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LAKE ERIE INTENSIVE STUDY: CLADOPHORA SURVEILLANCE PROGRAM--WESTERN BASIN

Prepared by

Richard C. Lorenz
and
Charles E. Herdendorf

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THE OHIO STATE UNIVERSITY
CENTER FOR LAKE ERIE AREA RESEARCH
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TABLE OF CONTENTS

TABLE OF CONTENTS (cont'd.)

LIST OF FIGURES

LIST OF FIGURES (cont'd)

LIST OF TABLES

INTRODUCTION

Eutrophication has greatly accelerated in all the Great Lakes, except Superior, due to human activities (Beeton 1965). This cultural eutrophication of the Lakes, especially Lake Erie (Burns 1976), has resulted in changes in the biota (Davis 1969; Christie 1974; Stuckey 1971; Munawar and Munawar 1976) and increases in the algal populations (Sly 1976). One of the most common organisms that is frequently associated with nutrient enrichment in the Great Lakes is the green alga *Cladophora*. This thesis is an ecological investigation into some of the environmental factors influencing the growth of *Cladophora* and the influence this alga has on the littoral region of western Lake Erie.

Lake Erie was the last of the five Laurentian Great Lakes to be discovered by the Europeans in 1669 (Sly 1976). Now, it is the most populated and developed of the Lakes and consequently, has been impacted the most by man's expanding population and industries. Localized degradation of Lake Erie was evident prior to the 1850's and by the 1930's, lake-wide effects were being observed (Sly 1976). Western Lake Erie, with a mean depth of 7.4 m, has always been one of the most productive regions in the Great Lakes and has supported *Cladophora* growth since the mid-1800's and possibly earlier (Taft and Kishler 1973).

In the Great Lakes, where sufficient nutrients (in particular, phosphorus) are available, *Cladophora* is capable of producing large quantities of biomass in the form of long filaments. The large volume of biomass produced and the concentrating effect of currents often result in large quantities of *Cladophora* being washed ashore, creating nuisance accumulations and obnoxious odors. To the public this is very tangible evidence of excessive algal growth, frequently interpreted as pollution. However, to the ecology of the nearshore region the *Cladophora* niche plays an important role by supporting a diverse and abundant community of organisms.

Purpose and Objectives

Recognition of the wide-scale deterioration of Lake Erie prompted the signing of the first Canadian/U. S. Water Quality Agreement in 1972, and the initiation of remedial action under the directorship of the International Joint Commission (IJC). The Water Quality Board of the IJC developed a Great Lakes International Surveillance Plan (GLISP) to coordinate a program to determine water quality conditions and assess the effectiveness of implemented pollution abatement measures. As a component of GLISP the Lake Erie *Cladophora* Surveillance Program (LECSP) was initiated in 1979. This thesis is an outgrowth of the LECSP in western Lake Erie.

The present investigation was largely based on an "in-lake study" undertaken in a complex natural system involving many phenomena and interrelations. This approach is considerably different from laboratory studies performed under controlled conditions where one or two of the numerous components of the environment are investigated. Studying the organism *in-situ* and drawing on previous controlled laboratory experiments provides for a more complete understanding of the alga and its niche. By no means were all aspects and interrelationships of *Cladophora* investigated, but based on previous work the parameters of study were narrowed and selected in hopes of concentrating on the most pertinent information.

The objectives of this study were to characterize the growth dynamics of the alga and determine the possible relationship(s) between environmental conditions and *Cladophora* growth. The environment parameters specifically investigated were temperature, light and the nutrients phosphorus and nitrogen. Studying the alga in its natural environment not only provided an understanding of the autecology but also the opportunity to characterize the synecology of *Cladophora*.

Previous Investigations

Taxonomic Considerations. The taxonomic nomenclature of the genus *Cladophora* (Chlorophyceae) at the species level is confusing and has undergone frequent modification. The present genus was developed in 1843 when Kützing united species of Conferva under the genus *Cladophora*, at which time there were 160 species. Many of these species have since been discarded or considered synonymous. The genus *Cladophora* encompasses fresh water, brackish, and marine species that are world-wide in distribution. Soderstorm's (1963) treatment of the genus lists two freshwater species, C. fracta (VAHL) Kutz. and C. glomerata (L.) Kutz., whereas Van Den Hoek (1963) recognizes nine freshwater species, and Prescott (1951) lists seven species.

Cladophora glomerata (L.) Kutz. is the species that is conspicuously abundant in many lakes, ponds and streams of the Laurentian Great Lakes Basin and is the subject of the present investigation. Several earlier authors (Neil and Owen 1964; Jackson 1966) refer to the alga of concern in the Great Lakes as C. fracta and the more recent authors (Herbst 1966; Kishler 1967; Auer and Canale 1980) refer to C. glomerata. Cladophora glomerata is one of the most variable plants in the genus due to its morphological plasticity. The taxonomic distinction between the above two species is slight, further adding to confusion. The taxonomic problems are thoroughly reviewed in Van Den Hoek's (1963) monograph.

Description and Life Cycle. Cladophora glomerata is an epilithic, rheophilic, macroscopic filamentous alga that inhabits the littoral zone of lakes, ponds and streams. A firm, non-shifting substrate with little net sedimentation is required for the filament's attachment. The alga commonly occurs on bedrock, in cobble areas, and along breakwalls. In addition, Cladophora colonizes a variety of submerged materials including wood, metals, rough glass, tile, gastropod and mollusc shells. Attachment to the substrate is provided by a holdfast resulting from a basal differentiation of the filament. The filaments are richly branched, producing a dense, bush-like, bright green thallus of interwoven filaments. Branches are generally single, originating from the upper end of the parent cell just beneath the septum. The cylindrical cells of the alga are relatively large, with a length several times their width. The cells range from approximately 35-100 µ in diameter to 120-700 u in length, becoming very slightly attenuated toward the apices of the branches, which are bluntly rounded. Cells are coenocytic with many chloroplasts and pyrenoids. Cellular division occurs by formation of a cross septa independent of nuclear division. The cell walls are thick and lamellate, layered with microfibrils in spirals (Prescott 1968). Cladophora does not secrete a mucilage, thus giving it a "rough, crisp" feeling and appearance.

A seasonal periodicity regarding relative abundance, vegetative growth and sporulation have been observed by numerous investigators. Cladophora most often exhibits a bimodal growth pattern in the Great Lakes with peaks in the early summer and fall (Bellis and McLarty 1967; Kishler 1967; Herbst 1969; Mantai 1978; Lorenz and Herdendorf 1982).

Reproduction of Cladophora glomerata is generally considered to be asexual. Conflicting reports on the production of sexual gametes and viable zygotes are contained in the European literature (reviewed by Van Den Hoek 1963). Sexual reproduction has not been reported for the alga in the Great Lakes (Hoffman and Gerloff 1980). Flagellated zoospores are a commonly observed asexual mode of reproduction in the Great Lakes. The zoospores are formed from unspecialized cells of the apical region of the filaments and released through an apical pore of the sporangium. Production of zoospores is environmentally controlled, often resulting in massive release of spores from many thalli and cells simultaneously. The swarming zoospores exhibit positive phototactic responses (Van Den Hoek 1963). After settling, the zoospores germinate, forming short plantlets within several days.

Akinete formation is another means of propagation and survival for the alga, generally when conditions become unfavorable. The transformation of the cell into an akinete is characterized by the cell contents becoming more dense, appearing a darker green, the accumulation of starch, thickening of the cell wall and the cell becoming somewhat club-shaped. The thallus loses its bushy branching pattern, becoming coarse and stiff taking on a zigzag pattern. Akinetes are capable of surviving unfavorable conditions and proliferating again under favorable conditions (Van Den Hoek 1963). In addition to the akinetes, the basal portions of attached filaments are capable of surviving adverse conditions and undergoing similar transformation as the akinetes. Filament fragmentation is another method of asexual propagation.

Historical Occurrence. Cladophora was the first alga to be identified from Lake Erie, possibly reflecting its abundance well into the past (Taft and Kishler 1973). Taft and Kishler (1973) stated that there is reason to believe that Cladophora was present in the glacial lakes and tributaries preceding present-day Lake Erie. The earliest recorded information indicates that this alga has been present in the Great Lakes region since at least the mid-1800's. Cladophora glomerata was reported from all the Great Lakes except Lake Superior in 1847 by

Bailey and in 1872 by Wood. Smith reported it from Lake Superior in 1871. Day (1882) listed the alga in the Niagara River and Campbell (1886) indicated its presence at the mouth of the Detroit River.

Photographs from Jay Cook of Gibraltar Island, postcards of the Bass Islands from 1865-1907 (Taft and Kishler 1973) and the first comprehensive plant survey of the region (Pieters 1901) all indicate the presence of _Cladophora_ in the Bass Island region of western Lake Erie during the late 1800's. In the early 1900's Muenscher (1928) reported its common presence on the rocks of the eastern basin shore, Gottschall (1930) indicated its occasional presence at Presque Isle, especially near sewer outlets, and Tiffany (1937) described its general presence. _Cladophora_ has thus been present in western Lake Erie for quite some time and its presence may not necessarily be a symptom of cultural eutrophication.

Distribution in the Great Lakes. The presence and increasing abundance of _Cladophora_ in the Laurentian Great Lakes has generally been associated with nutrient enrichment (Beeton 1966; Herbst 1969; Verduin 1969). In the upper Great Lakes _Cladophora_ is limited to areas of environmental perturbation such as adjacent to population centers and point source loadings where nutrient levels are elevated. On Lake Huron, Canale and Auer (1982) demonstrated that reductions in phosphorus loadings from a sewage treatment plant to a small stream at Harbor Beach, Michigan decreased the abundance and distribution of _Cladophora_, eliminating nuisance conditions. The presence of the alga in the more nutrient-rich lower Great Lakes Erie and Ontario (Vollenveider et al. 1974) is more general in distribution and is not normally limited by nutrient availability (Shear and Konasewich 1975; Wezernak et al. 1974). Kishler (1967) reported a general distribution of the alga in the Island Region of western Lake Erie and Wezernak et al. (1974) using remote sensing techniques reported 66-79% of the nearshore zone of Lake Ontario on the United States side to be colonized by Cladophora. Recently, the distribution of the major Cladophora populations in the Great Lakes has been reviewed by Auer and Canale (1981).

Temperature. Temperature has frequently been suggested as the controlling factor in the seasonal periodicity observed, which results in a marked decrease of Cladophora crop during the hottest period of the year (Bellis and McLarty 1967). The optimal and maximum temperatures tend to vary with the environmental setting. Culture studies generally report an optimal temperature for dry weight production in the range of 25-30^{o}C (Bellis 1968; Zuraw 1969; Whitton 1970; Gerloff and Fitzgerald 1976; Hoffman and Gerloff 1980). Several in situ productivity studies have observed temperature optimums in the 20-25^{o}C range (Adams and Stone 1973; Moore 1978) and field studies in the Great Lakes have indicated an optimum of approximately 18^{o}C (Kishler 1967; Herbst 1969; Taft 1975; Sweeney 1980). Storr and Sweeney (1971), in a culture experiment using Lake Erie water as the culture media, reported an optimal temperature of 18^{o}C with cessation of growth at temperatures approaching 25^{o}C. Laboratory studies with a Lake Huron isolate observed a 13^{o} to 17^{o}C optimum temperature with net photosynthesis occurring as high as 30^{o}C

(Graham et al. 1982). Initiation of Cladophora growth in Lake Erie was reported near 11^{o}C and to reach an optimum at 26^{o}C (Moore 1978). Taft and Kishler (1973) observed growth to begin in Lake Erie near 4^{o}C and found the alga to photosynthesize to within a degree of freezing. Zoosporogenesis is favored by temperatures between 15-20^{o}C (Mason 1965; Bellis and McLarty 1967; Hoffman and Gerloff 1980).

Light. Growth of Cladophora is reported to be favored by high light intensities (Manning et al. 1938; Whitton 1970; Mantai 1974; Wood 1975; Taft 1976; Wong and Clark 1976). Relatively inefficient utilization of low-light intensities was reported by McMillan and Verduin (1953) for Cladophora in Lake Erie. Recently, the optimum light intensity has been reported to be in the 300 to 600 $\mu E/m^2$ sec range, with the compensation point near the 25-35 $\mu E/m^2$ sec range (Graham et al. 1982). In addition to light quantity, light quality (Cook and Price, 1928) and photoperiod have been reported to influence biomass production and zoosporogenesis in the alga (Storr and Sweeney 1971; Hoffman and Gerloff 1980).

Photosynthesis. Widely varying photosynthetic and respiration rates are reported in the literature (McMillan and Verduin 1953; Adams and Stone 1973; Mantai 1974; Wood 1975; Mantai and Haase 1977). The wide variation in rates has been attributed to errors induced by long incubation periods of the in-situ bottle technique (Mantai and Haase, 1977). These errors include elevated pH levels, carbonate precipitation, self-shading, and increased photorespiration resulting in a general underestimation of natural photosynthetic rates.

Photosynthesis is temperature and light regulated. The photosynthetic rate increases as lake temperatures rise (Mantai 1974; Adams and Stone 1973). McMillan and Verduin (1953) and Mantai (1974) both report a temperature coefficient (Q_{10}) of approximately 2. The detailed study of Graham et al. (1982) reported that the bimodal growth pattern frequently observed in Cladophora in the Great Lakes is regulated by the photosynthetic and respiration rates of the alga, controlled by both temperature and light intensity.

Nutrients. Nitrogen and phosphorus generally have been considered the nutrient elements most likely to limit algal growth in aquatic systems (Hutchinson 1944). The presences and abundance of Cladophora in the Great Lakes has been linked to the availability of phosphorus and does not appear to be limited by nitrogen supply (Neil and Owen 1964; Gerloff and Fitzgerald 1976). Assessment of phosphorus and nitrogen availability to Cladophora and other plants has commonly been performed using tissue analysis (Gerloff and Skoog 1954; Gerloff and Krombholz 1966; Fitzgerald 1969).

Critical tissue levels for most of the essential elements have been established in laboratory experiments by Gerloff and Fitzgerald (1976). They report the alga to be characterized by relatively low critical nitrogen and phosphorus concentrations of 1.1% and 0.06%, respectively. Recently, Gerloff and Muth (1979) revised the critical level of phosphorus to 0.08%. Cladophora requires relatively high levels of

Boron, Sulfur and the vitamins B_1 and B_{12} in culture but the significance of these factors in natural populations has not been explored.

Cladophora has the ability to uptake luxury levels of nutrients when abundant supply is available, resulting in tissue concentrations greater than required for optimal growth (Gerloff and Fitzgerald 1976; Wong and Clark 1976; Mantai 1978). Luxury phosphorus is stored as polyphosphate (Lin 1977) which can provide the alga with a phosphorus source when external supplies become limiting (Kuhl 1974).

Bioaccumulation. Cladophora is capable of the uptake and accumulation of numerous other substances in addition to the required nutrients. The alga has the ability to bioaccumulate pesticides (Meeks 1966), radioisotopes (Williams 1970; Neil 1975), heavy metals (Bjerkelund and Ongley 1980) and toxic substances (Anderson et al. 1980; Haile et al. 1975).

pH. Cladophora is found in alkaline waters having a pH ranging from approximately 7-10 (Van Den Hoek 1963; Mason 1965; Bellis 1968; Wood 1975). The most recent and complete investigation into pH (Mantai and Haase 1977) stated that photosynthesis and respiration rates are strongly pH-dependent. Photosynthesis of Lake Erie Cladophora reported in the above study occurred at optimal rate at pH 8.2, with an upper limit of 9.6. Respiration rates had a bimodal pH response curve with peaks at pH 7.6 and 9.2

In addition to requiring an alkaline environment Cladophora favors a relatively high level of hardness. Minimum concentrations of 6.4 mg/l of calcium and 1.7 mg/l of magnesium are required for growth (Bellis 1968). Cladophora has the capabilities of utilizing bicarbonate ions as a carbon source (Raven 1970) and is thus capable of precipitating calcium and magnesium carbonates at the higher pH's (Wood 1975).

Water Movement. The Cladophoraceae in general are absent from completely quiet water as identified by Fritsch (1935). Neil and Owen (1964) reported that Cladophora of the Great Lakes is most prolific in areas of maximum water movement. Numerous species of aquatic organisms have an "inherent current demand" which Whitford and Schumucker (1961) have theorized is linked to a need for rapid exchange of materials with the environment. This rapid exchange is provided by a steep diffusion gradient produced by the water movement. Studies with Oedogonium in a 15 cm/sec current resulted in a tenfold increase of the phosphorus uptake and a respiration rate 70% greater than still water (Whitford and Schumucker 1961). Water movement in the Great Lakes is created by currents and wave action, which additionally prevents net accumulation of sediment, a condition required for Cladophora colonization.

Organisms in association with Cladophora. Cladophora filaments are frequently colonized by epiphytes, the majority of which are diatoms. The majority of epiphyton studies are on riverian Cladophora of Europe as reviewed by Whitton (1970). Seasonal variation in the abundance is often noted. Numerous Great Lakes researchers have noted the presence and frequent abundance of periphyton on Cladophora but detailed studies are lacking (Bellis and McLarty 1967; Zaraw 1969; Taft and Kishler 1973; Wood 1975). Some information is provided by Kishler (1967) and a more detailed account is presented by Rosen et al. (1982). Cladophora itself has been reported to be epizooic on fish (Vinyard 1953; Taft, personal communication).

The seasonal abundance of Cladophora influences not only the associated flora but also the distribution and abundance of the faunal community found in association with the alga (Blum 1957; Judd 1975; Barton and Hynes 1977). Bocsar and Judd (1972) reported approximately 35 species of invertebrates in association with Cladophora.

METHODS

Study Locations

Two monitoring sites representing different environmental conditions were selected in western Lake Erie. The westernmost site was established at Stony Point, Michigan; 41°56' latitude, 83°16' longitude (Figure 1). Stony Point is a submerged bedrock outcrop with overlying cobbles at the shallower depths (0-1.5 m) and is one of the few areas along the western shore of Lake Erie that provides a suitable natural substrate for Cladophora. Stony Point protrudes approximately 2 km into the lake and is generally influenced by the flow from the westernmost channels of the Detroit River (Herdendorf 1969), which receives wastewater effluent from the Detroit area. During the two years of monitoring the site was also influenced by the construction, dredging and dumping activities associated with the Point Mouille dredge spoil area, located approximately 10 km to the northeast.

The second site was established on the southeast side of East Point, South Bass Island, Ohio; 41°39' latitude, 82°48' longitude (Figure 1). Substrate at this site and much of the island region is gently sloping dolomite bedrock. The South Bass site is approximately 10 km north of the Ohio mainland and is representative of mid-western basin conditions. A detailed map of the two sites and their sampling stations are presented in Appendix A. In addition to the two routinely monitored sites numerous

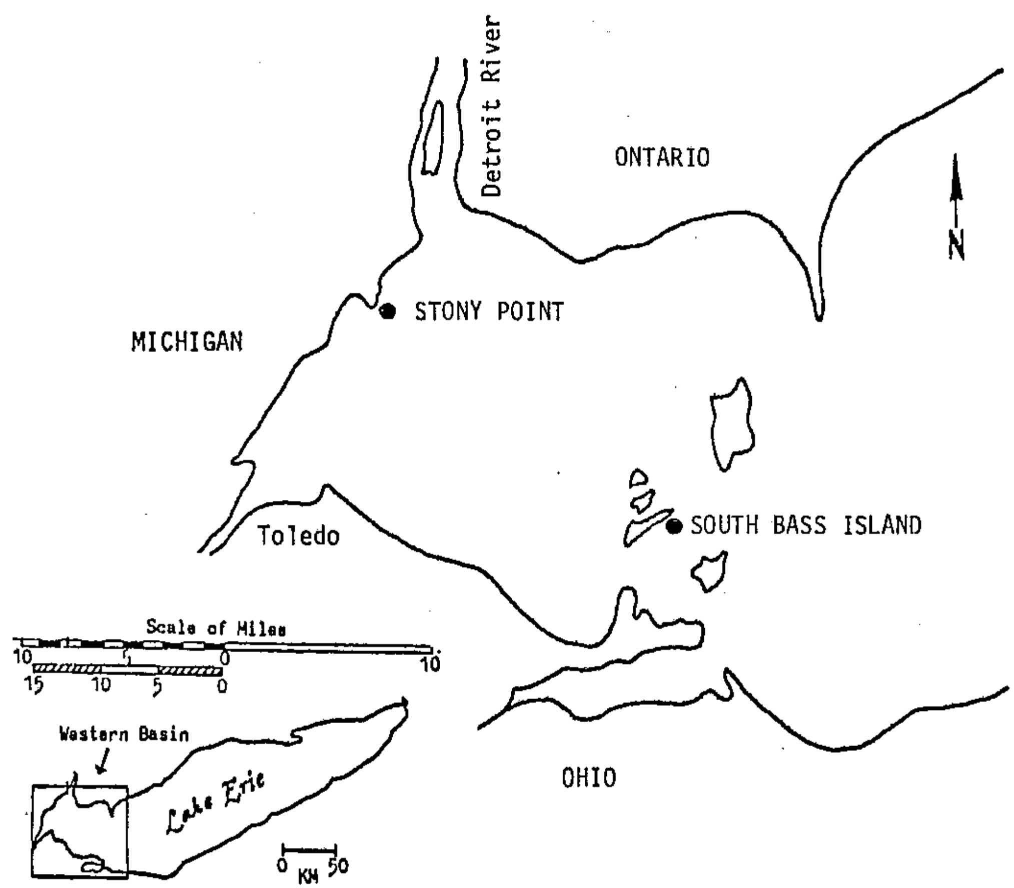


Figure 1. Western Lake Erie *Cladophora* Monitoring Sites.

observations were made throughout the western basin over the many months of study.

Field Procedures

Each site was visited at two-week intervals from mid-April to mid-November during 1979 and 1980. Sampling operations were conducted from boats utilizing SCUBA techniques for collection and observation. Monitoring stations at each site were established along a bottom transect running perpendicular to the shore at depths of 0.5, 1, 2 and 3 m. These depths were based on mean projected water levels for the season; 3.4 and 3.7 feet (1.036 m and 1.128 m) above low water datum for 1979 and 1980, respectively (U. S. Army Corps of Engineers 1980). Water levels during the present study were approximately 1.5 feet (0.457 m) above the 80-year average and 1 foot (0.305 m) below 1972-1973 record high levels. The 1, 2 and 3 m stations were marked with buoys to facilitate location. Sampling stations thus remained at one location, in relation relative to the bottom, throughout the season regardless of water depth at the time of sampling. This compensated for the frequently fluctuating water levels which average about 15 cm daily in western Lake Erie (Verduin 1969). In addition to the above four depths routinely monitored, observations were made in the "splash zone."

At each station (0.5, 1, 2 and 3 m) *Cladophora* standing crop, biovolume, filament length (mean and maximum) and percent coverage were determined *in-situ* from natural substrate. Standing crop and biovolume were determined by hand harvesting the alga within a 0.25 m^2 ring subjectively placed on the bottom to reflect an area of representative density at the station. At the shallower depths (0.5 and 1.0 m) of Stony Point, the cobble substrate was recovered and the Cladophora removed from the rocks in the laboratory. Underwater photography proved to be ineffective in documenting Cladophora growth due to the high turbidity. A grab-sample of Cladophora was collected outside the ring at each station for the analysis of total tissue phosphorus, boiling water extractable phosphorus, total tissue nitrogen and total tissue carbon.

Water samples for nutrient analysis were taken from 0.25 m above the bottom at the 1, 2, 3 and periodically 0.5 m stations along the transect. Additional water was collected from the 2 m station during the 1980 season for the analysis of suspended solids and chlorophyll. Water samples and Cladophora tissue nutrient samples were kept cool until processed at the South Bass Island laboratory.

Transparency of the water was measured using a 20 cm Whipple modified Secchi disk. For 1979, light at depth was measured with a protomatic light meter, recording in footcandles. Light was measured during the 1980 season as photosynthetically active radiation (PAR) in μ E/m^2 sec using both underwater spherical and cosine (columnar) quantum sensors (LI-193S and LI-192S, Li Cor). The spherical sensor allows measurement of radiation from virtually all directions within the 400-700 nm wavelength spectrum, representing the light that is available to the algae. The light values referred to in this thesis are from the spherical sensor. Incident light levels were recorded just above and just below the surface of the water. Light values recorded just below the surface were used as the incident light since measurements above the surface included light reflected from the surface of the water.

Water temperatures were measured at 0.1 m below the surface and 0.25 m above the bottom. Air temperature, wave height and percent cloud coverage were additionally recorded for each sampling date.

Shoreline accumulations of Cladophora were monitored on the public beach at Perry's monument, South Bass Island (Appendix A) during 1980. The quantity of Cladophora on this sandy beach was assessed by placing a 1x2 m frame on the area of densest accumulation. Biomass within this frame was harvested and weighed for wet weight. Sub-samples were taken for dry weight ($104^{o}C$) and ash free weight determinations. Photographs were additionally taken.

Laboratory Procedures

Water samples were processed upon returning to the South Bass Island laboratory. The water samples were split for the analysis of soluble reactive phosphorus (SRP), total dissolved phosphorus (TDP), total phosphorus (TP), ammonia nitrogen (NH_3), nitrate + nitrite nitrogen (NO_3+NO_2), total dissolved Kjeldahl nitrogen (TDKN), total Kjeldahl nitrogen (TKN), suspended solids and chlorophyll as indicated in Figure 2. Methods of analysis and the estimated standard deviations are listed in Table 1. The estimate of standard deviation is the recommended expression for quality control parameters involving pairs by the IJC

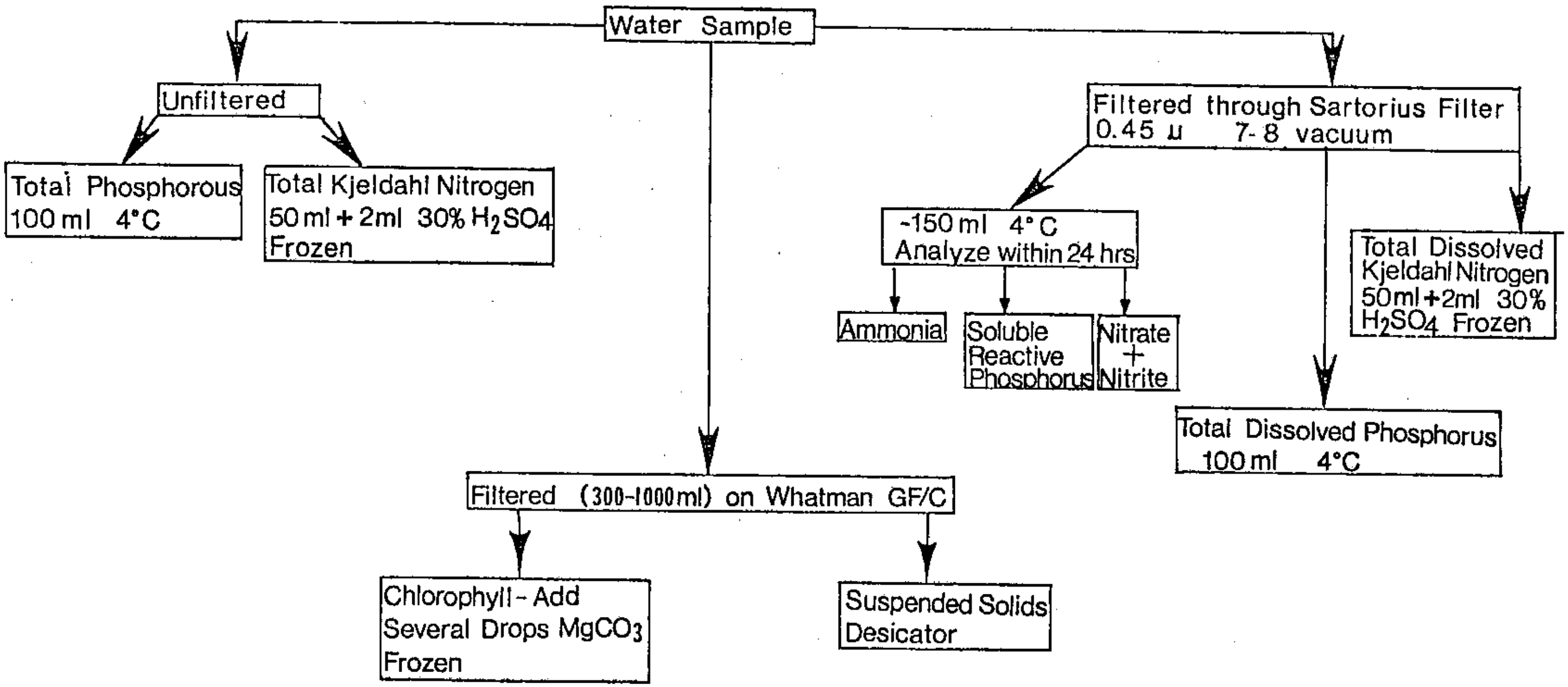


Figure 2. Water Sample Processing Scheme.

TABLE 1

ANALYTICAL METHODS FOR THE WESTERN LAKE ERIE CLADOPHORA SURVEILLANCE PROGRAM

PARAMETER	METHOD	REFERENCE	RANGE	DETECTION LIMIT AND UNITS	ESTIMATE OF STANDARD DEVIATION**
Soluble Reactive Phosphorus	AA II* Stannous Chloride	CCIW, 1979	0.5-100	0.5 µg P/L	0.5
Total Dissolved Phosphorus	AA II Stannous Chloride Persulfate + H_2SO_4 Autoclave Digestion	CCIW, 1979	0.5-200	0.5 µg P/L	0.6
Total Phosphorus	AA II Stannous Chloride Persulfate + H_2SO_4 Autoclave Digestion	CCIW, 1979	0.5-200	0.5 µg P/L	1.0
Ammonia	AA II Phenate	Technicon Industrial Method 154-71W	2.0-400	2.0 µg N/L	2.0
Nitrate + Nitrite	AA II Cadmium Reduction	Technicon Industrial Method 100-70W	5-1000	5 µg N/L	4.0
Total Kjeldahl Nitrogen	Semiautomatic Block Digestor AA II Phenate	EPA Method 351.1 1979	50-10000	50 µg N/L	43
Suspended Solids	GF/C Glass Fiber pad	APHA, 1975	0.2-250	0.2 mg/L	----
Chlorophyll	Acetone Extraction Spectrophotometer	LORENZEN, 1967 FAY, 1976	0.6-250	0.6 µg/l	0.8
Total Tissue Phosphorus	AA II Stannous Chloride Persulfate + H_2SO_4 Autoclave Digestion	CCIW, 1979	0.005-2.000	0.005 µg P/100 µg alga	0.008
Boiling Water Extractable Phosphorus	AA II Stannous Chloride Boiling water extraction	CCIW, 1979 Fitzgerald + Nelson 1966	0.005-2.000	0.005 µg P/100 µg alga	0.025
Total Tissue Nitrogen	Perkin-Elmer C-H-N elemental analyzer 203	CCIW, 1979	0.08-10.00	0.08 µg N/100 µg alga	0.08
Total Tissue Carbon	Perkin-Elmer C-H-N elemental analyzer 203	CCIW, 1979	0.3-50.0	0.3 µg C/100 µg alga	0.7
Biomass	$1/4\ m^2$ in situ sample				
Wet	Blot Dried	Carnes + Millner, 1980	0.01-500	0.01 g	15.5***
Dry	48 hrs. at 64°C then 104°C	----	0.001-250	0.001 g	2.2***
Ash Free Weight	104°C - 550°C Ash weight	APHA, 1975	0.001-200	0.001 g	1.5***
Biovolume	Volume displacement of blot dried Cladophora in graduated cylinder	Carnes + Millner 1980	0.5-250	0.5 ml	13.7***

*Technicon Auto Analyzer II

**Estimated Standard Deviation = $\bar{A}$ pairs/1.128 (ASTM, 1951)

***Calculated Standard Deviation based on three replicates

(Clark, 1981) and referenced in ASTM (1951). Nutrient analyses were done colorimetrically using automated procedures on the Technicon Auto Analyzer II. Kjeldahl samples were analyzed at Heidelberg College's Water Quality Laboratory.

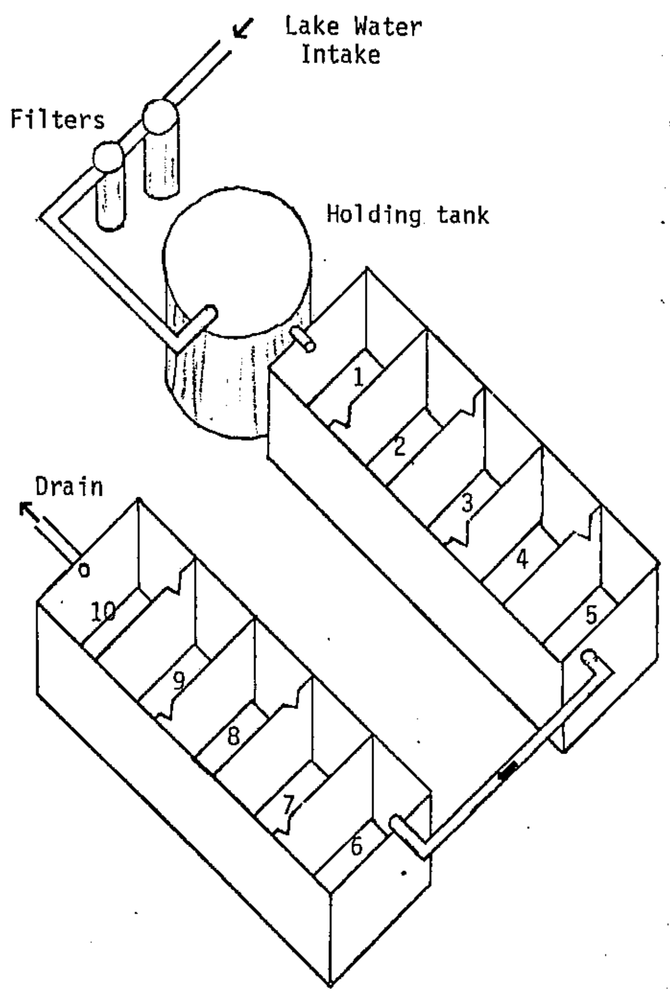
The sample for Cladophora tissue nutrient analysis was processed the same day as collection. After cleaning the Cladophora of extraneous material and organisms, the sample was divided; a portion was utilized for the analysis of boiling water extractable phosphorus (ExP) and the remaining material was dried at 64^{o}C for subsequent total tissue phosphorus (TTP), total tissue nitrogen (TTN), and total tissue carbon (TTC) analyses. Analysis of ExP was based on a modified procedure developed by Fitzgerald and Nelson (1966). The extraction procedure used fresh Cladophora (totaling between 0.05-0.1 g dry weight) rinsed in Gorham's medium (minus the P source, Appendix B) and extracted in 50 ml of Gorham's for 1 hour in a boiling water bath. The sample was centrifuged, filtered (Sartorius 0.45 μ), and the supernatant analyzed for total dissolved phosphorus (Table 1). Centrifuge pellets were dried at 64^{o}C and weighed.

