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ABSTRACT

Phillip Joe Smith. TROPHIC STATUS OF THREE NORTH CAROLINA COASTAL PLAIN IMPOUNDMENTS. (Under the direction of Dr. Vincent J. Bellis) Department of Biology, March, 1977.

Trophic status was evaluated for three North Carolina impoundments subjected to differing degrees of cultural influence. Bi-weekly sampling of each impoundment was carried out from October, 1973, through October, 1974. Water quality parameters measured included pH, conductivity, turbidity, major nutrients, dissolved oxygen profile, BOD, chlorophyll a phytoplankton species composition, density, diversity, and gross primary productivity.

Hardee Lake, surrounded by an urban subdivision and cultivated fields, was influenced by both domestic and agricultural enrichment. The algal floral composition, high cell density, low diversity, and high cyanophyte productivity in Hardee Lake during summer were indicative of advanced eutrophication.

Carson Lake was influenced by agricultural runoff and showed a trend toward eutrophication as evidenced by a blue-green algal dominance during summer. Agricultural source of nutrients appeared to have less effect on the trophic state of Carson Lake than the combined effect of both agricultural and urban stress had on the trophic state of Hardee Lake.

Sheppard's Millpond, a brown-water impoundment, was the least affected by cultural influence because the watershed has not experienced urban development and the millpond receives little agricultural runoff owing to a buffer zone. Lower trophic state may have resulted from growth constraints inherent in dark acidic water, reduced availability

of phosphorus complexed by particulate organic matter, and filtering out of nitrates by the forested watershed.

Based on nitrogen-to-phosphorus ratios all three impoundments appeared to be phosphorus limited. Greater concentrations of ortho-phosphate during spring and summer in Hardee Lake were accompanied by higher phytoplankton densities and greater frequencies of blue-green algal blooms. The contribution of nitrogen and phosphorus from agricultural and lawn fertilizer applications and septic tank seepage appeared to stimulate phytoplankton density and production in Hardee Lake.

Trophic evaluation based on direct measures of biological eutrophication showed that nutrient concentrations, phytoplankton density, diversity, and production in Hardee Lake were indicative of a hyper-eutrophic condition. Annual gross primary production rate of Carson Lake was indicative of an oligotrophic condition. (Sheppard's Millpond on the basis of its phytoplankton composition, high diversity, and low productivity was characteristic of oligotrophy.)

TROPHIC STATE OF THREE NORTH CAROLINA
COASTAL PLAIN IMPOUNDMENTS

A Thesis

Presented to
the Faculty of the Department of Biology
East Carolina University

In Partial Fulfillment
of the Requirements for the Degree
Master of Science in Biology

by

Phillip Joe Smith

March, 1977

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COASTAL PLAIN IMPOUNDMENTS

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INTRODUCTION

Relatively few limnological studies have been conducted on lakes of the southeast Coastal Plain. This report presents investigations of three lakes in the Coastal Plain of North Carolina during 1973-74. An attempt was made to quantify the existing degree of eutrophication in representative lakes and to establish baseline biological and limnological data which can be used to establish the trophic status and nutrient condition of other lakes and ponds in the region.

The Coastal Plain of North Carolina covers almost one-half of the state and extends from the Atlantic Ocean westward to the fall line which is bordered by the towns of Roanoke Rapids, Smithfield, and Wadesboro. The surface of this region is covered by a thin layer of sand and clay which conceals older formations varying in age from Cretaceous to Recent (Stuckey, 1965). Gently sloping uplands in the west are well drained by numerous tributaries flowing southeast to the lower wetlands and estuaries near the coast. These poorly drained pocosin and wetland areas generally remain in pine, evergreen shrub, or swamp forest vegetation. The climate, being influenced by varying distances from the ocean and estuaries, is moderate but humid and favorable for extensive agriculture in the uplands.

Located within the Coastal Plain are hundreds of small man-made lakes and ponds. Most of these impoundments receive agricultural drainage and can be classified as farm ponds, abandoned sand pits or millponds. In more populated areas, small lakes are frequently located within subdivisions and were created primarily for recreational or aesthetic purposes.

In recent years, expanding urbanization and more extensive use of fertilizer have placed increased stress on many Coastal Plain watersheds. Runoff from agricultural lands and septic tank seepage from urban areas have resulted in enrichment of local lakes and ponds. Hasler (1947) has proposed the term "cultural eutrophication" to describe this hastened eutrophication resulting from man's activities. Complaints of advanced eutrophication of local waters have brought attention to the lack of information concerning North Carolina Coastal Plain lakes and ponds.

A survey of the literature indicated that previous investigations have primarily stressed phytoplankton floristics, nutrient dynamics, or limnological parameters. There has been little emphasis toward integrating these approaches into a comprehensive ecological study within a single lake. These investigations have emphasized rural oligotrophic lakes with much less research effort being directed toward eutrophication of impoundments located within urban areas.

Phytoplankton investigations of southeastern coastal plain lakes have been conducted in Georgia (Schumacher, 1956) and North Carolina (Whitford, 1958). Both studies describe several distinct pond types including brown-water lakes (rich in humic acids), fertilized farm ponds, and clear-water lakes. Schumacher and Whitford found brown-water lakes to be lowest in total biomass, with Chrysophyceae most common in winter, Chlorophyceae dominant most of the year, and Cyanophyceae never among the dominant plankters. Whitford reported that ponds affected by agricultural runoff showed definite trends toward eutrophication with blooms of Anacystis and Anabaena during the summer months. Both

Whitford and Schumacher found clear-water ponds to have short period blooms of Cyanophyceae during the warmest months. Whitford suggested that these blooms resulted from slight shifts in temperature, pH or nutrient levels allowing specific organisms to become relatively abundant for a short period of time. In a later study, Phillips and Whitford (1959) investigated possible correlations between phytoplankton abundance and physico-chemical factors. A positive correlation was found only with pH. The authors did not attempt to explain this correlation.

Nutrient levels and productivity rates of unfertilized Coastal Plain lakes appear to be low, as reported by several recent studies. Polisini, et al. (1970) investigated a small oligotrophic pond in South Carolina and found the dissolved nutrients to be very low ($\bar{x}$ inorganic nitrogen = 0.10 ppm, $\bar{x}$ total phosphorus = 0.005 ppm) with no apparent seasonal changes in concentrations. Light-dark bottle productivity estimates were also very low, ranging from 0.06 to 1.14 mg O_2 /l/day.

Low productivity values were also reported by Tilly (1973) in a study of three Coastal Plain lakes and one lake in the Piedmont plateau of South Carolina. Values ranged from 102 to 396 mg $C/m^2/day$ and ranked low to moderate in primary productivity when compared to lakes studied elsewhere (Goldman, 1960). Tilly found no single physical factor which correlated well with productivity in all lakes investigated; however, obvious factors included nutrient levels, water temperature, light penetration, turbidity, water color, and oxygen stratification.

In view of these investigations it must be concluded that few

descriptive studies have been conducted on Coastal Plain lakes, especially in North Carolina. These studies have been basically confined to separate aspects of the physico-chemical environment with little concensus as to causal relationships or the exact role of the major environmental variables. It was the intent of this study to integrate these variables: phytoplankton, primary productivity, nutrient levels, and the physio-chemical environment into a one-year comprehensive ecological study and establish their interrelationships. Environmental parameters were therefore measured in three representative Coastal Plain lakes: (1) an urban lake, (2) a clear-water fertilized farm pond, and (3) (a brown-water millpond.)

DESCRIPTION OF STUDY AREA

Hardee Lake

Hardee Lake is located 3.5 km southeast of Greenville, Pitt County, N.C., 1.0 km south of N.C. 264, adjacent to SR 1727 (Fig. 1). The lake, constructed in 1965, was considered typical of urban influenced lakes of the Coastal Plain.

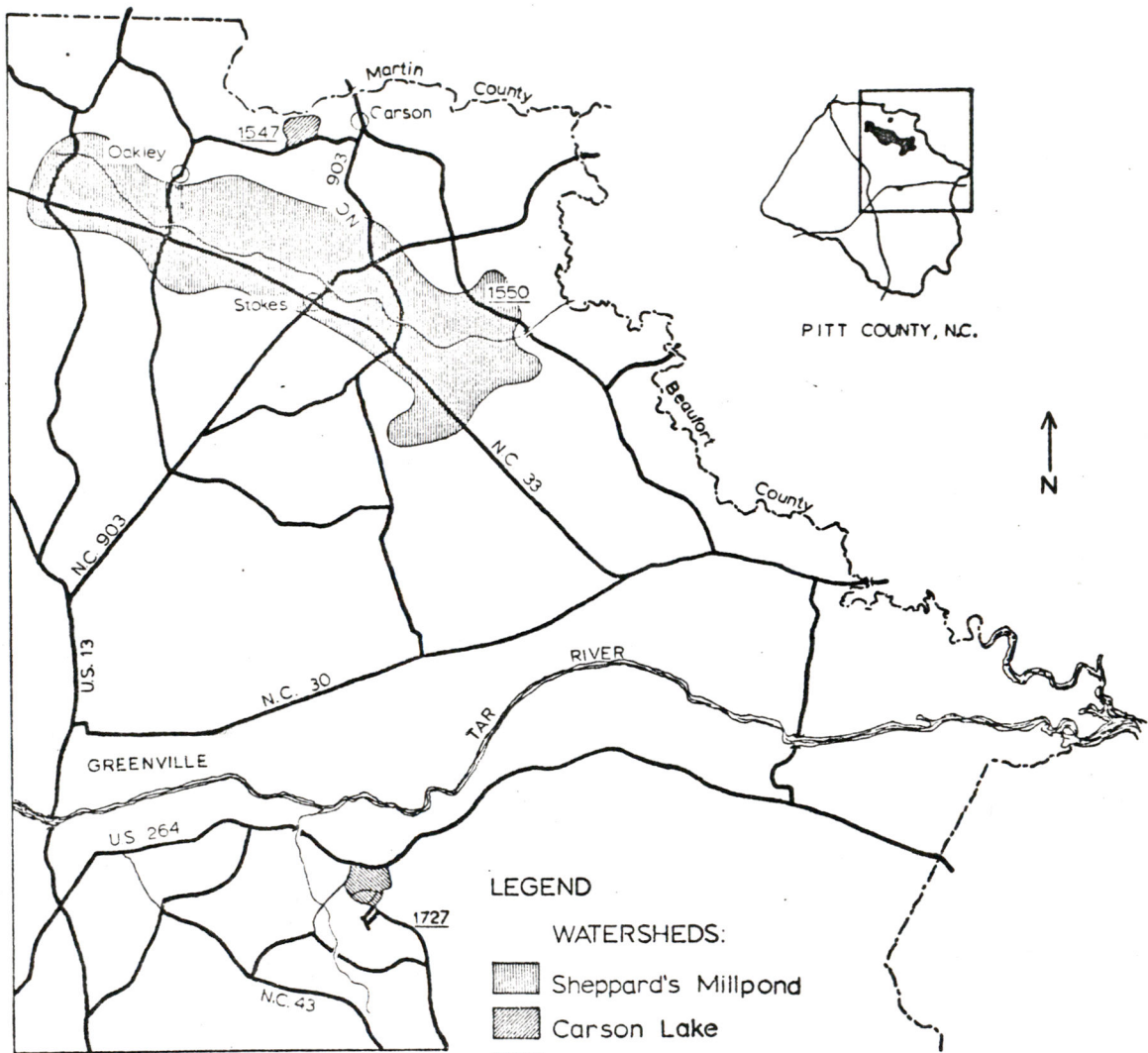
Hardee Lake has a surface area of 4.9 ha. and receives drainage from a watershed of 106 ha. The lake is irregular in shape with long inlet ditches entering on four sides (Fig. 2). The lake basin is less than 1 m deep along its northeastern edge and gradually slopes toward the southwest to a maximum depth of approximately 3 m near the dam. The average depth is 1.3 m.

The water source consists of small underwater springs and runoff from the surrounding watershed. Overflow occurs through three, 60 cm diameter culverts at the dam.

The majority of the soils in the Hardee Lake watershed are Wagram series which consists of well-drained soils on nearly level to sloping uplands (Karnowski, 1974). The soil is relatively poor in organic matter and plant nutrients. Remaining soils consist of Ocilla and Bibb series which are poorly drained soils, level uplands, and broad flats. Natural fertility and organic matter are also low in these soils. High soil moisture is a characteristic to both soil types and frequent flooding occurs in the Bibb series.

The marginal vegetation beside Hardee Lake consisted mainly of short herbaceous annuals and perennials. The following spring flora was

Figure 1. Northeastern Pitt County, N. C., showing location of Sheppard's Millpond, Carson Lake, and Hardee Lake.



LEGEND

WATERSHEDS:

- Sheppard's Millpond
- Carson Lake
- Hardee Lake

1550 COUNTY ROAD

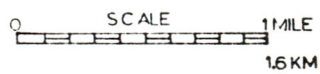
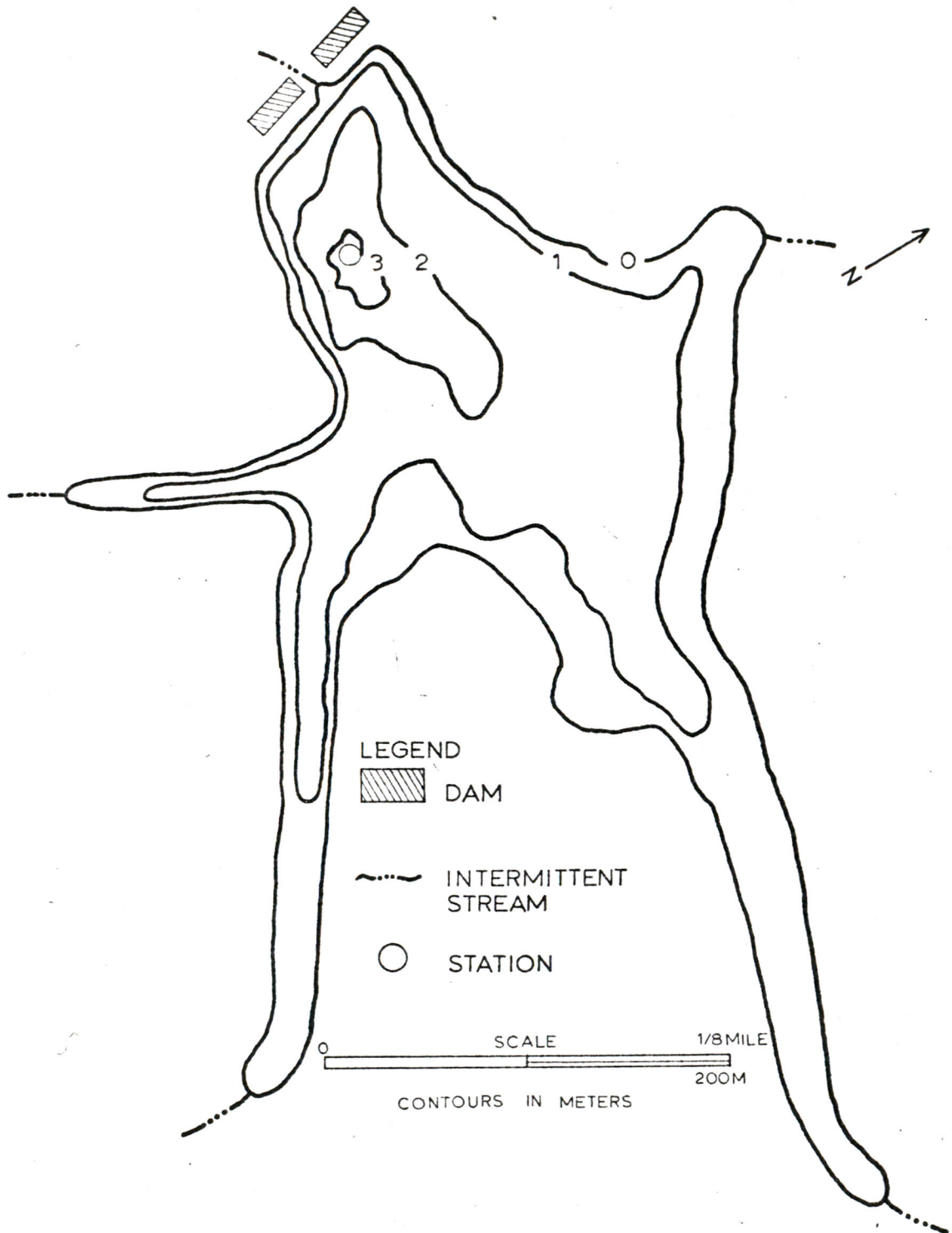


Figure 2. Bathymetry of Hardee Lake. Contours represent depth in meters.



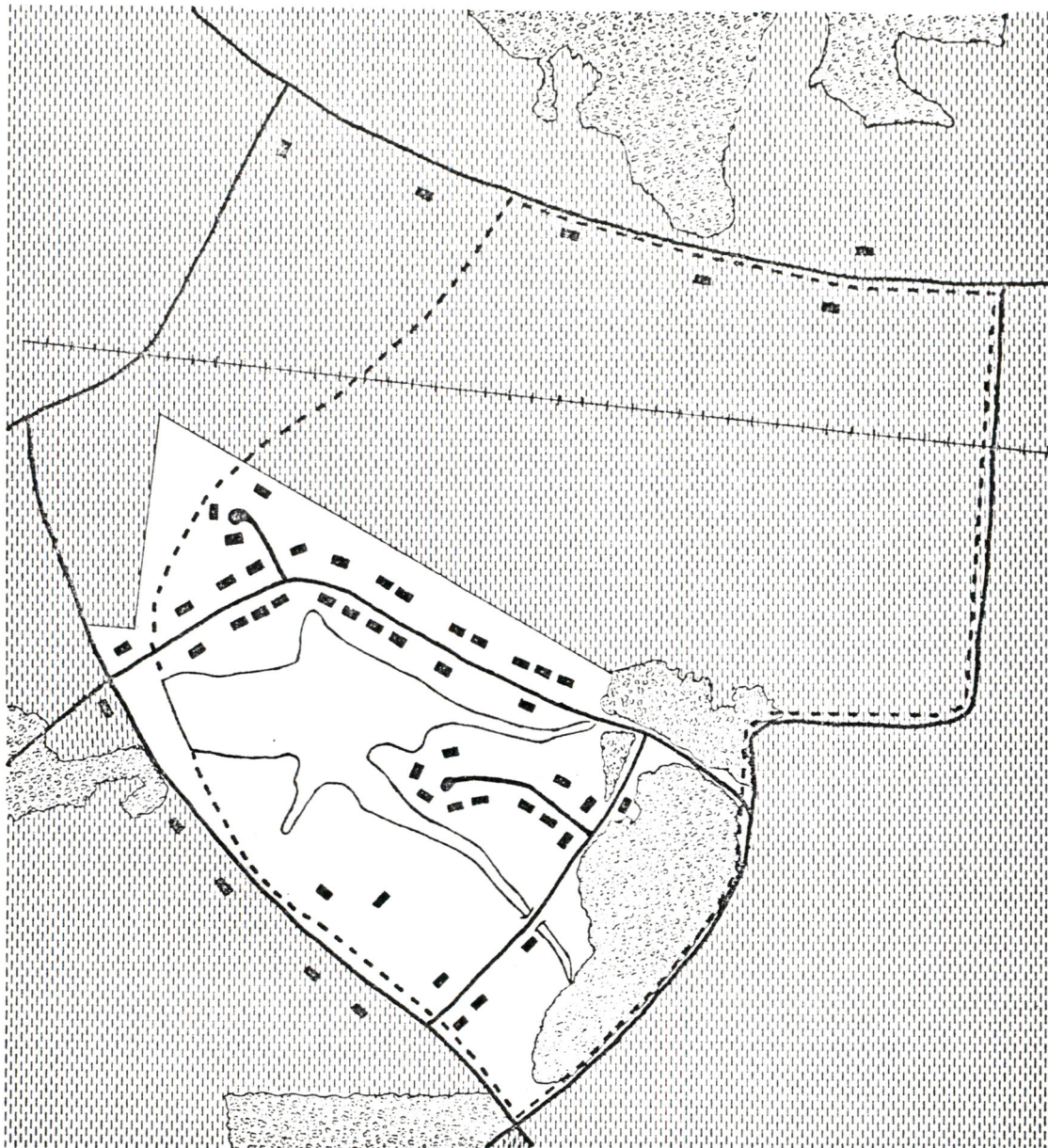
present: Juncus coriaceus Mackenz, Bohemeria cylindrica (L) Sw., Polygonum pennsylvanicum L., and Eupatorium Capillifolium Lam. Some small willows, Salix sp. and pine seedlings, Pinus echinata Mill., were present near the water's edge. Developed homesites and managed lawns lay beyond the lake margin.

The lake is surrounded by the Glennwood Subdivision with approximately fifteen homes situated on 0.42 ha. (15,000 sq. ft.) lots, adjacent to the lake margin. Many more homes are located within 100 m of the lake perimeter (Fig. 3). Domestic sewage from these homes is discharged into septic tanks, many of which are equipped with nitrification lines running near the water's edge. Soil surrounding the lake margin is approximately 80% Bibb and Ocilla series and severely limits septic tank filter fields because of the high water table and frequent flooding. When the septic tanks overflow, organic wastes flow down into the lake.

Northeast of Glennwood Subdivision lies agricultural land and a small stand of hardwood forest with Quercus falcata L., Acer rubrum L., and Liriodendron tuplipifera L. as dominants.

Major crops grown on the agricultural land are tobacco and corn which are supplied respectively with 2,000 and 400 lbs. of fertilizer per acre each growing season. An additional 150 lbs. per acre of liquid nitrogen is applied to the corn land (personal communication with Mr. Glenn H. Hardee). Runoff from these fields drains directly into ditches which flow into the lake (Fig. 3). It was anticipated that urban and agricultural stress placed on Hardee Lake would significantly

Figure 3. Hardee Lake and land use within the watershed.



LEGEND

IMPOUNDMENT

WATERSHED BOUNDARY

LAND USE

Woodlands

Agriculture

Urban

0 SCALE 1/2 MILE
0.8KM

affect its nutrient levels.

Hardee Lake was constructed for land use improvement and to provide water recreational facilities for residents of the surrounding subdivision. However, since its construction in 1965, there have been several fish kills and problems with thick algal blooms during the summer. These blooms emit odors of "dead fish" discouraging residents from swimming and fishing in the lake (personal communication with Mr. Glenn H. Hardee).

The Pitt County Health Department has been contacted on at least ten occasions with complaints of septic tanks failing due to high water table, improper installation, or soil type problems. Complaints such as these have brought about more stringent regulations concerning soil profiles and septic tank placement in subdivisions (personal communication with Mr. Willie Pate, Environmental Health Chief, Pitt County Health Department).

Hardee Lake exhibits characteristics typical of advanced eutrophication such as high organic productivity, seasonal algal blooms, and fish kills. The lake appeared to be under stress as a result of domestic and agriculture influence and was selected for comparison with other lake types in this area.

Carson Lake

Carson Lake is a farm impoundment located in the extreme northeastern corner of Pitt County, N.C., 5.0 km north of Stokes, 1.6 km west of N.C. 903, adjacent to SR 1547 (Fig. 1). The basin was excavated in the summer of 1971 and filled in the fall of the same year. Lake construction was to provide water for livestock, irrigation for field crops and recreational fishing and boating.

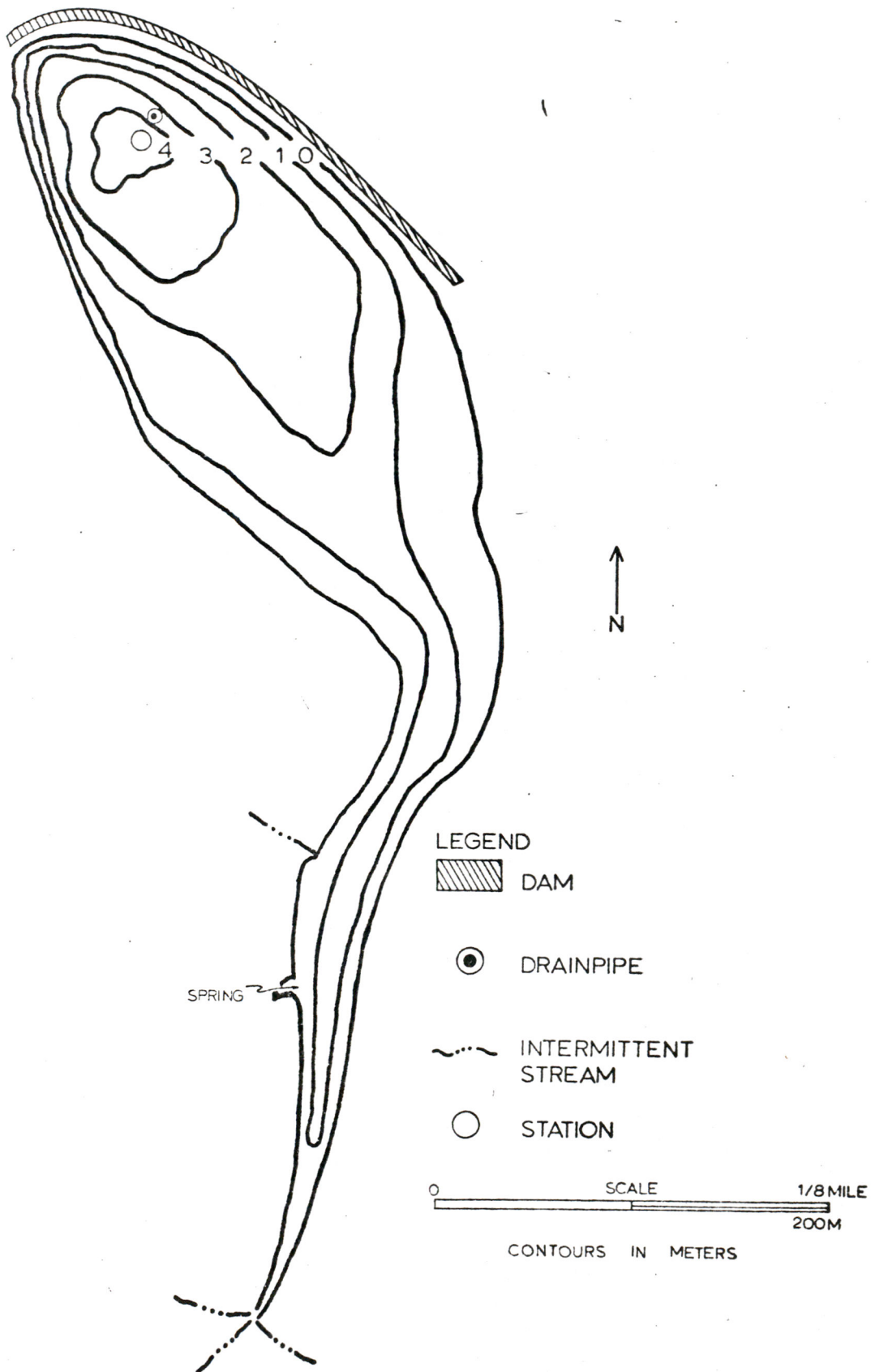
The lake has a teardrop-shaped basin with a surface area of 3.6 ha. and a watershed area of 44 ha. (Fig. 4). The water source is a small spring entering on the southwestern edge and runoff from adjacent fields via a long narrow arm, projecting from the southern end. Excess water overflows through a 30 cm diameter drainpipe approximately 5 m from the northeastern corner of the dam.

The basin is shallow in the projecting southern arm and slopes gradually toward the north to a maximum depth of 4.3 m. The slope near the dam drops off rapidly after only a few meters from the shoreline. The mean depth is 2.0 m.

During November and December 1973, the water level was lowered approximately 2 m to allow further dredging and landscaping of the southern arm. Upon completion, the sloping banks were left bare of vegetation. Later fescue was planted and by late spring had partially stabilized the soil. The effects of dredging and landscaping markedly increased the inorganic turbidity during the winter months of the study.

The majority of the soils of the watershed are of the Exum series and consist of moderately well-drained, fine sandy loam on level or gently sloping uplands (Karnowski, 1974). The soil is relatively poor

Figure 4. Bathymetry of Carson Lake. Contours represent depth in meters.



in organic matter and low in natural fertility but responds well to recommended applications of fertilizer and lime.

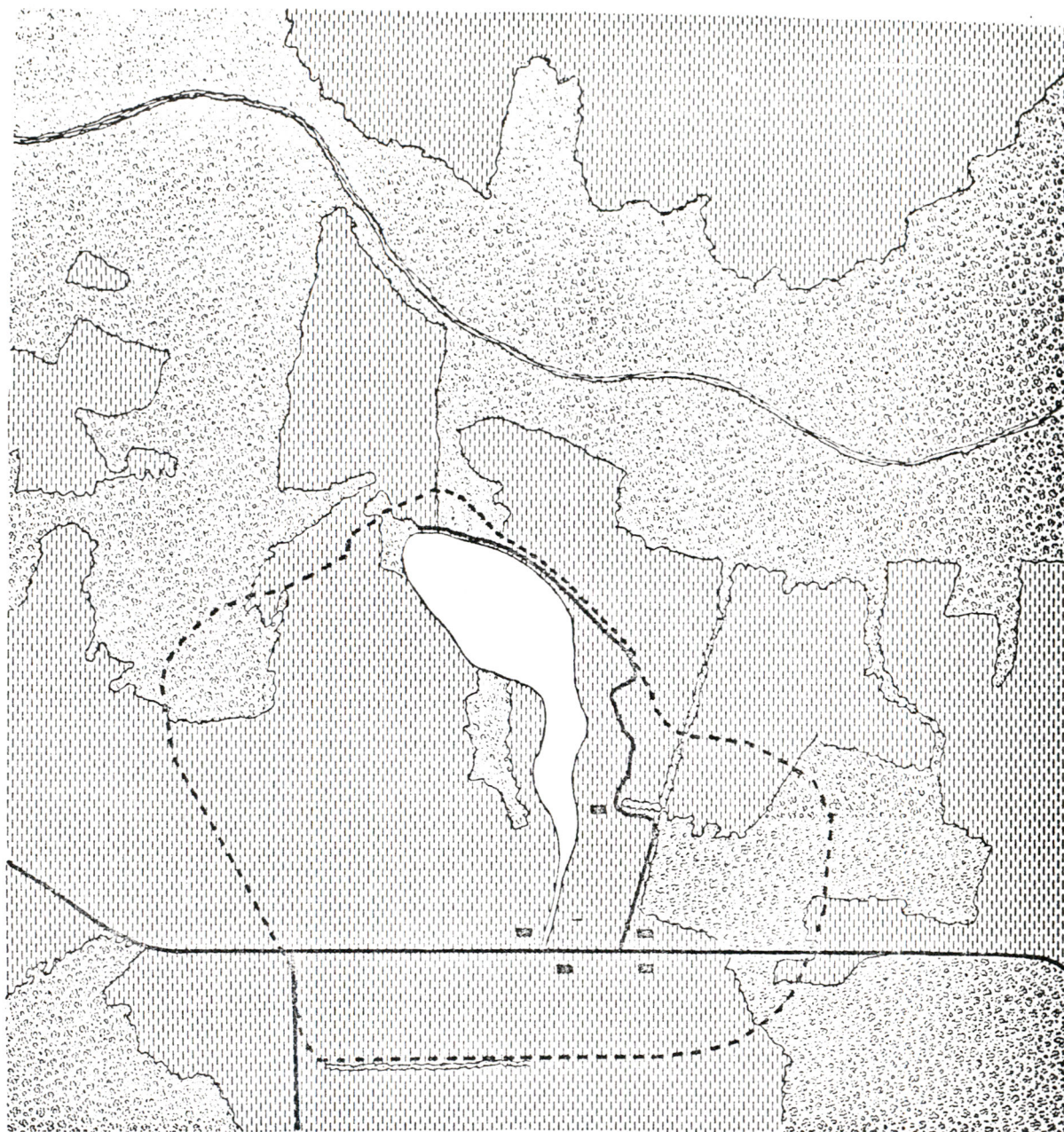
The shoreline vegetation was composed of small stand of trees, Pinus taeda L., Liquidambar styraciflua L. and Quercus sp., on the western edge and several perennial and annual grasses. Conspicuous weedy herbaceous species included Juncus sp., Lespedeza sp. Eupatorium cupillifolium Lam., Rumex sp., and Helenium sp.

Terrain surrounding the basin consisted of cultivated fields, (Fig. 5), on which the chief crops were corn and soybeans. These crops received approximately 350 and 250 lbs. of fertilizer per acre respectively each year (personal communication with Mr. Warren Carson).

There were only four homesites located within the Carson watershed from which domestic runoff might enter the lake. However, they were located well away from the shoreline and throughout the study there was no evidence of domestic waste entry into the lake.

Carson Lake was constructed with assistance from the Pitt County Soil and Water Conservation Service, and was considered by that agency as exemplary of proper lake construction and drainage for this area of the Coastal Plain. The lake, being less than four years old, was also considered to be a good example of a lake undergoing stabilization. Finally, being a farm impoundment, the lake represented a major form of waterbody in the Coastal Plain.

Figure 5. Carson Lake and land use within the watershed.



