50{,}000}{ml \text{ sample}} = \frac{B \times 1{,}000}{100} = B \times 10$$

where:

B = Volume of titrant from start to

PH 4.5 Bromocresol green/Methyl red end point.

N = Normality of the acid.

Reagent preparation

Phenolphthalein indicator solution was prepared by dissolving 0.5 g phenolphthalein in 50 ml of 95% ethyl alcohol.

50 ml distilled water was then added, mixed and then weak sodium hydroxide solution was added dropwise until a faint pink colour appeared.

To prepare a stock sulphuric acid solution, 3 ml of concentrated H_2SO_4 was diluted to I litre giving an approximately 0.I N solution.

Standard sulphuric acid solution was prepared by making 200 ml of 0.1 N stock solution up to 1,000 ml with distilled water to give 0.02 N solution. Standardized against Na_2CO_3.

Methyl red/Bromocresol green indicator solution was obtained by dissolving 0.02 g of methyl red, and 0.I0 g bromocresol green in 100 ml of 95% alcohol (Lind, 1974).

Soluble Nutrients

Samples for determination of soluble nutrients were filtered using double Whatman filter paper in a Buckner suction filtration apparatus. Where analyses of samples were to be delayed, they were refrigerated/frozen and allowed to thaw properly to room temperature before analysis. Refrigeration/Freezing retard further chemical changes in the samples (Lind, 1974; Vincent, 1983 and APHA, 1985).

Cations

Cations were analysed using a Pye Unicam Atomic Absorption Spectro-photometer. The absorbance technique was used for Calcium, Magnesium and Iron, and the emission technique for Sodium and Potassium (APHA 1985). Iron was also determined using the Parkin Elemer Atomic Absorption Spectrophotometer since it was not detectable with the Pye Unicam Atomic Absorption Spectrophotometer.

Orthophosphate (Phosphate-Phosphorus)

The orthophosphate analysis procedure described by Lind (1974) was adopted for this determination.

One drop of phenolphthalein indicator was added to a 50 ml sample. When a pink colour appeared, strong acid solution was added, dropwise until the colour disappeared. Not more than 5 drops of acid were added. 8.0 ml of'mixed reagent' was then added to the sample and mixed thoroughly. After 10 minutes, the absorbance of each sample was measured at 880 or 690 nm in a Bausch and Lomb Spectromic 20 spectrophotometer, using the reagent blank as the reference solution. The reagent blank and the sample were subjected to the same procedure. Contamination at any step of the procedure showed up as a blue colouration in the blank. The concentration of phosphorus in each sample was determined from a standard phosphorus calibration curve.

$$mg\ Phosphorus\ L^{-1} = \frac{mg\ Phosphorus\ from\ curve \times 1{,}000}{ml\ sample}$$

Reagent preparation (phosphate phosphorus)

Distilled water stored in a polyethylene container was used for all reagent blands. The phenolphthalein indicator

used in this analysis was the same as that for alkalinity determination.

Sulphuric acid solution was prepared by adding 7 ml concentrated sulphuric acid to distilled water and making this up to 50 ml. Ammonium molybdate reagent was prepared by dissolving 40 g $(NH_4)_6\ MO_7O_{24}\cdot\ 4H_{20}$ in 100 ml of distilled water. This was refrigerated in a polyethylene bottle. Potassium antimonyltartrate was prepared by dissolving 1.3715 g potassium antimonyl tartrate $(K\ (SbO)\ C_4\ H_4\ O_6\ .\ 0.5\ H_2O)$ in 400 ml of distilled water, and made up to 500 ml in a volumetric flask, and stored in a polyethylene bottle in a refrigerator. Ascorbic acid solution was obtained by dissolving 1.76 g of ascorbic acid in 100 ml distilled water. This was stored by freezing in a polyethylene bottle. Strong acid solution was prepared by adding 30 ml concentrated sulphuric acid slowly to 60 ml distilled water. Mixed reagent was prepared by adding 5 ml potassium antimonyl tartrate solution to 50 ml of the sulphuric acid solution and mixed. 15 ml of the ammonium molybdate solution was then added and mixed. 30 ml ascorbic acid solution was also added and mixed. This reagent was prepared fresh for each set of analyses.

To prepare stock phosphorus solution, where 1.00 ml contains 0.05 mg phosphorus, 0.2197 g potassium dihydrogen phosphate (KH_2PO_4) oven-dried at 105^oC for 1 hour, was dissolved in distilled water, and made upto 1.0 litre and 1ml chloroform was added as preservative. The solution was stored in the dark under refrigeration. This

solution can remain stable for several months (Lind 1974) Standard phosphorus solution (1.00 ml = 0.5 ug phosphorus) was prepared from the stock phosphorus solution by diluting 10.0 ml to 1.0 l with distilled water.

Standard Curve for Phosphorus

Standard phosphorus solution (1.00 ml = 0.5 ug P) was diluted as follows:

ml of standard solution made up to 50 ml with distilled water	Phosphorus concentration ug L^{-1}
0.5	5
1.0	10
3.0	30
5.0	50
10.0	100

The absorbance values obtained were used to plot a standard phosphorus curve.

Nitrate-Nitrogen

The phenoldisulphonic acid method (APHA 1966) was used for the determination of Nitrate-nitrogen concentration in the water samples /using steel crucibles. 100 ml of water sample was evaporated to dryness on a water bath, and 2.0 ml of phenoldisulphonic acid were added to

the residue and allowed to stay for 10 minutes. Then 10 - 15 ml of distilled water followed by 5 ml strnng ammonium solution were added. The yellow mixture was stirred and allowed to cool. Absorbance was measured at 410 nm with a Bausch and Lomb Spectronic 20 spectrophotometer, using distilled water as a blank. The concentration of nitrate-nitrogen was read from the calibration curve.

Preparation of a standard curve for Nitrate-Nitrogen

Stock nitrate solution was prepared by dissolving 0.7218 g anhydrous potassium nitrate (KNO_3) in distilled water and making this up to 1,000 ml. This solution contains 100 mg L^{-1} nitrogen. Standard nitrate solution was prepared from the stock nitrate solution by evaporating 50 ml of the stock nitrate solution to dryness on a hot water bath. The residue was dissolved with 2.0 ml phenoldisulphonic acid reagent and diluted to 500 ml, with distilled water (1.00 ml = 10.0 ug nitrogen).

For the standard nitrate-nitrogen curve, standard nitrate solution was diluted to give a range of 0.0 - 10.0 mg L^{-1} nitrogen. This range was achieved by making 0, 5, 15, 25, 35, 50, 75 and 100 ml of standard nitrate solution up to 100 ml with distilled water. This gave the following concentrations respectively 0, 0.5, 1.5, 2.5, 3.5, 5.0, 7.5 and 10.0 mgl^{-1}. These standards were run in the spectronic 20, and values obtained, used in plotting the curve.

The concentration of nitrate-nitrogen in the samples was calculated thus:

$$mg\ L^{-1}\ nitrate\text{-}nitrogen = \frac{mg\ nitrate\text{-}nitrogen\ from\ curve \times 1000}{ml\ sample}$$

Silica

Silica concentration in each sample was determined according to the method described by Lind (1974). In this procedure both phosphorus and silica react with molybdate to form acids. However, the addition of oxalic acid destroys the molybdophosphoric acid, leaving only the molybdosilicic acid, which produces a yellow colour proportional in intensity to the concentration of silica. The reagent blanks were also run through the same procedures, including filtration, so as to compensate for any contamination.

To a 50 ml filtered sample, 1.0 ml 1 + 1 V/V HCl and 2.0 ml ammonium molybdate reagents were added in rapid succession and mixed by swirling. After standing for 5 - 10 minutes, 1.5 ml oxalic acid solution was added and swirled. After 2 minutes, 2.0 ml of reducing agent was added and mixed. The blue colour developed after 5 minutes was measured using 1-cm matched tubes with a spectronic 20 set at 650 nm. Silica concentration was then determined from a standard curve prepared from dilutions of silica standard solution (1.00 ml = 10.0 ug $Si0_2$). Silica concentration was calculated using the formula:

$$mg\ L^{-1}\ Si0_2 = \frac{mgSi0_2\ from\ standard\ curve \times 1{,}000}{ml\ sample.}$$

Preparation of Reagents

Hydrochloric acid 1+1 V/V was prepared by adding and mixing equal volumes of concentrated hydrochloric acid and deionized water.

Ammonium molybdate, solution was obtained by dissolving 5 g of ammonium molybdate ($(NH_4)_6\ MO_{24}\ 4H_2O$) in deionized water warming slowly and then diluting to 50 ml. The PH of this solution was adjusted to 7 - 8 using ammonium hydroxide solution. The solution was stored in polyethylene bottles.

Oxalic acid solution was prepared by adding 5 g of Oxalic acid ($H_2C_2O_4.2H_2O$) to deionized water and diluting to 50 ml.

Reducing agent was prepared by dissolving 0.5 g of 1-amino-2-naphthol-4-sulphonic acid and 1g anhydrous sodium sulphite (Na_2SO_3) in 50 ml distilled water. This was added to a solution of 30 g sodium bisulphite ($NaHSO_3$) dissolved in 150 ml distilled water. The mixture was filtered into a polyethylene bottle and then stored in a refrigerator. When this reagent became dark coloured, it was discarded for a fresh one.

Stock silica solution was prepared by dissolving 4.73 g of sodium metasilicate pentahydrate, $(Na_2Si)_3.5H_2O$) in recently boiled and cooled distilled water and diluted to 1,000 ml. This contained 1,000 mg L^{-1} SiO_2. The stock solution was stored in a tightly stoppered plastic bottle.

From the stock, standard silica solution was prepared by diluting 10 ml to 1,000 ml with recently boiled and cooled distilled water. This solution contained approximately 10.0 mg L^{-1} SiO_2 or 1.00 ml = 10.0 SiO_2 (0.010 mg SiO_2).

Preparation of a standard curve for silica

0, 5, 15, 25, 35, 50, 75 and 100 ml of standard silica solution were diluted to 100 ml. The silica concentration of which is 0, 0.05, 0.15, 0.25, 0.35, 0.50, 0.75 and 1.00 mg respectively. Their absorbances were measured with the spectronic 20 and values plotted on a graph to give a standard silica curve.

3.22 Analyses of algae

Enumeration of algae in natural water bodies is difficult except samples are concentrated. Sedimentation is a preferred method of concentration because it is non-selective (as would be the result with filtration) and non-destructive (as would result from centrifuging) (APHA, 1985). Samples for analyses of algae were treated with Lugol's solution (iodine with acetic acid) which incidentally is the best algal preservative yet known (Vollenweider, 1974). It was added to the sample in the ratio 1:100 part of sample. The solution stains chromatophores and pyrenoids of algal cells and shows flagella and cilia well thereby facilitating counting and identification. It also increased the weight of the algae which aids sedimentation. The rate of sedimentation depends on the height of the water sample column. In this case, the Kilner (400 ml) jars used were low, about 8 cm in height. Hence, sedimentation was fast. However, analyses of algae in the samples were reserved till 2 - 3 weeks later when it was convenient, especially when chemical analyses had been completed.

The preserved and sedimented samples were concentrated by carefully decanting a known volume of the supernatant and shaking the concentrate (also of known volume). An aliquot of 1 ml was withdrawn by quick suction with a wide bore dropping pipette and introduced into a Sedgewick rafter counting chamber quickly, to prevent uneven settlement of algae, through one of two openings formed by a diagonally placed cover slip. As the sample enters through one opening, air escapes through the other, facilitating spreading. On filling, the cover slip gyrates to cover the chamber. Care was taken to exclude bubbles. With quick introduction of sample, the distribution of algae within the chamber is considered fairly homogenous (Vollenweider, 1974). The Sedgewick rafter counting cell chamber is of 1 ml capacity with a dimension of 20 mm x 50 mm base x 1 mm height = 1000 mm^3 volume. The base of the rafter cell is divided into 1,000 tiny squares (1 x 1 mm) each of which constitutes a field of view at x 100 magnification on a Wild M40 inverted microscope.

3.23 Qualitative/Quantitative Analyses

The Sedgewick rafter counting cell was inverted for about 5 - 10 min, to allow algae settle on the cover slip. The inverted rafter cell was then placed on the inverted microscope and the general view of the distribution of algae within the rafter cell noted. A practical knowledge of characteristic features of some algal taxa gained from a pilot study conducted a month before sampling, aided recognition of some of the taxa present. The Algae present in ten fields of view (each from a transect) from each sample, were drawn and their dimensions taken, with the aid of the calibrated eye-piece graticule. As each algal cell was encountered

in a field of view at x 100, magnification was changed to x 400 for proper viewing of its characteristic features.

Diatoms are best identified using frustule characteristics. For this it is necessary to clear them of organic matter which is done through acid digestion. One ml of sample concentrate was taken in a test tube. To this, 1 ml of concentrated sulphuric acid was added and shaken. The solution became hot due to the reaction of acid and water (no heating was necessary) Patrick and Reimer (1966). After 5 minutes, 2 ml of a saturated solution of potassium permanganate was added slowly because it could cause vigorous effervescence. The mixture turned brown or purple and was allowed to settle and then shaken to assist mixing. After 5 minutes, 2 ml of a saturated solution of oxalic acid was added. This caused profuse bubbling. The oxalic acid reduced the purple or brown coloured solution to a clear solution, bleaching the Frustules white. The solution was centrifuged at 4,000 p.p.m for 5 minutes, to sediment the frustules. The supernatant was poured out to waste. The residue was resuspended in tap water and then centrifuged, to wash the frustules. Three washings were made, to reduce the acidity of the residue to neutral. Alcohol was added after the final washing, after most of the water had been decanted. Some drops of the diatom suspension were evaporated on a hot cover slip, heated on an electric hot plate adjusted to low heat. A drop or two of the high refractive diatom mounting medium (Hephrax) was placed at the centre of a microscope slide and the frustule containing cover slip was inverted over the mountant and heated on the electric hot plate. Some bubbles were formed, which disappeared on cooling The slide was then removed from the hot plate. On cooling, hard permanent mount of clear diatom frustules was obtained. The slides were then

viewed on the inverted microscope. Since the contents of the diatoms had been digested, the markings on the frustules were clear and identification could be done readily.

Identification of the algae was done with the following literature: Desikachary (1959), Patrick and Reimer Volumes 1 and 2 (1966), Haughey (1968), Weber (1971), Lind (1971), Prescott (1975), Watanabe (1977), Cassie and Freeman (1980), and Cassie (1983). Unidentifiable specimens were recorded as such. In addition to drawing, microphotographs of some of the algae were taken. Only one preparation from each sample was analysed. It is regretted that a statistically high level of accuracy could not be achieved. The number also of each kind of algae encountered in the rafter squares was recorded. Empty cells were ignored since they were considered dead. Counts were made as unit or clump-count i.e an algal entity was recorded as one, irrespective of being unicellular, filamentous or colonial. For cells traversing the margins of the squares, those on the upper and right margins were counted while those on the lower and left margins were ignored. To obtain counts of organisms per litre of pond water (population density, Calculation was as follows:

$$\text{Organism per litre of pond water} = \frac{\text{organism ml}^{-1} \text{ of concentrate} \times 1000}{\text{concentration factor.}}$$

where

$$\text{Concentration factor} = \frac{\text{Volume of pond water sedimented}}{\text{Volume of concentrate.}}$$

$$\text{Organisms ml}^{-1} \text{ of concentrate} = \text{organism per square} \times 1{,}000 \text{ squares.}$$

Using the formula of the geometric shape that best suits the alga, algal volumes were calculated (Cylinder: $\pi r^2 h$, Cone: altitude (πr^2), Cube: length x breadth x height, Sphere: $\frac{4}{3}\pi r^3$, (Kovala and Larrance 1966; Vincent 1983).

Algal biomass was computed by multiplying the volume, thus obtained by the number (population density) of the particular algae present in a litre of pond water (Vollenweider 1974; De Seve and Goldstein, 1981). This value gave an idea of the standing crop of algae at a given time. This method of biomass determination was preferred because fresh weight method does not give accurate estimate of biomass because of the variable amount of water in plant materials. Also, the dry organic weight method over estimates biomass because of inclusions of bacteria, and fungi matter (Vollenweider, 1974).

3.24 Abundance

Abundance of algae was calculated by dividing the total number of a particular alga by the number of fields of occurrence, and computing the abundance per litre from this by simple multiplication (Oosting, 1958). In this study, for the purpose of determining the most widely distributed taxa, abundance values greater than 1 were considered high. Values of 1 were regarded as low.

3.25 Percentage frequency

The percentage frequency was obtained by dividing the number of fields of occurrence by ten (ten fields of view were analysed qualitatively) and multiplying by hundred. Frequency values were classified thus: 10-30 low; 40-60 moderate; 70-100 high. Abundance along with frequency have been shown (Oosting 1958) to give an idea of the distribution pattern of plants.

Those algae that recorded both high abundace and moderate/high frequency values were considered most widely distributed.

3.26 Biomass

Biomass values and "indicator species" occurrence (Palmer, 1980) See appendix 22 were used to assess and compare the trophic status of the ponds. The Kruskal Wallis non-parametric ANOVA statistic was used to analyse the variation between monthly biomass values in the ponds, while the Pearson's rank correlation statistic was used to determine the relationship between physico-chemical factors and algal biomass in each of the ponds. Both analyses were done at 95% confidence limit with a main frame Cyber 72 Computer.

CHAPTER FOUR

RESULTS

4.1 PHYSICO-CHEMICAL PROPERTIES

Values for wind run, sunshine hours and relative humidity, prevalent during the study period are shown on Table 1. The North East (N.E.) dry harmattan wind dominated from December 1986 to February 1987, with the highest run occurring in December. Sunshine hours mean per week varied from 7.7 (December) to 9.8 (February). December and February had lower relative humidity values than January and March. There was no rain during this period (IAR, 1986/87).

There were marked differences between air and water temperatures (Table 2 and Fig. I). Water temperature was lowest in December and January in all the ponds, while air temperature was lowest in January mainly.

The values of secchi disc transparency in the ponds are shown on Table 2 and Fig. 2). The highest light penetration was recorded in the By-pass pond (127 cm) in December. The Kubanni pond was next with very slight variation in transparency (63 - 74 cm). The lowest transparency values were from the stabilization ponds. (2.6 - 22cm).

PH (Table 2 and Fig. 3) showed little variation during the study period. The highest values were observed in the stabilization ponds with stabilization pond three topping at PH 10.10-11.10; the least values were from the Kubanni pond (PH 6.65-7.43).

Conductivity (Table 2 and Fig. 4) showed a general increase from November to March. The By-Pass pond had the highest conductivity (410-840 umhos/cm) while Kubanni pond had the least values (182-318 umhos/cm). The conductivity values of the stabilization ponds were between these.

The variation in the concentration of dissolved oxygen is shown in Table 2 and Fig. 5. It lacked consistency. Dissolved oxygen was highest in stabilization pond three. Variation is more marked in the stabilization ponds than in By-Pass and Kubanni ponds.

Figure 6 shows the variations in the Biochemical Oxygen Demand. Values for the stabilization ponds were generally higher than those for the By-Pass and Kubanni ponds.

There was a general increase in concentration of cations during the period. Calcium concentration was highest in Kubanni pond. The highest concentrations of magnesium (Table 2 and Fig. 8) were recorded from the Kubanni pond, followed by the By-Pass pond. Stabilization Pond One was next while stabilization pond three had the least values. Sodium concentration (Table 2 and Fig. 9) was highest in the By-Pass pond and lowest in Kubanni pond.

Figure 10 and Table 2 show variation in potassium concentration during the study period. Potassium concentration was lowest in the ponds in November and highest in January. For the By-Pass and stabilization ponds, the concentrations dropped in February.

in the stabilization ponds (Fig 11 and Table 2).

Values for Nitrate-Nitrogen concentrations are shown in Table 2 and Fig. 12. Concentrations of Nitrate-Nitrogen were higher than those of Phosphate-phosphorus. The stabilization ponds had higher concentration of Nitrate-Nitrogen than the other ponds.

Generally, Silica concentrations in the ponds were high in November and January. Lowest values were recorded in March (Fig. 13 and Table 2). The Kubanni pond had the highest concentration followed by stabilization ponds one and three respectively and the By-Pass pond had the least values.

The trend in alkalinity in the ponds (Fig. 14 and Table 2) followed a similar pattern to conductivity, except that instead of a further rise in concentration in March, there was a drop. The By-Pass pond had the highest alkalinity followed by Kubanni and then the stabilization ponds.

Iron was not detectable in any sample using the Pye Unicam Atomic Absorption Spectrophotometer. With the Parkin Elmer Atomic Absorption Spectrophotometer dissolved iron was present in traces in the Bye-Pass pond (March) and Stabilization Pond Three, December and January, otherwise it was not detectable (Table 2).

4.2 SUSPENDED ALGAE

The biomass of suspended algae in the ponds is graphically presented in Figure 15. Stabilization pond one had a strikingly higher algal biomass than the rest of the ponds. The Kubanni pond had the least values. Peaks in algal biomass occurred variously during the study period.

Most of the major groups of algae were represented in the ponds although only the Chlorophyta, Cyanophyta and Bacillariophyta were fairly constantly present in each sample. Others were either sparse or absent altogether (Table 3). The Chrysophyta, Euglenophyta and Pyrrophyta were almost exclusively restricted to the By-Pass pond, during the period of study.

4.21 Biomass

The order of magnitude of thetotal biomass of major algal groups in the ponds (Table 3) were as follows:

By-Pass pond: Chlorophyta> Bacillariophyta> Cyanophyta> Euglenophyta> Pyrrophyta> Chrysophyta.

Stabilization pond one: Cyanophyta> Chlorophyta> Bacillariophyta.

Stabilization pond three: Cyanophyta> Chlorophyta> Bacillariophyta> Pyrrophyta.

Kubanni pond: Bacillariophyta> Cyanophyta> Chlorophyta> Euglenophyta> Chrysophyta> Pyrrophyta.

4.22 Distribution of algae

The list of constutuent members of suspended algal communities occurring in samples from the ponds is presented in appendices 1 - 20. Data on number (Units L^{-1}), Individual volume ($\mu m^3 L^{-1}$), Biomass ($mm^3 L^{-1}$), Abundance and frequency (%) are tabulated along with the list.

Abundance and Frequency when considered alongside each other give an idea of the distribution pattern of plants (Oosting, 1958). On this basis then, those species thatwere both highly frequent and abundantwere considered more widely distributed than the others.

Hence, of the communities of algae flourishing in the By-Pass pond, the most widely distributed species were:- (November) - Ankistrodesumus falcatus var acicularis (A. Braun) G.S. West, Euglena sp, Navicula exigua (Gay) Mull and Cyclotella striata (kg) Grun (Appendix 1).

(December): Spirulina major Kuetzing, Oscillatoria anguitissima West and West, Navicula pupula kg, Nitzschia paleace Grun, Cyclotella striata (kg) Grun, Nitzschia amphibia Grun, Nitzschia kutzingiana Hilse, and Navicula cryptocephala (Appendix 5)

(January): Stichococcus bacillaris Nagelli, Trachelomonas pulcherrima var, minor Playfair and an unidentified unicell (157) (Appendix 9).

(February): Coelastrum sphaericum Nageli (Appendix 13)

(March): Ankistrodesmus falcatus var mirabilis (West & West) G.S West, Coelastrum sp chlorella sp Ankistrodesmus gracilis Korshikov, Kirchneriella sp and Crucigenia rectangularis (A. Braun) Gay (Appendix 17).

For stabilization pond one, the most widely distributed species were: November): Microcystis aeruginosa Kutz. (Appendix 2)
(December): Arthrospira sp, Microcystis flos-aquae and Microcystis aeruginosa Kutz. (Appendix 6).
(January): Microcystis aeruginosa Kutz (Appendix 10).
(February): Microcystis aeruginosa Kutz. (Appendix 14).
(March): Microcystis aeruginosa Kutz (Appendix 18).

The most widely distributed species of suspended algae in stabilization pond three were as follows:- (November): Stichococcus

bacillaris Nageli, Micractinum sp. Chlorococcum sp and Microcystis aeruginosa Kutz (Appendix 3).

(December): Microcystis floss-aquae, Microcystis aeruginosa Kutz (Appendix 7).

(January): Microcystic aeruginosa Kutz and Micractinum quadrisetum (Appendix 11).

(February): Micractinum quadrisetum and an unidentified unicell (262) (Appendix 15).

(March): Microcystis aeruginosa Kutz (Appendix 19).

In the Kubanni pond, the most widely distributed species were:- (November): Ankistrodesmus falcatus (Corda) Ralfs, Closterium ehrenbergii Menegh, Aphanocapsa endophytica G.M. Smith, Oscillatoria formosa Bory, Trachelomonas volvocina. Ehrenberg, Navicula radiosa kg. Navicula viridula kg, Fragilaria brevistriata, Cyclotella striata (kg) Grun (Appendix 4).

(December): Nitzschia sp, Nitzschia philippinarum Hust, Nitzschia amphibia Grun and Nitzshia kutzingiana (Hilse (Appendix 8).

(January): The species were almost equally represented in the population (Appendix 12).

(February): Gleocapsa querternata (Breb) Kutz (Appendix 16).

(March): Chlorosphaera lacustris Snow and Aphanocapsa musicola Menegh (Appendix 20). The order of magnitude of the percentages of indicator species, among the widely distributed species is:- Stabilization Pone One (100%) Stabilization Pond Three (54%) By-Pass pond (50%) Kubanni pond (38%).

4.23 Correlation between physico-chemical factors and biomass

Pearson's correlation coefficients of relationship between physico-chemical factors and algal biomass is tabulated in Table 5. The biomass of algae in the By-Pass pond correlates significantly with Dissolved Oxygen alkalinity, BOD, PH and potassium, in a descending order.

In stabilization pond one, pH, BOD, Temperature, D.O and Silica were more related to algal biomass than the other physico-chemical factors determined. In stabilization pond three, pH, D.O, Silica,conductivity and temperature were more related to biomass than other factors.

Conductivity, Magnesium, Potassium, Sodium, pH, Nitrate-Nitrogen Transparency, Silica, D.O and BOD were more related to biomass than the other physico-chemical factors in the Kubanni pond.

CHAPTER FIVE

5. DISCUSSION

Available published information on algal studies in ponds, are too sparse to be of a concrete background against which to compare the present findings. Consequently discussion on some of the results of this investigation had to be related to,or explained in the light of observations made by other workers on lake ecosystems. This is justified by studies conducted by Rao (1953) on a group of six small ponds which showed that "patterns in small pools and ponds are similar to what obtains in large aquatic systems like lakes."

5.1 Physico-chemical Properties

The slight differences in water temperatures between ponds on the same sampling date was probably due to diurnal variation in temperature. Sampling usually started in the morning and ended after mid-day, by which time some ponds would already have increased in temperature due to solar radiation. Such spatial variation in temperature between ponds was however low, compared to temporal variation during the sampling period. Diurnal or seasonal variation in temperature is considered as affecting the metabolism and activities of aquatic species and other chemical reaction taking place in the water (Reid, 1976). The monthly variation in temperature (Fig. 1) was quite marked and may have been partially responsible for the temporal variation in the distribution of algae in the ponds. Howland (1932) noted that diatom frequency was influenced by temperature. The highest biomass of diatoms (Bacillariophyceae) in the ponds (except Kubanni) were recorded

during the coldest month (January). The minimum temperature recorded was 14.5^{o}C which is higher than the 10 - 12^{o}C considered by Bioret (1929) to be the lower critical limit for production in temperate regions. Temperature therefore, was not critical in the ponds during the study period.

Increased temperature enhances evaporation which leads to concentration of ions in waters. But the evaporative concentration of ions observed in the ponds is attributable to a combined effect of increased temperature and the low relative humidity (Table 1) characteristic of the dry season.

The effect of light is closely related with temperature. Light intensity increases with solar radiation. When this happens water is heated up. The extent to which light is able to penetrate water determines the euphotic zone. Seasonal variation in climate may affect light penetration of both atmosphere and water. The harmattan dust haze of the dry season reduces incoming radiation and helps to reduce light penetration of water (Anyam, 1980). However, the dust haze occurs occasionally, rarely lasting for over 5 days. (Mortimore, 1970). The nature of the dissolved and suspended materials are factors which also affect light penetration of water.

Transparency in the By-Pass pond was generally higher than values for the other ponds possibly because the sandy nature of its

basin (personal observation) does not necessitate suspension of silt in the water. Sand grains are larger and weightier than silt and so they settle out fast. Furthermore, the suspended algae in the pond was not as dense as to make the water turbid. This relative clearness of the By-Pass pond had strong relation with the relatively high diversity of algal taxa found in it. Dykyjova and Kvet (1978), Jewson and Taylor (1978) associated diversity of algal taxa with transparency because of increased opportunity and rate of photosynthesis for the algae. In the stabilization ponds, low transparency values (turbidity) was due to high density of algal growth (Bloom) resulting from nutrient enrichment of sewage. The limited light penetration resulting from turbidity may have retarded photosynthesis and consequently the development of other algae (Jewson and Taylor 1978, Dykyjova and Kvet 1978) thereby causing their elimination. Transparency values for the Kubanni pond were the least. The basin of the Kubanni pond consist of clayey ironstone (Ologe, 1973) which releases fine silt particles into the water. This suspension of fine silt made the water turbid. The biomass and diversity of algal taxa in the Kubanni pond were low compared to the By-Pass pond because of low light penetration caused by the fine silt.

pH is one of the factors considered as affecting the distribution of algae in water bodies. It generally rises with increasing carbonate and bicarbonate ions, though it may be locally depressed by

the accumulation of carbon dioxide and raised by its active removal in photosynthesis (Reid, 1961; Mabaye 1972; Talling and Talling 1965). The PH values of the By-Pass and the stabilization ponds signify alkalinity while those of the Kubanni pond portray slight acidity (Table 2). Algal distribution have been found to relate with alkalinity/acidity of aquatic systems. Significant relationship existed between PH and algal biomass in all the ponds (page 85). Worthington and Ricardo (1936) observed a relationship between PH and distribution of phytoplankton in some East African lakes. Woodson and Gore, (1968) working on two small ponds in Chesterfield Virginia, found that population of algae in the acidic pond was less dense than in an alkaline one.

The high algal biomass in the stabilization and By-Pass ponds (Table 4) may have had effect on the PH of the pond water. Since photosynthesis of such large volume of algae would lead to increased free carbondioxide withdrawal, thereby increasing the PH of the water (Mara 1976; Holdway et al. 1978).

In water bodies conductivity is usually roughly proportional to the concentration of dissolved solids (Le Cren and Mc Connell 1980). Therefore increasing conductivity values as were observed in all the ponds, were likely to be the result of increasing concentration of dissolved matter. The low relative humidity

with high rate of evaporation may have caused evaporative concentration of ions in the water (Green, 1975). Another causal factor may be increasing mineralization resulting from decomposing materials in the water (Talling 1957a). A significant correlation was established between conductivity and algal biomass in stabilization pond three and Kubanni pond (Table 5), though the relationship was stronger in the Kubanni pond. This is understandable since algae depend on dissolved ions for development. Where there is low ionic composition (low conductivity) there would be a correspondingly low algal biomass.

Oxygen is well known to influence the biological activities of an aquatic system (Woodson and Gore, 1968). The aerobic organisms in the system require oxygen for respiration. Oxygen is also used up in the decomposition process (Talling, 1957b). Oxygen from the atmosphere dissolves in water and this is influenced by temperature and wind (Reid, 1976). Aquatic plants also contribute towards dissolved oxygen concentration through photosynthesis, therefore, where there is a high standing crop (biomass) of algae, there would be a corresponding high level of dissolved oxygen. This is supported by findings in this study, both standing crop of algae and dissolved oxygen were higher in the stabilization ponds than in the By-Pass and Kubanni ponds respectively. The

positive correlation values for dissolved oxygen and algal biomass were significant in all the ponds.

Higher values of biochemical oxygen demand were recorded from the stabilization ponds which apparently received higher loading of organic materials (from sewage), than the other ponds. The biological/chemical decomposition of these organic materials result in high oxygen demand. Algae and bacteria are implicated in the mineralization of this waste organic matter into more stable and useable substances which are unobjectionable when discharged into other bodies of water (Mara 1976, Palmer 1980). The mineralization of the organic matter by bacteria is more efficient by aerobic process which demands for high oxygen supply. Thus the higher the organic content, the higher the biochemical oxygen demand as exemplified in this study. There was marked difference between B O D values of the stabilization ponds - Stabilization pond One had higher B O D than Stabilization pond Three. This demonstrated the level of organic decomposition of the waste water as it passed through the system. By the time the waste water gets to the third stabilization pond, a substantial quantity of organic matter would have been mineralized.

The reason for a net production of dissolved oxygen in the stabilization ponds despite the high biochemical oxygen demand was due to the excessively large standing crop of

while
algae, produced oxygen far in excess of what was required for biological cum chemical decomposition of organic matter.

Cations are essential constituents of algal cells. Sze and
ions
Kingsbury (1972) state that metals in the right proportions are activators of enzyme systems. Calcium can be leached from practically all rocks but is much more prevalent in waters from regions with deposits of lime stone, dolomite and gypsum. Regions where granite or silicious sand predominate have very low concentrations of calcium in the waters. Concentration in waters from limestone areas range from about 30 - 100 mg L^{-1} (Lind, 1974). Calcium concentrations were generally low in all the ponds, much lesser than 30 mg L^{-1}, which shows that their catchments are poor in limestone. Low calcium concentrations can also be attributed to precipitation of calcium as carbonates, on evaporative concentration (Moss, 1969). These low calcium values suggest softness of the waters (High concentrations of calcium and magnesium ions give an indication of hardness) (Lind, 1974).

Magnesium in natural water comes mainly from leaching of igneous and carbonate rocks. In areas where these sources are common, magnesium concentration in water often range from 5 - 50 mg L^{-1}. Magnesium is related to water hardness in the same manner as calcium (Lind, 1974). Magnesium is of concern to the ecologist in its role as essential nutrient in plant growth and development especially as
(Lind, 1974).
relates to its function in the chlorophyll molecule Concentration of magnesium ions were very low in the ponds, suggesting softness of the waters. High algal biomass in the stabilization ponds with high

demand for magnesium for its chlorophyll was probably responsible for the relatively lower concentration of magnesium there.

The findings of Talling and Talling (1965) showed sodium to be always present in higher quantity than potassium. A similar observation was made in this study. The high sodium concentration in the By-Pass and stabilization ponds may be as a result of high levels of sodium chloride in the human and animal wastes that get into the ponds. High cyanophycean biomass is associated with high sodium concentration in the By-Pass and stabilization ponds (Table 3). It is probable then that these blue green algae need appreciable amount of sodium (Hutchinson, 1967). Provasoli (1958) noted that the presence of sodium in sewage and other artificial influents may in part underlie the association of blue green algae with pollution. There was a weak correlation between algal biomass and calcium. Magnesium and sodium were only significantly correlated with algal biomass in the By-Pass pond while potassium showed a strong relationship in the By-Pass and Kubanni ponds.

Dissolved iron was scarcely detectable in most of the ponds (Table 2) even though two types of instruments were used, as explained in chapter three. Hutchinson points out that there is normally very little dissolved iron in fresh waters, hardly exceeding 1 mg L^{-1} since in well oxygenated lake waters, iron compounds likely to be most constantly present are suspended insoluble Ferric hydroxide (Hutchinson, 1967). Iron is involved in the cycling of certain other nutrients (e.g phosphorus) and normally only a small part of it is available to phytoplanktom organisms (Hutchinson, 1967). Nevertheless,

its presence in minute quantities is still capable of sustaining many freshwater algae (Beadle, 1974) in the ponds. Bishai (1962) and Ruttner (1953) showed that among the factors which help in the formation of dissolved iron is low pH (not above 7.5, ideally 4.5. The By-Pass and Stabilization ponds had pH values exceeding this. Hence, dissolution of iron may not have been favoured. However, in the Kubanni pond pH values did not exceed 7.5. Although no trace of iron was recorded in the samples, it is possible that iron was present in the parts per billion range. It would be expected that since the basin of the Kubanni is rich in iron stone, an appreciable quantity of iron should be dissolved in the water. This is what was recorded by Anyam (1980) who reported between 2.5 ppm and 7.91 ppm iron in the Kubanni lake. Possibly most of the iron was in the insoluble Ferric state (Hutchinson, 1967). The availability of iron rather than its concentration has been considered critical in stimulating algal production (Schelske, Hooper and Heartl, 1963; Watzel, 1968; and Allen, 1972). Therefore if dissolved iron was present in minute traces (at parts per billion range) it would still be of use in algal development.

