PHYTOPLANKTON IN COOTE'S PARADISE

AN ECOLOGICAL STUDY OF PHYTOPLANKTON IN COOTE'S PARADISE

By

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ABSTRACT

During the period June, 1973 to May, 1974 limnological studies were carried out on the waters of Cootes Paradise, a marsh and wildlife sanctuary in Hamilton, Ontario. All of the indicies of eutrophication measured indicated that the marsh ranked among the most eutrophic of aquatic systems in temperate regions. The secondary treated sewage which was discharged into the western end of the marsh from the Dundas Sewage treatment plant was the primary source of nutrients.

The phytoplankton populations showed a prolonged summer bloom typical of aquatic systems polluted by sewage effluent. Chlorophyll a, used as an index of biomass, was highest during the spring and summer, and lowest during the fall and winter. The converse was true for the nutrients. Phytoplankton decreases and increases were correlated with changes in the light/temperature regimes during the fall and spring transition periods. Temperature had a pronounced effect upon chlorophyll variations between January and May 1974 in West Pond.

Weekly biomass variations during the summer at stations 4 and 12 were related to a complex of interactions involving eleven environmental parameters. Station 4 was

located in the western end of the marsh and station 12 was in the eastern end. Nitrate-nitrogen was suspected to be the nutrient which was limiting algal growth in the western end of the marsh. Phosphorous mining in the sediments and nitrification of ammonia were observed in the Desjardins Canal and West Pond.

The west and east-end sample stations of the marsh were significantly different in phytoplankton composition and nutrient status when compared to each other. Algal genera and species typical of highly eutrophic waters were observed in West Pond and in the main open water area (station 12). Chlorophyta were the dominant group in West Pond, while Cyanophyta formed the dominant group in the main area during the summer of 1973. Species composition and dominance of major algal groups changed with the seasons at both station 4 and station 12.

During the summer, chlorophyll averaged 695 mg/M^3 in the West Pond stations and about 196 mg/M^3 in the main open water area stations. N/P ratios were lower in the west end stations than in the east end stations. Nutrients in the sewage effluent had a greater effect on algal activity at those stations near the point of discharge (stations 1 through 6). By the time the waters reached station 6, 80% of inorganic phosphate and about 90% of nitrate-nitrogen were removed. In this respect, the West Pond, area (20 acres) can be regarded as a sewage lagoon

performing further treatment on the incoming sewage effluent. As a result, a decreased nutrient loading was discharged into the main open water area. This may have been a significant factor in determining the different phytoplankton structure in the main open water area.

Diurnal studies indicated that observed variations of various parameters were not great enough to affect an interpretation of seasonal changes based on data collected on a bi-weekly schedule (providing that sampling was consistent). Diurnal studies also suggested that wind speed, incident solar radiation, and previous light history may have been important in explaining chlorophyll variations.

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Section 1

INTRODUCTION

The eutrophication or accelerated ageing of natural fresh water or marine aquatic systems has long been, and still is, a problem of primary ecological, political, and economic concern. The term 'eutrophication' means nothing more than enrichment with nutrients and the consequent increase in biological productivity of aquatic systems (Pogg 1969). The term productivity can be defined as the quantity of organic matter produced by living organisms from a specific amount of raw materials in the environment in a unit time period (Ruttner 1973). Much of the deterioration of water quality is caused by incomplete treatment of domestic sewage, and industrial effluent wastes. Overfertilization of agricultural land and consequent runoff of fertilizers into lake basins, together with the fall-out products of atmospheric pollution also contribute to the problem. This thesis is concerned with the investigation of the environmental effects of the discharge of a daily average of two million gallons of secondary treated sewage into the waters of Coote's Paradise. Coote's Paradise is a marsh and wild-life sanctuary in Hamilton, Ontario. The responses of phytoplankton to the nutrients (most of which came from the sewage effluent) and to other physical parameters

have been studied.

The earliest description of what today would be described as a 'eutrophic lake' was made by Leeuwenhoek, in the year 1674 (Fogg 1969). The problem, therefore, is not new. Classical examples of formerly oligotrophic (unpolluted) lakes which are now eutrophic include, Lake Windermere in England, Loch Leven in Scotland, the Untersee basin of the Zurichsee in Switzerland (Brook 1965); Lake Erie (Lange 1971), Lake Michigan (Schelske and Stoermer 1971), Lake Kinneret in Israel (Halmann 1972), and Lake Washington in the U.S.A. (Hutchinson 1973). The eutrophication phenomonon is not unique to temperate regions, but is also prevalent in the tropics (Keeney 1972, Viner 1973). The results of this research confirm that the waters of Coote's Paradise rank among most eutrophic of temperate aquatic environments when chlorophyll is used as the index of eutrophication.

The phytoplankton ecologist is primarily concerned with investigating the causal factors of the eutrophication process and the possible mechanisms for prevention and reversal (Rawson 1956, Palmer 1969, Ryther and Dunstan 1971, Bush and Welsh 1972, Halmann 1972, Winner 1972, Fogg 1973, Hutchinson 1973, Takahashi and Nash 1973, Viner 1973). A classical example of a successful reversal of eutrophication was that of Lake Washington (Hutchinson 1973). One of the benefits of this report is that it will provide a groundwork

to suggest possible mechanisms for ameliorating the situation in Coote's Paradise.

In an attempt to establish water quality standards, researchers have developed various indicies of eutrophication. The list includes: cell concentration (Haertel 1972), indicator phytoplankton species (Palmer 1969, Archibald 1972), chlorophyll a concentration (Vollenweider 1969, Winner 1972), nitrogen levels (Keeney 1972), phosphorous concentrations (Fitzgerald 1971, Hutchinson 1973), silicon concentrations (Lewin and Guillard 1963), trace elements (Patrick et al. 1969), secchi depth and turbidity (Winner 1972, Ruttner 1973), pigment ratios (Margalef 1967, Platt and Rao 1970), primary production rates (Hutchinson 1973), assimilation ratios (Glooschenko et al. 1974), and changes in species diversity (Margalef 1967, Archibald 1972). Most of the above indices were studied in Coote's Paradise to put the marsh in a proper perspective in relation to other temperate freshwater bodies. Practically all of the parameters measured were similar to or higher than the ranges reported by other workers.

Living protoplasm has an approximate chemical formula of: $C_{106}H_{263}O_{110}N_{16}P_1$ .....Halmann (1972) and many workers (Hutchinson 1957, Pogg 1969, Maloney 1970), Takahashi and Nash 1973) directed their attentions towards the limiting and stimulating potentials of nitrogen and phosphorous as factors which stimulate the development and persistence of algal blooms in freshwaters.

Hutchinson (1973), in an extensive review on the eutrophication problem in freshwaters, reported that phosphorous may be the principal nutrient limiting the growth of algae. Moss (1972), reported that increased phosphorous loadings can come from septic tank leakage from cottages which border recreational lakes. The increased phosphorous results in eutrophication of these lakes. Halmann(1972) provided convincing evidence that phosphate was the only limiting factor in Lake Kinneret, Israel.

Keeney (1972), reported that nitrogen and phosphorous are the two most important nutrients which are likely to limit algal productivity in freshwater lakes. Gerloff and Skoog (1957) found that nitrogen may be the important nutrient limiting algal growth in eutrophic Lake Mendota.

Present literature sources (Mortimer 1941, Harter 1968, Austin and Lee 1973), indicate that phosphorous mining is an important phenomonon affecting the nutrient status of lakes. Kuznetsov (1968), and Keeney (1972) reported that nitrification of ammonia is also significant in lakes when nitrate concentrations are low. Attempts were made to identify phosphorous mining and nitrification of ammonia and to study their effects of algal activity. In addition, the effects of wind as an important environmental factor controlling algal activity was investigated. The research of Haertel (1972), and that of Harris and Lott (1973), have indicated that wind effects should not be neglected in phytoplankton studies.

An opportunity was offered to investigate the changes in the composition of phytoplankton populations which accompany environmental seasonal changes. Such studies are rare in polluted marsh ecosystems. Most of the work done on marsh ecology concentrated on productivity of higher plants (Jervis 1969), or from a resource management viewpoint (Lugo 1972). In other freshwater systems, reports on phytoplankton periodicity are numerous. Fogg (1969), Macan (1970), Munawar and Nauwerck (1971), Round (1971), Lowe (1972) and Moss (1972) are some examples of attempts to elucidate the causal factors of phytoplankton periodicity. Concurrent with the discussion on the seasonal periodicity of algae, an attempt was made to identify the presence of species indicative of highly eutrophic waters.

Diurnal studies (sampling at two-hour intervals for a twenty-four hour period) were carried out to investigate short-term variability of various environmental and biological parameters. Short-term variations are very critical when ecological interpretations are made from data collected once or twice weekly over a few seasons. The variable which has received most attention in diurnal studies is chlorophyll a (Yentsch and Ryther 1957, Yentsch and Scagel 1958, Schimada 1958, Steeman-Heilsen and Jorgensen 1962, McAllister 1963, Glooschenko et al. 1972). A discussion of the difficulties and caution which must be exercised when attempting to interpret diurnal chlorophyll variations was presented.

The body of this thesis showed that ecological interpretations of natural phenomona (such as those investigated in this study) are difficult to come by. A good example was the causal factors affecting the periodicity of phytoplankton in time and space. The difficulty was the result of the paucity of ecological tools available for the measurement, identification and control of an n-dimensional complex of environmental variables, which characterizes living systems. At best, however, broad generalizations about mechanisms are possible. Such generalizations were possible in this thesis.

(1.2) Description and History of Coote's Paradise

Coote's Paradise is a wild life sanctuary made up of some 1000 acres of woodland, marshy vegetation and open water. The total marsh and open water area has the shape of a long narrow triangle with its base adjacent to Burlington Heights (fig. 1). The marsh lies at the western extremity of Lake Ontario within the Dundas Valley on the property of the Royal Botanical Gardens, Hamilton, Ontario. It is separated from the lake by Hamilton Harbour directly east of the marsh.

The south shore is indented by several steep-sided inlets choked with submergent aquatic, emergent and terrestrial vegetation. On the average, the land on the north and south shores rises about 50 feet above the water level. There are two large peninsulas, namely Princess Point and Bulls

Point, extending into the water. The former rises gently to about 20 feet above the water level whilst Bulls Point slopes steeply to about 100 feet above the water level.

The water level at its deepest point after the spring run-off rarely exceeds 2 meters in the east end and 1 meter in the west end. The west end is arbitrarily defined as that area west of Spencer's Creek (fig. 1). Spencer's Creek is the major source of incoming water. The sewage plant in the town of Dundas discharges about two million gallons of secondary treated effluent into the marsh daily. The effluent is discharged at the extreme west end of the Desjardins Canal (fig. 1). Other inflow creeks and streams dry up soon after the spring run-off. Water level may also be affected by the water level of Lake Ontario, and by wind induced seiches in the lake.

The Desjardins Canal bisects the whole length of the marsh (three miles) in an east to west direction. The canal is fringed by a line of willow trees on both sides in the western end of the marsh and is recognizable in the east end (main open water area) by the presence of old piles projecting out of the water. The canal was originally built in 1837 to allow navigation of shallow draft boats for trade with Dundas. Presently, it no longer serves its original purpose.

According to Charles Durand (1897), "Coote's Paradise (in the early 1800's) was named after a Captain Coote,

a wonderful sportsman who hunted there before the 1800's..." It was described as a paradise harbouring a great diversity of terrestrial and aquatic flora and fauna, including beaver, mink, muskrat, duck, wild-fowl, other birds, snakes and salmon among other fish. A study done by Kay (1949), classified 35 species of fish including pike, bass, perch, minnow, shad, and suckers. Kay's (1949) summer transparency reports of the west and east end of the marsh water were secchi depths of 35 and 45-100 cm respectively. Kay also included a classification list of the local marsh flora but did not include the algae. The geological survey of the watershed soils indicated that the incoming streams fed the marsh primarily with silt and clay particulate materials. Kay (1949), and Durand (1897), offered the only documented biological information on the marsh. The fact that salmon thrived in the marsh in the early 1800's (Durand 1897), is an indication that the water quality was similar to that of Lake Ontario. Twenty-four years ago no salmon were found (Kay 1949). There are also no salmon in Lake Ontario today. Conversations with local residents indicate that since the construction of the Dundas Sewage plant and increased agricultural useage of the watershed, the waters of the marsh showed visual signs of deterioration.

The results of this study showed that since Kay's work (1949), the transparency of the water in the marsh has decreased by approximately one-half during the summer. The

decrease in transparency may be due to the accumulated particulate silt and clay material held in suspension by wind action on the water. Transparency may also be decreased by the presence of greater algal concentrations. However, in the absence of detailed phytoplankton algae studies in Kay's (1949) report the former statement is only speculative. Dissolved oxygen concentrations seem to be higher now than in the late 40's. Again this may be due to greater photosynthetic activity of a presumably larger algal population.

The staff of the Royal Botanical Gardens (personal communication) indicate that there were no major changes in the terrestrial and emergent vegetation types during the last twenty odd years. However, a gradual decrease of faunal types have been observed, especially in the number of wild fowl nesting sites.

In the light of the information presented above, it appears that Coote's Paradise is gradually deteriorating in its capacity to function as a wild life sanctuary and as a recreational area.

Section II

METHODS AND MATERIALS

(2.1) Station Locations

In order to obtain water quality data representative of the whole marsh water area, thirteen stations were selected which included the point of discharge of effluent from the Dundas Sewage Plant (which was not assigned a station number). Figure 1 shows the open water area and station locations. Stations 1 through 6 were located in the western end of the marsh and station 7 through 13 in the eastern end. The differentiation between east and west is strictly for convenience. Station 1 was located in the upper end of the Desjardins Canal; station 2 at the entrance to West Pond; stations 3 and 4 in the northern and southern half of West Pond and station 6 about 10 meters east of the mouth of Spencer's Creek where the waters of the creek and those leaving West Pond mix. Station 7 was located in the eastern end of the main open water area at a point where the combined waters of Spencer's Creek and West Pond mixes with that of the main body. Stations 8 and 9 were positioned in the northern half of the main area and 10 to 12 in the southern half. Station 12 was opposite Princess Point and station 10 off

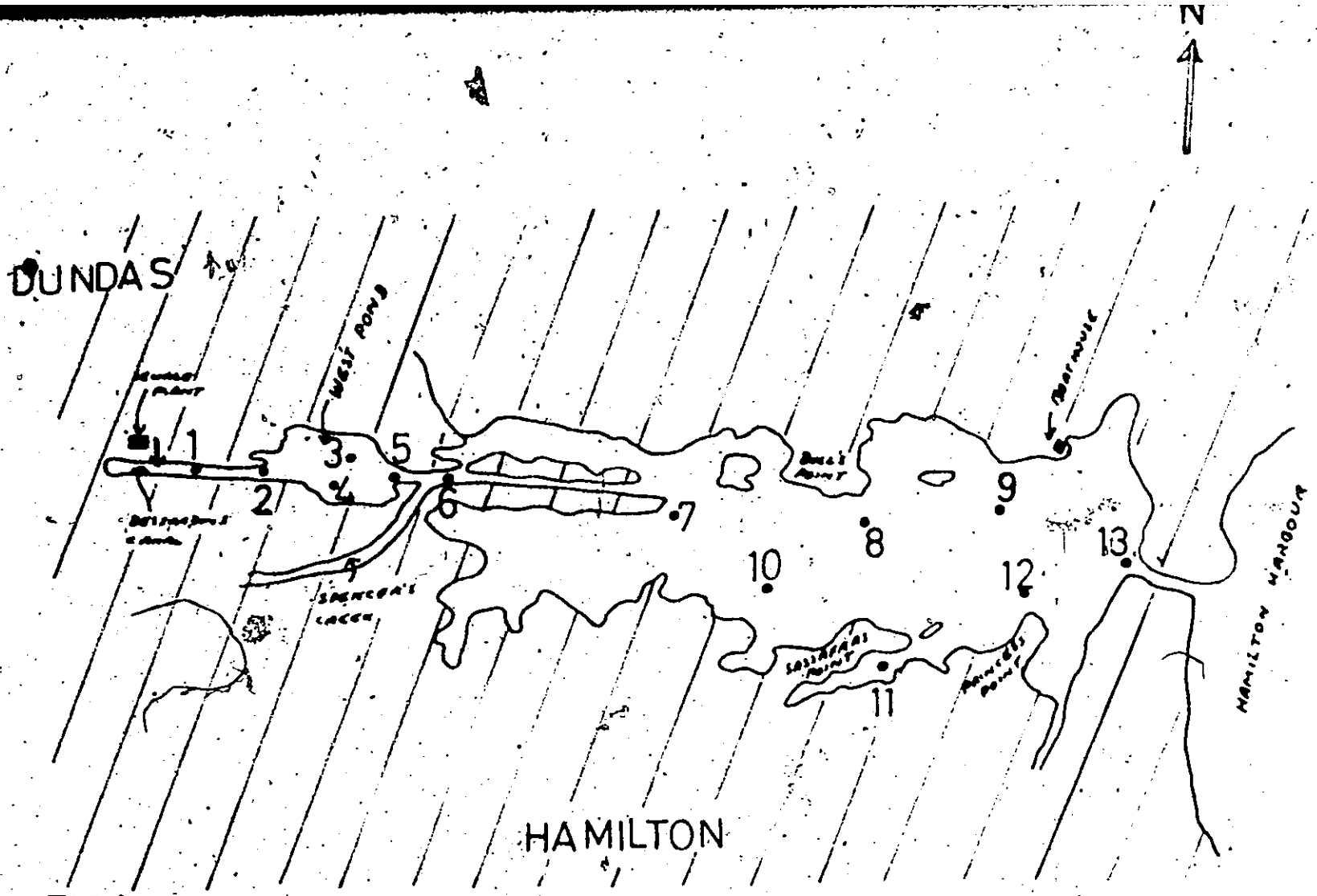


FIG.1

Map of the study area showing the station locations. The arrow (next to station 1) indicates the point of discharge of the sewage effluent into the Desjardins Canal. (1 inch = .5 mile)

Kingfisher's Point. Station 11 was located in the inlet between Princess and Sassafras Points, because of its partial isolation from the effects of wind. Station 13 was positioned about 20 meters west of the channel connecting the marsh with Hamilton Harbour.

(2.2) Sampling Routine

Transportation between stations involved the use of either a 12 foot aluminum canoe or a 12 foot flat bottomed 6-seater aluminum boat both powered by a 1.5 horse-power outboard Johnson Motor. The boats were stored in the McMaster University boathouse. The boathouse is located in the north-east end of the marsh. It took about two hours on the average to sample all stations (depending on weather conditions) and another 30 minutes to dock the boat and return to the University. The University is about 5 miles driving distance from the boathouse.

Most of the sampling was done between 9:30 a.m. and 12:30 p.m. on Mondays and Thursdays of each week. The intensive sampling schedule began on June 14, 1973 and ended on September 6, 1973. Most of the data collected before June 14, 1973 was discarded. A diurnal series of samples was collected at station 12 on August 2, 16 and 30 respectively and at station 11 on August 30. Sampling for the diurnal studies was initiated at 2 a.m. and ended 12 midnight for each day, with a two hour interval between

samples.

After September 6, 1973 sampling was done on a weekly basis for selected stations. The selected stations were regarded as representative. The choice of stations was justified by summer data analysis. No sampling was done during December 1973 because of the adverse conditions presented by ice formation. The routine commenced again on January 15, 1974, and ended on June, 1974. Again only selected stations were sampled. Between January 15 and April 30, 1974, stations 1, 4 and 12 and the sewage effluent were sampled. For the remainder of the study period stations 1, 4, 5, 6, 9, 12 and the sewage effluent were sampled. Data for the whole year was collected for stations 4 (except for December 1973) and station 12 (except for December 1973 and March 1974). No samples were taken during March 1974 for station 12 because of the risk involved in chopping holes through ice which was in the process of breaking up and melting. During periods of "safe" ice cover samples were obtained by chopping holes through the ice with an axe.

(2.3) Description of Variables

The variables included in this study are: Air and water temperatures (°F), secchi depth or transparency (in centimeters), turbidity (Formazin Turbidity Units), hourly wind speeds (m.p.h.), available direct sunlight

hours per day, surface and bottom dissolved oxygen (ppm and %-saturation), inorganic nitrate and ammonia (ppm), total inorganic and particulate PO_4-Phosphate (ppm), chlorophyll a (mg Chl a M^{-3}), and cell numbers (cells per ml). Species identifications were also carried out in conjunction with cell counts. Data for primary productivity and assimilation ratios (mg O_2/m^3/hour and mg O_2/mg Chl a/hr respectively) were obtained from unpublished results of Dr. J. P. Harris whose work was done concurrently with these studies. Wind speed and daily direct sunlight hours data were obtained from the meteorological unit at the Royal Botanical Gardens, Hamilton, Ontario.

(2.4) Methods of Collection, Measurement and Analyses

(2.4.a) Physical Parameters

Temperature data was collected with a six-probe YSI Telethermometer (range 30°F-110° ± 0.25°F). Temperature was recorded in degrees Fahrenheit because the thermistor was calibrated to give readings in °F. Air temperatures were taken at approximately 1 meter above the water surface, and the water temperatures at 5 to 10 cm below the water surface. An average of two readings was recorded. The Tele-Thermometer was sensitive enough to give reliable measurements. During the winter it was impossible to measure air temperatures below 30°F. This inadequacy was partially overcome by using air temperature data collected

by the meterological unit at the Royal Botanical Gardens. The more critical temperature reading desired was that of the water which would never fall below 32°F.

Secchi depth or transparency readings were done with a secchi disc (21 cm diameter) which was weighted and connected to a lowering string marked with 5 cm intervals. Secchi depth readings give a rough measurement of water transparency and serves as a useful index in assessing water quality (Ruttner 1973). Secchi depth has also been used as an index of eutrophication (Winner 1972). The maximum depth of visibility of the disc was obtained by lowering the disc until it was no longer visible on the "shaded" side of the boat, raising it until just visible and taking the average of the two readings. During periods of strong winds and under currents it was difficult to obtain a good secchi value. Waves produced by wind action obliterated a "smooth" water surface. Water currents pulled the disc away from a vertical to an oblique position giving a reading analgous to the hypotenuse of a right angle triangle rather than the vertical. Secchi depths readings are invalid if one can see the bottom of a body of water. This problem arose during the winter at station 4 when it was possible to see the bottom of West Pond. During the periods of ice cover secchi readings are impractical. Despite the problems, the method served its purpose well. The degree of error involved during the calm

weather was ± 1.0 cm and about ± 3 cm during windy conditions. An added advantage is that the secchi depth reading can be used to estimate the compensation depth by multiplying the secchi depth value by 3 (Riley 1941), Winner, (1972), and Sen Gupta (1972) used this approximation for compensation depth estimation. The compensation depth is that depth of a water column at which photosynthesis (assimilation) is equivalent to respiration (Ruttner 1973).

Turbidity data gives an estimate of suspended material in the water and is inversely related to secchi depth. Winner (1972) suggests that turbidity values give a reasonable index of water quality if it can be equated to seston (all suspended particulate matter) content. Turbidity was measured against a scale of 0-100 Formazin Turbidity Units (F.T.U.) ± 2.5 FTU with a Hach Model 2100A Turbidimeter. On a scale of zero to 100 FTU, 1 FTU is approximately equivalent to 1.604 milligrams/litre of particulate (dry wt.) material. The FTU to dry weight conversion was achieved by gravimetric experiments.

Since there was no suitable equipment available to measure hourly wind speed and total number of daily available sunlight hours, data for these variables was supplied by the Royal Botanical Gardens meteorological unit located about 2 miles northwest of the marsh. Wind stress and available sunlight are important in algal studies because they both have some effects on algal photosynthesis

Harris & Lott 1973).

(3.4.1) Chemical Parameters

Dissolved Oxygen

The modified Winkler method described by Strickland and Parsons (1968) was used for dissolved oxygen determinations. The method has a detection limit of 0.005 mg. at O_2/litre and proved itself reliable in this study. The method involved the following steps: after the water sample was collected, it was immediately treated with 2 ml. manganous sulphate solution followed by a 2 ml. alkaline iodide. Manganous hydroxide is precipitated and dispersed throughout the sample. In the presence of oxygen the manganese (II) hydroxide is oxidized to basic hydroxides of higher valency states. The sample was then acidified with concentrated sulphuric acid which, in the presence of iodide, reduces the oxidized manganese back to its divalent state and releases iodine equivalent to the original dissolved oxygen. The iodine was titrated against standard sodium thiosulphate to a colourless end point with 2% starch as an indicator.

Water samples for dissolved oxygen were collected in 300 ml B.O.D. bottles by carefully tilting the mouth and allowing the surface water sample in with minimum bubbling. The sample was treated as described above and then acidified with 2 ml concentrated sulphuric acid in the laboratory.

Titrations were carried out with an automatic 10 ml buret against standard sodium thiosulphate. The thiosulphate solution was standardized on each sampling day with exactly 0.01 N potassium iodide solution. The latter step is necessary to make sure that the thiosulphate is not deteriorating. Two 50 ml aliquots for each sample were titrated and the average recorded if there was a difference not greater than 0.05 ml thiosulphate. If the difference was greater, an average of 3 readings was recorded. Oxygen titrations were done on the same day of sampling. If for any reason the titrations could not be done on the same day, the acidified samples were stored in a refrigerator and titrated the next day (as was the case with the diurnal samples).

Blank determinations were carried out concurrently with the f-factor determination. The f-factor was obtained as follows: Adding the reagents in the reverse order; sulphuric acid, alkaline iodide and manganous sulphate, to distilled water in a BOD bottle. 50 ml aliquots were withdrawn and added to 5 ml 0.01N potassium iodate. The aliquot plus KIO_3 was then titrated against the thiosulphate. The f-factor was the result of the division of the volume of KIO_3 by the volume of thiosulphate. The blank was determined in a similar manner except that no KIO_3 was used. The dissolved oxygen of the sample was computed by the formula: mg at.O_2/ litre = 0.1006 X f X V where V was the volume of thiosulphate required to titrate the 50 ml sample aliquot. Milligram at./

litre dissolved O_2 was converted to mg O_2/l by multiplying by 16 (Strickland and Parsons 1968). Milligram O_2/l or ppm dissolved O_2 was also converted to % O_2 saturation by dividing ppm O_2 by the 100% saturation value of oxygen at the water temperature at which the sample was taken. The latter calculations were carried out with the aid of tables published by the Precision Scientific Company (1966).

The only modification made to the method was using 2 ml of reagents rather than 1 ml. This was necessary because 1 ml of reagents was not enough to tie up all the oxygen in the samples which was more than often greater than 8 ppm - the upper range for the Strickland & Parsons (1968) method. The modified Winkler method for oxygen determinations is widely used in fresh and marine water analyses. The main disadvantage encountered by using this method involved sampling during windy conditions. The presence of waves made it very difficult to obtain samples without some air bubbles occurring in the water while flowing into the B.O.D. bottle. Since a surface sample was desired this problem could not be overcome.

Total Inorganic Phosphorous - (PO_4^{3-}-P) and Particulate Phosphorous

The role of phosphorous in aquatic systems is intensively studied by limnologists (Hutchinson 1957, Haertel 1972, Winner 1972, Takahashi & Nash 1973). Methods for analysis vary whether orthophosphate, total inorganic phosphate,

colloidal, soluble organic, particulate or other forms of phosphorous need to be detected. The generally accepted idea is that soluble inorganic phosphate represents the most readily utilized source for phytoplankton (Hutchinson 1973, Perman & Moses 1972, Fitzgerald 1971). Phosphorous determinations in this study involved analysis for total inorganic phosphate. Analyses for acid digestable particulate phosphorous were also done. Particulate phosphorous was expressed as ppm inorganic phosphate.

The Autoanalyser

The method used is that recommended by Technicon Internation Systems Corp. #93-70W (1971), for the Technicon Autoanalyser II. The analyser automatically samples specific aliquots of previously filtered field water samples and mixes them with fixed volumes of reagents. The sampling rate can be set between 30 to 60 samples per hour. After mixing with reagents each sample develops a colour whose intensity is a function of the concentration of the chemical species in question (PO_4-P). The coloured solution is next pumped across the path of a light source of specific wave length (660 nm) in a colourimeter. The amount of light absorbed or transmitted by the coloured sample is a function of the concentration of the dye in the sample. The concentration of the chemical species is printed out by a digital printer and a peak is simultaneously described by a chart recorder. All of the above

steps are continuous and the autoanalyser needs only intermittent checks. Samples are separated from each other in the continuous flow system by air bubbles introduced before and during reagent mixing.

Phosphorous Analyses

The range of total inorganic phosphorous analysed by the Technicon method was 0.0 to 10.0 ppm with a minimum detection of 0.2 ppm. This range proved to be satisfactory for the waters of Coote's Paradise during the preliminary survey period. Before each run the machine was standardized with various concentrations of standard phosphate solutions. Samples were filtered on the day of collection with GF/C glass fiber filter paper and stored in 10 ml screw cap glass vials. A 2 ml volume of each sample was transferred to disposable type sample cuvettes arranged in a circle in the sample holder of the autoanalyser. To further decrease contamination between samples a double distilled water blank was placed between each pair of samples. This method of preparation was used for the phosphorous analysis of the filtrates from each station.

Preparation of the samples for particulate phosphorous analyses was as follows: A known volume of sample water containing both phytoplankton and other sestonic material was filtered and the filter paper (GF/C type) was collected. The latter was dried in a dessicator overnight

and acid digested the following day by a method recommended by W. Blythe (Canada Centre for Inland Waters, Burlington, Ontario). Each filter was digested until about 0.5 ml of material remained. The 0.5 ml was diluted back to 100 ml with distilled water and filtered into clean conical flasks. The samples were then run through the autoanalyser and the concentrations were recorded.

The chemical reactions which produce the coloured complex between the sample and reagents are as follows: the sample is first treated with 7.9 N sulphuric acid and heated by a temperature bath at 90°C in the manifold of the autoanalyser. The acidification treatment hydrolyses all condensed phosphates to orthophosphates. The orthophosphates are then complexed by acidic ammonium molybdate reagent into phosphomolybdic acid. The latter is then reduced to a molybdenum blue complex by reaction with ascorbic acid reagent. A wavelength of 660 nm is used in the colourimeter. The reagents are introduced into the flow system in the order described above. Subsequent peak generation on a chart recorder and print out from a digital printer of the sample concentration has already been described.

When sample concentration fell below 0.05 ppm a zero was recorded. If, on the other hand, the sample concentration exceeded 10 ppm the original sample was diluted and reanalysed. The major problem encountered in the use of the autoanalyser was that the whole complex of parts required

frequent cleaning and servicing. Before and after each run the system was flushed with 7.9 N sulphuric acid followed by at least 500 ml double distilled water. Sample cups were disposable and never reused. If samples had to be stored they were treated with a drop of 30% sulphuric acid and stored in a refrigerator until the next day. Pickling and storage did not affect the actual phosphorous values had the analyses been done the same day. However, samples stored for longer periods had values which were quite variable when compared to the actual concentrations. This variation may be caused by the acid used as a preservative. When samples are preserved under acidic conditions, polyphosphate to orthophosphate transformations occur (Allen & Kramer 1972).

Nitrate + Nitrite Nitrogen and Ammonia Nitrogen

Analysis for Nitrate/Nitrite and Ammonia could not be carried out during the summer because of insufficient time. A 10 ml filtered aliquot sample for each station was preserved with a drop of chloroform and stored at 4°C (Golterman 1971). The chloroform prevents oxidation by microorganisms and refrigeration introduces a second safety factor. Analyses were carried out in the late summer. It was possible to do about 100 samples per day using the Technicon Autoanalyser II method recommended by Technicon International Corp., (method #100-70W, January 1971). The mechanics of the method was similar for that described for

total inorganic phosphorous except for a different manifold system, wavelength and reagents. The Autoanalyser was not used for ammonia analyses because a manifold for that special flow system was unavailable. The method for ammonia determinations will be discussed below.

The working concentration range for the Technicon method for nitrate plus nitrite analyses was 0.0 to 2.0 ppm with an acceptable detection limit of 0.04 ppm. Values below 0.01 ppm were recorded as zero. Samples which exceeded the range were diluted and analysed again. The sampling rate was 40 samples per hour and double distilled water blanks were alternated with the samples. The colourimeter wavelength was 630 nm.

The chemical reaction involves the following steps: the sample is first passed through a copper-cadium reactor column which reduces all nitrate to nitrite. The nitrite ion then reacts with sulfananilimide reagent under acidic conditions (phosphoric acid) to form a diazo compound. The diazo compound is next coupled with N-I-Napthylethylenediamine dihydrochloride reagent to form a reddish-purple dye. The intensity of the colour is a function of the nitrite concentration. Positive interactions or interferences can occur in the presence of divalent metallic ions such as mercury or cadmium. These ions form coloured complexes (with the reagents) which have similar absorbtion bands in the region of colour measurement. Since no analyses were done

for metallic ions it is not known what the likely effects were.

Before each run the system was flushed with double distilled water for one hour and the column was activated with standard nitrate reagent. Prepared standards were run before the samples were determined to check accuracy and to standardize the machine. If the system was kept clean and connections were secure it ran very well. Delays occurred when pressure in the system was too high and flow pattern of reagents was unsteady. Most of the time this problem was caused by oxidized and dirty copper-cadmium filings. On the average, more time was spent watching the autoanalyser compared to when phosphorous analyses were done. After September 1973, samples preserved for nitrate analyses were not kept longer than one month.

Another problem with the nitrate + nitrite method was the preparation of the copper-cadmium reductor column. The Technicon method recommends the use of powdered cadmium but this was not available. Cadmium was prepared by filing cadmium sticks to the desired texture. The filings were washed several times with 5% copper sulphate solution and doubled distilled water to remove collodial copper. The filings were washed with diethyl ether before copper sulphate treatment to remove grease and dirt. The clean filings were introduced into a U-shaped capillary glass tubing with the aid of a Pasteur Pipet. The column prepared in the

above manner was good to reduce at least 500 samples.

Ammonia

Ammonia analyses were carried out using the method of Hardwood and Kuhn (1970). Samples for ammonia analyses collected after September 1973, were all done on the same day whereas those for the summer were done in September 1973. The same preservation method for nitrate was used for ammonia.

The chemistry of the method consists basically of reacting a sample containing ammonia with phenate and hypochlorite. In the presence of sodium nitroprusside catalyst colour development proceeds very rapidly at room temperature to give a blue coloured complex. The intensity of the colour is a function of the ammonia concentration. The colour is stable for more than one hour. Standards ranging from 15 to 0.3 ppm were prepared with ammonium chloride. 2 ml of 5% (w/v) trisodium phosphate buffer were added to 1 ml of each standard and the volume made up to 10 ml with distilled water. 5 ml of reagent A (prepared from 15 ml of phenol stock plus 0.02 gm sodium nitroprusside made up to 100 ml) and 2.5 ml reagent B (prepared from 15 ml commercial bleach + 15 ml 27% NaOH diluted to 50 ml) were added with shaking. The volume of each standard was made up to 25 ml with distilled water and left for 25 minutes for colour development. Samples and a blank were prepared

in the same way.

After colour development the extinction of each standard and samples was measured against the blank at 630 nm in 1/2" glass cells with a Bausch and Lomb Spectronic 20 Spectrophotometer. A standard curve was prepared and the concentrations of the unknowns were calculated from the standard curve using a Compucorp 340 Statistician Calculator. When a 1 ml sample was used the sensitivity was good only to the 2.0 ppm level. When samples fell below 2.0 ppm they were done once more using a 3 or 4 ml volume instead of 1 ml. This increased the sensitivity and the true concentration was obtained by dividing the answer by the number of ml used. By increasing the volume, ammonia values as low as 0.5 ppm can be detected.

(2.4.c) Biological Parameters

Cell Counts and Identification

Cell counts and an estimate of species abundance were calculated for stations 4 and 12. 60 ml aliquots were transferred from the thoroughly agitated 2 liter sample bottles to 60 ml screw cap poly-bottles. Each sample was fixed with Lugol's solution. Lugol's solution was recommended by Dr. M. Munawar, taxonomist at the Canada Centre for Inland Waters in Burlington, Ontario as the best preservative for phytoplankton. Munawar and Nauwerck (1971), Lund et al.

[illegible], Moss (1972), and Kiefer (1973) used Lugol's solution in their phytoplankton studies. Other workers used formalin (Patten 1962), iodine (Tett 1973), or a combination of water, ethyl alcohol and formalin (Cairns et al. 1968).

Samples were prepared for counting and identification by transferring a 1 ml aliquot from the stock bottle to a 10 ml Utermohl type sedimentation chamber. The chamber is designed for use with an inverted microscope. In these studies a Zeiss inverted microscope equipped with phase contrast was used. The 1 ml aliquots used for summer and early fall samples were diluted to 10 ml. A settling time of at least 6 hours was allowed before counting. Lund et al. (1959) recommends a minimum settling time of 3 hours for a 10 ml sample. During winter and early spring (1974) a full 10 ml aliquot of the sample was necessary to obtain enough cells. At no time was concentration of the cells necessary. Other workers (Patten 1962, Tett 1973, Sager and Hasler 1969) working with smaller cell numbers had to concentrate cells. The presence of large amounts of clay type particles and other particulate material made it difficult to work with station 12 samples.

Sager and Hasler (1969) estimated cell counts by counting 30 randomly chosen fields. In this study 40 fields were counted for the summer and fall populations and at least 100 random fields for the winter and early spring populations. The total cell count (cells/ml) was estimated by taking the

cell average of the number of fields counted and multiplying it by 19,290. The latter number represents the number of times the "floor" area of the counting chamber is greater than the area of the field enclosed by the objective lens. A magnification of 750 x was used (x40 objective, x15 eyepiece, and x1.25 body magnification).

According to Lund et al. (1959) an accuracy of ± 20% is achieved if 100 cells are counted. If the number of cells ranged between 400 to 1,600 the accuracy increases to between 10 and 5% respectively. Using Lund's figures the estimated accuracy for the summer and fall populations was at least ± 10% with most falling in the ± 7% range. During the winter, the accuracy was at least ± 20% for both stations 4 and 12. During early spring the accuracy of counts for station 4 ranged between ± 7 to ± 10%, while for station 12 the accuracy of counts was ± 20%.

Species identification were attemped with the aid of various manuals and texts (Whitford and Schumacher 1969, Prescott 1970a, 1970b, Palmer 1969, Patrick 1959 and Drouet 1959). In all cases, it was possible to identify at least to the generic level. It may be quite possible that the identifications reported gave only a rough estimate of the richness per sample. This suggestion is supported by virtue of the fact that Patrick (1963) recommends that at least 7000 cells be counted to obtain a reliable picture of species richness. Patrick (1963) states that 200 to 500 cells

would only give a small percentage of species present. However, Lowe (1972) in an exhaustive study of diatom populations dynamics in a central Iowa ditch, counted only 400 valves for species identification. If Lowe's data is realistic, then the identifications done in this study may also be realistic because cells counted averaged about 500 per sample. However, the main object of cell identification in this report was to get a fairly accurate picture of the abundance of the major algal groups.

Chlorophyll a

Chlorophyll a data was obtained by using the method described by Strickland and Parsons (1968). No correction was made for pheophytin. Approximately 2 liter volumes of surface water was collected from each station by lowering the two liter bottle about 30 cm below the water surface, raising it up gradually and making sweeping movements in various directions below and at the surface. The object of this technique was to get a mixed vertical and horizontal sample. The bottles were stored in a light-proof styrofoam box and returned to the laboratory within two and a half hours. Phytoplankton were collected by filtering known volumes and collecting the filter paper. Millipore filters and GF/C glass fiber filter paper were used.

Preliminary analyses during May and early June 1973 indicated that less than one liter of water had to be

filtered to obtain enough cells for extraction of the pigment. Filtration was done often enough to allow the colour of the filter paper to serve as a useful guide in determining how much water need be filtered. Not more than 100 ml and 200 ml were required for the west and east end stations respectively. At certain times, as little as 25 ml were filtered for stations 2, 3, 4 and 5. During the autumn, winter and early spring the volume required was as much as one liter.

During the period prior to June 14th it was very difficult to extract all the chlorophyll from the samples because a tissue grinder was not used. Larger volumes of solvent were tried but this only partially solved the problem. The filters were also cut up into very small pieces and this increased the extraction. This method only extracted between 70-80% of the pigment. In general, the larger the volume filtered the greater was the error. It was not until the end of June that a manual test-tube type tissue grinder was used. Since data collected after June 14, 1973 was used in this thesis corrections had to be made to the chlorophyll data for the latter half of June. This was achieved by using both methods of extraction and calculating the error involved for several samples. A correction factor was then applied to the late June values. Tripicate extractions were also done with the grinding method for each station during September 1973 to determine standard errors. The average error for the west end stations was

± 4.55% and 4.06% for the east end stations.

The actual method of extraction of chlorophyll a involved the following steps: after filtration the filter paper was folded with the algae on the inside and stored in plastic vials in a freezer. Within half an hour the filter paper was ground up in a 10 ml tissue grinder in a few ml of 90% acetone. The filter was cut up into small pieces and was ground up for about 4 to 5 minutes until a green suspension was formed. The resulting suspension was transferred to a 15 ml graduated centrifuge tube and the volume made up to 10 ml with 90% acetone. The tube was sealed with a cork bung, vigourously shaken and stored in the freezer for at least 2 hours. After storage the sample was removed, 2 ml 90% acetone were added, sealed with Parafilm wax and centrifuged at 7000 rpm for 5 to 7 minutes. The clear supernatant was transferred to 5 ml, 5 cm path length quartz cuvettes.

The extinction for each sample was measured against a 90% blank acetone solution at 750, 663, 645 and 630 nm respectively with a Zeiss PMQ II spectrophotometer. The extinction value obtained at 750 nm was subtracted from those at the other wave lengths to correct for any turbidity not attributable to pigments. An acetone blank was also run against each wave length as a precautionary check against the reagent.

Chlorophyll a calculations were done with the aid of the SCOR UNESCO FORMULA: (Strickland and Parsons 1968)

$$11.64E_{663} - 2.16E_{645} + 0.10\ E_{630}$$

where E is the extinction value at the wavelengths indicated by the subscripts. This formula expresses chlorophyll a as mg Chla/m^3. The chlorophyll a value obtained by use of the formula is divided by the volume of the sample filtered in liters to arrive at the true answer. This step is necessary because the formula assumes that a 1 liter sample was filtered. The method recommended by Strickland and Parsons (1968) has a detection limit of 0.02 mg Chla/m^3.

If it was not possible to determine chlorophyll on the same day, the ground up extract (or the filter paper) was stored in the freezer overnight and the analysis continued the next day. Samples were never stored for periods longer than 16 hours. Digested samples stored longer than 36 hours experienced pigment deterioration.

Section III

RESULTS AND DISCUSSION

(3.1) Seasonal and Weekly Variations of Physical, Chemical and Biological Parameters

Freshwater and marine aquatic systems in temperate regions of the world characteristically exhibit marked seasonal trends of physical, chemical, and biological parameters (Rhode 1953, Sverdrup 1953, Hulburt 1964, Round 1971, and Ruttner 1973). The waters of Coote's Paradise are no exception to the generally accepted trend. This section will be devoted to an interpretation of the observed weekly and seasonal variations between June 1973 and May 1974 in Coote's Paradise. Chlorophyll a will be referred to as chlorophyll in the body of the discussion.

(3.1.a) Station 1 and the Sewage Effluent

Figure 2 shows the biomass (chlorophyll) and dissolved oxygen plots during the summer of 1973, and the winter and spring of 1974. Biomass showed pronounced fluctuations during the summer, averaging 450 mg Chl/M^3 (Table 1). The overall picture was a high summer (450 mg Chl/M^3), low winter, (average of 26.5 mg Chl/M^3), and an increasing spring (average of 83 mg Chl/M^3) chlorophyll concentration. This seasonal trend of chlorophyll variation

SUMMER, FALL, WINTER AND SPRING VARIABLE COMPARISONS FOR STATIONS 1, 4 AND 12.

