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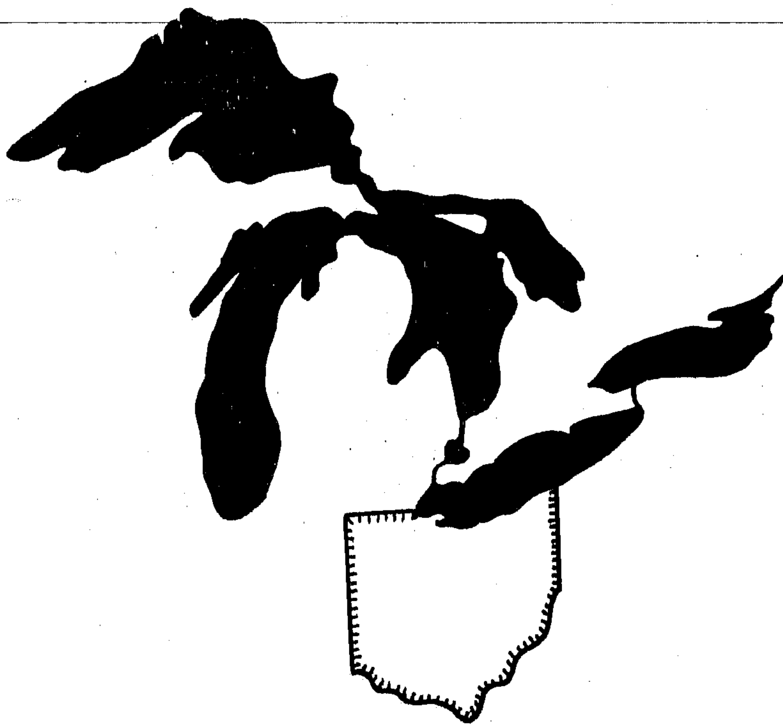

PROGRESS REPORT

WESTERN LAKE ERIE <u>CLADOPHORA</u> SURVEILLANCE PROGRAM

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES (Cont'd.)

INTRODUCTION

Growth of the attached filamentous green alga, *Cladophora glomerata*, in the Great Lakes has progressively increased with the eutrophication of the lakes. *Cladophora* forms luxurious beds on rocky bottoms throughout the nearshore regions of Lakes Erie and Ontario and is present in localized areas in the remaining three Great Lakes. This alga frequently detaches from its substrate in the spring and early summer months and washes ashore. Currents can accumulate large amounts of drifting *Cladophora*, creating nuisance problems at beaches and water intakes.

The process of detachment is not fully understood but has been attributed to temperature and nutrient limitations. In the upper three Great Lakes *Cladophora* is limited to areas high in nutrient inputs, such as treatment plant outfalls and densely-populated areas (Saginaw Bay). Lakes Erie and Ontario appear to support growth throughout their basins where the substrate is suitable.

The Center for Lake Erie Area Research (CLEAR) undertook a study of *Cladophora* in the western basin of Lake Erie during the 1979 season. The study was designed to monitor growth rates, densities and seasonal distributions and to determine possible nutritional and physical relationships between the alga and its aquatic environment. Investigative efforts were sponsored by a grant from the U.S. Environmental Protection Agency, Large Lakes Research Station. Similar projects were simultaneously carried out in the central and eastern basins of Lake Erie.

PROCEDURES

Sites

Two monitoring sites were established in western Lake Erie which are indicative of two different situations of nutrient loading in the basin. The western-most site was established at Stony Point, Michigan (~41°56' latitude, 83°16' longitude). Stony Point protrudes approximately 3 kilometers (km) out into Lake Erie and is located roughly 20 km southwest of the mouth of the Detroit River (Figure 1). The site is located on the northeast tip of the point, which is a residential area, and is influenced by the loading of the Detroit River as it mixes with the lake. This site is referred to as *Cladophora* site-1 (CS-1).

A second site was established on the southeast side of East Point, South Bass Island, Ohio (~41°39' latitude, 82°48' longitude). The site is approximately 8 km offshore from the mainland (Figure 1). This location is representative of the mid-western basin conditions and is generally located outside the more-heavily polluted water that flows along the south shore of Lake Erie. This site is referred to as Cladophora site-2 (CS-2).

Both sites possess the firm non-shifting substrate with little sedimentation that Cladophora requires for growth. The Stony Point site has a cobble bottom from 0-2 meters (m) which gives way to bedrock at the deeper depths. The South Bass site possesses a shelving bedrock bottom from 0->3 m.

Sampling Methods

Initial observations were made in mid-April, 1979, with sampling then continuing through mid-November, 1979. Each site was visited bimonthly with roughly 15 days in between. Sampling periods were planned to occur at the middle and end of each month. Logistics allowed only one site to be visited per day. The remaining site was visited on the following day, weather permitting. The actual sampling dates are listed in Table 1. Sampling operations were based out of a small boat utilizing SCUBA gear for collection and observation.

At each site four sampling stations were set up to investigate variations with depth. Monitoring stations were established on the lake bottom at depths of 1/2, 1, 2 and 3 m of water and marked with buoys. Depths were calibrated according to the mean projected water levels for the season--3.4 feet above chart datum (U.S. Army Corps of Engineers). During early summer the splash zone area, to a limited extent, was added as an additional station at the sites.

For each site at the various stations the following parameters were measured: biological--percent coverage, length (maximum and mean), biomass expressed as wet, dry, ash and ash-free weight and bio-volume; physical--depth, temperature (surface and bottom), light (surface and bottom), secchi depth and weather; water nutrients--soluble reactive phosphorus (SRP), soluble phosphorus (OP), total phosphorus (TP), ammonia (NH_4), nitrite-nitrate (NO_2-NO_3) and total Kjeldahl nitrogen (TKN); plant nutrients--boiling water extractable phosphorus (ExP), total tissue phosphorus (TTP) and total tissue nitrogen (TTN).

Biomass sampling utilized a 1/4-square-meter (m^2) ring which was placed on the substrate with collection of all Cladophora within. Collection was via hand picking with support of SCUBA. At CS-1 all rocks within the ring were collected and transferred back to the laboratory in water, where the filaments were picked for biomass determination. Separate sub-samples were taken for chemical analysis and kept cool until processed for either ExP or dried at 64°C for TTP and TTN determinations. Coverage and length were measured in situ. Water samples were collected near the bottom at the Cladophora beds.

The bioassay method of Fitzgerald and Nelson (1966) was used to measure ExP on fresh material. Tissue analysis for TP uses a mixed-acid digestion, and TTN analysis is determined on a Perkin-Elmer 240 C-H-N elemental analyzer. Nutrients were analyzed on a Technicon auto-analyzer employing standard methods recommended by the Environmental Protection Agency.

PRELIMINARY RESULTS

Sample analysis is approximately 75 percent complete as indicated in Table 2. The results included here are only preliminary. Many figures have not been converted to per square meter ($/m^2$) values, and the biomass figures are reported on a 64°C dry-weight basis instead of the final 104°C or ash-free basis.

Biological

Cladophora's biomass peaked between 29 June and 15 July 1979 and dropped significantly thereafter. *Cladophora* site-2, at 1 m, had complete filament detachment in less than 10 days after the peak biomass (Figure 2). *Cladophora* site-1 had a slower rate of detachment at 1 m (Figure 3). The months of August and September supported very little Cladophora biomass at these depths. A small autumn pulse of biomass was observed, representing approximately 10 percent of the summer biomass. A peak summer biomass of approximately 108 g/m^2 (based on 64°C) was observed at both sites. The peak biomass, however, was observed at different depths and dates at the two sites. The CS-1 *Cladophora* population had an approximate two-week lag in biomass and a peak biomass at a depth of 1/2 m as compared to CS-2's peak biomass occurring at 2 m. Maximum filament length reached 90 cm at CS-2 (2 m) on 15 June.

Cladophora at depths of 1/2 m and greater exhibited the biannual pulses and detachment generally associated with the alga. The *Cladophora* of the splash zone, however, did not show the same trends. The splash zone and buoys supported *Cladophora* throughout the summer and fall, with die back occurring during the low water levels and frosts of fall.

Physical

Water temperatures at both sites followed a similar pattern with peak temperatures observed at the end of July. Peak temperatures at 1 m were 25.7°C and 23.7°C at CS-1 and CS-2, respectively (Figures 4 and 5). Temperatures between 1/2 and 3 m varied about 1°C, with the higher temperatures at the shallower depths.

Secchi depth and light values generally were greater at CS-2. Secchi depth for CS-1 (at 3 m) ranged from 0.35-1.30 m and for CS-2 from 0.5-1.70 m (Figures 6 and 7).

Chemical

Nutrient levels in western Lake Erie have the potential of fluctuating dramatically from day to day. The data points on the graphs are connected only to show possible seasonal trends and do not represent actual day-to-day conditions. Generally there is not a great difference in nutrient values at the various depths at one site.

Levels of NH_4 and NO_2-NO_3 generally declined during the summer months at both sites. The NH_4 concentrations, however, fluctuated with CS-1 generally having the higher values (Figures 8 and 9). Ammonia values for the spring and summer, at 1 m, ranged from a high of 70.7 ppb at CS-2 on 13 July to a low of below detection limit at CS-2 on 31 August. Nitrite-nitrate concentrations were fairly similar for the two sites. Values at 1 m ranged from a high of 1.5 ppm at CS-1 on 30 July to below detection limit on 30-31 August at CS-1 and CS-2 (Figures 10 and 11).

Total phorphorus levels at the two sites fluctuated throughout the season. High peaks were attained in early spring and late August-early September. *Cladophora* site-1 had roughly twice the TP concentrations that CS-2 had. *Cladophora* site-1 (1 m) had the highest level at 200 ppb on 13 September and CS-2 the lowest at 15 ppb on 18 May (Figures 12 and 13).

Soluble reactive phosphorus levels fluctuated throughout the season with CS-2 having a higher seasonal level than CS-1. Values of SRP, at 1 m, ranged from 15.2 ppb on 5 June at CS-2 to below detection limit on 30-31 August and 28 September at CS-1 and CS-2 (Figures 14 and 15).

The ExP method is a bioassay technique to assess the amount of luxurious phorphorus within the algal cells. Luxurious phosphorus is phosphorus (P) taken up by the cell that is in excess of its needs and is essentially stored P. Large amounts of ExP are indicative of a non-limiting supply of P and small amounts of a limiting supply. The ExP values are reported on a 64^{o}C dry-weight basis.

Trends in ExP are similar between the two sites. Extractable P levels increase in the cells during early spring as growth begins and peaks in late May-early June (Figures 16 and 17). Levels of ExP decline thereafter to values below 0.1 percent of *Cladophora* dry weight, at which time the alga detaches. The autumn pulse of growth is represented with increasing levels of ExP.

DISCUSSION

Biomass

Previous quantitative biomass data is scattered and generally not a complete representation of the seasonal distribution, Kishler's (1967) and Taft and Kishler's (1973) Erie Island data being an exception. The present study represents an intensive examination of two sites indicative of the western basin of Lake Erie that were sampled at regular intervals throughout the season.