Phosphorus is one of the most important elements to living organisms. The ratio of phosphorus to other elements in organisms tends to be greater than the ratio in the primary sources of the biological elements (Hutchinson, 1967). The importance of phosphorus is associated with energy transfer (Woodson and Core, 1968). Phosphate phosphorus values for the By-Pass and Kubanni ponds were relatively lower than for the stabilization ponds. High phosphate-phosphorus concentration in the stabilization ponds was attributable to sewage and detergents. Algal biomass peak coincided with the

phosphate-phosphorus peak, confirming the usefulness of phosphorus in algal development. Phosphate-phosphorus was available in the investigated ponds in appreciably high concentrations (Table 2), but substantially higher values were recorded at the stabilization ponds. Phosphate-phosphorus enrichment has been reported to occur with considerable inflow of sewage into aquatic systems. Moss (1981) reported that phosphorus from decomposing gull excreta or droppings entered the shallow lake (Hickling broad, Norwich) from the catchment. The phosphorus, was absorbed by phytoplankton resulting in their increased density.

Productivity has been shown to be controlled most by the availability of phosphorus and nitrogen, assuming that adequate light is available (Biggar and Corey, 1969, Welch et al., 1975). Einsele (1944) found that phosphate added to water disappeared in a few days having been taken up by algae. This confirms the role of phosphate phosphorus in the development of algae and explains the reduced phosphate phosphorus level corresponding with high algal biomass (Table 2 and 4). However, phosphate-phosphorus concentration was relatively low in By-Pass and Kubanni ponds. Inspite of this the By-Pass especially supported a rich algal flora possibly because phosphorus was non limiting.

"Many phytoplankton are exceptionally efficient in their ability to use phosphate and can extract it in significant amount from water where it is present in minute quantities" (Maitland, 1978). Sze and Kingsbury (1972) reported that phytoplankton have the ability to store phosphorus for later use. A similar observation was made by Flint (1938) in Lake Sarah (New Sealand).

Like phosphate-phosphorus, Nitrate-Nitrogen had its highest values in the sewage stabilization ponds, due to high No_3-N concentration in the influents. Moss (1981), recorded a build-up of Nitrate Nitrogen in the shallow lake (Hickling broad, Norwich) as it received influent contaminated with animal dropping, from the catchment. A comparatively high level of Nitrate-Nitrogen ($180 - 1680 \times 10^{-3}$ mgL^{-1}) was recorded in all the ponds. Hence nitrate nitrogen was not limiting in any of the ponds (Green, 1975). Phytoplankton communities have been shown to respond strongly to nitrogen enrichment (Vincent, 1983). Hence, the stabilization pond One with higher concentration of nitrate-nitrogen, supported a higher biomass of algae than the other ponds. According to Strom (1924), "If eutrophic waters are unfavourable to desmids they should be favourable to blue-green algae and diatoms". This inference was supported by observations in this investigation where the eutrophic water, of the stabilization ponds were more favourable to blue green algae (Microcystis sp , Spirulina sp. etc)

(Table 3 and the appendices) than to desmids. These observations are in harmony with accepted views that blue-green algae are favoured by high concentration of organic matter and nitrogen (Reid, 1976; Hutchinson, 1967). However, diatoms were not favoured in the eutrophic waters of the stabilization ponds because of the effects of organic enrichment. Excess organic enrichment is detrimental to development of most diatoms. The correlation between nitrate-nitrogen and algal biomass (Table 5) was significant in stabilization pond three and the Kubanni pond, buttressing the points raised above.

Silica is of significance as a major nutrient for diatoms, the dominant phytoplakters of most lakes. Silica is extremely common in nature as a constituent of igneous rocks, quartz and sand. The major source of silica in natural water is from decomposition of aluminosilicate mineral in the drainage basin from which water flows (Lind, 1974). The concentration values of silica in all the ponds (0.35 - 4.58 mg/L^{-1} Table 2) fall within the range normally found in natural waters 1 - 10 mg Si L^{-1} (Lind, 1974).

The highest concentration of silica was recorded in the Kubanni pond (Table 2) which holds silt in suspension throughout the year. This silt suspension was probably responsible for the high silica level in the water. Pearsall (1929) in his study of the English Lakes observed that silted lakes had more silica in solution than rocky lakes. Silica is important as a major nutrient for diatoms, which are capable of utilizing it even at low concentrations (Hutchinson 1967). The diatom (Bacillariophyta) composition (Table 3) of the

Kubanni pond was correspondingly the highest among the investigated ponds. The reason for the By-Pass pond supporting high diatom biomass too, despite its relatively low silica concentration is the ability of diatoms in utilizing silica at low concentrations (Hutchinson, 1967). The stabilization ponds, though contained high concentration of silica, did not support a rich diatomaceous flora, possibly because of the supressing effects of blue-green algal bloom which made the water persistently turbid. Under such bloom conditions, some species were eliminated as a result of shading and competition (Reed, 1978, Dykyjova and Kvet 1978). Furthermore with increased organic matter loading, pollution intolerant species are eliminated (Palmer 1980). The peaks of diatom biomass (Table 3) in the By-Pass pond (January), Kubanni pond (November), and Stabilization pond one (March) coincide with periods of relatively low silica concentration due, possibly, to depletion of silica as a result of rapid uptake by the high density of diatoms (Stent, 1981). Interaction between silica concentration and diatom growth have been studied in Lake Constance, U.S.A. by Sommer and Stable (1983). The concentration of dissolved reactive silica was found to decrease markedly during period of diatom peak (Moss, 1981, Sommer and Stabel, 1983).

Alkalinity, PH and conductivity have been shown to be related (Anyam, 1980). However, the variation in alkalinity in the ponds did not follow a similar pattern with PH and conductivity. Some non-apparent factors may have caused this anomaly.

5.2 Suspended Algae

The biomass of suspended algae in Stabilization pond one was the highest of all the four ponds. This pond received the highest loading of raw sewage and so was organically most enriched which was why during the study period it had a persistent bloom of Microcystis aeruginosa. The supressing effect of the bloom and the inability of other species to thrive under heavy organic loading was one of the factors responsible for the low diversity of algal taxa (Appendices 1 - 20) (Reid, 1975). Stabilization pond three had lower organic matter (Table 2) as reflected in the B O D values because most of it had been mineralized in the preceeding ponds, through biological and chemical degradation (Palmer, 1980), therefore, a comparatively lower biomass of algae was recorded there (i.e Stabilization pond three) compared to Stabilization pond one (that receives the raw sewage). Consequently, the species composition of Stabilization pond three was higher than for Stabilization pond one. The least algal biomass was recorded in the Kubanni pond, which incidentally had the lowest concentration of ions (Potassium, Sodium, Nitrate-Nitrogen) and also the lowest value for PH. This was summed up in low conductivity values (Table 2). This low concentration of ions (nutrients) coupled with the effects of the reduced light penetration due to suspended silt in the water deterred development of suspended algae. Effective light penetration is considered necessary for algal production (Imevbore, 1965; Biswas, 1966 and Egborge, 1974).

The Chlorophyta, Cyanophyta and Bacillariophyta were more favoured in all the ponds than other algal groups (Table 3). Of the four ponds, the By-Pass pond supported more species. The By-Pass

pond was more consistently transparent than the other ponds due to fast settling of suspended matter. The high density of blue green (cyanophycean) algae in the Stabilization ponds (Table 3), lends support to the claim that waters rich in organic materials support a rich Cyanophycean flora (Pearsall, 1932; Rao, 1953; Rao, 1955 and Hutchinson, 1967). It is apparent from the results obtained from the Stabilization ponds that highly eutrophic waters do not support a prolific development of Chlorophyta. The Bacillariophyta recorded were mainly pollution tolerant species e.g Gomphonema spp, Nitzschia spp and Navicula spp. (Palmer, 1980).

The other algal taxa, the Chrysophyta, Euglenophyta and Pyrrophyta, apparently were not favoured by the physico-chemical factors prevalent during the study period. They were sparsely represented in the samples.

Species composition in the ponds varied from month to month (Appendices 1 - 20) in line with variation in physico-chemical factors. Consequently, the composition of the most widely distributed taxa of suspended algae also varied in this direction.

Using biomass (Kristiensen, 1964) and distribution of pollution indicators (Palmer, 1980), productivity/trophic status was compared in the ponds. The order of the magnitude was:- Stabilization pond one> By-Pass pond > Stabilization pond Three> Kubanni pond. This sequence, corresponds with the magnitude of the exposure of the ponds to sources of nutrient enrichment. The Stabilization pond one received a higher loading of organic material (raw sewage) than Stabilization pond three (partially treated sewage). These stabilization ponds receiving mainly sewage,

were more enriched than the By-Pass pond which received mainly undergroundseepages and comparatively less household waste water (sullage) and relatively negligible quantity of excrement. The Kubanni pond received mainly underground seepages and even though it got organically enriched through human and animal activities in its surrounding, this was occasional and the resident time of water in the pond (personal observation) was lower compared to the other ponds. Moreover the soil of the basin apparently is not rich in minerals. Hence, it was least productive.

Statistically significant relationships were established between certain physico-chemical factors and algal biomass in the ponds. This indicates that these physico-chemical factors prevalent in the ponds, played important roles in controlling the growth and development of suspended algae during the study period

Results have thus confirmed the hypothesis that if physico-chemical factors are different in the ponds, then the species composition would be different. Tables 2 and 5 and appendices 1 - 20 show this clearly.

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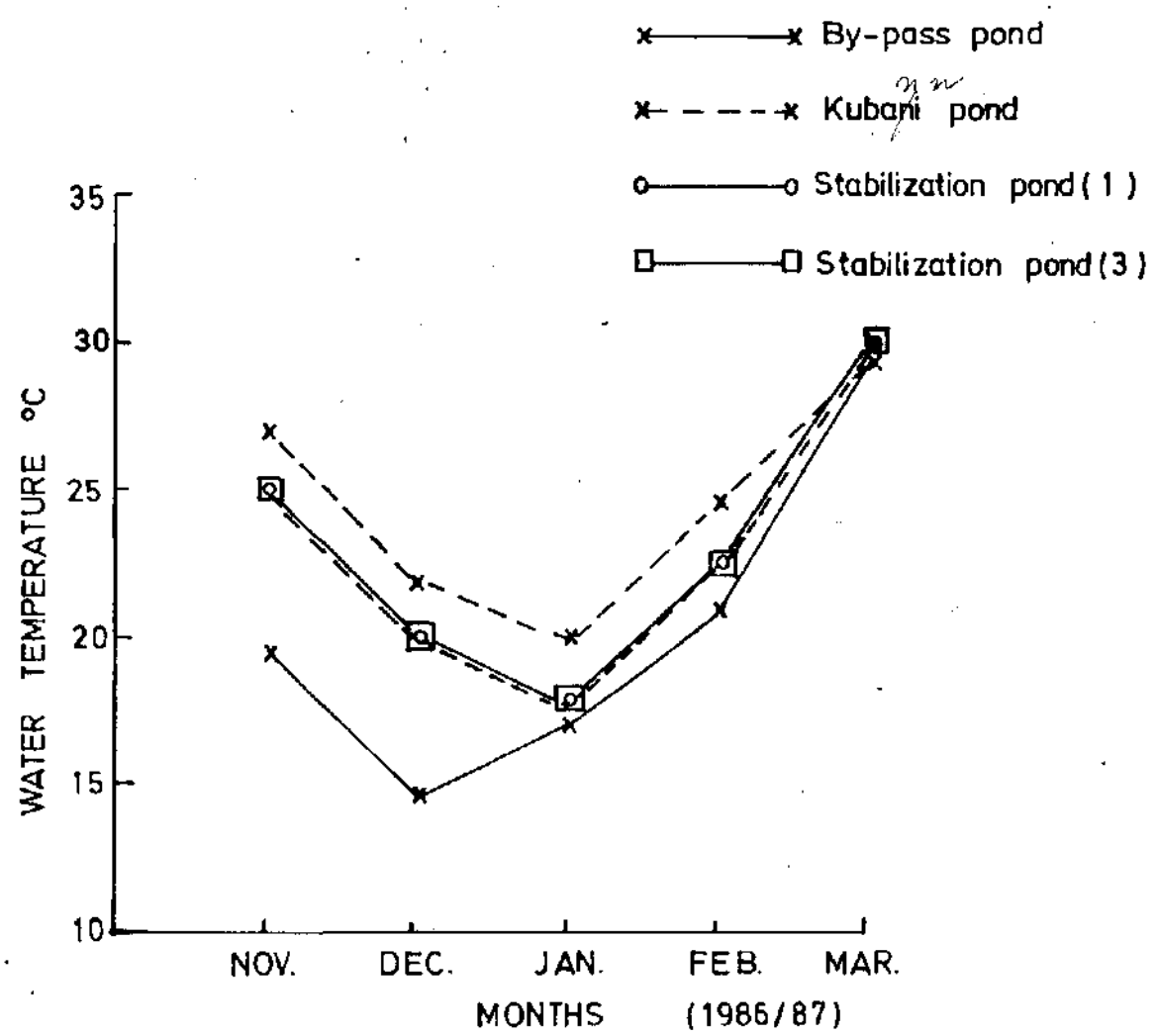


Fig.1. Water temperature in the ponds.

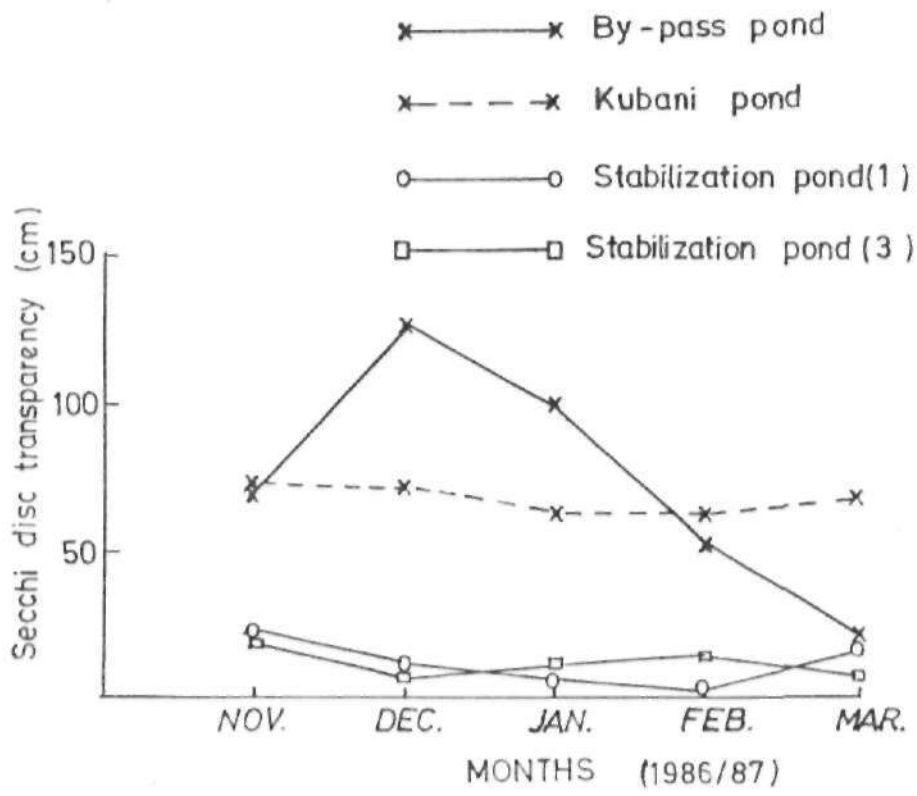


Fig. 2. Secchi disc transparency

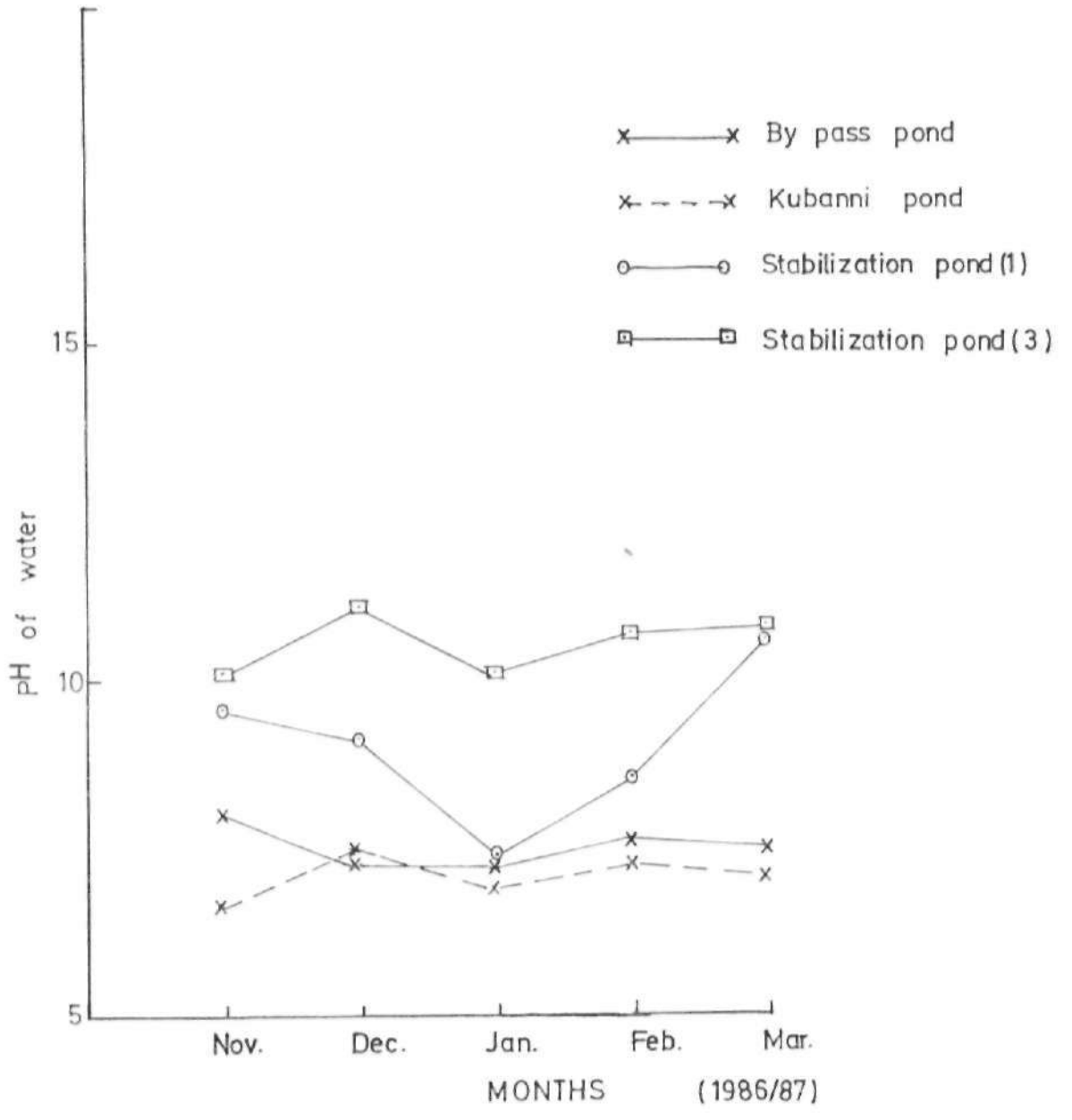


Fig.3 PH of water in the ponds.

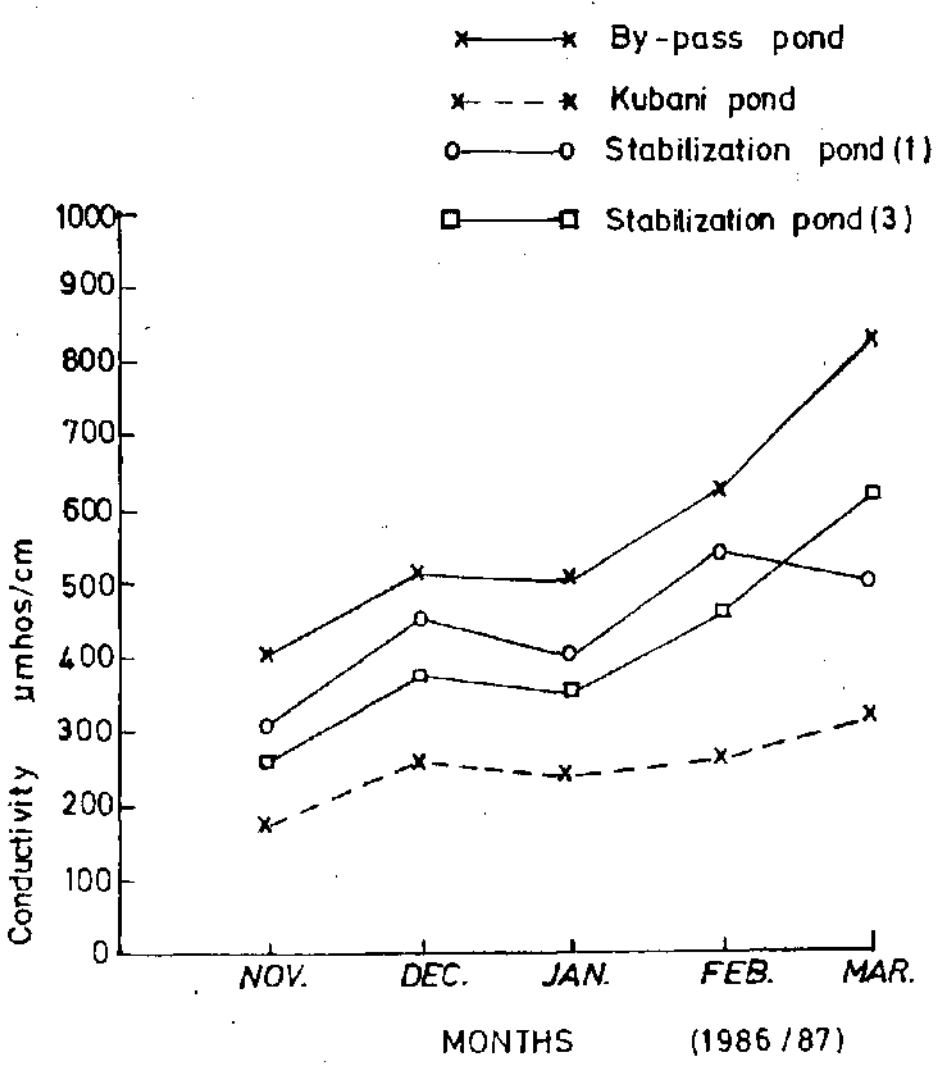


Fig. 4. Conductivity µmhos/cm.

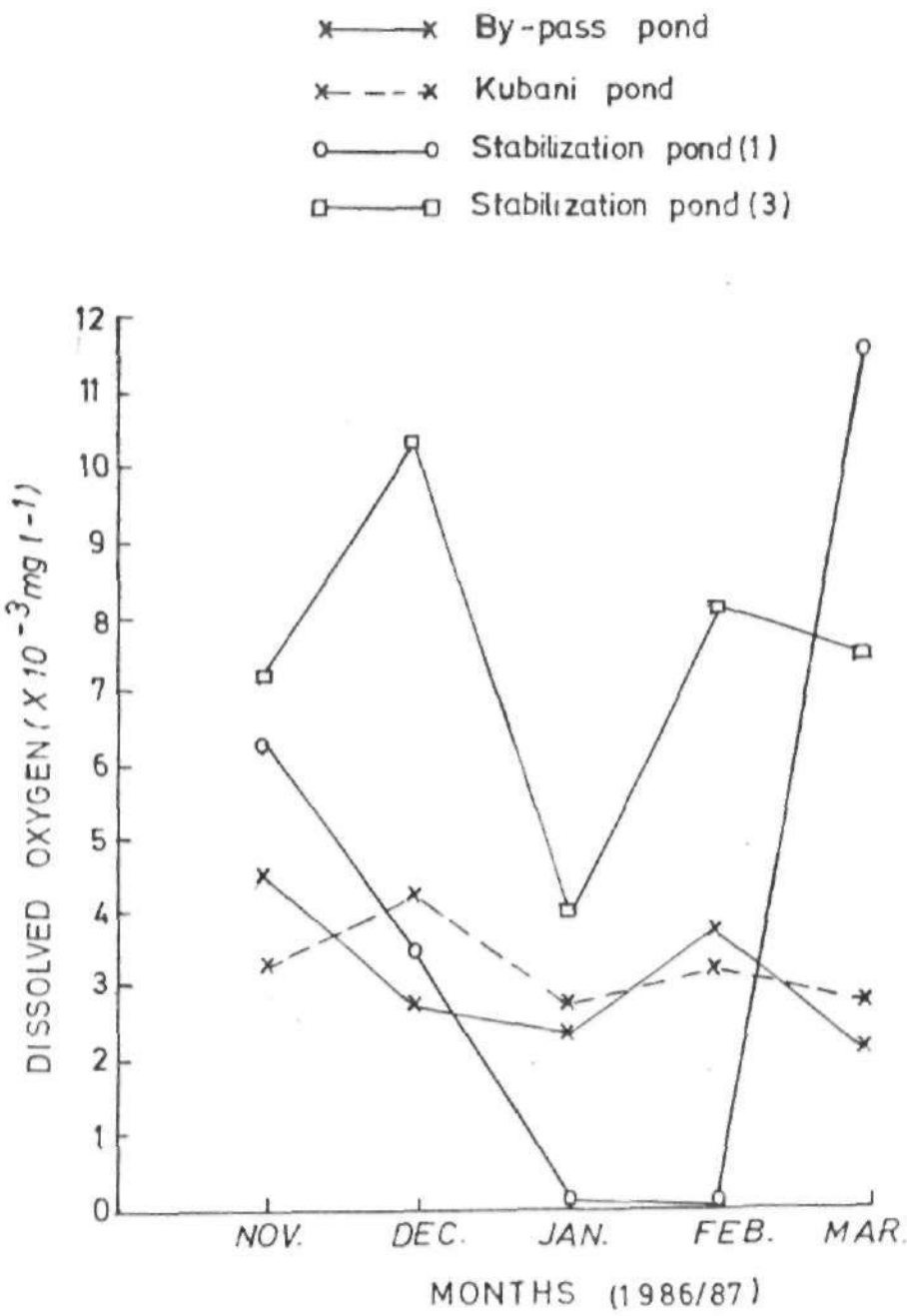


Fig. 5 Dissolved oxygen

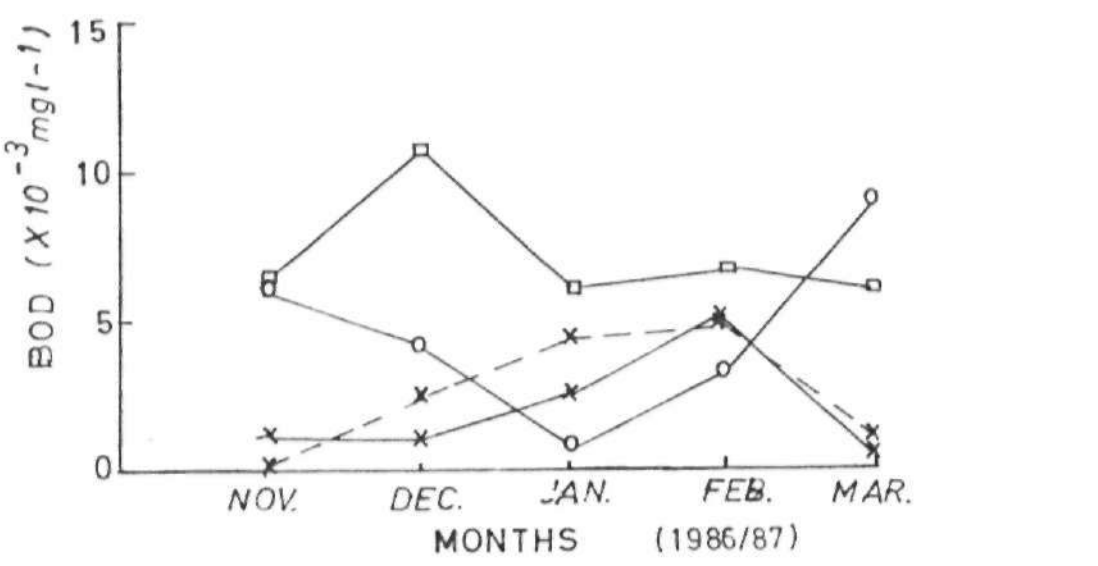


Fig.6 Biochemical oxygen demand.

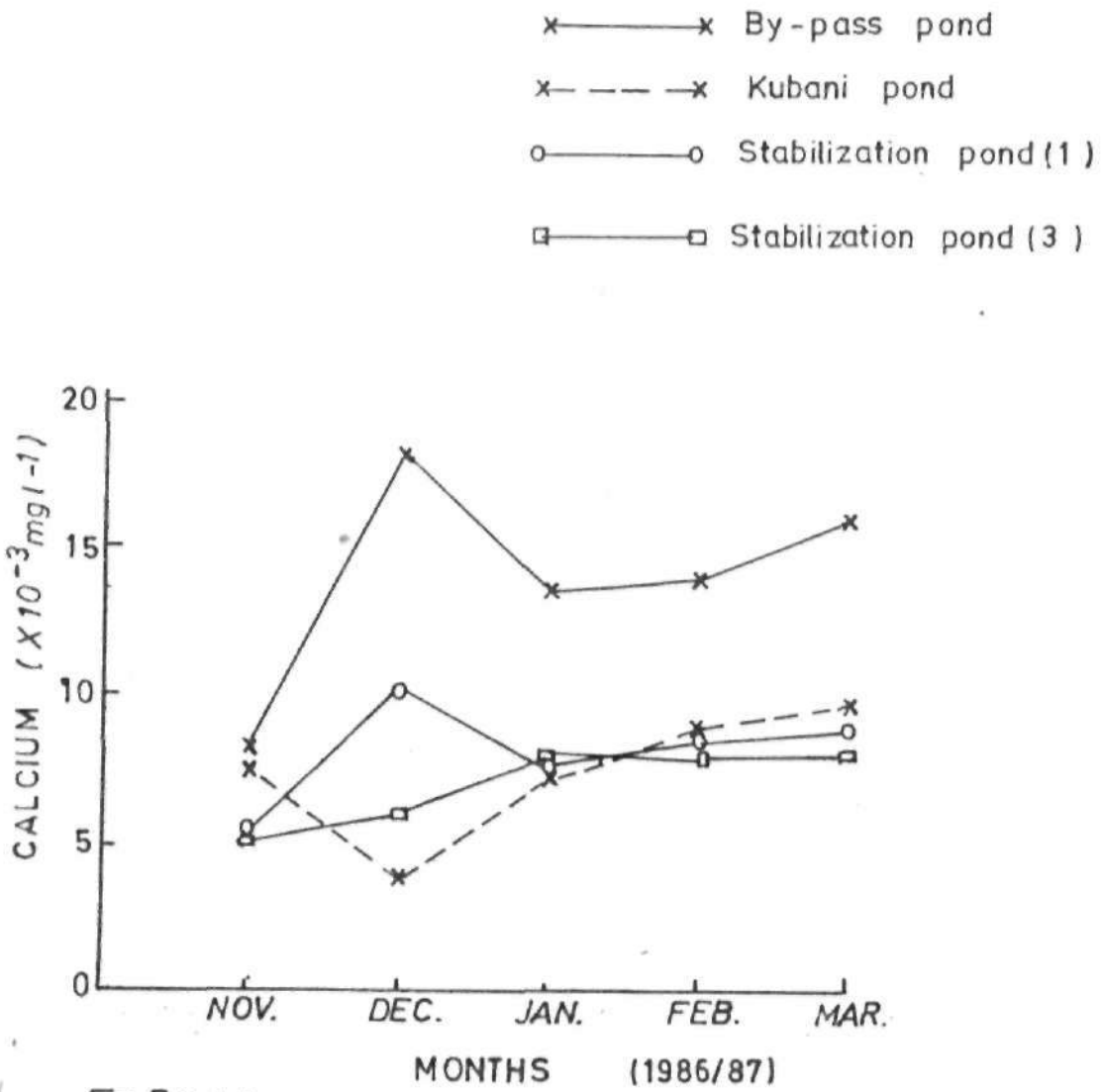


Fig. 7. Calcium concentration in the ponds.

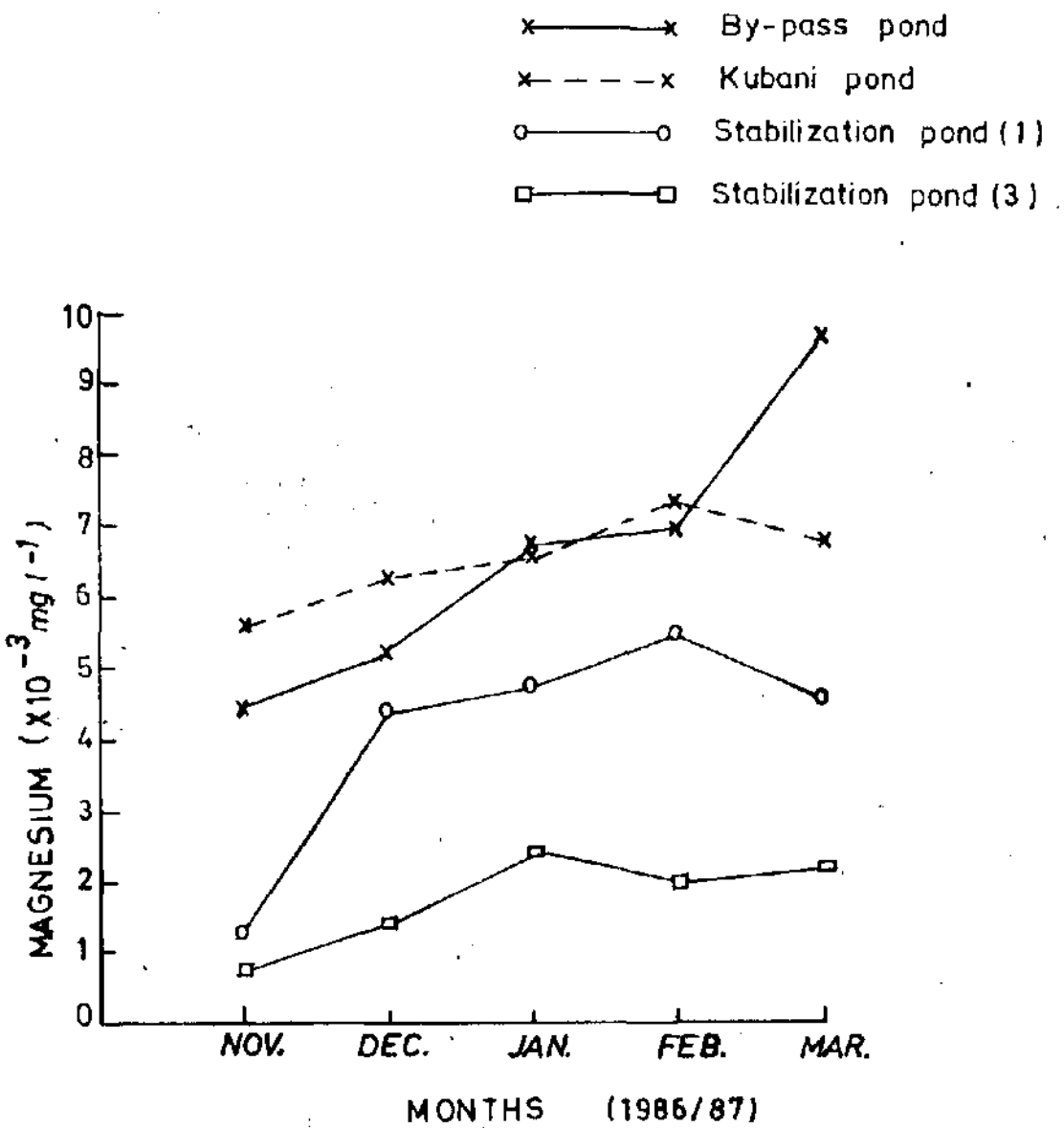


Fig.8. Magnesium concentration in the ponds.

