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A Synoptic Study of the Limnology of Lake Thonotosassa, Florida Part I. Effects of Primary Treated Sewage and Citrus Wastes

by

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ABSTRACT

Limnological sampling of Lake Thonotosassa was initiated in 1970 to document current conditions following 15 years of artificial enrichment by organic wastes from primary treated sewage and citrus processing plants, and to provide base-level data for a long-term study of the rates of change following the installation of a secondary sewage treatment facility. Results from the first year of study indicated that the lake was in an advanced state of eutrophy. Inorganic nutrient levels were high; oxygen deficits occurred in the hypolimnion and at the mud-water interface; phytoplankton volumes were large and dominated by blue-green algae; primary productivity rates were comparable with those of grossly polluted lakes; small-bodied herbivores dominated the zooplankton; and benthic invertebrate populations were comprised of an overwhelming abundance of oligochaetes and chironomids. Construction of the new sewage treatment plant reduced the organic load and B.O.D. of the incoming waters and benthic diversity in the inlet subsequently increased. However, in the lake itself decreases in coliform bacteria concentrations were the only signs of immediate influence.

INTRODUCTION

Increasing numbers of Florida lakes are being subjected to human influence in the form of agricultural, industrial and domestic pollution. This cultural eutrophication threatens the recreational assets of the lakes and has stimulated research on a few lakes in the central peninsula (BREZONIK & SHANNON 1971; SHANNON & BREZONIK 1972). However, detailed limnological studies of Florida lakes are lacking, especially for small lakes in the west coast area.

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Lake Thonotosassa, a shallow west coast lake, has been subjected to organic pollutants in the form of untreated citrus processing wastes and primarily treated domestic sewage for more than 15 years. The lake has been known as one of the area's finest sport fishing and recreational sites, but in January 1969, massive oxygen depletion caused the death of an estimated 26.5 million fish; the largest fish kill in the United States during 1969 (STROUD 1971).

In January 1970, we initiated a sampling program in Lake Thonotosassa to collect extensive physical, chemical and biological data to: 1) document current limnological conditions, and 2) to provide base-level data for a longterm study of the rates of regression (change) following the installation of a secondary sewage treatment plant. This paper presents the results of our first year of study.

Description of study area

Lake Thonotosassa is located in northeast Hillsborough County, Florida, (T 28S, R 20E) and has a surface area of approximately 300 ha. It is 2.5 km long and 1.5 km wide at the broadest point, with a maximum depth of 4.9 m and a mean depth of 3.5 m.

Water supply to the lake is derived principally from runoff from surrounding citrus groves and from Baker Creek, an improved drainage canal originating in Dover, Florida (Fig. 1). Pemberton Creek, originating in Plant City, Florida, enters Baker Creek approximately 1.5 km southeast of the lake. The outlet from the lake, Flint Creek, is located in the northeast corner and drains into the Hillsborough River.

Sources of pollution

Prior to April 1970, one vegetable, five citrus processing plants and the Plant City sewage treatment plant, a 1.5 million gallon per day (MGD) trickling filter system, discharged their wastes directly into Pemberton Creek (Anon., 1969). During the dry winter months when citrus processing reached a peak, the flow of the creek was composed primarily of effluents from these plants. Citrus pulp and the smell of oranges were evident several kilometers downstream. By the time the effluent reached Lake Thonotosassa (11 km downstream) the organic materials were in an advanced state of decay and the creek was usually anaerobic.

In April 1970, a new extended aeration treatment plant opened in Plant City to serve the above industries and the municipality.

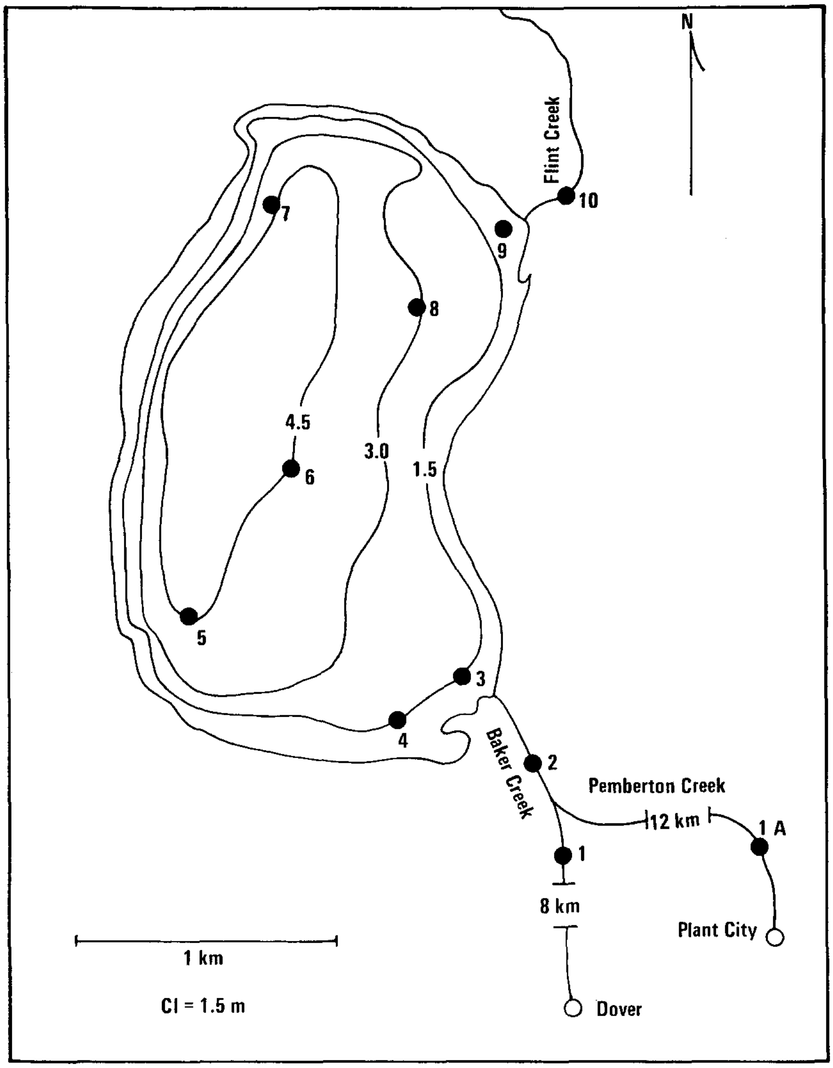

Fig. 1. Map of Lake Thonotosassa and vicinity, Hillsborough County, Florida showing location of sampling stations.

This plant with 5.5 MGD capacity utilizes activated sludge, aeration basins, clarifiers and 8 acres of polishing ponds to treat approximately 3.5 MGD of domestic and industrial sewage. The effluent is chlorinated and discharged into Pemberton Creek. The organic load of the effluent is high from November to May, tapering off as the citrus season ends.

Methods

Physical-Chemical Measurements

From January 1970 through January 1971 surface samples were collected weekly at each station shown in Fig. 1, and a vertical profile was taken at Station 6 in the middle of the lake. Stations were sampled at approximately the same time each week (0800—1100) to minimize the effects of hourly fluctuations. Two diurnal studies (collections made at 4 hour intervals) were made in the summer and fall. All water samples were collected with a PVC Van Dorn water sampler and were placed on ice for transport to the laboratory. The samples were analyzed within 10 hours of collection using procedures given in *Standard Methods for the Examination of Water and Wastewater* (A.P.H.A. 1965) unless otherwise noted.

Water temperature was recorded with a mercury thermometer or an electric thermistor. Transparency was measured with a Secchi disc and turbidity was determined with a Hellige turbidimeter. Total dissolved solids (TDS) were determined by weight upon evaporation, at 103°C, of samples filtered through Whatman No. 1 filter paper. Hydrogen-ion concentration was determined in the field with a portable pH meter and a portable colorimeter utilizing cresol red and bromcresol purple indicator solutions. A correction factor was determined for the latter to render comparable values.

Chemical analyses were made using standard wet chemistry methods and a Hach DR colorimeter. Dissolved oxygen concentration was determined using Alsterberg (azide) modification of the Winkler method. Biochemical oxygen demand (BOD) was measured with a dilution technique (A.P.H.A. 1965). Alkalinity was measured by titrating samples with 0.02N H_2SO_4 using phenolphthalein and methyl orange indicators (Welch 1948). Free carbon dioxide was measured by titration with 0.0454N Na_2CO_3. Nitrite-nitrogen was determined with the diazotization method and nitrate-nitrogen by subtraction following reduction with cadmium sulfate. Ammonia-nitrogen was measured using direct nesslerization. Ortophosphate analyses were conducted with the stannous chloride method. Polyphosphate was measured with the total phosphate method in which polyphosphate is converted to ortophosphate by heating in acid and concentrations are determined by subtraction. Sulfate was measured turbidimetrically.

Coliform Bacteria

Samples for coliform group determinations were collected bi-weekly and were maintained in the dark, at environmental temperatures, prior to analyses. The membrane filter technique was used and samples were incubated for 24 hours at 37°C on M-Endo medium.

Primary Production

Primary productivity measurements were made using the light and dark bottle method (Odum 1971). Water samples were collected with a PVC water bottle from surface, ½, 1, 2, and 3 m depths and three 250 ml bottles (one clear, one opaque, and one for initial oxygen determination) were filled from each sample. Light and dark bottles were suspended for 24 hrs at depths from which the samples were collected. Dissolved oxygen was determined with the Alsterberg (azide) modification of the Winkler method (A.P.H.A. 1965), and conversion of milligrams of oxygen per liter into milligrams of carbon was made using formulae of Strictland & Parsons (1968) and a PQ (photosynthetic quotient) of 1.25 (Ryther 1956).

Phytoplankton Abundance

Phytoplankton samples were collected bi-weekly from February, 1970, through January, 1971, at 6 stations in the lake (4—9). At each station a 150 ml bottle was filled with surface water and preserved with modified Lugol's solution (EDMONDSON 1959). A modification of the Utermohl sedimentation technique and an inverted microscope were used to count the samples (HUDSON & COWELL 1966). Phytoplankton were identified with keys by PRESCOTT (1951, 1970), SMITH (1951), and the Federal Water Pollution Control Administration (1966). Standing crops were recorded as volume per liter (i.e., μL/L).

Zooplankton Abundance

Zooplankton (excluding Protozoa) were collected bi-weekly at stations 4—9 with a 10 liter Juday trap fitted with No. 25 silk bolting cloth (64 μ). At the shallow stations (4 and 9) samples were collected at the surface and 1 m; other stations (5—8) were sampled at surface, 1, and 3 m depths. All samples were preserved with modified Lugol's solution.

In the laboratory samples were concentrated to contain a reasonable number of organism (usually 20 ml), and a 1 ml subsample was withdrawn and placed in a Sedgwick-Rafter cell. All the rotifers in 15 randomly selected fields were identified and counted under 50 X magnification. The contents of the cell were then returned to the sample and the procedure was repeated; 30 fields were used during periods of low rotifer density. The genera and common species of rotifers were identified with keys and descriptions given by EDMONDSON (1959b) and VOIGT (1957).

Densities of copepod nauplii were determined by counting all the organisms in two 1 ml subsamples of the original concentrate. To enumerate the larger copepods and cladocerans samples were concentrated to 5 ml, placed in a rotary counting chamber, and all organisms were identified and counted. Identifications were made using keys by BROOKS, WILSON and YEATMAN given in EDMONDSON (1959b).

Benthos

Benthic samples were taken bi-weekly at seven stations in Lake Thonotosassa (3—9) and four stations (1, 1A, 2 and 10) on creeks leading to and from the lake (Fig. 1). Samples were collected with an Ekman dredge (15.24 cm x 15.24 cm) with a surface area of 232 cm^2 and were washed through a 23.6 mesh/cm screen (.234 mm openings). Samples were preserved in 15% formalin.

Macroscopic benthic organisms were separated from detritus by flotation in a sugar solution of 1.12 sp. gr. (ANDERSON 1959) and were preserved in 80% ethanol. Identifications were made using taxonomic keys listed by DYE (1972). Slides of larval Chironomidae were made according to techniques given by BECK (1965).

Adult chironomids and cast pupal skins were collected, preserved, and identified several times during the study period to provide data on periods of emergence.

The Shannon index of diversity (SHANNON & WEAVER 1949; MARGALEF 1968) was calculated using WILHM's (1970) short computer program and was employed to indicate the effects of pollution.

Sediment samples for particle size analyses were taken twice during the study period with a 3 cm diameter PVC core tube attached to an iron pipe. The core tube was forced into the bottom and a 20—30 cm core was extracted and frozen for future analysis. Only the upper 8 cm were used to determine percentages of sand, silt, clay and organic matter since HUNT (1953), FORD (1962) and OLIVER

(1971) indicate that freshwater benthic organisms rarely occur at deeper depths. The pipette procedure of BARNES (1959) was used for sand, silt, and clay analyses and organic content was determined by ignition in a muffle furnace for 4 hrs at 550°C.