The peak biomass of Cladophora occurred during late June and July in 1979 with a peak standing crop of approximately 108 g/m^2. The major period of detachment was late July-early August. Kishler's (1967) major production months were May, June, October and November with detachment occurring in June, July and December or March. Owens (1975), working in Lake Ontario, reports a maximum biomass of 224 g/m^2 in early July with maximum production at 1.5 m. Kishler's (1967) data, although not reported in g/m^2 and lacking in completeness, has been roughly converted to an average of 92 g/m^2 for 1 m at a location close to CS-2. Kishler has noted that peak biomass and biomass distribution vary from year to year depending on the environmental conditions.

The depth at which peak biomass occurs varies significantly between sites, sampling times and authors. Sweeney (1975) reports maximum biomass at 6 m in Lake Ontario during the end of July while others report 1.5 and 3 m (International Joint Commission, 1975). The present study had peak biomass at 1/2 m at CS-1 and approximately the same peak biomass at 2 m at CS-2. The 2-m production peak is deeper than Kishler's findings in the island area. Cladophora production appeared first and developed earlier at CS-2 than CS-1. Cladophora site-2 consequently had the earlier and more rapid breakoff of the filaments.

Beach accumulations of a significant amount of Cladophora were only observed at two places in the western basin, both on beaches of South Bass Island. Throughout the spring Cladophora was generally present on the bathing beach at South Bass near Perry's Monument and generally absent in the summer and fall. (A park crew of six spent one morning raking up this Cladophora in late May.) No Cladophora windrows were observed or reported along the western basin shoreline by the nearshore crew which monitored the area throughout the season.

Two distinctive growth patterns were observed for Cladophora, each representative of different environments. The most important environment (in relation to biomass) and the Cladophora community most generally referred to by other researchers is the lake bottom; the lake bottom Cladophora being defined as growth from approximately 1/2 m of depth and deeper. It is in this wide zone of growth that the seasonal fluctuation in biomass occurs and the associated problems of filament detachment is greatest.

The splash-zone or fringe *Cladophora* differs from lake bottom growth in that it remains green (actively growing) during much of the open-water season. This zone of growth is the most visible to the public and is generally found on rocky shorelines, breakwalls, buoys, docks and bottoms of boats. This zone of growth is in a very high energy environment which extends approximately 1/8 m above water level to approximately 1/2 m below the surface; but you might say that this is only the "fringe" of the problem, with the vast majority of the *Cladophora* occurring on the much larger surface areas of the lake bottom. *Bangia*, a Rhodophyta which is a recent invader of the Great Lakes, and blue-green algae (*Oscillatoria*) also compete in this zone.

Substrate

Cladophora requires a solid substrate for growth which, in its natural habitat, is normally bedrock or cobble bottoms (growth was also observed on backs of snails and clams). *Cladophora* site-1 possessed a suitable cobble bottom for growth, but it was noted that some selectivity in substrate occurred (particularly at early stages of growth). Adjacent rocks appearing to be of the same type had varying amounts of growth. Early growth was observed from older brown holdfasts and occurred primarily along the edges or sides of the rocks. Areas of patchiness were encountered throughout most of the season but were generally small in order, and the 1/4-m^2 sampling ring generally eliminated this patchiness. This selectivity may quite well be attributed to competition since it was most predominate in the earlier stages of growth.

Cladophora site-2's flat shelving bedrock provided a much more uniform substrate for growth. On the bedrock *Cladophora* favored the crevices for early growth as opposed to the flat surfaces. As the season progressed a uniform distribution was attained with patchiness observed only during the short breakoff period.

Temperature

The effect of temperature on *Cladophora* has been studied by researchers in both the laboratory and *in situ* with varying results. Storr and Sweeney (1971) in laboratory studies noted the optimum growth to be near 18°C with cessation of growth at 25°C. Gerloff and Fitzgerald (1976) show an optimum or near-optimum temperature in the laboratory of approximately 22-23°C and indicate the alga is relatively insensitive to high temperatures, with optimum yields maintained at 30-31°C. Taft and Kishler (1973) indicate that Lake Erie *Cladophora* initiates growth around 4°C and that the main growth is completed by the time the water temperature reaches above 18°C. Present results indicate that 18°C is not necessarily the optimal, with peak standing crop and production occurring between 19-22°C at CS-2 and 22.3-24.8°C at CS-1.

Light

The earlier and deeper growth of *Cladophora* at CS-2 can not be attributed to higher water temperatures. Temperatures at CS-2 were routinely the same or less than CS-1 temperatures. Light penetration is an important factor possibly influencing these earlier and deeper growths. The water around the islands is generally clearer than the Ohio and Michigan shorelines which are directly influenced by the Maumee and Detroit Rivers. Secchi depths were routinely greater at CS-2 than CS-1. Kishler's study of 1966-67 reported growth of *Cladophora* ranging from the water surface to 5 feet deep at Catawba Cliffs and to 13-1/2 feet deep at Kelleys Island shoal. The Catawba Cliffs area is influenced by the high suspended soilds of the water that flows along the south shore, and Kelleys Island shoal is generally associated with the "clearer" water of the mid-western basin as it mixes with the central basin. Millner (personal communication) reports *Cladophora* growth to beyond 3 m of depth in the central and eastern basins with secchi depths much greater than in the western basin. Neil and Owens (1964) found growth in decreasing quantities to a depth of 7.7 m in western Lake Ontario and 13.8 m in the clearer water of eastern Lake Ontario, again indicating light as influencing the depth of growth. Light is believed to be limiting the depth of growth in the western basin of Lake Erie and responsible for the variation between sites in depth of maximum biomass.

Other physical parameters such as water movement and siltation, however, can not be ruled out as limiting. Depths of 1/2, 1 and 2 m had a noticeable wave-generated current to a diver laying on the bottom. At 3 m the water movement was not noticed. *Cladophora* has been characterized as requiring water movement and a fairly "clean" surface for growth. A slight silt coating was observed at 3 m, especially at CS-1 where the 3-m station was located further offshore.

Nutrients

The ammonia levels in the lake showed a general decline in the first half of the season with the exception of high peaks at both sites during the peak biomass periods. Peaks in SRP were also present at peak biomass periods indicating a possible release of nutrients from the *Cladophora* beds. Observations at CS-1 on this date reveal that large amounts of aquatic marsh plants forming floating mats on the surface were present, indicating a recent disturbance in the area. Weather data notes that close to an inch of rain fell two days prior to sampling. The runoff of this storm may be responsible for these SRP and NH_4 peaks. Ammonia levels do not indicate that NH_4 was limiting in the western basin.

Nitrite-nitrate levels just prior to *Cladophora* breakoff dropped below 0.4 ppm at both sites indicating that these levels might be limiting. Values below 0.3 ppm for NO_2-NO_3 have been reported limiting for algae (Sawyer, 1947). These low values for NO_2-NO_3, however, are not believed to become a limiting source of nitrogen since NH_4 values are high at the same time and NH_4 is utilized by Cladophora (Fitzgerald, 1969). Whether or not nitrogen was limiting will be better judged after all the data is analyzed (TKN and TTN). At present nitrogen is not felt to be limiting in the western basin for Cladophora growth.

Soluble reactive phosphorus levels of the water reached the lowest levels of the first half of the season (May-15 July) just prior to peak biomass periods at both sites, 3 ppb at CS-2 and 1 ppb at CS-1. Total P values showed a similar trend having the lowest at CS-1 (23 ppb) and close to the lowest level at CS-2 (19 ppb) just prior to peak biomass. Both SRP and TP levels increased after peak biomass. The declining nutrient levels prior to detachment and increasing levels afterwards may very possibly be linked to Cladophora's uptake and release of nutrients. Further monitoring efforts will be able to bear these relationships out.

Thomas (1975) has reported that prolific growth of Cladophora is present in areas where the average spring and annual TP concentrations exceed 15 ppb. The lowest levels of TP at the 2 sites did not fall below this 15-ppb mark all year, indicating the P was not limiting in the water, but did approach critical levels at peak biomass periods.

Cladophora has the capability to uptake more P from its environment than is actually required. This excess, which is stored in the cell, is referred to as luxurious P. The boiling water ExP bioassay technique assays this water soluble P within the cells. Laboratory and field results of Fitzgerald and Nelson (1966) have established that levels below approximately 0.08 percent ExP are representative of phosphorus-limiting conditions and concentrations greater than 0.08 percent are indicative of surplus P levels in the environment.

Initial results of ExP show a declining level as the alga reaches peak biomass and subsequent detachment. Extractable P levels at detachment are near the critical 0.08 percent level indicative of limiting P conditions. Low luxurious P levels, however, may not be directly linked to water P levels and possibly are secondary cause-and-effect relationships. Light, temperature or other nutrients may be limiting, causing a shutdown of P uptake. It is also possible that growth rates outpace uptake capabilities and the alga starves or that physiological alterations in the aging cells play a role in the declining ExP levels. The values, however, clearly indicate that P within the alga cells declined to critical levels, at which time detachment occurs. The cause of the luxurious P decline is yet unknown and may play a key role in the detachment phenomenon. Data from other areas hopefully will provide additional insight.

PRELIMINARY CONCLUSIONS

1. Two distinctive Cladophora growth patterns were observed: 1) the splash zone, or fringe growth, which appeared in late spring and remained present throughout the season; and 2) the lake bottom growth that appeared in early spring and reached maximum biomass around late June-early July, with subsequent detachment and recurrence of growth in the fall.

2. A peak biomass of approximately 108 g/m^2, based on 64^oC dry weight, occurred during late June-early July 1979.

3. Maximum depth of growth and depth of maximum biomass are influenced by light penetration.

4. Water temperatures between $19-24.8^oC$ were associated with maximum growth.

5. Nitrogen and phosphorus levels of the western basin appear not to be limiting.

6. Extractable phosphorus levels within the cells decline during periods of peak growth, reaching critical levels, at which time filament detachment occurs.

SCHEDULE FOR COMPLETION OF PROJECT

Sample analysis is ongoing in Columbus and is planned to be completed by April. Tissue nutrients are presently being analyzed. Various digestion and sample preparations methodologies are being analyzed to determine the best procedures for the phosphorus and nitrogen tissue determinations.

Presentation of this research is planned for the Great Lakes Meeting this May. The submitted abstract for the Great Lakes Meetings is attached.

A meeting of investigators involved in the Cladophora Surveillance Program for Lake Erie is highly recommended before the next season.

REFERENCES CITED

Fitzgerald, G.P. 1969. Field and laboratory evaluations of bioassays for nitrogen and phosphorus with algae and aquatic weeds. Limnol. Oceanog. 14:206-212.

Fitzgerald, G.P. and T.C. Nelson. 1966. Extractive and enzymatic analyses for limiting or surplus phosphorus in algae. J. Phycol. 2:32-37.

Gerloff, G.C. and G.P. Fitzgerald. 1976. The nutrition of Great Lakes Cladophora. USEPA, Office of Research and Development, Environmental Laboratory, Duluth, Minnesota.

International Joint Commission. 1975. Cladophora in the Great Lakes. Great Lakes Research Advisory Board, Windsor, Ontario, Canada.

Kishler, W.J. 1967. A quantitative study of Cladophera glomerata (L.) Keutzing in the island region of Western Lake Erie. Masters thesis. The Ohio State Univ., Columbus, Ohio.

Millner, G. 1980. Personnel communication. Great Lakes Laboratory, State University College, Buffalo, New York.

