Winter 1980

Benthic Macroinvertebrates in a Hydrilla Infested Central Florida Lake

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BENTHIC MACROINVERTEBRATES IN A HYDRILLA INFESTED CENTRAL FLORIDA LAKE

BY

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B.A., Wesleyan College, 1974

THESIS

Submitted in partial fulfillment of the requirements
for the degree of Master of Science: Biology
in the Graduate Studies Program
of the College of Natural Sciences at the
University of Central Florida; Orlando, Florida

Winter Quarter
1980

ABSTRACT

Benthic macroinvertebrates and physicochemical parameters were monitored simultaneously with hydrilla in a central Florida lake. Changes in the benthos were described in relation to plant growth. Twenty-seven of the 54 taxa of benthic macroinvertebrates collected were members of the Family Chironomidae. Chironomids and oligochaetes numerically dominated the benthos, comprising 82% of the individuals collected. The greatest numbers of species and individuals were found during the winter when hydrilla biomass was low. Hydrilla biomass ranged from 0.382 kg/m^2 in April, 1977 to 2.275 kg/m^2 in October, 1977. Low numbers of species and individuals were collected from bottom sediments during summer and fall. Dissolved oxygen concentrations at the bottom were approximately 2.0 ppm during summer and fall and possibly limited benthic organisms. The annual means for the Shannon and Simpson Indices for the benthos were 1.92 and 0.36, respectively.

ACKNOWLEDGMENTS

I am grateful to Dr. John A. Osborne for providing research opportunities and guidance. I am most thankful to Mr. Donald Schmitz for his invaluable assistance and his partnership when sampling. I gratefully acknowledge Mr. Jerrel Daigel for his instruction in benthos identification. I thank Drs. Franklin F. Snelson, Jr. and Roseann S. White for their guidance and their review of the manuscript. Finally, I am indebted to Dr. I. Jack Stout for his counseling and encouragement. I express my deepest appreciation to my husband, Patrick Killian, for his love and patience.

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INTRODUCTION

Benthic macroinvertebrates function on several trophic levels in freshwater ecosystems. As herbivores and carnivores, they feed on living tissues of vascular plants, algae and other invertebrates (Cummins, 1973; Brinkhurst, 1974). Benthic macroinvertebrates serve as a primary food source for many fish (Ball and Hayne, 1952; Gerking, 1962). As detritivores, they are involved in recycling of organic matter (Brinkhurst and Jamieson, 1971).

Benthic macroinvertebrates have various requirements for growth and reproduction. Their distribution in freshwater is affected by such factors as water quality, type of bottom sediment and diversity and abundance of plants (Wetzel, 1975). For example, it has been observed that more species of benthic macroinvertebrates are in littoral zones of lakes than in profundal zones (Rosine, 1955; Cole and Underhill, 1965; Jonasson, 1969). Due to the presence of plants, the littoral zone is a more diverse habitat than the bottom sediment of the profundal zone. Numerous investigators have reported that the abundance and diversity of macroinvertebrates is dependent on the species, distribution and abundance of aquatic macrophytes (Macan, 1961; Petre, 1968; McLachlan, 1969, 1975). In a detailed analysis of nutrient rich experimental ponds, Hall, et al. (1970) reported that the benthic community shifted from large bottom dwellers to small mobile browsers when Elodea canadensis and Potamogeton sp. replaced Chara.

Hydrilla verticillata Royle, an exotic submerged aquatic macrophyte, was introduced into South Florida in the early 1960's. By 1967, it was found throughout Florida and has now spread into Georgia, Alabama, Louisiana, Texas, Mississippi, California and Iowa (Blackburn, et al., 1969; Haller, 1976). In early spring hydrilla grows rapidly from apical meristem fragments, roots, tubers or turions. By efficiently utilizing carbon dioxide and light it spreads throughout the water column forming dense surface mats by late summer (Haller, 1976; Bowes, et al., 1977). Extensive growths of hydrilla may alter the dynamics of a lake by contributing significantly to factors such as oxygen, pH, alkalinity, food supply, habitat and nutrients (Steward, 1970; Steward and Elliston, 1974; Haller and Sutton, 1975; Bowes, et al., 1977). These factors relate directly to the diversity and abundance of benthic macroinvertebrates.

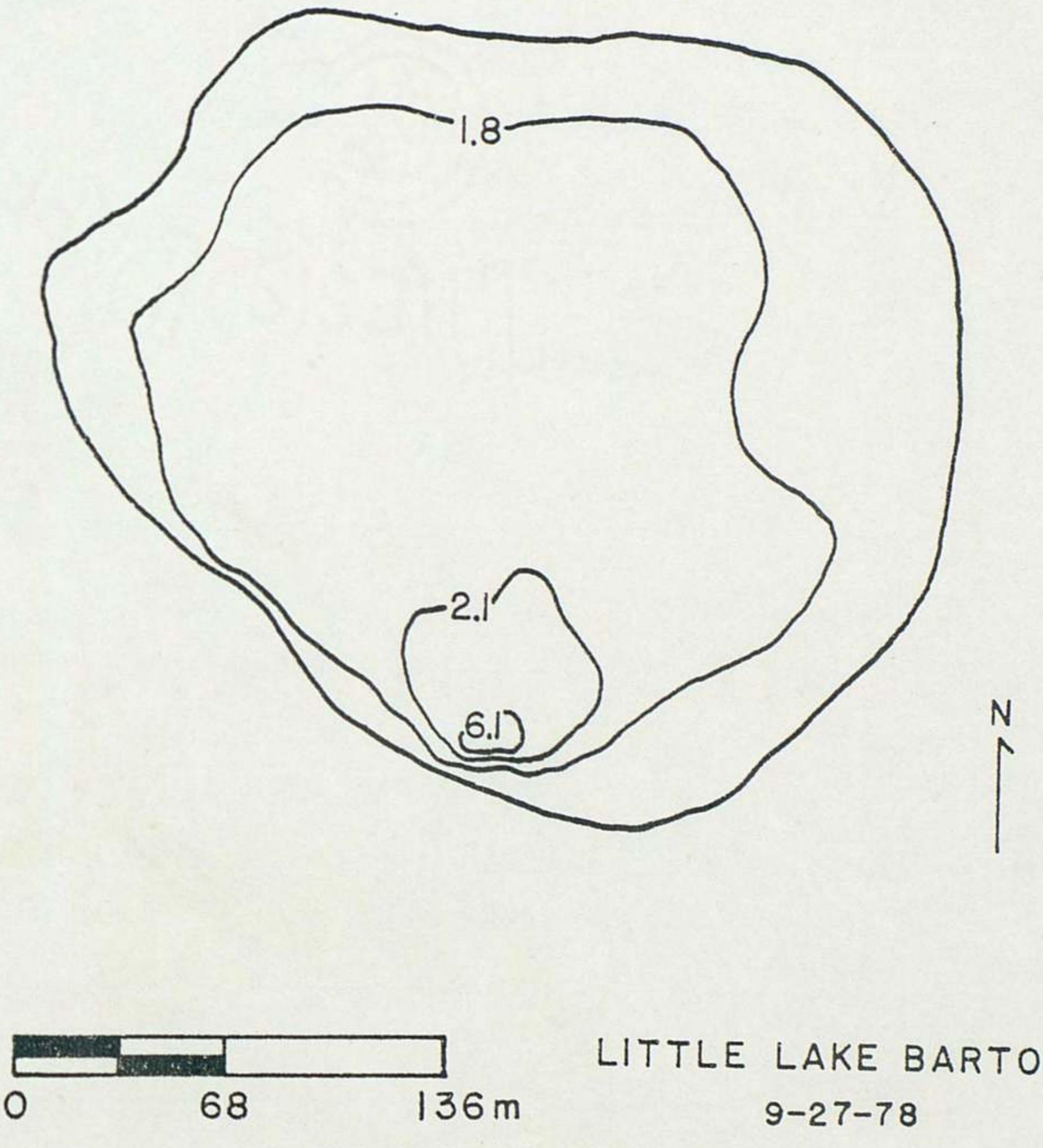
The objective of this study was to describe the diversity and abundance of benthic macroinvertebrates as related to the growth of hydrilla in a central Florida lake.

METHODS AND MATERIALS

Little Lake Barton, a solution basin located in Orlando, Florida (latitude: $28^{\circ}36'$N; longitude: $81^{\circ}22'$W), has a surface area of 5.42 ha and a mean depth of 1.63 m (Figure 1). The lake is nearly circular with a shoreline development of 1.04 and volume development of 0.77. Bottom sediment is composed of sand overlaid by sapropel. Runoff into the lake is from surrounding lawns, roadways and commercial areas; the soil of the drainage area consists of excessively to moderately drained fine sands (Leighty, 1960).

Hydrilla has infested Little Lake Barton for approximately seven years. During the study it dominated the littoral and profundal zones of the lake. Little Lake Barton was stocked with grass carp by the Florida Department of Natural Resources in October, 1976 (32 fish/ha) and in October, 1977 (15 fish/ha) for hydrilla control. From October, 1976 to October, 1978 hydrilla biomass decreased 45% due to feeding of grass carp (Osborne and Sassic, 1979). Other less abundant littoral plants in Little Lake Barton were *Typha latifolia* L., *Sagittaria latifolia* Willd., *Pontederia lanceolata* L., *Nuphar luteum* (L.), and *Eichhornia crassipes* (Mart.) Solms.

Figure 1. Bathymetric map of Little Lake Barton.



LITTLE LAKE BARTON

9-27-78

Physicochemical measurements were taken monthly from January to December, 1977 at six random stations. Water samples were collected with a 1.2 L Kemmerer water sampler at 1.0 m below the surface.

Water temperature was measured at 0.5 m intervals in the water column with a YSI Model 44 telethermometer. Visible light penetration was determined with a standard black and white 20 cm Secchi disc. Color and turbidity were measured spectrophotometrically using a Beckman Model 26 spectrophotometer with the procedures outlined in Environmental Protection Agency (1974) and American Public Health Association (1971). Depth was measured at each station with a weighted line.

Hydrogen-ion concentration was determined with a Sargent-Welch pH meter; carbonate, bicarbonate and total alkalinity were determined by titration (American Public Health Association, 1971). Inorganic carbon was calculated by using alkalinity and pH data (Bachmann, 1959). Specific conductivity was taken with a YSI Model 33 specific conductivity meter.

Dissolved oxygen concentrations were determined with a YSI BOD probe and meter at 1.0 m below the surface and at the bottom; the meter was calibrated with the modified azide Winkler method (American Public Health Association, 1971). Orthophosphate concentrations were measured spectrophotometrically with the ascorbic acid-ammonium molybdate method (American Public Health Association, 1971). Nitrate nitrogen was determined using the brucine method (Environmental Protection Agency, 1974). Nitrite nitrogen was determined by procedures outlined in Standard Methods for the Examination of Water and Wastewater (American Public Health Association, 1971).

Algae was filtered from water samples onto glass fiber filters (pore size = 0.45 mμ). Chlorophyll pigment was extracted from the filters in 10 ml of acetone for 48 hr at 4 C. Chlorophyll concentrations were calculated by the equation of Richards with Thompson (1959).

Hydrilla was collected bimonthly at twenty random stations from February to December, 1977. A submersed aquatic plant sampler was used to obtain samples (Osborne and Sassic, 1979). Samples were washed in nylon bags and spun at 540 rpm for 4 minutes in a garment washer to remove excess water. Fresh weight biomass (kg/m^2) was determined to the nearest 0.001 kg.

Benthic macroinvertebrates were collected monthly at six random stations with a 0.0225 m^2 tall-form Ekman grab. Two samples per station were pooled and washed through a #30 mesh sieve. Organisms were hand-picked live from washed samples under light and magnification using a dilution technique and preserved in 90-5-5% solution of ethyl alcohol, formalin and water. Chironomidae larvae were permanently mounted on glass slides for identification

(Beck, 1976). Identification was accomplished with Berner (1950), Pennak (1953), Needham and Westfall (1955), Ward and Whipple (1959), Beck and Beck (1966, 1969), Parrish (1968), Usinger (1968), Mason (1968) and Beck (1976). The Shannon Index for species diversity ($\bar{d}$) and the Simpson Index for dominance (SI) were used to determine changes in benthic community structure. Enumeration data per species were used to calculate the indices as follows: $\bar{d} = -\Sigma(n_i/N) \log_2(n_i/N)$ and $SI = \Sigma n_i(n_i-1)/N(N-1)$ where n_i equals the number of individuals of the ith species and N equals the number of individuals of all species (Simpson, 1949; Wilhm and Dorris, 1968).