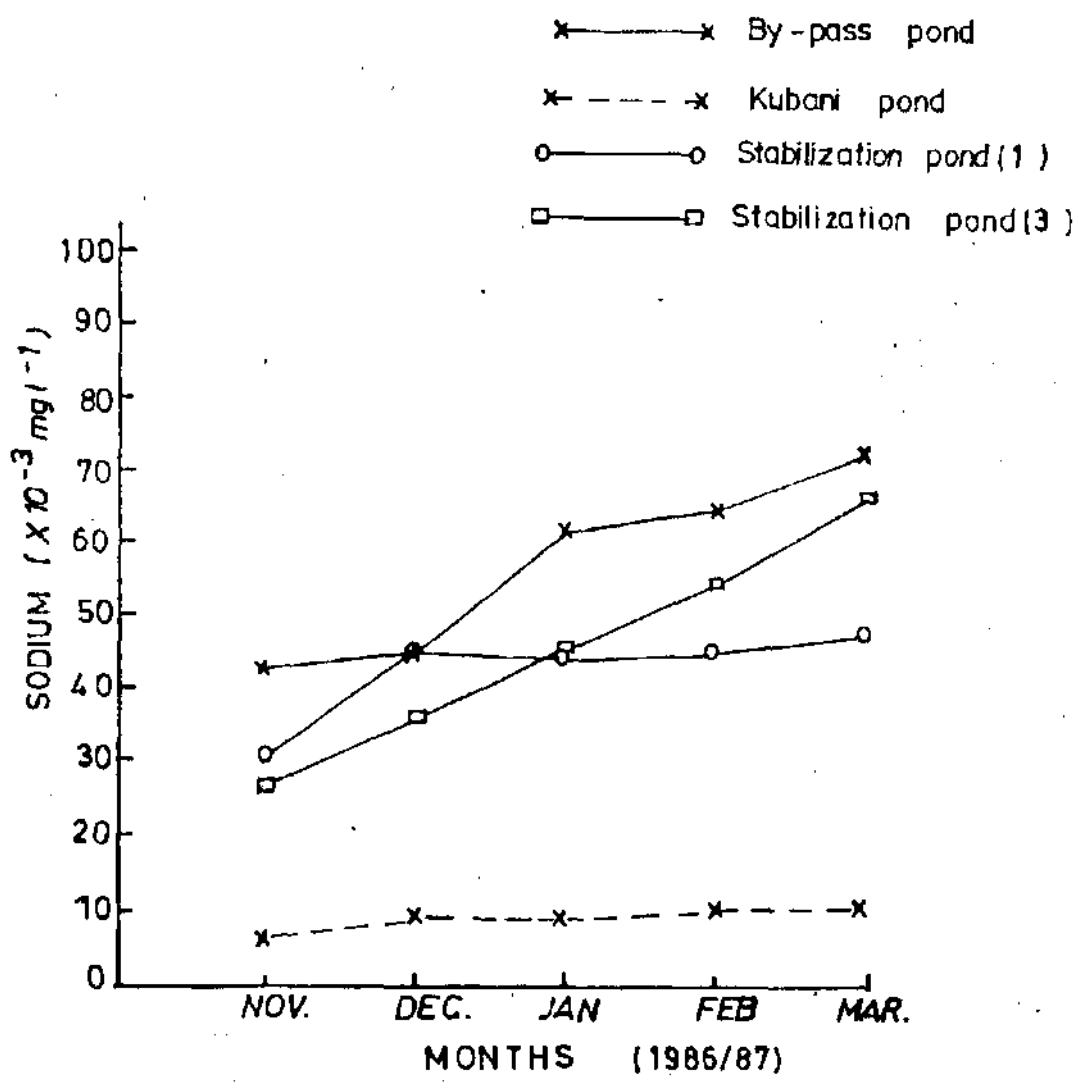


Fig. 9. Sodium concentration in the ponds

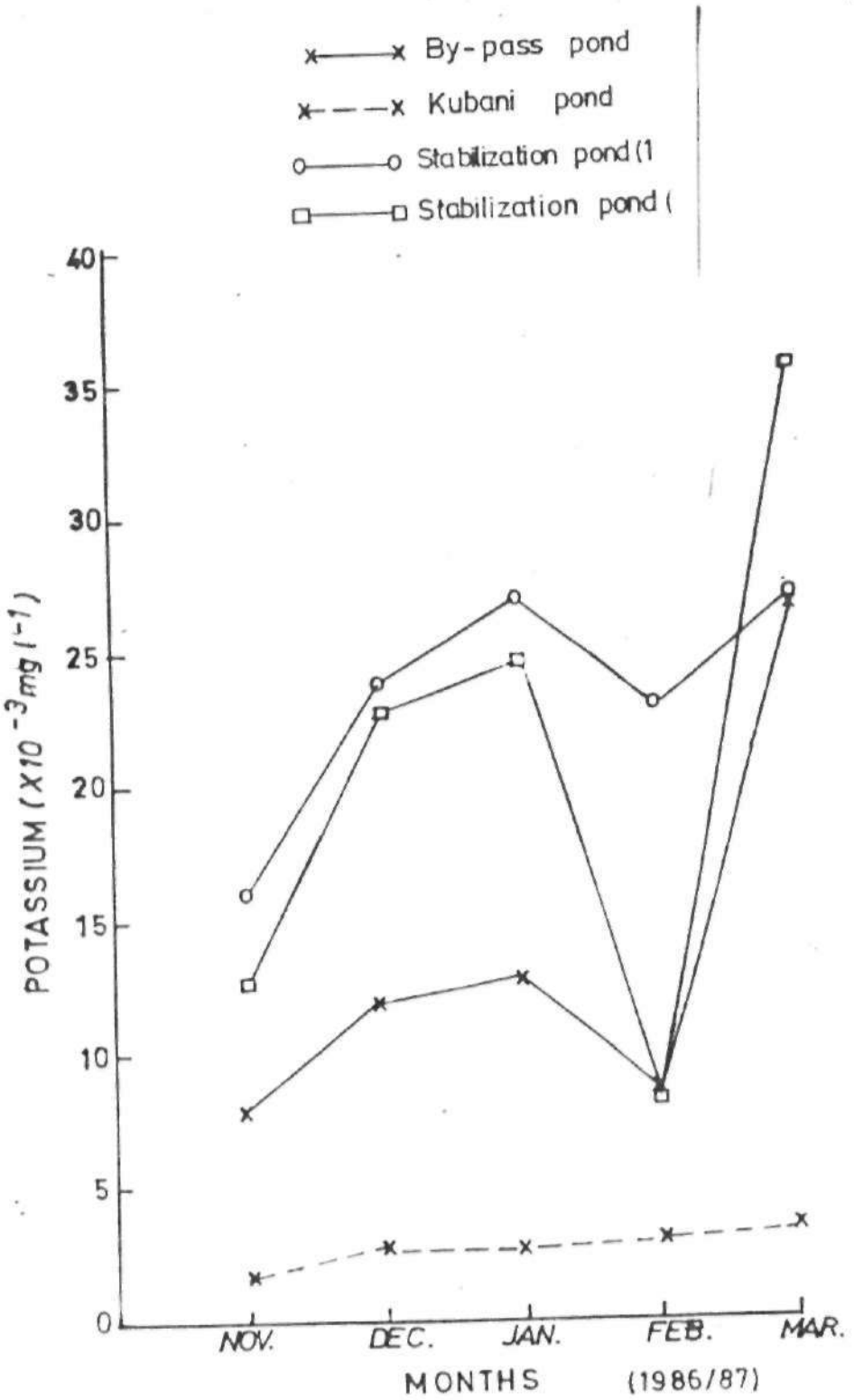


Fig.10 Potassium concentration in the ponds

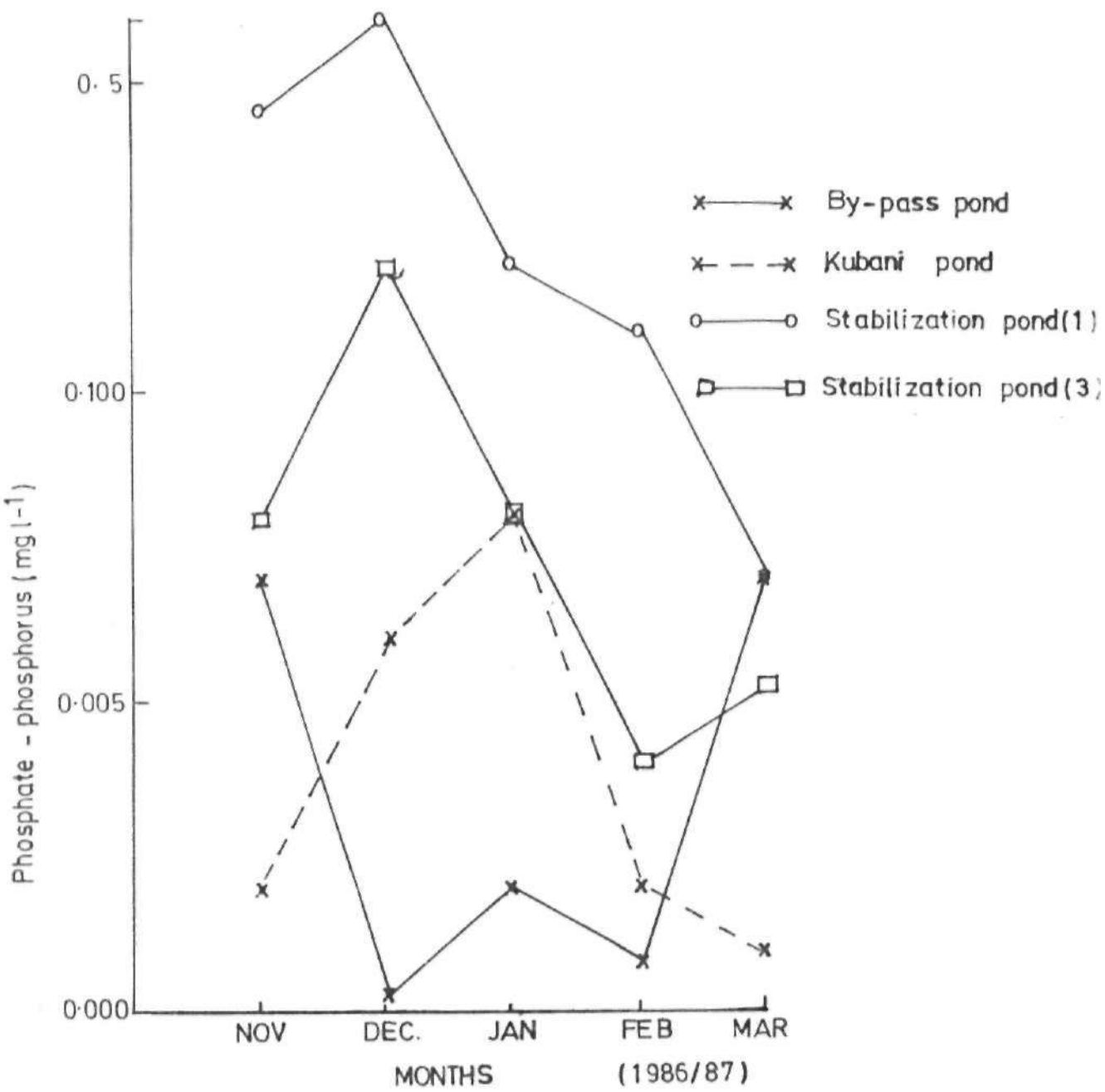


Fig.11. Phosphate - phosphorus concentration in the ponds.

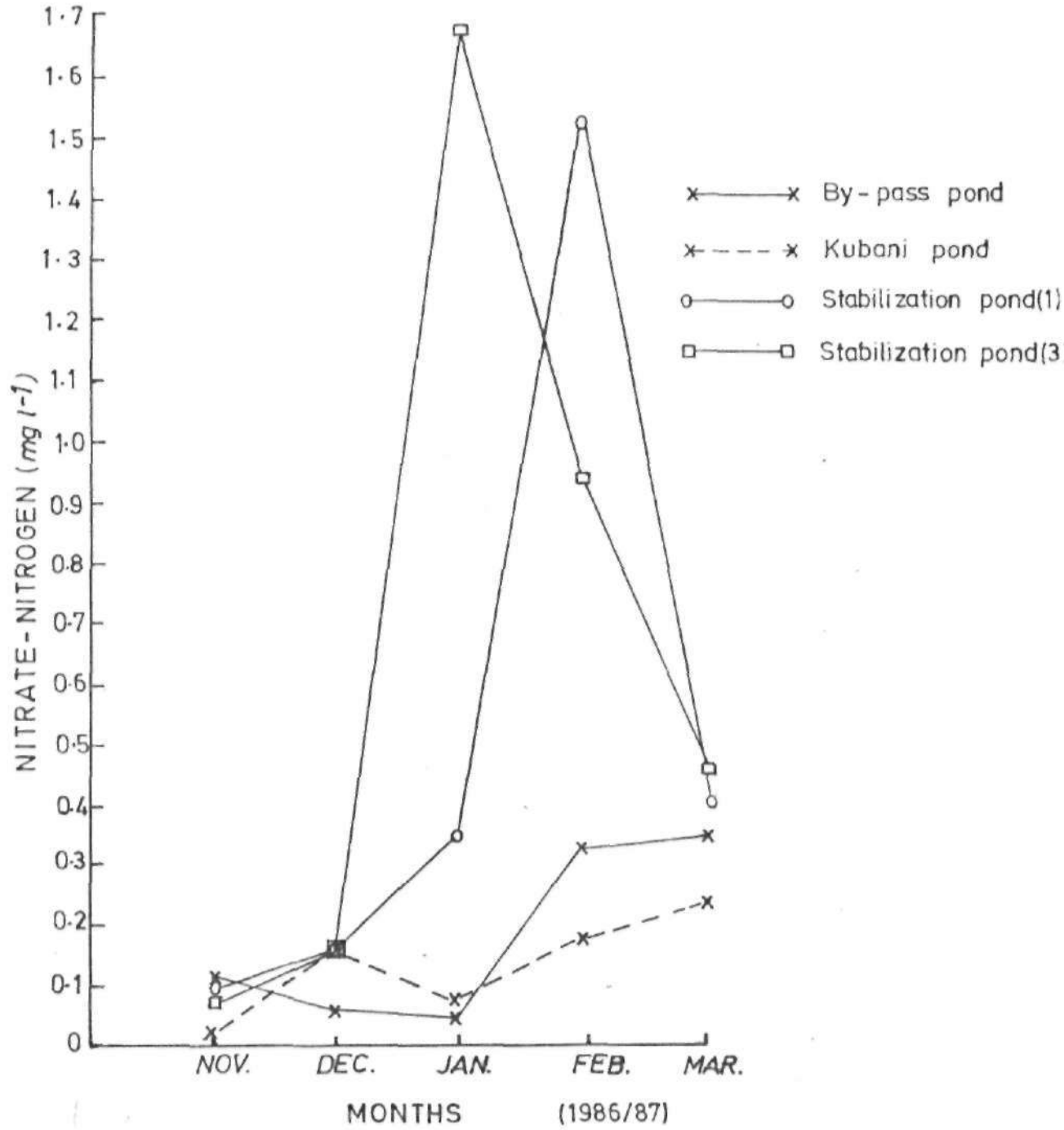


Fig.12 Nitrate - nitrogen concentration in the ponds.

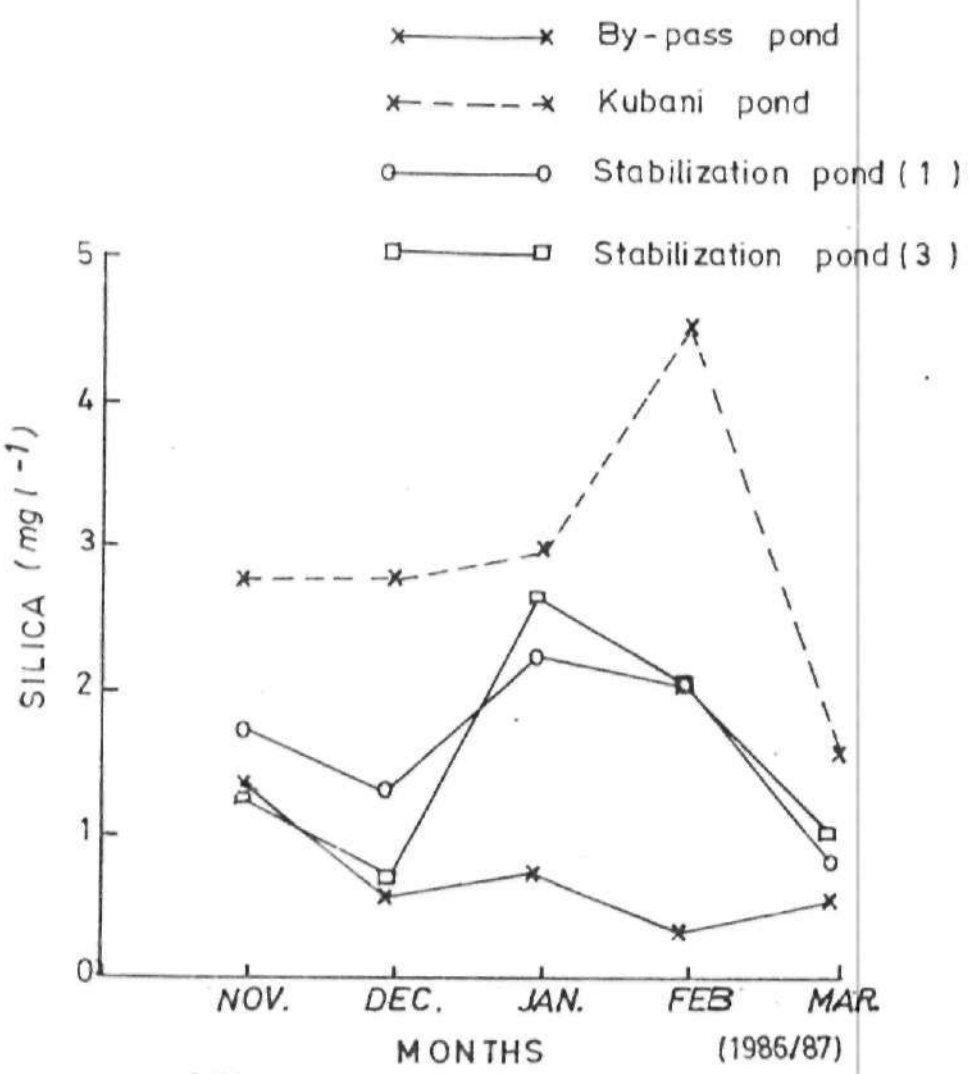


Fig.13. Silica concentration in the ponds.

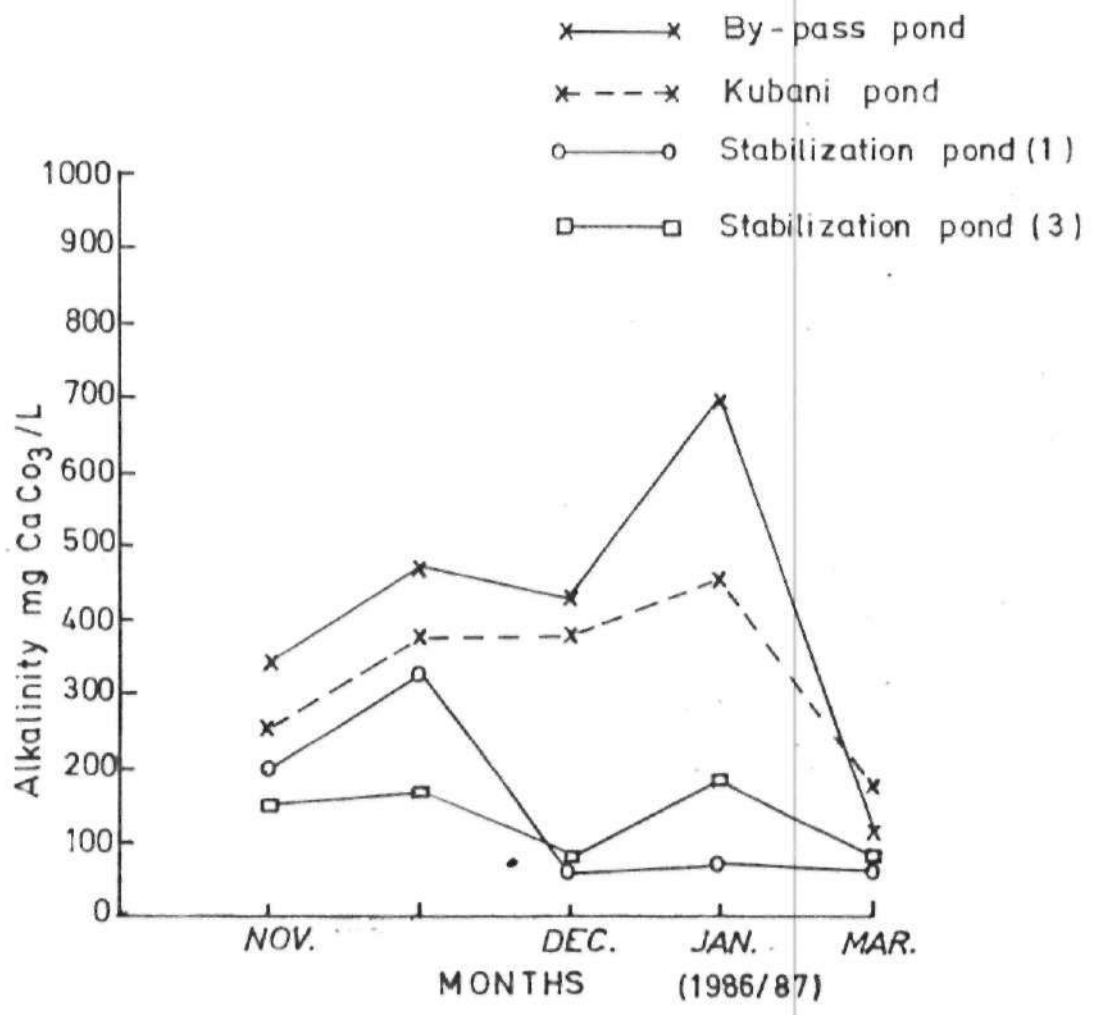


Fig.14. Alkalinity of water in the ponds.

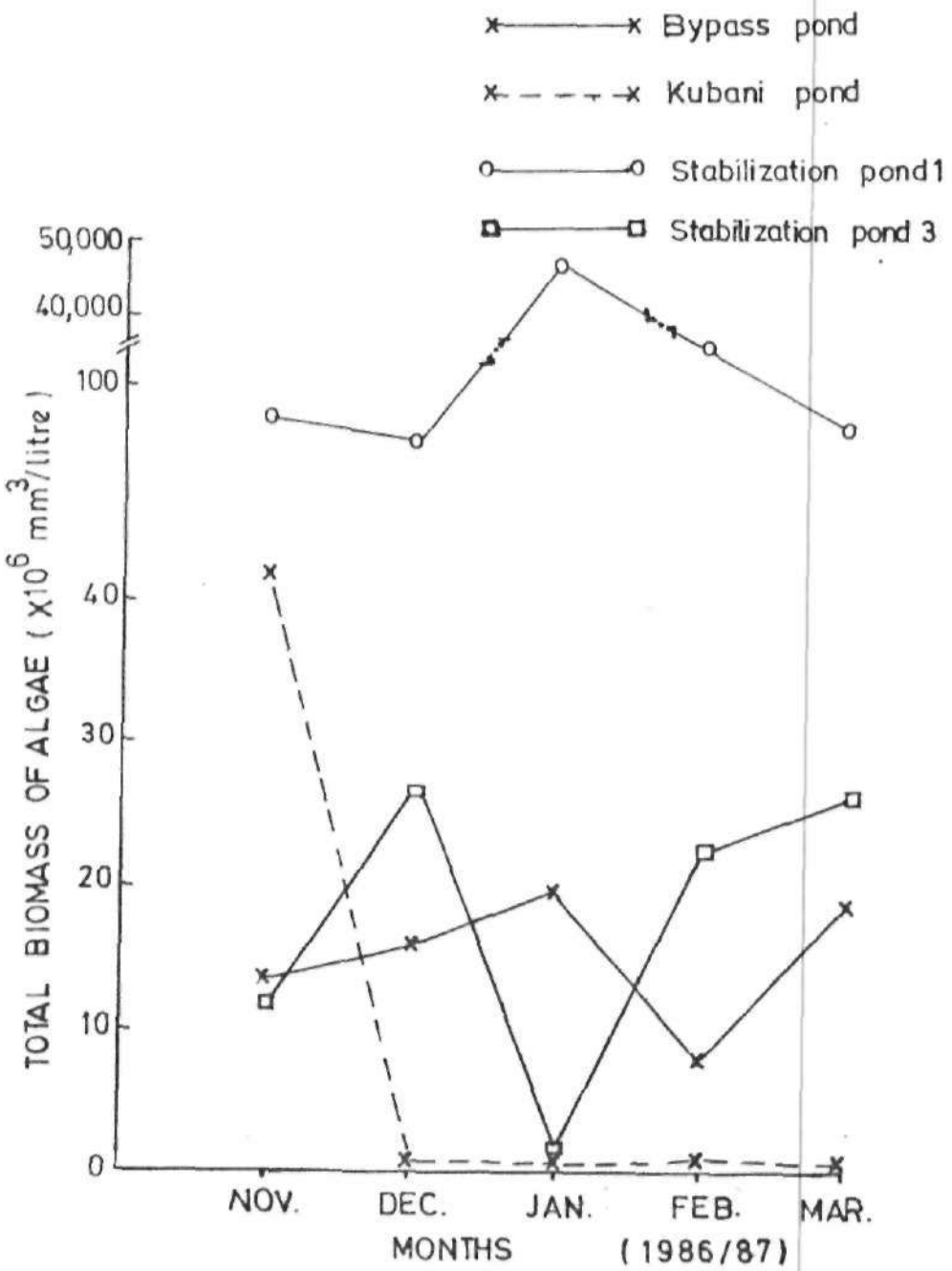


Fig 15 Biomass of suspended algae in the ponds.

FIG. 6 LOCATION MAP

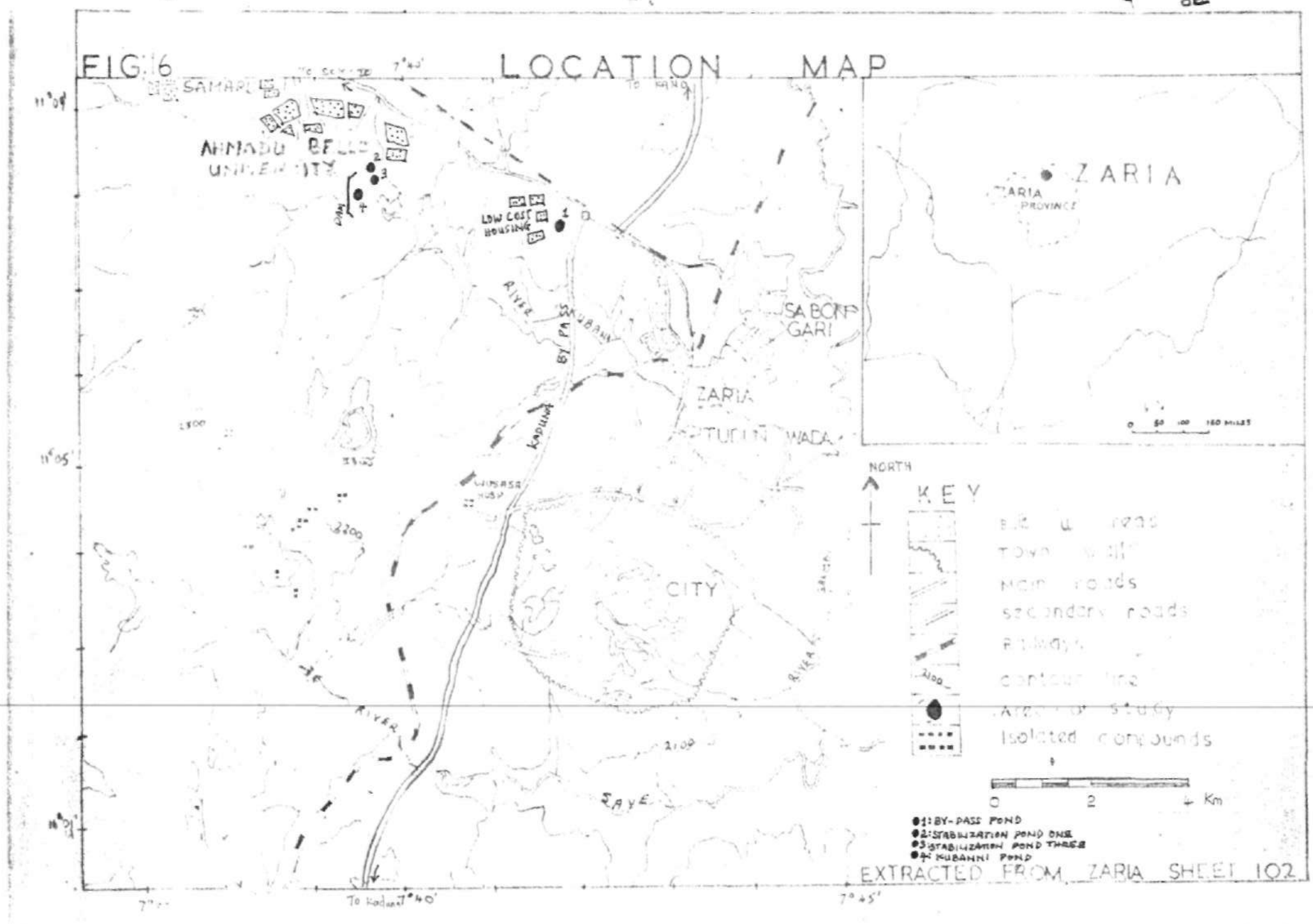


TABLE 1: WEATHER DATA DURING STUDY PERIOD*

NOVEMBER 1986 - MARCH 1987

MONTH	WINDRUN (PER DAY) AND DIRECTION ON SAMPLING DATES	SUNSHINE HOURS (PER DAY) (MONTHLY MEAN)	RELATIVE HUMIDITY % (MONTHLY MEAN)
NOVEMBER	49 SE	8.2	56.5
DECEMBER	161 N.E	8.5	42.3
JANUARY	142 N.E	8.7	22.8
FEBRUARY	126 N.E	7.8	22.8
MARCH	136 S.W	9.1	23.3

*Source: Samaru Weather Report

Farm system Research Programme

Institute for Agricultural Research

Ahmadu Bello University

Samaru - Zaria

TABLE 2

DATA FOR PHYSICOCHEMICAL FACTORS IN THE PONDS ON THE VARIOUS SAMPLING DATES

POND	DATE (TIME)	TEMPERATURE AIR°C	TEMPERATURE WATER°C	SECCHI DISC TRANSPARENCY (cm)	PH	CONDUCTIVITY (umhos/cm)	DISSOLVED OXYGEN ($X10^{-3}mgL^{-1}$)	BIOCHEMICAL OXYGEN DEMAND (BOD) ($X10^{-3}mgL^{-1}$)	CALCIUM ($X10^{-3}mgL^{-1}$)	MAGNESIUM ($X10^{-3}mgL^{-1}$)	SODIUM ($X10^{-3}mgL^{-1}$)	POTASSIUM ($X10^{-3}mgL^{-1}$)	DISSOLVED IRON ($X10^{-3}mgL^{-1}$)	PHOSPHATE-PHOSPHORUS ($X10^{-3}mgL^{-1}$)	NITRATE-NITROGEN ($X10^{-3}mgL^{-1}$)	SILICA ($X10^{-3}mgL^{-1}$)	ALKALINITY $mgCaCO_3/L$
BY-PASS POND	20/11/56 (9.30 am)	26.0	19.0	67.5	8.05	410	4.25	1.09	9.9	4.5	43.0	9.0	0	7.00	120.00	1360.00	348
	30/12/56 (10.00 am)	22.0	14.5	127.0	7.35	519	2.80	1.40	18.5	5.2	43.6	12.1	0	0.01	60.00	560.00	475
	28/01/57 (9.30 am)	18.0	17.0	100.0	7.30	510	2.40	2.32	13.6	6.5	62.0	13.0	0	2.0	70.00	770.00	435
	26/02/57 (8.30 am)	25.0	21.0	54.0	7.75	630	3.80	5.15	14.2	7.1	65.1	8.9	0	0.40	330.00	350.00	760
	31/03/57 (11.50 am)	34.0	30.1	23.0	7.51	940	2.15	0.65	16.3	9.6	72.4	26.8	0.12	7.00	1350.00	570.00	111
STABILIZATION POND ONE	20/11/56 (11:30 am)	32.5	25.0	22.0	9.56	315	6.40	6.40	5.5	2.4	30.4	16.1	0	460.00	100.00	1730.00	200
	30/12/56 (3.20 pm)	24.2	20.0	11.5	9.17	462	3.50	11.10	10.4	4.4	44.0	24.1	0	620.00	160.00	1330.00	325
	28/01/57 (9.30 am)	19.5	19.0	6.0	7.40	410	0.10	6.25	7.7	4.8	45.0	27.0	0	230.00	360.00	2250.00	65
	26/02/57 (11.15 am)	30.0	22.5	2.5	8.55	550	0.10	6.76	8.5	5.5	46.3	23.0	0	120.00	1530.00	2060.00	70
	31/03/57 (1.15 pm)	35.0	30.0	18.0	10.60	510	11.6	6.20	9.1	4.6	49.0	27.3	0	54.00	350.00	540.00	65
STABILIZATION POND THREE	20/11/56 (1.30 pm)	32.5	25.0	20.0	10.12	265	7.20	5.00	5.3	0.8	26.5	12.6	0	50.00	90.00	1330.00	159
	30/12/56 (3.45 pm)	24.0	20.0	8.0	11.10	390	10.30	4.10	6.2	1.4	36.0	22.7	0.07	250.00	160.00	750.00	170
	28/01/57 (10.00 am)	19.5	17.3	11.5	10.10	360	4.00	0.18	5.1	2.5	46.2	24.5	0.25	80.00	1650.00	2630.00	72
	26/02/57 (12.20 pm)	30.0	22.5	14.5	10.70	470	8.20	3.16	8.1	2.0	54.4	5.5	0	40.00	960.00	2050.00	196
	31/03/57 (1.40 pm)	35.0	29.8	7.5	10.80	617	7.50	9.30	8.2	2.2	67.3	35.5	0	52.00	460.00	1060.00	93
KUBAMBA POND	20/11/56 (2.00 pm)	33.6	27.0	74.5	6.65	152	3.37	0.87	7.5	5.6	6.5	1.8	0	2.00	30.00	2510.00	262
	30/12/56 (4.15 pm)	24.5	22.0	72.0	7.43	270	4.29	2.49	4.1	6.4	5.8	2.7	0	6.00	160.00	2510.00	391
	28/01/57 (11.00 am)	21.0	20.0	64.0	6.95	255	2.75	4.54	7.5	6.7	9.0	2.7	0	8.00	90.00	3000.00	353
	26/02/57 (10.10 am)	31.0	24.0	63.0	7.35	273	3.40	4.90	8.3	7.2	10.1	3.1	0	2.00	180.00	4590.00	460
	31/03/57 (2.15 pm)	34.0	29.0	69.0	7.10	318	2.90	1.00	9.5	6.8	11.5	3.6	0	1.00	240.00	1590.00	169

TABLE 3: BIOMASS OF THE COMPONENT GROUPS OF ALGAE IN THE PONDS

		CHLOROPHYTA $X10^6 um^3 L^{-1}$	CYANOPHYTA $X10^6 um^3 L^{-1}$	EUGLENOPHYTA $X10^6 um^3 L^{-1}$	CHRYSOPHYTA $X10^6 um^3 L^{-1}$	EUGLENOPHYTA $X10^6 um^3 L^{-1}$	PYRROPHYTA $X10^6 um^3 L^{-1}$	Unidentified Unicells $X10^6 um^3 L^{-1}$	TOTAL BIOMASS $(X10^9 um^3 L^{-1}$
By-Pass Pond	NOV	7,431	1,104	3,654	332	1,379	29	1,756	15,69
	DEC	794	477	1,024	0	10	0	214	2.52
	JAN	3,266	4,853	8,512	0	374	0	3,481	20.11
	FEB	6,896	161	1,561	0	0-0	2	22,706	31.33
	MAR	13,210	2,072	0	0	3,636	556	2,321	21.80
TOTAL		31,597	8,667	14,751	332	5,399	587	30,478	
Stabilization	NOV	196	59,543	65	0	0	0	213	60.02
Pond One	DEC	14	26,230	28	0	0	0	67.0	26.34
	JAN	0	4,070,543	13	0	0	0	214	4,070.77
	FEB	198	186.332	0	0	0	0	553	187,08
	MAR	10	43,739	277	0	0	0	1.0	44.03
TOTAL		418	4,386.387	383	0	0	0	1,048	
Stabilization	NOV	99	12.035	140	0	0	0	0	12.27
Pond Three	DEC	2	26,382	184	0	0	0	0	26.57
	JAN	467	807	276	0	0	0	908	2.46
	FEB	1,244	20,575	303	0	0	0	368	22.49
	MAR	141	25,853	225	0	0	53	71	26.34
TOTAL		1,953	85,652	1,128	0	0	53	1,347	
Kubanni Pond	NOV	2,354	2,520	6,215	0	97	4.9	146	11.34
	DEC	24	291	269	0	0.3	0	25	0.61
	JAN	16	4	13	0	0	0	0.1	0.033
	FEB	142	11	1,027	0	0	0	1,197	2.38
	MAR	60	53	0	22	0	0	59	0.14
		2,596	2,879	7,524	22	97.3	4.9	1,427	

TABLE 4: TOTAL BIOMASS OF ALGAE $X10^{9}um^{3}$/Litre IN THE PONDS

PONDS	MONTH	MONTHLY TOTAL	MEAN
BY-PASS POND	NOVENBER	15.69	
	DECEMBER	2.52	
	JANUARY	20.11	
	FEBRUARY	31.33	
	MARCH	21.80	
	GRAND TOTAL	91.43	18.29
STABILIZATION POND ONE	NOVEMBER	60.02	
	DECEMBER	26.34	
	JANUARY	4,070.77	
	FEBRUARY	187.08	
	MARCH	44.03	
	GRAND TOTAL	4,388.24	877.65
STABILIZATION POND THREE	NOVEMBER	12.27	
	DECEMBER	26.57	
	JANUARY	2.46	
	FEBRUARY	22.49	
	MARCH	26.34	
	GRAND TOTAL	90.13	18.03
KUBANNI POND	NOVEMBER	11.34	
	DECEMBER	0.61	
	JANUARY	0.033	
	FEBRUARY	2.38	
	MARCH	0.14	
	GRAND TOTAL	14.503	02.90

1. Order of Magnitude of lagal biomass in the ponds = Stabilization Pond One > Bye Pass > Stabilization Pond Three > Kubanni Pond.
2. The means were tested by Kruskal-Wallis non parametric One way ANOVA.

