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PRELIMINARY INVESTIGATIONS OF PERIPHYTON AND WATER QUALITY RELATIONSHIPS IN THE EVERGLADES WATER CONSERVATION AREAS

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Environmental Sciences Division
Resource Planning Department
South Florida Water Management District
West Palm Beach, Florida

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DEFINITIONS

Periphyton - Periphyton represent a community of microorganisms (primarily algae) that live attached to or upon the surface of submerged substrates. Young [115] expanded the definition to include "... that assemblage of organisms growing upon the free surfaces of submerged objects in water, and covering them with a slimy coat." Periphyton are further described as "... that slippery brown or green layer usually found adhering to the surfaces of water plants, wood, stones or other objects immersed in water and may gradually develop from a few gelatinous plants to culminate in a wooly, felted coating that may be slippery or crusty with contained marl or sand." Wetzel and Westlake [102] suggest that periphyton include all of the plant organisms, excluding rooted macrophytes, growing on submerged materials in water. The German term "Aufwuchs" was first used to describe organisms growing on or attached to a substrate, but not growing into or penetrating the substrate. Both terms, "periphyton" and "Aufwuchs" have become synonymous in the literature, with "periphyton" becoming the accepted term for all organisms attached to submerged substrates as discussed in the English language literature [106].

Natural Substrate Periphyton - Natural substrate periphyton are defined as those organisms which grow on or attached to submerged aquatic vegetation. In this study, natural substrate periphyton were synomynous with the term "epiphytic" periphyton (i.e. growing on plants). In the WCA, natural substrate periphyton were collected primarily from the following six plant species: Cladium jamaicense (sawgrass), Utricularia spp. (bladderwort), Typha angustifolia and T. domingensis (cattail), Rhynchospora tracyi (beakrush), and Panicum hemitomon (maidencane). Natural substrate periphyton were

sampled in the WCA by scraping epiphytic algae from sawgrass or cattail stems, or by collecting floating Utricularia - periphyton mats and preserving the material by oven drying at 70°C. This qualitative sampling method was used to estimate the nutrient content (nitrogen and phosphorus) of natural substrate periphyton. Quantitative estimates of periphyton biomass per unit area were difficult to measure from natural substrate materials. To increase the precision of these estimates, uniform artificial substrates (glass slides) were used to collect periphyton populations from each site.

Artificial Substrate Periphyton - Artificial substrate periphyton are defined as those algae which colonize standard laboratory microscope slides (2.54 x 7.62 cm) suspended 2.5 cm below the water surface in wood racks (See Figure 4). Artificial substrates were used as a comparative method of measuring periphyton growth rates and species composition differences between WCA sampling sites.

Periphyton Standing Crop - The amount of organic matter present (yield) per unit area at any given time [59].

Periphyton (Chlorophyll a) Net Primary Production - Net primary production is defined as the rate of storage of organic matter in plants in excess of their respiratory needs measured on a per square meter basis, over a specific time period [59]. In this study the rate of algal chlorophyll a accumulation on glass slides incubated in the marsh over a seven to eight week incubation period was utilized as an index of periphyton net primary production.

Ecophene - An ecophene refers to an organism which possesses the ability to change its cell morphology in response to changing environmental or physiological conditions [16]. This study reports at least five ecophenes of the filamentous blue-green Schizothrix calcicola and two ecophenes of the filamentous blue-green Microcoleus lyngbyaceus as common WCA periphyton species.

EXECUTIVE SUMMARY

Submerged and floating mats of predominantly blue-green algae, commonly referred to as periphyton, are a conspicuous feature of the Water Conservation Areas (WCA). Periphyton are communities of microorganisms (primarily algae) that live attached to the surfaces of stems and leaves of aquatic plants and other submerged substrates. As primary producers, periphyton convert carbon dioxide, water and other nutrients into organic plant material which is foraged upon by a wide variety of Everglades invertebrates (amphipods, crayfish, snails, insect larvae, etc.) and juvenile fishes. In some portions of the Everglades, periphyton carbon fixation and standing crop measurements have been shown to exceed adjacent macrophyte communities. Consequently, the periphyton represent an important primary food source of the Everglades food chain.

Recent studies of algal populations in WCA-3A show that some blue-green algae have the ability to fix free nitrogen from the atmosphere and utilize it for cell growth. As a result, periphyton can play an important role in the cycling of nitrogen in the marsh ecosystem.

In addition to their importance as a food source, periphyton photosynthesis and metabolism greatly influence both diurnal dissolved oxygen concentrations and calcium carbonate (marl) deposition in the marsh.

Periphyton growth rates, species composition, and community structure characteristics are very sensitive to changes in water quality. Periphyton populations enriched by excessive nitrogen or phosphorus concentrations cause a reduction in the number of sensitive algal species and an increase in the abundance of "pollution tolerant" species. Due to their sensitivity as water quality indicators, biologists have used these organisms as a

monitoring tool for the assessment of water quality and environmental change in aquatic environments.

Although the periphyton are recognized as an important component of the Everglades ecosystem, little is known concerning their population dynamics and water quality relationships in the WCA. The purposes of this study were (1) to provide a baseline inventory of attached algal communities at representative WCA interior and peripheral marsh sites, (2) to develop quantitative methods of measuring changes in periphyton populations, between sites and over time, and (3) to investigate the response of periphyton populations to changes in water quality, water depths and hydroperiod. This information will provide a basis for evaluating the effects of future water management alternatives in the WCA.

Preliminary results showed that filamentous blue-green algae (Myxophyceae) were the dominant algae comprising WCA-2A and WCA-3A populations, while desmids and filamentous green algae (Chlorophyceae) dominated interior WCA-1 sites. Marsh water phosphorus concentrations were shown to be the major factor affecting periphyton growth rates and the phosphorus content of the algae. Desmid and filamentous green algae populations dominated in marsh waters containing low concentrations of major ions, while filamentous blue-green algae populations dominated in waters containing high concentrations of major ions.

Hydrogen ion concentration (pH) was also an important factor regulating periphyton species composition with filamentous blue-greens dominating under alkaline pH conditions and desmids and filamentous greens dominating under acid pH conditions.

Concentrations of inorganic nitrogen and phosphorus were low at

interior WCA-2A and WCA-3A sites during 1978-79 indicating "oligotrophic" (low nutrient concentrations) water quality conditions. Periphyton growth rates (as measured by chlorophyll a) and the phosphorus content of periphyton cell tissue were also low in comparison to literature values. These data suggest that periphyton may be nutrient limited with respect to phosphorus at these interior sites. Because of their low availability, nutrients are rapidly recycled in a "closed" system in the interior marshes with the majority of nutrients being tied up in either living plant biomass or in the organic peats (dead plant material). Rainfall appears to be the major source of nitrogen and phosphorus to the interior marshes.

Nutrient concentrations at peripheral marsh sites located south of the S-10 discharge structures in WCA-2A were consistently high throughout 1978-79. High periphyton growth rates and the high phosphorus content of the algae were characteristic of peripheral marsh sites. Periphyton populations at these sites were dominated by "eutrophic" water quality indicator organisms (organisms tolerant of high nutrient concentrations). These data suggest that periphyton species composition and algal growth rates in the northeastern portion of WCA-2A are significantly impacted by nutrients entering the marsh via the S-10 discharge structure.

Large scale shifts in periphyton species composition may have far reaching impacts. If the characteristics of the primary producer component of the food web is altered, the effects on secondary and tertiary consumers may be compounded. Certainly, the relationship between periphyton species composition and the invertebrate macrofauna needs to be investigated.

Periphyton species composition and growth rates on glass slides were significantly influenced by site differences in water quality (major ion content, pH and phosphorus concentrations). Water depth and hydroperiod

length were not significantly correlated with the development of periphyton communities on glass slides during 1978-79.

INTRODUCTION

The Everglades region of south Florida represents one of the largest freshwater marshes in North America [11, 12, 86]. The Water Conservation Areas (WCA) are a remnant of the original Everglades marsh and form a major freshwater link between the agricultural areas south of Lake Okeechobee and the marshlands of Everglades National Park (Figure 1).

The WCA serve five major functions: (1) provide flood protection for urban east coast areas, (2) provide municipal and agricultural water supplies, (3) maintain well field recharge and prevent salt water intrusion into the Biscayne aquifer, (4) provide Everglades National Park with a guaranteed supply of fresh water, and (5) furnish important wetland habitat for Everglades plants and wildlife, including a number of rare or endangered species [72, 96].

Plant communities of the area have been described by Davis [11, 12] and Loveless [44, 45]. Stewart and Ornes [87], Volk et al [100] and Davis and Harris [13] have studied the nutrient content of the soils, water and marsh vegetation.