Total tissue P, TTN, and TTC analyses were performed using dried, mortar and pestle ground, Cladophora. Analysis of TTP utilized 10 mg of algae placed in 100 ml of distilled water and digested using the same procedure as was used for a TP water sample (Table 1). Total tissue N and TTC were analyzed on a Perkin-Elmer C-H-N elemental analyzer using 1-1.5 mg of algal material. Tissue nutrient analyses were run in duplicate and reported as means on a percent of alga dry weight (64^{o}C) basis (mg nutrient/100 mg alga). The equations for calculation of the percent tissue nutrients are listed in Appendix B.

The 0.25 m^2 Cladophora standing crop samples were cleaned of sediment, debris and large organisms by rinsing with a stream of water and visual examination prior to biomass and biovolume (volume displacement) determinations. Prior to analysis the samples were blotted to dryness between paper towels. Biovolume was determined by the volume displacement (mls) resulting from submerging the sample in a graduated cylinder. A series of biomass determinations were made on each sample. Wet weight (live weight) was based on blot-dried material. The dry weight of the sample was determined at both 64^{o}C (DW 64^{o}) and 104^{o}C (DW 104^{o}). The DW 64^{o} determination was performed for comparative purposes with other participants in the LECSP that did not determine the DW 104^{o}. Ash free weight (AFW) was determined by subtraction after ashing in a muffle furnace at 550^{o}C (DW 104^{o} - Ash weight = AFW). Biovolume and standing crop values were multiplied by four to arrive at the final values expressed as g/m^2.

Light Gradient Experiment

To compliment the field data on the light requirements of Cladophora a light gradient experiment was conducted from October 31 to November 25, 1980 in the laboratory at South Bass Island. The purpose of this experiment was to determine the minimum light requirement of Cladophora under controlled conditions. The gradient was designed to approximate



Tank number	PAR $\mu E/m^2.sec$
1	-
2	0
3	14
4	29
5	6
6	79
7	168
8	-
9	55
10	44

Tanks: 114 liters
61 L X 48 W X 38 W cm

Flow Rate: 57 l/hr

Temperature: 15^{0}C

Photoperiod: 14hrs

Figure 3. Cladophora Light Gradient Experiment Diagram.

conditions encountered in the lake. The gradient consisted of ten 114 l tanks in a series, equipped with a flow-through water system (Figure 3). Lake water was pumped from Fisheries Bay (Appendix A) into the lab where it was filtered through two Aqua-Pure AP-110 filter cartridges used to maintain a constant water clarity, as defined by turbidity readings. Flow rate through the tanks was approximately 57 l/hr. The water was initially heated to 15^{o}C in the first tank and maintained at 15^{o}C throughout the gradient, each tank having a separate thermostatic control and heater. Each tank was agitated, by two air lines venting near the bottom, to provide water movement and a constant temperature.

A bank of fluorescent lights set on a 14 hour photoperiod were suspended above each tank. Light levels of 0, 6, 14, 29, 44, 55, 79, and 168 μ E/m^2 sec were provided to the tanks as indicated in Figure 3. PAR was measured 15 cm off the bottom of each tank using the spherical quantum sensor.Light intensities were adjusted by the height of the lights and with layers of window screen placed on top of the tanks.

Flat rocks with established Cladophora growth were collected on October 30 from the tip of Peach Orchard Point (Appendix A) in approximately 0.25 m of 9.5^{o}C water. One rock was placed in each tank and adjusted so that the surface of the rock was 15 cm off the bottom of the tank. Filament length, percent coverage, and light were measured weekly. Soluble reactive P, NO_3+NO_2, and NH_3 were measured several times to assess the availability of these nutrients. The pH, temperature and turbidity were monitored frequently using an Orion 701 pH meter and Hach ratio turbometer. Total Tissue C, TTN, TTP and percent AFW were assessed at termination of the experiment.

OBSERVATIONS AND RESULTS

Physical Environment

During 1979 and 1980 ice covered the two sites from January-March. By mid-April water temperatures had warmed to between 4-8°C. Temperatures rose into the middle teens by mid-May and reached a maximum of 24-26°C in early August, with Stony Point warming slightly faster than the mid-basin, South Bass Island site. Figures 4 and 5 illustrate the bottom water temperatures at the 1 m station for Stony Point and South Bass Island, respectively. From May-June, during the period of increasing standing crop, temperatures ranged from 10°C to 22°C. Lake temperatures dropped below 20°C in late September, reaching 5°C by late November. The temperature difference between stations (0.5 -3 m) was generally less than 1°C; however, in the spring under calm conditions differences as great as 5°C were recorded between the surface nearshore and bottom offshore stations. Temperature data for all stations, surface and bottom, are reported in Appendix C.

Light levels at depth are often low in western Lake Erie due to rapid attenuation, particularly at the Stony Point site. Total suspended solids and corrected chlorophyll a at Stony Point were twice as high as recorded at South Bass Island, averaging 27 mg/l and 29.5 μg/l, respectively in 1980 (Table 2). The Secchi disk transparencies at Stony Point averaged 0.6 m at the 2 m station over the two seasons, with transparencies greater than 1 m recorded only 4 out of the 32 sampling periods (Figure 4). Transparencies were generally similar between

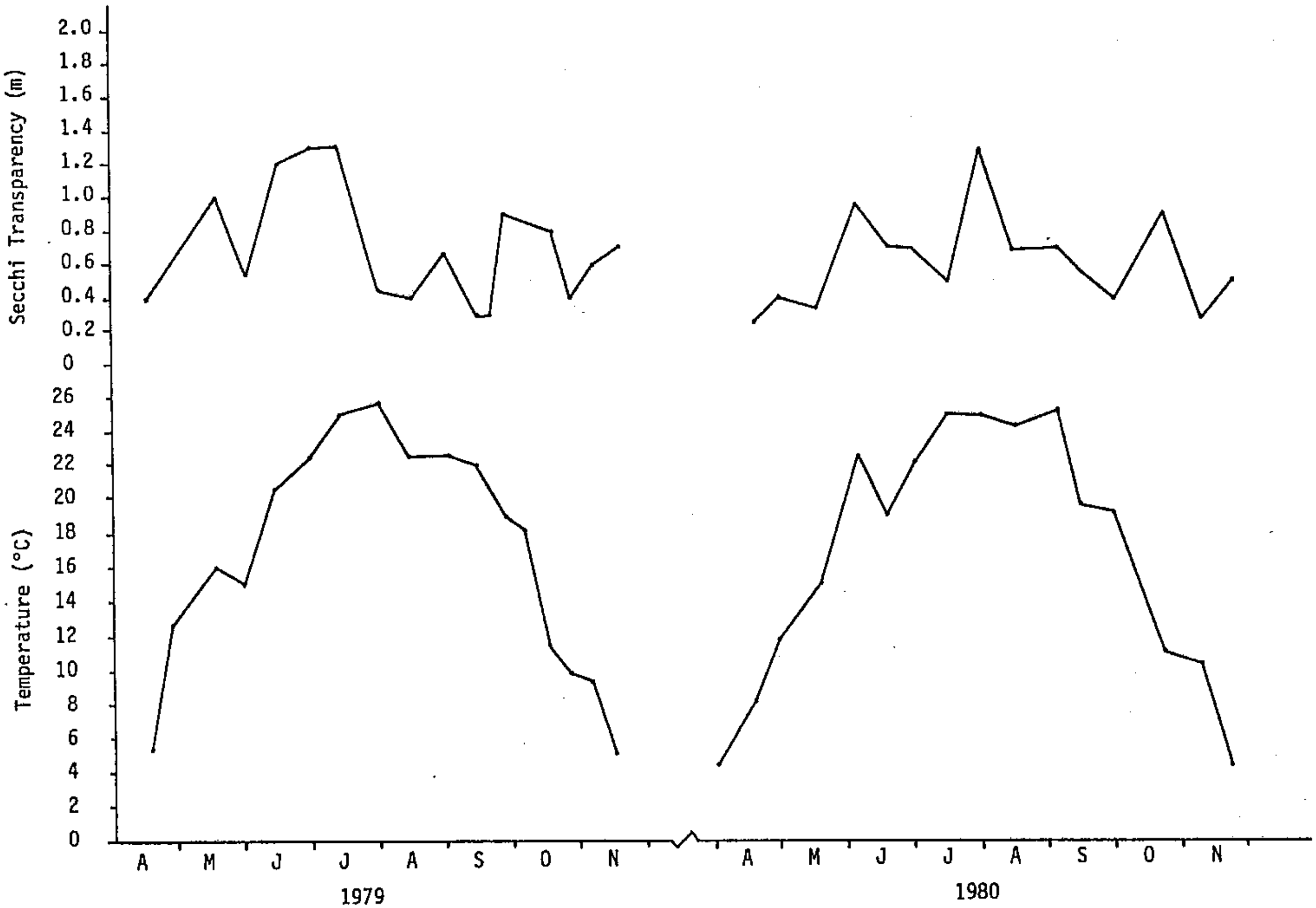


Figure 4. Lake Temperatures and Secchi Transparencies at Stony Point, 2m Station, 1979 and 1980.

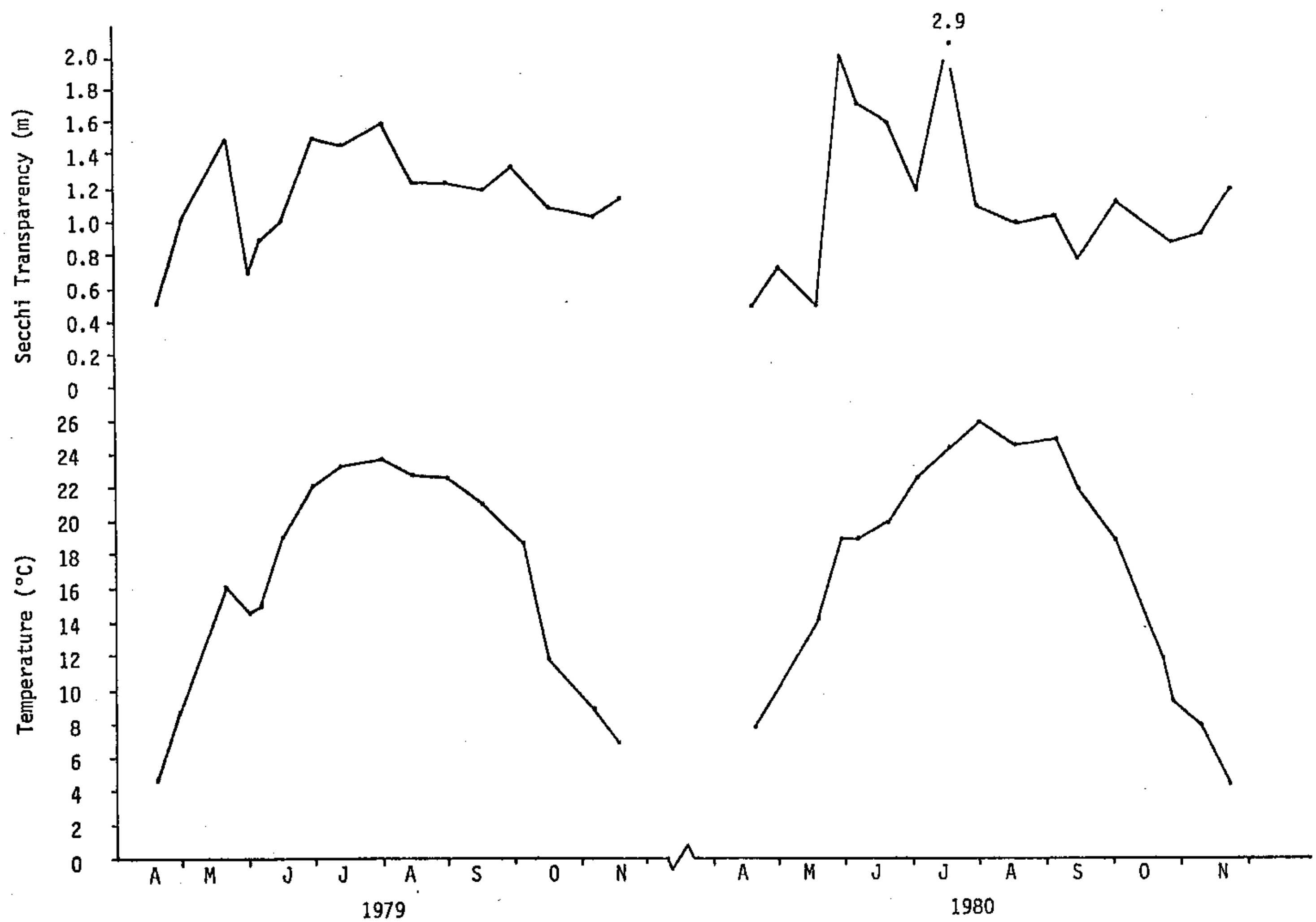


Figure 5. Lake Temperatures and Secchi Transparencies at South Bass Island, 2m Station, 1979 and 1980.

TABLE 2

SUMMARY OF WATER QUALITY OBSERVATIONS AT STONY POINT AND SOUTH BASS ISLAND SITES, 1979 and 1980

	STONY POINT				SOUTH BASS			
	1979		1980		1979		1980	
	range	mean	range	mean	range	mean	range	mean
SRP (µg P/L)	<0.5-6.5	3.1	1.0-17.5	5.6	<0.5-15.0	6.0	<0.5-12.0	3.7
TDP (µg P/L)	3-17	6.4	4-36	12	1-17	7.6	2-18	8.7
TP (µg P/L)	24-200	73	35-214	93	12-53	31	14-75	44
$NO_3 + NO_2$ (µg N/L)	<5-1570	460	15-2480	570	<5-1120	370	<5-1890	570
NH_3 (µg N/L)	2-67	21	2-250	82	<1-72	20	1-96	18
TKN (µg N/L)	501-1667	849	590-1622	1064	312-1101	564	413-956	652
TDKN (µg N/l)	173-772	391	338-917	586	202-972	404	275-658	399
Secchi transp. (m)	0.3-1.3	0.7	0.2-1.4	0.6	0.5-1.7	1.2	0.5-2.9	1.2
Temperature (^{o}C)	5.3-25.7	16.6	3.8-26.2	16.7	4.6-24.0	16.5	4.3-26.0	16.9
PAR ($\mu Em^2 sec$) 1m	-----		1.5-735	263	-------		122-1435	580
2m	-----		0-114	30	-------		19-700	240
3m	-----		0-48	9	-------		2-295	101
Total suspended solids (mg/L)	-----		9.8-69.8	27.1	-------		6.5-22.2	11.6
corrected chlorophyll a (µg/L)	-----		7.3-93.3	29.5	-------		1.9-30.3	11.9

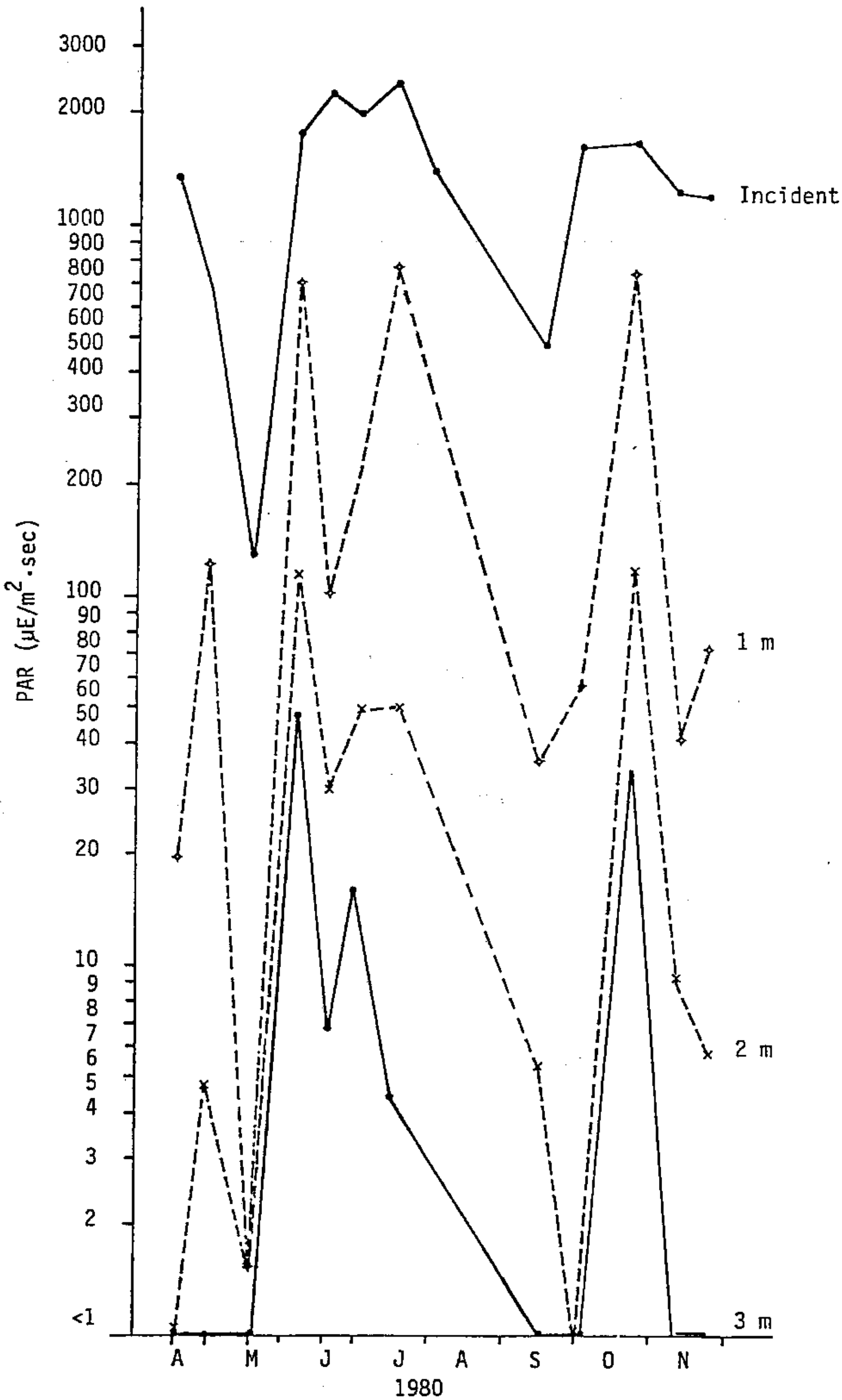


Figure 6. Photosynthetically Active Radiation at Stony Point, 1980.

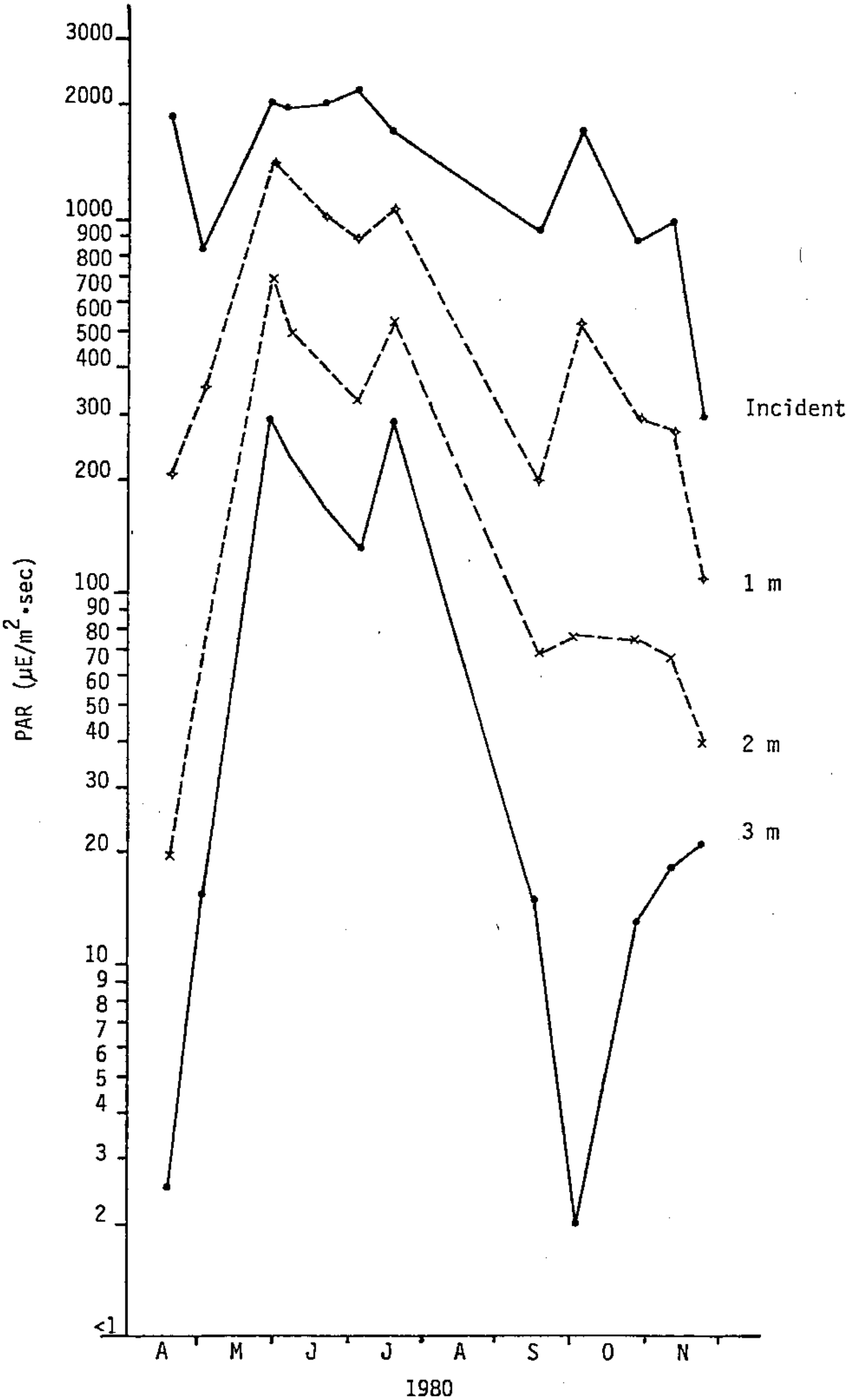


Figure 7. Photosynthetically Active Radiation at South Bass Island, 1980.

stations with the slightly greater values occuring at the deeper depths (Appendix C). PAR at the 3 m depth of Stony Point in 1980 did not exceed 50 $\mu E/m^2$ sec and light levels of zero were not uncommon (Figure 6). Light values measured at the 2 m depth were less than 50 $\mu E/m^2$ sec from mid-April to mid-July, except during early June when a maximum of 114 $\mu E/m^2$ sec was recorded.

Light penetration at the South Bass Island site was roughly twice as great as Stony Point, with Secchi disk transparencies averaging 1.2 m for the two years (Table 2). Levels of PAR at 3 m were less than 50 $\mu E/m^2/sec$ in April, greater than 100 $\mu E/m^2/sec$ from late May through July, and less than 50 $\mu E/m^2$ sec from mid-September through November, 1980 (Figure 7). The lack of light data for the month of August was the result of instrument failure.

Chemical Environment

Water quality in the western basin of Lake Erie exhibits wide fluctuations, particularly at the Stony Point site (Table 2). The nutrients measured generally peaked in the spring and declined throughout the summer, increasing again in the autumn (Figures 8-11).

Concentrations of SRP measured at the two sites from April to August both years remained above 1 µg P/l, except during the end of April, 1980 (Figures 8 and 9). Yearly mean values of SRP ranged from 3.1-6.0 µg P/l (Table 2). Levels of TP remained above 15 µg P/l throughout the two seasons with an increase in mean concentration from 1979 to 1980

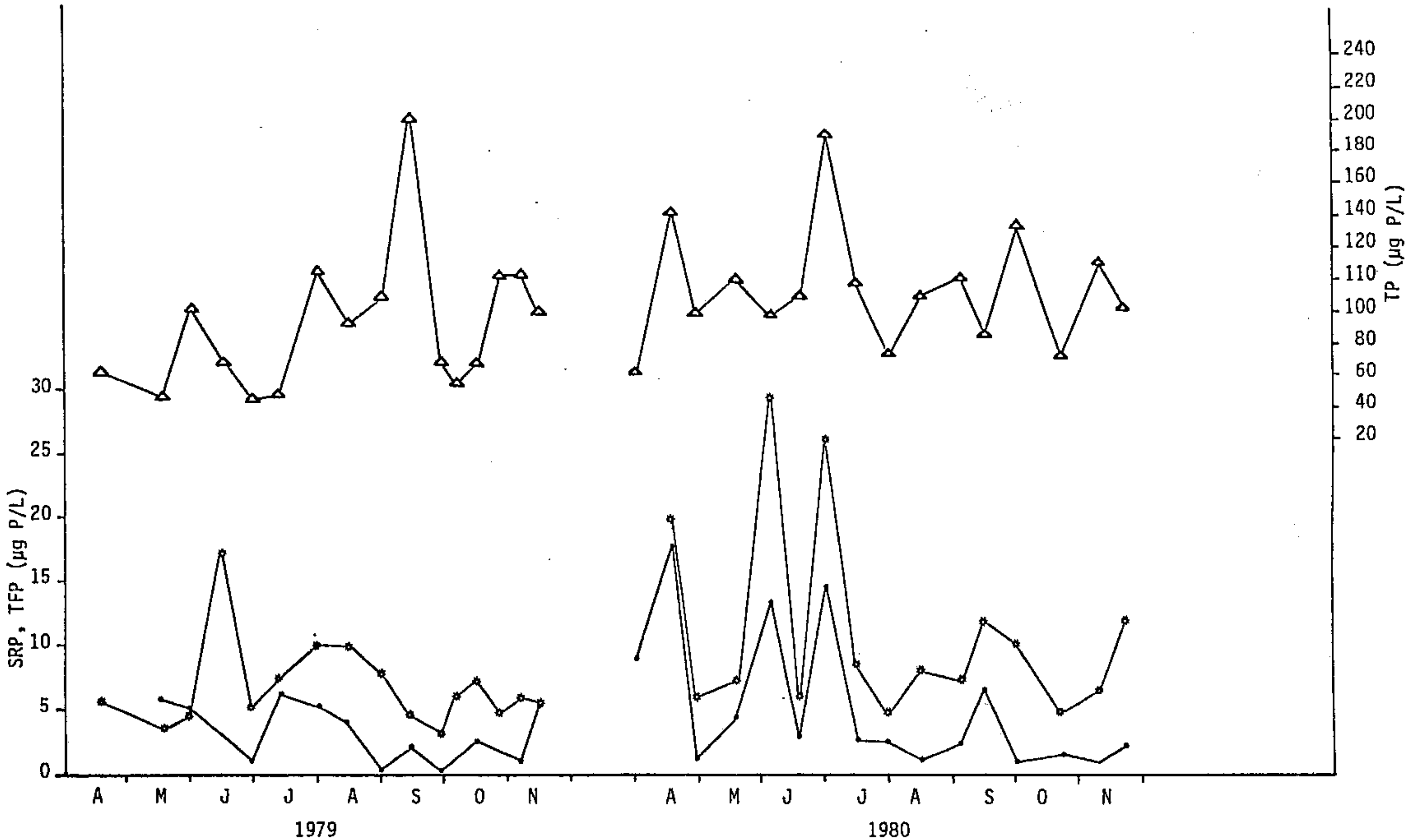


Figure 8. Lake Water Phosphorus concentrations at Stony Point, 1m station, 1979 and 1980.

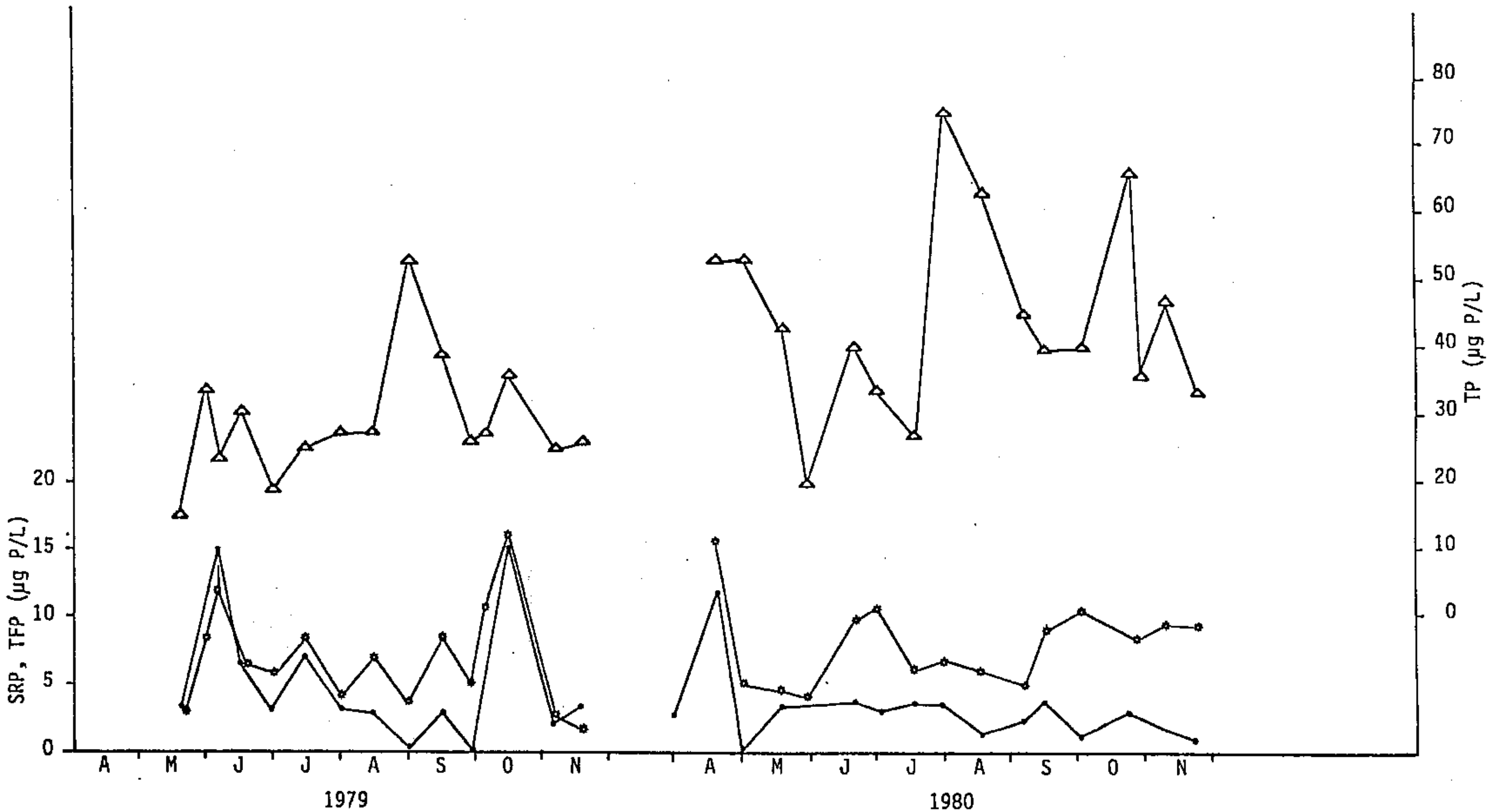


Figure 9. Lake Water Phosphorus concentrations at South Bass Island, 1m Station, 1979 and 1980.

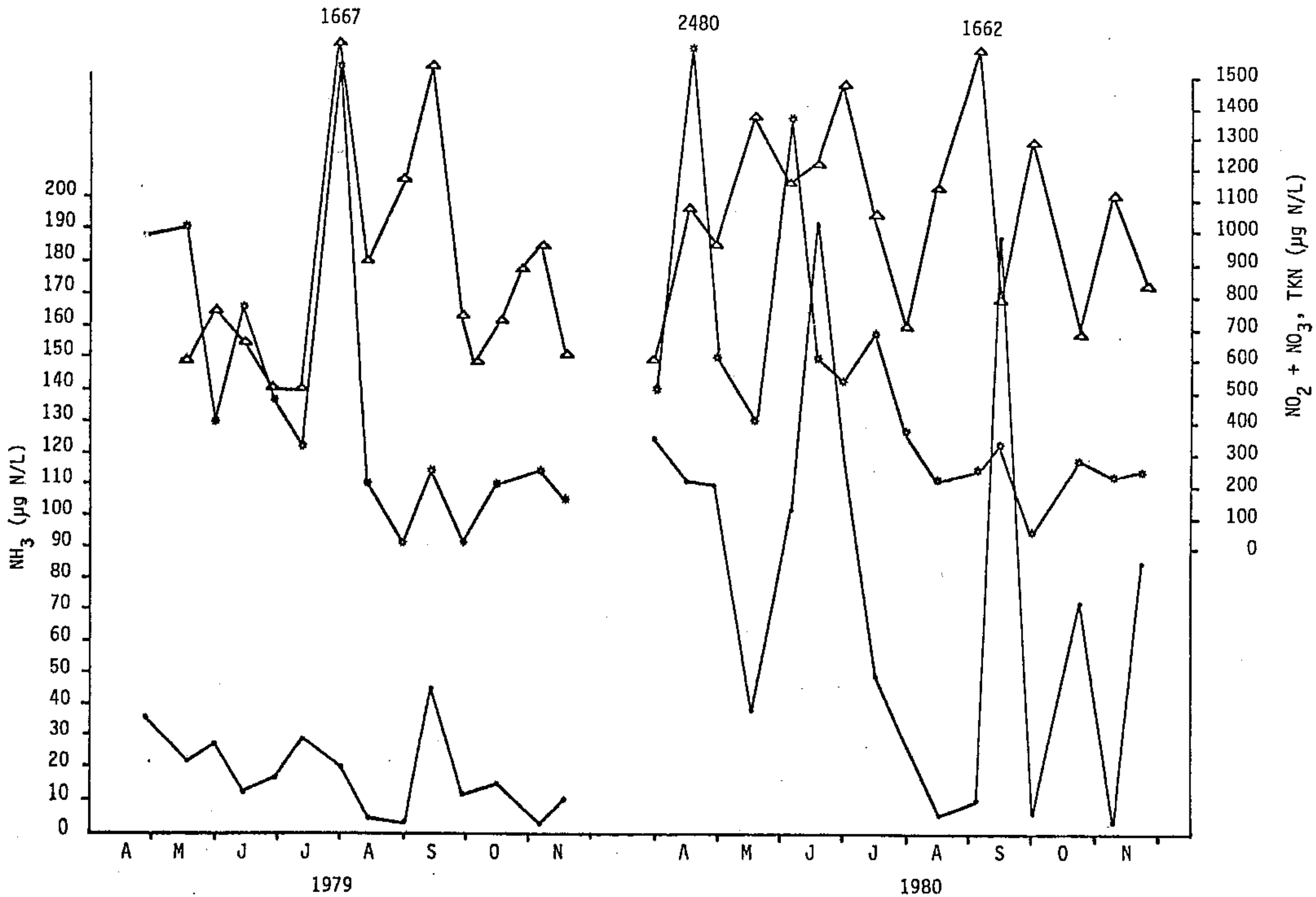


Figure 10. Lake Water Nitrogen Concentrations at Stony Point, 1m Station, 1979 and 1980.