Neil, J.H. and G.E. Owens. 1964. Distribution, environmental requirements and significance of Cladophora in the Great Lakes. Pub. No. 11, Great Lakes Research Div. The Univ. of Mich., Ann Arbor, Mich. p. 113-121.

Owen, G.E. 1975. In: Cladophora in the Great Lakes. IJC, Great Lakes Research Advisory Board, Windsor, Ontario, Canada.

Sawyer, C.N. 1947. Fertilization of lakes by agricultural and urban drainage. Jour. NEWWA. 61:109-127.

Storr, J.F. and R.A. Sweeney. 1971. Development of a theoretical seasonal growth response curve of Cladophora glomerata to temperature and photoperiod. Proc. 14 Conf. Great Lakes Res. p. 119-127.

Sweeney, R.A. 1975. In: Cladophora in the Great Lakes. IJC, Great Lakes Research Advisory Board, Windsor, Ontario, Canada.

Taft, C.E. and W.J. Kishler. 1973. Cladophora as related to pollution and eutrophication in Western Lake Erie. Water Resources Center, The Ohio State Univ., Columbus, Ohio.

Thomas, N. 1975. In: Cladophora in the Great Lakes. IJC, Great Lakes Research Advisory Board, Windsor, Ontario, Canada.

TABLES

TABLE 1

1979 <u>CLADOPHORA</u> SAMPLING DATES

Julian Date	Dates	Site	
106	April 16	CS-1 & 2	water samples
107	April 17	CS-1	site selection, with visual observations
108	April 18	CS-2	visual observations
117	April 27	CS-1	
118-119	April 28-29	CS-2	site selection
137	May 17	CS-1	
138	May 18	CS-2	
151	May 31	CS-1	
152	June 1	CS-2	
156	June 5	CS-2	water samples only
164	June 14	CS-1	
165	June 15	CS-2	
170	June 19		<u>Cladophora</u> surveillance cruise of the island area with Canale and Auer of University of Michigan
179	June 28	CS-1	
180	June 29	CS-2	
193	July 12	CS-1	
194	July 13	CS-2	
205	July 24	CS-2	visual observations
211	July 30	CS-1	
212	July 31	CS-2	
225	August 13	CS-1	
226	August 14	CS-2	
242	August 30	CS-1	
243	August 31	CS-2	
256	September 13	CS-1	
258	September 15	CS-2	
271	September 28	CS-1 & 2	visual observations
277	October 4	CS-2	
278	October 5	CS-1	
288	October 15	CS-2	
289	October 16	CS-1	
309	November 5	CS-2	
310	November 6	CS-1	
320	November 16	CS-1	
321	November 17	CS-2	

TABLE 2

SAMPLE ANALYSIS BREAKDOWN AS OF JANUARY 1980

	Complete	Incomplete
Biological		
Percent coverage	X	
Length	X	
Wet weight	X	
64°C weight	X	
104°C weight	½	½
Ash weight		X
Ash-free weight		X
Physical		
Temperature	X	
Light	X	
Secchi depth	X	
Water Nutrients		
Soluble reactive phosphorus (SRP)	X	
Soluble phosphorus (OP)	X	
Total phosphorus (TP)	X	
Ammonia (NH_4)	X*	
Nitrite-nitrate (NO_2-NO_3)	X*	
Total Kjeldahl nitrogen (TKN)		X
Tissue Nutrients		
Boiling-water extractable phosphorus (ExP)	X	
Total tissue phosphorus (TTP)		X
Total tissue nitrogen (TTN)		X

*--denotes all samples have been run, but autumn values have not been read off chart yet.

FIGURES

WESTERN LAKE ERIE

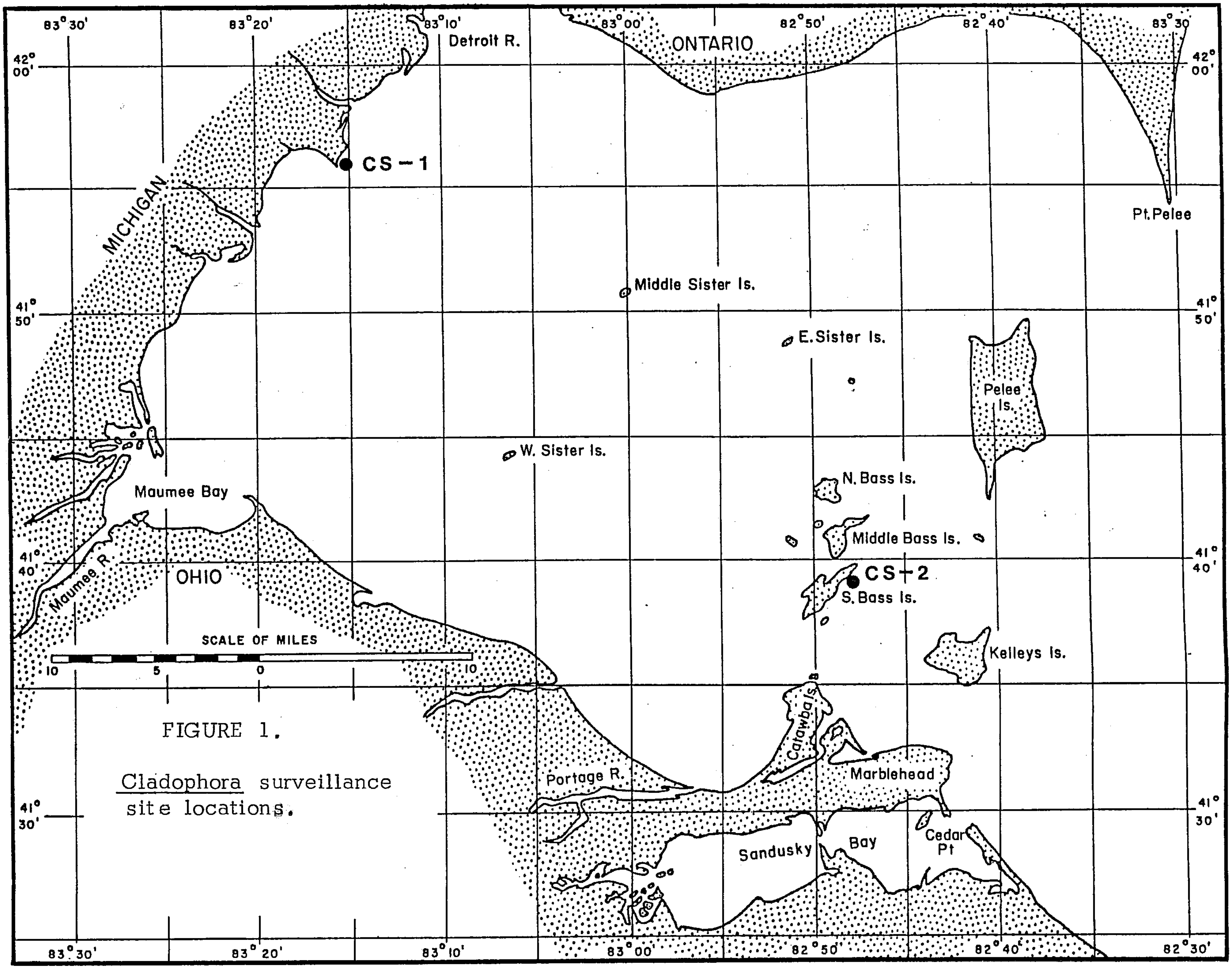

FIGURE 1.

Cladophora surveillance site locations.

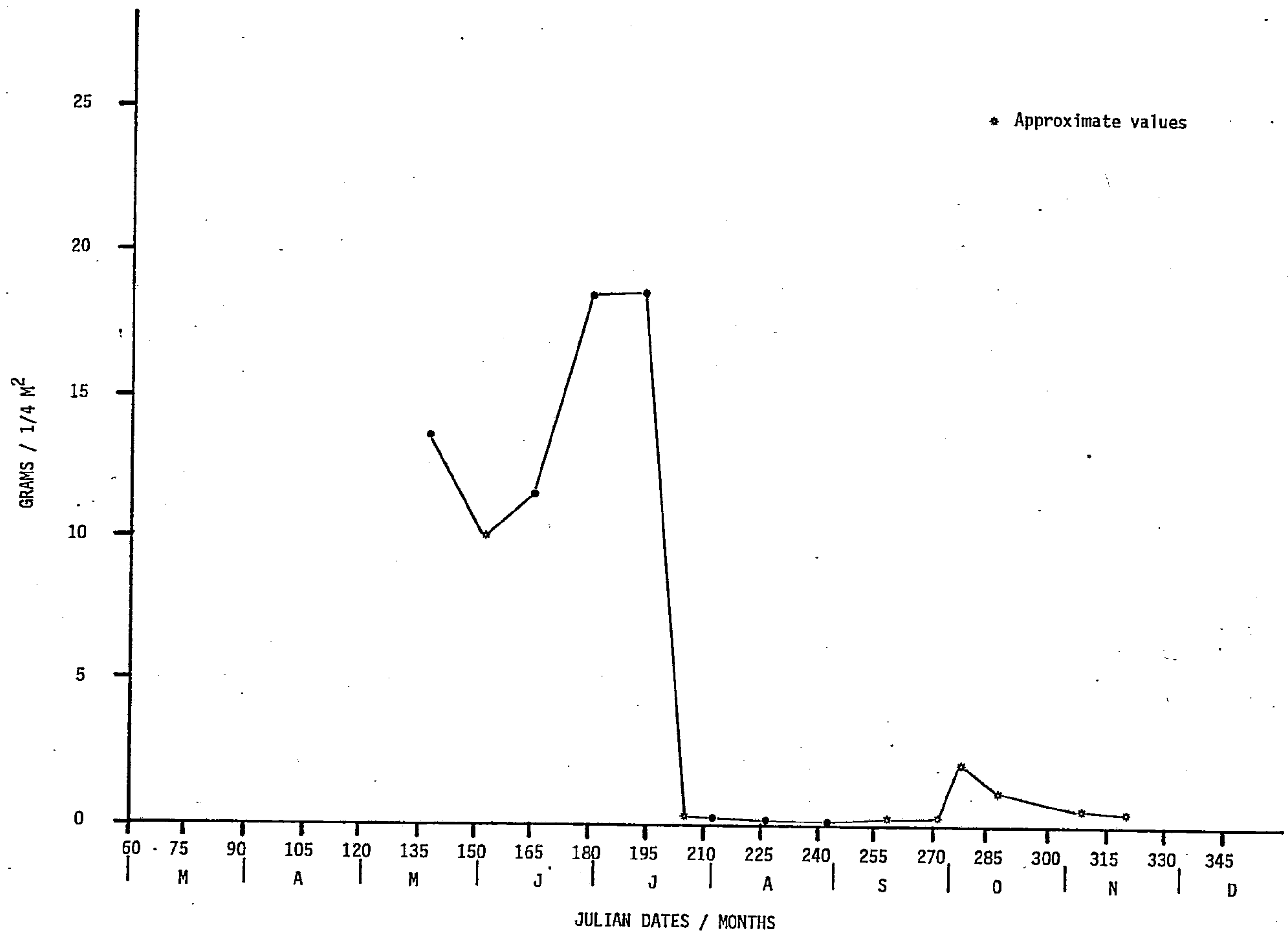

Figure 2. Cladophora dry weight (64°C), CS-2, 1 meter.