Submerged and floating mats of predominately blue-green algae, commonly referred to as periphyton, are a conspicuous feature of the Water Conservation Areas. The periphyton are a community of microorganisms (primarily algae) that live attached to the surface of stems and leaves of aquatic plants and other submerged substrates. By the process of photosynthesis, periphyton convert carbon dioxide, water, and other nutrients into organic plant material which is foraged upon by a wide variety of Everglades invertebrates (amphipods, crayfish, snails, insect larvae, etc.) and juvenile fishes. In the aquatic slough communities of Everglades National Park, periphyton were found to be responsible for the majority of

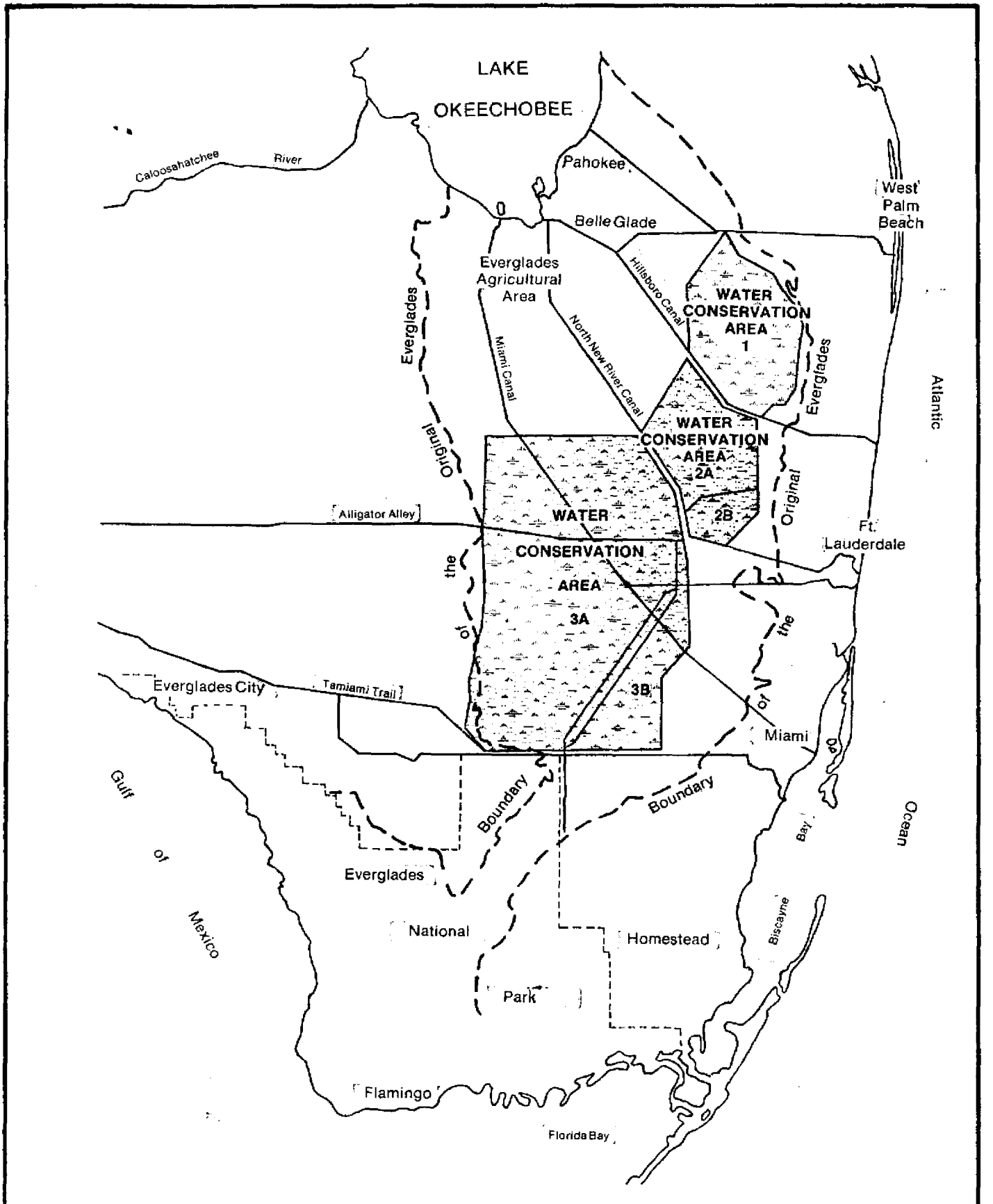


Figure 1 LOCATION OF EVERGLADES WATER CONSERVATION AREAS IN SOUTH FLORIDA

carbon fixed by photosynthetic processes in comparison to surrounding macrophyte vegetation [6]. Periphyton biomass in some portions of the Everglades is considerably larger than the macrophyte vegetation on which it grows [114]. Consequently, the periphyton represent an integral component of the Everglades food chain.

Recent studies of algal populations in WCA-3A show that some blue-green algae have the ability to fix free nitrogen from the atmosphere and utilize these substances for cell growth [28]. As a result, periphyton can play an important role in the cycling of nitrogen in the marsh ecosystem.

In addition to their importance as a food source, periphyton photosynthesis and metabolism greatly influence both diurnal dissolved oxygen concentrations [27, 32, 111], calcium carbonate (marl) deposition [27, 29], soil building, and nutrient uptake processes within the marsh.

Over the past three decades, studies of periphyton populations (especially the diatom component) have become widely accepted as reliable monitors or "indicators" of water quality or environmental change in aquatic habitats [106]. The majority of these studies utilized glass slide substrates for the collection of colonizing periphyton algae. Descriptions of periphytic assemblages have historically been based on the identification and enumeration of algae colonizing the glass slide substrates. The rationale for this approach lies in the concept that one of the first effects of pollution is to cause a reduction of sensitive species with an increase in the number of tolerant species [63, 65].

Other common measures of periphyton community structure have included species diversity indices, indices of community similarity, dry weight, ash-free dry weight, chlorophyll *a* and ATP measurements as well as primary

production rate estimates using oxygen production or ^{14}C assimilation methods [106].

Although the periphyton are recognized as important components of the Everglades [27, 48] little data exists regarding their seasonal periodicity, species composition, pigment concentrations, nutrient requirements, or community structure. Previous periphyton studies in the area have been primarily restricted to metabolic [32, 111] and general taxonomic studies in the vicinity of Everglades National Park [27, 99, 100, 114]. Periphyton studies of the WCA have received much less attention [26, 27, 28].

The primary objectives of this study were threefold: (1) provide an inventory of attached algal communities at representative interior and peripheral marsh sampling sites; (2) develop quantitative methods for measuring changes in periphyton biomass production, species composition, and nutritional status; and (3) develop an adequate water quality/ biological data base to assess possible relationships between parameters. Quantitative data presented here may be used to estimate the direction and rate of ecological change within the marsh, and may be useful in assessing future water management alternatives within the study area.

DESCRIPTION OF STUDY AREA

The original Everglades covered an area of more than 10,000 km^2 and occupied a shallow 65 km wide, peat-filled depression that extended from Lake Okeechobee approximately 160 km south to the mangrove estuaries of the Shark River Slough (Figure 1). The area is characterized by poor drainage with an average slope from Lake Okeechobee to Florida Bay of about 3 cm/km. The region's vegetation is a vast sawgrass marsh dotted with tree islands and interspersed with wet prairies and aquatic sloughs [11, 12, 44, 45]. Surface water is usually present in the marsh for the greater portion of the year, but during drought the area is dry and susceptible to fires.

The study area lies within $29^{o}30'$ - $26^{o}30'$ latitude North and is subject to relatively small changes in photoperiod in comparison to temperate marshes. The region has a subtropical climate with over 75 percent of the annual rainfall occurring between June and October. As a result, the marsh has marked seasonal fluctuations in water levels. In general, the months of November to May represent the dry season.

In addition to rainfall, water levels in portions of the marsh are influenced by the storage of surface water runoff from surrounding agricultural or urban areas. Some areas of the Everglades have been continuously inundated for several years, producing a number of ecological changes to the marsh. A number of these effects have been discussed in several papers [1, 14, 30, 46, 51].

Considerable change has occurred in the Everglades over the past 75 years due to drainage and flood control practices. The greatest impact on the region's hydrology was from the drainage and agricultural development of the Everglades Agricultural Area south of Lake Okeechobee.

Today, the remainder of the Everglades is divided into four separate entities which include the three Water Conservation Areas and Everglades National Park (Figure 1). Water levels in all of the WCA's are managed by the South Florida Water Management District (SFWMD), primarily in accordance with flood control regulation schedules developed by the U.S. Army Corps of Engineers. Water Conservation Area 1 (WCA 1), designated the Loxahatchee National Wildlife Refuge, covers an area of 572 km^2. The wildlife and recreational resources of WCA 1 are managed by the U.S. Fish and Wildlife Service. The Florida Game and Fresh Water Fish Commission, under lease with the SFWMD, manages wildlife resources in Water Conservation Area 2 (WCA 2, 544 km^2), and Water Conservation Area 3 (WCA 3, 2367 km^2).

METHODS AND MATERIALS

Water chemistry samples were collected concurrently with the development of periphyton communities on glass slides during four seasonal surveys (February - April, 1978; July - August, 1978; November 1978 - January 1979; and June - August, 1979) at selected sites shown in Figure 2. Table A-1 (Appendix) presents location descriptions and vegetation characteristics at each site.

Physical and Chemical Measurements

Water chemistry samples were collected at least four times during each incubation period. Field data (temperature, dissolved oxygen, specific conductance, and pH) were recorded using a Hydrolab^{R} Surveyor II electronic recording instrument. Surface water chemistry samples were collected in a plastic bucket, filtered through a Millipore^{R} membrane filter (pore size, 0.45 μ), and stored in polyethylene bottles on ice. Routine laboratory analyses were performed within 5-7 days of collection. These analyses included:

1. Dissolved nutrients (ortho-phosphorus, total dissolved phosphorus, nitrate, nitrite, and ammonia)
2. Total phosphorus, total nitrogen, and total organic carbon
3. Major cations and anions (sodium, potassium, calcium, magnesium, chloride, calcium carbonate alkalinity, and silicate).