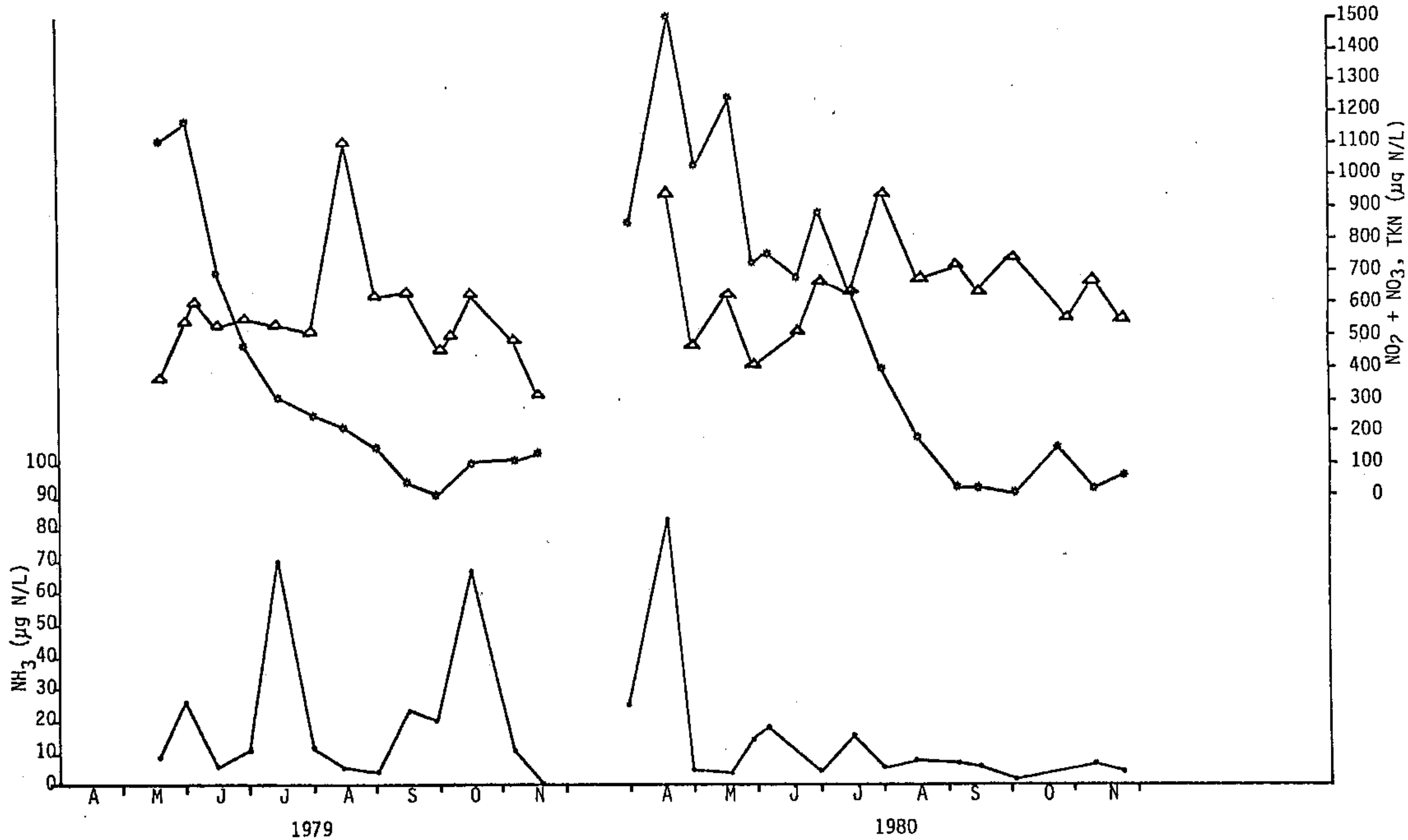


Figure 11. Lake Water Nitrogen Concentrations at South Bass Island, 1m Station, 1979 and 1980.

occurring at both sites. Nitrate+nitrite levels for the period from April to August of both years remained above 200 µg N/l (Figures 10 and 11). Ammonia values averaged between 18-21 µg N/l, except at Stony Point in 1980 where the mean was 78 µg N/l. Larger fluctuations and higher means for both TKN and TP were observed at Stony Point (Table 2). Additional water quality parameters for the Stony Point area and the western basin nearshore region in general are presented in Fay and Herdendorf (1982).

Major Filamentous Algae of the Littoral Region

The littoral region is an important component of aquatic systems as it forms an interface between the land and open water. This region is of particular interest to ecologists due to the associated high productivity and the development of distinctive zones. Little information exists on the distribution, seasonal growth dynamics and interaction among the algal taxa and environment within this dynamic region. The following description of the littoral zone resulted from observations made over a period of several years throughout the western basin. These observations were made from the shore, boats and underwater utilizing SCUBA techniques.

Cladophora is generally the dominant alga (in terms of biomass) found along the rocky littoral regions of Lake Erie; however, it is only one of the numerous epilithic filamentous algae found in this region. Three distinctive environments within the littoral region are inhabited by the epilithic algal community; 1) the infralittoral zone (defined as the region below mean water level for a particular season, represented here by the 0.5, 1, 2, and 3 m stations), 2) the eulittoral zone, or "splash zone" (the wave-influenced region extending from approximately 20 cm below to 20 cm above mean water level), and 3) the supralittoral zone (a zone associated with vertical shorelines that is entirely above the water line but is influenced by the spraying of waves). Cladophora inhabits both the infralittoral and eulittoral zones (Figure 12).

The distribution, abundance and zonation of the major filamentous algae in the littoral regions of western Lake Erie is complex due to the heterogeneity of the shoreline and the endless diversity of microhabitats encountered. Each location is unique, reflecting differences in biological and physico-chemical interaction resulting from varying degrees of slope, aspect, water movement, water quality, substrate, light and other factors. The zonation of the algae depicted in Figure 12 is a generalization of conditions found in the western basin of Lake Erie, as are the following descriptions. All species and zones are not necessarily present throughout the basin or at one particular time. Four major taxonomic groups are represented in the littoral region, the Chlorophyceae, Cyanophyceae, Rhodophyceae, and Bacillariophyceae. The Bacillariophyceae, although abundant and important, have been omitted from the present study.

The littoral region is a dynamic, high-energy environment that is susceptible to wide seasonal fluctuations in environmental conditions that invariably influence the algal association. In response to

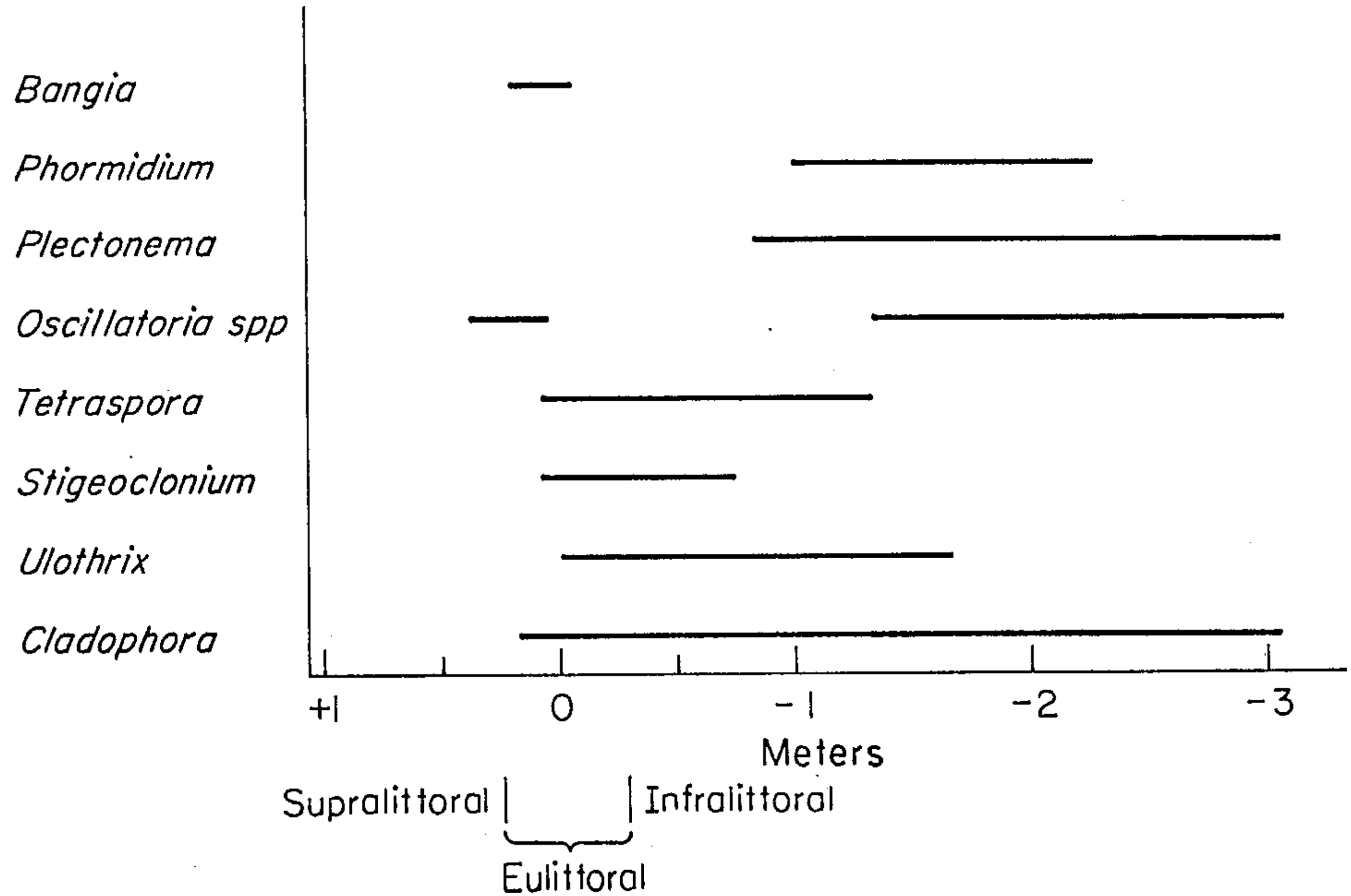


Figure 12. Zonation of the Major Macroscopic Shoreline Algae.

changing environmental conditions a seasonal succession of algae is observed. Perhaps the harshest seasonal event encountered is the scouring action of ice. At the beginning of the open water season the exposed areas of the eulittoral and upper infralittoral zones have been denuded of previous algal growth. During early April the filamentous green alga Ulothrix zonata colonizes the water line. The Ulothrix zone expands with the fluctuating and rising water levels of the spring, colonizing an area from the waterline to a depth of approximately 1 m. Distinctive bands of Ulothrix are often noted on vertical substrates resulting from the rapid colonization of zoospores along the fluctuating water line. Coverage may be as great as 100% in some areas while it may be absent in similar adjacent areas. In late April, when water temperatures approach 10°C, the maximum standing crop and distribution of Ulothrix is observed. Substrates are colonized to a depth of 1-1.5 m with maximum filament lengths of 3-4 cm occurring just below the water line. The abundance of Ulothrix declines as the season progresses but has been observed as late as July in a few locations.

Sparse patches of Bangia atropurpurea (a filamentous red alga) are found in the upper portions of the eulittoral zone concurrently with the colonization of Ulothrix. Bangia slowly increases in abundance, obtaining its maximum coverage and length by June. During June at Stony Point filaments of Bangia averaged 4-6 cm with a maximum length of 12 cm. The abundance of Bangia declines after June and is generally absent by late August. This conspicuous red alga has been observed to be most abundant on a vertical substrate, such as boulders, breakwalls and steep rocky shorelines, where it occupies a narrow (5-20 cm), interrupted band along the shoreline. Bangia, unlike Cladophora, is a recent invader into the Great Lakes and was first reported in western Lake Erie in 1969 (Kishler and Taft 1970). In the present study, the alga has been observed throughout the basin, but did not colonize the South Bass Island site or other similar areas that possess a gently sloping horizontal splash zone.

Zonation of the major attached filamentous algae is most prominent in the spring (April and May). At this time, the initial growth of Cladophora occurs at 1 m while Ulothrix is well-established at the shallower depths, (0.5 m to the water line). Above Ulothrix, on vertical substrates, Bangia colonizes a narrow band from the water line to 5-15 cm above and if shaded a thick mat of Oscillatoria sp. commonly colonizes the supralittoral zone, above the Bangia (Figure 12).

The blue-green algae Plectonema wollei and Phormidium sp. are most evident during the summer (July-September). These two algae are commonly found entangled on the Cladophora stubble (old holdfasts of 1-2 cm) at the 1 to 3 m depth. The green alga Tetraspora lubrica appears during July, forming green beads on the shallower denuded rocks previously occupied by Cladophora. Bangia and Ulothrix reappear in the fall (late October), at which time the water temperature is below $10^{o}C$.

Growth Dynamics of Cladophora

Cladophora was observed during the first sampling date (mid-April) in the infralittoral zone at depths of 0.5-1 m. Cladophora appeared as short (0.5-3 cm with occasional 5-10 cm) filaments arising from brown over-wintered holdfasts. These filaments were observed most frequently in crevices and along the edges of rocks. By early May the density and extent of Cladophora had expanded shoreward to include the area previously occupied by Ulothrix (0.5-waterline). The deepest depths of colonization were found from May-July, with growth extending to approximately 2.25 m and 1.75 m at Stony Point for 1979 and 1980, respectively, while at the South Bass Island site growth was present to the 3 m depth, both years. Peak periods of production, as assessed by increase in filament length and standing biomass, occurred from May to June and from mid-September to November. The maximum standing crop was generally achieved from mid-June to mid-July (Figures 13 and 14).

The filaments became gradated in color as they elongated in the spring, changing from a dark green at the basal portions to a light yellow-green in the apical cells. Microscopically the basal cells appeared densely packed with chloroplasts and protoplasm while the apical cells contained a large (20-50% and greater) vacuolar volume with a reticulate network of chloroplasts. During peak standing crop the filaments appeared coarse and wiry, lacking the usual feathery branching pattern.

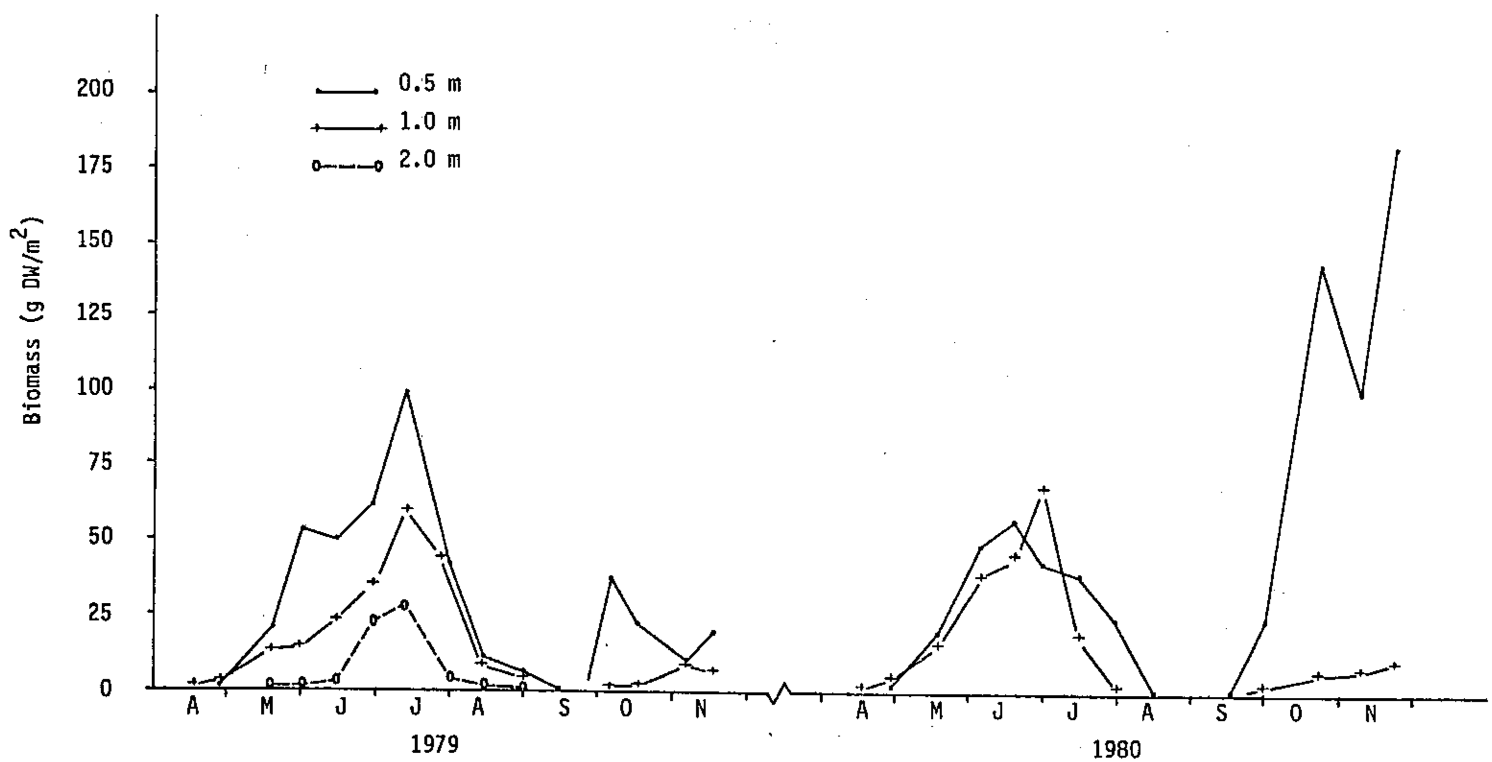


Figure 13. _Cladophora_ Standing Crops at Stony Point, 1979 and 1980.

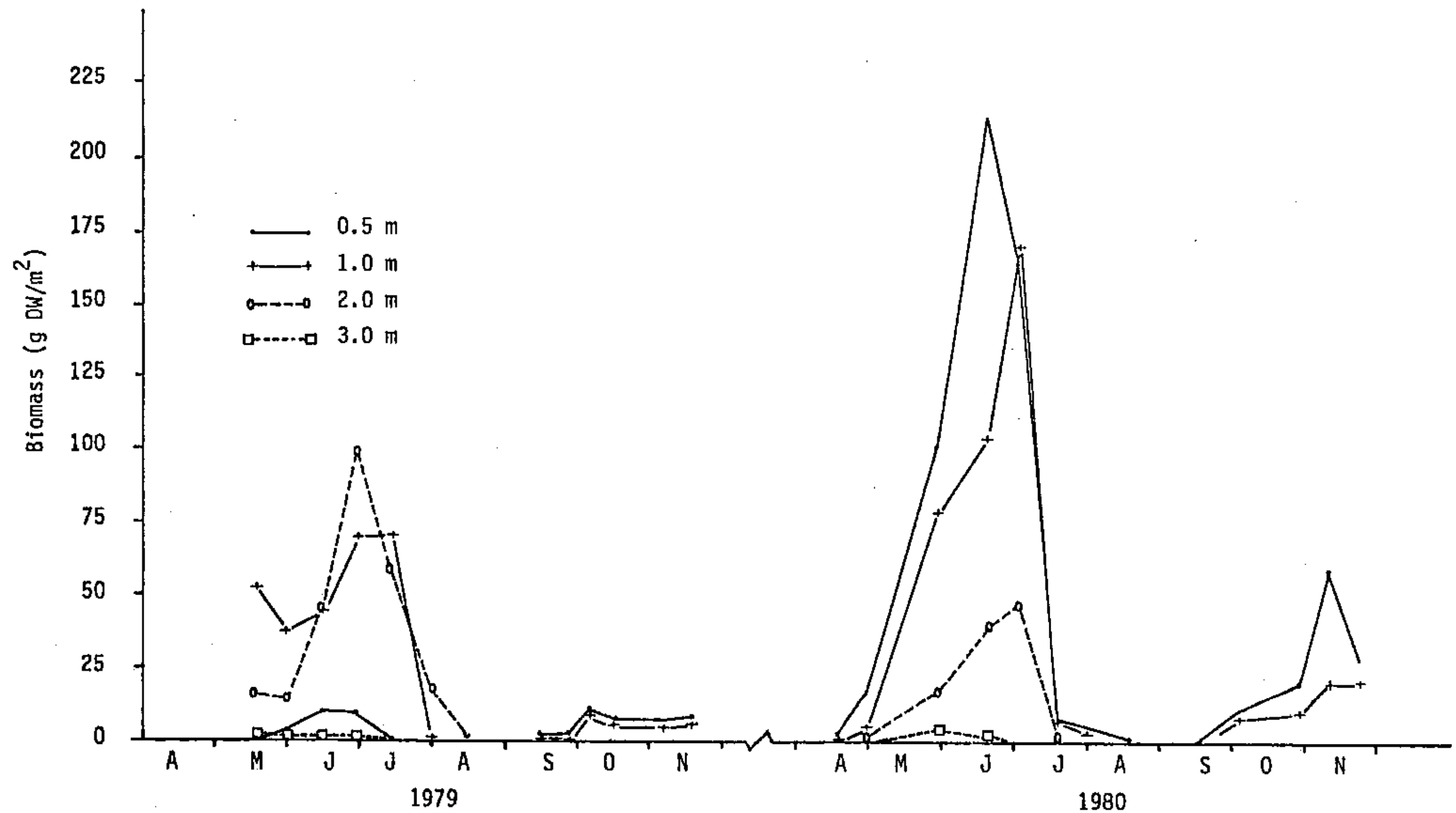


Figure 14. Cladophora Standing Crops at South Bass Island, 1979 and 1980.

The standing crop in the infralittoral zone declined during July and by August only short (0.5-2.0 cm), brown, silt-and-epiphyte-laden filaments and associated holdfasts remained. Loss of standing crop resulted from the sloughing of the upper portions of the filaments, causing a shortening of the filaments. Mid-depth areas (1-2 m) generally were the last to decline in standing crop, but the decline was sharper when it occurred. The decline of standing crop/filament length was fairly uniform for the area at each specific depth. The loss of biomass from the Cladophora beds was most prominent during periods of rough water, although during the declining biomass period (July) the slightest disturbance dislodged filaments from the thallus. From August to mid-September the infralittoral zone did not support Cladophora growth.

A fall resurgence of growth appeared in the infralittoral zone during late September. This fall pulse of growth extended to approximately a 1 m depth and remained present into December. Although the area of colonization is not as extensive as the spring pulse, the fall resurgence can be prolific. For example, fall growth at 0.5 m at Stony Point represented the maximum standing crop for the site in 1980 (Figure 13).

Cladophora colonized the eulittoral zone in May, intermixing with and finally replacing Ulothrix. Cladophora persisted in this "splash zone" throughout the late summer months (July-September) in contrast to the absence of growth in the infralittoral zone during this period. The alga noticeably decreased in growth and became patchy in distribution in the eulittoral zone during August, but remained present. From mid-September on into December lush growth was present in this zone, frequently becoming intermixed with Ulothrix late in the year.

In the early fall (mid-September to October) Cladophora of the eulittoral zone sporulated, resulting in large areas of filaments with whitish tips. Microscopic examination of the apical portions of the filaments at this time revealed the formation of zoospores by the process of protoplasm concentration, fragmentation, and the rounding into spheres within otherwise undistinguishable cells (see Van Den Hoek 1963). Movement of these zoospores soon became apparent and a lateral apical pore developed just below the crosswall. Upon opening of the apical pore the zoospores quickly shot out as if under pressure and began flagellar movement. Examination of numerous filaments revealed rows of cells devoid of contents with apical pores, indicating a concurrent period of zoosporogenesis. The empty cells (sporangia) were most frequently located apically and in such quantity that the tips of the filaments appeared white for some distance. The fall resurgences of growth in the infralittoral zone appeared shortly after this massive eulittoral sporulation.

Little data are available on the growth dynamics of Cladophora during the winter months. Several observations made at South Bass Island during the winter of 1979-80 prior to heavy ice cover (December and January) noted short filaments of Ulothrix and Cladophora present along the shore. Observations made under the ice in late January at a depth of approximately 0.25 m revealed green Cladophora filaments of 1-4 cm in length. At the end of March a wooden minnow cage was pulled from the lake having approximately 8 cm filaments of Cladophora attached along the upper half of the structure, indicating winter growth.

Standing Crop

The quantity and distribution of Cladophora standing crop varied with the year, site, and depth. Both sites supported a greater total (all depths) maximum standing crop in 1980 than in 1979 (Figure 15). The two sites had similar total maximum standing crops in 1979 while South Bass Island site supported the greatest standing crop in 1980. The initial pulse of Cladophora (May-July) generally produced a larger standing crop per m^2 than the fall pulse, the exception being 0.5 m at Stony Point in 1980. The greater total standing crop observed in the spring resulted from the greater area of colonized substrate.

The depths supporting the maximum standing crop at each site are reported in Table 3. The maximum standing crop was 214 g/m^2 (DW 104) from 0.5 m at South Bass Island in 1980. The general trend in standing crop was a decreasing quantity with increasing depth. The exception was at South Bass Island in 1979 where peak standing crop occured at the 2 m depth.

The maximum filament length observed was 90 cm, at the 2 m depth of South Bass in 1979. Mean filament length was significantly related to the AFW as indicated by the correlation coefficients in Table 4. The

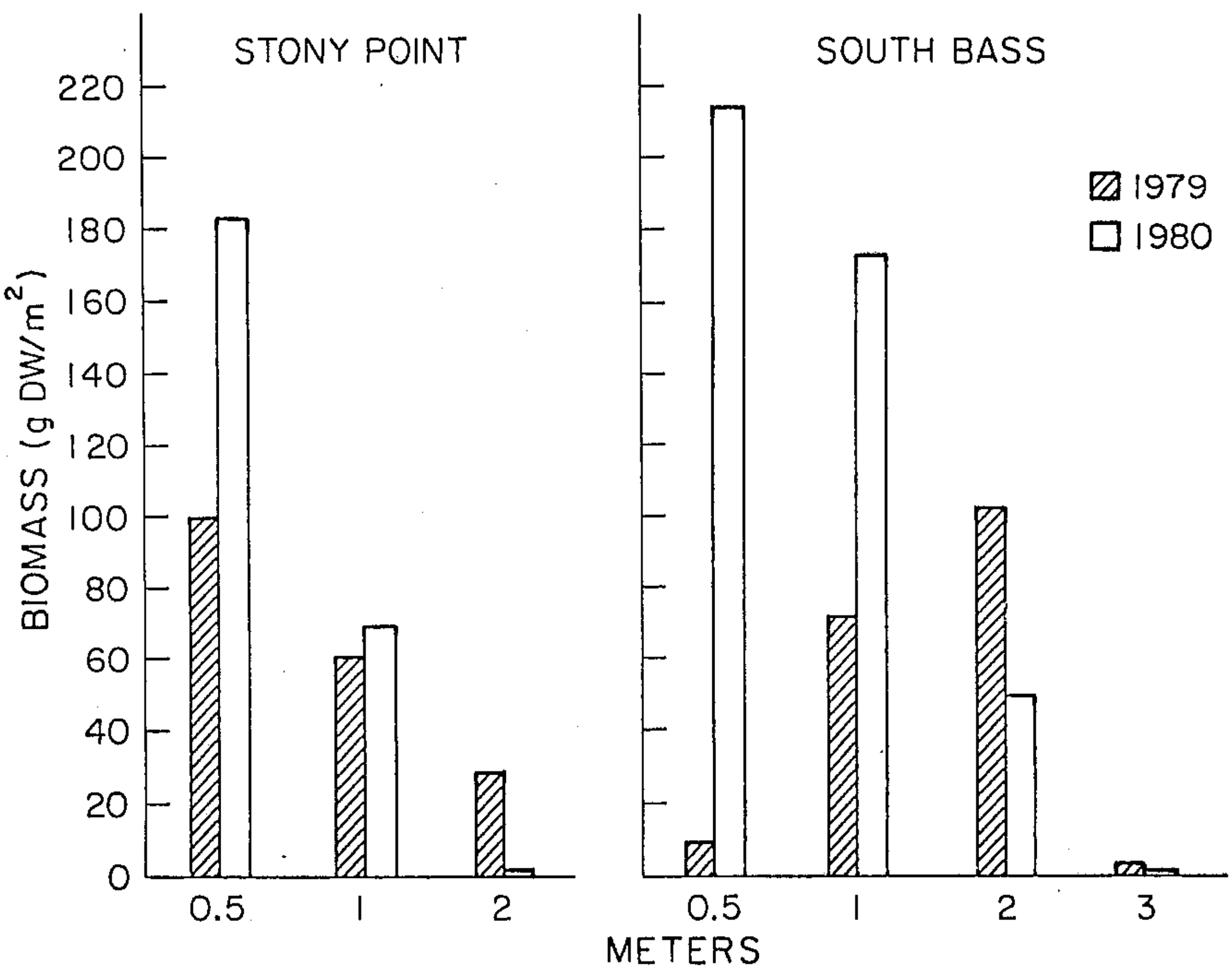


Figure 15. _Cladophora_ Maximum Standing Crop and Depth Distribution at Stony Point and South Bass Island, 1979 and 1980.

TABLE 3

<u>CLADOPHORA</u> MAXIMUM STANDING CROP VALUES FOR THE STONY POINT AND SOUTH BASS ISLAND SITES, 1979 and 1980

Site	Year	Month	Depth	DW* (g/m^2)	AFW** (g/m^2)	Biovolume (ml/m^2)	Max. Filament (cm)
Stony Point	1979	July	0.5	100	55	444 (June)	37
	1980	Nov.	0.5	184	110	1020	40 (July)
South Bass	1979	June	2.0	102	59	728	90
	1980	June	0.5	214	116	1052 (July)	45

*Dry Weight 104°C

**Ash Free weight

TABLE 4

LINEAR CORELATION COEFFICIENTS BETWEEN VARIABLES

Variables	Site	Year	Depth	n	r
AFW - Mean Filament Length	Both sites	1979 & 1980	0.5 m	34	0.77**
	Both sites	1979 & 1980	0.5 m (excluding fall values)	30	0.92**
	Both sites	1979 & 1980	1.0 m	29	0.85**
	Both sites	1979 & 1980	2.0 m	13	0.73*
D.W. 104 - Biovolume	Both sites	1979 & 1980	All depths	70	0.95**
	Stony Point	1979 & 1980	All depths	36	0.95**
	South Bass Island	1979 & 1980	All depths	34	0.96**
AFW - Biovolume	Both sites	1979 & 1980	All depths	70	0.98**
	Stony Point	1979 & 1980	All depths	36	0.99**
	South Bass Island	1979 & 1980	All depths	34	0.97**
TTC - TTN	Both sites	1979 & 1980	All depths	90	0.84**
TTP - TTN	Both sites	1979 & 1980	All depths	89	0.48**
ExP - TTP	Both sites	1979 & 1980	All depths	81	0.87**
AFW - TTC	Both sites	1979 & 1980	All depths	74	0.48**
AFW - TTN	Both sites	1979 & 1980	All depths	76	0.43**
AFW - TTP	Both sites	1979 & 1980	All depths	75	0.01
NO_3+NO_2 - TTN	Both sites	1979 & 1980	1.0 m	27	0.05
NH_3 - TTN	Both sites	1979 & 1980	1.0 m	26	0.36
	Stony Point	1979	1.0 m	9	0.06
	Stony Point	1980	1.0 m	8	0.80*
SRP - TTP	Both sites	1979 & 1980	1.0 m	29	0.66**
	Stony Point	1979	1.0 m	10	0.33
	Stony Point	1980	1.0 m	9	0.85**
SRP - AFW	Both sites	1979 & 1980	1.0 m	27	0.03
	Stony Point	1979	1.0 m	6	0.88*
	Stony Point	1980	1.0 m	9	0.34

n = number of pairs

r = correlation coefficient

relationship between mean filament length and AFW was approximately a 1:2 ratio. Changes in filament length had a greater influence on AFW as depth decreased. Biovolume correlated well with the standing crop values, having approximately a 10:2 relationship (Figure 16). The highest correlation, r=0.99, occurred between biovolume and AFW, for the two years at Stony Point (Table 4).

Biovolume and standing crop values represent the amount of biomass present at the time of sampling and actually are only a portion of the total production. Sloughing of biomass occurs frequently as is evident by accumulation of Cladophora on the shorelines. Little shoreline accumulation actually occurred at the two sites; the Stony Point shoreline consisted of breakwalls and South Bass Island site of flat bedrock, neither conducive to accumulation. Accumulations of Cladophora were observed most frequently and to the greatest extent in areas of net deposition, such as bays and coves where currents tend to concentrate materials. Beach accumulations were not evident along the Michigan shoreline near Stony Point; however, the alga was quite evident on the shorelines throughout the Island Region.