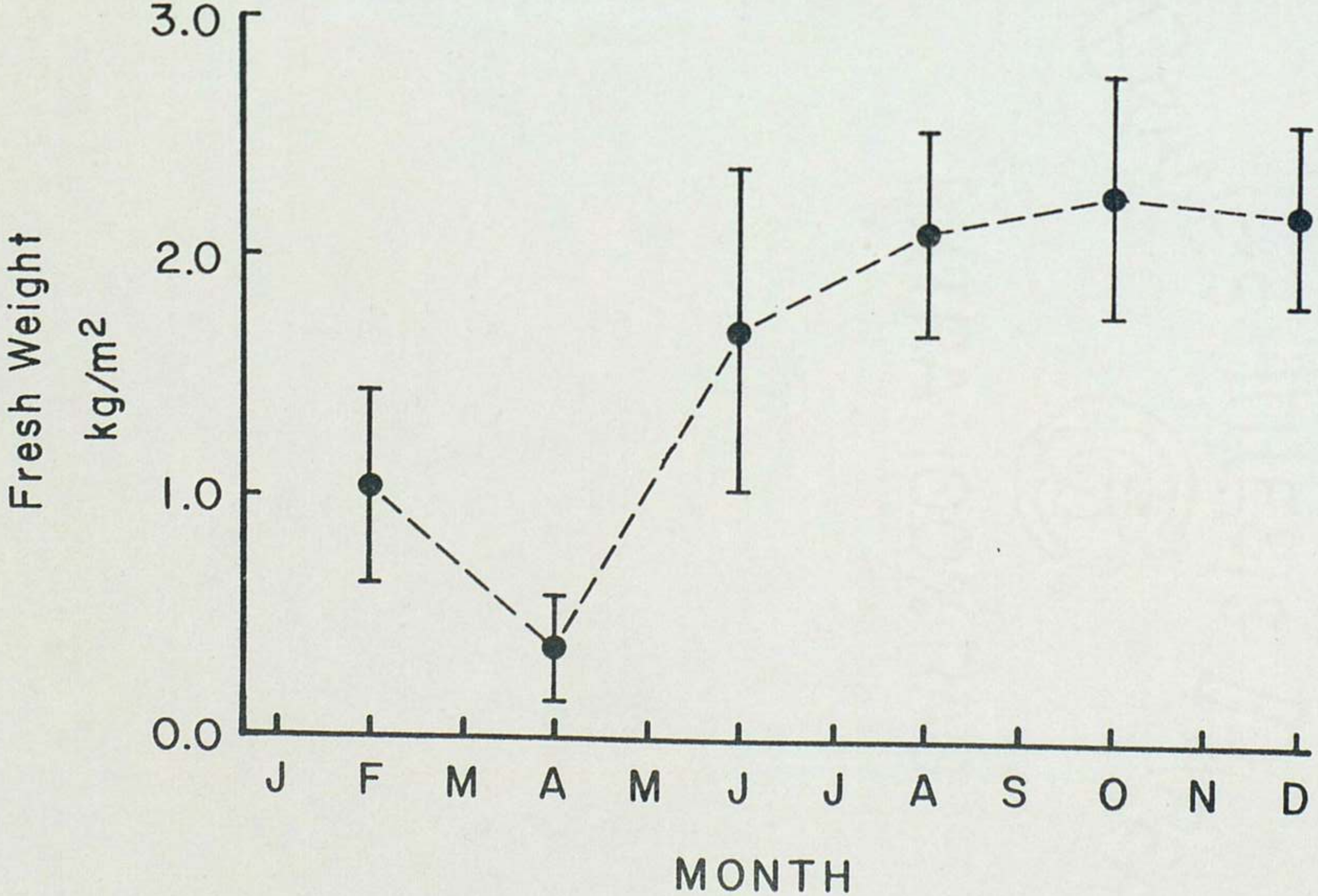
RESULTS AND DISCUSSION

Description of the Environment

Hydrilla biomass declined in winter and was lowest in April, 1977 (0.382 kg/m^2) (Figure 2). The decline of hydrilla in winter was probably due to cooler water temperatures, a decrease in solar radiation and grazing by grass carp. Water temperatures were lowest in January and February, 1977 (Table 1). As the water warmed in the spring, hydrilla biomass increased exponentially to a seasonal maximum in October, 1977 (2.275 kg/m^2) (Figure 2). Water temperatures were relatively uniform from surface to bottom in Little Lake Barton during summer and fall; hydrilla formed dense surface mats during these seasons (Table 1). Monthly mean water temperature was highest in June, 1977 (30.9 C at the surface and 30.0 C at the bottom).

Light penetrated to the bottom in Little Lake Barton during summer and in areas where matting of hydrilla did not occur (Table 1). From June to November, 1977, light transmission was greatest, and turbidity and color were low (Table 1). By absorbing nutrients usually available for phytoplankton and by reducing water circulation, the summer growth of hydrilla probably aids in decreasing turbidity. During winter when hydrilla biomass was low, turbidity and color were high (Table 1). Turbidity was highest in April,

Figure 2. Monthly mean hydrilla biomass and 95% confidence limits in Little Lake Barton from February to December, 1977.



Fresh Weight
kg/m2
3.0
2.0
1.0
0.0
J F M A M J J A S O N D
MONTH

Table 1. Monthly and annual mean values for physicochemical and chlorophyll parameters in Little Lake Barton from January to December, 1977.

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual
Surface temperature (C)	14.3	14.7	26.0	25.1	26.7	30.9	30.3	29.4	27.9	19.8	19.1	18.4	23.6
Bottom temperature (C)	11.7	14.0	24.0	24.9	25.8	30.0	28.9	28.5	26.3	19.6	17.4	15.9	22.2
Secchi transparency (cm)	123	103	118	84	123	*	*	*	208	*	*	195	125
Color (Pt-Co units)	30.1	31.3	24.3	21.1	18.2	13.0	9.9	11.7	11.4	12.5	13.0	14.7	17.6
Turbidity (FT units)	1.3	1.8	2.2	4.9	3.4	0.5	0.6	0.8	1.2	0.4	0.2	0.8	1.5
Dissolved oxygen at surface (ppm)	9.6	9.6	7.1	8.0	9.9	8.3	9.6	8.0	4.3	3.1	7.2	9.3	7.8
Dissolved oxygen at bottom (ppm)	8.1	9.0	5.4	7.9	9.7	7.7	6.6	5.7	1.8	2.0	3.0	6.8	6.1
pH	7.8	7.3	7.2	8.1	8.7	9.2	9.0	9.2	7.1	7.4	7.8	7.9	8.1
Carbonate alkalinity (ppm $CaCO_3$)	0.0	0.0	0.0	0.0	10.7	15.3	12.3	13.3	0.0	0.0	1.7	0.0	4.4
Bicarbonate alkalinity (ppm $CaCO_3$)	77.9	78.6	77.3	79.5	53.2	27.5	22.7	19.0	51.3	68.3	53.5	58.0	55.6
Total alkalinity (ppm $CaCO_3$)	77.9	78.6	77.3	79.5	63.8	42.8	35.0	32.3	51.3	68.3	55.2	58.0	60.0
Inorganic carbon (ppm)	19.5	21.7	22.1	19.5	15.1	9.8	8.1	7.4	16.1	18.1	14.5	14.4	15.5
Specific conductivity (micromhos/cm at 25 C)	165	171	221	220	195	173	153	144	158	159	147	149	171
Orthophosphate (ppm)	0.016	0.010	0.014	0.009	0.003	0.004	0.002	0.005	0.001	0.001	0.001	0.002	0.006
Nitrate nitrogen (ppm)	0.070	0.050	0.093	0.075	0.072	0.100	0.072	0.068	0.067	0.059	0.073	0.068	0.072
Nitrite nitrogen (ppm)	0.012	0.013	0.013	0.012	0.011	0.012	0.015	0.011	0.012	0.014	0.014	0.013	0.013
Chlorophyll (mg/m^3)	81.6	58.5	45.6	23.9	24.9	9.7	4.6	4.7	3.3	3.5	2.5	5.4	22.4

* Secchi disc was visible on the lake bottom.

1977 (4.9 FT units), while color was highest in February, 1977 (31.1 Pt-Co units) (Appendix I, Figures 6 and 7). The annual mean color value for Little Lake Barton was 17.6 Pt-Co units. This value was similar to those reported by Shannon and Brezonik (1972) and Nordlie (1976) for clear alkaline central Florida lakes. Very clear lakes yield color values that approach 0.0 Pt-Co units (Wetzel, 1975).

Chlorophyll concentrations were high in winter when hydrilla biomass was low and decreased with growth of hydrilla. Chlorophyll concentrations remained low through summer and fall (Appendix I, Figure 8). Dense stands of submerged macrophytes inhibit the growth of phytoplankton by successfully competing for light and nutrients (Hasler and Jones, 1949; Stangeberg, 1968; Goulder, 1969).

Total alkalinity and inorganic carbon decreased while pH increased in Little Lake Barton during the summer growing season (Appendix I, Figures 9, 10 and 11). Alkalinity in Little Lake Barton was primarily due to the presence of bicarbonate ions (Table 1). Carbonate alkalinity was present only from May to August and in November, 1977 (Table 1). Bicarbonate alkalinity was lowest in summer (Appendix I, Figure 12). The decrease in bicarbonate alkalinity during the height of the growing season was probably due to the utilization of bicarbonate ions for photosynthesis by hydrilla. Many submerged angiosperms and macroalgae have the ability to assimilate bicarbonate ions (Raven, 1970). Steward and Elliston (1974) found that sodium bicarbonate caused an enhancement of hydrilla growth. A sharp rise in total alkalinity and inorganic carbon occurred between September and October, 1977, at a time when hydrilla biomass was highest (Appendix I, Figures 9 and 10). This abrupt change in the bicarbonate alkalinity may have been caused by respiration of hydrilla. In hard water environments specific conductivity varies proportionally with bicarbonate and carbonate alkalinity (Otsuki and Wetzel, 1974). Seasonal variations in specific conductivity in Little Lake Barton patterned changes in alkalinity (Appendix I, Figure 13). Specific conductivity was highest in April, 1977 (220 micromhos/cm at 25 C) as was alkalinity. During summer and fall specific conductivity was lowest (Table 1).

Orthophosphate, nitrate and nitrite nitrogen concentrations were relatively low during the study (Table 1). The annual mean concentration for orthophosphate was 0.006 ppm; nitrate nitrogen was 0.072 ppm and nitrite nitrogen was 0.013 ppm. Orthophosphate concentrations peaked in winter when hydrilla biomass was low but decreased with growth of hydrilla in the late spring and summer (Appendix I, Figure 14). Tissue contents of phosphorus in hydrilla have been reported to be directly related to solution levels of the mineral (Steward and Elliston, 1974). Although differences in nitrate and nitrite nitrogen concentrations were observed between months, seasonal patterns were not evident in Little Lake Barton (Appendix I, Figures 15 and 16).

Accelerated photorespiration in the water column caused by dense mats of vegetation may cause a depletion of dissolved oxygen in littoral zones of lakes (Penfound, 1956; Busemi, 1958; Hough, 1974). Dense mats of hydrilla reduced water circulation and light penetration in Little Lake Barton during summer and fall, and influenced dissolved oxygen concentrations. Dissolved oxygen concentrations at the bottom were at or below 2.0 ppm (approximately 20% saturation) in September and October, 1977 (Table 1). Dissolved oxygen may have been limiting to benthic organisms during summer and fall. Concentrations between 1.0 and 2.0 ppm dissolved oxygen (10-15% saturation) are lethal to a majority of benthic macroinvertebrates (Wetzel, 1975). In winter and spring when hydrilla biomass was low dissolved oxygen concentrations were highest (Appendix I, Figures 17 and 18).

Benthic Macroinvertebrates

A total of 54 taxa of benthic macroinvertebrates was collected from Little Lake Barton during the study (Table 2). Classification of the benthos is given in Appendix II. Twenty-seven of the 54 taxa were members of the Chironomidae. Chironomids and oligochaetes numerically dominated the benthos; Chironomids comprised 60% of the organisms while oligochaetes accounted for 22%. Generally, chironomids and oligochaetes dominate the benthic community of eutrophic lakes (Pennak, 1953; Gaufin and Tarzwell, 1955; Beck, 1969; Brinkhurst and Jamieson, 1971). The most abundant species in Little Lake Barton were Chironomus stigmaterus, Nais sp., Limnodrilus hoffmeisteri, Chaoborus punctipennis, Dicrotendipes sp., Nimbocera sp. and an unidentified species of Hydracarina (Table 2). Turbificid worms, particularly Limnodrilus hoffmeisteri, are common in lakes which are organically polluted. Members of Hydracarina are most abundant in lakes with rooted vegetation such as Little Lake Barton (Pennak, 1953). The chironomids and Chaoborus punctipennis are adapted to low oxygenated waters and are common in eutrophic lakes in Florida (Provost, 1958; Beeton, 1965; Beck and Beck, 1969; Cowell, et al., 1975).