   Kruskal-Wallis Statistic (Chi-square) = 11.23.

   Probability of significance = 0.0106 which is much less than the significance level 0.05. Hence showing that there was a significant difference in algal biomass in the 4 ponds investigated.

TABLE 5

PEARSON'S CORRELATION COEFFICIENTS OF RELATIONSHIP BETWEEN PHYSICO-CHEMICAL FACTORS AND ALGAL BIOMASS IN THE PONDS

		Temperature	Transparency	pH	Conductivity	Dissolved Oxygen (D.O)	Biochemical Oxygen Demand (B.O.D)	Calcium	Magnesium	Sodium	Potassium	Phosphate-Phosphorus	Nitrate Nitrogen	Silica	Alkalinity
By-Pass Pond	By-Pass Pond (Biomass)	0.154	0.135	-0.642*	0.205	-0827*	-0.729*	0.27	0.326	0.166	0.64*	0.305	0.294	0.13	-0.732*
Stabilization Pond One	(Biomass)	-0.612*	-0.417	-0.791*	-0.239	-0.5*	-0.72*	-0.162	0.223	0.159	0.431	-0.159	-0.13	0.6*	-0.397
Stabilization Pond Three	(Biomass)	0.536*	-0.441	0.713*	0.592*	0.88*	0.477*	-0.004	-0.172	0.346	0.146	0.311	-0.633*	-0.755*	0.434
Kubanni Pond	(Biomass)	0.397	0.662*	-0.781*	-0.881*	0.55*	-0.546*	0.097	-0.572*	-0.814*	-0.83*	-0.341	-0.723*	-0.59	-0.321

*At 95% confidence limit, Pearson's correlation coefficient = $Or > 0.5$ indicates a significant relationship.

PLATE I

The Investigated Ponds

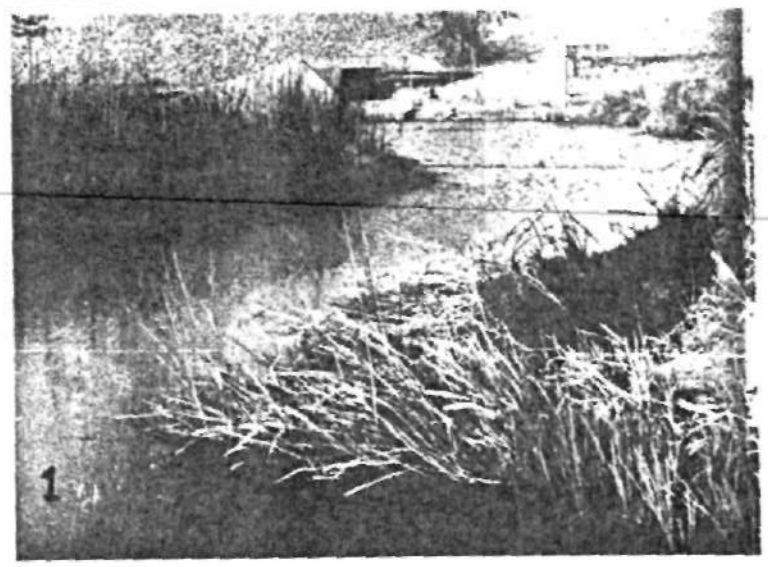
1. The Kubanni Pond, with the dam at the background.

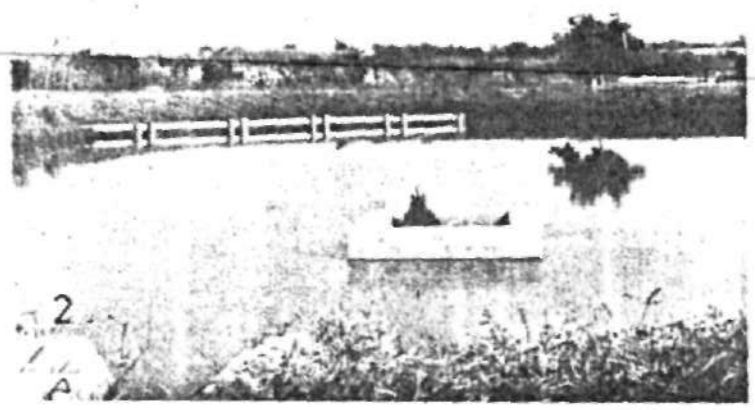
2. Stabilization pond three.

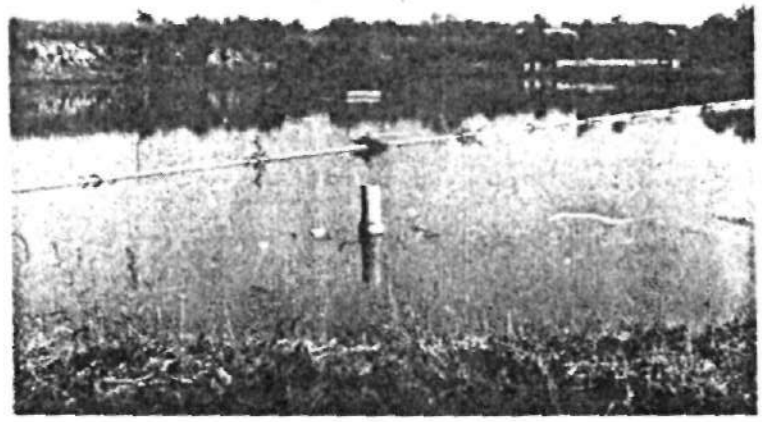
3. Stabilization pond One.

4. By Pass Pond.

Plate 1


1


2




4

PLATES II - VI

Photographs of some of the algae whose drawings and dimensions appear on plates VII to XXXVIII.

PLATE II

1.	Coelastrum sp	Mag x 1000
2.	Tetraedron sp	" x 6500
3.	Staurodesmus sp ?	" x 5000
4.	Euglena sp	" x 713
5.	Unidentified unicell	" x 1700
6.	Unidentified	" x 1000
7.	? Staurodesmus sp	" x 1167
8.	Unidentified unicell	" x 4000
9.	Trachelomonas sp	" x 2000

Plate II

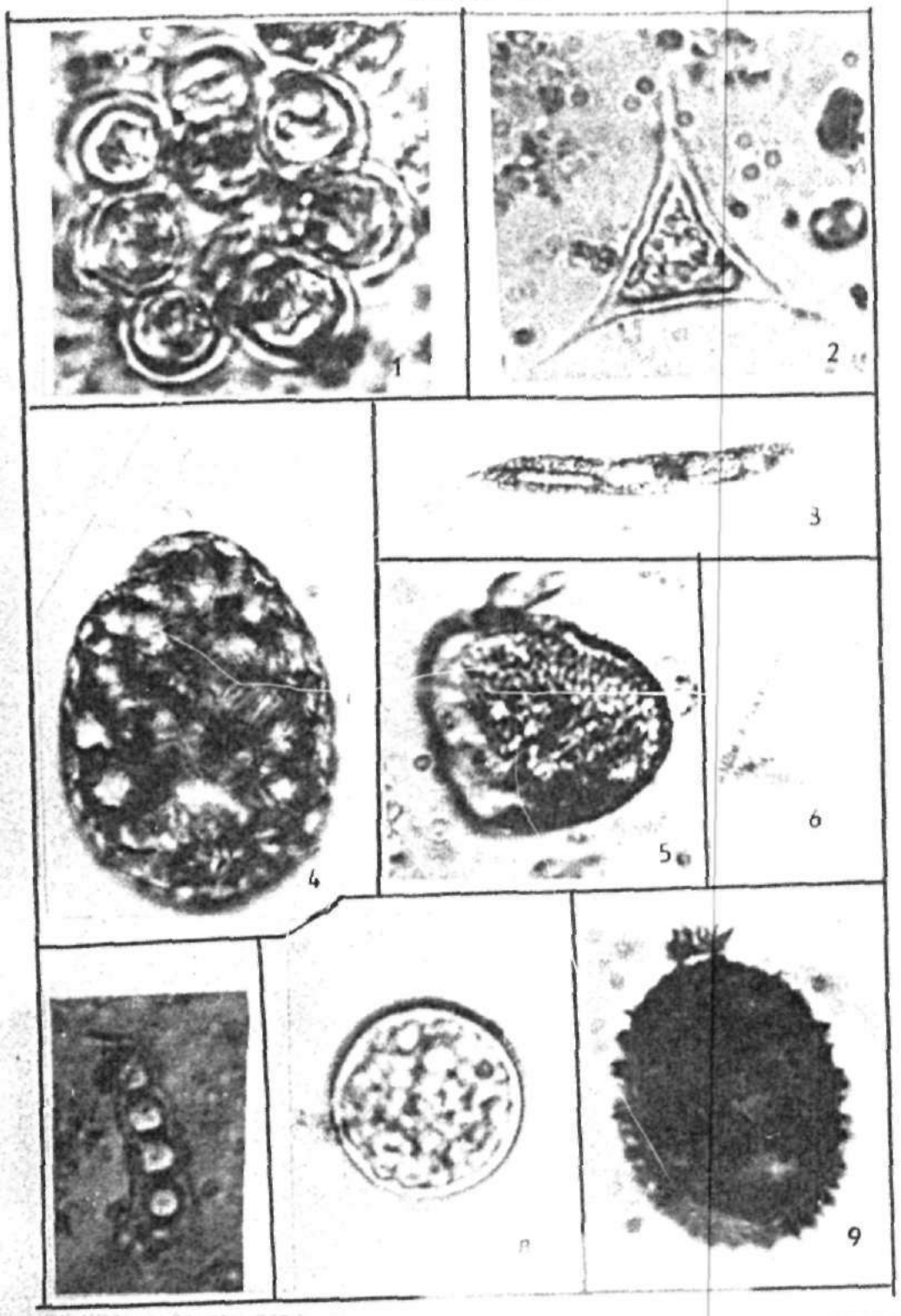


PLATE III

1.	Microcystis aeruginosa Kuts.	Mag	x 720
2.	Micractinum sp	"	x 1,000
3.	Anabaena sp	"	x 1,000
4.	Unidentified (BPF66)	"	x 600
5.	Spirulina major Kuetzing.	"	x 1,000
6.	Spirulina spp	"	x 1,000
7.	Unidentified unicell	"	x 3,167
8.	? Coelastrum sp	"	x 267
9.	Unidentified colony	"	x 2,000
10.	Chrysococcus rufescens ?	"	x 4,333

Plate III

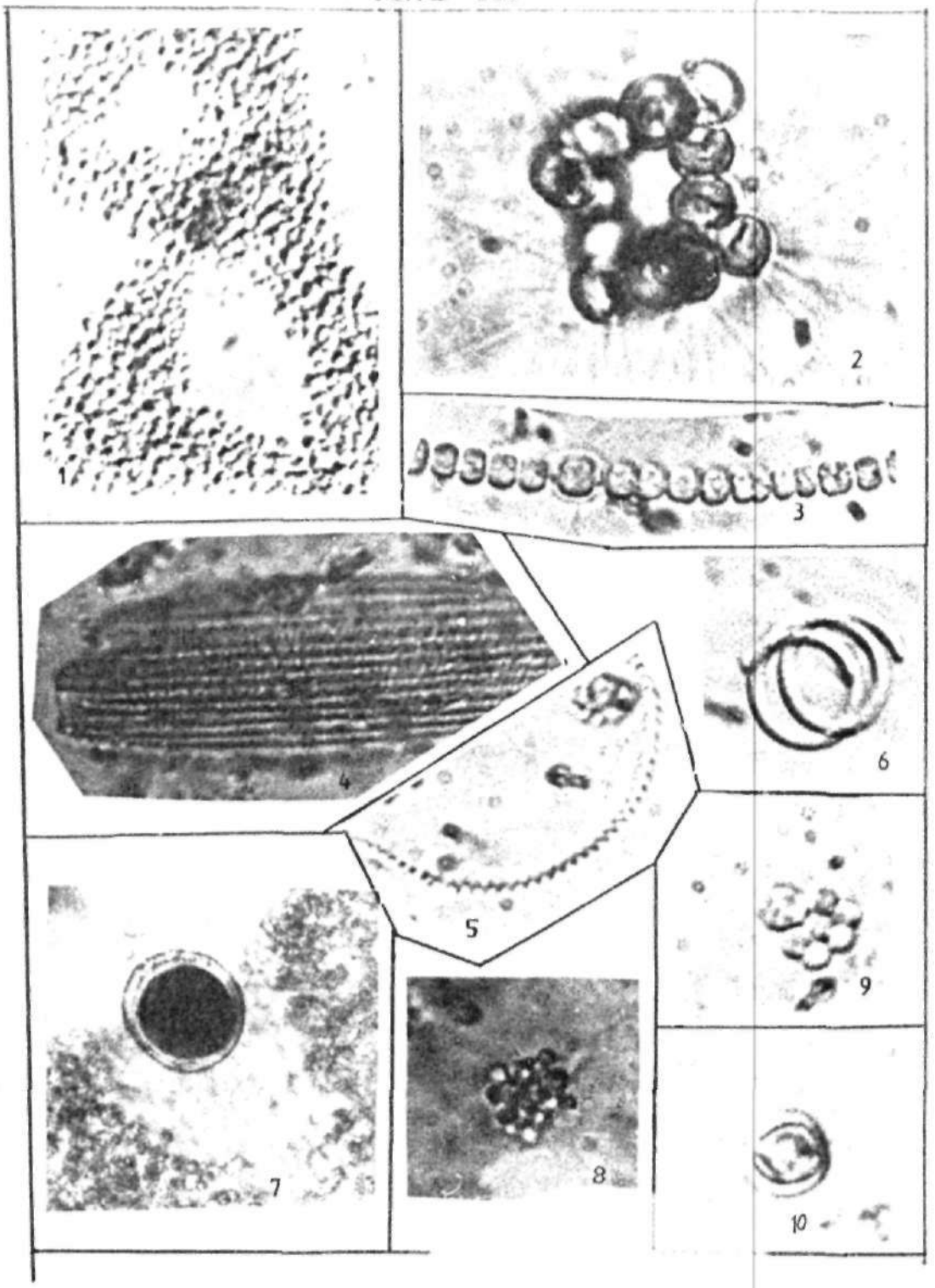


PLATE IV

1.	Coelastrum sp ?	Mag	x 3,200
2.	Unidentified diatom ?	"	x 216
3.	Unidentified hexagonal diatom	"	x 475
4.	Oscillatoria subbrevis Schmidle	"	x 2,000
5.(a)	Cyclotella meneghiniana (b) Nitzschia sp	"	x 2,074
6.	Euglena sp	"	x 4,400
7.	Trachelomonas sp	"	x 1,556
8.	Nostoc sp	"	x 2,125

Plate IV

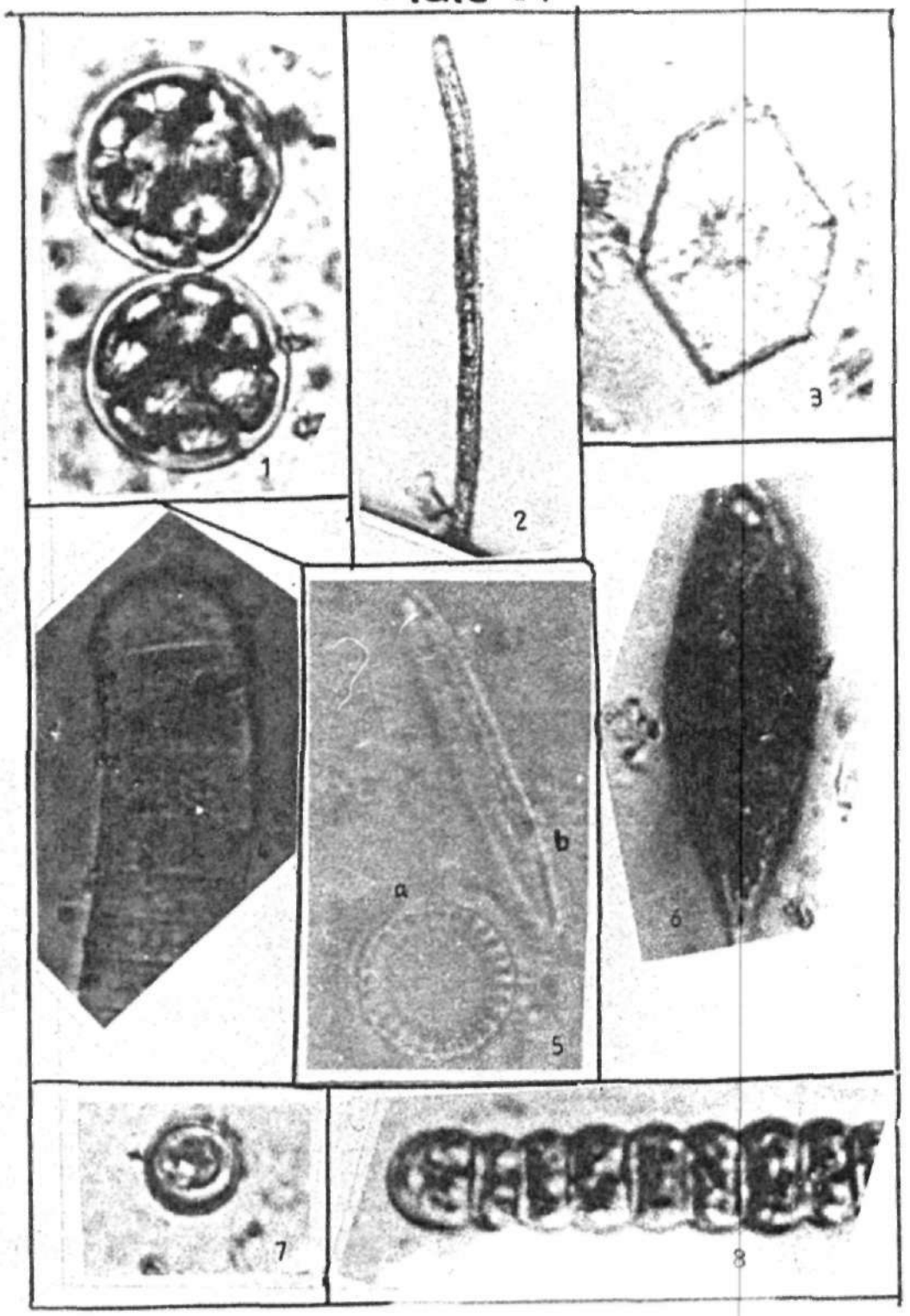


PLATE V

1.	Unidentified colony	Mag x 3,000
2.	Unidentified colony	" x 3,000
3.	Cosmarium magaritiferum Menegh	" x 1,368
4.	Phacus curvicauda Swirenko	" x 1,400
5.	Micractinum quadrisetum	" x 2,667
6.	Pediastrum sp	" x 1.200
7.	Spirogyra sp	" x 750
8.	Lepocinclis ovum (Ehr) Lemmermann.	" x 1,869
9.	Nephrocytium sp ?	" x 4,617
10.	Ankistrodesmus falcatus	" x 1,333

Plate V

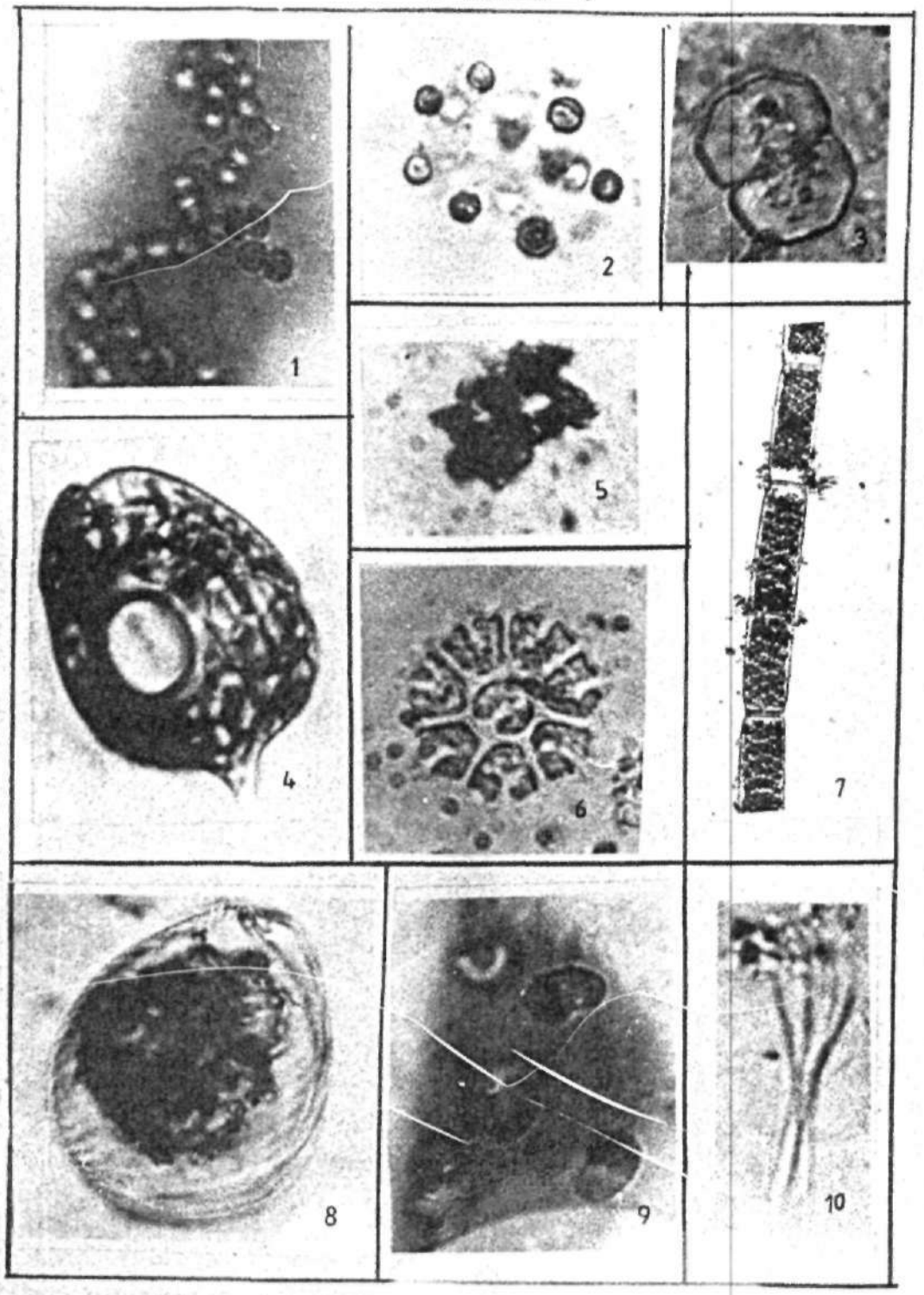
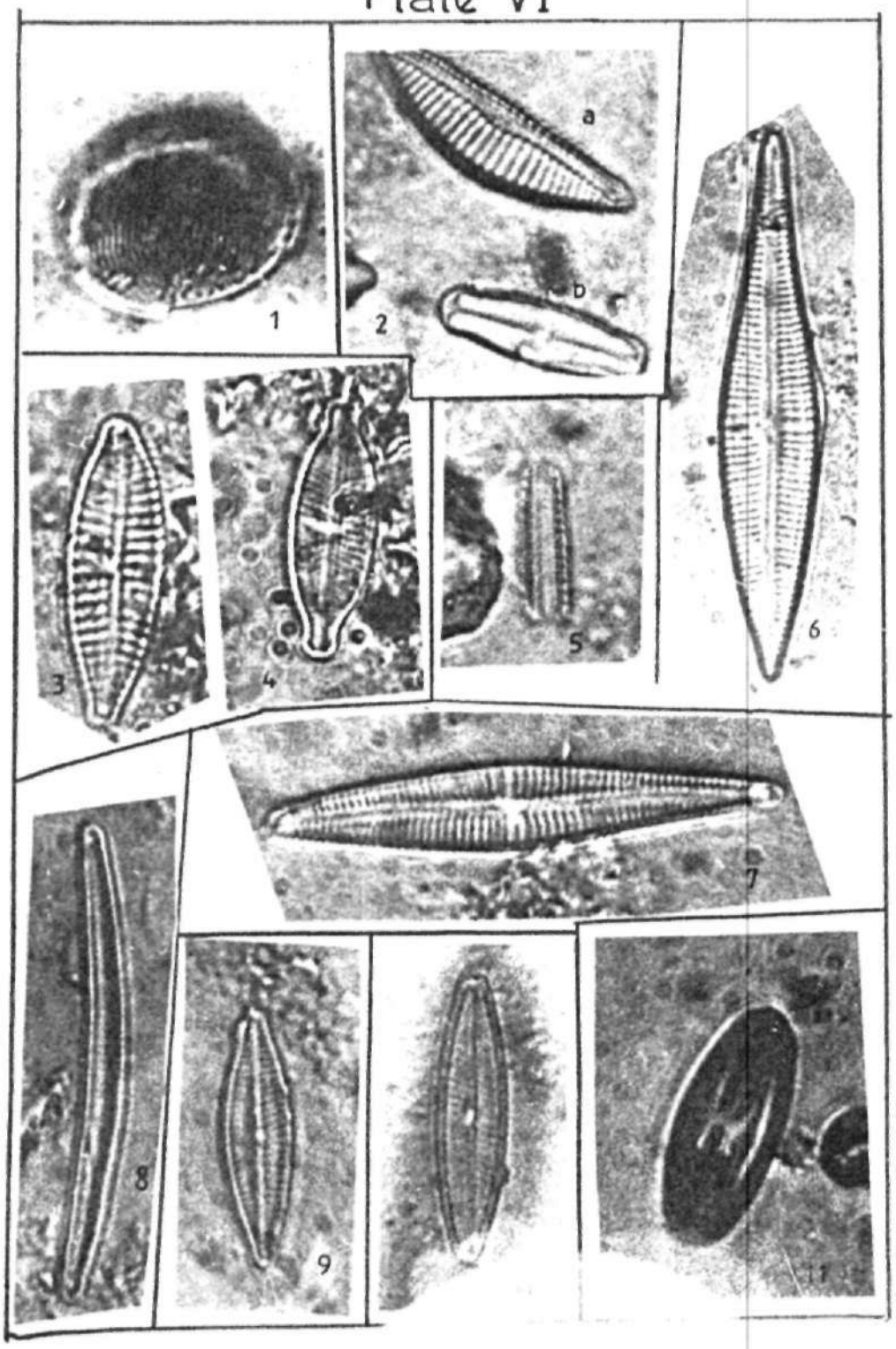


PLATE VI

1.	Unidentified	Mag x 1,737
2.	Cymbella ventricosa Kg (b) Navicula pupula Kg	" x 1,000
3.	Gomphonema angustatum kg.	" x 1,714
4.	Navicula decusis Oestr.	" x 1,714
5.	Surirella angustata Kutz	" x 875
6.	Gomphonema lanceolatum Ehr.	" x 1,000
7.	Gomphonema gracile Ehr.	" x 1,444
8.	Synedra sp	" x 1,000
9.	Navicula ? radiosa Kg del	" x 1,833
10.	Navicula heufleri Gran	" x 1,200
11.	Navicula auriculata Hust	" x 2,800

Plate VI



KEY FOR DRAWINGS ON PLATES

VII - XXXVIII

L = Length of specimen in um

B = Breadth of specimen in um

S = The numbers of striae present in 10um of the specimen.

C = The number of carinal dots present in 10um of the specimen.

D = Diameter of specimen in um

X100 or 400 refer to the magnification at which the specimens were viewed with the microscope.

Drawings were not made to scale.

PLATE VII

1. Dictyosphaerium sp
2. Trachelomonas sp (Plate IV, 7)
3. Ankistrodesmus falcatus cf var mirabilis (West & West) G.S. West.
4. Euroglena sp ?
5. Oscillatoria tenuis. F. tergestina Rabenh.
6 Spirogyra elipsospora. Transeau.
7. Tetraedron sp
8. Aphanocapsa cf endophitica. G.M. Smith
9. Staurodesmus validus (West) Thon ?
10. Gleocystis major Gerneck
11. Unidentified (KN59)
12. Staurodesmus sp ?
13. Monoraphidium sp ?
14. Scenedesmus quadicanda (Turp) de Breb.
15. Chrysococcus rufescus ?
16. Tetradesmus wisconsinense G.M. Smith.
17. Closterium moniliferum cf. var concavum. Ehrenberg.
18. Unidentified unicell (KN76).
20. Scendesmus sp.
20 Merismopedia glauca
21. Unidentified unicell (KN82)

Plate VII

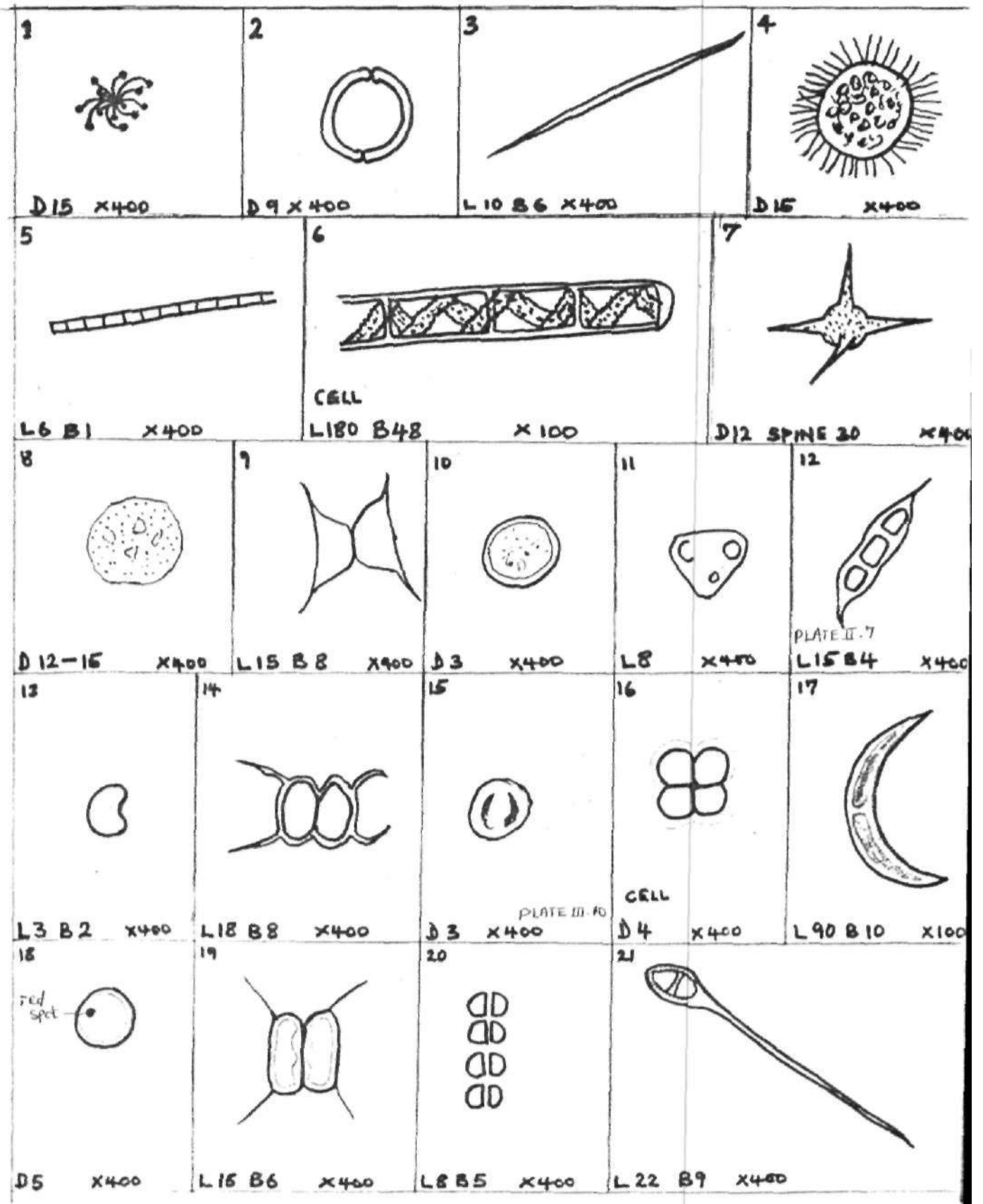

1
D15 ×400
2
D9 ×400
3
L10 B6 ×400
4
D15 ×400
5
L6 B1 ×400
6
CELL
L180 B48 ×100
7
D12 SPINE 20 ×400
8
D12–16 ×400
9
L15 B8 ×400
10
D3 ×400
11
L8 ×400
12
PLATE II-7
L15 B4 ×400
13
L3 B2 ×400
14
L18 B8 ×400
15
PLATE III-10
D3 ×400
16
CELL
D4 ×400
17
L90 B10 ×100
18
red spot
D5 ×400
19
L16 B6 ×400
20
L8 B5 ×400
21
L22 B9 ×400

PLATE VIII

22. Trachelomanas sp

23. Scenedesmus acuminatus Chodat.

24. Unidentified (KM13), (BJ98)

25. Unidentified unicell (BN126)

26. Nostoc sp.

27. Staurodesmus sp ?

28. Euglena sp

29. *Unidentified unicell (Plate II, 5).*

30. Tetrastrum cf. triangulare. Komarek.

31. Stichococcus cf. bacillaris Nageli

32. Unidentified lunate unicell (KN89)

33. Tetraedron sp.

34. Pediastrum sp.

35. Scenedesmus quadricauda var quadrispina (Chod) G.M. Smith.

36. Unidentified unicell (KN99)

37.