LEGEND

 IMPOUNDMENT

 WATERSHED BOUNDARY

LAND USE

 Woodlands

 Agriculture

0 SCALE 1/2 MILE
0.8KM

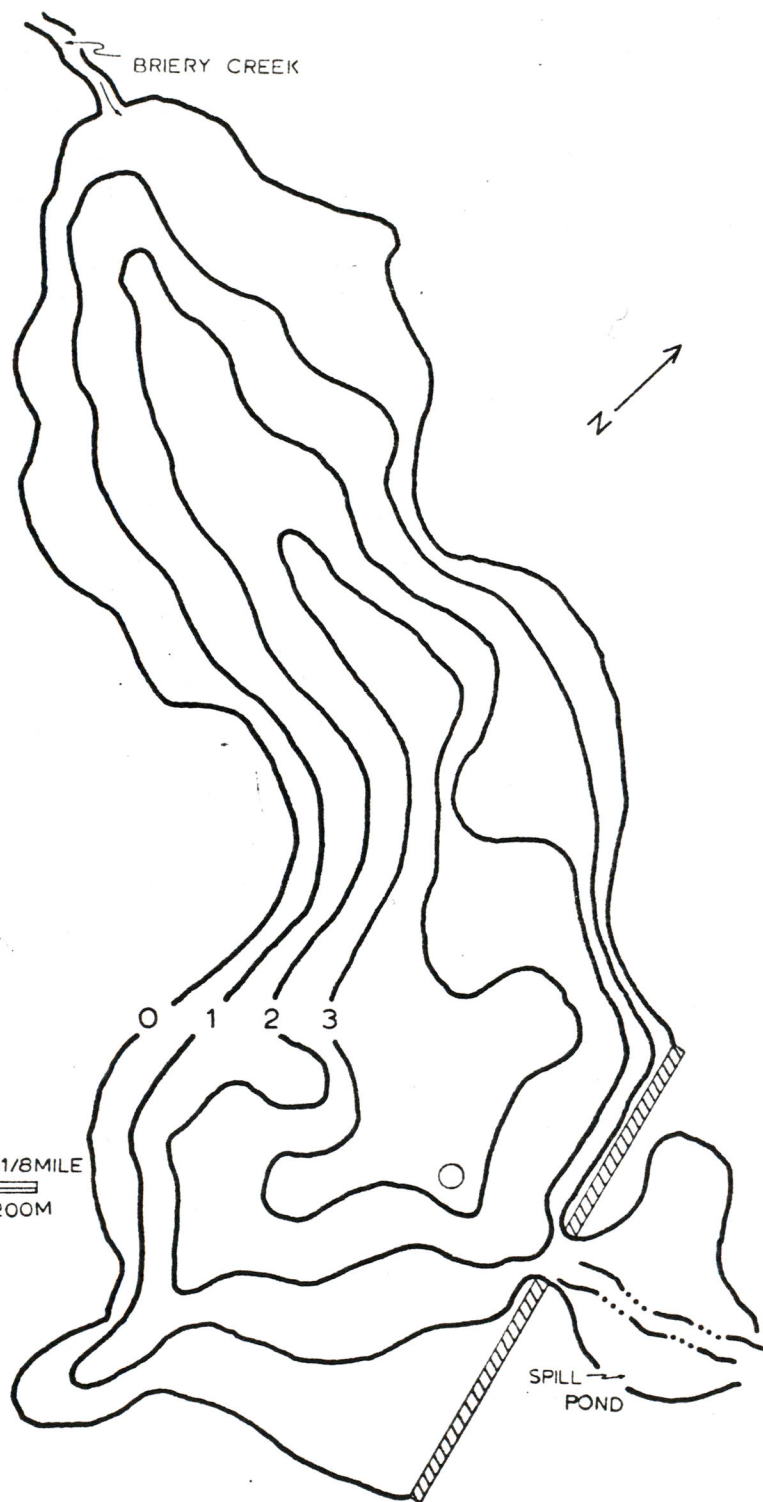
Sheppard's Millpond

Sheppard's Millpond is located in the northeastern corner of Pitt County, N.C., 6.8 km east of Stokes, 200 m west of Briery Creek bridge of SR 1550 (Fig. 1). The millpond is over 100 years old and was formed when the outlet stream of Briery Swamp was dammed to supply water power for a grist mill. The millpond is the oldest and largest artificial impoundment in Pitt County and is typical of many brown-water lakes in the Coastal Plain. The brown water color results from swamp runoff containing acidic organic materials known as "humic acids." Brown-water lakes are often termed dystrophic and are characterized by low pH, low alkalinity, and typically contain only small quantities of dissolved nutrients.

The millpond has a shallow irregular basin of 54.6 ha. with a maximum depth of 3 m near the dam and a mean depth of 2.2 m (Fig. 6). The main water source is Briery Creek which begins 6.3 km west of Stokes and drains a watershed of over 4,500 ha. Excess water overflows through 11.9 m wide concrete spillway into a small spill pond (approx. 0.5 ha). During rainy weather, this pond remains well flushed; however, in dry weather there is little flow over the spill way.

The millpond supports an abundant growth of duckweed throughout the year. Predominant among these were Spirodela oligorrhiza and Wolffiella floridana. These floating aquatics reach dense levels when concentrated by the wind or during dry periods when there is little flow to wash them over the spillway. At times, the duckweed covers over two-thirds of the millpond in dense mats 2 cm thick.

Figure 6. Bathymetry of Sheppard's Millpond. Contours represent depth in meters.



BRIERY CREEK



LEGEND

 DAM

 INTERMITTENT
STREAM

 PERENNIAL
STREAM

 STATION

0 SCALE 1/8 MILE
200M
CONTOURS IN METERS

SPILL
POND

The millpond is surrounded by stands of mixed forest dominated by Pinus taeda L., Quercus falcata L., Liquidambar styraciflua L., Acer rubrum L., and associated shrubs. Dense stands of Taxodium distichum L., grow along the margin and shallow eastern corner, and scattered stands of cypress were found in the deeper water near the dam.

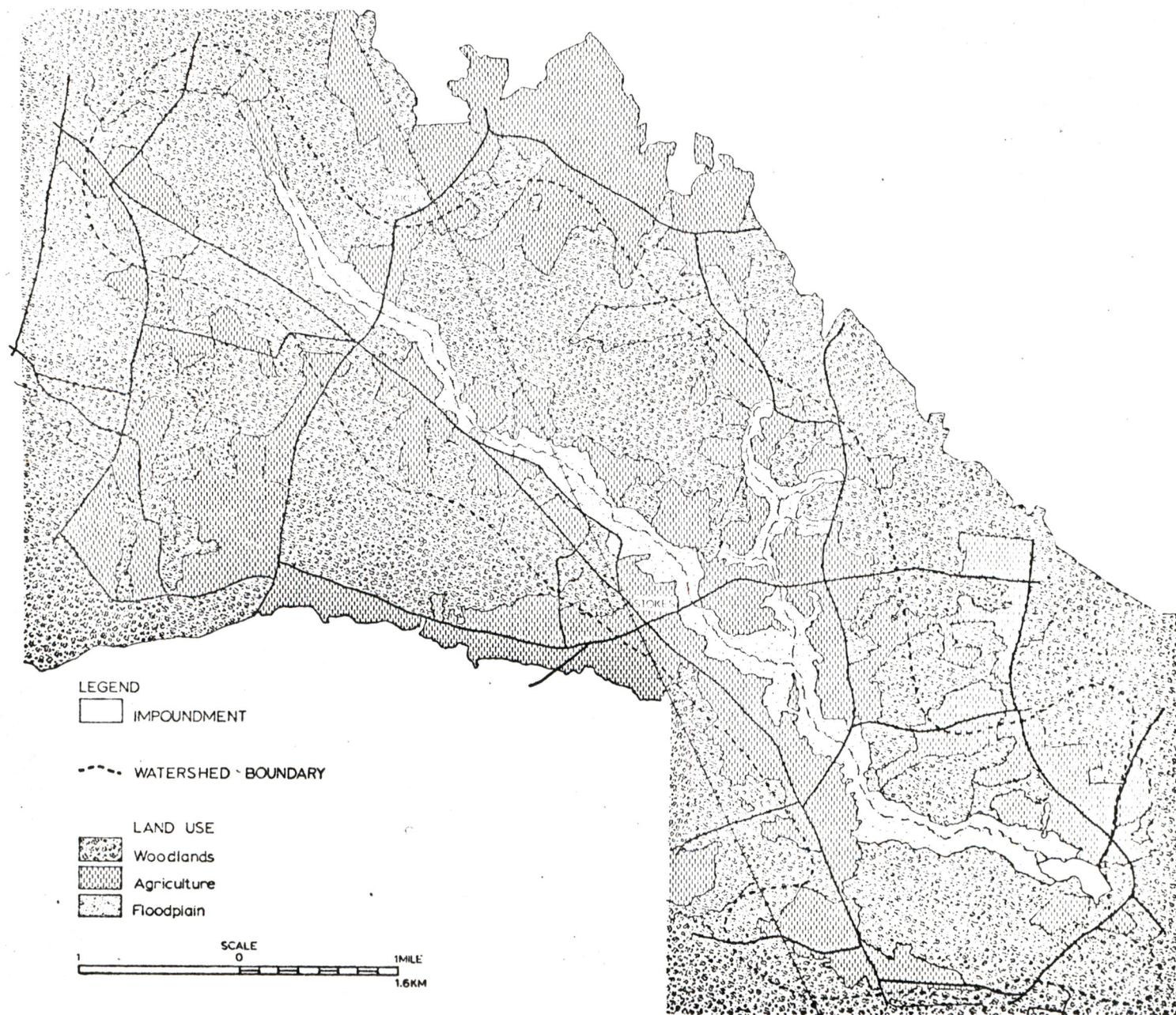
During the spring of 1973, approximately 80 ha. of the pine and hardwood forest near the southern shore were clearcut. The present study was not begun until the fall of 1973; therefore, in the absence of 'before cutting' data, the possible effect of clearcutting on the millpond could not be determined.

The dominant soil type, a Coxville-Exum association, consists of poorly to moderately drained soils on uplands, and occupies approximately 50% of the watershed (Karnowski, 1974). The remaining soils, approximately 30% Bibb, 10% Bladen, and 10% Lenior are poorly drained fine sandy loam on flood plains, or nearly level uplands and are low in natural fertility and organic content.

The most densely populated area encompassed by the extensive watershed is Stokes, a small town located 6.8 km west of the millpond (Fig. 7). Little or no domestic effluent is contributed by this farm community of approximately 200 residents which utilizes septic tanks for waste disposal.

The Sheppard grist mill has not been in use since 1939. Since that time, the millpond and surrounding area have been left relatively unchanged except for occasional timbering, recreational fishing and hunting. The pond supports numerous largemouth bass, sunfish, and chain pickerel, and provides excellent winter habitat for migrating wood ducks.

Figure 7. Sheppard's Millpond and land use within the watershed.



The millpond by reason of its age, rural setting, and minimal cultural influence is similar to many stabilized brown-water lakes in the Coastal Plain. For these reasons Sheppard's Millpond was selected for comparison with other lakes in the county representing other aspects of use and culturally induced stress.

MATERIALS AND METHODS

Sampling Intervals, Stations, and Parameters

The lakes and millpond were sampled at intervals of approximately two weeks, usually near the first and fifteenth of each month, from 24 October 1973, through 16 October 1974. To facilitate comparisons, collections were made on the same day in all three impoundments, usually between 0930 and 1330 EST. Plans to sample only on clear days were hindered by highly variable weather; however, dark and rainy days were avoided.

Water samples and limnological measurements were taken at the surface and bottom at stations marked by anchored buoys near the deepest part of each impoundment (Figs. 2,4,6). At each station, 13 chemical, 5 biological, and 4 physical parameters were measured. Chemical parameters included biochemical oxygen demand and major nutrients: nitrogen (Kjeldahl, ammonia, dissolved nitrate, and nitrite) and phosphorus (total phosphorus and dissolved orthophosphate). Standard limnological measurements included dissolved oxygen, temperature, pH, color, total alkalinity (as mg/l CaCO_3), and specific conductance. Biological parameters included phytoplankton identification and enumeration, primary productivity and chlorophyll a analysis. Water temperature, secchi disc transparency, turbidity, and total suspended matter were the physical parameters measured.

Field Procedures

On each sampling date, pertinent field information was recorded including date and time of sampling, air temperature, general weather conditions and other habitat notes such as visible algal blooms, water-level, and wildlife present.

Surface and bottom water samples were collected using a Van Dorn water sampler. Water samples for later laboratory analysis were immediately transferred into amber polypropylene bottles and placed in an iced styrofoam collar. All sample bottles had been previously acid washed in 0.1 N HCL and thoroughly rinsed with distilled water.

Dissolved oxygen and temperature profiles were determined using a galvanic cell oxygen analyser equipped with a thermistor (Precision Scientific). The probe membrane was always calibrated no more than 24 h prior to collection periods against the Alsterberg (azide) modification of the Winkler method (American Public Health Association, 1971). Surface and bottom pH readings were obtained electrometrically using a Model 6 portable pH meter (Corning Scientific Instruments).

Apparent water color and turbidity were determined using the techniques described by the Hach Chemical Company for use with their Model DR-EL colorimeter. Water transparency was estimated at all three stations using a standard Secchi disc while water level was measured from reference points etched on the face of each dam. Specific conductivity was measured using a Model 33, referenced (25C), direct reading conductivity meter (Yellow Springs Instrument). Total alkalinity was determined in the field using acid titration (American Public Health Association, 1971) and expressed as mg/l CaCO_3 .

Plankton samples were collected by two methods. Horizontal plankton tows were made at each station using a No. 20 nylon plankton net. Quantative surface plankton samples were collected using a Van Dorn water sampler. All plankton samples were immediately preserved by the

addition of 5 ml Untermohl solution (Handbook of Phycological Methods, 1973).

Gross primary productivity was estimated using the light and dark bottle method (Gaardner and Gran, 1927). Replicate pairs of clear and opaque 300 ml BOD bottles were filled with water collected at 1.0 m intervals. Following determination of initial dissolved oxygen concentrations, pairs of light and dark bottles were suspended from the surface and allowed to incubate for 24 h. Following incubation, final dissolved oxygen concentrations were determined for each light and dark bottle. Net primary productivity was indicated by an increase in oxygen in the light bottles while a decline in the dark bottles would reflect respiratory consumption. Gross primary productivity was determined by summing net primary productivity and respiratory rate.

It is well documented that extended incubation periods increase the possibility of deleterious bottle effects (Vollenweider and Nauwerck, 1961; Vollenweider, 1965). However, this was unavoidable if simultaneous productivity estimates were to be made for each impoundment. Because of limitations in time and available equipment and the long distances to be traveled between each impoundment, it was impractical to reduce exposure time.

Laboratory Procedures

The procedures described in Standard Methods (American Public Health Association, 1971) were employed for determinations of nutrient and biochemical oxygen demand. Water samples for nutrient analysis

were maintained in the dark at 4 C until analyzed. Kjeldahl nitrogen and total phosphorus concentrations were determined from unfiltered water samples. Nitrate, nitrite, and orthophosphate concentrations were determined from water samples filtered through 0.45 μ metricel GA-6 filters.

Duplicate BOD samples were incubated five days in the dark at 20 C. Initial and final dissolved oxygen concentrations were determined using a Model 51 A portable oxygen meter (Yellow Springs Instrument) with calibrated self-stirring BOD probe.

Chlorophyll a concentrations were estimated by fluorometric assays using a Turner III fluorometer (Strickland and Parsons, 1968). Between 250 and 500 ml of the sample was filtered through fiber glass filters (Gelman GA-6) and the filters macerated in a tissue grinder in 90% acetone. Chlorophyll a was determined after 2 h in the fluorometer. The fluorometer was calibrated periodically with chlorophyll extracted from natural phytoplankton populations and measured in a Coleman Double Beam Spectrophotometer.

Total suspended matter (non-filterable residue) was determined according to Standard Methods (American Public Health Association, 1971) using fiberglass filters (Gelman GA-6), oven-dried at 105 C and weighed on a Mettler Analytical Balance.

A Leitz research microscope was used to examine fresh plankton net samples for fragile organisms which might deteriorate before the preserved quantitative samples could be counted. Quantative samples were concentrated by centrifuging 500 ml of sample for 30 min and decanting the supernatant. The phytoplankton in the concentrated sample

(approximately 50 ml) were then identified and counted as follows: After thoroughly shaking the sample to freely suspend all plankton organisms, a subsample was pipetted into a Palmer counting cell (Palmer and Maloney, 1954). When covered with a No. 1 cover slip, the volume contained is 0.1 ml. A Whipple disc was employed for the counting grid and calibrated against a stage micrometer for both 10X and 40X objectives (Jackson and Williams, 1962). Most samples were counted using the 10X objective, however, for samples containing large numbers of cells or dominant nannoplankton forms the 40X objective was used. A minimum of 20 Whipple fields were counted diagonally for each 0.1 sample; then using the appropriate conversion factors, the organisms were recorded as numbers per ml. Phytoplankton were identified to genus in all cases, and to species when possible. Questionable Cyanophyta species were verified by Frances Drouet while unknown species of Chlorophyta and Euglenophyta were identified by L. A. Whitford. Colonial or filamentous forms as well as fragments were counted as single units. Certain fragile forms such as Volvox aureus and Synura uvella were often broken up by the centrifuge process. In this event the total number of cells was counted and divided by the average number of cells per colony.

Phytoplankton species diversity indices were calculated as:

$H' = \sum p_i \ln p_i$. This index was described by Shannon and Weaver (1949) where p_i equals the importance probability for each species. Evenness components of diversity were computed using the formula $V_H = \frac{(H' - H'_{\min})}{(H'_{\max} - H'_{\min})}$ (Pielou, 1966). The resulting value is the ratio of observed diversity to maximum diversity. The index may range between 0 (all individuals of the same species) and 1 (each individual of a different species).

Climate Data for Study Area

Daily rainfall data for the Pitt County area was obtained from the Greenville station of the National Oceanic and Atmospheric Administration National Weather Service. Solar radiation values for the Greenville latitude were obtained from a table by B.Y.H. Liu computing the mean daily radiation at the top of the atmosphere, using a solar constant of 2.0 langleys/min. (Chang, 1968)

Methods of Data Analysis

All surface and bottom data from each station was compiled separately according to the individual impoundment and placed on punch cards. Statistical tests were performed at East Carolina University using SPSS package program with a Burroughs 5500 computer.

Summary statistics were obtained for surface and bottom data for each impoundment and included mean, range, and standard deviation. Cross correlation analysis was performed between all surface parameters of each individual impoundment with significance levels provided by the correlation program. Only correlations with significance levels of 5% or less were considered too great to be attributed to chance alone.

Analysis of variance tests were performed on surface and bottom values of the individual impoundments and between surface values of the three combined impoundments. Significant F-values were provided by the analysis of variance program with significantly different groups determined using Duncan's New Multiple Range test (Steel and Torrie, 1960).

RESULTS

Physical Factors

Water temperature All three impoundments exhibited a circulatory pattern characteristic of warm monomictic lakes, with one circulation of the water column occurring during the winter months. During this period, temperature was generally constant throughout the water column, usually with surface and bottom temperature differing by less than 2 C. Following vernal warming, moderate thermal stratification developed, continued throughout the summer and began to dissipate in October with the beginning of fall mixing.

Light penetration Although the waters of Sheppard's Millpond were dark brown from humic acid content, transparency values averaged over 9 dcm and remained significantly* higher than Hardee Lake or Carson Lake values (Table 1, Fig. 8). The Millpond's forested watershed contributed little runoff and also resulted in significantly lower total suspended matter and turbidity values (Figs. 9 & 10).

Secchi disc transparencies remained low during winter and spring in Carson Lake in association with dredging and landscaping operations. Low transparencies and high total suspended matter values were recorded throughout the summer in Hardee Lake and coincided with frequent blue-green algal blooms.

Cultivation of surrounding fields in late March and April followed by heavy rains increased silt input and resulted in high turbidity,

* All references to significant differences refer to statistical differences presented in Table 2 of discussion section.

Table 1. Summarized limnological data for Hardee Lake, Carson Lake, and Sheppard's Millpond (October, 1973-October, 1974)

Parameter	Hardee Lake	Carson Lake	Sheppard's Millpond
Water Temperature (C)			
Surface	$\bar{x}$ 19.1 R 5.5-28.5 sd 6.4	$\bar{x}$ 19.7 R 4.0-30.5 sd 7.4	$\bar{x}$ 18.8 R 5.5-30.0 sd 7.0
Mid-Depth	$\bar{x}$ 18.6 R 9.0-26.0 sd 6.3	$\bar{x}$ 18.2 R 6.5-29.5 sd 7.5	$\bar{x}$ 16.2 R 5.5-23.0 sd 5.4
Bottom	$\bar{x}$ 17.8 R 7.0-25.5 sd 6.1	$\bar{x}$ 15.9 R 4.0-25.0 sd 5.4	$\bar{x}$ 13.6 R 5.0-21.5 sd 4.4
Secchi Disc Transparency (dcm)	$\bar{x}$ 4.2 R 1.3-7.9 sd 1.6	$\bar{x}$ 3.7 R 0.2-9.2 sd 2.5	$\bar{x}$ 9.2 R 3.5-14.3 sd 2.6
Turbidity (JTU)	$\bar{x}$ 81 R 15-250 sd 56	$\bar{x}$ 112 R 15-345 sd 100	$\bar{x}$ 44 R 10-95 sd 20
Total Suspended Matter (mg/l)	$\bar{x}$ 37.0 R 8.7-144.2 sd 28	$\bar{x}$ 37.0 R 8.7-119.8 sd 29.7	$\bar{x}$ 8.0 R 2.8-27.0 sd 6.0
Water Color (Pt-Co)	$\bar{x}$ 208 R 90-500 sd 111	$\bar{x}$ 275 R 65-500 sd 186	$\bar{x}$ 175 R 100-305 sd 52
Dissolved Oxygen (mg/l)			
Surface	$\bar{x}$ 11.0 R 5.4-14.7 sd 2.1	$\bar{x}$ 9.6 R 5.4-12.1 sd 1.6	$\bar{x}$ 6.5 R 3.6-13.2 sd 3.0
Mid-Depth	$\bar{x}$ 8.3 R 1.1-14.0 sd 3.1	$\bar{x}$ 6.9 R 1.0-12.0 sd 3.3	$\bar{x}$ 2.8 R 0.0-8.1 sd 3.0
Bottom	$\bar{x}$ 4.7 R 0.4-11.7 sd 3.7	$\bar{x}$ 4.4 R 0.0-12.0 sd 3.6	$\bar{x}$ 2.1 R 0.0-7.7 sd 2.4

Table 1. (Continued)

Parameter	Hardee Lake	Carson Lake	Sheppard's Millpond
Percentage Saturation			
Surface	$\bar{x}$ 118 R 52-178 sd 29	$\bar{x}$ 103 R 57-154 sd 20	$\bar{x}$ 68 R 39-136 sd 20
Mid-Depth	$\bar{x}$ 85 R 13-171 sd 33	$\bar{x}$ 70 R 12-143 sd 33	$\bar{x}$ 23 R 00-72 sd 24
Bottom	$\bar{x}$ 46 R 05-106 sd 34	$\bar{x}$ 41 R 00-98 sd 32	$\bar{x}$ 18 R 00-69 sd 20
pH			
Surface	$\bar{x}$ 7.6 R 5.8-9.4 sd 1.3	$\bar{x}$ 6.7 R 5.5-8.6 sd 0.9	$\bar{x}$ 5.7 R 5.0-6.9 sd 0.4
Bottom	$\bar{x}$ 6.5 R 5.6-7.4 sd 0.5	$\bar{x}$ 6.4 R 5.7-7.8 sd 0.5	$\bar{x}$ 5.6 R 4.9-6.3 sd 0.4
Total Alkalinity (mg/l) (as mg/l CaCO_3)	$\bar{x}$ 17.5 R 2.0-32.0 sd 8.8	$\bar{x}$ 10.8 R 4.0-16.0 sd 4.3	$\bar{x}$ 7.8 R 2.0-16.0 sd 3.4
Carbonate Alkalinity (mg/l)	$\bar{x}$ 10.0 R 8.0-12.0 sd 1.0	No Data	No Data
Specific Conductivity ($\mu\text{mho/cm}$)	$\bar{x}$ 89 R 55-143 sd 20	$\bar{x}$ 68 R 40-96 sd 16	$\bar{x}$ 46 R 30-71 sd 13
Kjeldahl Nitrogen (mg/l)			
Surface	$\bar{x}$ 2.97 R 0.00-10.0 sd 2.77	$\bar{x}$ 1.60 R 0.00-4.50 sd 1.12	$\bar{x}$ 1.47 R 0.00-4.40 sd 1.11

Table 1. (Continued)

Parameter	Hardee Lake	Carson Lake	Sheppard's Millpond
Bottom	$\bar{x}$ 2.91 R 0.00-6.80 sd 2.31	$\bar{x}$ 1.63 R 0.00-3.50 sd 1.15	$\bar{x}$ 2.18 R 0.00-4.90 sd 1.53
Ammonia Nitrogen (mg/l)			
Surface	$\bar{x}$ 0.22 R 0.00-2.30 sd 0.47	$\bar{x}$ 0.09 R 0.00-0.57 sd 0.15	$\bar{x}$ 0.05 R 0.00-0.28 sd 0.07
Bottom	$\bar{x}$ 0.36 R 0.00-1.75 sd 0.48	$\bar{x}$ 0.31 R 0.00-1.00 sd 0.36	$\bar{x}$ 0.13 R 0.00-1.24 sd 0.30
Nitrate Nitrogen (mg/l)			
Surface	$\bar{x}$ 0.69 R 0.00-4.64 sd 1.10	$\bar{x}$ 0.68 R 0.00-2.70 sd 0.94	$\bar{x}$ 0.18 R 0.00-0.54 sd 0.16
Bottom	$\bar{x}$ 0.42 R 0.00-1.50 sd 0.53	$\bar{x}$ 0.39 R 0.00-2.12 sd 0.61	$\bar{x}$ 0.27 R 0.10-0.60 sd 0.19
Nitrite Nitrogen (mg/l)			
Surface	$\bar{x}$ 0.013 R 0.000-0.033 sd 0.010	$\bar{x}$ 0.006 R 0.000-0.018 sd 0.005	$\bar{x}$ 0.006 R 0.000-0.026 sd 0.005
Bottom	$\bar{x}$ 0.010 R 0.000-0.029 sd 0.008	$\bar{x}$ 0.007 R 0.000-0.018 sd 0.005	$\bar{x}$ 0.014 R 0.000-0.049 sd 0.013
Total Phosphorus (mg/l)			
Surface	$\bar{x}$ 0.18 R 0.01-0.44 sd 0.09	$\bar{x}$ 0.17 R 0.00-0.43 sd 0.10	$\bar{x}$ 0.13 R 0.00-0.42 sd 0.11

Table 1. (Continued)

Parameter	Hardee Lake	Carson Lake	Sheppard's Millpond
Bottom	$\bar{x}$ 0.30 R 0.40-0.92 sd 0.24	$\bar{x}$ 0.19 R 0.00-0.75 sd 0.17	$\bar{x}$ 0.20 R 0.03-0.43 sd 0.13
Orthophosphate (mg/l)			
Surface	$\bar{x}$ 0.014 R 0.000-0.107 sd 0.028	$\bar{x}$ 0.010 R 0.000-0.050 sd 0.017	$\bar{x}$ 0.014 R 0.000-0.071 sd 0.019
Bottom	$\bar{x}$ 0.028 R 0.000-0.125 sd 0.035	$\bar{x}$ 0.025 R 0.000-0.184 sd 0.051	$\bar{x}$ 0.022 R 0.000-0.132 sd 0.041
Biological Oxygen Demand (mg O ₂ /l)			
Surface	$\bar{x}$ 5.1 R 2.1-10.0 sd 2.2	$\bar{x}$ 3.1 R 0.0-10.0 sd 2.0	$\bar{x}$ 3.2 R 1.2-6.6 sd 1.5
Bottom	$\bar{x}$ 4.5 R 0.8-8.8 sd 2.2	$\bar{x}$ 3.4 R 0.0-12.6 sd 2.7	$\bar{x}$ 3.8 R 0.6-6.4 sd 1.6
Chlorophyll <u>a</u> (µg/l)	$\bar{x}$ 234.2 R 51.2-1160.0 sd 293.6	$\bar{x}$ 46.8 R 9.6-146.4 sd 36.3	$\bar{x}$ 58.2 R 0.0-150.0 sd 46.7
Phytoplankton Numbers (Cells/ml)	$\bar{x}$ 38,856 R 181-470,843 sd 98,131	$\bar{x}$ 2,506 R 32-12,751 sd 3,089	$\bar{x}$ 1,861 R 147-15,728 sd 3,119
Species Diversity	$\bar{x}$ 1.07 R 0.07-1.85 sd 0.48	$\bar{x}$ 1.02 R 0.13-1.69 sd 0.48	$\bar{x}$ 1.45 R 0.58-2.39 sd 0.42
Species Evenness	$\bar{x}$ 0.58 R 0.04-0.99 sd 0.25	$\bar{x}$ 0.67 R 0.18-0.94 sd 0.24	$\bar{x}$ 0.78 R 0.21-0.96 sd 0.18

Table 1. (Continued)

Parameter	Hardee Lake	Carson Lake	Sheppard's Millpond
Gross Primary	$\bar{x}$ 4.9	$\bar{x}$ 2.0	$\bar{x}$ 2.1
Productivity (g $O_2/m^2/day$)	R 0.6-11.2	R 0.2-3.7	R 0.1-5.2
	sd 3.0	sd 0.9	sd 1.7

Figure 8. Seasonal variation in Secchi disc transparency within Sheppard's Millpond, Carson Lake, and Hardee Lake (dcm).

Figure 9. Seasonal variation in total suspended matter within Sheppard's Millpond, Carson Lake, and Hardee Lake (mg/l).