The greatest number of individuals and species of benthic macroinvertebrates occurred during winter in Little Lake Barton (Figure 3). The numbers of individuals as well as numbers of species declined in early spring and remained low until late fall. Peak numbers in February, 1977 were caused primarily by an increase in Chironomidae larvae (6881/m^2), declined in spring and remained low throughout the summer (Table 2). Chaoborus punctipennis and Hydracarina followed seasonal trends similar to the chironomids, with maximum winter populations and low summer populations

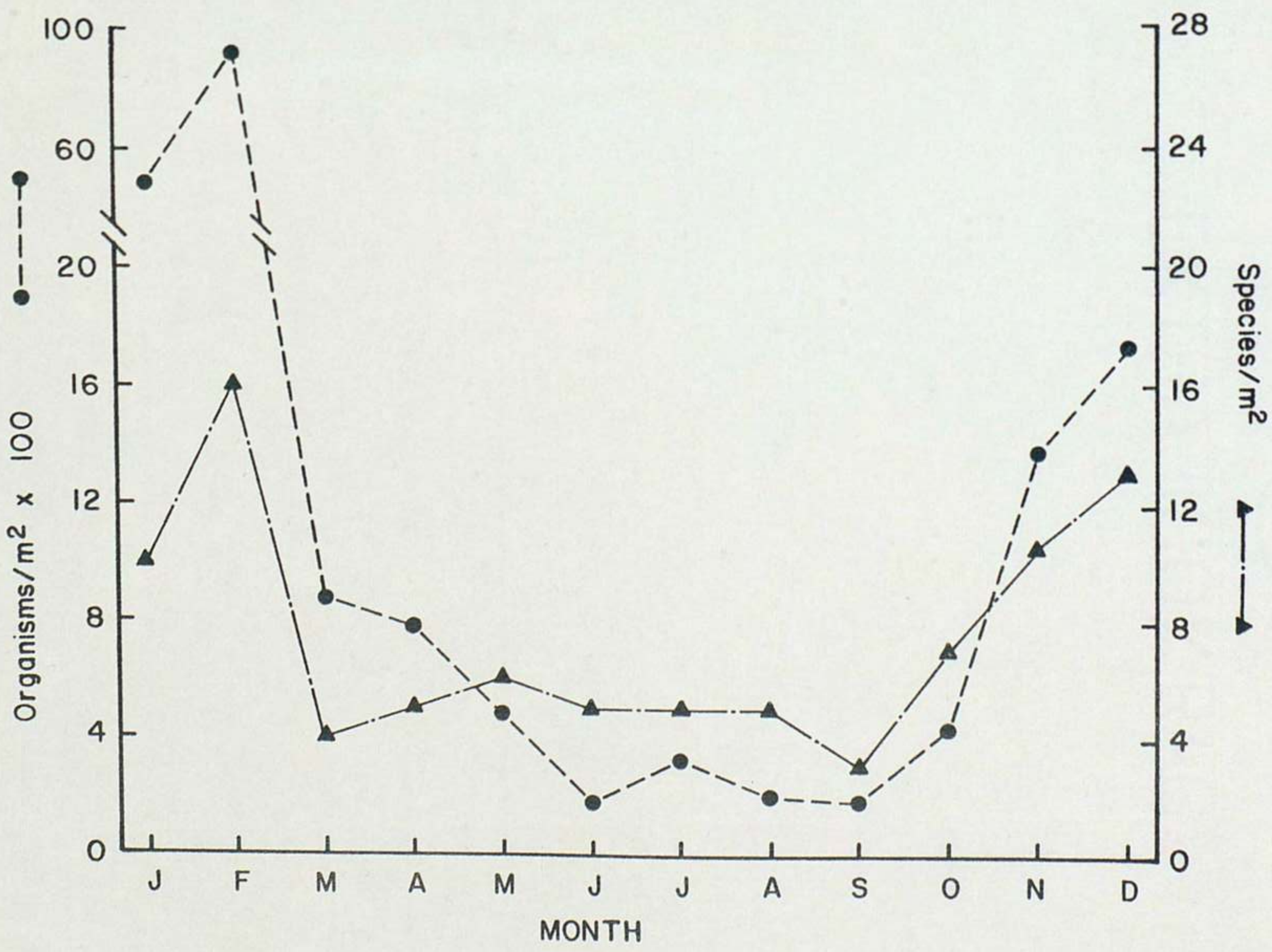
(Table 2).

The low numbers of species and individuals during summer in Little Lake Barton were probably due to the emergence of nymphs and Chironomidae pupae and/or a result of low oxygen concentrations. Bottom dwellers with high respiratory demands (e.g. Hyalella azteca) would have to migrate upward in the water column to avoid low oxygen concentrations. During summer when oxygen concentrations were low in Little Lake Barton, hydrilla may have acted as an alternative habitat for benthic macroinvertebrates. Martin and Shireman (1976) found that chironomids, Gyralus sp. (a pulmonate snail), Hyalella azteca (an amphipod), mayfly nymphs and caddisfly larvae were abundant in hydrilla during summer in Lake Wales, a central Florida lake. Chironomids increased in abundance from 142/kg of hydrilla in May, 1976 to 865/kg of hydrilla in September, 1976 in Lake Wales. Gyralus sp., mayfly nymphs and caddisfly larvae were most abundant during winter in Little Lake Barton, as were chironomids, and were found in very few numbers during summer (Table 2). Hyalella azteca was only collected in May, 1977 ($4/m^2$). Hyalella azteca and Gyralus sp. do not emerge and leave the environment like most aquatic insects; therefore, their continued abundance would be expected throughout the summer in Little Lake Barton. Hyalella azteca normally reach maximum population density in bottom sediments of temperate lakes during

Table 2. Monthly and annual mean munbers (organisms/m²) of benthic macroinvertebrates collected in Little Lake Barton from January to December, 1977.

	Numbers of organisms/m²												
Organisms	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual
Oligochaeta													
Limnodrilus hoffmeisteri	318	56	7	4	4	4	11	30	70	26	130	78	61
Nais sp.	1932	951	7	70	82	33	0	30	0	41	270	215	302
Hirudinea													
Dina parva	0	0	0	0	4	0	0	0	0	0	0	0	<1
Placobdella phalera	0	0	0	0	4	0	0	0	0	0	0	0	<1
Helobdella sp.	0	0	0	0	0	4	0	0	0	0	0	0	<1
Hydracarina													
Unknown species	233	888	11	0	167	52	63	26	19	78	26	67	136
Crustacea													
Hyalella azteca	0	0	0	0	4	0	0	0	0	0	0	0	<1
Palaemontes paludosus	0	4	0	0	0	4	0	0	0	0	0	0	<1
Insecta-Diptera													
Ablabesymia peleenis	30	26	0	0	0	4	0	4	0	11	4	19	8
Labrundinia neopilosella	0	0	0	0	0	0	0	0	0	0	0	4	<1
Larsia berneri	0	11	0	0	0	0	0	0	0	0	0	0	1
Monopelopia boliekae	4	22	0	0	0	0	0	0	0	0	0	0	2
Procladius sublettei	0	4	0	4	0	4	4	33	0	78	0	22	12
Tanypus stellatus	0	4	0	0	0	4	0	0	0	0	0	0	<1
Brilla pax	0	0	0	0	0	0	0	0	0	4	0	4	<1
Cricotopus remus	4	0	0	0	4	4	4	0	0	0	11	15	4
Orthocladius sp.	0	0	0	0	0	0	0	0	0	0	4	0	<1
Psectrocladius sp.	0	0	0	0	0	0	0	0	0	0	4	26	3
Psectrocladius vernalis	7	7	0	0	0	0	0	0	0	0	4	4	2
Chironomus stigmaterus	1506	3304	237	459	93	26	0	0	0	37	107	514	524
Cryptochironomus fulvus	0	0	0	0	0	0	0	0	0	0	0	7	<1
Cryptocladopelma edwardsi	44	30	0	4	0	0	0	0	0	19	26	100	19
Dicrotendipes sp.	59	881	7	22	4	0	15	4	0	22	229	185	119
Einfeldia sp.	0	0	0	0	0	0	0	0	11	4	0	0	<1
Endochironomus nigricans	0	0	0	0	4	0	0	0	0	0	0	0	<1
Glyptotendipes paripes	15	89	0	0	0	0	0	0	0	15	45	30	16
Goeldichironomus holoprasinus	0	0	0	0	0	0	0	0	0	0	4	0	<1
Lauterborniella varipennis	0	0	0	0	0	0	4	0	0	0	0	0	<1
Parachironomus hirtalatus	163	111	4	0	11	0	11	33	30	19	48	41	39
Paralauterborniella elachista	0	0	0	0	0	0	0	0	0	0	4	0	<1
Polypedilum halterale	4	0	0	0	0	0	0	4	0	0	7	4	2
Pseudochironomus sp.	0	4	4	0	0	0	107	15	4	15	52	4	17
Cladotanytarsus sp.	0	4	0	78	0	0	11	0	0	7	11	7	10
Nimbocera sp.	4	2098	30	7	19	0	0	0	0	30	30	26	187
Tanytarsus spp.	0	318	0	0	0	0	59	0	4	11	285	89	64
Chaoborus punctipennis	448	237	544	104	63	30	0	15	30	15	33	115	136
Probezzia sp. 1	0	4	4	7	0	0	0	0	0	0	0	19	3
Probezzia sp. 2	0	0	0	0	11	7	0	4	4	0	0	7	3
Chrysops sp.	0	4	0	0	0	0	0	0	0	0	0	0	<1
Insecta-Ephemeroptera													
Callibaetis floridanus	0	4	0	0	0	0	0	0	0	0	0	0	<1
Caenis diminuta	15	18	4	0	15	0	4	0	0	0	7	11	6
Insecta-Odonata													
Enallagma sp.	0	0	0	0	4	0	0	0	0	0	0	0	<1
Perithemis seminole	4	7	4	4	0	0	0	4	0	0	11	11	4
Celithemis bertha	4	0	0	0	0	0	0	0	0	0	0	0	0
Insecta-Hemiptera													
Sigara sp.	0	22	0	0	0	0	0	0	0	0	0	0	2
Insecta-Coleoptera													
Hydrovatus sp.	0	4	0	0	0	0	4	0	0	0	0	0	<1
Insecta-Trichoptera													
Leptocella tavara	19	41	0	0	0	0	0	0	0	0	0	7	6
Oecetis sp.	0	4	0	0	0	0	0	0	0	0	0	0	<1
Orthotrichia sp.	15	15	0	4	4	0	11	0	0	0	0	11	5
Oxyethira sp.	0	0	0	0	0	0	0	0	0	0	19	33	4
Gastropoda													
Helisoma sp.	4	0	0	0	0	0	4	0	0	0	0	0	<1
Gyralus sp.	22	30	0	4	0	4	0	0	4	0	15	48	11
Physa sp.	0	0	0	0	0	0	11	0	0	0	0	0	1
Viviparus georgianus wareanus	0	0	0	0	4	0	0	0	0	0	0	0	<1
Total	4858	9195	859	771	501	180	323	202	176	432	1386	1723	-

Figure 3. Monthly mean numbers of organisms and species of benthic macroinvertebrates collected in Little Lake Barton from January to December, 1977.


Organisms/m² x 100
100
60
20
16
12
8
4
0
Species/m²
28
24
20
16
12
8
4
0
J
F
M
A
M
J
J
A
S
O
N
D
MONTH

summer (Hargrave, 1970). Populations of snails increase in spring, fall and summer as reproductive periods occur (DeWit, 1954; Harmon, 1974). Although caddisflies, mayflies and chironomids emerge during summer, higher numbers of these organisms can be expected in summer because of their fluctuating growth cycles (Pennak, 1953; Roback, 1974; Wetzel, 1975). Chironomus stigmaterus, for instance, emerges all year long in Florida lakes (Beck and Beck, 1969).

The Shannon Index is a measure of the species diversity of a community; the value $\bar{d}$ generally ranges from 0-4 in aquatic environments and approaches 0 when most individuals of a community belong to the same species (Wilhm and Dorris, 1968). The Simpson Index expresses the dominance of one or more species in a community and ranges from 0-1 (Simpson, 1949). Repetitive sampling of the same species results in a high Simpson Index and a low Shannon Index (Simpson, 1949; Wilhm and Dorris, 1968).

The annual mean Shannon Index for benthic macroinvertebrates in Little Lake Barton was 1.92 while the Simpson Index was 0.36. Osborne, et al. (1976) reported an annual mean Shannon Index of 1.92 and a Simpson Index of 0.38 for benthic macroinvertebrates in Spring Lake, a clean central Florida sand bottom lake. Although Shannon and Simpson Indices were similar between Little Lake Barton and Spring Lake, their species compositions were different. Benthic macroinvertebrate species in Spring Lake were dominated by Chironomidae, Trichoptera, Ephemeroptera and Odonata. The dominant species in Little Lake Barton were chironomids and oligochaetes. Chironomids and oligochaetes were also dominant in Lake Thonotosassa, a central Florida lake polluted by citrus processing and sewage effluent (Cowell, et al., 1975). However, diversity values were much lower for benthic macroinvertebrates in Lake Thonotosassa (less than 1.0) than in Little Lake Barton.

There was no significant difference (P = 0.05) between monthly mean values for the Shannon and Simpson Indices except between the months of February and March, 1977 (Figures 4 and 5). The low Shannon Index (0.75) in March, 1977 was the result of a decrease in numbers of species as well as individuals, possibly due to cold weather conditions in late February (Figure 3). Chaoborus punctipennis and Chironomus stigmaterus were dominant in March, 1977 and probably caused the high Simpson Index (0.78) for that month. In winter and spring, species diversity is usually higher than in summer due to good water quality, abundant food sources and the fact that many species emerge as adults in summer (Ransom and Dorris, 1972). Osborne, et al. (1976) reported diversity values lower than 2.0 for six oligotrophic lakes in central Florida during summer. Low diversity values were attributed to low species numbers,

Figure 4. Monthly means (± 95% confidence limits) of the Shannon Index for benthic macroinvertebrates in Little Lake Barton, January to December, 1977.