Analyses were performed using a Technicon^{R} Industrial Systems II AutoAnalyzer, a Perkin Elmer^{R} Model 306 Atomic Absorption Spectrophotometer, and an Astro^{R} Model 1600 Total Organic Carbon Analyzer. Analytical chemistry methods used in this study were either recommended or approved by the Environmental Protection Agency [21] or the American Public Health

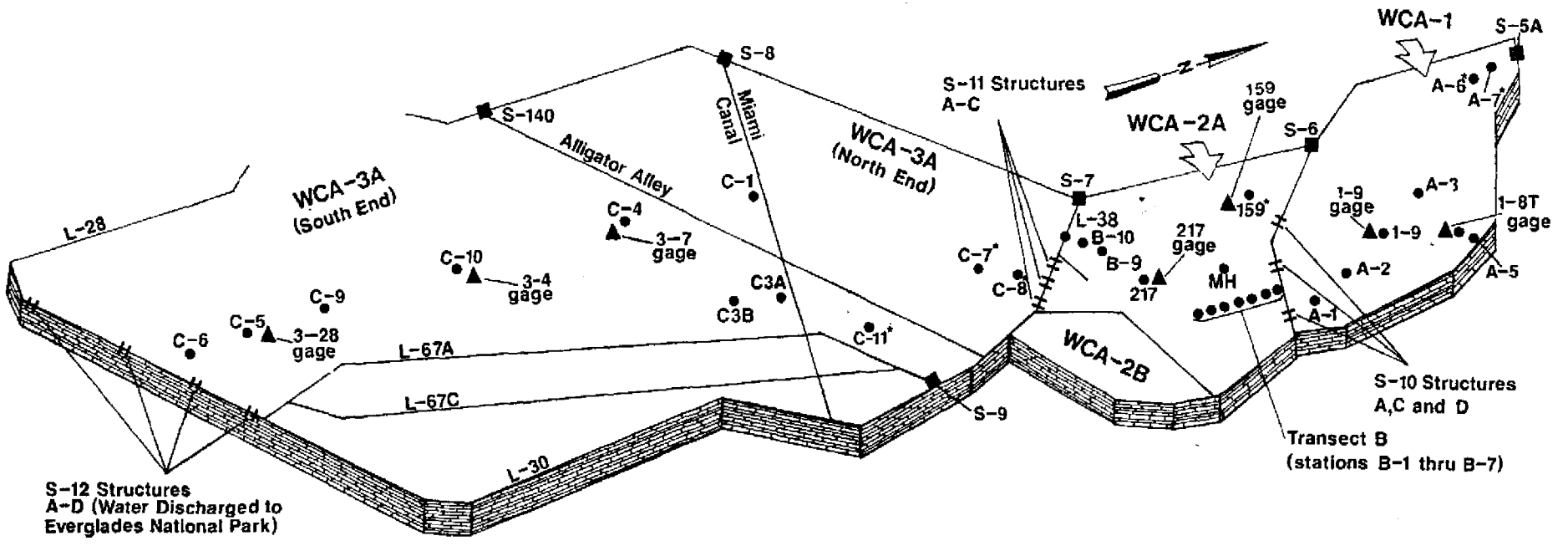


FIGURE 2. LOCATION OF PERIPHYTON/WATER QUALITY SAMPLING STATIONS IN THE EVERGLADES WATER CONSERVATION AREAS, FEBRUARY 1978-AUGUST 1979.

Association [2].

Measurements of rainfall and surface water elevations were obtained from gauging stations located near field sampling sites. Hydrological data reported in this study were derived from U.S. Army Corps of Engineers records of the 1-7 and 1-8T gauges in WCA-1, the 2-17 gauge in WCA-2A and the 3-7 and 3-28 gauges in WCA-3A. Water depths were measured at the time of sample collection and correlated with nearby gauge data. Soil (peat) depths were measured at each site with a steel rod.

Development of Periphyton Sampling Techniques

Vertical glass slides (2.5 x 7.5 cm) suspended 2.5 cm below the water surface were used to monitor the development of periphyton communities. Artificial substrates were used since a majority of periphyton investigations have used glass slides [9, 65, 80, 104, 105, 106] and because the method allows control of experimental conditions such as incubation time, substrate type, and water depth. A pilot study was conducted to compare possible differences that may exist between periphyton communities developing on natural substrates (i.e. cattail and sawgrass culms or leaves) and those growing on artificial substrates (glass slides).

Five substrate types were incubated for 30 days at the Melaleuca Head (MH) site in WCA-2A during October-November, 1977. One substrate tested consisted of replicate glass slides incubated 2.5 cm below the water surface in a commercial sampling device* (Fig. 3a). Four other substrate types of known surface area were also examined. These consisted of (1) glass slides, (2) dead cattail (Typha sp.) leaves, (3) dead sawgrass

*Periphytometer II^{R}, Design Alliance Corp., Cincinnati, Ohio

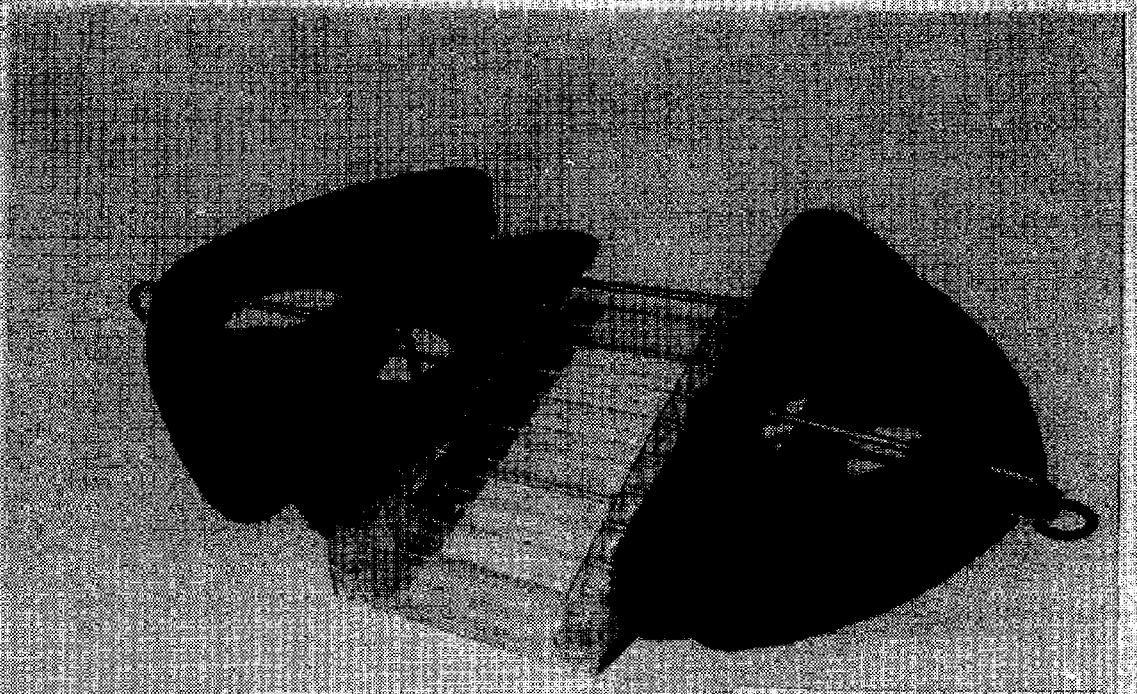


FIGURE 3a. PERIPHYTOMETER^{R} II SLIDE RACK, DESIGN ALLIANCE CORP., CINCINNATI, OHIO.