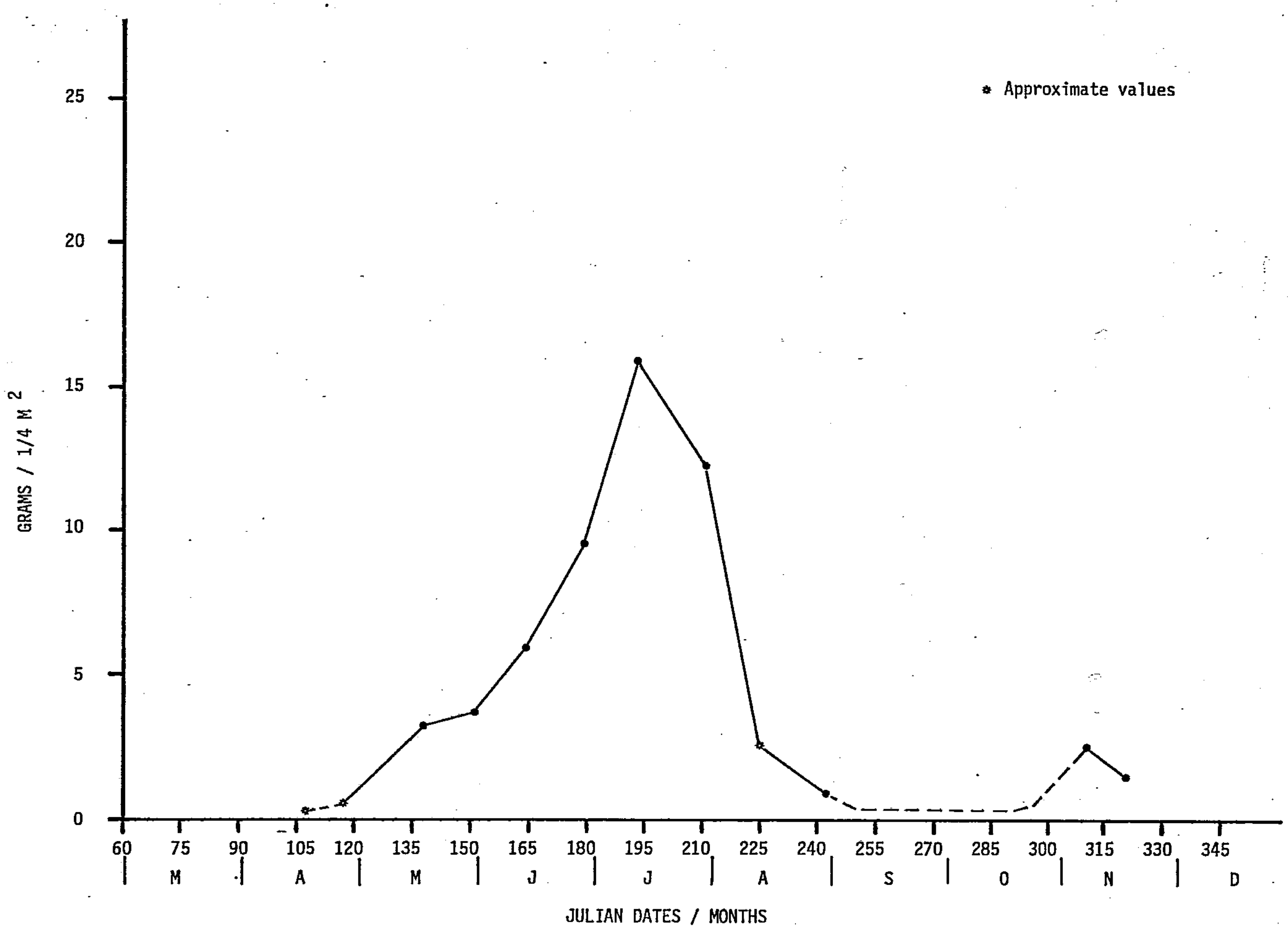

Figure 3. Cladophora dry weight (64°C), CS-1, 1 meter.

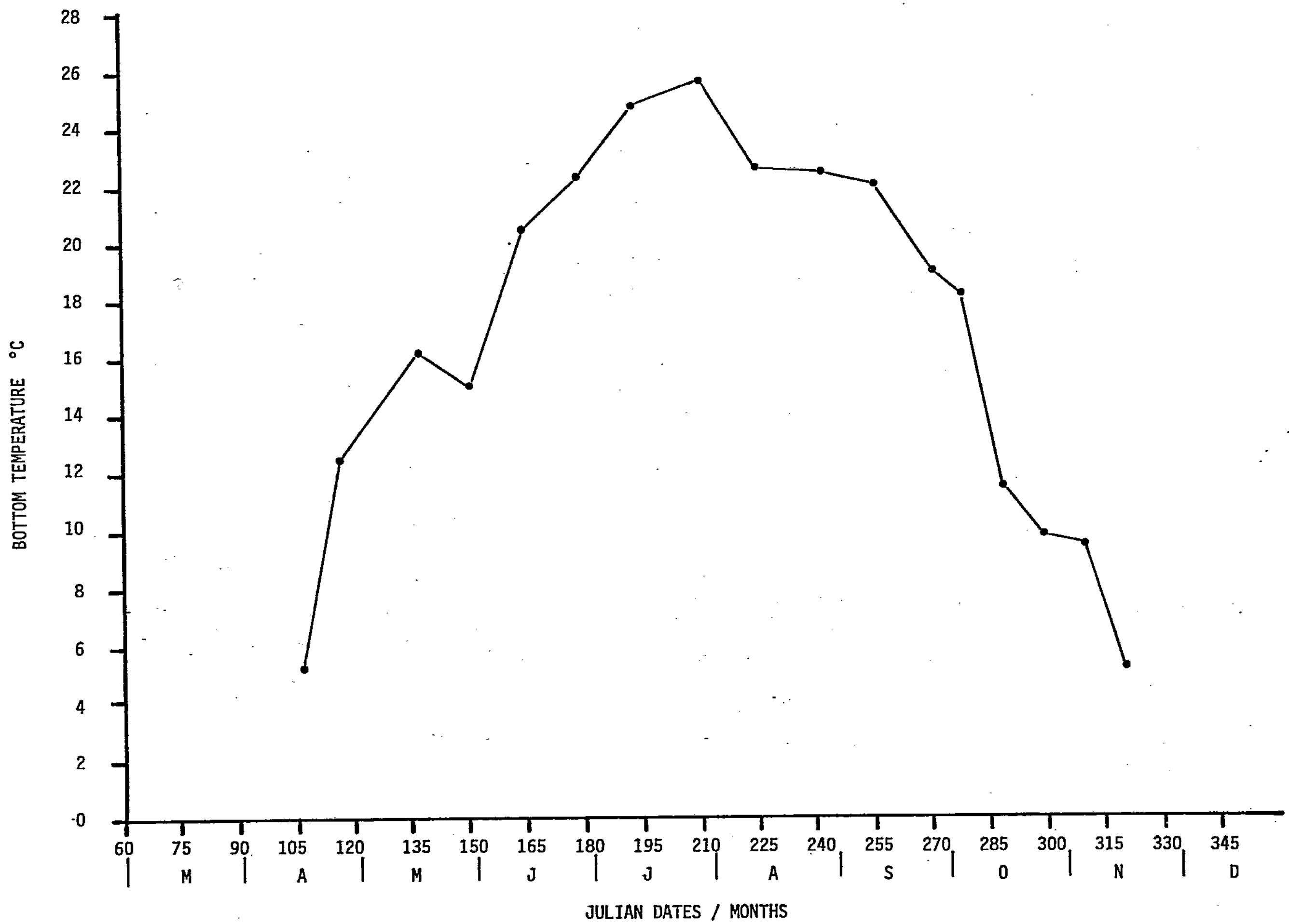

Figure 4. Water temperature, CS-1, 1 meter.

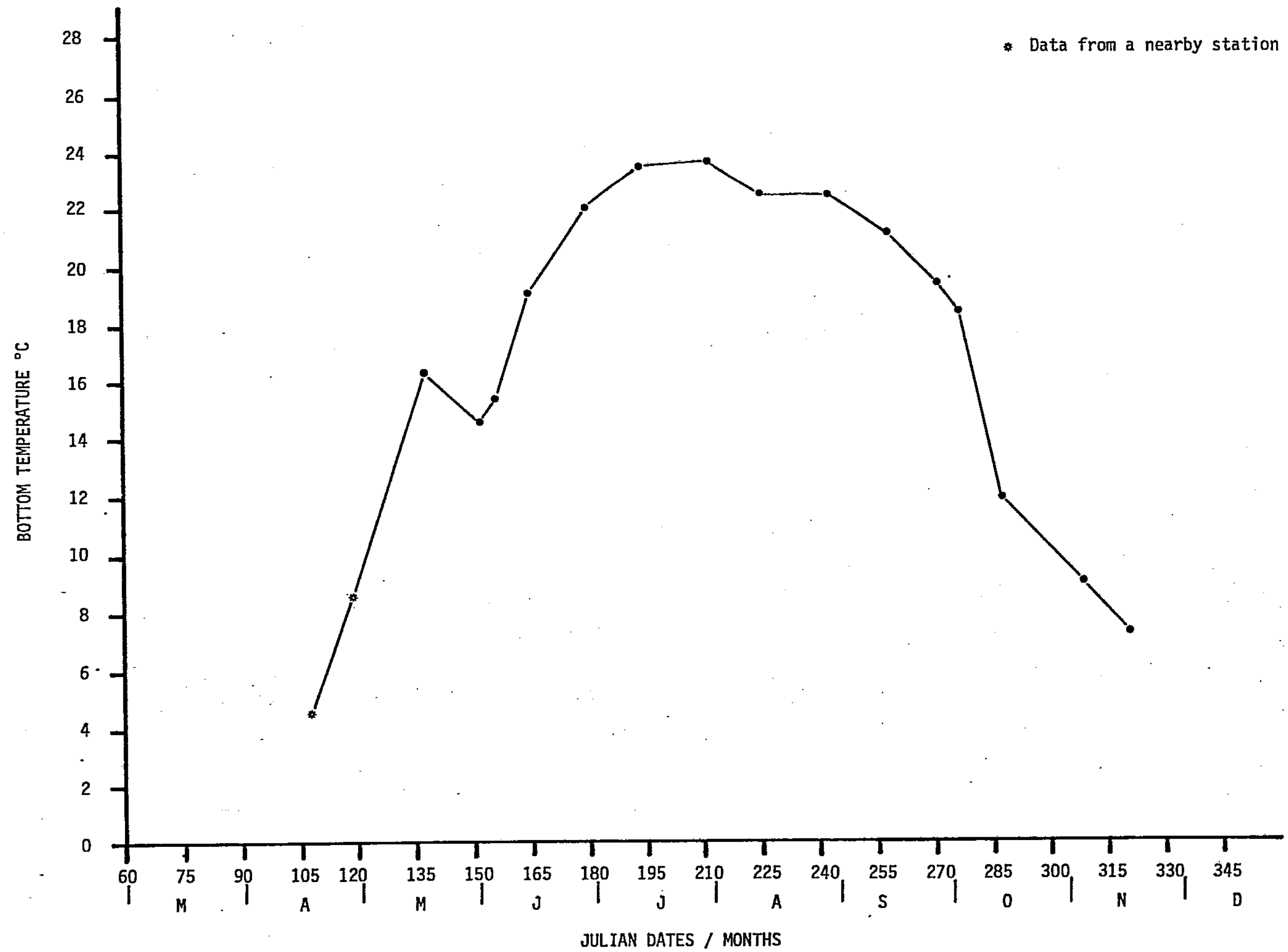

Figure 5. Water temperature, CS-2, 1 meter.