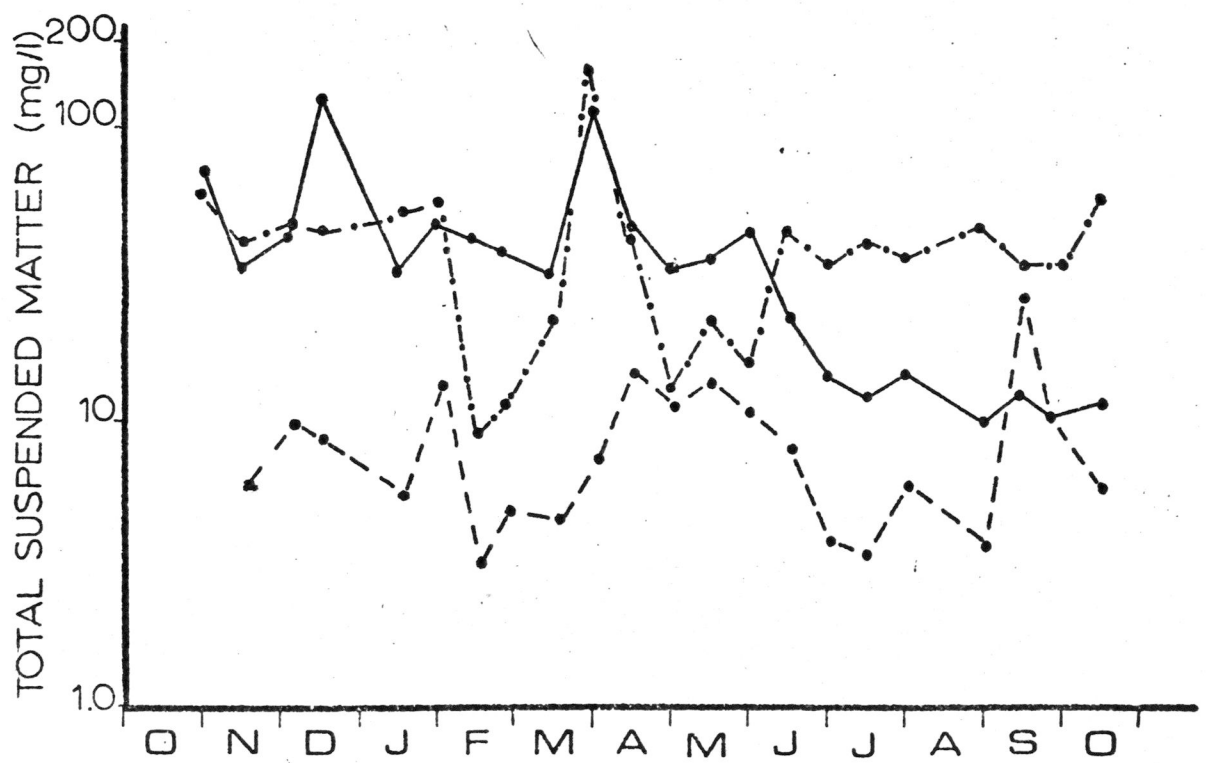
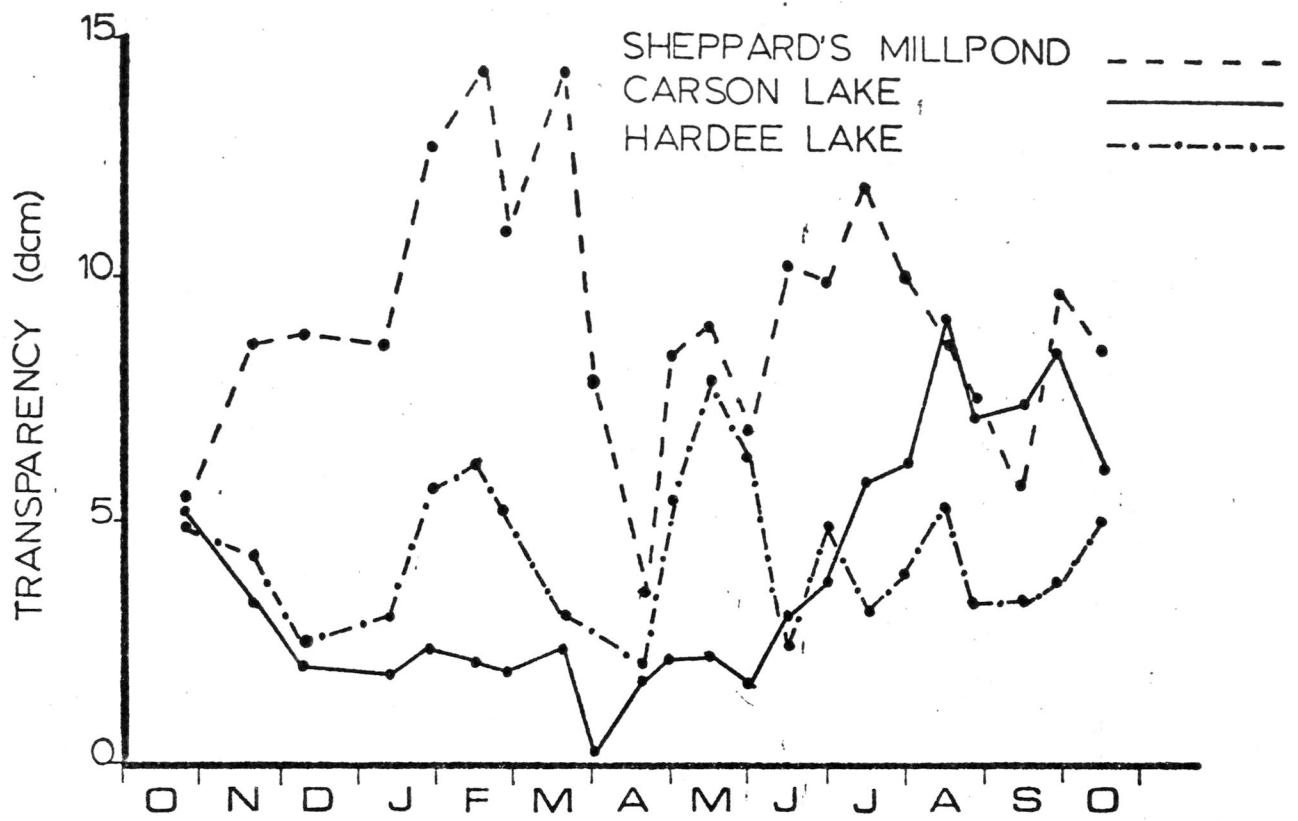
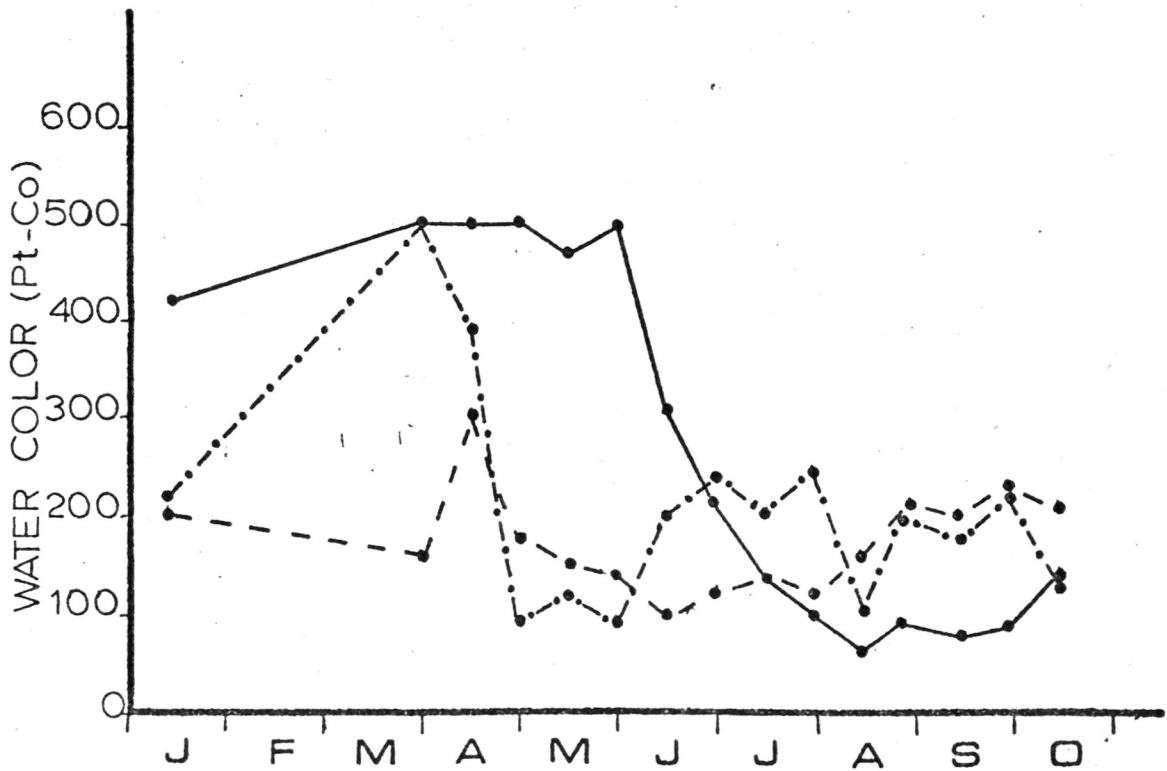
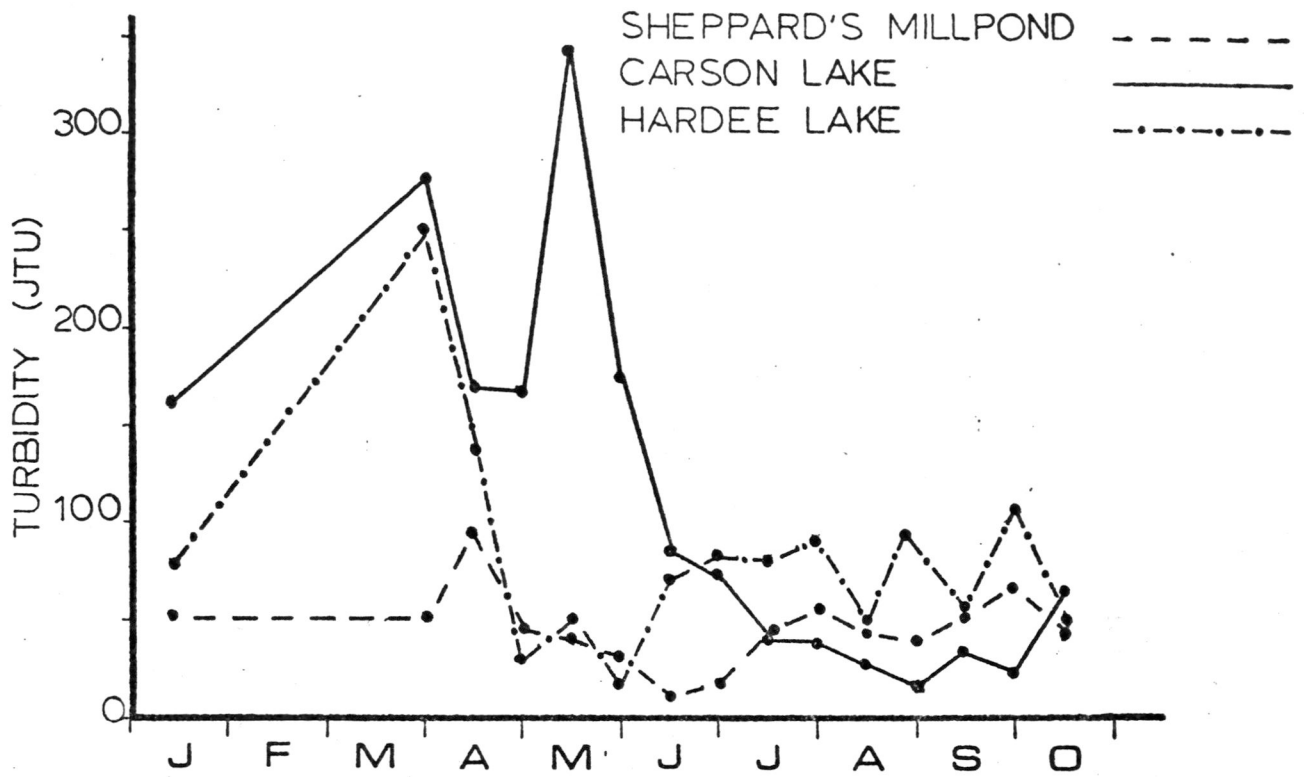


Figure 10. Seasonal variation in turbidity within Sheppard's Millpond, Carson Lake, and Hardee Lake (JTU).

Figure 11. Seasonal variation in water color within Sheppard's Millpond, Carson Lake, and Hardee Lake (Pt-Co).



high total suspended matter, and high water color values in both Hardee and Carson Lakes. This trend is also shown in the minimum Secchi disc values for all three impoundments (Table 1, Figs. 8, 9, 10, 11).

Chemical Factors

Dissolved oxygen-percent saturation Dissolved oxygen and percent saturation values followed a definite seasonal pattern increasing with the general increase in solar radiation and increased photosynthesis during the warmer months (Figs. 12 & 13).

Surface oxygen and saturation values were highest in Hardee Lake with oxygen concentrations frequently exceeding 12.0 mg/l (Table 1). During the summer surface waters were usually supersaturated however, dense blooms of blue-green algae often inhibited light penetration to the lower depths which contributed to intense oxygen depletion of this area (App C, Table 3).

Surface oxygen levels of Carson Lake averaged 9.6 mg/l with a mean saturation value of 103%. Oxygen concentrations in the lower water column remained high until mid-June when this area became essentially anaerobic. Once established, the anoxic condition remained until late September (App. D, Table 3).

Surface oxygen concentrations and saturation values for Sheppard's Millpond averaged 6.5 mg/l and 68%, respectively, and remained relatively low throughout most of the study (Table 1). By 30 May, anaerobic conditions existed below the 0.5 m zone. This condition persisted throughout the summer (App. E, Table 3).

Figure 12. Seasonal variation in dissolved oxygen within Sheppard's Millpond, Carson Lake, and Hardee Lake (mg/l).

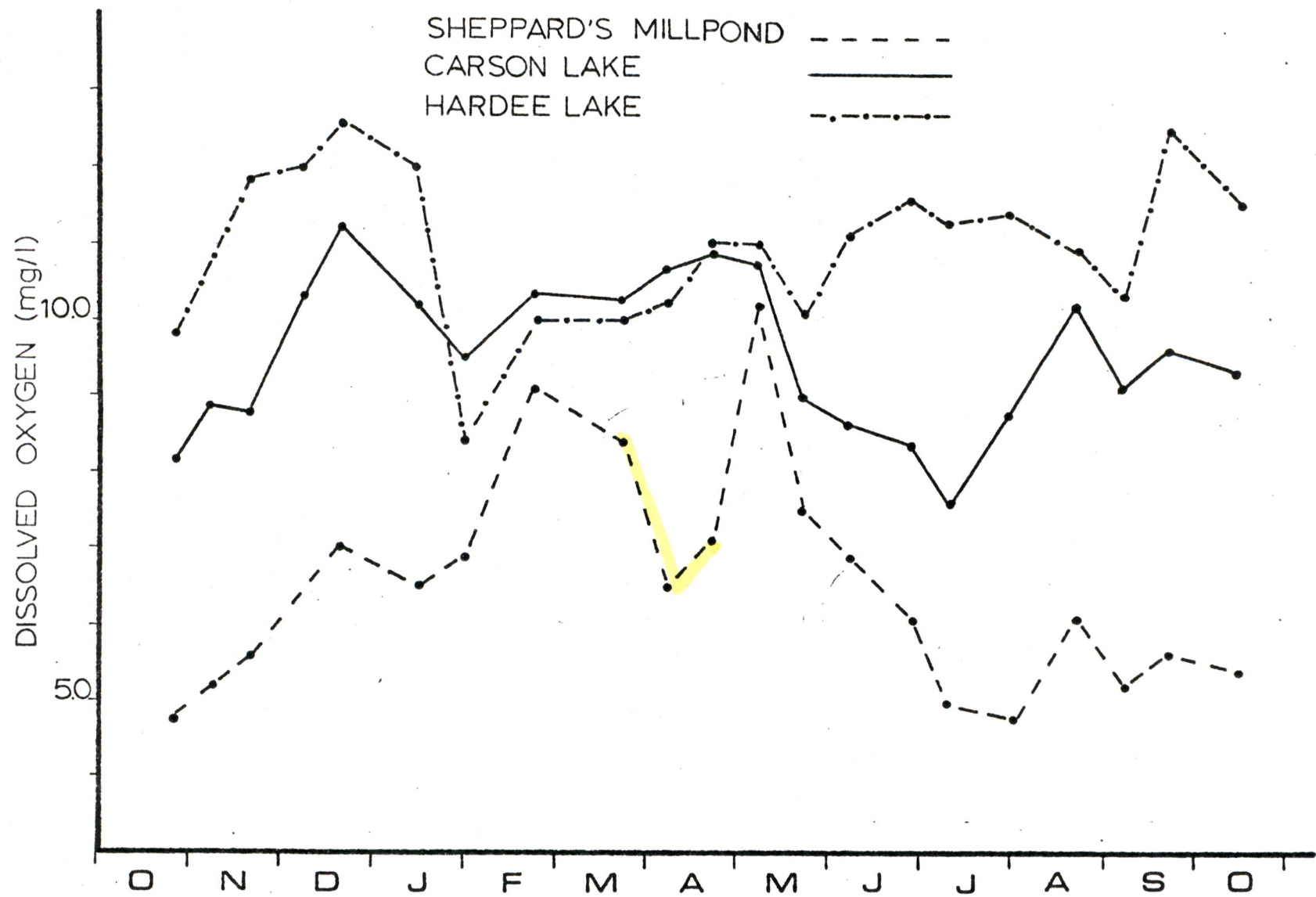
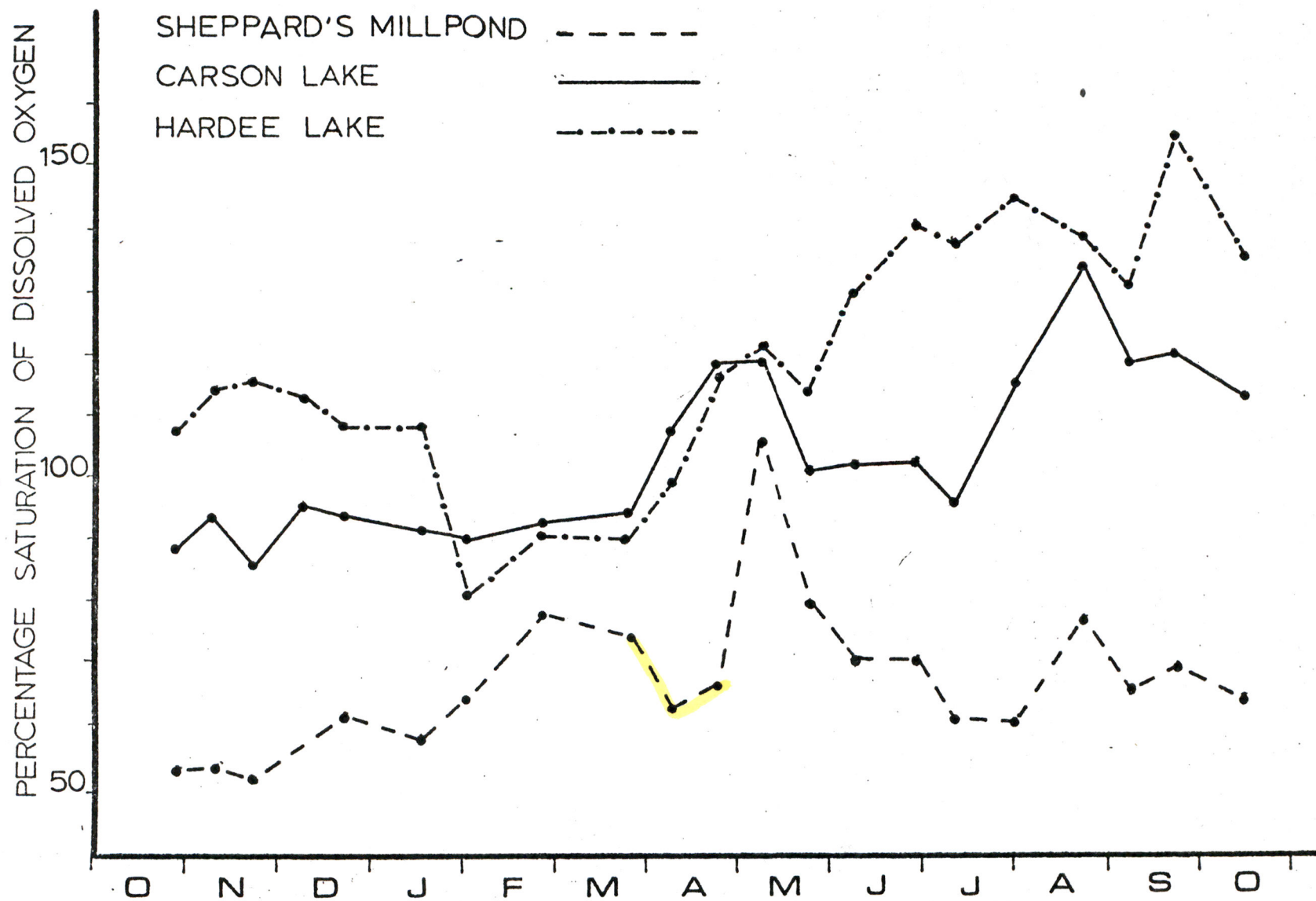


Figure 13. Seasonal variation in percent saturation of oxygen at the surface of Sheppard's Millpond, Carson Lake, and Hardee Lake.



On the 16 June, thick mats of Spirodela oligorrhiza were observed covering the entire surface of the spillpond below the dam (Fig. 6). This mat inhibited light penetration and diffusion of atmospheric oxygen across the surface. As a result, oxygen became depleted and approximately 300 dead fish were counted floating at the surface.

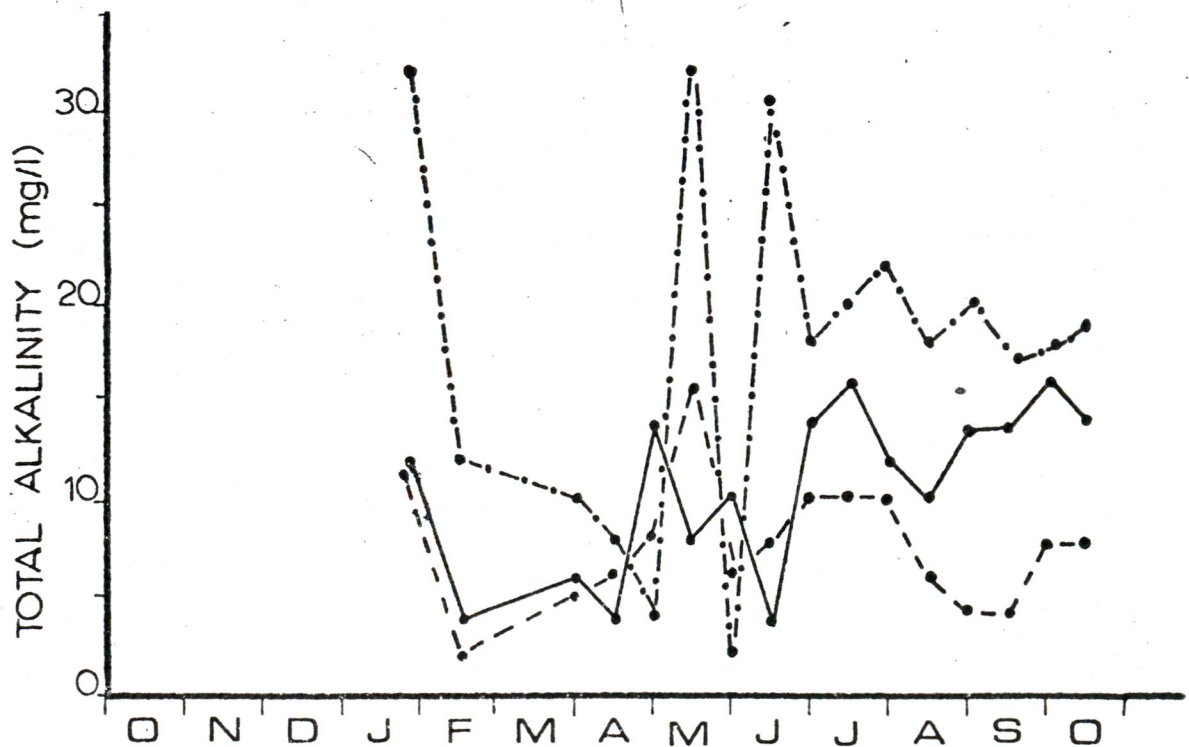
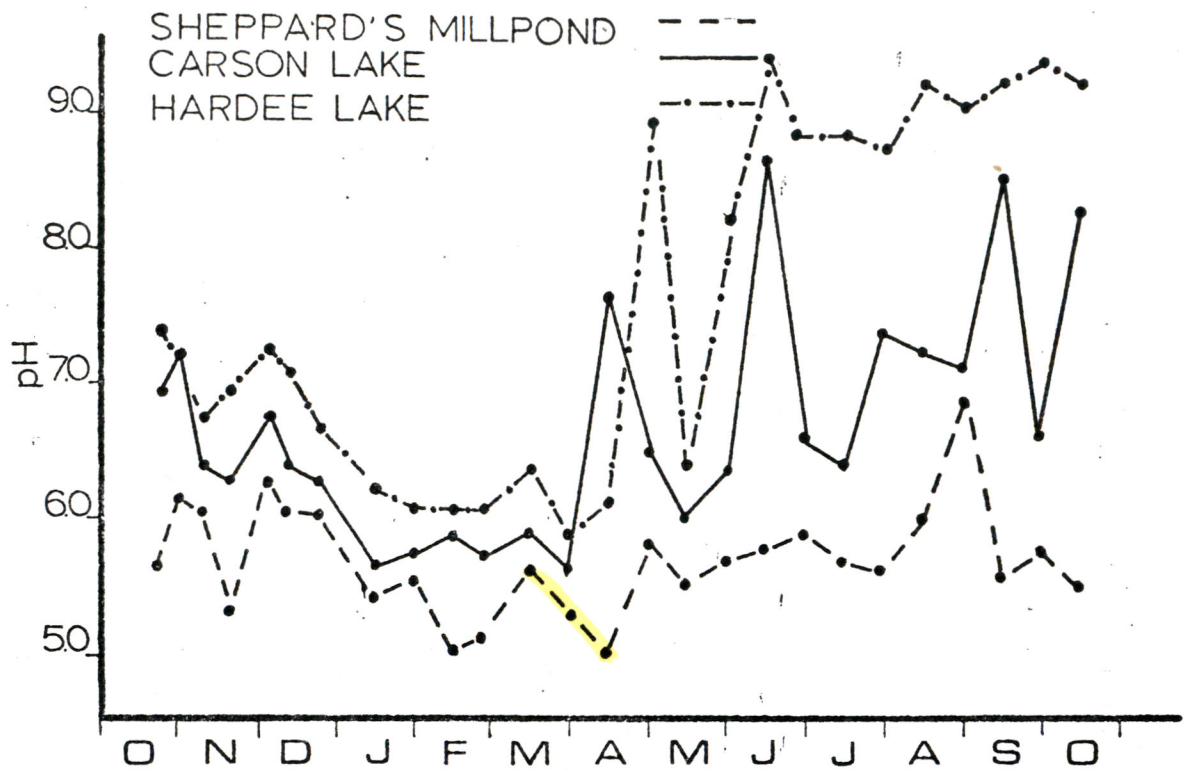
pH, total alkalinity, carbonate Surface pH differed significantly among the three impoundments with mean pH values of 7.6, 6.7, and 5.7 for Hardee Lake, Carson Lake, and Sheppard's Millpond respectively (Table 1, Fig. 14). Values for Hardee Lake averaged pH 6.4 during winter; however, with warmer temperatures and increased photosynthetic activity in spring, pH increased to as high as 8.9 (4-30-74) and frequently approached pH 9.0 during the daylight hours for the remainder of the study.

During the winter, surface pH values in Carson Lake averaged 6.0 but then increased in summer to a maximum value of pH 8.6 recorded in mid-June (Fig. 14). Following the June maximum, pH fluctuated between pH 6.4 and 8.5 in association with fluctuating phytoplankton densities and productivity rates.

The surface waters of Sheppard's Millpond remained acidic throughout the study with values ranging from pH 5.0 (2-14-74 and 4-17-74) to pH 6.9 (8-30-74) (Table 1, Fig. 14). The strong acidity was attributed to the presence of dissolved humic acids (2.7 mg/l) and traces of H_2S produced by sulfate reducing bacteria (sulfur bacterial action was evident from strong H_2S odor released from bottom water samples, especially during summer collections).

Figure 14. Seasonal variation in pH within Sheppard's Millpond, Carson Lake, and Hardee Lake.

Figure 15. Seasonal variation in total alkalinity within Sheppard's Millpond, Carson Lake, and Hardee Lake (as CaCO_3).



Total alkalinity was significantly higher in Hardee Lake, with a mean concentration of 17.5 mg/l (as CaCO_3) as compared to 10.8 and 7.8 mg/l for Carson Lake and Sheppard's Millpond respectively (Table 1, Fig. 15). Measurable amounts of carbonate alkalinity were observed in Hardee Lake during hot summer days when increased photosynthetic activity reduced the amount of free carbon dioxide, shifting the carbonate-bicarbonate ratio toward carbonate (App. C, Table 6-A).

Specific conductivity Specific conductivity differed significantly within the three impoundments with mean values of 89, 68, and 46 $\mu\text{mho/cm}$ for Hardee Lake, Carson Lake, and Sheppard's Millpond respectively (Table 1, Fig. 16). Conductivity values for Hardee Lake were highest, (143 $\mu\text{mho/cm}$) following heavy rainfall during the month of August.

Kjeldahl nitrogen Surface Kjeldahl nitrogen averaged 2.97 mg/l in Hardee Lake and was significantly higher than seasonal mean values for Carson Lake or Sheppard's Millpond (Table 1, Fig. 17). Kjeldahl nitrogen was higher in Hardee Lake during summer and early fall when large amounts of organic nitrogen were bound up in algal blooms. Concentrations of 8.00 mg/l or higher were recorded in April, August, and September, and were associated with pulses of Volvox aureus, Schizothrix calicola, and Calothrix parietina respectively (App. C, Table 8).

Kjeldahl nitrogen values were lower in Carson Lake and Sheppard's Millpond with seasonal means of 1.60 and 1.47 mg/l respectively (Table 1). Concentrations for each impoundment generally remained below 2.50 mg/l until early summer when levels increased in association with increased phytoplankton density and organic matter derived from runoff concentration (Fig. 17).

Figure 16. Seasonal variation of specific conductivity within Sheppard's Millpond, Carson Lake, and Hardee Lake ($\mu\text{mho}/\text{cm}$)

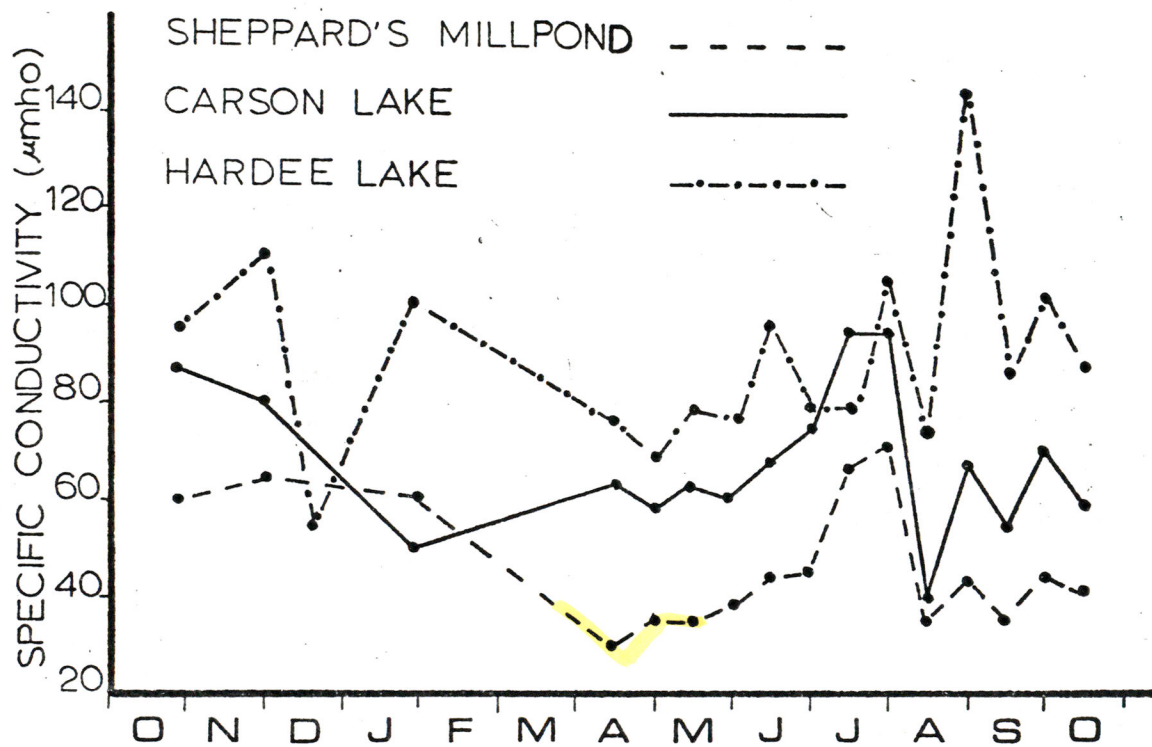
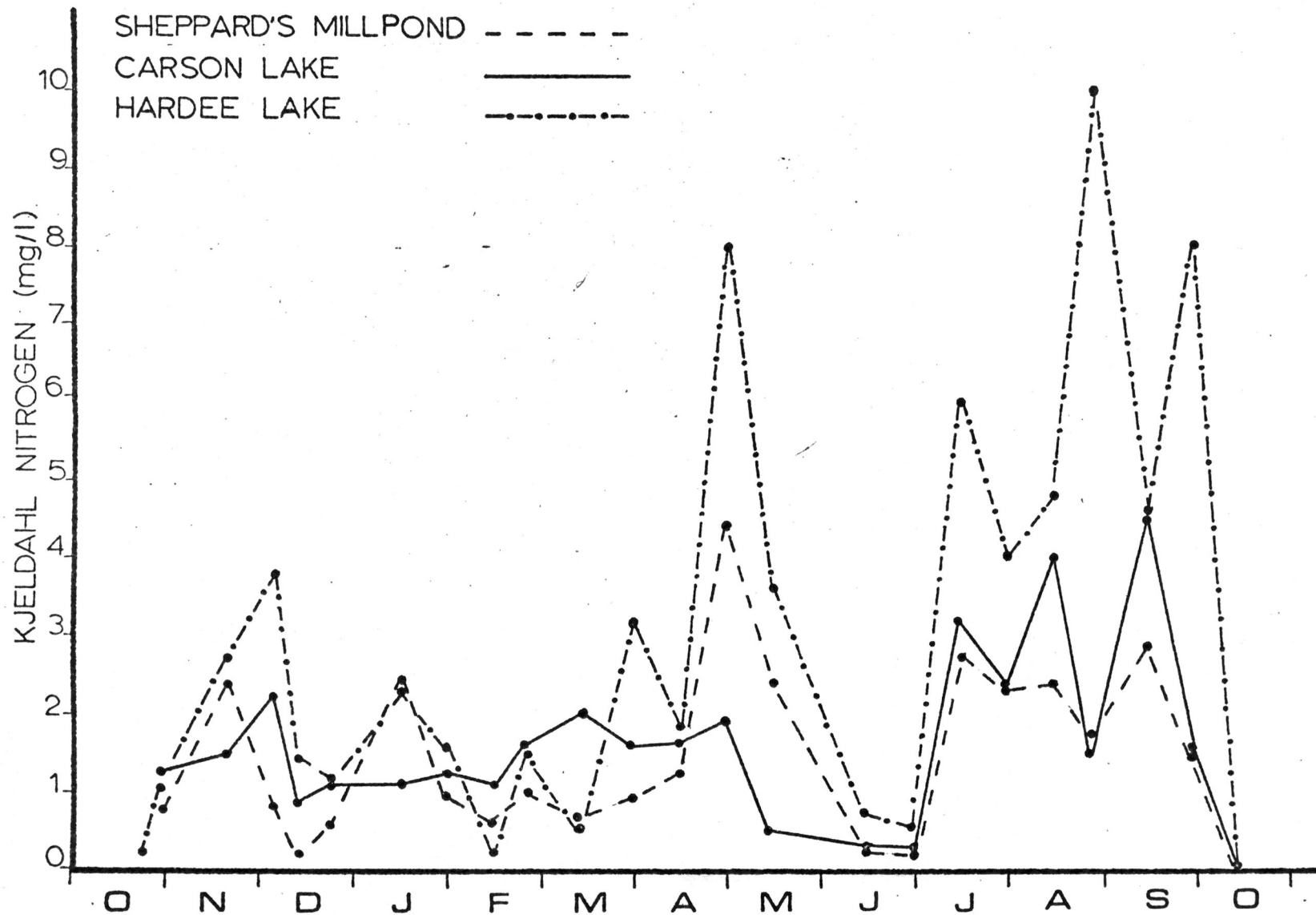


Figure 17. Seasonal variation in Kjeldahl nitrogen within Sheppard's Millpond, Carson Lake, and Hardee Lake (mg/l).



Ammonia nitrogen Ammonia concentrations of Hardee Lake remained high in winter, then dropped to trace or zero levels during most of the summer (Fig. 18). Ammonia concentration averaged 0.22 mg/l and ranged from <0.01 (10-15-74) to 2.3 mg/l (7-30-74), (Table 1). The unusually high value recorded on 30 July occurred following the die-back stage of a S. calicola bloom.

Ammonia concentrations within Carson Lake and Sheppard's Millpond were much lower and averaged 0.09 mg/l and 0.05 mg/l respectively (Table 1). Ammonia concentration in Carson Lake was also highest in winter, then dropped to zero levels several times during spring and late fall. In contrast, ammonia concentration in Sheppard's Millpond were generally highest in summer and fall in response to the extreme anaerobic (reducing environment) conditions at that time.

Nitrate nitrogen Surface nitrate-nitrogen concentrations for Hardee Lake and Carson Lake averaged 0.69 mg/l and 0.68 mg/l respectively. Nitrate concentration was significantly lower in Sheppard's Millpond and averaged only 0.18 mg/l for the year (Table 1, Fig. 19). Nitrate concentration was much higher during winter in each of the impoundments when circulation of the water column resuspended bottom sediments. In Carson Lake nitrate increased greatly when dredging operations brought about sediment resuspension. Lower nitrate levels during summer in all the impoundments may have resulted from increased nutrient uptake due to greater phytoplankton density. The highest nitrate concentration (4.64 mg/l) was recorded in Hardee Lake in April and followed spring application of fertilizer to adjacent fields. Similar increases were also recorded for Carson Lake and Sheppard's Millpond.

Figure 18. Seasonal variation in ammonia nitrogen within Sheppard's Millpond, Carson Lake, and Hardee Lake (mg/l).