PHYSICAL-CHEMICAL MEASUREMENTS

Comparison of Stations

Table 1 gives the annual means of the physical-chemical measurements of surface samples collected at ten stations (1—10) in the Lake Thonotosassa drainage. Stations 1 and 2 in the inlet to the lake and station 3 at the mouth of the inlet differed markedly from the other stations (4—10). Temperature, dissolved oxygen and pH were lower at these stations than in the lake, and other parameters (total alkalinity, free CO_2, turbidity, phosphate, nitrogen and sulphate concentrations) were generally higher.

Table 1. Annual means of selected physical and chemical parameters at ten stations in the Lake Thonotosassa Drainage, January 1970 - January 1971. Means are for surface samples collected at weekly intervals.

	STATION NUMBER									
Parameter	1	2	3	4	5	6	7	8	9	10
Temperature (°C)	21.5	23.4	24.8	25.2	25.1	25.1	25.3	25.2	25.5	25.7
Dissolved oxygen (mg/L)	1.83	5.55	6.92	7.79	8.82	8.53	8.94	8.43	8.88	8.84
(% Sat.)	20.7	66.3	85.7	96.7	108.2	103.9	109.3	104.3	109.0	109.4
pH	6.10	7.01	7.42	7.61	7.67	7.65	7.69	7.68	7.73	7.67
Total alkalinity (ppm CO_3)	29	116	89	79	77	78	77	76	77	76
CO_2, free (ppm)	44.0	23.1	9.5	7.6	6.7	7.2	7.5	7.8	7.4	8.0
Turbidity (ppm)	10.0	18.9	13.1	11.8	11.3	11.2	11.0	11.1	11.5	11.4
T.D.S. (mg/L)						157.5				
SO_4 (ppm)	16.6	17.2	20.9	11.4	11.7	9.5	9.5	9.2	9.2	8.2
PO_4 - Ortho (ppm)	2.89	3.41	2.85	2.61	2.70	2.54	2.46	2.56	2.51	2.58
PO_4 - Meta (ppm)	0.79	0.96	0.93	0.66	0.67	0.38	0.47	0.66	0.50	0.68
PO_4 - Total (ppm)	3.68	4.37	3.78	3.27	3.37	2.92	2.93	3.22	3.01	3.26
N-NH_3 (ppm)	0.73	0.68	0.58	0.47	0.45	0.45	0.42	0.43	0.45	0.44
N-NO_2 (ppm)	0.002	0.014	0.007	0.001	0.001	0.001	0.000	0.000	0.001	0.001
N-NO_3 (ppm)	0.074	0.098	0.039	0.021	0.021	0.025	0.016	0.016	0.018	0.018

Stream flow at Station 1 (Baker Creek above the confluence with Pemberton Creek) was not detectable except in periods of heavy rainfall, and measurements at this station generally reflected conditions prevalent in the stagnant runoff from surrounding pasture land. Stream flow at Station 2 (below the confluence with Pemberton Creek) was considerably more rapid and differences between this station and station 1 are due to the effluents from the sewage treatment plant and citrus processing plants in Plant City. Station 3 was intermediate between stations 2 and 4 for all parameters, probably because of initial dilution of the effluents by lake water.

Annual means of all parameters at lake stations 4—9 and Station 10 in the outlet differed only slightly (Table 1). Statistical comparisons, using Tukey's w procedure (STEEL & TORRIE 1960) showed no significant differences and indicated that a single station could be used to represent the entire lake. Since vertical profiles of all parameters were made at Station 6, in the center of the lake, it was used for seasonal comparisons.

Temperature, dissolved oxygen, pH and free CO_2 were the only parameters showing vertical stratification. Alkalinity, total dissolved solids, turbidity, phosphates, nitrogen compounds and sulfates did not differ significantly from surface to the bottom and seasonal comparisons of these are based solely on surface samples.

Temperature

Thermal stratification of Lake Thonotosassa occurred from May to September. However, the maximum difference between surface and 4 m was 5°C in July, and usually the gradient was less than 3°C. Temperatures were essentially homothermous from November through April. Surface temperatures ranged from 14—34°C and averaged 25.1°C. Incoming creeks were approximately 2°C colder throughout the year.

Dissolved Oxygen

Dissolved oxygen in the inlet (Baker Creek) to Lake Thonotosassa was low (0.2 to 5.9 mg/L) before the opening of the secondary sewage treatment plant (Fig. 2). However, concentrations showed a marked increase following the opening and reached 10.9 mg/L (supersaturation) by late May. In early June two of the citrus processing plants discharged caustic materials into the sewage treatment plant causing it to become anaerobic (personal communication, R. LARSEN, Supervisor, Plant City sewage treatment plant). Dissolved oxygen in Baker Creek dropepd to 0.6 mg/L the following week and recovery took approximately 5 weeks (Fig. 2). Concentrations ranged between 5.0 and 9.2 mg/L (70—100% saturation) throughout the remainder of the summer and fall. Another marked decrease occurred in December and January commensurate with the start of citrus processing, and concentrations reached a low of 3.4 ppm the second week in January. However, remedial action by the sewage treatment plant produced a substantial increase in dissolved oxygen in late January.

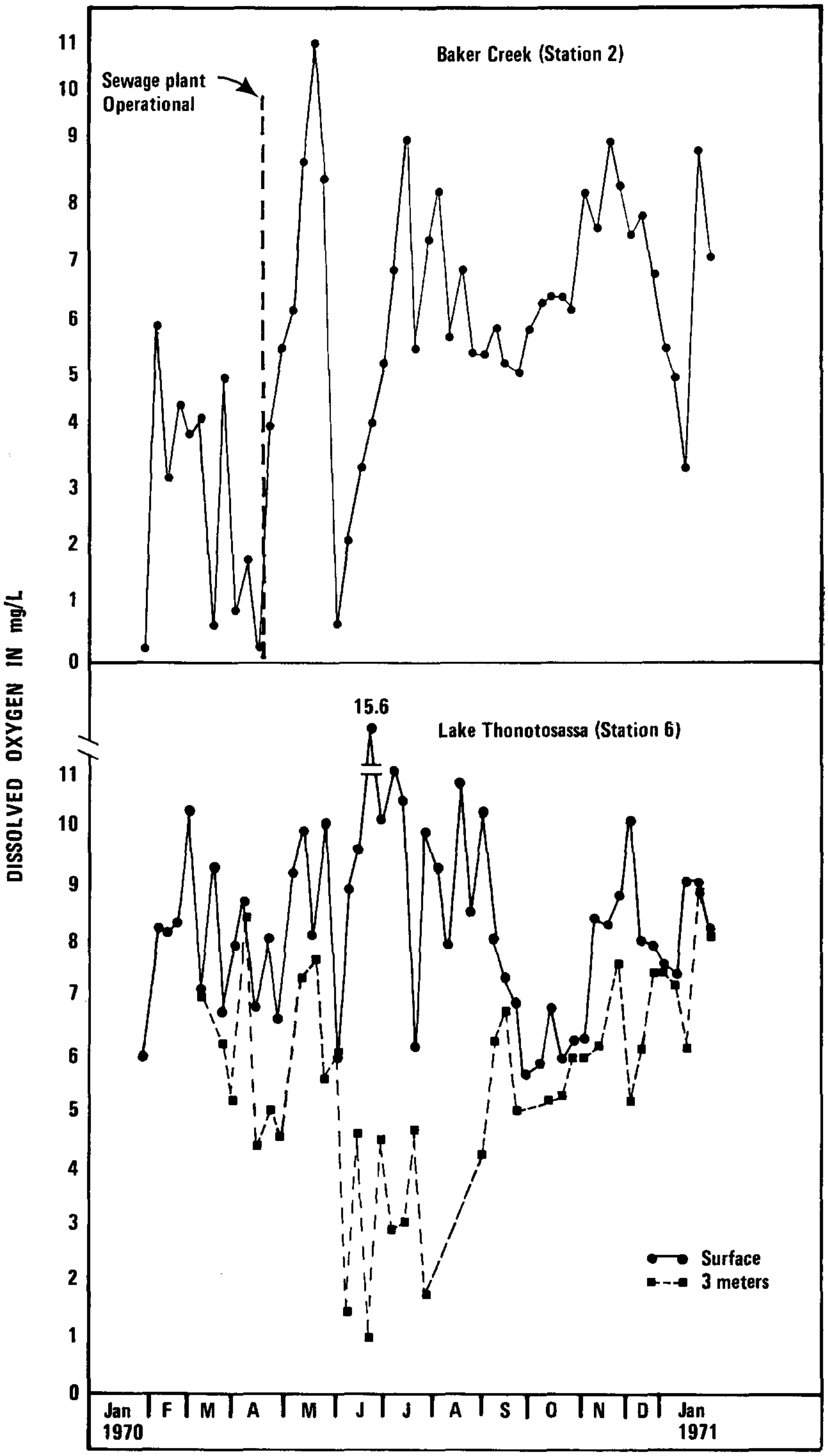

Fig. 2. Dissolved oxygen concentrations in Baker Creek (Station 2) and Lake Thonotosassa (Station 6), January 1970 through January 1971.

Table 2. Monthly means of selected physical-chemical parameters at Station 6 in Lake Thonotosassa, January 1970 - January 1971. Determinations represent surface samples only.

Parameter	Jan 1970	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan 1971
Temperature (^{o}C)	17.5	17.5	21.9	26.8	28.4	30.5	31.6	29.9	31.1	25.7	19.6	19.3	17.7
Dissolved oxygen (ppm)	5.97	8.33	8.45	7.70	9.40	10.08	9.64	9.22	9.40	6.16	8.06	8.77	8.39
(% Sat)	64.0	87.7	97.3	97.6	123.0	123.3	135.8	125.0	117.5	77.4	87.8	94.7	87.8
pH	7.52	7.06	7.37	7.49	8.03	7.66	8.00	8.01	8.06	7.49	7.50	7.56	7.36
Total Alkalinity (ppm CO_3)	48	56	66	75	84	78	79	83	83	81	83	79	85
CO2 free (ppm)	*	*	*	*	*	*	*	*	*	6.72	7.84	8.99	10.49
Turbidity (ppm)	10.0	10.7	10.2	12.8	12.0	11.0	10.6	11.0	13.8	11.0	10.2	10.3	10.4
Secchi disc (cm)	*	*	*	*	95	84	74	64	50	66	83	81	93
T. D. S. (mg/L)	*	*	*	*	*	*	142.0	143.3	160.0	165.0	170.0	160.0	165.0
SO_4 (ppm)	6.0	6.3	9.0	14.4	13.5	8.2	10.0	11.2	6.8	9.8	7.8	9.3	7.0
PO_4 - Ortho (ppm)	2.58	2.72	3.77	2.65	3.52	2.92	2.67	2.16	2.54	2.01	1.88	1.75	1.96
PO_4 - Meta (ppm)	0.00	0.17	0.20	0.49	0.81	1.05	0.27	0.36	0.56	0.18	0.15	0.14	0.28
PO_4 - Total (ppm)	2.58	2.89	3.97	3.14	4.33	3.97	2.94	2.52	3.10	2.19	2.03	1.89	2.24
$N\text{-}NH_3$ (ppm)	0.59	0.57	0.58	0.54	0.56	0.42	0.36	0.35	0.39	0.43	0.41	0.41	0.39
$N\text{-}NO_2$ (ppm)	0.000	0.001	0.000	0.000	0.001	0.000	0.000	0.001	0.000	0.002	0.000	0.002	0.002
$N\text{-}NO_3$ (ppm)	0.000	0.026	0.032	0.068	0.033	0.011	0.008	0.013	0.014	0.023	0.019	0.014	0.032

* No measurement of parameter

Dissolved oxygen concentrations in the lake did not reflect the fluctuations caused by changes in the operation of the sewage treatment plant. Surface values ranged from 5.7 to 15.6 mg/L with highest concentrations during periods of peak primary production. Concentrations were near or above saturation from March through September (Table 2). Vertical profiles in the summer months showed pronounced stratification and reduction of dissolved oxygen at the 3 m sampling depth (Fig. 2). Concentrations at 3 m during June, July and August ranged between 1.0 and 4.7 mg/L and often differed from surface values by as much as an order of magnitude. At other times of the year surface values exceeded those at 3 m by 2 fold or less. During periods of heavy wind action (winter and early spring) concentrations at the two sampling depths were nearly uniform.

B.O.D.

The biochemical oxygen demand at Station 2 (Baker Creek) showed a gradual decline following the installation of the secondary sewage treatment plant in April (Fig. 3). B.O.D. values routinely exceeded 100 mg/L before April but declined to less than 30 mg/L in December. Periodic surface samples from stations within the lake yielded B.O.D. values of less than 17 mg/L, and at station 10 in the outlet (Flint Creek) values consistently ranged between 1 and 7 mg/L (Fig. 3).