	STATION 1				STATION 4				STATION 12			
VARIABLE	Su	F	W	Sp	Su	F	W	Sp	Su	F	W	Sp
NITRATE ppm	1.58	NO	6.39	3.38	0.36	0.76	4.04	1.73	0.51	1.15	3.75	1.13
AMMONIA ppm	7.40	SAMPLES	10.49	8.79	0.14	17.39	8.42	1.87	0.11	0.90	1.17	1.15
TOT:NIT ppm (NO_2+NO_3+NH_4)	8.98		16.88	12.17	0.57	18.15	12.46	3.60	0.62	2.05	4.82	2.28
Chla mgM^{-3}	450.0		26.55	83.0	695.0	231	21.01	155.7	196.1	66.1	2.04	58.74
% SAT. O_2	86.2		66.6	60.4	253.4	97.1	77.3	138.5	117.7	89.6	81.75	108.11
PO_4^{-3}-P sol. ppm	11.26		5.07	7.82	2.26	7.17	4.70	1.87	0.15	0.14	0.52	0.63
TEMP. °F	76.2		45.66	53.0	78.06	52.54	36.8	54.5	76.95	51.72	32.44	54.15
TURBIDITY F.T.U.	25.2		23.16	11.1	27.00	19.40	18.9	17.5	41.12	60.66	11.61	35.33
N/P RATIO	0.14		1.25	0.43	0.05	0.10	0.86	0.925	3.40	8.21	7.21	1.80
CELLS/ml					3.6×10^5	1.4×10^5	$.045 \times 10^5$	0.982×10^5	2.19×10^5	0.178×10^5	$.0096 \times 10^5$	0.264×10^5
SECCHI cm	27.9			68	17	30	45	30	17	25		26

TABLE 1

is well documented for aquatic systems (Hutchinson 1957, Round 1971, and Ruttner 1973).

The summer chlorophyll average of 450 mg/M³ can be compared with 64 mg/M³ in highly eutrophic Gaynor Lake, Colorado (Winner 1972), 67 mg/M³ in polluted prairee lakes in South Dakota (Haertel 1972), 100 to 300 mg/M³ in tropical Lake George, South Africa (Viner 1973), and 300 mg/M³ in 'hypereutrophic' Moses Lake, Washington, U.S.A. (Bush and Welch 1972). The winter chlorophyll average of 26.5 mg/M³ was higher than the 7 mg Chl/M³ yearly average for mesotrophic Lake Ontario (Glooschenko et al. 1972a); and was comparable to 32 mg Chl/M³ for the polluted western basin of Lake Erie during the summer (Glooschenko et al.,1974a), and 38 mg Chl/M³ in highly polluted Saginaw in Lake Huron (Glooschenko et al. 1973). Vollenweider (1969) reported that a range of 1 to 20 mg Chl/M³ was the normal range expected to occur in temperate freshwater lakes. The above comparisons clearly indicate that the waters of station 1 are highly eutrophic.

Figure 2 shows that during the summer, peaks of chlorophyll were usually followed by low dissolved oxygen concentrations. The low oxygen values may have been the result of high biological and chemical oxygen demand created by organic material in the sediment, dead algal cells, and incompletely decomposed organic material in the effluent. In addition, it can be expected that the frequent, large blooms of duckweed (Lemna sp.) which covered the entire

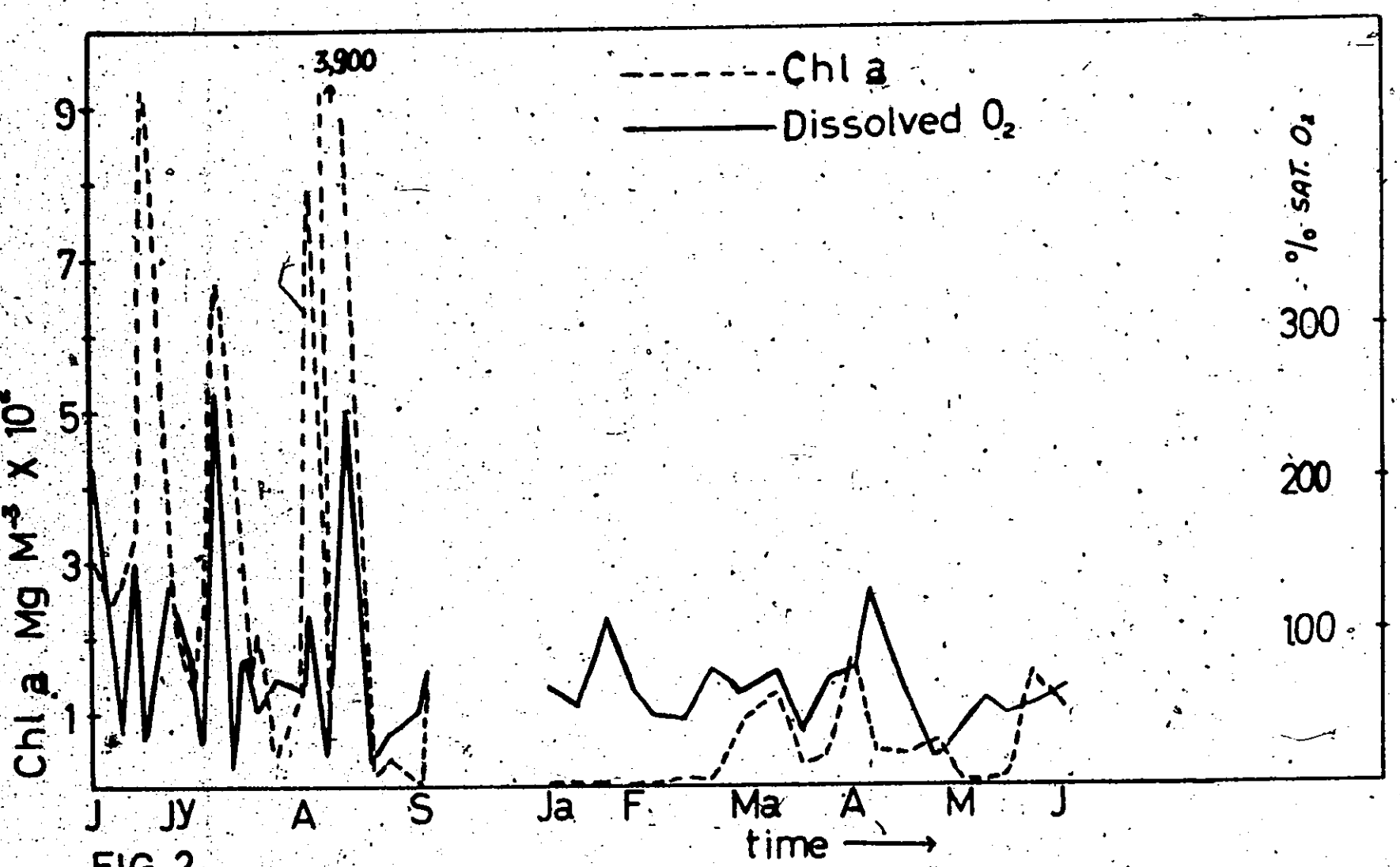


FIG. 2

Chlorophyll a and Dissolved Oxygen fluctuations at station 1 between June 14, 1973 and May 31,1974. No samples for Oct., Nov., and Dec., 1973.

surface of the canal contributed large amounts of organic material to the sediment when they (duckweed) died.

The sharp decreases in chlorophyll frequently coincided with the times when there was an extensive mat of duckweed covering the water surface. The mat of duckweed effectively shaded the phytoplankton from the potentially available solar radiation required for photosynthesis. In a sense, the algae suffered from 'light starvation' and could not maintain a high cell concentration. There were times, however, when chlorophyll was low in the absence of duckweed. At these times, oxygen was also lower than normal and a bad odour prevailed. The probable causes for the low oxygen values were discussed above. It may have been possible that decomposing activities produced chemicals which were toxic to the algae, thus causing a lower chlorophyll concentration. It was also possible that the frequent large blooms of algae produced substances which inhibited their own cellular activities. Some authors (Hutchinson 1957, Fogg 1969, and Macan 1970) agree that this self-inhibiting phenomonon is one of the many causal factors affecting algal periodicity.

Figure 3 a. shows the summer distribution of soluble inorganic phosphate at station 1. Soluble inorganic phosphate averaged 5.45 ppm in the sewage effluent and 11.26 ppm in the waters of station 1. Station 1 was located some distance from the point of discharge of the sewage effluent. Since the sewage plant was identified to

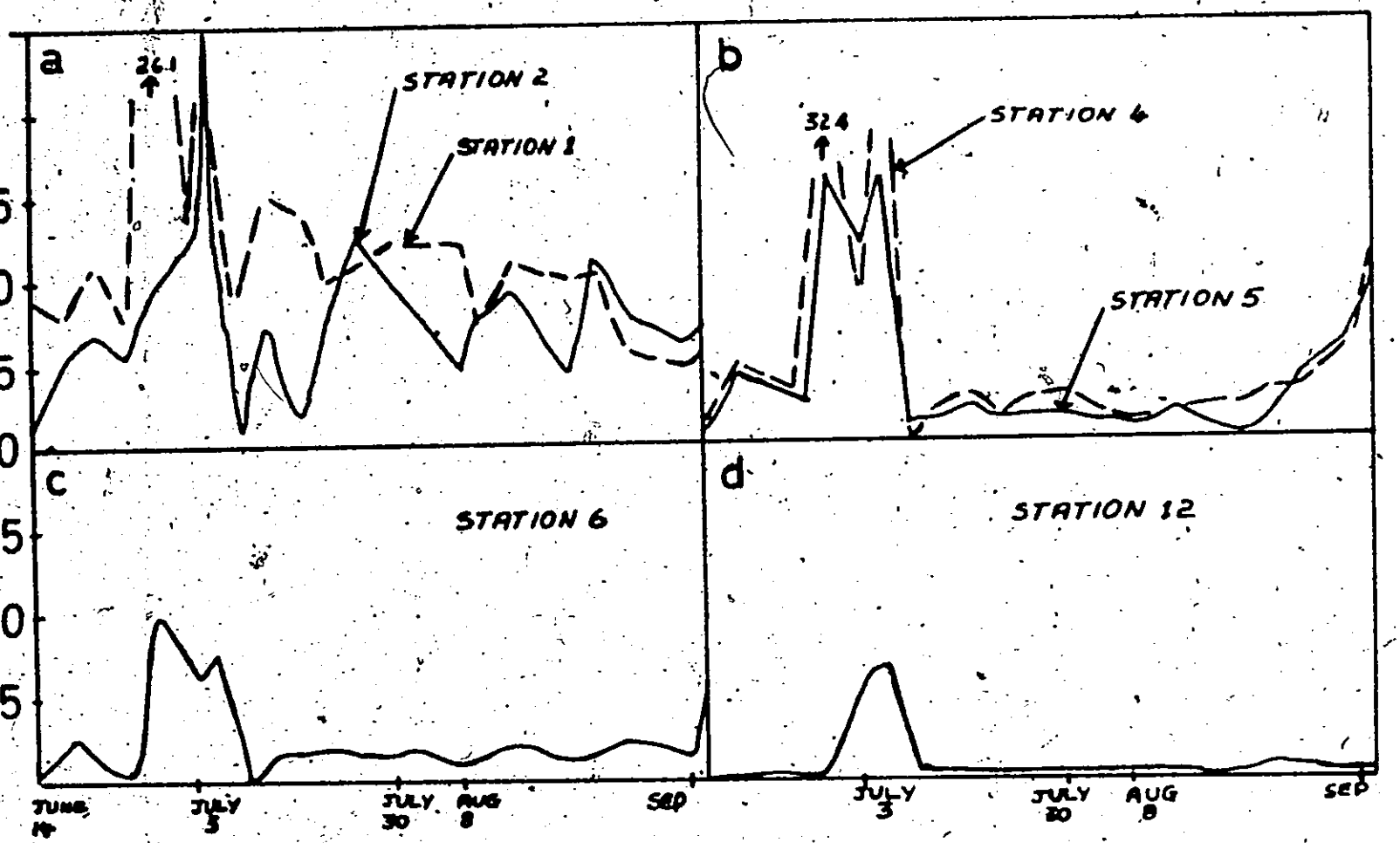


FIG. 3 A comparsion of soluble inorganic phosphate variations during the summer of 1973, at stations 1,2 4,6 and 12.

to the major source of nutrients to the canal, then the higher phosphate in the canal needed some explanation. Harris and Bacchus (1974), suggested that the higher phosphate levels in the canal may have been attributable to phosphorous mining in the sediments of the canal. Phosphorous mining has been demonstrated by Mortimer (1941), Harter (1968), and Austin and Lee (1973). Others, (Foree et al. 1971, and Li et al. 1972) have provided a theory for phosphorous mining based on experiments done in some Wisconsin lakes. Phosphorous can be precipated as a ferric phosphate gel in the presence of oxygen (Li et al. 1972). However, in the absence of oxygen (under anoxic conditions), the oxidized phosphate is reduced to soluble ferrous phosphate which is released to the overlying water. On many occasions during the summer, surface dissolved oxygen values ranged between 14 to 19% saturation (1.1 to 1.7 ppm). It is therefore, not difficult to envisage anoxic conditions in the sediments of the canal, which would contribute to the higher levels of soluble inorganic phosphate.

Inorganic phosphate values were lower in the winter and early spring than in the summer. This can be explained in terms of the absence of the phosphorous mining phenomenon observed in the summer when temperatures were higher. The fact that oxygen never experienced the low values measured during the summer makes it clear that sufficient oxygen was present to keep the phosphate level

down. On February 2, 1974 the inorganic phosphate measured 0.13 ppm. On the same day the level was 0.1 ppm in the sewage effluent. This low value was due to a phosphorous removal alum experiment undertaken by an engineering research group from McMaster University at the Dundas Sewage Plant.

During the spring of 1974, the occurrence of floods diluted inorganic phosphate on two occasions to 3.8 and 4.3 ppm respectively, compared to a spring average of 7.82 ppm. As the temperatures and biomass increased in April, 1974 inorganic phosphate levels increased to values as high as 11.2, 10.1, 12.0 and 13.8 ppm. On these particular days the surface dissolved oxygen was low and averaged between 2 to 4 ppm (= 2.3 to 48% SAT) compared to a range of 6.2 to 13.62 ppm (= 65-128% SAT) for the month of March. The late spring data indicated that phosphorous mining was beginning to occur more frequently.

On the whole nitrate and ammonia were lower in the summer than in the winter and spring. This is a reflection of the lower winter biomass exercising a decreased requirement for nutrients. Nutrient build up in the winter and spring is a phenomenon well documented for temperate fresh water lakes (Hutchinson 1957, Round 1971, and Ruttner 1973). During the summer an interesting sequence of events involving nutrient conversions in the canal and their effects on biomass at stations 3 and 4 in West Pond was observed.

Analysis of the ammonia at station 1 showed fluctuations (Figure 4) which occurred approximatley every two weeks. When the ammonia fluctuations were compared to the seasonal changes of nitrate and dissolved oxygen the following interpretration was possible - when ammonia concentration was high (15 to 30 ppm), and oxygen concentrations were below saturation, nitrate concentrations were low. (June 18, June 25, July 26 and 30; and August 20, 1973). Conversely, when oxygen was above 100% saturation or close to saturation, ammonia values were low and nitrate concentration were greater than 2 ppm (June 18 and 25, July 26 and 30, and August 20, 1973). The 2 ppm nitrate was larger than the summer average of 1.58 ppm. It is clear from these observations that there was biological conversion of ammonia to nitrate (nitrification). As the analysis was for $NO_2^- + NO_3^-$, it is not known how the total is partitioned. Most of it could be nitrate nitrogen because oxygen was always measurable and nitrite represents an intermediate product in the autotrophic nitrification of ammonia via the reaction:

$$2O_2 + NH_4^+ \rightarrow NO_3^- + H_2O + 2H^+$$ (Keeney 1972).

Nitrification of ammonia to nitrite by Nitrosomonas and nitrite to nitrate by Nitrobacter (both members of the Nitrobacteriaceae) was reported by Quastel and Sholefield (1951), Russell (1968) and Keeney (1972). There were times, however, when oxygen was above saturation (July 3 and August 9) or near saturation (July 23) and both ammonia and nitrate

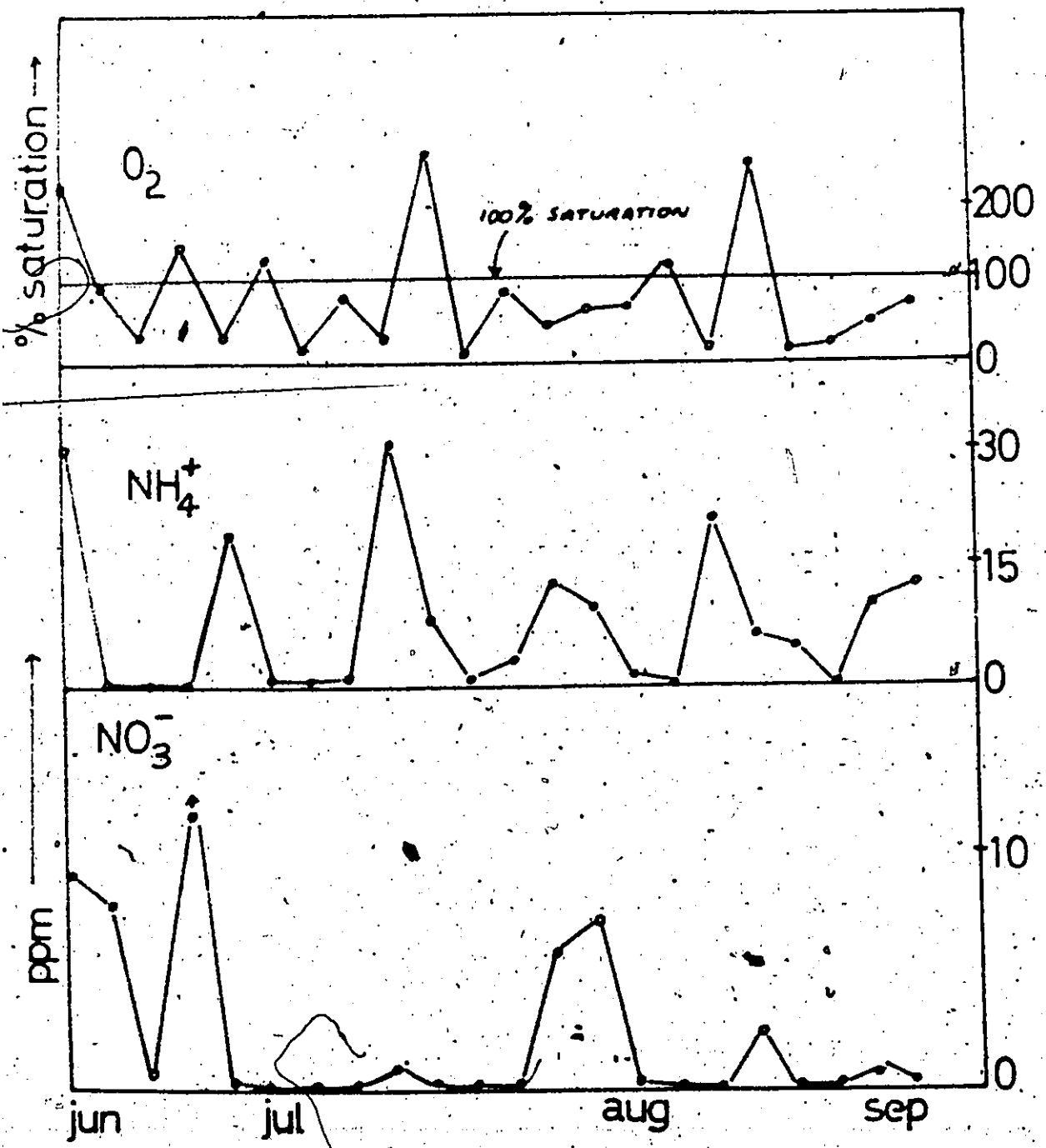


FIG.4 (See text)

concentrations were low. These events are undoubtedly correlated to the periodic output of ammonia in the sewage effluent. Kuznetsov (1968) reported that anaerobic microorganisms (in an anoxic environment) can more efficiently utilize nitrogen rather than carbon as an energy source. Just how much ammonification can be accomplished by anaerobes in the canal is not known. It is certain however, that periodic ammonia output by the plant (as high as 16 ppm) contributes this nutrient for nitrification. It will be shown when station 4 is discussed that the oxygen, ammonia and nitrate conversions in the canal affects the biomass in West Pond.

During the winter at station 1 an inverse correlation ($P = 0.05$) between nitrate and ammonia was observed (Table 2, fig. 5) and the same for the sewage effluent ($P = 0.001$). There was also a positive correlation ($P = 0.01$) between the ammonia in the effluent and the canal. This latter correlation supports the above case that the sewage plant contributes ammonia to the canal.

Table 1 shows the comparison of the other variables at station 1 for the summer 1973, winter and spring of 1974. Note the variation of the nitrogen to phosphorous (N/P) ratios. Because most authors (Ryther and Dunstan 1971 and Halmann 1972) suggest C:N:P ratio of 106:16:1 based on the approximate formula $C_{106}H_{263}O_{110}N_{16}P_1$ for protoplasm (Halmann 1972), the N/P ratio serves as a useful index in P or N limitation

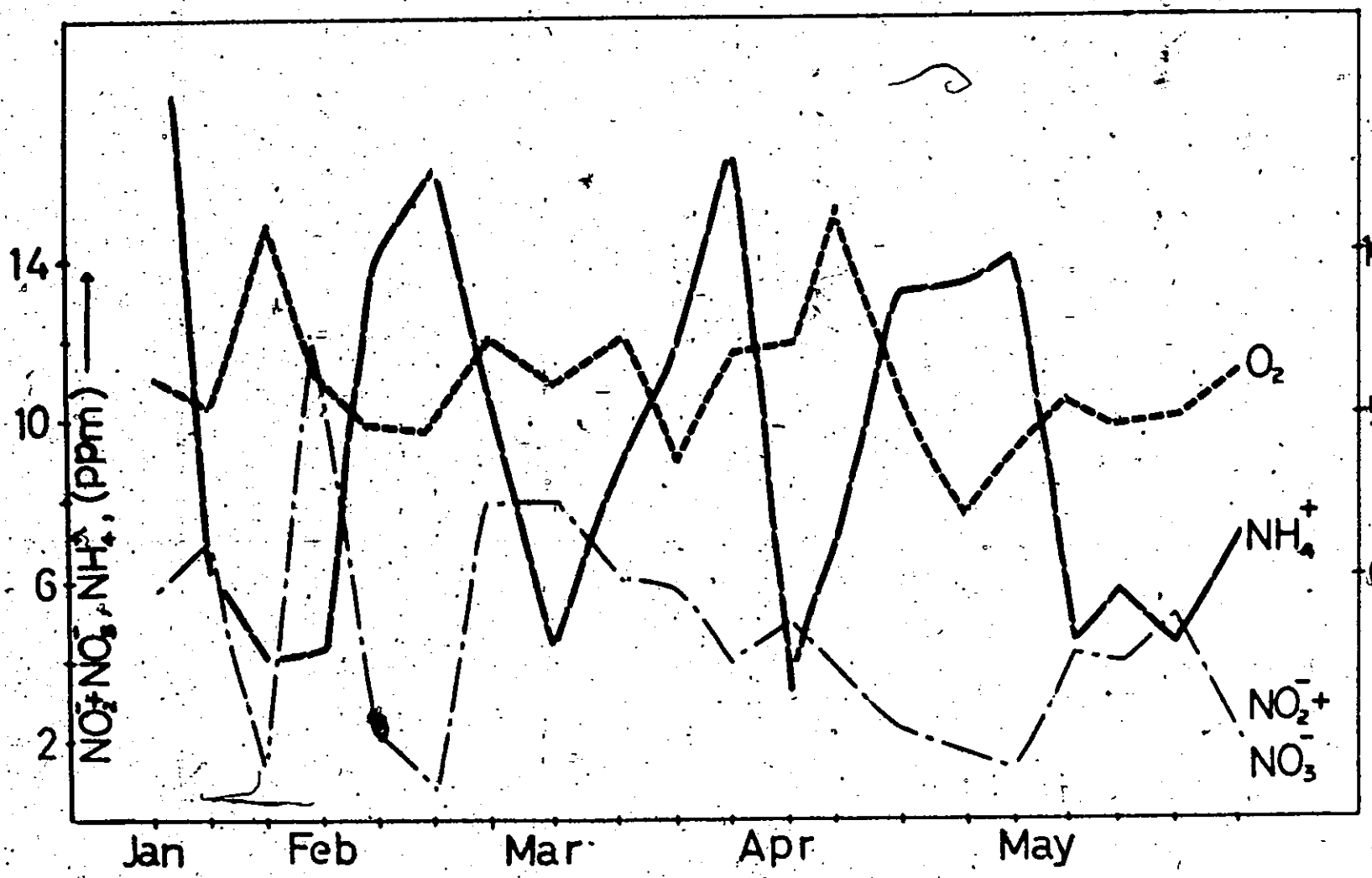


FIG. 5 Diagram showing the relationship between nitrate + nitrite Nitrogen, ammonia Nitrogen, and dissolved oxygen at station 1, during the winter and spring of 1974.

TABLE 2

STATION	VARIABLES	DEGREES OF FREEDOM	SEASON	CORRELATION	PROBABILITY
1	NH_4^+ and NO_3^-	9-1	WINTER	-0.600	0.05
EFFLUENT	"	10-1	"	-0.851	0.001
EFFLUENT and STATION 1	NH_4^+ and NH_4^+	10-1	"	+0.755	0.01
4	NH_4^+ and NO_3^-	17-1	OCT - MARCH	-0.494	0.05
4	NH_4^+ and O_2	15-1	"	-0.510	0.05
4	NO_3^- and O_2	15-1	"	+0.290	N.S.
4	Temp. and Chl a	18-1	JAN - MAY	+0.907	0.001
4	Temp. and Cell No.	19-1	"	+0 903	0.001
4	Chla and Cell No.	19-1	"	+0.99	0.001

studies. The significance of the N/P ratio will be discussed more fully when station 4 is considered.

On none of the sampling days during the winter was the water temperature near freezing (32°F) at station 1. The higher than expected water temperature of 45.6°F was a direct consequence of the warm sewage effluent which averaged about 48°F. When the average chlorophyll for the summer, winter and spring are compared to the respective seasonal average temperatures it is clear that temperature had some effect on the biomass periodicity (Table 1). A further discussion of temperature effects will be presented later in the station 4 section.

Secchi depth or transparency during the winter was not valid because the water was clear enough to see the bottom. During the spring the average secchi depth was 68 cm. This is quite transparent when compared to the summer average of 28.00 cm. The seasonal difference of secchi depths was a function of the biomass and turbidity (Table 1). Even though transparency was greater during the winter a large biomass could not be supported because of the limiting effects of lower temperatures and shorter day lengths (Ruttner 1973). To fully appreciate the significance of the secchi depth some comparisons with other water bodies will be made. Ruttner (1973) gives the following secchi depths values for four Wisconsin lakes, Crystal lake, Trout lake, Helmet lake and Mud lake had

transparencies of 13.5 m, 5.9 m, 1.9 m and 1.5 m respectively. The yearly average of station 1 was about 0.49 m - about three times less transparent than Mud lake.

(3.1.b) Station 2

Station 2 (fig. 1) is located at the entrance to West Pond. Figure 6 shows the distribution of chlorophyll and dissolved oxygen at station 2 between June 14 and October 4, 1973. No samples were taken for the winter and spring of 1974. Average chlorophyll for the summer of 1973 (June to September 6) was 456 mg/M³. This compares to 450 mg Chl/M³ for station 1. Chlorophyll fluctuations were much less pronounced than at station 1, falling only once below 100 mg/M³ on July 30. The periodicity may partly be explained by the mixing of station 2 waters with water from the canal and West Pond depending on changes in wind speed and direction. The effect of wind was easily observed by following the drifting of duckweed (Lemna sp.) which was frequently abundant. Other factors such as light availability, temperature, nutrient status, and competitive interactions may also affect chlorophyll fluctuations, but these were difficult to identify. Biomass showed a significant decrease after September 6 as fall approached. The average chlorophyll value for early fall was 65 mg/M³.

Dissolved oxygen showed a similar relationship to biomass as for station 1 - i.e. oxygen lows following or

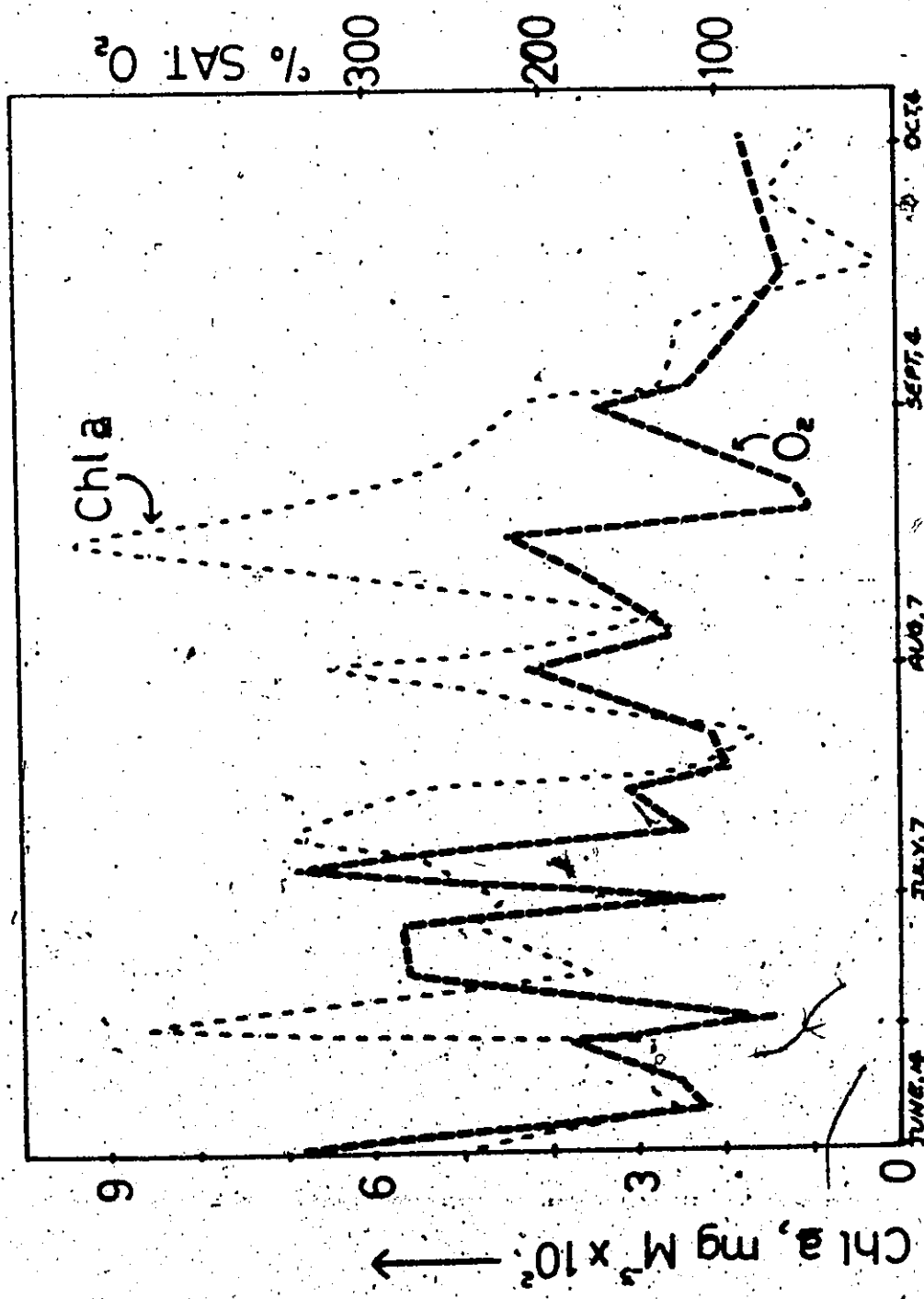


FIG.6 Diagram showing Chlorophyll a and Dissolved Oxygen fluctuations between June 14 and Oct. 4, 1973, at station 2.

coinciding with biomass peaks. Between June and the first week of September oxygen fell below the 100% saturation value five times, the lowest being = 50% saturation. The highest oxygen values recorded were 340 and 346% saturation. This was the result of an overall high photosynthetic activity of the constant large crop of algal cells. The large summer biomass average of 450 mg Chl/M^3 qualifies the waters of station 2 to be highly eutrophic. According to Keeney (1972) the nutrient status (0.89 ppm NO_3^- and 7.83 ppm PO_4^{3-}) of station 2 certainly gives it polytrophic status. As a result, one would not expect such high dissolved oxygen concentrations. Archibald (1972), reported dissolved oxygen figure of 64.41% saturation for a heavily polluted river which had a similar nutrient status to station 2. Despite the pressure of a presumably high biological oxygen demand (for respiration and decomposition) the photosynthetic activity produces more oxygen than is needed for the B.O.D. (biological oxygen demand) much of which was removed upstream at station 1. Of course, dissolved oxygen might be considerably below 100% saturation during the night. However, no samples were taken after daylight to prove that this was the case.

A significant inverse relationship existed between ammonia and dissolved oxygen concentrations ($r = -0.488$, $n = 26-1$, $P = 0.01$), during the period June, 1973 to October 4, 1973. This phenomonon (also identified at station 1)

was probably the result of the nitrification of ammonia. The station 2 data did not clearly show the occurrence of high nitrate concentrations coinciding with low ammonia and high dissolved oxygen concentrations. Nitrate concentrations were always below 2.00 ppm, and frequently fell below 0.5 ppm. It is possible that the algae preferred nitrate as a nitrogen source and quickly used up this nutrient when it is produced in large quantities by the nitrification process. This latter suggestion can be supported by the fact that during the last week of August and the whole of September 1973, ammonia concentrations were consistently greater than 8.00 ppm. Nitrate values continued to remain low (as during the summer which had an average of 0.89 ppm) and dissolved oxygen concentrations were frequently below the 100% saturation level. During this period, biomass was still high (a range of 99.00 to 750 mg Chl/M^3) and the ammonia concentrations did not show any appreciable decreases.

Total inorganic soluble phosphate averaged 7.73 ppm during the summer. Figure 3 c. shows the summer phosphate fluctuations at station 2. Compared to station 1 (figure 3 c) the values are lower. Although the biomass was about the same as station 1, the lower phosphate levels at station 2 probably reflects more precipitation of insoluble ferric phosphate due to the higher average dissolved oxygen concentration than at station 1 (in additon to uptake by biomass).

From the last week of August to the first week of October the secchi depth showed a steady increase from [illegible] cm (August 27) to 75 cm (October 4). This was a result of the decreasing biomass as fall approached. Inversely, the turbidity showed a consistent decrease during the same period falling from 17 F.T.U. to 6.0 F.T.U. Other non-living particulate material may also have contributed to the observed secchi and turbidity variations. However, it was quite obvious that the large algal crop was the primary contributor.

(3.1.c) Stations 3 and 4

Stations 3 and 4 were respectively located in the south west and north east areas of West Pond (figure 1). Both of these stations showed indentical fluctuations in chemistry and biomass during the summer. This part of the discussion, therefore will concentrate on station 4 which was sampled for a 12 month period (June 1973 - May 1974) except in December 1973 when unfavpurable weather conditions made sampling difficult. Station 4 will be considered as typical of West Pond as a whole. The first part of this section will deal with the variations of biomass, nutrients and physical parameters and how they relate in a general sense as the seasons progressed. A more thorough discussion involving all variable interactions which might contribute to the weekly variations of biomass in West Pond between

June and October 1973 will follow.

Seasonal Progression of Chlorophyll and Changing Light/Temperature Effects

Figure 7 shows the plot of the seasonal variations of chlorophyll (mg/M^3) between June 14, 1973 and May 31, 1974 in West Pond. Distinct chlorophyll trends were observed in the summer, fall, winter and spring. Table 1 gives the average chlorophyll values for the four seasons. The summer period averaged 695 mg/M^3, and the fall, winter and spring were 231, 21.01 and 155.7 mg Chl/M^3 respectively. The overall picture presented by West Pond was of a large and persistent summer bloom which decreased as fall and winter approached. As spring approached a smaller bloom was evident. There was also a small, weak winter pulse. In view of the two major blooms described, the 12 month plot can be regarded as an exception to the generally accepted phenomenon of spring and fall blooms which occur in natural oligotrophic freshwater lakes (Hutchinson 1957 and Round 1971). Edmondson (1969), reported a similar chlorophyll pattern in polluted Lake Washington. It is important to note that Lake Washington experienced a similar nutrient supply (contributed from sewage effluent) and eutrophication problem as West Pond. One might wonder if the seasonal chlorophyll pattern observed in West Pond is typical of eutrophic waters which are continuously supplied with

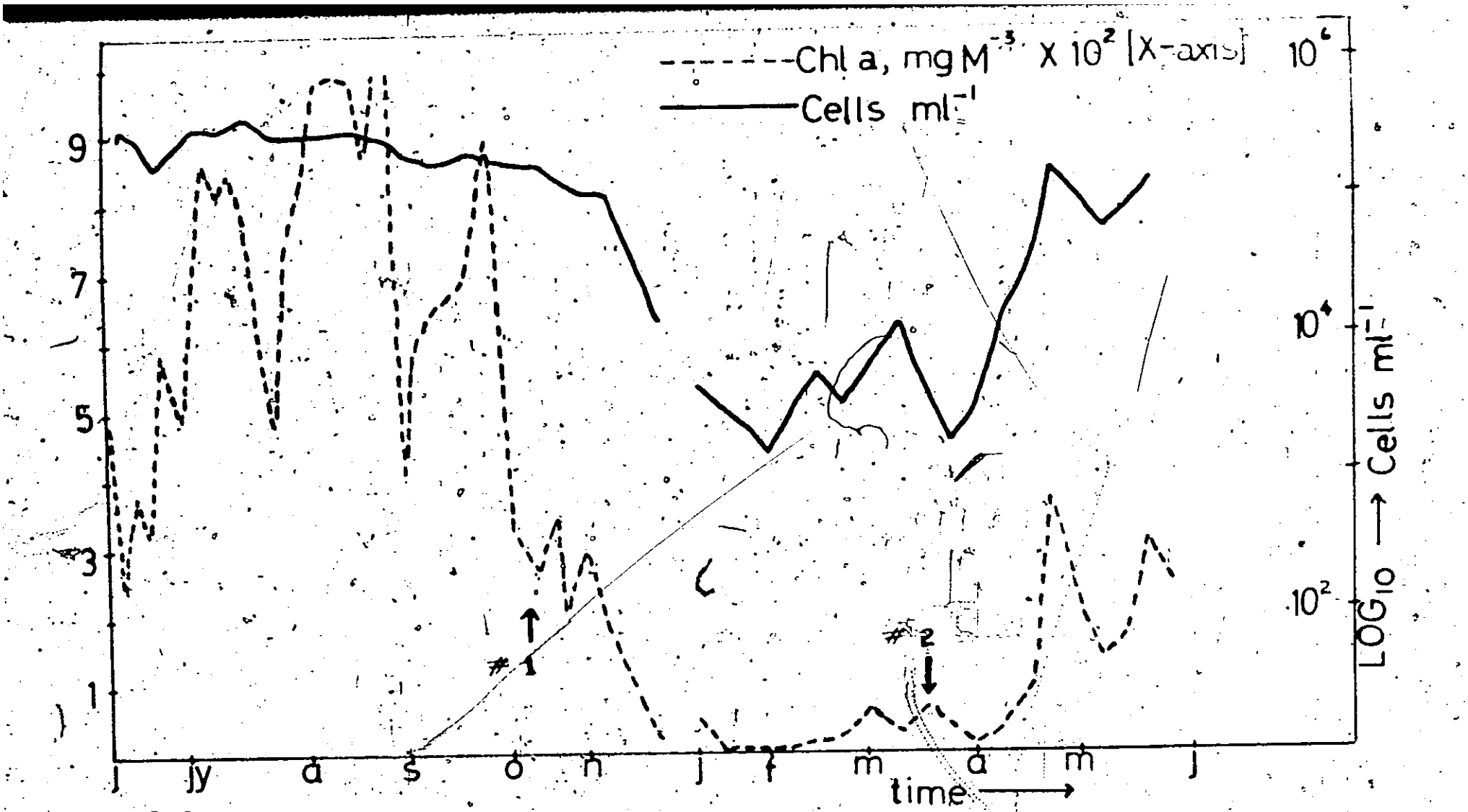


FIG. 7

A comparsion between cell concentration ($\log_{10}$) and chlorophyll a at station 4 (West Pond), between June 14, 1973 and May 31, 1974.

sewage effluent. A similar chlorophyll pattern was observed in the polluted western basin of Lake Erie which also receives sewage effluent (Glooschenko et al. 1974). This further supports the above suggestion that waters which are contaminated with sewage effluent experience a characteristic prolonged summer phytoplankton bloom.

Round (1971) attempted to explain the seasonal phytoplankton blooms or pulses by describing shock or cardinal points which occur immediately after or before a bloom. The cardinal points have been identified to occur at times when the light/temperature regimes or nutrients status changed drastically. Ruttner (1973) defined the cardinal points as the environmental conditions necessary for maximum or minimum physiological activity. The two light/temperature cardinal points described by Round (1971) occur during the March/April (spring) and the September/October (fall) transition periods. These points may be identified by the position of arrows #1 and 2 in figure 7. Arrow #1 represented the time period when daylengths (light duration) and temperatures were falling. The temperature changes which occurred at this time were 73°F (September 27, Chl = 888 mg/M³), 67.8°F (October 4, chlorophyll = 318 mg/M³) and 55°F (October 20, Chl = 271 mg/M³). The temperature drop was 18°F (figure 8). As the temperature continued to decrease the biomass followed suit to a fall

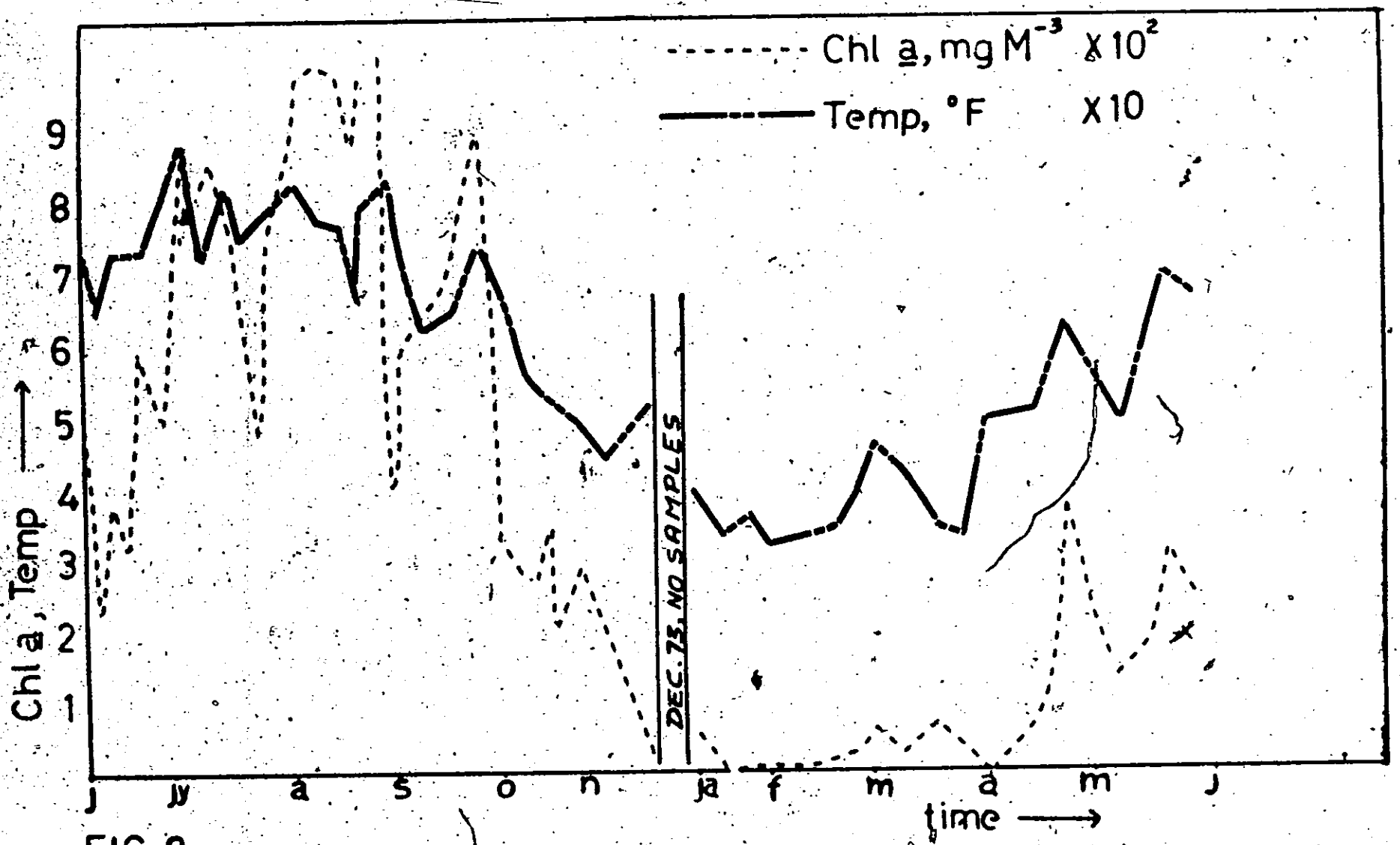


FIG. 8 Seasonal variations of chlorophyll and temperature at station 4 between June 14, 1973 and May 31, 1974.

low of 18 mg Chl/M³ (temperature = 50°F). Figure 7 also shows a plot of the annual variations of cell concentrations (cells/ml; $\log_{10}$ scale). Note the corresponding decrease in cell numbers during the same period.