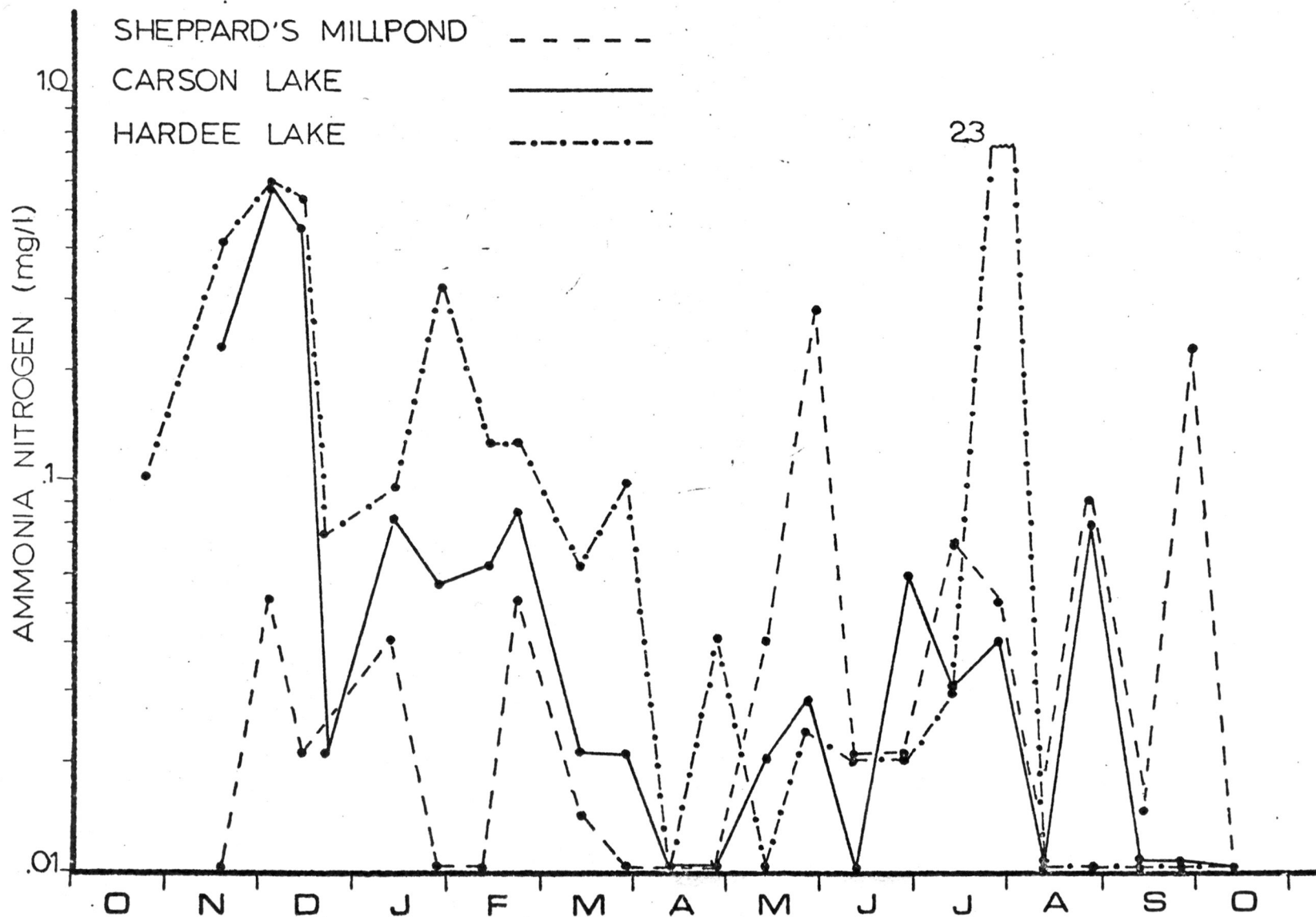
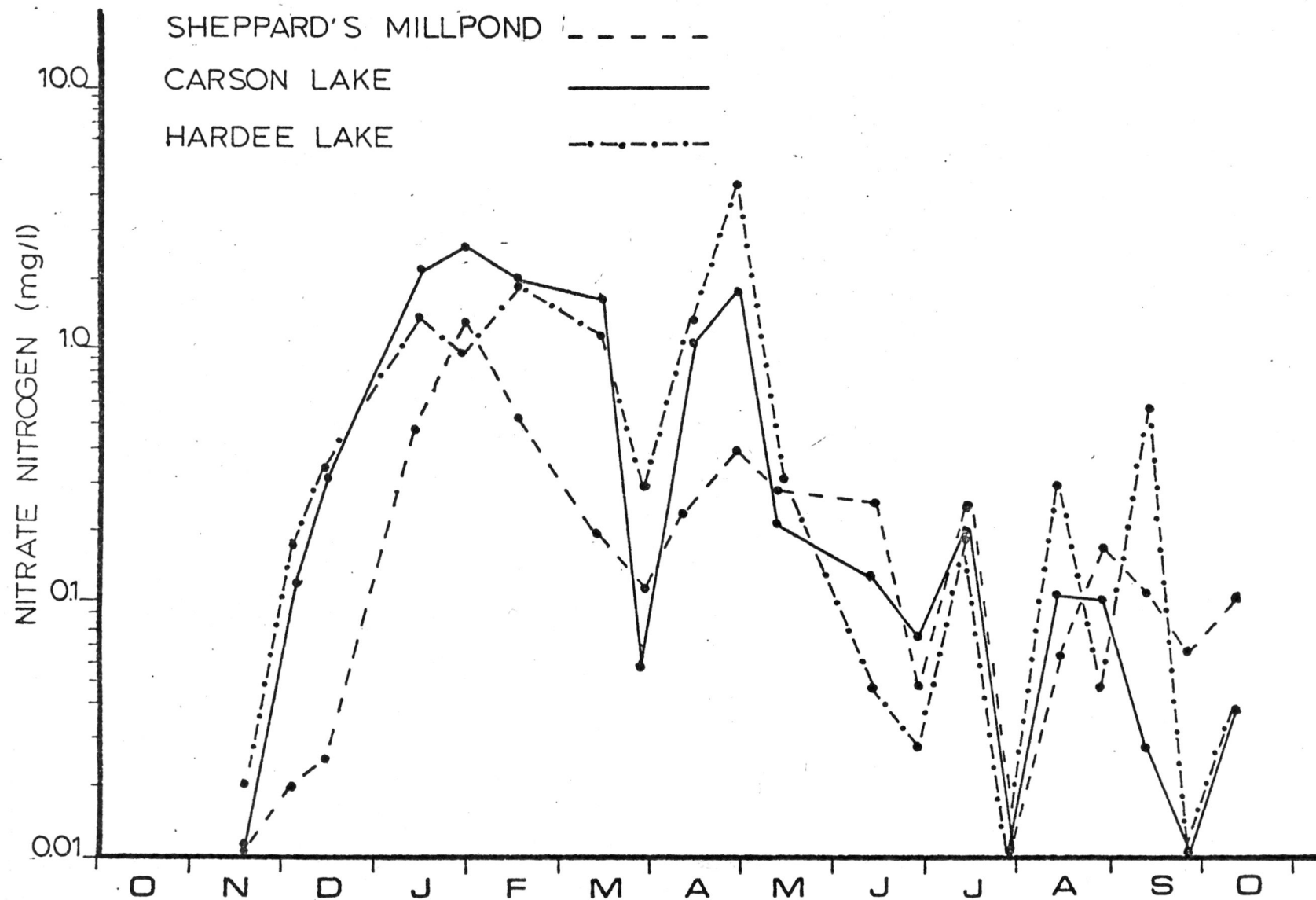


Figure 19. Seasonal variation in nitrate nitrogen within Sheppard's Millpond, Carson Lake, and Hardee Lake (mg/l).



Nitrite nitrogen Surface nitrite-nitrogen levels remained very low in all three impoundments throughout the study. Nitrite in Hardee Lake averaged 0.013 mg/l and was significantly higher than Carson Lake or Sheppard's Millpond both of which had a mean nitrite concentration of 0.006 mg/l (Table 1). Nitrite levels in Hardee Lake were highest in winter and early spring, decreased in May, and then dropped to trace or zero concentrations throughout late summer and fall (Fig. 20). Carson Lake and Sheppard's Millpond did not attain high nitrite levels in winter and spring as did Hardee Lake. Nitrite concentrations for these two impoundments generally remained below 0.01 mg/l and did not exhibit any apparent seasonal trend.

Total phosphorus Surface total phosphorous concentrations were similar in Hardee and Carson Lakes with respective means of 0.18 and 0.17 mg/l. Total phosphorus within Sheppard's Millpond was slightly lower with a mean value of 0.13 mg/l (Table 1, Fig. 21). Anomalous maximum concentrations were recorded in each impoundment during December in association with unusually high phytoplankton densities for that season. Following the December peak, phosphorus concentration dropped in each impoundment.

Orthophosphate Orthophosphate levels were extremely low or at trace levels (< 0.001 mg/l) in all three impoundments (Table 1, Fig. 22). Orthophosphate in Carson Lake averaged 0.010 mg/l while the yearly mean for both Hardee Lake and Sheppard's Millpond was 0.014 mg/l. There was no apparent seasonal trend but rather irregular pulses throughout the year. Orthophosphate pulses were generally inversely related to phytoplankton blooms. Lowest orthophosphate occurred when phytoplankton density was greatest.

Figure 20. Seasonal variation in nitrite nitrogen within Sheppard's Millpond, Carson Lake, and Hardee Lake (mg/l).

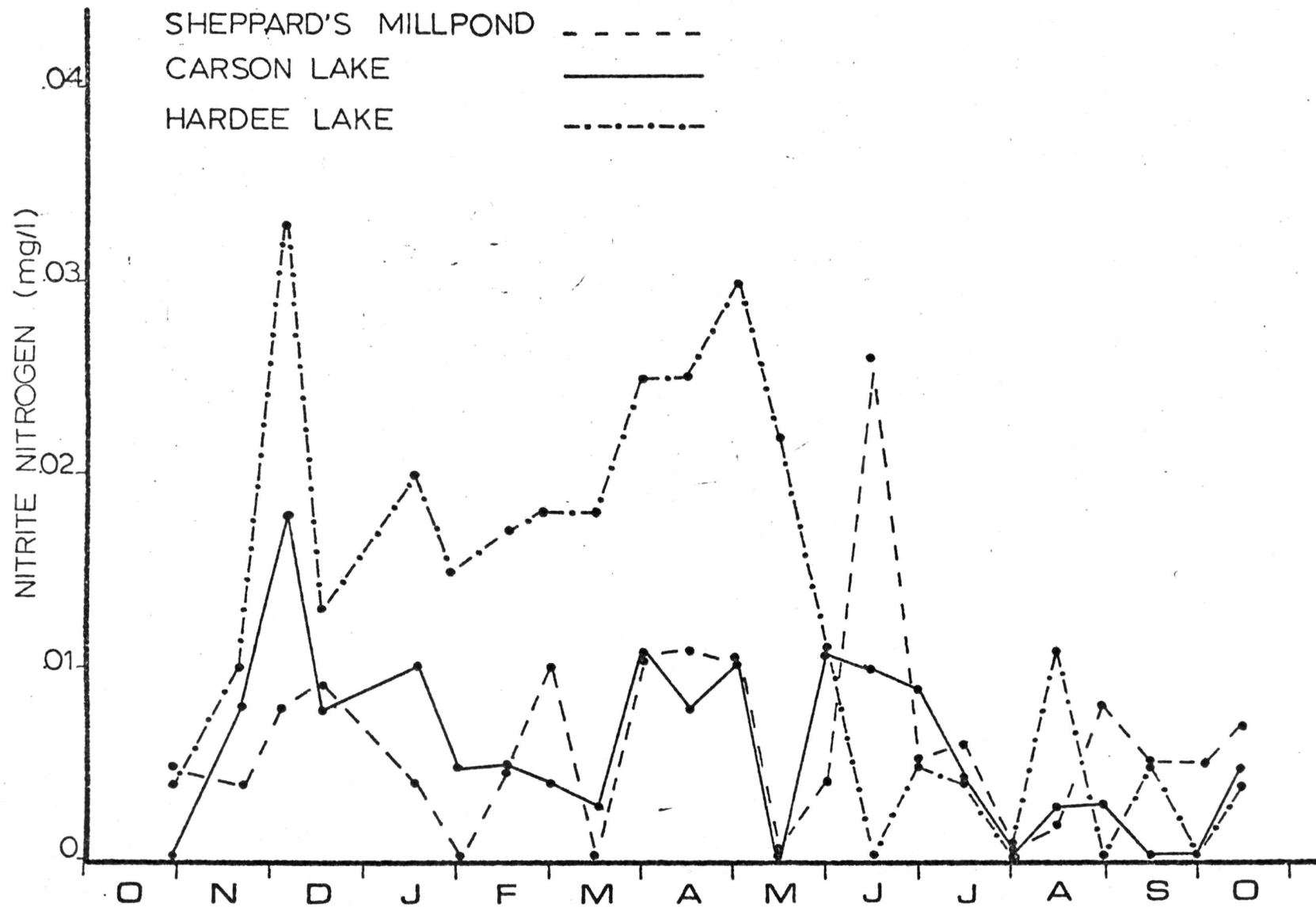


Figure 21. Seasonal variation in total phosphorus within Sheppard's Millpond, Carson Lake, and Hardee Lake (mg/l).

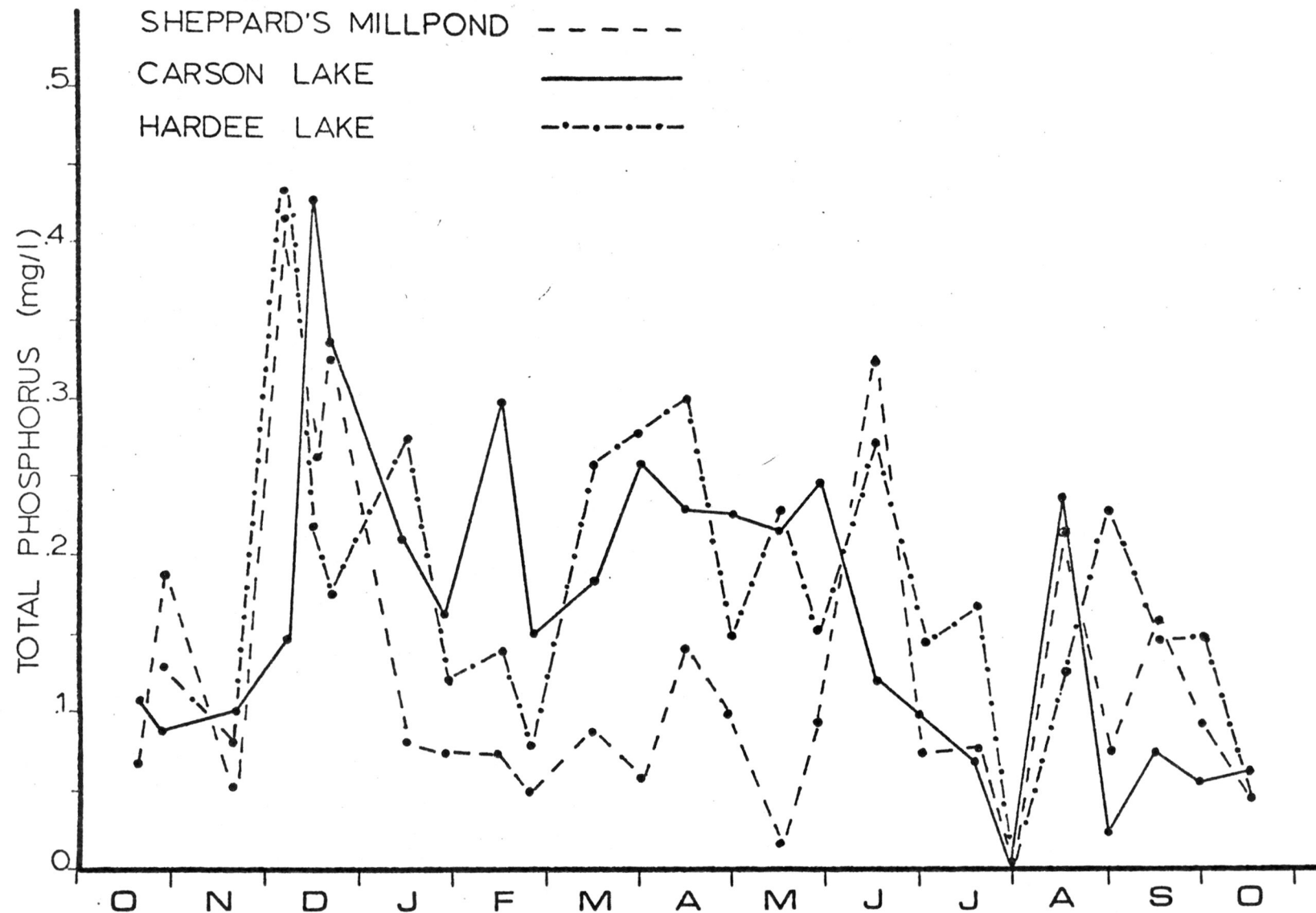
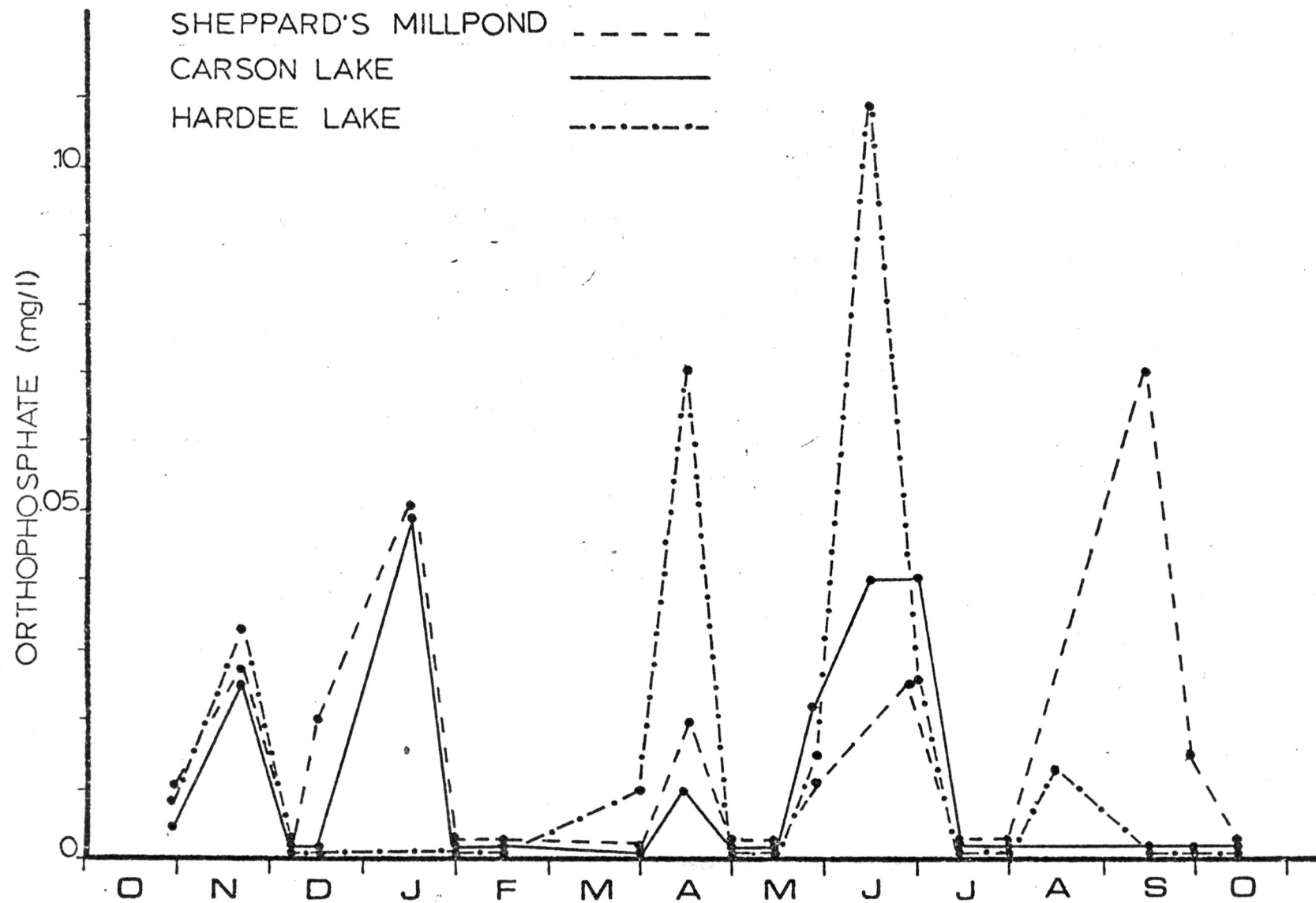


Figure 22. Seasonal variation in orthophosphate with Sheppard's Mill-pond, Carson Lake, and Hardee Lake (mg/l).



Biological Factors

Biological Oxygen Demand Biological Oxygen Demand (5 day) averaged 5.1 mg O₂/l in Hardee Lake. This was significantly higher than the BOD values for Carson Lakes or Sheppard's Millpond (Table 1, Fig. 23). BOD values of Hardee Lake were highest during summer when environmental conditions were favorable for blue-green algal blooms.

Mean BOD levels in Carson Lake and Sheppard's Millpond were similar and averaged 3.1 and 3.2 mg O₂/l respectively. The highest value for Carson Lake (10.0 mg O₂/l) was recorded in late October during a dense Ceratium hirundinella bloom.

BOD values for Sheppard's Millpond remained low, usually below 4.5 mg O₂/l throughout the study. The maximum value reported (6.6 mg O₂/l) occurred on 29 September following a massive phytoplankton bloom (over 14,000 cells/ml) (Fig. 23).

Chlorophyll-a Chlorophyll a measurements were made from 30 April to 15 October in each of the impoundments under study. Chlorophyll a was significantly higher in Hardee Lake and averaged over 234 ug/l (Table 1 Fig. 24). Chlorophyll a began to increase in May, peaked in late August during a Schizothrix calicola bloom, then decreased with decreasing phytoplankton density in the fall. The maximum value (1160 ug/l) for Hardee Lake was five times greater than the mean chlorophyll value and probably resulted at least in part from surface algal concentration by wind fetch.

Chlorophyll a in Carson Lake was much lower (mean 46.9 ug/l) with peak values recorded in mid-June and mid-September during high blooms of Anabaena circinalis and Calothrix parientina.

Figure 23. Seasonal variation in Biological Oxygen Demand within Sheppard's Millpond, Carson Lake, and Hardee Lake (mg O₂/l).

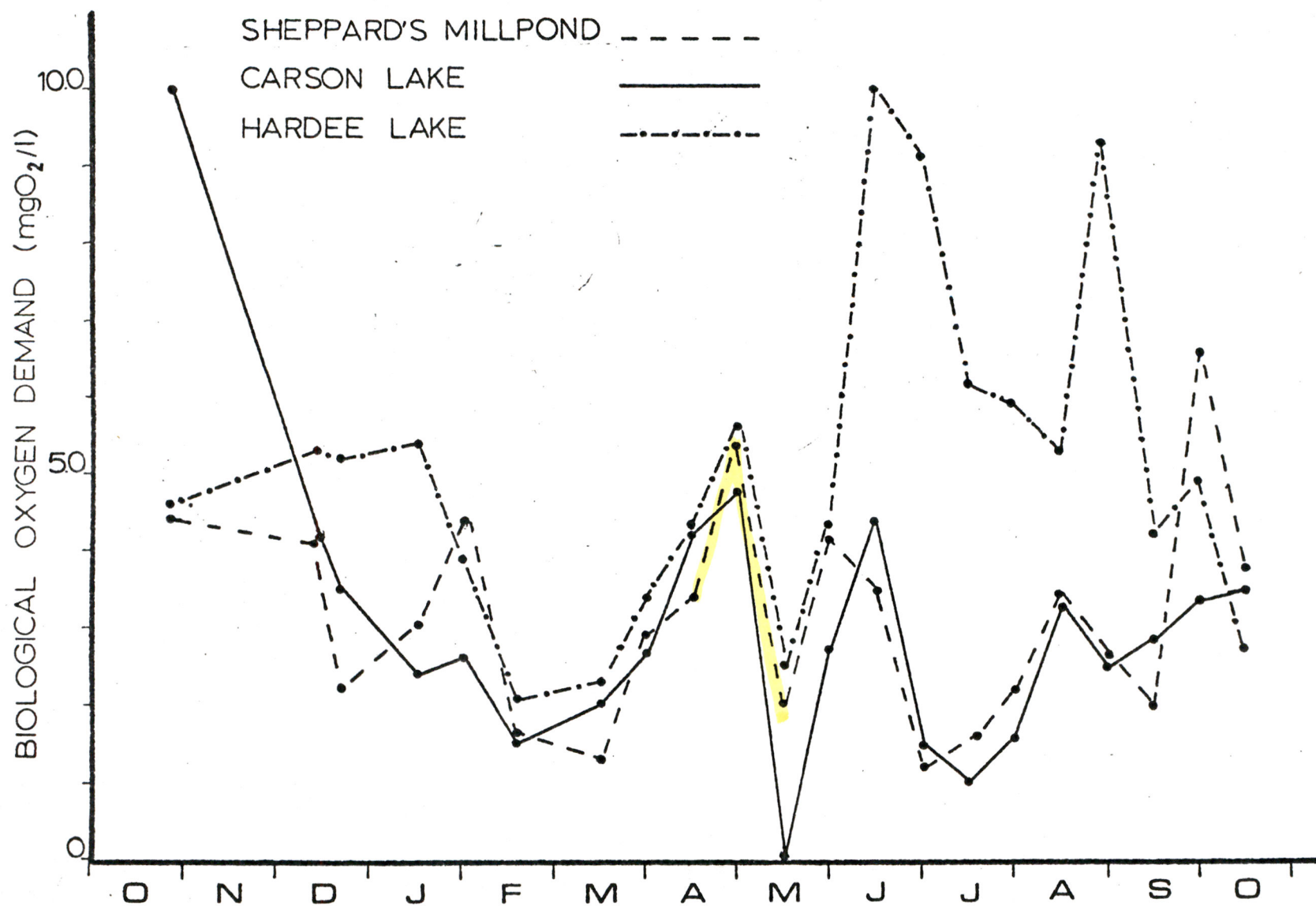
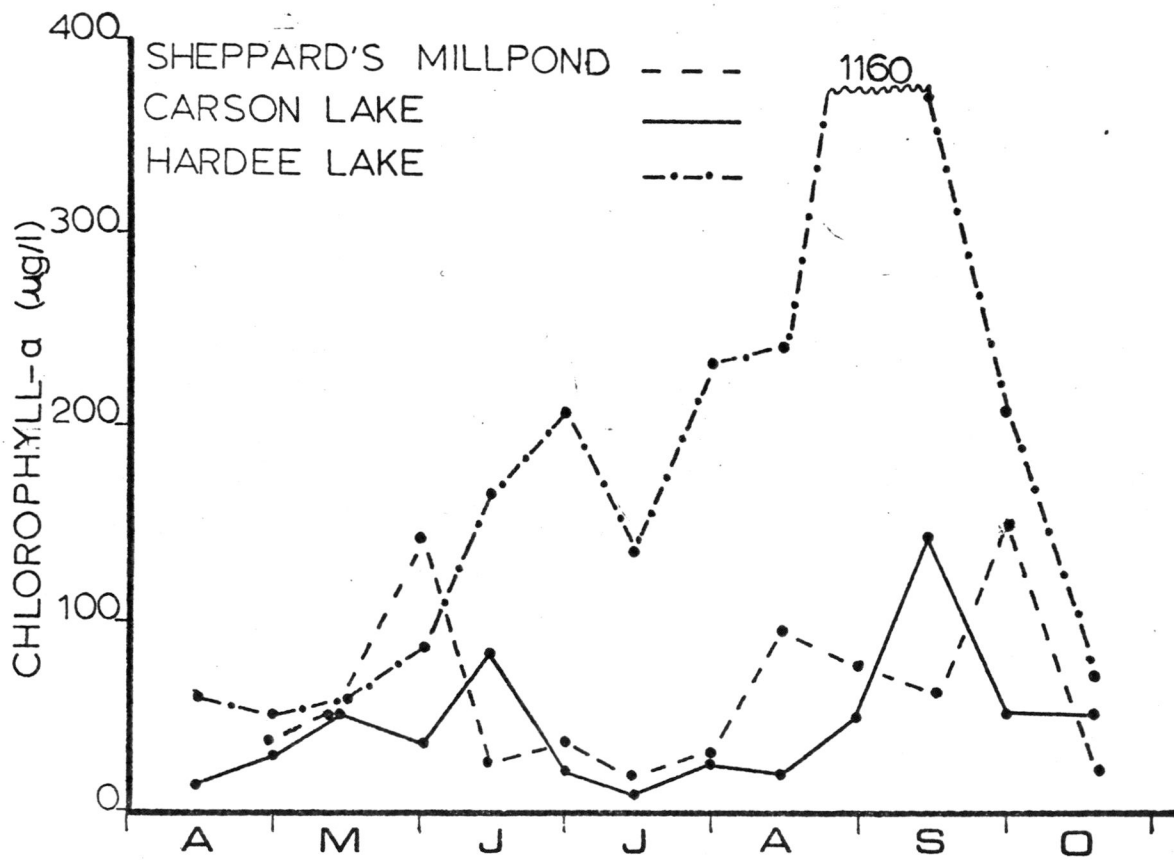


Figure 24. Seasonal variation in chlorophyll a within Sheppard's Mill-pond, Carson Lake, and Hardee Lake ($\mu\text{g/l}$).



The mean chlorophyll-a concentration in Sheppard's Millpond was 58.2 ug/l. Values ranged from <0.01 ug/l in April to the peak value, 150 ug/l, obtained in mid-September following the phytoplankton peak.

Phytoplankton Phytoplankton density was significantly higher in Hardee Lake than in Carson Lake or Sheppard's Millpond and was characterized by a predominantly Cyanophyta-Chlorophyta flora (Table 1, Figs. 25 & 26). A total of 45 genera were identified from Hardee Lake with the dominant species including Sphaerocystis schroteri, Anabaena circinalis, Anacystis cyanea, Schizothrix calicola, and Calothrix parietina (App. A Table 1). With the exception of Sphaerocystis schroteri, these are eutrophic indicator species (Hutchinson, 1967). Sphaerocystis schroteri was most abundant in early winter and late summer (Fig. 27). Anabaena circinalis and Anacystis cyanea were present in low numbers during winter, increased to bloom proportions in mid-May and remained numerous through fall. Schizothrix calicola, the most numerous species, was present only during the summer months when it reached densities as high as 400,000 cells/ml (Fig. 28). Calothrix parientina was present in late May, disappeared in June, and became very numerous again in September and October.

In addition to these dominant forms, other species of algae became abundant for brief periods during spring and fall. The diatom Cyclotella kutzingiana was dominant during March, decreased shortly afterward and was observed rarely during the rest of the study (Fig. 28). Volvox aureus formed a dense bloom in late April and early May, then disappeared for the rest of the study. Ankistrodesmus falcatus was present in low numbers throughout the year and was the most numerous phytoplankter in late October.

Figure 25. Seasonal variation in phytoplankton density within Sheppard's Millpond, Carson Lake, and Hardee Lake (cells/ml). Smooth curves drawn through data points representing biweekly collections.

+ indicates Volvox aureus bloom; however, cell fragmentation prevented accurate cell count.

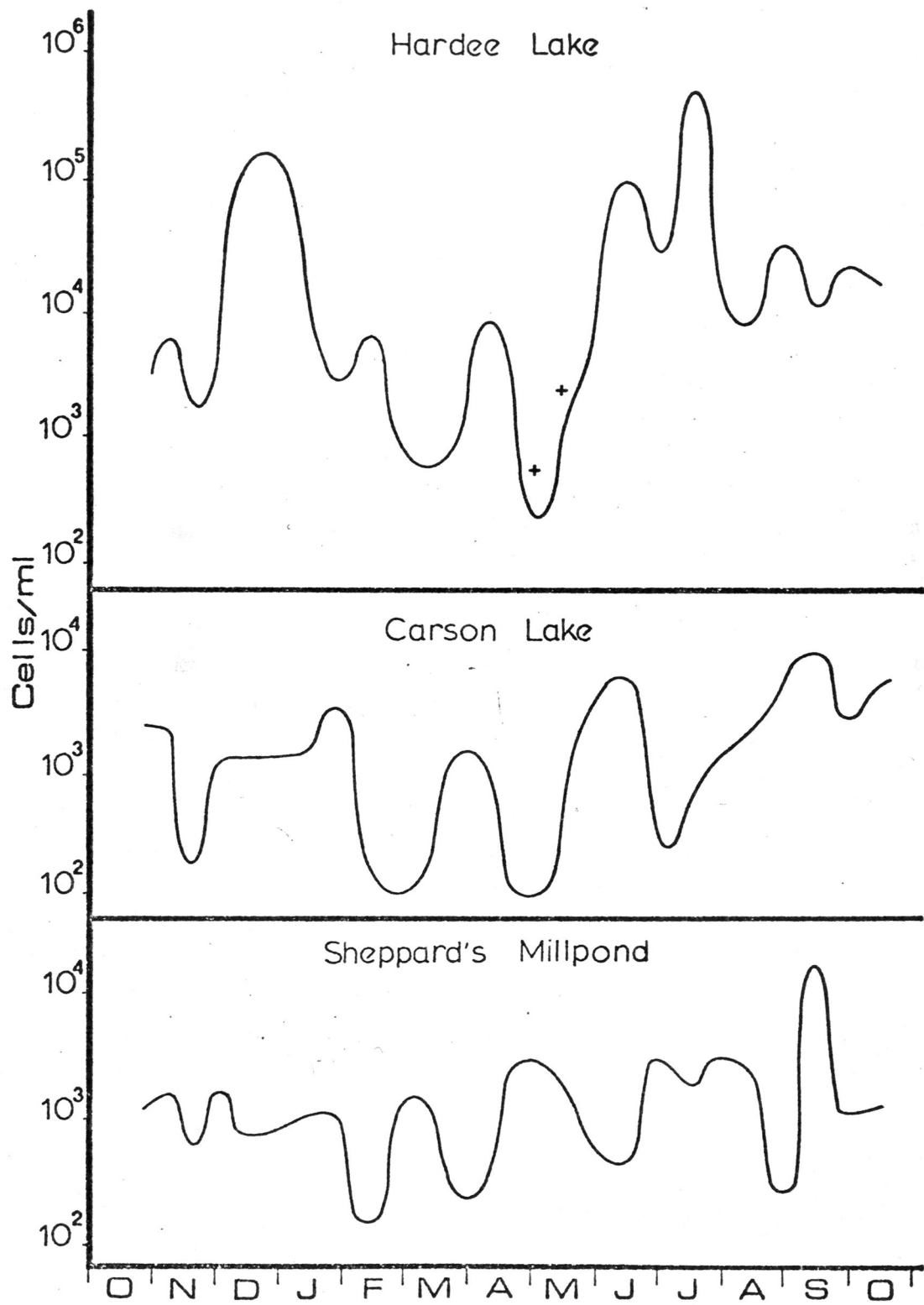
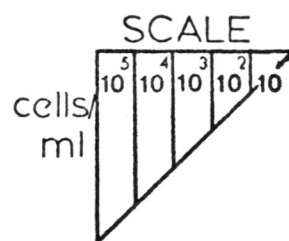
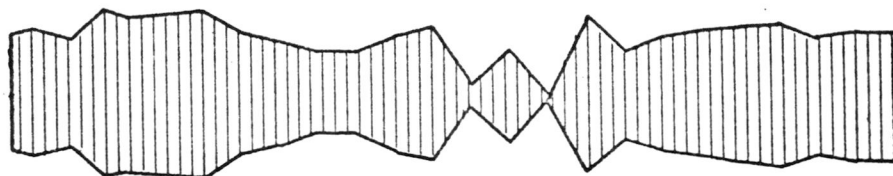


Figure 26. Seasonal variation in relative dominance of the algal classes in Hardee Lake (cells/ml).