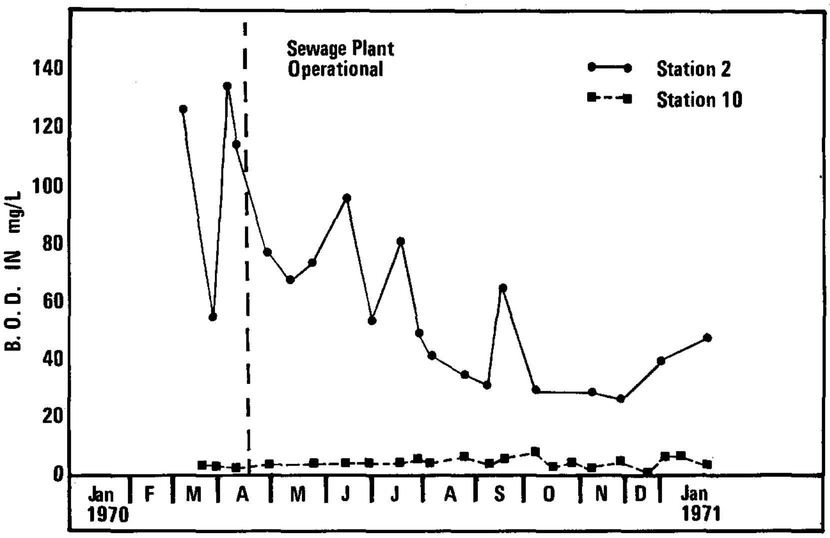

Fig. 3. Biochemical oxygen demand in the inlet (Baker Creek, Station 2) and outlet (Station 10) to Lake Thonotosassa, January 1970 through January 1971.

Alkalinity and pH

Total alkalinity and pH of the surface water in the inlet to the lake showed pronounced increases following the opening of the sewage treatment plant (Fig. 4). Alkalinity increased from 40 to 180 ppm and pH from approximately 6.0 to 8.4. The acid discharges of the citrus processing plants in June caused the alkalinity to drop to pre-operational levels and pH decreased to a low of 3.4. Subsequent increases in both parameters occurred in July. Alkalinity decreased again in August but increased throughout the remainder of the study reaching 198 ppm on the last sampling date in January. From July through January pH fluctuated between 6.7 and 7.7, but during the last three months was comparatively stable (approximately 7.5).

Samples from the lake did not show large fluctuations in total alkalinity or pH (Fig. 4). Total alkalinity increased slightly following the opening of the sewage plant but remained fairly constant, approximately 80 ppm, from June through January. Alkalinity measurements in the lake indicated only methyl orange (bicarbonate) alkalinity except in September when slight phenolphthalein (carbonate) alkalinity was recorded (phenolphthalein alkalinity was never recorded in the inlet). The annual range of surface pH in the lake was 6.7 to 9.0, but values were approximately 8.0 throughout the summer and approximately 7.5 during the remainder of the year. Effects of the opening of the sewage plant and the following acid discharge produced only slight changes (Fig. 4).

Vertical profiles of pH showed decreases with depth during the summer months and at other times of the year following extended periods of calm weather. However, differences between surface and bottom were generally less than 0.5 pH units, and diurnal studies indicated that differences of this magnitude could be expected at any sampling depth within the course of a single day.

Transparency and Turbidity

Limits of Secchi disc visibility in Lake Thonotosassa were comparatively low (Table 2). Monthly means showed maximum visibility in May and January when values were 95 and 93 cm respectively. Minimal values occurred in September ($\bar{x}$ = 50 cm). The highest reading obtained was 120 cm, recorded at Station 7 on May 27, and the lowest was 40 cm at several stations during September.

Surface turbidity values at Station 6, measured with the Hellige turbidimeter, ranged from 8 to 16 ppm. High values occurred in April and September while low values were most prevalent during

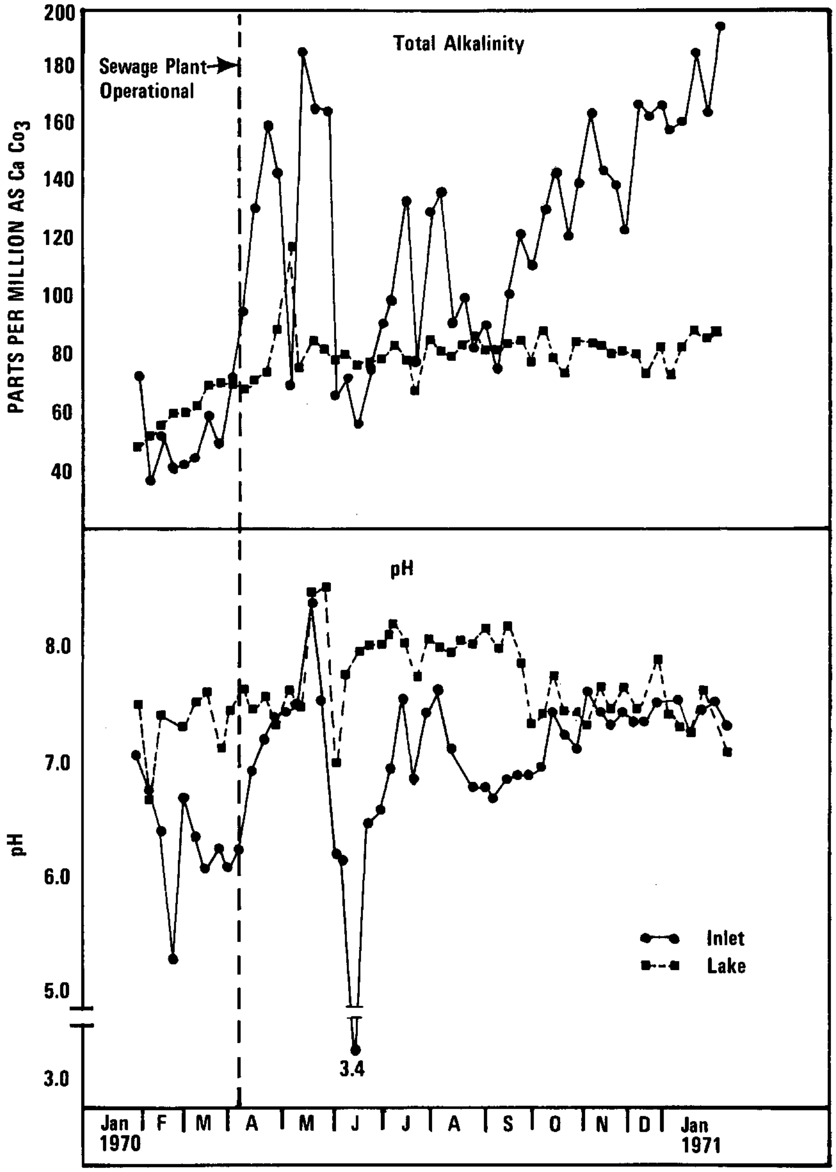

Fig. 4. Total alkalinity and pH of surface samples collected in the inlet (Station 2) to Lake Thonotosassa and in the lake (Station 6). January 1970 through January 1971.

the winter months (Table 2). The turbidity appears to be organic in nature since values showed good correlation with the total volume of phytoplankton (r = 0.74).

T.D.S.

Total dissolved solids were measured only from July through January. Monthly means ranged from 142 to 170 mg/L and the seven month average was 158 mg/L (Table 2).

Sulfates

Sulfate concentrations in the inlet were 2-fold greater [in the inlet] than those in the lake. Peak sulfate concentration occurred in spring (April—May). Monthly means in the lake ranged from 6.0 to 14.4 ppm.

Phosphate

Total phosphate concentrations in the drainage were high throughout the year, ranging from 1.75 to 8.00 ppm (Fig. 5). Concentrations at Station 2 in the inlet and Station 6 in the lake were comparable from January to June, 1970 ($\bar{x} = 3.55$ and 3.38 ppm respectively). However, from June through January, 1971, concentrations were approximately 2-fold higher in the inlet, ranging from 3.10 to 6.90 ppm while the range at Station 6 was 1.75 to 4.20 ppm. No marked effects due to the operation of the new sewage plant were noted.

Seasonal variation of total phosphate in the lake at Station 6 showed a late winter and early spring increase to a peak of 5.75 ppm in May, followed by a steady decrease to the minimum of 1.75 ppm in late December (Fig. 5). Most of the phosphorus was in the form of orthophosphate (Table 2). However, comparatively large amounts of polyphosphate were found in late spring and early summer; the mean for June was 1.05 ppm. Polyphosphate concentrations were low (< 0.20 ppm) during the fall and winter months.

Nitrogen Compounds

Ammonia-nitrogen and nitrate-nitrogen were the principle forms of inorganic nitrogen in the Lake Thonotosassa drainage. Nitrite-nitrogen occurred in small concentrations ($\bar{x} = 0.014$ ppm) at Station 2 but was present only in trace amounts in the lake (Table 1).

Surface ammonia-nitrogen concentrations were 1.5-fold greater in the inlet than the lake. Annual ranges at the two stations were 0.36 to 1.34 ppm and 0.22 to 0.70 ppm respectively. In the inlet peaks occurred in winter (February), in spring (March—April) and late summer (August—September), but in the lake values were high only in winter and spring (Fig. 5). From May through January concentrations in the lake were relatively constant (ap-

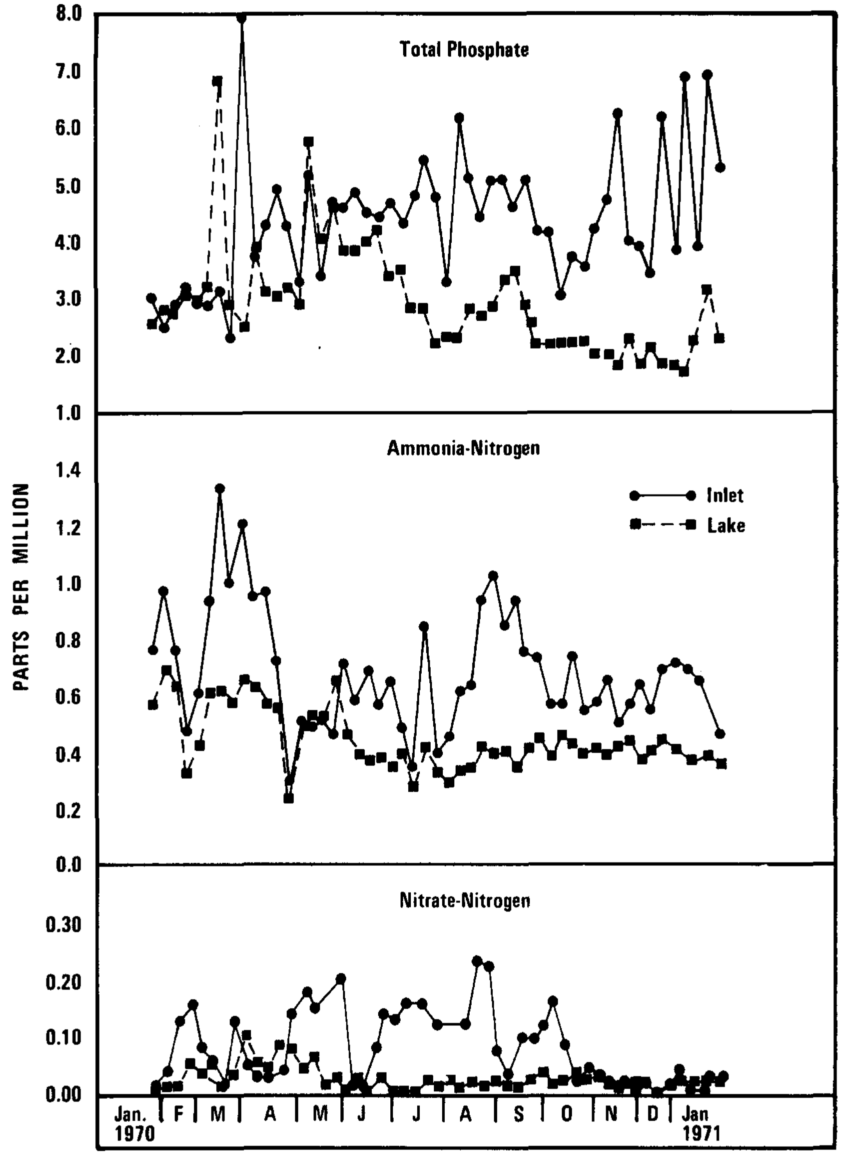

Fig. 5. Comparison of seasonal concentrations of total phosphate, Ammonia-Nitrogen, and Nitrate-Nitrogen in the inlet (Station 2) to Lake Thonotosassa and in the lake (Station 6), 1970—1971. Values represent surface samples only.

proximately 0.4 ppm) and did not reflect changes observed in the inlet. Slight decreases in ammonia-nitrogen were recorded at both the inlet and lake following the opening of the sewage treatment plant in April.