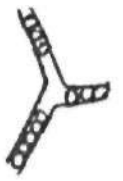
Plate VIII

22

L21, B15 ×400

23

COLONY
L25, B20 × 400

24

L18, B2 ×400

25

L20, B5 ×400

26

L.50, B5

27

PLATE II-7
L30, B5 ×400

28

L38, B9 ×400

29

L20, B13 ×400 PLATE II-5

30

COLONY
D.12 ×400

31

L3, B1·5 ×400

32

L.18 B1 ×400

33

L.5 ×400

34

COLONY
D 25 PLATE V.6

35

L24, B.25

36

L.8 B.9 ×400

37

L5, B3 ×400

38

D.9 ×400

39

D.3 × 400

40

L9 B4 ×400

41

PLATE III-7
D.6 ×400

42

L30 B.12 400

43

CELL
L3, B2 PLATE V-9 ×400

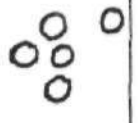
44

CELL
D.3 ×400

PLATE IX

45. Unidentified colony (KN110)

46. Dictyosphaerum sp

47. Characium sp ?

48. Kirchneriella sp ?

49. Unidentified flagellate (KN116)

50. Chroomonas sp

51. Coelastrum sp

52. Unidentified unicell (KN133)

53. Coelastrum sp ?

54. Unidentified (KN143)

55. Cosmarium reniforme Archer

56. Cosmarium contracium Kirchner

57. Unidentified colony (KN131).

58. Selenastrum westii. G.M. Smith.

59. Unidentified unicell (KN149)

60. Oscillatoria sp.

61. Cosmarium cf. magaritiferum Menegh.

62. Chlamydomonas globosa Snow.

63. Kirchneriella sp. ?

Plate IX

45

CELL
L8,B4 ×400

46

L.10,B9 ×400

47

L.6,B1·5 ×400

48

D12 ~ ½×400

49

L15,B10 ×400

50

L10,B5 ×400

51

COLONY
D20

52

L.15,B8 ×400

53

COLONY PLATE III·8
D.45 ×400

54

L.19,B15 ×400

55

L8,B6 ×400

56

L.18,B12 ×400

57

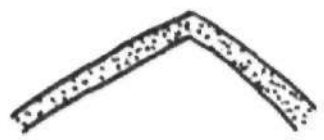
CELL
L8, B3 ×400

58

CELL
L20,B3 ×400

59

L19,B5 ×400

60

L.67, B3 ×400

61

PLATE V. 3
L.19, B15 ×400

62

D.12 ×400

63

L10,B2 ×400

PLATE X

64. Volvox sp ?

65. Tetraedron sp.

66. Aphanothece sp.

67. Kirchneriella sp.

68. Scenedesmus quadricauda

69. Unidentified filament.

70. Oscilatoria limnetica Lemmermann.

71. Scenedesmus sp.

72. Trachelomonas sp ?

73. Oscillatoria sp

74. Phormidium tenue (Menegh) Gomont ?

75. Ankistrodesmus falcatus var acicularis (A. Braun) G.S. West

76. Unidentified (BD75)

77. Scenedesmus sp

78. Haematococcus lacustris (Girod) Rostaf.

Plate X

64

D27 ×400

65

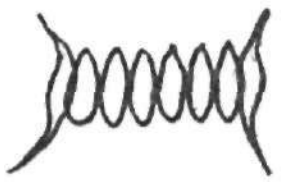
L5, B5 ×400

66

L8, B5 ×400

67

L15 B6 ×400

68

L25, B8 ×400

69

L300 B6 × 100

70

L30, B2 ×400

71

L12, B9 ×400

72

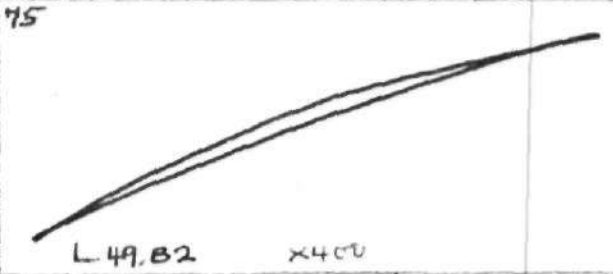
D9 ×400

73

L45, B5 ×400

74

L8, B2 ×400

75

L49, B2 ×400

76

L30, B8 ×400

77

L5, B3 ×400

78

D8 ×400

PLATE XI

79. Euglena sp.

80. Euglena sp.

81. Pyramimonas tetrahynchus Schmarda ?

82. Unidentified unicell (BN23).

83. Rhodomonas ovalis Nygaard

84. Ophiocytum parvulum Perty A. Braun ?

85. Unidentified unicell

86. Unidentified unicell (BN25).

87. Oocystis sp.

88. Unidentified unicell (BD113).

89. Unidentified filament (BN32).

90. Unidentified unicell (BN34).

91. Oscillatoria prolifica (Grev) Gomont.

92. Anabaena sp

93. Chlamydomonas sp

94. Cosmarium sp

95. Crucigenia rectangularis

96. Unidentified colony

97. Oscilatoria pseudogeminata Biswas

Plate XI

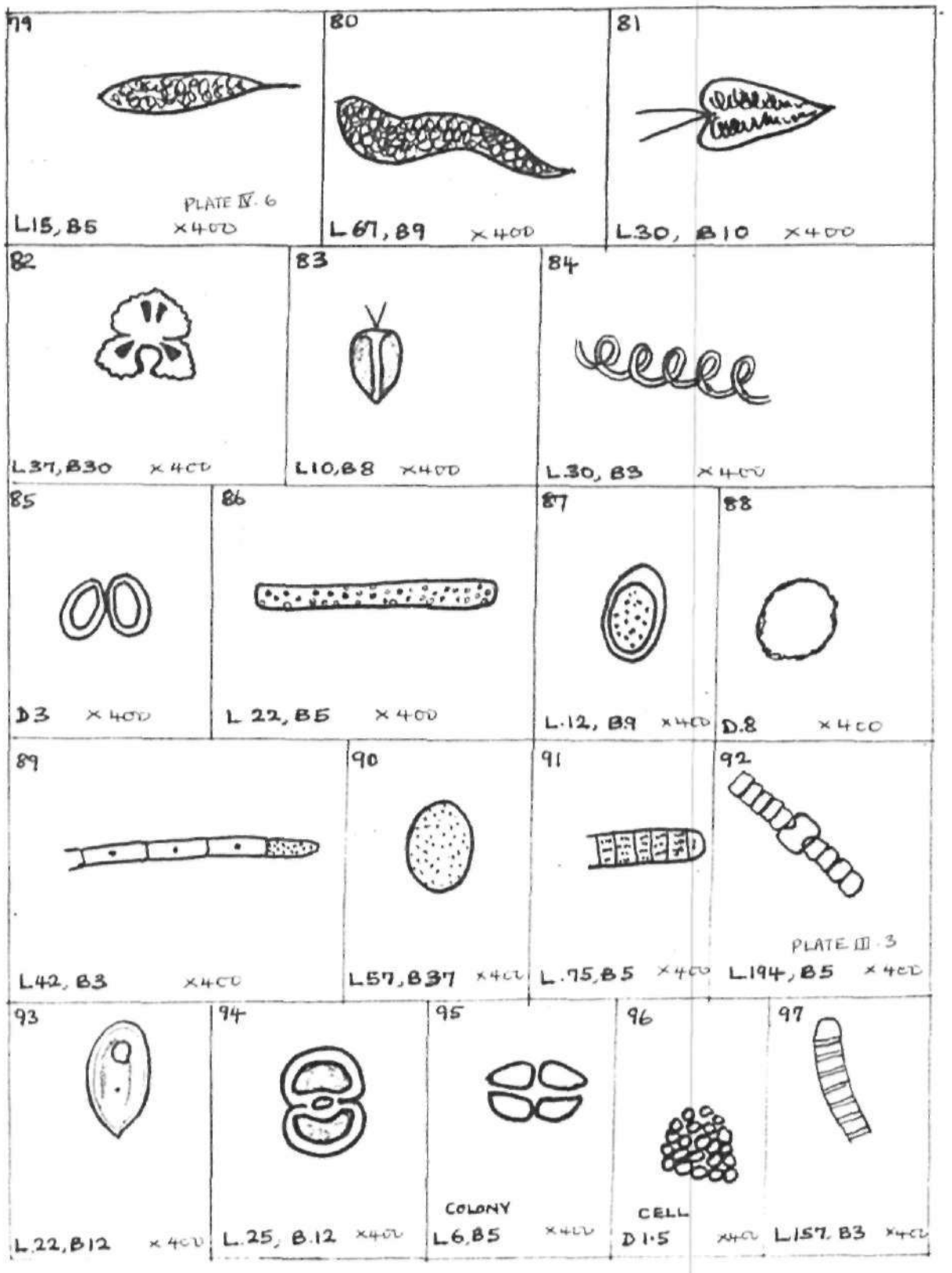

79
L15, B5 ×400
PLATE IV. 6
80
L67, B9 ×400
81
L30, B10 ×400
82
L37, B30 ×400
83
L10, B8 ×400
84
L30, B3 ×400
85
D3 ×400
86
L 22, B5 ×400
87
L·12, B9 ×400
88
D.8 ×400
89
L42, B3 ×400
90
L57, B37 ×400
91
L·75, B5 ×400
92
PLATE III 3
L194, B5 ×400
93
L22, B12 ×400
94
L·25, B·12 ×400
95
COLONY
L6, B5 ×400
96
CELL
D 1·5 ×400
97
L157, B3 ×400

PLATE XII

98. Unidentified colony (BN135)

99. Unidentified colony (BN136), (SPON 19).

100. Lyngbya sp

101. Euglena sp.

102. Arthrospira platensis Banerji cf.

103. Unidentified unicell (SPON3).

104. Stichococcus sp.

105. Unidentified unicell (SPON 12), (SPOJ 10).

106. Unidentified unicell (SPON 13).

107. Aphanothece saxicola Naegeli

108. Aphanocapsa endophytica G.M. Smith.

109. Cyanarcus harmiformis Pascher.

110. Unidentified (SPON 20).

111. Micractinum sp.

112. Unidentified colony.

113. Volvox sp.

114. Unidentified unicell.

115. Tetradesmus wisconsinenses Smith

116. Lyngbya contorta Lemm.

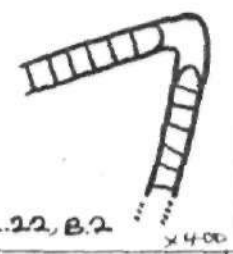
Plate XII

98

CELL
D5 ×400

99

CELL
D3 × 400

100

L.22, B.2 ×400

101

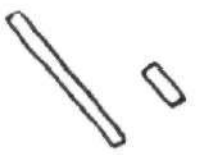
L.72, B13 ×400

102

L.45, B2 ×400

103

D.36 ×400

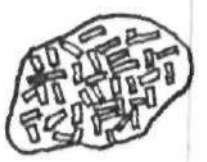
104

L34, B1·5 × 400

105

L60, B37 ×400

106

L.18, B.8 ×400

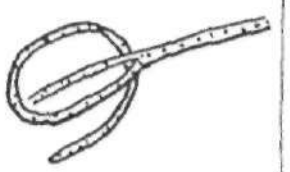
107

COLONY
L.224, B89 ×400

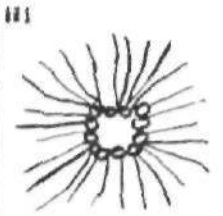
108

D.12 × 400

109

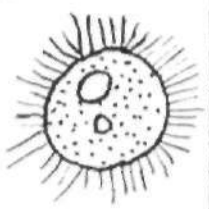
L6, B1 ×400

110

L.45, B.1·5 × 400

111

COLONY
L34, B.30 ×400

112

CELL
D3 ×400

113

D11 ×400

114

L15, B11 ×400

115

D5 ×400

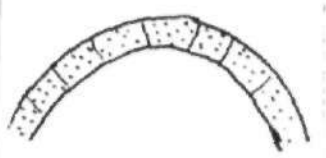
116

L60, B5 ×400

Plate XIII

117

CELL
L.5, B2 ×400

118

L.12, B3 ×400

119

L.6, B.5 ×400

120

L.15, B.11 ×400

121

L.7, B5 ×400

122

L.5, B2 ×400

123
L.22, B10 ×400

124

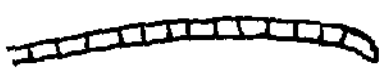
CELL
D.3 ×400

125

D.6 ×400

126

L.74, D.8 ×400

127

L.49, B2 ×400

128

D.13 ×400

PLATE XIV

129. Scenedesmus arcuatus var playdisca G.M. Smith cf

130. Trachelomonas sp ?

131. Crucigenia rectangularis (A. Braun) Gay.

132. Oscillatoria lacustris (Kleb) Geitler

133. Scenedesmus dentriculatus Lagerheim ?

134. Phormidium retzii (Ag) Gom.

135. Unidentified unicell (BD112).

136. Oocystis cf solitaria Wittrock

137. Unidentified unicell

138. Oscillatoria putrida

139. Spirulina sp.

140. Oscillatoria subbrevis Schmidle.

Plate XIV.

129



COLONY
L.25, B.25

130



L.6, B.5

131



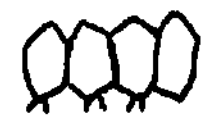
COLONY
L.8, B.6

132



L.30, B.5

133



L.24, B.6

134



L.27, B.8

135



L.5, B.2

136



COLONY
L.13, B.9

137



D.15

138



L.34, B.3

139



L.25, B.1

140



L.516, B.12 PLATE IV. 4

PLATE XV

141. Trachelomonas volvocina Ehrenberg.

142. Unidentified filament (BJ9)

143 " unicell (BJ14)

144. " colony (BJ30)

145. " unicell (BJ31)

146. " unicell (BJ39)

147. " colony (BJ41)

148. " unicell (BJ42)

149. " colony (BJ48)

150. " " (BJ52)

151. " "

152 " unicell (BN68).

153. Chlamydomonas reinbardii Dangeard.

154. Aphanothece nidulans P. Richter

155. Unidentified (BJ69)

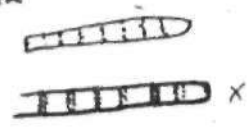
156. Kirchneriella sp.

157. Unidentified unicell (BJ5).

Plate XV

141

D.9

142

L.12, B1.5

143

D.6

144

CELL
D.5

145

D.5

146

L11, B5

147

CELL
L.5, B.2

148

L.10, B.8

149

CELL
L.6, B.5

150

UPPER CELL
L5, B4
LOWER
D.4

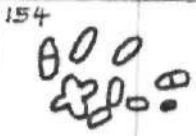
151
COLONY
D.3

152

D.7

153

LB, B.6

154

CELL
L.4, B.2

155

L 46, B2

156

L.6, B.5

157

D.5

PLATE XVI

158. Tetrastrum sp.

159. Unidentified colony (BJ114).

160. Scenedesmus quadricauda cf. var Westii G.M. Smith.

161. Unidentified colony (BN144)

162. Spirogyra porticalis (Muell.) Cleve cf.

163. Unidentified filament (KJ16).

164. " unicell (SPJ9)

165. " " (SPTJ18).

166. " " (SPTJ7).

167. Anacystis sp.

168. Micractinum sp.

169. Unidentified flagellate.

170. " (SPTJ19).

171. Kirchneriella sp.

172. Unidentified unicell.

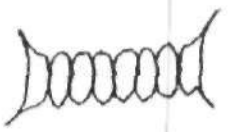
Plate XVI

158

CELL
D. 8

159

CELL
L.10, B.8

160

COLONY
L.24, B.6

161

COLONY
L.8, B.3

162

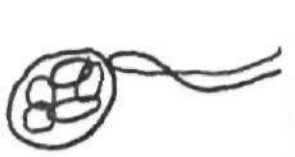
L.150, B.40

163

L.33, B.1

164

L.37, B25

165

D.8

166

L.24, B19

167

CELL
L.6, B.5

168

COLONY
D.4.5

169

D.21

PLATE X 5

170

L.45, B33

171

L.6, B.2

172

D 10

PLATE XVII

173. Trachelomonas charkowiensis Swirenko

174. Unidentified unicell (SPTM12)

175. Unidentified unicell (BN57) (KN28).

176. Unidentified unicell

177. Stigeoclonium sp?

178. Pediastrum sp.

179. Oscillatoria corallinae (Kutz) Gomont

180. Selenastrum westii

181. Scenedesmus sp ?

182. Coelastrum sp ?

183. Scenedesmus sp

184. Unidentified unicell (BJ67).

185. Plate II, 6.

186. Cosmarium sp.

187. Tetraedron sp.

188. Unidentified.

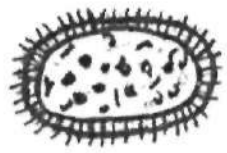
189. Oscillatoria curviceps C.A. Agardh

190. O. tenius F. tergestina Rabenh.

191. Unidentified unicell

192. " flagellate.

Plate XVII

173

L.23, B.15

174

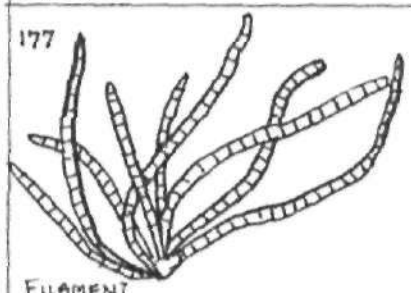
L.13, B.6

175

L.10, B.5

176

L.5, B.4

177

FILAMENT
L.115 B.4

178

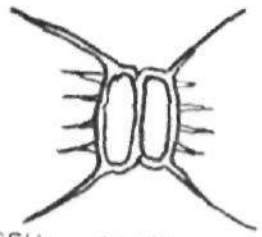
COLONY
D.11

179

L.10, B.1

180

COLONY
D.20

181

CELL L.6, B.5. SPINE L.8.

182

CELL
D.7

183

CELL
D.7

184

L.10, B.6

185

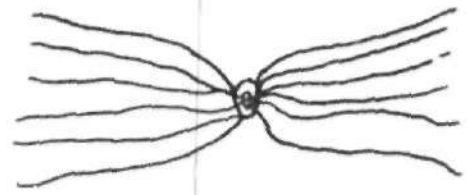
L.12, B.0.5

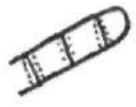
186

L.6, B.4

187

L.12, B.12

188

CELL D.4 FILAMENT L.10, B.0.5

189

L.35, B.8

190

L.40, B.1

191

D.3

192

D.10

PLATE XVIII

193. Spirulina major Kuetzing

194. Oscillatoria perornata Skuja

195. O. lemmermannii Wolosz.

196. O. limnetica Lenmermann.

197. Ankistrodesmus sp.

198. Dinobryon sertularia Ehrenberg.

199. Unidentified unicell (BN96).

200. Kirchneriella sp.

201. Kirchneriella sp ?

202. Oscillatoria sp.

203. Crucigenia fenestrata. Schmidle.

204. Ulothrix variabilis Kuetzing

205. Coelastrum sphaericum Nageli.

206. Chlorochromonas minuta Lewis.

207. Chlamydomonas sp.

208. Chlorochromonas sp.

209. Phormidium tenue (Menegh). Gomont ?

210. Euglena sp.

211. Unidentified unicell (BN130).

212. Phacus curvicauda Swirenko

213. Nostocopsis sp ?

Plate XVIII

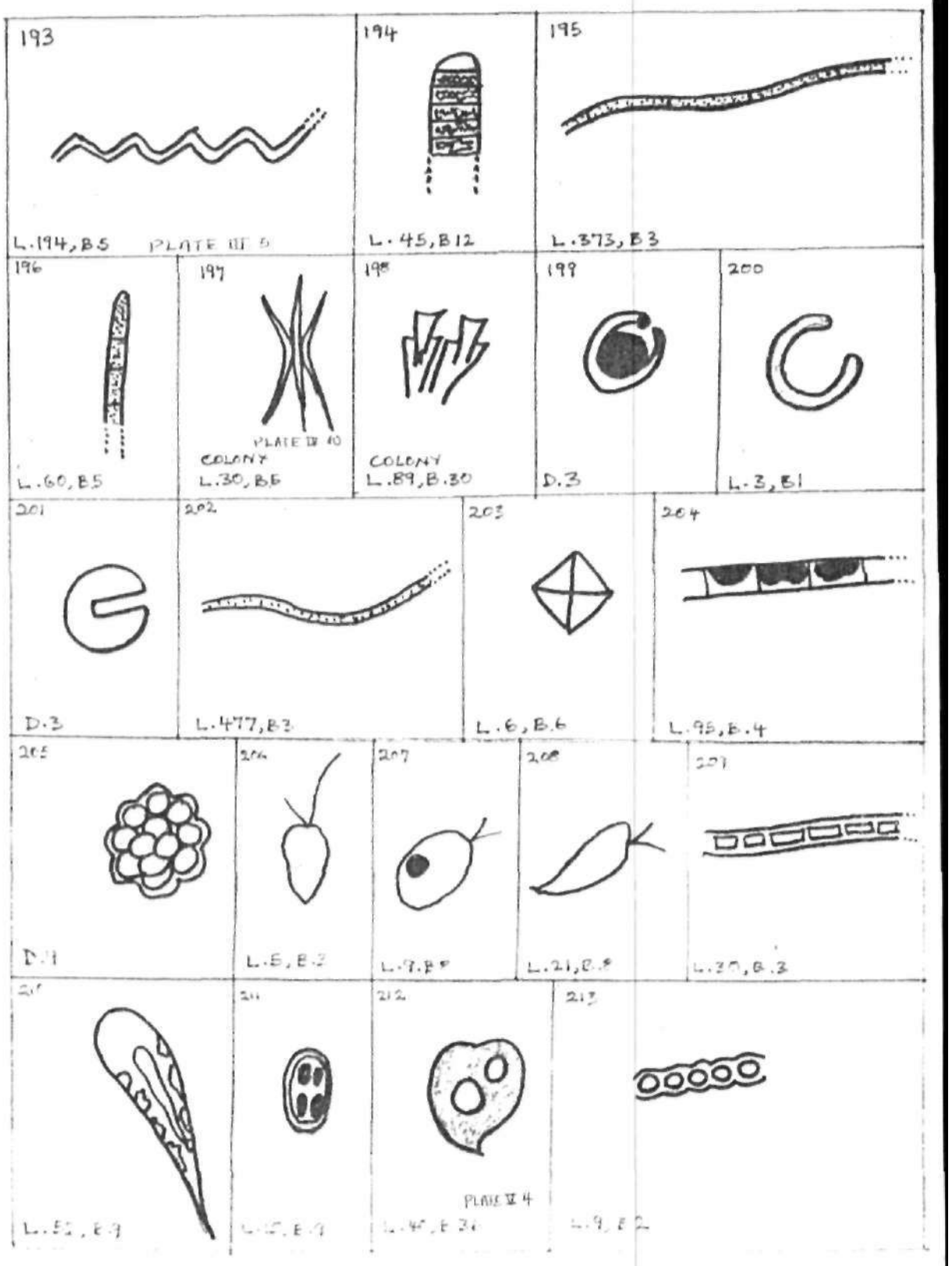

193
L.194, B.5
PLATE III 5
194
L.45, B.12
195
L.373, B.3
196
L.60, B.5
197
PLATE III 10
COLONY
L.30, B.6
198
COLONY
L.89, B.30
199
D.3
200
L.3, B.1
201
D.3
202
L.477, B.3
203
L.6, B.6
204
L.95, B.4
205
D.1
206
L.5, B.2
207
L.7.B.
208
L.21, B.
209
L.37, B.3
210
L.5, B.3
211
212
PLATE II 4
213

PLATE XIX

214. Unidentified unicell

215. Ophiocytium sp.

216. O. capitatum cf. var longispins Moebius Lenmermann.

217. Tetraedron sp.

218. Micractinum sp.

219. Unidentified (BPF66).

220 Lepocinclis ovum (Ehr) Lemmermann

221. Phacus curvicauda Swirenko

222. Unidentified colony (BM54).

223. " " (BM58).

224. Dactylococcopsis smithii Chodat & Chodat.

225. Chroococcus pallidus Naegeli

226. Chlorella sp.

227. Unidentified colony (BN13).

228. Ophiocytium capitatum var longispinum (Moeb) Lenmermann?

229. Raphidiopsis curvata Fritzsch cf. Rech.

230. Oscillatoria corallinae (Kutz) Gomont.

231. Unidentified (BM22).

Plate XIX

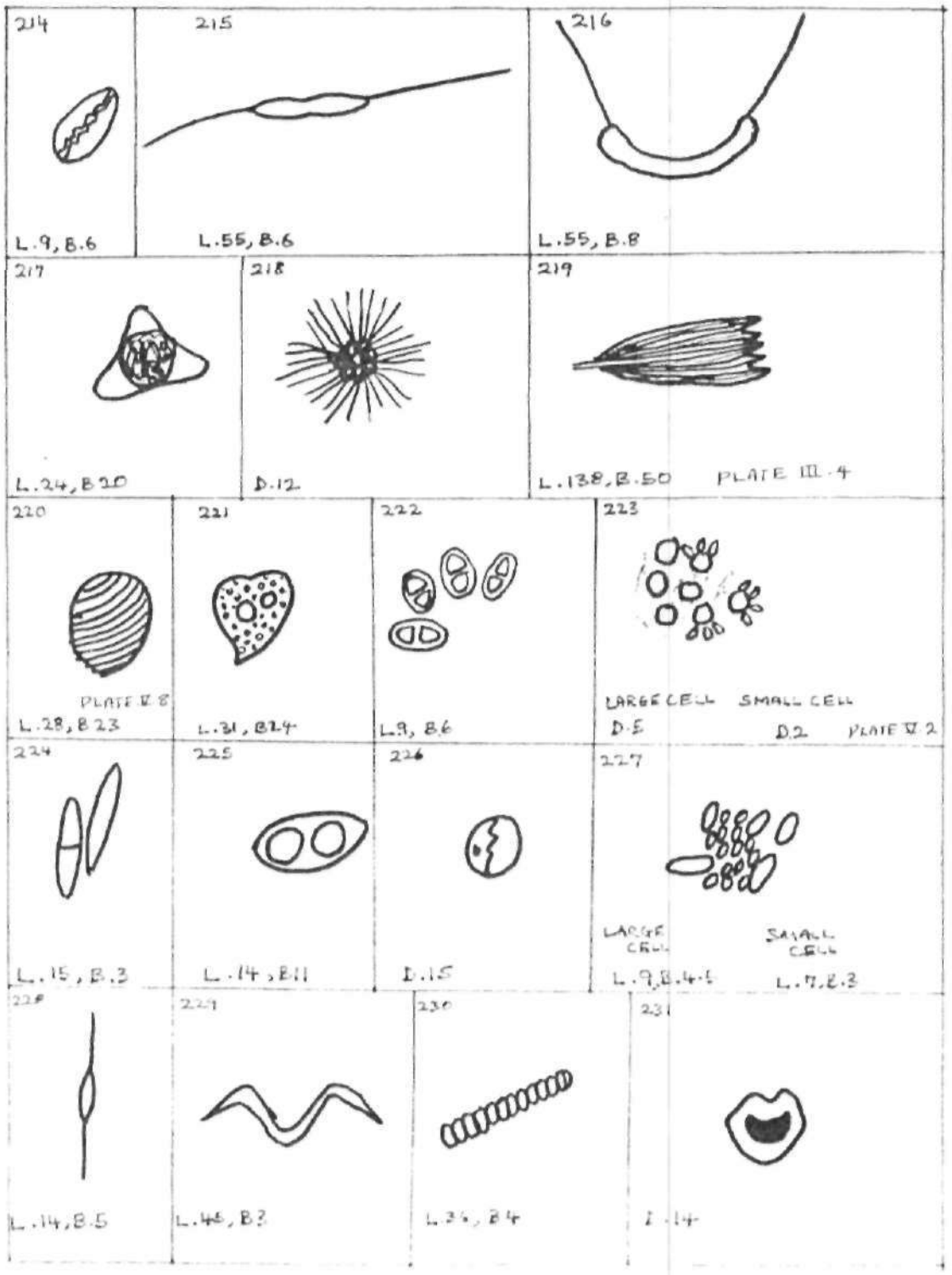

214
L.9, B.6
215
L.55, B.6
216
L.55, B.8
217
L.24, B.20
218
D.12
219
L.138, B.50
PLATE III-4
220
PLATE V-8
L.28, B.23
221
L.31, B.24
222
L.9, B.6
223
LARGE CELL
SMALL CELL
D.5
D.2
PLATE V-2
224
L.15, B.3
225
L.14, B.11
226
D.15
227
LARGE CELL
SMALL CELL
L.9, B.4.5
L.7, B.3
228
L.14, B.5
229
L.46, B.3
230
L.36, B.4
231
L.14

PLATE XX

232. Microcystis elebans (Bred) Kutz.

233. Unidentified colony

234. " flagellate (SPTF28).

235. " flagellate

236. Merismopedia elegans A. Braun ?

237. Golenkinia sp.

238. Arthrospira platensis

239. Unidentified flagellate (SPTM11)

240. " " (SPTM20).

241. Arthrospira sp.

242. Unidentified unicell

243. Nostoc sp.

244. Unidentified unicell

245. Chroomonas sp?

246. Chlorochromonas sp

247. Cosmarium sp.

Plate XX

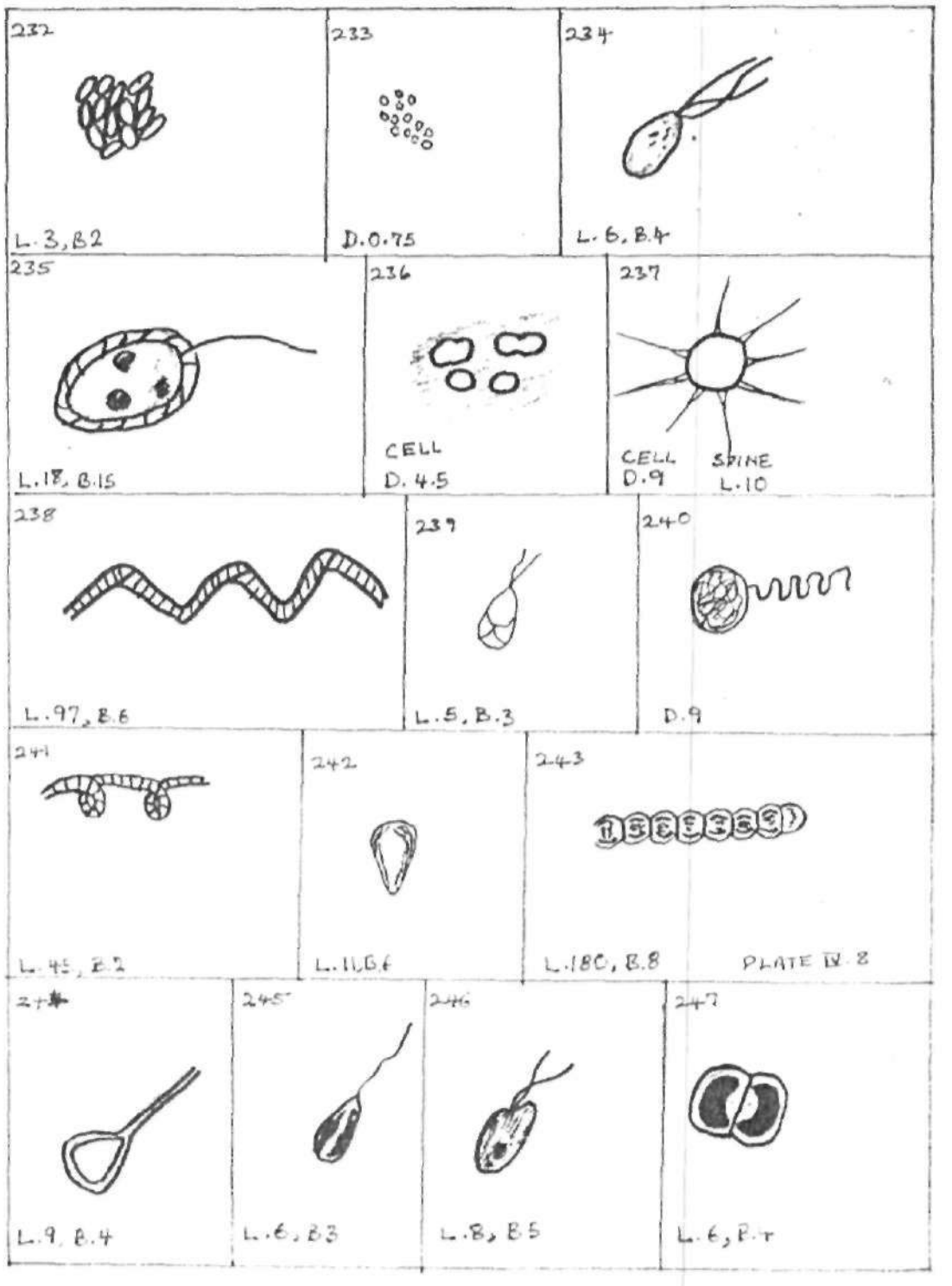

232
L. 3, B2
233
D. 0.75
234
L. 6, B.4
235
L. 18, B.15
236
CELL
D. 4.5
237
CELL
D. 9
SPINE
L. 10
238
L. 97, B.6
239
L. 5, B. 3
240
D. 9
241
L. 45, B.2
242
L. 11, B.6
243
L. 180, B.8
PLATE IV. 8
244
L. 9, B.4
245
L. 6, B.3
246
L. 8, B.5
247
L. 6, B. 7

Plate XXI

248



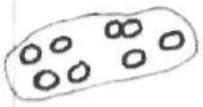
L.307, B12 PLATE IV 2

249



D.3

250



D.2

251



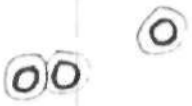
D.6

252



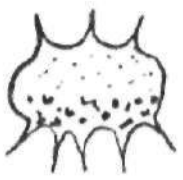
CELL
D.2

253



CELL
D.2

254



L.9, B.7

255



L.134, B6 PLATE V·7

256

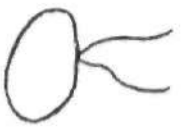
L.104, B.15

257



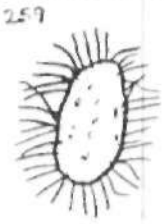
L.8, B.4

258



L.8, B.5

259



L.12, B8

260



L.3, B1

261

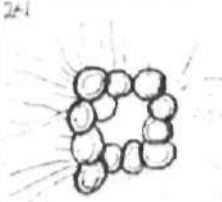


PLATE III·2
X450

L24, B18

262



L.11, B.2

263



L.11, B8

264



L.9, B4

Plate XXII

265

D8 ×400

266

CELL
D1 ×400

267

CELL
L5, B3

268

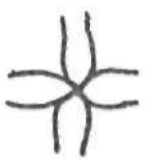
L5, B.8

269

CELL
L5, B4

270

L.9, B.15

271

L.8, B5

272

L.18, E10

273

L.10, B2

274

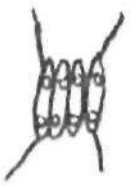
D6

275

L.10C, B3

276

CELL
L5, B3

277

COLONY
L4, B4

278

D7

279

L.30, B.18

Plate XXIII

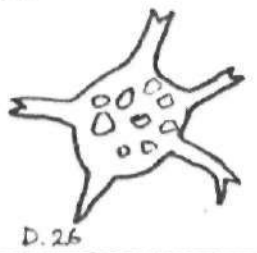
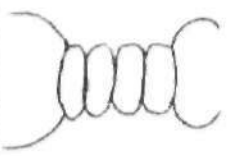
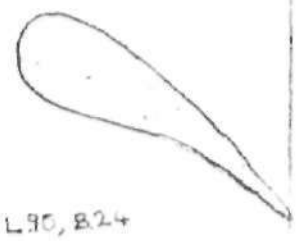
280  CELL D.11	281  D.26	282  CELL D.8	283  D 24
284  L.10, B.8	285  L.11, B.3	286  L.12, B4	287  L 15, B 13
288  L.450, B.10	289  L.12, B1	290  L.20, B.2	291  COLONY L.9, B.8
292  L.22, B2	293  COLONY L.9, B.4	294  L.9, B.8	295  L.5, B.1.5
296  L.120, B3	297  L.90, B.24	298  L.60, B5	299  L.130, B.0.5

PLATE XXIV

300. Spirulina gigantea Schmidle

301. S. princeps West and West.

302. S. laxissima West.

303. Scenedesmus sp.

304. Scenedesmus sp.

305. Scenedesmus dimorphus (Turp) Kuetz.

306. Trachelomonas pulcherrima Playfair

307. Unidentified (BD130).

308. Gleocapsa sp.

309. Oscillatoria

310. O. accutissima Kufferath.

311. O. chalybea Mertens

312. O. hamelii Fremy

313. O. prolifica (Grev) Gomont.

314. O. perornata Skuja

315. Oscillatoria sp?

316 Arthrospira jeneri (Kuetz) Stizenberger.

317. Crucigenia alternans Smith.

318. Coelastrum sp.

319. Koliella longiseta Hindak

Plate XXIV

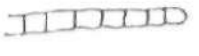
300  L.22, B3	301  L30, B5	302  L.25, B5	303  COLONY L·12 B9
304  COLONY L·8, B.6	305  COLONY L.18, B5	306  L·, B9	307  L.36, B21
308  L 8	309  L.42, B.6	310  L.96, B.2	311  L·, B.6
312  L.63, B 4	313  L.82, B·4·5	314  L.85, B5	315  L.39, B3
316  L 80, B5	317  D 9	318  D·33	319  L·15, B·3

PLATE XXV

320. Crucigenia sp.

321. Oscillatoria curviceps C.A. Agardh.

322. Unidentified unicell (KD20).

323. " " (KD52), (BF11).