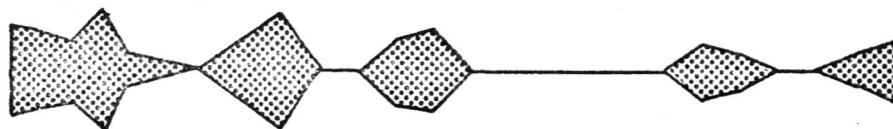
HARDEE LAKE



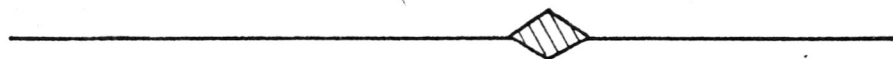
Chlorophyta



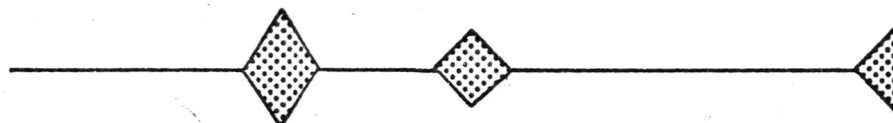
Euglenophyta



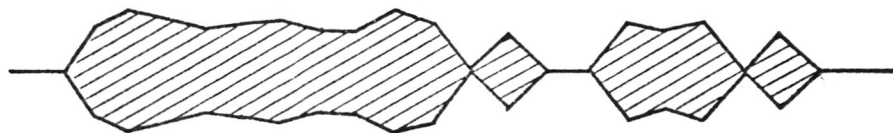
Pyrrhophyta



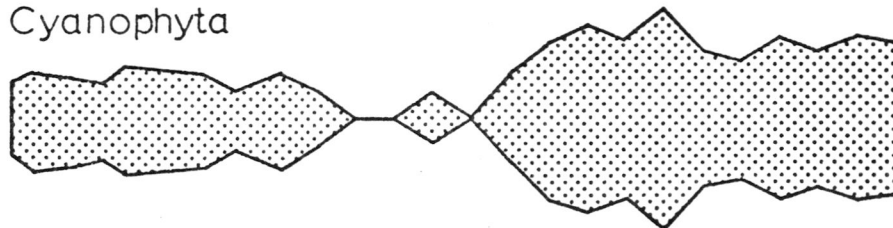
Cryptophyta



Chrysophyta



Cyanophyta

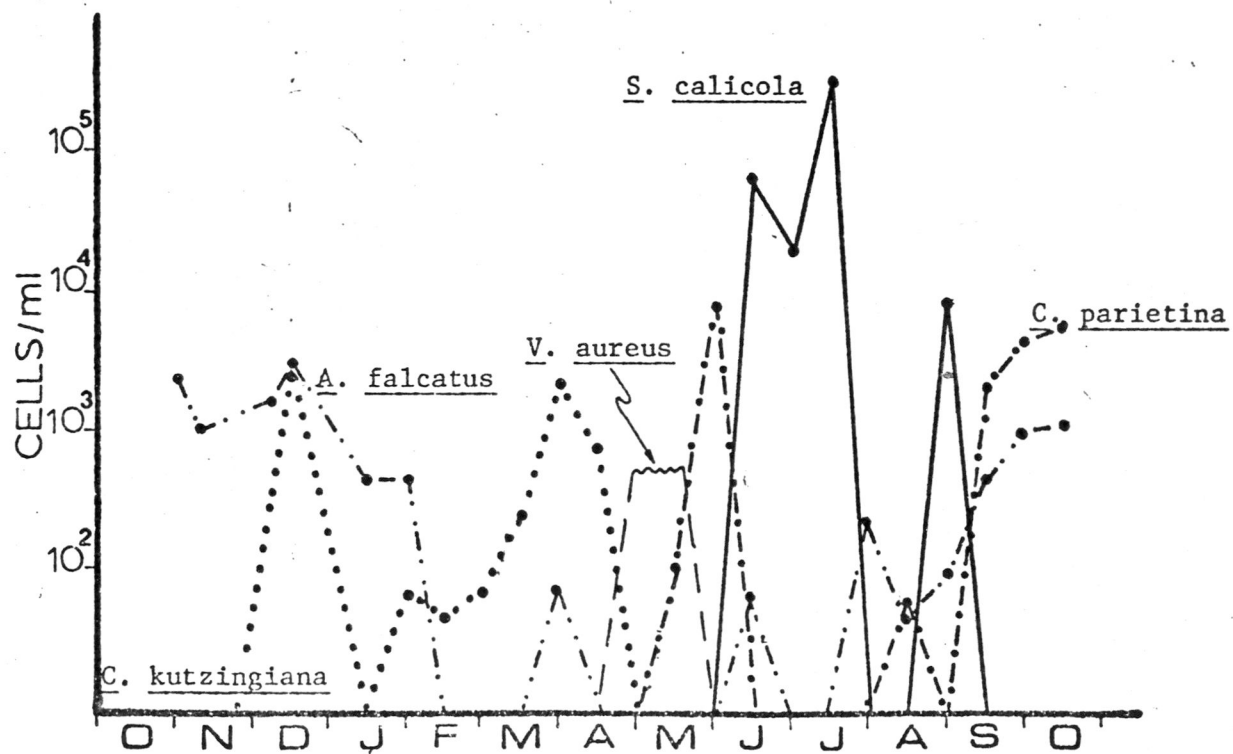
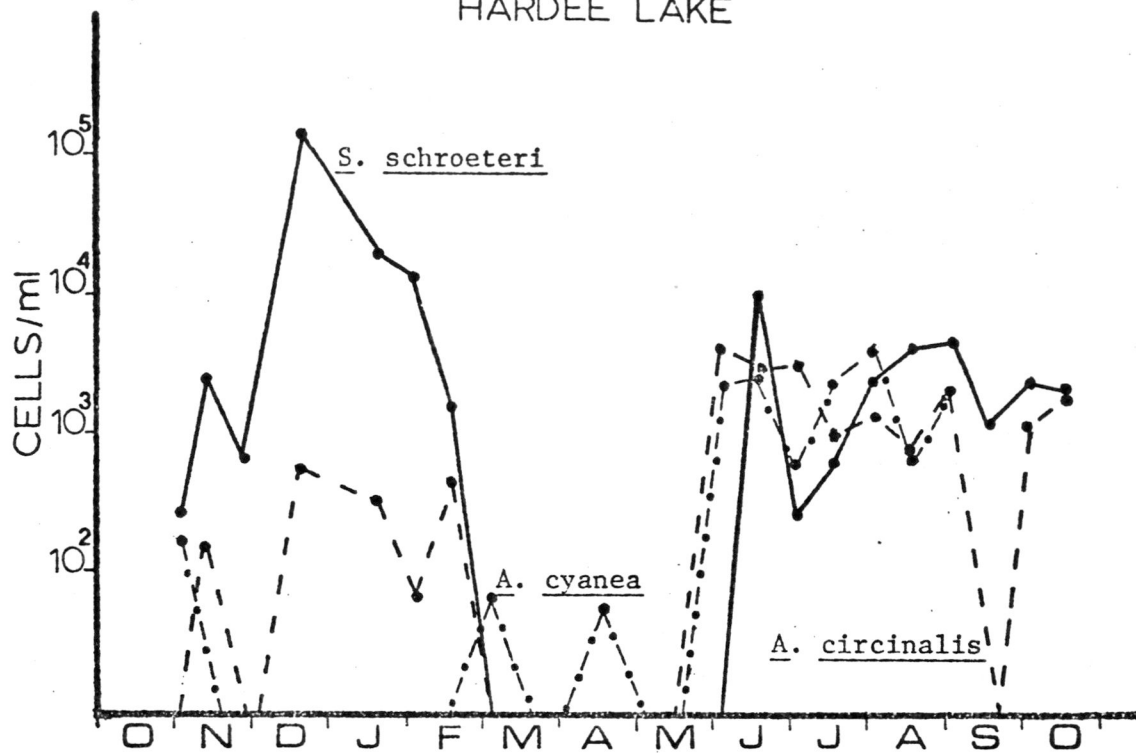


O N D J F M A M J J A S O

Figures 27 & 28. Seasonal distribution of the dominant phytoplankton in Hardee Lake (cells/ml).

↘ indicated Volvox aureus bloom; however, cell fragmentation prevented accurate cell count.

HARDEE LAKE



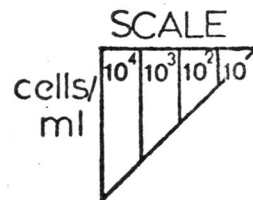
The Carson Lake flora mainly consisted of ephemeral species of Cyanophyta and Chlorophyta which became abundant for brief periods then declined (App. A, Table 1 Figs. 25 & 29). Dominant forms included eutrophic indicator species Calothrix parietina, Anabaena circinalis, Ceratium hirundinella, Lepocinclis fusiformis, and Ankistrodesmus falcatus. Calothrix parietina, the most numerous species, and Anabaena circinalis were present in low numbers in early winter but became abundant by late summer (Fig. 30). Ceratium hirundinella formed a dense bloom in November, was present briefly during April, and then began to increase again in the fall. Lepocinclis fusiformis attained the highest recorded cell density for Carson Lake (8,800 cells/ml) in early December, but was not found again during the study. Ankistrodesmus falcatus was the most frequently encountered species, being a dominant form during March and April and sharing dominance with Calothrix parietina and Anabaena circinalis in late August (Fig. 31). Sphaerocystis schroteri, an oligotrophic indicator species, was numerous in spring and became the dominant species in October.

Sheppard's Millpond had the most species with a total of 72 taxa identified and seven classes of freshwater algae represented (App. A Table 1). Phytoplankton density averaged less than 2,000 cells/ml throughout the year (Fig. 25).

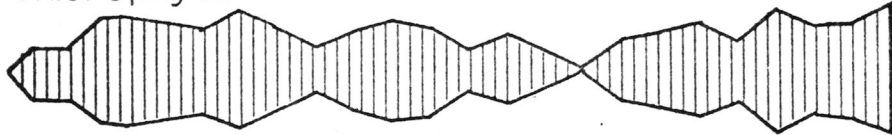
Widely tolerant Trachelomonas and Cryptomonas species formed the base flora while more ephemeral species exhibited brief dominance during the year (Fig. 32). The predominant species included Trachelomonas woycicki, Trachelomonas volvicina, Trachelomonas superba, and Cryptomonas obovata.

Figure 29. Seasonal variation in relative dominance of the algal classes in Carson Lake (cells/ml).

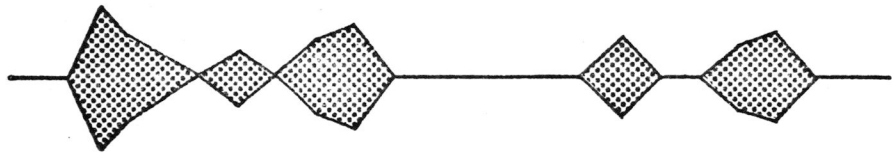
CARSON LAKE



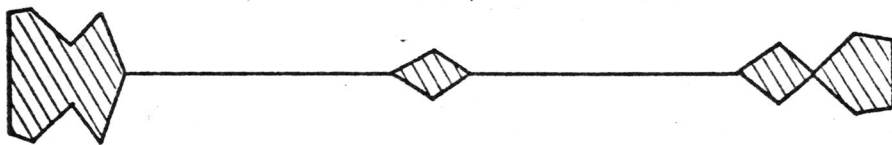
Chlorophyta



Euglenophyta



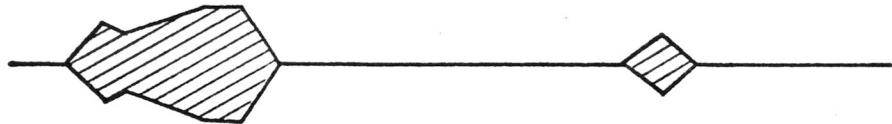
Pyrrhophyta



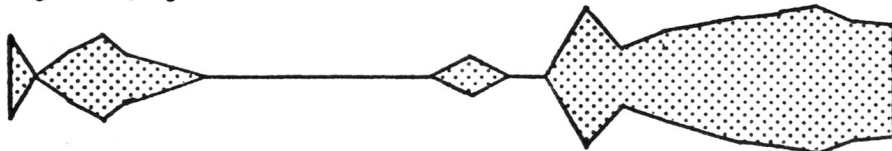
Cryptophyta



Chrysophyta



Cyanophyta



O N D J F M A M J J A S O

Figures 30 & 31. Seasonal distribution of the dominant phytoplankton in Carson Lake (cells/ml).

CARSON LAKE

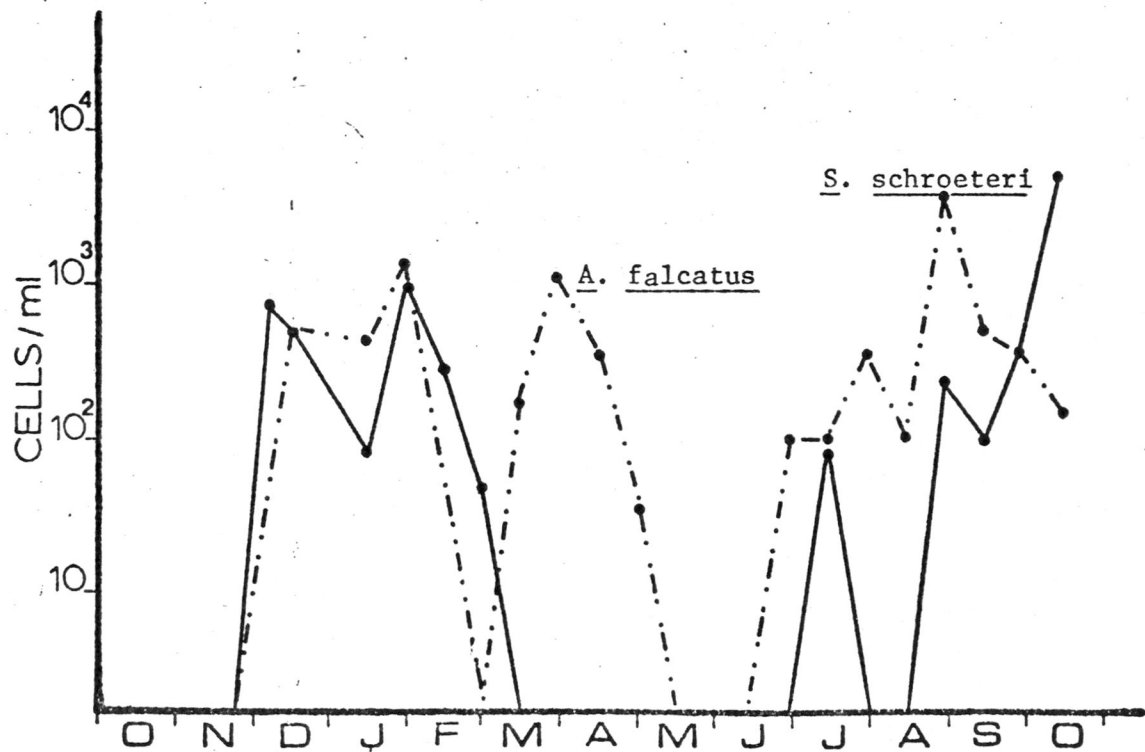
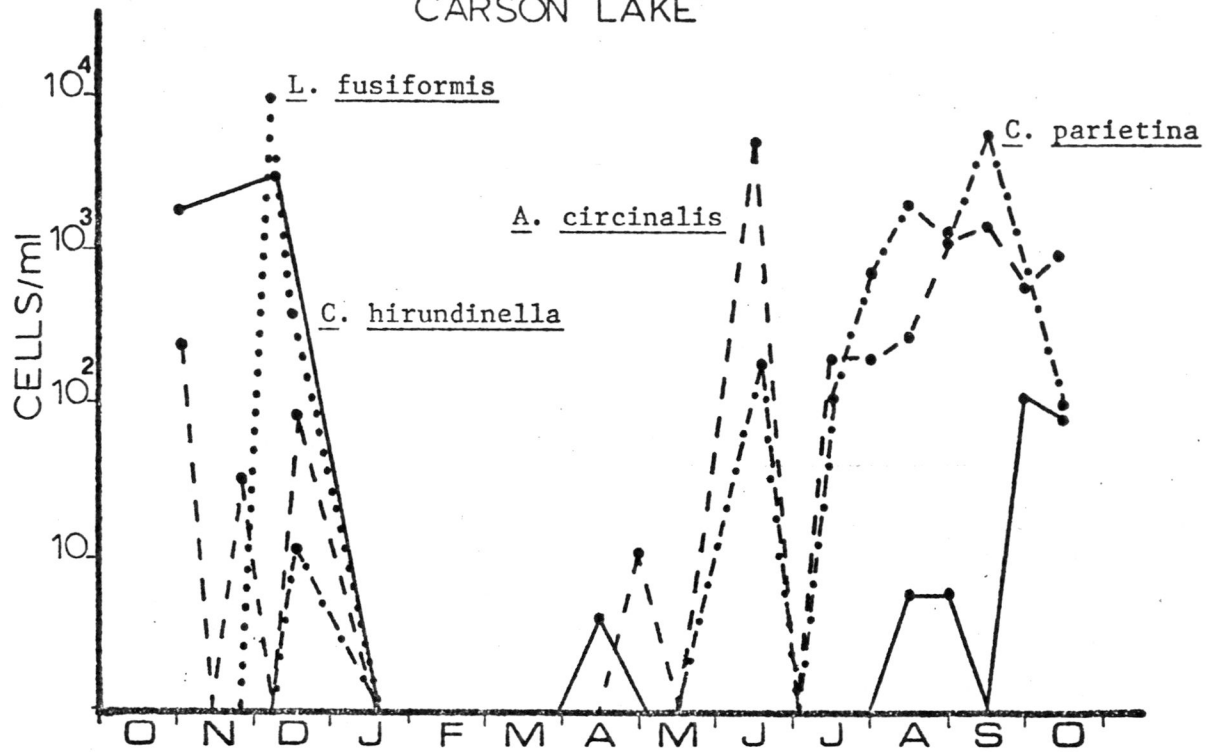
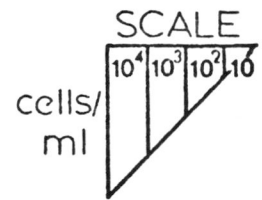
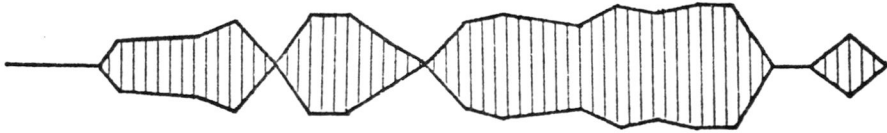


Figure 32. Seasonal variation in relative dominance of the algal classes in Sheppard's Millpond (cells/ml).

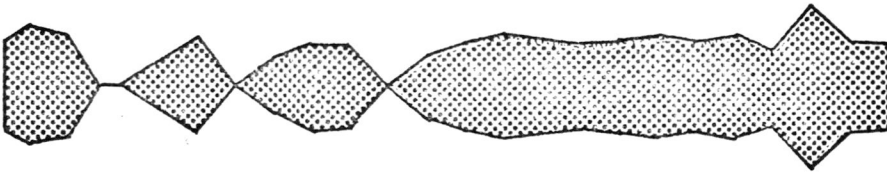
SHEPPARD'S MILLPOND



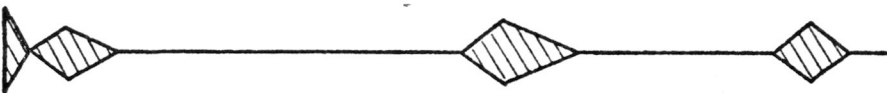
Chlorophyta



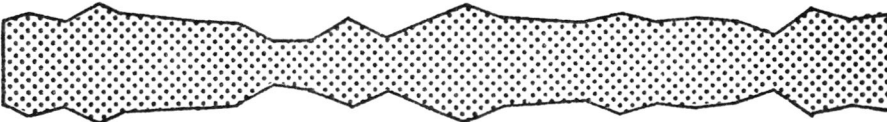
Euglenophyta



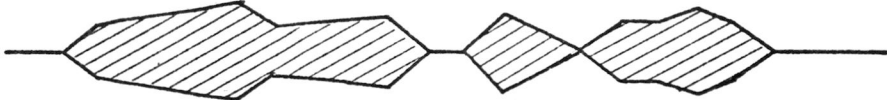
Pyrrhophyta



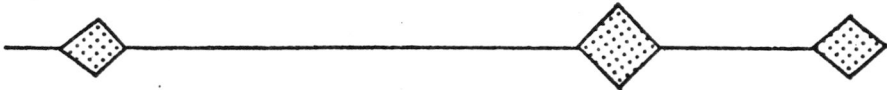
Cryptophyta



Chrysophyta



Cyanophyta



O N D J F M A M J J A S O

Trachelomonas woycicki, attained the highest cell density observed in Sheppard's Millpond with densities of over 1,400 cells/ml. This species, previously unreported in North America was found only in September (Fig. 33).

The above phytoplankton dominance was periodically interrupted by other species. Colonies of Synura uvella became numerous in January and February but were not found thereafter (Fig. 34). Sphaerocystis schroteri was present in low numbers in December and became dominant for short periods again in early March and mid-July.

Although the above mentioned species were the predominant forms, the flora was quite diverse in the millpond. Genera were often represented in relatively equal abundance, with one species seldom exhibiting clear dominance.

Species diversity Species diversity was significantly higher in Sheppard's Millpond with a mean value of 1.45 (Shannon and Weaver, 1949) (Fig. 36). Highest diversity values were obtained during spring and summer. Minimum diversity (0.53) was recorded during the Trachelomonas woycicki bloom, while the maximum value (2.39) was recorded when 15 species were represented (Table 1).

Diversity indices for Hardee and Carson Lakes were similar with mean values of 1.07 and 1.02 respectively (Table 1). Diversity was lower in Hardee Lake in summer when nutrient conditions favored mono-specific blooms.

Diversity in Carson Lake ranged from 0.13 (11-18-73) to 1.76 (12-10-73) (Table 1). The minimum value occurred when a single species,

Figures 33 & 34. Seasonal distribution of the dominant phytoplankton in Sheppard's Millpond (cells/ml).

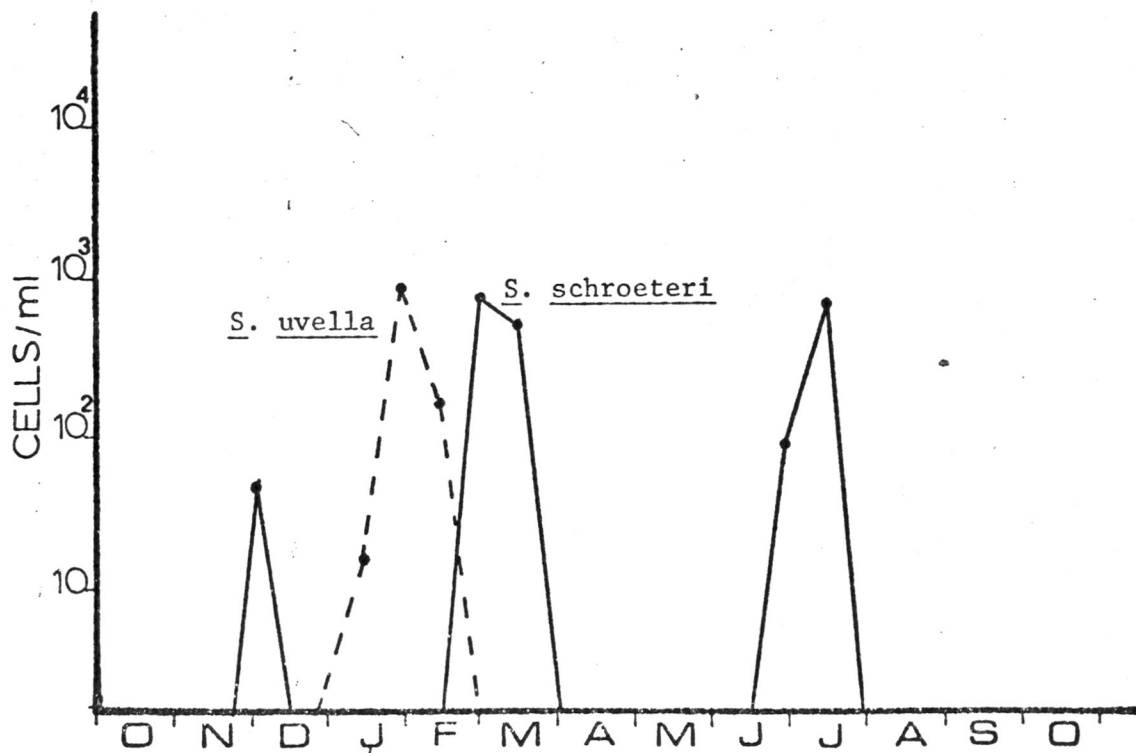
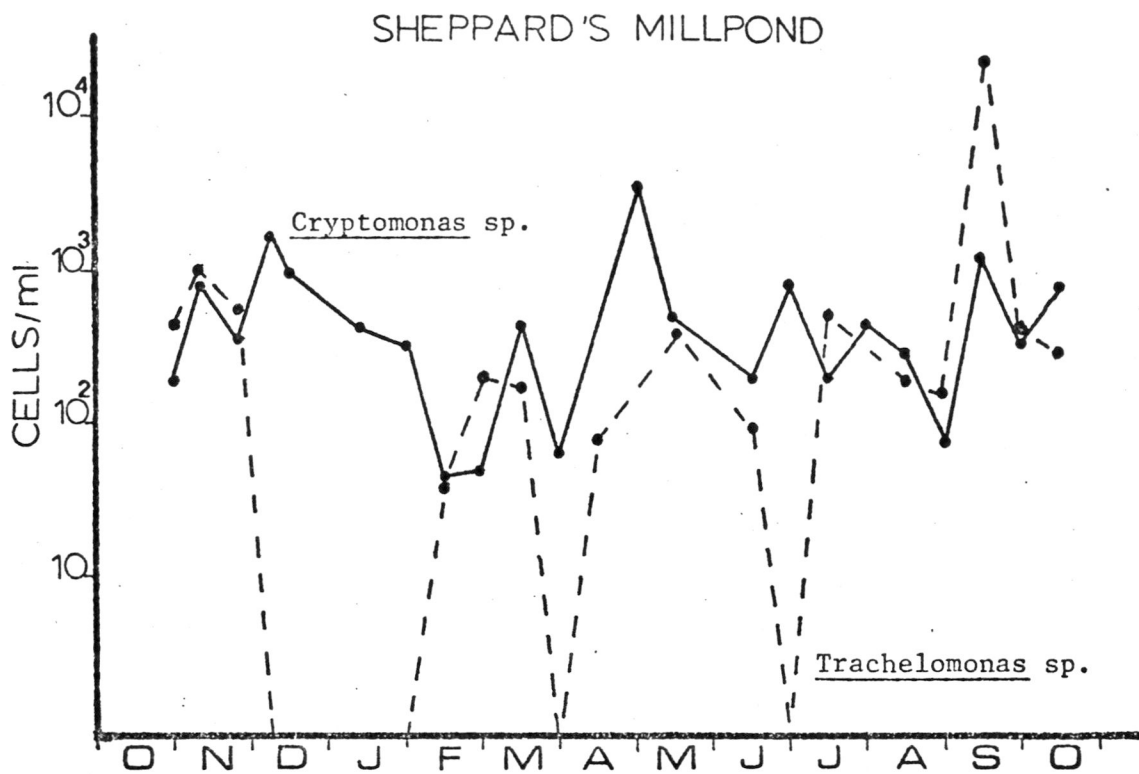
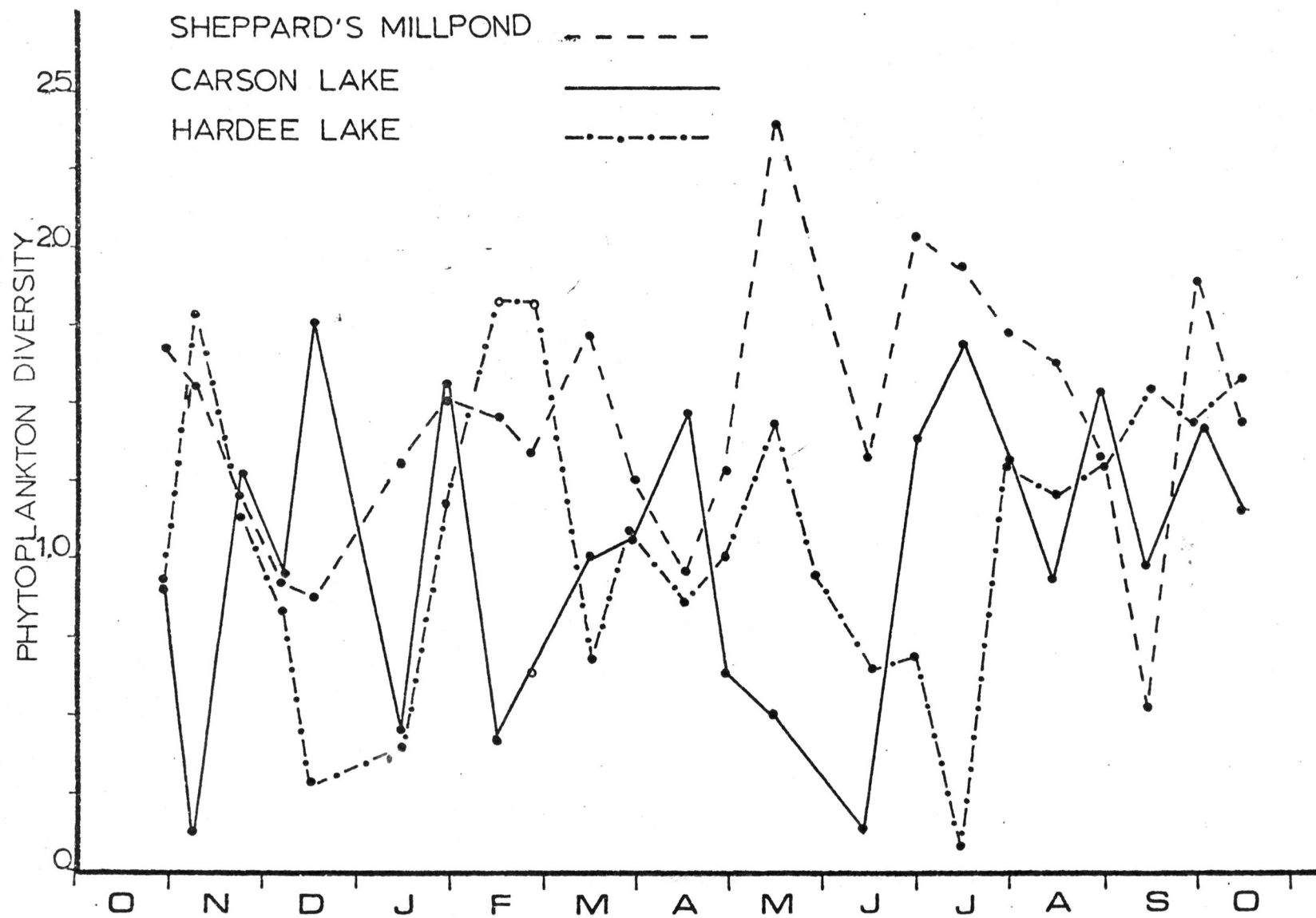


Figure 35. Seasonal variation in phytoplankton diversity within Sheppard's Millpond, Carson Lake, and Hardee Lake.



Ceratium hirundinella, dominated the flora while maximum diversity occurred when seven species were present in relatively equal numbers.

Species evenness Species evenness indices were highest in Sheppard's Millpond with an annual mean of 0.78 as compared to means of 0.58 and 0.67 for Hardee and Carson Lakes respectively (Table 1, Fig. 36).

Gross primary productivity Productivity was significantly higher in Hardee Lake with the major part of the productivity occurring in summer (Table 1, Fig. 37). The greatest rate of production ($11.2 \text{ g O}_2/\text{m}^2/\text{day}$) was recorded in late June and coincided with a bloom of the blue-green alga Schizothrix calicola. Primary productivity declined rapidly in winter and was lowest in early spring when the flora was dominated by Cyclotella kutziana and Closteriopsis longissima.

Phytoplankton primary productivity in Carson Lake remained at relatively low levels throughout the year (Fig. 37). The daily mean primary productivity rate over this period was $2.0 \text{ g O}_2/\text{m}^2/\text{day}$. The observed range was 0.2 (1-13-74) to $3.7 \text{ g O}_2/\text{m}^2/\text{day}$ (10-27-73) (Table 1). Declining productivity in Carson Lake during winter coincided with decreasing solar radiation, but may also have been affected by increasing turbidity resulting from dredging operations and winter rains. Following stabilization of the soils and lower turbidity levels in May, productivity values increased and remained around $2.0 \text{ g O}_2/\text{m}^2/\text{day}$ until termination of the study. During the fall, a bloom of Ceratium hirundinella contributed to the highest productivity measurement ($3.7 \text{ g O}_2/\text{m}^2/\text{day}$). The lowest production level ($0.2 \text{ g O}_2/\text{m}^2/\text{day}$)

Figure 36. Seasonal variation in species evenness within Sheppard's Millpond, Carson Lake, and Hardee Lake.