In an attempt to quantify the accumulation of biomass on the shoreline, the public swimming beach of South Bass Island, adjacent to Perry's Monument (approximately 1 km southwest of the monitoring site, see Appendix A) was monitored periodically. It was quickly evident that shoreline accumulation defies easy quantitative measurement. Fluctuations occurred daily; it was not unusual for the beach to be

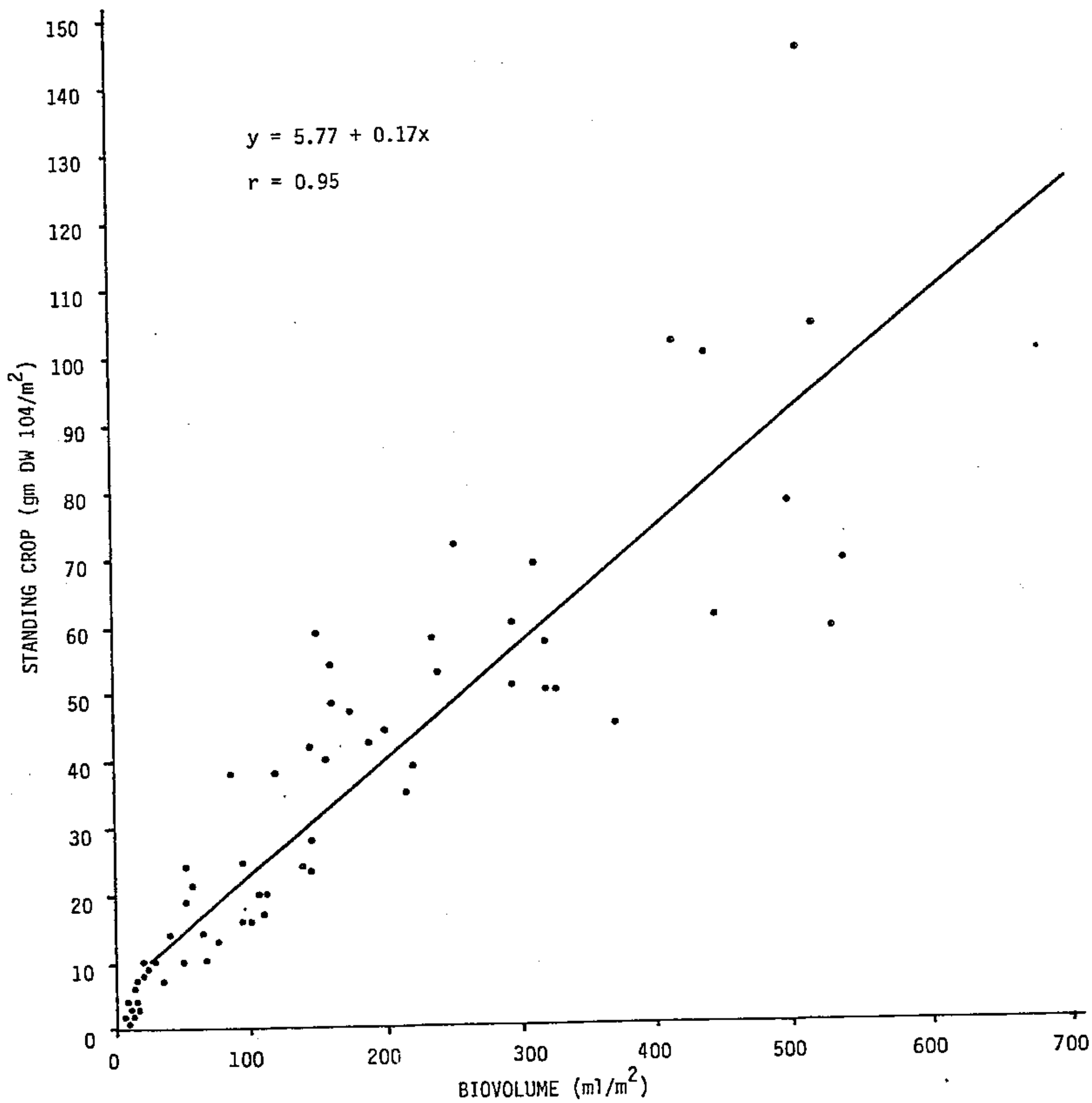


Figure 16. Linear Relationship Between Cladophora Biovolume and Standing Crop, All Depths, 1979 and 1980.

cluttered with Cladophora one day and be clear the next day. Areal distribution also varied with the wind and wave patterns, so that one part of the beach was affected and the other not. It is quite possible that the varying amounts of beach Cladophora largely reflected the movement of the same material in and out of the area. Extraneous material such as aquatic angiosperms were also present, further complicating an accurate assessment. In addition to these problems, the beach monitoring effort in 1980 was curtailed in May due to competition for the beach Cladophora with the Village of Put-in-Bay. The village frequently maintained the beach, hauling away pick-up truck loads of Cladophora and associated debris.

After ice-out at the end of March, the beach was free of debris. With the first major storm in April, dark green-brownish Cladophora filaments (akinetes) appeared on the beach in fairly large quantities. The first quantitative sample taken on April 16, 1980 (prior to any visual new growth), resulted in 43.5 kg/m^2 wet weight, 14.7 kg/m^2 DW 104, and 5.3 kg/m^2 AFW. Subsequent monitoring indicated slightly smaller quantities present until mid-May, when the village maintenance program commenced.

The largest amount of Cladophora washed ashore in the Island region during June and July. The material on the beaches at this time was bright green. The hot, sunny days soon started the decomposition process, encouraging the flies and discouraging the people. A large portion of the southeast shoreline of South Bass, from the airport to

Perry's Monument, had nuisance quantities of Cladophora. A real estate salesperson indicated that he would hesitate to even show a property on the shore near the airport during this time.

Observations with SCUBA revealed extensive mats of detached green Cladophora thalli suspended just off the bottom of the lake, in areas not capable of supporting growth (i.e. mud substrate in Fisheries Bay), indicating the transport of this material into the area. Streams of detached alga were frequently noted in June floating in the water along the west shore of South Bass Island.

Tissue Nutrients

Tissue nutrients (nitrogen, phosphorus, and carbon) declined following the onset of growth in April, increased from mid-May through June, and then declined throughout the summer (Figures 17 and 18). Tissue algal nutrients again rose in October, in conjunction with the renewed fall growth.

Total tissue phosphorus levels at both sites averaged greater than 0.2% over the two years. The levels of phosphorus did not drop below 0.1% and 0.08% for Stony Point and South Bass Island, respectively (Table 5). Boiling water extractable phosphorus and TTP were significantly correlated ($r = 0.87$, Table 4), as would be expected.

Total tissue carbon and TTN followed similar fluctuations over the seasons (Figures 17 and 18) and were significantly correlated ($r = 0.84$).

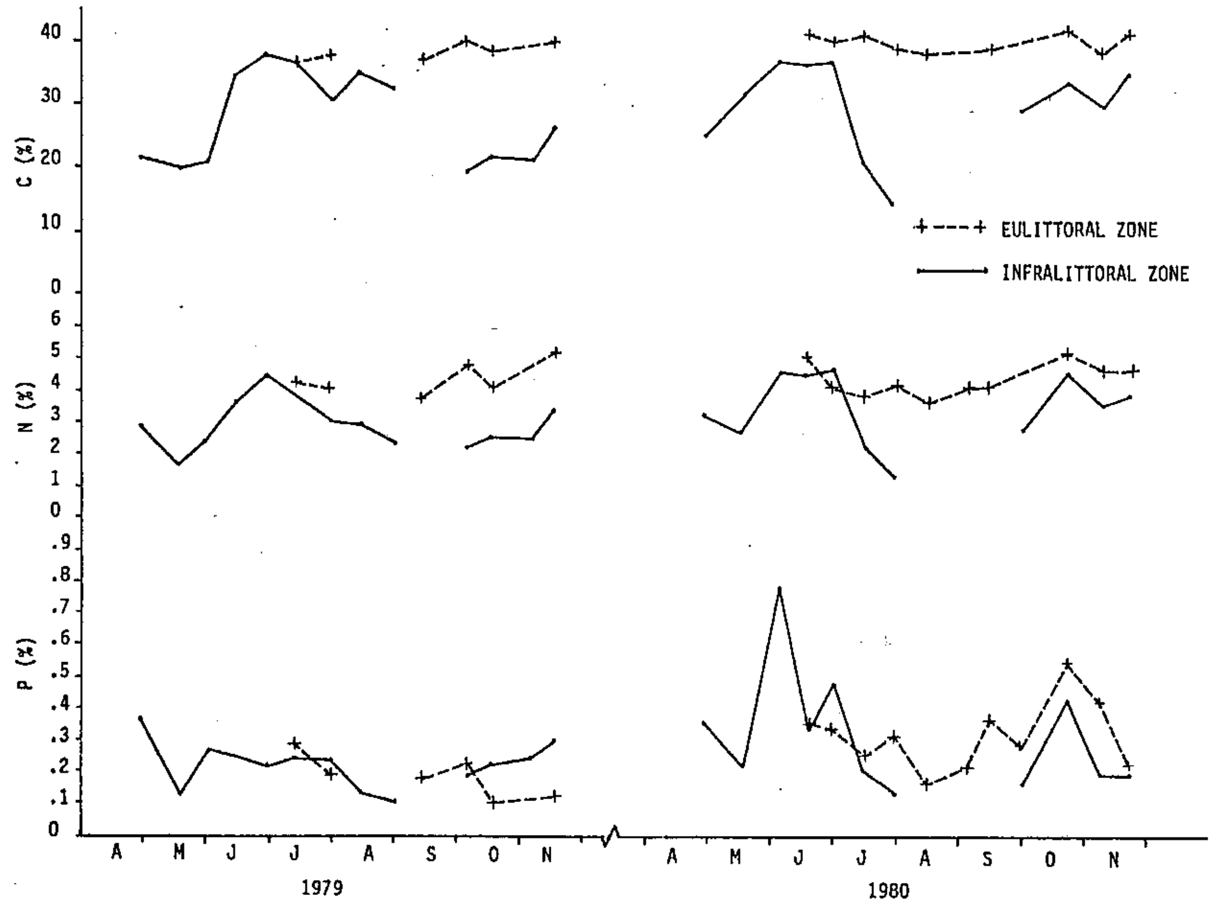


Figure 17. Cladophora Tissue Nutrients for Stony Point, 1979 and 1980.

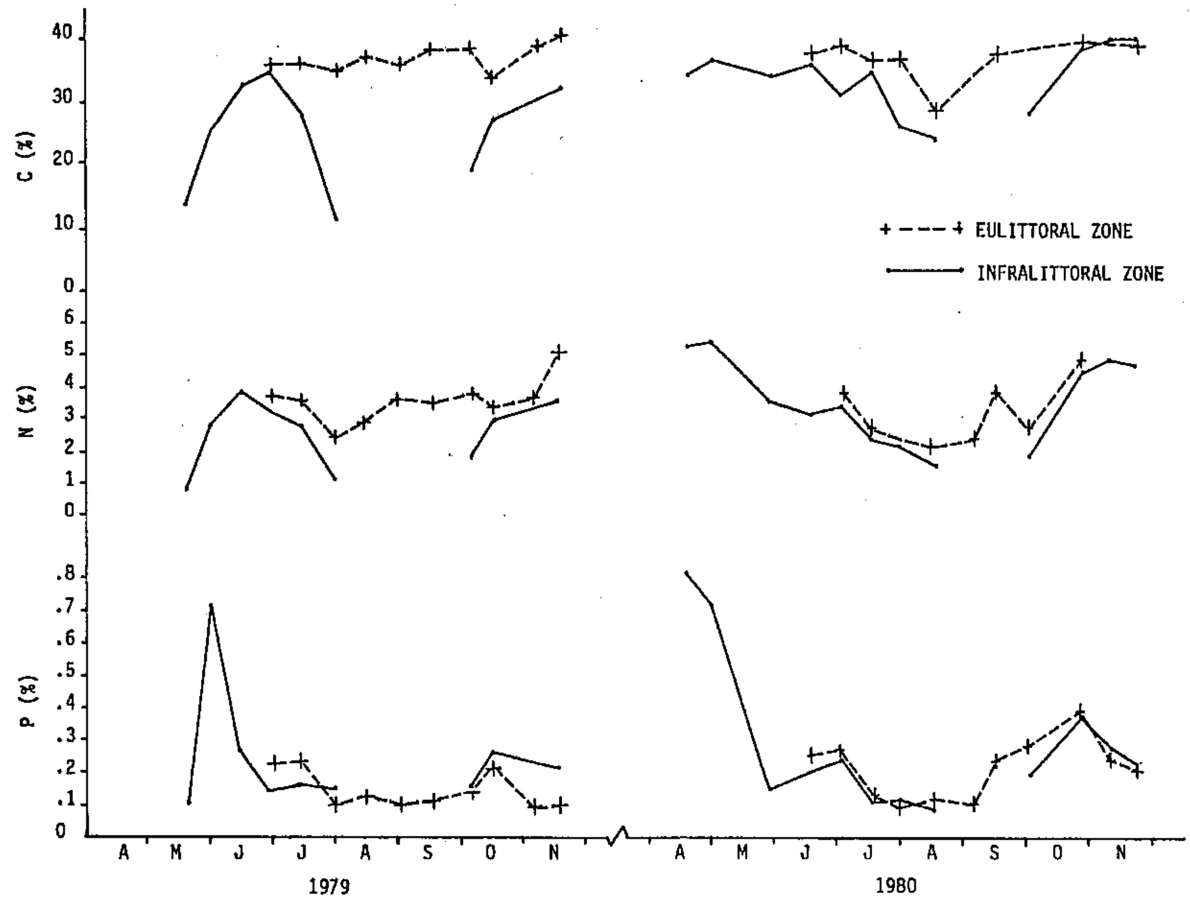


Figure 18. Cladophora Tissue Nutrients for South Bass Island, 1979 and 1980.

TABLE 5

ANNUAL RANGES AND MEANS FOR *CLADOPHORA* TISSUE NUTRIENTS

AT STONY POINT AND SOUTH BASS ISLAND SITES, 0.5-3m STATIONS, 1979 AND 1980

Site	Year	Total Tissue P %		Total Tissue N %		Total Tissue C %		C/N	
		Range	Mean	Range	Mean	Range	Mean	Range	Mean
STONY POINT	1979	0.103-0.411	0.232	1.44-5.14	3.17	17.5-37.8	29.4	7.2-14.5	9.6
	1980	0.141-0.810	0.332	1.31-4.85	3.39	13.7-37.1	29.7	7.4-10.4	9.1
SOUTH BASS	1979	0.081-0.715	0.251	0.90-3.96	2.64	12.2-35.3	25.8	7.9-16.3	10.1
	1980	0.097-0.381	0.212	1.36-4.92	3.06	13.8-40.5	30.3	7.1-14.7	10.3

Mean TTN levels for both sites during both years were greater than 2.6 percent (Table 5). Total tissue nitrogen remained above 1.2 percent during the two years, except in mid-May, 1979 at the 1 m depth of South Bass Island where it dropped to 0.9 percent (Figure 18). Carbon levels of the alga averaged between 25-30 percent. The carbon content averaged an order of magnitude higher than nitrogen as indicated by the C/N ratio that ranged from 7.1-16.3, averaging approximately 10. Tissue phosphorus values were not closely related to either nitrogen or carbon (Table 4).

Tissue analysis for the nutrients was performed using ground algal material representative of the whole thallus. An analysis of various segments along the thallus indicated that tissue nutrients varied along the length of the filaments. The apical portion of the filament contained lower concentrations of ExP, TTP, TTN and TTC than basal portions (Table 6). The basal cells were generally a darker green and had a more dense protoplast than the newer apical cells. Analysis of the whole thallus gave values between the two extremes.

The ExP data was highly variable and the validity of the results are subject to suspicion. Extractable phosphorus values greater than TTP were encountered, which is theoretically impossible according to the definition of these two phosphorus components. The occurrence of larger ExP values than TTP occurred most frequently from the splash zone and 0.5 m depths when phosphorus levels were greater than 0.2%. Due to the inconsistency and errors in the ExP data, little emphasis has been placed

TABLE 6

CLADOPHORA TISSUE NUTRIENT ANALYSIS BY FILAMENT SEGMENTS

AT SOUTH BASS ISLAND, 0.5 m ON MAY 28, 1980

Filament Segment	ExP %	TTP %	TTN %	TTC%	C/N
Apical	0.140	0.139	3.34	33.00	9.9
Basal	0.166	0.217	4.34	36.21	8.3
Whole	-----	0.156	3.71	34.38	9.3

on this parameter. It is interesting to note that when dealing with the mean data, the relationship between the two phosphorus components is fairly consistent, with a mean difference of 0.05%.

Seasonal trends in tissue nutrients (Figures 17 and 18) were similar to the standing crop fluctuations. Tissue levels of nitrogen and carbon had more defined trends than phosphorous which tended to fluctuate frequently. Statistically TTC and TTN had relatively low coefficients of linear correlation with AFW, indicating only a slight linear relationship (Table 4). Phosphorus was not correlated at all to AFW.

Tissue levels of nitrogen were not correlated to the levels of available nitrogen (NH_3, NO_2+NO_3) in the environment (Table 4). The relationship between SRP and TTP was highly variable; in general there was not a significant linear relationship between available phosphorous and internal phosphorous. However, site specific fluctuations in SRP levels correlated with fluctuations in TTP, as evident at Stony Point in Figure 19. There was no correlation between available phosphorus and AFW.

Organisms Found in Association with Cladophora

The lush growth of Cladophora in the rocky littoral region greatly increases the available substrate surface area, creating a habitat capable of supporting large quantities of flora and fauna. Populations of epiphytic algae and stalked protozoa increase on the Cladophora

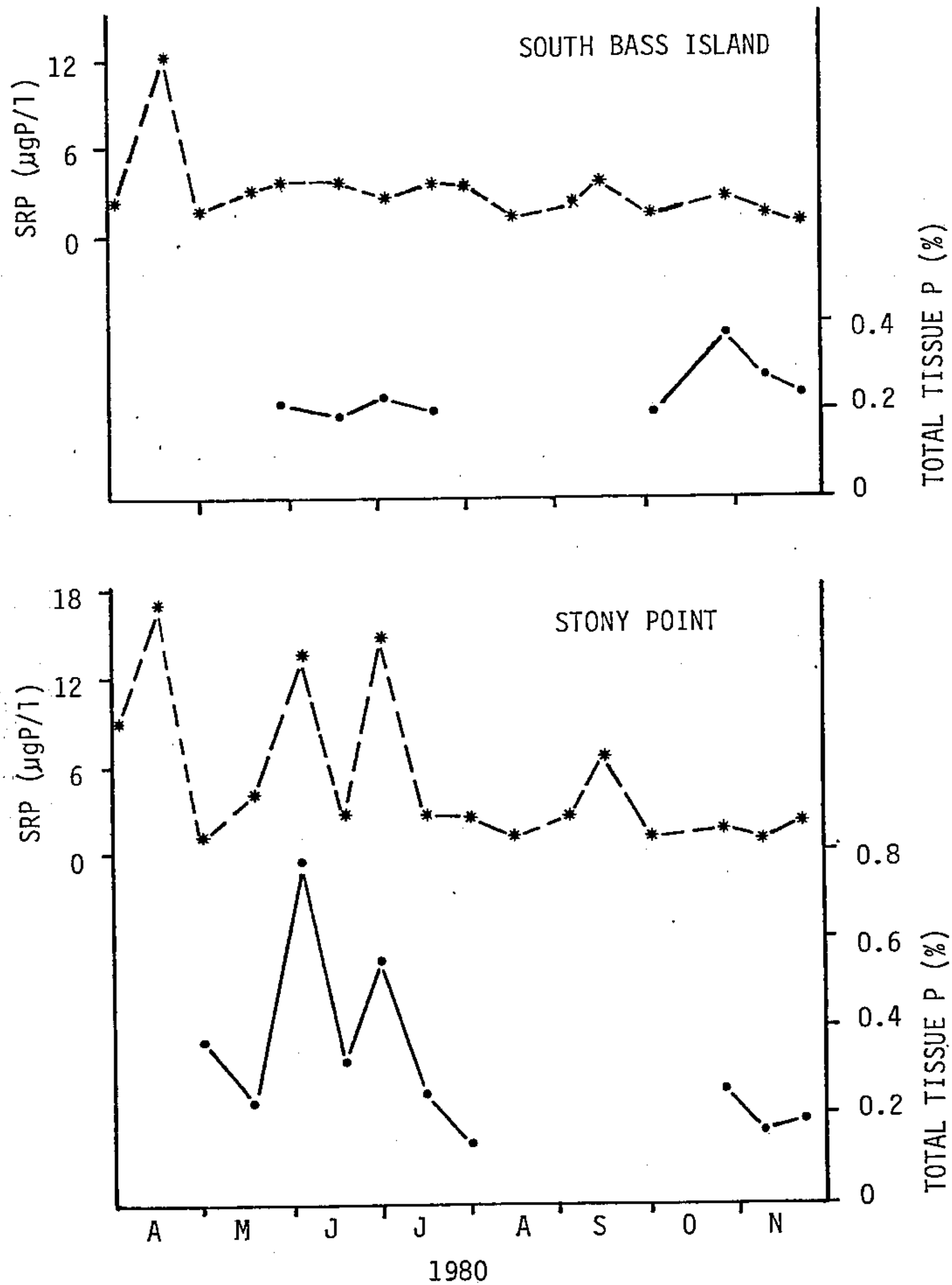


Figure 19. Relationship Between Total Tissue Phosphorus and Soluble Reactive Phosphorus.

filaments as the season progresses. A large increase in epiphytes occurs just prior to peak standing crop and remain prevalent until filament detachment in July. Following the peak standing crop the epiphyton population on Cladophora often become so dense that the filaments are obscured. The most common epiphytes are the diatoms, Cocconeis sp. and Rhoicosphenia curvata. Some of the more common organisms are listed in Table 7.

Included within the Cladophora association are numerous invertebrates which are supported by the abundant flora. The invertebrate community includes protozoa, rotifers, annelids, mollusks, arthropods and other organisms indicated in Table 7. Gammarus sp. are perhaps the most evident of the invertebrates. The Gammarus population dynamics coincide with the fluctuations in Cladophora biomass, reaching peak abundance near peak standing crop.

Perch, smallmouth bass, carp, drum and minnows have all been observed within Cladophora beds. Underwater observations in the area of Cladophora beds revealed fish fecal pellets several centimeters long, green in color, and over 90% composed of Cladophora filaments. The pellets were tightly packed with Cladophora filaments largely intact, with only the outer layer appearing to be subject to the action of digestive enzymes. The presence of the alga coincides with the spawning and emergence of many species of fish. Fish eggs and larvae (some of which have been identified as carp) are quite numerous from May-June.

TABLE 7

SUMMARY OF ORGANISMS FOUND IN ASSOCIATION WITH *CLADOPHORA*

FLORA	FAUNA
Fungi	Protozoa
	Ciliates
Cyanophyceae	
Fischerella sp.	Aquatic worms
Microchaete sp.	Planaria
Oscillatoria sp.	Nematodes
Phormidium sp.	Trematodes
Plectonema sp.	Oligochaetes
	Leaches
Chlorophyceae	
Chlorosarcina sp.	Rotataria
Gongrosira sp.	
Stigeoclonium sp.	Arthropoda
Ulothrix sp.	Insects
	Microcrustaceans
Bacillariophyceae	*Gammarus* sp.
Achnanthes sp.	Crayfish
Cocconeis sp.	
Cymbella sp.	Mollusca
Diatoma sp.	Pelecypoda
Fragilaria sp.	Gastropoda
Gomphonema sp.	
Navicula sp.	Pisces - adults, larvae and eggs
Nitzschia sp.	*Aplodinotus grunniens* - Drum
Rhoicosphenia sp.	*Cyprinus* - Carp
Tabellaria sp.	*Etheostoma* - Darters
	Micropterus dolomieui - Smallmouth bass
Rhodophyceae	*Notropis* - Shiners
Asterocystis sp.	*Perca flavescens* - Perch
Bangia atropurpurea	
	Aves
Vascular Plants	Ducks
Vallisneria americana	Shorebirds

Large amounts of fungus are often observed surrounding the fish eggs found in the Cladophora beds.

Cladophora Survey of the Western Basin

Cladophora has been considered to be present basin-wide in western Lake Erie; however, little distribution data is available outside the Island Region. In 1980, a preliminary survey was conducted in the eastern portion of the Island Region. This limited survey indicated the presence of the alga in this general region and supported the hypothesis that the depth to which Cladophora colonizes in the western basin is light controlled. The depth of alga colonization and light penetration (Secchi depth and PAR levels) both increased as site locations progressed northward from Kelly's Island to Chickenolee Reef (Figure 20).

In 1981, the survey was expanded to cover most of the western basin. From June 27-29, data on the nearshore region and shoreline structures were obtained by observations from a boat while SCUBA techniques were utilized on the reefs, shoals and submerged shorelines. Cladophora standing crop, biovolume, filament length, maximum depth of growth, PAR profiles, Secchi depth and temperature data were collected at sites throughout the basin.

A major portion of the western basin does not have suitable substrate to support Cladophora. Much of the United States shoreline is low-lying, consisting of unconsolidated sediments, and the Canadian side

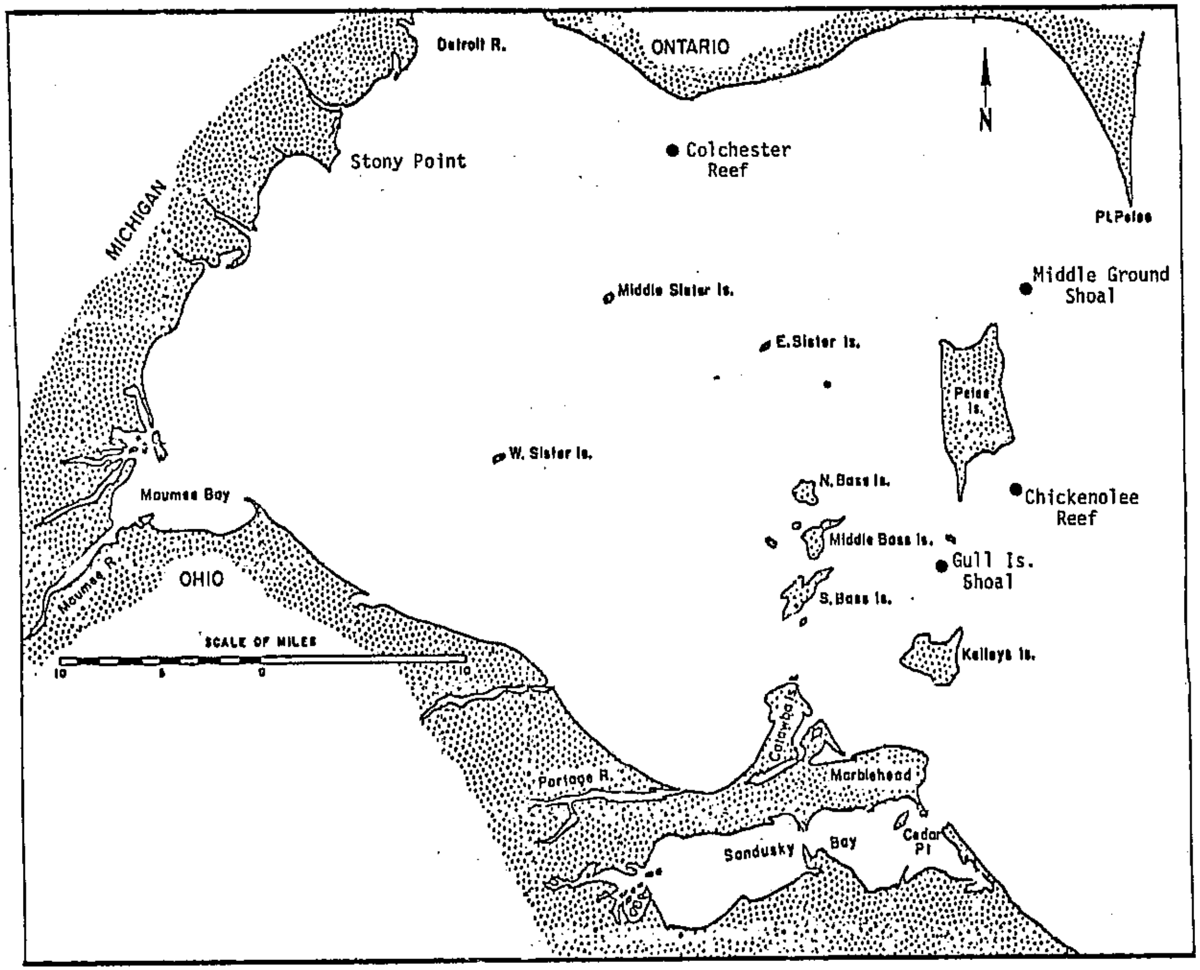


Figure 20. Western Lake Erie Cladophora Survey Station Locations.

has steep erodable bluffs. The largest extent of bedrock is located in the Island region of the basin. Exposed bedrock is found along the shorelines and as shelves on the eastern sides of most of the islands and as isolated peaks on the tops of the major reefs.

Survey results identified Cladophora on the vast majority of all suitable substrate in the western basin, including rocky shorelines, submerged shoreline shelves, reefs and man-made structures such as concrete, stone, wood and metal breakwalls, buoys and ships (Figure 20). In areas with unsuitable natural substrate, the alga was observed on man-made structures. Occasionally Cladophora was found on only one side of a breakwall or was absent completely, as was the case on the metal navigational buoys at Middle Ground Shoal and off Pelee Point. These buoys were exclusively colonized by Ulothrix. Bangia was also frequently observed in the splash zone throughout the basin.

The depth to which Cladophora was found on the island shelves and reefs varied with location (Table 8). Depth of colonization was generally greater the further north the site was located. Correspondingly, Secchi transparencies were greater and the extinction coefficients of light (K) were smaller at the northern sites. Depth distribution of Cladophora was greatest on the isolated reef areas, not located near land.

Standing crop values varied from 10-229 g/m^2 DW (Table 9). Middle Ground Shoal standing crop was patchy and concentrated in the cracks of

TABLE 8

WESTERN BASIN *CLADOPHORA* SURVEY OBSERVATIONS, 1980 AND 1981

Location*	Substrate	Deepest depth of growth (m)	Secchi Transparency (m)	k**	Surface Water Temperature (°C)
1981					
Marblehead Peninsula	Limestone Bedrock	2.5	0.80	1.59	22
Catawba Point, Ohio	Dolomite Bedrock	1.5	0.55	----	22.5
East Kelly's Island	Limestone Bedrock	4.5	2.00	0.89	21
Gull Island Shoal	Limestone Bedrock	3.2	1.50	0.78	21
North Bass Island	Dolomite Bedrock	4.5	1.50	1.06	23
Chickenolee Reef	Limestone Bedrock	6.0	2.15	0.68	22
West Sister Island	Limestone Bedrock	2.0	1.05	----	22.5
Middle Sister Island	Limestone Bedrock	3.0	1.45	----	22
East Sister Island	Limestone Bedrock	4.5	2.60	0.74	23.5
Colchester Reef	Limestone Bedrock	7.0	2.25	0.61	22
Middle Ground Shoal	Limestone Bedrock	4.8	2.15	0.48	21
South Bass Island	Dolomite Bedrock	3.0	1.30	1.13	21
Stony Point, Mich.	Limestone Bedrock	1.5	0.50	1.90	21
1980					
East Kelly's Island	Limestone Bedrock	3.4	1.60	----	21
Gull Island Shoal	Limestone Bedrock	3.8	1.95	0.88	22
Chickenolee Reef	Limestone Bedrock	4.6	2.20	0.49	23

*See Figure 23
**Extinction coefficient

TABLE 9

WESTERN BASIN CLADOPHORA SURVEY BIOMASS DATA, 1981

Location	Depth of biomass sample (m)	Standing Crop (g/m^2)			% AFW	Biovolume (ml/m^2)	Filament Length (cm)
		wet weight	DW 104°C	AFW			
East Kelly's Island	1.0	875.7	229.1	72.6	32	1040	15
Gull Island Shoal	1.5	948.8	138.5	83.3	60	1280	25
North Bass Island	1.5	378.1	65.6	36.0	55	600	20
Chickenolee Reef	3.0*	692.0	88.5	43.8	49	820	25
West Sister Island	1.5	542.9	78.5	53.5	68	584	20
Middle Sister Island	1.5	528.9	63.0	42.6	68	596	15
East Sister Island	1.5	914.9	84.0	60.2	72	1020	25
Colchester Reef	3*	584.0	89.7	55.9	62	604	10
Middle Ground Shoal	4*	70.7	10.0	5.0	50	120	10

the bedrock, possibly the result of scouring action of sand moving across the shoal. The largest DW standing crop collected was from Kelly's Island (229 g/m^2); this also represented the lowest in % AFW (organic matter). The % AFW was greatest (62-78%) in the areas located in the northwest region of the western basin. These algal filaments in the northwest region visibly appeared "healthier", a bright green color and more firmly attached than found in other areas.

Light Gradient Experiment

Water nutrient data from the light gradient experiment is presented in Table 10. All nutrient levels measured were greater than the minimal field values monitored in association with the presence of Cladophora growth, indicating non-limiting conditions for these nutrients. The pH of the tanks ranged from 7.89-8.56, varying due to daily and diurnal fluctuations of the incoming lake water and photosynthetic activity of Cladophora. Several pH profiles are presented in Figure 21. Sharp increases in pH were evident in the two highest illuminated tanks (6 and 7). The decline in pH from Tank 7 to 10 is believed to be the result of the buffering action of the lake water. Assessment of productivity on the basis of pH change in a flow through system with a fluctuating pH source is not possible. From the pH curves, however, it appears that there was high productivity in tank 6 and 7 and low productivity in Tanks 3-5.