Nitrate-nitrogen concentrations were 4 to 5-fold greater in the inlet than in the lake (Table 1). Moreover, the inlet station showed four peaks during the year while the lake station showed only one distinct peak (Fig. 5). Maximum differences between the two stations occurred in the summer months when inlet values routinely exceeded 0.10 ppm and lake values were consistently less than 0.03 ppm.

Coliform bacteria

Fig. 6 shows the seasonal abundance of coliform bacteria in Baker Creek (Station 2) near the inlet to Lake Thonotosassa. In March and April, prior to the opening of the secondary sewage treatment plant in Plant City, numbers of colonies (per 100 ml) were extremely high, ranging from 2.5×10^6 to 4.0×10^6. Densities dropped more than two orders of magnitude within three months of the opening of the plant, and with the exception of an August peak of unknown cause ranged from 25,000 to 50,000/100 ml from July through November. December and January data showed slight increases to 45,000 to 85,000/100 ml. Coliform determinations also were made at Station 1, upstream from the confluence of Baker and Pemberton Creeks. Numbers of colonies per 100 ml at this station ranged from 90 to 2,200 and corroborated the assumption that Pemberton Creek is the prime source of the pollution.

Surface samples collected at stations 6 and 9 in the lake showed marked reductions (2 to 3 orders of magnitude) in the numbers of coliform colonies which most likely were due to the dilution of the creek effluents by lake water. A single set of samples collected prior to the opening of the sewage treatment plant yielded 8,200/100 ml at Station 6 and 750/100 ml at Station 9. Bi-weekly samples were collected at Station 6 from July through January and coliform densities ranged between 100 and 850 colonies/100 ml.

Primary production

Productivity experiments were conducted at 2—3 month intervals at Station 6 in the middle of the lake using the oxygen light and dark bottle technique. Gross productivity was high even though the zone of production (euphotic zone) was confined to the upper 1 to 2 m (Fig. 7). Values ranged from 0.21 to 2.27 g of $C/m^2/day$ and the average of the five sampling dates was 1.25 g of $C/m^2/day$; winter and early spring rates were 5 to 10-fold lower than the remainder of the year. There were no significant correlations between observed carbon assimilation rates and standing crops of phytoplankton or concentrations of major inorganic nutrients (PO_4 and NO_3).

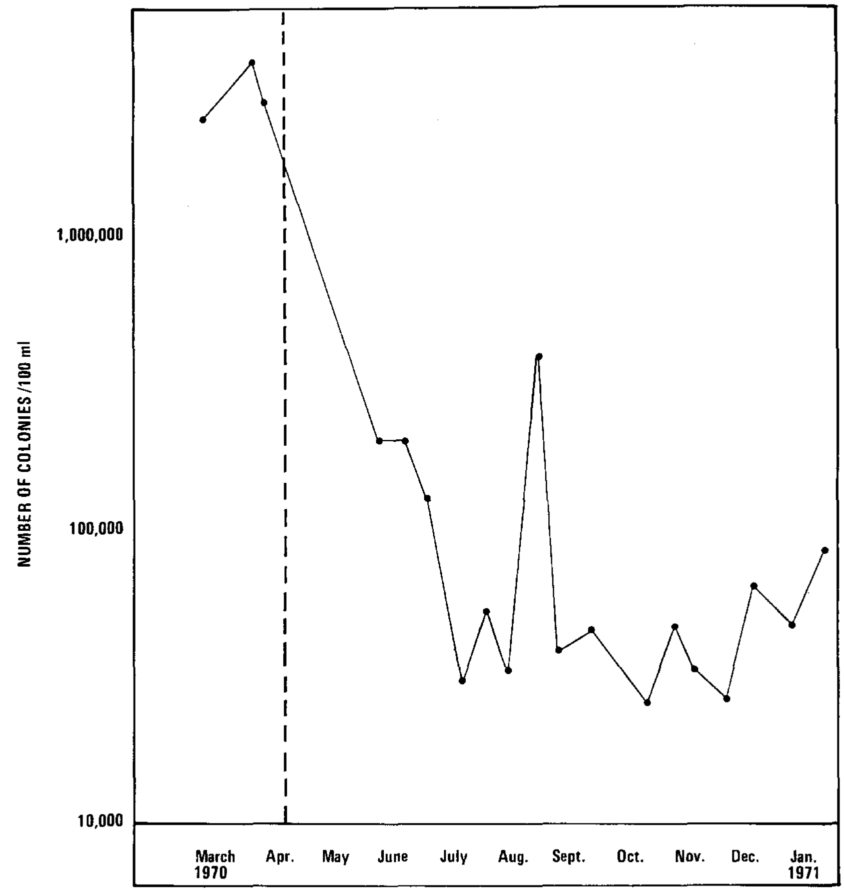

Fig. 6. Number of coliform bacteria colonies per 100 ml in the inlet to Lake Thonotosassa (Station 2), March 1970 through January 1971. Dotted line indicates date of initial operation of secondary sewage treatment plant in Plant City, Florida.

Maximum daily production occurred at the surface on all sampling dates. High turbidity was responsible for the shallow depth of the euphotic zone. Net assimilation of carbon occurred only at surface and ½ m (Fig. 7).

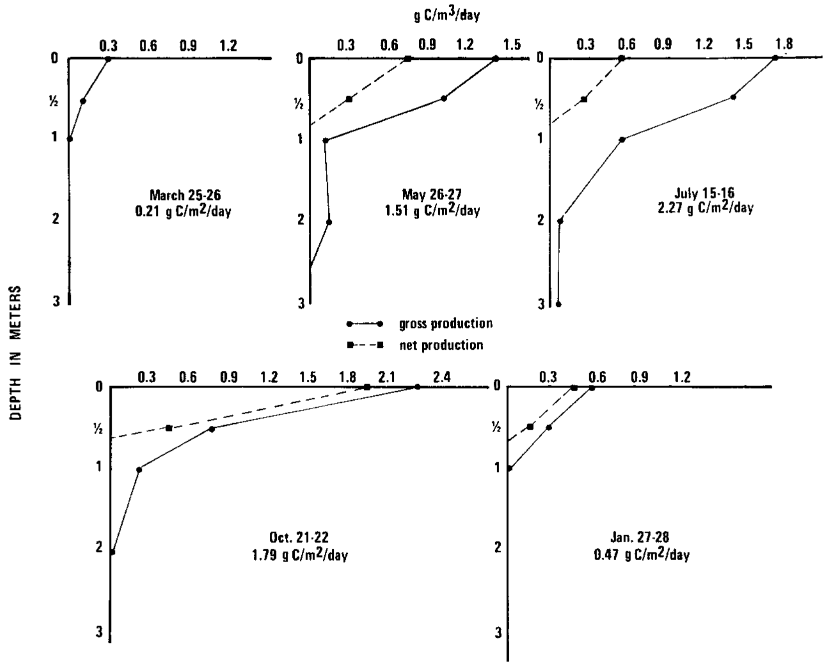

Fig. 7. Vertical profiles of gross and net primary production in Lake Thonotosassa for selected dates in 1970—1971. Total gross production for the euphotic zone (gC/M²/day) is given for each date.

Phytoplankton

Initial collections were made at 6 stations (4—9), located throughout the lake, to determine the horizontal distribution of phytoplankton. However, analyses of the first six months data showed no significant differences between stations in either total volumes of phytoplankton or indices of species richness. Comparisons of vertical distribution showed slight differences except during periods of pronounced thermal stratification (> 3°C). Subsequent to these analyses, phytoplankton composition and abundance were determined from surface samples collected at Station 6 only.

Standing crops of phytoplankton in Lake Thonotosassa were high throughout the year with a peak in September and a minimum in January. Mean monthly volumes ranged from 2.26 to 14.72 μL/L (6,000 to 107,000 cells, filaments and/or colonies per ml) and the annual mean was 5.78 μL/L (Table 3).

The number of species in individual collections ranged from 8 in the summer months (July, August and September) to 16 in

Table 3. Mean volume (µL/L) and percent occurrence of the major groups of phytoplankton in Lake Thonotosassa, Florida. February 1970 - January 1971.

Month	Mean Volume and Percent Occurrence (in parenthesis) in Surface Samples					Monthly Mean Volume
	Diatoms	Chlorophyceae	Cryptophyceae	Myxophyceae	Dinoflagellates	
Feb	4.16 (60.7)	0.84 (12.2)	1.86 (27.1)			6.86
Mar	2.78 (52.0)	2.12 (39.6)	0.36 (6.7)		0.09 (1.7)	5.35
Apr	2.38 (44.1)	1.77 (32.8)	0.49 (9.1)	0.12 (2.2)	0.64 (11.8)	5.40
May	2.62 (39.4)	3.08 (46.3)	0.01 (0.2)	0.60 (9.0)	0.34 (5.1)	6.65
June	0.36 (7.8)	1.88 (40.9)	0.52 (11.3)	1.66 (36.1)	0.18 (3.9)	4.60
July	0.84 (12.8)	1.19 (18.1)	0.02 (0.3)	4.50 (68.6)	0.01 (0.2)	6.56
Aug	0.38 (4.2)	0.46 (5.1)	0.08 (0.9)	8.06 (89.8)		8.98
Sept	0.45 (3.1)	0.40 (2.7)	0.06 (0.4)	13.34 (90.6)	0.47 (3.2)	14.72
Oct	0.78 (18.3)	1.08 (25.3)	1.24 (29.0)	1.17 (27.4)		4.27
Nov	1.12 (38.2)	0.86 (29.4)	0.80 (27.3)	0.15 (5.1)		2.93
Dec	0.98 (38.1)	0.87 (33.9)	0.48 (18.7)		0.24 (9.3)	2.57
Jan	1.06 (46.9)	0.86 (38.0)	0.34 (15.1)			2.26
Annual Mean	1.45 (24.7)	1.27 (21.6)	0.50 (8.5)	2.49 (42.5)	0.16 (2.7)	5.87

March. Only 47 species were found regularly in the lake. However, the use of small samples and a volumetric counting technique prevented determination of the total number of species.

The summer bloom of blue-green algae consisted predominantly of *Anabaena spiroides* var. *crassa* LEMMERMANN and *Oscillatoria* sp. Both species were present throughout the summer and population peaks occurred in September when these forms comprised 90.6% of the phytoplankton. *Anabaena spiroides* var. *crassa* was the dominant blue-green from April to June; *Oscillatoria* dominated from July to November.

Diatoms were the volumetrically dominant group during the winter and early spring, but summer populations were comparatively low (Table 3). The most abundant diatom was *Melosira granulata* (EHR.) RALFS, which comprised 93% of the winter-spring diatom bloom and 81% of the annual mean volume. The only other diatom occurring frequently were *Stephanodiscus Hantzschii* GRUN. and *Cyclotella stilligera* (CLEVE & GRUN.) VAN HEURCK. *Stephanodiscus Hantzschii* occurred from April to January and was the dominant diatom during the summer. *Cyclotella stilligera* was abundant only in April and May.

The green algae (Chlorophyceae) were more abundant in the spring and early summer months, and were the dominant phytoplankton group in May and June (Table 3). Chlorophyceae populations were not dominated by a single species. Three to nine species were recorded for individual sampling dates and volumetric dominance often changed from one sampling date to another.

The Cryptophyceae were represented by a single species of *Cryptomonas*. Peak populations occurred in February and October when this organism comprised approximately 27% of the total phytoplankton. Summer standing crops were low, generally accounting for less than 1% of the total volume (Table 3).

Two dinoflagellates, *Ceratium hirundinella* (O.F.M.) DUJ. and *Glenodinium* sp., were found in the lake. *Ceratium* occurred only sporadically in trace amounts. *Glenodinium* was most abundant in spring and early summer, but also occurred in September and December. However, these dinoflagellates were minor components of the phytoplankton comprising only 2.7% of the total volume.

ZOOPLANKTON

Composition of the Zooplankton

Collections from the six sampling stations in Lake Thonotosassa yielded 23 species of Rotifera and 11 species of Copepoda and Cladocera (Table 4). Fifteen species of rotifers were encountered frequently and individual samples contained 10 to 14 species in all months except January, August, and September when 8, 7, and 4 species respectively were recorded. Only 5 species of Copepoda

TABLE 4

List of the planktonic species of zooplankton in Lake Thonotosassa, 1970—1971. Species frequently encountered are indicated by asterisks.