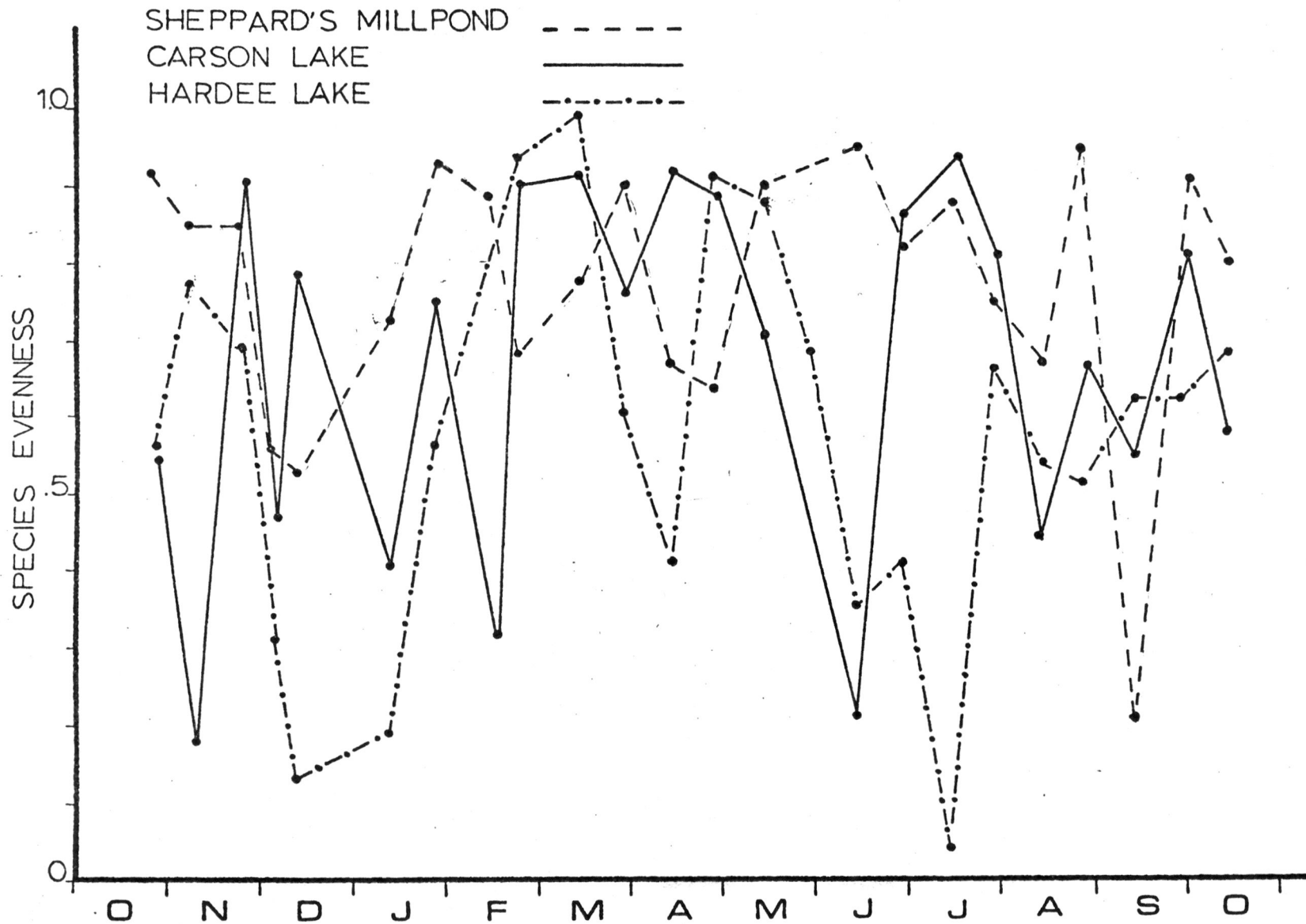
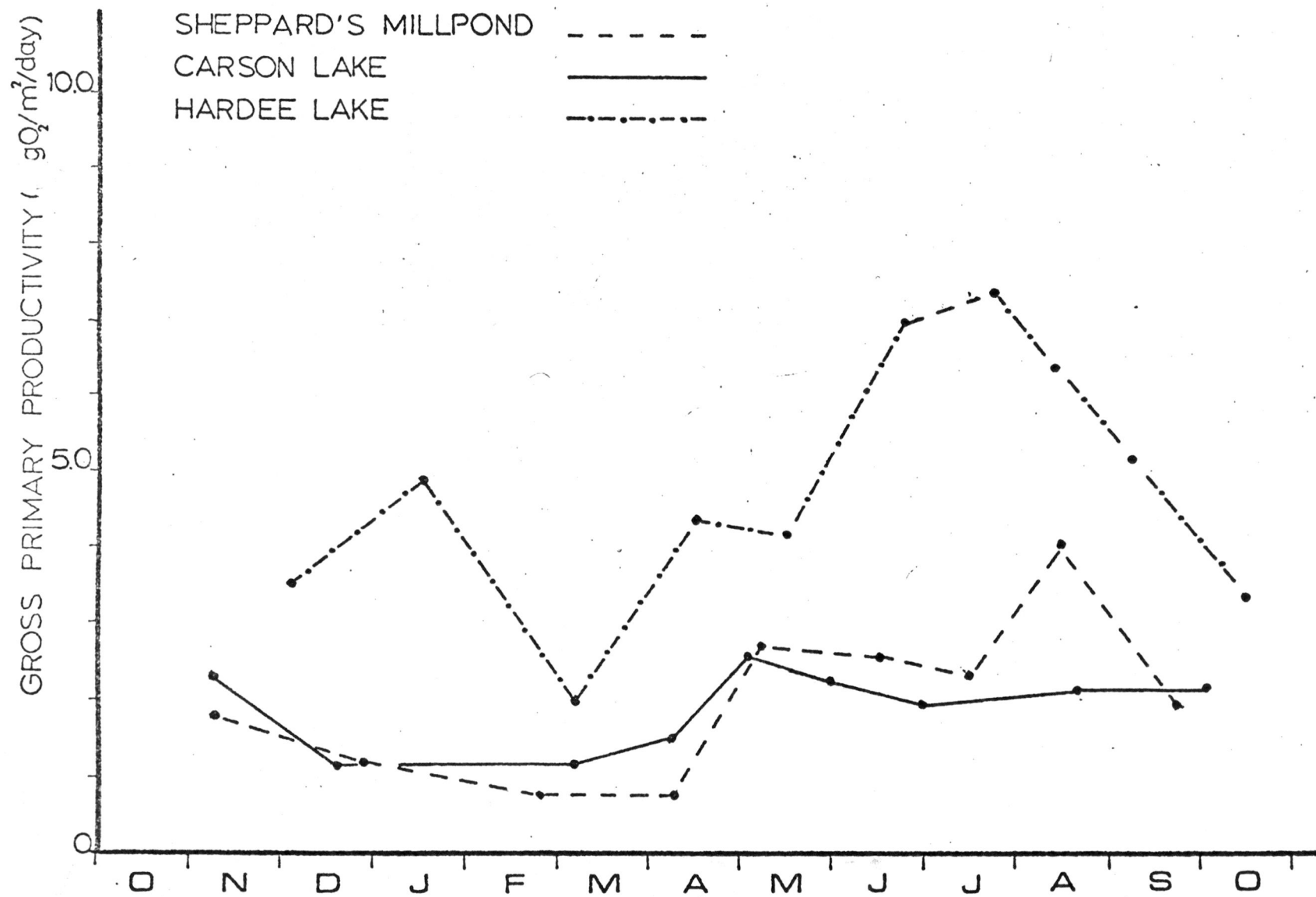


Figure 37. Seasonal variation in gross primary productivity within Sheppard's Millpond, Carson Lake and Hardee Lake ($\text{g O}_2/\text{m}^2/\text{day}$) (points computed using running average; Pollack and Sterling, 1968).



occurred in mid-winter in conjunction with a depauperate phytoplankton dominated by Nitzschia accicularis.

Gross primary productivity estimates for Sheppard's Millpond were similar to those for Carson Lake. The daily mean was $2.1 \text{ g O}_2/\text{m}^2/\text{day}$ and the observed range was between 0.1 (11-19-73) and $5.2 \text{ g O}_2/\text{m}^2/\text{day}$ (8-15-74) (Table 1, Fig. 37). Productivity consistently remained low throughout the winter, less than $1.0 \text{ g O}_2/\text{m}^2/\text{day}$, while maximum production estimates were recorded in late summer and fall and coincided with a Cryptomonas-Trachelomonas dominated phytoplankton assemblage.

DISCUSSION

The capacity of an impoundment to support biological production depends upon numerous physical and chemical factors. Of the several criteria used to evaluate trophic status, the following were selected for use in evaluating the impoundments described in this study: phytoplankton characteristics (density, diversity, production) and macro-nutrient concentrations.

Phytoplankton

In this study significant differences in phytoplankton composition and density were found among the three impoundments. These differences indicate different trophic states and an attempt will be made to explain these differences in terms of history of each impoundment and land use in its watershed.

During the summer cyanophyte densities frequently reached bloom proportions in Hardee Lake and as might be expected the episodes of high phytoplankton densities were accompanied by significantly higher photosynthetic activity (Table 2). The dominant cyanophyte species at this time were Anabaena circinalis, Anacystis cyanea and Schizothrix calicola (Figs. 27, 28). This summer flora appeared to be influenced by nutrient enrichment in that the taxonomic composition approximated that of enrichment indicator genera reported by Hasler (1947) and Hammer (1964). These investigators described several lakes which received nutrient enrichment from agricultural runoff or sewage input from nearby development. The resultant nutrient enrichment was accompanied by summer phytoplankton blooms in which the dominant genera were the

Table 2. Comparison of Significantly Different Parameters
Using Duncan's New Multiple Range Procedure

Parameter	Annual Mean Value for Each Parameter*		
	Hardee Lake	Carson Lake	Sheppard's Mill- pond
Transparency (dcm)	<u>4.2</u>	<u>3.7</u>	<u>9.2</u>
Total Suspended Matter (mg/l)	<u>37.0</u>	<u>37.0</u>	<u>8.0</u>
Turbidity (JTU)	<u>81</u>	<u>112</u>	<u>44</u>
Dissolved Oxygen (mg/l)	<u>11.0</u>	<u>9.6</u>	<u>6.5</u>
Percent Saturation	<u>118</u>	<u>103</u>	<u>68</u>
pH	<u>7.6</u>	<u>6.7</u>	<u>5.7</u>
Total Alkalinity (mg/l)	<u>17.5</u>	<u>10.8</u>	<u>7.8</u>
Conductivity (umho/cm)	<u>89</u>	<u>68</u>	<u>46</u>
Kjeldahl Nitrogen (mg/l)	<u>2.97</u>	<u>1.60</u>	<u>1.47</u>
Nitrate Nitrogen (mg/l)	<u>0.69</u>	<u>0.68</u>	<u>0.18</u>
Nitrite Nitrogen (mg/l)	<u>0.013</u>	<u>0.006</u>	<u>0.006</u>
Biological Oxygen Demand (mg O ₂ /l)	<u>5.1</u>	<u>3.1</u>	<u>3.2</u>
Chlorophyll <u>a</u> (ug/l)	<u>234.2</u>	<u>46.8</u>	<u>58.2</u>
Phytoplankton No. (Log _N)	<u>3.75</u>	<u>3.09</u>	<u>3.03</u>
Species Diversity (H)	<u>1.07</u>	<u>1.02</u>	<u>1.45</u>
Gross Primary Productivity (g O ₂ /m ² /day)	<u>4.9</u>	<u>2.0</u>	<u>2.1</u>

*Any two means not underscored by the same line are significantly different at the 5% level by Duncan's New Multiple Range Procedure.

cyanophytes, Anabaena, Anacystis and Aphanizomenon. Since cyanophytes are thought to bloom in response to increased nutrient availability, some investigators (Prescott, 1964; Brooks, 1969) have suggested that these cyanophytes (particularly the three genera listed above) might be useful indicators of cultural enrichment.

The high nutrient concentrations resulted in greater phytoplankton densities and significantly higher BOD and chlorophyll a concentrations reported for Hardee Lake (Table 2).

Carson Lake did not appear to be as eutrophic as Hardee Lake. This was indicated by the significantly lower phytoplankton density, BOD, and chlorophyll a concentrations characteristic of this Lake (Table 2). However the dominant phytoplankton genera observed in Carson Lake, Anabaena and Calothrix, have been generally accepted as indicators of eutrophication (Hutchinson, 1967).

Cyanophytes were essentially absent from Sheppard's Millpond where Cryptomonas, an indicator of oligotrophy, and the widely tolerant Trachelomonas (Hutchinson, 1967), constituted the dominant phytoplankters. Absence of cyanophytes was probably the result of growth constraints placed upon these organisms by the dark acidic water characteristics of Sheppard's Millpond. Shapiro (1973) reported lowering the pH in experimental test ponds resulted in decreased cyanophyte dominance.

Diversity

Species diversity, as measured by any one of several diversity indices, has frequently been correlated with trophic state (Odum, 1963; Margalef, 1963). Systems having higher diversities are generally

associated with water lower trophic state. Species of oligotrophic waters have been reported to exhibit lower growth rates than species growing in eutrophic lakes (Moss, 1973a). This lower growth rate was viewed as a response to low influx of growth limiting nutrients such as nitrate or phosphate.

Of the three impoundments discussed in this study, Sheppard's Millpond may be classed as the most diverse. Its diversity index ($\bar{X} = 1.45$) was significantly higher than either Hardee or Carson Lakes (Table 2). Diversity values obtained for Sheppard's Millpond were similar to values previously reported for moderately complex systems (Margalef 1958), and were consistently higher than diversity values for either Hardee or Carson Lakes.

Diversity values for Hardee Lake ($\bar{X} = 1.07$) were similar to those observed for Carson Lake ($\bar{X} = 1.02$) with the lowest values occurring during the mid-summer months in both systems.

The primary difference in phytoplankton population dynamics among these lakes was the low diversity evident in Hardee and Carson Lakes compared to the high diversity of Sheppard's Millpond. This difference may be due in part to the faster growing rates of cyanophytes and their competitive advantage over non-nuisance algae for available nutrients.

A cyclic trend was observed in each of the impoundments studied in that stocks of potentially limiting nutrients accumulated during the winter as a result of low utilization by light-limited algae. These reserve nutrients, especially nitrate and phosphate, were soon exhausted by populations of algae undergoing naturally occurring spring

and summer peaks and was similar to observations reported by Hutchinson (1967).

As spring nutrient concentrations are reduced by algal uptake, cyanophytes possessing heterocysts are capable of fixing molecular nitrogen. Wetzel (1975) reported cyanophyte and heterocyst numbers reached their maximum when inorganic nitrogen approached zero. Blue-green algae possessing heterocysts were observed frequently throughout the summer in Hardee and Carson Lakes. Cyanophyte ability to fix nitrogen is a definite growth advantage when competing for limiting nutrients with algae that lack heterocysts. Furthermore, phosphate uptake kinetics favor cyanophytes. Shapiro (1973) found the half-saturation constants for phosphate uptake by blue-green algae was significantly lower than those for green algae over a wide range of environmental conditions. In this study with the nitrogen and phosphate requirements relatively assured, the cyanophytes out produced less competitive algae and thus led to the low diversity values observed in Hardee and Carson Lakes.

Cyanophytes generally are not abundant in acid brown-water impoundments such as Sheppard's Millpond. The assemblage here was a slower growing Cryptomonas-Trachelomonas assemblage in which neither genus attained numerical dominance. For this reason, the diversity of Sheppard's Millpond remained consistently higher than those for either Hardee or Carson Lakes.

Nutrient availability and phytoplankton densities appeared to influence species diversity in Hardee Lake and Sheppard's Millpond. This might be deduced from significant negative correlations between

species diversity and total phosphorus concentrations and species diversity and phytoplankton numbers (Table 3). Apparently when nutrients, especially phosphorus, became more available, phytoplankton numbers increased and resulted in lowered diversity.

The principle of higher diversity reflecting lower trophic state was supported in this study by the pattern of relative distribution of individuals among representative species or the evenness index. There was a definite gradient of evenness among the lakes studied. In order of increasing evenness this sequence was: Hardee Lake (0.58), Carson Lake (0.67) and Sheppard's Millpond (0.78) respectively. Value approaching 1.0 are generally associated with lower trophic status (Weiss and Kuenzler, 1976). Species evenness decreased with increased phytoplankton biomass and was inversely correlated with phytoplankton numbers in all three impoundments (Table 3).

Phytoplankton Production

An expected pattern was observed in common for all three impoundments in that gross primary productivity exhibited a positive correlation with solar radiation, water temperature, pH, and percent oxygen saturation (Table 3). Such seasonal correlations were expected and have already been adequately described by Goldman and Wetzel (1963). The relationship between productivity and pH and productivity and oxygen saturation simply represent expected increases in daytime oxygen production and carbon dioxide uptake (hence higher pH) resulting from photosynthetic activity by a large algal biomass. Thus higher pH and increased daytime oxygen concentration are symptoms of potential eutrophication rather than causes of it (Wetzel, 1966).

Table 3. *Selected Correlations for Comparison of Lakes**

	Hardee Lake	Carson Lake	Sheppard's Millpond
Diversity vs. Total-P.	-.56		-.46
Diversity vs. Phytoplankton Nums.	-.50		-.36
Evenness vs. Phytoplankton Nums.	-.63	-.48	-.74
GPP vs. Solar Radiation	.47	.43	.53
GPP vs. Water Temp.	.51	.60	.46
GPP vs. pH	.52	.51	.49
GPP vs. O_2 Saturation	.49	.63	.41
Phytoplankton Nums. vs. Turbidity		-.50	
Phytoplankton Nums. vs. Total Sus. Mat.		-.53	
Ammonia-N. vs. Chlo. <u>a</u>			.81
Ammonia-N. vs. BOD			.49
Ortho-P. vs. BOD		.57	
Conductivity vs. Chlo. <u>a</u>	.86		
Conductivity vs. Phytoplankton Nums.	.48		

*Only partial correlations with levels of significance less than 05% are presented.

**All significant correlations all presented in Appendix B, Tables 1, 2, & 3.

Comparisons of the data on primary productivity obtained for the three impoundments in this study with similar data obtained for other lakes noted in the literature indicates that:

(1) Gross primary productivity values for the study impoundments were generally greater than values reported for Coastal Plain impoundments in South Carolina (Polisini, et al. 1970; and Tilly, 1973).

(2) Hardee Lake exhibited a mean gross daily productivity of 4.9 g O₂/m²/day or approximately 1500 mg C/m²/day assuming a photosynthetic quotient of 1.2 (Ryther 1956; Strickland, 1960). This rate of photosynthesis is higher than rates obtained on moderately polluted systems (Steeman Nielsen, 1955; Goldman and Wetzel, 1963) but is similar to those obtained in fertilized ponds (Hepher, 1962; Welch, 1968). Productivity values obtained for Hardee Lake during summer were often much higher (maximum of 11.2 g O₂/m²/day; 3500 mg C/m²/day). Wetzel (1966) found rates on the hypereutrophic Goose and Sylvan Lakes (Indiana) similar to the summer results reported here, which he considered maximal for North America.

(3) Daily mean gross productivity for Carson Lake was 2.0 g O₂/m²/day (600 mg C/m²/day) and was similar to values cited for oligotrophic lakes (800 mg C/m²/day) by Nygaard (1949). Mean daily production and trophic status were lower for Carson Lake than for Hardee Lake. This difference may have been due, at least in part, to a reduction of the euphotic zone by relatively high water turbidity which occurred in Carson Lake during the winter of 1974 as a result of dredging of sediments from along the lake edge. This turbidity must have imposed severe light limitation on the phytoplankton. Evidence in support of this explanation

was provided by the significant negative correlation found between phytoplankton density and turbidity and phytoplankton density and total suspended matter (Table 3). During mid-summer a dramatic decrease in turbidity occurred and was followed thereafter by a two-fold increase in primary production.

(4) Compared to productivity of other lakes of dystrophic nature having a forested drainage area and low phytoplankton density, the relatively high production, $2.1 \text{ g O}_2/\text{m}^2/\text{day}$ ($650 \text{ mg C}/\text{m}^2/\text{day}$), of Sheppard's Millpond is noteworthy. Nygaard (as cited by Wetzel, 1975) reported mean daily production of three dystrophic lakes in Denmark ranged from 80 to $250 \text{ mg C}/\text{m}^2/\text{day}$. Most dystrophic studies have been conducted in Europe or in latitudes farther north than the present study area (Nygaard, 1955; Wetzel, 1973). In this respect, the high rate of productivity in Sheppard's Millpond appears to be more similar to productivity rates cited by Shannon and Brezonik (1972) for acid brown-water lakes of north and central Florida. Other parameters measured in this study such as conductivity, total phosphorus and nitrogen, also indicate Sheppard's Millpond to be very similar to the acid colored lakes of the Florida region.

Nutrients

In the present study, no single nutrient correlated with any biological indicator of trophic status in all three impoundments (App. B, Tables 1, 2, and 3). Absence of significant correlations between nutrients and biological indicators of trophic status suggests that few environmental factors act independently to produce a direct effect on the observed trophic characteristics of each impoundment.

However nutrient concentrations of the respective impoundments does indicate differing degrees of influence on algal production.

Phosphorus and nitrogen concentrations observed in this investigation were high in comparison to concentrations reported for Piedmont, North Carolina (Weiss, 1970) and Coastal Plain impoundments in South Carolina (Polisini, et al., 1970; Tilly, 1973). The high total phosphorus concentrations observed were not necessarily indicative of cultural influence.

Nutrient concentrations in this study fluctuated erratically often with no apparent trend. Although a budget of water inflow and outflow was not measured, it must be recognized that rainfall events most likely, had considerable influence on fluctuating nutrient concentrations. Appendix F, Table 1 lists monthly rainfall for the Pitt County area.

Inorganic nitrogen was considerably higher in Hardee and Carson Lakes than in Sheppard's Millpond. The relatively lower inorganic nitrogen concentrations in Sheppard's Millpond probably resulted from the fact that this part of the watershed is wooded. This forested margin forms a buffer zone which may reduce agriculture runoff into the millpond. This explanation is substantiated by Gilliam and Lutz (1972) who reported nitrate nitrogen concentrations were significantly higher under cultivated and fertilized fields than in unfertilized wooded areas. Hardee and Carson Lakes lacked a wooded buffer zone and exhibited nitrate concentrations significantly higher than those found in Sheppard's Millpond (Table 2). Although nitrate concentrations in Sheppard's Millpond were reduced, inorganic nitrogen in the form of ammonia appeared to stimulate phytoplankton growth. This was evidenced by significant

positive correlations between ammonia nitrogen and chlorophyll a and ammonia nitrogen and BOD (Table 3).

Eutrophication of a body of water results from an increase in the quantity of limiting nutrients; most often nitrogen (N) and/or phosphorus (P). The most readily available forms of these nutrients for algal uptake are nitrate, ammonia, and orthophosphate. Algal growth is responsible for the removal of inorganic nitrogen and soluble orthophosphate from waters with a molar ratio of 16:1. When the algae die, settle, and decompose, inorganic nitrogen and orthophosphate are released again with a molar ratio of 16:1 (Stumm and Morgan, 1970). During periods of algal blooms when the rate of production of organic material is greater than the rate of destruction of organic material, the nitrate and phosphate levels may be reduced sufficiently to become limiting. The N:P ratio can rise above 35:1 under severe P limitation and can drop to very low levels when luxury uptake of P takes place. The atomic ratios of nitrogen and phosphorus were calculated for the three study impoundments to determine the demand for these elements by growing algae. Total nitrogen to total phosphorus ratios for all three impoundments (calculated from annual means) exceeded 30:1. The N:P ratio is well in excess of 16 and this elemental composition supports the notion of a phosphorus-limited population.

Some evidence of this study indicates that orthophosphate may be limiting and that increased orthophosphate concentrations in summer resulted in increased algal blooms.

Hammer (1964) reported that peak phytoplankton densities often lagged peak orthophosphate concentrations by as much as two weeks. In

addition the highest cyanophyte blooms developed in lakes with the highest orthophosphate concentrations.

Orthophosphate concentrations increased from trace levels (<0.001 mg/l) during winter in Hardee Lake to approximately 0.07 mg/l in late April and to over 0.11 mg/l in June (Fig. 22). This increase in orthophosphate was accompanied shortly thereafter by a dense Volvox aureus bloom in early May and a massive bloom of cyanophytes in June and July (Fig. 25 and 28).

Maximum orthophosphate concentrations in Carson Lake were observed in mid-January and mid-June. These orthophosphate concentrations preceded a moderate increase in phytoplankton density in late January and a cyanophyte bloom during June which was the second highest phytoplankton density observed in Carson Lake (Fig. 25 and 30).

In Sheppard's Millpond the maximum orthophosphate concentration was recorded during mid-September and was accompanied by the maximum observed phytoplankton density of the Millpond (Fig. 25 and 33).

It appeared that the greatest phytoplankton densities were recorded when orthophosphate concentrations were over 0.05 mg/l. This phytoplankton response appeared to be similar to laboratory results reported by Chu (1942). Chu found that the growth of planktonic algae representative of the divisions Chlorophyta, Cyanophyta, and Chrysophyta was hindered when the concentration of orthophosphate was less than 0.05 mg/l. The annual mean orthophosphate concentration was not significantly different among the three study impoundments. However, orthophosphate was considerably higher in Hardee Lake during spring and summer. It is possible that the summer cyanophytes were responding

to the increased levels of orthophosphate in a manner similar to that described by Hammer (1964) and Chu (1942) and thus resulted the significantly higher phytoplankton densities in Hardee Lake and the greater frequency of blue-green algal blooms. The stimulatory effect of orthophosphate on phytoplankton biomass in Hardee Lake was supported by significant positive correlations between orthophosphate and BOD (Table 3).

Several conclusions may be stated regarding the effect of nutrients on the study impoundments. Based on N:P ratios calculated for each impoundment it appeared they were phosphorus limited in that in relation to phosphorus, nitrogen was present in excess. It appeared that greater orthophosphate concentrations during the summer in Hardee Lake substantially influenced phytoplankton density and production. Eutrophication of this impoundment resulted from development of surrounding land for agriculture and urban use. The small surface area of the watershed, excessive application of agricultural fertilizers and septic tank seepage from nearby homes contributed to the high rate of productivity in Hardee Lake.

Carson Lake appeared to be less affected by cultural enrichment than Hardee Lake and was evidenced by significantly lower biomass and productivity rates. Factors which limited phytoplankton growth may include reduced light transparency, very low concentrations of orthophosphate and rates of input and regeneration of phosphorus from all sources. It appeared that agricultural influence had less effect on Carson Lake than the combined effect of agricultural and domestic influence had on Hardee Lake. However, if nutrient input were allowed

to increase as a result of urban development or excessive fertilizer application in the Carson watershed, then dense algal blooms and undesirable water quality similar to the conditions in Hardee Lake may be anticipated.

Sheppard's Millpond exhibited the least cultural enrichment of the three study impoundments. Lower trophic state in Sheppard's Millpond may have resulted from reduced availability of nutrient forms present in the waters rich in organic matter. Wetzel (1975) reported that in dystrophic or brown stained waters much of the phosphorus present may be complexed with dead particulate organic matter or organic colloids and thus not readily available to support algal growth. In addition, ammonium oxidation by nitrifying bacteria is inhibited severely by acidic waters and dissolved organic compounds, especially tannins. Reduced availability of nutrients for photosynthetic algal assimilation together with growth constraints resulting from the acidic, brown stained water inhibited biological productivity. Cultural stress from the watershed of Sheppard's Millpond was minimal because it had not experienced urban development, received minimal agricultural runoff and had a wooded buffer zone which may have effectively filtered out potential nutrients.

Trophic Status

Trophic evaluation between the general extremes of very oligotrophic and very eutrophic systems have been attempted many times. Weiss and Kuenzler (1976) proposed that trophic classification of North Carolina lake systems be based on total phosphorus, conductivity, and Secchi disc values.

Table 4 compares the three study impoundments with the trophic scale suggested by Weiss and Kuenzler. It is apparent that the ranking of the impoundments is not consistent and the independent scales are not directly equated. Trophic measurements such as these are simple to use but must be interpreted with caution. Normally, acidic conditions or highly colored waters characteristic of some Coastal Plain impoundments may inhibit growth of organisms which would otherwise have flourished at a particular nutrient concentration of phosphorus. In these instances the phosphorus scale appears to be inadequate to describe the quality of the acidic humic waters of Sheppard's Millpond. Trophic evaluation based on Secchi disc transparencies may also be non-conclusive. If turbidity is primarily the product of autochthonous, particulate organic matter, living or dead, one might expect a negative relationship between Secchi disc values and degree of eutrophication. However, if significant fractions of the turbidity is caused by allochthonous materials, as with dredging activity in Carson Lake, such a relationship would not be in evidence.

Based on specific conductivity Sheppard's Millpond would be classified as oligo-mesotrophic while Hardee and Carson Lakes would be considered mesotrophic. Conductivity was significantly different in all three impoundments with a gradient of increasing conductivity values in the sequence of Sheppard's Millpond, Carson Lake and finally Hardee Lake (Table 2). Conductivity was significantly correlated with chlorophyll a and phytoplankton numbers in Hardee Lake (Table 3). The greater content of ionized salts in Hardee Lake reflect greater nutrient availability for phytoplankton and may be the most useful of the three parameters in future trophic evaluation of Coastal Plain impoundments.

Table 4. Range of Trophic Classification Suggested for
North Carolina Lakes

Trophic State	Total P. mg/m ³	Secchi Depth Meters	Conductivity mhos/cm
Oligotrophic	< 10	> 3.0	< 19
Oligo-Mesotrophic	10-19	1.5-3.0	20-49 Sheppard's Millpond
Mesotrophic	20-39	1.0-1.5 Sheppard's Millpond	50-99 Hardee Carson
A Eutrophic	40-79	0.5-1.0	100-150
B Eutrophic	80-150 Sheppard's Millpond	0.1-0.5 Hardee Carson	150-199
Hypereutrophic	>150 Hardee Carson	< 0.1	>200

Modified from Weiss and Kuenzler (1976)

In situations when contradictory results in trophic classification are obtained, indices that are more direct measures of biological eutrophication of the individual impoundment should be emphasized.

Hardee Lake, Carson Lake, and Sheppard's Millpond differed in biological characteristics of phytoplankton density, species composition, diversity and production. Hardee Lake was significantly higher than Carson Lake and Sheppard's Millpond with respect to BOD, chlorophyll a, phytoplankton density, and production. These higher values apparently were indicative of more advanced eutrophication. In addition to greater absolute values of production and biomass in Hardee Lake, the clearly marked summer peak in production, predominance of blue-green algal blooms, low diversity, and generally higher nutrient levels provide further evidence of advanced eutrophy.

Carson Lake exhibited a lower degree of eutrophication than Hardee Lake. Although phytoplankton species composition and nutrient concentrations were indicative of cultural influence, the absence of dense summer algal blooms and low primary productivity rate was more typical of oligotrophic aquatic systems.

Sheppard's Millpond due to its dystrophic nature is not easily compared with Hardee or Carson Lake. However, in view of its phytoplankton composition, high diversity, and lower productivity, it appeared to be more characteristically oligotrophic.

SUMMARY AND CONCLUSIONS

The composition and density of cyanophytes in this study indicated a higher degree of cultural eutrophication in Hardee Lake than in Carson Lake. The presence of oligotrophic indicator phytoplankers in Sheppard's Millpond was indicative of little cultural influence from the surrounding watershed.

Low phytoplankton diversity observed in Hardee and Carson Lakes was explained as a function of fast growing cyanophytes which were more competitive for limiting nutrients than other algae which lacked heterocysts and were less efficient in phosphate uptake. This led to the numerical prominence of blue-green algae during summer and the low diversity values observed in Hardee and Carson Lakes. Numerical prominence was not attained by cyanophytes in Sheppard's Millpond and resulted in a more diverse system.

Compared with primary productivity values given in the literature on lakes of differing trophic status, production levels in Hardee Lake were typical of advanced eutrophy while Carson Lake productivity levels were more characteristic of oligotrophy. Primary productivity in Sheppard's Millpond was higher than values cited for dystrophic lakes of Europe and northern United States. This high productivity may be due in part to the warmer growing season, greater light intensity, and higher nutrient concentrations of the Coastal Plain which are more conducive to photosynthesis.

Phosphorus and nitrogen concentrations of the three study impoundments were high when compared to values reported for rural Coastal Plain

impoundments of South Carolina and Piedmont North Carolina. Based on nitrogen and phosphorus ratios it appeared that all three impoundments were phosphorus limited. Some evidence of this study indicated that increased orthophosphate concentrations resulted in increased algal biomass in each impoundment. Greater orthophosphate concentrations in Hardee Lake during spring and summer were accompanied by higher phytoplankton densities and the greater frequency of blue-green algal blooms. The contribution of nitrogen and phosphorus from fertilizer application and sewage inflow modified phytoplankton density and production in Hardee Lake.

Carson Lake appeared to be less affected by cultural enrichment than Hardee Lake as evidenced by the low phytoplankton biomass and productivity. Agricultural influence appeared to have less effect on Carson Lake than the combined effect of agricultural and domestic influence on Hardee Lake. If nutrient input were increased through urban development in the Carson watershed, then algal blooms and undesirable water quality similar to those of Hardee Lake may be anticipated.

Sheppard's Millpond was the least affected by nutrient enrichment. This may have resulted from reduced availability of phosphorus in particulate or colloidal complexes, inhibition of phytoplankton growth by the dark acidic water, and filtering out of potential nutrients (NO_3) by the vegetated buffer zone surrounding this impoundment.

Trophic evaluation using the suggested trophic scales of total phosphorus, conductivity and Secchi disc transparencies (Weiss and Kuenzler, 1976) may not be consistent or directly equated. The trophic

scales of total phosphorus and Secchi disc transparencies were considered inadequate when considering highly colored acidic waters or aquatic systems with significant fractions of allochthonous materials. It was suggested that specific conductivity may be a useful parameter in measuring trophic status of Coastal Plain impoundments. In situations when contradictory results in trophic classification are obtained, more direct measures of biological eutrophication should be emphasized. These include phytoplankton density, production and chlorophyll a concentrations.

In this study measures of nutrient concentrations, phytoplankton density, diversity, production and also phytoplankton composition indicated a higher degree of eutrophication in Hardee Lake than in Carson Lake. Sheppard's Millpond on the basis of its phytoplankton community, high diversity, and low productivity was more indicative of oligotrophy.