324. Scenedesmus quadricauda var maximus West & West cf.

325. Unidentified unicell (SP0D14)

326. Micractinum pusillum Fresenius.

327. Chroococcus sp.

328. Aphanothece sp.

329. Unidentified unicell (BJ28).

330. " " (BJ32).

331. " desmid (BJ36).

332. " unicell (BJ49), (BM64).

333. " colony (BJ57).

334. " unicell (BJ96).

Plate XXV

320 320



D.4
COLONY
D.4

321



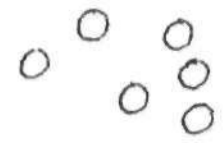
L.200, B13

322



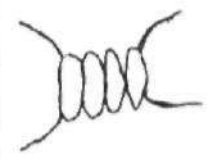
CELL
D.1.5

323



CELL
D.2.5

324



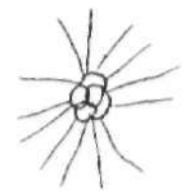
COLONY
L.30, B.10

325



D 18 ×400

326



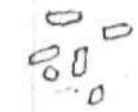
COLONY: D.12 ×400

327



CELL: D.3 ×400

328



CELL: L3, B.1·5 ×400

329



D3 ×400

330



D13·5 ×400

331



L·75, B.12 ×400

332



L8.B5 ×400

333



D5 ×400

334



D5 ×400

PLATE XXVI

335. Chlorella sp ?

336. Scenedesmus acuminatus (Lag) Chodat)

337. Unidentified (SPTJ11).

338. " unicell (SPTJ17).

339. Chlamydomonas sp ?

340. Golenkinia radiata

341. Tetraedron sp.

342. Micractinum sp.

343. Pediastrum boryanum Turp Meneghii

344. Rhodomonas sp.

345. Unidentified unicell (BF12).

346. " " (BF58).

Plate XXVI

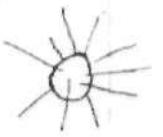
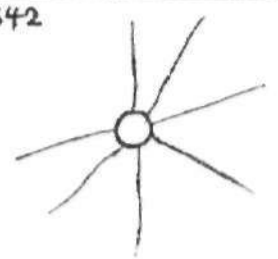
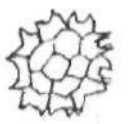
335  D.9 ×400	336  L35, B.5 ×400	337  L.46, B.38 ×400
338  L17, B.12 ×400	339  D.3 ×400	340  D.6 ×400
341  L.24, B28 ×400	342  D.6 ×400	343  D.16 ×400
344  L.7, B5 ×400	345  D.3 ×400	346  D.5 ×400

Plate XXVII

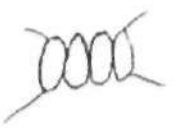
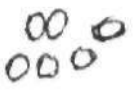
347  D 9 ×400	348  CELL: D.5 ×400	349  CELL: L.3·5, B.3 ×400
350  CELL D.3·5	351  L48, B.45 ×100	352  L8, B.6 ×400
353  L.7, B.5 ×400	354  L.32, B.4	355  CELL: D2 ×400
356  CELL D.2 ×400	357A  L.75, B.4 ×400	358 357B  D·7 ×400
359	360	361

PLATE XXVIII

358. Navicula decusis Oestr.

359. Fragilaria brevistriata

360. Gomphonema parvulum (Kutz) Grun.

361. Navicula pupula (Kg)

362. N. menisculus Schurmann.

363. N. salinarum Grun.

364. Achnanthes hungarica Grun

365. Nitzschia kutzingiana Hilse.

366. Navicula luzonensis Hust.

367. Cymbella turgida (Greg) Cleve.

368. Nitzschia dissipata (Kg) Grun

369. Nitzschia apiculata

370. Achnanthes microcephala kg.

371. Achnanthes convergens H. Kobayasi

372. Synedra sp.

Plate XXVIII

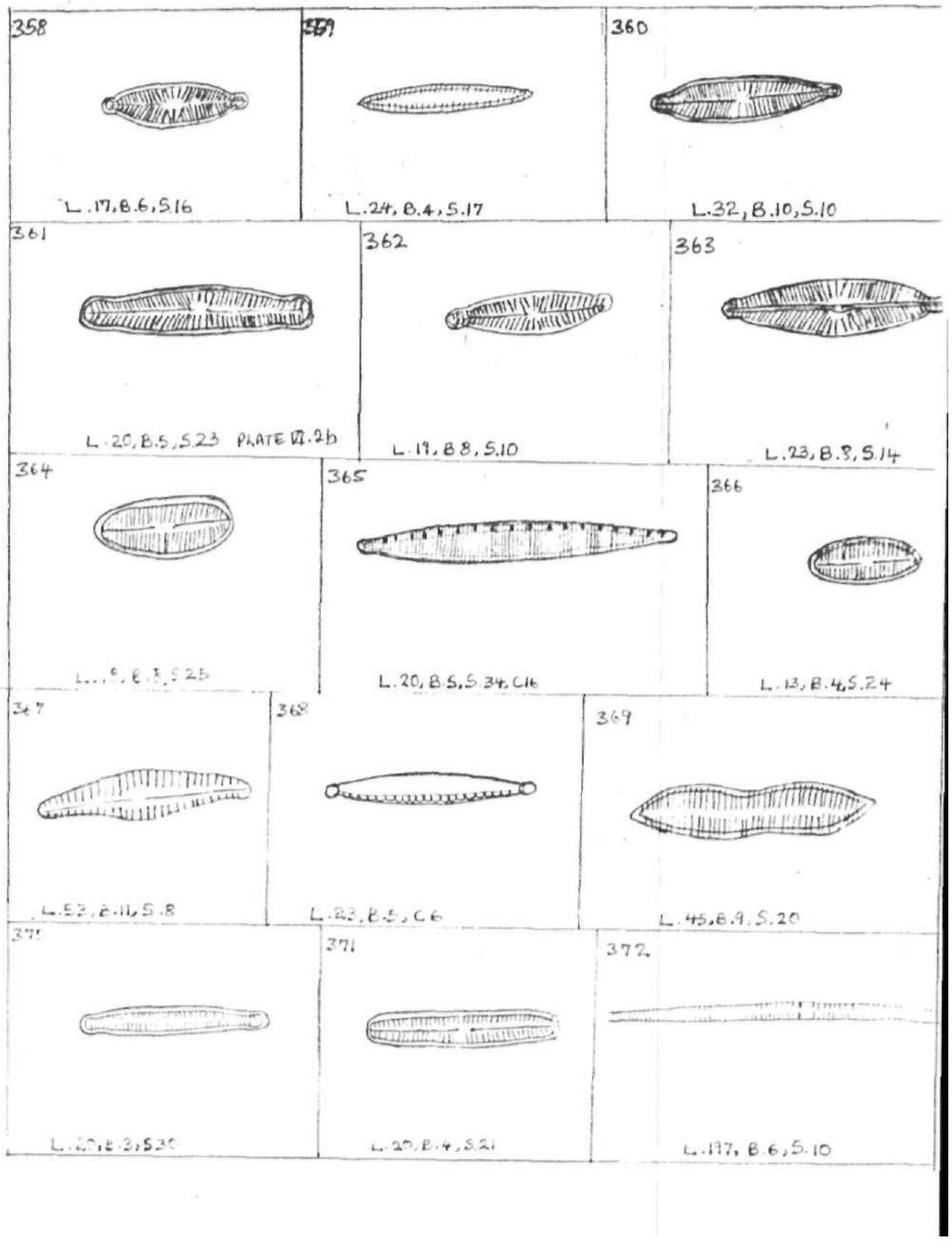


PLATE XXIX

373. Nitzschia acicularis W. Smith

374. Gomphonema olivaceum Lingb Kutz.

375. Nitzschia sp.

376. Navicula cuspidata Kg. var. ambigua (Ehr) Cleve

377. Achnanthes sp.

378? Frustularia sp.

379. Nitzschia sp.

380. Navicula pupula Kg.

381. Gomphonema consector Hohn and Hellerm

382. G. sp parvulum Kuts.

383. Achnanthes sp.

384. A. exigua Grun.

385. Nitzschia paleace Grun.

386. N. amphibia Grun

387. Nitzschia sp.

388. Gomphonema gracile Ehr.

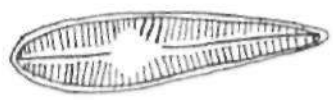
389. Nitzschia stagnorum Rabb.

390. Cyclotella sp.

Plate XXIX

373

L.132, B.4, C.19

374

L.56, B.17, S.9

375

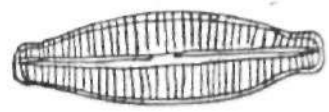
L. 47, B.7. S.13, C

376

L.75, B.21, S.19

377

L.9, B.4, S.20

378

L.22, B.8, S.13

379

L.27, B.7, C.6

380

L.21, B14, S.18 PLATE VI.2

381

L.20, B.8, S.12

382

L.14, B.7. S.10

383

L.18, B.7, S.16 PLATE VI.3

384

L.20, B.8, S.18

385

L.29, B.5, S.36 C.10

386

L.45, B.5

387

L.33, B.6.5. 38, C.8

388

L.46, B 9, S.12 PLATE VI.7

389

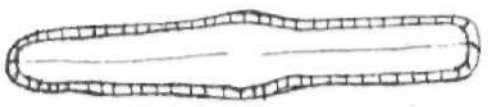
L.53, B.10, S26, C9

390

D.12

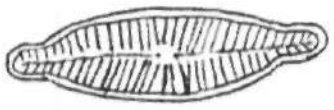
Plate XXX

391



L.26, B.4, S16

392



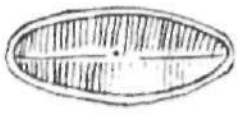
L.19, B.6, S.17

393



L.53, B.12, S.19

394



L. 6, B.5, S. About 30

395



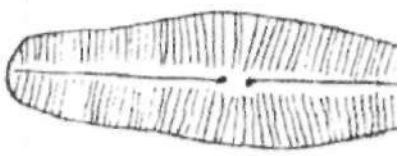
D.15

396



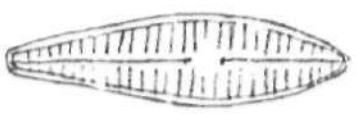
L.85, B.4, S.17

397



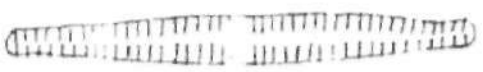
L. 21, B.15, S.15-17

398



L.24, B 7, S.10

399



L.50, B.3, S.9

Plate XXXI

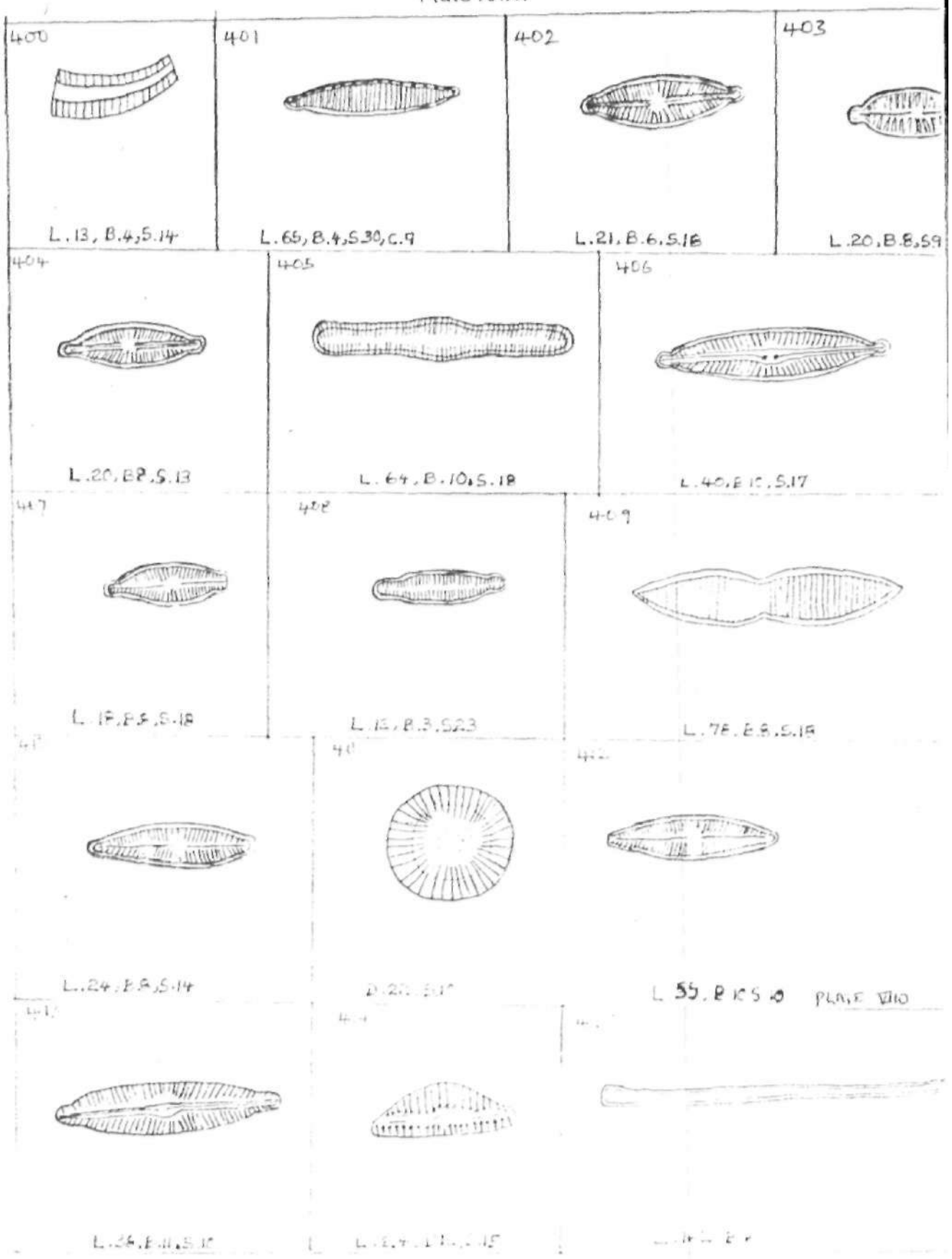

400
L.13, B.4, S.14
401
L.65, B.4, S.30, C.9
402
L.21, B.6, S.18
403
L.20, B.8, S.9
404
L.20, B?, S.13
405
L.64, B.10, S.18
406
L.40, B 10, S.17
407
L.18, B.8, S.18
408
L.12, B.3, S23
409
L.78, B.8, S.19
410
L.24, B.8, S.14
411
L.24, B.11, S.12
412
L.55, B.15 S.10
PLATE VIII

Plate XXXII

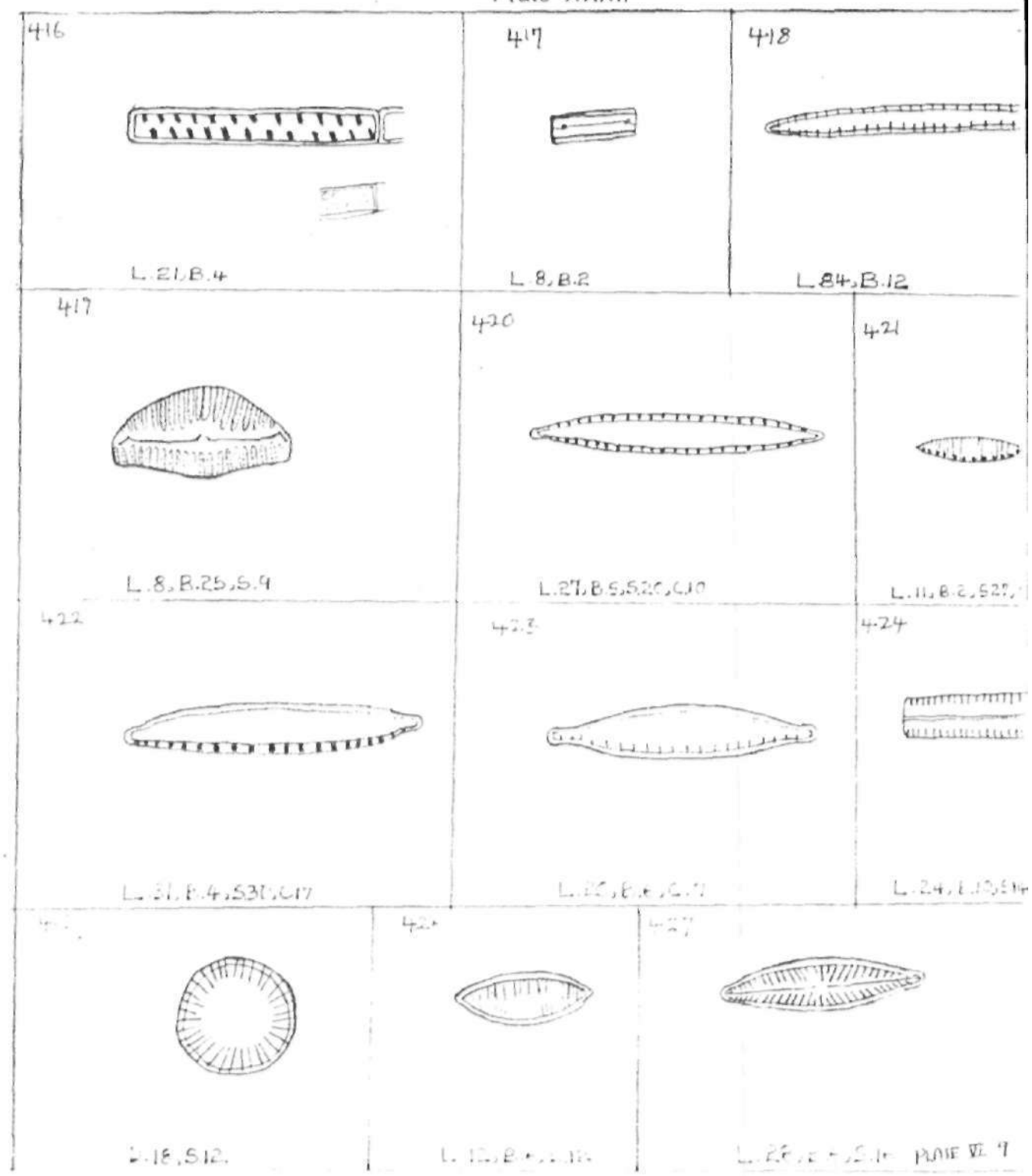


PLATE VI 9

PLATE XXXIII

428. Surirella sp.

429. Eunotia sp.

430. Melosira distans (Ehr) Kg.

431. Synedra acus var radians

432. Unidentified

433. "

434. Navicula auriculata Hust.

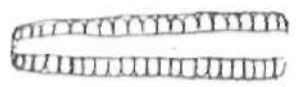
435. Unidentified hexagonal diatom

436. Gomphonema lanceolatum

437. Nitzschia subrostrata Hust.

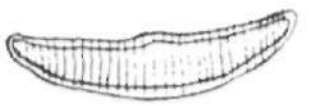
Plate XXXIII

428



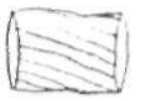
L.37, B.8, S.16-18 ×1000

429



L.21, B.5, S 13-14

430



L.18, B.15

431



L.204, B.4, S.18

432



L.17, B.8 PLATE VI 5

433



L.29, B.18

434



PLATE VI. 11

L.16, B6, S.18-20

435



D.80 PLATE IV. 3



L.54, B.10, S.12 PLATE VI. 6



L. 48. B. 3, S. 17

PLATE XXXIV

438. Navicula pygmaea Kg

439. Synedra sp.

440. Navicula cryptocephala Kg var cryptocephala Patr & Reimer

441. Nitzschia sp.

442. Unidentified centric diatom (BD134).

443. Hantzschia amphioxys Fhr Grun

444. Stephanodiscus hantzschii Grun

445. Cyclotella ocellata

446? Frustulia sp.

447. Cymbella sp.

448. Diatoma elongatum

449. Gomphonema tetrastigmatum Horikawa et Okuno.

450. Eunotia pectinalis (Null) Rabh.

Plate XXXIV

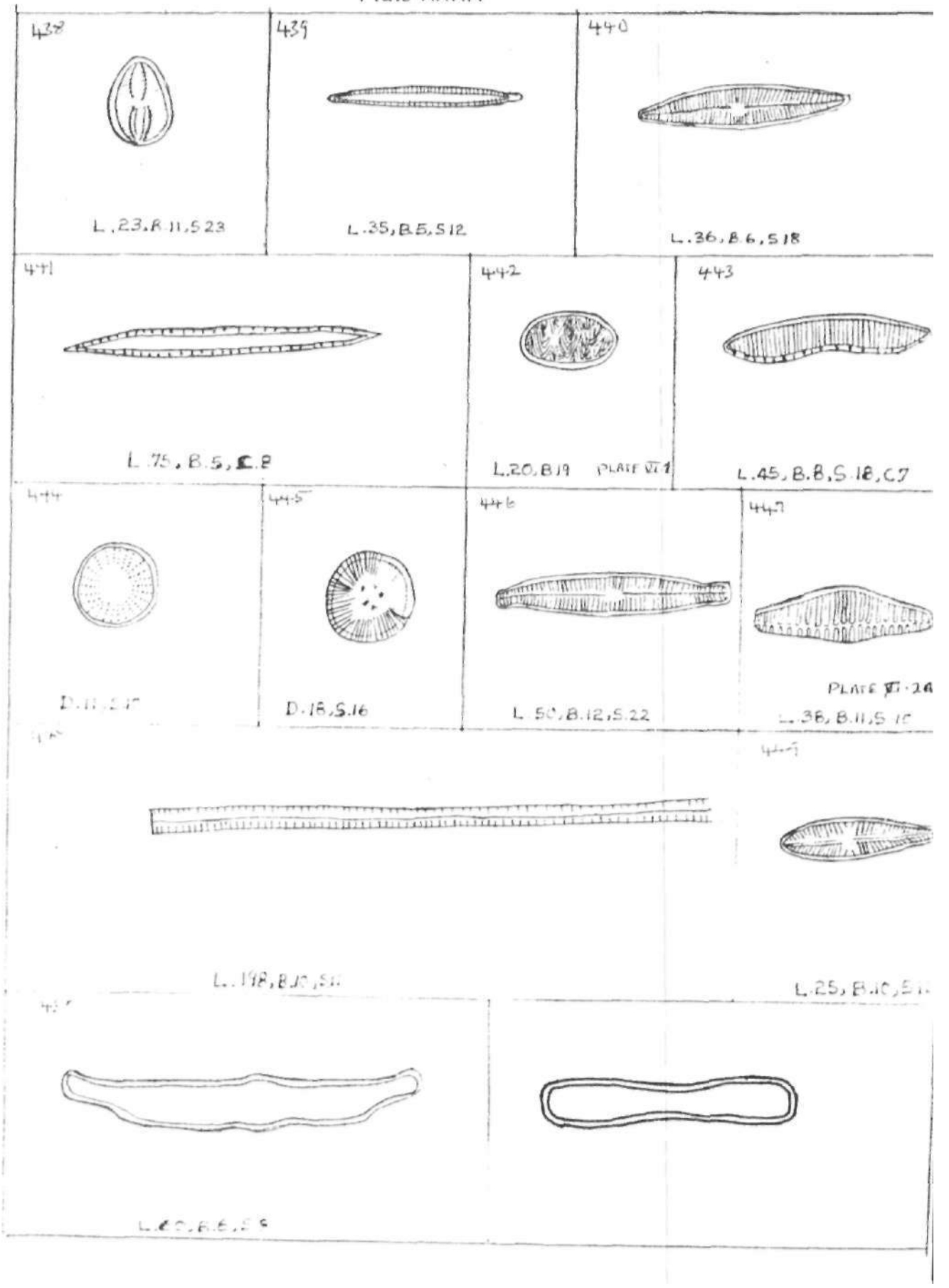

438
L.23, B.11, S.23
439
L.35, B.5, S.12
440
L.36, B.6, S.18
441
L.75, B.5, S.8
442
L.20, B.9
PLATE VI.1
443
L.45, B.8, S.18, C.7
444
D.11, S.17
445
D.18, S.16
446
L.50, B.12, S.22
447
L.38, B.11, S.16
PLATE VI.24
L.198, B.10, S.11
L.25, B.10, S.11
L.60, B.6, S.8

Plate XXXV

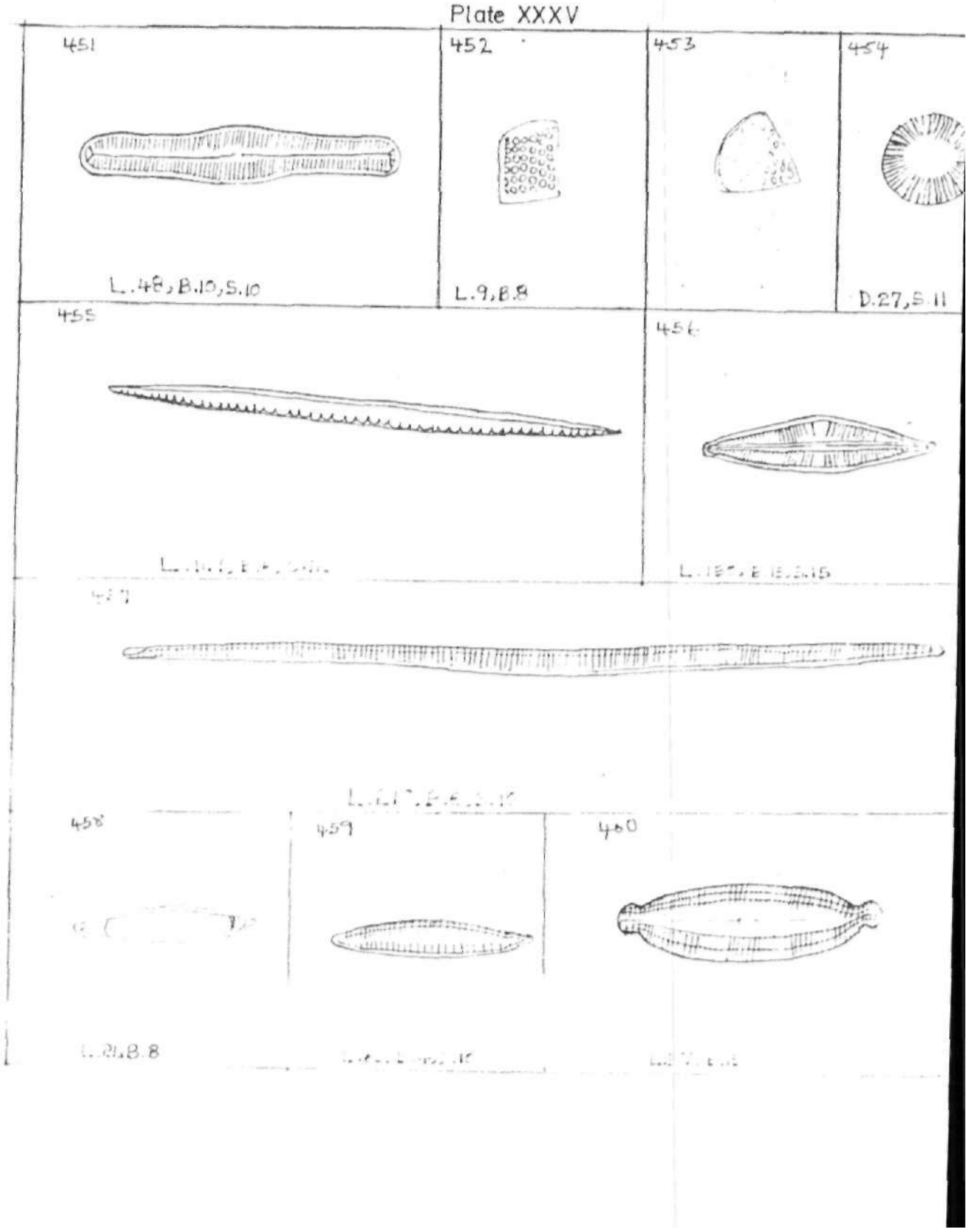

451
L.48, B.10, S.10
452
L.9, B.8
453
454
D.27, S 11
455
456
458
459
460
L.21, B.8

Plate XXXVI

461



L.65, B.18, S.10.

462



D.8. S.10

463



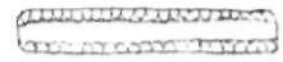
L.35, B.5, C.9

464



L.150, B.7, S.16

465



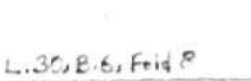
L.30, B.6, Fold.7

466



L.114, B.6.5.12

467



L.30, B.6, Fold P

468



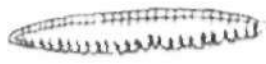
L.75, B.5, C.10

469



L.27, B.8, S.12

470



L.30, B.6.5.24

471



L.22, B.6.5.12

472



D.8. S.12

473



PLATE IX-6

D.30. S.9

Plate XXXVII

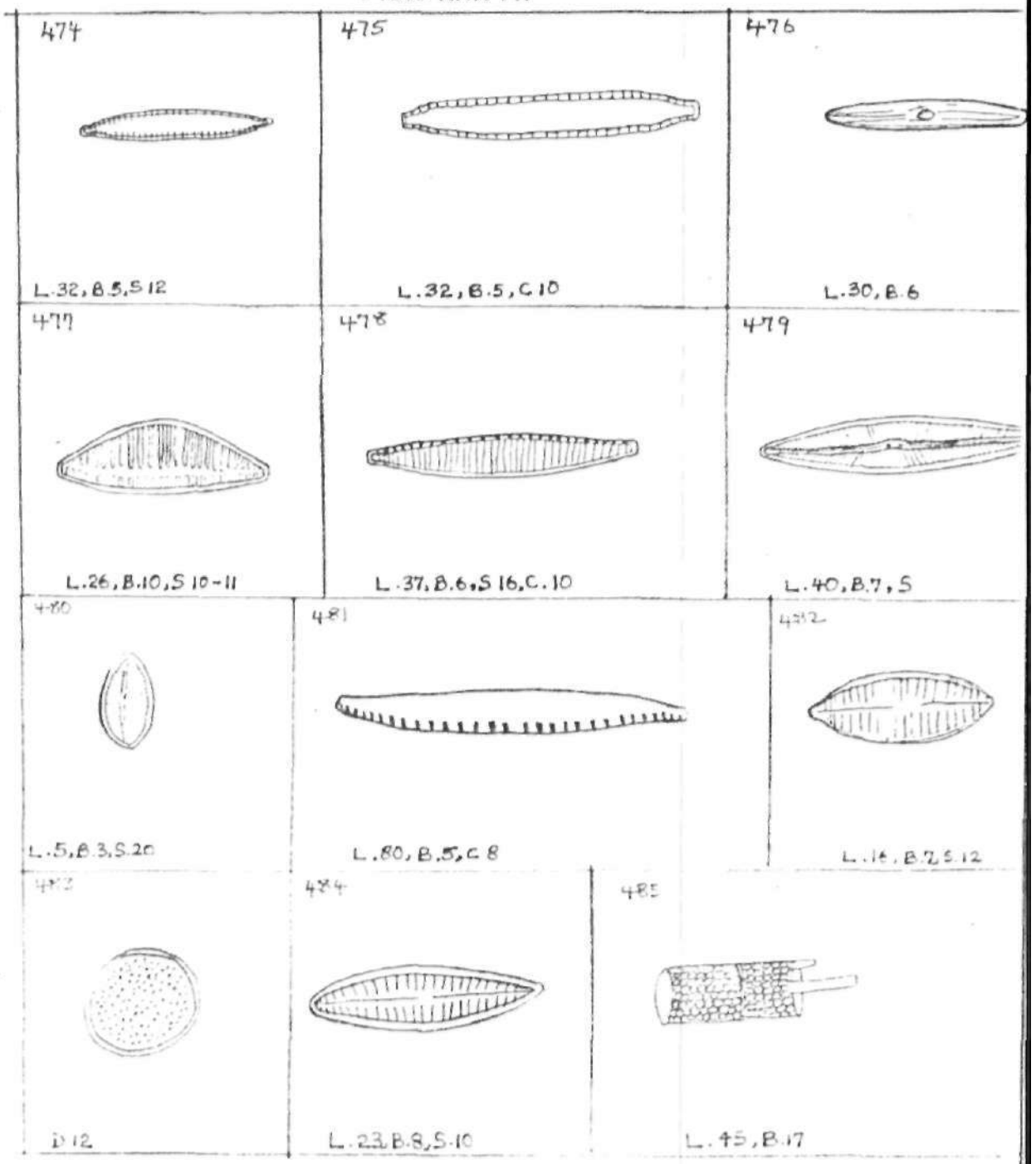
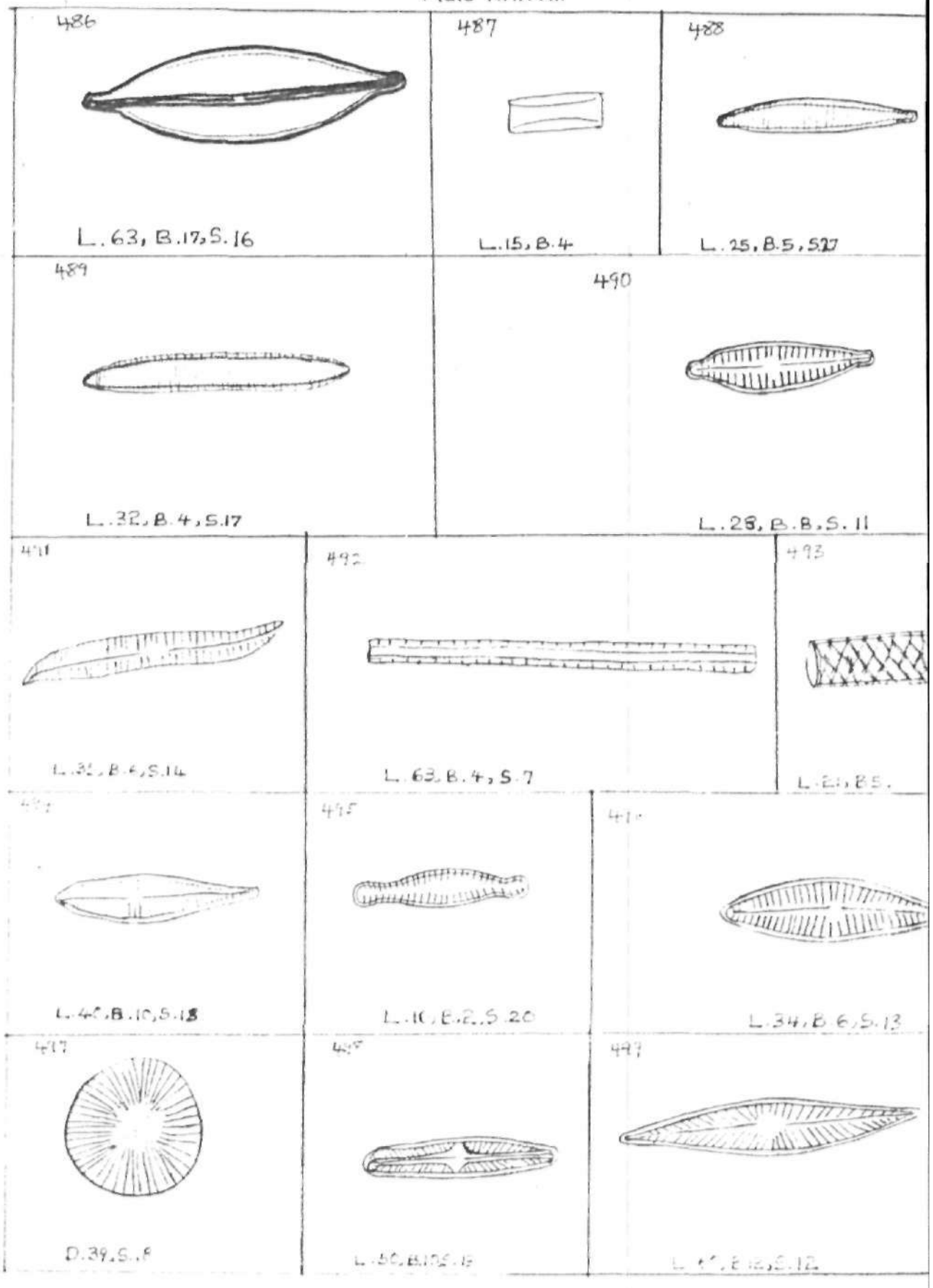