Values of PAR capable of supporting Cladophora growth were assessed by the increase in filament length. The data presented in Table 11

TABLE 10

WATER NUTRIENT DATA FROM THE LIGHT GRADIENT EXPERIMENT

DATE	NUTRIENT (µg/l)	TANK 1	4	5	6	7	10
11/5	SRP	7.0	2.7	---	---	2.7	3.7
	NH_3	47.3	27.4	---	---	30.4	62.1
	NO_3+NO_2	115	116	---	---	120	124
11/9	SRP	5.5	5.6	---	---	3.7	3.8
	NH_3	98.9	58.8	---	---	32.3	20.5
	NO_3+NO_2	75	83	---	---	90	103
11/22	SRP	5.9	7.0	7.8	6.8	4.7	3.9
	NH_3	55.5	36.8	32.8	19.8	11.5	8.6
	NO_3+NO_2	128	144	150	145	131	135

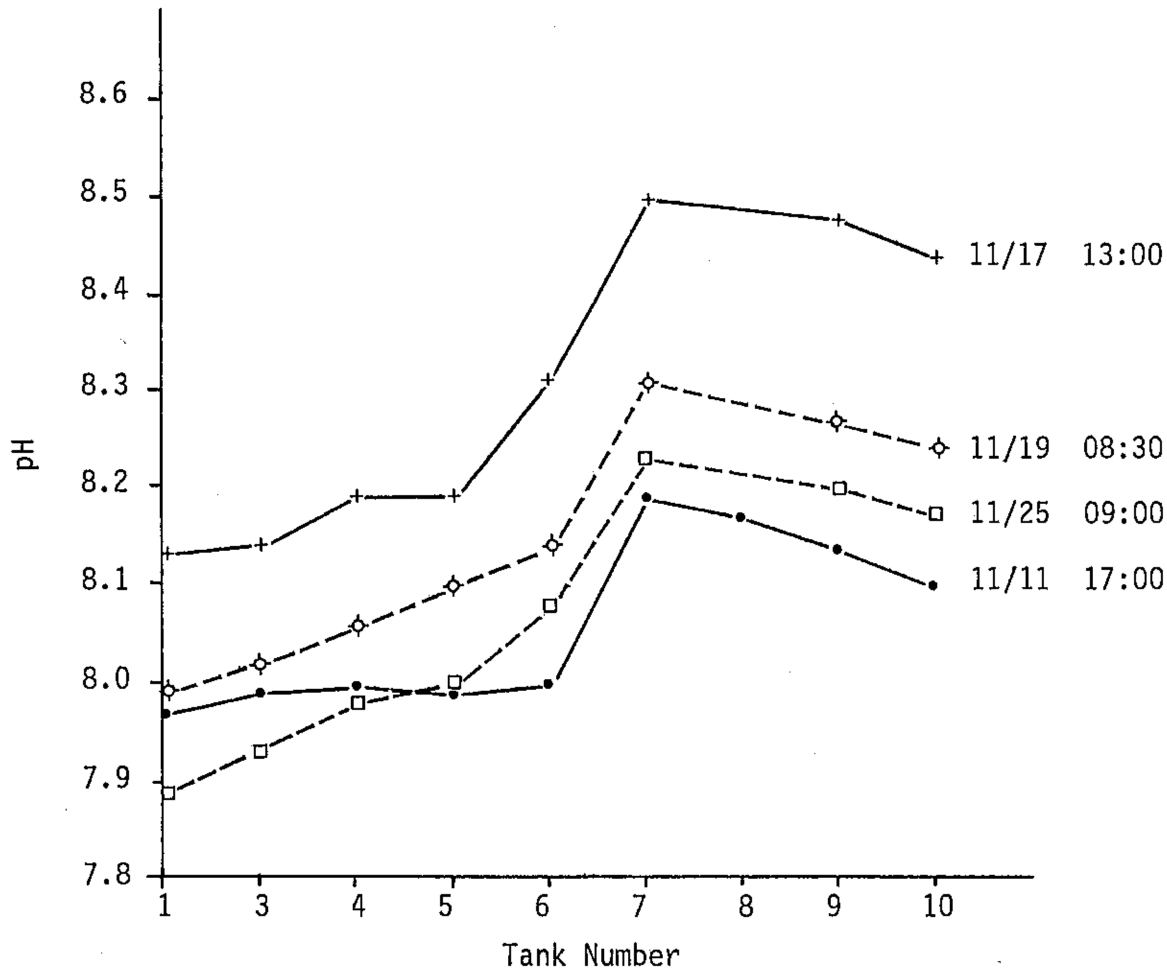


Figure 21. Cladophora Light Gradient Experiment, pH profiles.

represent the average increase in filament length on a weekly basis, under the various light levels. After one week, growth was evident at light levels of 55 $\mu E/m^2$ sec and greater (Figure 22). During the second, third and fourth week growth was observed at PAR values of 29 $\mu E/m^2$ sec and greater. The amount of growth increased with increasing light values from 29-168 $\mu E/m^2$ sec. Filament length did not increase at levels of 14, 6 or 0 $\mu E/m^2$ sec.

Two growth regimes are evident in Figure 22. The rate of filament increase was relatively slow at light values of 44 $\mu E/m^2$ sec or less and relatively fast at light levels of 55 $\mu E/m^2$ sec and greater. The minimal PAR at which Cladophora was capable of growth, under the conditions of the experiment, was between 14 and 29 $\mu E/m^2$ sec.

Tissue nutrients and AFW at the termination of the experiment are presented in Table 12. The algal material from the 6 $\mu E/m^2$ sec tank is believed to have been mislabeled or confused in handling. If the 6 $\mu E/m^2$ sec data are considered erroneous, the tissue nutrients (Figure 23) and AFW (Figure 24) data points fit fairly well to similar shape curves. The curves all asymptote at aproximately the 44 $\mu E/m^2$ sec light level. The tissue nutrients nitrogen and phosphorus, under all light conditions remained above 2.0 μg N/l and 0.2 μg P/l, respectively.

TABLE 11

CLADOPHORA FILAMENT LENGTH (CM) INCREASE
DURING THE LIGHT GRADIENT EXPERIMENT

LIGHT LEVEL ($\mu E/m^2$ sec)	from 10/30-11/6 (cm)	11/6-11/12 (cm)	11/12-11/18 (cm)	11/18-11/25 (cm)	TOTAL (cm)
0	0	0	0	0	0
6	0	0	1.5	0	1.5
14	0	0	0	0	0
29	0	1.5	2	2	5.5
44	0	2	1.5	4	7.5
55	0.5	2	4	3.5	10.0
79	2.5	4	11	12.5	30
168	5	16	11	22.5	54.5

TABLE 12

CLADOPHORA TISSUE NUTRIENT DATA ON THE 25th DAY OF THE LIGHT GRADIENT EXPERIMENT

LIGHT LEVEL ($\mu E/m^2$ sec)	P (%)	N (%)	C (%)	C/N	% AFW
0	0.27	2.15	15.32	7.12	19.3
6	0.49	4.11	27.78	6.74	57.3
14	0.36	2.96	22.28	7.53	59.5
29	0.40	3.81	30.99	8.13	59.3
44	0.37	3.98	32.72	8.22	69.8
55	0.37	4.27	32.84	7.69	67.7
79	0.41	4.48	31.16	6.96	68.3
168	0.46	5.01	32.01	6.39	68.4

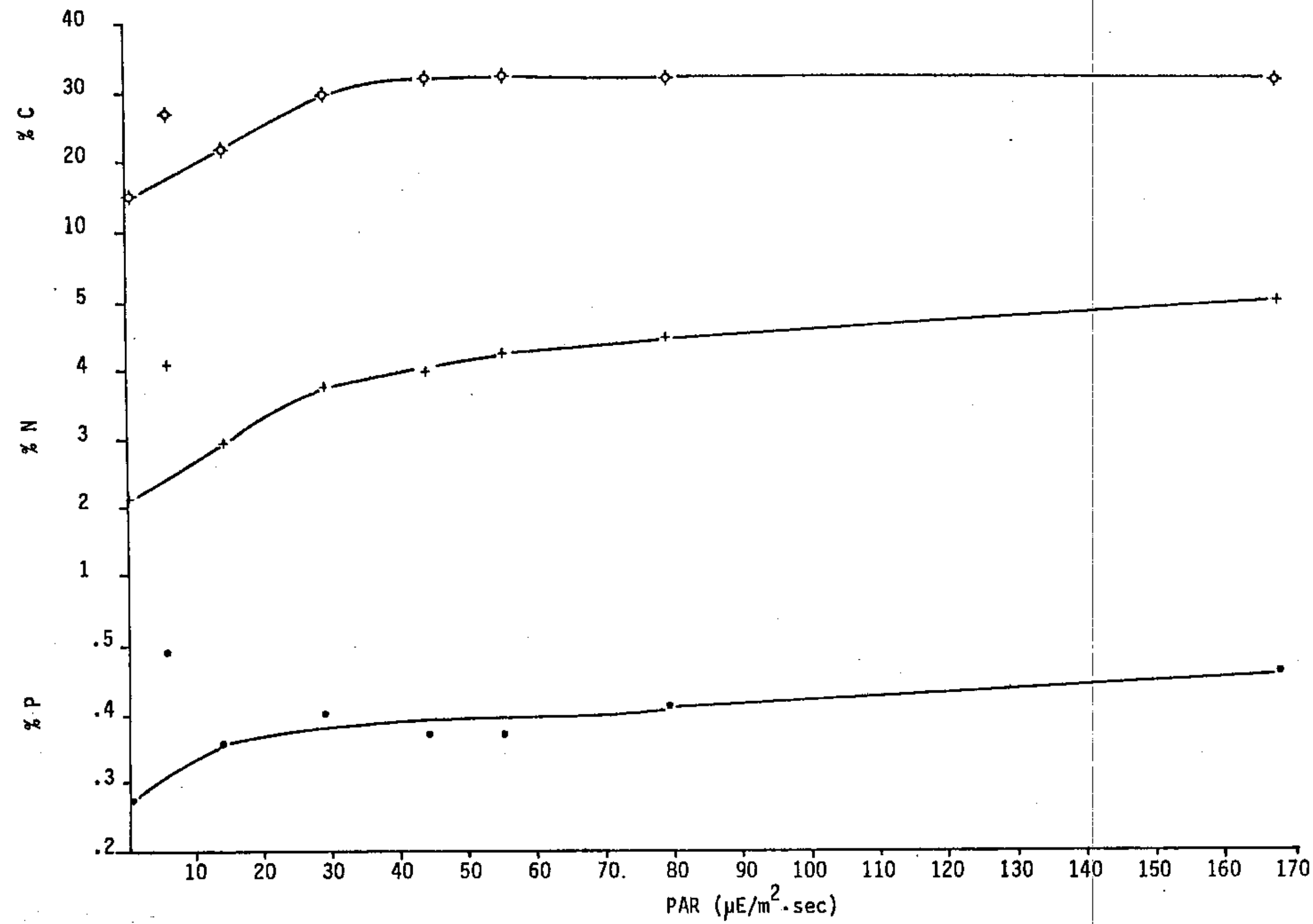


Figure 23. Cladophora Light Gradient Experiment, Tissue Nutrients at Termination of Experiment.

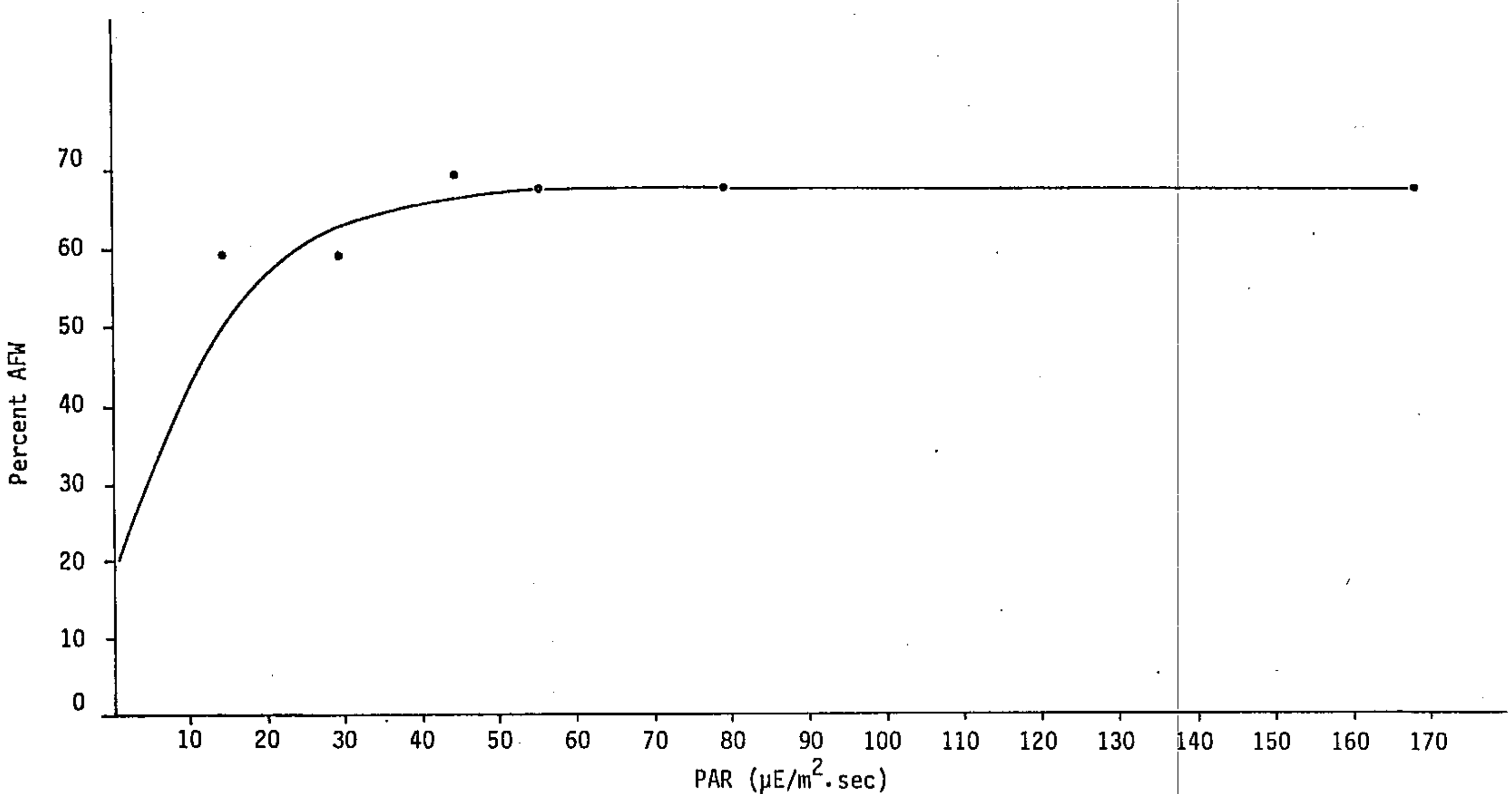


Figure 24. *Cladophora* Light Gradient Experiment, Percent Ash-free Weight at Termination of Experiment.

DISCUSSION

Distribution

Areal. Cladophora has been present in the Laurentian Great Lakes since the earliest recorded information (Bailey 1847). The distribution of Cladophora in the Great Lakes has generally increased in response to the cultural eutrophication which has influenced large areas of the Lakes (Beeton 1966; Herbst 1969; Verduin 1969). The increase in abundance and distribution of Cladophora has not been well-documented due to lack of baseline data. Historical records are based largely on evidence provided by fishermen and longtime shoreline residents. Distribution data has recently been complied for all of the Great Lakes by Auer and Canale (1981).

To provide a comprehensive data base of the distribution of the alga in western Lake Erie a survey was conducted in June of 1981. Results of the survey (Figure 20) indicate that Cladophora is present throughout the basin and is generally found wherever suitable natural or artificial substrate is available. Biomass values were obtained from select areas to provide some measure of abundance as well as distribution.

The presence of Cladophora "throughout the western basin" may lead to a misunderstanding about the extent of distribution. A significant portion of the littoral region along the Michigan, Ohio and Canadian shorelines does not provide suitable substrate to support this alga. Verber (1957) reported that 3% of the bottom of the western basin is composed of bedrock with some of this bedrock occurring at depths not capable of supporting Cladophora due to light limitations. A large majority of this bedrock and hence, Cladophora growth, is in the Island region.

Early records for western Lake Erie indicate that present-day distribution may not vary significantly from distributions reported in the late 1800's-early 1900's. The general impression received from personal conversations with lifelong residents along Lake Erie is that the abundance of this "moss" may have reached peak levels between the mid-1940's to mid-1960's. Present-day abundance is reported not to be as "bad" as it was a few decades ago. These observations are generally based on shoreline accumulations that can be influenced by currents and wind patterns as well as actual abundance.

One of the utilities of this study is to provide a data base for Cladophora which would allow the assessment of future changes in distribution and abundance. A general thrust in recent years has been to decrease phosphorus loadings to the Great Lakes in order to obtain concentrations of phosphorus that will limit algal productivity. If this goal is achievable, Cladophora could be used as a biological indicator of the effectiveness and extent of nutrient control and management strategies. Since Cladophora is sessile, it reflects conditions that are site-specific and less variable in temporal distribution than planktonic algae, thus making it a good indicator organism. This concept may not be as applicable in western Lake Erie where annual mean levels of SRP are greater than 3 µg P/l, but has been successfully demonstrated in Lake Huron where ambient levels are often below detection limits (Canale and Auer 1982).

Temporal. Cladophora of the infralittoral and eulittoral zones displayed two different patterns of temporal distribution in the lake. The infralittoral zone had a bi-modal growth pattern with the alga present from late April to mid-July and again from late September to December. Cladophora colonized the eulittoral zone during May and remained present into December. The alga in the eulittoral zone became patchy in distribution and noticeably declined in density during August, but remained present.

Several observations made during the winter and early spring, soon after ice-out, indicated that Cladophora is capable of surviving and, at least in isolated cases, has the potential for growth during the winter months. However, at the onset of the ice-free season (April) Cladophora is not generally found colonizing the littoral zone.

Cladophora Biomass

Cladophora growth was assessed by determining the standing crop present on each sampling date. Standing crop data represents only the amount of biomass present at the time of sampling and should not be equated to production. Standing crops do not account for the sloughing of algal filaments.

The observation of Cladophora biomass on the shore throughout a large part of the spring and early summer indicate that there is frequent sloughing and thus export of biomass from the algal beds. The largest loss of standing crop generally occurs in association with wave activity. Sloughing of biomass is not strictly linked to physical forces and has been observed under calm conditions in June and July, near the period of peak standing crop.

To assess the toal biomass production of Cladophora a sampling scheme must be designed to account for biomass lost due to sloughing. An attempt at such a measurement was undertaken in Lake Huron (Auer, personal communication) by enclosing a small section of the lake with a screen cage. Unfortunately, the securing of such a structure in a rocky nearshore region of the Great Lakes is not easily accomplished and the structure failed during the periods of greatest potential biomass export. An alternative method is the measurement of algal productivity in the laboratory or in-situ in enclosed containers (McMillan and Verduin 1953; Mantai 1974). These results are often bias due to constraints placed on the system by the experimental design (Mantai and Haase 1977). The recent in-depth modeling effort of Auer et al. (1982), using laboratory and field data provides the best estimates for Cladophora production and may prove to be useful in Lake Erie.

Representation of the abundance of Cladophora as standing crop, although not representing a measure of total production, does present a good estimate of the growth dynamics. Plots of the bimonthly standing crop data (Figures 13 and 14) resulted in fairly smooth "growth" curves which appear to be representative of the actual seasonal trends. For routine monitoring, the most feasible assessment of the abundance of Cladophora is standing crop data, as long as its limitations are realized.

In the present study, considerable variation was encountered in maximum standing crops and seasonal distribution, making short-term trends difficult to determine. In a similar study in the Island Region of western Lake Erie Kishler (1967) also noted that peak standing crop and seasonal distribution varied from year to year, depending on environmental conditions. The maximum standing crop of 102 g/m^2 DW 104 at the South Bass Island site in 1979 is similar to Kishler's 1965 value. Kishler (1967) reported maximum standing crop values in the South Bass Island area, at 1 m during June and July of 1965, ranging from 64-120 g/m^2 DW, averaging 95 g/m^2 DW. In 1966, at a site location (Village Intake N) close to the present site, Kishler reported a much larger standing crop of 340 g/m^2 DW. At the South Bass Island site in 1980 a maximum value of 214 g/m^2 DW was obtained, considerably less than Kishler's maximum. To properly assess Cladophora trends in a natural system, influenced by numerous interacting components, a data base must be established over a number of years.

Throughout 1979, the maximum standing crops (DW 104) at Stony Point were significantly greater than values from South Bass Island at the 0.0547 level of confidence. The distribution free sign test resulted in a relatively small annual median difference of 9.65 g/m^2 between the two sites with an 83 percent confidence interval of 3.5-15.5 g/m^2. For 1980, there was no significant difference in the maximum standing crops throughout the year between the two sites. Fall standing crop values at Stony Point were significantly ($\alpha = 0.000$) greater than at South Bass Island with a median difference of 21.0 g/m^2 and an 88 percent confidence interval of 14.4 to 43.6 g/m^2.

Western Lake Erie Cladophora standing crops are compared to other sites of the LECSP in Table 13 and Figure 25. The Walnut Creek, Pennsylvania site, located in the central basin, supported the smallest standing crop. Similar standing crops were supported at Hamburg, New York (eastern basin) and Stony Point, Michigan in 1979 and 1980 and South Bass in 1979. Rathfon Point in Long Point Bay, Ontario (eastern basin) clearly supported the largest standing crop (Figure 25). In comparison, the standing crop in Lake Huron at Harbor Beach, Michigan was in the 200-300 g/m^2 DW range (Canale and Auer 1982) and in Lake Ontario maximum standing crop has reached 1062 g/m^2 DW (Neil 1975).

The distribution of biomass in relation to depth varied with sites. Cladophora extended to approximately 2 m at Stony Point and to 3 m at South Bass Island. At the central and eastern basin sites colonization extended past 3 m with the standing crop often greatest at 3 m (Table

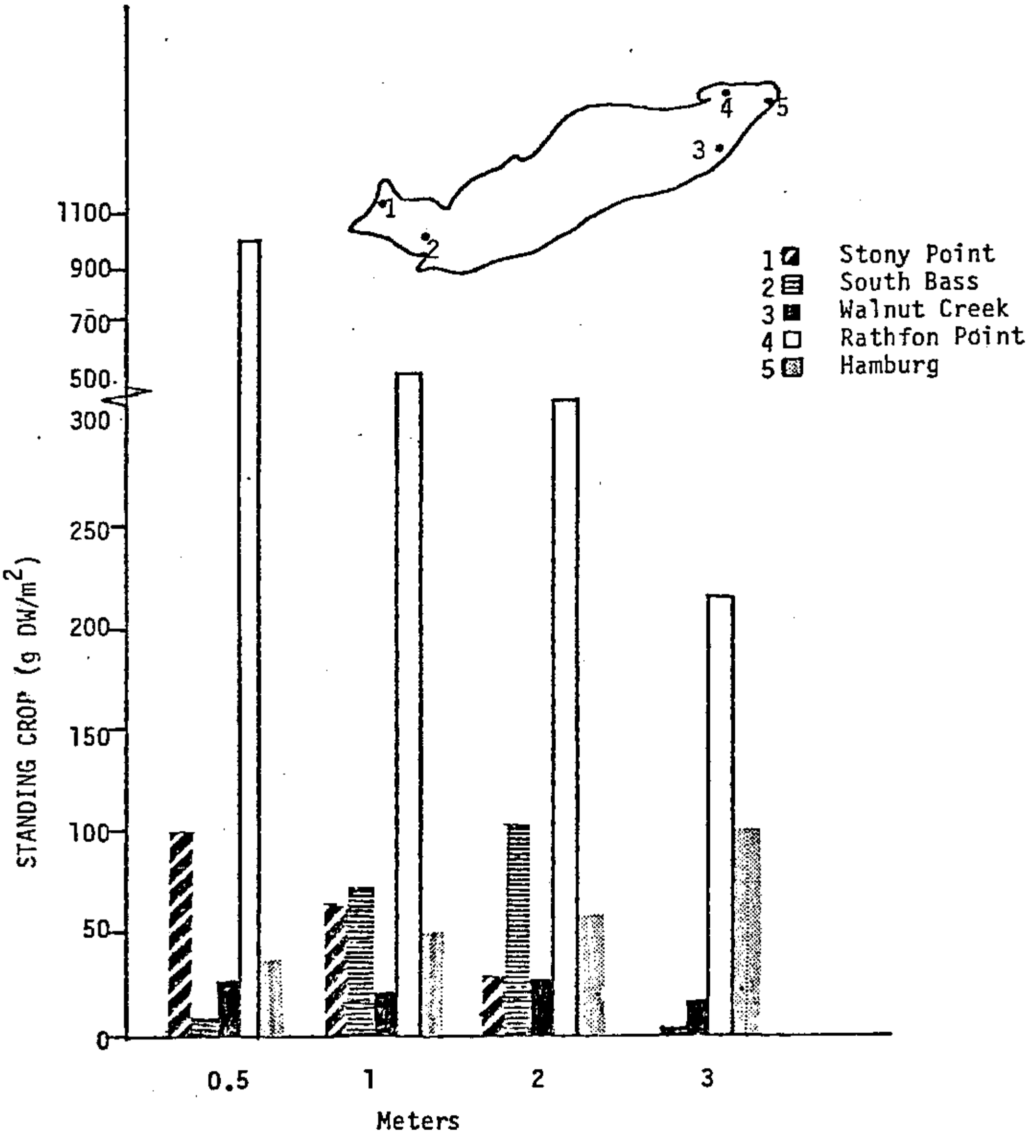


Figure 25. Comparison of 1979 Cladophora Peak Standing Crops at the Five Lake Erie Cladophora Surveillance Program Sites.

TABLE 13

COMPARISON OF MAXIMUM STANDING CROP VALUES[1]
FROM THE 1979 AND 1980 LECSP

SITE	YEAR	DEPTH (m)				TRANSECT[2] AVERAGE
		0.5	1	2	3	
Stony Point	1979	107 g/m^2	64	30	0	50
	1980	186 g/m^2	70	T	0	64
South Bass	1979	10 g/m^2	75	110	2	49
	1980	218 g/m^2	174	49	T	110
Walnut Creek	1979[4]	24 g/m^2	20	24	16	21
	1980[3]	18 g/m^2	37	18	59	33
Rathfon Point	1979[4]	983 g/m^2	444	410	214	513
	1980	--- g/m^2	---	---	---	---
Hamburg	1979[4]	36 g/m^2	48	52	100	59
	1980[3]	0.1 g/m^2	63	61	86	53

[1]Based on DW 64°, except Rathfon Point, DW 105°

[2]Transect Average = Σ of 0.5, 1, 2, and 3m/4

[3]Data from Catherine Carnes, Great Lakes Laboratory, State University College at Buffalo, New York. Personal Communication, 1981.

[4]Data from Sweeney 1980.

13). Sampling at these sites could have been more comprehensive if sampling had continued to the deepest depth of colonization.

Nutrient Relationships

The distribution and abundance of *Cladophora* has generally been linked with the availability of nutrients in the environment. For the Great Lakes, phosphorus has been implemented as the limiting nutrient factor controlling this alga (Neil and Owen 1964; Herbst 1969; Pitcairn and Hawkes 1973). In the upper Great Lakes *Cladophora* is limited to areas of nutrient enrichment, such as around Duluth, Milwaukee, Green Bay, Saginaw Bay and at the mouths of numerous rivers (Auer and Canale 1981). In Lake Huron the direct relationship between *Cladophora* distribution/abundance and phosphorus levels was illustrated by phosphorus removal at a small sewage treatment plant that discharged into the lake. Following phosphorus removal the distribution and abundance of the alga greatly diminished, eliminating the nuisance conditions previously experienced (Canale and Auer 1982).

In Lakes Erie and Ontario ambient lake levels of phosphorus and nitrogen are sufficient to support *Cladophora* in most of the nearshore regions. Nitrogen availability to the alga at the two sites in western Lake Erie was relatively high. Nitrate + nitrite and ammonia, both available forms of nitrogen (Gerloff and Fitzgerald 1976), were not limiting, averaging greater than 350 μg N/l and 15 μg N/l respectively. Levels of SRP at the two sites averaged greater than 3 μg P/l. Field data from the LECSP indicates that SRP concentrations as low as 1 μg P/l are capable of supporting Cladophora growth. For example, the lush growth at Rathfon Point, Ontario in 1979 (983 g DW/m^2) was produced with average SRP values of approximately 1 µg P/l (Neil 1981). The delineation of actual limiting phosphorus levels are hampered by the fact that measurement of SRP at levels of 1 µg P/l and below are approaching the detection limit of measurement.

Total phosphorus and TDP cannot be accurately used to assess the availability of phosphorus for algal utilization, but are often the only data available. Thomas (1975) noted prolific growth of Cladophora in Lake Huron where the average spring and annual TP concentrations exceeded 15 µg P/l. At both western Lake Erie sites TP averaged over 30 µg P/l.

An effective alternative to assessing the nutrient availability in the system is to measure the concentration of the nutrient in the alga. Nutrient levels within the alga provide a direct evaluation of the conditions to which the alga has been exposed. This approach eliminates the problem of measuring low levels of phosphorus in the water.

Cladophora is capable of nutrient uptake in excess of immediate requirements. When nutrients are abundant, tissue nutrient levels are usually high, and when nutrients are scarce, tissue nutrients are low. The "luxury uptake" provides the alga with a mechanism to survive short periods of low nutrient availability in the environment.

In the upper Great Lakes tissue phosphorus levels decrease as the distance from the nutrient source increases and environmental levels decline (Lin 1971, 1977; Auer and Canale 1980). In the western basin of Lake Erie, at the two sites, there is not a "source" gradient of nutrients but there are temporal variations in nutrient availability which are reflected in the tissue nutrient levels. Total tissue phosphorus levels at Stony Point in 1980 followed a very similar pattern of increasing and declining as SRP levels did (Figure 19). At South Bass Island TTP concentrations remained fairly constant as did SRP levels in the water.

The critical tissue concentrations for various elements required for Cladophora growth have been determined in the laboratory by Gerloff and Fitzgerald (1976). Critical concentration is defined as the level of internal nutrient above which relatively little increase in yield is observed over a specific culture period. The critical concentrations of phosphorus and nitrogen reported by Gerloff and Fitzgerald (1976) are 0.06% and 1.1% respectively. Gerloff and Muth (1979) have recently revised the critical phosphorus level to 0.08%.

Tissue phosphorus and nitrogen at the western basin sites averaged above 0.2% and 2.5%, respectively, well above limiting conditions. These values were greater than the values reported from the central and eastern basins (Sweeney 1980; Neil 1981), reflecting the higher availability of nutrients in western Lake Erie. Levels of TTP, TTN and TTC in the present study reached the lowest levels just after the onset of growth in mid-May and again in early August, declining from peak levels in June. Mantai (1974, 1978) reported similar declines in phosphorus and nitrogen in eastern Lake Erie. During May and August tissue levels of phosphorus and nitrogen approached, but generally did not drop below critical levels as defined by Gerloff and Fitzgerald (1976). The one exception was nitrogen in mid-May, 1979 at the South Bass Island site.

The decline in tissue nutrients were observed despite the fact that in many cases forms of available phosphorus and nitrogen were present in quantities that were previously sufficient to support higher tissue levels. In western Lake Erie where the level of available nutrients are relatively high, factors other than nutrient availability must be responsible for the decline in tissue concentrations. The relatively low values observed, just after the onset of growth are probably the result of the high nutrient requirements of the alga during active growth. The decline in TTP, TTN and TTC in July and August are the result of a negative energy balance; this will be discussed in the next section.

Environmental Factors Influencing Seasonal Periodicity

Maximum productivity of *Cladophora* in the infralittoral zone generally occurred from May through June and again in October and November, resulting in a two-cycle annual growth pattern. This bi-modal growth pattern, with a marked decrease in standing crop occurring during the hottest months, has been previously reported for Lake Erie (Kishler

1967; Mantai 1974, 1978; Neil 1975) and in other lentic and lotic environments (Whitton 1970). Bellis and McLarty (1967) noticed a tendency for the interval between the spring and fall periods of intensive growth to increase in successively more southern locations. For example, in Texas the observed maxima was reported in March and November (Thurman and Kuehne 1952). Previous investigators have suggested that temperature is the controlling factor in this seasonal periodicity (Bellis 1968; Herbst 1969; Whitton 1970).

Maximum growth in the present study occurred between the 12-20^{o}C range. When lake temperatures rose above approximately 20^{o}C, the standing crop (AFW) began to decline soon thereafter (Figures 26 and 27). Present field observations of optimum temperatures for Cladophora growth are similar to Taft and Kishler's (1967) observations in western Lake Erie of 10-18^{o}C. Laboratory studies of Storr and Sweeney (1971) report an optimum temperature of 18^{o}C and Graham et al. (1982) a 13-17^{o}C range for optimum net photosynthesis. The limiting maximum temperature of approximately 20^{o}C is in close agreement with the 18^{o}C temperature report by Taft and Kishler (1973) in western Lake Erie. Several other investigators have reported higher maximum temperatures of 25^{o}C (Storr and Sweeney 1971; Zuraw 1969) and 30^{o}C (Whitton 1970). Preliminary laboratory results of Graham et al. (1982) indicate a maximum temperature in the 30^{o}C range, varying with light intensities. The influence of temperature on the seasonal periodicity has recently been conclusively defined by the extensive laboratory investigations into the energetics of Cladophora by Graham et al. (1982). Based on the work of

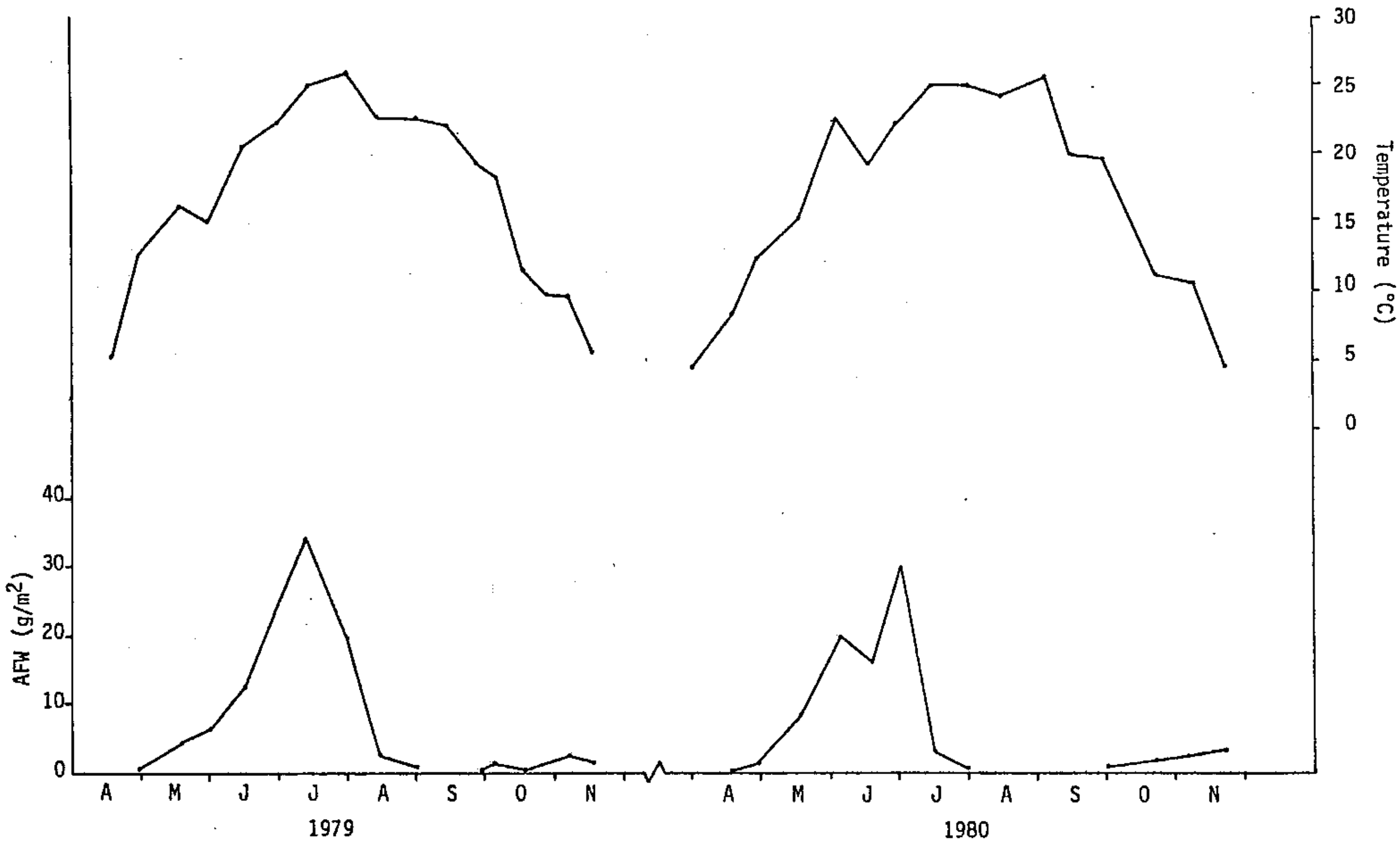


Figure 26. Water Temperatures and <u>Cladophora</u> Ash-free Weights at Stony Point, 1m Station, 1979 and 1980.