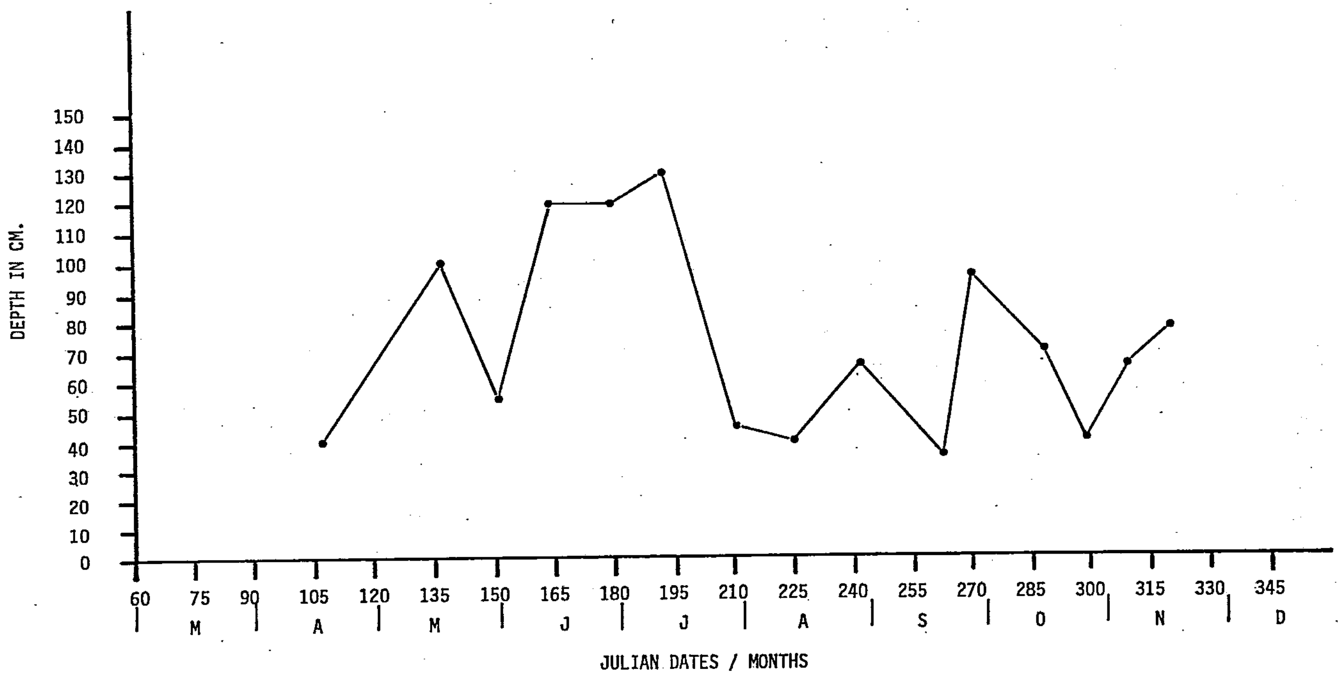

Figure 6. Secchi depth, CS-1, 3 meters.

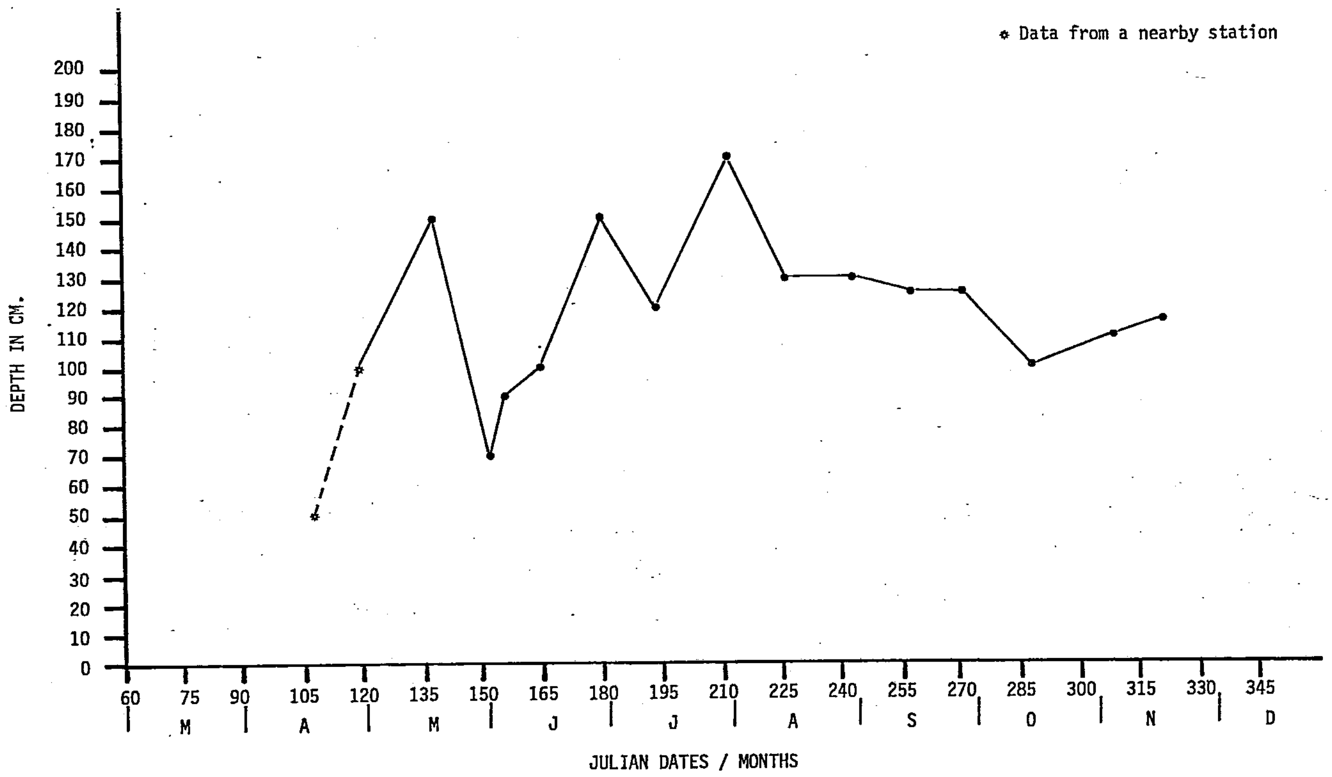

Figure 7. Secchi depth, CS-2, 3 meters.

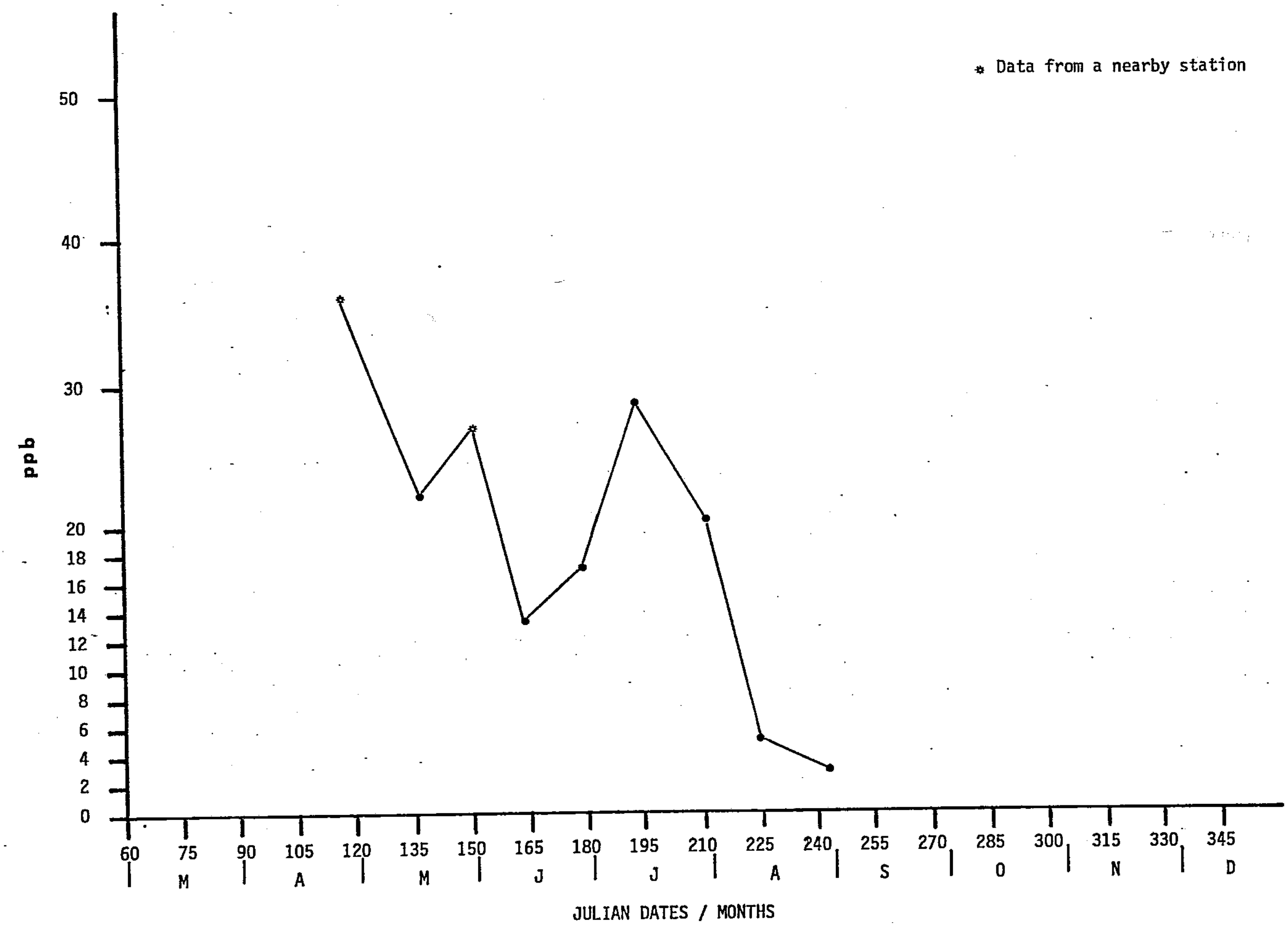

Figure 8. Ammonia levels of the lake, CS-1, 1 meter.