It was difficult to interpret the effects of shorter daylengths on algal biomass. However, an indirect interpretation was possible. Data supplied by the Royal Botanical Gardens in Hamilton gave average values of the number of direct sunlight hours available on a daily basis during the fall transition period. The average figures for the months of September, October, and November were 6.62, 4.71, and 2.36 hours of sunlight per day respectively.

The decreasing number of daily hours of sunlight as fall approached meant that photosynthesis did not occur for the extended time periods which occurred during the summer when available sun light hours averaged 8.9 per day. The limiting effect of the extent, duration, and quality of light is a phenomenon well documented for algal photosynthesis (Delvin 1969, Goldman 1969 and Round 1971). The effect of temperature has been similarly demonstrated (Goldman 1969, Ruttner 1973 and Takashashi and Nash 1973).

The cardinal point identified by arrow #2 during the March/April transition period represented conditions when the average daily sunlight hours and temperatures were increasing. The average temperatures for the last two weeks of March 1974 was 34°F compared to 49.7°F for the first three weeks of April. Between March 29 and April 4

the temperature increased by 16.3°F (fig. 8). The average daily direct sunlight hours for March and April were 3.1 and 6.2 respectively. These figures showed a marked transition which occurred when the spring blooms of algae commenced. The situation here was opposite to that observed during the September/October transition period. Again, Round's cardinal point was identified and explainable in terms of the changing light/temperature regime.

A further observation was made during the winter and spring regarding the relationship between chlorophyll, cell concentration, and temperature variations. Figure 9 shows the plots of chlorophyll, cell numbers per ml, and temperature, between January 15 and May 31, 1974 in West Pond. The graph clearly shows that changes in biomass and cell numbers definitely followed temperature changes in time. Positive and significant correlations (Table 2) were calculated between temperature and chlorophyll ($r = 0.907$, $p = 0.001$) and temperature with cell numbers per ml ($r = 0.903$, $p = 0.001$). These correlations demonstrated the strong influence of temperature on biomass variations during the winter and spring.

(ii) Nitrate, Ammonia, Phosphate and Chlorophyll

Some interpretation of the seasonal variations in nutrient status and how they relate to biomass will now be presented.

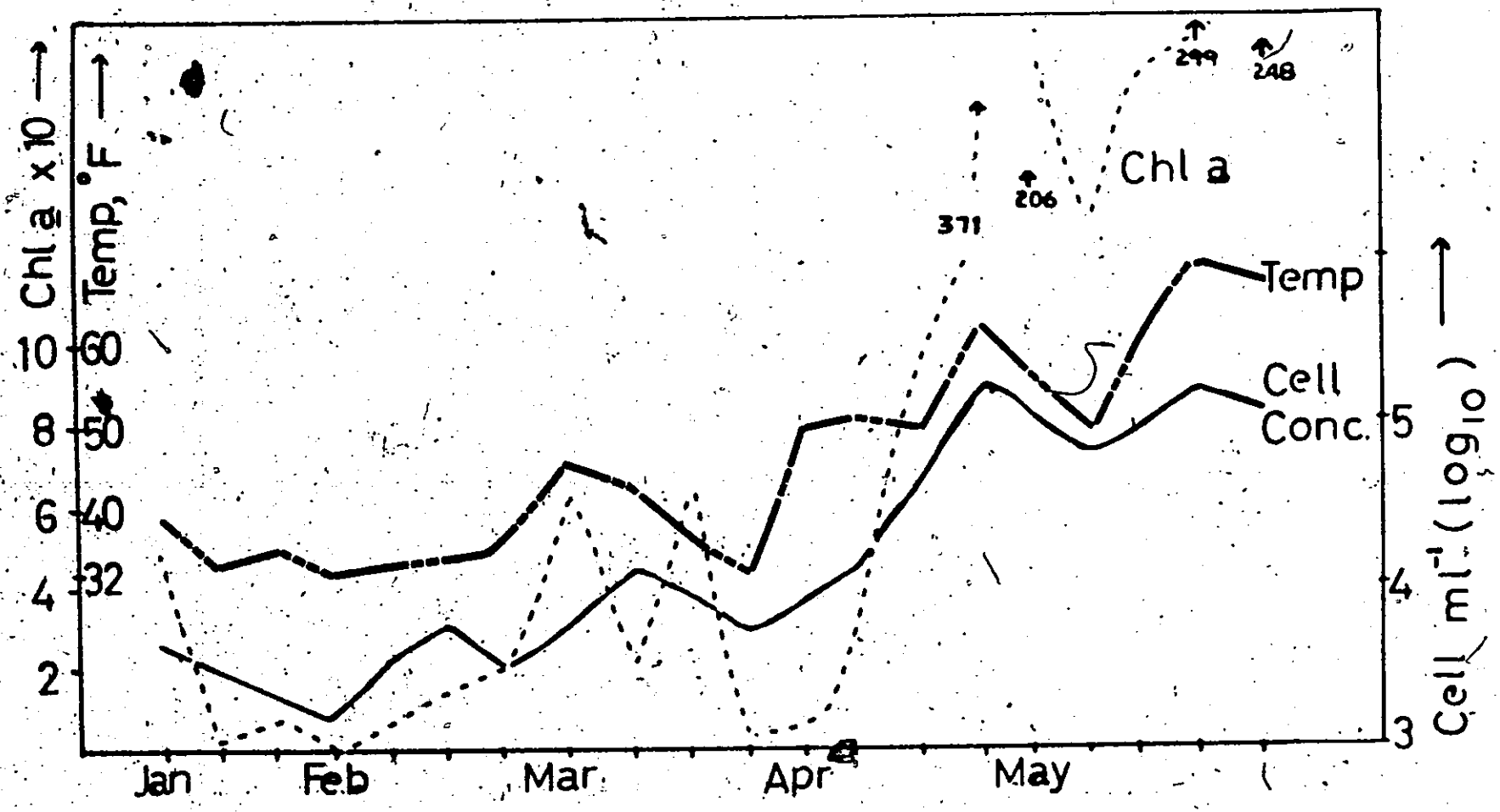


FIG.9. Graph showing the distinct relationship between temperature, cell concentration, and chlorophyll during the winter and spring of 1974, at station 4.

Table 1 gives the seasonal averages of nitrate + nitrite N, ammonia N, and total soluble inorganic phosphate. The figures show that the nutrient status during the summer and spring were lower than in the fall and winter. This was a direct result of the overall higher summer and spring biomass exercising a greater demand of the ambient nutrient supplies. The converse was true for the winter and fall when biomass was low due to lower temperatures and shorter daylengths. The strong effect of temperature on biomass was already stressed. Nutrient buildup during the colder months of the year when biological activity is at a minimum is the normal situation for freshwater lakes (Brown 1971, Ruttner 1973 and Takahashi and Nash 1973).

Figures 10 and 11 show the seasonal variations of the various nutrients in West Pond. One would expect that nutrient supplies might have been exhausted during the summer due to the extended summer algal bloom (226 to 1318 mg Chl /M^3). It must be emphasized that biomass recorded as chlorophyll in West Pond were higher than any reported for a temperate freshwater body. The station 1 discussion gave comparable chlorophyll figures reported for other highly eutrophic freshwater lakes. Table 1 shows that biomass at station 1 was lower than at station 4. Nutrients could not be exhausted in West Pond during the summer because, (1) the sewage plant always provided a constant supply (8.87 ppm nitrate, 5.95 ppm ammonia and 5.5 ppm

phosphate), (2) there was phosphorous mining and nitrification in the canal, and (3) phosphorous mining and nitrification were also identified in West Pond (will be discussed later).

(iii) Oxygen, Chlorophyll and Production

Dissolved oxygen concentrations averaged 253.4% saturation during the summer, decreased to below 100% during the fall and winter and increased to a 138.5% saturation in the spring of 1974. The dissolved oxygen trend closely followed the chlorophyll changes as the seasons progressed (figure 10). The high average summer dissolved oxygen concentrations were a direct result of the intense photosynthetic activity of the unusually large crop of algal cells. On a per cell basis the oxygen production may not be any higher than algal cells in other freshwater systems (but see below). But the combined effect of many photosynthetic cells closely packed together per unit volume of water supersaturates the water volume. The cell population ranged between 200,000 to 500,000 cells per ml (average of 3.5×10^9 cells per liter) during the summer. The cell concentration was very high when compared to other temperate freshwater lakes. For example Nalewajko (1966) reported a summer cell number range of 598 to 2,646 cells/ml for Lake Ontario.

The supersaturated dissolved oxygen levels may be explained in terms of primary production (rate of oxygen evolution or production per unit volume of water per hour,

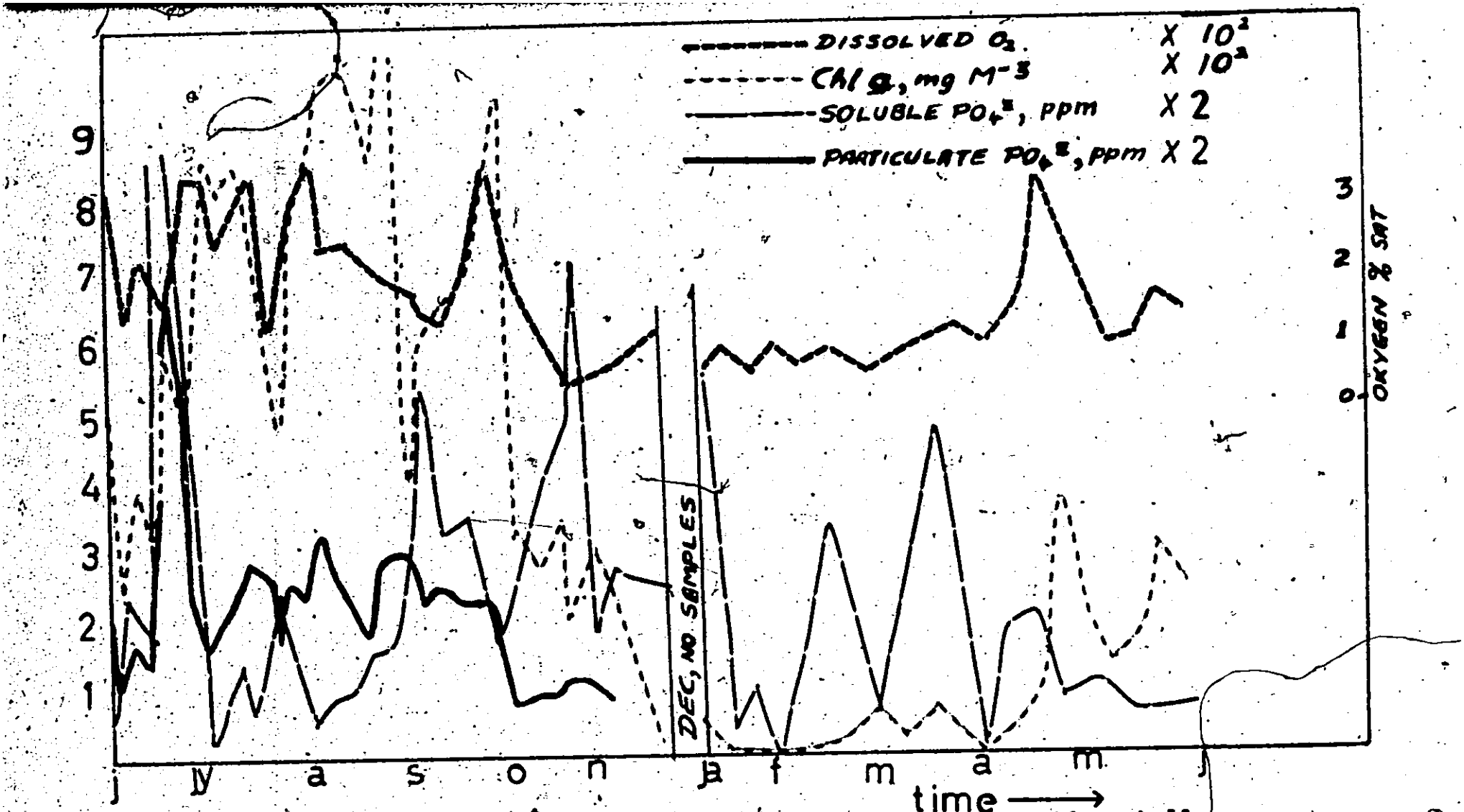


FIG.10 Graph showing the annual periodicity of dissolved oxygen, chlorophyll, soluble inorganic phosphate, and particulate phosphate at station 4, between June 14,1973 and May 31, 1974. (see text for discussion)

mg oxygen/m³/h), or in terms of assimilation ratios (rate of oxygen produced per unit wt. of chlorophyll per hour, mg O_2/mg Chl/h. For purposes of comparison to West Pond the figures quoted will be converted to rates of oxygen production. The conversion is based on the assumption that the ratio of O_2 evolved to carbon fixed is close to unity (Parsons and Takahashi 1973).

Data for primary production and assimilation ratios were obtained from research results carried out in West Pond by Harris and Bacchus (1974, in press) during the summer of 1973. The data calculations revealed an average primary production figure of 1.65 g $O_2/m^3/h$ with a high of 3.17 g $O_2/m^3/h$. These figures are very high when compared to 0.48 g $O_2/m^3/h$ for polluted Lake Erie (Glooschenko et al. 1974b), 0.296 g $O_2/m^3/h$ for eutrophic Lake Cochrane, South Dakota, (Haertel 1972), 0.266 g $O_2/m^3/h$ for polluted Gaynor Lake in Colorado (Winner 1972), 0.26 g $O_2/m^3/h$ for Lake Ontario (Glooschenko et al. 1974b), 0.16 g $O_2/m^3/h$ reported by Hutchinson (1973), 0.05 g $O_2/m^3/h$ for polluted Saginaw Bay in Lake Huron (Glooschenko et al. 1973) and 0.013 g $O_2/m^3/h$ in Lake Michigan (Schelske and Stoermer 1971).

The assimilation ratios for West Pond averaged 2.37 mg O_2/mg Chl/h with a maximum of 4.56 mg O_2/mg Chl/h. These values are also high when compared to a maximum of 4.0 mg O_2 per mg Chl/h during fertilization experiments in Great Central Lake, B.C. by Takashashi and Nash (1973). Assimilation

ratios of 1.2 to 1.6 mg O_2/mg Chl/h were reported for Lake Ontario (Glooschenko et al. 1974b) and 3.0 mg O_2/mg Chl/h for Lake Huron (Glooschenko et al. 1973). The production figures reported here may also be underestimated because the incubation times were too long. The formation of large numbers of oxygen bubbles immediately after incubation of the B.O.D. bottles made it impossible to fix all of the dissolved oxygen produced by photosynthesis. This was an added source of error which could have caused an underestimation of the actual production figures. However, the very high values reported here are what would be expected in such a highly eutrophic water body as West Pond.

iv) Weekly Biomass Fluctuations and Associated Physio-Chemical Interactions. June - October 1973

It was mentioned earlier, that West Pond supported a prolonged and persistent summer crop of phytoplankton which never fell below 200 mg Chl/M^3. However, biomass fluctuations did occur above this minimum level. A closer examination of the West Pond's data revealed what appeared to be a very complex set of interactions involving several variables which may account for the biomass variations. The interactions involved the following 11 variables; available sunlight hours, water temperature, secchi depth, turbidity, chlorophyll, dissolved oxygen, particulate

phosphorous, soluble phosphorous, nitrate + nitrite nitrogen, ammonia nitrogen and wind speed. It was also discovered that the nitrate-oxygen - ammonia conversions observed in the Desjardins Canal at station 1 affected biomass in West Pond. A case for possible nitrate limitation will be built on the basis of the nitrification process discussed for station 1 and how it affected biomass in West Pond. The phenomenon of luxury consumption of phosphorous will also be discussed. Discussion of nitrification and possible luxury consumption of phosphorous are necessary before an interpretation of the eleven variable interactions is attempted.

Nitrate Limitation

Figure 11 identifies biomass pulses which occurred in West Pond between three to seven days after nitrification occurred in the canal at station 1 (refer to fig. 4 for the nitrate-oxygen-ammonia conversion graph). Figure 11 indicates the nitrate levels at station 1 before nitrification and the biomass at station 4 at the same time in West Pond. The graph also shows the biomass pulses which occurred after nitrification (three to seven days) and the nitrate concentrations (after nitrification) which preceeded the biomass pulses. The biomass pulses suggested that nitrate nitrogen may have been limiting algal activity during the summer.

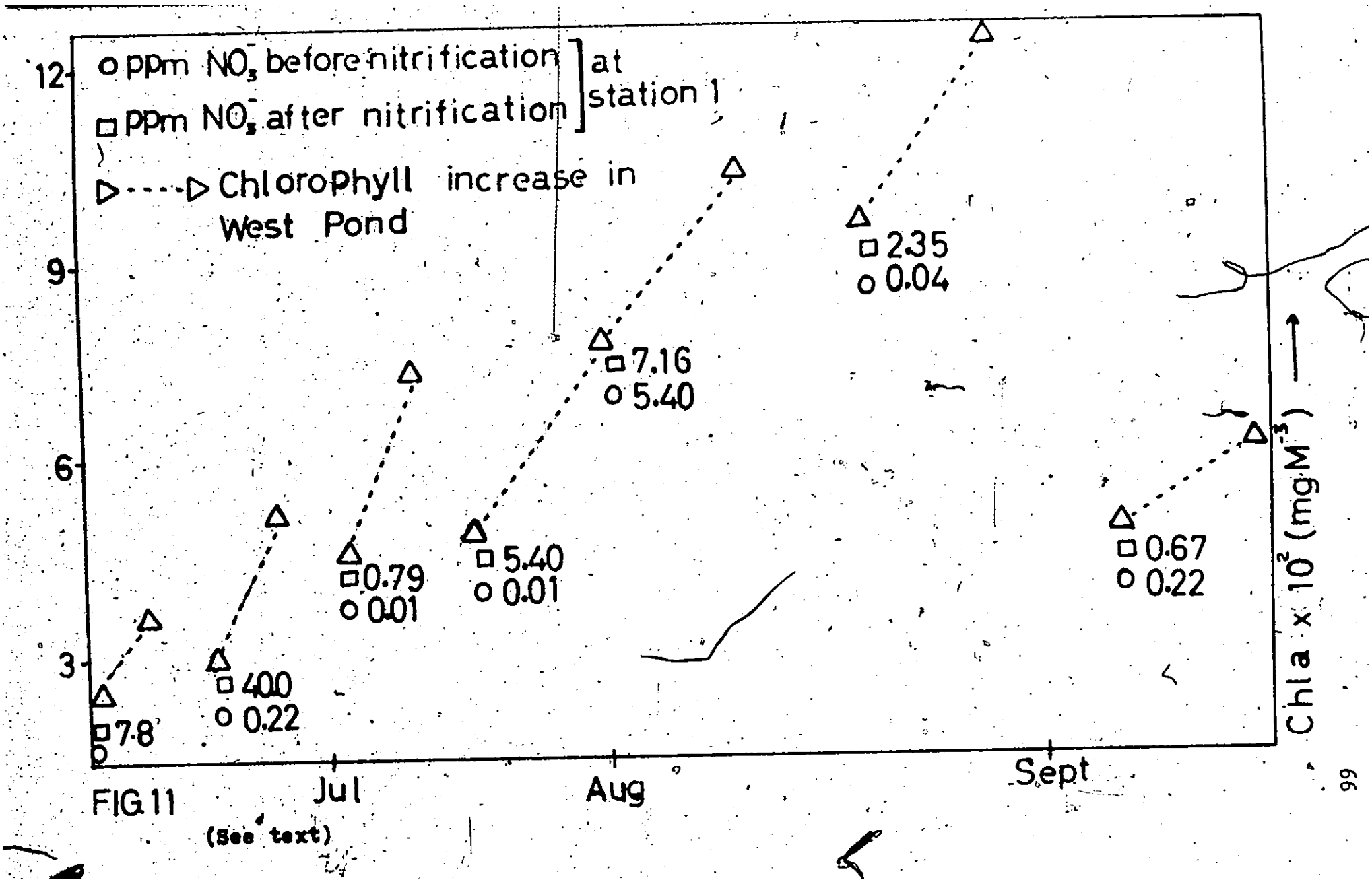


FIG 11

(See text)

A case for nitrate limitation can also be made on the basis of the nitrogen to phosphate ratio (N/P) previously mentioned in the station 1 discussion. The use of the N/P ratio as in index in nutrient limitation studies is based on the approximate chemical formula of living protoplasm:

$C_{106}H_{263}O_{110}N_{16}P$ (Halmann 1972),

assuming that living organisms require nitrogen to phosphorous in the ratio of 16 to 1. Ryther and Dunstan (1971) recommended an N/P ratio of 15 to 1 for marine phytoplankton and 16 to 1 for freshwater types. However, a working ratio of 10 to 1 has been established (Ryther and Dunstan 1971).

In West Pond the average N/P ratio was 0.05 during the summer. This very low ratio suggested that nitrate may be limiting in West Pond. Figure 12 shows that the nitrate levels frequently fell below the 0.3 ppm recognized to cause noxious algal blooms (Haertel 1972, Bush and Welch 1972). However, there occurred intermittent peaks of nitrate greater than 0.3 ppm. At these times the actual N/P ratio may have been a little higher than the average summer figure quoted above. For example, on August 20, 1973, the ratio was 1.00. This was still low when compared to the working value of 10 quoted above. As will be discussed later, nitrate is only one of many factors affecting algal activity. The interesting point made here is that nitrate limitation is usually observed

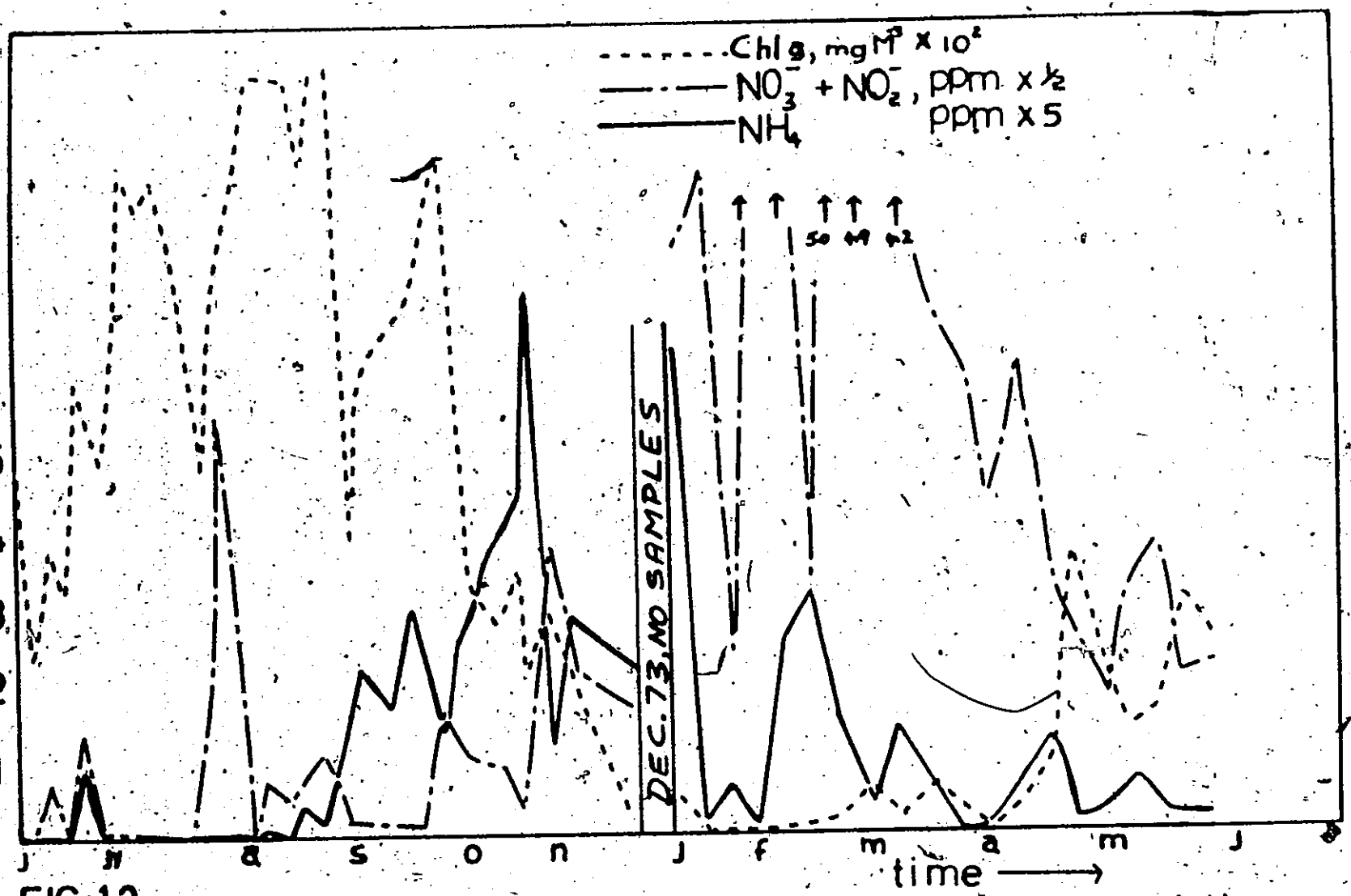


FIG. 12 Chlorophyll, nitrate + nitrite Nitrogen, and ammonia Nitrogen variations at station 4 between June 1973 and May 1974. (see text for discussion).

in marine aquatic systems and phosphate limitation in freshwater systems (Keeney 1972, Halmann1972, Ryther and Dunstan 1971, and Hutchinson 1973). In West Pond (a freshwater system) nitrate, rather than phosphate limitation was suspected.

Luxury Consumption of Phosphorous

As discussed above, phosphorous limitation of growth is the usual case for phytoplankton algae in freshwaters (Chu 1942, Fuhs 1969, O'Kelley 1969, Legge and Dingledein 1970, Fitzgerald 1971, Schindler 1971, O'Brien 1972, Droop 1973, Hutchinson 1973). The reason for this is that it is more difficult for run-off water to leach potential phosphorous salts from the soil in the water-shed which would feed a lake. To make this point more clear, Hutchinson (1973), reported that because phosphorous is an element with an odd atomic number (At. no. = 15) it is much rarer than its neighbours, silicon and sulphur. While in the earth it is partly lost as insoluble iron phosphide to the metallic core and is not easily available to the surface. The same cannot be said for nitrate salts which are highly soluble in water. Phosphorous was never limiting in West Pond because of two reasons: (1) the lowest level recorded (0.5 ppm) was at least 25 times greater than the concentration required to stimulate eutrophic algal conditions (Halmann1972, Haertel

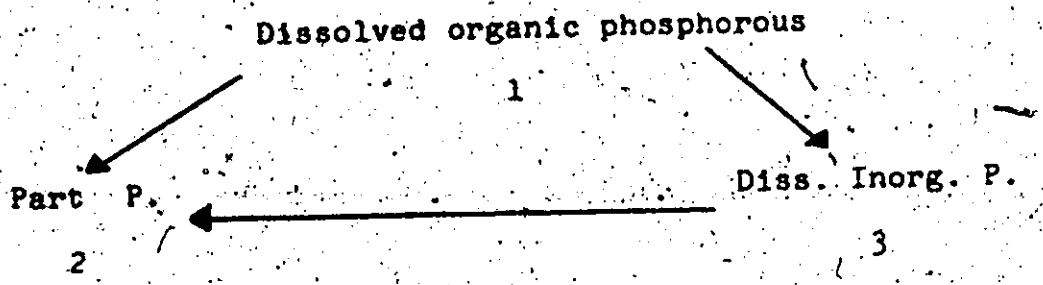
1972, Bush and Welch 1972), (2) luxury uptake or consumption of phosphate was suspected.

The luxury uptake phenomenon refers to the ability of algae to actively take up soluble phosphate with subsequent storage when external supplies are abundant (Fogg 1973). Luxury consumption of phosphorous is recognized by many workers (Kuenzler and Perras 1965, Schindler 1971, Wheater 1972, Fogg 1973, and Hutchinson 1973, 1957). It has been observed for both marine and freshwater algae (Fogg 1973).

Particulate phosphate analysis was done to determine how much phosphate was contained in the algal cells in West Pond where the phosphate concentration was always high (see above). A positive significant correlation was found between particulate phosphate and biomass ($r = 0.661$, $p = 0.001$). Figure 10 shows the relationship clearly. A significant negative correlation was also calculated between soluble phosphate and biomass ($r = -0.497$, $p = 0.01$). Figure 10 clearly shows this inverse relationship. These correlations meant that the ambient soluble phosphate supply was partly controlled by the ability of algae to actively uptake and store phosphate. The positive correlation between particulate phosphate and biomass meant that as the biomass increased the concentration of phosphate in the algae also increased. The significance of these correlations was supported by a

negative significant correlation between particulate phosphate and soluble phosphate ($r = -0.403$, $p = 0.05$). Table 3 gives the correlations, degrees of freedom and probability.

The case for possible luxury consumption of phosphate which can only occur in high phosphate situations was strengthened by the fact that the algae species (Scenedesmus quadricauda Chod.) which comprised 80% of the population 80% of the time in West Pond during the summer has been shown to store 50% of its cell phosphorous in the form of polyphosphate (Fogg 1973). A thorough discussion of luxury uptake by Fogg (1973) quoted a figure of 0.06 µg P per 10^6 cells as the limiting phosphorous requirement concentration. In West Pond the average phosphorous concentration was 1.26 µg P per 10^6 cells for the summer. The analyses showed that particulate phosphate concentrations ranged between 4 to 14 ppm. Finally, in tracer studies of the phosphorous cycle in seawater, Watt and Hayes (1963) described a dynamic equilibria system involving these forms of phosphorous. The scheme was as follows:



The reaction 3 to 2 represented uptake of orthophosphate (soluble phosphorous) by living organisms (phytoplankton and

TABLE 3

CORRELATION COEFFICIENTS FOR VARIABLES AT STATION 4

JUNE 14 - OCTOBER 20, 1973

VARIABLES	DEGREES OF FREEDOM	CORRELATION COEFFICIENTS	PROBABILITY
SUNSHINE HOURS & WATER TEMP.	24	+0.7202	P = 0.001
SUNSHINE HOURS & BIOMASS	24	+0.5404	P = 0.01
SUNSHINE HOURS & NH_4^+	24	-0.51	P = 0.01
SUNSHINE HOURS & OXYGEN	24	+0.717	P = 0.001
WATER TEMP. & BIOMASS	24	+0.414	P = 0.05
WATER TEMP. & OXYGEN	24	+0.596	P = 0.001
WATER TEMP. & AMMONIA	24	-0.6252	P = 0.001
WATER TEMP. & PHOSPHATE (SOL.)	24	-0.4205	P = 0.05
WATER TEMP. & SECCHI	24	-0.22	NEGATIVE BUT NOT SIGNIFICANT
BIOMASS & AMMONIA	24	-0.35	P = 0.1
BIOMASS & OXYGEN	24	+0.3627	P = 0.05
BIOMASS & PHOSPHATE	24	-0.4969	P = 0.01
BIOMASS & SECCHI	24	-0.5416	P = 0.01
BIOMASS & TURBIDITY	24	+0.3045	POSITIVE BUT NOT SIGNIFICANT

continued . . .

continued

VARIABLES	DEGREES OF FREEDOM	CORRELATION COEFFICIENTS	PROBABILITY
TURBIDITY AND SECCHI	24	-0.7174	P = 0.001
OXYGEN AND AMMONIA	24	-0.52246	P = 0.01
OXYGEN AND TOT. INORG. PHOSPHATE	24	-0.5279	P = 0.01
BIOMASS AND PART PO_4-P	24	+0.661	P = 0.001
PART PO_4-P AND SOL. P	20	-0.403	P = 0.05
WIND AND BIOMASS	19	+0.501	P = 0.02

bacteria, but not zooplankton). If this scheme is also the case for freshwater systems, then the above discussion did not consider the effects of bacteria and dissolved organic phosphorous.

(v) Complex Interactions between Variables

The interactions among the eleven variables which may contribute to biomass activity in West Pond were identified with the aid of significant positive and negative correlations (Table 3) and summarized by means of a diagram (figure 13).

Positive correlations between sunshine hours and water temperature and those (sunshine hours and water temperature) with biomass, was not surprising. Short and long wave radiation would heat up the water, and available short wave radiation would be utilized for photosynthesis. Increases in the water temperature would stimulate algal growth resulting in a larger biomass. The larger biomass would photosynthesize more, thus producing more oxygen. This was supported by the positive correlation between dissolved oxygen and biomass (Table 3).

Figure 10 shows that there was an overall inverse relationship between dissolved oxygen and soluble phosphate, and a similar relationship between biomass and soluble phosphate. Table 3 gives the significant correlations. As the biomass increased, photosynthesis increased. This

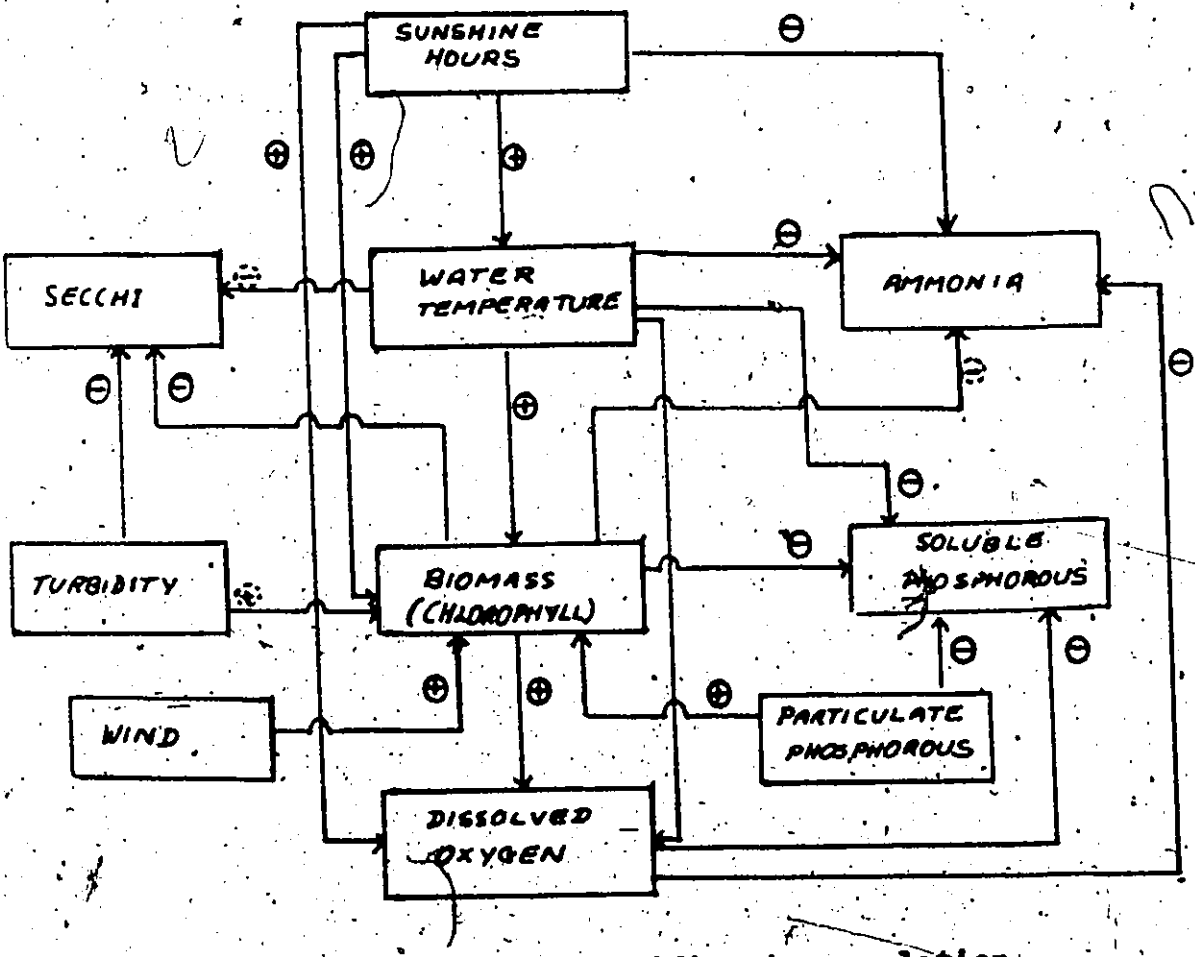


FIG.13

⊕ = Positive significant correlation

⊖ = Negative significant correlation

⊕ = Positive insignificant correlation

⊖ = Negative insignificant correlation

Block diagram showing interactions between various variables (based on correlation coefficients) at station 4.

caused increased uptake of phosphorous. Higher oxygen production then occurred when the soluble phosphate concentrations were low and biomass was high. These interactions would explain the inverse relationships described above. The negative correlation between water temperature and phosphate indicated that higher temperatures stimulated photosynthesis and uptake of phosphate. The phosphate-biomass-oxygen-temperature relationship can be seen in figure 13.

Peaks in biomass were usually associated with a prior high or simultaneous high nitrate level (fig. 12). The actively photosynthetic algae were producing oxygen, some of which was utilized for the nitrification of ammonia via the reaction:

$$NH_4^+ + 2\,O_2 \rightarrow NO_3^- + H_2O + 2H^+ \quad \text{(Keeney 1972)}$$

This was supported by the significant inverse relationship between ammonia and dissolved oxygen (Table 3). Nitrification was also discussed for station 1. The inverse relationship between biomass and ammonia may offer an alternative interpretation for the inverse relationship between oxygen and ammonia. As the biomass increased, uptake of ammonia occurred concurrent with the increased oxygen production. This would result in the observed negative relationship between dissolved oxygen and ammonia.

The intense productivity (3.17 g $O_2/M^3/h$) and high assimilation ratios (4.56 mg O_2/mh Chl/h) and large biomass

(700 mg Chl/M³) and subsequent death and decay was likely to produce a heavy oxygen demand on the sediment. This would occur both during the day and the night. During the day photosynthesis would not be expected to occur throughout the whole water column because the secchi depth readings were in the 20 cm range during the summer. This meant that no photosynthesis would occur below approximately two and a half times the secchi depth (about 50 cm) (See methods for this calculation). This would leave about 50 centimeters of water where no oxygen production was possible. In addition, stratification of the water column on calm days would prevent diffusion of oxygen downwards.

Evidence for stratification of the water column was inferred from surface and bottom dissolved oxygen profiles. During the summer, on June 18, July 3, July 26 and August 20, the surface to bottom dissolved oxygen were 128 to 48, 338 to 104, 182.0 to 81 and 248 to 80 percent saturation, respectively. These conditions would be likely to produce an anoxic environment near the sediment surface. Anoxic conditions would release soluble ferrous phosphate by the reduction of ferric phosphate. The turbulence produced by the action of wind (to be discussed in detail later) would mix the water column and bring the phosphorous to the surface. The point to be made here is the activity of decomposers must be recognized as an important factor affecting the nutrient status of the water.

Here a system has been discussed which recycled phosphorous and nitrified ammonia.

Other significant relationships identified, included those between water temperature and biomass with secchi depth; and also, secchi depth with turbidity. As the positive effect of temperature increased biomass the secchi depth decreased and the turbidity increased.

Finally the relationship between wind and biomass must be discussed. A significant positive correlation was found between the average of the mean wind speeds of the two days before the biomass was sampled and the biomass (Table 3). This correlation may be explained by the fact that wind generates enough mixing in shallow lakes and ponds to considerably stir up the sediments. During windy periods, there was little difference between surface and bottom dissolved oxygen concentrations. Stirring of sediments can release important nutrients which may be in short supply in surface waters.

Harris and Lott (1973), and Haertel (1972), have demonatrated the effect of wind on algal productivity and its importance as an environmental factor. In the early summer of 1971, Haertel (1972) calculated both positive and negative correlations between wind stress and chlorophyll content in a shallow South Dakota lake. There are two possible explanations for a negative correlation.

Firstly, too much wind would increase the concentration of suspended particles. These particles could effectively shade out much of the available light required for phytoplankton activities resulting in a decreased biomass. Secondly, under high light intensities, a moderate wind stress might circulate algae down from inhibiting light intensities at the surface (Haertel 1972). Since samples were taken from the surface, the chlorophyll can be expected to be low during times of moderate wind stress. The positive correlation might be explained by wind stress generating release of scarce micro or macronutrients from sediments, thus enhancing production, growth, and cell division of phytoplankton.

The above interpretations, correlations and summary of figure 13 represented only those variables which gave significant correlations. Even though a reasonable scheme was presented it must be stressed that other variables may be equally important. For example, the effect of trace elements as limiting factors (Gerloff and Skoog 1957, Ryther and Kramer 1961, Patrick et al. 1969, Lange 1971, and Manahan and Smith 1973) was not considered, nor was the possibility of significant variability between sampling periods (except for wind). There also existed the possibility for the existence of unidentifiable variables (Patten 1968). The time of day when variables were collected was also a critical factor. The discussion of the diurnal studies

done at station 12 will emphasize this point. There was, however, the advantage that the inferences were possible without the aid of controlled field or laboratory experiments.

(3.1.d) Stations 5 and 6 (June 14 - September 6, 1973)

Station 5 was located at the exit of West Pond and station 6 was some distance east of West Pond at a point where the waters leaving West Pond mixed with those of Spencer's Creek (fig. 1). Station 5 showed pronounced chlorophyll fluctuations (fig. 14) which were partly due to changing wind directions. An east wind would bring the waters of Spencer's Creek to station 5 and effectively dilute the chlorophyll. When flow from Spencer's Creek was minimal and there was westerly wind, chlorophyll at station 5 was similar to station 4's. Despite the fluctuations the average summer chlorophyll value of 419 mg/M³ at station 5 was still high.

Average chlorophyll for the summer at station 6 was 135 mg/M³ - much lower than the other west end stations (1, 2, 3, 4 and 5). The lower chlorophyll at station 6 was a direct result of dilution from Spencer's Creek which had a biomass concentration less than 10 mg/Chl/M³. Figure 15.A shows the summer chlorophyll plot. Most of the time the biomass was well below the 200 mg Chl/M³ level.