Plate XXXVIII



APPENDIX 1: BY-PASS POND, NOVEMBER (BN)

CHLOROPHYTA	specimen's no. on plates vii-xxxviii	Population density ($X10^3 inits\ l^{-1}$)	Volume (um^3)	Biomass ($X10^6 um^3 L^{-1}$)	Abundance	Frequency
Spirogyra elipsospora Transeau	(6)	75	300026	2251.95	1	30
Crucigenia fenestrosta Schmidle	(203)	25	144	3.6	1	30
Stichococcus bacillaris Nageli	(31)	25	5	0.13	1	10
Pyramimonas tetrahynchus Schmarda ?	(81)	50	9420	471.00	2*	20
Kirchneriella sp	(63)	50	234	11.7	1	20
Oocystis sp	(87)	25	522	13.05	1	10
Stigeoclonium sp ?	(177)	150	30	13.5	6	10
Ankistrodesmus falcatus var acicularis (A. Braun) G.S. West	(75)	200	85	17.00	1.6*	50**
Ankistrodesmus cf fractus (West and West) Brunnthaler	(290)	75	254	19.05	1	30
Cosmarium sp	(94)	25	1147	28.68	1	10
Crucigenia apiculata Chodat	(29[illegible])	75	30	2.25	3	10
Volvox sp	(113)	25	1767	44.18	1	10
Ophiocytum parvulum Perty A. Braun ?	(84)	25	212	5.3	1	60**
Chlamydomonas sp	(294)	25	530	13.25	1	10
Ankistrodesmus gracilis Korshikov	(292)	75	198	14.85	1	30
Scenedesmus quadricauda var longispina (Chod) G.H. Smith	(293)	25	114	28.50	1	10
Chlamydomonas sp	(284)	25	33	0.95	1	10
Kirchneriella sp ?	(203)	50	4	0.2	1	20
Kirchneriella cf contonta (Schmidle) Bohlin	(295)	25	14	0.35	1	10

* = Relatively high abundance
** = Relatively high frequency

APPENDIX 1 (CONT'D)

CHLOROPHYTA	specimen's no. on plates vii-xxxviii	Population density ($X10^3$ Units L^{-1})	Volume (um^3)	Biomass $X10^6 um^3 L^{-1}$	Abundance	Frequency (%)
Tetrastrum cf triangulare Komarek	(30)	50	85	4.25	1	20
Coelastrum sphaericum Nageli	(205)	25	139	3.48	1	10
Cosmarium cf margaritiferum Menegh	(61)	50	902	45.1	2	10
Chlamydomonas sp	(207)	25	267	6.68	1	10
Closterium moniliferum var concavum Ehrenberg cf (17)		25	64590	1614.75	1	10
Pediastrum sp.	(176)	25	1865	46.63	1	10
Coelastrum sp?	(182)	25	47570	1189.25	1	10
Monoraphidium sp ?	(13)	50	250	12.50	1	10
CYANOPHYTA						
Aphanocapsa cf endophytica G.M. Smith	(8)	100	902	90.20	1	40
Oscillatoria aciculata		50	742	37.10	1	20
Oscillatoria prolifica (Grev) Gomont	(91)	25	3925	98.13	1	10
Anabaena sp.	(92)	50	3807	190.40	1	20
Oscillatoria limnetica Lemmermann	(70)	25	1060	26.50	1	10
Oscillatoria pseudogeminata Biswas	(97)	50	1063	53.15	1	20
Spirulina major Kuetzing	(193)	100	3807	380.7	1	40
Oscillaforia limosa Ag.	(296)	75	176	13.2	1.5	20
Oscillatoria lemmermanii Wolosz	(195)	25	1413	35.33	1	10

APPENDIX 1 (CONT'D)

	specimen's no. on plates vii-xxxviii	Population density ($X10^3$ Units L^{-1})	Volume (um^3)	Biomass $X10^6 um^3 L^{-1}$	Abundance	Frequency (%)
Oscillatoria lemmermanii Wolosz	(195)	25	1413	35.33	1	10
Oscillatoria chlorina Kutz	(298)	50	1178	58.90	1	20
Oscillatoria angustissima West and West	(299)	25	3320	83.00	1	10
Merismopedia glauca (Ehrenb) Naegeli	(20)	25	126	3.15	1	10
Phormidium tenue (Mengh) Gomont?	(209)	25	1271	31.78	1	10
Nostocopsis sp?	(213)	25	16	0.4	1	10
Lyngbya sp.	(100)	25	69	1.73	1	10
EUGLENOPHYTA						
Euglena sp	(79)	175	2512	439.6	1.4	50
Euglena sp	(80)	25	1653	41.33	1	10
Phacus curvivauda Swirenko	(212)	25	8157	203.93	1	10
Euglena sp	(210)	25	21704	542.6	1	10
Euglena sp.	(297)	25	2543	63.58	1	10
Trachelomonas charkowiensis Swirenko	(173)	25	3533	88.33	1	10
PYRROPHYTA						
Rhodomonas ovalis Nygaard	(83)	50	581	29.05	2	10

APPENDIX 1 (CONT'D)

CHRYSOPHYCEAE	specimen's no on plates vii-xxxviii	Population density ($X10^3$ Units L^{-1}	Volume (um^3)	Biomass ($X10^6 um^3 L^{-1}$	Abundance	Frequency (%)
Chlorochromonas minuta Lewis	(206)	25	14	0.35	1	10
Chlorochromonas sp	(208)	25	353	8.83	1	10
Dinobryon sertularia Ehrenberg	(198)	25	12560	314.00	1	10
Chrysococcus rufescens	(15)	25	353	8.83	1	10
BACILLARIOPHYCEAE						
Fragilaria brevistriata	(359)	125	294	36.75	1	50
Nitzchia palea (Kutz) W. Smith	(468)	75	294	22.05	3	10
Navicula exigua (Greg) Mull	(404)	125	226	28.25	1.3	40
Fragilaria construens (Ehr) Grun	(422)	25	393	9.83	1	10
Stauroneis phoenicentron (Ehr)?	(456)	25	14067	351.68	1	10
Navicula pupula (kg)	(361)	50	480	24.00	1	20
Stephanodiscus carconensis Grun	(413)	25	79	1.98	1	10
Navicula luzonensis Hust	(366)	25	137	3.43	1	10
Achnanthes exigua Grun	(384)	25	1271	31.78	1	10
Nitzschia dissipata (Kutz Grun	(423)	75	392	29.40	1.5	10
Diatoma elongatum	(448)	50	6029	301.45	1	20
Diatoma anceps	(464)	25	432	10.80	1	10
Cyclotella striata (Kg) Grun	(454)	150	381	57.15	1.5	40

APPENDIX 1 (CONT'D)

	specimen's no on plates vii-xxxviii	Population density ($X10^3$ Units L^{-1})	Volume (um^3)	Biomass ($X10^6 um^3$ L^{-1})	Abundance	Frequency (%)
Nitzschia apiculata	(369)	25	2543	63.58	1	10
Navicula cuspidata kg var ambigua (Ehr) Cleve	(376)	50	36173	1808.65	1	20
Navicula viridula Kutz	(413)	50	707	35.35	1	20
Nitzschia holsatica Hust		25	942	23.55	1	10
Navicula pygmaea kg	(438)	75	804	60.30	1	30
Nitzschia amphibia Grun	(386)	25	314	7.85	1	10
Synedra tubulata	(459)	25	134	3.35	1	10
Achnanthes minutissimia Kutz	(476)	25	226	5.65	1	10
Gomphonena pervulum (Kutz) Grun	(360)	25	236	5.90	1	10
Entomoneis sp.		25	4743	118.70	1	10
Cymbella ventricosa Ag	(414)	50	1250	62.50	1	20
Navicula auriculata Hust	(434)	25	602	15.05	1	10
Nitzschia kutzingiana Hilse	(365)	25	353	8.83	1	10
Navicula pupula Kg	(380)	125	275	34.38	1.7	30
Navicula decusis Oestr	(358)	25	662	16.55	1	10
Cymbella prostrate (Berk) Cl	(419)	50	1385	69.25	2	10
Navicula rhynchocephala Kg		25	820	20.50	1	10
	(390)	25	177	4.43	1	10
Nitzschia filiformis (W. Sm) Schutt	(463)	25	824	20.6	1	10
Nitzschia paradoxa	(492)	25	8139	203.48	1	10

APPENDIX 1 (CONT'D)

	specimen's no. on plates vii-xxxviii	Population density (X10^{3}Units L^{-1}	Volume (um^3)	Biomass X10^{6}um^3 L^{-1}	Abundance	Frequency (%)
Cyclotella meneghiniana Kg	(473)	25	400	10.00	1	10
Eunotia pectinalis Mull Rabh	(450)	25	5024	125.6	1	10
Navicula peregrina (Ehr) Kutz	(412)	25	750	18.75	1	10
Achnanthes microcephala Kg	(370)	25	113	2.83	1	10
Unidentified unicell (BN23)	(82)	25	1110	27.75	1	10
Unidentified filament (BN32)	(89)	25	297	7.43	1	10
Unidentified unicell (BN33)	(88)	25	269	6.68	1	10
Unidentified unicell BN34)	(90)	25	65253	1631.33	1	10
Unidentified unicell (BN57)	(175)	50	196	9.80	1	20
Unidentified unicell (BN68)	(152)	25	381	9.53	1	10
Unidentified unicell (BN87)	(285)	25	64	1.6	1	10
Unidentified unicell BN96)	(199)	25	63	0.15	1	10
Unidentified unicell (BN126)	(25)	25	1147	28.68	1	10
Unidentified unicell (BN130)	(211)	25	695	17.38	1	10
Unidentified colony (BN135)	(98)	25	48	1.20	1	10
Unidentified colony (BN136)	(99)	25	28	0.70	1	10
Unidentified colony (BN144)	(161)	25	42	1.05	1	10
Unidentified unicell (Plate II 5)	(29)	25	267	6.68	1	10
Unidentified unicell (BN 25)	(86)	25	234	5.85	1	10

APPENDIX 2: STABILIZATION POND ONE, NOVEMBER (SPON)

	specimen's no on plates vii-xxxviii	Population density ($X10^3$ Units L^{-1})	Volume (um^3)	Biomass $X10^6 um^3 L^{-1}$	Abundance	Frequency (%)
CHLOROPHYTA						
Spirogyra porticalis (Muell.) Cleve cf	(162)	25	7821	195.53	1	10
Stichococcus bacillaris Nageli	(31)	50	5	0.25	1	20
CYANOPHYTA						
Arthrospira platensis Banerji cf	(102)	75	283	21.23	1.5	20
Microcystis aeruginosa Kutz (Plate III.1)		325	179055	58192.88	6.5	70
Aphanothece saxicola Naegeli	(107	25	52205	1305.13	1	10
Aphanocapsa endophytica G.M. Smith	(108)	25	902	22.55	1	10
Cyanarcus harmiformis Pascher	(109)	25	19	0.48	1	10
Spirulina gigantea Schmidle	(300)	25	280	0.70	1	10
BACILLARIOPHYCEAE						
Melosira granulata (Ehr) Ralfs	(485)	3	12428	31.07	1	10
Cymbella affinis Kutz	(465)	3	4689	11.72	1	10
Comphonena lanceolatum (Ehr)	(398)	3	2637	6.59	1	10
Achnanthes convergens cf H. kobayasi		3	848	2.12	1	10
Navicula radiosa Kg/var tenella (Breb et kg.) Grun	(427)	3	4974	12.44	1	10
Nitzschia kutzingiana Hilse	(365)	3	424	1.06	1	10

APPENDIX 2 (CONT'D)

	specimen's no. on plates vii-xxxviii	Population density ($X10^3$ Units L^{-1})	Volume (μm^3)	Biomass $X10^6 \mu m^3 L^{-1}$	Abundance	Frequency (%)
Unidentified unicell (SPON 3)	(103)	25	7217	180.43	1	10
Unidentified cylindrical unicell (SPON 5)	(102)	25	107	2.68	1	10
Unidentified unicell (SPON 12)	(105)	25	401	10.03	1	10
Unidentified (SPON 19)	(99)	25	35	0.88	6	10
Unidentified (SPON 20)	(110)	25	636	15.90	1	10
Unidentified unicell (SPON 13)	(106)	25	113	2.83	1	10

APPENDIX 3: STABILIZATION POND THREE, NOVEMBER (SPTN)

	Specimen's no. on plates vii-xxxviii	Population density ($X10^3$ Units L^{-1})	Volume (μm^3)	Biomass ($X10^6 \mu m^3 L^{-1}$)	Abundance	Frequency (%)
CHLOROPHYTA						
Chlamydomonas sp	(284)	50	267	13.35	1	20
Stichococcus bacillaris Nageli	(31)	1025	5	5.13	10.3	40
Micractinum sp.	(111)	300	21	16.80	4	80
Tetradesmus cf. wisconsinense G.M. Smith	(16)	125	53	6.63	1.6	30
Scenedesmus quadricauda var quadrispina (Chod) G.M. Smith (35)		25	114	2.85	1	10
Tetradesmus cf. smithii Prescott	(282)	150	53	7.95	6	10
Volvox sp.	(113)	25	695	17.38	1	10
Chlorococcum sp.		200	140	28.00	1.6	50
CYANOPHYTA						
Microcystis aeruginosa (Kuetz) (Plate III.1)		700	17105	11973.50	3.5	80
Spirulina princeps West and West	(301)	25	14	0.04	1	10
Spirulina laxissima West	(302)	75	79	5.93	1	30
Lyngbya contorta Lemm	(116)	25	1178	29.45	1	10
Aphanocapsa endophytica G.M. Smith	(108)	50	522	26.10	1	20

APPENDIX 3 (CONT'D)

	specimen's no on plates vii-xxxviii	Population density ($X10^3$ Units L^{-1})	Volume (um^3)	Biomass ($X10^6_{um^3}$ L^{-1})	Abundance	Frequency (%)
BACILLARIOPHYCEAE						
Comphonena angustatum (Kg) Rabh var producta Grun	(490)	2.5	2648	6.62	1	10
Comphonena parvulum (Kg) Grun	(360)	5	2858	7.15	1	20
Comphonena lanceolatum Ehr.	(398)	7.5	2858	14.29	1	30
Nitzschia philippinarum Hust	(401)	2.5	1987	4.97	1	10
Synedra ulna (Nitzsch) Ehr	(457)	2.5	2867	7.17	1	10
Cyclotella striata (Kg) Grun var baltica Grun	(411)	5	92	0.46	1	20
Melosira ikapoensis O. Mull var procera O. Mull	(452)	2.5	3956	98.90	1	10

APPENDIX 4: KUBANNI POND, NOVEMBER (KN)

	specimen's no on plates vii-xxxviii	Population density ($X10^3$Inits L^{-1}	Volume (um^3)	Biomass $X10^6 um^3 L^{-1}$	Abundance	Frequency (%)
CHLOROPHYTA						
Chlamydononas globosa Snow	(62)	25	38	.950	1	10
Ankistrodesmus falcatus (Corda) Ralfs		350	22	7.700	2	70
Dictyosphaerium sp.	(1)	75	58	4.350	1	30
Coelastrum sp.	(51)	25	1762	44.050	1	10
Chlamydomonas sp	(284)	75	38	2.850	1.5	20
Scenedesmus quadricauda cf var maximus West & West	(324)	50	267	13.350	1	20
Euroglena sp ?	(4)	50	1768	88.400	1	20
Spirogyra elipsospora Transeau	(6)	100	5087	508.700	2	20
Ankistrodesmus falcatus/cf var mirabilis (West & West) G.S. West	(3)	50	212	10.6	2	10
Tetraedron sp.	(7)	25	14	.350	1	10
Staurodesmus validus (West) Thon?	(9)	25	267	6.68	1	10
Staurodesmus sp?	(12)	25	269	6.73	1	10
Scenedesmus quadricauda (Turp) de Breb	(14)	25	267	6.68	1	10
Tetradesmus wisconsinense G.M. Smith	(16)	25	56	1.4	1	10
Closterium	(17)	125	106	1.63	1.3	40
Scenedesmus quadricauda var/cf quadrispina (Chod) G.M. Smith	(35)	50	212	10.6	1	20
Tetrastrum triangulare Komarek	(30)	50	144	7.2	1	20

APPENDIX 4 (CONT'D)

	specimen's no on plates vii-xxxviii	Population density ($X10^3$ Units L^{-1})	Volume (um^3)	Biomass $X10^6 um^3 L^{-1}$	Abundance	Frequency (%)
Stichococcus	(31)	125	5.3	0.63	1.7	30
Tetraedron sp	(33)	25	6	0.16	1	10
Pediastrum sp	(34)	150	2205	110.25	1	20
Scenedesmus acuminatus Chodat	(23)	25	225	5.63	1	10
Scenedesmus quadricauda var Westii G.M. Smith	(160)	75	115	8.63	1	30
Chlamydomonas sp	(93)	75	14	1.05	3	10
Nephrocytium sp. ?	(43)	25	5559	138.98	1	10
Kirchneriella sp?	(48)	50	79	3.95	2	10
Dictyosphaerum sp	(46)	25	108	2.7	1	10
Characium sp?	(47)	50	11	0.55	1	20
Cosmarium reniforme Archer	(55)	25	4176	104.4	1	10
Coelastrum sp.	(53)	25	47570	1189.25	1	10
Cosmarium contracium Kirchner	(56)	50	902	45.1	2	10
Selenastrum Westii G.M. Smith	(58)	25	98	2.45	1	10
Cosmarium/cf margaritiferum Menegh	(61)	25	473	11.83	1	10
Kirchneriella sp?	(63)	25	234	5.85	1	10

APPENDIX 4: (CONT'D)

	specimen's no on plates vii-xxxviii	Population density ($X10^3$ Units L^{-1})	Volume (μm^3)	Biomass $X10^6 \mu m^3 L^{-1}$	Abundance	Frequency (%)
CYANOPHYTA						
Aphanocapsa endophytica G.M. Smith	(8)	350	522	182.7	2.8	50
Oscillatoris corallinae (Kutz) Gomont	(230)	25	39	0.98	1	10
Merismopedia glauca	(20)	50	126	6.3	1	20
Oscillatoria sp.	(60)	25	473	11.83	1	10
Oscillatoria formosa Bory	(127)	475	4878	2317.05	2.1	90
Chroococcus sp.	(44)	50	14	0.7	1	20
PYRRPOHYTA						
Chroomonas sp. ?	(50)	25	196	4.9	1	10
EUGLENOPHYTA						
Euglena sp.	(28)	25	2512	62.8	1	10
Trachelomonas volvocina Ehrenberg	(141)	300	113	33.84	1.7	70
BACILLARIOPHYCEAE						
Diatoma anceps	(464)	50	432	21.6	2	10
Cymbella affinis	(465)	25	2034	50.85	1	10
Achnanthes convergens H. kobayasi		75	432	32.4	1.5	20
Cymbella ventricosa Kg	(477)	75	64	4.8	1	30

APPENDIX 4: (CONT'D)

	specimen's no. on plates vii-xxxviii	Population density ($X10^3$ Units L^{-1})	Volume (um^3)	Biomass $X10^6 um^3 L^{-1}$	Abundance	Frequency (%)
Cymbella minuta		50	1016	50.8	1	20
Diatoma elongatum	(448)	25	1415	39.63	1	10
Achnanthes minutissima	(476)	100	226	22.6	2	20
Synedra sp.		125	432	54.00	1.7	30
Synedra sp.	(439)	50	550	27.5	1	20
Synedra ulna (Nitzsch) Ehr	(457)	50	2967	148.35	1	20
Synedra pulchella Kg	(466)	25	2741	68.53	1	10
Navicula radiosa Kg	(469)	125	424	53.00	1.3	40
Navicula decusis Oestr	(358)	75	339	25.43	1	30
Navicula tripunctata (O.F. Mull.) Bory	(479)	100	3815	381.5	1	40
Navicula hungarica var capitata	(403)	25	1192	29.8	1	10
Navicula viridula Kg	(413)	350	22	7.7	2	70
Caloneis silicula (Ehr) Cleve	(405)	25	791	19.78	1	10
Fragilaria brevistriata	(359)	125	251	31.38	1.3	40
Fragilaria construens	(422)	75	393	29.475	1	30
Eunotia sp.	(461)	125	12717	1589.63	1.7	30
Eunotia pectinalis	(450)	25	5024	125.6	1	10
Nitzschia sp.	(387)	50	85	4.25	1	20
Nitzschia kutzingiana Hilse	(365)	100	141	14.1	2	20
Nitzschia dissipata (Kg) Grun	(368)	100	3601	36.7	2	20

APPENDIX 4: (CONT'D)

	specimen's no. on plates vii-xxxviii	Population density ($X10^3$ Units L^{-1})	Volume (um^3)	Biomass $X10^6 um^3 L^{-1}$	Abundance	Frequency (%)
Nitzschia angustata	(489)	25	238	5.95	1	10
Nitzschia sp.	(470)	25	334	8.35	1.7	30
Nitzschia fonticola	(421)	25	285	7.13	1	10
Nitzschia filiformis (W. Smith) Hust	(463)	50	824	41.2	1	20
Nitzschia sigma (Kg.) W. Smith	(481)	50	3312	165.6	1	20
Nitzschia sp.	(387)	25	1130	28.25	1	10
Nitzschia paradoxa	(492)	25	90961	2274.03	1	10
Comphonema angustatum (Kg) Rabh	(410)	100	236	23.6	1	40
Cymbella turgida (Greo) Cleve	(367)	75	3279	245.93	1.5	20
Fragilaria pucina		25	15260	381.5	1	10
Coscinodiscus sp.	(483)	25	177	4.43	1	10
Cyclotella striata (Kg.) Grun	(154)	200	381	76.2	1.6	50
Cyclotella glomerata	(417)	25	678	16.95	1	10
Cyclotella michiganiana Kg	(473)	175	381	66.68	1	10
Unidentified unicell (KN28)	(175)	75	196	14.7	1	30
Unidentified colony (KN33)	(39)	25	168	4.2	1	10
Unidentified unicell (KN76)	(18)	25	65	1.63	1	10

APPENDIX 4: (CONT'D)

	specimen's no. on plates vii-xxxviii	Population density ($X10^3$Units L^{-1})	Volume (um^3)	Biomass $X10^6 um^3 L^{-1}$	Abundance	Frequency (%)
Unidentified (KN82)	(21)	25	1105	27.63	1	10
Unidentified lunate unicell (KN89)	(32)	50	12	0.6	1	20
Unidentified unicell (KN99)	(36)	25	25	0.63	1	10
Unidentified unicell (KN100)	(37)	25	35	0.88	1	10
Unidentified unicell (KN101)	(38)	25	380	9.5	1	10
Unidentified unicell (KN103)	(42)	25	16	0.4	1	10
Unidentified colony (KN104)	(40)	25	10	0.25	1	10
Unidentified unicell (KN105)	(41)	25	38	0.95	1	10
Unidentified unicell (KN108)	(287)	25	225	5.63	1	10
Unidentified colony (KN110)	(45)	25	32	0.8	1	10
Unidentified flagellate (KN116)	(49)	25	902	22.55	1	10
Unidentified cylindrical unicell (KN118b)	(286)	25	151	3.78	1	10
Unidentified colony (KN131)	(57)	25	6	0.15	1	10
Unidentified unicell (KN133)	(52)	25	424	10.6	1	10
Unidentified unicell (KN149)	(59)	25	373	9.33	1	10
Unidentified cylindrical unicell (KN155)	(288)	25	352	8.80	1	10
Unidentified (KN59)	(11)	25	42	1.05	1	10
Unidentified (KN32)	(21)	25	594	14.85	1	10
Unidentified (KN143)	(54)	25	267	6.68	1	10

APPENDIX 5: BY-PASS POND DECEMBER (BD)

	specimen's no. on plates vii.-xxxviii	Population density ($X10^3$ Units L^{-1})	Volume (um^3)	Biomass $X10^6 um^3 L^{-1}$	Abundance	Frequency (%)
EUGLENOPHYTA						
Trachelomonas pulcherrima Playfair	(306)	25	381	9.53	1	10
Trachelomonas spp?	(130)	25	16	0.40	1	10
Unidentified (BD75)	(76)	25	132	3.30	1	10
Unidentified unicell	(137)	25	9	0.23	1	10
Unidentified unicell (BD113)	(88)	25	267	6.68	1	10
Unidentified unicell (BD112)	(135)	25	7	0.18	1	10
Unidentified (BD130)	(307)	25	8157	203.93	1	10
CHLOROPHYTA						
Spirogyra porticalis (Muel) Cleve	(162)	50	11775	588.75	1	20
Kirchneriella sp?	(63)	50	339	16.95	1	20
Stichococcus bacillaris Nagelli	(31)	300	11	3.30	2	60
Haematococcus lacustris (Girod) Rostaf	(78)	25	267	6.68	1	10
Scenedesmus sp.	(303)	25	6	0.15	1	10
Ankistrodesmus falcatus var acicularis (A. Braun(G.S. West/ cf (75)		150	191	28.65	1	60
Coelastrum sphaericum Nageli	(205)	50	1761	88.05	1	20

APPENDIX 5 (CONT'D)

	specimen's no. on plates vii-xxxviii	Population density ($X10^3$Units L^{-1})	Volume (um^3)	Biomass $X10^6 um^3 L^{-1}$	Abundance	Frequency (%)
Kirchneriella sp.	(201)	75	57	4.28	1	10
Scenedesmus sp.	(304)	25	6	0.15	1	10
Scenedesmus dimorphus (Turp) Kuetz.	(305)	50	6	0.30	1	20
Kirchneriella sp	(67)	75	71	5.33	1	30
Cosmarium sp	(186)	25	1147	28.68	1	10
Scenedesmus sp	(71)	25	48	1.20	1	10
Scenedesmus arcuatus varplaydisca G.M. Smith cf	(129)	25	15	0.38	1	10
Crucigenia rectangularis (A. Braun) Gay	(131)	25	56	1.40	1	10
Scenedesmus denticulatus Lagerheim?	(133)	25	125	3.13	1	10
Oocystis solitaria Wittrock	(136)	25	226	5.65	1	10
Gleocystis major Gerneck	(10)	175	65	11.38	1	20
CYANOPHYTA						
Oscillatoria limosa	(296)	25	480	12.00	1	10
Oscillatoria chalybea Mertens	(311)	25	367	9.18	1	10
Oscillatoria acutissima Kufferath	(310)	25	850	21.25	1	10
Oscillatoria limnetica Lemmermann	(70)	50	2257	112. 5	1	10
Oscillatoria lacustris (Kleb) Geitler	(132)	25	348	8.70	1	10
Oscillatoria geitleriana (Fremy) Elenkis	(309)	25	484	12.10	1	10
Aphanocapsa endophytica G.M. Smith	(8)	25	522	13.05	1	10

APPENDIX 5 (CONT'D)

	specimen's no on plates vii-xxxviii	Population density ($X10^3$ Units L^{-1})	Volume (um^3)	Biomass $X10^6 um^3 L^{-1}$	Abundance	Frequency (%)
Gleocapsa sp.	(305)	50	381	19.05	1	20
Oscillatoria putrida	(139)	25	62	15.50	1	10
Spirulina major Kuetzing	(193)	250	37	9.25	1.4	70
Oscillatoria rubescens De Candolle	(275)	25	42	1.05	1	20
Oscillatoria corallinae	(230)	25	9	0.23	1	10
Aphanothece sp.	(66)	150	33	4.55	1	60
Oscillatoria tenuis F. tergestina Rabenh	(190)	25	11	0.28	1	10
Oscillatoria prolifica (Grev) Gomont	(313)	50	545	27.25	2	10
Arthrospira jeneri (Kuetz) Stizenberger	(316)	150	353	52.95	2	30
Oscillatoria anguitissima West & West	(299)	125	708	88.50	1.3	40
Oscillatoria perornata Skuja	(314)	50	13	0.65	1	20
Phormidium retzii (Ag) Gom	(134)	25	145	3.63	1	10
Oscillatoria hamelii Fremy	(312)	50	945	47.25	1	10
Oscillatoria minima Grickhorn		25	450	11.25	1	10
Oscillatoria sp?	(315)	25	276	6.9	1	10
BACILLARIOPHYTA						
Nitzschia philippinarum Hust	(401)	50	99	4.95	1	20
Diatoma hiemale?	(487)	25	622	5.53	1	10
Cyclotella kutzingiana Thwaites	(425)	50	92	4.600	1	20
Navicula pupula Kg	(361)	400	275	110.00	1.8	90
Nitzschia paleace Grun	(385)	100	141	141.00	1.8	90

APPENDIX 5 (CONT'D)

	specimen's no on plates vii-xxxviii	Population density ($X10^3$ Units L^{-1})	Volume (um^3)	Biomass $X10^6 um^3 L^{-1}$	Abundance	Frequency (%)
Nitzschia palea (Kg) W. Smith	(468)	50	141	7.05	1	10
Hantzschia amphioxys Ehr Grun	(443)	25	2261	56.53	1	10
Cyclotella striata (Kg) Grun var battica Grun	(411)	200	39	7.80	1.3	60
Cyclotella ocellata	(445)	75	39	2.93	1	30
Stephanodiscus hantzschii Grun	(444)	25	39	0.98	1	10
Navicula cuspidata Kg var ambigua (Ehr) Cleve	(486)	25	850	21.25	1	10
Nitzschia subrostrata Hust	(437)	75	106	7.95	1	30
Nitzschia amphibia Grun	(396)	200	127	25.40	1.3	60
Navicula radiosa Kg	(469)	50	622	31.10	1	20
Nitzschia kutzingiana Hilse	(422)	175	392	68.60	1.4	50
Navicula cryptocephala Kg var cryptocephala Patr & Reimer	(440)	150	530	79.50	1.2	50
Diatoma elongatum	(448)	25	12400	31.00	1	10
Fragilaria brevistriata	(359)	25	550	13.75	1	10
Stephanodiscus carconensis Grun	(365)	25	64	1.60	1	10
Synedra acus var radians	(431)	25	198	4.95	1	10
Navicula heufleri Grun	(496)	25	452	11.3	1	10
Achnanthes lanceolata Breb var lanceolata Patr & Reimer	cf (426)	25	424	10.60	1	10
Nitzschia acicularis W. Smith	(373)	25	876	21.90	1	10
Eunotia pectinalis (Kull) Rabh	(450)	25	5024	125.60	1	10
Surirella angustata Kutz	(465)	25	2748	68.70	1	10

APPENDIX 5 (CONT'D)

	specimen's no. on plates vii-xxxviii	Population density ($X10^3$ Units L^{-1})	Volume (um^3)	Biomass $X10^6 um^3 L^{-1}$	Abundance	Frequency (%)
Achnanthes convergens H. kobayasi	(371)	25	157	3.93	1	10
Nitzschia subtilis Kg	(488)	25	198	4.95	1	10
Cyclotella meneghiniana Kg	(473)	25	113	2.83	1	10
Comphonema tetrastigmatum Horikawa et Okuno	(449)	25	424	10.60	1	10
Comphonema olivaceum (Lingb) Kutz	(374)	25	240	6.00	1	10
Comphonema consector Hohn and Hellerm	(381)	25	654	16.35	1	10
Pinnularia subcapitata Goeg var paucistrata (Grum) Cleve	(498)	25	3533	88.33	1	10
Navicula decusis Oestr. var decusis Patr & Reimer	(358)	25	602	15.05	1	10
Navicula luzonensis Hust var luzonensis Patr & Reimer	(366)	25	460	11.50	1	10
Unidentified centric diatom (BD134) (Plate III, 1).		25	95	2.38	1	10

APPENDIX 6: STABILIZATION POND ONE, DECEMBER (SPOD)

	specimen's no. on plates vii-xxxviii	Population density ($X10^3$Units L^{-1}	Volume (um^3)	Biomass $X10^6 um^3 L^{-1}$	Abundance	Frequency (%)
CHLOROPHYTA						
Scenedesmus quadricauda var longispina Chod G.M. Smith	(293,	44	114	5.06	1	20
Micractinum sp	(169)	89	105	9.35	1	40
CYANOPHYTA						
Arthrospira sp	(102)	111	44	4.88	1.3	40
Oscillatoria anguitissima West and West	(299)	22	27	0.59	1	10
Microcystis floss-aquae		333	7217	2403.26	3	50
Microcystis aeruginosa Kutz (Plate III.1)		200	112757	22551.40	1.13	80
Microcystis robusta (cf) (Clark) Nygaard		89	14095	1254.46	1	40
Microcystis sp.		44	355	15.76	1	20
BACILLARIOPHYCEAE						
Coscinodiscus radiatus Ehr	(480)	2	3946	8.46	1	10
Melosira ikapoensis O. Mull	(452)	2	64	0.14	1	10
Cyclotella stelligera Cleve et Grun	(472)	2	265	0.58	1	10
Cyclotella/cf michiganiana Kg.	(473)	2	380	0.84	1	10
Achnanthes delicatula Kg	(392)	2	500	1.10	1	10
Nitzschia sp	(441)	2	176	0.39	1	10
Nitzschia vermicularis (Kg.) Grun?	(455)	2	1005	2.21	1	10

APPENDIX 6 (CONT'D)

	specimen's no. on plates vii-xxxviii	Population density ($X10^3$ Units L^{-1})	Volume (um^3)	Biomass $X10^6 um^3 L^{-1}$	Abundance	Frequency (%)
Navicula cryptocephala/cf var cryptocephala Patr & Reimer	(440)	2	275	0.61	1	10
Cymbella affinis Kg	(465)	2	5307	10.61	1	10
Comphonena parvulum (Kutz) Grun	(360)	2	522	1.04	1	10
Fragilaria construens?	(424)	2	126	0.26	1	10
Comphonena angustatum Kg Rabh	(490)	2	846	1.73	1	20
Unidentified unicell (SPOD 14)	**(325)**	**22**	**3044**	**66.97**	**1**	**10**

APPENDIX 7: STABILIZATION POND THREE DECEMBER (SPTD)

	specimen's no on plates vii-xxxviii	Population density ($X10^3$ Units L^{-1})	Volume (um^3)	Biomass $X10^6 um^3 L^{-1}$	Abundance	Frequency (%)
CHLOROPHYTA						
Scenedesmus quadricauda	(276)	25	60	1.50	1	10
CYANOPHYTA						
Microcystis flos-aquae		25	8157	203.93	11	100
Microcystis aeruginosa Kutz. Plate		450	57732	25979.40	2.6	70
Arthrospira platensis f granulata		25	7948	198.70	1	10
BACILLARIOPHYCEAE						
Melosira grunulata (Ehr.) Ralfs	(485)	2.5	1130	2.83	1	10
Coscinodiscus radiatus (Ehr.	(480)	2.5	3846	9.62	1	10
Cyclotella comta (Ehr.) Kg	(497)	2.5	346	0.87	1	10
Cyclotella kutzingiana Thwaites	(425)	2.5	95	0.24	1	10
Melosira distans (Ehr.) Kg	(430)	2.5	29438	64.76	1	10
Comphonema tetrastignatum Horikawa et Okuno	(449)	2.5	1526	3.82	1	10
Comphonema lanceolatum Ehr. var insignis (Greg) Cleve		2.5	66	0.17	1	10
Navicula cuspidata var ambigua (Ehr.) Cleve	(436)	2.5	26984	67.46	1	10
Nitzschia acicularis W. Smith	(373)	2.5	245	0.61	1	10
Nitzschia stagnorum Rabh	(389)	2.5	10450	26.13	1	10
Nitzschia palea (Kg) W. Smith	(468)	2.5	3052	7.63	1	20