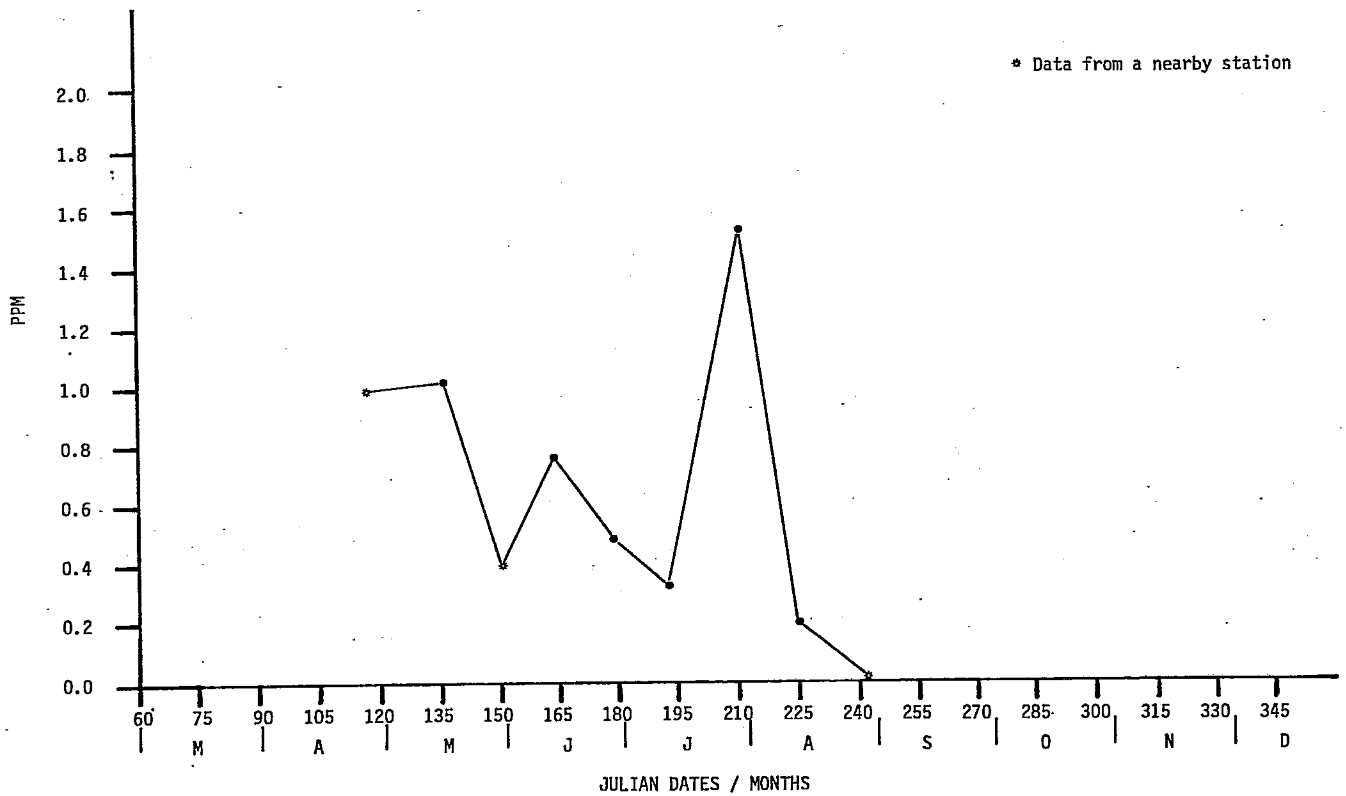

Figure 10. Nitrite-nitrate levels of the lake, CS-1, 1 meter.

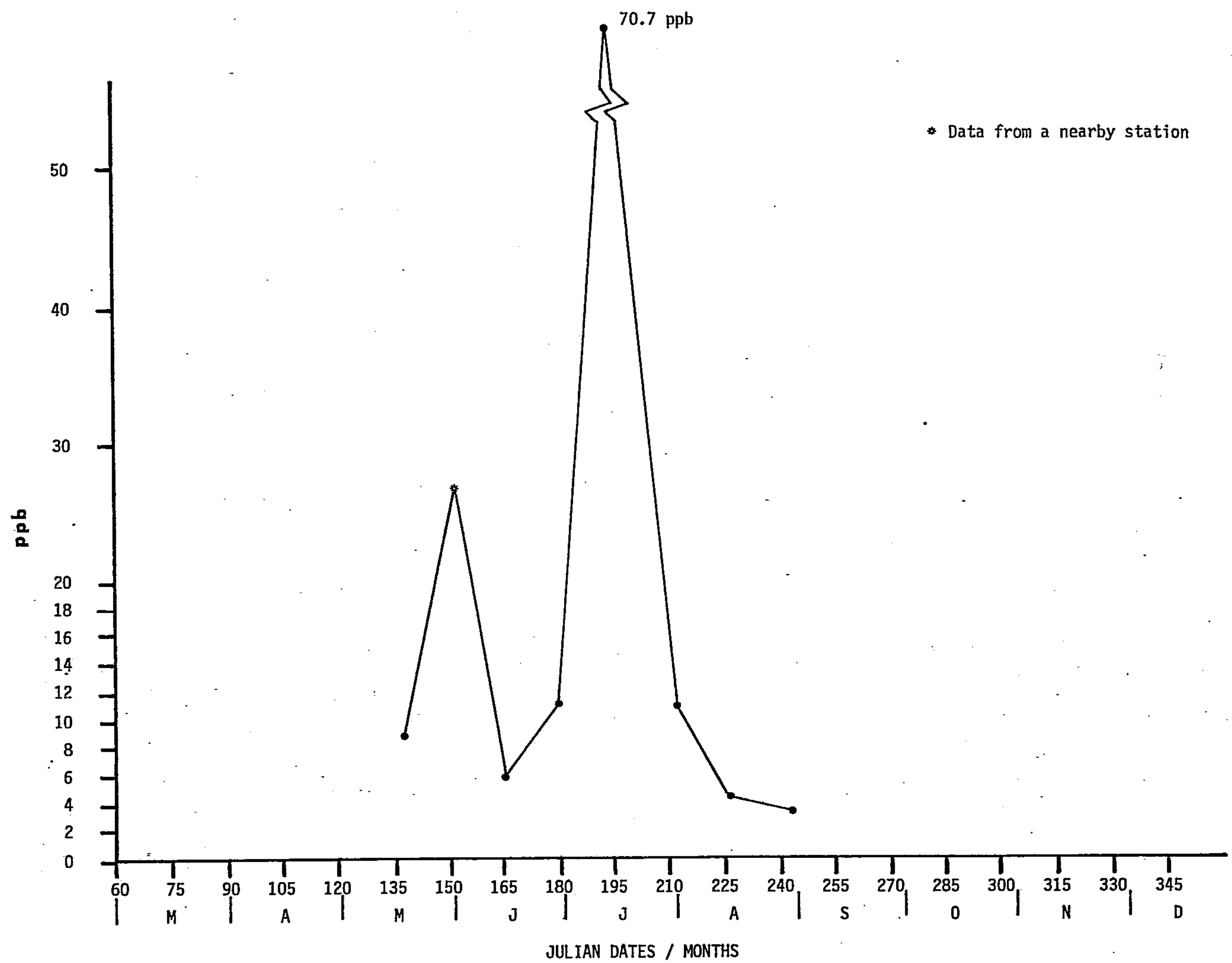

Figure 9. Ammonia levels of the lake, CS-2, 1 meter.

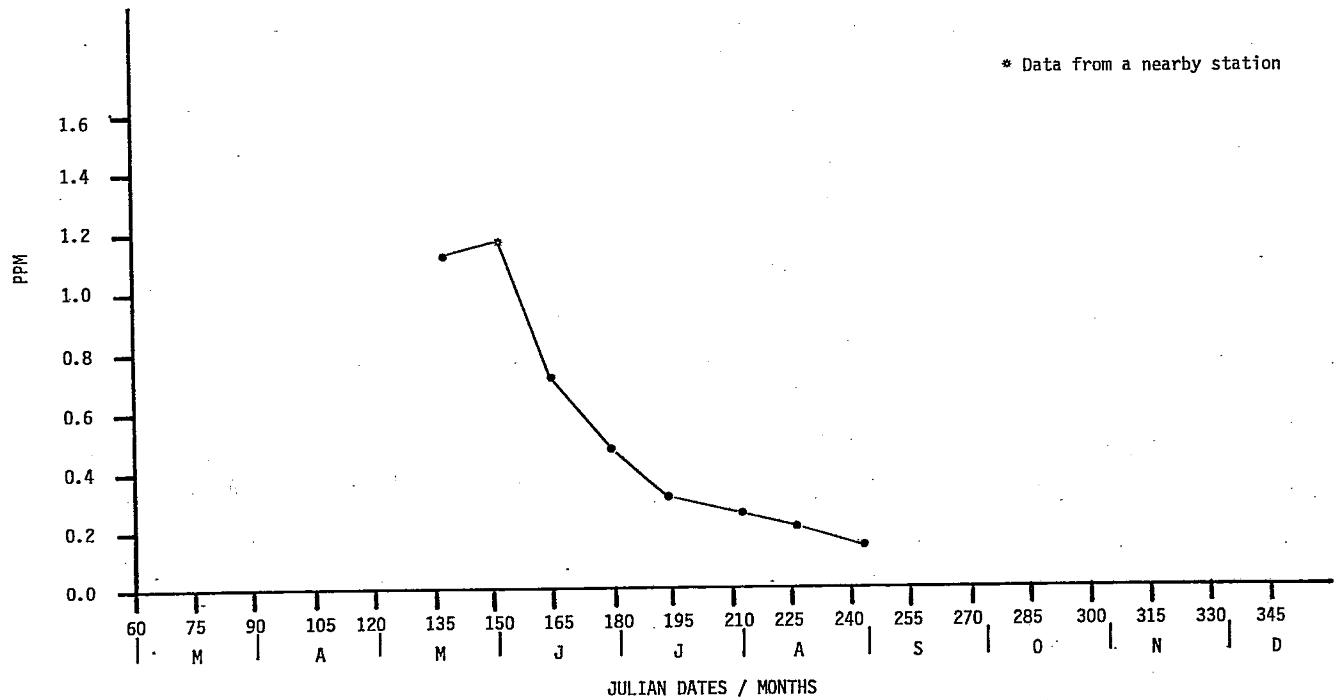

Figure 11. Nitrite-nitrate levels of the lake, CS-2, 1 meter.