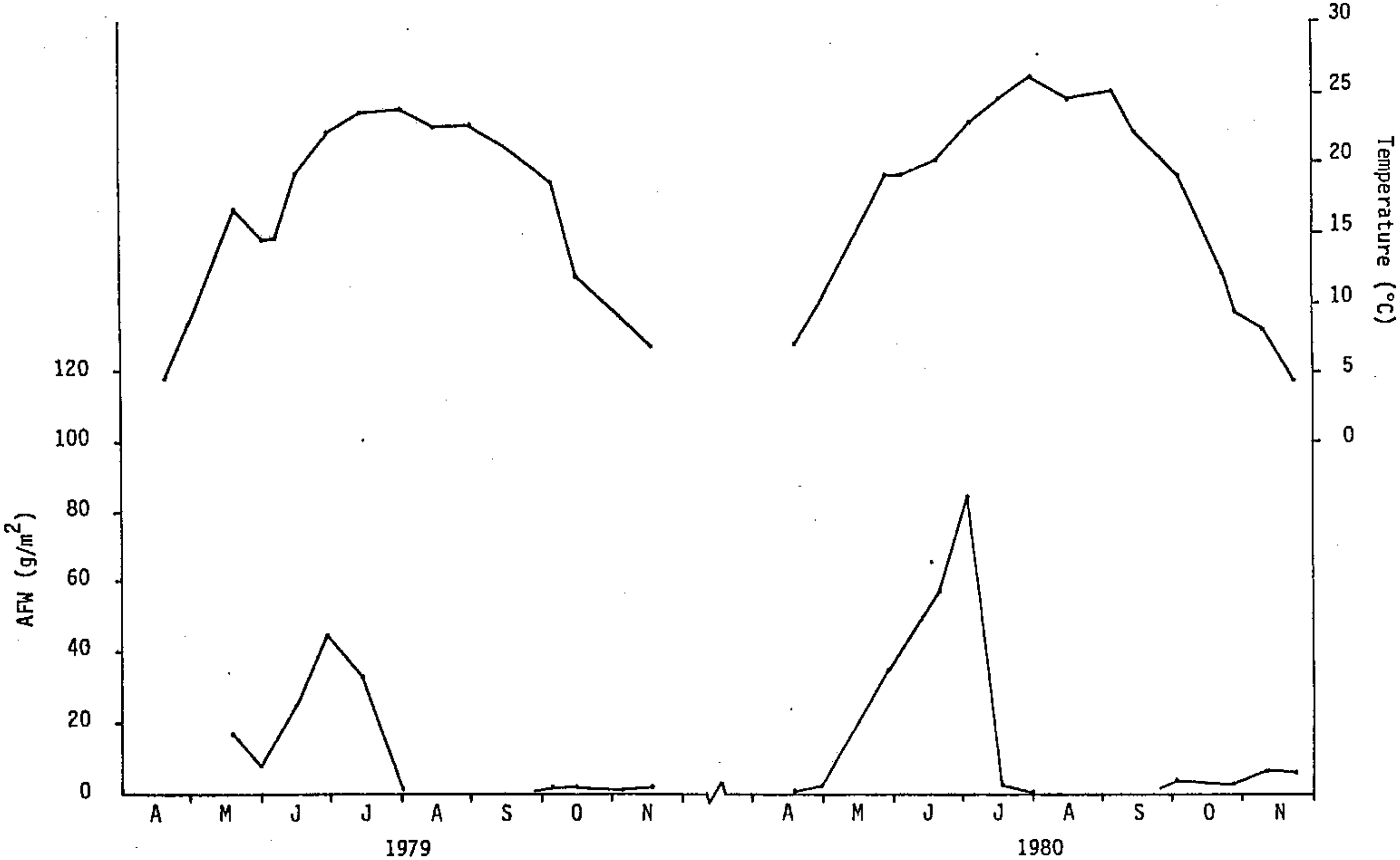


Figure 27. Water Temperatures and <u>Cladophora</u> Ash-free Weights at South Bass Island, 1m Station, 1979 and 1980.

Graham et al. (1982) and field observations of the present study the environmental factors influencing the growth dynamics of Cladophora in western Lake Erie can be defined.

Growth of the alga occurs when environmental conditions enable gross photosynthesis to be greater than respiration, resulting in a positive net photosynthetic rate. The photosynthetic and respiration rates are both controlled by temperature and light. When water temperatures rise to the $4^{O}C$ range in the spring the photosynthetic/respiration ratio (P/R) approaches 1, enabling the alga to initiate "growth". As temperatures rise from approximately $4-10^{O}C$, Cladophora begins to appear and slowly increase in distribution, with growth rapidly increasing once temperatures approach $10^{O}C$. The maximum net photosynthesis and hence production takes place in the late spring (May-June) as temperatures are in the $10-20^{O}C$ range. When temperatures reach $20-25^{O}C$ (July) a P/R ratio of less than 1 is obtained, leading to senescence, tissue nutrient decline, and subsequent detachment of the filaments. Net photosynthesis not only declines with the higher summer temperatures but also decreases at higher light levels (Graham et al. 1982). The higher light values at 0.5 m may be responsible for the earlier decline in biomass at 0.5 m than at the deeper depths in 1980 (Figures 13 and 14). Growth of Cladophora remained absent in the infralittoral zone until temperatures decline below $20^{O}C$, in late September. The fall resurgence of growth developed as lake temperatures dropped from $20-10^{O}C$. The bimodal periodicity of Cladophora is thus the result of a negative energy balance in the summer caused by both temperature and light conditions creating a P/R ratio of less than 1.

The observation of short, bright green filaments under the ice in January indicates the ability of Cladophora to survive near freezing temperatures. Graham et al. (1982) reported no net photosynthesis at $1^{o}C$, but noticed the alga remained bright green. The ability of Cladophora to grow during the winter months was evident by the long filaments on the minnow car in March. Graham et al. (1982) suggest that net photosynthesis is possible at $2^{o}C$ at light levels of 150-300 $\mu E/m^2$ sec.

Minimum Light Requirement of Cladophora

The vertical distribution of Cladophora in the western basin varied with time and location. The greatest depth of growth was attained during the spring pulse, generally from late May to late June. At Stony Point Cladophora generally did not colonize past the 2 m depth and at South Bass Island the alga extended to approximately 3 m. Cladophora at other locations in the western basin was observed as deep as 7 m. The variation in depth of colonization at the different sites when compared to light data suggests that light attenuation is influencing the extend of vertical growth. Temperature and nutrient availability at the deeper depths (3 m) were not appreciably different than the shallower depths. From the limited light data available it appeared as if PAR values in the range of 50 μ E/m^2 sec were limiting to Cladophora growth (Figure 6).

The light gradient experiment was designed to quantify the light requirement necessary to sustain Cladophora growth, under conditions as close to the natural lake enviornment as possible. Under experimental conditions growth, defined as increase in filament length, increased as light intensity increased. The optimum PAR, for maximum growth, was not achieved and is therefore greater than 168 μ E/m^2 sec, the highest light level in the gradient. Light was thus limiting at all PAR levels of the experiment. The optimum light intensities of 300 to 600 μ E/m^2 sec defined by Graham et al. (1982) are consistent with these results.

In the light gradient experiment values of approximately 50 μ E/m^2 sec (PAR) and greater maintained a higher rate of growth than values less than this (Figure 22). Levels of PAR less than approximately 30 μ E/m^2 sec represented the minimum levels below which growth was not observed. PAR values between 30-50 μ E/m^2 sec were considered in the critical range. The minimum value of 30 μ E/m^2 sec is close to one percent of the incident light. The results of this experiment are in close agreement with the preliminary results of Graham et al. (1982) that PAR values of 35 μ E/m^2 sec and greater are capable of providing postive net photosynthesis.

In extrapolating the results from the light gradient experiments to the natural environment several factors must be considered. The light levels in the gradient were constant for the total 14-hour period, resulting in approximately 40 percent greater total daily illumination than a 14-hour field day, due to twilight effects. Light levels in the lake were generally monitored near mid-day (11:00-15:00), at peak levels. A field PAR value of 30 μ E/m^2 sec would be close to the daily maximum PAR; thus, the actual mean for the day would be less than 30 μ E/m^2 sec at that depth. The results of the light gradient experiment are only valid for temperatures near 15^{o}C, since net production is also influenced by temperature. Fifteen degrees C is near the optimum temperature for growth and a 5^o C increase or decrease will negatively influence production. Due to the above-mentioned reasons and other uncertainties in the natural environment 50 μ E/m^2 sec, the upper values of the critical range, was considered the minimum PAR capable of supporting Cladophora in western Lake Erie.

Results of the 1981 survey support the contention that light is limiting the vertical distribution of Cladophora in western Lake Erie. Locations with greater secchi depths and lower extinction coefficients generally supported growth to a deeper depth. To field test the minimal level of 50 μ E/m^2 sec, the depth of Cladophora growth and light conditions throughout the basin were compared to the 50 μ E/m^2 sec value.

The survey data represents conditions at each site for the specific time at which the site was visited and cannot be taken as the conditions necessarily present over time. The sessile nature of Cladophora helps to eliminate some of the short-term variations encountered. For example, the distribution of Cladophora does not fluctuate on a daily basis in response to short-term environmental conditions, thus eliminating some of the time dependence relative to depth distribution. Light availability, however, is highly time dependent, varying with time of day, weather, and physical water characteristics. To eliminate some of the time dependency of the light data, in order to achieve an "average representation" of light conditions expected at each site, several assumptions were made.

To test the hypothesis that PAR less than approximately 50 μ E/m^2 sec is limiting to Cladophora, the maximum depth of growth at the sites in the survey were compared to the depth at which 50 μ E/m^2 sec would be expected to occur under "normal conditions" for that site. It has been shown that,

$$I_z = I_o e^{-kz} \qquad (1)$$

where: I_z = PAR at depth z

I_o = incident PAR

k = extinction coefficient

z = depth

The extinction coefficient (k) for each site was calculated from light profile data taken at each site. Equation 1 may be rewritten as follows,

$$k = \frac{\ln I_o - \ln I_z}{z} \qquad (2)$$

to solve for K. High extinction coefficients were prevalent along the southern shore and lower values were found in the northern reef areas. Extinction coefficients ranged from 1.59-0.48 (Table 8).

Once the extinction coefficient is known the depth at which 50 μ E/m^2 sec will occur at each site can be calculated by rewriting Equation 1 as,

$$z = \frac{\ln I_o - \ln I_z}{k} \qquad (3)$$

where: k is site specific calculated value

I_z is 50 μ E/m^2 sec, the minimum light value for growth

I_o is incident light.

An average incident light (I_o) value of 2000 μ E/m sec (Li-cor 1980) was used in all calculations to eliminate the variability between sites sampled at different times of the day and under different weather conditions. The 2000 μ E/m^2 sec value is similar to the average field incident PAR value of 2009 μ E/m^2 sec recorded at the two routinely monitored sites, from May-July 1980. Equation 3 thus becomes,

$$z = \frac{\ln 2000 - \ln 50}{\text{site specific } k} \qquad (4)$$

where: z represents the depth at which PAR will be 50 μ E/m^2 sec.

If 50 μ E/m^2 sec is the minimum level of PAR capable of supporting _Cladophora_ the calculated depth from Equation 4 should be similar to the field observed depth of deepest colonization at that site. The calculated depth at which 50 μ E/m^2 sec was obtained and actual depth to which the alga was observed compared well (Table 14). The several reef areas where the 50 μ E/m^2 sec depth was greater than the observed depth of growth can possibly be explained by the movement of sediment on and off the deeper portions of the reefs. For example, areas of sand were encountered on Chickenolee Reef. _Cladophora_ filaments may also have detached at the deeper depths prior to the time of the survey in late June. Old holdfasts were evident at the deeper depths of Gull Island Shoal.

The results of routine monitoring, the light gradient experiment, and the survey of the western basin all support the theory that _Cladophora_ in western Lake Erie is light-limited at PAR levels below approximately 50 μ E/m^2 sec. The depth at which light attenuates to 50 μ E/m^2 sec in the western basin varies from less than 2 m to over 7 m. The increase in the turbidity of western Lake Erie over the past century that has contributed to the decline of aquatic vascular plants (Stuckey 1979) may also have decreased the total colonizable substrate available to _Cladophora_. If in the future the turbidity of the basin decreases in response to decreased loadings and phosphorus levels remain above 1 μg P/l the quantity of _Cladophora_ would increase due to a greater vertical distribution.

TABLE 14

COMPARISON OF OBSERVED DEPTH OF CLADOPHORA COLONIZATION

TO PREDICTED $50 \mu E/m^2.sec$ DEPTH

LOCATION 1981	K	PREDICTED Z_{50} $\mu E/m^2.sec$ (m)	MAX. OBSERVED DEPTH (m)
Marblehead Peninsula	1.59	2.3	2.5
East Kelly's Island	0.89	4.1	4.5
Gull Island Shoal	0.78	4.7	3.2
North Bass Island	0.73	5.1	4.5
Chickenolee Reef	0.68	5.4	6.0 *
East Sister Island	0.74	5.0	4.5
Colchester Reef	0.61	6.1 **	7.0
Middle Ground Shoal	0.48	7.7	4.8 ***
Stony Point	1.90	1.9	1.5
South Bass Island	1.13	3.3	3.0
1980			
Gull Island Shoal	0.88	4.2	3.8
Chickenolee Reef	0.49	7.5	4.6 *
Stony Point	1.87	2.0	1.8
South Bass Island	0.95	3.8	3.0

* portions of reef covered with sand

** light reading late in the day

*** deepest depth not located due to flat and level topography of the reef and the presence of gill nets

K - extinction coefficient

Cladophora Niche

Cladophora is part, often a dominant part, of a very dynamic and productive region of the lake. As a component of this environment Cladophora must compete with, be influenced by and influence other organisms of this region. The development of algal zonation and seasonal distribution patterns allows a wide variety of organisms to inhabit the rocky nearshore zone. Of the macroscopic algae present in the littoral region, Cladophora colonizes the largest zone (Figure 12). Bangia, a relatively new invader into western Lake Erie, has been able to expland from a few scattered sitings in 1969 (Taft and Kishler 1970) to a general distribution in the basin. The success of this alga is due to the ability of Bangia to out-compete the endemic species in the dynamic splash zone.

Lush growth of Cladophora in the rocky littoral regions greatly alters the microenvironment, particularly on the flat, barren bedrock shorelines of the Islands. The presence of extensive Cladophora beds greatly increase available surface area and provide a habitat for a wide variety or organisms, in what might otherwise be a relatively unproductive area. Large surface areas and the "rough", relatively mucilage free cell wall of Cladophora (Rosen et al. 1982) provide an excellent substrate for epiphytic organisms, particularly the diatoms. The abundant epiphytic organisms in turn provide the base for a diverse invertebrate community (Table 7). This Cladophora association represents a highly productive community which attracts the vertebrates.

Observation of fish fecal pellets containing large amounts of Cladophora indicate that fish ingest the alga as well as the invertebrates. The undigested nature of a large extent of the filaments in the pellets suggest that Cladophora may not be intentionally consumed, but ingested in association with invertebrates. Although the alga is not fully digested, it may still provide a source of nutrition for the fish, vitamins in particular (Cladophora requires relatively high levels of vitamin B_{12} and B_1 for growth (Gerloff and Fitzgerald 1976)). Visual observation of fish and the size of the fecal pellets suggest that they are from either perch or smallmouth bass. Previous investigators have reported the sand shiner, striped shiner (Gillen and Hart 1980) and the fathead minnow (Coyle 1930) from lotic environments to feed on Cladophora. Cladophora in the Great Lakes generally has not been considered to be a food source.

The growth dynamics of Cladophora closely coincide with the reproduction of many species. The physical environment created by Cladophora in the spring (May-June) provides a substrate used for reproduction by both invertebrates and fish. For example, Gammaris abundance and life cycle has a similar cycle as the standing crop of Cladophora. Barton and Hynes (1978) suggest that Gammaris is preadapted to exploit the presence of Cladophora. Numerous fish eggs and the spawning activities of carp have been observed in the algal beds. All organisms found in association with Cladophora must be able to adapt to the severe seasonal fluctuations in abundance, from dense meadows with filaments 90 cm in length to flat bedrock with holdfasts of approximately 1 cm.

The presence of larval fish in the *Cladophora* beds suggest that they may be using the beds as a refuge. *Cladophora* has also been suggested to be detrimental to fish eggs such as walleye which require a rocky substrate to spawn (Shear and Konasewich 1975). The reduction of light by the filaments increases the susceptibility of the eggs to fungal attack.

The macrophyte dominated littoral regions of lakes have long been known as "nursery areas" for numerous aquatic species. In the Great Lakes, and particularly the southwestern shores of the western basin of Lake Erie, large tracts of marshlands, river mouths, and nearshore habitat which represent highly productive and diverse environments have been destroyed. *Cladophora* beds may be providing one of the few refuges for an important community that is having its habitat destroyed.

CONCLUSIONS

1. The distribution and abundance of the filamentous green alga, *Cladophora glomerata* in the Great Lakes has generally been linked to the availability of phosphorus. At the two sites monitored in western Lake Erie neither phosphorus or nitrogen were limiting. Available forms of these nutrients were relatively high in the environment and algal tissue nutrient concentrations remained above critical levels, as defined by Gerloff and Fitzgerald (1976).

2. *Cladophora* was found to colonize available substrate throughout the western basin of Lake Erie. The largest populations of this alga were located in the Island Region due to the large areas of exposed bedrock.

3. *Bangia*, a filamentous red alga, which was first reported in western Lake Erie in 1969, was found throughout the basin in 1981. The rapid spread of this marine invader can be attributed to its ability to out-compete other endemic species, such as *Ulothrix* and *Cladophora*, at the highly dynamic air/water interface of the lake.

4. The greatest limiting factor to *Cladophora* distribution in western Lake Erie is the availability of substrate; only 3 percent of the lake bottom in western Lake Erie provides suitable rocky substrate.

5. In areas with suitable substrate the vertical distribution of *Cladophora* is limited by the high light attenuation in western Lake Erie. Photosynthetically active radiation below approximately 50 $\mu E/m^2$ sec was determined to be limiting to colonization. The depth at which 50 $\mu E/m^2$ sec was reached varied from less than 2 m to greater than 7 m in western Lake Erie. Greatest depths of *Cladophora* colonization and the lowest light extinction coefficients occurred in the northern reef areas. The highest light attenuations and least depths of colonization were located along the southern shore.

6. Growth of *Cladophora* in the infralittoral zone exhibited a bimodal pattern with peaks in June and July and again in October and November. The abundance and distribution of the standing crop varied from season to season. A maximum standing crop of 214 g DW/m^2 was obtained at South Bass Island in June of 1980 at 0.5 m. Maximum standing crop at Stony Point, Michigan was 184 g DW/m^2 in November of 1980 at 0.5 m. The greatest vertical distribution was obtained during the first half of the season. The eulittoral zone supported growth from May to December in contrast to the infralittoral zone that lacks growth in the late summer.

7. The decline and subsequent absence of the alga in the infralittoral zone during the late summer months (July through August) is the result of an environmentally induced negative energy balance. The energetics of the alga are regulated by the effects of light and temperature on photosynthesis and respiration. Field observations

indicate an optimum temperature for growth in the range of 12-20°C. Temperatures above approximately 20°C appear to be limiting. The higher temperatures of summer result in respiration surpassing productivity. The declining standing crop in the summer months was accompanied by increasing epiphyte colonization and declining, but not limiting, tissue phosphorus and nitrogen levels.

8. Nuisance accumulations of shoreline *Cladophora* were generally confined to the Island Region. Nuisance conditions were most widespread from June-July, with shoreline accumulations often greater than 5 kg/m^2 (DW 104). In localized areas large amounts of *Cladophora* washed ashore during the first few major storms after ice-out (April), probably representing biomass from the previous year's fall crop.

9. Although accredited with nuisance conditions at times, the *Cladophora* niche is important in the nearshore region, supporting a diverse and abundant association of flora and fauna. A wide variety of organisms were identified within the *Cladophora* community. Further investigations are needed into the complex community strucutre of grazers and consumers that interact with the productive *Cladophora* association.

10. *Cladophora* has the potential to be utilized in the monitoring of water quality. Its presence in the upper Great Lakes is a positive indicator of nutrient enrichment and might be utilized as a quick and

inexpensive way to survey large areas of shoreline for nutrient sources. This study provides baseline data on the 1979-1980 Cladophora conditions in western Lake Erie upon which future trends can be based. The capability of Cladophora to scavenge and bioaccumulate a wide variety of substances provides an excellent means to monitor these substances. Due to bioaccumulation, many substances such as PCB's, organochlorine pesticides, metals and radioactive substances, which are present in the environment near the detection limits, can be better assessed at the higher levels in the alga. The sessile nature of the alga provides site-specific information and the capability to continuously monitor the environment, enabling the documentation of events not otherwise observed.

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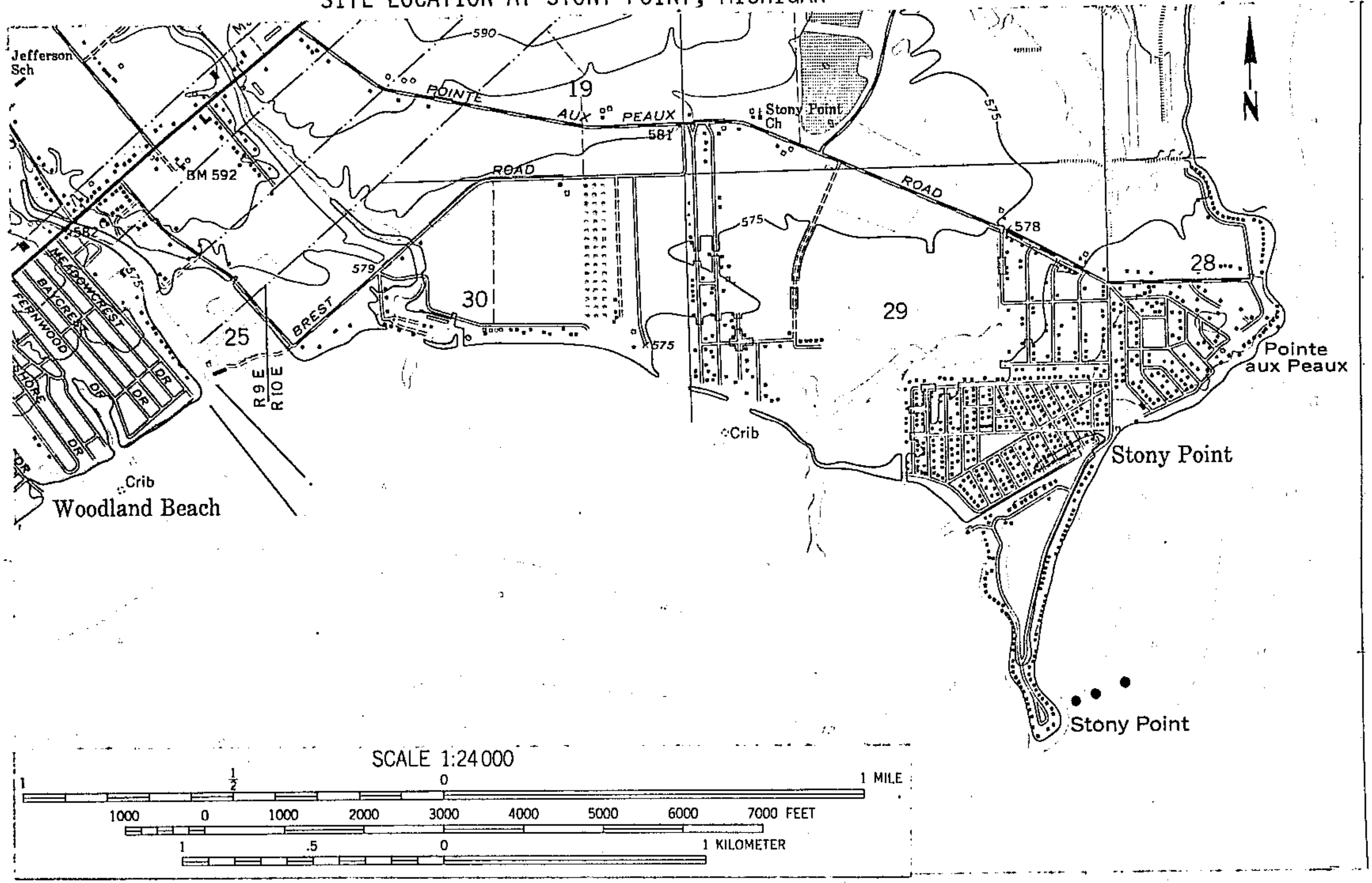
APPENDIX A

SITE AND STATION LOCATIONS
FOR THE WESTERN LAKE ERIE CLADOPHORA SURVEILLANCE PROGRAM

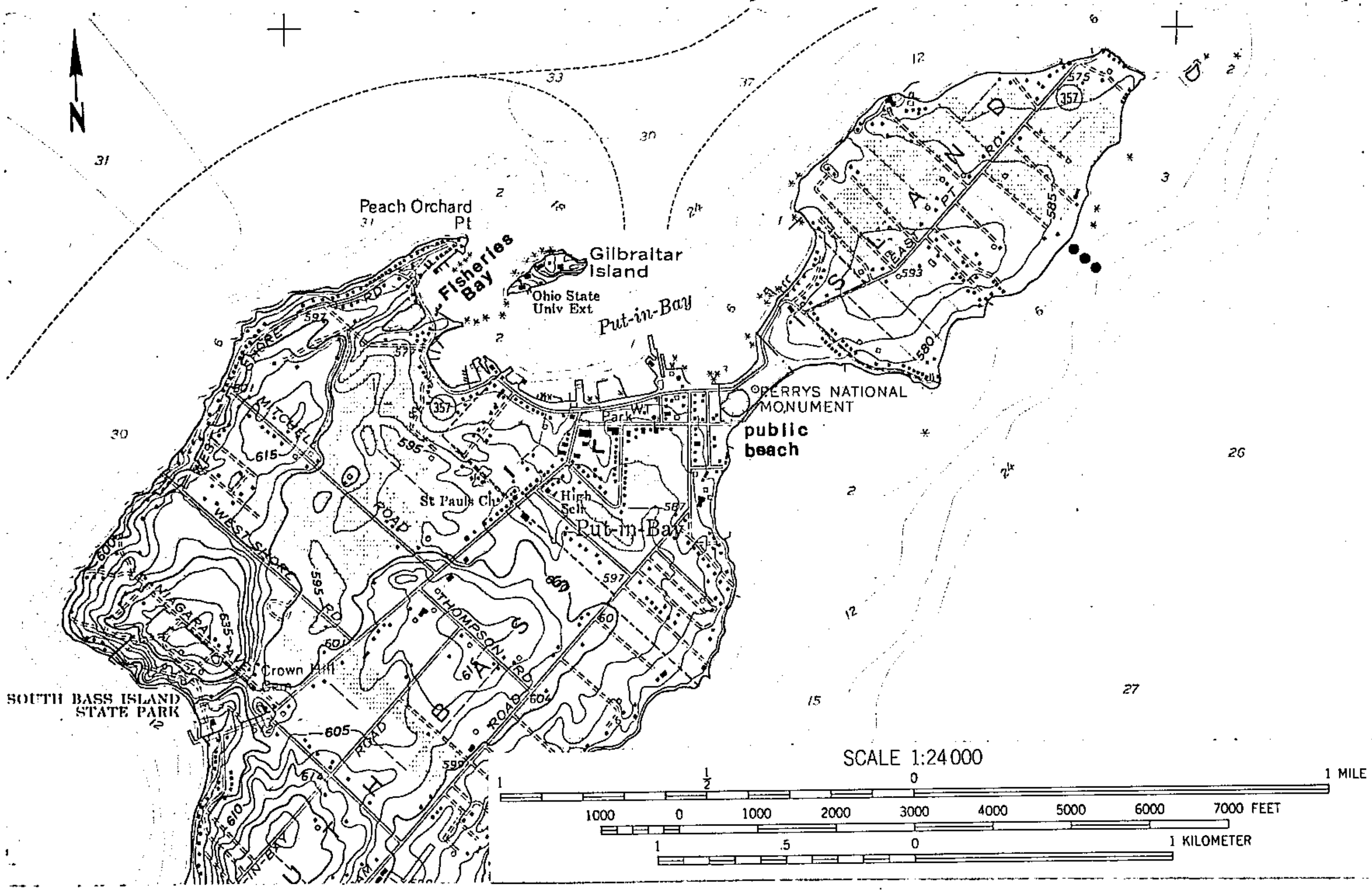
APPENDIX A-1

SITE LOCATION AT STONY POINT, MICHIGAN



APPENDIX A-2

SITE LOCATION AT SOUTH BASS ISLAND, OHIO



APPENDIX A-3

STATION LOCATIONS AT STONY POINT, MICHIGAN

STATION DEPTH (m)	DISTANCE BETWEEN STATIONS (m)	DISTANCE OFF SHORE (m)
0.5	14.8	14.8
1.0	10.2	25.0
2.0	39.1	64.1
3.0	96.0	160.1

APPENDIX A-4

STATION LOCATIONS AT SOUTH BASS ISLAND, OHIO

STATION DEPTH (m)	DISTANCE BETWEEN STATIONS (m)	DISTANCE OFF SHORE (m)
0.5	6.8	6.8
1.0	4.5	11.3
2.0	22.7	34.0
3.0	19.3	53.3

APPENDIX B

TISSUE NUTRIENT INFORMATION

APPENDIX B -1
GORHAM'S MEDIUM - MINUS PHOSPHATE *

REAGENT	mg/l
$NaNo_3$	496
$MgSO_4.7H_2O$	75
$CaCl_2.2H_2O$	36
$Na_2SiO_3.9H_2O$	58
Na_2CO_3	20
Ferric Citrate	6
Citric Acid	6
EDTA	1

pH 7.0

* Hughes,E.O.,P.R.Groham,and A. Zehnder. 1958. Toxicity of a unialgal culture of Microcystis aeruginosa. Can. J. Microbiol. 4:225-236.