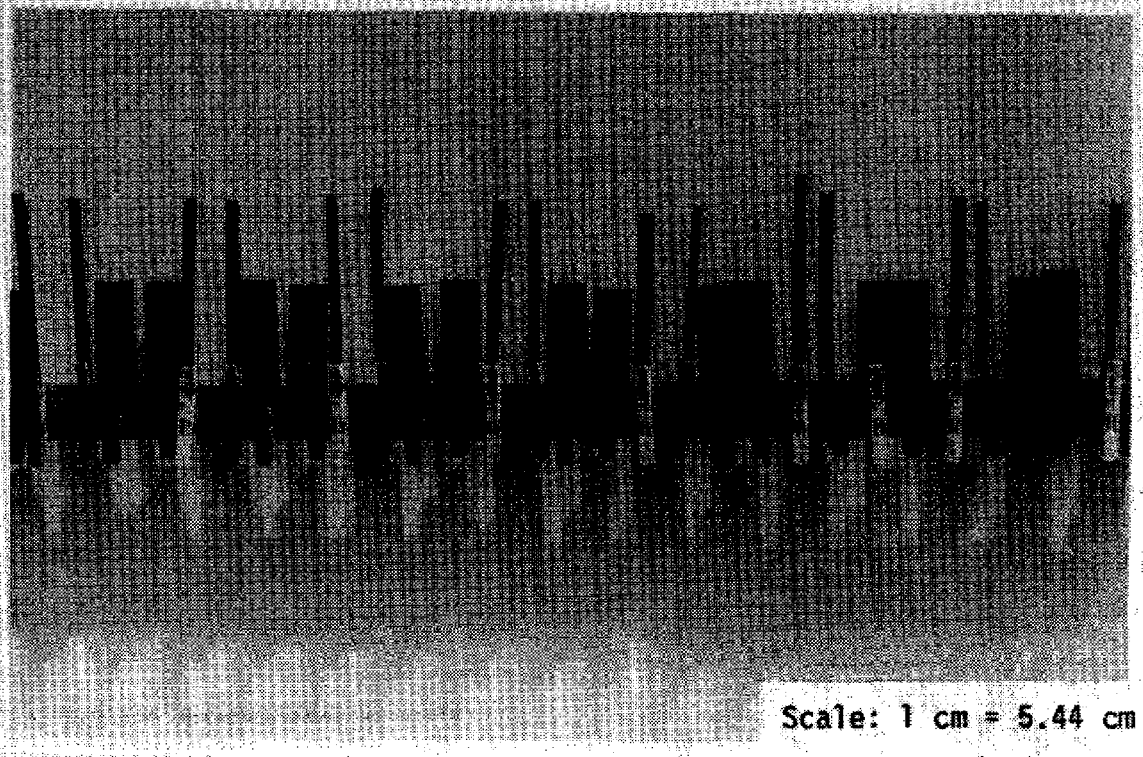


FIGURE 3b. IMPROVISED CLOTHESPIN RACK HOLDING SAWGRASS LEAVES AND GLASS SLIDE SUBSTRATES.

(Cladium jamaicense) leaves, and (4) freshly cut sawgrass leaves. Each material was incubated 30 cm below the water surface (approximately mid-depth) in an improvised rack (Figure 3b) attached to vertical stakes anchored to the marsh bottom.

Fifteen replicates of each substrate were processed at the end of the incubation period for chlorophyll a content, and five additional replicates of each substrate were processed for cell density estimates, total number of species present, species diversity indices, and species composition.

Based on results of the pilot study (See Discussion Section of this report), the Periphytometer II^{R} rack was chosen for the initial survey (February - April, 1978). During the first survey, a number of plastic racks were disturbed by alligators and were lost or destroyed. As a result, a similar but larger and heavier redwood sampling rack* was constructed for use during the remaining three surveys. Glass slides were held in place by plastic report binders and rubber bands (Figure 4).

Periphyton Analyses

Periphyton communities colonizing glass slides during the four seasonal surveys were analyzed for (a) chlorophyll a production rates, (b) relative abundance of major algal groups, and (c) diatom community analysis.

Chlorophyll a was measured by the acid addition (correction for phaeophytin) method [2]. Slides were collected and placed immediately in 70 ml glass bottles containing filtered marsh water, stored in the dark on ice, and transported to the lab within six hours. Slides were then scraped and filtered on Whatman GF/C filters (0.45 micron pore size).

*The redwood rack was designed by Mr. Jeff Goldstein, Department of Biology, Antioch College, Yellow Springs, Ohio.

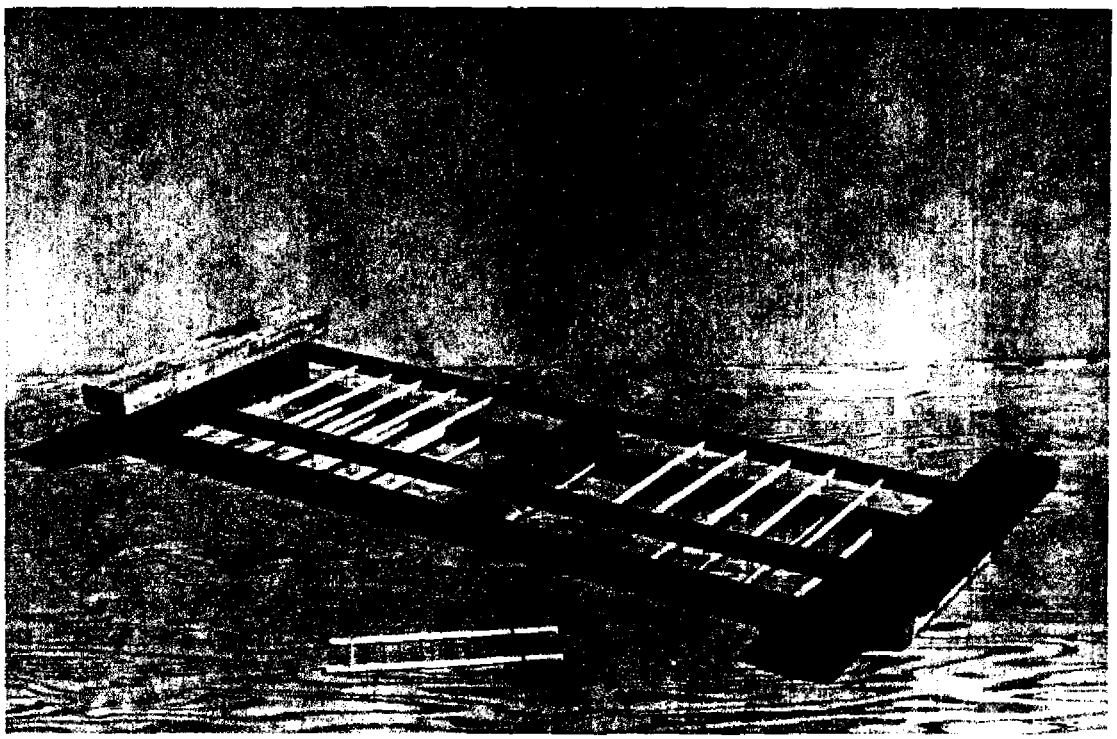


FIGURE 4. REDWOOD SLIDE RACK CONTAINING GLASS SLIDE SUBSTRATES HELD IN A VERTICAL POSITION. WOOD CROSS PIECES AT EACH END STABILIZE RACK WHILE FLOATING. IN FOREGROUND, PLASTIC REPORT BINDERS SERVE AS A CARTRIDGE FOR HOLDING FIVE GLASS SLIDES. RACK HAS A 50 SLIDE CAPACITY AND WAS USED DURING THE SUMMER AND WINTER 1978 AND SUMMER 1979 SURVEYS.

Filters were washed with saturated magnesium carbonate and frozen. Pigments were extracted by grinding for one minute and treatment with an acetone-magnesium carbonate (90:10 percent by volume) solution at -10°C for 24 hours. Chlorophyll *a* levels were determined spectrophotometrically using the equations of Strickland and Parsons [90]. Chlorophyll *a* concentrations were reported as mg chlorophyll *a* m^{-2} $week^{-1}$.

Periphyton species composition and cell volumes were determined by removing colonizing algae from slides, preserving with 5 percent formalin, and counting under a Wild M-40 inverted plankton microscope. Preliminary microscopic examination found most periphyton populations comprised of clumped assemblages of filamentous blue-green and green algae and diatoms. Cell counts of these samples were biased due to the unequal distribution of the clumped filaments. To overcome this problem, the algal suspension was subjected to ultrasonic vibration using a Heat Systems® microprobe (Model W-ZZ5R) for 15 seconds at an estimated 6.5 khz. This procedure dispersed the filaments uniformly without severely altering their cell morphology. Possibly some delicate flagellate forms may have been damaged by this procedure, but analysis of fresh material showed that flagellate algae represent a very minor component of the Everglades periphyton community (<0.2 percent). Algal cells containing chloroplasts were enumerated by pipetting two or five mls of the sonicated suspension into a plankton counting chamber. Counts were made on an inverted Wild M-40 microscope at 400X magnification. Total counts per sample ranged from 500-1600 cell units.

Coccoid and filamentous blue-green algae were identified to species where possible based on Drouet [16, 17, 18] and Drouet and Daily [19]. Filamentous green algae were identified to the genera level using Prescott

[70] and Whitford and Schumacher [110]. Desmid references were Kim [39] and Prescott, Croasdale and Vinyard [71]. Diatom references were Hustedt [33, 34, 35, 36], Patrick and Reimer [66, 67] and Schmidt et al [76].

Algal cell volumes were estimated using equations for the closest geometrical shape resembling each species, and by applying reasonable corrections for each calculation [20, 43, 58, 109]. Volumes of irregular shapes (i.e. some diatoms and desmids) were estimated by constructing styrofoam models and calculating conversion factors for their average length, width, and depth measurements. Total periphyton cell volumes were reported as cubic microns per square millimeter (μ^3/mm^2) of slide surface. The relative contribution of each algal group was expressed as a percentage of the total algal volume present. Average cell volume, percent relative abundance and species diversity indices were calculated using the SFWMD ALGAESTAT computer program [84].

Permanent quantitative Hyrax^R mounts of diatoms were made from algae colonizing replicate glass slides using modified procedures of Werff [108] and Sullivan et al [93]. Diatom frustules were "cleaned" using 50 percent hydrogen peroxide and potassium dichromate. Counts from these slides were converted to number of diatoms/mm^2 using the methods described by Sullivan et al [93].