Rotifera
Anuraeopsis fissa (GOSSE) *
**Asplanchna priodonta* (GOSSE)
**Asplanchna* sp.
**Brachionus angularis* (GOSSE)
**B. calyciflorus* PALLAS
**B. havanensis* ROUSSELET
B. quadridentata HERMAN
**Conchiloides dossuarius* (HUDSON)
Conchilus unicornis ROUSSELET
**Filinia longiseta* (EHRENBERG)
Gastropus minor (ROUSSELET)
**Hexarthra mira* (HUDSON)
**Keratella cochlearis* (GOSSE)
**K. serrulata* (EHRENBERG)
Lecane sp.
Lepadella sp.
**Microcodon clavus* EHRENBERG
Monostyla sp.
Platyias patulus (O. F. MULLER)
**Polyarthra vulgaris* CARLIN
Pompholyx sulcata HUDSON
**Synchaeta stylata* WIERZEJSKI
**Trichocerca similis* (WIERZEJSKI)
Copepoda
Calanoida
**Diaptomus floridanus* MARSH
Cyclopoida
Cyclops bicuspidatus thomasi S. A. FORBES
**Ergasilus chautauquaensis* + FELLOWS
**Eucyclops agilis* (KOCH)
**Mesocyclops edax* (S. A. FORBES)
Branchiopoda
Cladocera
**Bosmina longirostris* (O. F. MULLER)
Ceriodaphnia sp.
Chydorus sphaericus (O. F. MULLER)
**Daphnia ambigua* SCOURFIELD
**Diaphanosoma brachyurum* (LIEVEN)
Macrothrix laticornis (JURINE)

+parasitic form

were encountered: a single calanoid species, *Diaptomus floridanus* MARSH; three species of free-living cyclopoids, *Cyclops bicuspidatus thomasi* S. A. FORBES, *Eucyclops agilis* (KOCH) and *Mesocyclops edax* (S. A. FORBES); and one parasitic cyclopoid, *Ergasilus chautauquaensis* FELLOWS. Six species of Cladocera were recorded, dominated by the small, planktonic herbivore, *Bosmina longirostris* (O. F. MULLER) which comprised 93% of the population. *Daphnia ambigua* SCOURFIELD and *Diaphanosoma brachyurum* (LIEVEN) were the only other Cladocera found in more than trace amounrs.

Horizontal and Vertical Distributions

The six sampling stations were selected to include all areas of the lake and to provide data on the horizontal distribution of the zooplankton. There were no differences in the taxonomic composition between stations but quantitative data showed marked variations for all species. Numerical differences on individual sampling dates (at any depth) ranged from zero to two orders of magnitude. However, no station was consistently higher or lower than another and differences in the annual stations means of the major groups of zooplankton were comparatively small (Table 5).

TUKEY's w-procedure (STEELE & TORRIE 1960) was used to make multiple comparisons of the annual mean densities of rotifers, copepods (nauplii, copepodids and adults) and cladocerans, at the six stations. These comparisons, at similar sampling depths, showed no

TABLE 5

Horizontal and vertical distribution of major groups of zooplankton in Lake Thonotosassa, Florida. Data represent means (No/L) of 26 sampling dates from February 1970—January 1971.

Depth (m)	Station Number						Annual mean of all Stations
	4	5	6	7	8	9	
				Rotifera			
0	548	871	841	781	671	654	728
1	511	874	732	726	656	601	683
3	—	665	608	554	472	—	575
		Copepoda (adults and copepodids) and *Cladocera*					
0	3.7	3.7	4.6	3.4	5.7	7.7	4.8
1	7.3	8.1	7.1	6.7	10.0	9.3	8.1
3	—	22.4	22.1	22.5	19.9	—	21.7
				Copepoda nauplii			
0	29.9	44.0	51.3	39.4	42.7	44.1	41.9
1	23.5	54.7	57.1	47.7	54.7	43.7	46.9
3	—	68.4	78.7	69.5	60.4	—	62.3

significant differences between stations for copepods (nauplii, copepodids or adults) or cladocerans, but rotifers showed horiozontal patchiness which correlated positively with the depth of the station.

Rotifers were most abundant at Station 5, and followed in order of decreasing abundance, by stations 6, 7, 8, 9, and 4 (Table 5). No significant differences were found between the three stations with depths of > 3.5 m (5, 6, and 7) or between the shallower stations (4, 8, and 9). However, Station 4 (1.1 m) was significantly different (5% level) from 5, 6, and 7, and Station 9 (1.2 m) was significantly different from Station 5 and 6. Station 8 (2.9 m) differed only from Station 5.

Comparisons of the vertical distributions yielded similar results at all stations. Rotifer densities decreased with depth while copepods and cladocerans increased (Table 5). Mean differences between surfaces and 3 m samples were significant at the 1% level. Comparisons of horizontal and vertical distributions of individual species of rotifers, copepods, and cladocerans indicated that most followed those described above for the individual groups.

Seasonal Cycles

To facilitate comparisons of seasonal abundance, data from the six sampling stations were pooled to yield a single numerical estimate (for each species) for each sampling date. Pooling was accomplished by first obtaining a mean for each sampling depth, and then taking a weighted average of the surface, 1 and 3 m values (the surface sample was assumed to be representative of the first one-half meter; the 1 m sample of the next $1\frac{1}{2}$ m, and the 3 m sample of the bottom $1\frac{1}{2}$ m). This, densities reported are those for the total water column and are based upon 16 samples for individual dates, and a minimum of 32 samples for monthly means. With this procedure the absence of a species during any month should not be attributed to a sampling error.

The seasonal abundances of the major species of Rotifera, Copepoda and Cladocera found in Lake Thonotosassa from February 1970, through January 1971, are presented in Tables 6 and 7. Rotifers were the numerically dominant group and comprised 90.3% of the zooplankton during the year; copepod nauplii comprised 7.8% while only 1.9% were copepods and cladocerans. Annual mean densities for the three groups were 645.0, 55.9 and 13.5 organisms per liter respectively.

The rotifer populations of Lake Thonotosassa showed three peaks of abundance, one in the winter, another in late spring, and a smaller peak in late fall; minimal values occurred in late summer

TABLE 6

Seasonal abundances of the major species of Rotifera in Lake Thonotosassa, February 1970—January 1971. Each monthly mean represents a minimum of 32 samples

Species	Monthly mean in number per liter												Annual*
	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	mean
Polyarthra vulgaris	393	333	364	128	46	51	113	6	23	72	171	208	155
Keratella cochlearis	400	280	124	218	446	10					15	38	119
Conchiloides dossuarius	456	6	100	322	94	2		18		T**	4	28	79
Anuraeopsis fissa	168	220	31	4	6		15		82	34	75	4	52
Asplanchna sp.	29	8	6			T	6	T					4
Synchaeta stylata	2			4	46	8			T	106	75	2	22
Brachionus angularis	3		14	92	304	376	59		80	26	1	T	88
Brachionus calyciflorus		3	2	120	107	5				2	1	T	19
Hexarthra mira		3	16	350	279		35	42	16				57
Trichocerca similis		2	4	15	8	2	5		1	70	20	1	11
Keratella serrulata			4	127	50					45	5	1	18
Brachionus havaensis				8	10	1			4	57	16	2	8
Microcodon clavus										4	76	1	9
Other Rotifera	6	3	2	4	4	5	1		11	T	1		4
Total All Species	1457	858	667	1392	1400	460	234	66	217	416	460	285	645

*based on 26 sampling dates

**T = Trace amount, < 1 per liter

(Table 6). The maximum standing crop of 2,534 rotifers per liter occurred in late May and the minimum of 62/L occurred in early September. Each peak was comprised of a different assemblage of species and was not dominated by any one species (Table 6).

The dominant species during the winter peak were *Polyartha vulgaris*, *Keratella cochlearis*, *Conchiloides dossuarius* and *Anuraeopsis fissa* (Table 6). *Polyarthra vulgaris* was the only rotifer to occur throughout the year and was the most abundant rotifer, comprising 24% of the annual standing crop. Seasonal abundance of this species indicated high populations in the winter and spring, low summer densities, and increasing densities during the fall. *Keratella cochlearis*, *C. dossuarius* and *A. fissa* also were abundant in the winter and spring but disappeared during the summer months and then reappeared in late fall. These species comprised 18.4, 12.2 and 8.1% respectively of the annual standing crop of rotifers.

Seventeen species of rotifers were collected during the spring but the pulse (May-June)was dominated by the following seven species which comprised 96% of the population at this time: *P. vulgaris*, *K. cochlearis*, *K. serrulata*, *C. dossuarius*, *Brachionus angularis*, *B. calyciflorus*, and *Hexarthra mira*. The first three species were holdovers from the winter pulse but the other four appeared first in late March or early April and reached peak abundance in May and June. *Brachionus angularis*, *B. calyciflorus* and *K. serrulata* disappeared in mid – to late summer and then reappeared briefly during the fall peak. *Hexarthra mira*, except in July, was present throughout the summer and disappeared in late October (Table 6).

The late fall peak (Nov.—Dec.) was dominated by *P. vulgaris*, *A. fissa*, *Syncheata stylata*, *Trichocerca similis*, *B. havanensis* and *Microcodon clavus* (Table 6). Seasonal cycles of *S. stylata*, *T. similis* and *B. havanensis* were similar to those described for *B. angularis*, *B. calycifloris* and *K. serrulata*, except they reached peak abundance in the fall while the latter group was most abundant in the spring. *Microcodon clavus* was found only from November through January.

The copepod population of Lake Thonotosassa showed typical spring and fall peaks of abundance (Table 7). The spring peak extended from late March through June and averaged 18.4 organisms per liter while the fall peak (October through November) averaged 12.0 per liter. Densities declined rapidly following each peak and reached minimal values (1.4/L) in late August and early January.

Cyclopoida were the numerically dominant copepods in all months except May and October and comprised 60% of the annual population. Seasonal cycles of the three, free-living cyclopoids *(Cyclops bicuspidatus thomasi*, *Eucyclops agilis*, and *Mesocyclops edax)* cannot be presented since the small sample size (10 L) frequently

TABLE 7

Seasonal abundances of the major species of Copepoda and Cladocera in Lake Thonotosassa, February 1970 through January 1971. Each monthly mean represents a minimum of 32 samples.

Species	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Annual mean
	Monthly mean in number per liter												
Copepoda (adults and copepodids)													
Cyclopoida*	5.6	5.8	13.3	4.4	10.4	4.2	3.2	4.5	6.5	3.8	1.8	1.0	5.2
Ergasilus chautauquaensis			0.2	1.0	1.0	0.4	0.4	0.2	0.2	0.2	0.1	T**	0.3
Diaptomus floridanus	1.2	1.8	10.3	10.8	4.7	2.2	0.5	0.4	9.7	3.6	0.8	0.6	3.7
Total Copepoda	6.8	7.6	23.8	16.2	16.1	6.8	4.1	5.1	16.4	7.6	2.7	1.6	9.2
Bosmina longirostris	1.1	2.2	18.3	30.2	1.1	T	T				T	0.1	4.1
Daphnia ambigua	T	T	0.2	1.0	0.1								0.1
Diaphanosoma brachyurum				0.2	1.6	0.4							0.2
Ceriodaphnia sp.	T			0.1	T	T					T	T	T
Macrothrix laticornis	T									T	T	T	T
Total Cladocera	1.1	2.2	18.5	31.5	2.8	0.4	T	0	0	T	T	0.1	4.4
Total All Species (except nauplii)	7.9	9.8	42.3	47.7	18.9	7.2	4.1	5.1	16.4	7.6	2.7	1.7	13.6
Copepod nauplii	40.4	39.7	113.2	58.1	45.6	73.3	49.4	15.8	102.8	61.9	43.6	24.0	55.9

*combined densities of *Cyclops bicuspidatus thomasi*, *Eucyclops agilis* and *Mesocyclops edax* (see text)
**T = < .1 per liter

failed to provide sufficient adult specimens for identification; quantitative data are reported for the order only. However, on an annual basis, *M. edax* was the numerically dominant cyclopoid. The parasitic cyclopoid, *Ergasilus chautauquaensis* was present in low densities in all monhts except February and March.

Calanoid copepods averaged 3.7/L on an annual basis and comprised 40% of the copepod population. *Diaptomus floridanus*, the only calanoid in the lake, reached peak abundance in April and May, and again in October (Table 7). Densities were low ($< 1/L$) in late summer and winter.

Copepod nauplii were 6-fold more abundant than the copepodids and adults. Peak densities of more than 100/L occurred in April and October, and minimums occurred in September and January.

The Cladocera of Lake Thonotosassa showed a single spring (May) peak which was totally dominated by *Bosmina longirostris* (Table 7). This small, planktonic herbivore reached a maximum density of 45.2 per liter the second week in May. Subsequently, densities declined markedly and by mid August *B. longirostris* disappeared from the lake. The only other Cladocera present in mor than trace amounts were *Daphnia ambigua* and *Diaphanosoma brachyurum*. The former reached a peak density of 1.1/L the last week of May and the later peaked at 2.4/L in mid-June; both disappeared by August.