APPENDIX B-2
EQUATIONS FOR TISSUE NUTRIENT CALCULATIONS

BOILING WATER EXTRACTABLE PHOSPHORUS:

$$\text{ExP} = \frac{\text{(liters in sample) (mgP/l of sample)}}{\text{mg DW } 64^{o}\text{C of Cladophora in sample}} \times 100 = \text{mgP/100mg Cladophora}$$

TOTAL TISSUE PHOSPHORUS:

$$\text{TTP} = \frac{\text{(liters in sample) (mgP/l of sample)}}{\text{mg DW } 64^{o}\text{C of Cladophora in sample}} \times 100 = \text{mgP/100mg Cladophora}$$

TOTAL TISSUE CARBON/NITROGEN:

$$\text{TTN} = \frac{\mu\text{gN}}{\mu\text{g DW } 64^{o}\text{C of Cladophora}} \times 100 = \mu\text{gN/100ug Cladophora}$$

APPENDIX C

DATA SET FOR THE WESTERN LAKE ERIE CLADOPHORA SURVEILLANCE PROGRAM, 1979 and 1980

Cladophora Site - 1 is Stony Point, Michigan

Cladophora Site - 2 is South Bass Island, Ohio

1979 CLADOPHORA BIOLOGICAL DATA
CLADOPHORA SITE - 1

DATE	DEPTH (m)	COVERAGE (%)	LENGTH (cm) Mean	LENGTH (cm) Max.	BIOMASS IN GRAMS/m^2 Wet	Dry (64°C)	Dry (104°C)	Ash	Ash-free	BIOVOLUME (ml/m^2)
107	0.5	15	0.5	1.5	-	-	-	-	-	-
	1.0	30	0.5	6.0	-	-	-	-	-	-
	2.0	T*	0.2	0.5	T	T	-	-	T	T
	3.0	0	0.0	0.0	0	0	0	0	0	0
117	0.5	15	0.5	6.0	6.7	1.8	1.7	1.0	0.8	8
	1.0	30	0.7	7.0	8.3	2.3	2.3	1.5	0.8	10
	2.0	1	0.4	3.0	T	T	T	-		T
	3.0	0	0.0	0.0	0	0	0	0	0	0
137	0.5	45	3.0	11.0	110.0	19.6	19.0	10.4	8.1	112
	1.0	40	3.0	12.0	67.0	13.9	13.4	8.7	4.7	40
	2.0	1	<1.0	1.0	T	T	T	T	T	T
	3.0	0	0.0	0.0	0	0	0	0	0	0
151	0.5	50	8.0	25.0	195.7	54.6	53.4	36.4	17.0	162
	1.0	40	7.0	15.0	65.0	14.3	13.9	7.3	6.6	64
	2.0	1	1.5	2.0	T	T	T	T	T	T
	3.0	0	0.0	0.0	0	0	0	0	0	0
164	0.5	50	9.0	19.0	184.8	53.5	50.8	24.8	26.0	296
	1.0	40	7.0	13.0	105.9	25.1	23.6	11.2	12.5	144
	2.0	5	4.0	8.0	13.2	2.8	2.7	1.2	1.5	14
	3.0	0	0.0	0.0	0	0	0	0	0	0
179	0.5	90	20.0	26.0	307.6	66.0	61.5	21.6	39.9	444
	1.0	70	20.0	35.0	163.8	38.2	35.7	12.4	23.3	216
	2.0	25	13.0	17.0	107.7	24.9	23.5	6.6	16.8	140
	3.0	0	0.0	0.0	0	0	0	0	0	0

1979 CLADOPHORA BIOLOGICAL DATA (continued)
CLADOPHORA SITE - 1

DATE	DEPTH (m)	COVERAGE (%)	LENGTH (cm) Mean	LENGTH (cm) Max.	BIOMASS IN GRAMS/m^2 Wet	Dry (64^oC)	Dry (104^oC)	Ash	Ash-free	BIOVOLUME (ml/m^2)
193	0.5	90	23.0	37.0	318.7	106.7	100.4	45.4	55.0	440
	1.0	80	16.0	30.0	202.3	64.0	60.8	26.8	34.0	296
	2.0	45	13.0	19.0	124.7	30.1	28.2	9.9	18.3	144
	3.0	0	0.0	0.0	0	0	0	0	0	0
211	0.5	too turbid	9.0	18.0	119.0	44.3	42.4	25.7	16.7	144
	1.0	too turbid	10.0	25.0	142.9	49.2	46.9	27.2	19.7	176
	2.0	too turbid	7.0	15.0	11.5	4.4	4.2	2.4	1.9	14
	3.0	0	0.0	0.0	0	0	0	0	0	0
225	0.5	25	7.0	17.0	~40.0	~13.2	-	-	-	-
	1.0	20	5.0	13.0	~32.0	~10.4	-	-	-	-
	2.0	1	4.0	8.0	T	T	T	T	T	T
	3.0	0	0.0	0.0	0	0	0	0	0	0
242	0.5	20	3.0	6.0	10.0	5.0	4.9	3.8	1.1	-
	1.0	15	1.5	3.0	7.4	4.1	4.0	3.3	0.7	-
	2.0	1	1.0	3.0	T	T	T	T	T	T
	3.0	0	0.0	0.0	0	0	0	0	0	0
256	0.5	20	2.0	4.0	-		brown holdfasts		-	-
	1.0	15	1.0	2.0	-		brown holdfasts		-	-
	2.0	1	1.0	2.0	T	T	T	T	T	T
	3.0	0	0.0	0.0	0	0	0	0	0	0
271	0.5	20	2.0	4.0	-		brown holdfasts		-	-
	1.0	15	1.0	2.0	-		brown holdfasts		-	-
	2.0	1	1.0	2.0	T	T	T	T	T	T
	3.0	0	0.0	0.0	0	0	0	0	0	0

1979 CLADOPHORA BIOLOGICAL DATA (continued)
CLADOPHORA SITE - 1

DATE	DEPTH (m)	COVERAGE (%)	LENGTH (cm) Mean	LENGTH (cm) Max.	BIOMASS IN GRAMS/m^2 Wet	Dry (64°C)	Dry (104°C)	Ash	Ash-free	BIOVOLUME (ml/m^2)
278	0.5	40	2.0	4.0	-	38.2	37.4	32.0	5.4	-
	1.0	20	1.5	3.0		trace of new growth				-
	2.0	1	1.0	2.0	T	T	T	T	T	T
	3.0	0	0.0	0.0	0	0	0	0	0	0
289	0.5	45	2.0	3.0	-	22.6	22.0	18.1	4.0	-
	1.0	20	<1.0	2.0	-	-	-	-	-	-
	2.0	1	<1.0	1.0	T	T	T	T	T	T
	3.0	0	0.0	0.0	0	0	0	0	0	0
310	0.5	30	2.0	5.0	21.9	11.0	10.8	8.1	2.7	20
	1.0	10	2.0	4.0	19.6	10.4	10.3	8.0	2.3	20
	2.0	1	<1.0	3.0	T	T	T	T	T	T
	3.0	0	0.0	0.0	0	0	0	0	0	0
320	0.5	40	2.5	4.0	53.6	21.3	20.9	14.2	6.7	56
	1.0	10	2.0	3.0	13.6	6.5	6.4	4.7	1.7	12
	2.0	T	<1.0	<1.0	T	T	T	T	T	T
	3.0	0	0.0	0.0	0	0	0	0	0	0

*T stands for "trace."

1979 CLADOPHORA TISSUE NUTRIENT DATA
CLADOPHORA SITE - 1

DATE	Depth (m)	E x P (%)	TTP (%)	TTN (%)
137	0.5	-	0.130	1.72
	1.0	-	0.154	1.44
151	0.2	0.736	0.269	4.89
	0.5	0.314	0.275	2.39
	1.0	0.375	0.266	2.22
164	0.5	0.006	0.249	3.73
	1.0	0.243	0.282	3.59
	2.0	0.230	0.268	2.97
179	0.5	0.240	0.219	4.46
	1.0	0.211	0.235	4.32
	2.0	0.533	0.411	5.14
193	S	-	0.259	4.24
	0.5	0.239	0.247	3.93
	1.0	0.185	0.254	4.01
	2.0	0.310	0.300	3.90
211	S	-	0.195	3.87
	0.5	0.090	0.240	3.09
	1.0	0.134	0.265	3.35
	2.0	0.241	0.372	3.88

DATE	Depth (m)	E x P (%)	TTP (%)	TTN (%)
225	0.5	0.081	0.145	2.92
	1.0	0.099	0.137	-
	2.0	0.196	0.216	3.36
242	0.5	0.062	0.107	2.38
	1.0	0.067	0.103	2.29
256	S	-	0.177	3.85
278	S	-	0.229	4.78
	0.5	0.077	0.189	2.20
289	S	-	0.104	4.08
	0.5	0.115	0.221	2.59
310	0.5	0.149	0.253	2.50
	1.0	0.145	0.259	2.73
320	S	0.317	-	5.23
	0.5	0.269	0.302	3.40
	1.0	0.327	0.340	3.79

1979 CLADOPHORA WATER NUTRIENT DATA
CLADOPHORA SITE - 1

DATE	DEPTH (m)	SRP (ppb)	OP (ppb)	TP (ppb)	NH_3 (ppb)	NO_2-NO_3 (ppm)	TKN (ppb)
117	-2.0	-	5.4	43.3	35.6[a]	0.984[a]	-
137	1.0	5.8	3.5	26.6	22.3	1.011	586.08
	3.0	4.5	2.8	27.2	22.8	0.894	
151	1.0	5.1	4.3	83.1	26.8[a]	0.394[a]	745.60
	2.0	16.9	4.5	75.4	19.8[a]	0.395[a]	
164	1.0	3.0	17.1	48.7	13.3	0.757	638.17
	2.0	2.2	9.0	47.6	23.8	0.741	
	3.0	3.0	10.7	41.6	29.9	0.728	
179	0.5	1.5	5.4	36.0	33.0	0.483	
	1.0	1.1	5.2	23.5	17.0	0.483	507.95
	2.0	1.4	8.7	26.9	15.6	0.485	
	3.0	2.6	8.3	35.1	9.0	0.485	
193	0.5	6.2	11.5	31.7	28.6	0.325	
	1.0	12.1	7.2	27.0	28.8	0.324	501.44
	2.0	6.0	8.0	30.7	67.4	0.327	
	3.0	5.0	4.6	25.5	58.2	0.318	
211	0.5	6.5	-	-	20.9	1.575	
	1.0	5.1	-	105.0	20.5	1.525	1666.89
	2.0	5.7	10.6	136.5	42.5	1.535	
	3.0	3.8	7.9	143.5	46.2	1.435	
225	0.5	4.6	11.0	104.5	8.5	0.199	
	1.0	4.0	9.9	72.5	5.1	0.199	898.60
	2.0	3.3	8.4	108.0	1.5	0.208	
	3.0	3.2	11.2	249.0	6.9	0.268	

1979 CLADOPHORA WATER NUTRIENT DATA (continued)
CLADOPHORA SITE - 1

DATE	DEPTH (m)	SRP (ppb)	OP (ppb)	TP (ppb)	NH_3 (ppb)	NO_2-NO_3 (ppm)	TKN (ppb)
242	0.5	0 > 0.5[c]	7.5	101.0	10.0	0.015	1165.55
	1.0	0 > 0.5[c]	7.8	88.8	3.0	< 0.005[b]	
	2.0	0 > 0.5[c]	7.5	83.4	2.0	0 < 0.005[c]	
	3.0	0 > 0.5[c]	7.0	97.2	4.2	0.012	
256	0.5	0 > 0.5[c]	4.5	178.0	36.5	0.244	1530.16
	1.0	2.1	4.3	200.0	45.0	0.244	
	2.0	2.5	5.8	299.5	51.1	0.249	
	3.0	0 > 0.5[c]	3.6	135.0	62.1	0.245	
271	0.5	0 > 0.5[c]	3.9	53.3	1.8	0.025	735.83
	1.0	0 > 0.5[c]	-	-	11.8	0.012	
	2.0	0 > 0.5[c]	2.7	44.6	5.7	0.010	
	3.0	0 > 0.5[c]	-	-	20.9	0.153	
278	0.5	-	8.8	33.8	-	-	592.59
	1.0	-	6.0	35.1	-	-	
	2.0	-	6.5	35.2	-	-	
	3.0	-	9.4	60.1	-	-	
289	0.5	2.2	4.0	44.5	2.8	0.155	713.04
	1.0	2.5	7.3	47.3	15.3	0.200	
	2.0	2.1	3.1	52.8	12.2	0.180	
	3.0	2.1	3.3	58.1	3.0	0.114	
299	2-S	-	4.7	102.7	-	-	894.78
310	0.5	2.1	5.1	88.0	3.0	0.233	949.66
	1.0	1.2	5.9	104.1	3.6	0.234	
	2.0	1.9	8.6	83.5	8.0	0.237	
	3.0	1.6	6.5	97.0	12.8	0.236	

1979 CLADOPHORA WATER NUTRIENT DATA (continued)
CLADOPHORA SITE - 1

DATE	DEPTH (m)	SRP (ppb)	OP (ppb)	TP (ppb)	NH_3 (ppb)	NO_2-NO_3 (ppm)	TKN (ppb)
320	0.5	3.6	4.0	104.4	19.8	0.145	610.66
	1.0	5.7	5.1	80.2	10.4	0.157	
	2.0	3.8	4.9	61.3	22.3	0.158	
	3.0	5.7	3.5	97.5	9.2	0.161	

[a]Sample preserved with $HgCL_2$.

[b]Levels below detection limit, with no response.

[c]Levels below detection limits, but above baseline. Detection limits for: SRP--0.5 ppb; NH_3--1.0 ppb; NO_2-NO_3--0.005 ppm.

1979 CLADOPHORA PHYSICAL DATA
CLADOPHORA SITE - 1

DATE	DEPTH (m)	TEMPERATURE (°C) surface	TEMPERATURE (°C) bottom	LIGHT (footcandles) surface	LIGHT (footcandles) bottom	LIGHT (footcandles) % available	SECCHI (m)	WEATHER waves (ft.)	WEATHER clouds (%)
107	0.5	5.3	5.3	-	-	-	-	1	15
	1.0	5.3	5.3	-	-	-	-		
	2.4	5.3	5.3	1600	<16	<1.0	0.4		
	3.0	5.3	5.3	1600	<16	<1.0	0.4		
117	0.5	12.5	-12.5	-	-	-	-	<1	10
	1.0	12.5	-12.5	-	-	-	-		
	2.0	12.5	-12.0	4100	<41	<1.0	-		
	3.0	12.5	-12.0	-	-	-	-		
137	0.5	16.4	16.4	-	-	-	-	1+	40
	1.0	16.1	16.2	5300	970	18.3	1.0		
	2.0	16.1	15.9	6300	600	9.5	1.0		
	3.0	16.1	-15.8	5500	150	2.7	-1.0		
151	0.5	-15.0	-15.0	-	-	-	-	2	98
	1.0	-15.0	-15.0	2900	69	2.4	0.4		
	2.0	-15.0	-15.0	3200	25	0.8	0.55		
	3.0	-15.0	14.6	3700	10	0.3	0.55		
164	0.5	20.8	20.8	7500	2000	26.7	-	1	15
	1.0	20.5	20.5	7500	1300	17.3	B.O.		
	2.0	20.4	19.2	7000	650	9.3	1.2		
	3.0	20.0	19.0	7500	200	2.7	1.2		
179	0.5	22.5	22.5	7000	2500	35.7	-	<1	20
	1.0	22.3	22.3	7000	1500	21.4	B.O.		
	2.0	22.1	22.1	7000	750	10.7	1.3		
	3.0	21.6	21.6	7000	200	2.9	1.2		

1979 CLADOPHORA PHYSICAL DATA (continued)
CLADOPHORA SITE - 1

DATE	DEPTH (m)	TEMPERATURE (°C) surface	TEMPERATURE (°C) bottom	LIGHT (footcandles) surface	LIGHT (footcandles) bottom	LIGHT (footcandles) % available	SECCHI (m)	WEATHER waves (ft.)	WEATHER clouds (%)
193	0.5	25.5	25.5	6700	2300	34.3	-	calm	Hazy
	1.0	25.2	24.8	7000	1900	27.1	B.O.		
	2.0	24.9	24.7	6500	800	12.3	1.35		
	3.0	24.6	22.7	6500	310	4.8	1.3		
211	0.5	25.7	25.7	5500	17	0.31	.3	1-2	Hazy
	1.0	25.7	25.7	6700	17	0.25	.25		
	2.0	25.7	-25.0	9500	15	0.16	.45		
	3.0	25.7	-25.0	9500	0.4	0.004	.45		
225	0.5	22.6	22.6	6400	400	6.3	-	1	85
	1.0	-22.6	-22.6	7100	120	1.7	.38		Hazy
	2.0	-22.6	-22.5	3500	2.5	0.07	.38		
	3.0	-22.6	-22.5	4900	0.05	0.001	.4		
242	0.5	24.0	24.0	6800	1500	22.1	-	<1	0
	1.0	23.0	22.5	6800	320	4.7	.5		
	2.0	23.5	22.5	7000	55	0.8	.65		
	3.0	23.0	22.5	7000	42	0.6	.65		
256	0.5	22.0	22.0	-	-	-	.3	2-3	Hazy
	1.0	22.0	22.0	-	-	-	.3		
	2.0	22.0	22.0	-	-	-	-		
	3.0	22.0	22.0	-	-	-	-		
263	2.0	-	-	5600	2	0.036	.30	1	10
	3.0	-	-	5600	0.25	0.005	.35		

1979 CLADOPHORA PHYSICAL DATA (continued)
CLADOPHORA SITE - 1

DATE	DEPTH (m)	TEMPERATURE (^{o}C) surface	TEMPERATURE (^{o}C) bottom	LIGHT (footcandles) surface	LIGHT (footcandles) bottom	LIGHT (footcandles) % available	SECCHI (m)	WEATHER waves (ft.)	WEATHER clouds (%)
271	0.5	19.0	19.0	1600	230	14.4	-	calm	100
	1.0	19.0	19.0	1900	200	10.5	.8		
	2.0	19.0	19.0	2500	85	3.4	.9		
	3.0	19.0	19.0	4500	55	1.2	.95		
278	0.5	18.5	18.5	7000	2000	28.6	-	<1	40
	1.0	18.2	18.2	5000	550	11.0	-		
	2.0	18.2	18.2	6000	200	3.3	-		
	3.0	18.0	18.0	5000	100	2.0	-		
289	0.5	12.0	11.8	2300	370	16.1	-	1	100
	1.0	11.5	11.5	1900	240	12.6	.7		
	2.0	11.5	11.5	2600	110	4.2	.8		
	3.0	11.5	11.5	1900	3.5	0.18	.7		
299	0.5	9.8	-9.8	-	-	-	-	3	80
	1.0	9.8	-9.8	-	-	-	-		
	2.0	9.8	-9.8	3200	1.2	0.0375	0.4		
	3.0	9.8	-9.8	3700	0.12	0.0032	0.4		
310	0.5	9.5	9.5	-	-	-	0.55	2	95
	1.0	9.5	9.5	-	-	-	0.60		
	2.0	9.5	9.5	460	0.15	0.033	0.60		
	3.0	9.5	9.5	1000	0.07	0.007	0.65		
320	0.5	5.3	5.3	2600	350	13.5	0.48	1	60
	1.0	5.3	5.3	3400	150	4.4	0.53		
	2.0	5.4	5.4	3700	35	1.0	0.70		
	3.0	5.4	5.4	3400	7.8	0.2	0.77		

1979 CLADOPHORA BIOLOGICAL DATA
CLADOPHORA SITE - 2

DATE	DEPTH (m)	COVERAGE (%)	LENGTH (cm) Mean	LENGTH (cm) Max.	BIOMASS IN GRAMS/m² Wet	Dry (64°C)	Dry (104°C)	Ash	Ash-free	BIOVOLUME (ml/m²)
138	0.5	10	0.4	0.6	T[1]	T	T	-	T	T
	1.0	60	10.0	17.0	256.2	54.5	52.7	35.9	16.8	240
	2.0	85	14.0	25.0	95.6	16.7	15.9	8.3	7.6	100
	3.0	15	6.0	10.5	7.0	1.7	1.6	1.0	0.6	6
152	0.5	75 P[2]	<0.5	4.0	13.4	3.5	3.4	2.2	1.2	12
	1.0	50 P	-	-	131.3	38.6	37.9	30.0	7.9	120
	2.0	50	10.0	18.0	77.5	13.6	13.0	5.7	7.3	76
	3.0	10	2.5	7.0	1.6	0.4	used for chem. analysis		T	10
165	0.5	25 P	1-12	25.0	48.7	10.0	9.4	4.5	5.0	52
	1.0	50 P	1-15	30.0	251.9	47.2	44.8	19.6	25.2	370
	2.0	100	45.0	90.0	270.9	53.2	50.0	18.7	31.2	326
	3.0	10	< 1.0	2.0	0.5	0.2	used for chem. analysis		T	T
180	0.5	33 P	4.0	7.0	19.2	9.5	9.2	6.6	2.6	22
	1.0	75	30.0	45.0	392.8	74.0	69.1	24.7	44.4	540
	2.0	100	30.0	60.0	494.7	110.2	101.9	43.2	58.7	728
	3.0	1	2.0	4.0	T	T	T	-	T	T
194	0.5	5	1.5	4.0	T	T	T	-	T	T
	1.0	33	20.0	40.0	223.9	74.8	71.5	38.0	33.4	252
	2.0	33	15.0	20.0	222.6	61.5	58.2	25.6	32.6	240
	3.0	1	1.0	2.0	T	T	T	-	T	T
205	0.5	3	1.0	1.5	supplementary sampling period--biomass not sampled					
	1.0	10	2.0	4.0	supplementary sampling period--biomass not sampled					
	2.0	33	4.0	8.0	supplementary sampling period--biomass not sampled					
	3.0	0	0.0	0.0	0.0	0.0	0.0	-	0.0	

1979 CLADOPHORA BIOLOGICAL DATA (continued)
CLADOPHORA SITE - 2

DATE	DEPTH (m)	COVERAGE (%)	LENGTH (cm) Mean	LENGTH (cm) Max.	BIOMASS IN GRAMS/M^2 Wet	Dry (64°C)	Dry (104°C)	Ash	Ash-free	BIOVOLUME (ml/m^2)
212	0.5	1[3]	<0.5	0.5	T	T	T	-	T	T
	1.0	5[3]	0.5	1.0	T	T	T	-	T	T
	2.0	10[3]	1.0	2.0	33.3	17.8	17.3	13.4	3.9	112
	3.0	0	0.0	0.0	0.0	0.0	0.0	-	0.0	0
226	0.5	1[3]	<0.5	0.5	T	T	T	-	T	T
	1.0	1[3]	0.5	1.0	T	T	T	-	T	T
	2.0	1[3]	1.0	2.0	T	T	T	-	T	T
	3.0	0	0.0	0.0	0.0	0.0	0.0	-	0.0	0
243	0.5	1[3]	<0.5	0.5	T	less than 226		-	T	T
	1.0	1[3]	0.5	1.0	T	less than 226		-	T	T
	2.0	1[3]	1.0	2.0	T	less than 226		-	T	T
	3.0	0	0.0	0.0	0.0	0.0	0.0	-	0.0	0
258	0.5	2	1.0	3.0	T	trace of new growth		-	T	T
	1.0	2	1.0	3.0	T	trace of new growth		-	T	T
	2.0	1	1.0	2.0	T	less than 243		-	T	T
	3.0	0	0.0	0.0	0.0	0.0	0.0	-	0.0	0
271	0.5	60	2.5	5.0	supplementary sampling period--biomass not sampled					
	1.0	60	1.5	3.0	supplementary sampling period--biomass not sampled					
	2.0	1	1.0	2.0	T	same as 258		-	T	-
	3.0	0	0.0	0.0	0.0	0.0	0.0	-	0.0	0
277	0.5	60	1.5	3.0	-	10.5	9.8	7.8	2.0	20
	1.0	50	1.5	3.0	-	8.7	8.4	6.7	1.7	18
	2.0	1	1.0	2.0	T	same as 258		-	T	T
	3.0	0	0.0	0.0	0.0	0.0	0.0	-	0.0	0

1979 CLADOPHORA BIOLOGICAL DATA (continued)
CLADOPHORA SITE - 2

DATE	DEPTH (m)	COVERAGE (%)	LENGTH (cm) Mean	LENGTH (cm) Max.	BIOMASS IN GRAMS/m^2 Wet	Dry (64°C)	Dry (104°C)	Ash	Ash-free	BIOVOLUME (ml/m^2)
288	0.5	50	1.5	2.0	-	7.8	7.6	5.4	2.2	14
	1.0	30	1.5	3.0	-	4.5	4.3	3.3	1.0	8
	2.0	1	1.0	2.0	T	same as 258		-	T	T
	3.0	-	0.0	0.0	0.0	0.0	0.0	-	0.0	0
309	0.5	50	1.0	2.5	14.1	7.4	7.3	5.6	1.7	-
	1.0	30	1.5	2.5	7.0	3.7	3.6	2.8	0.8	-
	2.0	1	1.5	2.5	T	T	T	-	T	T
	3.0	T	< 1.0	2.0	T	T	T	-	T	T
321	0.5	50	2.0	4.0	slight increase from 309--too cold for collection					
	1.0	30	1.5	3.0	slight increase from 309--too cold for collection					
	2.0	5	1.5	3.0	slight increase from 309--too cold for collection					
	3.0	T	1.0	2.0	T	T	T	-	T	T

[1]T stands for "trace."

[2]P stands for "patchy distribution."

[3]Holdfasts covered with mud and epiphytes.

1979 CLADOPHORA TISSUE NUTRIENT DATA
CLADOPHORA SITE - 2

DATE	DEPTH (m)	E x P (%)	TTP (%)	TTN (%)
117	0.5	-	0.372	2.82
	1.0	-	0.361	2.72
138	1.0	0.002	0.081	0.90
	2.0	0.027	0.086	1.64
	3.0	0.004	0.142	1.59
152	0.5	0.201	0.433	1.75
	1.0	1.000	0.715	2.96
	2.0	0.559	0.571	2.28
	3.0	0.391	0.420	2.34
165	0.5	0.156	0.214	3.36
	1.0	0.252	0.268	3.81
	2.0	0.240	0.285	3.31
	3.0	-	0.374	3.22
180	S	-	0.125	3.87
	0.5	0.041	0.106	1.92
	1.0	0.107	0.153	3.38
	2.0	0.231	0.296	3.96
	3.0	-	0.228	3.46
194	S	-	0.232	3.59
	1.0	0.099	0.166	2.74
	2.0	0.112	0.212	3.04
212	S	-	0.093	2.45
	2.0	-	0.145	1.22
226	S	-	0.126	3.00
243	S	-	0.099	3.17
258	S	-	0.117	3.63
277	S	-	0.102	2.63
	0.5	0.042	0.158	1.86
	1.0	0.190	0.216	2.52
288	S	-	0.232	3.47
	0.5	0.430	0.266	3.07
	1.0	0.110	0.262	2.67
309	S	-	0.094	3.79
	1.0	0.095	-	-
321	S	-	-	5.10
	0.5	0.346	0.220	3.64
	1.0	0.200	-	-

1979 CLADOPHORA WATER NUTRIENT DATA
CLADOPHORA SITE - 2

DATE	DEPTH (m)	SRP (ppb)	OP (ppb)	TP (ppb)	NH_3 (ppb)	NO_2-NO_3 (ppm)	TKN (ppb)
138	1.0	3.3	2.8	15.0	9.0	1.112	378.20
	3.0	2.4	1.3	11.8	10.4	1.128	
152	1.0	11.5	8.4	34.2	-	1.169[a]	552.54
	3.0	12.4	9.9	42.5	26.6[a]	0.915[a]	
156	1.0	15.2	12.0	23.3	-	-	617.11
	3.0	15.0	16.1	31.6	-	-	
165	1.0	6.5	6.5	30.5	6.0	0.716	533.17
	2.0	7.6	8.7	38.0	1.0	0.750	
	3.0	9.5	10.7	32.3	11.2	0.771	
180	1.0	3.0	5.7	19.0	11.2	0.475	552.54
	2.0	4.8	9.1	19.0	23.6	0.527	
	3.0	6.9	6.2	27.2	25.3	0.550	
194	0.5	8.1	17.0	26.6	72.0	0.310	539.63
	1.0	7.2	8.4	25.4	70.7	0.311	
	2.0	9.9	8.3	39.0	71.2	0.303	
	3.0	13.0	10.6	16.5	65.6	0.294	
212	0.5	2.8	-	-	11.0	0.238	523.48
	1.0	3.0	3.8	27.6	11.0	0.252	
	2.0	2.3	4.5	26.5	12.8	0.267	
	3.0	6.8	17.0[b]	40.8	24.2	0.297	
226	1.0	2.7	6.8	27.7	4.5	0.212	1101.41
	2.0	3.7	4.8	27.4	4.0	0.213	
	3.0	2.3	5.2	29.6	3.0	0.213	

1979 CLADOPHORA WATER NUTRIENT DATA (continued)
CLADOPHORA SITE - 2

DATE	DEPTH (m)	SRP (ppb)	OP (ppb)	TP (ppb)	NH_3 (ppb)	NO_2-NO_3 (ppm)	TKN (ppb)
243	1.0	0 > 0.5[c]	3.5	52.8	3.5	0.148	620.34
	2.0	3.0	10.1	49.8	12.0	0.156	
	3.0	0 > 0.5[c]	6.6	35.6	3.1	0.152	
258	1.0	2.8	8.2	38.7	23.0	0.037	646.17
	2.0	3.3	10.8	43.5	17.7	0.036	
	3.0	2.5	7.2	37.0	16.2	0.038	
271	1.0	0 > 0.5[c]	5.1	26.4	20.0	0 > 0.005[c]	
	2.0	0 > 0.5[c]	4.3	29.8	2.5	0 > 0.005[c]	465.37
	3.0	8.1	-	-	1.7	0 > 0.005[c]	
277	1.0	-	10.6	27.5	-	-	504.11
	2.0	-	17.0	29.2	-	-	
	3.0	-	13.6	25.2	-	-	
288	1.0	15.0	16.0	36.1	67.5	0.097	636.49
	2.0	13.7	16.9	40.4	63.2	0.100	
	3.0	13.9	14.9	38.9	64.0	0.100	
309	1.0	2.0	2.5	25.4	9.6	0.110	491.16
	2.0	3.9	3.0	30.5	4.0	0.123	
	3.0	3.2	5.1	39.6	5.0	0.126	
321	0.5	3.6	1.2	26.9	0 > 1.0[c]	0.133	
	1.0	3.3	1.3	26.1	0 > 1.0[c]	0.135	312.25
	2.0	2.8	1.6	27.4	0 > 1.0[c]	0.144	
	3.0	3.4	2.2	26.5	2.0	0.147	

1979 CLADOPHORA PHYSICAL DATA
CLADOPHORA SITE - 2

DATE	DEPTH (m)	TEMPERATURE (°C) surface	TEMPERATURE (°C) bottom	LIGHT (footcandles) surface	LIGHT (footcandles) bottom	LIGHT % available	SECCHI (m)	WEATHER waves (ft.)	WEATHER clouds (%)
108	2.1	4.6	4.6	1700	15	0.9	0.5	1	-
119	2.0	8.6	8.5	2900	<29	<1.0	1.0	2	40
138	0.5	16.0	16.6	-	-	-	-	<1	Hazy
	1.0	15.7	16.4	6000	700	11.7	B.O.[1]		
	2.0	15.7	16.2	-	-	-	1.5		
	3.0	15.7	15.2	6000	400	6.7	1.5		
152	0.5	15.0	14.8	-	-	-	-	0	Hazy
	1.0	15.0	14.6	2700	170	6.3	0.55		
	2.0	15.2	14.5	3600	22	0.6	0.7		
	3.0	14.8	14.3	4200	5.1	0.1	0.7		
156	1.0	15.7	15.4	-	-	-	0.9	<1	75
	3.0	15.2	14.8	-	-	-	0.9		
165	0.5	19.3	19.1	-	-	-	-	1-2	50
	1.0	19.3	19.1	7000	960	13.7	1.0		
	2.0	19.0	18.7	7200	380	5.3	1.0		
	3.0	19.0	18.7	7500	100	1.3	1.0		
180	0.5	22.3	22.3	-	-	-	-	1-2	90
	1.0	22.1	22.0	5200	970	18.7	B.O.		
	2.0	21.7	21.7	4400	320	7.3	1.5		
	3.0	21.6	21.3	4200	25	0.6	1.5		
194	0.5	23.5	23.5	450	140	31.1	-	1	100
	1.0	23.5	23.5	500	100	18.2	B.O.		
	2.0	23.6	23.6	700	68	9.7	1.45		
	3.0	23.6	23.4	770	41	5.3	1.2		

1979 CLADOPHORA PHYSICAL DATA (continued)
CLADOPHORA SITE - 2

DATE	DEPTH (m)	TEMPERATURE (°C) surface	TEMPERATURE (°C) bottom	LIGHT (footcandles) surface	LIGHT (footcandles) bottom	LIGHT (footcandles) % available	SECCHI (m)	WEATHER waves (ft.)	WEATHER clouds (%)
212	0.5	24.0	24.0	-	-	-	-	<1	Hazy
	1.0	23.7	23.7	5000	950	19.0	B.O.		
	2.0	23.7	23.4	5000	500	10.0	1.6		
	3.0	23.7	23.0	5000	42	0.8	1.7		
226	0.5	22.5	22.5					calm	75
	1.0	22.5	22.5	6500	650	10.0	B.O.		
	2.0	22.5	22.5	6000	510	8.5	1.25		
	3.0	22.5	22.5	6500	140	2.2	1.3		
243	0.5	23.0	23.0	6500	1400	21.5	-	1-2	0
	1.0	22.5	22.5	6500	600	9.2	.75		
	2.0	22.5	22.5	6500	350	5.4	1.25		
	3.0	22.5	22.0	6500	300	4.6	~1.3		
258	0.5	21.5	21.5	6200	1400	22.6		<1	10
	1.0	21.7	21.2	6000	870	14.5	1.0		
	2.0	21.5	21.2	6000	250	4.2	1.2		
	3.0	21.5	21.2	6600	75	1.1	1.25		
271	0.5	20.0	20.0	1200	370	30.8	-	calm	99
	1.0	20.0	19.5	1200	290	24.2	B.O.		
	2.0	20.0	19.5	1600	140	8.8	1.35		
	3.0	20.0	19.5	920	19	2.1	1.25		
277	0.5	~18.7	~18.7	1250	350	28.0	-	calm	100 rain
	1.0	18.7	18.5	1350	325	24.1	-		
	2.0	18.5	18.5	1000	60	6.0	-		
	3.0	18.5	18.5	1000	40	4.0	-		

1979 CLADOPHORA PHYSICAL DATA (continued)
CLADOPHORA SITE - 2

DATE	DEPTH (m)	TEMPERATURE (°C) surface	TEMPERATURE (°C) bottom	LIGHT (footcandles) surface	LIGHT (footcandles) bottom	LIGHT (footcandles) % available	SECCHI (m)	WEATHER waves (ft.)	WEATHER clouds (%)
288	0.5	13.0	13.0	6800	2000	29.4	-	1	10
	1.0	12.5	12.0	7400	1200	16.2	B.O.		
	2.0	12.0	11.5	6200	250	4.0	1.1		
	3.0	11.5	12.0	6200	130	2.1	1.0		
309	0.5	9.5	9.5	7700	970	12.6	-	<1	75
	1.0	9.0	9.0	7500	650	8.7	B.O.		
	2.0	9.0	9.0	5600	350	6.3	1.05		
	3.0	9.0	9.0	5200	120	2.3	1.10		
321	0.5	7.3	7.3	4900	1500	30.6	-	1	10
	1.0	7.3	7.3	4900	760	15.5	-		
	2.0	6.8	6.8	4900	360	7.5	1.15		
	3.0	6.8	6.8	-	-		1.15		

[1] B.O. stands for "bottom out."