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APPENDIX A

TABLE

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1. List of phytoplankton species.....	92

Table 1. List of Phytoplankton Species

	Location		
	Hardee Lake	Carson Lake	Sheppard's Millpond
CHLOROPHYTA			
<u>Eudorina elegans</u> Ehr.	+		
<u>Eudorina</u> sp.	+		
<u>Gonium sociale</u> (Duj.) Warming			+
<u>Pandorina morum</u> Bory	+		+
<u>Sphaerocystis schroeteri</u> Chodat	+	+	+
<u>Volvox aureus</u> Ehr.	+		+
<u>Pediastrum duplex</u> Meyen	+		
<u>Ankistrodesmus acicularis</u> Corda		+	
<u>Ankistrodesmus convolutus</u> Corda	+		
<u>Ankistrodesmus falcatus</u> (Corda)	+	+	+
Ralfs			
<u>Cerasterias staurastroides</u>	+		
West & West			
<u>Closteriopsis longissima</u> Lemm.	+	+	+
<u>Closteriopsis longissima</u> var.		+	
tropica West & West			
<u>Kirchneriella obesa</u> var. <u>major</u>	+		
(Bernard) G. M. Smith			
<u>Tetraedron gracile</u> (Reinsch)	+		
Hansg.			
<u>Tetraedron muticum</u> (A. Braun)			+
Hansg.			
<u>Tetraedron</u> sp.	+		
<u>Crucigenia fenestrata</u> Schmidle	+		
<u>Crucigenia quadrata</u> Morren			+
<u>Crucigenia tetrapedia</u> (Kirch.)			+
W. & G. S. West			
<u>Scenedesmus dimorphus</u> (Turp.)	+		
Kutz.			
<u>Scenedesmus quadricauda</u> (Turp.)	+	+	
Breb.			
<u>Scenedesmus</u> sp.	+		
<u>Mougeotia caimani</u> Transeau			+
<u>Mougeotia</u> sp.	+	+	+
<u>Spirogyra</u> sp.	+	+	
<u>Closterium idiosporum</u> West &			+
G. S. West			
<u>Closterium didymotocum</u> Corda		+	
<u>Closterium</u> sp.	+	+	+
<u>Hyalotheca</u> sp.			+
<u>Staurastrum</u> sp.	+	+	+

Table 1. (Continued)

	Location		
	Hardee Lake	Carson Lake	Sheppard's Millpond
EUGLENOPHYTA			
<u>Euglena acus</u> Ehr.			+
<u>Euglena sanguinea</u> Ehr.			+
<u>Euglena spirogyra</u> Ehr.			+
<u>Euglena</u> sp.	+		+
<u>Lepocinclis fusiformis</u> (Carter) Lemm.	+	+	
<u>Lepocinclis</u> sp.			+
<u>Phacus brevicauda</u> (Klebs) Lemm.			+
<u>Phacus chloroplastes</u> Prescott		+	+
<u>Phacus longicauda</u> Ehr.	+		+
<u>Phacus orbicularis</u> Huebner			+
<u>Phacus suecicus</u> Lemm.			+
<u>Phacus</u> sp.	+	+	+
<u>Trachelomonas crebea</u> (Kellicott) Deflandre			+
<u>Trachelomonas hispida</u> (Perty) Stein		+	+
<u>Trachelomonas horrida</u> Palmer			+
<u>Trachelomonas intermedia</u> Dangeard			+
<u>Trachelomonas planktonica</u> var. oblongata Drez.			+
<u>Trachelomonas robusta</u> Swir.			+
<u>Trachelomonas rotunda</u> Swir.			+
<u>Trachelomonas superba</u> (Swir.) Deflandre		+	+
<u>Trachelomonas varians</u> (Lemm.) Deflandre			+
<u>Trachelomonas volvicina</u> Ehr.	+	+	+
<u>Trachelomonas woycicki</u> Koczwara var. <u>pusilla</u> Drez.			+
<u>Trachelomonas</u> sp. A.			+
<u>Trachelomonas</u> sp. B.			+
<u>Trachelomonas</u> sp. C.			+
<u>Trachelomonas</u> sp. D.			+
<u>Trachelomonas</u> sp. E.			+
<u>Trachelomonas</u> sp. F.	+	+	+

PYRRHOPHYTA

<u>Gymnodinium</u> sp.			+
<u>Ceratium hirundinella</u> (O. F. Muell) Dujardin	+	+	+

Table 1. (Continued)

	Location		
	Hardee Lake	Carson Lake	Sheppard's Millpond
CRYPTOPHYTA			
<u>Cryptomonas obovata</u> Skuja	+	+	+
<u>Cryptomonas tetrapyrenoidosa</u> Skuja	+		+
CHLOROMONADOPHYTA			
<u>Gonyostomum semen</u> Ehr. Diesing			+
CHRYSOPHYTA			
<u>Characiopsis difflugicola</u> Huber-Pestalozzi		+	
<u>Characiopsis gibba</u> Borzi		+	
<u>Tribonema</u> sp.			+
<u>Uroglenopsis americana</u> (Calkins) Lemm.			+
<u>Dinobryon sertularia</u> Ehr.	+		+
<u>Synura adamsii</u> G. M. Smith			+
<u>Synura uvella</u> Ehr.	+	+	+
<u>Cyclotella kutziana</u> (Thw.) Chauvin	+	+	+
<u>Melosira granulata</u> var. <u>angustissima</u> O. Muller			+
<u>Tabellaria fenestrata</u> (Lyng.) Kutz.			+
<u>Tabellaria</u> sp.			+
<u>Fragilaria</u> sp.	+		+
<u>Synedra</u> sp.		+	+
<u>Eunotia</u> sp.			+
<u>Navicula</u> sp.	+	+	+
<u>Gomphonema constrictum</u> Ehr.			+
<u>Nitzschia acicularis</u> W. Smith	+	+	
<u>Nitzschia</u> sp.	+		+
CYANOPHYTA			
<u>Agmenellum quadriduplicatum</u> Breb.	+	+	
<u>Gomphosphaeria lacustris</u> Chodat	+	+	+
<u>Gomphosphaeria wichurae</u> Drouet and Daily	+		
<u>Anacystis cyanea</u> (Kutz.) Drouet and Daily	+	+	+
<u>Oscillatoria</u> sp.			+
<u>Schizothrix calicola</u> (Ag.) Gom.	+		
<u>Spirulina major</u> Kutz.			+

Table 1. (Continued)

	Location		
	Hardee Lake	Carson Lake	Sheppard's Millpond
CYANOPHYTA			
<u>Anabaena circinalis</u> Rab.	+	+	+
<u>Anabaena</u> sp.	+	+	+
<u>Stigonema</u> sp.			+
<u>Scytonema</u> sp.			+
<u>Calothrix parietina</u> (Nag) Thur.	+	+	+

APPENDIX B

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Table 1. Correlations of parameters measured for Hardee Lake*

	Solar Radiation	Water Temp.	Transparency	Color	Turbidity	Tot. Sus. Mat.	Diss. Oxygen	% Saturation	pH	Total Alk.	Conductivity	Nitrite-N	Nitrate-N	Ammonia-N	Kjeldahl-N	Ortho-P	Total-P	GPP	Chlo.-a	BOD	Phytoplankton Nums.	Diversity	Evenness
Solar Radiation	.77							.36	.59			.39			.39			.47		.41			.35
Water Temp.								.61	.86			.65			.46			.51		.48			
Transparency				-.78	-.72	-.68											-.49					.43	.54
Color					.96	.85			-.58								.47						
Turbidity						.92			-.54														
Tot. Sus. Mat.											.49												-.37
Diss. Oxygen								.82			-.45												
% Saturation									.73									.49		.38			
pH												-.64			.47			.52		.55			
Total Alk.													-.57										
Conductivity																			.86		.48		
Nitrite-N													.58					.53		-.54			
Nitrate-N																							
Ammonia-N																							
Kjeldahl-N																			.55				
Ortho-P																				.57			
Total-P																						-.56	-.43
GPP																				.54			
Chlo.-a																				.50			
BOD																							
Phytoplankton Nums.																						-.50	-.63
Diversity																							.62
Evenness																							

*Only partial correlations with levels of significance less than 05% are presented.

Table 2. Correlations of parameters measured for Carson Lake*

	Solar Radiation	Water Temp.	Transparency	Color	Turbidity	Tot. Sus. Mat.	Diss. Oxygen	% Saturation	pH	Total Alk.	Conductivity	Nitrite-N	Nitrate-N	Ammonia-N	Kjeldahl-N	Ortho-P	Total-P	GPP	Chlo.-a	BOD	Phytoplankton Nums.	Diversity	Evenness
Solar Radiation	.80	.38				.44	.34	.41					-.38	-.44				.43					
Water Temp.		.75	-.75	-.76	-.55	-.28	.55	.65	.49			-.40	-.52		.40		-.39	.60				.38	
Transparency			.94	-.83	-.71			.63	.61			-.60	-.48		.51	.46						.46	
Color				.88	.70			.56	.62			.68	.62									.53	
Turbidity					.73			.55	.57													.50	
Tot. Sus. Mat.						.43				.59				.42									
Diss. Oxygen							.63										.75						
% Saturation								.52									.39	.63				.56	
pH													-.47		.37		.51					.36	
Total Alk.																	.51					.52	
Conductivity																	.47	.66					
Nitrite-N														.59						.48			
Nitrate-N																							
Ammonia-N																							
Kjeldahl-N																.39							
Ortho-P																	.57	.49					
Total-P																							
GPP																							
Chlo.-a																							
BOD																							
Phytoplankton Nums.																							
Diversity																							.66
Evenness																							

*Only partial correlations with levels of significance less than 05% are presented.

Table 3. Correlation of parameters measured for Sheppard's Millpond*

	Solar Radiation	Water Temp.	Transparency	Color	Turbidity	Tot. Sus. Mat.	Diss. Oxygen	% Saturation	pH	Total Alk.	Conductivity	Nitrite-N	Nitrate-N	Ammonia-N	Kjeldhal-N	Ortho-P	Total-P	GPP	Chlo.-a	BOD	Phytoplankton Nums.	Diversity	Evenness
Solar Radiation	.80			-.48														.53				.43	
Water Temp.							-.41								.37			.46			.38		
Transparency				-.70	-.61	-.54	.52	.37			.66											.46	.46
Color					.84				-.57		-.49							-.48				-.47	
Turbidity									-.67									-.50					
Tot. Sus. Mat.																					.76	-.42	-.64
Diss. Oxygen								.88					.44										
% Saturation																		.41					
pH													-.48				.62	.49					
Total Alk.																						.70	
Conductivity																							
Nitrite-N																	.76	.48				-.39	
Nitrate-N																							
Ammonia-N																			.81	.49			
Kjeldhal-N																					.38		
Ortho-P																							
Total-P																						-.46	
GPP																							
Chlo.-a																				.53			
BOD																							
Phytoplankton Nums.																						-.36	-.74
Diversity																							.65
Evenness																							

*Only partial correlations with levels of significance less than 05% are presented.

APPENDIX C

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Table 1. Seasonal variations in water temperatures
of Hardee Lake (C)

Date	Surface	Mid-Depth	Bottom
10-24-73	19.5	----	16.5
10-25-73	18.0	----	----
10-27-73	23.0	----	----
10-28-73	19.0	----	----
11- 8-73	15.0	----	12.0
11-19-73	12.0	----	12.5
11-20-73	13.5	----	----
12- 2-73	14.0	11.0	11.0
12-10-73	10.5	9.5	9.5
12-11-73	8.5	----	----
12-18-73	5.5	----	----
1 -12-74	13.5	----	----
1 -13-74	10.0	10.5	10.5
1 -27-74	14.0	----	----
1 -28-74	15.5	14.5	13.0
2 -14-74	9.0	9.0	7.0
2 -21-74	12.0	10.0	10.0
3 -17-74	11.0	11.0	10.5
3 -30-74	12.5	12.0	13.0
3 -31-74	13.5	----	----
4 -17-74	18.5	18.5	18.5
4 -18-74	19.0	----	----
4 -29-74	20.5	18.0	16.0
4 -30-74	22.0	----	----
5 -13-74	17.5	17.0	16.5
5 -14-74	22.0	----	----
5 -30-74	22.0	22.0	20.5
5 -31-74	22.5	----	----
6 -16-74	26.0	25.0	24.5
6 -17-74	26.5	24.5	24.0
6 -29-74	23.5	23.0	22.0
6 -30-74	25.0	23.0	23.0
7 -15-74	27.0	26.0	25.5
7 -30-74	28.0	26.0	25.5
7 -31-74	28.5	----	----
8 -15-74	26.5	25.5	24.5
8 -25-74	26.0	24.5	24.0
8 -26-74	26.0	25.5	24.5
9 -15-74	28.0	25.5	25.5
9 -16-74	27.5	----	----
9 -29-74	23.5	21.0	20.5
10-15-74	22.0	20.0	19.0
10-16-74	22.5	----	----
	$\bar{x}$ 19.1	$\bar{x}$ 18.6	$\bar{x}$ 17.8
	R 5.5-28.5	R 9.0-26.0	R 7.0-25.5
	sd 6.4	sd 6.3	sd 6.1

Table 2. Seasonal variations in Secchi disc transparency (dcm) total suspended matter (mg/l) turbidity (JTU) and water color (Pt-Co) of Hardee Lake

Date	Transparency	Total Suspended Matter	Turbidity	Water Color
10-24-73	5.0	----	----	----
10-27-73	---	61.4	----	----
11- 8-73	4.2	----	----	----
11-19-73	4.3	41.6	----	----
12- 2-73	2.8	44.1	----	----
12-10-73	2.5	45.5	----	----
1-13-74	3.0	51.8	78	220
1-28-74	5.7	15.4	----	----
2-14-74	6.2	8.7	----	----
2-21-74	5.2	12.6	----	----
3-17-74	3.1	23.0	----	----
3-30-74	1.3	144.2	250	500
4-17-74	2.0	40.4	135	390
4-30-74	6.4	13.0	28	90
5-13-74	7.9	21.3	48	120
5-30-74	6.3	16.0	15	90
6-16-74	2.4	45.3	70	200
6-29-74	4.9	33.2	82	240
7-15-74	3.0	40.5	80	205
7-30-74	3.9	33.0	88	244
8-15-74	5.3	----	45	105
8-25-74	3.3	44.9	90	200
9-15-74	3.4	31.1	50	180
9-29-74	3.7	31.9	105	220
10-15-74	5.0	15.5	45	130
	$\bar{x}$ 4.2	$\bar{x}$ 37.0	$\bar{x}$ 81	$\bar{x}$ 208
	R 1.3-7.9	R 8.7-144.2	R 15-250	R 90-500
	sd 1.6	sd 28	sd 56	sd 111

Table 3. Seasonal variations in dissolved oxygen of Hardee Lake (mg/l)

Date	Surface	Mid-Depth	Bottom
10-24-73	7.3	----	7.5
10-25-73	11.1	----	----
10-27-73	11.1	----	----
10-28-73	10.7	----	----
11- 8-73	12.0	----	8.7
11-19-73	11.8	----	7.9
11-20-73	12.8	----	----
12- 2-73	11.2	10.3	9.3
12-10-73	13.0	10.0	9.5
12-11-73	11.0	----	----
12-18-73	14.7	----	----
1- 2-74	12.0	----	----
1-13-74	11.3	7.7	6.5
1-27-74	5.4	----	----
1-28-74	7.9	7.4	5.7
2-14-74	10.5	10.5	9.6
2-21-74	11.0	12.4	11.7
3-17-74	9.7	8.8	5.4
3-30-74	10.4	9.9	6.4
3-31-74	9.6	----	----
4-17-74	11.0	10.2	9.5
4-18-74	10.0	----	----
4-29-74	12.9	10.7	5.6
4-30-74	14.5	----	----
5-13-74	7.6	7.8	2.4
5-14-74	9.2	----	----
5-30-74	9.8	8.6	2.6
5-31-74	10.3	----	----
6-16-74	12.9	10.8	0.5
6-17-74	12.9	1.1	0.5
6-29-74	10.9	9.5	1.5
6-30-74	13.9	5.6	0.6
7-15-74	8.4	3.6	0.5
7-30-74	11.0	3.8	0.4
7-31-74	12.0	----	----
8-15-74	13.8	9.2	1.8
8-25-74	7.6	10.9	1.7
8-26-74	7.9	2.6	0.7
9-15-74	12.2	14.0	0.7
9-16-74	14.1	----	----
9-29-74	13.2	9.0	8.2
10-15-74	11.1	6.0	2.6
10-16-74	10.8	----	----
	$\bar{x}$ 11.0 R 5.4-14.7 sd 2.1	$\bar{x}$ 8.3 R 1.1-14.0 sd 3.1	$\bar{x}$ 4.7 R 0.4-11.7 sd 3.7

Table 4. Seasonal variations in percent saturation
of oxygen of Hardee Lake (%)

Date	Surface	Mid-Depth	Bottom
10-24-73	79	----	76
10-25-73	116	----	----
10-27-73	129	----	----
10-28-73	115	----	----
11- 8-73	119	----	81
11-19-73	109	----	74
11-20-73	123	----	----
12- 2-73	109	94	85
12-10-73	116	87	81
12-11-73	94	----	----
12-18-73	116	----	----
1-12-74	115	----	----
1-13-74	100	69	58
1-27-74	52	----	----
1-28-74	79	73	54
2-14-74	91	91	79
2-21-74	100	110	106
3-17-74	84	80	48
3-30-74	97	92	61
3-31-74	92	----	----
4-17-74	116	107	100
4-18-74	108	----	----
4-29-74	143	104	57
4-30-74	167	----	----
5-13-74	79	80	22
5-14-74	106	----	----
5-30-74	113	99	29
5-31-74	118	----	----
6-16-74	159	130	06
6-17-74	161	13	06
6-29-74	128	110	17
6-30-74	167	65	07
7-15-74	105	44	06
7-30-74	141	47	05
7-31-74	154	----	----
8-15-74	173	112	22
8-25-74	96	82	20
8-26-74	98	32	08
9-15-74	156	171	09
9-16-74	178	----	----
9-29-74	155	101	99
10-15-74	128	66	28
10-16-74	124	----	----
	$\bar{x}$ 118 R 52-178 sd 29	$\bar{x}$ 85 R 13-171 sd 33	$\bar{x}$ 46 R 05-106 sd 34

Table 5. Seasonal variations in pH of Hardee Lake

Date	Surface	Bottom
10-24-73	7.3	6.7
10-27-73	7.4	---
10-28-73	7.1	---
11- 8-73	6.7	6.7
11-19-73	6.9	6.5
12- 2-73	7.2	6.8
12-10-73	7.0	6.7
12-18-73	6.6	---
1 -13-74	6.2	6.2
1 -28-74	6.0	6.0
2 -14-74	6.0	6.0
2 -21-74	6.0	5.9
3 -17-74	6.3	6.1
3 -30-74	5.8	5.9
3 -31-74	5.8	---
4 -17-74	6.1	5.6
4 -30-74	8.9	7.1
5 -13-74	6.4	5.8
5 -30-74	8.2	5.9
6 -16-74	9.4	7.1
6 -17-74	9.2	---
6 -29-74	8.8	7.2
7 -15-74	8.8	6.7
7 -30-74	8.7	6.0
8 -15-74	9.2	7.2
8 -25-74	9.0	7.0
8 -26-74	8.7	6.6
9 -15-74	9.2	6.7
9 -16-74	9.1	---
9 -29-74	9.4	7.4
10-15-74	9.3	6.3
	$\bar{x}$ 7.6	$\bar{x}$ 6.5
	R 5.8-9.4	R 5.6-7.4
	sd 1.3	sd 0.5

Table 6. Seasonal variations in total alkalinity of Hardee Lake
(as mg/1CaCO₃)

Date	
1-28-74	32.0
2-14-74	12.0
3-30-74	10.0
4-17-74	8.0
4-30-74	4.0
5-13-74	32.0
5-30-74	2.0
6-16-74	28.0
6-29-74	18.0
7-15-74	20.0
7-30-74	22.0
8-15-74	18.0
8-25-74	20.0
9-15-74	17.0
9-29-74	18.0
10-15-74	19.0
	$\bar{x}$ 17.5
	R 2.0-32.0
	sd 8.8

Table 6A. Seasonal variations in carbonate alkalinity of Hardee Lake (mg/l)

Date	Surface
6-16-74	10.0
6-29-74	10.0
7-15-74	10.0
7-30-74	8.0
8-15-74	10.0
8-25-74	10.0
9-15-74	10.0
9-29-74	12.0
10-15-75	10.0
	$\bar{x}$ 10.0
	R 8.0-10.0
	sd 1.0

Table 7. Seasonal variations in specific conductivity of Hardee Lake
($\mu\text{mho/cm}$)

Date	
10-28-73	95
12- 2-73	110
12-18-73	55
1-28-74	100
4-17-74	76
4-30-74	68
5-13-74	78
5-30-74	76
6-16-74	96
6-29-74	79
7-15-74	78
7-30-74	105
8-15-74	74
8-25-74	143
9-15-74	86
9-29-74	102
10-15-74	86
$\bar{x}$	81
R	55-143
sd	20

Table 8. Seasonal variations in Kjeldahl nitrogen of Hardee Lake (mg/l)

Date	Surface	Bottom
10-24-73	0.21	----
10-27-73	1.08	----
11-19-73	2.72	2.56
12- 2-73	3.80	----
12-10-73	1.40	----
12-18-73	1.08	----
1-13-74	2.28	2.12
1-28-74	1.56	----
2-14-74	0.20	----
2-21-74	1.48	0.48
3-17-74	0.52	1.44
3-30-74	3.16	----
4-17-74	1.88	4.00
4-30-74	8.00	----
5-13-74	3.60	0.64
6-16-74	0.76	0.64
6-29-74	0.56	0.40
7-15-74	6.00	5.20
7-30-74	4.00	4.00
8.15-74	4.80	5.60
8-25-74	10.00	5.20
9-15-74	4.60	4.90
9-29-74	8.00	6.80
10-15-74	0.00	0.00
	$\bar{x}$ 2.97	$\bar{x}$ 2.91
	R 0.00-10.0	R 0.00-6.80
	sd 2.77	sd 2.31

Table 9. Seasonal variations in ammonia
nitrogen of Hardee Lake (mg/l)

Date	Surface	Bottom
10-24-73	0.10	----
11-19-73	0.41	0.52
12- 2-73	0.58	1.00
12-10-73	0.53	----
12-18-73	0.07	----
1-13-74	0.10	0.06
1-28-74	0.32	----
2-14-74	0.14	----
2-21-74	0.14	0.13
3-17-74	0.06	0.02
3-30-74	0.10	----
4-17-74	0.01	0.01
4-30-74	0.04	----
5-13-74	0.01	0.02
5-30-74	0.24	----
6-16-74	0.02	0.02
6-29-74	0.02	0.16
7-15-74	0.03	0.23
7-30-74	2.30	0.18
8-15-74	0.01	0.86
8-25-74	0.01	0.51
9-15-74	0.01	1.75
9-29-74	0.01	0.22
10-15-74	0.00	0.00
	$\bar{x}$ 0.22	$\bar{x}$ 0.36
	R 0.00-2.30	R 0.00-1.75
	sd 0.47	sd 0.48

Table 10. Seasonal variations in nitrate
nitrogen of Hardee Lake (mg/l)

Date	Surface	Bottom
11-19-73	0.02	0.02
12- 2-73	0.18	0.14
12-10-73	0.33	0.31
1-13-74	1.54	1.32
1-28-74	1.00	----
2-14-74	1.92	----
3-17-74	1.24	1.50
3-30-74	0.30	----
4-17-74	1.40	1.35
4-30-74	4.64	----
5-13-74	0.32	0.34
6-16-74	0.05	0.01
6-29-74	0.03	0.03
7-15-74	0.20	0.16
7-30-74	0.00	0.00
8-15-74	0.32	0.52
8-25-74	0.05	0.39
9-15-74	0.16	0.44
9-29-74	0.00	0.04
10-15-74	0.04	0.04
	$\bar{x}$ 0.69	$\bar{x}$ 0.42
	R 0.00-4.64	R 0.00-1.50
	sd 1.10	sd 0.53

Table 11. Seasonal variations in nitrite
nitrogen of Hardee Lake (mg/l)

Date	Surface	Bottom
10-27-73	0.004	----
11-19-73	0.010	0.010
12- 2-73	0.033	0.022
12-10-73	0.013	0.011
1-13-74	0.020	0.015
1-28-74	0.015	----
2-14-74	0.017	----
2-21-74	0.018	0.010
3-17-74	0.020	0.010
3-30-74	0.025	----
4-17-74	0.020	0.015
4-30-74	0.030	----
5-13-74	0.022	0.029
5-30-74	0.011	----
6-16-74	0.000	0.000
6-29-74	0.005	0.005
7-15-74	0.004	0.008
7-30-74	0.000	0.000
8-15-74	0.011	0.003
8-25-74	0.000	0.013
9-15-74	0.005	0.009
9-29-74	0.000	0.005
10-15-74	0.004	0.004
	$\bar{x}$ 0.013	$\bar{x}$ 0.010
	R 0.000-0.033	R 0.000-0.029
	sd 0.010	sd 0.008

Table 12. Seasonal variations in total phosphorous of
Hardee Lake (mg/l)

Date	Surface	Bottom
10-27-73	0.13	-----
11-19-73	0.08	0.04
12- 2-73	0.44	0.42
12-10-73	0.22	0.20
12-18-73	0.18	-----
1-13-74	0.28	0.25
1-28-74	0.12	-----
2-14-74	0.14	-----
2-21-74	0.08	0.50
3-17-74	0.26	0.35
3-30-74	0.28	-----
4-17-74	0.30	0.92
4-30-74	0.15	-----
5-13-74	0.23	0.72
5-30-74	0.15	-----
6-16-74	0.27	0.29
6-29-74	0.15	0.17
7-15-74	0.17	0.17
7-30-74	0.01	0.04
8-15-74	0.13	0.23
8-25-74	0.23	0.13
9-15-74	0.15	0.18
9-29-74	0.15	0.25
10-15-74	0.05	0.12
	$\bar{x}$ 0.18	$\bar{x}$ 0.30
	R 0.01-0.44	R 0.04-0.92
	sd 0.09	sd 0.24

Table 13. Seasonal variations in orthophosphate of
Hardee Lake (mg/l)

Date	Surface	Bottom
10-27-73	0.008	----
11-19-73	0.030	0.025
12- 2-73	0.000	0.030
12-10-73	0.000	0.005
1-13-74	0.000	0.050
1-28-74	0.000	----
2-14-74	0.000	----
3-30-74	0.010	----
4-17-74	0.070	0.060
4-30-74	0.000	----
5-13-74	0.000	0.010
5-30-74	0.015	----
6-16-74	0.107	0.125
6-29-74	0.025	0.043
7-15-74	0.000	0.010
7-30-74	0.000	0.000
8-15-74	0.013	0.015
9-15-74	0.000	0.000
9-29-74	0.000	0.000
10-15-74	0.000	0.001
	$\bar{x}$ 0.014	$\bar{x}$ 0.028
	R 0.000-0.107	R 0.000-0.125
	sd 0.028	sd 0.035

Table 14. Seasonal variations in biological oxygen demand of Hardee Lake (mg O₂/l).

Date	Surface	Bottom
10-24-73	4.6	10.6
12-10-73	5.3	6.7
12-18-73	5.2	----
1-13-74	5.4	4.1
1-28-74	3.9	2.2
2-14-74	2.1	2.3
3-17-74	2.3	1.7
3-30-74	3.4	4.3
4-17-74	4.3	3.9
4-30-74	5.6	5.2
5-13-74	2.5	7.6
5-30-74	4.3	4.5
6-16-74	10.0	7.0
6-29-74	9.1	2.4
7-15-74	6.2	5.1
7-30-74	5.9	5.5
8-15-74	5.3	5.3
8.25-74	9.3	3.8
9-15-74	4.2	2.3
9.29-74	4.9	3.0
10-15-74	2.7	4.9
	x 5.1	x 4.5
	R 2.1-10.0	R 0.8-8.8
	sd 2.2	sd 2.2

Table 15. Seasonal variations in chlorophyll a
of Hardee Lake ($\mu\text{g/l}$)

Date	
4-30-74	51.2
5-13-74	60.4
5-30-74	85.2
6-16-74	165.7
6-29-74	207.0
7-15-74	134.0
7-30-74	232.0
8-15-74	240.0
8-25-74	1160.0
9-15-74	370.0
9-29-74	206.5
10-15-74	72.0
	$\bar{x}$ 234.2
	R 51.2 - 1160.0
	SD 293.6

Table 16. Seasonal variations in phytoplankton abundance of Hardee Lake

Date	Number of Species	Cells/ml	Diversity	Evenness
10-27-73	5	3,139	0.91	0.56
11- 8-73	10	5,905	1.79	0.78
11-19-73	5	1,532	1.12	0.69
12- 2-73	9	25,002	0.70	0.32
12-10-73	9	152,380	0.28	0.13
1-13-74	8	24,755	0.39	0.19
1-28-74	8	2,342	1.18	0.56
2-14-74	11	5,451	1.85	0.80
2-21-74	7	769	1.83	0.94
3-17-74	2	545	0.69	0.99
3-30-74	6	3,511	1.09	0.60
4-17-74	10	6,361	0.86	0.41
4-30-74	3	181 ¹	1.01	0.92
5-13-74	7	990 ¹	1.43	0.89
5-30-74	4	16,035	0.94	0.68
6-16-74	6	92,796	0.64	0.35
6-29-74	5	27,772	0.66	0.41
7-15-74	7	470,843	0.07	0.04
7-30-74	7	9,891	1.30	0.67
8-15-74	9	6,804	1.21	0.55
8-25-74	13	29,167	1.26	0.51
9-15-74	12	9,593	1.55	0.62
9-29-74	10	21,971	1.43	0.62
10-15-74	9	14,775	1.58	0.69
		$\bar{x}$ 38,856	$\bar{x}$ 1.07	$\bar{x}$ 0.58
		R 181-470,843	R 0.07-1.85	R 0.04-0.99
		sd 98,131	sd 0.48	sd 0.25

¹This value exclusive of dominant form, Volvox aureus, fragmented in centrifugation process.

Table 17. Seasonal variations in gross primary productivity of Hardee Lake (mg O₂/l)

Date	
10-27-73	4.4
11-19-73	3.3
12-10-73	2.9
1-13-74	6.1
2-14-74	5.0
2-21-74	0.6
3-17-74	0.6
4-17-74	2.3
4-30-74	8.9
5-13-74	1.3
5-30-74	6.9
6-16-74	5.6
6-29-74	11.2
7-15-74	7.3
7-30-74	7.9
8-15-74	7.5
8-25-74	4.3
9-15-74	6.6
9-29-74	2.7
10-15-74	1.6

$\bar{x}$ 4.9
 R 0.6 - 11.2
 sd 3.0

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Table 1. Seasonal variations in water temperatures of Carson Lake (C)

Date	Surface	Mid-depth	Bottom
10-24-73	18.0	----	18.0
10-25-73	18.5	----	----
10-27-73	22.0	----	----
10-28-73	19.0	----	----
11- 8-73	13.5	----	12.0
11-19-73	12.0	12.0	12.0
11-20-73	14.0	----	----
12- 2-73	12.0	10.0	9.0
12-10-73	11.5	10.5	9.5
12-11-73	8.5	----	----
12-18-73	4.0	4.0	4.0
1-12-74	13.0	----	----
1-13-74	10.0	10.0	10.0
1-27-74	13.5	----	----
1-28-74	15.0	14.5	14.5
2-14-74	9.0	6.5	7.5
2-21-74	10.0	10.0	10.0
3-17-74	11.5	11.0	10.5
3-30-74	12.5	12.0	12.5
3-31-74	14.0	----	----
4-17-74	21.5	19.0	17.5
4-18-74	20.0	----	----
4-29-74	21.5	16.5	16.0
4-30-74	22.5	----	----
5-13-74	18.5	16.5	16.0
5-14-74	22.0	----	----
5-30-74	22.5	21.5	18.5
5-31-74	23.0	----	----
6-16-74	28.0	22.5	18.5
6-17-74	26.5	22.5	18.5
6-29-74	24.0	22.5	18.0
6-30-74	26.0	22.5	18.0
7-15-74	29.5	26.5	20.0
7-30-74	30.0	27.5	20.5
7-31-74	30.0	----	----
8-15-74	30.5	25.5	21.5
8-29-74	30.0	29.5	25.0
8-30-74	30.0	29.0	24.0
9-15-74	29.5	27.0	24.0
9-16-74	27.5	----	----
9-29-74	25.0	24.5	20.0
10-15-74	23.0	20.0	19.0
10-16-74	25.5	----	----
	$\bar{x}$ 19.7	$\bar{x}$ 18.2	$\bar{x}$ 15.9
	R 4.0-30.5	R 6.5-29.5	R 4.0-25.0
	sd 7.4	sd 7.5	sd 5.4

Table 2. Seasonal variations in Secchi disc transparency (dcm) total suspended matter (mg/l) turbidity (JTU) and water color (Pt-Co) of Carson Lake

Date	Transparency	Total Suspended Matter	Turbidity	Water Color
10-24-73	5.1	----	---	---
10-27-73	---	68.8	---	---
11- 8-73	3.8	----	---	---
11-19-73	3.3	33.0	---	---
12- 2-73	2.3	40.1	---	---
12-10-73	1.1	119.8	---	---
12-18-73	1.4	----	---	---
1-13-74	1.8	30.9	160	420
1-28-74	2.3	45.5	---	---
2-14-74	2.1	43.9	---	---
2-21-74	1.9	36.2	---	---
3-17-74	2.4	30.5	---	---
3-30-74	0.2	111.4	275	500
4-17-74	1.8	42.6	170	500
4-29-74	2.2	30.3	168	500
5-13-74	2.2	34.8	345	475
5-30-74	1.7	43.9	175	500
6-16-74	3.0	22.3	85	310
6-29-74	3.8	14.1	75	220
7-15-74	5.8	10.9	40	140
7-30-74	6.2	13.6	37	100
8-15-74	9.2	----	25	65
8-29-74	7.2	9.3	15	95
9-15-74	7.4	12.9	32	80
9-29-74	8.4	8.7	20	90
10-15-74	6.0	10.1	60	135
	$\bar{x}$ 3.7	$\bar{x}$ 37.0	$\bar{x}$ 112	$\bar{x}$ 275
	R 0.2-9.2	R 8.7-119.8	R 15-345	R 65-500
	sd 2.5	sd 29.7	sd 100	sd 186

Table 3. Seasonal variations in dissolved oxygen of Carson Lake (mg/l)

Date	Surface	Mid-Depth	Bottom
10-24-73	7.9	----	8.5
10-25-73	5.4	----	----
10-27-73	11.2	----	----
10-28-73	10.3	----	----
11- 8-73	8.3	----	7.0
11-19-73	8.0	----	6.0
11-20-73	9.4	----	----
12- 2-73	10.9	7.2	7.3
12-10-73	11.3	9.0	8.3
12-11-73	11.5	----	----
12-18-73	11.7	10.3	4.7
1-12-74	9.4	----	----
1-13-74	10.0	9.8	7.5
1-27-74	8.4	----	----
1-28-74	10.0	9.1	7.9
2-14-74	11.3	12.0	12.0
2-21-74	10.4	10.1	8.8
3-17-74	9.6	6.0	2.5
3-30-74	10.8	10.4	8.6
3-31-74	10.6	----	----
4-17-74	11.3	9.6	4.8
4-18-74	11.0	----	----
4-29-74	11.1	7.9	8.2
4-30-74	12.1	----	----
5-13-74	9.5	7.8	2.1
4-14-74	8.6	----	----
4-30-74	7.5	6.7	1.6
5-31-74	7.2	----	----
6-16-74	9.5	2.0	0.2
6-16-74	9.9	2.6	0.0
6-29-74	6.8	4.3	0.3
6-30-74	7.5	3.7	0.3
7-15-74	6.8	4.9	0.8
7-30-74	9.1	1.8	0.3
7-31-74	9.8	----	----
8-15-74	10.2	1.0	0.3
8-29-74	11.7	10.9	2.0
8-30-74	8.0	7.6	1.2
9-15-74	9.0	1.7	0.9
9-16-74	9.7	----	----
9-29-74	9.9	9.9	5.4
10-15-74	9.5	5.1	4.8
10-16-74	8.9	----	----
	$\bar{x}$ 9.6	$\bar{x}$ 6.9	$\bar{x}$ 4.4
	R 5.4-12.1	R 1.0-12.0	R 0.0-12.0
	sd 1.6	sd 3.3	sd 3.6