Benthos

Composition of the Benthos

The benthic fauna of the Lake Thonotosassa drainage comprised eleven orders of invertebrates, but Diptera (especially Chironomidae) predominated and contained the largest number of species (Table 8). Oligochaete worms and chironomids were the numerically dominant organisms comprising 94.4% of the total numbers collected. Oligochaetes comprised 69.7% and chironomids 24.7%.

Distribution and Abundance of the Benthos

The largest numbers of benthic invertebrate taxa, 33 and 32, were recorded from stations 1 and 10 respectively. The deeper stations (5, 6, 7, and 8) had comparatively few taxa (11, 11, 19, and 18 respectively) while the other stations ranged between 24 and 29 taxa. Most taxa were more abundant in the creeks (stations 1, 1A, 2, 3, and 10)* and shallow areas (stations 4 and 9) of the lake

*Station 3 in the lake at the mouth of Baker Creek is designated hereafter as a creek station because of detectable currents.

TABLE 8

Distribution of the taxa of benthic invertebrates found in Lake Thonotosassa, 1970—1971. Asterisks denote species found with regularity.

Taxon	Distribution (Station No.)
*Oligochaeta	All stations
*Hirudinea	1, 2, 3, 4, 8, 9, 10
Isopoda	
Asellus militaris (HAY)	1
Amphipoda	
**Hyalella azteca* (SAUSSURE)	1, 2, 4, 5, 8, 9, 10
Insecta	
Ephemeroptera	
Caenis hilaris (SAY)	1, 2, 9, 10
unidentified BAETIDAE	1, 1A, 2
Odonata	
Aphylla sp.	1A
Orthemis ferruginea (FABRICIUS)	1A
Pachydiplax longipennis (BURMEISTER)	1
Perithemis seminole (CALVERT)	1A, 2
Enallagma sp.	1, 1A
Hemiptera	
unidentified Corixidae	1, 1A, 2, 3
Coleoptera	
Berosus sp.	1A
Tropisternus lateralis nimbatus (SAY)	1A
Peltodytes oppositus ROBERTS	1
unidentified Elmidae	1
Trichoptera	
Oecetis sp.	2, 4, 9, 10
Diptera	
Chironomidae	
Chironominae	
Chironomini	
**Chironomus crassicaudatus* MALLOCH	All stations
C. attenuatus WALKER	1
C. (Kiefferulus) dux JOHANNSEN	1, 3, 4, 8
C. (Einfeldia) sp.	10
C. (Dicrotendipes) fumidus JOHANNSEN	10
C. (Dicrotendipes) sp.	1, 2, 3, 8, 9, 10
C. sp.	1, 2, 3, 4, 6, 7, 8, 9, 10
Parachironomus monochromus (WULP)	2, 4
**Glyptotendipes paripes* (EDWARDS)	1, 2, 3, 4, 5, 6, 7, 8, 9, 10
G. lobiferus (SAY)	10
Goeldichironomus holoprasinus (GOELDI)	1, 1A, 3, 4, 8, 9, 10
**Polypedilum halterale* (COQUILLETT)	2, 3, 4, 8, 9, 10
P. illinoense (MALLOCH)	1, 2, 3, 4, 9, 10
P. sp.	1A, 2, 3, 4,
**Cryptochironomus fulvus* (JOHANNSEN)	1, 2, 3, 4, 5, 6, 7, 8, 9, 10

TABLE 8 (Continued)

Taxon	Distribution (Station No.)
C. blarina (TOWNES)	10
C. ponderosus (SUBLETTE)	only adults collected
Harnischia sp.	1, 2, 3, 4, 10
Tanytarsini	
Cladotanytarsus sp.	1A
* *Tanytarsus* (several species)	1, 2, 3, 4, 8, 9, 10
unidentified (2 genera)	several stations
Orthocladinae	
Cricotopus sp.	1, 2, 3, 4, 9
Microcricotopus alternantherea (DENDY and SUBLETTE)	10
Nanocladius sp.	3
Tanypodinae	
Tanypus (Apelopia) neopunctipennis SUBLETTE	1
* *T. stellatus* (COQUILLET)	1, 1A, 2, 3, 4, 5, 6, 7, 9, 10
T. punctipennis (MEIG.) = *T. carinatus* SUBLETTE	1
T. sp.	1, 1A, 3, 4, 5, 6, 7, 8
* *Procladius culiciformis* (LINNAEUS)	1, 1A, 2, 3, 4, 7, 8, 9, 10
P. sp.	1, 10
* *Coelotanypus* sp.	All stations
Ablabesmyia mallochi (WALLEY)	2, 3
A. ornata BECK	1, 2
A. sp.	4, 9
Conchapelopia sp.	1, 3
Ceratopogonidae	
* *Palpomyia* sp.	All stations
Culicidae	
* *Chaoborus punctipennis* (SAY)	4, 5, 6, 7, 8, 9, 10
Psychodidae	
Telmatoscopus albipunctatus (WILL.)	1A
Mollusca	
* *Viviparus georgianus* LEA	2, 3, 4, 6, 8, 9, 10
* *Sphaerium* sp.	1, 2, 3, 5, 9, 10
Elliptio sp.	8 (probably elsewhere)
Anodonta sp.	10 (probably elsewhere)

(Table 9). Annual mean densities for total organisms ranged from a minimum of 1,581/m^2 at Station 5 (the deepest station) to 36,340/m^2 at Station 2 in Baker Creek. Species diversity values (H′) at all stations were less than 1 throughout the year. Annual means ranged from 0.24 to 0.41 and between station differences were not significant (F10, 263 df = 1.324). Further discussion of the distribution and abundance will be limited to the species which occurred frequently (see Table 8).

Most of the between-station variability in annual mean densities was attributable to the depth distribution of oligochates (grouped

TABLE 9

Annual mean densities of the taxa of benthic invertebrates found with regularity in the drainage at the eleven sampling stations in Lake Thonotosassa. Densities represent means of 24 sampling dates during 1970—1971.

Taxon	Mean Density (No/m²) at Station											Mean of All Stations
	1A	1	2	3	4	5	6	7	8	9	10	
Oligochaeta	10,846	603	31,243	13,526	3351	246	977	762	3643	2825	4642	6,606
Hirudinea	2	79	101	113	4	0	0	0	2	9	54	33
Amphipoda												
Hyalella azteca	0	735	14	0	11	2	0	0	2	13	262	94
Insecta												
Chaoborus punctipennis	0	0	0	0	23	673	1037	1229	240	36	39	298
Palpomyia sp.	66	468	179	100	699	23	4	45	23	524	359	226
Coelotanypus sp.	7	100	160	4	50	86	45	16	4	27	16	47
Procladius culiciformis	11	29	25	167	50	0	0	2	7	32	106	39
Tanypus stellatus	316	206	7	27	47	7	13	38	0	14	25	64
Tanytarsus spp.	5	7	258	97	2	0	0	0	4	11	52	40
Cryptochironomus fulvus	0	5	321	165	125	43	16	14	54	155	432	121
Polypedilum halterale	0	0	2273	940	11	0	0	0	5	29	65	302
Glyptotendipes paripes	0	7	5	104	925	9	27	11	4126	32	2111	669
Chironomus crassicaudatus	3100	544	1299	201	151	389	911	572	744	23	18	723
Other insects*	36	274	430	326	88	99	80	21	207	33	240	166
Mollusca												
Viviparus georgianus	0	0	20	14	57	0	4	0	11	14	7	12
Sphaerium sp.	0	233	5	14	9	4	0	0	0	5	206	43
Total	14389	3290	36340	15798	5603	1581	3114	2710	9072	3782	8634	9483

*includes all other species listed in Table VIII (primarily chironomids) into a single taxon because of problems in identification). Annual mean densities per square meter of these worms ranged from 4,624 to 31,243 at creek stations (1A, 2, 3, and 10), 2,825 to 3,643 at the sandy lake stations (4, 8, and 9) and 246-977 at the deep stations (5, 6, and 7). Densities at Station 1, the only station not directly affected by the organic effluents, were significantly lower than those from the other creek stations (Table 9).

The seasonal abundance of oligochaetes, plotted as means of all eleven stations, showed a marked spring peak and uniform densities throughout the remainder of the year (Fig. 8A). However, the peak

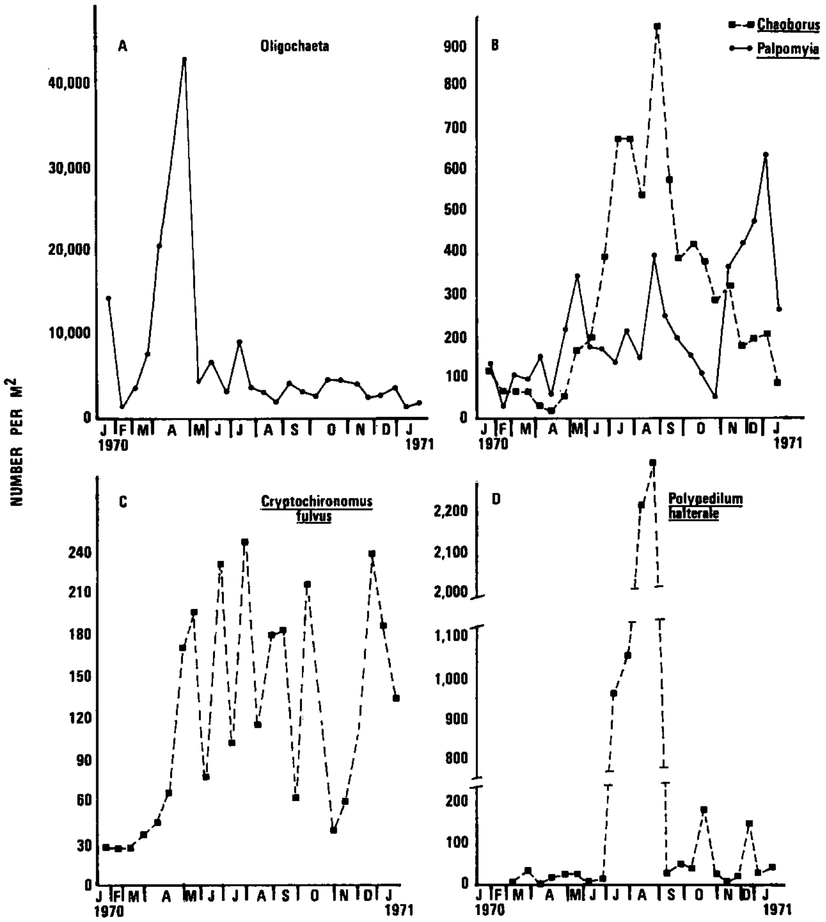

Fig. 8. Abundance of Oligochaeta (A); *Chaoborus* and *Palpomyia* (B); *Cryptochironomus fulvus* (C); and *Polypedilum halterale* (D) in the Lake Thonotosassa drainage January 1970 through January 1971. Abundance for each date is given as the mean of the eleven sampling stations.

reflects almost exclusively changes which occurred at the creek stations 1A, 2, and 3 (the stations most directly influenced by the polluting effluents). Stations 2 and 3 reached population peaks of 409,002 and 80,685/m² respectively the second week in April, but in early May densities declined drastically to levels comparable to those of other shallow areas of the lake. The spring peak at Station 1A occurred somewhat later (May and June) when densities as high as 68,457/m² were recorded; these populations also showed subsequent decreases. In contrast, the oligochaete population at the lake stations showed no marked fluctuation in densities or seasonal peaks.

Two unidentified species of leeches (Hirudinea) were found in the Lake Thonotosassa drainage. However, they were common only at creek stations 1, 2, 3 and 10 (Table 9) and no seasonal cycles were observed.

Hyalella azteca (SAUSSURE), the only amphipod present, was found almost exclusively at the shallow creek stations 1 and 10 where large growths of aquatic grasses (*Hydrochloa caroliniensis* and *Panicum repens*) occurred. Large numbers of amphipods (up to 4,000/m²) were found in May and June, and again in November. Summer populations were extremely small.

The only insects other than Chironomidae to occur with frequency in the Lake Thonotosassa drainage were larvae of the phantom midge, *Chaoborus punctipennis* (SAY) and the ceratopogonid, *Palpomyia sp. Chaoborus punctipennis* occurred primarily at the deep stations (5, 6, and 7) where annual mean densities ranged from 673 to 1,229/m² (Table 9). Smaller numbers (23—240/m²)were found at the other lake stations (4, 8, and 9) and in the outlet (Station 10). No specimens were collected from the incoming creeks (stations 1, 1A, 2, and 3). A single population peak of *Chaoborus* occurred in late summer and was followed by a steady decline to a winter minimum (Fig. 8B).