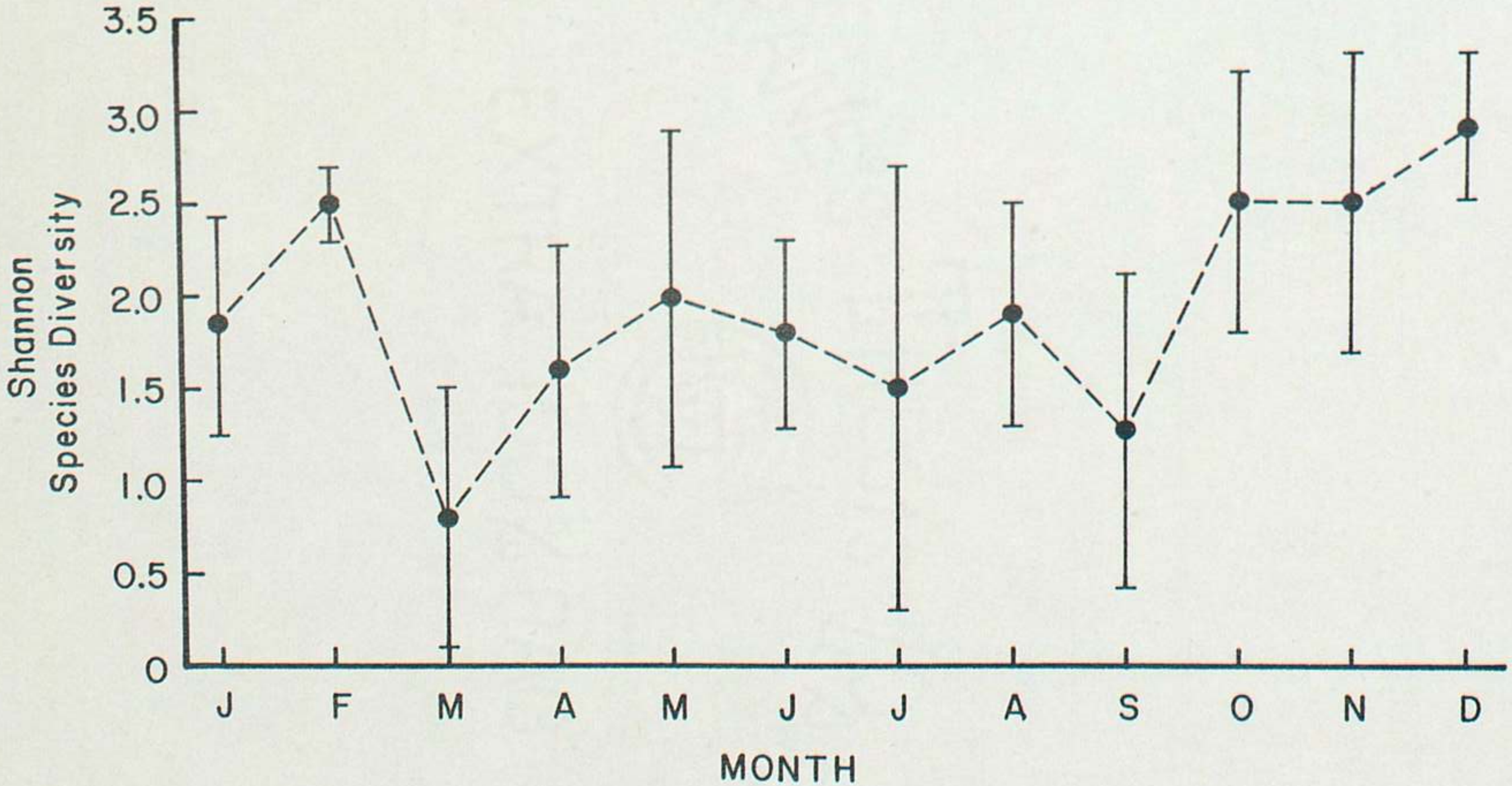
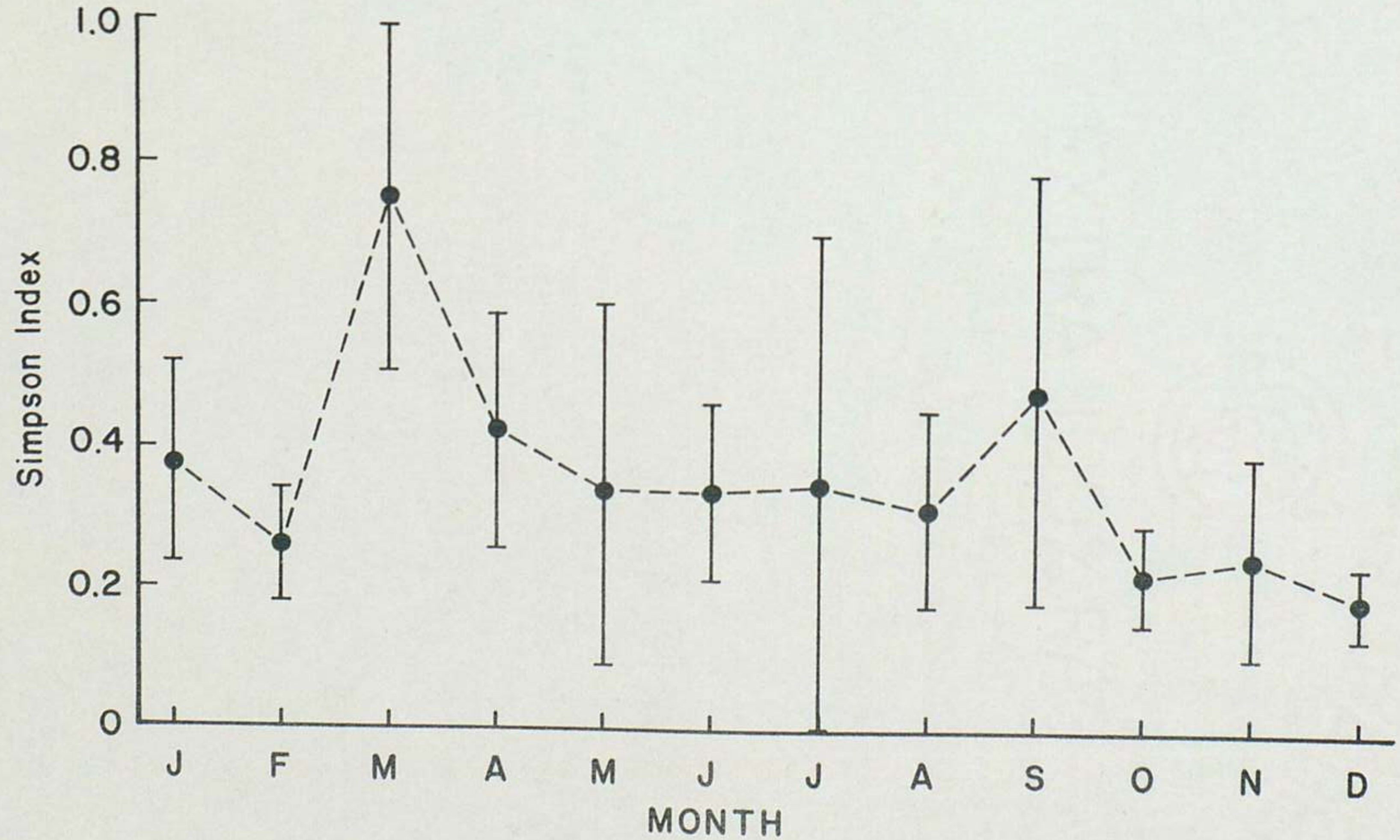

Shannon
Species Diversity
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0
J
F
M
A
M
J
J
A
S
O
N
D
MONTH

Figure 5. Monthly means ($\pm$ 95% confidence limits) of the Simpson Index for benthic macroinvertebrates in Little Lake Barton, January to December, 1977.


1.0
0.8
0.6
0.4
0.2
0
Simpson Index
J
F
M
A
M
J
J
A
S
O
N
D
MONTH

resulting from summer stress conditions. The low number of species and number of individuals of the species in Little Lake Barton may have resulted from many of the benthic macroinvertebrates inhabiting hydrilla instead of residing in the sediment. Summer emergence and summer stress conditions probably aided in causing low diversity.

SUMMARY

The growth of hydrilla influenced changes in oxygen concentrations, alkalinity, inorganic carbon, nutrients, pH, turbidity, color and light penetration in Little Lake Barton, Florida. These physicochemical factors affected the species diversity and abundance of benthic macro-invertebrates. During winter when hydrilla biomass was low, total alkalinity and inorganic carbon concentrations were high while pH was low. Chlorophyll concentrations increased since nutrients utilized in hydrilla metabolism during the growing season were available for phytoplankton growth. This higher phytoplankton density in winter caused increased turbidity and color. Hydrilla grew rapidly when water temperatures increased in spring. By summer the lake was covered with dense mats of hydrilla which reduced water circulation and light penetration to the bottom. As phytoplankton populations decreased, turbidity decreased. Total alkalinity and inorganic carbon decreased while pH increased.

Species diversity and abundance of benthic macro-invertebrates was greatest in winter. Chironomids and oligochaetes numerically dominated the benthos; twenty-seven of the 54 taxa collected were members of the Chironomidae

family. Species diversity and abundance of benthic macroinvertebrates were lowest in summer. Although many benthic macroinvertebrates emerge as adults in summer, some may have life cycles that fluctuate enough to produce substantial larvae numbers during summer. Low species diversity and abundance may have resulted from organisms with high respiratory demands inhabiting hydrilla instead of bottom sediments during stressful conditions. Oxygen conditions were often below tolerance levels for many benthic macroinvertebrates during late summer and early fall when shading by hydrilla reduced community photosynthesis.

Appendix I. Monthly means of physicochemical and chlorophyll parameters in Little Lake Barton, January to December, 1977.

Figure 6. Monthly mean values ($\pm$ 95% confidence limits) for turbidity from January to December, 1977 in Little Lake Barton.

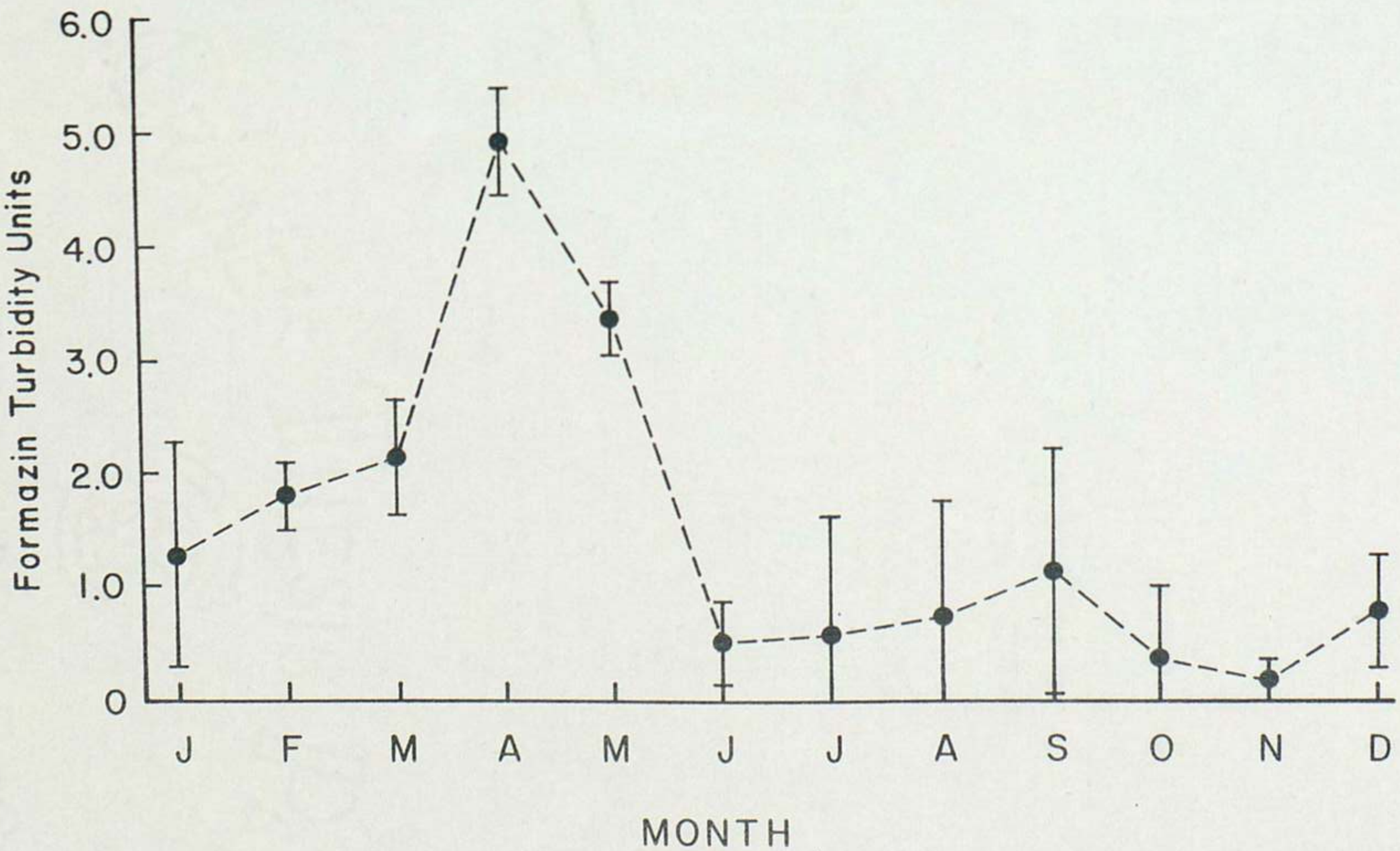

Formazin Turbidity Units
6.0
5.0
4.0
3.0
2.0
1.0
0
J
F
M
A
M
J
J
A
S
O
N
D
MONTH

Figure 7. Color monthly mean values ($\pm$ 95% confidence limits) in Little Lake Barton, January to December, 1977.