Table 4. Seasonal variations in percent saturation of oxygen of Carson Lake (%)

Date	Surface	Mid-Depth	Bottom
10-24-73	82	---	88
10-25-73	57	---	---
10-27-73	129	---	---
10-28-73	111	---	---
11- 8-73	80	---	65
11-19-73	74	---	56
11-20-73	91	---	---
12- 2-73	101	64	63
12-10-73	99	80	72
12-11-73	98	---	---
12-18-73	89	79	36
1-12-74	90	---	---
1-13-74	88	87	66
1-27-74	81	---	---
1-28-74	99	89	77
2-14-74	97	98	98
2-21-74	92	89	78
3-17-74	88	55	22
3-30-74	101	96	80
3-31-74	103	---	---
4-17-74	128	103	50
4-18-74	121	---	---
4-29-74	126	81	83
4-30-74	139	---	---
5-13-74	100	80	21
5-14-74	99	---	---
5-30-74	86	76	17
5-31-74	84	---	---
6-16-74	122	23	02
6-17-74	124	30	00
6-29-74	81	50	03
6-30-74	93	43	03
7-15-74	89	61	09
7-30-74	120	23	03
7-31-74	129	---	---
8-15-74	136	12	03
8-29-74	154	143	24
8-30-74	105	99	14
9-15-74	118	21	11
9-16-74	122	---	---
9-29-74	119	119	59
10-15-74	110	56	52
10-16-74	109	---	---
	$\bar{x}$ 103	$\bar{x}$ 70	$\bar{x}$ 41
	R 57-154	R 12-143	R 00-98
	sd 20	sd 339	sd 32

Table 5. Seasonal variations in pH of Carson Lake

Date	Surface	Bottom
10-24-73	6.9	6.9
10-27-73	7.2	---
10-28-73	7.1	---
11- 8-73	6.4	6.4
11-19-73	6.3	6.2
12- 2-73	6.7	6.2
12-10-73	6.4	6.2
12-11-73	6.3	---
12-18-73	6.3	6.3
1-13-74	5.6	5.8
1-28-74	5.7	5.7
2-14-74	5.9	6.0
2-21-74	5.7	5.7
3-17-74	5.9	5.9
3-30-74	5.6	5.7
3-31-74	5.5	---
4-17-74	7.6	7.8
4-29-74	6.5	6.0
5-13-74	6.0	5.8
5-30-74	6.4	6.1
6-16-74	6.3	6.3
6-17-74	8.6	---
6-29-74	6.6	6.5
7-15-74	6.4	6.7
7-30-74	7.4	6.9
8-15-74	7.3	6.9
8-29-74	6.9	6.5
8-30-74	7.2	6.8
9-15-74	8.5	7.0
9-16-74	8.1	---
9-29-74	6.6	6.3
10-15-74	8.3	6.5
	$\bar{x}$ 6.7	$\bar{x}$ 6.4
	R 5.5-8.6	R 5.7-7.8
	sd 0.9	sd 0.5

Table 6 . Seasonal variations in total alkalinity of Carson Lake
(as mg/lCaCO₃)

Date	
1-28-74	12.0
2-14-74	4.0
3-30-74	6.0
4-17-74	4.0
4-22-74	14.0
5-13-74	8.0
5-30-74	10.0
6-16-74	4.0
6-29-74	14.0
7-15-74	16.0
7-30-74	12.0
8-15-74	10.0
8-29-74	14.0
9-15-74	14.0
9-29-74	16.0
10-15-74	14.0

$\bar{x}$ 10.8
R 4.0-16.0
sd 4.3

Table 7 . Seasonal variations in specific conductivity of Carson Lake ($\mu\text{mho}/\text{cm}$)

Date	
10-27-73	87
12- 2-74	80
1-28-74	50
4-17-74	63
4-29-74	58
5-13-74	63
5-30-74	60
6-16-74	69
6-29-74	75
7-15-74	96
7-30-74	95
8-15-74	40
8-29-74	66
9-15-74	54
9-29-74	70
10-15-74	59
$\bar{x}$	68
R	40-96
sd	16

Table 8 . Seasonal variations in Kjeldahl nitrogen
of Carson Lake (mg/l)

Date	Surface	Bottom
10-27-73	1.24	-----
11-19-73	1.44	1.24
12- 2-73	2.24	-----
12-10-73	1.08	-----
12-18-73	1.08	-----
1-13-74	1.08	1.16
1-28-74	1.24	-----
2-14-74	1.04	-----
2-21-74	1.20	1.56
3-17-74	2.00	1.60
3-30-74	1.60	-----
4-17-74	1.60	2.40
4-30-74	1.92	-----
5-13-74	0.48	0.32
6-16-74	0.36	0.36
6-29-74	0.32	0.40
7-15-74	3.20	3.20
7-30-74	2.40	2.80
8-15-74	4.00	2.20
8-29-74	1.50	2.80
9-15-74	4.50	3.50
9-29-74	1.60	1.20
10-15-74	0.00	0.00
	$\bar{x}$ 1.60	$\bar{x}$ 1.63
	R 0.00-4.50	R 0.00-3.50
	sd 1.12	sd 1.15

Table 9 . Seasonal variations in ammonia nitrogen
of Carson Lake (mg/l)

Date	Surface	Bottom
11-19-73	0.22	0.25
12- 2-73	0.57	0.23
12-10-73	0.19	----
12-18-73	0.19	----
1-13-74	0.08	0.10
1-28-74	0.06	----
2-14-74	0.06	----
2-21-74	0.07	0.09
3-17-74	0.02	0.02
3-30-74	0.01	----
4-17-74	0.01	0.01
4-30-74	0.01	----
5-13-74	0.02	0.03
5-30-74	0.28	----
6-16-74	0.01	0.14
6-29-74	0.06	0.94
7-15-74	0.03	1.00
7-30-74	0.04	1.00
8-15-74	0.01	0.35
8-29-74	0.08	0.19
9-15-74	0.01	0.49
9-29-74	0.01	0.15
10-15-74	0.00	0.00
	$\bar{x}$ 0.09	$\bar{x}$ 0.31
	R 0.00-0.57	R 0.00-1.00
	sd 0.15	sd 0.36

Table 10. Seasonal variations in nitrate
nitrogen of Carson Lake (mg/l)

Date	Surface	Bottom
11-19-73	0.01	0.01
12- 2-73	0.14	0.13
12-10-73	0.33	----
1-13-74	2.28	0.95
1-28-74	2.70	----
2-14-74	2.10	----
3-17-74	1.86	2.12
3-30-74	0.06	----
4-17-74	1.22	0.79
4-30-74	1.94	----
5-13-74	0.24	1.12
6-16-74	0.15	0.15
6-29-74	0.08	0.03
7-15-74	0.20	0.20
7-30-74	0.00	0.00
8-15-74	0.13	0.05
8-29-74	0.08	0.13
9-15-74	0.03	0.02
9-29-74	0.00	0.00
10-15-74	0.04	0.07
	$\bar{x}$ 0.68	$\bar{x}$ 0.39
	R 0.00-2.70	R 0.00-2.12
	sd 0.94	sd 0.61

Table 11. Seasonal variations in nitrite nitrogen of Carson Lake (mg/l)

Date	Surface	Bottom
10-27-73	0.000	-----
11-19-73	0.008	0.008
12- 2-73	0.018	0.018
12-10-73	0.008	-----
1-13-74	0.010	0.005
1-28-74	0.005	-----
2-14-74	0.005	-----
2-21-74	0.004	0.010
3-17-74	0.003	0.009
3-30-74	0.011	-----
4-17-74	0.008	0.008
4-30-74	0.010	-----
5-13-74	0.000	0.013
5-30-74	0.011	-----
6-16-74	0.010	0.011
6-29-74	0.009	0.010
7-15-74	0.004	0.006
7-30-74	0.000	0.000
8-15-74	0.003	0.002
8-29-74	0.003	0.007
9-15-74	0.000	0.000
9-29-74	0.000	0.000
10-15-74	0.005	0.007
	$\bar{x}$ 0.006	$\bar{x}$ 0.007
	R 0.000-0.018	R 0.000-0.018
	sd 0.005	sd 0.005

Table 12. Seasonal variations in total phosphorus of Carson Lake (mg/l)

Date	Surface	Bottom
10-24-73	0.11	----
10-27-73	0.09	----
11-19-73	0.10	0.03
12- 2-73	0.15	0.28
12-10-73	0.43	----
12-18-73	0.34	----
1-13-74	0.21	0.21
1-28-74	0.17	----
2-14-74	0.30	----
2-21-74	0.15	0.20
3-17-74	0.19	0.28
3-30-74	0.26	----
4-17-74	0.23	0.75
4-30-74	0.23	----
5-13-74	0.22	0.20
5-30-74	0.25	----
6-16-74	0.12	0.25
6-29-74	0.10	0.23
7-15-74	0.07	0.11
7-30-74	0.00	0.00
8-15-74	0.24	0.13
8-30-74	0.04	0.02
9-15-74	0.08	0.15
9-29-74	0.06	0.10
10-15-74	0.07	0.12
	$\bar{x}$ 0.17	$\bar{x}$ 0.19
	R 0.00-0.43	R 0.00-0.75
	sd 0.10	sd 0.17

Table 13. Seasonal variations in ortho. phosphate of
Carson Lake (mg/l)

Date	Surface	Bottom
10-27-73	0.005	-----
11-19-73	0.025	0.022
12- 2-73	0.000	0.000
12-10-73	0.000	-----
1-13-74	0.050	0.000
1-28-74	0.000	-----
2-14-74	0.000	-----
3-30-74	0.000	-----
4-17-74	0.010	0.040
4-30-74	0.000	-----
5-13-74	0.000	0.000
5-30-74	0.022	-----
6-16-74	0.040	0.026
6-29-74	0.042	0.184
7-15-74	0.000	0.000
7-30-74	0.000	0.000
9-15-74	0.000	0.000
9-29-74	0.000	0.000
10-15-74	0.000	0.000
	$\bar{x}$ 0.10	$\bar{x}$ 0.025
	R 0.000-0.050	R 0.000-0.184
	sd 0.017	sd 0.051

Table 14. Seasonal variations in biological oxygen demand of Carson Lake (mg O₂/l)

Date	Surface	Bottom
10-24-73	10.0	12.6
12-10-73	4.1	7.8
12-18-73	3.5	3.6
1-13-74	2.4	2.2
1-28-74	2.6	---
2-14-74	1.5	1.9
3-17-74	2.0	1.8
3-30-74	3.7	3.2
4-17-74	4.3	2.4
4-29-74	4.8	4.8
5-13-74	0.0	0.0
5-30-74	2.8	0.9
6-16-74	4.4	5.1
6-29-74	1.5	4.2
7-15-74	1.0	2.7
7-30-74	1.6	2.8
8-15-74	3.4	2.8
8-29-74	2.5	2.6
9-15-74	2.9	1.8
9-29-74	3.4	2.3
10-15-74	3.5	2.6
	$\bar{x}$ 3.1	$\bar{x}$ 3.4
	R 0.0-10.0	R 0.0-12.6
	sd 2.0	sd 2.7

Table 15. Seasonal variations in chlorophyll a
of Carson Lake ($\mu\text{g/l}$)

Date	
4-17-74	14.4
4-29-74	32.8
5-13-74	54.8
5-30-74	39.6
6-16-74	85.2
6-29-74	24.0
7-15-74	9.6
7-30-74	25.6
8-15-74	22.4
8-29-74	50.8
9-15-74	146.4
9-29-74	52.0
10-15-74	52.0
	$\bar{x}$ 46.8
	R 9.6-146.4
	sd 36.3

Table 16. Seasonal variations in phytoplankton abundance of Carson Lake

Date	Number of Species	Cells/ml	Diversity	Evenness
10-27-73	5	2,513	0.90	0.55
11- 8-73	2	2,457	0.13	0.18
11-19-73	4	176	1.28	0.92
12- 2-73	8	12,751	0.92	0.47
12-10-73	11	1,200	1.76	0.80
1-13-74	3	1,682	0.47	0.42
1-28-74	10	3,284	1.57	0.75
2-14-74	5	193	0.40	0.33
2-21-74	2	52	0.64	0.91
3-17-74	3	214	1.01	0.91
3-30-74	4	1,569	1.06	0.76
4-17-74	8	591	1.49	0.92
4-29-74	2	32	0.64	0.90
5-13-74	4	380	0.50	0.71
6-16-74	2	5,331	0.15	0.21
6-29-74	5	260	1.40	0.86
7-15-74	6	628	1.69	0.94
7-30-74	6	1,332	1.32	0.82
8-15-74	7	2,606	0.89	0.45
8-29-74	10	5,110	1.55	0.67
9-15-74	6	8,376	0.99	0.55
9-29-74	6	2,076	1.46	0.81
10-15-74	9	4,822	1.15	0.59
		$\bar{x}$ 2,506	$\bar{x}$ 1.02	$\bar{x}$ 0.67
		R 32-12,751	R 0.13-1.69	R 0.18-0.94
		sd 3089	sd 0.48	sd 0.24

Table 17. Seasonal variations in gross primary productivity of
Carson Lake ($\text{g O}_2/\text{m}^2/\text{day}$)

Date	
10-27-73	2.6
10-27-73	3.7
11-19-73	0.5
12-10-73	1.4
1-13-74	0.2
2-14-74	1.3
3-17-74	1.1
3-30-74	1.0
4-17-74	2.2
4-29-74	3.5
5-13-74	2.9
5-30-74	2.0
6-16-74	2.2
6-29-74	1.5
7-15-74	2.1
7-30-74	2.1
9-15-74	2.6
9-29-74	2.1
10-15-74	2.3
	$\bar{x}$ 2.0
	R 0.2-3.7
	sd 0.9

APPENDIX E

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Table 1. Seasonal variations in water temperatures of Sheppard's Millpond (c)

Date	Surface	Mid-Depth	Bottom
10-24-73	17.0	----	15.0
10-25-73	17.5	----	----
10-27-73	23.0	----	----
10-28-73	18.0	----	----
11- 8-73	12.0	----	----
11-19-73	12.5	----	10.5
12- 2-73	9.0	----	9.5
12-10-73	11.0	10.0	9.5
12-18-73	5.5	5.5	5.0
1-12-74	12.0	----	----
1-13-74	9.5	9.0	9.0
1-27-74	11.5	----	----
1-28-74	14.0	11.0	10.5
2-14-74	7.5	7.5	6.5
2-21-74	8.0	----	7.0
3-17-74	10.5	10.5	10.5
3-30-74	11.5	11.0	11.5
3-31-74	13.0	----	----
4-17-74	20.0	17.0	15.0
4-18-74	22.0	----	----
4-29-74	19.5	17.0	15.0
4-30-74	17.0	----	----
5-13-74	18.5	14.0	10.5
5-14-74	18.5	----	----
5-30-74	23.0	16.0	14.5
5-31-74	23.0	----	----
6-16-74	25.0	19.0	15.0
6-17-74	26.5	18.5	15.0
6-29-74	22.5	18.0	15.0
6-30-74	26.0	20.0	15.0
7-15-74	28.5	22.5	16.0
7-30-74	30.0	22.5	17.0
7-31-74	27.5	----	----
8-15-74	26.5	21.0	16.5
8-29-74	27.0	22.0	21.0
8-30-74	25.5	22.5	21.5
9-15-74	29.0	23.0	21.0
9-16-74	25.0	----	----
9-29-74	24.0	19.0	18.0
10-15-74	20.5	16.0	15.5
10-16-74	24.0	----	----
	$\bar{x}$ 18.8	$\bar{x}$ 16.2	$\bar{x}$ 13.6
	R 5.5-30.0	R 5.5-23.0	R 5.0-21.5
	sd 7.0	sd 5.4	sd 4.4

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Table 2 . Seasonal variations in Secchi disc transparency (dcm)
total suspended matter (mg/l) turbidity (JTU) and water
color (Pt-Co) of Sheppard's Millpond

Date	Transparency	Total Suspended Matter	Turbidity	Water Color
10-24-73	5.4	----	----	----
11-8-73	7.4	----	----	----
11-19-73	8.6	2.9	----	----
12-2-73	8.8	9.5	----	----
12-10-73	8.9	8.8	----	----
12-18-73	11.1	----	----	----
1-13-74	8.6	5.5	50	200
1-28-74	12.7	13.8	----	----
2-14-74	14.3	2.8	----	----
2-21-74	10.8	4.7	----	----
3-17-74	14.3	4.4	----	----
3-30-74	7.9	6.7	50	160
4-17-74	3.5	14.7	95	305
4-29-74	8.4	11.1	43	180
5-13-74	9.0	13.3	40	150
5-30-74	6.9	9.8	28	140
6-16-74	10.2	7.5	10	100
6-29-74	9.9	3.7	15	120
7-15-74	11.9	3.3	35	140
7-30-74	9.9	5.9	53	120
8-15-74	8.6	----	45	160
8-29-74	----	3.6	37	210
9-15-74	5.8	27.0	50	200
9-29-74	9.7	9.2	65	225
10-15-74	8.6	5.9	45	210
$\bar{x}$ 9.2	$\bar{x}$ 8.0	$\bar{x}$ 44	$\bar{x}$ 175	
R 3.5 - 14.3	R 2.8 - 27.0	R 10 - 95	R 100 - 305	
sd 2.6	sd 6.0	sd 20	sd 52	

Table 3. Seasonal variations in dissolved oxygen of Sheppard's Millpond (mg/l)

Date	Surface	Mid-Depth	Bottom
10-24-73	3.8	----	0.6
10-25-73	3.9	----	----
10-27-73	6.8	----	----
10-28-73	5.6	----	----
11- 8-73	5.3	----	----
11-19-73	6.1	----	1.3
12- 2-73	5.5	----	2.3
12-10-73	7.5	6.0	5.0
12-18-73	8.0	7.7	7.3
1-12-74	6.8	----	----
1-13-74	5.8	3.0	2.5
1-27-74	6.2	----	----
1-28-74	8.1	1.9	1.4
2-14-74	10.3	7.6	6.1
2-21-74	10.0	----	7.5
3-17-74	9.0	8.1	7.7
3-30-74	7.0	7.2	0.7
3-31-74	6.8	----	----
4-17-74	4.3	1.0	0.9
4-18-74	5.5	----	----
4-29-74	9.4	7.9	1.4
4-30-74	13.2	----	----
5-13-74	10.3	3.4	1.6
5-14-74	6.5	----	----
5-30-74	5.8	0.3	0.2
5-31-74	5.5	----	----
6-16-74	7.6	0.2	0.3
6-17-74	7.9	0.2	0.3
6-29-74	3.6	0.1	0.1
6-30-74	4.8	0.3	0.4
7-15-74	4.1	0.2	0.2
7-30-74	4.5	0.0	0.0
7-31-74	4.8	----	----
8-15-74	8.7	0.0	0.5
8-29-74	4.8	1.7	1.5
8-30-74	4.9	1.0	0.9
9-15-74	4.5	0.9	1.0
9-16-74	6.1	----	----
9-29-74	5.6	1.3	1.5
10-15-74	5.1	2.2	2.2
10-16-74	5.6	----	----
	$\bar{x}$ 6.5	$\bar{x}$ 2.8	$\bar{x}$ 2.1
	R 3.6-13.2	R 0.0-8.1	R 0.0-7.7
	sd 2.1	sd 3.0	sd 2.4

Table 4. Seasonal variations in percent saturation of oxygen of Sheppard's Millpond (%)

Date	Surface	Mid-Depth	Bottom
10-24-73	39	---	06
10-25-73	40	---	--
10-27-73	79	---	--
10-28-73	58	---	--
11-8-73	49	---	--
11-19-73	57	---	12
12-2-73	47	---	20
12-10-73	68	53	43
12-18-73	63	61	57
1-12-74	63	---	--
1-13-74	50	26	22
1-27-74	55	---	--
1-28-74	79	17	13
2-14-74	86	63	50
2-21-74	83	---	62
3-17-74	80	72	69
3-30-74	64	66	06
3-31-74	65	---	--
4-17-74	47	06	05
4-18-74	63	---	--
4-29-74	102	44	14
4-30-74	136	---	--
5-13-74	105	33	14
5-14-74	68	---	--
5-30-74	67	03	02
5-31-74	64	---	--
6-16-74	91	02	03
6-17-74	99	02	03
6-29-74	41	01	01
6-30-74	59	03	04
7-15-74	53	02	02
7-30-74	59	00	00
7-31-74	61	---	--
8-15-74	109	00	05
8-29-74	60	10	09
8-30-74	60	11	10
9-15-74	58	10	11
9-16-74	74	---	--
9-29-74	67	14	16
10-15-74	57	22	22
10-16-74	67	---	--
	$\bar{x}$ 68	$\bar{x}$ 23	$\bar{x}$ 18
	R 39 - 136	R 00 - 72	R 00 - 69
	sd 20	sd 24	sd 20

Table 5. Seasonal variations in pH of Sheppard's Millpond

Date	Surface	Bottom
10-24-73	5.6	5.6
10-27-73	6.2	---
10-28-73	6.1	---
11-8-73	6.0	---
11-19-73	5.3	4.9
12-2-73	6.2	6.1
12-10-73	6.1	6.0
12-18-73	6.0	5.6
1-13-74	5.4	5.2
1-28-74	5.5	5.6
2-14-74	5.0	5.2
2-21-74	5.1	5.3
3-17-74	5.6	5.7
3-30-74	5.3	5.4
3-31-74	5.4	---
4-17-74	5.0	5.0
4-29-74	5.8	5.9
5-13-74	5.5	5.5
5-30-74	5.7	5.8
6-16-74	5.8	5.6
6-17-74	5.8	---
6-29-74	5.9	5.9
7-15-74	5.7	5.7
7-30-74	5.6	6.0
8-15-74	6.0	6.2
8-29-74	5.7	5.8
8-30-74	6.9	6.3
9-15-74	5.6	5.8
9-16-74	5.9	---
9-29-74	5.8	5.6
10-15-74	5.6	5.5
	$\bar{x}$ 5.7	$\bar{x}$ 5.6
	R 5.0 - 6.9	R 4.9 - 6.3
	sd .4	sd .4

Table 6. Seasonal variations in total alkalinity of Sheppard's Mill-pond (as mg/lCaCO₃)

Date

1-27-74	12.0
2-14-74	2.0
3-30-74	6.0
4-17-74	6.0
4-30-74	8.0
5-13-74	16.0
5-30-74	6.0
6-16-74	8.0
6-29-74	10.0
7-15-74	10.0
7-30-74	10.0
8-15-74	6.0
8-29-74	4.0
9-15-74	4.0
9-29-74	8.0
10-16-74	8.0

$\bar{x}$ 7.8
R 2.0 - 16.0
sd 3.4

Table 7. Seasonal variations in specific conductivity of Sheppard's Millpond ($\mu\text{mho/cm}$)

Date	
10-27-73	60
12-2-73	65
1-27-74	60
4-17-74	30
4-30-74	35
5-13-74	35
5-30-74	38
6-16-74	44
6-29-74	45
7-15-74	66
7-31-74	71
8-15-74	35
8-29-74	43
9-15-74	35
9-29-74	44
10-15-74	41
$\bar{x}$	46
R	30 - 71
sd	13

Table 8. Seasonal variations in Kjeldahl nitrogen of Sheppard's Millpond (mg/l)

Date	Surface	Bottom
10-27-73	0.88	----
11-19-73	2.40	3.48
12-2-73	0.80	----
12-10-73	0.20	----
12-18-73	0.60	----
1-13-74	2.40	2.80
1-28-74	0.92	----
2-14-74	0.60	----
2-21-74	1.00	1.36
3-17-74	0.60	1.64
3-30-74	0.96	----
4-17-74	1.20	2.52
4-30-74	4.40	----
5-13-74	2.40	0.48
6-16-74	0.36	0.32
6-29-74	0.28	0.36
7-15-74	2.80	2.80
7-30-74	2.40	3.60
8-15-74	2.40	4.00
8-25-74	1.70	3.20
9-15-74	2.90	4.90
9-29-74	1.60	1.20
10-15-74	0.00	0.00
	$\bar{x}$ 1.47	$\bar{x}$ 2.18
	R 0.00 - 4.40	R 0.00-4.90
	sd 1.11	sd 1.53

Table 9. Seasonal variations in ammonia
nitrogen of Sheppard's Millpond (mg/l)

Date	Surface	Bottom
11-19-73	0.01	0.01
12-2-73	0.05	0.08
12-10-73	0.02	----
1-13-74	0.04	0.04
1-28-74	0.01	----
2-14-74	0.01	----
2-21-74	0.05	0.03
3-17-74	0.02	0.01
3-30-74	0.01	----
4-17-74	0.01	0.01
4-30-74	0.01	----
5-13-74	0.04	0.03
5-30-74	0.28	----
6-16-74	0.02	0.01
6-29-74	0.02	0.01
7-15-74	0.07	0.06
7-30-74	0.05	0.04
8-15-74	0.01	0.13
8-25-74	0.09	0.19
9-15-74	0.02	1.24
9-29-74	0.23	0.21
10-15-74	0.00	0.00
	$\bar{x}$ 0.05	$\bar{x}$ 0.13
	R 0.00 - 0.28	R 0.00 - 1.24
	sd 0.071	sd 0.30

Table 10. Seasonal variations in nitrate nitrogen of
Sheppard's Millpond (mg/l)

Date	Surface	Bottom
11-19-73	0.00	0.01
12-2-73	0.02	0.03
12-10-73	0.03	----
1-13-74	0.50	0.60
1-28-74	0.14	----
2-14-74	0.54	----
3-17-74	0.20	0.22
3-30-74	0.12	----
4-17-74	0.24	0.41
4-30-74	0.40	----
5-13-74	0.30	0.16
6-16-74	0.26	0.56
6-29-74	0.05	0.10
7-15-74	0.26	0.26
7-30-74	0.00	0.46
8-15-74	0.07	0.45
8-29-74	0.18	0.29
9-15-74	0.16	0.23
9-29-74	0.07	0.14
10-15-74	0.11	0.11
	$\bar{x}$ 0.18	$\bar{x}$ 0.27
	R 0.00 - 0.54	R 0.10 - 0.60
	sd 0.16	sd 0.19

Table 11. Seasonal variations in nitrite nitrogen
of Sheppard's Millpond (mg/l)

Date	Surface	Bottom
10-27-73	0.005	-----
11-19-73	0.004	0.007
12-2-73	0.008	0.013
12-10-73	0.009	-----
12-18-73	0.010	-----
1-13-74	0.004	0.020
1-28-74	0.000	-----
2-14-74	0.005	-----
2-21-74	0.010	0.010
3-17-74	0.000	0.007
3-30-74	0.011	-----
4-17-74	0.011	0.020
4-30-74	0.010	-----
5-13-74	0.000	0.000
5-30-74	0.004	-----
6-16-74	0.026	0.000
6-29-74	0.005	0.017
7-15-74	0.006	0.002
7-30-74	0.000	0.004
8-15-74	0.002	0.049
8-29-74	0.008	0.036
9-15-74	0.005	0.012
9-29-74	0.005	0.020
10-15-74	0.007	0.010
	$\bar{x}$ 0.006	$\bar{x}$ 0.014
	R 0.000 - 0.026	R 0.000 - 0.049
	sd 0.005	sd 0.013

Table 12. Seasonal variations in total phosphorous of Sheppard's Millpond (mg/l)

Date	Surface	Bottom
10-24-73	0.07	0.00
10-27-73	0.19	----
11-19-73	0.06	0.03
12-2-73	0.42	0.43
12-10-73	0.26	----
12-18-73	0.33	----
1-13-74	0.08	0.30
1-28-74	0.08	----
2-14-74	0.08	----
2-21-74	0.05	0.36
3-17-74	0.09	0.19
3-30-74	0.06	----
4-17-74	0.14	0.18
4-29-74	0.10	----
5-13-74	0.02	0.17
5-30-74	0.10	----
6-16-74	0.32	0.07
6-29-74	0.08	0.30
7-15-74	0.07	0.07
7-30-74	0.00	0.10
8-15-74	0.23	0.31
8-29-74	0.07	0.03
9-15-74	0.16	0.39
9-29-74	0.10	0.18
10-15-74	0.05	0.08
	$\bar{x}$ 0.13	$\bar{x}$ 0.20
	R 0.00 - 0.42	R 0.03 - 0.43
	sd 0.11	sd 0.13

Table 13. Seasonal variations in orthophosphate of Sheppard's Millpond (mg/l)

Date	Surface	Bottom
10-27-73	0.010	-----
11-19-73	0.028	0.030
12-2-73	0.000	0.000
12-10-73	0.020	-----
1-13-74	0.050	0.000
1-28-74	0.000	-----
2-14-74	0.000	-----
3-30-74	0.000	-----
4-17-74	0.020	0.030
4-29-74	0.000	-----
5-13-74	0.000	0.000
5-30-74	0.012	-----
6-29-74	0.025	-----
7-15-74	0.010	0.010
7-30-74	0.000	0.000
9-15-74	0.071	0.132
9-29-74	0.015	0.015
10-15-74	0.000	0.000
	$\bar{x}$ 0.014	$\bar{x}$ 0.022
	R 0.000 - 0.071	R 0.000 - 0.132
	sd 0.019	sd 0.041

Table 14. Seasonal variations in biological oxygen demand of Sheppard's Millpond (mg O₂/l)

Date	Surface	Bottom
10-24-73	4.4	---
12-10-73	4.1	5.4
12-18-73	2.2	5.1
1-13-74	3.0	4.6
1-28-74	4.4	4.0
2-14-74	1.6	2.1
3-17-74	1.3	1.3
3-30-74	2.9	2.6
4-17-74	3.4	3.3
4-29-74	5.4	6.2
5-13-74	2.0	0.6
5-30-74	5.2	3.6
6-16-74	4.6	6.1
6-29-74	1.2	6.4
7-15-74	1.6	4.1
7-30-74	2.2	3.2
8-15-74	3.4	4.4
8-29-74	2.6	4.3
9-15-74	2.0	4.4
9-29-74	6.6	2.5
10-15-74	3.8	2.7
	$\bar{x}$ 3.2	$\bar{x}$ 3.8
	R 1.2 - 6.6	R 0.6 - 6.4
	sd 1.5	sd 1.6

Table 15. Seasonal variations in chlorophyll a of Sheppard's Millpond ($\mu\text{g/l}$)

Date	
4-17-74	0.0
4-29-74	37.3
5-13-74	52.8
5-30-74	142.1
6-16-74	28.4
6-29-74	38.0
7-15-74	18.4
7-30-74	27.6
8-15-74	96.0
8-29-74	77.9
9-15-74	64.4
9-29-74	150.0
10-15-74	24.0
	$\bar{x}$ 58.2
	R 0.0 - 150.0
	sd 46.7

Table 16. Seasonal variations in phytoplankton abundance of Sheppard's Millpond

Date	Number of Species	Cells/ml	Diversity	Evenness
10-27-73	6	1,169	1.67	0.93
11-8-73	6	1,536	1.54	0.86
11-19-73	4	580	1.19	0.86
12-2-73	6	1,408	0.92	0.56
12-10-73	6	785	0.88	0.53
1-13-74	7	1,009	1.33	0.73
1-28-74	10	1,015	1.51	0.94
2-14-74	5	147	1.46	0.90
2-21-74	7	943	1.35	0.68
3-17-74	12	1,526	1.73	0.78
3-30-74	4	218	1.26	0.90
4-17-74	4	475	0.95	0.68
4-29-74	9	2,645	1.27	0.65
5-13-74	15	1,759	2.39	0.90
6-16-74	4	392	1.33	0.96
6-29-74	12	2,349	2.05	0.82
7-15-74	10	1,639	1.94	0.88
7-30-74	10	2,700	1.74	0.75
8-15-74	11	2,423	1.64	0.68
8-29-74	4	240	1.33	0.96
9-15-74	12	15,728	0.53	0.21
9-29-74	8	981	1.91	0.91
10-15-74	12	1,130	1.45	0.81
$\bar{x}$ 1,861		$\bar{x}$ 1.45	$\bar{x}$ 0.78	
R 147 - 15,728		R 0.53 - 2.39	R 0.21 - 0.96	
sd 3,119		sd 0.42	sd 0.18	

Table 17. Seasonal variations in gross primary productivity of Sheppard's Millpond ($\text{g O}_2/\text{m}^2/\text{day}$)

Date	
10-24-73	1.1
10-27-73	4.2
11-19-73	0.1
12-10-73	0.2
1-13-74	1.5
2-14-74	0.8
3-17-74	0.5
3-30-74	1.1
4-17-74	0.5
5-13-74	2.8
5-30-74	4.7
6-16-74	3.2
6-29-74	2.0
7-15-74	1.3
7-30-74	3.4
8-15-74	5.2
8-29-74	4.7
9-29-74	0.9
10-15-74	1.0
$\bar{x}$ 2.1	
R 0.1 - 5.2	
sd 1.7	

APPENDIX F

TABLE

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Table 1. Meteorological record for Greenville, Pitt County, N.C.
(October 1973 - October 1974)

Month	Solar radiation (Ly/min) ¹	Rainfall ² (cm)
10	631.5	7.01
11	484.7	2.67
12	411.4	22.45
01	444.4	16.54
02	575.5	12.34
03	724.0	17.27
04	874.6	9.04
05	970.5	11.18
06	1011.8	5.82
07	993.5	14.96
08	916.0	44.96
09	786.5	20.98
10	631.5	0.00

¹Average monthly solar radiation values calculated using the table prepared by Professor Benjamin Y. H. Liu, University of Minnesota, assuming a solar constant of 2.00 langleys/minute.

²Rainfall data for Greenville compiled by Greenville Station of the National Oceanic and Atmospheric Administration National Weather Service.