Palpomyia sp. occurred at all stations but was more abundant at the shallow stations (1, 2, 4, 9 and 10) (Table 9). Spring (May), summer (August) and late fall (November and December) peaks in larval population densities indicate at least three generations per year (Fig. 8B).

The eleven species of the subfamily Tanypodinae comprised less than 10% of the total Chironomidae and only *Coelotanypus sp.*, *Procladius culiciformis* (LINNAEUS) and *Tanypus stellatus* COQUILLETT occurred with regularity.

Coelotanypus sp. occurred at all stations in the drainage and, based on annual means, showed comparatively small differences between stations (Table 9). However, seasonal comparisons showed a winter and early spring peak at the deeper lake stations (5 and 6) and a later spring peak at the creek and shallow lake stations. In summer there were only occasional occurrences of larvae at shallow lake stations. Populations increased at all stations from October through January.

Procladius culciformis was restricted primarily to creek and shallow lake stations and was most abundant at stations 3 and 10 (Table 9). Population densities at all stations were low at all times of the year except summer. For example, densities of *P. culiciformis* at stations 3 and 10 exceeded 1,000/m² in July but collections from fall and winter contained few or no larvae.

Tanypus stellatus was most abundant at the creek stations 1 and 1A, although it occurred at all stations except Station 8 (Table 9). Population peaks occurred in July and October when 4,047 and 1,119/m² were found at stations 1A and 1 respectively.

The Tanytarsini (Chironomidae) were not identified to species and of the four genera found, only two, *Cladotanytarsus* and *Tanytarsus*, were identifiable (BECK, W. M. JR., Personal communication). *Cladotanytarsus* occurred infrequently at station 1A only. The distribution of the several species of *Tanytarsus* was restricted to creek and shallow lake stations, but populations were most abundant in the creeks (especially Station 2) (Table 9). Population peaks were observed in late May, October and early January when densities of 3,143, 1,420 and 688 larvae per m² respectively were recorded at Station 2.

Four species of the tribe Chironomini (subfamily Chironominae) comprised 77.6% of the Chironomidae collected in the Lake Thonotosassa drainage: *Cryptochironomus fulvus* (JOHANNSEN), 5.2%; *Polypedilum halterale* (COQUILLET), 12.9%; *Glyptotendipes paripes* (EDWARDS), 28.6%; and *Chironomus crassicaudatus* (MALLOCH), 30.9%.

Cryptochironomus fulvus was found at all stations in the drainage except Station 1A (Table 9). However, it was more abundant at the creek and shallow lake stations, and only occurred at deep stations 5, 6, and 7 during the winter and early spring; summer population occurred at stations 2, 3, 4, 9 and 10. Six population peaks of approximately 200 larvae per m² each occurred between May and December (Fig. 8C), suggesting five or six generations per year.

Polypedilum halterale was extremely abundant during the summer (Fig. 8D). Distribution of the species was limited primarily to shallow stations (2, 3, 9 and 10) and it occurred only sporadically at other stations (Table 9). At stations 2 and 3 population densities exceeded 25,000 and 10,000/m² respectively during July and August. These peaks were followed by massive emergences in August and September and subsequent reductions in larval densities. Smaller peaks of approximately 1,900 and 1,600 larvae per m² occurred at Station 2 in October and early December. Fall and winter populations at Station 3 were quite small (range: 0—129/m²), probably due to extensive dredging of the lower part of Baker Creek during this interval.

Glyptotendipes paripes occurred at all stations except 1A, but was most abundant at stations 4, 8, and 10 (Table 9). Annual mean densities at these stations ranged from 925 to 4,126 larvae per m² and exceeded those at other stations by one to two orders of magnitude. Three major larval population peaks (ranging from 1,527 to 3,139/m²) and emergences occurred during the summer, and two minor peaks (744 and 1,021/m²) occurred in the fall (Fig. 9). Maximum density of 27,426 larvae per m² was recorded at Station

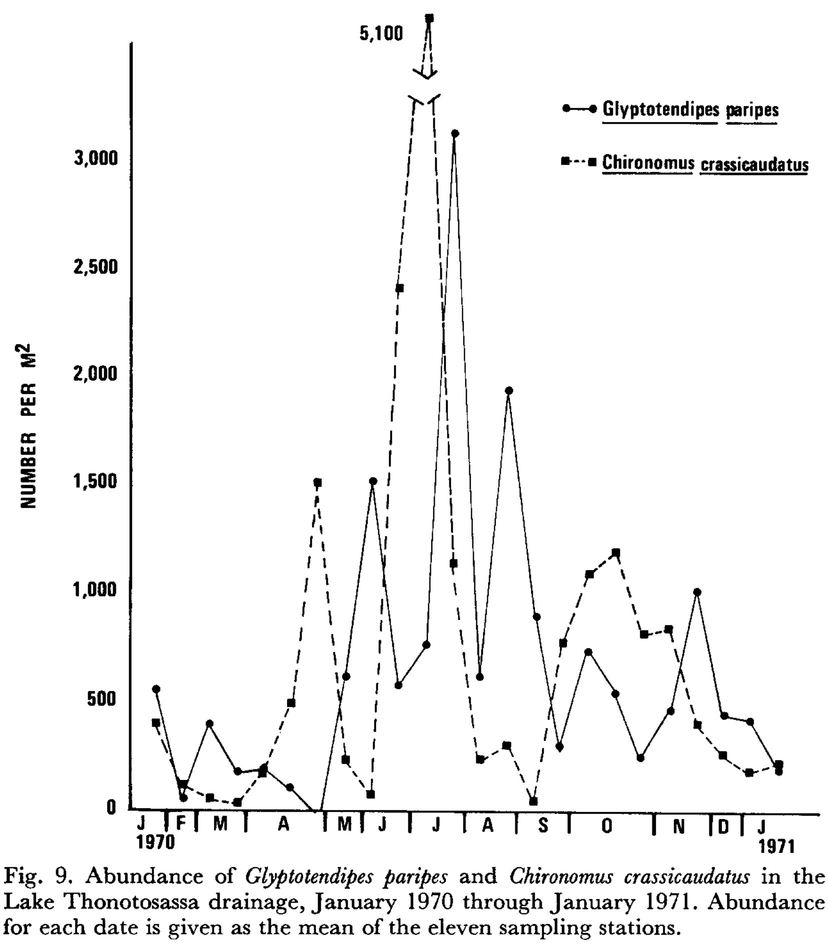

Fig. 9. Abundance of *Glyptotendipes paripes* and *Chironomus crassicaudatus* in the Lake Thonotosassa drainage, January 1970 through January 1971. Abundance for each date is given as the mean of the eleven sampling stations.

10 in July. Adult populations reached nuisance proportions along the shoreline at periodic intervals throughout the summer.

Chironomus crassicaudatus was found at all sampling stations and was the only species which occurred in large numbers at both shallow and deep stations (Table 9). It was found at the shallow stations throughout the year, but was absent at deep stations during the summer months. Spring, summer and fall peaks of larval populations were observed (Fig. 9). The largest peak occurred in early July when the mean density for the eleven stations reached 5,100/m². Extremely large adult populations were observed along the shoreline in spring, summer and fall.

Only two Mollusca, *Viviparus georgianus* (LEA) and *Sphaerium sp.* were found with frequency in the Lake Thonotosassa drainage (Table 9). *Viviparus georgianus* occurred in comparatively low densities throughout the year at shallow lake and stream stations with sandy substrates. *Sphaerium* was most abundant at shallow creek stations 1 and 10 where annual mean densities exceeded 200/m² (Table 9). The species was collected only once from a deep water (3 m) station. At Station 10 the population reached a peak of 3,530/m² in August and at Station 1 a peak of 2,841/m² occurred in early November. Densities at other times of the year ranged from 0—500/m².

MAJOR FACTORS INFLUENCING BENTHIC INVERTEBRATE POPULATIONS

Dissolved Oxygen

The polyethylene bag technique (FREMLING & EVANS 1963) was used to measure dissolved oxygen concentrations at the mud-water interface. Experiments were conducted at two weeks intervals at each station but the incidence of vandalism was high. Total recovery of the bags was achieved only once. For most of the study period recovery rates ranged from 30—60%.

Annual ranges and mean percent saturation values at stations 1, 1A, 5, 6, and 7 were markedly lower than those at the other stations (Table 10). Dissolved oxygen concentration at stations 1, 5, 6, and 7 were consistently low (0.2 to 1.6 ppm) during the summer. Station 1A, closest to the citrus and sewage plant, was anaerobic for two months in the winter when citrus processing was in progress. Benthic diversity at these stations was reduced drastically during these periods and only species capable of surviving low oxygen concentrations were found (e.g., oligochaetes and *Chaoborus punctipennis*).

Table 10. Range and mean percent saturation of dissolved oxygen at the mud-water interface at the eleven stations in the Lake Thonotosassa drainage. January 1970 to January 1971.

Station	Percent Saturation Mean	Range
1	14.5	0-35
1A	20.1	0-60
2	62.5	15-81
3	75.6	4-95
4	71.1	25-117
5	32.2	10-60
6	40.2	8-65
7	25.6	6-66
8	61.4	19-84
9	60.8	34-82
10	60.9	30-74

Sediments

Particle size analyses were conducted on sediments collected at each station in July 1970 and January 1971. Differences in the percent composition of the sediments between sampling dates were minor ($< 10\%$) at all but two stations, and since the differences at the latter were probably attributable to sampling error, the data were combined.

The substrate at stations 1, 2, 3, 4, 8, 9, and 10 was primatily sand ($> 84\%$); silt, clay and organic matter percentages were low (Table 11). Sand percentages were considerably lower ($< 50\%$) at the other stations (1A, 5, 6, and 7) while silt and organic matter percentages were larger. Stations 5, 6, and 7 collected large amounts of organic matter and silt since they were located in the deeper areas of the lake. Station 1A, located near the citrus and sewage plants, had a layer of organic matter covering the stream bed. The marked differences in substrate composition at Station 8, compared with the other deep stations (5, 6, and 7) were probably responsible for the differences in the benthic fauna between these stations and for the similarities between Station 8 and shallow

Table 11. Sand, silt, clay, and organic matter percentages of upper 8cm of sediment at eleven stations in Lake Thonotosassa Drainage, 1970. Values are means of two (January + July) determinations.

Station No.	Percentages of Major Components of Sediment: Sand	Silt	Clay	Organic Matter
1	91.2	8.0	0.3	0.5
1A	44.4	27.5	5.6	22.5
2	89.2	7.6	1.7	1.5
3	86.6	9.5	2.8	1.1
4	94.2	3.2	0.8	1.8
5	47.9	26.4	5.1	20.6
6	49.0	25.8	8.0	17.2
7	41.5	32.6	8.1	17.8
8	91.8	7.2	0.8	0.2
9	84.4	10.1	2.5	3.0
10	86.4	10.4	0.8	2.4

stations. Current patterns, basin configuration and wave action apparently prevented silt and organic matter deposition at Station 8.

The sand portion of the sediments was further analyzed to determine proportions of each of five grain sizes: 500 μ, 250 μ, 125 μ, 62 μ and < 62 μ. Sand grains of the 125 μ size were the dominant form at all stations except 1, 4, 8, and 10 where the 250 μ size predominated. The distribution of *Glyptotendipes paripes* showed a good correlation with the percentages of 250 μ grain sizes ($r = 0.79$).

Discussion

Studies of the process of eutrophication (natural and cultural) of freshwater lakes normally involve determinations of the rate of nutrient enrichment and of the time it takes for the lake to respond to this enrichment. Because the response is reflected in a multitude of physical, chemical and biological parameters which are often difficult to measure or interpret, eutrophication indices have been employed to determine the tropic state of the lake (see reviews of eutrophication indices by Fruh et al 1966 and Hooper 1969). In addition, useful indices (in the sense of Hooper 1969) or multivariate statistical approaches using carefully selected parameters (see Brezonik & Shannon 1971) should enable prediction of future events and evaluation of the consequences of proposed discharges of effluents or other water management practices.

The indices are of lesser value in highly eutrophic lakes and may only indicate the degree of eutrophy unless subsequent measures are taken to prevent inflow of nutrients to the lake. In culturally altered lakes diversion of effluents or improvement of the water quality of the effluents should be reflected by eutrophication indices and long-term measurements should enable the determinations of rates of deceleration and of recovery of the lake.

The following eutrophication indices will be compared and discussed for Lake Thonotosassa: 1) oxygen budgets, 2) transparency, 3) nutrients, 4) productivity, 5) biological indicators, and 6) diversity and stability. These indices include most of those in the utilized or proposed categories outlined by HOOPER (1969).

Oxygen Budgets

The shape of the oxygen curve and changes in the hypolimnetic oxygen deficit are meaningful indices in deep, stratified lakes, but not in shallow lakes approaching senescence (HOOPER 1969). Clinograde oxygen curves and hypolimnetic oxygen deficits in Lake Thonotosassa occurred only in summer when the lake was thermally stratified. During the rest op the year wind driven currents were sufficient to mix the entire lake and maintain circulation of oxygen.