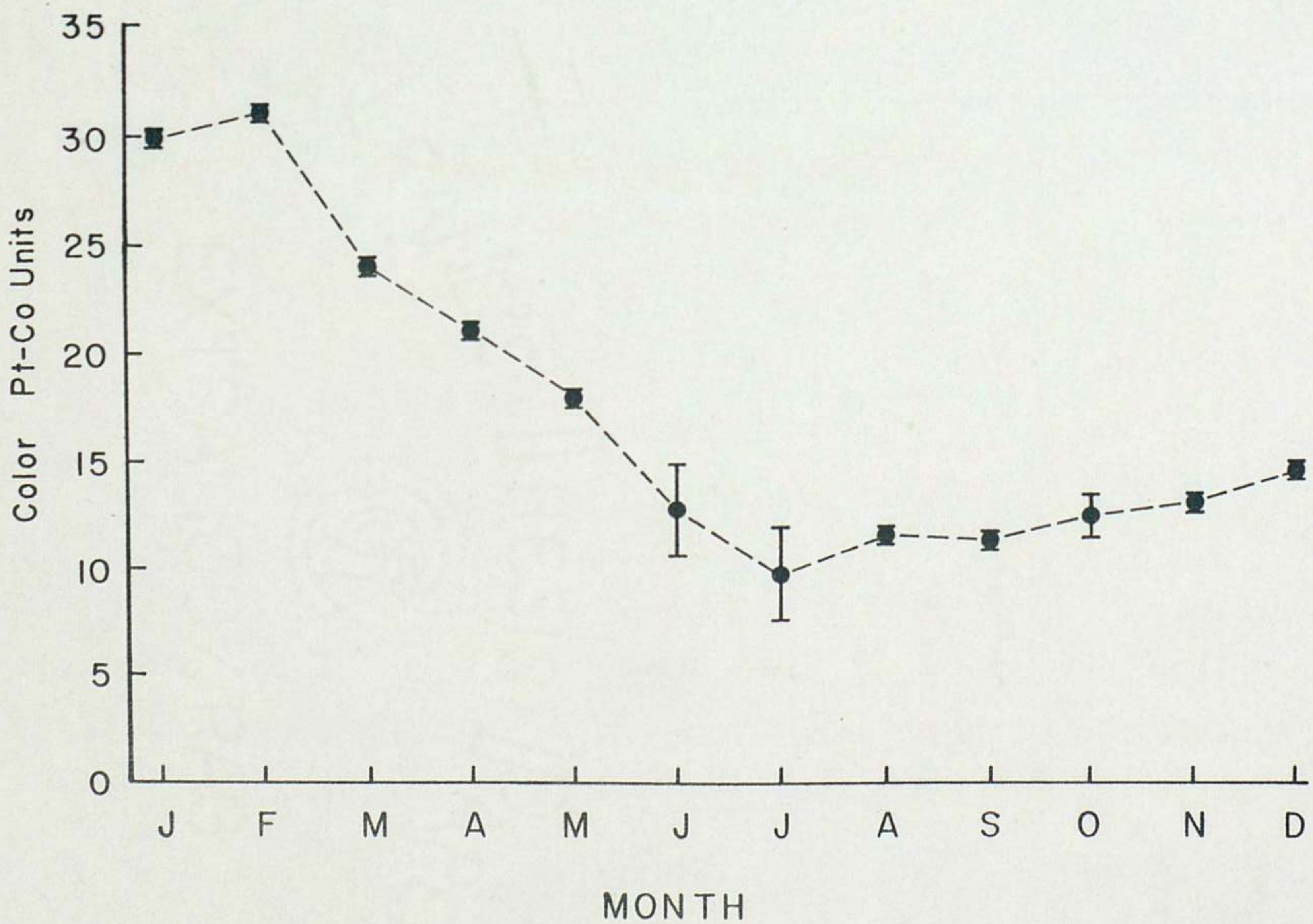

Color Pt-Co Units
35
30
25
20
15
10
5
0
J
F
M
A
M
J
J
A
S
O
N
D
MONTH

Figure 8. Monthly means and 95% confidence intervals for chlorophyll concentrations in Little Lake Barton from January to December, 1977.

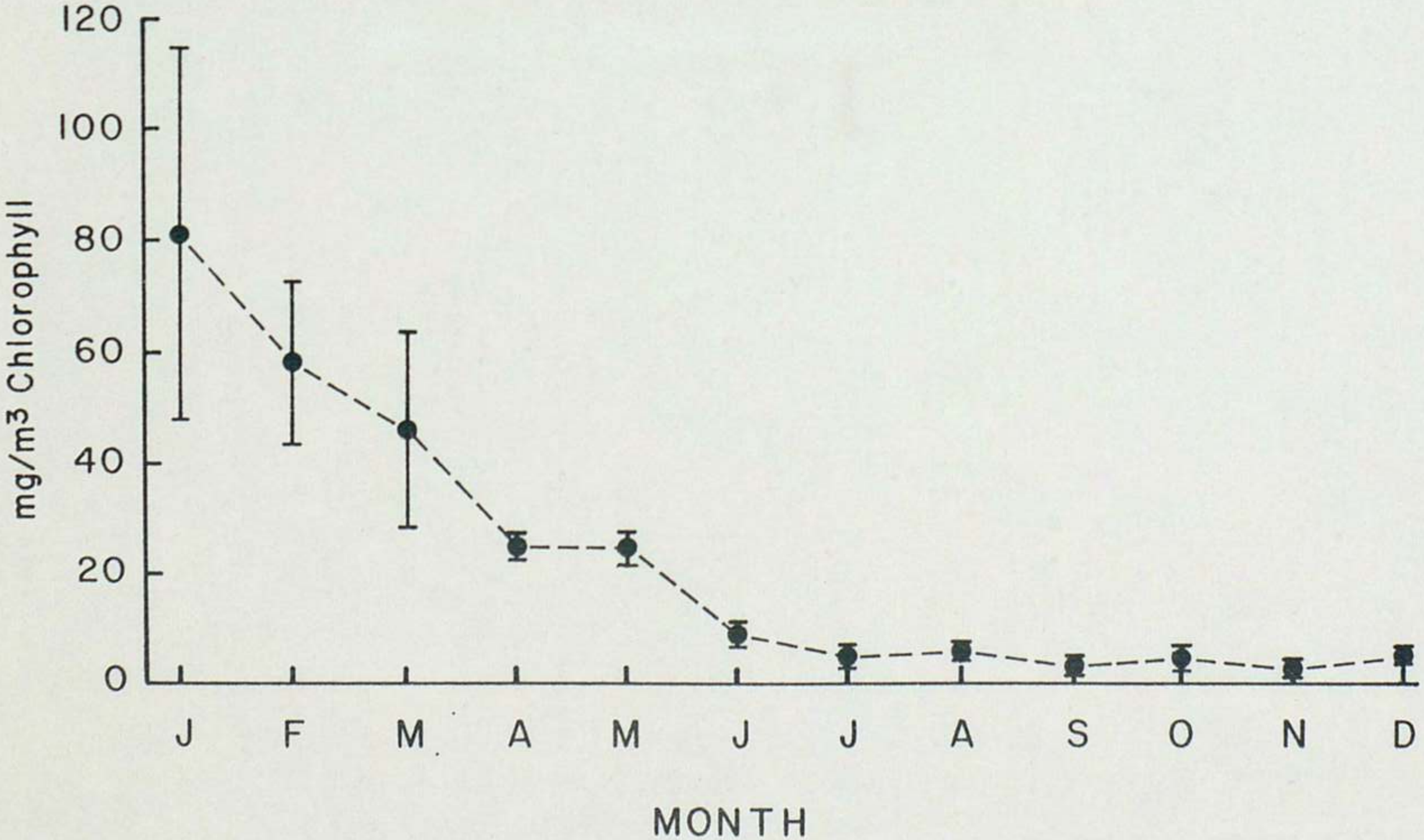

mg/m3 Chlorophyll
120
100
80
60
40
20
0
J
F
M
A
M
J
J
A
S
O
N
D
MONTH

Figure 9. Total alkalinity monthly means ($\pm$ 95% confidence limits) in Little Lake Barton, January to December, 1977.

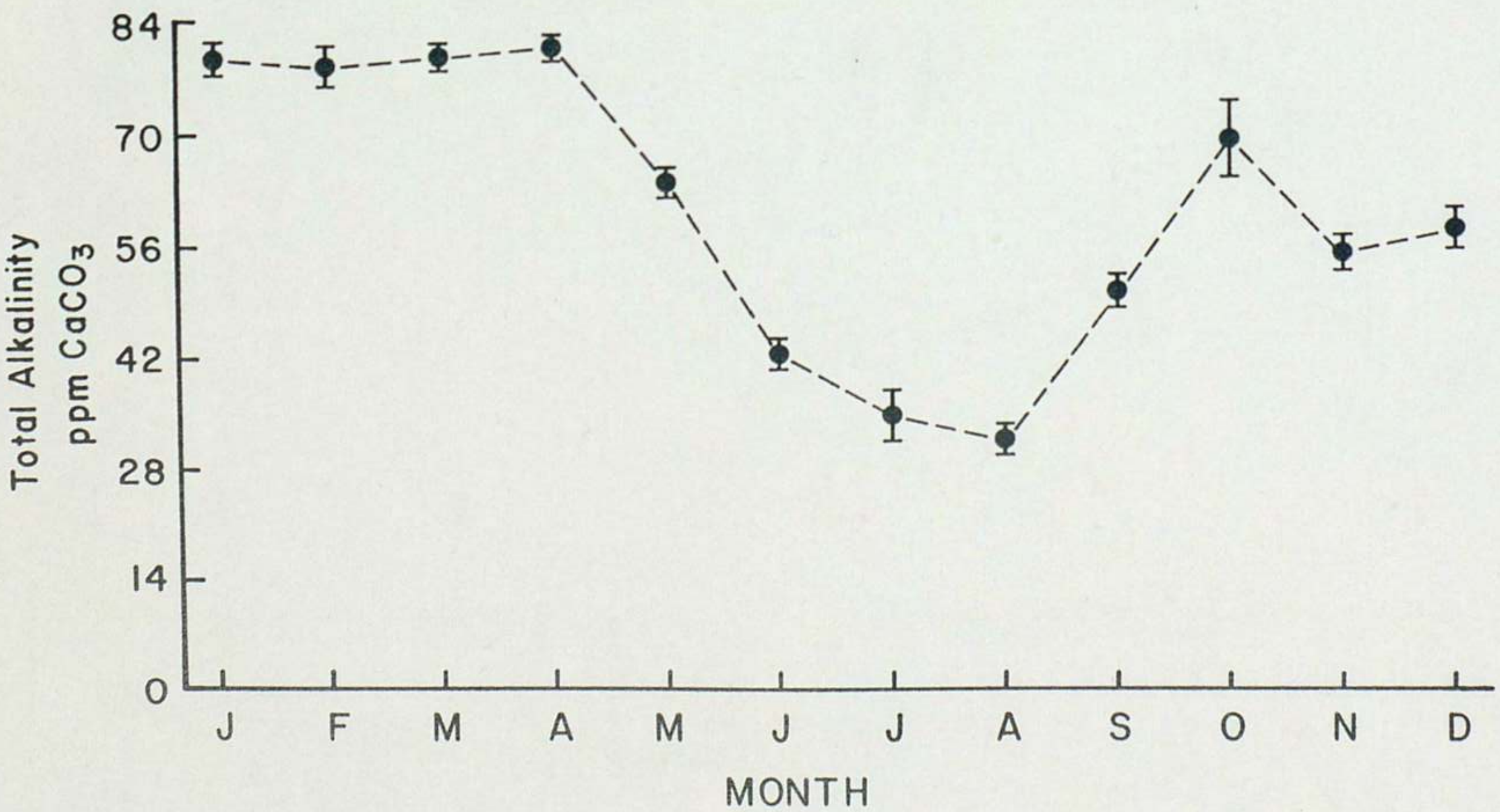

Total Alkalinity
ppm CaCO3
84
70
56
42
28
14
0
J
F
M
A
M
J
J
A
S
O
N
D
MONTH

Figure 10. Inorganic carbon monthly means and 95% confidence limits in Little Lake Barton from January to December, 1977.