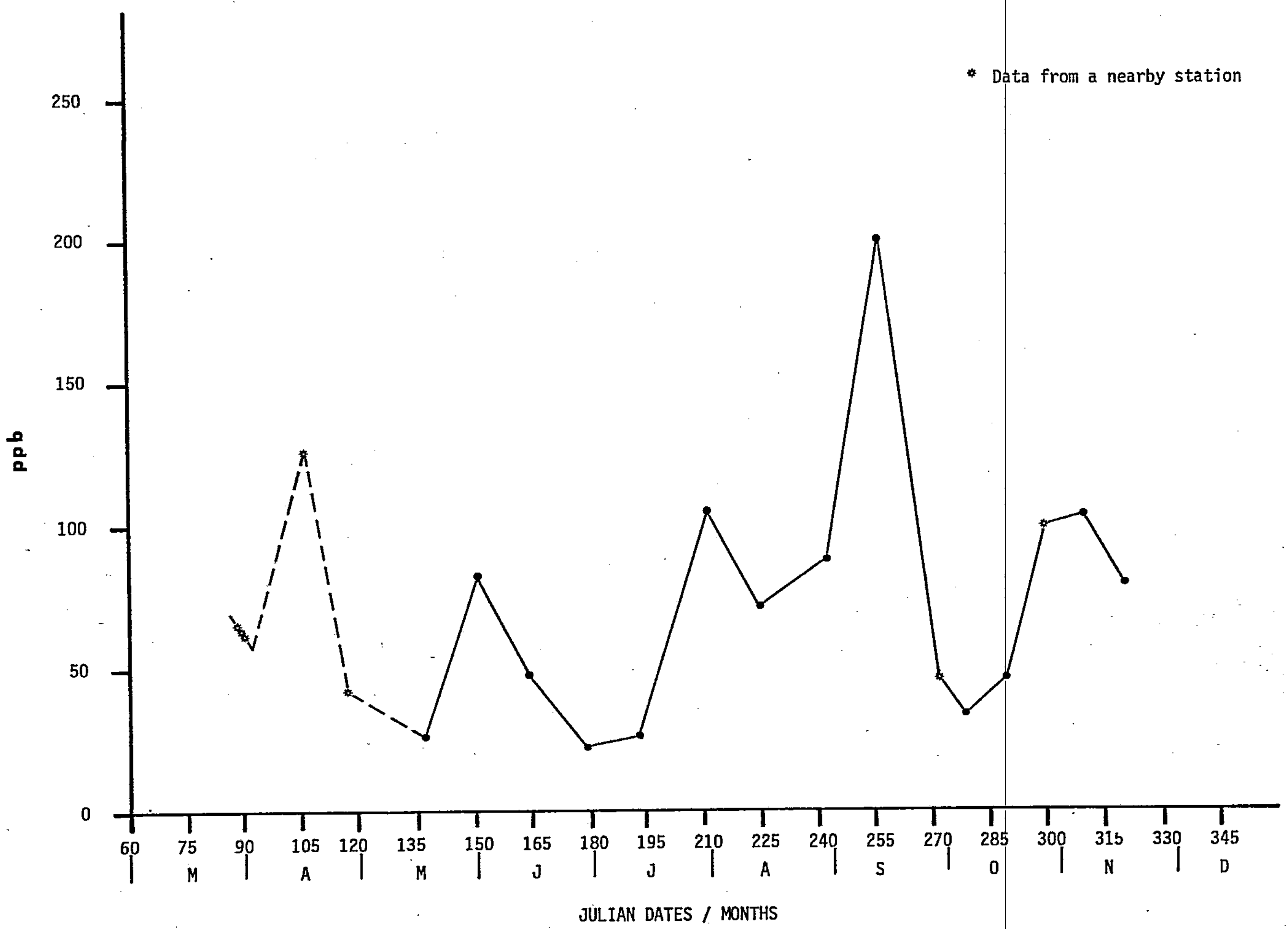

Figure 12. Total phosphorus levels of the lake, CS-1, 1 meter.

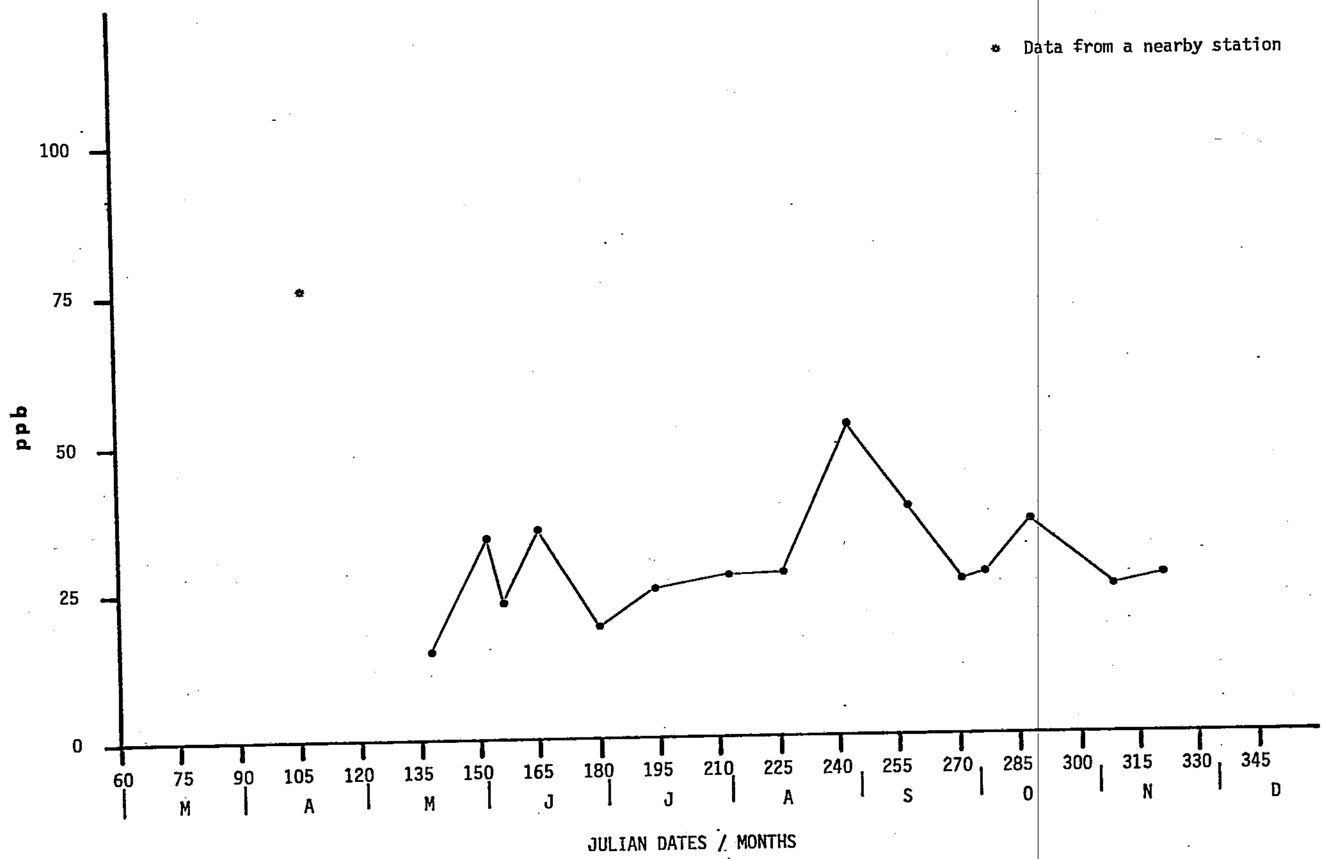

Figure 13. Total phosphorus levels of the lake, CS-2, 1 meter.

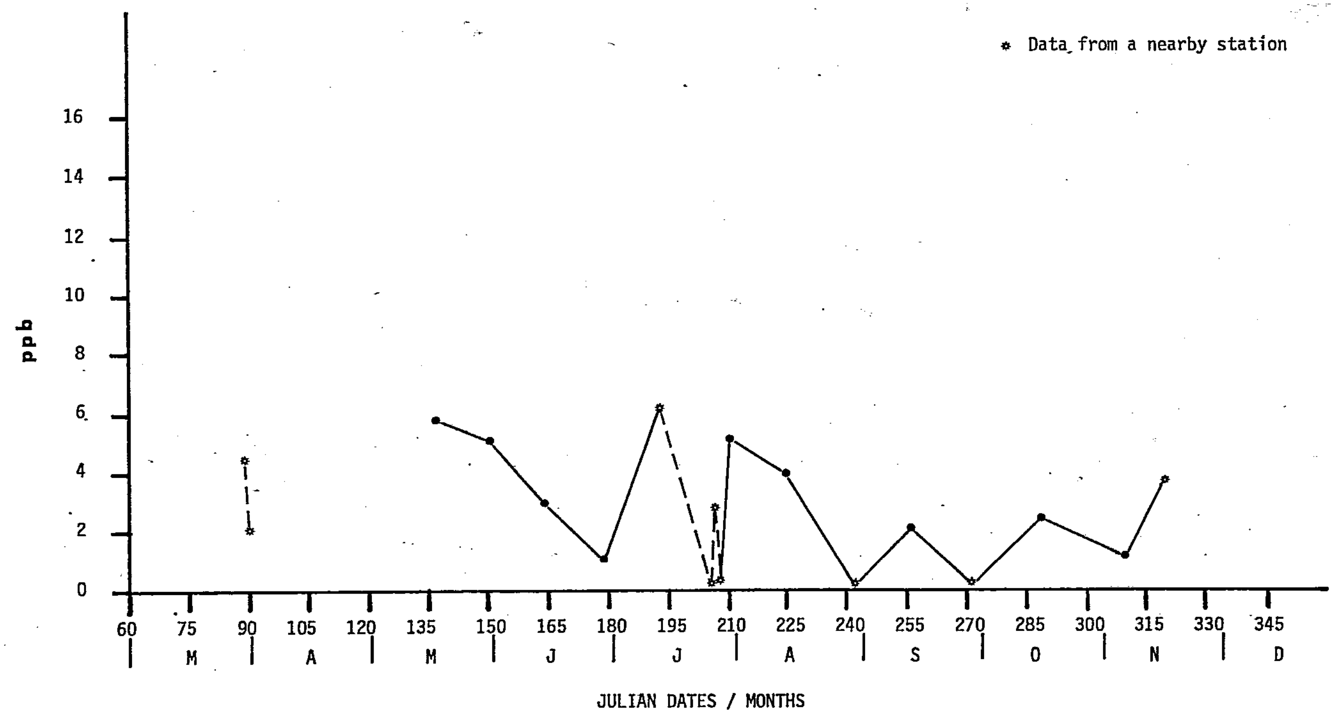

Figure 14. Soluble reactive phosphorus levels of the lake, CS-1, 1 meter.