The principle factor causing the summer oxygen deficit in the hypolimnion was the oxidation of the organic matter (chiefly citrus pulp) which has accumulated over the past 15 years. Although Plant City's secondary treatment plant now removes much of the organic load (and the associated B.O.D.), detectable changes in either of the above indices are not likely to be noticed in the near future.

Transparency

Transparency changes have been used to assess the rate of eutrophication but may be difficult to interpret since they do not distinguish between the various types of suspended matter (HOOPER 1969). If the suspended matter is chiefly inorganic, as in western Lake Erie, the transparency may not change even though the increase in plankton densities had been significant (BEETON 1969). However, in Lake Thonotosassa where the turbidity is caused for the most part by phytoplankton ($r = +0.74$) the index should be a good indicator of change.

Nutrients

EDMONDSON (1969) suggested that the nitrate to phosphate ratio (N : P ratio) in lake water could be used diagnostically to indicate the degree of pollution by sewage (or the eutrophic state of the lake). His study of Lake Washington showed that before sewage was diverted into the lake, nitrate (NO_3) was in excess of phosphate during the spring phytoplankton pulse. However, addition of sewage, richer in phosphorus than the natural water supply, reversed the ratio. The N : P ratio also can be used to show recovery rates following the elimination of the polluting effluents as it should after an initial delay begin to return toward original values. The delay apparently depends upon the length of time the lake has been receiving pollutants and the amount of nutrients stored in the bottom muds (RODHE 1969).

The N : P ratio in Lake Thonotosassa showed a distinct excess of phosphate at all times of the year. Moreover, it appears likely that the ratio will remain this way since the new sewage treatment plant has not appreciably lowered nutrient levels in the incoming water (see Fig. 5). Incoming nitrate levels (at Station 2) were as much as 20-fold greater than corresponding levels in the lake and the annual means showed a 4-fold difference. These differences suggest that the inorganic nitrogen (especially NO_3) in the lake is being tied up in the organic fraction. Data for organic (KJELDAHL) nitrogen are not available, but BEETON (1969) compared 38 years of data from Lake Michigan which showed that organic nitrogen increased and inorganic nitrogen decreased as the lake became more eutrophic. Organic nitrogen will be monitored in Lake Thonotosassa starting in 1973 and will be used along with the N : P ratio to detect any changes in nutrient levels.

Productivity

Gross productivity has been used to indicate the trophic state of lakes undergoing natural eutrophication and to indicate the degree of eutrophy in lakes polluted by sewage and other organic wastes. RODHE (1969) reviewed the northern European literature and indicated that mean rates during the growing season ranged from 300 to 1,000 mg of $C/m^2/day$ in natural eutrophic lakes and from 1,500 to 3,000 mg of $C/m^2/day$ in culturally eutrophic lakes; some daily rates in the latter reached 6,000 mg of $C/m^2/day$. These rates agree with those observed in polluted lakes in the United States. EDMONDSON (1969) reported a maximum of 6,090 mg of $C/m^2/day$ in sewage polluted Lake Washington, and (SAUNDERS 1964) indicated that the primary productivity of the polluted western basin of Lake Erie ranged from 98 to 7,340 mg of $C/mg^2/day$.

Rates of gross productivity in Lake Thonotosassa were of comparable magnitude ranging from 210 to 2,270 mg of $C/m^2/day$ even though the euphotic zone was comparatively shallow (1 to 2 m). No significant correlations existed between rates of primary productivity and concentrations of major inorganic nutrients. Instead of showing spring and fall peaks of productivity corresponding with increases and decreases in nutrient levels, production in Lake Thonotosassa increased in spring, peaked in summer, and continued at high levels through fall before declining in winter. JONASSON (1969) observed a similar effect in the highly eutrophic (and polluted) Lake Pedersborg (Denmark) and concluded that the seasonal variation in primary production in nutrient-rich lakes becomes atypical compared with the moderately eutrophic (natural) lakes.

This index appears to be one of the better indices of eutrophication provided measurements are made at frequent intervals and throughout the year.

Biological Indicators

The appearance of new species of organisms and the disappearance of others have been perhaps the most useful indices of eutrophication (HOOPER, 1969). But in a majority of the eutrophic lakes (like Lake Thonotosassa) where previous studies have been not conducted, the disappearance and appearance of species can only be inferred by comparison with other lakes. Indicators in this case are often the dominant species (or group), especially those which reach nuisance proportions.

Standing crops of phytoplankton in Lake Thonotosassa were comparable to those of highly eutrophic lakes (see EDMONDSON 1969, VERDUIN 1959, 1960). Populations were dominated by the blue-green (Myxophyceae) algae *Anabaena spiroides* var. *crassa* and *Oscillatoria* sp. which reached nuisance proportions (scums) in late summer and early fall.

HUTCHINSON (1967) stated that the chemical factors regulating growth of the Myxophyceae were not properly understood. Other investigators have indicated that blooms occur coincident with high concentrations of organic nitrogen, but Edmondson (1967) has disputed this contention. His studies of Lake Washington showed that *Oscillatoria* populations increased as inorganic nitrogen and phosphorus levels decreased; but there was no change in the levels of dissolved (KJELDAHL) nitrogen (EDMONDSON 1969). Our data from Lake Thonotosassa showed no correlation between inorganic nutrient levels (NO_3 and PO_4) and blue-green abundance. It may be that organic substances (i.e. organic nitrogen) are important at times when inorganic salts are reduces to very low levels (LUND 1969).

The comparatively low summer populations of rotifers and copepods in Lake Thonotosassa also may be attributable to the large volumes (and percent composition) of blue-green algae. LUND (1969) stated that blue-greens, compared with smaller green algae, are relatively free from the grazing of herbivores. Our data show that the zooplankton decline coincided with the increases (in density and percent composition) of the blue-greens. The minimum density of total zooplankton occurred in eraly September at the peak of the blue-green bloom. Subsequent increases in zooplankton densities during the fall occurred concurrently with the decline of the blue-green populations and with the increase in green algae and diatom densities.

The dominance of small-bodied planktonic herbivores in Lake Thonotosassa also is typical of highly eutrophic lakes (HRBÁČEK 1962, BROOKS 1969). Moreover, studies by HRBÁČEK and his coworkers in Czechoslovakia (see BROOKS 1969) have shown that the relative dominance of these small-bodied zooplankters is frequently determined by the food selection and size-related filtering efficiency of planktivorous fish. BROOKS (1969) further stated that there is reason to believe that the primary effect of chemical enrichment, both natural and cultural, on zooplankton populations is through alteration of populations of planktivorous fish. Thus, the large populations of gizzard shad, *Dorosoma cepedianum*, which have appeared in Lake Thonotosassa in recent years may be regulating the zooplankton populations. More recent (1971) introductions and development of large populations of the African cichlid, *Tilapia* sp., which consumes large numbers of copepods while bottom feeding (B. C. COWELL, unpublished data) may reduce densities of these zooplankton to even lower levels.

Benthic organisms have been excellent indicators of past and present conditions of water (FRUH, et al. 1966, KNIGHT & LAUFF 1969). Moreover, because of the low mobility, life cycles of one year or more in some species, and the diversity of habitats occupied, the composition and abundance of benthic organisms has been related closely to environmental extremes (e.g. see GAUFIN & TARZWELL 1955, MACKENTHUN 1966, BRINKHURST 1966, 1970).

The dominant organisms of pollution related associations (cultural eutrophication) in freshwaters are generally oligochaetes and chironomids. Species of these organisms often are able to adapt to periods of anaerobic (or close to) conditions and to heavy accumulations of organic sediments usually associated with organic pollution (BRUNDIN 1951, GAUFIN 1958, BEETON 1965, BECK 1969). Oligochaetes and two species of chironomids, *Glyptotendipes paripes* and *Chironomus crassicaudatus*, dominated the benthos of the Lake Thonotosassa drainage and adults of the chironomid species reached nuisance proportions along the shoreline. *Glyptotendipes paripes* and *C. crassicaudatus* both have been linked to the advanced eutrophic state of other Florida lakes caused by agricultural runoff and the disposal of sewage in lakes (Beck & Beck 1969, Crossman 1967, Provost 1958, Provost & Branch 1959). Future changes in the distribution and abundance of these organisms in Lake Thonotosassa may be indicators of lake recovery.

Diversity and Stability

In recent years individual species have been abandoned as indicators in favor of associations of organisms and the abundance of such associations (see Gaufin & Tarzwell 1956, Beck 1969, Hooper 1969). In eutrophic lakes or organically polluted waters large numbers of individuals of only a few species are found while in water of better quality, larger numbers of species and smaller numbers of individuals per species are found. A variety of mathematical formulae have been used to express such relationships quantitatively. Wilhm (1970) has recommended the Shannon-Weaver information theory index (equals $\bar{d}$ of Margalef 1968) since his studies indicated that it shows changes in community composition not reflected by numbers of individuals or numbers of species alone. Furthermore, Hooper (1969) has stated that if the premise that high diversity is equated with high stability (or resistance to perturbation) is accepted, then diversity indices can be used predictively to forecast major changes in community structure.

Diversity indices (in eutrophication studies) usually have been applied to the benthic organisms only because of the previously described relationships to environmental extremes. Wilhm (1970) gives ranges of the diversity index (H') for waters of different quality. Diversity indices in Lake Thonotosassa were less than 1 throughout the year and indicate moderate to grossly altered water. Changes in this index probably will be the first signs of recovery of the lake.

Conclusions

The foregoing eutrophication indices show that fifteen years of artificial enrichtment of Lake Thonotosassa by organic wastes from sewage and citrus processing plants has produced conditions which reflect advanced states of eutrophy. Inorganic nutrient levels are high; phytoplankton populations are extremely large and dominated by blue-green algae; primary production rates are comparable with those of grossly polluted lakes; small bodied herbivores (rotifers and *Bosmina longirostris*) dominate the zooplankton; benthic populations are comprised of an overwhelming abundance of oligochaetes and chironomids and diversity is low.

Construction of a new secondary sewage treatment plant to process the organic wastes has (in 9 months) reduced the level of incoming pollution, and benthic diversity in the inlet subsequently has increased. However, in the lake proper decreases in coliform bacteria are the only signs of immediate influence. Moreover, since nutrient levels of the incoming creek are still high, it is doubtful that there will be appreciable changes in many indices in the near future. We plan to monitor the lake in alternate years beginning in 1973.

SUMMARY

1. Limnological studies of Lake Thonotosassa, Florida were initiated in 1970 to document current conditions following 15 years of pollution by primarily treated sewage and citrus processing wastes, and to provide base-level data for a long-term study of the rates of change following the installation of a secondary sewage treatment plant to process both wastes. Samples for physical-chemical measurements were collected weekly and biological samples biweekly from January 1970 through January 1971.
2. Physical-chemical measurements showed marked differences between stations located on the inlet and stations in the lake. However, no differences were found between lake stations and a single station was used to represent the entire lake. The lake had a moderating effect upon the incoming waters; parameters did not fluctuate markedly as in the inlet. Thermal stratification and hypolimnetic oxygen deficits occurred in the deeper parts of the lake during summer. Transparency was low throughout the year and turbidity showed a positive correlation with the total volume of phytoplankton. Phosphate concentrations were extremely high but nitrate-nitrogen levels were low.
3. Densities of coliform bacteria were extremely high in the inlet (2.5×10^6 to 4.0×10^6 colonies/100 ml) prior to the opening of the secondary sewage treatment plant. At the same time, samples from the lake showed densities of 750 to 8,200/100 ml. Decreases of approximately two orders of magnitude accompanied the opening of the new sewage plant.
4. Gross primary production ranged from 0.21 to 2.27 g of C m^2/day. No correlations were observed between productivity rates and standing crops of phytoplankton or concentrations of major inorganic nutrients.
5. Phytoplankton volumes were comparable to those of highly eutrophic lakes and averaged 5.87 μL/L for the year. The populations were dominated by blue-green algae (*Anabaena spiroides* and

Oscillatoria sp.) which comprised 42.5% of the annual mean volume.

6. Zooplankton populations were dominated by small-bodied herbivores (rotifers and *Bosmina longirostris*). Rotifers (23 species) comprised 90.3% of the zooplankton.
7. The benthic fauna was dominated by oligochaetes and chironomids. The distribution and abundance of species varied with station depth, substrate composition, and dissolved oxygen levels. Larval densities of a few species were exceptionally high and adult chironomids *(Glyptotendipes paripes* and *Chironomus crassicaudatus)* reached nuisance proportions along the shoreline of the lake.
8. Eutrophication indices and their possible value as indicators of lake recovery are discussed.

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