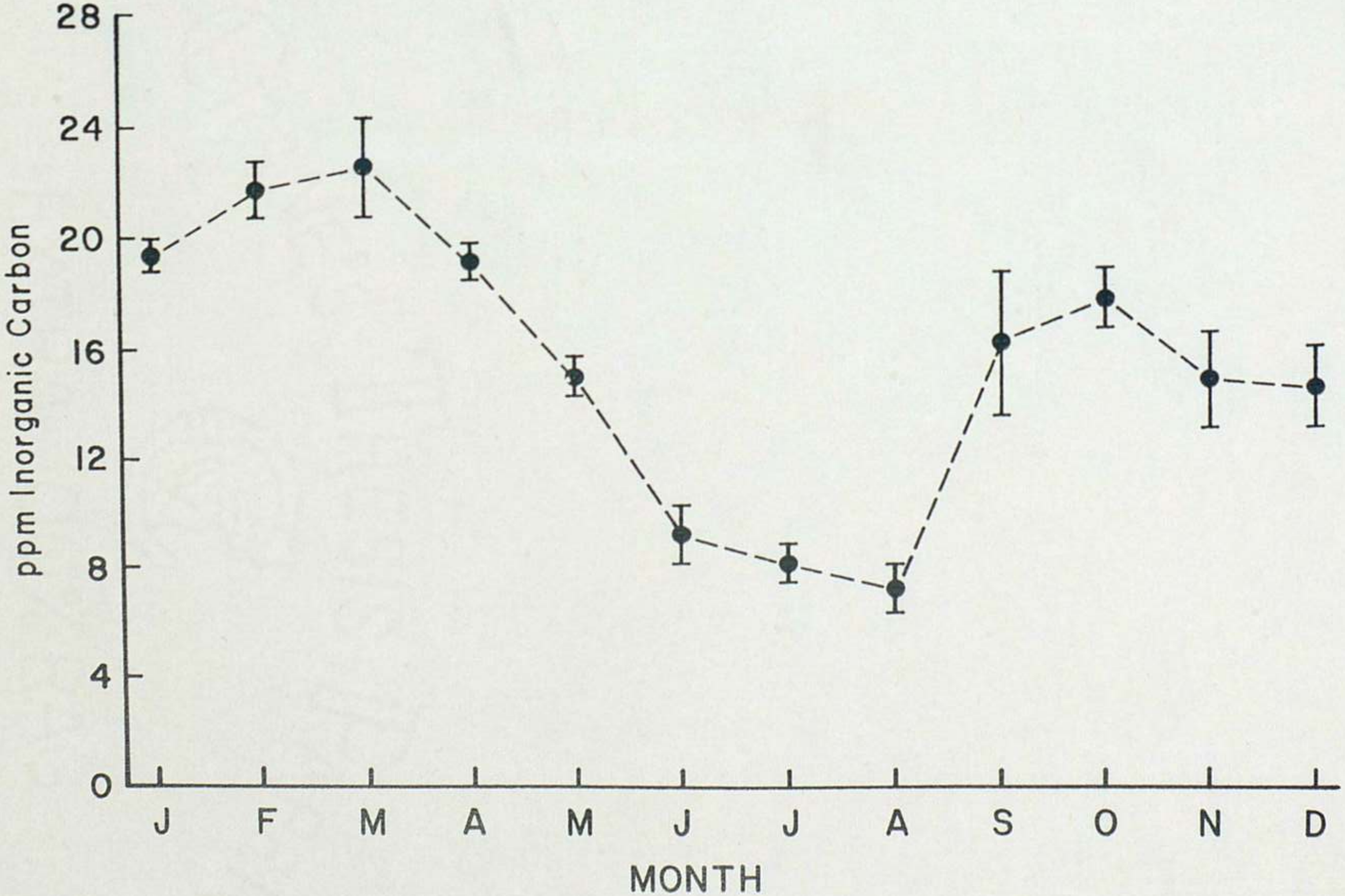
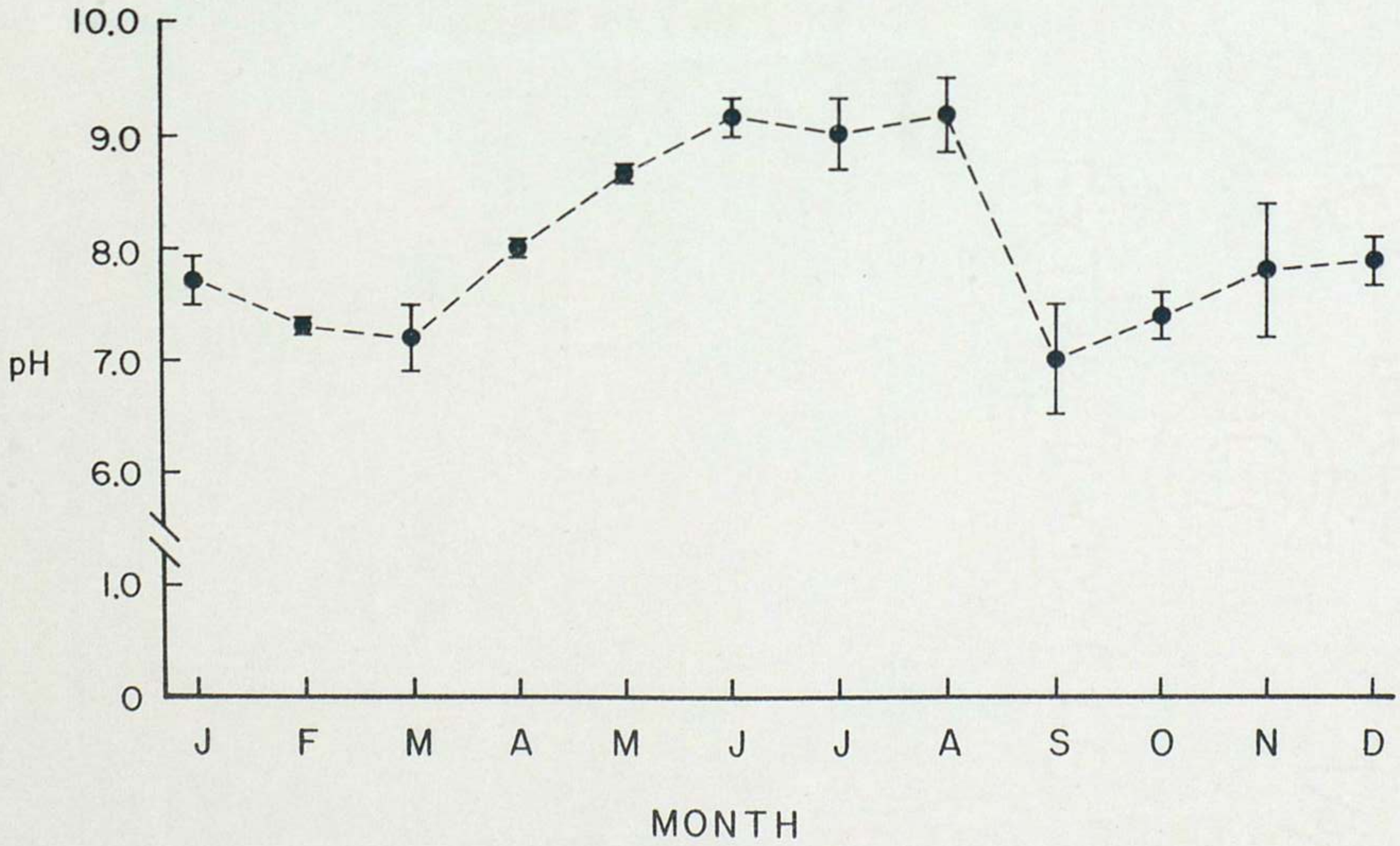
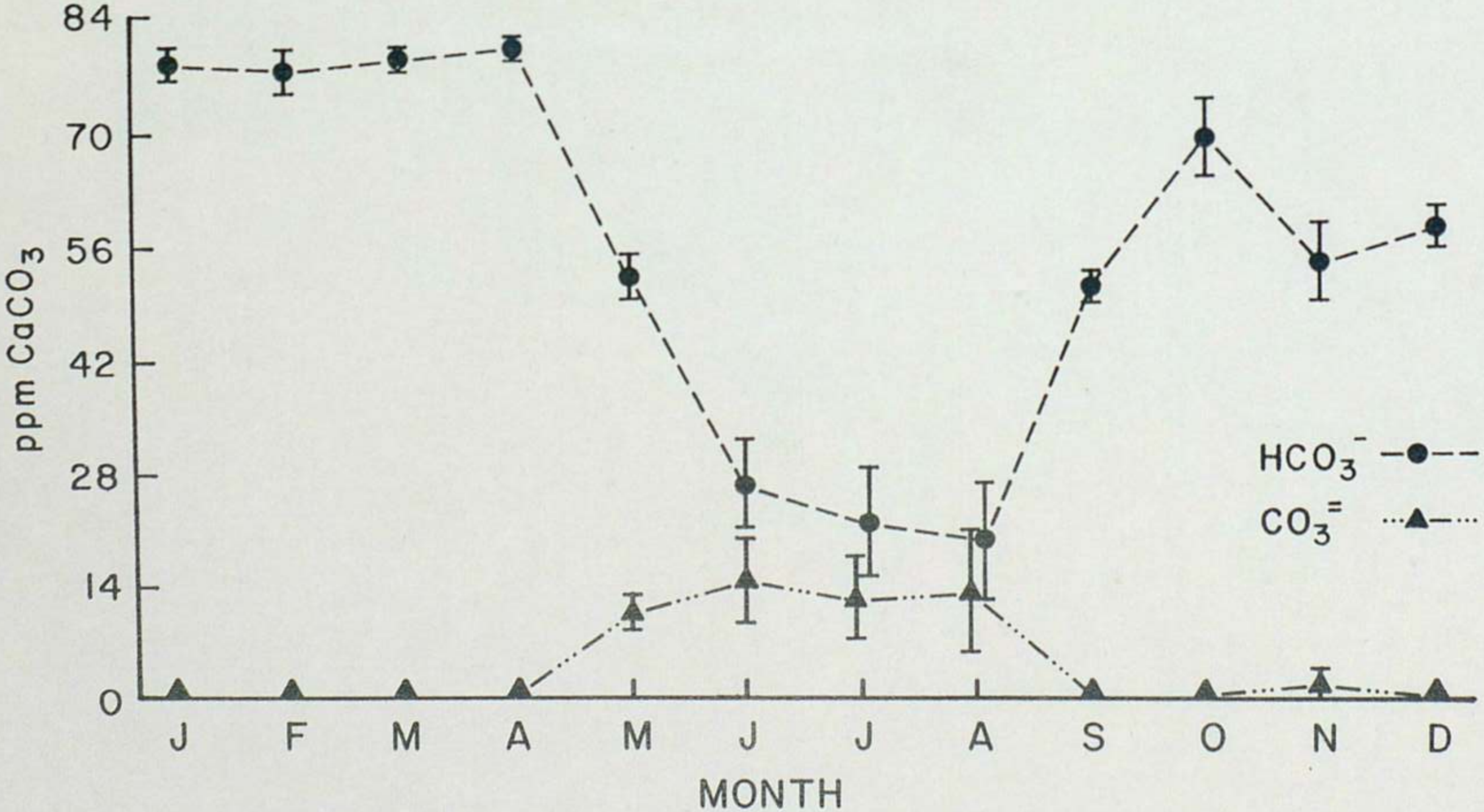

ppm Inorganic Carbon
28
24
20
16
12
8
4
0
J
F
M
A
M
J
J
A
S
O
N
D
MONTH

Figure 11. Monthly means for hydrogen ion concentrations (± 95% confidence limits) from January to December, 1977 in Little Lake Barton.



10.0
9.0
8.0
pH
7.0
6.0
1.0
0
J
F
M
A
M
J
J
A
S
O
N
D
MONTH

Figure 12. Monthly means and 95% confidence limits for bicarbonate and carbonate alkalinity from January to December, 1977 in Little Lake Barton.



84
70
56
42
28
14
0
ppm $CaCO_3$
J F M A M J J A S O N D
MONTH
HCO_3^-
$CO_3^=$

Figure 13. Monthly means for specific conductivity ($\pm$ 95% confidence limits) in Little Lake Barton from January to December, 1977.