Algal nutrient content analyses were based on the collection of duplicate natural substrate periphyton samples from leaves and stems of submerged vegetation at each sampling location. Samples were collected in 500 ml plastic bottles (ca. 3-5 grams dry weight of algae) and placed on ice. In the lab samples were washed with distilled water, filtered, oven dried at 70°C, and macerated to pass through a 0.5 mm screen. Total

Kjeldahl nitrogen (TKN) and total phosphorus (TP) were analyzed by a modification of the Kjeldahl block digestion technique [3], using one gram samples digested with Kjeldahl reagents in a Technicon^{R} block digestor apparatus for one hour at 400°C. After digestion, samples were analyzed for percent TKN and percent total phosphorus on a Technicon AutoAnalyzer^{R}. Data in this report are expressed as percent elemental N or P on a dry weight basis.

Community and Statistical Analyses

The Shannon index of general diversity [59] was used to compare the distribution of individuals among species within a sample. A cluster analysis program [69] was used to reduce species abundance data into smaller natural groupings based on similarities of species composition and abundance between sites. Use of the Biotic Similarity (B) index in periphyton surveys is discussed in Weitzel [106] and Sullivan et al [93]. This program was modified to include a real number format for the culstering of water chemistry parameters between sampling sites. In this sense a Water Chemistry Similarity Index (W) was defined as follows:

$$W = \frac{1}{t} \sum_{i=1}^{t} \frac{\text{Min } (n_iA, n_iB)}{\text{Max } (n_iA, n_iB)}$$

where:

t = number of parameters considered

n_iA = mean value of indicator parameter i present at Station A

n_iB = mean value of indicator parameter i present at Station B

Min (n_iA, n_iB) = the minimum value of the pair: n_iA, n_iB

Max (n_iA, n_iB) = the maximum value of the pair: n_iA, n_iB

The Water Chemistry Similarity Index is defined for paired water quality parameters between two samples or stations, with a group average sorting strategy. If two stations have identical water quality values at each site the calculated index is 1.0 (maximum similarity).

Tests of relationships between variables were conducted utilizing both stepwise multiple regression and factor analyses. The regression program package used was modified from the Systems/360 IBM Scientific Subroutine Package (360A-CM-03X) Version II, Manual H20-0205-3, pp. 413. Factor analyses were conducted using the FACTO routine of the System/360 IBM Scientific-Subroutine Package (360A-CM-03X) Version 3, Manual H20-0205-3, pp. 429. The method of factoring used was a principal component solution with Varimax-rotation. Analyses were performed on a CDC-3100 computer. In this study, the minimum acceptable eigenvalue was >1.0.

PHYSICAL-CHEMICAL RESULTS

Temperature

Mean annual air temperature for the WCA is approximately 23°C with lowest readings occurring in January (mean January temperature = 17.7°C) and highest temperatures occurring in July and August (mean temperatures for both months = 26.7°C) [95]. Marsh water temperatures during the period of study averaged 23.8°C and ranged from winter lows of 13.4°C to summer highs of 35.7°C.

Marsh Hydrology

Surface water levels in the WCA's varied widely in response to seasonal rainfall patterns and water management practices. Figure A-1 (Appendix) presents a plot of the weighted total monthly rainfall and stage level elevations at the 1-7 gauge (WCA-1), 2-17 gauge (WCA-2A), 3-7 gauge (north end of WCA-3A) and the 3-28 gauge (south end of WCA-3A) for the period of study (See Figure 2 for locations). Surface water levels in the WCA generally increased during the months of May through December and decreased between the months of January and April.

Rainfall during 1978 and 1979 generally followed historical trends. Sampling sites in the interior of WCA-1 and north end of WCA-3A experienced typical wet and dry periods during the summer of 1979. In contrast, stations located in WCA-2A and the south end of WCA-3A had continuous inundation throughout the entire study period.

Soil Depths

Large accumulations of unconsolidated Holocene sediments (organic peat) were present at interior WCA-1 sites, ranging in depth from 3.2-3.6 m.

Peat accumulation in WCA-2A was generally less, ranging from 0.5-1.5 m in depth. Peat depths in WCA-3A ranged from 0.20-0.75 m with lowest accumulations occurring at Sites C-5 and C-6 located just north of the Tamiami Trail. Extensive radiocarbon dating of these soils have shown no Holocene sediments older than 5500 years BP [25].

Water Quality

Table 1 presents mean concentrations of major ions and nutrients at WCA interior and peripheral marsh sampling sites. Surface waters in WCA-2A, WCA-3A, and the peripheral marsh of WCA-1 were highly mineralized. Specific conductivity was generally high, ranging from 328-1082 μmhos/cm, while hydrogen ion (pH) concentrations were near neutral (6.8-7.1). The dominant major ions at these sites were bicarbonate (HCO_3^-), chloride, sodium, calcium and sulfate with silica, magnesium, potassium, and iron present in lesser quantities (Table 1). In contrast, surface waters in the interior of WCA-1 were low in dissolved minerals, poorly buffered, acid, and considered soft (Table 1).

Concentrations of nitrogen (N) and phosphorus (P) were very low at interior marsh sites in comparison to peripheral marsh sites adjacent to canals. Highest total dissolved P concentrations throughout the study occurred at Sites B-1, B-2, and B-3, located south of the S-10C discharge structure in WCA-2A. These concentrations ranged from 0.013 to 0.310 mg/l. Figures 5 and 6 present the areal distribution of average total dissolved P and inorganic N concentrations at twenty-six sampling sites located across the Water Conservation Areas during 1978 and 1979. Lowest average total dissolved P concentrations ranged from 0.003 - 0.005 mg/l at interior sites located in WCA-2A, WCA-3A and WCA-1 (Figure 5). Slightly higher mean concentrations of phosphorus were noted at sites located near the

TABLE 1. WATER CHEMISTRY FROM WATER CONSERVATION AREA PERIPHYTON SAMPLING SITES. MEAN VALUES, FEBRUARY 1978 - AUGUST 1979.

	WCA-1		WCA-2A		WCA-3A	
	Interior[1] Sites	Peripheral[2] Sites	Interior[3] Sites	Peripheral[4] Sites	Interior[5] Sites	Peripheral[6] Sites
Major Ions (mg/l)						
Ca^{+2}	7.0	39.9	66.5	75.5	49.1	87.1
Mg^{+2}	1.9	13.0	26.6	29.7	5.5	17.7
Na^{+}	14.2	67.5	117.2	140.8	23.1	58.0
K^{+}	0.6	3.7	6.0	6.4	1.1	3.2
Cl^{-}	27.0	98.5	172.7	192.6	37.8	88.0
$SO_4^{=}$	7.3	22.3	39.3	46.1	16.8	27.4
HCO_3^{-}	21.3	163.5	294.6	334.9	176.3	380.0
Nutrients (mg/l)						
Total P	0.018	0.013	0.012	0.095	0.009	0.030
Total Diss. P	0.005	0.006	0.006	0.057	0.003	0.008
NO_3+NO_2	0.007	0.009	0.006	0.086	0.008	0.230
NH_4	0.09	0.06	0.02	0.18	0.08	0.03
SiO_2	5.2	21.6	17.7	21.2	8.8	6.3
TOC	23.9	32.8	36.9	36.6	24.4	42.5
pH	5.9	6.8	7.0	7.1	6.9	7.1
Conductivity (µmhos/cm)	132	676	1003	1082	328	663
Alkalinity (meq/l)	0.35	2.68	4.83	5.49	2.89	4.88

[1]Sites A-2, A-3, 1-9; [2]Sites A-1, A-5, 1-8T; [3]Sites B-5, B-6, B-7, 217, B-9; [4]Sites B-1, B-2, B-3, B-4, B-10, L-38; [5] Sites C-3B, C-4, C-5, C-6, C-9, C-10; [6]Sites C-1, C-3A, C-8. (Refer to Figure 2).