APPENDIX 8: KUBANNI POND DECEMBER (KD)

	specimen's no. on plates vii-xxxviii	Population density ($X10^3$ Units L^{-1})	Volume (um^3)	Biomass $X10^6_{um^3}L^{-1}$	Abundance	Frequency (%)
CHLOROPHYTA						
Crucigenia rectangularis (A. Braun) Gay	(131)	3	134	0.40	1	10
Kirchneriella sp	(67)	3	31	0.09	1	10
Cosmarium margaritiferum Menegh	(61)	3	902	2.71	1	10
Crucigenia alternans Smith	(317)	3	156	0.47	1	10
Coelastrum sp.	(318)	3	5559	16.68	1	10
Scenedesmus incrassatulus Bohlin	(267)	3	112	0.336	1	10
Ankistrodesmus gracilis Korshikov	(292)	3	106	0.32	1	10
Characium sp ?	(270)	3	16	0.05	1	10
Actinastrum hantzschii Lag	(271)	3	451	1.35	1	10
Staurodesmus validus (West) Thom	(272)	3	125	0.38	1	10
Apiocystis brauniana Negeli ?	(274)	3	113	0.34	1	10
Koliella longiseta Hindak	(319)	3	35	0.11	1	10
Crucigenia sp.	(320)	3	134	0.40	1	10
CYANOPHYTA						
Chroococcus sp	(44)	3	71	0.21	1	10
Oscillatoria subbrevis Schmidle	(140)	3	67824	203.47	1	10
Oscillatoria limnetica Lemmermann	(70)	3	46	0.14	1	10
Oscillatoria rubescens De Candolle	(275)	3	707	2.12	1	10
Oscillatoria curviceps C.A. Agardh	(321)	3	28260	84.78	1	10

APPENDIX 8 (CONT'D)

	specimen's no. on plates vii-xxxviii	Population density ($X10^3$Units L^{-1})	Volume (um^3)	Biomass $X10^6 um^3 L^{-1}$	Abundance	Frequency (%)
EUGLENOPHYTA						
Trachelomonas sp.	(2)	3	113	0.34	1	10
BACILLARIOPHYCEAE						
Nitzschia kutzingiana Hilse.	(365)	24	393	9.43	1-1	70
Synedra tubulata	(459) ?	15	353	5.30	1.5	30
Nitzschia holsatica Hust		3	294	0.88	1	10
Nitzschia amphibia Grun	(386)	18	622	11.20	1.2	50
Nitzschia angustata	(489)	3	628	1.88	1	10
Nitzschia philippinarum (Hust	(401)	21	275	5.78	1.8	40
Nitzschia sp.	(387)	36	314	11.30	2	60
Nitzschia paleaceae Grun	(385)	12	530	6.36	1.3	30
Navicula cryptocephala Kg var Cryptocephala Patr & Reimer	(440)	9	550	4.95	3	10
Nitzschia vermicularis (Kg) Grun?	(455)	3	5024	15.07	1	10
Coscinodiscus subtilis Ehr.	(453)	3	4069	12.21	1	10
Cyclotella glomerata	(417)	3	77	0.23	1	10
Cyclotella sp.		24	77	1.85	2.7	30
Cyclotella michiganiana Kg.	(473)	3	39	0.12	1	10
Cymbella affinis	(465)	6	2162	12.97	2	10
Fragilaria brevistriata	(359)	3	10348	31.04	1	10

APPENDIX 8 (CONT'D)

	specimen's no. on plates vii-xxxviii	Population density X10^3Units L^{-1})	Volume (um^3)	Biomass X$10^6 um^3 L^{-1}$	Abundance	Frequency (%)
Synedra ulna (Nitzsch.) Ehr.	(457)	3	37303	111.91	1	10
Synedra arcus var radians	(431)	3	1963	5.89	1	10
Synedra sp.	(439)	3	2049	6.15	1	10
Navicula cryptocephala var exilis (Kg) Grun	(402)	15	650	9.75	1.7	30
Navicula bremensis Hust	(408)	3	294	0.88	1	10
Pinnularia sub capitata Greg cf var paucistrata	(498)	3	1206	3.62	1	10
Achnanthes exigua Grun	(384)	3	75	0.23	1	10
Unidentified unicell (KD20)	(322)	6	2	0.012	2	10
Unidentified unicell (KD25)	(265)	3	33	0.10	1	10
Unidentified colony (KD26)	(265)	3	1.3	0.004	1	10
Unidentified unicell (KD48)	(307)	3	8157	24.47	1	10
Unidentified unicell (KD52)	(323)	9	14	0.13	3	10
Unidentified unicell (KD49)	(273)	3	35	0.11	1	10

APPENDIX 9: BY-PASS POND JANUARY (BJ)

	specimen's no. on plates vii-xxxviii	Population density ($X10^3$Units L^{-1})	Volume (um^3)	Biomass $X10^6 um^3 L^{-1}$	Abundance	Frequency (%)
CHLOROPHYTA						
Chlamydomonas sp	(284)	400	113	45.20	1	40
Coelastrum sphaericum Nageli	(205)	200	4834	996.8	1	20
Volvox sp (113)		100	7217	721.70	1	10
Volvox sp (279)		100	907	90.28	1	10
Micractinum pusillum Fresenius	(326)	100	38	3.800	1	10
Ankistrodesmus fusiformes Corola		100	34	3.40	1	10
Scenedesmus incrassatulus Bohlin	(267)	100	264	26.4	1	10
Koliella longiseta Hindak	(319)	100	32	3.20	1	10
Tetradesmus smithii Prescott	(282)	100	56	5.60	1	10
Crucigenia rectangularis	(95)	100	150	30.00	1	20
Chlamydomonas reinhardii Dangeard	(153)	200	321	64.20	2	10
Scenedesmus dimorphus (Turp) Kuetzing	(305)	100	234	23.40	1	10
Apiocystis brauniana/cf Naegeli	(274)	100	65	6.50	1	10
Scenedesmus bijuga/cf var alternans (Reinsch) Hansgirg	(121)	200	65	13.00	1	20
Chlamydomonas sp.	(93)	100	320	32.00	1	10
Scenedesmus arcuatus/cf var platydisca G.M. Smith	(129)	100	95	9.50	1	10
Tetraspora smitnii Prescott	(124)	100	112	11.2	1	10
Tetrastrum sp.	(158)	100	881	88.1	1	10

APPENDIX 9 (CONT'D)

	specimen's no. on plates vii-xxxviii	Population density ($X10^3$Units L^{-1})	Volume (um^3)	Biomass $X10^6 um^3 L^{-1}$	Abundance	Frequency (%)
Haematococcus lacustris (Girod) Rostaf	(78)	500	2138	1069.00	1	10
Stichococcus bacillaris (Nagelli	(31)	1600	14	22.4	4	40
CYANOPHYTA						
Chroococcus dispersus var minor G.M. Smith	(327)	100	1808	180.8	1	10
Chroococcus sp.	(44)	100	42	4.2	1	10
Aphanothece sp.	(328)	600	14	8.40	2	30
Oscillatoria sp	(315)	100	1081	108.1	1	10
Oscillatoria limnetica Lemmermann	(70)	200	323	64.60	1	20
Oscillatoria tenuis f tergestina Rabeh	(190)	200	1507	301.4	2	10
Spirulina Major Kuetzing	(193)	200	1413	282.6	1	20
Oscillatoria rubescens De Candolle	(275)	100	48	4.80	1	10
Oscillatoria sp.	(202)	100	38465	3846.5	1	10
Aphanothece nidulans P. Richter	(154)	300	78	23.4	1	10
Aphanocapsa endophytica	(8)	100	9	0.9	1	10
Spirulina laxissima West (	(302)	100	42	4.2	1	10
Cyanarcus harmiformis Pascher	(109)	100	14	1.4	1	10
Oscillatoria sp	(60)	100	86	8.60	1	10
Oscillatoria hameli Fremy	(312)	100	138	13.8	1	10

APPENDIX 9 (CONT'D)

	specimen's no. on plates vii-xxxviii	Population density ($X10^3$ Units L^{-1})	Volume (um^3)	Biomass	$X10^6 um^3 L^{-1}$ Abundance	Frequency (%)
EUGLENOPHYCEAE						
Trachelomonas pulcherrima var minor Playfair (306)		700	381	266.70	1.75	40
Trachelomonas volvocina Ehrenberg	(141)	400	267	106.8	1.3	30
Unidentified unicell (BJ5)	(157)	2900	65	188.5	4.8	60
Unidentified filament (BJ9)	(142)	100	21	2.1	1	10
Unidentified unicell (BJ14)	(143)	100	113	22.6	1	20
Unidentified unicell (BJ28)	(329)	500	65	32.50	1	50
Unidentified colony (BJ30)	(144)	100	260	26.00	1	10
Unidentified unicell (BJ31)	(145)	200	65	13.00	1	20
Unidentified unicell (BJ32)	(330)	300	1432	429.6	1	30
Unidentified desmid. (BJ36)	(331)	100	10739	1073.9	1	10
Unidentified unicell (BJ39)	(146)	100	1431	143.1	1	10
Unidentified colony (BJ41)	(147)	100	113	11.3	1	10
Unidentified unicell (BJ42)	(148)	100	88	8.8	1	10
Unidentified colony (BJ48)	(149)	100	98	9.8	1	10
Unidentified unicell (BJ49)	(332)	100	137	13.7	1	10
Unidentified colony (BJ52)	(150)	100	76	7.6	1	10
Unidentified colony (BJ57)	(333)	200	14	2.8	2	10
Unidentified unicell (BJ65)	(120)	200	48	9.6	1	20
Unidentified unicell (BJ67)	(184)	700	65	45.5	2.3	30

APPENDIX 9 (CONT'D)

	specimen's no. on plates vii-xxxviii	Population density ($X10^3$ Units L^{-1})	Volume (um^3)	Biomass $X10^6 um^3 L^{-1}$	Abundance	Frequency (%)
Navicula pygmaea Kg	(438)	100	1900	190.00	1	10
Navicula radiosa Kutz	(469)	100	4774	477.4	1	10
Nitzschia sp	(475)	100	334	33.4	1	10
Nitzschia kutzingiana Hilse	(365)	100	648	64.8	1	10
Nitzschia paleaceae Grun	(365)	200	184	36.8	1	20
Nitzschia acicularis. W. Smith	(373)	300	509	152.7	1	30
Nitzschia subrostrata Hust	(437)	100	385	38.5	1	10
Gomphonena angustatum Kg Rabh	(490)	100	480	48.00	1	10
Cyclotella pseudosteligera	(462)	100	157	15.7	1	10
Cyclotella kutzingiana Thwaites	(425)	200	308	61.6	1	20
Synedra tubulata	(459)	100	389	38.9	1	10
Coscinodiscus sp	(483)	10	113	1.15	1	10
Eunotia pectinalis var undulata	(450)	100	17550	1755.00	1	10
Synedra arcus var rachans	(431)	100	226	22.6	1	10
Gomphonena affine var/cf insigna (Greg) Andrews		100	5087	508.7	1	10
Asterionella formosa	(506)	100	37680	3768.0	1	10
Rhoicosphenia curvata	(485)	100	1910	191.00	1	10
Unidentified hexagonal diatom (Plate IV.3)		100	5137	513.7	1	10

APPENDIX 10: STABILIZATION POND ONE, JANUARY (SPOJ)

	specimen's no. on plates vii-xxxviii	Population density ($X10^3$Units L^{-1})	Volume (um^3)	Biomass $X10^6 um^3 L^{-1}$	Abundance	Frequency (%)
CYANOPHYTA						
Microcystis aeruginosa'plate III.1)		1900	2142391	4070542.9	1.9*	100**
BACILLARIOPHYCEAE						
Gomphanena parvulum (Kg) Grun	(360)	10	353	3.53	1	10
Melosira granulata (Ehr.) Ralfs	(485)	10	502	5.02	1	10
Cyclotella sp.	(390)	10	346	3.46	1	10
Coscinodiscus sp.	(483)	10	113	1.13	1	10
Unidentified unicell (SPOJ10)	(105)	800	267	213.6	2	40**

APPENDIX 11: STABILIZATION POND THREE JANUARY (SPTJ)

	specimen's no on plates vii-xxxviii	Population density ($X10^3$ Units L^{-1}	Volume (um^3)	Biomass $X10^6 um^3 L^{-1}$	Abundance	Frequency (%)
CHLOROPHYTA						
Scenedesmus sp.	(278)	176	251	44.18	1	40**
Micractinum quadrisetum	(168)	528	400	211.2	1.7*	70**
Coelastrum sp.	(53)	44	4800	211.2		
CYANOPHYTA						
Microcystis aeruginosa (Plate III.1).		660	1209	797.94	1.9*	80**
Anacystis sp.	(167)	44	56	2.46	1	10
Spirulina princeps West & West	(301)	176	39	6.86	1	40**
BACILLARIOPHYCEAE						
Fragilaria brevistriata	(359)	44	393	17.29	1	10
Cyclotella pseudostelligera	(462)	44	123	5.41	1	10
Cyclotella meneghiniana Kg	(473)	88	113	9.94	1	10
Cyclotella striata (Kg) Grun	(454)	30	265	7.95	1.5*	20
Cyclotella sp.	(390)		125	1.25	1	10
Caloneis silicula ?	(405)	4.4	1731	7.62	1	10
Melosira granulata (Ehr) Ralfs		4.4	9361	41.19	1	10
Melosira distans (Ehr) Kutz	(485)	4.4	2000	8.80	1	10
Melosira sokida Eulenstein			942	4.14	1	10
Comphonena lanceolatum (Ehr)	(416)	8.8	10174	89.53	1	20

APPENDIX 11 (CONT'D)

	specimen's no. on plates vii-xxxviii	Population density ($X10^3$ Units L^{-1})	Volume (um^3)	Biomass $X10^6 um^3 L^{-1}$	Abundance	Frequency (%)
Navicula meniculus Schumann	(362)	4.4	10990	48.36	1	10
Navicula decusis Oestr.	(358)	4.4	509	2.24	1	10
Navicula salinarum Grun	(363)	4.4	7385	32.49	1	10
Unidentified unicell (SPTJ7)	(166)	44	320	14.08	1	10
Unidentified (SPTJ11)	(337)	44	10275	452.1	1	10
Unidentified unicell (SPTJ17)	(338)	44	448	19.71	1	10
Unidentified unicell (SPTJ16)	(165)	44	1432	63.01	1	10
Unidentified (SPTJ19)	(170)	44	8157	358.91	1	10

APPENDIX 12: KUBANNI POND, JANUARY (KJ)

	specimen's no. on plates vii-xxxvili	Population density ($X10^3$Units L^{-1})	Volume (um^3)	Biomass $X10^6 um^3 L^{-1}$	Abundance	Frequency (%)
CHLOROPHYTA						
Chlorella sp?	(335)	11.63	381	4.43	1	10
Scenedesmus acuminatus (Lag) Chodat	(336)	11.63	100	1.16	1	10
Haematococcus lacustris (Girod) Rostaf	(78)	11.63	902	10.49	1	10
CYANOPHYTA						
Aphanocapsa endophytica G.M. Smith	(8)	11.63	320	3.72	1	10
BACILLARIOPHYCEAE						
Coscinodiscus sp.	(483)	1	216	0.22	1	10
Navicula cryptocephala/cf var cryptocephala Patr & Reimer	(440)	2	565	1.3	1	10
Navicula viridula Kg.	(413)	1	452	0.45	1	10
Synedra ulna (Nitzsch) Ehr	(457)	1	10174	10.7	1	10
Nitzschia sp.	(441)	2	491	0.98	1	10
Unidentified filament (KJ16)	(163)	11	11	0.12	1	10

APPENDIX 13: BY-PASS POND, FEBRUARY (BF)

	specimen's No. on plates vii-xxxviii	Population density ($X10^3$ Units L^{-1})	Volume (um^3)	Biomass $X10^6 um^3 L^{-1}$	Abundance	Frequence (%)
CHLOROPHYTA						
Chlamydomonas sp?	(339)	33.4	14	0.47	2*	10
Ankistrodesmus cf falcatus var mirabilis (West & West) G.S. West (3)		16.7	5	0.08	1	10
Ankistrodesmus fractus (West & West) Brunnthaler	(290)	16.7	42	0.70	2*	10
Chlorochromonas sp		16.7	113	1.89	1	10
Apiocystia brauniana Naegeli	(274)	16.7	143	2.39	1	10
Cosmarium sp.	(247)	16.7	22	0.37	1	10
Coelastrum sphaericum Nageli	(205)	500	11459	5729.50	1.3*	40*
Scenedesmus acuminatus Chodat	(23)	100	648	64.8	1	10
Micractinum sp	(342)	100	113	11.3	1	10
Scenedesmus quadricauda var longispina (Chod) G.M. Smith	(293)	200	432	86.4	1	20
Tetraedron sp.	(341)	200	297	59.4	1	20
Micractinum pusillum Fresenius	(326)	100	902	90.2	1	10
Golenkinia radiata	(340)	100	113	11.3	1	10
Crucigenia rectangularis (A Braun) Gay	(131)	500	60	30.00	2.5*	20
Tetraspora smithii Prescott	(124)	100	56	5.60	1	10
Kirchneriella sp.	(63)	100	28	2.8	1	10
Pediastrum boryanum Turp Maneghii	(343)	100	1256	125.6	1	10
Stichococcus bacillaris Nageli	(31)	67	1.3	0.09	4*	10
Raphidiopsis carvata Fritzsch et Rich	(229)	67	318	21.3	1	10
Ophiocytium capitatum cf longispinum Moebius Lemmermann	(216)	100	2612	261.2	1	10
Ophiocytium sp	(215)	200	1696	339.2	1	20
Ophiocytium sp		100	509	50.9	1	10

APPENDIX 13 (CONT'D)

	specimen's no. on plates vii-xxxviii	Population density ($X10^3$ Units L^{-1})	Volume (um^3)	Biomass $X10^6 um^3 L^{-1}$	Abundance	Frequency (%)
CYANOPHYTA						
Nostoc sp.	(243)	16.7	9043	151.02	4*	10
Cyanarcus hamiformis Pascher	(109)	33.4	9	0.30	2	10
Oscillatoria rubescens De Candolle	(275)	16.7	371	6.20	1	10
Chroococcus sp	(44)	16.7	209	3.49	1	10
PYRROPHYTA						
Rhosomonas sp	(344)	16.7	65	1.09	1	10
Rhodomonas minuta Skuja		16.7	33	0.55	1	10
Chroomonas sp?	(245)	16.7	14	0.23	1	10
BACILLARIOPHYCEAE						
Cyclotella stelligera Cleve et Grun	(472)	200	38	7.6	1	20
Cyclotella glomerata	(417)	400	28	11.2	4*	10
Cyclotella sp	(390)	100	113	11.3	1	10
Cyclotella striata (Kg) Grun		200	227	45.4	1	10
Melosina granulata (Ehr) Ralfs		100	7630	763.00	1	10

U APPENDIX 13 (CONT'D)

	specimen's no. on plates vii-xxxviii	Population density ($X10^3$ Units L^{-1})	Volume (um^3)	Biomass $X10^6 um^3 L^{-1}$	Abundance	Frequency (%)
Navicula radiosa Kg	(499)	300	480	144.00	1	30
Navicula pygmaea Kg	(438)	100	4019	401.9	1	10
Navicula heufleri Grun	(496)	100	622	62.2	1	10
Coscinodiscus sp	(483)	100	154	15.4	1	10
Rhoicosphenia carvata (Kutz) Grun	(503)	10	1910	19.10	1	10
Achnanthes microcephala Kg	(370)	10	450	4.50	1	10
Unidentified ornamented diatom (Plate IV, 2)	(509)	10	7630	76.3	1	10
Unidentified unicell (BF11)	(323)	217	14	3.04	13*	10
Unidentified unicell (BF12)	(345)	50	4	0.2	3*	10
Unidentified unicell (BF14)	(251)	16.7	65	1.09	1	10
Unidentified unicell BF34)	(248)	100	8266	826.6	1	10
Unidentified unicell (BF36)	(338)	100	65	6.50	1	10
Unidentified unicell (BF38)	(265)	200	179	35.8	1	20
Unidentified unicell (BF58)	(346)	100	65	6.50	1	10
Unidentified (BF63)	(347)	100	381	38.1	1	10
Unidentified (BF66)	(219)	100	217037	21703.7	1	10
Unidentified (BF29)	(126)	100	79	7.9	1	10

APPENDIX 14: STABILIZATION POND ONE FEBRUARY (SPOF)

	specimen's no. on plates vii-xxxviii	Population density ($X10^3$ Units L^{-1}	Volume (um^3)	(Biomass $X10^6 um^3 L^{-1}$	Abundance	Frequency (%)
CHLOROPHYTA						
Scenedesmus quadricauda (Turp) De Breb	(14)	43.5	4556	198.19	1	10
CYANOPHYTA						
Microcystis aeruginosa Kutz	(Plate 3.1)	696	267277	186024.79	1.6*	100*
Microcystis cf floss-aquae	(188)	43.5	3580	155.73	1	10
Aphanocoqsa littoratis Hansg.	(348)	43.5	3250	141.38	1	10
Gleocapsa sp	(253)	87	68	5.92	1	20
Spirulina laxissima West G.S.	(302)	43.5	97	4.22	1	10
Unidentified colony	(Plate III, 8)	87	6352	552.62	1	20

APPENDIX 15: STABILIZATION POND THREE, FEBRUARY (SPTF)

	specimen's no. on plates vii-xxxviii	Population density ($X10^3$ Units L^{-1})	Volume (um^3)	Biomass $X10^6 um^3 L^{-1}$	Abundance	Frequency (%)
CHLOROPHYTA						
Stichococcus bacillaris Nageli	(31)	400	11	4.4	2*	20
Eudorina sp?	(259)	400	381	152.4	1.3*	30
Scenedesmus quadricauda var maximus West & West	(324)	200	251	50.2	1	20
Micractinum quadrisetum?	(261)	1100	624	686.4	2.75*	40*
Chlamydomonas sp?	(263)	100	381	38.1	1	10
Micractinum pusillum Fresenius	(326)	100	87	8.7	1	10
Haematococcus lacustris (Girod) Rostaf	(78)	100	2138	213.8	1	10
Micractinum sp	(342)	200	452	90.4	1	20
CYANOPHYTA						
Microcystis aeruginosa Kutz (Plate III.1)		600	33409	20045.4	1.5*	10
Aphanothece sp	(328)	100	5	0.5	1	10
Aphanocapsa endophytica G.M. Smith	(8)	100	113	11.3	1	10
Gleocapsa sp	(253)	100	65	6.5	1	10
Microcystis elabens (Breb) Kutz (349)	(232)	100	3317	331.7	1	10
Microcystis lamelliformis Holsinger	(350)	100	763	76.3	1	10
Merismopedia elegans A. Braun?	(236)	200	452	90.4	2*	10

APPENDIX 15: (CONT'D)

	specimen's no on plates vii-xxxviii	Population density ($X10^3$Units L^{-1})	Volume (um^3)	Biomass $X'0^6_{um}{}^3L^{-1}$	Abundance	Frequency (%)
BACILLARIOPHYCEAE						
Melosira granulata (Ehr) Ralfs	(485)	10	9361	187.22	1	20
Gyrosigma sp.?	(491)	10	1272	12.72	1	10
Gomphonema tetrastigmatum Horikawa et Okuno	(449)	10	5878	58.78	1	10
Gomphonena lanceolatum Ehr	(398)	10	2090	20.90	1	20
Synedra sp	(439)	10	1050	10.5	1	10
Achnanthes microcephala Kg	(370)	10	127	12.7	1	10
Unidentified ornamented diatom? (Plate IV, 2)		10	29164	291.64	1	10
Unidentified unicel (SPTF6)	(258)	100	35	3.5	1	10
Unidentified unicell (SPTF20)	(262)	500	31	15.5	1.3*	40*
Unidentified flagellate (SPTF28)	(234)	100	76	7.6	1	10
Unidentified (SPTF29)	(351)	100	498	49.8	1	10

APPENDIX 16: KUBANNI POND, FEBRUARY (KF)

	specimen's no on plates vii-xxxviii	Population density ($X10^3$ Units L^{-1})	Volume (um^3)	Biomass $X10^6 um^3 L^{-1}$	Abundance	Frequency (%)
CHLOROPHYTA						
Ankistrodesmus falcatus	(3)	34.5	62	2.14	1	10
Haematococcus lacustris (Girod) Rostaf	(78)	69	113	7.80	1	20
Spirogyra porticalis (Muell) Cleve	(162)	34.5	3815	131.62	1	10
CYANOPHYTA						
Gleocapsa quarternata (Breb) Kutz	(249)	173	56	9.69	1.3*	40*
Aphanothece sp	(328)	34.5	22	0.76	1	10
Gleocapsa sp	(253)	69	4	0.28	2*	10
BACILLARIOPHYCEAE						
Cyclotella sp.		69	177	12.21	1	20
Navicula pupula Kg	(380)	34.5	236	8.14	1	10
Unidentified ornamented diatom?	(248)	34.5	29164	1006.16	1	10
Unidentified unicell (KF1)	(248)	34.5	33912	1169.96	1	10
Unidentified colony (KF7)	(250)	34.5	14	0.48	1	10
Unidentified unicell (KF8)	(251)	34.5	113	3.90	1	10
Unidentified colony (KF9)	(252)	104	125	13.80	1.5*	20
Unidentified unicell (KF10)	(32)	34.5	64	2.21	1	10
Unidentified (KF17)	(255)	34.5	179	6.18	1	10

APPENDIX 17: BY-PASS POND, MARCH (BM)

	specimen's no on plates vii-xxxviii	Population density ($X10^3$Units L^{-1})	Volume (um^3)	Biomass $X10^6 um^3 L^{-1}$	Abundance	Frequency (%)
CHLOROPHYTA						
Ankistrodesmus falcatus var mirabilis(West & West)	G.S. West(3)	2100	236	495.00	2.1*	100**
Coelastrum sp	(53)	1000	1761	1761.00	2*	50**
Volvox sp		600	5559	3334.8	2*	30
Chlorella sp	(226)	3000	1762	5286.00	7.5*	40**
Ankistrodesmus gracilis Korshikov	(292)	2200	377	829.4	2.8*	80**
Scenedesmus quadricauda var maximus West & West	(324)	400	251	100.4	1.3*	30
Micractinum quadrisetum (Lemm) G.M. Smith (Plate III, 2) III		100	402	40.2	1	10
Kirchneriella sp	(63)	1200	71	85.2	2*	60**
Scenedesmus cf incrassatulus Bohlin	(269)	100	225	28.8	1	10
Kirchneriella contorta		200	29	5.8	1	20
Crucigenia rectangularis (A. Braun) Gay		500	65	32.5	1.3*	40**
Scenedesmus acuminatus Chodat	(23)	200	321	64.2	1	20
Tetraedron sp.	(352)	200	113	22.6	1	20
Tetraedron trigonium Hansgirg	(33)	100	65	6.50	1	10
Staurastrum sp.	(251)	100	9175	917.5	1	10
Tetradesmus cf wisconsinensis Smith	(115)	300	260	78.00	1	30
Golenkinia radiata Chodat	(340)	100	65	6.50	1	10
Ankistrodesmus falcatus var acicularis (A Braun)	G.S. West (75)	200	133	26.6	2*	10
Ophiocytium capitatum of var longispinum (Moeb)	Lemmermana (228)	100	236	23.6	1	10
Ophiocytium sp	(215)	100	650	65.00	1	10

APPENDIX 17 (CONT'D)

	specimen's no. on plates vii-xxxviii	Population density ($X10^3$ Units L^{-1})	Volume (um^3)	Biomass $X10^6 um^3 L^{-1}$	Abundance	Frequency (%)
CYANOPHYTA						
Oscillatoria corallinae (Kutz) Gomont	(230)	100	734	73.4	1	10
Gleocapsa sp	(253)	100	902	90.2	1	10
Aphanothece sp	(328)	100	65	6.5	1	10
Aphanocapsa endophytica	(8)	200	7217	1443.4	1	20
Oscillatoria sp.	(60)	100	3768	376.8	1	10
Dactylococcopsis smithii Chodat & Chodat		200	150	30.00	2*	10
Chroococcus sp	(44)	200	140	28.00	1	20
Chroococcus pallidus Maegeli	(225)	100	236	23.6	1	10
EUGLENOPHYTA						
Lepocirclis ovum (Ehr) Lemmermann	(220)	100	2057	205.7	1	10
Trachelomonas sp	(173)	100	65	6.5	1	10
Phacus curvicauda Swirenko	(221)	200	3044	608.8	2*	10
Euglena sp.	(79)	200	14094	2814.8	1	20
PYRROPHYTA						
Glenodinium cf pulvisculus/(Ehr) Stein	(283)	100	5559	555.9	1	10

APPENDIX 17 (CONT'D)

	specimen's no. on plates vii-xxxviii	Population density ($X10^3$ Units L^{-1}	Volume (um^3)	Biomass $X10^6 um^3 L^{-1}$	Abundance	Frequency (%)
Unidentified colony (BM13)	(227)	100	21624	2162.4	1	10
Unidentified (BM18)	(338)	100	381	38.1	1	10
Unidentified (BM22)	(231)	100	143	14.3	1	10
Unidentified unicell (BM25)	(345)	100	65	6.5	1	10
Unidentified colony (BM54)	(222)	100	226	22.6	1	10
Unidentified colony (BM55)	(223)	100	455	45.5	1	10
Unidentified unicell (BM64)	(332)	100	311	31.10	1	10

APPENDIX 18: STABILIZATION POND ONE, MARCH (SPOM)

	specimen's no. on plates vii-xxxviii	Population density ($X10^3$ Units L^{-1})	Volume (um^3)	Biomass $X10^6 um^3 L^{-1}$	Abundance	Frequency (%)
CHLOROPHYTA						
Micractinum sp.	(111)	3 0	17	5.10	1.5*	20
Scenedesmus quadricauda (Turp) De Breb	(14)	100	53	5.3	1	10
CYANOPHYTA						
Spirulina major Kuetzing	(193)	500	62	31.00	1	50*
Microcystis aeruginosa Kutz (Plate III.1)		3100	14095	43694.50	3.1*	100*
Arthrospira khannae Drouet and Strickland	(354)	300	44	13.2	1	30
Unidentified	(188)	10	4	0.04	1	10
BACILLARIOPHYCEAE						
Coscinodiscus sp	(483)	10	35	0.35	1	10
Cyclotella kutzingiana Thwaites	(425)	10	113	1.13	1	1
Comphonema parvulum Grun	(360)	10	4616	46.16	1	1
Comphonema gracile Ehr	(388)	10	4616	46.16	1	1
Comphonema angustatum (Kg) Rabh	(410)	10	1521	15.21	1	1
Cymbella turgida (Greg) Cleve	(367)	10	380	3.8	1	1
Navicula viridula Kutz cf	(413)	10	2850	28.5	1	1
Navicula cuspidata Kg/var ambigua Ehr Cleve	(376)	10	13155	131.55	1	1
Nitzschia angustata	(489)	10	393	3.93	1	1
Unidentified (SPOM12)	(Plate IV.3)	100	11	1.1	1	10

APPENDIX 19: STABILIZATION POND THREE MARCH (SPTM)

	specimen's no. on plates vii-xxxviii	Population density ($X10^3$ Units L^{-1})	Volume (um^3)	Biomass $X10^6 um^3 L^{-1}$	Abundance	Frequency (%)
CHLOROPHYTA						
Scenedesmus pannonicus	(353)	400	251	100.4	1	40**
Golenkinia radiata Chodat	(340)	1100	381	38.1	1	10
Micractinum pusillum Fresinius	(326)	100	20	2.0	1	10
CYANOPHYTA						
Aphanocapsa muscicola Menegh	(355)	500	35	17.5	1	50**
Aphanocapsa montana Cramer	(356)	100	112	11.20	1	10
Arthrospira khannae Droulet and Strickland	(354)	500	2526	1413.00	1	50**
Microcystis aeruginosa (Plate III.1)		3000	8137	24411.00	3	100**
PYRROPHYTA						
Rhodomonas sp.	(344)	200	267	53.4	1	20
BACILLARIOPHYCEAE						
Melosira solida Eulenstein	(452)	10	450	4.5	1	10
Melosira italica (Ehr) Kg.	(416)	10	332	3.32	1	10
Cyclotella striata (Kg) Grun	(411)	10	177	1.77	1	10
Cyclotella comta (Ehr) Kg.	(497)	10	1194	11.94	1	10
Cyclotella kutzingiana Thwaites	(425)	10	177	3.44	1	20
Gomphonena angustatum (Kg) Rabh.	(410)	10	4295	42.95	1	10

APPENDIX 19 (CONT'D)

	specimen's no. on plates vii-xxxviii	Population density ($X10^3$Units L^{-1}	Volume (um^3)	Biomass ($X10^6 um^3 L^{-1}$	Abundance	Frequency (%)
Comphonena parvulum (Kg) Grun	(360)	10	1005	10.05	1	10
Comphonena tetrastigmatum Horikawa et Okuno	(449)	10	2261	22.1	1	10
Comphonena gracile Ehr.	(388)	20	4300	86.00	1	10
Nitzschia paleaceae Grun	(385)	10	2261	22.61	1	10
Nitzschia sp. dissipata	(368)	10	735	7.35	1	10
Navicula cuspidata Kg var ambigua Ehr Cleve	(376)	10	850	8.50	1	10
Unidentified cylindrical unicell (SPTM4)	(357)	300	44		1	30
Unidentified flagellate (SPTM11)	(239)	100	14	1.4	1	10
Unidentified unicell (SPTM12)	(174)	100	179	17.9	1	10
Unidentified flagellate (SPTM20)	(240)	100	381	38.1	1	10

APPENDIX 20: KUBANNI POND, MARCH (KM)

	specimen's no. on plates vii-xxxviii	Population density ($X10^3$ Units L^{-1})	Volume (um^3)	Biomass $X10^6 um^3 L^{-1}$	Abundance	Frequency (%)
CHLOROPHYTA						
Kirchneriella lunaris/cf var irregularis G.M. Smith	(280)	96	234	20.124	1	30
Micractinum sp.	(111)	96	105	9.03	1	30
Chlorosphaera lacustris Snow	(357B)	172	179	30.79	1.2*	50**
CYANOPHYTA						
Aphanothece sp.	(328)	96	9	0.79	1	30
Aphanocapsa muscicola Menegh	(355)	200	113	22.600	1.2*	60**
Chroococcus	(327)	143	209	29.89	1.7*	30
CHRSOPHYCEAE						
Chrysococcus rufescens Klebs	(15)	57	381	21.72	2	10
Chrysococcus sp (Plate III, 10)		57	267	15.22	1	20
Unidentified (KM7) Plate		29	267	7.64	1	10
Unidentified (KM13) (Plate	(24)	57	902	51.41	1	20

APPENDIX 21: MANUFACTURER'S PROCEDURE FOR CALIBRATING THE YSI DISSOLVED OXYGEN METER

A. Switch instrument to OFF and adjust meter mechanical zero.

B. Switch to red line and adjust.

C. Prepare probe for operation, plug into instrument, wait 10 - 15 minutes for probe to polarise.

D. Switch to zero and adjust.

E. Adjust salinity knob to fresh.

F. Switch to temperature and read.

G. Use probe temperature and true local atmospheric pressure (or feet above sea level) to determine correct calibration values from tables 1 and 2.

Example:

Probe temperature = 21°C

Altitude = 1000 ft.

From table 1, calibration value for 21°C is 9.0 ppm.

From table 2, the altitude factor for 1000 ft is about 0.96. The correct calibration value is 9.0 ppm x 0.96 factor = 8.64 ppm.

APPENDIX 22: TYPICAL EXAMPLES OF POLLUTION TOLERANT GENERA (PALMER, 1980)

Blue green algae:	Microcystis, Oscillatoria
	Schizothrix
Diatoms:	Cyclotella, Comphonena, Nitzschia .
Flagellate algae:	Chlamydomonas, Euglena,
	Cryptomonas.
Green algae:	Ankistrodesmus. Chlorella
	Scenedesmus.

TYPICAL EXAMPLES OF POLLUTION TOLERANT SPECIES IN STABILIZATION PONDS (PALMER, 1980)

Euglena viridis, Euglena gracilis, Nitzschia palea, Oscillatoria limosa, Oscillatoria tenuis, Arthrospira jenneri, Stigeochenium tenue, Chlorella vulgaris, Anabaena constricta, Phormidium uncinatum, Oscillatoria princeps and Microcystis aeruginosa.