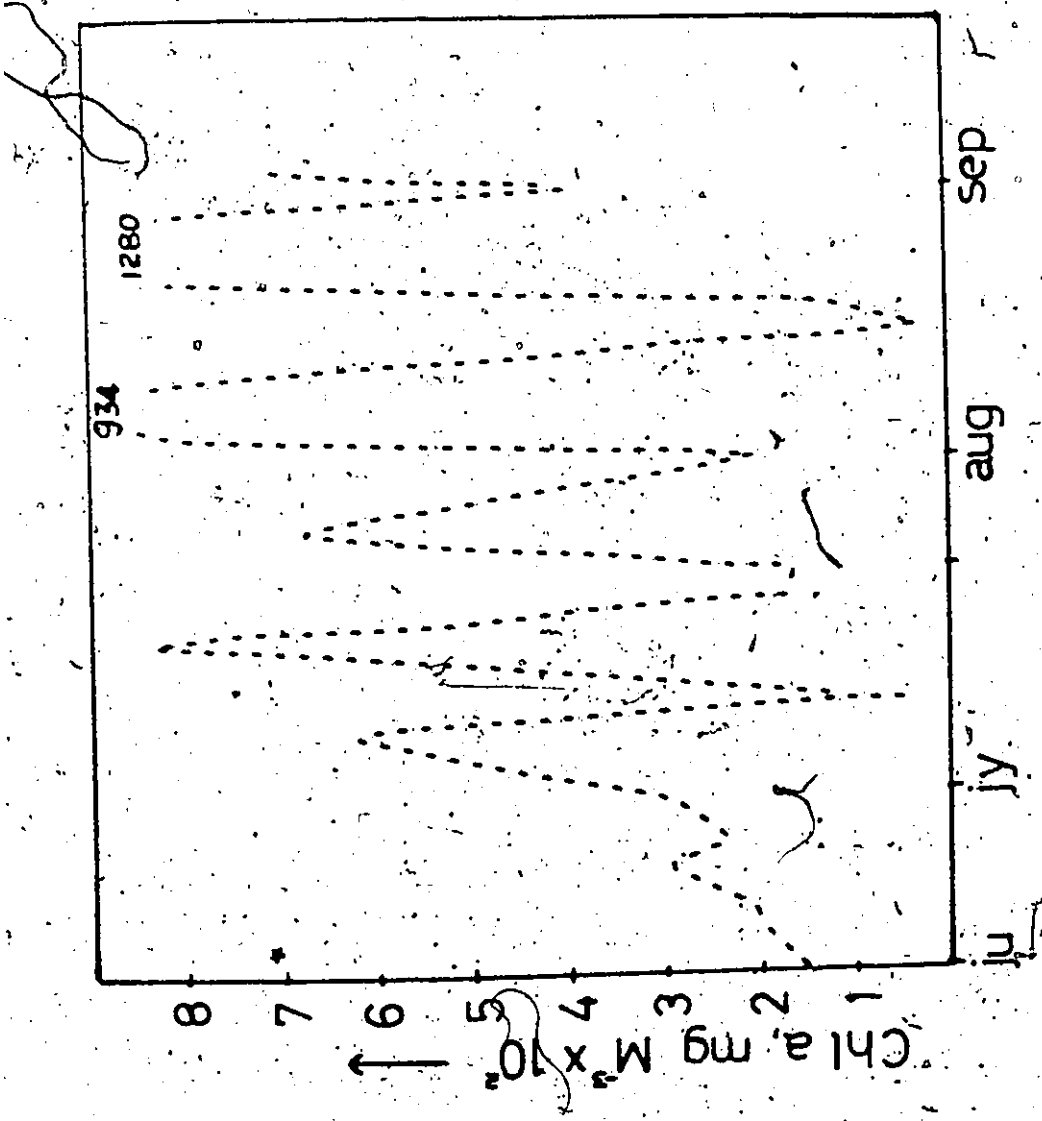


FIG.14 Graph of the marked chlorophyll fluctuations at station 5 between June 14, and Sept. 9, 1973.

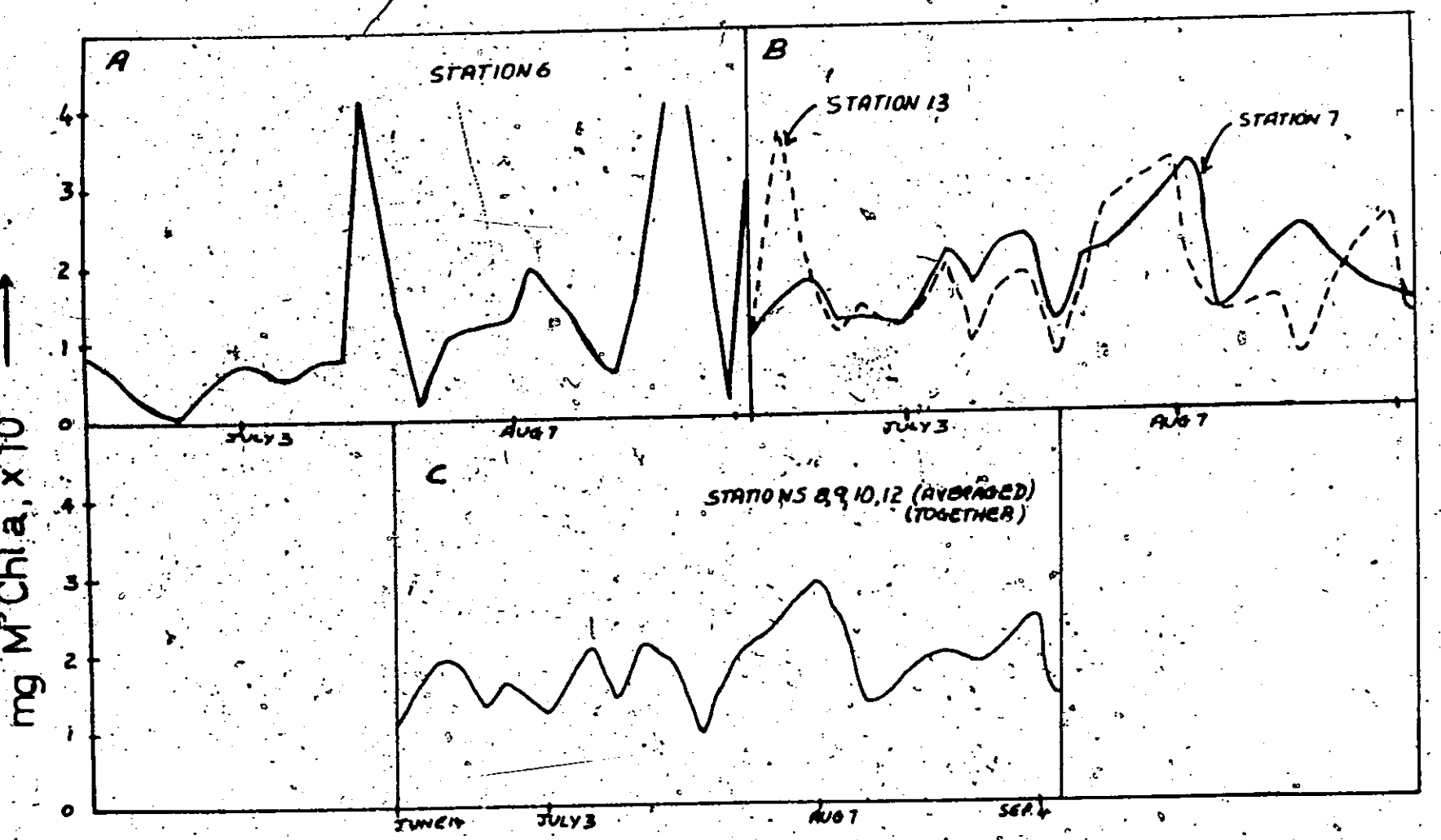


FIG.15 Chlorophyll a variations at stations 7, 8,9,10,12 (averaged together), and station 6 between June 14,1973 and Sept. 6, 1973.

Soluble phosphorous variations for stations 5 and 6 are shown in figures 3 b and 3 c respectively. The summer averages were 4.05 ppm (station 5) and 2.41 ppm (station 6). The phosphorous variation at station 5 closely followed that of station 4 (fig. 3 b). During the latter half of June and the first week of July, soluble phosphorous concentrations were unusually high at both stations 5 and 6. A similar high soluble phosphorous was also observed at stations 1, 2, 3 and 4 (figures 3 a, b, and c, station 3 not included). For sake of comparison figure 3 d shows a similar situation for the main body stations (represented by station 12). This phenomenon cannot be explained by the data collected unless the sewage plant effluent was responsible. Unfortunately, the effluent was not sampled during this time.

The average phosphorous concentrations at stations 5 and 6 can be compared to stations 1, 2, 3 and 4 (Table 4). The average nitrate concentrations are also included. The concentrations changed along a distance gradient between stations 1 and 6. Figure 16 shows a plot of biomass, soluble and particulate phosphate and nitrate averaged over the summer for stations 1 through 6. The calculations showed that by the time the water reached station 6 the soluble phosphrous concentrations were reduced by 78.7% and nitrate by 85%. These percentages meant that the large standing crop of algae along the canal and in West Pond were

TABLE 4

DECREASE IN SOLUBLE PO_4^{-3}-P AND $NO_3^- + NO_2^-$ NITROGEN FROM STATIONS 1 - 6 WITH BIOMASS VALUES -

STATION	BIOMASS*	SOL. PO_4-P*	$NO_2^- + NO_3^-$-N*
1	450	11.26	1.60
2	456	7.73	0.89
3	665	5.26	0.35
4	695	5.37	0.31
5	419	4.05	0.24
6	135	2.41	0.25

* VALUES ARE AVERAGED OVER THE WHOLE PERIOD JUNE 14th - SEPTEMBER 6th, 1973.

NB., SEWAGE EFFLUENT AVERAGED 5.45 PPM SOL. PO_4^{-3}-P.

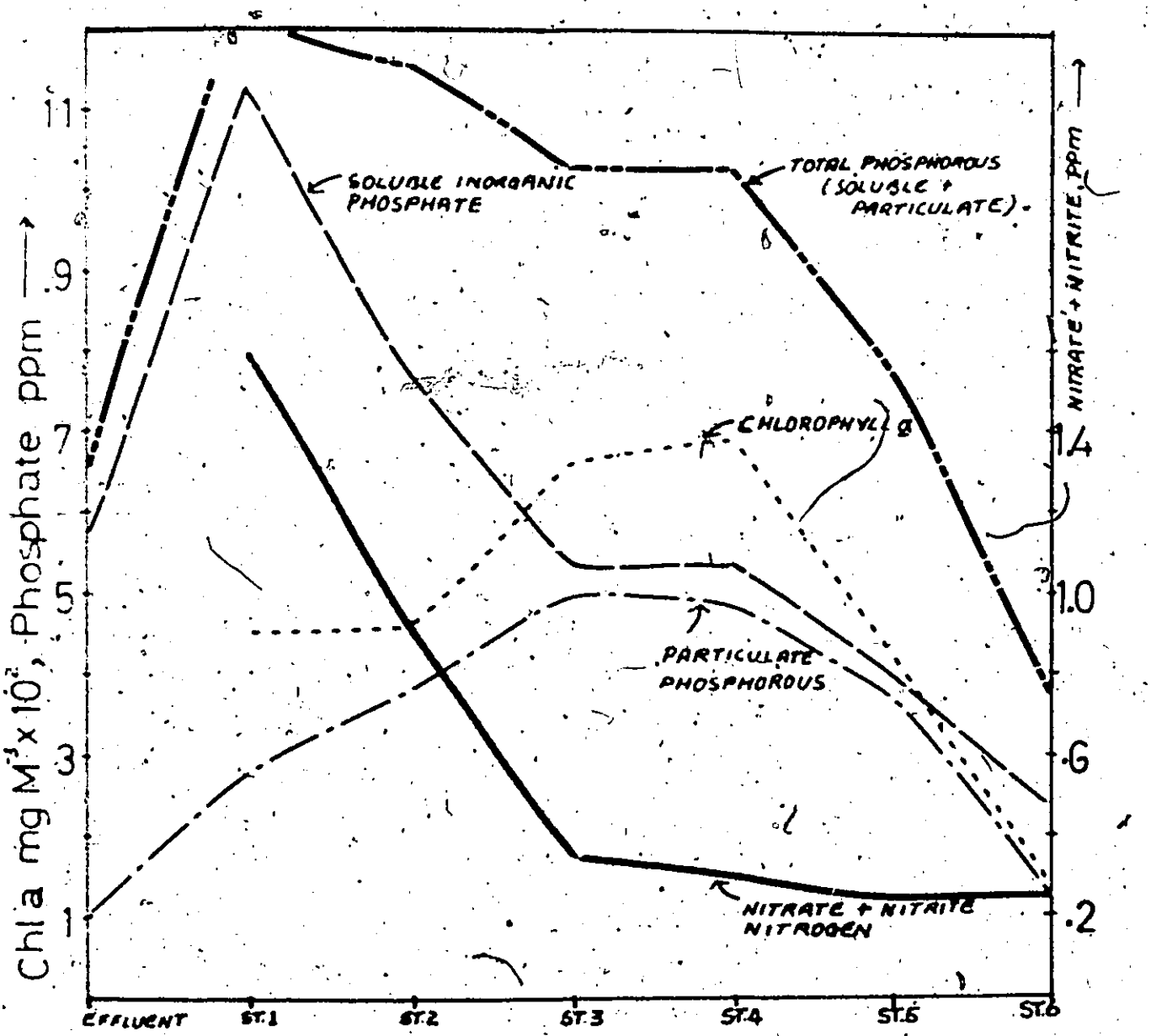


FIG16

(See text)

actually functioning as a tertiary sewage treatment unit (only that there were no artificial controls) actively taking up the nutrients. The high cell numbers and production rates discussed for West Pond add credibility to support this uptake phenomenon. The interpretations presented here demonstrated the adaptability and potential of phytoplankton when faced with constant forcing nutrient functions providing all other environmental factors were in the optimum range.

3.1.e) The Main Body Stations (7, 8, 9, 10, 11, 12 and 13)

Station 12 has been chosen as representative of the main body stations. Station 11 which was located in a sheltered inlet between Sassafras and Princess Points is the sole exception. The reason for choosing station 12 was based on a comparison of the average chlorophyll variations in time of stations 8, 9, 10 and 12 combined, with station 12 (fig. 17). As the graph shows, there was little difference. It was expected that because of the locations of stations 7 and 13, that they would have been different from the other main body stations (fig. 1). However, when the chlorophyll plots of stations 7 and 13 (fig. 15 B) were compared to the average combined chlorophyll of stations 8, 9, 10 and 12 (fig. 15 C), there was a distinct similarity. As a result, station 12 will be considered as typical of stations 7 through 13.

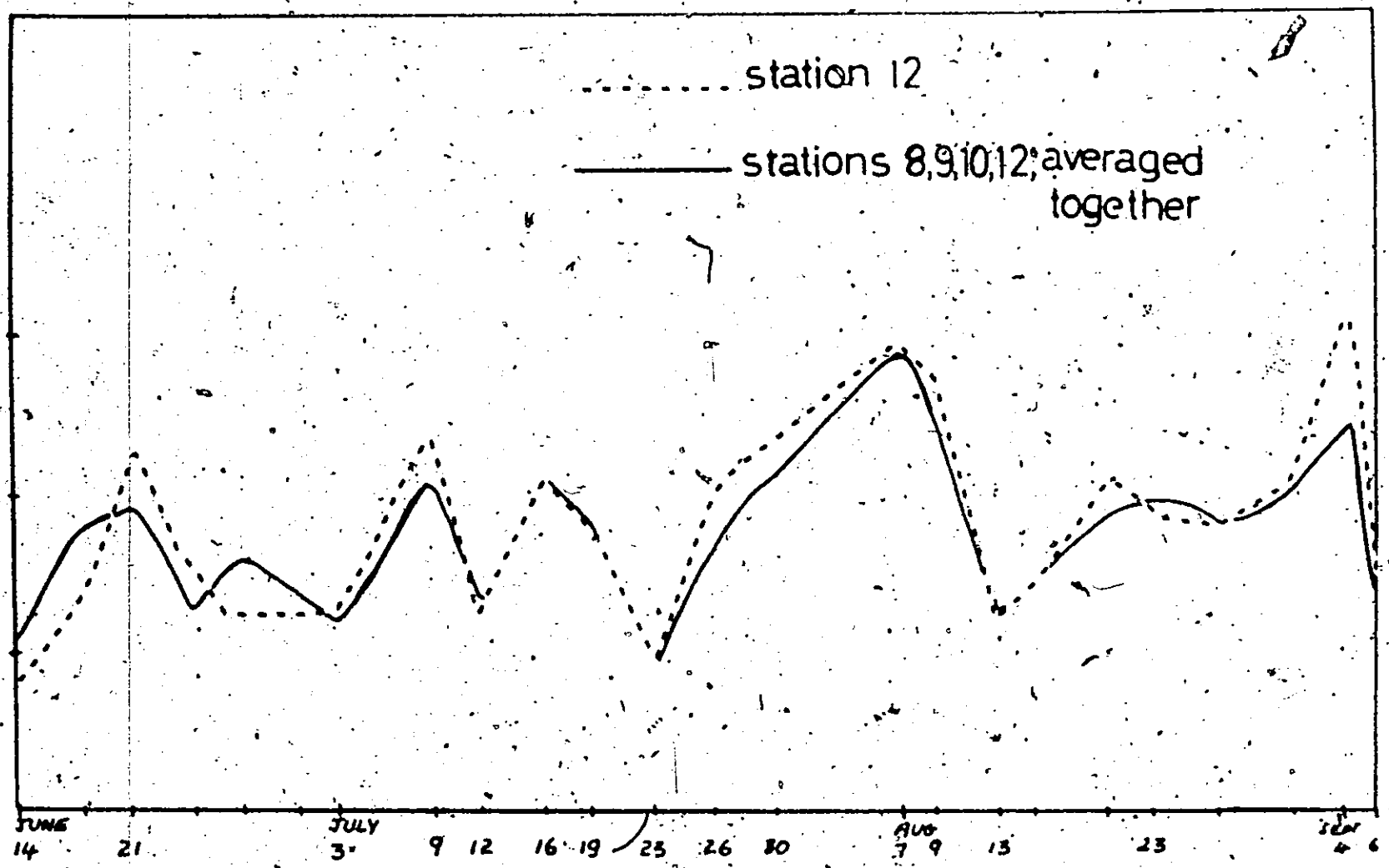


FIG.17

Plot showing the comparsion of chlorophyll at station 12 with the the total average chlorophyll for stations 8,9,10, and 12 (combined) during the summer of 1973. Note the similarity between the plots.

(1) Station 12 (June 14, 1973 - May 31, 1974)

Figures 18 and 19 show the seasonal variations of chlorophyll dissolved oxygen, nitrate + nitrite nitrogen, soluble phosphorous, temperature, secchi depth, and turbidity at station 12. The overall seasonal progression of nutrients biomass, and physical parameters were similar to that described for station 4. However, biomass was lower during all seasons at station 12 than at station 4 (Table 1). Nitrate levels were higher during the summer and fall when compared to station 4. The phosphate concentrations were considerably lower throughout all seasons at station 12 (Table 1) than at station 4.

Nutrient concentrations were lower in the summer than in the other seasons (Table 1). This was the result of lowered output from West Pond, dilution of the waters leaving West Pond by Spencer's Creek, and more uptake by a larger summer biomass in West Pond. Nutrient build up in the fall and winter, and subsequent decrease as spring approached was identified (as for station 4). Round's (1971) September/October and March/April cardinal points and the corresponding biomass decrease and increase were also identified. Figure 19 shows the temperature relationship with chlorophyll between June 1973 and May 1974. The relationship between available sunlight hours and biomass with respect to the cardinal points was the same as for station 4.

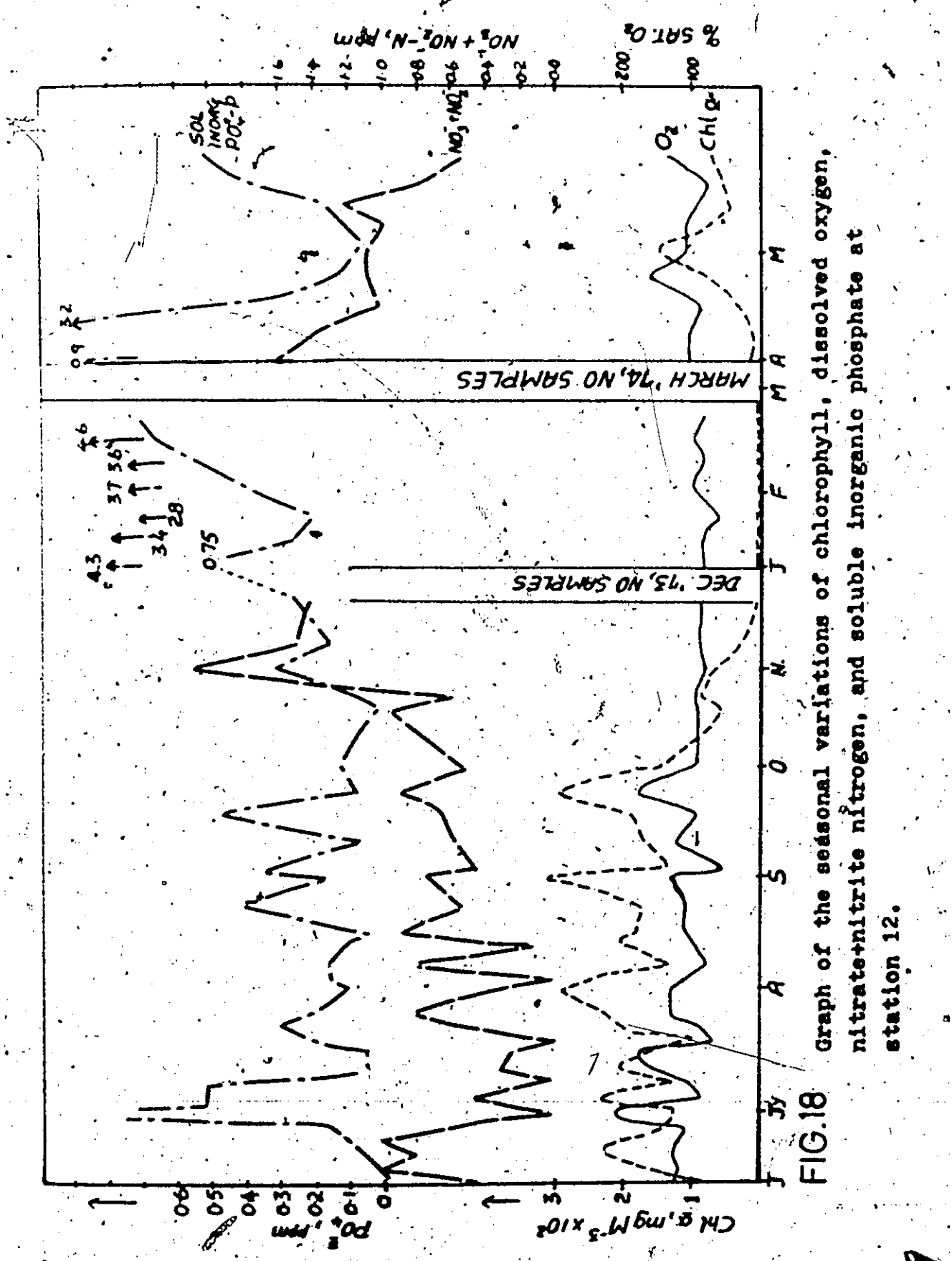


FIG.18 Graph of the seasonal variations of chlorophyll, dissolved oxygen, nitrate+nitrite nitrogen, and soluble inorganic phosphate at station 12.

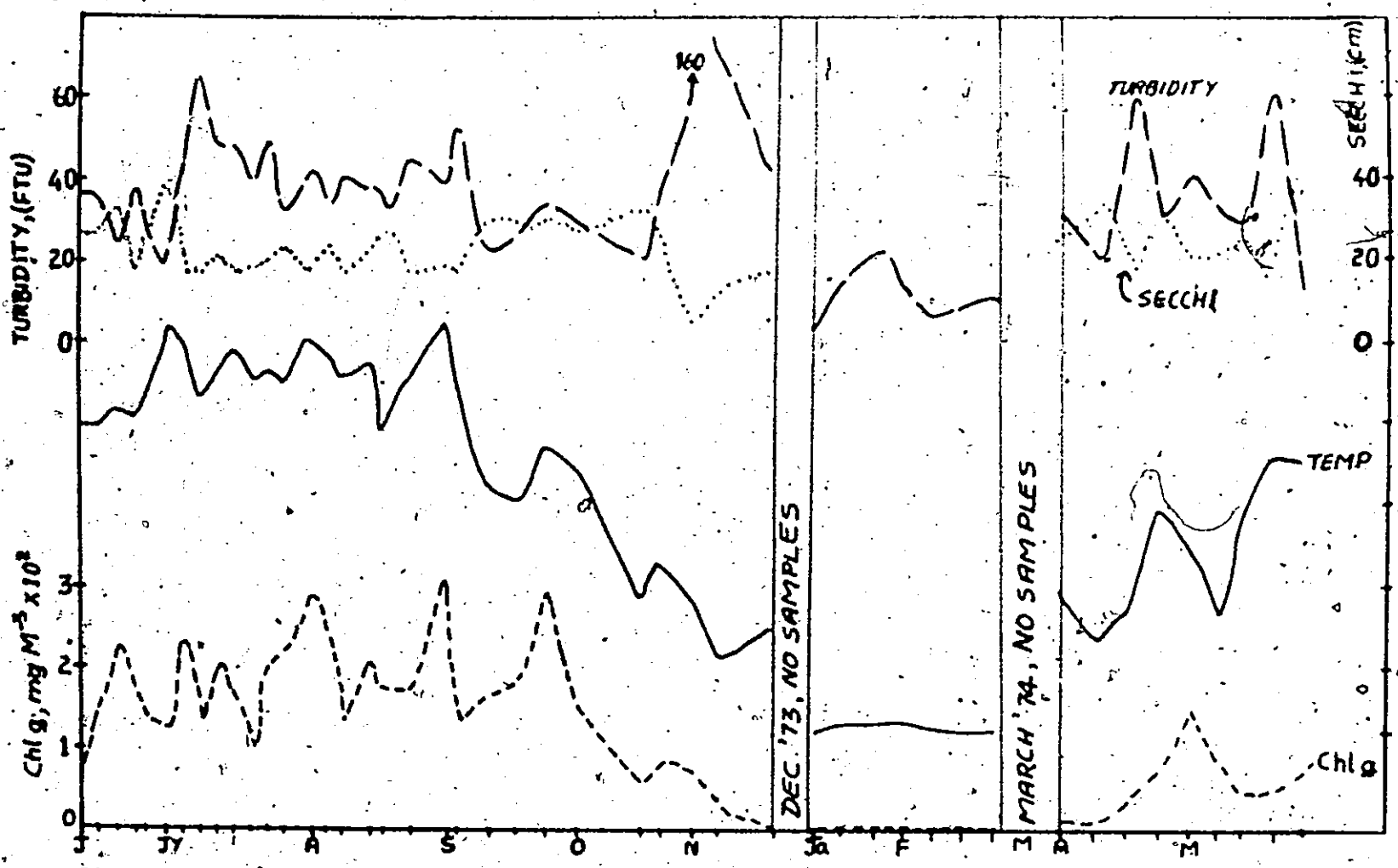


FIG.19 Graph of the seasonal variations of chlorophyll, temperature, secchi depth, and turbidity at station 12. Note the inverse relationship between secchi and turbidity, and the positive correlation between temperature and chlorophyll.

The dissolved oxygen concentration changes from season to season were no different to that observed at station 4. Levels were above 100 percent saturation in the summer and spring, and below 100 percent saturation in the fall and the winter (Table 1). On the average, the dissolved oxygen concentrations were lower than at station 4. The summer station 12 average was 138% saturation compared to a 253% saturation level for station 4. This was probably a direct result of the lower average summer biomass of 144 mg Chl/M³ at station 12 compared to a 695 mg Chl/M³ for West Pond (station 4).

The plots of secchi depth and turbidity in figure 15 show a clear inverse relationship. The lower summer secchi depth was partly due to the large standing crop of algae - an inverse relationship similar to that experienced at station 4.

(11) Variations between June and October 1973.

Examination of the chlorophyll-distribution during the summer and early fall of 1973 revealed the occurrence of six distinct peaks and one smaller peak, all of which were above the 100 mg Chl/M³ level (fig. 18). This observation resulted in three questions viz: 1. What caused the fluctuations? 2. Why was the average chlorophyll concentration about three times lower than at station 4? and 3. Was it possible that a similar set of variable interactions

was operating at Station 12 as was identified at station

A partial answer to the first question was that biomass variations closely followed temperature variations (fig. 19). Examination of the data revealed that each peak of biomass corresponded to small increases in temperature. The calculations based on a linear regression analysis (Table 4) showed that for every rise of 1°F there was a 4.37 mg chl/M³ increase in biomass. Of course, this may have been merely a coincidental effect and some other unidentifiable variable (or complex of variables) may have been responsible. It should be remembered at this point that the role of temperature was more obvious during the winter and spring at station 4.

In response to the second question, the most obvious area to be investigated was the possibility of nitrate or phosphorous limitation. Many workers have demonstrated that phosphorous and nitrate are the two of the most important nutrients responsible for the development of algal blooms (Bush and Welch 1972, Halmann 1972, Hutchinson 1973). The significance of the N/P ratio has already been discussed. A comparison of the N/P ratios for all the stations showed that the west end stations had lower N/P ratios than the east end stations (Table 5). The higher N/P ratios which characterized the main body stations were the result of much lower phosphate concentrations. The higher nitrate

TABLE 5

N/P RATIOS FOR ALL STATIONS

ESPECIALLY LOW ARE STATIONS 3 AND 4

PERIOD	STATION	N/P	BIOMASS mg/m³
June - Sept.	1	0.14	450
14 6	2	0.11	456
1973	3	0.06	665
	4	0.05	695
	5	0.05	419
	6	0.11	135
	7	0.43	161
	8	0.36	160
	9	0.52	153
	10	0.14	183
	11	0.18	168
	12	0.63	182
	13	1.37	163

TABLE 6

CORRELATION COEFFICIENTS FOR VARIABLES AT STATION 12

JUNE 14 - OCTOBER 20, 1973

VARIABLES	DEGREES OF FREEDOM (N-1)	CORRELATION COEFFICIENTS	PROBABILITY
SUNSHINE HOURS & WATER TEMP.	24	+0.532	P = 0.01
WATER TEMP. & BIOMASS	24	+0.492	P = 0.01
WATER TEMP. & TURBIDITY	24	+0.5912	P = 0.001
WATER TEMP. & SECCHI	24	-0.759	P = 0.001
BIOMASS & OXYGEN	19	+0.587	P = 0.01
BIOMASS & NITRATE	15	+0.645	P = 0.01
WATER TEMP. & AMMONIA	24	-0.4489	P = 0.02
OXYGEN & PHOSPHOROUS	24	-0.4776	P = 0.02
SUNSHINE HOURS & TURBIDITY	24	+0.395	P = 0.05
SUNSHINE HOURS & AMMONIA	24	-0.597	P = 0.001
SUNSHINE HOURS AND SECCHI	24	-0.574	P = 0.01
TURBIDITY & SECCHI	24	-0.786	P = 0.001

concentrations (Table 1) at station 12 were the result of input from Spencer's Creek. The lower phosphate levels were the result of a decreased output from West Pond and dilution of the waters leaving West Pond by Spencer's Creek. It should be remembered that West Pond removed a large percentage of the soluble inorganic phosphate. In addition to this, run-off water into the main area can leach more nitrate than phosphate from the surrounding terrain (see Sec. 3.1.c.iv) for discussion of this point).

Even though the main body stations had higher N:P ratios than the west end stations, the ratios were still considerably lower than the working ratio of 10 to 1 recommended by Ryther and Dunstan (1971). The average nitrate concentrations (0.51 ppm) were also higher than the 0.3 ppm value required to stimulate nuisance algal blooms (Bush and Welch 1972, Sawyer 1947). The cell concentration is also important when discussing nutrient limitation. Viner (1973) reported that the concentration at which a nutrient is limiting increases with increasing cell concentration. Because of the large cell concentrations (2.2×10^4 cells/liter) which were present at station 12 nitrate limitation may have been possible. Quantitative laboratory experiments would be necessary to prove this. Working with a mixed cell population would also complicate the problem because different species

may simultaneously be limited by different nutrients.

A case for phosphate limitation appeared to be more plausible because on many occasions the concentrations fell below the limits of detection, or were just barely detectable (fig. 18). In an attempt to more accurately detect the low phosphate concentrations a more sensitive analysis was tried on some of the sampling days. The results revealed that soluble phosphate concentrations never fell below 0.14 ppm. This concentration was higher than that recognized (0.01 to 0.06 ppm) to stimulate algal blooms (Maloney 1970, Fitzgerald 1971, Haertel 1972).

The point made before concerning the level at which a nutrient becomes limiting, when the cell concentration is increasing would also be valid here. That is an increasing cell concentration would increase the level at which a nutrient is normally limiting (Viner 1973). Allen and Kramer (1972) reported that turnover times for phosphorous in natural systems varies between a matter of minutes to tens of hours. With this last point in mind, it is conceivable that phosphate was never limiting at station 12, in spite of the large cell concentrations (0.92 to 4.16 x 10^5 cells/ml.). In fact, Maloney (1970), achieved cell concentrations as high as 10 x 10^6 cells/ml in culture experiments when the phosphate concentrations were as low as 0.06 ppm.,

A partial answer to the third question was possible on the basis of the correlations coefficients listed in Table 6 and the diagram in figure 20. The situation here was similar to the variable interaction complex identified at station 4 except that there were fewer significant correlations. The fewer significant correlations may have been the result of the fact that there was greater variance in the station 12 data. In addition, the station 4 algal population was very different than station 12's, in that there was almost a monoculture of Scenedesmus quadricauda persisting throughout the summer at station 4. Furthermore, the sewage effluent had much less influence at station 12 than at station 4.

The interpretation of figure 20 would be similar to that presented for figure 13 (station 4). The one significant difference (besides the fewer correlations) was the positive significant correlation between nitrate N and chlorophyll ($r = 0.645$, $P = 0.01$). At station 4 the correlation was negative and insignificant (Table 3). This observation emphasizes that although broad similarities exist in the ecological behaviour of aquatic systems, predictability on a finer scale is not always possible.

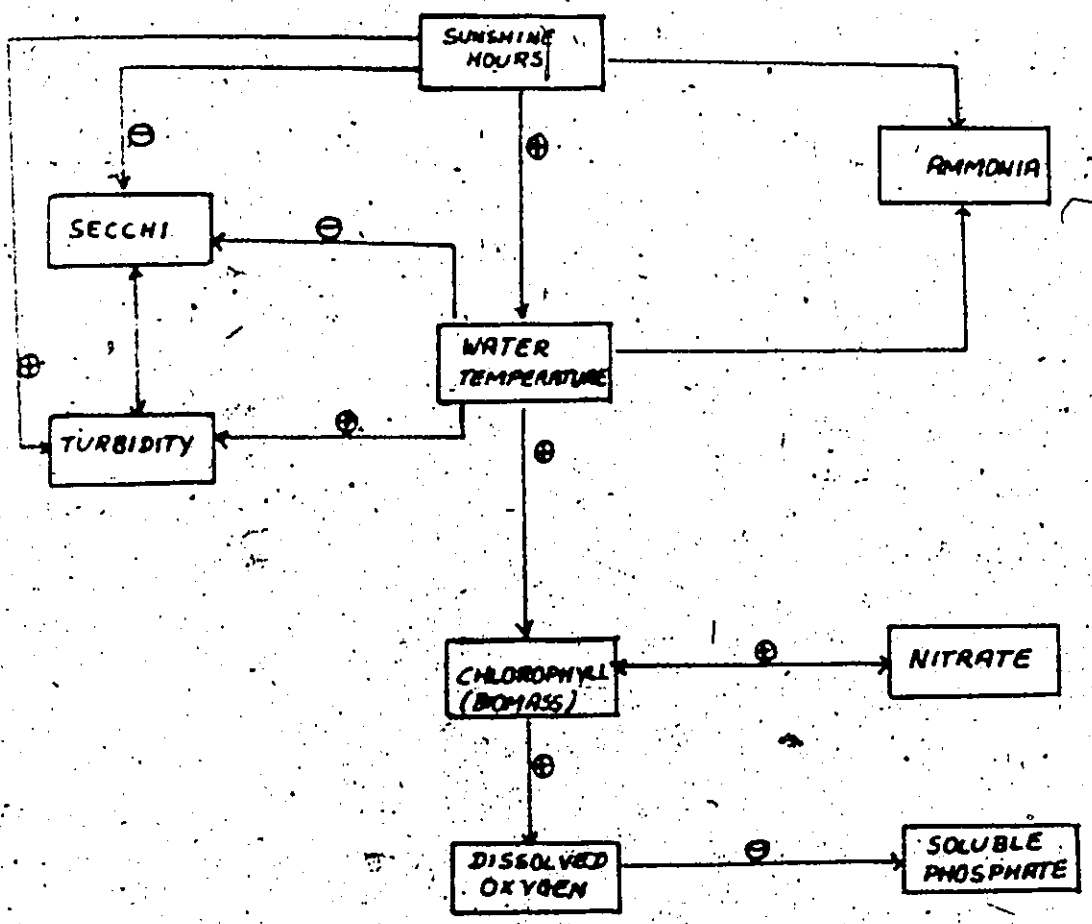


FIG. 20

⊕ Positive significant correlation

⊖ Negative significant correlation

Block diagram showing variable interrelationships at station 12.

Station 11

Despite its location (fig. 1) which afforded it increased influence of wind effects, measurements of the parameters at station 11 did not reveal any significant differences from the main body stations. The biomass and nutrient distribution over the summer were not atypical with respect to the other main body stations.

Secchi depth readings were more accurate because the hindrance provided by wave action at the main body stations was not as pronounced. Figure 21 shows the variations of chlorophyll, dissolved oxygen, and nitrate between June 14 and November 22, 1973. Surface dissolved oxygen fell below the 100% saturation level as frequently as at station 12 during the same period (figs. 18 and 21). Station 11 was, however, half as deep (3 feet) as station 12 (about 6 feet). This would mean that biological decomposition activity exerted a greater demand on surface dissolved oxygen concentrations.

Figure 21 shows that there was a tendency for an inverse relationship between biomass and dissolved oxygen. This relationship indicated that more decomposition may have been occurring when biomass was high. Diurnal studies (to be discussed later) indicated that marked stratification occurred at station 11. Differences between surface and bottom dissolved oxygen ranged between 46% saturation (10 cm above the sediment) to 160% saturation at the surface.

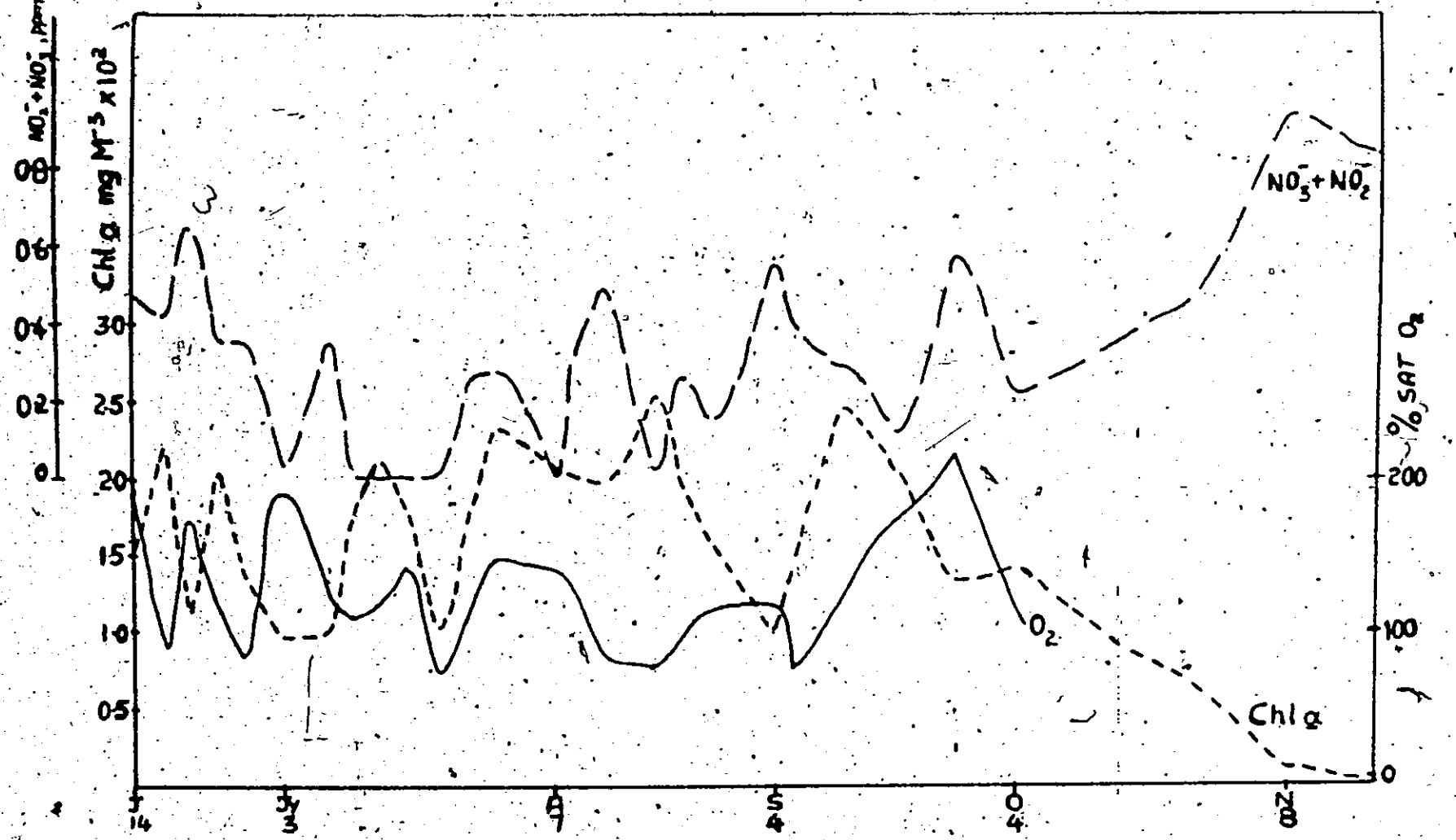


FIG. 21 Chlorophyll, dissolved oxygen, and nitrate variations at station 11 between June 14, 1973 and November 22, 1973.

This observation indicated that a gradient does exist in the water column. During the day photosynthetic activity also contributed to the observed dissolved oxygen gradient.

As the diurnal studies will show, the oxygen gradient disappears after midnight. This would have been the result of surface cooling during the night when temperatures are lower. As the surface water cooled, it became heavier (density of water increases as the temperature decreases) and sank to the bottom of the water column, at the same time displacing the warmer, lighter bottom water to the surface. This process continued until the whole water column became isothermal. This would cause the disappearance of the dissolved oxygen stratification. Such a mixing phenomonon occurs during the fall and spring turnover periods in temperate lakes (Moss 1972, and Ruttner 1973).

(4.2) Interpretation of the Diurnal Studies

The primary objective of a diurnal study in a natural fresh water system is to identify the biological, physical and chemical variations and interactions which may occur during the course of a twenty-four hour period. Observed variations, if large enough would be critical in the interpretation of seasonal changes based on weekly samples if the sampling time was not consistent. Three diurnals were done at station 12 on August 2, 16 and 30 and one at station 11 on August 30. The variables which

were recorded every two hours included biomass, cell concentration, soluble and particulate phosphate, nitrite + nitrate nitrogen, ammonia nitrogen, secchi depth, turbidity, wind speeds, water and air temperature, and incident short wave solar radiation.

(3.2.a) Station 12 - The Problem of Chlorophyll Bleaching

Figures 22 a, 23 a and 24 a show the diurnal plots of biomass, solar radiation, and surface and bottom dissolved oxygen on August 2, 16 and 30 respectively. Distinct diurnal variations were obvious for all the variables. The variable which will receive the most attention in the following discussion will be chlorophyll, because many of the diurnal studies reported stressed the importance of chlorophyll variations (Yentsch and Ryther 1957, Shimada 1958, Yentsch and Lee 1966, and Glooschenko 1971).

On August 2, chlorophyll showed a decrease in the early morning, an increase towards noon, a sharp decrease between noon and 6 p.m. and a subsequent increase between 8 p.m. and 12 midnight. The decrease between noon and 6 p.m. represented a 36% drop in chlorophyll (122 mg/M^3 to 77 mg/M^3). Several workers have suggested that the observed diel changes of chlorophyll may be the result of a physiological reaction to changes in light intensity (Yentsch and Ryther 1957, Shimada 1958, Yentsch and Lee 1966, and Glooschenko 1971).