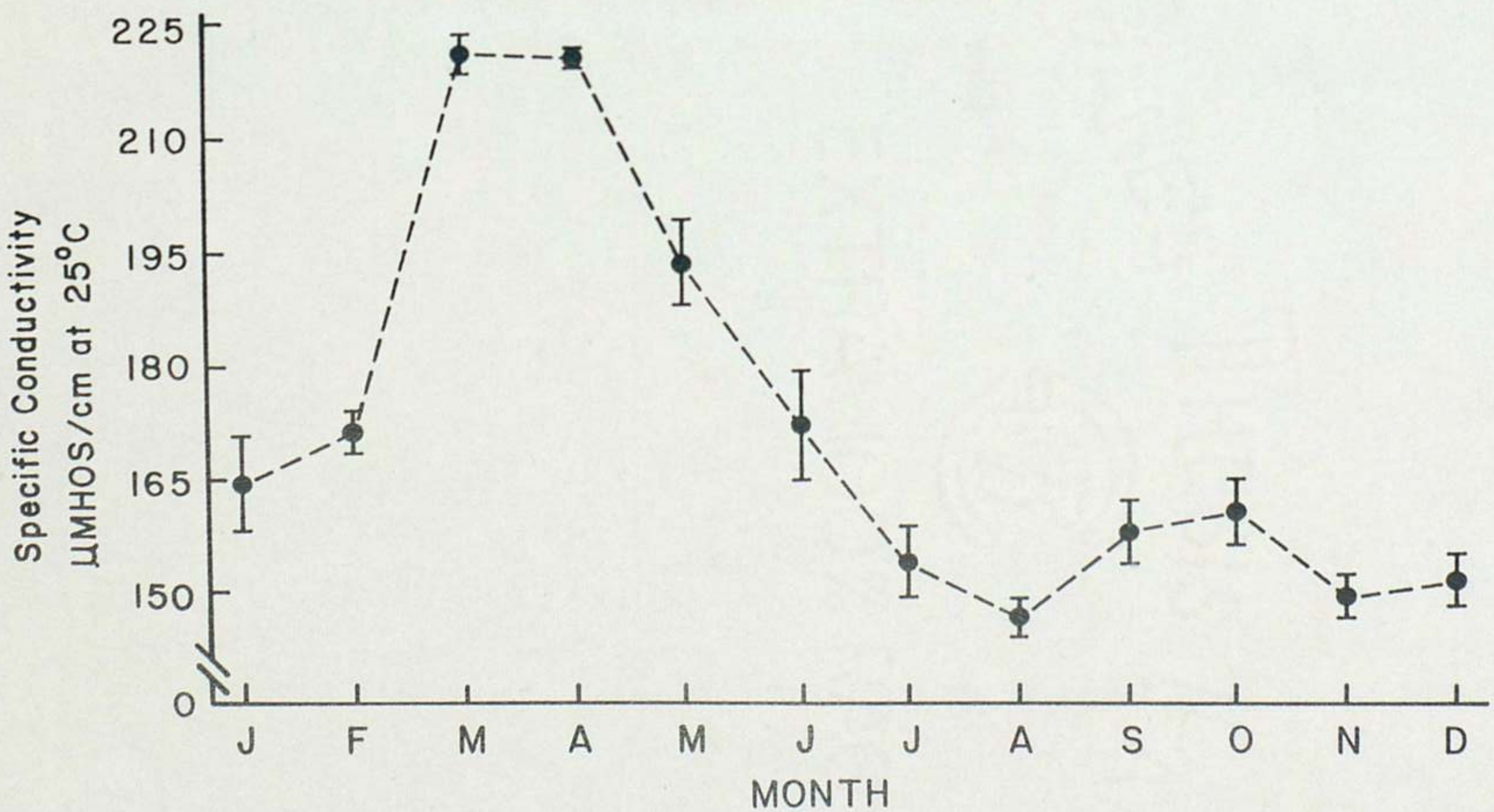
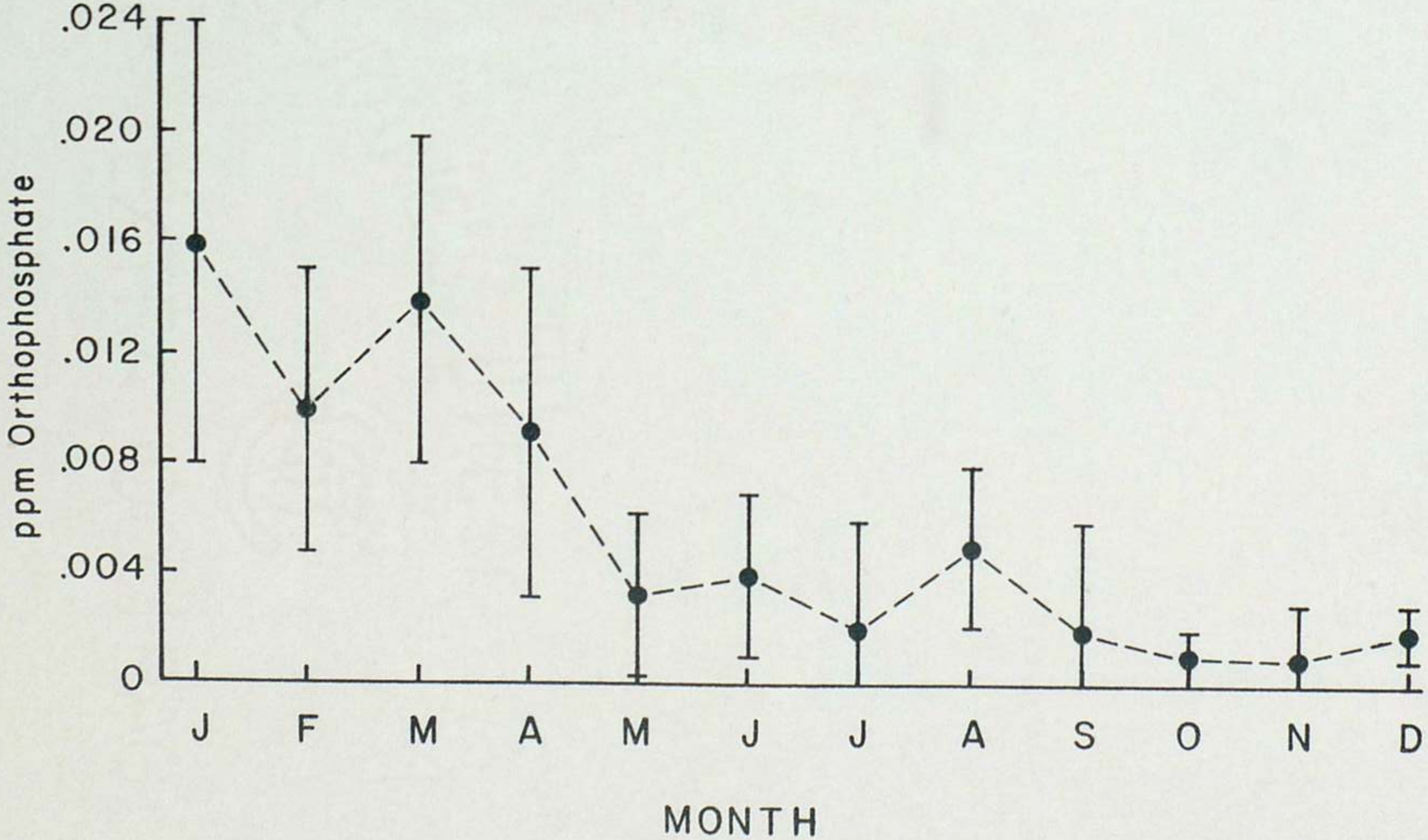

Specific Conductivity
μMHOS/cm at 25°C
225
210
195
180
165
150
0
J
F
M
A
M
J
J
A
S
O
N
D
MONTH

Figure 14. Monthly means ($\pm$ 95% confidence limits) for orthophosphate concentrations from January to December, 1977 in Little Lake Barton.



ppm Orthophosphate
.024
.020
.016
.012
.008
.004
0
J
F
M
A
M
J
J
A
S
O
N
D
MONTH

Figure 15. Monthly mean values ($\pm$ 95% confidence limits) for nitrate-nitrogen concentrations from January to December, 1977 in Little Lake Barton.

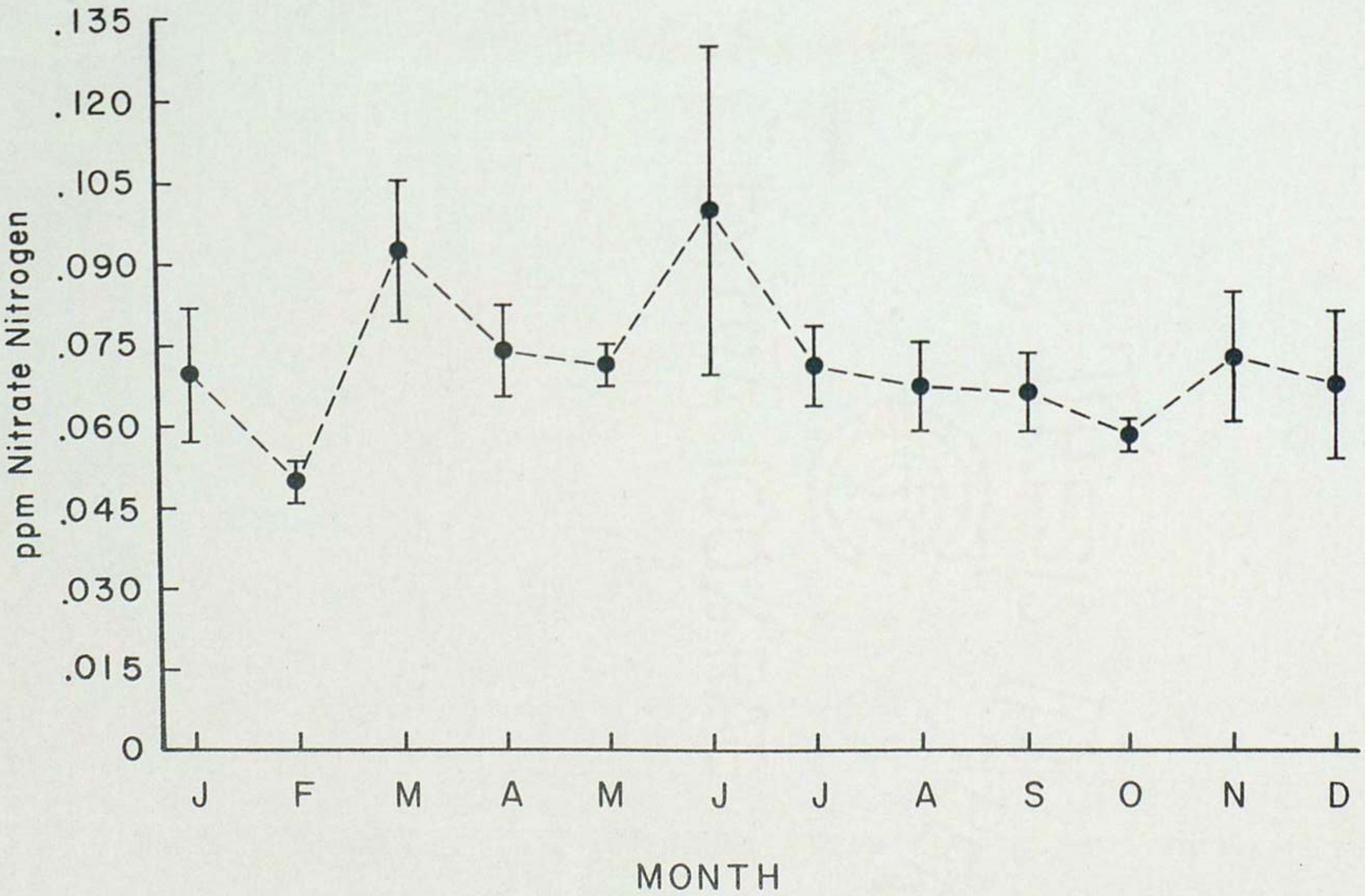

ppm Nitrate Nitrogen
.135
.120
.105
.090
.075
.060
.045
.030
.015
0
J
F
M
A
M
J
J
A
S
O
N
D
MONTH

Figure 16. Nitrite-nitrogen monthly means and ± 95% confidence limits in Little Lake Barton from January to December, 1977.