1980 CLADOPHORA BIOMASS DATA
CLADOPHORA SITE 1

DATE	DEPTH (METERS)	COVERAGE %	LENGTH (cm) mean	LENGTH (cm) max	WET g/m²	DRY (64°C) g/m²	DRY (104°C) g/m²	ASH g/m²	ASH-FREE g/m²	ASH-FREE %	BIO-VOLUME ml
108	0.5	T	1	1	---	T	T	---	T	--	T
	1.0	T	1	2	---	T	T	---	T	--	T
	2.0	0	0	0	0	0	0	0	0	--	0
	3.0	0	0	0	0	0	0	0	0	--	0
120	0.5	T	1	1	---	T	T	---	T	--	T
	1.0	5 P	2	5	---	< 4	< 4	---	< 4	--	< 8
	2.0	0	0	0	0	0	0	0	0	--	0
	3.0	0	0	0	0	0	0	0	0	--	0
138	0.5	too turbid	7	10	---	~ 20	~ 20	~ 11	~ 9	44	~ 120
	1.0	too turbid	5	7	---	~ 16	~ 16	~ 8	~ 8	--	~ 100
	2.0	0	0	0	0	0	0	0	0	--	0
	3.0	0	0	0	0	0	0	0	0	--	0
156	0.5	50 P	16	23	211.8	49.9	49.2	20.8	28.4	58	320
	1.0	70 P	9	16	158.8	39.8	39.0	19.2	19.8	51	220
	2.0	1	1	3	---	T	T	---	T	--	T
	3.0	0	0	0	0	0	0	0	0	--	0
170	0.5	80	8	12	224.9	57.8	57.1	28.7	28.4	50	320
	1.0	60	6	12	133.0	44.8	44.2	28.1	16.2	37	200
	2.0	0	0	0	0	0	0	0	0	--	0
	3.0	0	0	0	0	0	0	0	0	--	0
183	0.5	too turbid	20	40	137.4	43.3	42.6	24.3	18.3	43	188
	1.0	too turbid	12	20	223.0	69.8	68.8	38.7	30.1	44	312
	2.0	0	0	0	0	0	0	0	0	--	0
	3.0	0	0	0	0	0	0	0	0	--	0
197	0.5	60	2	4	73.0	38.7	38.1	31.5	6.6	17	88
	1.0	40	2	4	36.4	19.0	18.8	15.5	3.3	18	52
	2.0	0	0	0	0	0	0	0	0	--	0
	3.0	0	0	0	0	0	0	0	0	--	0

1980 CLADOPHORA BIOMASS DATA (CONT.)
CLADOPHORA SITE 1

DATE	DEPTH (METERS)	COVERAGE %	LENGTH (cm) mean	max	WET g/m^2	DRY (64^oC) g/m^2	DRY (104^oC) g/m^2	ASH g/m^2	ASH-FREE g/m^2	ASH-FREE %	BIOVOLUME ml
212	0.5	60	2	3.5	43.0	24.4	24.1	20.6	3.6	15	52
	1.0	50	1.5	3	--		brown	holdfasts		--	--
	2.0	0	0	0	0	0	0	0	0	--	0
	3.0	0	0	0	0	0	0	0	0	--	0
228	0.5	40	<1	2	--		brown	holdfasts		--	--
	1.0	40	<1	<1	--		brown	holdfasts		--	--
	2.0	0	0	0	0	0	0	0	0	--	0
	3.0	0	0	0	0	0	0	0	0	--	0
248	0.5	40	<1	<1	--		brown	holdfasts		--	--
	1.0	30	<1	<1	--		brown	holdfasts	--	--	
	2.0	0	0	0	0	0	0	0	0	--	0
	3.0	0	0	0	0	0	0	0	0	--	0
259	0.5	50	0.5	1	--		brown	holdfasts		--	--
	1.0	20	0.2	0.5	--		brown	holdfasts		--	--
	2.0	0	0	0	0	0	0	0	0	--	0
	3.0	0	0	0	0	0	0	0	0	--	0
275	0.5	60	3	7	79.9	24.7	24.5	16.1	8.4	34	96
	1.0	10	0.5	3	--	T	T	--	T	--	T
	2.0	0	0	0	0	0	0	0	0	--	0
	3.0	0	0	0	0	0	0	0	0	--	0

1980 CLADOPHORA BIOMASS DATA (CONT.)
CLADOPHORA SITE 1

DATE	DEPTH (METERS)	COVERAGE %	LENGTH (cm) mean	LENGTH (cm) max	WET g/m^2	DRY (64^oC) g/m^2	DRY (104^oC) g/m^2	ASH g/m^2	ASH-FREE g/m^2	ASH-FREE %	BIOVOLUME ml
296	0.5	70 P	7	10	451.3	147.8	145.4	93.5	51.9	36	508
	1.0	40	2	3	13.8	6.9	6.8	5.2	1.7	25	
	2.0	0	0	0	0	0	0	0	0	--	
	3.0	0	0	0	0	0	0	0	0	--	
314	0.5	75 P	6	9	349.0	103.8	102.2	55.9	46.3	45	416
	1.0	40	2	3	--	<8	<8	--	<4	--	<16
	2.0	0	0	0	0	0	0	0	0	--	0
	3.0	0	0	0	0	0	0	0	0	--	0
327	0.5	75 P	8	13	705.3	185.6	183.5	73.7	109.8	60	1020
	1.0	50 P	5	8	27.0	10.8	10.7	7.1	3.6	34	68
	2.0	0	0	0	0	0	0	0	0	--	0
	3.0	0	0	0	0	0	0	0	0	--	0

T - Trace amounts
P - Patchy distribution

1980 CLADOPHORA TISSUE NUTRIENT DATA
CLADOPHORA SITE 1

DATE	DEPTH (M)	ExP %	TTP %	TTN %	TTC %	C/N
120	1.0	0.449	0.370	3.24	24.88	7.7
138	0.5	0.295	0.229	3.22	32.90	10.2
	1.5	0.234	0.235	2.63	28.86	10.0
156	0.5	0.551	0.810	4.56	37.10	8.1
	1.0	0.732	0.780	4.35	34.61	8.0
	1.75	0.748	0.964	4.66	34.06	7.3
170	S	-----	0.370	4.99	40.96	8.2
	0.5	0.291	0.377	----	-----	----
	1.0	0.239	0.324	4.31	36.33	8.4
	1.5	-----	0.533	4.40	32.24	7.3
183	S	-----	0.351	4.16	39.90	9.6
	0.5	0.489	0.421	4.30	37.02	8.6
	1.0	0.497	0.548	4.85	35.70	7.4
	1.2	-----	0.412	3.66	29.50	8.1
197	S	-----	0.258	3.91	41.19	10.5
	0.5	0.100	0.207	2.19	20.90	9.5
	1.0	0.090	0.225	2.04	17.95	8.8
212	S	-----	0.318	4.24	39.30	9.3
	0.5	0.063	0.151	2.43	32.48	13.4
	1.0	0.022	0.141	1.31	13.67	10.4
228	S	-----	0.169	3.69	38.56	10.5
248	S	-----	0.221	4.19	38.96	9.3
259	S	-----	0.372	4.22	39.11	9.3

1980 CLADOPHORA TISSUE NUTRIENT DATA (CONT.)
CLADOPHORA SITE 1

DATE	DEPTH (M)	ExP %	TTP %	TTN %	TTC %	C/N
275	0.25	0.278	0.284	4.60	40.12	8.7
	0.5	0.129	0.169	2.79	29.03	10.4
296	S	-----	0.547	5.22	42.15	8.1
	0.5	0.403	0.440	4.58	34.61	7.6
	1.0	0.222	0.262	2.96	24.73	8.4
314	S	-----	0.424	4.71	38.50	8.2
	0.5	0.198	0.219	3.59	30.07	8.4
	0.75	0.162	0.171	2.86	26.18	9.2
327	S	-----	0.229	4.61	41.07	8.9
	0.5	0.203	0.205	3.91	35.34	9.0
	1.0	0.160	0.188	2.97	27.23	9.2

S - Splash Zone
ExP - Boiling Water Extractable Phosphorus
TTP - Total Tissue Phosphorus
TTN - Total Tissue Nitrogen
TTC - Total Tissue Carbon
C / N - Carbon to Nitrogen Ratio
% based on 64°C Dry Weight

1980 CLADOPHORA WATER NUTRIENT DATA
CLADOPHORA SITE - 1

DATE	DEPTH (METERS)	SRP (ppb)	TFP (ppb)	TP (ppb)	NH_4 (ppb)	NO_2-NO_3 (ppm)	TFKN (ppb)	TKN (ppb)
092	2	8.9	----	42.1	125.6	0.495	---	590
108	1	17.2	19.7	141.0	111.7	2.480	767	1073
	2	17.5	20.0	153.0	105.0	2.440		
	3	15.9	18.2	166.0	114.1	2.385		
120	0.5	1.0	7.0	65.8	87.0	0.605		
	1	1.1	6.1	79.1	110.8	0.598	730	947
	2	2.3	----	88.1	146.2	0.571		
	3	3.2	11.1	81.0	170.0	0.569		
138	1	3.8	7.2	103.8	39.0	0.410	---	1376
	2	4.3	23.0	100.1	25.0	0.412		
	3	5.2	8.0	100.4	24.0	0.467		
156	0.5	26.8	36.5	87.9	159.0	1.370		
	1	13.4	29.5	78.8	101.5	1.360	917	1146
	2	13.4	21.6	82.0	120.0	1.390		
	3	14.3	20.4	191.5	154.0	1.360		
170	0.5	1.7	8.1	90.9	96.9	0.700		
	1	2.7	6.0	90.2	192.5	0.615	554	1216
	2	2.5	10.9	106.2	249.5	0.501		
	3	1.2	7.1	82.1	246.0	0.511		
183	0.5	11.7	30.6	214.6	119.0	0.584		
	1	14.6	26.1	191.2	220.0	0.530	647	1482
	2	11.9	16.8	84.0	112.5	0.345		
	3	12.4	16.2	100.0	142.0	0.301		

DATE	DEPTH (METERS)	SRP (ppb)	TFP (ppb)	TP (ppb)	NH_4 (ppb)	NO_2-NO_3 (ppm)	TFKN (ppb)	TKN (ppb)
197	0.5	3.0	8.1	97.0	57.0	0.707	647	1056
	1	2.5	24.0	97.0	49.0	0.683		
	2	2.5	9.1	100.0	71.9	0.673		
	3	2.4	8.1	81.0	49.0	0.693		
212	0.5	3.1	4.1	59.0	16.2	0.375	338	690
	1	2.4	4.8	53.5	25.7	0.371		
	2	2.4	5.4	152.6	14.1	0.444		
	3	2.5	6.9	50.3	17.3	0.477		
228	0.5	1.7	11.5	96.0	20.5	0.230	501	1143
	1	1.1	8.1	90.0	6.2	0.219		
	2	0.7	14.8	77.0	1.5	0.272		
	3	1.3	5.3	62.2	6.5	0.292		
248	0.5	---	8.1	90.2	29.3	0.250	570	1622
	1	2.4	7.4	102.0	10.2	0.252		
	2	2.4	10.5	177.8	9.8	0.256		
	3	3.0	8.2	82.1	13.3			
259	0.5	7.2	13.3	70.0	158.0	0.340	660	780
	1	6.6	12.0	66.9	188.0	0.335		
	2	5.4	13.2	67.8	175.5	0.302		
	3	5.7	21.4	79.0	162.0	0.306		
275	0.5	0.8	9.4	126.0	3.6	0.019	461	1283
	1	1.1	10.2	134.4	6.8	0.049		
	2	1.0	10.8	132.2	5.7	0.049		
	3	0.8	13.5	142.6	7.6	0.015		
296	0.5	3.3	6.9	34.5	12.3	0.280	404	680
	1	1.6	4.9	54.1	73.2	0.284		
	2	2.9	6.1	40.6	61.9	0.280		
	3	2.5	7.9	40.3	55.2	0.274		

DATE	DEPTH (METERS)	SRP (ppb)	TFP (ppb)	TP (ppb)	NH_4 (ppb)	NO_2-NO_3 (ppm)	TFKN (ppb)	TKN (ppb)
314	0.5	---	----	-----	----	-----	364	1113
	1	0.9	6.4	111.0	2.8	0.230		
	2	0.5	12.9	118.0	2.0	0.235		
	3	1.0	9.1	100.0	6.8	0.245		
327	0.5	1.4	16.0	91.8	89.1	0.261	650	833
	1	2.3	12.0	84.6	95.1	0.255		
	2	2.7	12.3	99.7	127.0	0.257		
	3	3.4	14.2	99.9	134.0	0.266		

1980 CLADOPHORA LAKE WATER DATA
CLADOPHORA SITE 1

DATE	DEPTH (METERS)	TEMPERATURE SURFACE	TEMPERATURE BOTTOM	SECCHI (METERS)	SUSPENDED SOLIDS (mg/1) TOTAL	SUSPENDED SOLIDS (mg/1) VOLATILE	CORRECTED CHLOROPHYLL a (mg/1)	WEATHER WAVES (ft.)	WEATHER CLOUDS/ AIR TEMP. (%)
092	2.4	----	4.5	----	-----	-----	-----		
108	0.5	8.0	8.0	----	-----	-----	-----	1	-----
	1.0	7.8	8.0	0.22	69.80	8.68	7.38		
	2.0	7.2	7.8	0.25	-----	-----	-----		6.8
	3.0	6.8	7.8	0.25	-----	-----	-----		
120	0.5	12.5	13.0	----	-----	-----	-----	0	100.0
	1.0	12.5	12.1	0.4	27.30	5.85	14.57		
	2.0	12.1	11.9	0.4	-----	-----	-----		12.5
	3.0	12.5	11.9	0.4	-----	-----	-----		
138	0.5	15.0	----	----	-----	-----	-----	2-3	100.0
	1.0	15.0	----	----	35.60	7.60	39.28		
	2.0	15.0	----	0.35	-----	-----	-----		14.5
	3.0	15.0	----	0.35	-----	-----	-----		
156	0.5	23.0	22.8	----	-----	-----	-----	0	40.0
	1.0	22.5	22.5	0.87	19.82	5.26	13.87		
	2.0	21.7	22.0	0.95	-----	-----	-----		21.2
	3.0	21.5	21.5	1.0	-----	-----	-----		
170	0.5	19.5	19.0	----	-----	-----	-----	0	10.0
	1.0	19.0	19.0	0.65	-----	-----	-----		
	2.0	19.0	18.0	0.7	25.58	7.44	18.66		20.5
	3.0	19.0	18.0	0.93	-----	-----	-----		

1980 CLADOPHORA LAKE WATER DATA (CONT.)
CLADOPHORA SITE 1

DATE	DEPTH (METERS)	TEMPERATURE SURFACE	TEMPERATURE BOTTOM	SECCHI (METERS)	SUSPENDED SOLIDS (mg/1) TOTAL	SUSPENDED SOLIDS (mg/1) VOLATILE	CORRECTED CHLOROPHYLL a (mg/1)	WEATHER WAVES (ft.)	WEATHER CLOUDS/ AIR TEMP. (%)
183	0.5	22.5	22.0	----	-----	-----	-----	1	50.0
	1.0	22.0	22.0	0.5	-----	-----	-----		
	2.0	21.0	20.5	0.7	24.76	5.56	7.25		24.0
	3.0	21.0	20.5	0.77	-----	-----	-----		
197	0.5	25.8	25.0	----	-----	-----	-----	0	40.0
	1.0	26.2	25.0	0.45	-----	-----	-----		
	2.0	25.2	25.0	0.50	26.84	6.74	29.09		33.0
	3.0	26.2	25.0	0.68	-----	-----	-----		
212	0.5	26.0	26.0	----	-----	-----	-----	0	20.0
	1.0	25.0	25.0	8.0.	-----	-----	-----		
	2.0	25.0	25.0	1.3	9.90	4.50	32.98		26.0
	3.0	25.0	25.0	1.4	-----	-----	-----		
228	0.5	24.3	24.3	----	-----	-----	-----	1	25.0
	1.0	24.1	24.3	0.6	-----	-----	-----		
	2.0	24.1	24.0	0.7	22.98	8.50	47.64		22.0
	3.0	24.1	24.0	0.8	-----	-----	-----		
248	0.5	25.5	25.5	----	-----	-----	-----	2	75.0
	1.0	25.5	25.5	----	-----	-----	-----		
	2.0	25.5	25.5	0.7	39.35	10.02	93.27		25.0
	3.0	25.5	25.5	0.7	-----	-----	-----		

1980 CLADOPHORA LAKE WATER DATA (CONT.)
CLADOPHORA SITE 1

DATE	DEPTH (METERS)	TEMPERATURE SURFACE	TEMPERATURE BOTTOM	SECCHI (METERS)	SUSPENDED SOLIDS (mg/1) TOTAL	SUSPENDED SOLIDS (mg/1) VOLATILE	CORRECTED CHLOROPHYLL a (mg/1)	WEATHER WAVES (ft.)	WEATHER CLOUDS/ AIR TEMP. (%)
259	0.5	19.7	19.7	----	-----	-----	-----	2	100.0
	1.0	20.2	19.7	0.5	-----	-----	-----		
	2.0	21.0	20.0	0.55	22.84	4.96	20.17		17.0
	3.0	21.0	20.5	0.65	-----	-----	-----		
275	0.5	19.5	19.5	----	-----	-----	-----	1	15.0
	1.0	19.0	19.5	0.4	-----	-----	-----		
	2.0	19.0	19.0	0.4	21.43	10.74	43.51		20.5
	3.0	18.75	19.0	0.45	-----	-----	-----		
296	0.5	11.9	11.9	----	-----	-----	-----	0	15.0
	1.0	11.1	11.1	1.0	-----	-----	-----		
	2.0	11.0	11.0	0.9	11.26	3.65	19.20		9.5
	3.0	11.0	11.0	0.8	-----	-----	-----		
314	0.5	10.5	10.5	----	-----	-----	-----	1	0
	1.0	10.0	10.5	0.3	-----	-----	-----		
	2.0	9.5	10.0	0.3	38.50	11.46	39.35		15.0
	3.0	8.0	8.5	0.4	-----	-----	-----		
327	0.5	4.7	4.7	----	-----	-----	-----	1	0
	1.0	4.0	4.5	0.5	-----	-----	-----		
	2.0	4.0	4.0	0.5	9.80	6.86	17.23		6.0
	3.0	3.8	4.0	0.5	-----	-----	-----		

B. O. - Bottom Out

1980 CLADOPHORA BIOMASS DATA
CLADOPHORA SITE 2

DATE	DEPTH (METERS)	COVERAGE %	LENGTH (cm) mean	max	WET g/m^2	DRY (64^oC) g/m^2	DRY (104^oC) g/m^2	ASH g/m^2	ASH-FREE g/m^2	ASH-FREE %	BIOVOLUME ml
026	0.25 under the ice	10 P	~1	---	T	T	T	---	T	--	T
109	0.5	-- P	2.5	6	---	<4	<4	---	<4	--	<8
	1.0	-- P	<1	1	---	T	T	---	T	--	T
	2.0	0	0	0	0	0	0	0	0	--	0
	3.0	0	0	0	0	0	0	0	0	--	0
121	0.5	20 P	6	12	---	~16	~16	---	~8	--	~80
	1.0	5	1	4	---	<4	<4	---	<4	--	<8
	2.0	1	1	3	---	<4	<4	---	<4	--	<4
	3.0		<1	2	---	T	T	---	T	--	T
149	0.5	100	20	25	557.7	102.8	100.8	51.0	49.8	49	680
	1.0	90	10	15	373.8	79.7	78.1	43.6	34.5	44	500
	2.0	65	6	10	76.4	16.6	16.3	8.9	7.5	46	100
	3.0	25	2.5	4.5	---	<4	<4	---	<1	--	<8
171	0.5	90	30	40	801.5	217.5	213.9	97.6	116.3	54	988
	1.0	90	35	45	386.2	106.4	104.5	47.5	57.0	55	520
	2.0	50	4	10	115.6	37.4	36.9	21.2	15.7	43	156
	3.0	1	1	3	---	T	T	---	T	--	T
184	0.5	95	30	45	423.7	167.5	165.6	67.5	98.0	59	1052
	1.0	80	20	30	670.2	174.1	172.5	87.3	85.2	49	920
	2.0	50	4	7	110.0	48.9	48.7	38.6	10.1	21	160
	3.0	0	0	0	0	0	0	0	0	--	0

1980 CLADOPHORA BIOMASS DATA (CONT.)
CLADOPHORA SITE 2

DATE	DEPTH (METERS)	COVERAGE %	LENGTH (cm) mean	LENGTH (cm) max	WET g/m^2	DRY (64^oC) g/m^2	DRY (104^oC) g/m^2	ASH g/m^2	ASH-FREE g/m^2	ASH-FREE %	BIOVOLUME ml
199	0.5	70	3	6	24.9	7.4	7.1	3.0	4.1	58	34
	1.0	50	2	4	15.4	6.5	6.4	4.4	2.0	31	20
	2.0	1	1	1	---	T	T	---	T	--	T
	3.0	0	0	0	0	0	0	0	0	--	0
213	0.5	75	2	6	---	< 7	< 7	---	< 4	--	< 30
	1.0	50	1	2	---	< 4	< 4	---	< 2	--	< 16
	2.0	1	0.5	1	---	T	T	---	T	--	T
	3.0	0	0	0	0	0	0	0	0	--	0
229	0.5	50	1	2	--	< 4		brown	holdfasts	--	
	1.0	40	< 1	1	--	T		brown	holdfasts	--	--
	2.0	0	0	0	0	0	0	0	0	--	0
	3.0	0	0	0	0	0	0	0	0	--	0
249	0.5	0	0	0	0			brown	holdfasts	--	0
	1.0	0	0	0	0			brown	holdfasts	--	0
	2.0	0	0	0	0	0	0	0	0	--	0
	3.0	0	0	0	0	0	0	0	0	--	0
260	0.5	0	0	0	0			brown	holdfasts	--	0
	1.0	0	0	0	0			brown	holdfasts	--	0
	2.0	0	0	0	0	0	0	0	0	--	0
	3.0	0	0	0	0	0	0	0	0	--	0

1980 CLADOPHORA BIOMASS DATA (CONT.)
CLADOPHORA SITE 2

DATE	DEPTH (METERS)	COVERAGE %	LENGTH (cm) mean	LENGTH (cm) max	WET g/m^2	DRY (54°C) g/m^2	DRY (104°C) g/m^2	ASH g/m^2	ASH-FREE g/m^2	ASH-FREE %	BIOVOLUME ml
276	0.5	90	2	3	26.3	10.1	10.0	6.8	3.2	32	28
	1.0	75	1.5	2.5	--	<8	<8	--	4	--	<16
	2.0	0	0	0	0	0	0	0	0	--	0
	3.0	0	0	0	0	0	0	0	0	--	0
301	0.5	75	7	--	104.0	19.7	19.4	4.5	14.9	77	108
	1.0	50	1.5	3	25.1	9.5	9.4	6.2	3.2	34	24
	2.0	0	0	0	0	0	0	0	0	--	0
	3.0	0	0	0	0	0	0	0	0	--	0
315	0.5	100	15	18	390.6	59.5	58.6	9.9	48.7	83	532
	1.0	50	3	5	Too cold for collection			~Twice 301 values		--	--
	2.0	0	0	0	0	0	0	0	0	--	0
	3.0	0	0	0	0	0	0	0	0	--	0
328	0.5	80	5	8	Too cold for collection			less than 315		--	--
	1.0	--	3	5	Too cold for collection			same as 315		--	--
	2.0	0	0	0	0	0	0	0	0	--	0
	3.0	0	0	0	0	0	0	0	0	--	0

1980 CLADOPHORA TISSUE NUTRIENT DATA
CLADOPHORA SITE 2

DATE	DEPTH (M)	ExP %	TTP %	TTN %	TTC %	C/N
109	0.25	1.444	0.827	5.37	35.32	6.6
121	0.25	0.972	0.728	5.52	36.86	6.7
149	0.5 - Apical	0.140	0.139	3.34	33.00	9.9
dark green	0.5 - Basal	0.166	0.217	4.34	36.21	8.3
	0.5 - Whole	-----	0.156	3.71	34.38	9.3
	1.0	0.100	0.217	2.73	30.83	11.3
	2.0	0.078	0.110	2.29	28.37	12.4
	3.0	-----	0.140	2.28	25.49	11.2
171	S	-----	0.265	3.72	38.37	10.3
	0.5	0.181	0.204	3.43	36.55	10.6
	1.0	0.200	0.196	4.29	36.42	8.5
	2.0	0.211	0.368	3.29	25.25	7.7
184	S	-----	0.249	3.94	39.42	10.0
	0.5	0.231	0.241	3.47	32.44	9.3
	1.0	0.244	0.233	3.15	30.69	9.7
	2.0	0.068	0.241	1.93	13.77	7.1
199	S	-----	0.116	2.75	37.05	13.5
	0.5	0.089	0.103	2.45	35.49	14.5
	1.0	0.031	0.204	1.36	14.12	10.4
213	S	-----	0.099	2.52	37.20	14.8
	0.5	0.041	0.118	2.29	26.83	11.7
229	S	-----	0.120	2.24	29.64	13.2
	0.5	0.028	0.097	1.76	25.47	14.5
249	S	-----	0.103	2.50	35.66	14.3

1980 CLADOPHORA TISSUE NUTRIENT DATA (CONT.)
CLADOPHORA SITE 2

DATE	DEPTH (M)	ExP %	TTP %	TTN %	TTC %	C/N
260	S	-----	0.251	3.91	38.32	9.8
276	S	-----	0.290	2.86	39.11	13.7
	0.5	0.187	0.196	1.98	29.20	14.7
301	S	-----	0.392	4.92	40.86	8.3
	0.5	0.386	0.381	4.54	38.97	8.6
	1.0	0.181	0.296	3.43	29.61	8.7
315	S	-----	0.249	4.71	40.03	8.5
	0.5	0.373	0.288	4.92	40.47	8.2
328	S	-----	0.216	4.71	40.44	8.6
	0.5	0.271	0.236	4.85	40.45	8.3

S - Splash Zone
ExP - Boiling Water Extractable Phosphorus
TTP - Total Tissue Phosphorus
TTN - Total Tissue Nitrogen
TTC - Total Tissue Carbon
C/ N - Carbon to Nitrogen Ratio
% based on 64^{o}C Dry Weight

1980 CLADOPHORA WATER NUTRIENT DATA
CLADOPHORA SITE - 2

DATE	DEPTH (METERS)	SRP (ppb)	TFP (ppb)	TP (ppb)	NH_4 (ppb)	NO_2-NO_3 (ppm)	TFKN (ppb)	TKN (ppb)
026	0.5	----	----	47.3	----	-----	---	558.36
090	0.5	2.6	----	----	24.5	0.855	---	---
109	1	11.9	----	----	83.2	1.890		
	2	11.9	15.5	52.9	96.4	1.815	658	956
	3	11.2	17.1	64.2	96.3	1.840		
121	1	T	5.0	52.9	4.0	1.035	309	472
	2	2.0	6.9	44.8	12.3	1.035		
	3	1.5	9.5	55.8	15.0	1.033		
138	2	3.2	4.2	42.9	3.2	1.240	---	634
	3	3.0	4.9	41.9	4.9	1.265		
149	0.5	2.8	5.9	13.9	31.5	0.727		
	1	3.4	3.9	19.8	15.3	0.724	306	413
	2	2.4	3.1	15.8	9.5	0.744		
	3	2.2	2.2	20.5	11.7	0.746		
157	1	3.4	----	----	17.9	0.736	---	---
	2	4.6	----	----	31.7	0.755		
	3	6.4	----	----	49.8	0.769		
171	1	3.5	9.9	39.9	10.0	0.682	434	522
	2	7.9	9.3	32.9	27.2	0.752		
	3	6.5	11.2	37.3	18.0	0.758		
183	1	2.8	10.6	33.8	4.5	0.879	486	676
	2	10.8	13.8	36.8	70.7	0.893		
	3	11.0	17.9	42.0	71.5	0.904		

DATE	(METERS)	SRP (ppb)	TFP (ppb)	TP (ppb)	NH_4 (ppb)	NO_2-NO_3 (ppm)	TFKN (ppb)	TKN (ppb)
198	1	3.5	6.0	27.1	15.1	0.628	406	641
	2	2.8	5.1	26.8	5.2	0.640		
	3	6.1	8.3	31.2	31.9	0.650		
213	0.5	2.8	7.8	61.0	2.2	0.401	406	952
	1	3.4	6.8	74.6	5.0	0.399		
	2	2.6	5.8	33.2	1.9	0.391		
	3	2.5	6.2	41.9	1.9	0.406		
229	1	1.4	5.9	63.1	7.1	0.182	378	679
	2	1.4	5.1	47.1	4.9	0.172		
	3	1.7	7.4	48.2	7.1	0.161		
249	1	2.3	4.9	45.1	5.9	0.029	363	728
	2	1.7	5.1	38.2	3.0	0.010		
	3	2.3	6.6	41.9	15.9	0.198		
259	1	3.7	9.0	39.8	5.0	0.025	382	641
	2	3.9	9.4	40.5	3.7	0.020		
	3	4.0	10.0	43.2	4.8	0.021		
276	1	1.2	10.5	40.1	1.2	< 0.005w	385	745
	2	2.4	11.4	51.9	1.7	< 0.005w		
	3	3.2	11.0	50.2	4.6	< 0.005w		
297	1	---	----	----	---	-----	---	---
	2	2.8	9.0	65.9	4.0	0.136		
	3	2.9	10.9	61.5	6.8	0.143		
301	1	---	8.5	35.8	---	-----	275	565
	2	---	9.5	45.4	---	-----		
	3	---	8.9	43.9	---	-----		
314	1	1.7	9.6	46.8	6.0	0.032	413	690
	2	1.2	9.6	48.9	4.2	0.040		
	3	1.4	9.0	45.9	5.5	0.044		
328	1	0.8	9.3	33.8	4.1	0.074	385	555
	2	1.3	9.4	35.8	11.5	0.084		
	3	1.5	9.3	35.6	20.2	0.085		

w - No Response

1980 CLADOPHORA LAKE WATER DATA
CLADOPHORA SITE 2

DATE	DEPTH (METERS)	TEMPERATURE SURFACE	TEMPERATURE BOTTOM	SECCHI (METERS)	SUSPENDED SOLIDS (mg/1) TOTAL	SUSPENDED SOLIDS (mg/1) VOLATILE	CORRECTED CHLOROPHYLL a (mg/1)	WEATHER WAVES (ft.)	WEATHER CLOUDS/ AIR TEMP. (%)
109	0.5	----	----	----	-----	-----	-----	0.5	Haze
	1.0	7.0	7.8	0.5	19.93	3.35	6.00		
	2.0	6.7	7.0	0.5	-----	-----	-----		10.6
	3.0	6.5	7.0	0.5	-----	-----	-----		
121	0.5	10.1	10.4	----	-----	-----	-----	0	100.0
	1.0	10.0	10.4	0.7	14.90	3.56	11.20		
	2.0	9.9	9.9	0.75	-----	-----	-----		11.5
	3.0	9.9	9.8	0.7	-----	-----	-----		
138	2.0	----	----	----	14.18	2.96	30.28	3	100.0
	3.0	14.3	----	0.5	-----	-----	-----		
149	0.5	22.0	22.0	----	-----	-----	-----	0	-----
	1.0	21.0	19.0	B.O.	-----	-----	-----		
	2.0	20.6	18.0	2.0	6.69	2.24	3.84		29.0
	3.0	18.6	17.0	2.0	-----	-----	-----		
157	0.5	----	----	----	-----	-----	-----	1-2	40.0
	1.0	19.2	19.0	B.O.	-----	-----	-----		
	2.0	19.0	19.0	1.7	6.51	1.63	3.19		16.9
	3.0	18.8	19.0	1.8	-----	-----	-----		
171	0.5	20.5	----	----	-----	-----	-----	0.5	10.0
	1.0	20.5	20.0	B.O.	-----	-----	-----		
	2.0	20.0	20.0	1.60	6.85	1.81	1.90		25.0
	3.0	20.0	19.0	1.75	-----	-----	-----		

1980 CLADOPHORA LAKE WATER DATA (CONT.)
CLADOPHORA SITE 2

DATE	DEPTH (METERS)	TEMPERATURE SURFACE	TEMPERATURE BOTTOM	SECCHI (METERS)	SUSPENDED SOLIDS (mg/1) TOTAL	SUSPENDED SOLIDS (mg/1) VOLATILE	CORRECTED CHLOROPHYLL a (mg/1)	WEATHER WAVES (ft.)	WEATHER CLOUDS/ AIR TEMP. (%)
183	2.0	----	----	----	6.67	1.92	3.50		
184	0.5	22.5	22.5	----	-----	-----	-----	1	5.0
	1.0	22.5	22.5	B.O.	-----	-----	-----		24.5
	2.0	22.5	22.0	1.2	-----	-----	-----		
	3.0	22.5	22.0	1.0	-----	-----	-----		
198	2.0	----	----	----	6.75	3.49	12.62		
199	0.5	25.5	24.8	----	-----	-----	-----	0.5	1.0
	1.0	24.8	24.4	B.O.	-----	-----	-----		26.9
	2.0	24.8	24.0	B.O.	-----	-----	-----		
	3.0	24.2	24.0	2.9	-----	-----	-----		
213	0.5	25.5	26.0	----	-----	-----	-----	1	98.0
	1.0	25.0	26.0	0.7	-----	-----	-----		27.0
	2.0	25.0	25.5	1.1	12.13	3.57	17.78		
	3.0	24.5	25.5	1.2	-----	-----	-----		
229	0.5	24.5	24.5	----	-----	-----	-----	1	70.0
	1.0	24.5	24.5	0.6	-----	-----	-----		22.0
	2.0	24.5	24.5	1.0	15.52	3.23	14.89		
	3.0	24.5	24.5	1.15	-----	-----	-----		

1980 CLADOPHORA LAKE WATER DATA (CONT.)
CLADOPHORA SITE 2

DATE	DEPTH (METERS)	TEMPERATURE SURFACE	TEMPERATURE BOTTOM	SECCHI (METERS)	SUSPENDED SOLIDS (mg/1) TOTAL	SUSPENDED SOLIDS (mg/1) VOLATILE	CORRECTED CHLOROPHYLL a (mg/1)	WEATHER WAVES (ft.)	WEATHER CLOUDS/ AIR TEMP. (%)
249	0.5	25.0	25.0	----	-----	-----	-----	0	5.0
	1.0	25.0	25.0	1.0	-----	-----	-----		
	2.0	25.0	25.0	1.05	11.02	4.96	29.92		26.0
	3.0	25.0	25.0	1.1	-----	-----	-----		
259	0.5	22.0	22.0	----	-----	-----	-----	1-2	75.0
	1.0	22.0	22.0	0.5	-----	-----	-----		
	2.0	22.0	22.0	0.8	22.18	4.82	18.71		18.0
	3.0	22.0	22.0	1.0	-----	-----	-----		
276	0.5	19.0	19.0	----	-----	-----	-----	0.5	80.0
	1.0	19.0	19.0	B.O.	-----	-----	-----		
	2.0	19.0	19.0	1.15	7.55	2.97	14.54		15.0
	3.0	19.0	19.0	1.10	-----	-----	-----		
297	2.0	----	12.0	----	-----	-----	-----	3	15.0
	3.0	----	12.0	----	-----	-----	-----		
301	0.5	9.0	9.0	----	-----	-----	-----	0.5	95.0
	1.0	9.0	9.5	0.95	-----	-----	-----		
	2.0	9.5	9.0	0.90	12.90	3.35	13.98		6.0
	3.0	9.5	9.0	0.90	-----	-----	-----		
314	2.0	----	----	----	11.75	3.82	21.78		

1980 CLADOPHORA LAKE WATER DATA (CONT.)
CLADOPHORA SITE 2

DATE	DEPTH (METERS)	TEMPERATURE SURFACE	TEMPERATURE BOTTOM	SECCHI (METERS)	SUSPENDED SOLIDS (mg/1) TOTAL	SUSPENDED SOLIDS (mg/1) VOLATILE	CORRECTED CHLOROPHYLL a (mg/1)	WEATHER WAVES (ft.)	WEATHER CLOUDS/ AIR TEMP. (%)
315	0.5	8.0	8.0	----	-----	-----	-----	0	50.0
	1.0	8.0	8.0	----	-----	-----	-----		6.0
	2.0	8.0	7.5	0.95	-----	-----	-----		
	3.0	8.0	7.5	1.20	-----	-----	-----		
328	0.5	4.25	4.5	----	-----	-----	-----	1	100.0
	1.0	4.25	4.5	B.O.	-----	-----	-----		
	2.0	4.5	4.5	1.2	7.87	2.38	9.27		7.0
	3.0	4.5	4.5	1.2	-----	-----	-----		

B .O. - Bottom Out