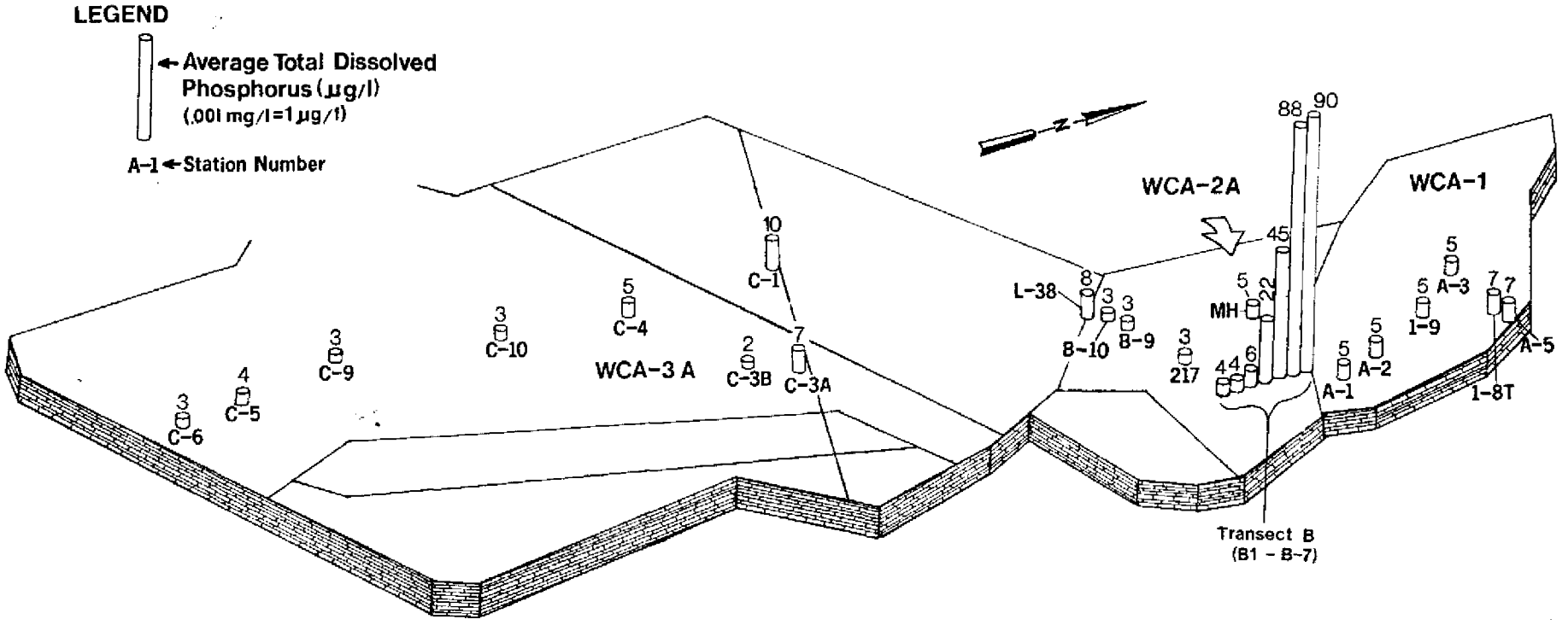


FIGURE 5. AVERAGE TOTAL DISSOLVED PHOSPHORUS CONCENTRATIONS AT 26 WCA SITES, FEBRUARY 1978-AUGUST 1979 (µg/l).

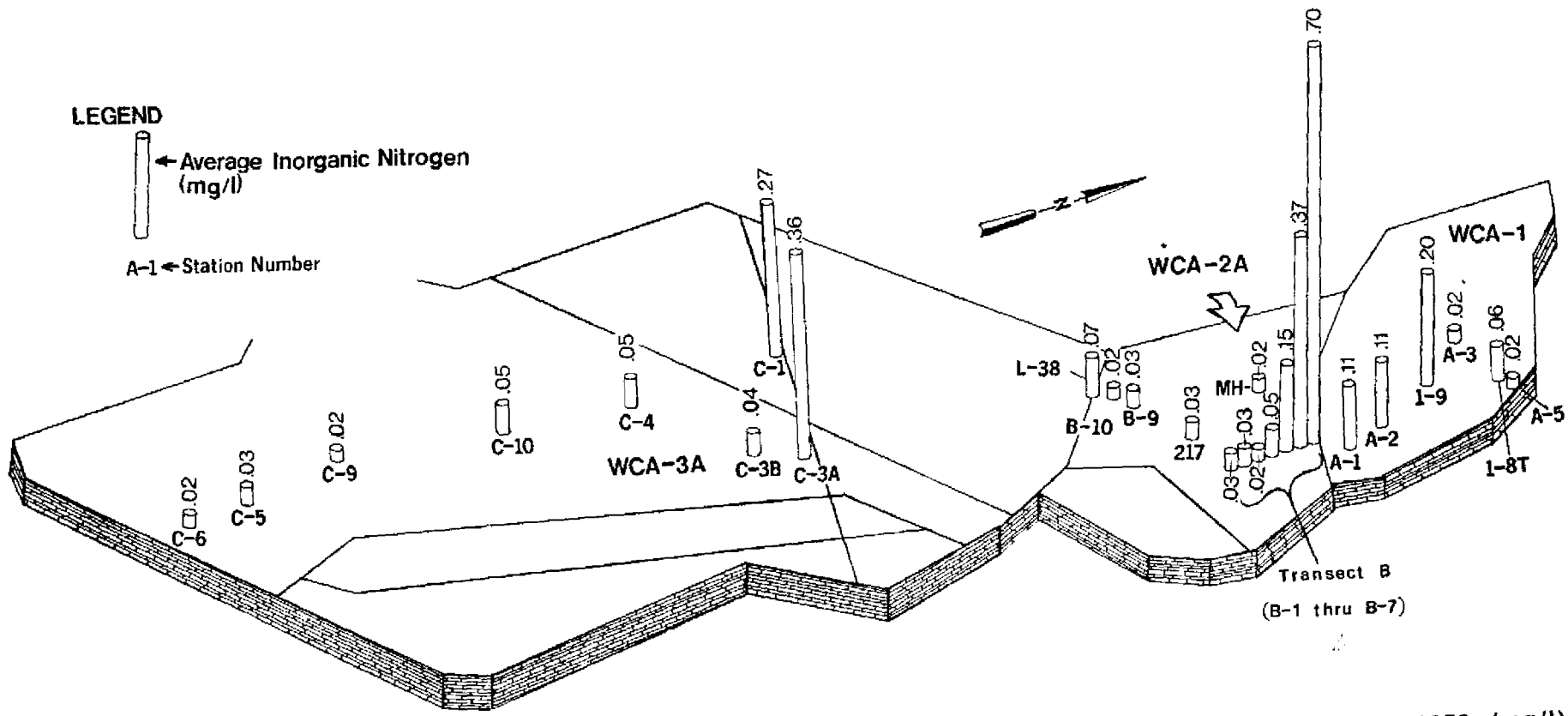


FIGURE 6. AVERAGE INORGANIC NITROGEN CONCENTRATIONS AT 26 WCA SITES, FEBRUARY 1978-AUGUST 1979 (mg/l).

Miami Canal, the L-38 Canal site located in WCA-2A, and the A-5 and 1-8T sites located on the periphery of WCA-1 (Figure 5).

Mean concentrations of inorganic N were relatively high at peripheral sampling sites adjacent to canals and low at interior sites (Figure 6). Inorganic N concentrations were consistently high at Sites B-1 and B-2 where average levels were 0.70 and 0.37 mg/l, respectively. However, the two highest nitrogen values recorded in the study were at Sites A-2 and 1-9 in WCA-1 where inorganic N levels of 1.29 and 1.54 mg/l were recorded during low water conditions in July 1979.

Water quality characteristics between sampling sites were compared by use of a cluster analysis [69] using six key water quality indicator parameters: total dissolved P, inorganic N, alkalinity, specific conductance, chloride, and median pH. Results of the cluster analysis are presented in the dendrogram display in Figure 7. The dendrogram illustrates five major groupings or categories based on water quality type. Table 2 presents indicator parameter mean ranges for each of the six water quality categories depicted in the dendrogram.

Category I Sites: These sites were low in dissolved minerals, poorly buffered, acidic, soft water marsh habitats in the interior of WCA-1 (Sites A-2, A-3, and the 1-9 gauge). Specific conductivity ranged from 108-162 μmhos/cm while calcium carbonate alkalinity ranged from 0.25-0.46 meq/l (Table 1). Scatter plot diagrams of chlorides versus alkalinity (Figure 8) and pH versus alkalinity (Figure 9) illustrates the low dissolved mineral content, acidic pH, and low buffering capacity of these sites relative to WCA-2A and WCA-3A interior sites. The low ionic content of these waters indicate they are primarily derived from rainfall. Table 3 compares the chemical composition of South Florida rainfall to the