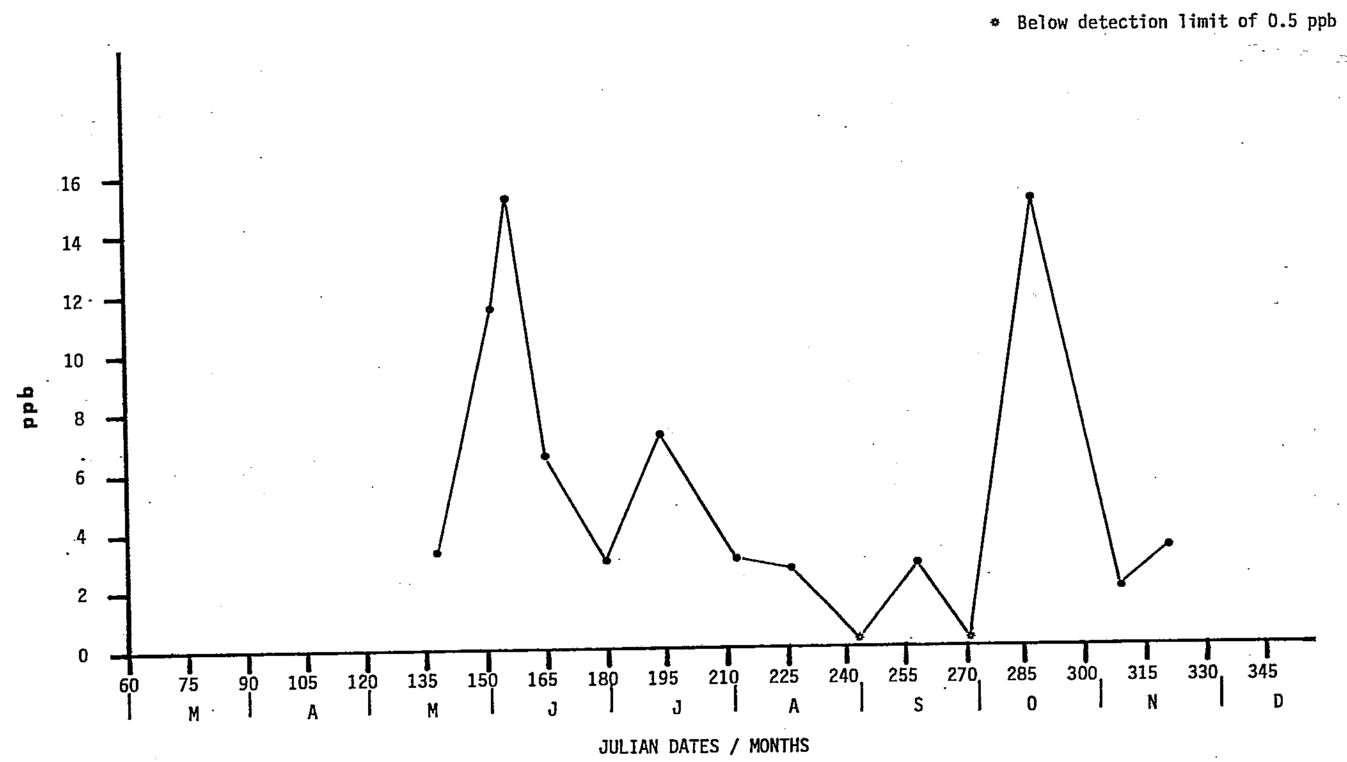

Figure 15. Soluble reactive phosphorus levels of the lake, CS-2, 1 meter.

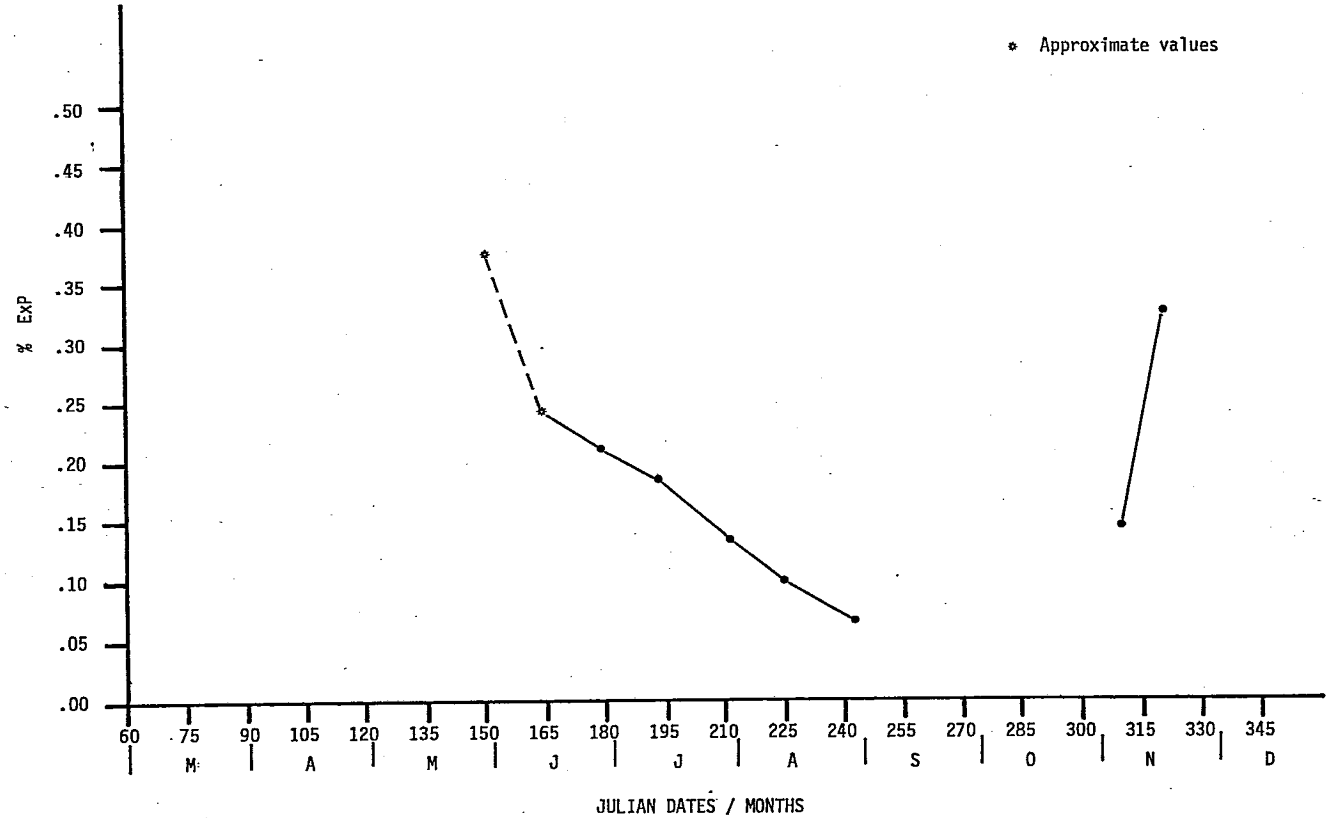

Figure 16. Extractable phosphorus of Cladophora, CS-1, 1 meter.

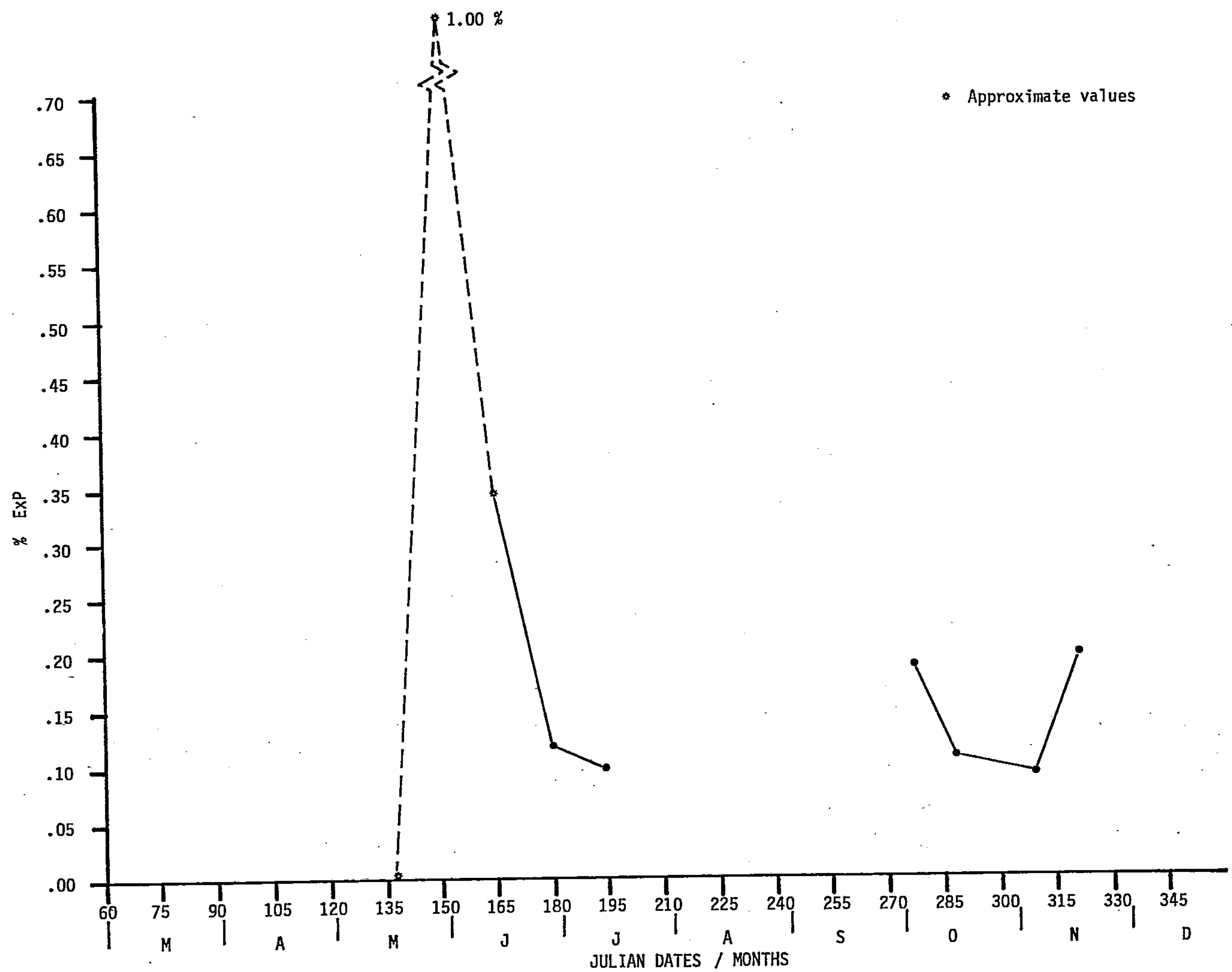

Figure 17. Extractable phosphorus of <u>Cladophora</u>, CS-2, 1 meter.

APPENDIX

ABSTRACT SUBMITTED FOR GREAT LAKES MEETINGS
INTERNATIONAL ASSOCIATION FOR GREAT LAKES RESEARCH

RICHARD C. LORENZ* and CHARLES E. HERDENDORF, Center for Lake Erie Area Research, Ohio State University, Columbus, Ohio 43210. - Environmental factors influencing the growth of *Cladophora* in western Lake Erie.

The attached green algae *Cladophora glomerata* forms luxurious beds on rocky bottoms throughout the shallow areas (0-3 m) of western Lake Erie with filaments up to 90 cm in length. During mid-summer storms this alga frequently becomes detached from the substrate and creates nuisance problems at beaches and water intakes. From mid-April to mid-November 1979, a study was undertaken at two sites (South Bass Island, Ohio and Stony Point, Michigan) to determine the environmental factors which influence the growth patterns of this alga. Growth was noted as early as mid-April with peak biomass observed in late June-early July. During August and September filaments were nearly absent on the substrate but growth at the nearby splash zone and marker buoys continued to be luxurious. At the shallower depths a resurgence of growth was observed in the fall, but only amounting to approximately 10% of the peak summer growth. Temperature, light, and phosphorus all appear to influence the growth of *Cladophora*. Western Lake Erie's total phosphorus and soluble reactive phosphorus levels indicate this nutrient is not limiting. The boiling water extractable P or "luxury P" within the algal cell however indicate that internal phosphorus may control the die back period. High luxury P values were found during the early growth stages and declined as the alga continued its rapid growth. As the luxurious P approaches critical low levels the filaments begin to detach.