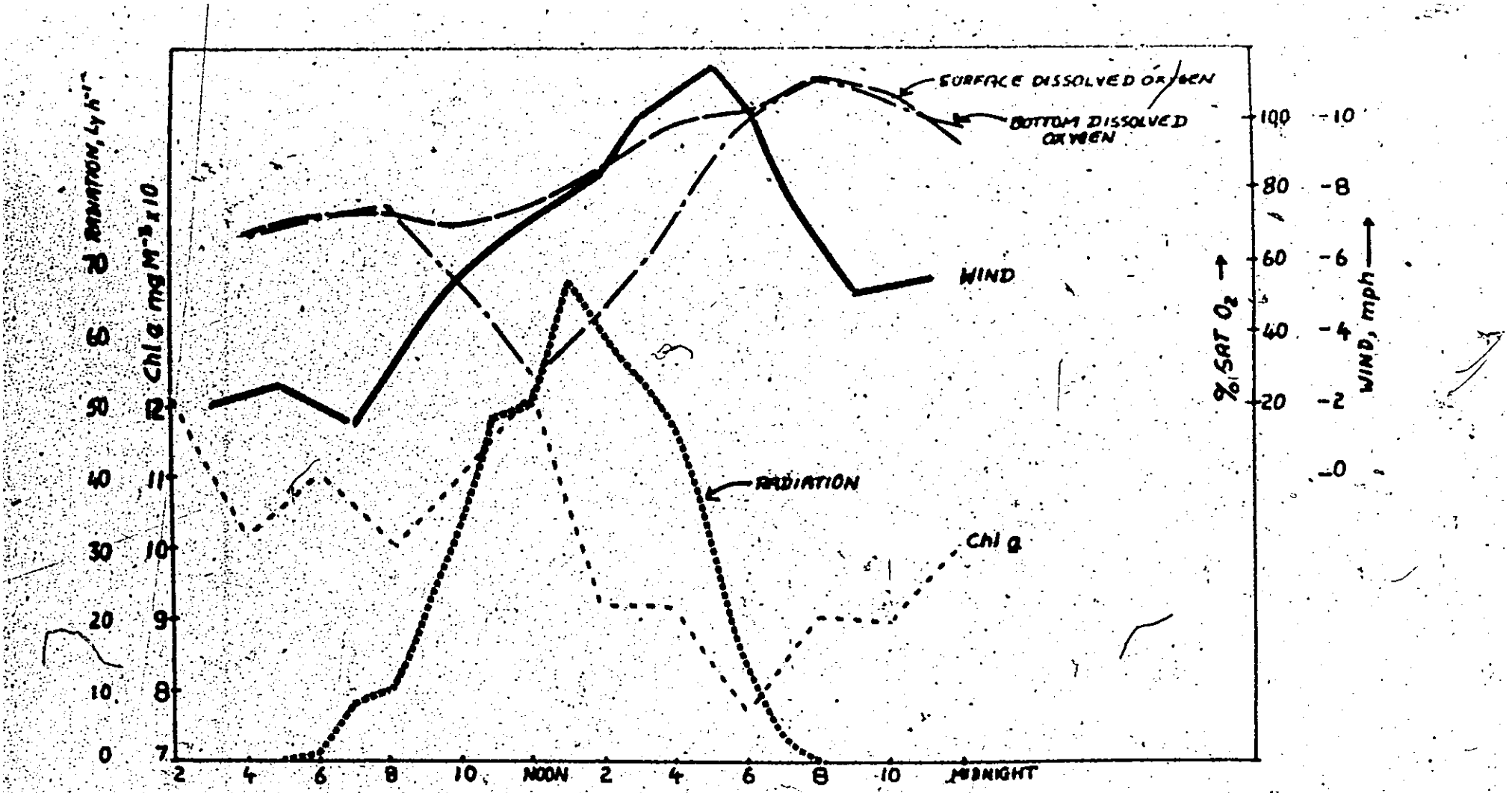


FIG. 22a Diurnal variations of chlorophyll, solar radiation, wind speed, surface and bottom dissolved oxygen at station 12 between 2 a.m. and 12 midnight on august 2, 1973.

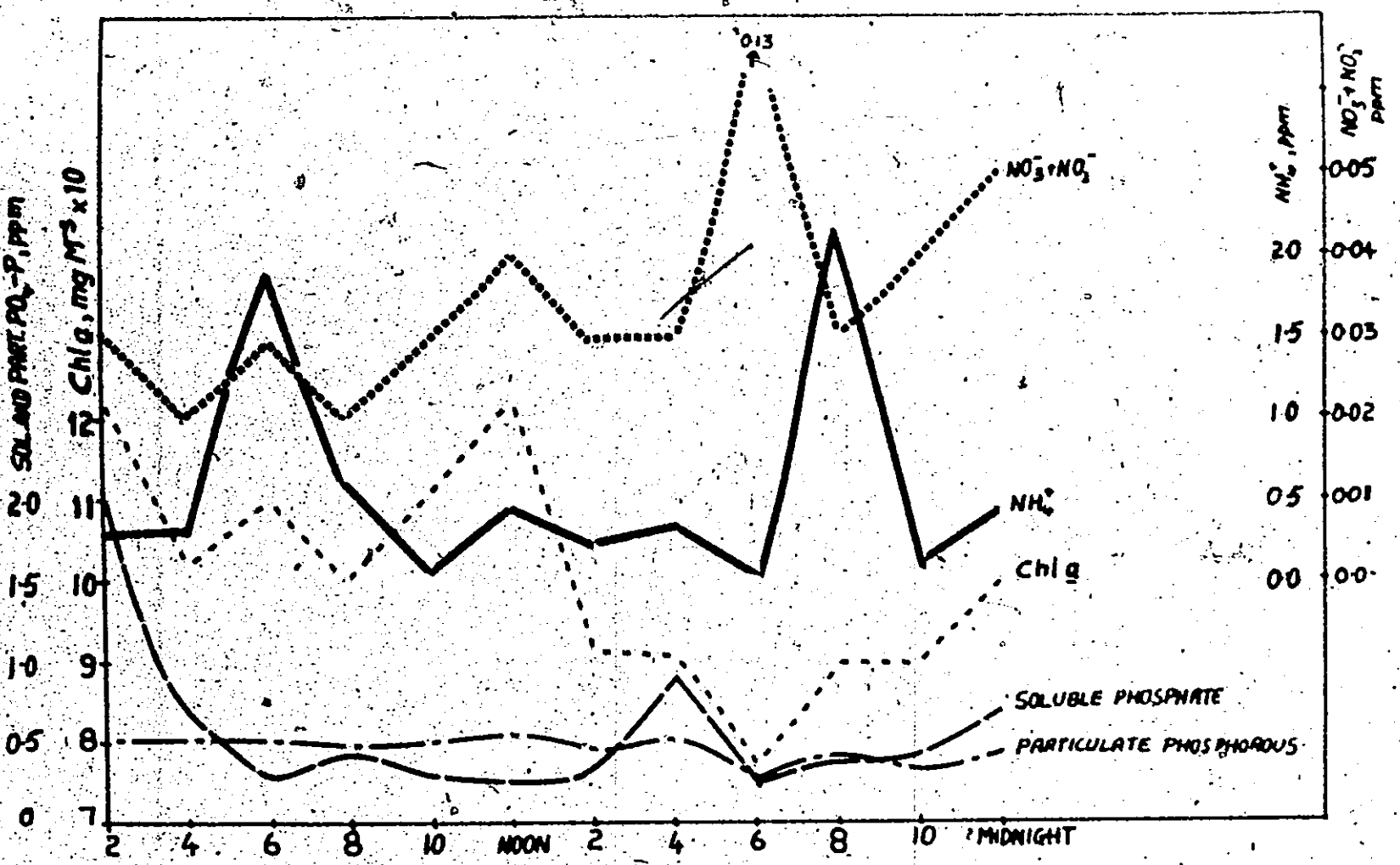


FIG. 22b Diurnal variations of chlorophyll, nitrate, ammonia, soluble and particulate phosphorous at station 12, on August 2, 1973.

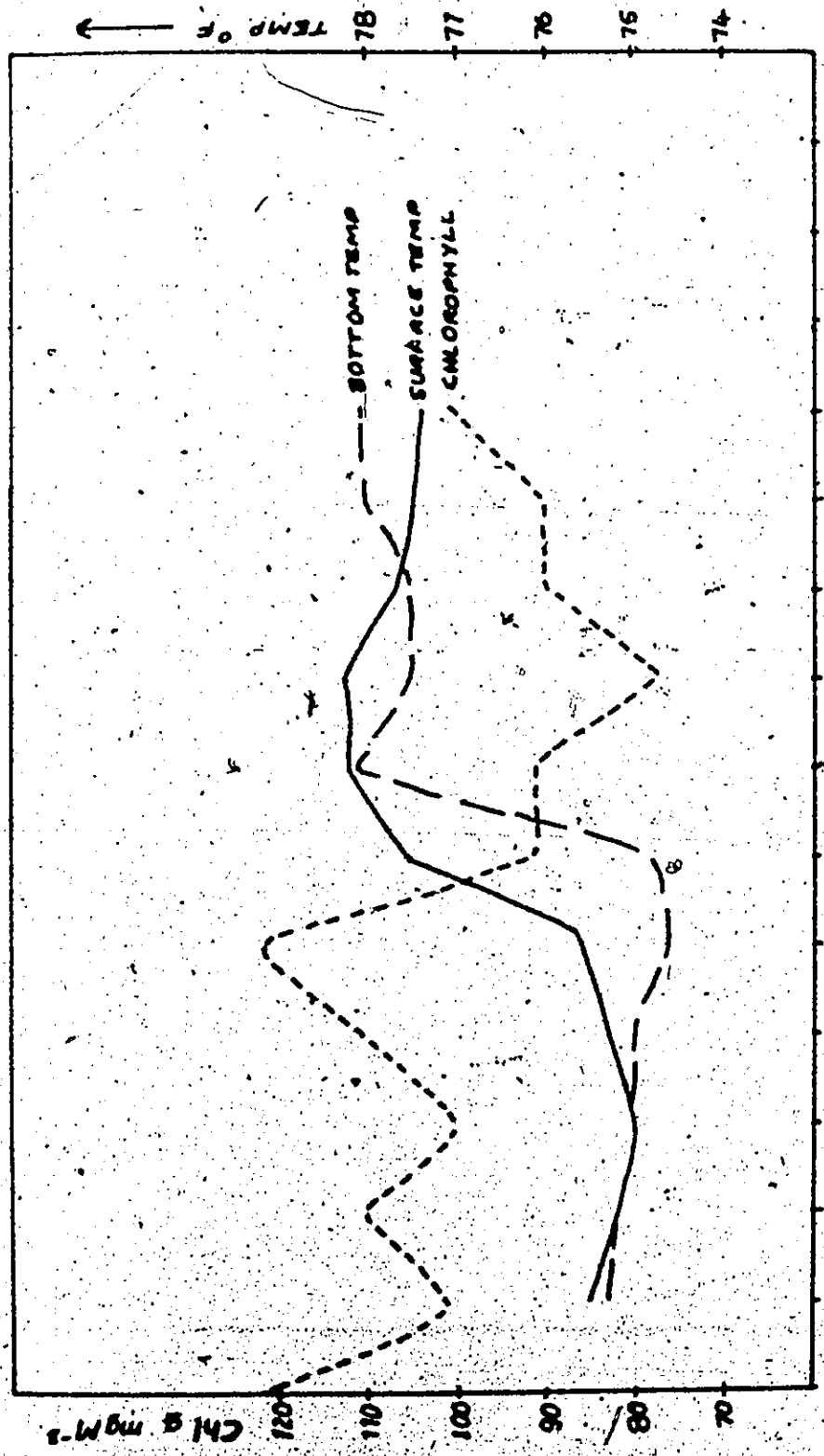


FIG 22c. Diurnal variations of chlorophyll, surface and bottom temperature at station 12 on August 2, 1973.

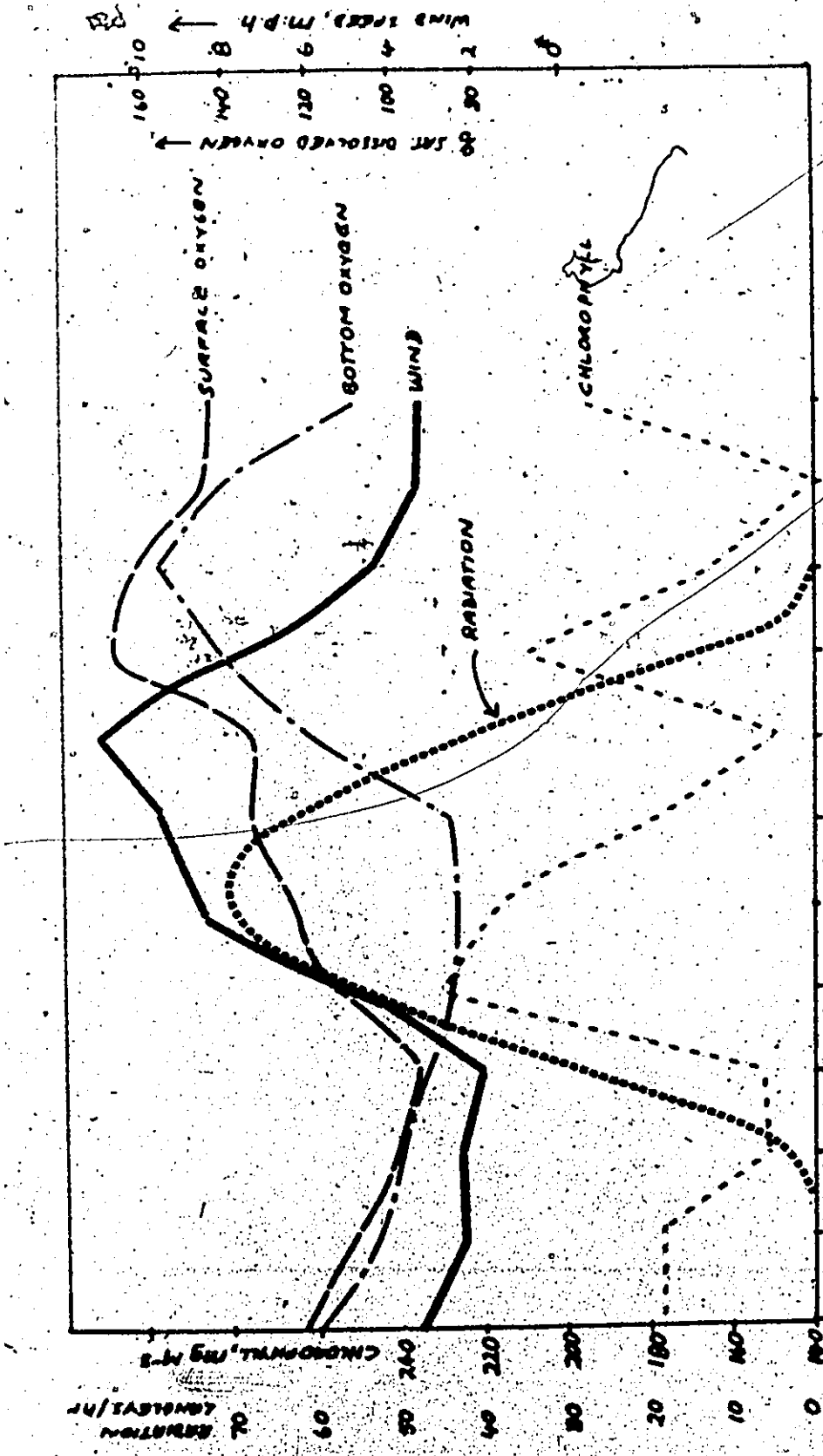


FIG.23a Diurnal variations of chlorophyll, solar radiation, wind speed, surface and bottom dissolved oxygen at station 12 on August 16, 1973

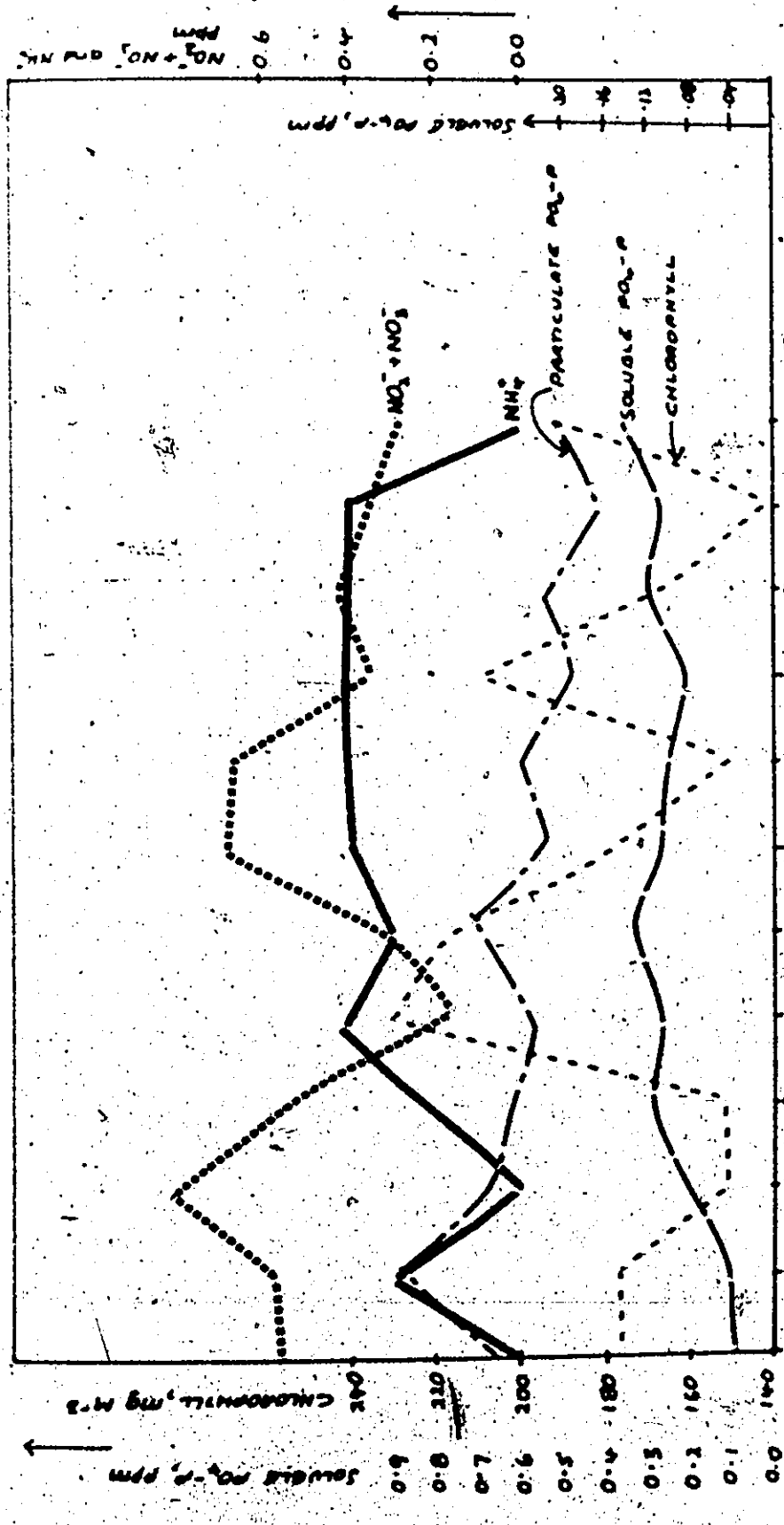


FIG.23b Diurnal variations of chlorophyll, nitrate, ammonia, soluble and particulate phosphorous at station 12 on August 16, 1973.

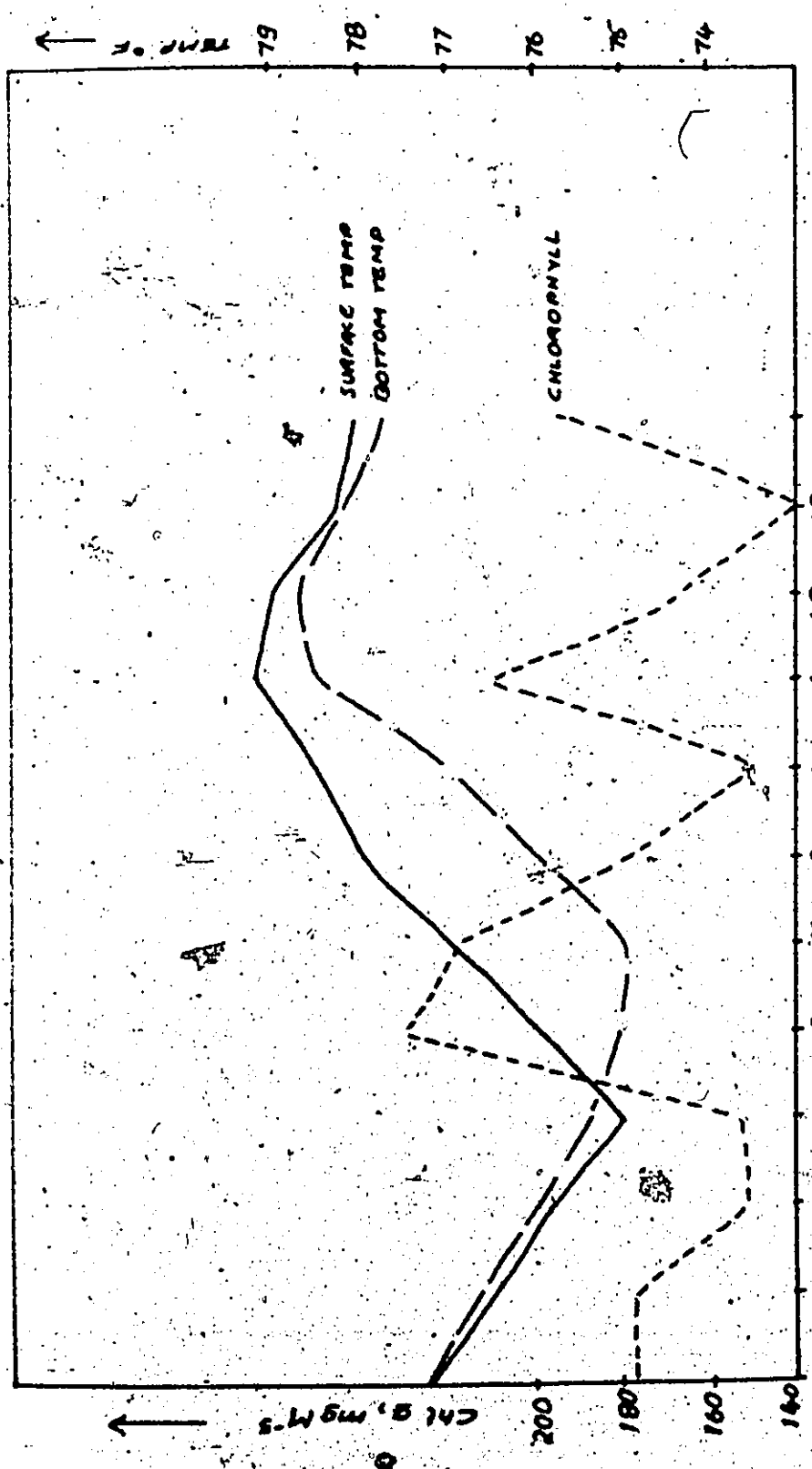


FIG. 23c Diurnal variations of chlorophyll, surface and bottom temperature at station 12 on August 16, 1973.

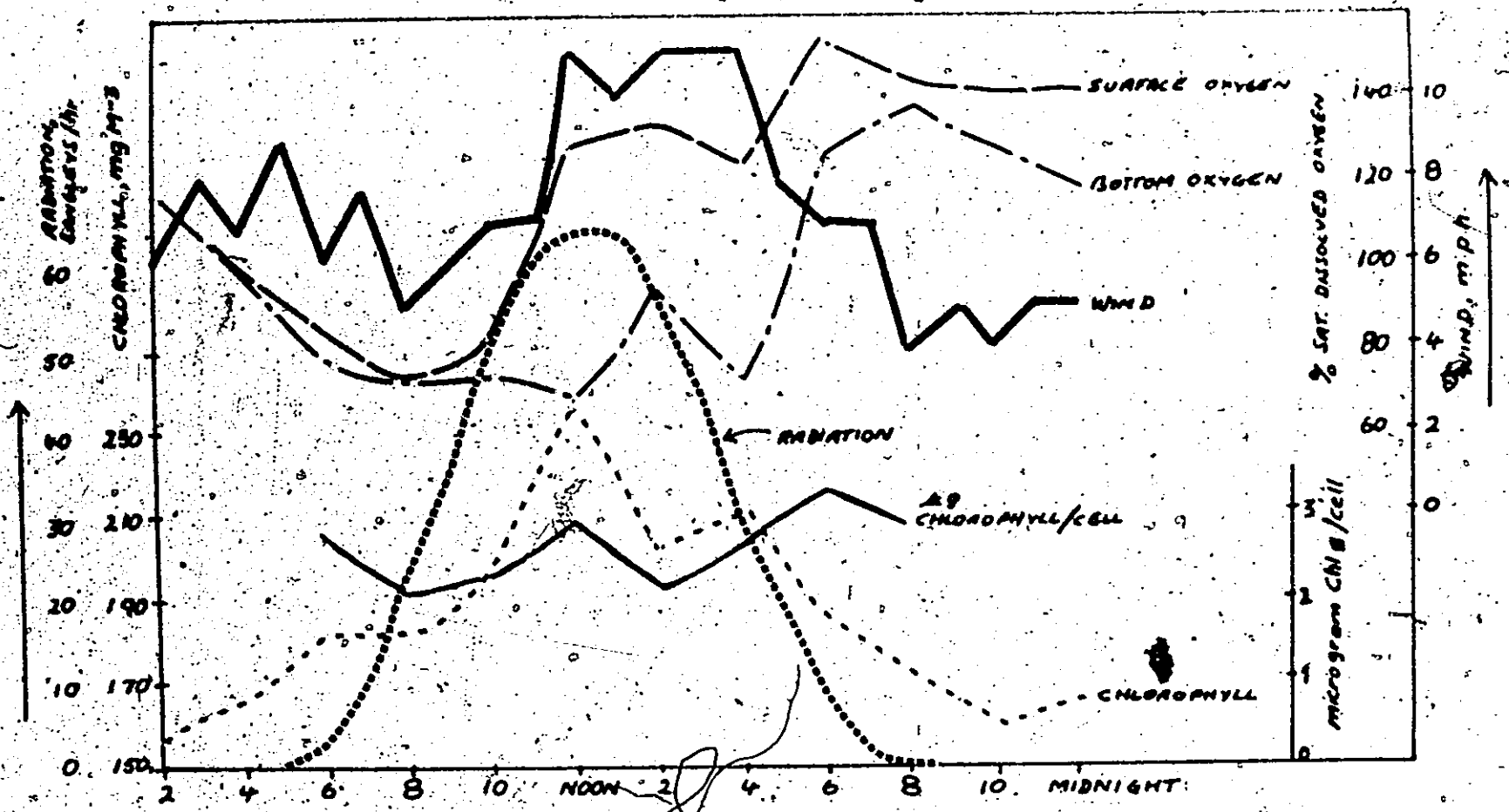


FIG.24a Diurnal variations of chlorophyll, solar radiation, wind speed, surface and bottom dissolved oxygen at station 12, August 30, 1973. Graph also shows changes in chlorophyll per cell between 6 a.m. and 8 p.m.

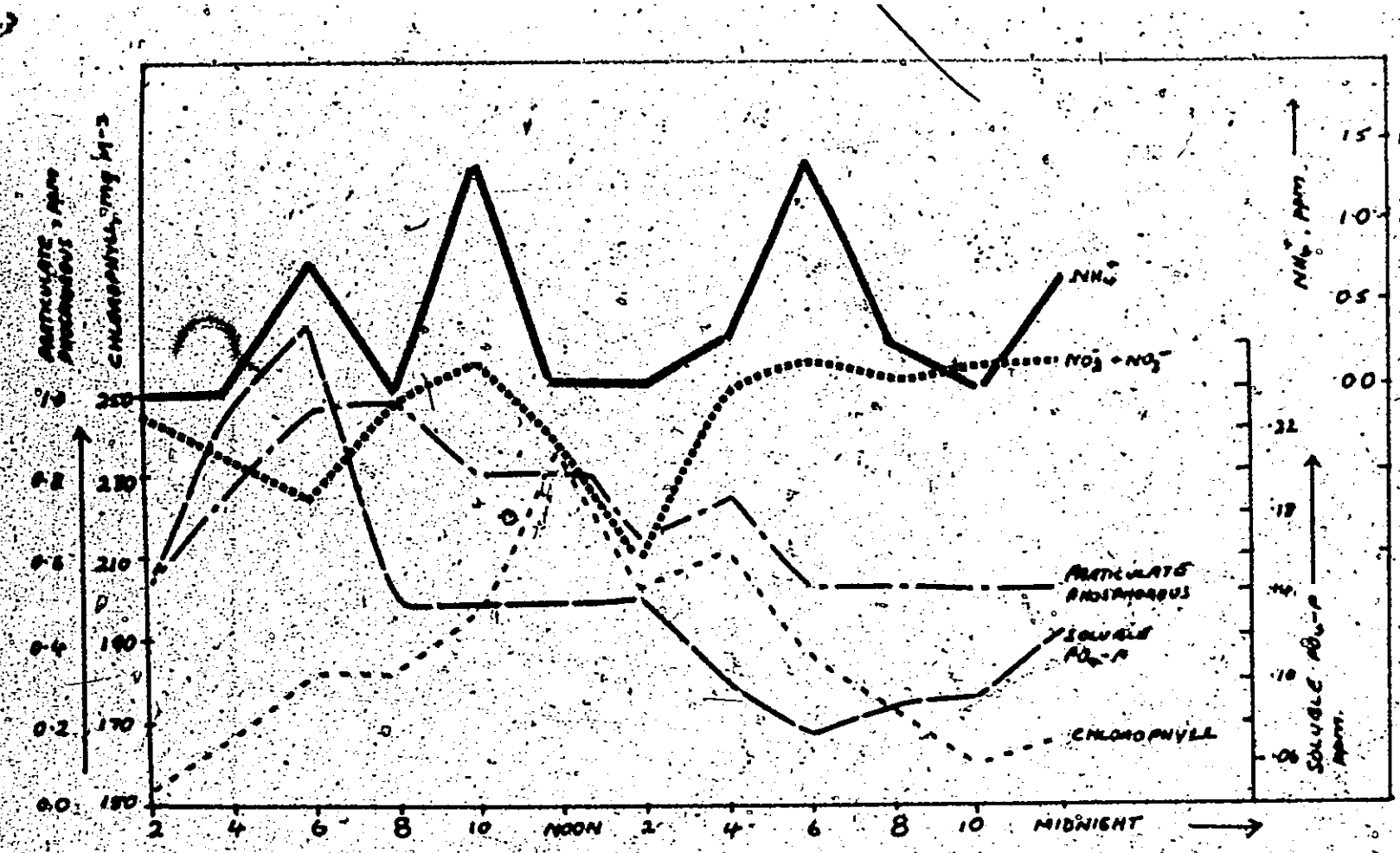


FIG. 24b Diurnal variations of chlorophyll, nitrate, ammonia, soluble and particulate phosphorous at station 12 on August 30, 1973.

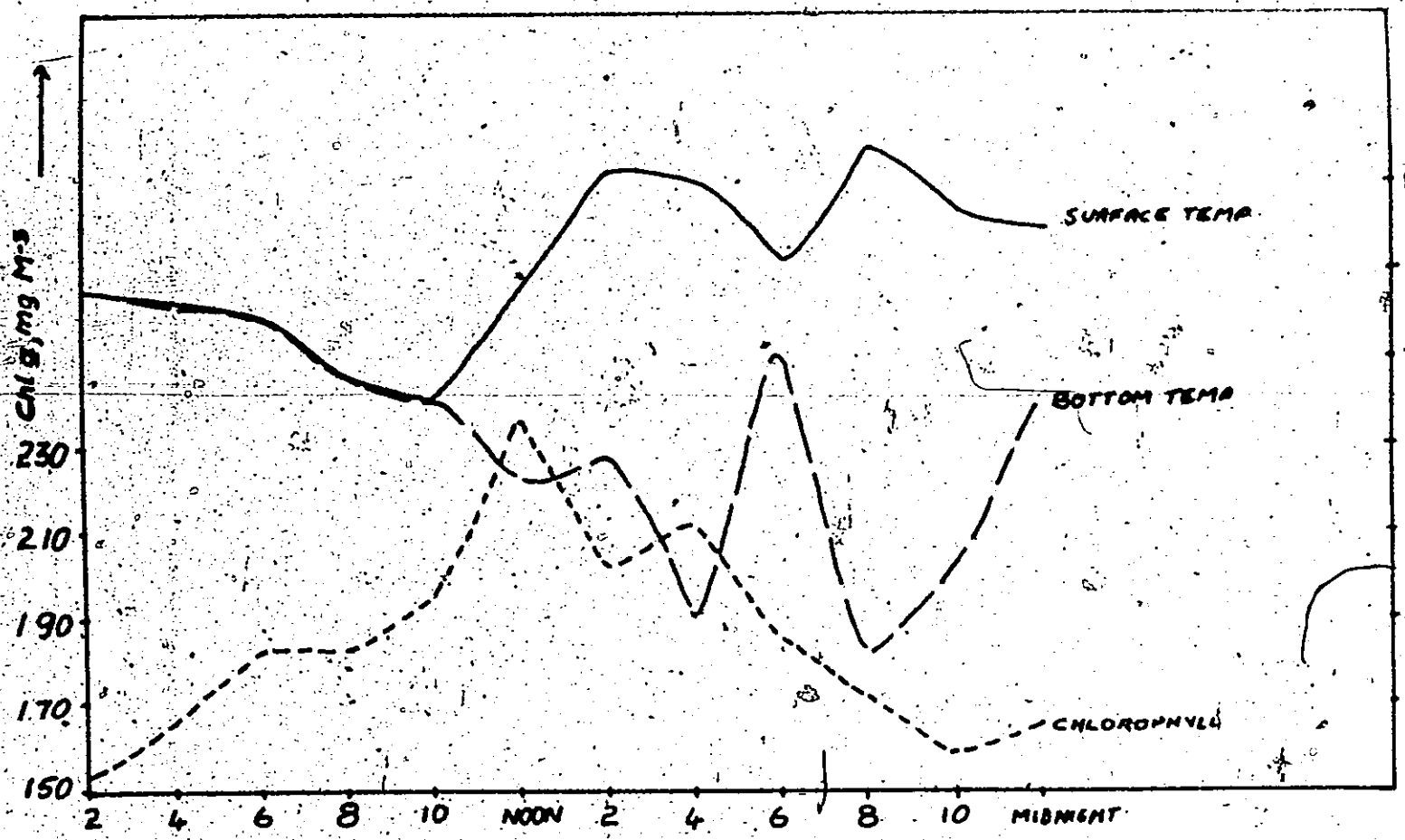


FIG. 24C Diurnal variations of chlorophyll, surface and bottom temperature at station 12 on August 30, 1973.

The physiological reaction has been identified as a change in chlorophyll per cell. This is the response to solar radiation variation which is reflected in photosynthetic activity (Shimada 1958, Yentsch and Lee 1966). If the 36% decrease in biomass actually represented a decrease in chlorophyll per cell, then it may be explainable in terms of the chlorophyll bleaching phenomonon recognized by some workers (Yentsch and Lee 1966, Glooschenko et al. 1972b). These workers argue that the phytoplankton at the water surface (during mid-day) respond to high light intensities by lowering their chlorophyll content to prevent photo-oxidation (destruction of the photosynthetic apparatus) (Yentsch and Lee 1966, Glooschenko et al. 1972b).

The observed decrease of biomass between noon and 6 p.m. may have also been the result of the possibility that the same volume of water was not sampled every time. The argument for chlorophyll bleaching would also have to be supported by doing a vertical sampling profile during the 24 hour period along with the cell counts and calculating the chlorophyll per cell. If the cells near the euphotic zone (just above the lower limit of photosynthetically useable light) did not show a decrease at the time when the decrease was observed at the surface, then the argument may be substantiated.

Present studies of the phytoplankton in the same area where the diurnals were done indicate that under wind

conditions of about 6 m.p.h. there was no observable vertical stratification of the cell population (Harris, personal communication). Figure 22 a shows the diurnal wind profile. At the time of the chlorophyll decrease, wind speeds were in excess of 6 m.p.h. and remained as such until midnight. Under these conditions, one would expect a well mixed water column evenly distributing the cells. On the basis of this assumption the chlorophyll variations may have been real.

However a significant negative correlation between wind speeds and chlorophyll ($r = -0.64$, $P = 0.02$) indicated that the wind might have circulated the cells down away from possible inhibiting light intensities (This possibility is supported by Haertel 1972), thus explaining the chlorophyll decrease.

Another point which may be discussed is that concerning the structure of the population. If a large percentage of the population was made up of motile cells then the cells may have migrated down away from inhibiting light intensities. The cells may have also been reacting positively to a change in the nutrient status of the water column. Ruttner (1973) made the point that in the event of a diminishing supply of nutrients at the water surface where algal activity is greatest, that the cells may move down to a level where the concentrations are greater.

Yentsch and Ryther (1957) and Glooschenko et al. (1972b) emphasized that the previous history of the phytoplankton is important to its light responses. Harris (1973) has shown that algae display marked hysteresis effects in their photosynthetic responses to increasing and decreasing light regimes - physiological adjustments which occurred in a matter of minutes. It is interesting to note that the daily total available solar radiation in langleys/day was much higher (450 ly/day) on August 2 than it was on August 1 (398 ly/day) and July 31 (203 ly/day). In other words, the phytoplankton had a previous history of lower solar radiation.

The chlorophyll variations during the second diurnal (fig. 23 a) were similar to the first diurnal except for a peak which occurred at 6 p.m. Chlorophyll showed its most marked decrease during the noon hours when the radiation was highest. The decrease in chlorophyll was 35% between 10 a.m. and 4 p.m. The previous light history of the population on this day was 476 ly/day and 471 ly/day on the two days before the diurnal was done, and 553 ly/day when the diurnal was done. Glooschenko (C.C.I.W., Burlington, personal communication) indicated that chlorophyll bleaching may be expected on days when the solar radiation is between 400 and 600 langleys/day. Bleaching conditions then were existent on August 16, 1973.

The third diurnal revealed a chlorophyll pattern which was much different from the first two (fig. 24 a).

Chlorophyll was distinctly higher during the day and lower during the early morning and night. If chlorophyll bleaching occurred on August 2 and 16, then this did not seem to be the case on August 30. In fact, there is general disagreement among limnologists concerning the time of day when chlorophyll achieves its highest concentration. Yentsch and Scagel (1958), Steeman-Neilsen and Jorgensen (1962) and Glooschenko (1971) reported highest *in situ* chlorophyll during the night, while Shimada (1958), Yentsch and Ryther (1957), McAllister (1963), and Lorenzen (1963) reported highest *in situ* values during the day. The situation on August 30 is in agreement with the latter authors.

In an attempt to determine qualitatively the change in chlorophyll per cell, cell counts were carefully done and plotted on fig. 24 a. The range of 2.06 to 3.33 micrograms chlorophyll per cell represented a difference of 37.8%. Figure 24 a shows that the lowest Chl/cell values occurred between 8 a.m. and 4 p.m. The data may be interpreted as follows: Chlorophyll synthesis occurred between 8 a.m. and 12 noon. At this time the solar radiation remained constant (greater than 60 ly/hr). This may have caused a decrease in chlorophyll synthesis between 12 noon and 2 p.m. with a subsequent increase in the afternoon. Glooschenko *et al.* (1972b) suggested that precursors of chlorophyll can build up during the daylight hours. This would explain chlorophyll synthesis during the afternoon and night. The interpretations indicate

that much caution is necessary in the discussion of causal factors affecting diurnal variations of chlorophyll.

3.2.b) Diurnal variation of other variables

Figures 22a,b,c; 23 a,b,c; and 24 a,b,c show the variations of the other parameters for all three diurnals. The temperature and dissolved oxygen profiles for all three days were similar. During the daylight there was stratification of temperature and dissolved oxygen. With increasing wind speeds the stratifications started to disappear during the nights. Positive and significant correlations were calculated between temperature and dissolved oxygen and chlorophyll and dissolved oxygen. This trend was similar to that discussed for station 4 except that the station 4 correlations were based on seasonal variations.

On the first diurnal soluble phosphate showed no particular variation. Particulate phosphate was positively correlated with chlorophyll ($r = 0.776$, $P = 0.01$). Secchi depth was negatively correlated with turbidity ($r = -0.875$, $P = 0.001$). Wind was positively correlated with turbidity ($r = 0.696$; $P = 0.01$) and negatively correlated with chlorophyll ($r = -0.64$, $P = 0.02$). The positive correlation with turbidity and negative correlation with biomass seemed to contradict each other because one would expect a positive relationship between chlorophyll

biomass) and turbidity. Turbidity is also a function of the particulate non-living material which was plentiful at station 12 (obvious from the brown colour of the water and easily observed when cell counts were done). The negative relationship between wind and biomass was previously interpreted to be due to the wind circulating the phytoplankton away from the surface where the samples were taken (Haertel 1972).

On the second diurnal, negative correlations were found between nitrate and chlorophyll ($r = -0.692$, $P = 0.01$), and chlorophyll with phosphate ($r = -0.623$, $P = 0.05$). These negative correlations meant that the nutrients were being actively utilized by the algae. Dissolved oxygen was positively correlated to temperature ($r = 0.95$, $P = 0.001$). This very significant correlation indicated that the photosynthetic activity of the algae was influenced by temperature changes (and was also a function of incident radiation).

On the third diurnal there was a positive correlation between wind and chlorophyll ($r = 0.83$, $P = 0.001$). Remember that wind had an opposite effect on chlorophyll on the first diurnal. The positive correlation can be interpreted as a wind induced circulation of the cells (algal) towards the water surface. The cell counts showed that the greatest cell concentration was found when the chlorophyll was highest (during the noon hour period).

c) Station 11 - Diurnal, August 30, 1973

A diurnal was done at station 11 mainly because the effects of wind were negligible compared to station 12. This station was located in a deep inlet flanked on both sides by a line of trees about 50 to 100 feet tall. Because of the tree cover on Sassafras and Princess points (fig. 1) the phytoplankton here received a smaller amount of direct sunlight than those at station 12.

Figures 25 a, b and c show the diurnal fluctuations of the parameters measured at station 11. Figure 25 a shows that chlorophyll experienced a sharp decrease between 10 a.m. and 12 noon and remained low until 4 p.m. Chlorophyll was highest during the night and early morning - a situation which contrasts with the third diurnal chlorophyll profile of station 12 (fig. 24 a). The chlorophyll profile at station 11 is in agreement with the in situ observations reported by others (Yentsch and Ryther 1957, Shimada 1958, McAllister 1963, Lorenzen 1963 and Glooschenko et al. 1972b).