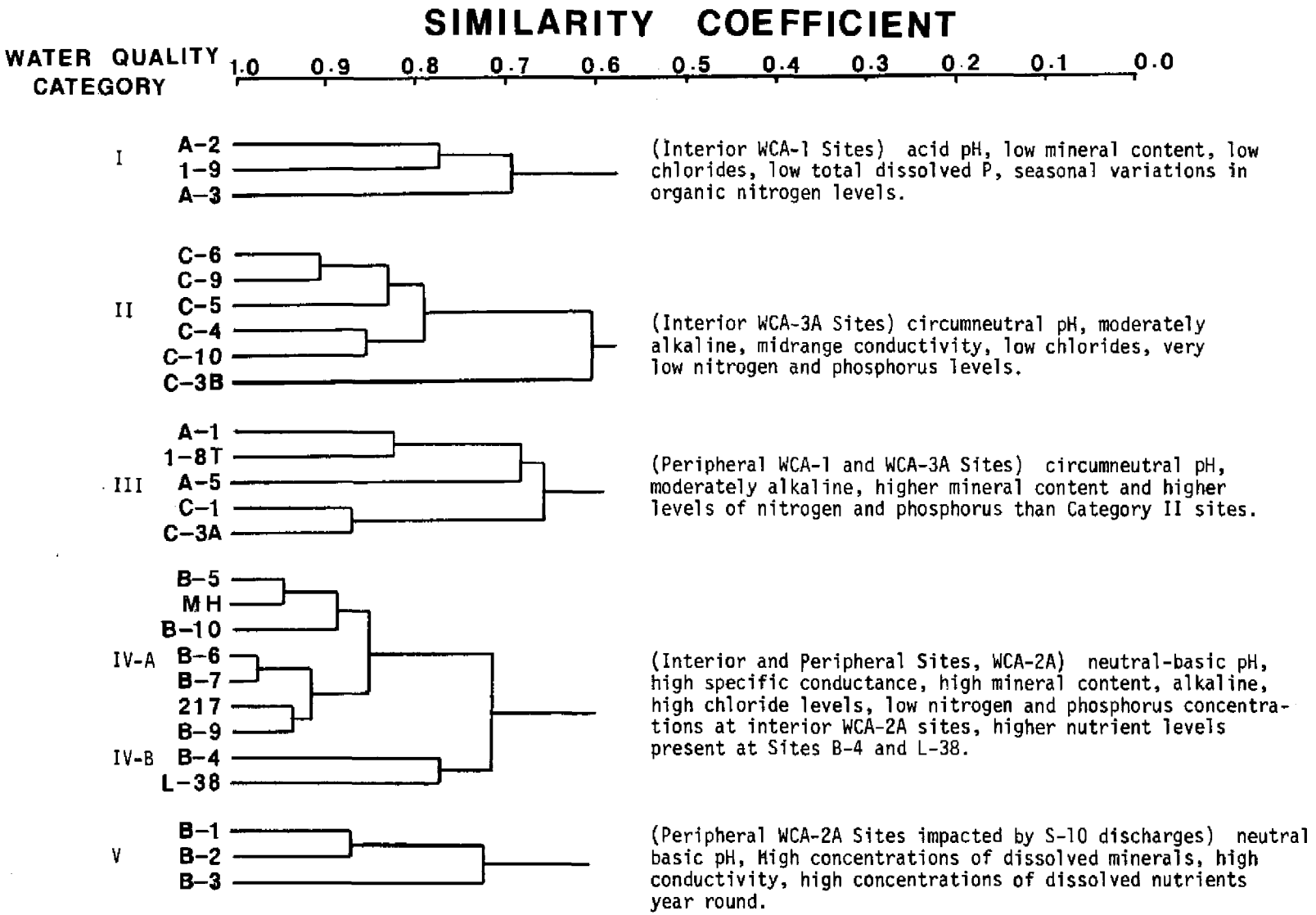


FIGURE 7 CLUSTER ANALYSIS OF 26 PERIPHYTON/WATER QUALITY SAMPLING STATIONS IN THE EVERGLADES WATER CONSERVATION AREAS ACCORDING TO SIX INDICATOR CHEMICAL PARAMETERS (SEE TEXT).

TABLE 2. RANGE OF STATION AVERAGES FOR SELECTED INDICATOR PARAMETERS USED IN THE CLUSTERING ANALYSIS OF WATER QUALITY SIMILARITIES FOR THE WATER CONSERVATION AREAS (1978-1979).

PARAMETERS	CATEGORY I	CATEGORY II	CATEGORY III	CATEGORY IV	CATEGORY V
Specific conductance (µmhos/cm)	108-162	304-441	584-712	716-1071	1076-1170
Alkalinity as $CACO_3$ (MEQ/l)	0.25-0.46	2.48-4.43	2.15-5.03	3.15-5.17	5.39-6.21
Chloride (mg/l)	24-31	28-76	85-91	117-193	201-219
Inorganic N (mg/l)	.02-0.20	.02-.05	.06-0.36	.02-.07	.15-0.70
Total Dissolved P (mg/l)	.005	.003-.005	.005-.010	.003-.022	.045-.090
pH (median)[a]	5.75-5.85	6.85-7.2	6.6-7.05	6.8-7.2	7.0-7.1

All values are ranges of station averages unless otherwise noted.

[a] Ranges of station median values

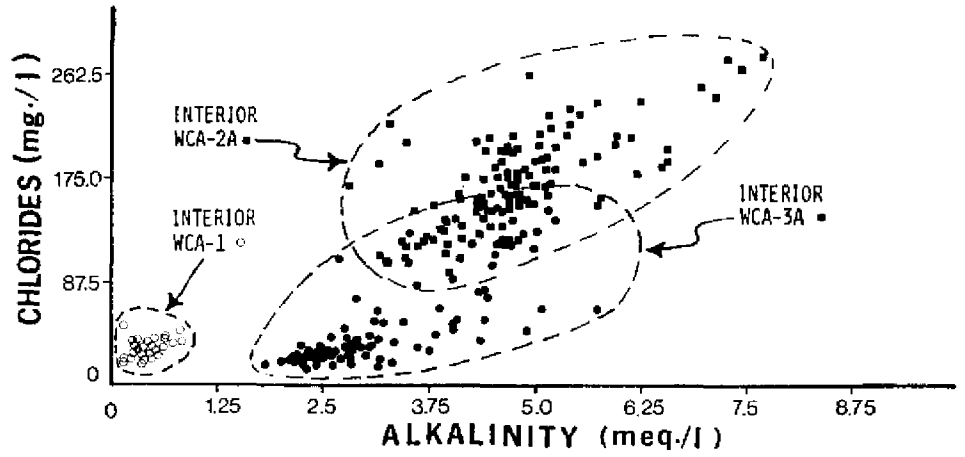


FIGURE 8. ALKALINITY VS. CHLORIDES AT INTERIOR WCA SITES, FEBRUARY 1978-AUGUST 1979.

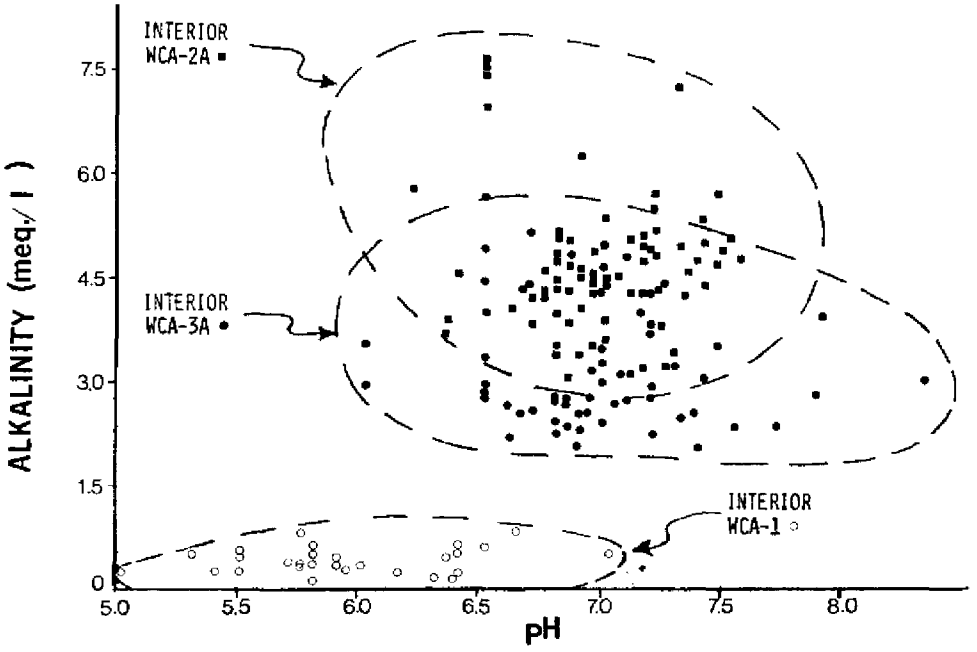


FIGURE 9. ALKALINITY VS. pH AT INTERIOR WCA SITES, FEBRUARY 1978-AUGUST 1979.

TABLE 3. CHEMICAL COMPOSITION OF RAINFALL AT SELECTED SOUTH FLORIDA SITES AND MARSH SURFACE WATER QUALITY FROM WATER CONSERVATION AREA 1.

Rainfall Collection Site	pH	Spec. Cond.	ALK (meq/l)	Cl (mg/l)	CA (mg/l)	NA (mg/l)	K (mg/l)	MG (mg/l)	Inorganic N (mg/l)	Total P (mg/l)
Pump Station	5.85*	26	0.18	4.3	3.45	2.94	0.43	0.81	0.48	0.078
S-2 (Belle	1.07	17	0.13	1.0	0.77	0.11	0.53	0.08	0.26	0.068
Glade, Fla.)	(12)	(23)	(26)	(24)	(11)	(11)	(11)	(11)	(26)	(26)
Okeechobee	5.35*	28	0.17	10.9	3.12	2.94	0.36	0.82	0.34	0.039
Field Station	1.04	20	0.18	29.8	0.31	.10	0.52	.07	0.16	0.062
(Okeechobee,	(12)	(20)	(24)	(24)	(12)	(12)	(12)	(12)	(23)	(24)
Fla.)										
S-131 Water		27	0.19	4.8	3.04	2.95	0.35	0.80	0.42	0.054
Control	ND	13	0.21	1.6	0.2	0.10	0.46	0.05	0.33	0.054
Structure (near		(26)	(31)	(30)	(15)	(15)	(15)	(15)	(32)	(31)
Lake Port, Fla.)										
Int. WCA1 Water										
Quality Site										
WCA-1 Marsh Water										
	5.78	108	0.25	24.4	5.96	11.94	0.48	1.63	0.02	0.028
Station A-3	0.47	32	0.13	8.2	1.76	3.21	0.15	0.43	0.01	0.062
	(14)	(13)	(17)	(17)	(16)	(15)	(15)	(15)	(17)	(16)
	5.85	162	0.46	30.6	8.15	17.84	0.80	2.46	0.11	0.012
Station A-2	0.47	41	0.15	7.1	2.17	4.36	0.42	0.78	0.38	0.007
	(13)	(12)	(16)	(16)	(15)	(14)	(14)	(14)	(16)	(15)
	5.75	126	0.32	25.4	6.88	12.47	0.53	1.56	0.20	0.012
1-9 Gage		41	0.22	6.2	2.29	3.06	0.35	0.55	.42	.007
	(7)	(6)	(9)	(9)	(9)	(9)	(9)	(9)	(9)	(9)

Upper value represents the mean, lower the standard deviation, value in bracketsisthe number of observations
*pH may have been affected by microbiological contamination. Unpublished SFWMD data, 1979.
ND = No Data

interior WCA-1 marsh water. Concentrations of chloride and sodium and measurements of specific conductance were somewhat higher for marsh water, whereas rainfall contained much higher concentrations of nitrogen and phosphorus.