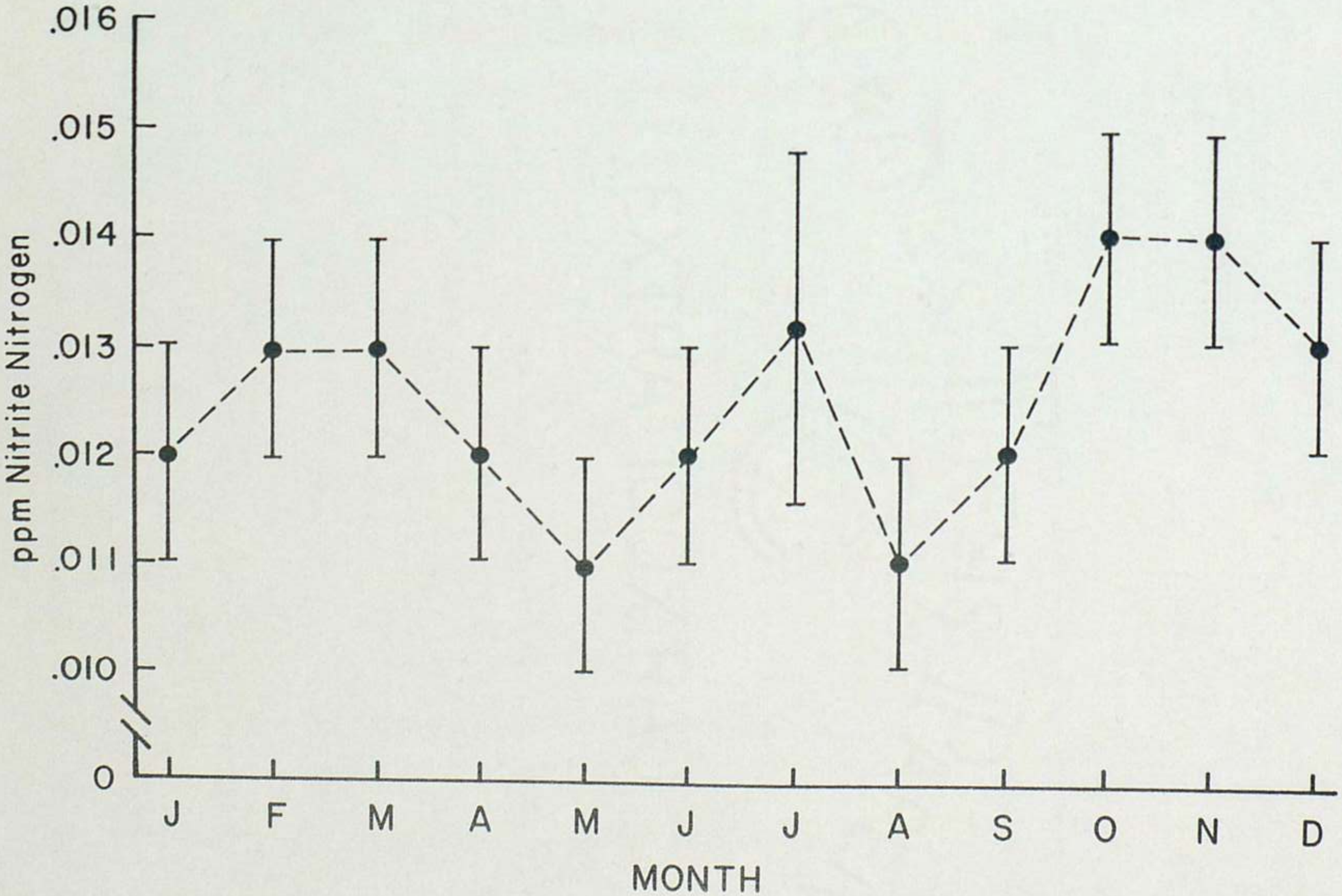
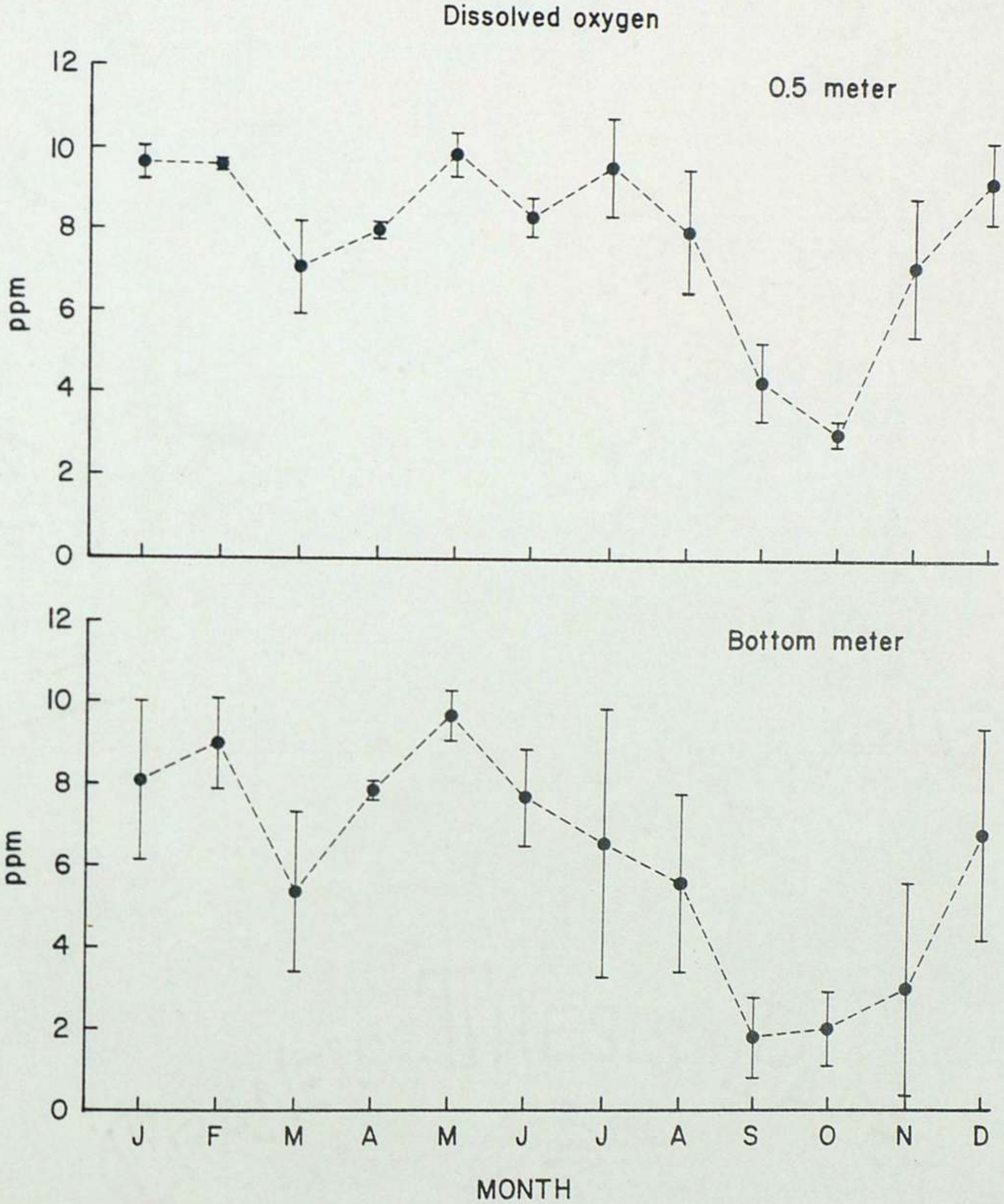
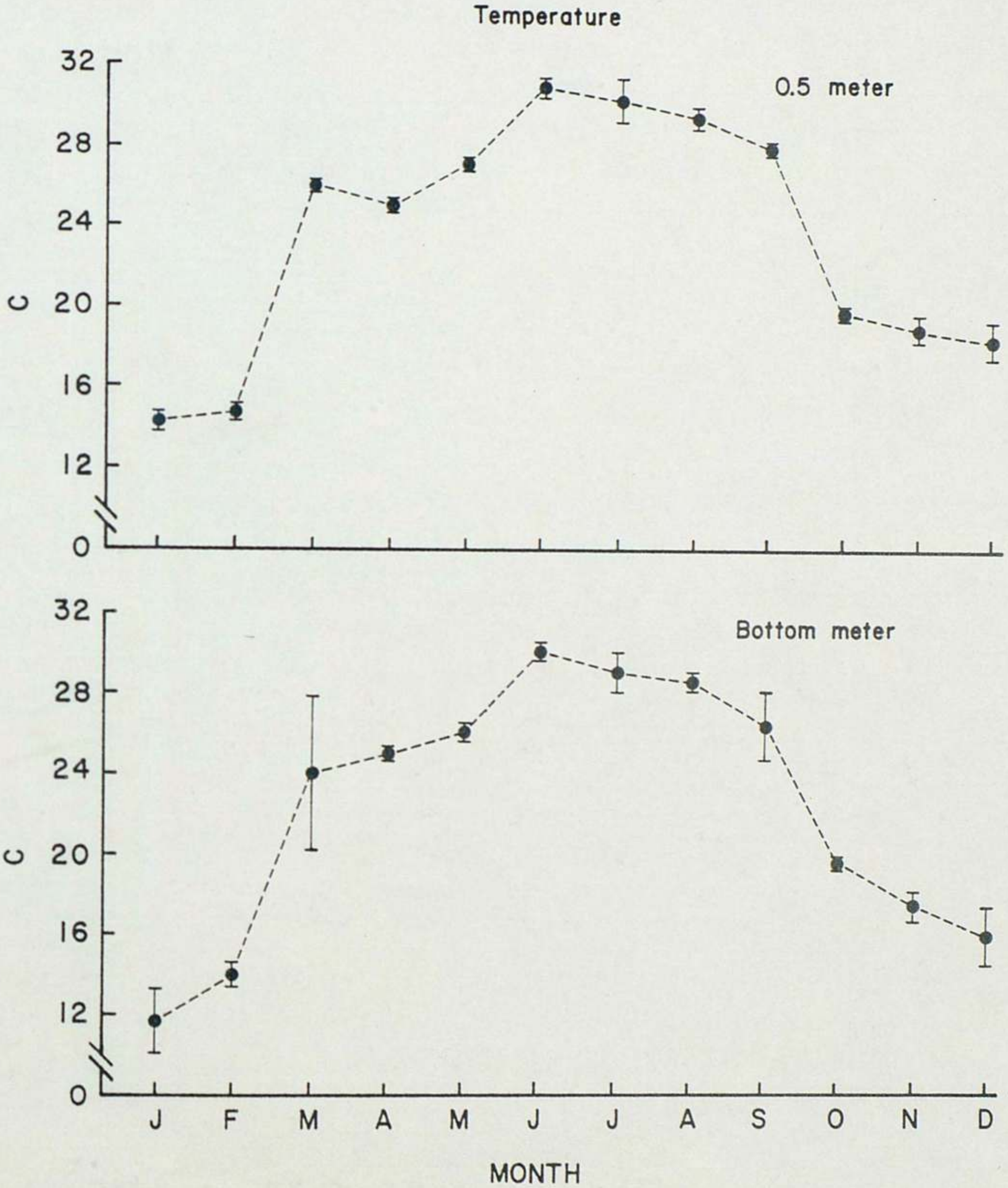

.016
.015
.014
.013
.012
.011
.010
0
ppm Nitrite Nitrogen
J
F
M
A
M
J
J
A
S
O
N
D
MONTH

Figure 17. Monthly mean dissolved oxygen concentrations ($\pm$ 95% confidence limits) from January to December, 1977 in Little Lake Barton.



Dissolved oxygen
0.5 meter
Bottom meter
ppm
12
10
8
6
4
2
0
J F M A M J J A S O N D
MONTH

Figure 18. Temperature monthly means and 95% confidence intervals from January to December, 1977 in Little Lake Barton.


Temperature
0.5 meter
Bottom meter
C
32
28
24
20
16
12
0
J F M A M J J A S O N D
MONTH

Appendix II. Classification of benthic macroinvertebrates collected in Little Lake Barton from January to December, 1977.

Annelida	
Oligochaeta	
Plesiopora	
Turbificidae	Limnodrilus hoffmeisteri
Naididae	Nais sp.
Hirudinea	
Arhynchobdellida	
Erpobdellidae	Dina Parva
Rhynchobdellida	
Glossiphoniidae	Placobdella phalera
	Helabdella sp.
Arthropoda	
Arachnoidea	
Hydracarina	Unknown species
Crustacea	
Amphipoda	
Talitridae	Hyalella azteca
Decapoda	
Palaemonidae	Palaemonetes paludosus
Insecta	
Diptera	
Chironomidae	
Tanypodinae	Ablabesymia peleenis
	Labrundinia neopilosella
	Larsia berneri
	Monopelopia boliekae
	Procladius sublettei
	Tanypus stellatus
Orthocladiinae	Brilla par
	Cricotopus remus
	Orthocladius sp.
	Psectrocladius sp.
	Psectrocladius vernalis
Chironominae	Chironomus stigmaterus
	Cryptochironomus fulvus
	Cryptocladopelma edwardsi
	Dicrotendipes sp.
	Einfeldia sp.
	Endochironomus nigricans
	Glyptotendipes paripes
	Goeldichironomus holoprasinus
	Lauterborniella varipennis
	Parachironomus hirtalatus
	Paralauterborniella elachista
	Polypedilum halterale
	Pseudochironomus sp.
	Cladotanytarsus sp.
	Nimbocera sp.
	Tanytarsus spp.
Chaoboridae	Chaoborus punctipennis
Insecta	

Diptera	
Chironomidae	
Ceratopogonidae	*Probezzia sp.* 1
	Probezzia sp. 2
Tabanidae	*Chrysops sp.*
Ephemeroptera	
Baetidae	*Callibaetis floridanus*
Caenidae	*Caenis diminuta*
Odonata	
Agrionidae	*Enallagma sp.*
Libellulidae	*Perithemis seminole*
	Celithemis bertha
Coleoptera	
Dytiscidae	*Hydrovatus sp.*
Hemiptera	
Corixidae	*Sigara sp.*
Trichoptera	
Leptoceridae	*Leptocella tavara*
	Oecetis sp.
Hydroptilidae	*Orthotrichia sp.*
	Oxythira sp.
Mollusca	
Gastropoda	
Pulmonata	
Physidae	*Physa sp.*
Planorbidae	*Helisoma sp.*
	Gyralus sp.
Ctenobranchiata	
Viviparidae	*Viviparus georgeanus wareanus*

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