Duplicate cell counts were done between 8 a.m. and 10 p.m. and the chlorophyll per cell was calculated and plotted on figure 25 a. The cell concentrations were relatively very stable during the 8 a.m. to 10 p.m. period. Chlorophyll per cell decreased by 35% between 10 a.m. and 2 p.m. and the decrease in chlorophyll was a 35% drop between 10 a.m. and 12 noon. These decreases occurred at a time

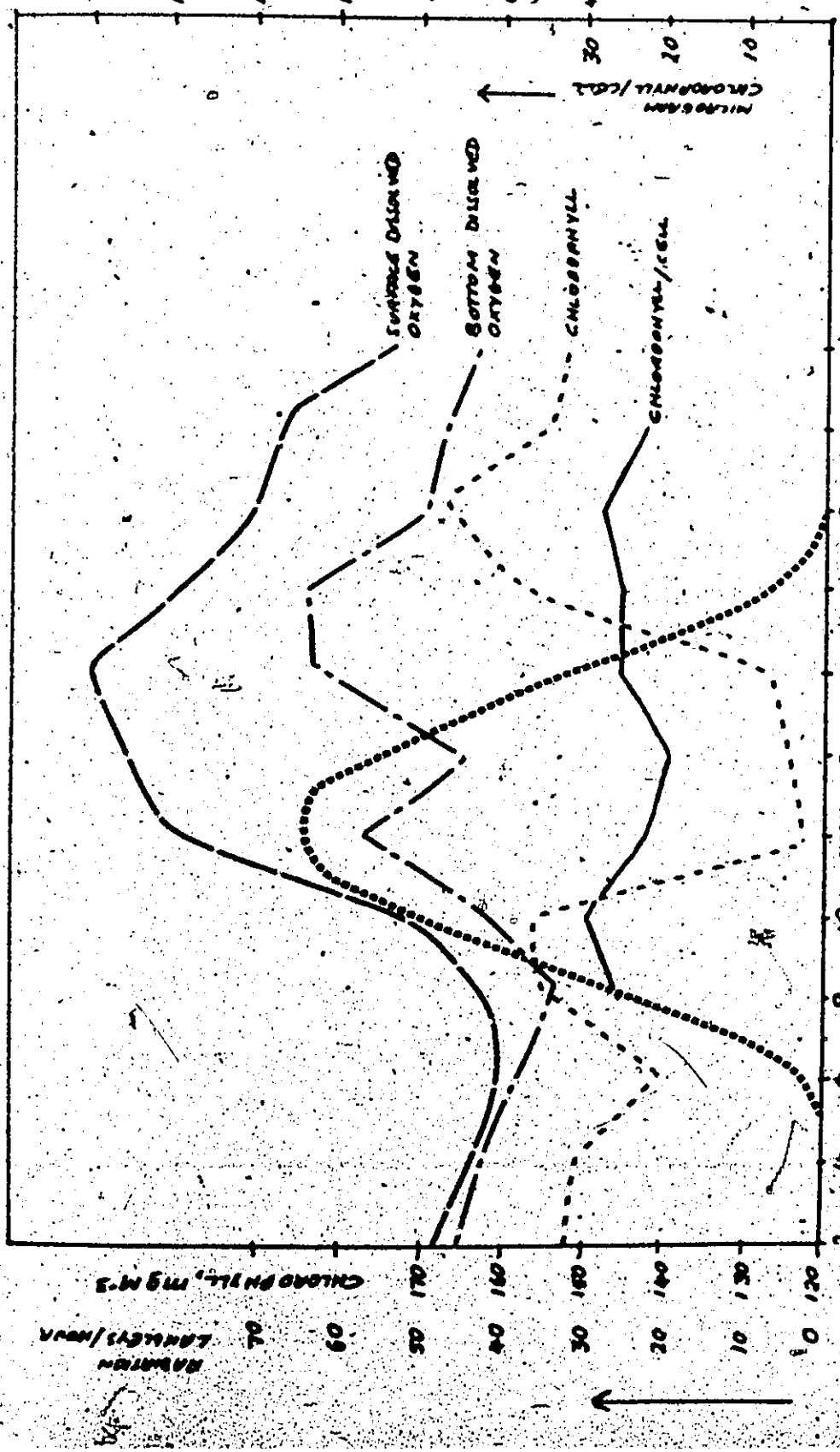


FIG.25a Diurnal variations chlorophyll, solar radiation, surface and bottom dissolved oxygen at station 11 on August 30, 1973. Graph also shows the changes in chlorophyll per cell between 8 a.m. and 10 p.m.

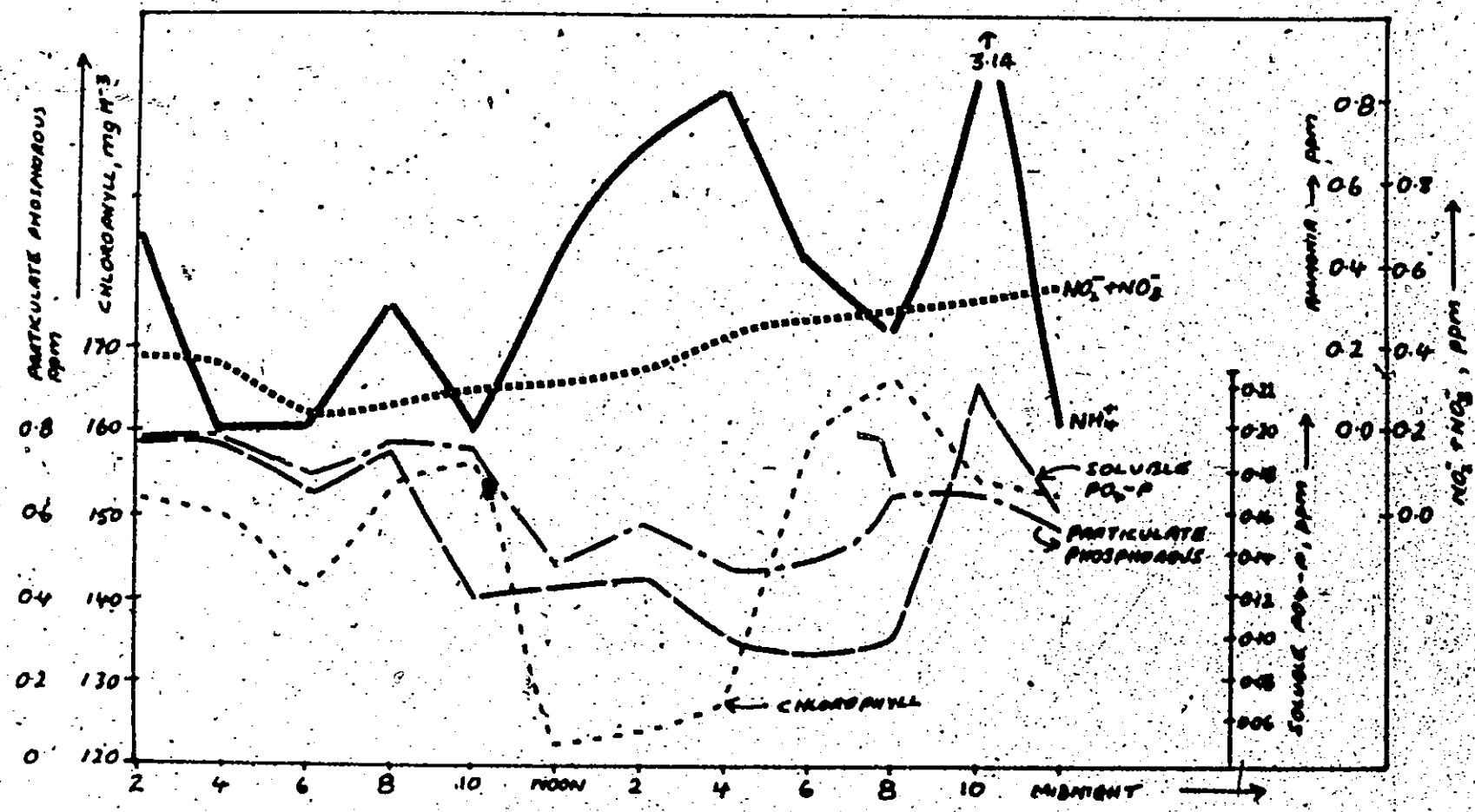


FIG 25b Diurnal variations of chlorophyll, nitrate, ammonia, soluble and particulate phosphorous at station 11 on August 30, 1973.

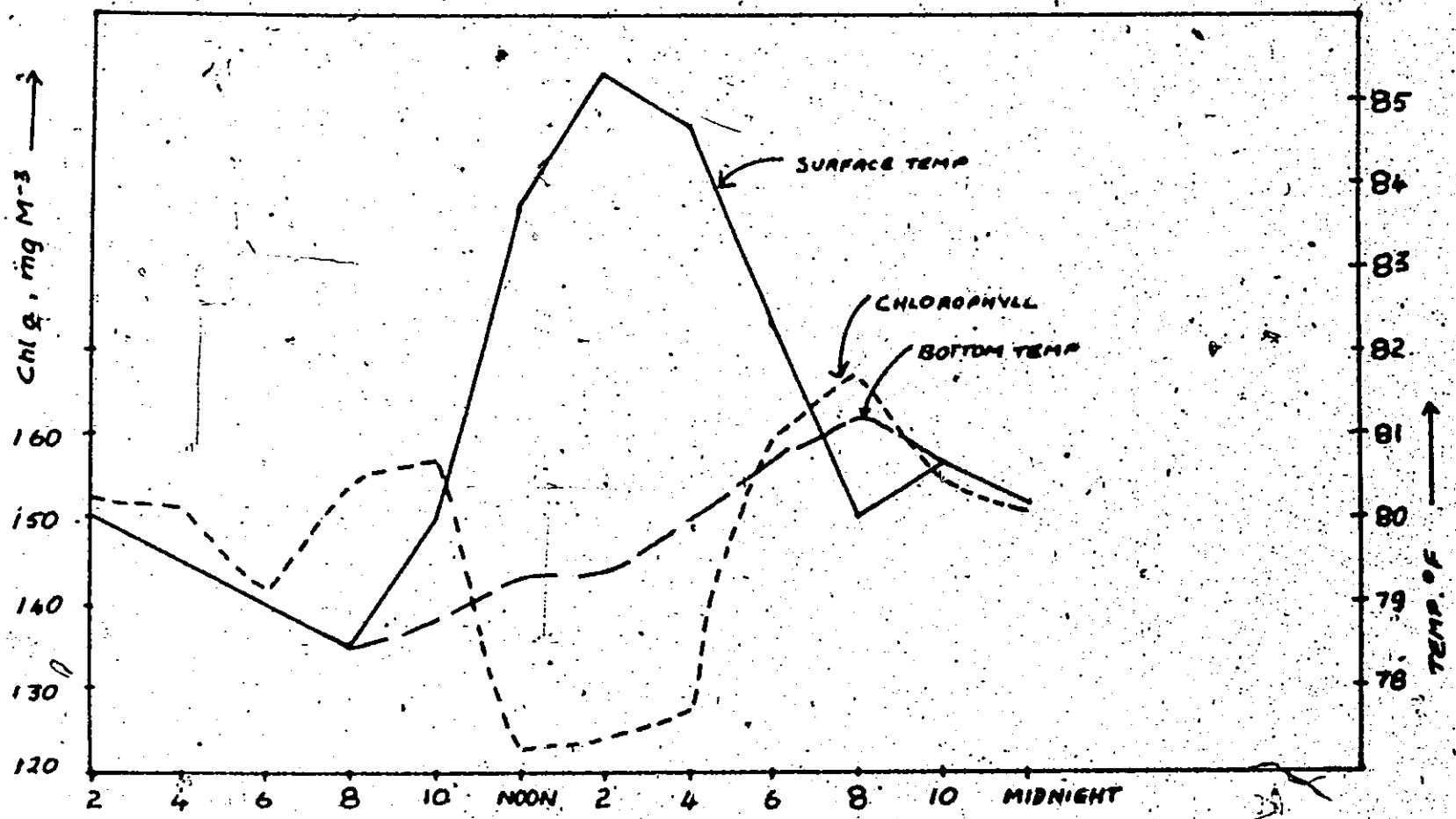


FIG.25c Diurnal variations of chlorophyll, surface and bottom temperature at station 11 on August 30, 1973.

when the solar radiation was greater than 60 langleys/hour (between 11 a.m. and 1 p.m.). After the period of high radiation chlorophyll per cell showed a gradual increase.

The argument presented above strongly suggests that chlorophyll bleaching occurred at station 11. The argument would be stronger if it were possible to do vertical profile throughout the diurnal period. However, this was quite impossible without disturbing a water column only three feet deep. The interpretations presented above are supported by the work of Glooschenko et al. (1972b).

A negative correlation was found between temperature and chlorophyll ($r = -0.754$, $P = 0.01$). The negative correlation was a by product of the solar radiation heating up the water and at the same time, adversely affecting the chlorophyll concentration. A comparison of fig. 25 a. and 25 c. shows the relationship between radiation and surface temperature. Note that the temperature curve lagged behind the radiation curve. This was due to the fact that time was required to heat up the water surface.

Temperature (surface) was significantly positively correlated to dissolved oxygen ($r = 0.921$, $P = 0.001$) and chlorophyll was negatively correlated to dissolved oxygen ($r = -0.747$, $P = 0.01$). The negative correlation is contradicting because one would expect a positive correlation, that is; the oxygen should be low when chlorophyll is low.

It is possible that even if bleaching did occur, the cells were still able to produce enough oxygen to account for the higher surface dissolved oxygen during the daylight hours. Glooschenko et al. (1972b), have shown that cells below the water surface do not experience chlorophyll bleaching. If this was the situation at station 11, then diffusion of oxygen to the surface may have occurred, thus explaining the high surface dissolved oxygen.

Figure 25 b. shows that nitrate showed no diurnal pattern while ammonia displayed a tendency towards an inverse relationship with chlorophyll (a significant correlation did not substantiate this). Soluble and particulate phosphate showed a slight tendency of lower concentrations during the day (fig. 25 b). The contribution of the nutrient levels to chlorophyll variations was therefore negligible.

The interpretation of diurnal studies has its difficulties. Both wind and solar radiation seemed to have their effects and no complete interpretation can be offered. The primary significance of the diurnal studies was the demonstration that chlorophyll varies during the course of one day. This variation emphasizes how critical the time of the day is when sampling a water body to study seasonal variations. This consistency of sampling time was strictly adhered to for all stations between June 1973

and May 1974 when this study was done. The diurnal variations of the water chemistry were not significant enough to affect an interpretation of seasonal changes.

(3.3) Periodicity of major algal groups and abundance relationships

This section will be devoted to the seasonal changes in the phytoplankton population structure in West Pond and station 12. Many workers have attempted to elucidate the ecological conditions which may contribute to the "wax and wane" or succession of algal groups or species in fresh and marine aquatic ecosystems (Macan 1970, Patrick 1963, Vince and Valiela 1973, Sparling and Nakewajko 1970, Munawar and Nauwerck 1971, Duthie and Sreenivasa 1971). In Coote's Paradise the phytoplankton did exhibit a marked periodicity between June 1973 and May 1974.

(3.3.a) Station 4 (West Pond)

Figure 7 shows the plot of the cell concentrations changes which occurred in West Pond between June 1973, and May 1974. The graph clearly shows that there was an extended and relatively constant cell population during the summer, a decrease in the fall and winter, and a subsequent increase in the spring. Table 1 gives the average seasonal cell concentrations. Between June and October 1973, average total cell numbers were greater than 3.0×10^5 cells/ml,

with a range of 1.987×10^5 to 4.6×10^5 cells per ml. These cell concentrations compare to 0.024×10^5 cells/ml in a productive inshore area of Lake Ontario (Sparling and Nalewajko 1970), 0.048×10^5 cells/ml for Lake Michigan (Schelske and Stoermer 1971), and 6.47×10^5 cells per ml for highly polluted Lake Hendricks, South Dakota (Haertel 1972). With regard to natural cell populations, the West Pond cell concentrations were typical of eutrophic aquatic systems.

Maloney (1970), achieved cell concentrations of 10^5 cells/ml in nutrient enrichment experiments when the cells were treated with sewage effluent. Wheater (1972) and Vinco and Valiela (1973) have demonstrated that sewage effluent was an excellent growth stimulator for phytoplankton. It is therefore obvious that the Dundas Municipal Sewage works positively contributed to the high cell concentrations found in West Pond. The plant discharges about two million gallons of secondary treated sewage daily into the Desjardins Canal which feeds into West Pond.

On the average, changes in cell numbers followed changes in chlorophyll. This was expected because biomass expressed as chlorophyll is a function of the cell concentration. The transition from the summer to the fall and from winter to spring (fig. 7) was interpretable using Round's (1971) light/temperature cardinal points. The interpretation would be identical to that presented for the seasonal biomass

changes which occurred in West Pond. Significant correlations were calculated between chlorophyll and cell concentration for the periods June to November 1973 ($r = 0.599$, $P = 0.02$), and January to May 1974 ($r = 0.990$; $P = 0.001$). Correlations may not always be as significant as those reported here because taxonomists (Munawar and Nauwerck 1971) feel that the use of cell volume rather than cell numbers will give more accurate comparisons. The rational behind the use of the cell volume is that it gives a more accurate picture of the species importance in a population. For example, a few members of a large species (Scenedesmus quadricauda) may have the same volume of large number of smaller species (Chroococcus sp.)

(3.3.b) The composition of the population in West Pond

It was difficult to identify all the species which made up the summer algal population in West Pond. However, it was possible to establish the population structure in terms of the four major algal groups and their representative genera. Table 7 gives a statistical summary of the four phyla viz., Chlorophyta (green algae), Bacillariophyta (Diatoms), Cyanophyta (blue-green algae), and Euglenophyta (euglenoids). The figures showed that the green algae dominated the population throughout the summer. The blue-greens, euglenoids and the diatoms ranked second, third and fourth respectively. In terms of frequency of occurrence per sampling day, the

TABLE 7

TABLE OF THE MAJOR ALGAL GROUPS AT STATION 4
FOR THE SUMMER OF 1973 (JUNE - SEPT.)

GROUP	AVERAGE DAILY % OF TOTAL POP.	FREQUENCY*	NO. OF GENERA	CELL NO. RANGE X 10^3	AVERAGE NO. OF CELLS PER ML/DAY
Chlorophyta	92.8	100	11	82.4-398.8	255,908
Euglenophyta	1.95	92.8	4	000-26.0	5,371
Bacillariophyta	1.15	85.0	3	000-26.9	3,167
Cyanophyta	4.10	78.0	6	000-40.5	11,258

N. B. Cell range is in cells/ml.

* For the sampling period.

situation was quite different. The decreasing order was greens, euglenoids, diatoms and blue-greens. Regarding the cell concentration per day, the figures may be misleading because of the cell volume problem discussed earlier. However, assessing the importance of each major group on the basis of the data presented here would be speculative because of the physiological differences of the species involved. This study cannot deal with such a problem.

The interesting feature of the Chlorophyta was that one species Scenedesmus quadricauda comprised 69 to 94 percent of the population between June and November 1973, fig. 26). The observed Chlorophyta dominance can be explained in terms of high phosphate levels, the low N/P ratio of West Pond, and the fact that the water was contaminated with sewage effluent. Pearsall (1932) and Ryther (1954) confirmed that green algae are the persistent group in waters characterized by low N/P ratios. Bush and Welch (1972), reported the dominance of Scenedesmus quadricauda in an area of Moses Lake where the N/P ratio was always low.

The low N/P ratio of West Pond was due to the high phosphate concentrations (.5 to 25 ppm) and low nitrate concentrations (0.0 to 2.74 ppm). Rhode (1948), and Soeder et al. (1971) demonstrated that Chlorophyta have a marked tolerance to soluble phosphorous concentrations greater than

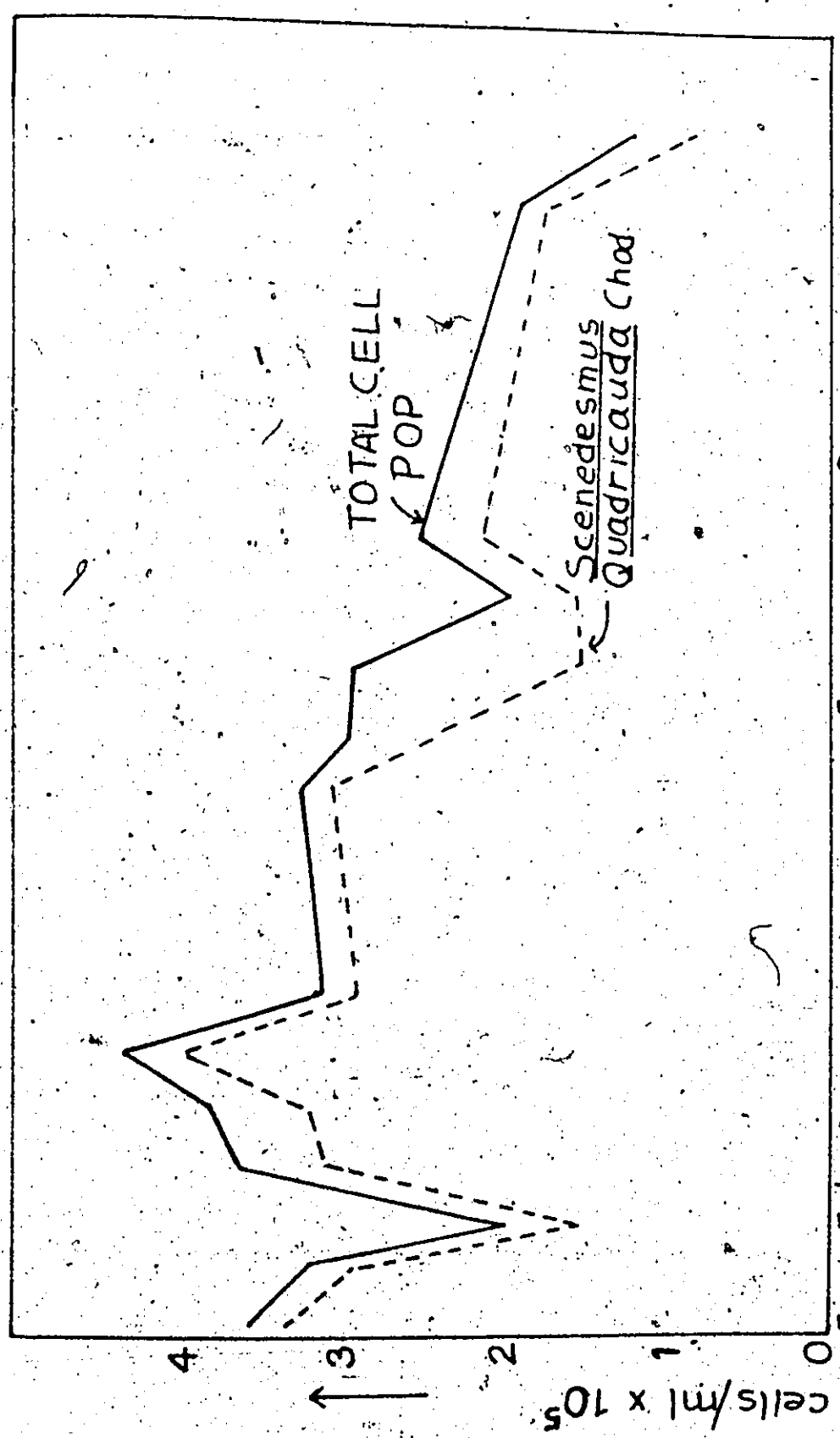


FIG.26 (See text)

ug/l. Moreover, Scenedesmus quadricauda ranked among the top five species of algae listed by Palmer (1969) as indicators of highly polluted aquatic systems.

Table 8 lists the genera which occurred in West Pond during the summer and early fall. Many of these were among Palmer's list of polluted waters indicator genera, including Chlamydomonas, Ankistrodesmus, Nitzschia, Navicula, Aphanocapsa and Merismopedia. The Euglenophyta types listed in table 8 were among the top 20 of the 60 genera which Palmer reported namely, Euglena, Trachleomonas, Phacus, and Lepocinclis. The Euglenophyta found in West Pond were also reported by Munawar (1970, 1972) to be typical in sewage ponds in India.

The use of algae as pollution indicators of fresh water systems has its disadvantages. Archibald (1972), reported that diatom species regarded as indicators of oligotrophic (unpolluted) waters can also occur in eutrophic systems. Patrick (1959) reported that it is much more difficult to make precise statements about genera than about species, and that only few generalizations can be made about the type of ecological conditions in which some genera find their best development. In spite of this, the population in West Pond contained well known pollution indicator species and genera.

In the light of the existing literature (Echlin 1966, Pogg 1969, Haertel 1972, Shapiro 1973, Hutchinson

TABLE 8

GENERA IDENTIFIED AT STATION 4 DURING THE SUMMER OF '73

Chlorophyta	Cyanophyta	Euglenophyta	Bacillariophyta
Scenedesmus	Merismeropedia	Euglena	Melosira
Chlamydomonas	Chroococcus	Phacus	Cyclotella
Actinastrum	Anabaena	Trachelomonas	Nitzschia
Tetraedron	Lyngbya	Lepoclinclis	Navicula
Ankistrodesmus	Dactylococcus		Asterionella
Chlorogonium	Aphanocapsa		
Kirchneriella			
Carteria			
Actinastrum			
Chlorella			

1973), it may be argued that blue-green algae should have been dominant in West Pond during the summer. The argument used is that the blue-green algae have a competitive advantage over other types when nutrient supplies become exhausted during the summer. This did not occur in West Pond. Reasons have already been given which explained the Chlorophyta dominance in West Pond. Blue-green algae have been reported to have a low soluble phosphorous requirement and some types (Anabaena flos-aquae (Lyng.) Breb.) can fix atmospheric nitrogen (Fogg 1969). Soluble phosphate concentrations never fell below 0.5 ppm.

(3.3.c) Periodicity of the major algal groups in West Pond January 1974 - May 1974

Figure 27 shows the percent composition of the major algal groups between January and May 1974. In oligotrophic freshwater systems, one would expect to find a dominant diatom population during the colder seasons (Munawar and Hauwerck 1971, Moss 1972). The West Pond data showed that this was not the case. Diatoms contributed to less than 5% of the population between January and March 1974 except on January 23 and February 2 when the percentage composition was 45 and 8.3%, respectively. Between March 27 and April 5, a short diatom pulse was evident. The population was made up of both centric (Centrales) and pennate (Pennales) types including Cyclotella sp., Melosira

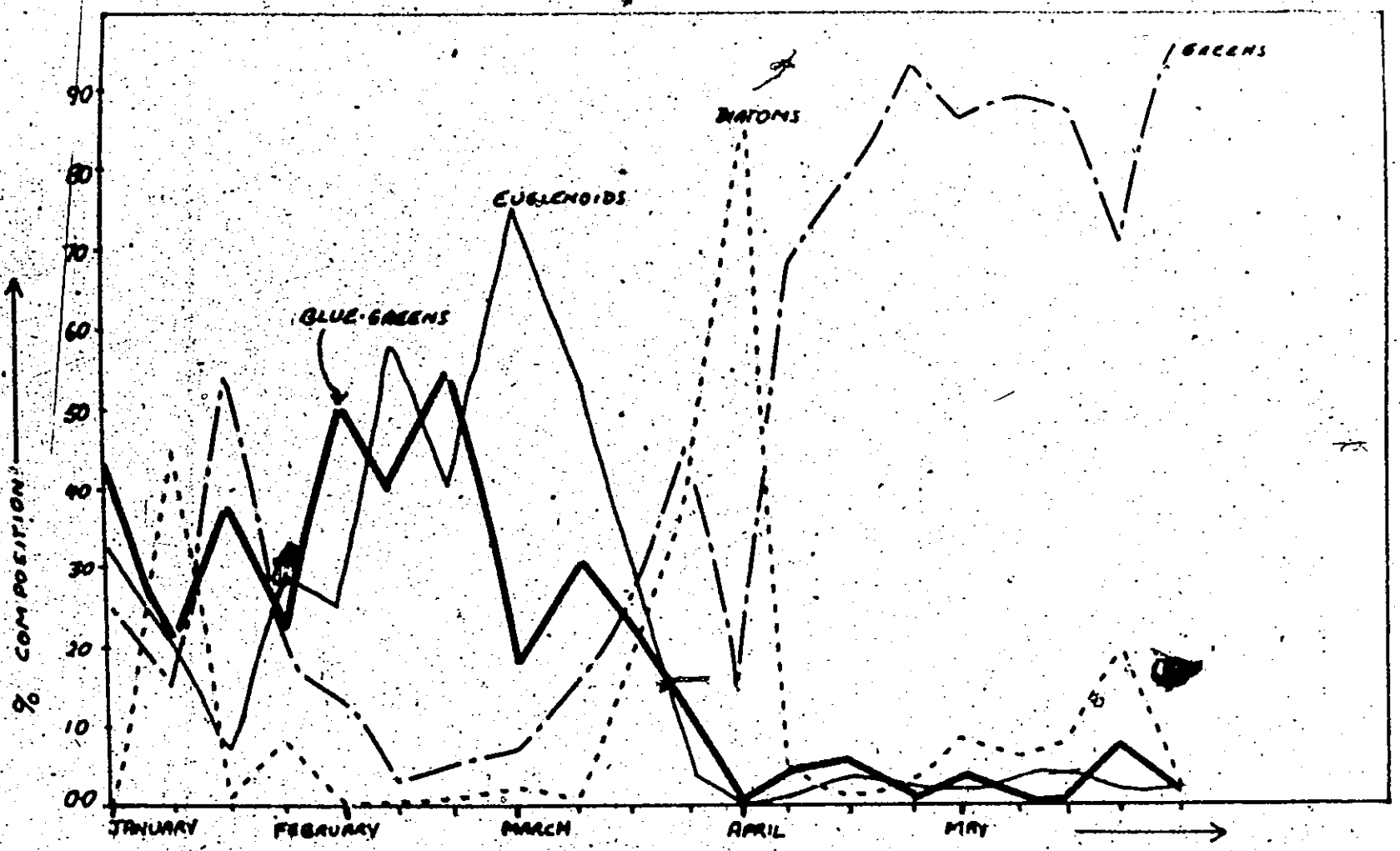


FIG.27 Diagram showing the percent composition of the four major algal groups at station 4 between January 15, 1974 and May 31, 1974.

sp., Nitzschia sp., Navicula radiosa Kutz., Achnanthes sp. and Melidium sp. For the remainder of the period, diatoms formed a negligible part of the population (fig. 27).

During the winter, the dominant types were the Euglenophyta and the Cyanophyta, except in early January when the Chlorophyta averaged 32% of the population. Scenedesmus sp. did not rank as an important species during this time. On January 30 a green algal pulse was recorded which was dominated by Chlamydomonas sp. The blue-green algae was dominated by filamentous species including the genera, Oscillatoria and Aphanizomenon. The euglenoids were mostly Euglena sp. with Euglena elastica Prescott dominating this group.

Figure 28 shows the actual cell concentration relationships among the four phyla during the period January 15 and March 7, 1974. The question that was asked at this time was, why were euglenoids and blue-greens dominant during the winter? There was some evidence which might explain the eulenoid persistence. During the winter, the water in West Pond was clear enough to display a thick, slimy, green mat which was stretched over the sediment surface. A similar sight was afforded in the Desjardins Canal. A sample of the green, slimy material was scooped up and returned to the laboratory for examination. Under the inverted microscope, the sample revealed the presence of thickly aggregated globular masses of spherically

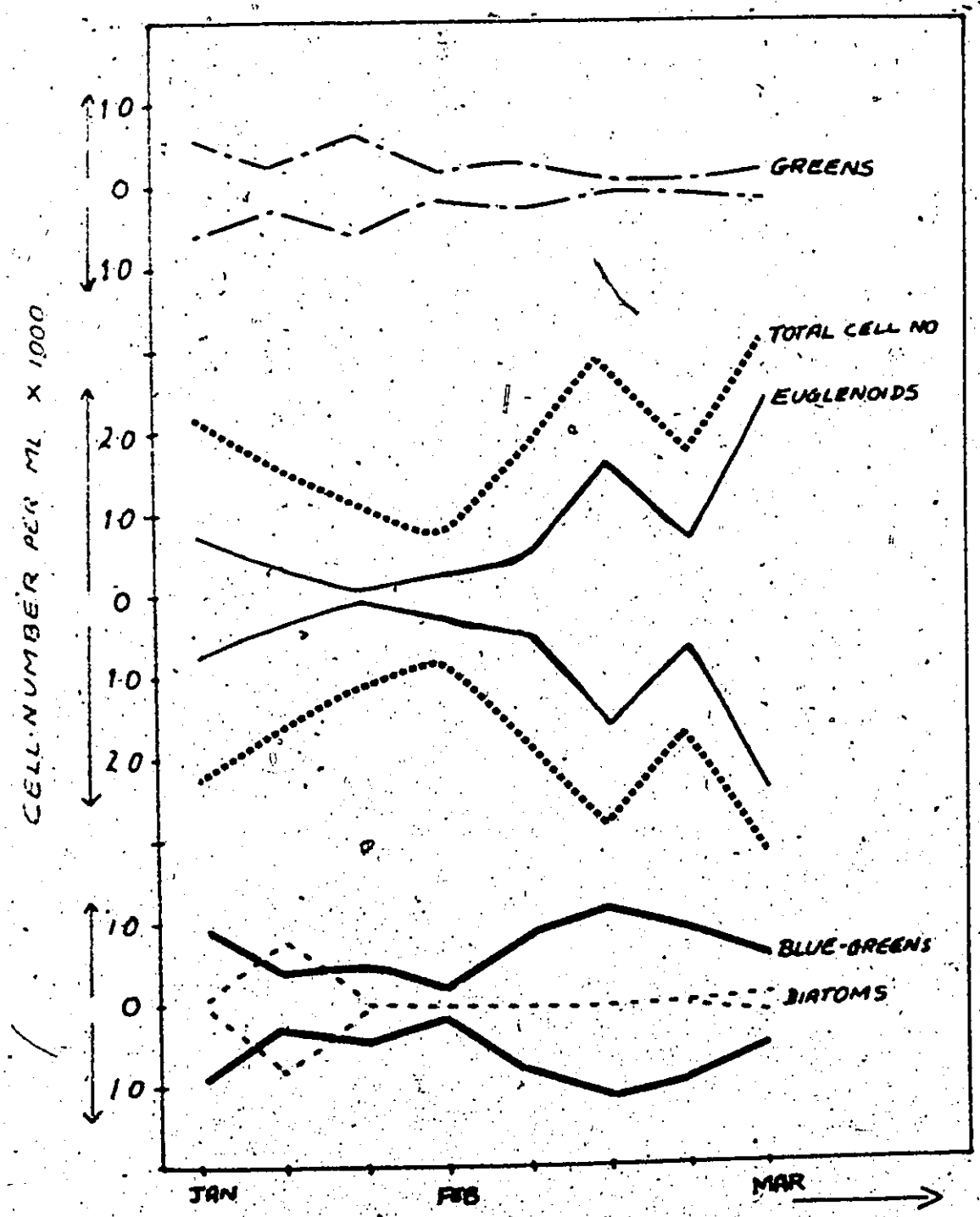


FIG.28 **Winter periodicity of the cell concentration of the four major algal groups at station 4 during the winter of 1974.**

shaped cells. As the sample warmed up to room temperature the spheres started to separate from each other, at the same time transforming themselves to the well known shape of Euglena elastica. Since the water in the canal was always warmer than West Pond's it is very conceivable that cells were separated from the canal's sediment surface and edges and were subsequently seeded into West Pond. A vertical temperature profile in West Pond revealed that the water just above the sediment surface was at least 3° F warmer than at the surface. It is also very conceivable that wind could have been effective in dislodging cells from the sediment surface. The occurence of floods during this time may also have disturbed the sediment. The data and observations cannot present a similar argument for the occurence of the other co-dominant group - the blue-green algae.

During the winter, the cell concentration range was 1,560 to 12,600 cells/ml. This range was much smaller than those of the summer and fall (table 1). However, the winter cell concentration can be considered high when compared to 84 to 261 cells/ml for Lake Ontario (Nalewajko 1966) and 1000 cells/ml for Gull Lake, Michigan (Moss 1972) during the winter. In fact, the winter cell concentration in West Pond was higher than the summer cell concentration range of Lake Ontario which was 598 to 2,646 cells/ml (Nalewjko 1966).

As spring approached, the green algae began to account for an increasingly greater percentage of the population (fig. 27). Between March and May 31, green algae ranged between 47 to 95.4% of the total cell population. Concurrent with the Chlorophyta increase Scenedesmus quadricauda began to occupy the position it enjoyed during the summer of 1973. Between April and May 31, this species accounted for 75 to 89.5% of the total cell population. During the green algal increase, the other three phyla consistently made up a decreasing percentage of the population. The spring cell concentration range for the whole population was 3,000 to 158,000 cells/ml - with a tendency to increase as the summer approached.

The important contribution of this part of the discussion is that distinct trends were observed in the structural changes of the phytoplankton population as the seasons progressed. The literature is scarce with information about phytoplankton succession in polluted marshes (Round 1971).

(3.3.d) Algal periodicity at station 12

The overall effect of seasonal environmental changes on the total phytoplankton population at station 12 was similar to West Pond (fig. 29). However, the population structure was definitely different. Scenedesmus quadricauda did not occupy a comparable position as that observed in

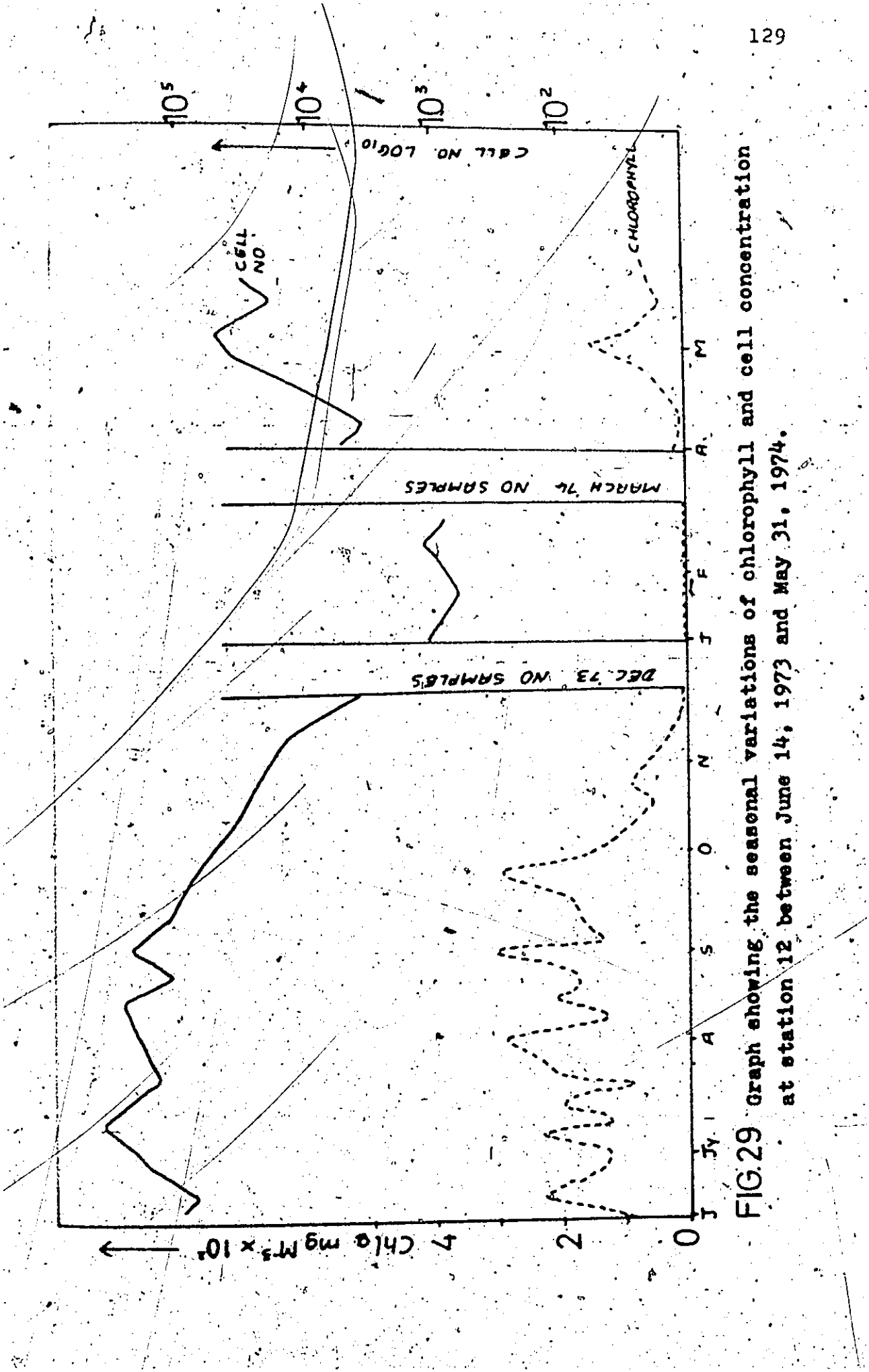


FIG.29 Graph showing the seasonal variations of chlorophyll and cell concentration at station 12 between June 14, 1973 and May 31, 1974.

West Pond. Rather, the dominant group was the Chlorophyta during the summer. Interestingly, the green algal cell concentration remained relatively constant throughout the summer, and appeared to be co-dominant with the blue-green algae (fig. 30). Between June and September 1973, the cell concentration ranged between 0.92×10^5 to 4.16×10^5 cells/ml with the highest numbers recorded in mid-summer. After September 20, the blue-green algae experienced a dramatic decrease accounting for a negligible portion of the algal population.

The persistent summer bloom of blue-green algae which accounted for more than 60% of the population may have been the result of lower phosphate concentrations, higher N/P ratios (table 1) and the decreased influence of the sewage effluent. In contrasts to the station 12 situation, West Pond was characterized by higher phosphate, lower N/P ratios and was more influenced by the sewage effluent. The West Pond population was dominated solely by Chlorophyta.

Table 9 summarizes the list of the identifiable genera and species which were found at station 12 during the study period. The blue-green population consisted primarily of filamentous species including, Oscillatoria sp. Gleotricha sp., Anabaena helicoida, Bernard, Nostoc sp.,

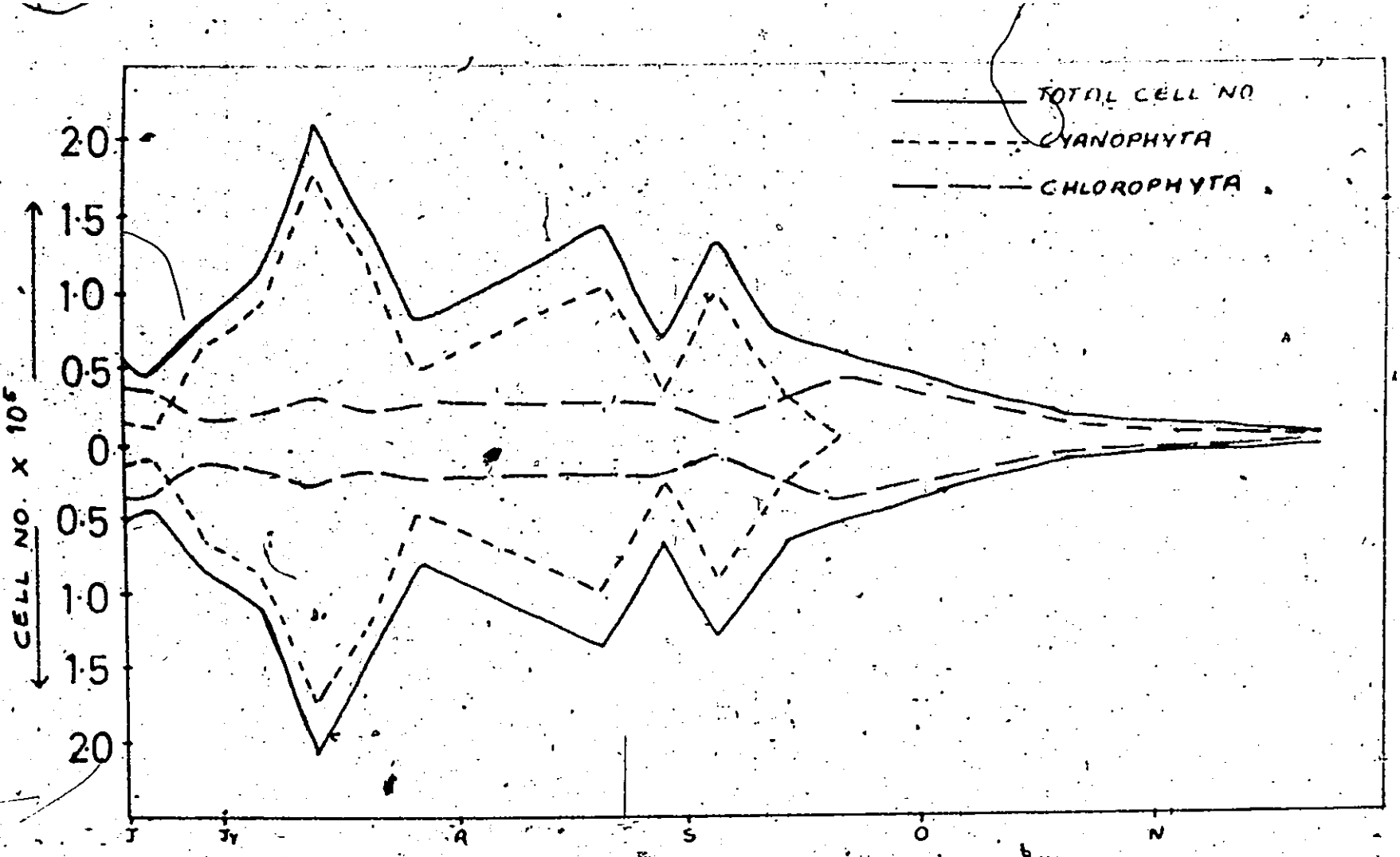


FIG.30 Periodicity of the total cell population compared to the periodicities of the blue-green algae and green algae between June 1973 and November 1973.(Station 12).

TABLE 9

GENERA AND SPECIES LIST FOR STATION 12

Chlorophyta

[illegible]rodesmus sp.
[illegible]trum sp.
[illegible]rococcus sp.
[illegible]mydomonas sp.
[illegible]rella sp.
[illegible]rococcus sp.
[illegible]sterium [illegible]tum Ehrenberg.
[illegible]sterium sp.
[illegible]steriopsis [illegible]lsima (Lemm.)
Closteriopsis sp.
Coelastrum sp.
Cosmarium sp.
Franchia droescheri (Lemm.)
Kirchneriella subsolitaria G.S. West
Micractinium quadrisetum (Lemm.)
Oocystis sp.
Pediastrum sp.
Selenastrum sp.
Scenedesmus quadricauda (Chod.)
S. acuminatus (Lag.) Chodat
Scenedesmus sp.
Tetradesmus sp.
Tetraedron lunala (Reinsch) Wille
Tetraedron sp.
Trochiscia aspera (Reinsch) Hansgirg

Euglenoids

Euglena elastica (Prescott)
Euglena sp.
Lepocinclis sp.
Phacus sp.
Trachleomonas sp.

Cyanophyta

Aphanizomenon sp.
Aphanocapsa sp.
Anabaena helicoida (Bernard)
Anabaena sp.
Chroococcus sp.
Gleotricha sp.
Merismopedia Trolleri (Backmann)
Merismopedia sp.
Oscillatoria limnetica (Lemm.)
Oscillatoria sp.
Nostoc sp.

Diatoms and Brown Algae

Achnanthes chilensis (Reimer)
Anomoeoneis sphaerophora var. sculpta O.F. Muell
Asterionella sp.
Cryptomonas ovata Ehrenberg
Cryptomonas sp.
Cyclotella sp.
Gyrosigma obtusatum (Sulliv.) Boyer
Melosira sp.
Navicula sp.
Nitzchia palea (Kutz.) W. Smith
Nitzschia sp.
Synedra sp.
Synura sp.

and Aphanizomenon sp. The non-filamentous types were Merismopedia trolleri Bachmann, Merismopedia sp., and Aphanocapsa sp. These genera were reported to be typical of overfertilized, shallow lakes and ponds (Rawson 1956, Munawar 1970, Bush and Welch 1972, and Haertel 1972).

As the fall of 1973 approached, diatoms and green algae showed a steady increase. Surprisingly, Scenedesmus quadricauda dominated the population during November 1973. However, the cells did look different and were perhaps a different strain or form more adaptable to colder temperatures. The occurence of physiological strains of the same species is not an unrealistic assumption. Other workers have reported on the occurence of physiological strains of Asterionella sp. (Round 1971).

During the early fall the centric diatoms were more numerous than the pennate forms. The most abundant genera was Melosira sp. Pennate diatoms became more abundant in November 1973, including species of Nitzschia and Navicula. Euglenoids formed less than 5% of the population during the fall. Brown flagellates (mostly Cryptomonas types) accounted for 2.5 to 7.6% of the cell population. Total cell concentration ranged between 4,000 and 30,000 cells/ml. This range was much smaller than the summer average (table 1).

The percentage composition of the major algal groups during the winter and spring is plotted on figure 31.

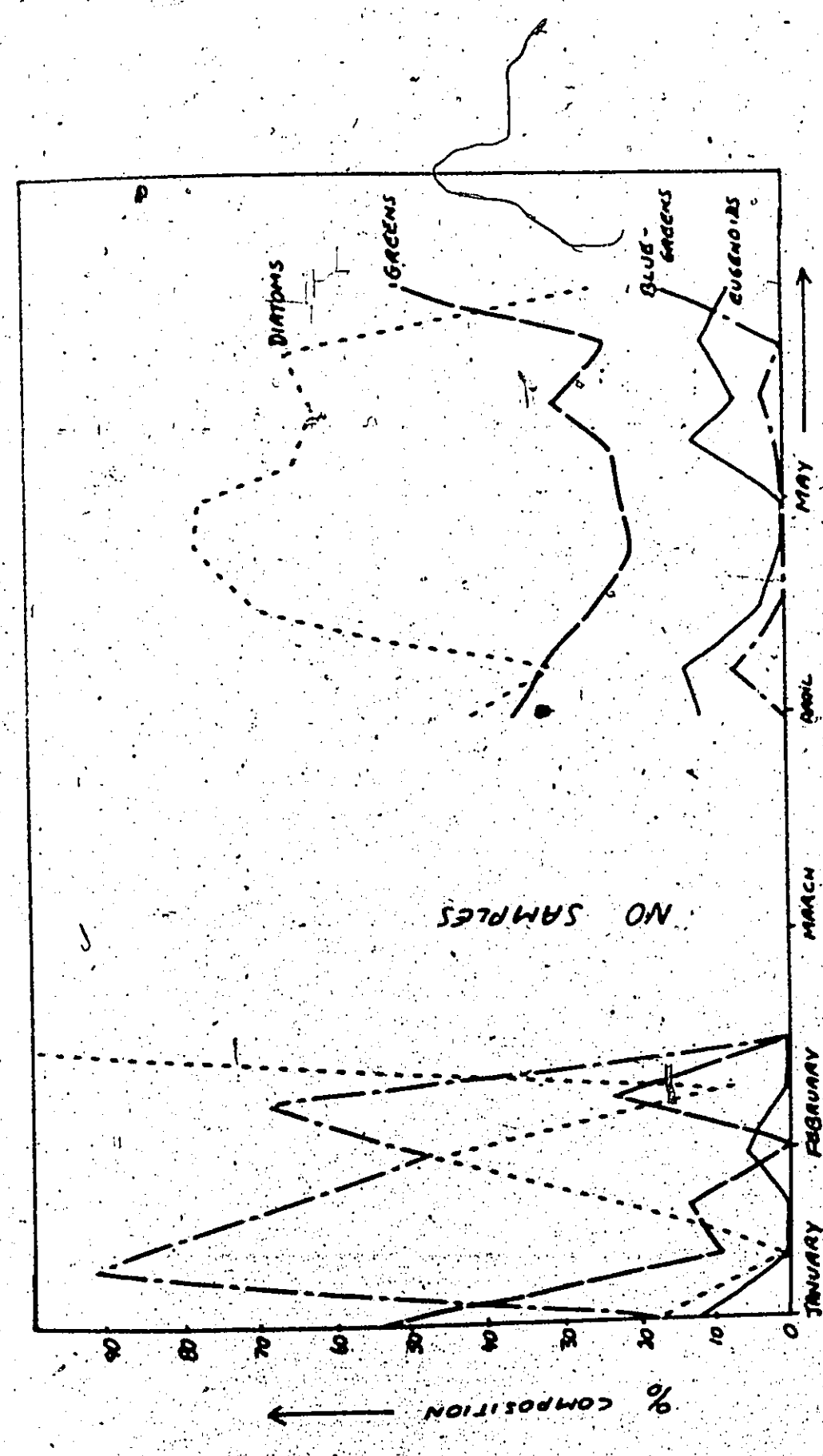


FIG.31 Diagram showing the percent composition of the major algal groups at station 12 between January and May 1974.

The graph does not take into account December of 1973 because no samples were taken. During January and February of 1974, winter samples were obtained by chopping holes through the ice. The cell concentration was very low during the winter with a range of 614 to 1446 cells/ml. All of the major groups fluctuated quite markedly, except the euglenoids which were negligible. The euglenoids, however, showed two peaks on January 16 and February 6. Blue-green algae constituted the greater portion of the population ranging between 17.5 to 91.2%. The green algae and diatoms ranged between 0 to 54% and 0 to 100% respectively. Figure 32 shows the comparison between the diatoms, green algae and the total cell population during the winter and spring.

During the spring of 1974, diatoms showed a steady increase with a decreasing trend towards the end of May when the green algae started to increase (fig. 31). During the early spring period the blue-green algae accounted for less than 3% of the population. On the last sampling day (May 31) blue-green algae was 16.3% of the cell population (6,500 cells/ml).

Between April 19 and May 23, diatoms contributed to more than 60% of the population. On April 3, there was a pulse of the pennate diatom Asterionella sp., followed by a mixed diatom pulse on April 11, consisting of Asterionella sp., Neidium sp., Melosira sp., Achnanthes sp.,

Cyclotella sp., Nitzchia sp., and Navicula sp., - mostly pennate types except Melosira sp., and Cyclotella sp., which are members of the order Centrales. Between April 19 and April 27 there was a Melosira pulse accounting for more than 50% of the cell population. Rawson (1956) considered species of the genera, Melosira and Asterionella to be indicative of eutrophic lakes where the nutrient supplies were generous. This was certainly the case at station 12 during the spring when nutrient levels were high (table 1). Lewin and Guillard (1963) reported that diatoms were more able to resist inhibition from high phosphate levels in natural situations than it was for other groups of algae. This may have been partly the reason why diatoms were dominant during the spring at station 12.

Brown flagellates averaged 14% of the population during the first half of April, decreased to less than 3% later in the month and averaged about 8% during May. The most conspicuous brown flagellate was Cryptomonas sp. The average cell concentration for Cryptomonas sp. for May was 3000 cells/ml compared to 450 cells/ml during April.

The cell concentration of the whole population showed an exponential increase during April (fig. 32). The average cell concentration for the first half of April was 5000 cells/ml compared to an average of 42000 cells/ml for the latter half of April. Total cell concentration dropped to a low of 20,000 cells/ml in early May and subsequently

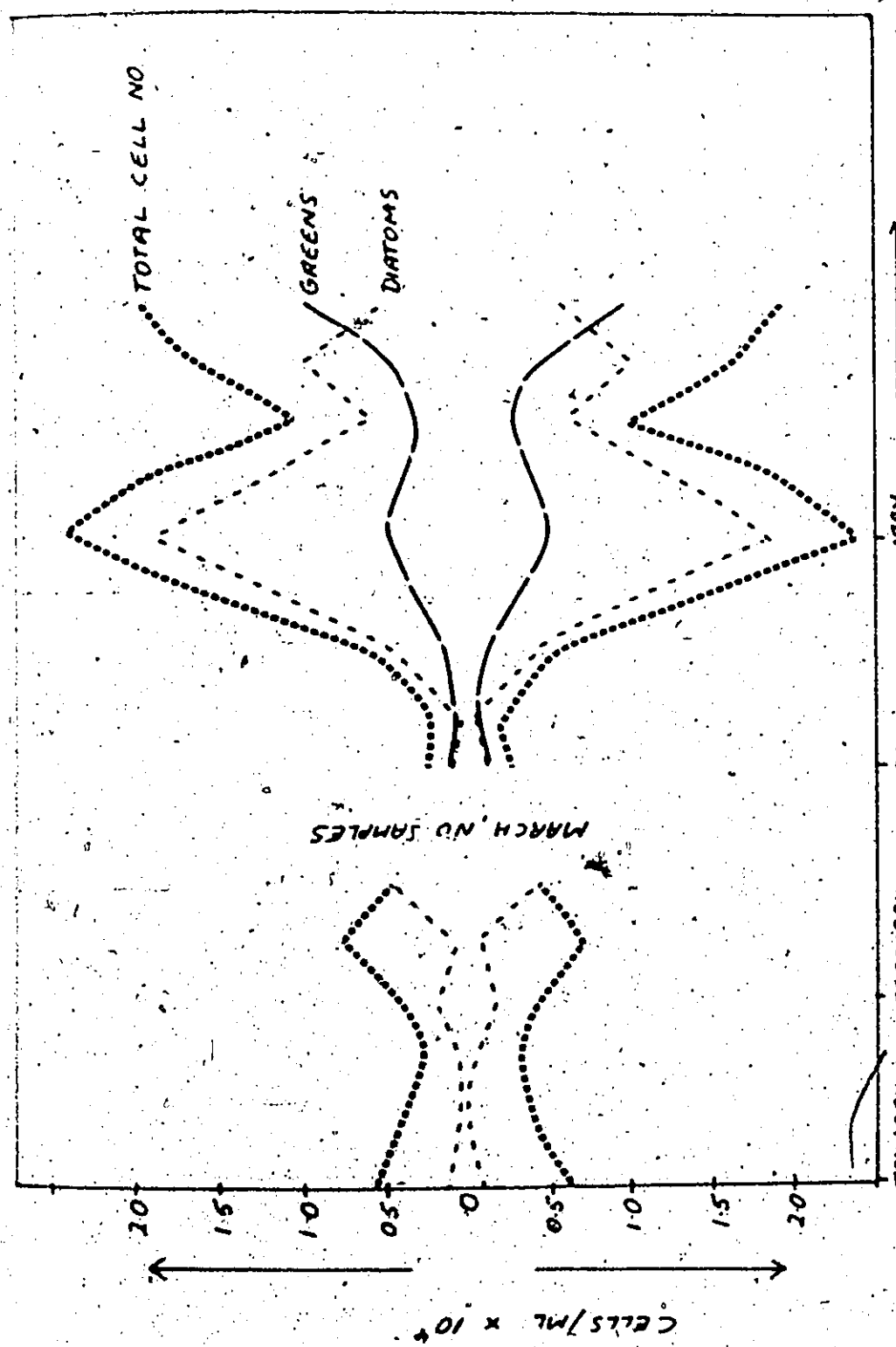


FIG.32 Graph showing the cell concentration relationship between the total cell concentration, diatoms, and green algae during the winter and spring of 1974 at station 12.

increased to 40,000 cells/ml towards the end of the month.

When the changes in population structure at station 12 is compared to that of West Pond it can be seen that there were distinct differences both locally and spatially in time. This discussion of the temporal changes in the phytoplankton composition does not pretend to be complete. An n- dimensional complex of environmental variables is involved, all of which cannot be identified. The above interpretation had its limits set by the available ecological tools used in this study.

3.3.e) Phytoplankton changes in relation to changes in nutrient status during the period January to May, 1974, stations 4 and 12

This section will deal briefly with the possible effects of nitrate, ammonia, and inorganic phosphate concentrations of each of the major algal groups between January and May 1974. Tables 10 and 11 give all the correlations between each algal group and each nutrient. Correlation coefficients were also calculated between the total cell concentrations and each of the nutrients for the same period.

There were only two significant correlations for the station 4 population. These were inverse correlations between the green algae and nitrate and the latter with the total cell population (table 10). All other correlations

TABLE 10

CORRELATION COEFFICIENTS BETWEEN

NITRATE, AMMONIA, AND PHOSPHATE, AND EACH MAJOR ALGAL GROUP.

JANUARY - MAY 1974 STATION 4.

VARIABLES	DEGREES OF FREEDOM	CORRELATION	SIGNIFICANCE (P)
GREEN ALGAE & NO_3^-	20-1	-0.648	P = 0.01
GREEN ALGAE & NH_4^+	"	-0.374	P = 0.10
GREEN ALGAE & PH^{-3}-P	"	-0.276	NOT SIGNIFICANT
BLUE-GREENS & NO_3^-	"	-0.124	"
BLUE-GREENS & NH_4^+	"	+0.059	"
BLUE-GREENS & PO^{-3}-P	"	+0.106	"
DIATOMS & NO_3^-	"	-0.340	"
DIATOMS & NH_4^+	"	-0.260	"
DIATOMS & PO^{-3}-P	"	-0.251	"
EUGLENOIDS & NO_3^-	"	-0.113	"
EUGLENOIDS & NH_4^+	"	+0.210	"
EUGLENOIDS & PO^{-3}-P	"	+0.200	"
ALL GROUPS & NO_3^-	"	-0.675	0.001
ALL GROUPS & NH_4^+	"	-0.141	NOT SIGNIFICANT
ALL GROUPS & PO^{-3}-P	"	-0.115	"

were insignificant, but generally showed a tendency to be inverse. The inverse correlations merely indicated that the nutrient concentrations were primarily a function of the cell concentrations during the colder seasons and not vice versa. This is strengthened by the fact that temperature was shown to be the most significant variable controlling algal biomass between January and May 1974. This latter point was discussed previously, and was supported by significant correlations between temperature and chlorophyll, and temperature with cell concentration (table 2).

The situation was similar at station 12. There were significant inverse correlations between the diatoms and nitrate, the green algae and nitrate, and the total cell concentration and nitrate (table 11). All other correlations were insignificant except for a significant positive correlation between phosphate and the euglenoids. This correlation was difficult to explain, unless it was purely coincidental. The conclusion then, would be that nutrients did not play a significant role in controlling algal cell concentration during the colder months of the sampling period.

TABLE 11

CORRELATION COEFFICIENTS BETWEEN

NITRATE, AMMONIA, PHOSPHATE AND EACH MAJOR ALGAL GROUP

AT STATION 12 (JANUARY - MAY 1974)

VARIABLES	DEGREE OF FREEDOM	CORRELATION COEFFICIENT	SIGNIFICANCE(P)
GREEN ALGAE & NO_3^-	16-1	-0.708	0.01
GREEN ALGAE & NH_4^+	"	-0.049	NOT SIGNIFICANT
GREEN ALGAE & PO_4^{3-}-P	"	-0.107	"
BLUE-GREEN ALGAE & NO_3^-	"	-0.260	"
BLUE-GREEN ALGAE & NH_4^+	"	-0.269	"
BLUE-GREEN ALGAE & PO_4^{3-}-P	"	-0.066	"
DIATOMS & NO_3^-	"	-0.659	0.01
DIATOMS & NH_4^+	"	+0.194	NOT SIGNIFICANT
DIATOMS & PO_4^{3-}-P	"	-0.375	"
EUGLENOIDS & NO_3^-	"	-0.395	"
EUGLENOIDS & NH_4^+	"	+0.038	"
EUGLENOIDS & PO_4^{3-}-P	"	+0.616	0.01
TOTAL CELL No. & NO_3^-	"	-0.892	0.001
TOTAL CELL No. & NH_4^+	"	+0.121	NOT SIGNIFICANT
TOTAL CELL No. & PO_4^{3-}-P	"	-0.421	0.1

Section IV

RECOMMENDATIONS FOR AMELIORATING THE PRESENT CONDITIONS IN COOTE'S PARADISE

The complete reversal of the eutrophication problem in the waters of Coote's Paradise may never be realized. However, the situation can be ameliorated if certain improvements are made. It must be remembered that Lake Washington, which experienced a similar eutrophication problem to Coote's Paradise was returned (almost) to its original state. This was achieved by diverting the sewage effluent into another water body.

If the Dundas Sewage Plant increases its capacity to handle a larger volume of sewage effluent, and includes a tertiary treatment unit, then the final effluent would contribute a considerably lower nutrient concentration into the waters of the marsh. Experiments by a McMaster engineering group used an alum compound which decreased the phosphate concentrations in the sewage effluent by as much as 98% (from a summer average of 5.45 ppm to 0.10 ppm). If this alum treatment is included along with the dredging of the Desjardins Canal and West Pond (which would eliminate phosphorous mining of the sediments) the phosphorous concentrations may not be high enough to stimulate the

development of massive algal blooms in the western end of the marsh. The inclusion of an alum treatment unit may be an expensive venture, but the cost should be weighed against the benefits.

If all of the above steps are taken, the dilution of the waters leaving West Pond by Spencer's Creek would further decrease the concentrations of nutrients discharged into the main open water area. The overall decreased nutrient concentration would effectively reduce the possibility for the development of algal blooms throughout the marsh. Contribution of phosphates from run-off water from the watershed would be minimal because of its low solubility in water. The point was already made concerning the difficulty of leaching phosphorous sources from the soil (see Sec. 3.1.c.iv) and its potential ability to increase the eutrophication in freshwaters.

Another recommendation would be to discharge the effluent (after proper treatment) into Lake Ontario or Hamilton Harbour. This may be necessary even if the marsh was dredged. The reasoning behind this suggestion is that the possibility would still exist for the development of certain types of noxious blue-green algae when phosphate concentrations are very low. These blue-green algae can fix atmospheric nitrogen in the absence of nitrate supplies in the water environment (Fogg 1969). If this problem were to occur, then the experimental results of Patrick et al. (1969), may be applied to solve the problem. Patrick et al.

, have demonstrated that by increasing the concentration of manganese, 'clean-water diatoms' can completely replace previous population of blue-green algae. Hutchinson (1973), also suggested that Patrick et al.'s (1969) work should be experimented with in eutrophic systems which support large blooms of blue-green algae.

The author does not pretend to be an expert in the treatment of sewage effluent wastes. The above suggestions should be discussed with experts in the field in order to arrive at any economically feasible solution. If steps are taken to increase the water quality in Coote's Paradise, and the effluent is discharged into the marsh, then a regular sampling schedule should be implemented to check on the nutrient concentrations (ammonia, nitrate, nitrite, phosphates), biological and chemical oxygen demand, and pathogenic bacteria counts, not less than twice weekly. The water quality would improve over a period of time. However, the characteristic brown colour of the waters in the main open water area will still persist, as long as Spencer's Creek waters are received by the marsh. Spencer's Creek brings in large amounts of silt and clay particles which have been accumulating over many years. The action of winds will continually stir up the bottom sediments and keep these particles in suspension. If the colour of the water is not a significant problem, and the improved effluent is still discharged into the marsh, then Spencer's Creek

will continue to serve the useful function of diluting the waters leaving West Pond.

The main problem involved in the implementation of the above recommendations is a financial one. The cleaning up of the waters in Coote's Paradise therefore, is entirely dependent upon the willingness of the municipalities concerned to allocate enough funds to defray the necessary expenses.

Section V

SUMMARY

The water of Coote's Paradise has experienced rapid eutrophication over the last 55 years.

All indicies of eutrophication used in this study qualify Coote's Paradise as one the most highly eutrophic (polytrophic) natural freshwater marsh ecosystems in temperate regions.

The two million gallons of secondary treated sewage effluent which is discharged into the extreme west end of the Desjardins Canal constitutes the primary source nutrients. This nutrient supply is primarily responsible for the present status of the marsh.

Biological activity of the phytoplankton between stations 1 and 6 effectively removes more than 80% of the nitrogen and phosphate (present at station 1) by the time the waters reach station 6. In this respect, this part of the marsh functions as a sewage lagoon providing additional treatment on the effluent. The removal of nutrients, plus dilution from Spencer's Creek results in a lower nutrient loading in the main open water area of the marsh.

The effect of the sewage effluent is more strongly felt in the west-end stations (1, 2, 3, 4 and 5) than those in the main open water area. This is evidenced by differences in the phytoplankton composition, and nutrient status, both spatially and temporarily (at stations 4 and 12).

Green algae, dominated by the species Scenedesmus quadricauda was the dominant group in West Pond during the summer, while blue-green algae were co-dominant with green algae at station 12 during the same period. Oscillatoria sp. was the most conspicuous of the blue-green algae.

Characteristic pollution indicator species and genera representing all the major algal groups were identified at stations 4 and 12.

An extended summer bloom of algae which seems to be typical of freshwater systems contaminated with secondary treated sewage was present both in West Pond, and in all the main open water area stations. Stations 1, 2, 5 and 6 showed more pronounced chlorophyll fluctuations than stations 3 and 4, and the main area stations.

Chlorophyll averaged between 450 to 695 mg/M^3 between stations 1 and 5, compared to a 196.0 mg/M^3 average for the main area stations.

Due to the high photosynthetic activity, the dissolved oxygen levels were consistently greater than 200% saturation in West Pond during the summer of 1973.

Nitrate was suspected as a possible nutrient limiting algal activity in West Pond because of low N/P ratios, frequent undetectable nitrate concentrations, and chlorophyll pulses in West Pond which were preceeded by pulses of high nitrate concentrations in the Desjardins Canal.

Nitrification of ammonia and phosphate mining were suspected at stations 1 and 4.

Nutrient concentrations were lower in the summer and spring and higher in the fall and winter at all stations. The converse was true for chlorophyll.

Decreases in chlorophyll in the fall and increases in the spring were correlated to the changing light/temperature regimes during the September/October and March/April transition periods.

Between January and May, 1974, temperature variation was identified as an important parameter causing chlorophyll and cell concentration variations.

A complex of interactions between the measured variables was identified at stations 4 and 12 during the summer. Significant correlations made it possible to construct two models which summarized the variable interactions.

Wind was recognized as an important environmental variable affecting algal activity at stations 4 and 12. The effect of wind was not as significant at station 11, because of its sheltered position.

Diurnal studies indicated that the availability of incident solar radiation, wind speed, and previous light history may be important in interpreting diurnal variations of chlorophyll. Diurnal studies also showed that stratification of temperature and dissolved oxygen occurs in the water column. Stratification breaks up due to wind induced turbulence during the day, and surface cooling during the night.

From an ecological viewpoint, the marsh offers an excellent opportunity to study the adaptability of phytoplankton when exposed to a constant supply of large amount of nutrients.

The interpretations and observations presented in this report were possible without the aid of controlled field, or laboratory experiments. Precise interpretations of ecological phenomona are difficult because an n-dimensional complex of environmental factors is involved many of which are difficult to identify and/or control.

Suggestions which might remedy the eutrophication problem in the waters of Coote's Paradise would require the following steps: A. Increase the present capacity of the Dundas Sewage Treatment Plant. B. Include a

tertiary sewage treatment unit to the plant. C. Dredge the western end of the Desjardins Canal and West Pond. D. Discharge the final effluent into a larger body of water or utilize it via a sprinkling system for agricultural purposes.

Aesthetically, the inexperienced observer would describe the waters of Coote's Paradise as 'deplorable' and foul smelling. This description is easily supported by the stench in the Desjardins Canal west of West Pond, the unusually green colour of West Pond's water in the summer, and the characteristic brown colour of the water in the main area. The brown colour of the water in the main area represents accumulated silt and clay material fed into the marsh by Spencer's Creek over the years.

APPENDIX

VARIABLE	EQUIPMENT
Temperature	YSI (Yellow Springs Instrument Co. Inc.) Tele-Thermometer. Range 30°F to 110 degrees ± 0.25 degrees F.
Secchi depth	Hand made 21 cm. diameter secchi disc. String calibrated in 5 cm. intervals. Weighted on the underside.
Turbidity	Hach model 2100 A turbidimeter. Variable range 0 → 0.62 ± 0.02 FTU; 0 → 10 ± 0.3 FTU; 0 → 100 ± 2.5 FTU; 0 → 1000 FTU ± 25 FTU. FTU = Formazin Turbidity Units.
Wind	Royal Botanical Gardens (Hamilton) Meterological Unit.
Sunlight Hours	Royal Botanical Gardens Meterological Unit.
Phosphorous	Technicon International Corp. Auto-analyser II with manifold #116-D050-01.
Nitrate and Nitrite-N	Technicon International Corp. Auto-analyser II with manifold #116-D063-01.
Ammonia-N	Bausch and Lomb Spectronic 20 Spectrophotometer 1/2" diameter glass-cells.

Chlorophyll a	ZEISS PMQ II Monochromatic Spectrophotometer, 5 cm. path length quartz cuvettes, model CL International Clinical Centrifuge, Fischer Scientific Duo-seal Vacuum Pump, 250 ml Buchner type millipore filter funnels (pyrex), 1000 ml Filtering Flash with tubulation, 10 ml manual tissue grinder.
Dissolved Oxygen	300 ml BOD bottles, 10 ml Automatic buret, Pasteur pipets, 50 ml pipets, 125 ml conical flasks.
Cell Counts	ZEISS #4758983 Inverted microscope equipped with phase, 10 ml Utermohl type counting chambers.

VARIABLE	REAGENTS	QUANTITY
Nitrite and Particulate Ex.-I.	**Ascorbic Acid Reagent**	
	Ascorbic acid, $C_6H_8O_6$	17.6 g
Technicon International Method #93-70W Jan. 1971	Acetone, $CH_3CO.CH_3$	50.0 ml
	Double distilled water	1000.0 ml
	Liquonox phosphate free solution	0.5 ml.
	Ammonium Molybdate Reagent	
	Ammonium molybdate, $(NH_4)_6$ $Mo_7O_{24}.4\ H_2O$	10.0 g
	Sulphuric acid, H_2SO_4 (1.2 N)	1000.0 ml
	Sulphuric Acid Reagent	
	Conc. Sulphuric acid	192.0 ml
	Double distilled water	808.0 ml
	Stock Standard Phosphate (100 ppm)	
	Anhydrous potassium dihydrogen phosphate, KH_2PO_4	0.143 g
	Conc. H_2SO_4	1.0 ml
	Distilled water	1000.0 ml
	30% Sulphuric Acid Reagent	
	Conc. Sulphuric Acid	30.0 ml
	Double distilled water	70.0 ml

VARIABLE	REAGENTS	QUANTITY
Nitrate-Nitrite N	Ammonium Chloride	
Technicon International Method for the AA II #100-70W. Nov. 1971	Ammonium Chloride, NH_4Cl	10.0 g
	Alkaline Water (pH 8.5)	1000.0 ml
	Liquonox solution	0.5 ml
	Colour Reagent	
	Sulfanamilamide $C_6H_8N_2O_2S$	20.0 g
	Conc. Phosphoric Acid H_3PO_4	200.0 ml
	N-1 Napthylethylenediamine dihydrochloride $C_{12}H_{14}N_2 \cdot 2HCl$	1.0 g
	Distilled water	2000.0 ml
	Cadmium Powder	
	Cadmium filings	8.0 g
	2% (w/v) Copper Sulphate soln.	1000.0 ml
	Distilled water	1000.0 ml
	Diethyl ether	100.0 ml
Ammonia-N	Na_3PO_4 buffer 5% (w/v)	1000.0 ml
Method by Hardwood and Kahn, 1970.	Phenol Stock Soln.	
	Phenol crystals (C_6H_5OH)	500.0 g
	Methanol (CH_3OH)	80.0 ml
	27% NaOH Soln.	
	NaOH pellets	270.0 g
	Distilled water	1000.0 ml

VARIABLE	REAGENTS	QUANTITY
Ammonia	Reagent A	
	Phenol Stock Soln.	15.0 ml
	Sodium nitroprusside crystals	0.02 g
	Distilled water	85.0 ml
	Reagent B	
	Commercial bleach	15.0 ml
	27% NaOH	15.0 ml
	Distilled water	20.0 ml
Chlorophyll a	Acetone reagent	
Strickland & Parsons, 1968 pp. 193-196	Acetone	900.0 ml
	Distilled water	100.0 ml
Dissolved Oxygen	Manganous Sulphate Reagent	
Strickland & Parsons, 1968 pp. 21-26	Manganous sulphate monohydrate $MnSO_4.H_2O$	365.0 g
	Distilled water	1000.0 ml
	Alkaline Iodide Reagent	
	Sodium Hydroxide pellets	500.0 g
	Potassium Iodide (KI)	300.0 g
	Distilled water	950.0 ml
	Standard Thiosulphate (0.01N)	
	Sodium Thiosulphate ($Na_2S_2O_3.5H_2O$)	2.9 g

VARIABLE	REAGENTS	QUANTITY
Dissolved Oxygen	Sodium Carbonate	
continued	(Na_2CO_3)	0.1 g
	Carbon Disulphide	
	(CS_2)	0.1 ml
	Distilled water	1.0 l
	Starch Indicator	
	Soluble starch	2.0 gm
	20% NaOH	
	Conc. Hydrochloric	
	acid (HCl)	
	Litmus paper	
	Glacial acetic acid	2.0 ml
	Potassium Iodate Reagent	
	(0.01 N)	
	Potassium Iodate, (KIO_3)	0.3567 g
	Distilled water	1000.0 ml
Cell Count	Lugol's Solution	
	Potassium Iodide, (KI)	2.0 g
	Iodine crystals	1.0 g
	Glacial acetic acid	20.0 ml
	Distilled water	200.0 ml

RAW DATA LIST

DATE	STAT	SOL. P	PAR. P	NO_3^- N	NH_4^+ N	O_2 PPM	O_2 % SAT	TEMP. °F A	TEMP. °F S	Chl.	Secc.	TURB.
4/10/73												
20/10/73				16.00								
23/10/73												
24/10/73												
1/11/73												
8/11/73												
22/11/73												
16/1/74												
23/1/74	Sewage Plant	7.30		7.4	8.9							
30/1/74	Sewage Plant	5.6		12.20	4.03							
6/2/74	Sewage Plant	0.10		13.30	4.23							175
13/2/74	Sewage Plant	1.95		6.40	7.86							150

DATE	STAT.	SOL. P	TAR. P	NO_3^- N	NH_4^+ N	O_2 PPM PPM	O_2 % SAT	TEMP. °F A	TEMP. °F W	COLOR	ODOUR	TURB
20/2/74	Sewage Plant	5.15		0.95	10.76							7.00
27/2/74	Sewage Plant	5.70		10.20	4.47							2.50
7/3/74	Sewage Plant	4.30		12.10	3.4							5.00
15/3/74	Sewage Plant	5.70		9.45	4.00							3.50
22/3/74	Sewage Plant	9.60		7.80	6.11							5.00
29/3/74	Sewage Plant	9.60		8.10	9.18				49			5.00
5/4/74	Sewage Plant	0.64		7.60	1.62	3.25	32.1		58			8.00
11/4/74	Sewage Plant	NO SAMPLE										
19/4/74	Sewage Plant	7.10		4.65	6.72			44.5	50.5			3.00
27/4/74	Sewage Plant	NO SAMPLE										
3/5/74	Sewage Plant	LOST SAMPLE										
10/5/74	Sewage Plant	0.65		7.70	0.12				62			3.00

DATE	STAG	SOL. P	PAR. P.	NO3 N	NH3 N	SATUR TEM	DIS. % SAT°	TEMP. A	TEMP. W			
16/5/74	Sewage Plant	2.9		7.45	1.20				53.0			2.00
23/5/74	Sewage Plant	5.2		8.85	0.16			76	56			5.00
31/5/74												
7/6/74												
14/6/74.												

RAW DATA LIST

DATE	STAT	SOL. P	PAR. P	NO_3^- N	NH_4^+ N	O_2 PPM PPM	O_2 % SAT	TEMP. A	TEMP. W	[illegible]	[illegible]	TURB
14/6/73	1	9.25	3.00	24.00	30.53	11.77	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
18/6/73	1	8.10	.84	7.8	0.00	9.18	95.13		64.5	242.94 43.32	-21.0	30
21/6/73	1	11.8	1.4	0.22	0.50	3.18	35.33		70.0	267.55	37.5	14
25/6/73	1	7.4	1.2	40.00	0.234	13.46	149.00		70	356.50		11
28/6/73	1	26.3	12.5	0.35	19.57	2.91	32.51		70.5	924.13	27.5	23
3/7/73	1	13.8	5.02	0.05	1.06	10.99	135.68	92	80	250.93	33.	12
5/7/73	1	21.0	5.9	0.07	1,67	1.83	21.78	73.5	77		22.5	22
9/7/73	1	9.63	.766	0.01	2.08	6.36	81.54	87	85	124.88	42.5	20
12/7/73	1	14.9	1.05	0.79	30.53	2.87	31.53	74.5	69.5	238.16 59.72	27.5	15
16/7/73	1	13.8	2.1	0.01	8.62	22.7	262.42	74.5	74.5	671.0 127.4	22.5	22
19/7/73	1	10.00	8.5	0.01	0.00	1.15	14.37	73	82	552.58 104.79		47
23/7/73	1	10.80	1.4	0.01	3.52	7.42	85.28	73	74	150.02	37.5	14

26/7/73	1	10.80	2.93	5.40	13.7	4.33	59.38	84	85	7.7		
30/7/73	1	12.00	1.10	7.16	10.13	5.94	69.88	79	76	39.4	32.5	17
7/8/73	1	11.8	1.1	0.02	1.82	5.37	67.97	73.5	83	125.7	42.5	15
9/8/73	1	7.5	1.67	0.02	0.00	9.58	116.12	89	78.5	797.8	40	20
13/8/73	1	11.6	2.52	0.04	21.46	1.92	21.35	77	70	113.4	30	25
20/8/73	1	10.2	7.50	2.35	5.97	22.13	251.47	78	73	3900.	12.5	27
23/8/73	1	10.35	0.80	0.01	5.59	1.79	18.45	63.2	64.2	17.45	30	22
27/8/73	1	5.0	0.76	0.22	0.00	3.21	36.89	79.5	74	36.42	40	14
4/9/73	1	4.90	0.60	0.67	20.33	4.1	50.61	94.5	81	5.14	30	15
6/9/73	1	6.6	0.93	0.49	23.36	6.35	73.41	76.5	74.5	131.7	TB	15
13/9/73												
20/9/73												
27/9/73												

RAW DATA LIST

DATE	STAT	SALT P	PAR. P.	NO3 N	NH3 N	O2 PPM PPM	O2 % SAT	TEMP A	TEMP S	PH	DEPTH	TURB
4/10/73												
20/10/73												
23/10/73												
24/10/73												
1/11/73												
8/11/73												
22/11/73												
16/1/74	1	10.5		5.7	25.6	7.23	64.0	43	50.5	2.10		35
23/1/74	1	3.10		6.9	6.35	6.71	54.5	39	44	1.48		51
30/1/74	1	2.95		1.4	4.03	13.03	109.0	41.0	45.5	3.62		7.5
6/2/74	1	0.13		12.0	4.23	9.00	64.3	12	35	2.47		8.0
13/2/74	1	4.20		2.15	13.9	5.51	47.0	38.5	47.5	3.14		21.0

RAW DATA LIST

DATE	STAT.	SOL. R	PAR. P	[illegible] H	BOD H	O, PPM IPM	O, % SAT	TEMP. A	W	[illegible]	[illegible]	[illegible]
20/2/74	1	6.00		4.85	10.2	9.71	[illegible]	[illegible]	33	7.11		[illegible]
27/2/74	1	6.60		7.8	10.04	9.05	74.8	30	46	8.83		10.00
7/3/74	1	5.30		7.80	4.26	7.86	64.9		50	91.74		10.00
15/3/74	1	6.00		6.05	8.75	8.62	75.3	35	49.5	118.5		30.00
22/3/74	1	11.20		5.80	11.41	4.20	36.15		48	33.22		[illegible]
29/3/74	1	8.30		[illegible]	16.28	10.15	70.00	28	41.5	42.30		12.00
5/4/74	1	3.8		4.85	3.62	8.62	73.0	41	47	169.6	35	17.00
12/4/74	1	8.7			6.72	13.62	127.8	58.5	55	45.82	55	8.6
19/4/74	1	10.10		2.20	13.00	6.42	58.6	42.5	53.5	40.87	65	7.50
27/4/74	1	12.00		1.70	13.22	2.29	20.7	67	52.5	53.89	70	11.00
3/5/74	1	13.8		1.30	13.99	3.83	34.5	52.5	51.6	5.30	70	11.00
10/5/74	1	4.30		4.20	4.4	6.13	55.2	54.5	52	4.00	70	8.5

DATE												
16/5/74	1	5.2		3.90	5.62	5.36	48.5	57	53.5	16.03	95	7.5
23/5/74	1	6.0		4.95	4.38	5.17	50.6	77	59	148.6	60	11.00
31/5/74	1	6.0		2.05	7.05	6.32	64.8	65	63.5	107.0	50	14
7/6/74												
14/6/74												

14/6/73	2	1.65	3.73	1.05	0.00	20.55	340.38		88	84.4	10.5	
18/6/73	2	5.15	1.61	0.00	1.14	10.21	110.37		67.5	250	27.5	17
21/6/73	2	6.8	1.65	1.75	0.234	10.83	121.68		71.0	288.71	31.5	17
25/6/73	2	5.5	1.8	0.00	0.31	17.67	184.0		71	279.4		19
28/6/73	2	9.2	27.0	0.09	0.42	6.19	69.55		72.0	852.5	20.5	25
3/7/73	2	14.5	3.8	0.06	0.4	22.69	280.13	96	80	353.7	17.5	15
5/7/73	2	23.4	7.35	0.30	9.94	4.510	53.06	77	76		32.5	13
9/7/73	[illegible]	1.00	3.00	0.07	0.00	23.15	285.80	92	80	480.6	22.5	31
12/7/73	2	7.0	1.9	7.80	1.89	9.47	106.40	73	71	452.0	22.5	18
16/7/73	2	1.8	6.6	0.01	0.00	29.12	346.66	74	77	528.9	17.5	29
19/7/73	2	6.8	3.2	0.01	0.00	9.77	123.6	76	83	695.5	17.5	25
23/7/73	2	12.6	3.375	1.09	1.06	13.26	154.2	72.5	75	560.0	17.5	19

RAW DATA LIST

DATE	STAT	SOLU P	PART P	NO3 N	NH4 N	O2 PPM PPM	O2 % SAT	TEMP. °F A	°F	Cl-	[illegible]	[illegible]
26/7/73	2	7.2	1.90	.09	0.06	8.44	99.39	84.5	79	.37	22.5	15
30/7/73	2	9.6	1.25	1.52	3.72	8.96	105.41	80	77	166.9	32.5	15
7/8/73	2	4.9	2.2	0.02	0.72	16.59	210.0	78	83	537.2	22.5	17
9/8/73	2	7.8	2.5	0.87	1.14	10.65	131.48	88.6	80	357.8	25	23
13/8/73	2	9.3	1.3	0.01	2.27	12.70	149.40	77	76	270.1	27.5	13
20/8/73	2	4.2	3.5	1.05	1.48	18.58	222.51	77	77.5	944.6	22.5	14
23/8/73	2	11.10	2.05	1.78	8.42	4.57	49.67	62.7	68.1	750.4	27.5	20
27/8/73	2	7.40	1.27	0.87	8.99	4.55	53.84	79.5	76.5	662.5	32.5	17
4/9/73	2	6.20	1.60	1.26	13.91	13.69	169.01	90.5	81	437.5	37.5	12
6/9/73	2	7.04	1.1	0.20	24.45	10.67	125.53	76	76	270.1	40	10
13/9/73	2	4.9	0.775	0.19	33.94	9.127	92.69	62.0	62.5	248.4	45	7.5
20/9/73	2	4.75	0.937	0.08	30.2	5.91	64.94	62.5	68.9	23.33	65	3.6
27/9/73	2	2.8	0.700	0.42	33.8	6.62	74.38	79.5	71.5	126.4	65	4.0

LAB DATA [illegible]

	STAT	[illegible] P	AMM. P	NO_3^- N	NH_4^+ N	O_2 PPM PPM	O_2 % SAT	TEMP A	TEMP W	[illegible]	[illegible]	[illegible]
4/10/73	2	3.1	0.597	2.18	28.1	7.94	85.37	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
20/10/73												
23/10/73												
24/10/73												
1/11/73												
8/11/73												
22/11/73												
16/1/74												
23/1/74												
30/1/74												
6/2/74												
13/2/74												

DATE												
16/5/74												
23/5/74												
31/5/74	2	3.2		1.4	2.54					286.2	45	15
7/6/74												
14/6/74												

RAW DATA [illegible]

	DAY	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	% SAT	TEM A	[illegible]	[illegible]	[illegible]	[illegible]
14/6/73	3	1.30	4.[illegible]	[illegible]	47.00	[illegible].67	[illegible]		[illegible]	114.[illegible]	17.[illegible]	[illegible]
18/6/73	3	4.30	1.75	0.00	0.00	17.41	183.2		75.5	211.2	22.5	15
21/6/73	3	3.80	2.45	0.81	0.47	15.14	171.0		72.5	307.[illegible]	22.5	21
25/6/73	3	4.3	2.1	0.00	0.31	14.20	215.0		72	264.[illegible]		27
28/6/73	3	17.7	26.1	0.69	2.95	12.90	146.5		73	42[illegible].7	22.5	21
3/7/73	3	7.6	4.86	0.05	0.00	27.54	148.6	87	83	310.2 33.0	17.[illegible]	23
5/7/73	3	14.3	4.3	0.01	0.00	18.61	210.3	78	75		17.5	23
9/7/73	3	.50	3.6	0.02	0.09	18.39	245.[illegible]	97	88	6[illegible]2.2 195.6	14.[illegible]	29
12/7/73	3	2.4	3.75	0.16	0.34	20.84	236.8	73	73	643.[illegible] 178.[illegible]	17.[illegible]	30
16/7/73	3	2.4	4.85	0.01	0.00	31.18	362.8	74	75	587.4 159.5		40
19/7/73	3	3.25	4.50	0.01	0.40	27.05	333.9	76	80.5	774.0 210.8	17.5	33
23/7/73	3	1.40	4.87	0.01	40.00	11.45	133.1	72	75	533.1	17.5	30

[illegible]/73	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]/73	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1/9/73	3	2.4	3.25	0.02	0.00	22.58	280.8	79.5	83.0	1163.	17.5	28
2/9/73	3	1.2	4.00	0.20	0.00	19.14	238.84	78	82.5	910.5	17	27
3/9/73	3	3.5	4.70	0.24	0.00	17.38	206.6	76	71	1040.	23.5	24
4/9/73	3	3.1	3.6	0.72	1.48	18.20	216.6	77	77	[illegible]	22.5	23
5/9/73	3	5.2	3.06	0.77	2.98	14.57	158.6	62.5	67.5	[illegible]	22.5	16
7/9/73	3	4.5	4.1	0.45	0.69	11.45	137.1	81	77.5	1183.	22.5	21
8/9/73	3	3.05	2.9	0.44	7.86	14.88	183.5	89	83.5	540.5	21.0	17
9/9/73	3	10.1	3.10	0.20	12.02	17.55	210.1	76	77.5	721.5	20	25
13/9/73												
20/9/73												
27/9/73												

RAW DATA SHEET

DATE	STAT	SOL. P PAR. P	PAR. + SOL. P	NO_3 N	NH_4 N	O_2 PPM PPM	O_2 % SAT	TEMP A	W	Cl a		
14/6/73	4	1.30 3.64	4.94	0.04	0.687	24.81 24.23 21.58	317.07 313.20 276.66	77	74	432.44	19.5	41
18/6/73	4	4.5 1.68	6.18	0.04	0.00	12.21 4.63	128.42 48.74	67	65.5	226	22.5	23
21/6/73	4	4.2 2.85	7.05	0.36	0.083	18.20 15.71	204.49 176.52	76	72.0	383.6	26.5	19
25/6/73	4	3.3 2.4	5.7	0.00	0.00	19.50 9.09	219.0 112.0	72	72	323.0	26.5	29
28/6/73	4	32.4 14.5	46.9	0.71	4.01	13.80 NR	156.82	75	73	592.1	22.5	13
3/7/73	4	9.2 4.47	13.7	0.00	0.00	27.44 8.49	338.76 104.81	87	81	490.4	26.5	18
5/7/73	4	17.7 9.67	27.37	0.71	0.00	19.92 18.89	231.62 219.65	78	75		17.5	27
9/7/73	4	.50 3.1	3.6	0.05	0.00	24.49 9.30	326.53 124.00	91.5	88	863.0	18.5	27
12/7/73	4	2.00 3.45	5.45	.013	0.00	20.82 19.81	234.00 222.58	71.5	72	809.4	17.5	28
16/7/73	4	2.80 4.40	7.20	0.015	0.00	22.27 15.81	257.43 182.77	75	74.5	844.6	17.5	27
19/7/73	4	1.4 5.4	6.8	0.01	0.00	27.13 23.47	334.9 289.75	76	81.5	769.0	17.5	29
23/7/73	4	2.4 5.37	7.8	0.015	0.00	11.32 10.74	130.11 123.44	74.5	74	623.1	17.5	25

RAW DATA LIST

DATE	STAT	SOL. P / PAR. P	PAR. + / SOL. P	NO_3 N	NH_4 N	O_2 PPM / PPM	O_2 % SAT	TEMP A	W	CHL	[illegible]	TURB
26/7/73	4	4.85 3.7	8.55	0.02	0.49	15.28 6.85	181.9 81.54	81.5	77	473.9	22.4	28
30/7/73	4	2.7 4.70	7.40	2.74	0.00	24.35 22.56	288.16 266.98	78	76.5	734.8	17.5	27
7/8/73	4	1.00 4.40	5.4	0.013	0.00	27.78 24.05	347.25 300.62	79.5	82	872.1	17.5	25
9/8/73	4	1.2 6.10	7.3	0.03	0.00	19.24 12.46	240.50 155.75	84.5	82	973.8	16	37
13/8/73	4	1.8 5.20	7.0	0.34	0.68	20.79 15.33	247.50 182.50	77	77	986.1	17.5	26
20/8/73	4	1.9 4.05	5.95	0.26	0.00	21.07 6.80	247.88 80.00	75.5	76	979.4	22.5	23
23/8/73	4	3.0 3.40	6.4	0.30	1.82	19.14 18.18	205.8 195.48	63	67.3	858.4	18.0	25
27/8/73	4	3.10 5.45	8.45	0.50	1.15	15.42 13.03	184.67 156.05	79	77.5	1318.	17.5	23
4/9/73	4	6.10 5.80	11.9	0.18	6.92	13.80 12.34	175.80 157.20	87.7	83.5	399.2	22.5	33
6/9/73	4	10.80 4.30	15.1	0.14	11.0	12.12 12.51	140.11 144.62	76	74.5	561.1	17.5	24
13/9/73	4	6.6 4.75	11.35	0.13	-8.62	13.54	136.77	60.0	62.1	646.8	22.5	25
20/9/73	4	7.0 4.2	11.2	0.05	14.66	19.75	203.61	60.7	63.8	683.0	22	20.1
27/9/73	4	3.4 4.1	7.5	0.74	6.50	30.24	343.64	80.5	73.3	888.6	22.5	26

RAW DATA LIST

DATE	STAT	SOL.P PAR.P	PAR.+ SOL.P	NO_3^- N	NH_4^+ N	O, PPM PPM	O_2 % SAT	TEMP °F A	W	Chl a	Secc.	Turb.
4/10/73	4	4.8 1.4	6.25	0.50	14.28	17.05	185.3	63.8	67.8	316.6	30 TB	12
20/10/73	4	7.9 1.7	9.7	0.44	18.44	11.76	110.3	54.5	55	271.4	20 TB	20
23/10/73	4	9.3		0.37	22.22				51	339.8	20 TB	15
24/10/73	4	14.4		0.21	35.44	6.035	53.0	55	51	204.9		11
1/11/73	4	3.5		1.96	6.73	7.28	63.0	49	49	285.3		118
8/11/73	4	5.15		1.05	13.57	7.95	64.0	41.5	44	178.0		36
22/11/73	4	5.10		0.85	11.07	2.16	107.0	52	50	18.4		11.5
16/1/74	4	11.0		3.80	31.60	8.81	67.25	41	39	50.5		18.0
23/1/74	4	0.90		4.20	0.27	13.75	96.15	38	33	3.98		82.0
30/1/74	4	1.95		1.10	2.98	7.703	55.4	39	35	7.29		29.0
6/2/74	4	0.13		7.35	1.31	13.79	94.4	12	32 35 38	1:45	ICE	6.25
13/2/74	4	2.65		4.90	12.30	10.35	71.8	36	33.2 35.0	6.28	30 TB	20.0

RAW DATA LIST

DATE	STAT.	SOL. P	PAR. P	NO_3 N	NH N	O_2 PPM PPM	O_2 % SAT	TEMP A	TEMP W	DO	[illegible]	TIME
20/2/74	4	6.60		1.65	15.4	11.76	81.6	32	33	14.1	35	20.2
27/2/74	4	3.50		5.00	7.72	10.20	73.9	29	36	19.4	30	13.50
7/3/74	4	1.30		4.90	2.00	8.05	71.2		45	62.2	30	25.00
15/3/74	4	5.10		4.15	7.00	10.63	84.0	35	42	23.8	30	20.00
22/3/74	4	9.30		3.4	3.60	14.08	100.6		34	62.9	40	17.00
29/3/74	4	1.20		3.00	0.00	14.17	111.0	.2	32.7	4.50	45	10.00
5/4/74	4	0.3		2.20	0.4	10.93	95.45	41	49	5.87	5	88.50
11/4/74	4	3.5		3.00	3.25	13.99	124.4	58.2	50.5	27.4	45	11.50
19/4/74	4	4.25		1.55	6.02	8.9	78.2	48	49.5	94.5	50	13.50
27/4/74	4	1.70		1.25	0.97	29.51	299.6	72	62.5	371.	20	25.00
3/5/74	4	2.10		0.90	1.52	18.92	180.2	50.0	55.5	206.	32	17.5
10/5/74	4	2.10		1.60	3.46	9.97	87.07	52	49	132.	21	34

RAW DATA LIST

DATE	STA	SOL. P	PAR. P	NO_3^- N	NH_4^+ N	O₂ PPM PPM	O₂ % SAT	TEMP °C	°C	pH		
16/5/74	4	1.00		1.85	1.20	10.61	105.6	54.5	60.5	165.9	28	21
23/5/74	4	1.2		1.04	0.94	14.55	159.8	75	69	299.7	22	30
31/5/74	4	1.4		0.66	0.95	13.42	144.3	65	66.8	248.9	26	25
7/6/74												
14/6/74												

RAW DATA LINE

DATE	STAT	SOL. P	BAR. P	NO_3^- N	NH_4^+ N	O_2 PPM PPM	O_2 % SAT	TEMP. °F A	TEMP. °F W	CHA		
14/6/73	5	0.50	1.0	0.02	0.00	12.42	5.30 155.25		82	241.4 26.8		18
18/6/73	5	4.30	1.68	0.02	0.23	7.60	78.35		64	195.06 32.88	22.5	23
21/6/73	5	3.65	3.55	0.00	0.12	17.80	201.13		72.5	208.10	21.5	23
25/6/73	5	2.4	1.9	0.01	0.68	14.70				205.4		30
28/6/73	5	16.2	16.5	1.35	0.00	6.58	72.31		69	235.0		72
3/7/73	5	12.4	4.0	0.77		21.53	265.80	90	80	317.2 54.2		33
5/7/73	5	16.0	9.3	0.66		16.45	200.61	78	79		17.5	30
9/7/73	5	1.0	2.8	0.01		19.45	237.19	90	79	626.1 169.9		39
12/7/73	5	1.6	0.50	0.012		8.81	95.76	70.5	68	39.74 14.81	17.5	18
16/7/73	5	1.8	2.7	0.017		18.99	218.27	75.5	74	453.00 97.10	17.5	35
19/7/73	5	1.4	5.9	0.015		29.16	360.00	76	81	841.07 185.7	17.5	34
23/7/73	5	1.5	0.65	0.01		6.90	76.66	72.5	70.5	170.60	27.5	33

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RAW DATA LIST

DATE	STAT	SOL. P	PART. P	NO$_3$ N	NH$_3$ N	O$_2$ PPM PPM	O$_2$ % SAT	TEMP A	TEMP W	CHA	SECC	TURB
26/7/73	5	1.70	1.75	0.03		9.41	109.41	82	75	167.5	07.5	125
30/7/73	5	1.50	5.15	0.025		25.54	304.05	78	77.5	675.6	17.5	34
7/8/73	5	1.00	0.70	0.015		13.39	167.37	69	82	186.5	22.5	29
9/8/73	5	1.0	5.45	0.02		19.92	253.75	87	83.5	801.6	17.0	33
13/8/73	5	2.0	6.00	0.52		20.92	249.05	79	79	934.3	17.5	34
20/8/73	5	0.81	0.33	0.01	0.00	8.62	96.85	77	72	23.02	42.5	29
23/8/73	5	1.35	0.85	1.04	0.08	14.33	147.73	64.5	64	113.9	30 TB	30
27/8/73	5	3.80	4.10	0.08	0.00	12.41	148.62	79	77.5	1280.	12.5	25
4/9/73	5	3.90	3.80	0.46	6.88	16.37	209.87	87.2	84.3	394.2	17.5	32
6/9/73	5	9.95	4.50	0.18	9.75	12.69	151.07	76	77	713.7	17.5	32
13/9/73												
20/9/73												
27/9/73												

RAW DATA LIST

DATE	STAT.	SOL. P	PAR. P	NO_3^- N	NH_4^+ N	O_2 PPM PPM	O_2 % SAT	TEMP. °F A	TEMP. °F X	CHL.	[illegible]	TURB.
20/2/74												
27/2/74												
7/3/74												
15/3/74												
22/3/74												
29/3/74												
5/4/74												
11/4/74												
19/4/74												
27/4/74	5	2.45		1.30	2.99	23.37	237.3	70.5	62.5	304.	22.5	21
3/5/74	5	1.4		0.90	1.31	15.42	141.5	52.6	58	135.	28.0	22.5
10/5/74	5	1.6		1.38	2.27	13.60	119.3	54	49.5	143.	24	40

RAW DATA LIST

DATE	STAT	SOL. P	PAR. P	NO_3^- N	NH_4^+ N	O: PPM PPM	O_2 % SAT	TEMP. A	TEMP. W			
16/5/74	5	0.20		1.20	0.216	9.39	89.4	57	56.5	36.3	32.5	20.0
23/5/74	5	0.80		0.86	0.39	12.27	136.3	77	70	196.4	16	46
31/5/74	5	1.00		0.73	0.67	9.96	101.1	61	62.5	195.0	25	24
7/6/74												
14/6/74												

DATE	STAT	SOL. P	PAR. P	NO_3^- N	NH_4^+ N	O_2 PPM PPM	O_2 SAT	TEMP A	TEMP	DIA		
14/6/73	6	.50	.29	0.02	0.00	10.22	125.40		79.5	80.44 14.84	34.5	24
18/6/73	6	2.7	.84	0.27	0.00	6.34	65.02		63.5	0	32.5	21
21/6/73	6	.80	.70	0.00	0.00	6.70	74.44		70.0	22.77 4.41	41.5	25
25/6/73	6	.35	.23	0.00	3.71	5.94		10		9.65 1.02		25
28/6/73	6	9.8	5.25	0.05	0.23	6.67	73.30		69	35.49 8.99	17.0	78
3/7/73	6	6.2	.31	0.51		6.48	75.46	80	75.5	76.31 10.46	26.0	30
5/7/73	6	7.6	2.85	0.02		5.42	63.00	73	NB 75		22.5	26
9/7/73	6	.20	.316	0.01		4.32	52.05	91	78	52.89 9.45	32.5	18
12/7/73	6	1.45	0.93	0.01		9.23	101.42	70.5	69	72.56 9.95	22.5	33
16/7/73	6	1.4	1.02	0.24		12.30	138.2	75	71	76.22	22.5	28
19/7/73	6	1.6	2.00	0.01		14.65	176.5	71.5	78	410.6 104.3	17.5	25
23/7/73	6	1.5	0.85	0.01		6.38	71.6	73	71.5	145.5	17.5	24

- RAW DATA LIST

DATE	STAT	SOL. P	PAR. P	NO_3^- N	NH_4^+ N	O_2 PPM PPM	O_2 % SAT	TEMP A°	W°	[illegible]	[illegible]	[illegible]
26/7/73	6	0.40	1.00	0.02		7.56	84.00	78	80	21.5	17.5	145
30/7/73	6	1.50		0.54		18.68	209.88	76.5	72.5	107.5	17.5	41
7/8/73	6	.85	1.05	0.02		13.07	163.37	76	82	125.8	27.5	23
9/8/73	6	1.3	2.425	0.34		13.64	164.33	85	78	189.2	36	25
13/8/73	6	2.1	3.9	0.42		15.23	173.06	77	77	174.5	17.0	27
20/8/73	6	1.15	0.70	0.00	0.31	11.90	135.22	79	73.5	57.31	35	20
23/8/73	6	1.80	1.175	0.89	0.27	12.67	130.61	64.5	64	161.4	38.5	38
27/8/73	6	2.10	2.10	0.65	0.00	10.44	120.69	78.4	74.5	654.2	26	23
4/9/73	6	1.3	0.50	0.86	0.00	7.80	106.85	87.4	91.2	18.32	32.5	29
6/9/73	6	6.50	1.85	0.49	4.60	8.85	102.31	76	74.5	300.5	20	28
13/9/73												
20/9/73												
27/9/73												

RAW DATA SHEET

DATE	STAT	SOL. P	PAR. P	NO$_3$ N	NH$_4$ N	O$_2$ PPM PPM	O$_2$ % SAT	TEMP. A	W			
4/10/73												
20/10/73	6	1.80	0.5	0.63	3.69	10.33		54.9	49	78.26	-33	16
23/10/73												
24/10/73	6	1.3		0.47	0.50	9.53		49	48.5	44.90	60	10
1/11/73												
8/11/73												
22/11/73	—											
16/1/74												
23/1/74												
30/1/74												
6/2/74												
13/2/74												

RAW DATA

DATE	STAT.	SOL. P	PAR. P	NO$_3$ N	NH$_4$ N	O$_2$ PPM PPE	O$_2$ % SAT.	TEMP. A	TEMP.			
20/2/74												
27/2/74												
7/3/74												
15/3/74												
22/3/74												
29/3/74												
5/4/74												
11/4/74												
19/4/74												
27/4/74												
3/5/74												
10/5/74	6	0.10		0.98	0.11	13.03	107.68	56	46.5	8.20	35.5	24

RAW DATA SHEET

DATE	STAT	SOL. P.	PAR. P.	NO_3^- N.	NH_4^+ N.	O_2 PPM PPM	O_2 % SAT	TEMP A	TEMP W	[illegible]	[illegible]	[illegible]
16/5/74	6	0.12		0.74	0.21	10.25	97.62	53.5	56	10.8	62	11.00
23/5/74	6	0.10		0.44	0.00	8.24	85.80	74	65	7.20	47	15.00
31/5/74	6	0.45		0.68	0.00	8.10	109.4	65.5	54.2	7.00	45	17.5
7/6/74												
14/6/74												

RAW DATA LIST

DATE	STAT	SOL. P	PART. P	NO_3^- N	NH_4^+ N	O_2 PPM - PPM	O_2 % SAT	TEMP A	TEMP W	CHL	SECC	TURB
14/6/73	7	0.0	.30	0.36		8.90	109.88		80	104.6 13.2	27.5	24
18/6/73	7	0.00	.34	0.82		12.05	131.69		68.5	147.3 9.01	32.5	20
21/6/73	7	.10	.517	0.60		11.31	126.36		70.5	169.9 15.17	31.5	25
25/6/73	7	.05	.425	0.27		10.73				117.6 10.78		30
28/6/73	7	8.05	6.25	0.35		8.12	92.3		73.0	118.7 16.54	33.5	28
3/7/73	7	8.10	3.45	0.045		16.13	199.13	86	81	111.0 11.95	38	22
5/7/73	7	4.8	3.05	0.018		4.92	56.55	77.5	74	.85	17.5	35
9/7/73	7	.20	0.55	0.015		8.98	115.13	89	85	204.2 15.14	17.5	40
12/7/73	7	0.4	1.22	0.018		7.45	84.65	71.5	73	158.2 8.56	17.5	57
16/7/73	7	0.25	0.61	0.01		12.64	147.83	73	75.5	209.7	22.5	35
19/7/73	7	.15	.66	0.01		13.51	162.77	76	78	227.7 20.4	22.5	43
23/7/73	7	.328	.90	0.01		6.86	78.85	71	74	116.3	17.5	45

RAW DATA LIST

DATE	STAT	SOL. P	PAR. P	NO_3^- N	NH_4^+ N	O_2 PPM PPM	O_2 % SAT	TEMP. °F A	TEMP. °F W	Chla	Cond	Chlor
26/7/73	7	.40	.675	0.02		8.00	94.1	79	76	188.3	17.5	55
30/7/73	7	.25	0.90	0.60		9.20	106.97	77.5	75	212.4	17.5	45
7/8/73	7	0.14	0.775	0.01		12.43	159.63	77.5	81	286.7	17.5	35
9/8/73	7	0.20	1.00	0.01		8.04	99.25	83.5	80.2	314.6	14	72
13/8/73	7	0.35	0.75	0.05		6.03	71.78	77	77	124.3	17.5	40
20/8/73 A	7	0.15	0.70	0.01	0.12	9.19	108.75	79.5	76.5	206.2	22.5	37
23/8/73	7	0.45	0.512	0.02	0.00	11.26	119.78	68	66	233.6	22.5	35
27/8/73	7	0.24	0.75	0.01	0.35	6.32	74.35	77.6	76.4	196.7	13.0	51
4/9/73	7	0.30	0.950	0.34	0.27	4.84	60.50	87.5	82.0	144.9	12.5	51
6/9/73												
13/9/73												
20/9/73												
27/9/73												

RAW DATA LIST

DATE	STAT	SOL. P	PAR. P	NO$_3$ N	NH$_3$ N	O$_2$ PPM PPM	O$_2$ % SAT	TEMP A	°F			
14/6/73	8	.00	.34	0.53		10.98	130.71		77	11.[illegible] 14.21	[illegible]	31
18/6/73	8	.10	.375	0.85		6.70	67.0		61.2	188.8 14.58	27.5	33
21/6/73	8	.10	.725	0.69		11.60	130.33		71.0	171.9 17.04	31.5	28
25/6/73	8	.05	.416	1.10		9.37				130.7 14.73		40
28/6/73	8	15.9	4.84	0.32		9.21	105.2		73.5	153.2 23.18	21.5	40
3/7/73	8	5.84	2.7	0.022		19.00	234.5	85.5	81	112.8 15.9	38.5	22
5/7/73	8	6.0	2.48	0.04		7.76	88.2	77	73		17.5	40
9/7/73	8	.20	.416	0.65		9.08	114.2	85.5	82.5	165.1 14.3	27.5	34
12/7/73	8	1.5	.73	0.81		10.25	117.8	74.5	74	126.1 5.38	17.5	49
16/7/73	8	0.04	0.40	0.47		13.95	162.2	72.5	75	160.0	22.5	33
19/7/73	8	.05	.383	0.47		17.43	223.4	76.5	84.5	175.11 19.31	23.5	35
23/7/73	8	.114	.75			7.00	81.39	73.5	75	95.29	17.5	45

RAW DATA LIST

DATE	STAT	SOL. P	PAR. P	NO_3^- N	NH_4^+ N	O_2 PPM PPM	O_2 % SAT	TEMP. A	TEMP. W	Chl a	Secchi	Turb
26/7/73	8	.16	.675	0.62		7.36	87.62	80	77	140.6	17.5	32
30/7/73	8	.12	.737	1.00		12.65	147.95	77	75.5	201.1	22.5	36
7/8/73	8	0.05	0.550	0.31		15.62	189.33	78.5	78.5	261.9	17.5	33
9/8/73	8	0.15	0.825	0.010		9.58	118.27	81	80.6	225.7	16	58
13/8/73	8	0.15	0.525	0.85		9.10	107.06	78.5	76.0	108.1	22.5	29
20/8/73	8	0.12	.55	0.42	0.04	9.94	118.33	77	77	178.5	27.0	34
23/8/73	8	0.30	0.425	0.03	0.16	11.33	124.51	65.2	69	195.2	25.0	34
27/8/73	8	0.12	0.55	0.60	0.00	10.62	125.68	80.5	76.5	184.3	22.5	40
4/9/73	8	0.125	0.50	1.02	0.04	11.70	147.17	85.6	82.5	136.4	22.5	35
6/9/73	8	0.200	0.975	0.96	0.48	9.05	107.73	77	77	144.9	15.0	74
13/9/73												
20/9/73												
27/9/73												

RAW DATA LIST

DATE	STAT	SOL. P	LABL. P	NO$_3$ N	NH$_4$ N	O_2 PPM	O_2 % SAT	TEMP A	TEMP W	CHA	[illegible]	TURB
14/6/73	9	.00	.31	0.48		10.53	128.41		79	135.63 19.73	[illegible]	37
18/6/73	9	.00	.47	0.72		8.30	83.0		61.5	184.71 14.88	27.5	35
21/6/73	9	.10	.45	0.14		12.44	139.77		71.3	162.99 11.72	32.5	19
25/6/73	9	.05	.44	1.25		10.85				122.45 11.81		30
28/6/73	9	8.95	5.0	0.78		9.21	104.66		73.5	162.97 26.48	21.5	41
3/7/73	9	8.9	2.55	0.01		19.32	247.57	85.5	81.5	123.78 17.16	33.5	23
5/7/73	9	4.2	3.0	0.12		7.78	89.42	77	79		28.5	31
9/7/73	9	.50	.45	0.01		8.04	99.26	80.5	80	192.28 11.82	27.5	25
12/7/73	9					8.69	99.88	74.5	74		17.5	47
16/7/73	9	0.05	0.48	0.71		12.70	147.67	72.5	75	137.0	22.5	43
19/7/73	9	.05	.35	0.83		15.13	191.52	77	83	163.0 10.0	22.5	35
23/7/73	9	.114	.75	1.78		6.90	80.23	72	75	95.0	17.5	46

RAW DATA LIST

DATE	STAT.	SOL. P	PAR. P	NO_3^- N	NH_4^+ N	O_2 PRS PPM	O_2 % SAT	TEMP. A	W	Chl a	Secc	TURB
26/7/73	9	.15	.625	0.73		7.98	95.00	80	77	153.1	17.5	42
30/7/73	9		.700	0.96		10.02	117.88	78.5	76	178.4	22.5	38
7/8/73	9	0.075	0.462	0.76		15.62	198.9	78.5	83.5	243.3	26	26
9/8/73	9	0.10	0.687	0.010		8.91	110.00	81	80	264.1	22	46
13/8/73	9	0.175	0.663	0.83		8.51	101.31	78.5	77	132.9	12.5	43
20/8/73	9	0.09	0.425	1.10	0.08	10.58	125.20	75	76.5	147.3	27	35
23/8/73	9	2:10	0.437	0.95	0.08	10.63	116.81	66.2	69.0	167.9	25	27
27/8/73	9	.06	0.487	0.53	0.12	11.30	133.73	81.5	76.5	176.7	22.5	33
4/9/73	9	1.0	0.50	0.97	0.99	14.20	179.75	90.5	83.2	173.5	15.00	25
6/9/73	9	0.12	0.675	1.13	0.31	6.08	72.4	77	77	111.4	14	57
13/9/73												
20/9/73												
27/9/73												

RAW DATA LIST

DATE	STAT.	SOL. P	PAR. P	NO_3^- N	NH_4^+ N	O_2 PPM PPM	O_2 % SAT	TEMP. °F A	W	CHL.	[illegible]	TURB.
20/2/74												
27/2/74												
7/3/74												
15/3/74												
22/3/74												
29/3/74												
5/4/74												
11/4/74												
19/4/74												
27/4/74												
3/5/74	9	0.10		0.98	1.09	14.20	133.2	52	55	140.11	28	30.5
10/5/74	9	0.10		1.06	0.247	11.06	94.5	50.5	47.5	81.77	18	36.0

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RAW DATA LIST

DATE	STAT	SOL. P	PAR. P	NO_3 N	NH_4 N	O: PPM PPM	O: % SAT	TEMP. A	TEMP. W			
16/5/74	9	0.14		1.12	0.66	11.31	109.8	55	58.5	42.46	25	32
23/5/74	9	0.40		0.72	0.83	7.66	81.4	74	66	57.09	16	51
31/5/74	9	0.5		0.54	0.27	11.88	123.7	61.5	64.8	77.82	43	14
7/6/74												
14/6/74												

RAW DATA LIST

DATE	STAT.	SOL. P	PAR. P	NO_3^- N	NH_4^+ N	O_2 PPM PPM	O_2 % SAT	TEMP. A	TEMP. W	[illegible]	[illegible]	[illegible]
14/6/73	10	.05	.29	.29		11.17	137.90		80	107.4 11.88	24.5	45
18/6/73	10	.00	.35	0.60		10.53	115.71		69	171.6 11.88	27.5	32
21/6/73	10	.05	.41	0.66		12.74	143.15		70.7	188.6 15.31	31.5	21
25/6/73	10	.05	.40	0.06		10.82				111.7 12.03		30
28/6/73	10	19.2	5.8	0.61		10.73	122.63		73.5	168.9 28.40	27.5	35
3/7/73	10	4.6	2.67	0.05		16.45	203.1	82	80	120.2 12.78	38	20
5/7/73	10	5.0	3.28	0.03		4.41	51.88	77	76		12.5	72
9/7/73	10	.30	0.60	0.015		8.17	104.87	87	85	233.9 30.31	22.5	44
12/7/73	10	0.25	0.70	0.02		8.93	101.47	70	73	155.2 11.20	17.5	47
16/7/73	10	0.25	0.60	0.02		11.31	132.28	73.5	75.5	204.3	17.5	60
19/7/73	10	.10	.66	0.01		11.31	139.63	76.5	80	204.6	17.5	45
23/7/73	10	.144	0.65	0.55		6.36	55.01	71.5	74.5	88.84	17.5	45

RAW DATA LIST

DATE	STAT.	SOL. P	PAR. P	NO$_3$ N	NH$_3$ N.	O$_2$ PPM PPM	O$_2$ % SAT	TEMP A	TEMP W	Chla	Secc	Colour
26/7/73	10	.17	0.65	0.02		8.04	94.58	79	76	152.6	22.5	30
30/7/73	10	0.14	1.00	0.37		8.49	98.72	77	75	220.0	17.5	60
7/8/73	10	0.09	0.725	0.01		15.18	189.75	78.5	82	299.1	16.0	45
9/8/73	10	0.350	0.850	0.01		8.14	100.49	87.6	80	263.0	30	45
13/8/73	10	0.250	0.750	0.39		6.61	78.69	77	77	167.3	16.0	44
20/8/73	10	0.125	0.650	0.08	0.04	8.52	100.82	75.5	76.5	194.7	18	40
23/8/73	10	0.25	0.487	0.02	0.00	10.92	118.69	64.4	68.2	223.5	23	33
27/8/73	10	0.14	0.725	0.02	0.00	7.93	93.84	77.5	76.5	194.2	15	54
4/9/73	10	1.1	0.725	0.48	0.35	8.37	104.62	86.5	82.2	224.5	17.5	40
6/9/73	10	0.21	0.925	0.46	0.16	6.05	72.45	77.5	77.5	150.8	15	61
13/9/73												
20/9/73												
27/9/73												

RAW DATA LIST

DATE	STAT	SOL. P	PAR. P	NO_3^- N	NH_4^+ N	O, PPM PPM	O, % SAT	TEMP A	TEMP W	CHL	[illegible]	[illegible]
14/6/73	11	.00	.36	.47		15.34	196.66		85	153.4 25.82	[illegible]	[illegible]
18/6/73	11	.10	.49	0.42		8.23	90.94		69.5	223.7 14:9	27.5	30
21/6/73	11	.05	.30	0.65		15.21	170.89		71.0	111.7 9.25	43.0	18
25/6/73	11	.05	.491	0.35		10.82	114.		71	204.2 33.1		33
28/6/73	11	9.1	3.8	0.34		7.29	82.84		73	137.0 25.22	37.5	23
3/7/73	11	12.0	2.53	0.02		15.51	191.48	80	80	95.34 6.94	36	17
5/7/73	11	4.2	3.35	0.03		7.70	86.51	79	72		27.5	24
9/7/73	11	.30	.30	0.35		9.25	118.6	89.5	85	101.8 5.91	32.4	27
12/7/73	11	0.10	0.566	0.01		9.57	111.28	78	75	175.9 15.41	22.5	29
16/7/73	11	0.10	0.50	0.01		10.15	119.4	73.5	76	209.6	17.5	44
19/7/73	11	.05	.516	0.01		11.42	140.9	77	80	173.7 7.50	17.5	30
23/7/73	11	.174	.625	0.01		5.94	69.88	75	76	101.4	22.5	33

RAW DATA LIST

DATE	STAT.	SOL. P	PAR. P	NO_3 N	NH_4 N	O_2 PPM PPM	O_2 % SAT	TEMP A	TEMP W	Chla	Secc	Other
26/7/73	11	0.175	.650	0.26		8.57	102.02	77.5	.77	182.0	27.5	27
30/7/73	11		.825	0.27		12.39	146.62	78.5	76.5	229.3	22.5	34
7/8/73	11	0.05	0.42	0.01		11.52	142.22	78	80.5	206.8	27.5	28
9/8/73	11	0.16	0.47	0.27		10.65	132.3	88.5	81.6	200.3	30	24
13/8/73	11	0.10	0.80	0.49		6.99	83.2	76.5	77	193.5	22.5	35
20/8/73	11	0.10	0.52	0.02	0.08	8.42	76.88	74	77.5	253.8	33	25
23/8/73	11	0.34	0.73	0.25	0.61	8.46	93.48	68	69.5	199.2	33	23
27/8/73	11	0.06	0.50	0.15	0.00	9.87	115.44	78.5	75.5	156.1	27.5	29
4/9/73	11	0.05	0.27	0.55	0.20	9.53	119.87	87.0	82.5	99.5	25	17
6/9/73	11	0.10	0.48	0.41	0.50	6.29	76.71	79	79	128.2	32.5	32
13/9/73	11	0.04	0.52	0.29	0.00	12.46 10.71	127.8 109.85	62.0	63.5	245.9	30	20
20/9/73	11	0.74	0.55	0.12	0.00	16.68 15.21	168.50 153.64	62.2	62	201.4	32.5	17.0
27/9/73	11	0.21	0.72	0.57	0.687	19.29 16.95	217.96 191.52	82.5	72.5	134.7	32.5	20

RAW DATA LIST

DATE	STAT	SOL. P	PAR. P	NO_3^- N	NH_4^+ N	O_2 PPM PPM	O_2 % SAT	TEMP A	TEMP W	Chl a	Secc	Turb
4/10/73	11	0.06	0.516	0.22	0.50	10.17 10.06	105.93 104.8	65.5	55	141.5	30	24
20/10/73	11	0.04	0.272	0.42	1.06	10.55 10.40		51.3	49	80.61	47.5	10
23/10/73												
24/10/73	11	0.11		0.44	2.19	8.62 8.43		48	50.5	70.70	37	15
1/11/73	11											
8/11/73	11	0.25		0.94	1.44	10.82		47	41.5	11.85	30	17.5
22/11/73	11	0.20		0.83	1.44	10.73		52	45	7.79	30	35
16/1/74												
23/1/74												
30/1/74												
6/2/74												
13/2/74												

DATE	STAT.	SOL.P PAR.P	PAR. SOL.P	NO$_3^-$ N	NH$_4^+$ N	O$_2$ PPM PPM	O$_2$ % SAT	TEMP. °F A	TEMP. °F W	CHA	[illegible]	TURB
14/6/73	12	.00 .28	0.28	.47	0.61	10.24	126.42		73	12.49	27.5	36
18/6/73	12	.00 .39	0.39	1.08	1.81	10.77	119.00		69.5	154.76 11.95	27.5	36
21/6/73	12	.05 .35	0.40	0.81	0.81	11.63	130.67		71.5	238.15 16.22	33.0	23
25/6/73	12	.10 .46	0.56	0.97	0.85	10.22	115.00		71	166.5 23.16	17.0	37
28/6/73	12	.15 .40	0.55	0.53	0.81	9.54	107.8	75	72.5	134.02 20.97	27.5	28
1/7/73	12	6.0 2.8	8.8	0.01	0.40	17.05	213.1	85	82	126.53 10.6	38	18
5/7/73	12	6.4 1.4	7.8	0.76	0.40	5.73	65.41	77	73	104.7	17.5	59
9/7/73	12	.50 0.43	0.93	0.46	0.00	6.46	79.75	83	80	235. 12.5	17.5	42
12/7/73	12	0.50 0.70	1.20	0.01	0.00	8.99	102.1	73	73	123.6 10.05	17.5	65
16/7/73	12	0.05 0.41	0.47	0.32	0.00	13.43	158.0	73.5	76	202.8	21.0	48
19/7/73	12	.05 .60	0.65	0.27	0.00	14.75	179.8	76	79	178.9 3.00	17	47
23/7/73	12	.196 .775	.97	0.01	0.00	5.88	68.37	71.5	75	96.56	17.5	39

RAW DATA LIST

DATE	STAT	SOL.P PAR.P	PAR.+ SOL.P	NO_3^- N	NH_4^+ N	O_2 PPM PPM	O_2 % SAT	TEMP. A	TP W	COND	Secc	TURB
26/7/73	12	.30 .812	1.12	0.49	0.77	7.87	92.58	78.5	76	198.1	17.5	50
30/7/73	12	0.2 .675	0.88	0.82	0.00	11.23	130.58	77.5	75	232.7	22.5	30
7/8/73	12	0.11 0.75	0.86	0.38	0.00	10.49	129.51	77.5	80	289.1	17.5	42
9/8/73	12	0.15 0.65	0.80	0.02	0.00	8.33	100.96	86	78.6	239.2	22	33
13/8/73	12	0.16 0.70	0.86	0.82	0.00	6.99	82.23	76	76	131.1	17.5	40
20/8/73	12	0.12 0.60	0.72	0.11	0.04	8.52	101.43	74	77	204.5	22.5	37
23/8/73	12	0.50 0.45	0.95	0.50	0.45	10.25	112.64	67.3	68.8	183.1	27.5	33
27/8/73	12	0.41 0.67	1.10	0.41	0.675	9.20	108.23	78	76	177.2	17.5	43
4/9/73	12	0.15 0.70	0.85	0.15	0.70	10.50	128.05	85.6	82.2	308.5	18	39
6/9/73	12	0.35 0.80	1.15	0.35	0.802	4.46	53.01	75	77	134.7	17	52
13/9/73	12	0.06 0.54	0.60	0.57	0.80	12.29 10.78	124.77 109.44	62.5	62.5	171.6	30	22.5
20/9/73	12	0.4 0.72	1.19	0.64	2.4	9.13 9.03	90.39 89.4	59.5	60.4	179.6	28.0	30.0
27/9/73	12	0.08 0.67	0.76	0.86	0.68	16.45 16.45	176.8 176.8	78.5	67.0	290.4	30	33

RAW DATA LIST

DATE	STAT	SOL.P PAR.P	PAR.+ SOL.P	NO_3^- N	NH_4^+ N	O_2 PPM PPM	O_2 % SAT	TEMP A	TF W	Chl	Secc	Turb
4/10/73	12	0.11 0.962	1.07	0.58	1.06	8.69 8.45	89.60 87.10	64	63.8	145.4	27.5	30
20/10/73	12	0.022 0.128	0.15	0.75	0.69	11.06 10.35	96.60 90.40	53.5	49	56.35	32.5	20
23/10/73												
24/10/73	12	0.06		0.60	1.06	9.92 9.46	90.00 86.00	47	52.5	86.84	20	40
1/11/73	12	0.30		2.12	0.687	9.58	83.00	49	49	69.85		160
8/11/73	12	0.15		1.50	0.40	11.78	92.00	44	41.5	30.79	12	74
22/11/73	12	0.25		1.44	1.14	10.73	87.00	48.7	45.2	7.53	17	40
16/1/74	12	0.50		4.25	2.60	11.90	82.00	36.0	32.0	4.65		3.0
23/1/74	12	0.25		3.40	0.50	12.74	89.16	36.5	33	0.40		15
30/1/74	12	0.20		2.90	0.46	7.85	54.8	41.5	33.0	1.50		22.0
6/2/74	12	0.40		3.70	0.61	13.60	94.4	12	33	0.80		16.5
13/2/74	12	0.50		3.60	1.21	11.98	82.0	33.5	32.5	1.43		6.00

RAW DATA LIST A

DATE.	STAT.	SOL. P	PAR. P	NO_3^- N	NH_4^+ N	O_2 PPM PPM	O_2 % SAT	TEMP A	TEMP W	Cl‰	Secchi	TURB
20/2/74	12	0.65		4.60	1.21	13.25	90.7		32	1.64		8.0
27/2/74	12	0.70		3.30	0.28	11.52	78.2	32	32	1.18		10.0
7/3/74												
15/3/74												
22/3/74												
29/3/74												
5/4/74	12	0.9		1.59	1.28	-	-	60.0	49.0	16.6		31
11/4/74	12	3.2		1.35	0.58	12.84	103.5	55.5	43.5	10.1	33	21
19/4/74	12	0.30		0.99	1.03	9.96	84.4	40.0	47.0	31.7	17	59
27/4/74	12	0.10		1.08	0.86	16.05	158.1	63.0	59.5	80.7	32.5	31
3/5/74	12	0.05		1.08	1.31	12.21	112.02	51	53.8	149.	20.0	40.5
10/5/74	12	0.10		1.00	0.28	12.45	105.5	48.5	47.0	77.6	20.0	33.0

RAW DATA LIST

DATE	STAT	SOL. P	PAR. P	NO_3^- N	NH_4^+ N	O_2 PPM PPM	O_2 % SAT	TEMP. °F A	W			
16/5/74	12	0.16		1.20	1.46	9.6	92.3	59.5	56.8	38.05	25	29
23/5/74	12	0.40		0.72	3.13	7.66	81.4	74	66	54.00	15	60
31/5/74	12	0.50		0.57	0.45	12.26	127.7	61.5	64.8	70:00	43	14
7/6/74												
14/6/74												

RAW DATA LIST

DATE	STAT.	SOL. P	PAR. P	NO_3^- N	NH_4^+ N	O_2 PPM PPM	O_2 % SAT	TEMP. A	TEMP. W	COND	Secc	Turb
26/7/73	13	.20	.75	1.35		7.67 6.52	90.23 76.70	72	76	146.5	22.5	40
30/7/73	13		.812	1.04		9.87 8.01	116.12 94.23	80.5	76	266.1	17.5	50
7/8/73	13	.05	.85	0.30		11.69 8.06	144.32 99.50	76	80	319.4	22.5	32
9/8/73	13		0.65	0.40		7.86 8.23	95.85 100.36	85.5	79	190.5	20	36
13/8/73	13	.15	0.613	0.84		5.55 4.79	64.53 55.69	74	75	119.2	17.5	45
20/8/73	13	0.09	0.40	1.09	0.04	10.63 9.13	125.80 108.05	74.5	76.5	142.0	32.5	25
23/8/73	13	0.40	0.187	2.13	0.725	8.27 9.68	91.88 107.55	66	70.2	68.64	42.5	20
27/8/73	13	0.10	0.60	0.68	0.00	9.20 8.05	107.60 94.15	79	75.5	151.4	22.5	30
4/9/73	13	0.10	0.675	0.79	2.2	10.40 8.60	130.00 107.5	84.5	82.2	243.4	18	39
6/9/73	13	0.180	0.575	0.78	0.876	4.92 4.84	58.57 57.61	74.5	77	118.7	17	47
13/9/73												
20/9/73												
27/9/73												

RAW DATA LIST

DATE	STAT	SOL. P	PAR. P	NO_3^- N	NH_4^+ N	O_2 PPM PPM	O_2 % SAT	TEMP A.	TEMP W	CHA	[illegible]	TURB
14/6/73	13	.00	.24	0.61		16.71 16.25 15.20	204. 198. 185.		79	84.26 17.55	32.5	26
18/6/73	13	.20	.575	0.88		12.60 6.86	139.22 75.80		69.5	359.0 35.74	22.5	43
21/6/73	13	.05	.45	0.95		11.98 11.88	134.61 133.50		71.5	207.8 18.75	36.5	23
25/6/73	13	.10	.316	1.14		8.70 6.94	105.2			103.7 10.44		25
28/6/73	13	0.12	.375	0.88		9.31 9.40	105.2 106.2	85	72.5	134.9 17.78	33.0	25
3/7/73	13	5.15	3.1	0.01		16.07 14.38	202.12 179.75	85	82	104.7 12.20	36.0	20
5/7/73	13	4.4	2.7	0.03		6.53 6.40	74.2 72.73	77	73		27.5	37
9/7/73	13	.20	.383	0.01		9.16 7.50	113.1 92.6	81	80	192.6 13.77	27.5	30
1277/73	13	0.15	0.70	1.72		7.72 7.85	86.74 88.20	73	71.5	87.21 7.20	22.5	53
16/7/73	13	0.10	0.525	0.49		12.74 9.68	148.14 112.58	74.5	75	155.6	17.5	47
19/7/73	13	.04	0.60	0.36		12.07 12.45	149.01 153.70	76	80	176.5 4.4	17.5	35
23/7/73	13	.027	.425	1.38		7.51 7.28	87.32 84.65	74	75	65.5	22.5	73

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