Concentrations of nitrogen and phosphorus at the interior WCA-1 sites varied seasonally. During the summer of 1978, inorganic N and total dissolved P concentrations were at or below detection limits.* As water levels declined in the dry season, nitrogen values increased substantially up to 1.54 mg inorganic N/l.

Category II Sites: Circumneutral pH (6.8-7.2), low chlorides, medium range conductivity (300-441 µmhos/cm), and moderate alkalinity grouped the interior WCA-3A sites (C-3B, C-4, C-5, C-6, C-9, and C-10) together in Figure 7. Inorganic N and total dissolved P levels were usually near or below detection limits.

Category III Sites: These sites were clustered due to similarities of circumneutral pH, moderate to high conductivity and alkalinity, and low to moderate concentrations of nitrogen and phosphorus. These sites were restricted to peripheral sampling sites located in WCA-1 and WCA-3A (Sites A-1, A-5, 1-8T, C-1, C-3B).

Category IV Sites: These sites were all located in WCA-2A. Each site had high specific conductivity, high concentrations of major ions, neutral-basic pH, and were alkaline (Table 2). Dissolved nutrient concentrations were low at interior WCA-2A sites with mean concentrations for inorganic N

*Instrumentation limits of detection for inorganic N = 0.01 mg/l, for total dissolved P = 0.002 mg/l.

ranging from 0.02-0.03 mg/l and total dissolved P ranging from 0.003-0.005 mg/l. Two peripheral WCA-2A sites (L-38 and B-4) were chemically similar to the interior sites with the exception of levels of dissolved nutrients. Nutrients were low to moderately high with average inorganic N concentrations ranging from 0.02-0.07 mg/l and average total dissolved P ranging from 0.007-0.022 mg/l (Figures 5 and 6). High nutrient levels at these two sites were attributable to nutrient inputs via canal water inflows.

Category V Sites: Three peripheral sites in WCA-2A (B-1, B-2, and B-3) were unique due to high concentrations of nitrogen and phosphorus present throughout the study. Average inorganic N levels at these sites ranged from 0.15-0.70 mg/l and average total dissolved P ranged from 0.045-0.090 mg/l (Figures 5 and 6). These sites also had high concentrations of major ions, high conductivity, and were strongly alkaline. High nutrient levels at these sites were a result of nutrient enriched canal water which is discharged into the WCA-2A marsh via the S-10 structures.

BIOLOGICAL RESULTS

Periphyton Species Composition on Glass Slides

A total of 225 species of algae representing 94 genera and 9 divisions were identified from the study area. Table A-2 presents a list of all algae identified, while Table 4 presents a generalized list of the dominant and common species characteristic of the study area.

Since different species of algae vary greatly in size, cell numbers do not give a true account of each species' biomass contribution to the total community [102, 109]. Cell volumes were used to express periphyton abundance in this study. Table 5 presents cell volume estimates for some of the more common algae identified from glass slides. Figures 10 and 11 show the percentage contribution by volume of the major groups of algae during the summer surveys of 1978 and 1979. Tables A-3 and A-4 list the cell volumes and relative abundances of those species which comprised more than five percent of the population at each site.

A cluster analysis [69] of the periphyton cell volume data was used as an exploratory tool to determine if the distribution of algal species was site related. Results of the clustering program for the summers of 1978-1979 are presented in Appendix B.

Filamentous blue-green algae (Myxophyceae) were the dominant group of algae in WCA-2A, WCA-3A, and peripheral WCA-1 sites, followed by filamentous green algae (Chlorophyceae), and diatoms (Bacillariophyceae). Desmids and filamentous green algae (Chlorophyceae) were the most important groups of algae at interior WCA-1 sites and were also present as common species at sites located in the south end of WCA-3A.

Fifteen blue-green taxa were identified from glass slide substrates. Only three filamentous blue-green species, Schizothrix calcicola (Ag.) Gom.,

TABLE 4. DOMINANT AND COMMON PERIPHYTON ALGAE IDENTIFIED FROM ARTIFICIAL SUBSTRATES INCUBATED IN THE WATER CONSERVATION AREAS - FEBRUARY 1978 - AUGUST 1979.

MYXOPHYCEAE (Blue-Greens)

Schizothrix calcicola (Ag.) Gom.*
Scytonema hofmannii Ag.*
Microcoleus lyngbyaceus (Kützz) Crouan*
Stigeonema spp.
Anacystis dimidiata (Kütz) Dr. and Daily
Spirulina subsalsa Oerst.

CHLOROPHYCEAE (Green Algae)

Mougeotia spp.*
Oedogonium spp.*
Spirogyra spp.
Bulbochaetae spp.

DESMIDIACEAE (Desmids)

Cosmarium spp.
Penium spp.*
Genicularia elegans West
Genicularia spp.
Desmidium spp.
Staurastrum spp.
Euastrum spp.

BACILLARIOPHYCEAE (Diatoms)

Mastogloia smithii v. lacustris Grun.
Anomoeoneis vitrea (Grun.) Ross comb. nov.
Cymbella ruttneri Hust.
Cymbella minuta v. psuedogracilis (Choln.) Reim.
Cymbella minuta v. silesiaca (Bleisch ex Rabh.) Reim.
Cymbella amphioxys (Kütz.?) Grun.
Diploneis elliptica (Kütz.) Cl.
Rhopalodia gibba (Ehr.) O. Mull.
Nitzschia sp. 7 sp. nov.**
Nitzschia storchii sp. nov.**
Synedra pahokeensis sp. nov.**

* Dominant taxon at several sites
** New species to science

TABLE 5. ESTIMATED CELL VOLUMES (CUBIC MICRONS) OF COMMON PERIPHYTON TAXA COLONIZING GLASS SLIDE SUBSTRATES IN THE WATER CONSERVATION AREAS

TAXON	Average Volume ($\mu^3 \times 10^3$)	Volume Ranges ($\mu^3 \times 10^3$)
(Coccoid Blue-Greens)		
Anacystis montana (col.)*	0.05	.005-1.0
Anacystis dimidiata (col.)	1.0	0.7-2.0
(Filamentous Blue-Greens)		
Microcoleus lyngbyaceus (Ecophene†1)	6.0Ψ	1.3-15.0
Microcoleus lyngbyaceus (Ecophene 2)	30.0Ψ	9.0-50.0
Schizothrix calcicola (Ecophene 1)	0.3	0.1-0.5
Schizothrix calcicola (Ecophene 2)	0.2	0.07-0.5
Scytonema hofmannii	150.0Ψ	8.0-1,100.0
(Coccoid Greens)		
Chlamydomonas cf. *angulosa*	2.0	1.7-2.5
Chlorella vulgaris	0.3	0.2-0.4
Oocystis sp.	0.6	0.4-0.8
Scenedesmus quadricauda	1.0	0.8-1.5
(Filamentous Greens)		
Mougeotia sp. 2 (col.)	60.0Ψ	25.0-100.0
Oedogonium sp. 2 (col.)	100.0Ψ	63.0-1,800.0
Spirogyra spp. (col.)	500.0Ψ	290.0-1,000.0
(Desmids)		
Cosmarium pyramidatum v. convexum	16.0	10.0-20.0
Desmidium cylindricum (per cell)	20.0	18.0-24.0
Geniculatia elegans (col.)	24.0Ψ	8.0-75.0
Gonatozygon sp. 1	3.5	1.3-4.0
Staurastrum tetracerum	0.6	0.4-0.8
(Diatoms)		
Anomoeoneis vitrea	0.36	0.24-0.38
Cymbella ruttneri	0.20	0.17-0.24
Cymbella minuta v. psuedogracilis	2.80	2.00-5.00
Gomphonema parvulum	0.36	0.23-0.75
Mastogloia smithii v. lacustris	1.30	0.95-2.00
Nitzschia storchii sp. nov.	0.38	0.22-0.50
Nitzschia sp. 7 sp. nov	0.15	0.08-0.17
Rhopalodia gibba	20.00	16.00-38.00
Synedra pahokeensis sp. nov.	0.55	0.46-0.84
(Dinoflagellates)		
Peridinium sp. 1	8.00	5.50-10.30

*Col. = Average volume of a colony of cells.

ΨCalculated cell volumes are highly variable due to differences in filament length

†Ecophene: variations in cell morphology in response to varying ecological conditions

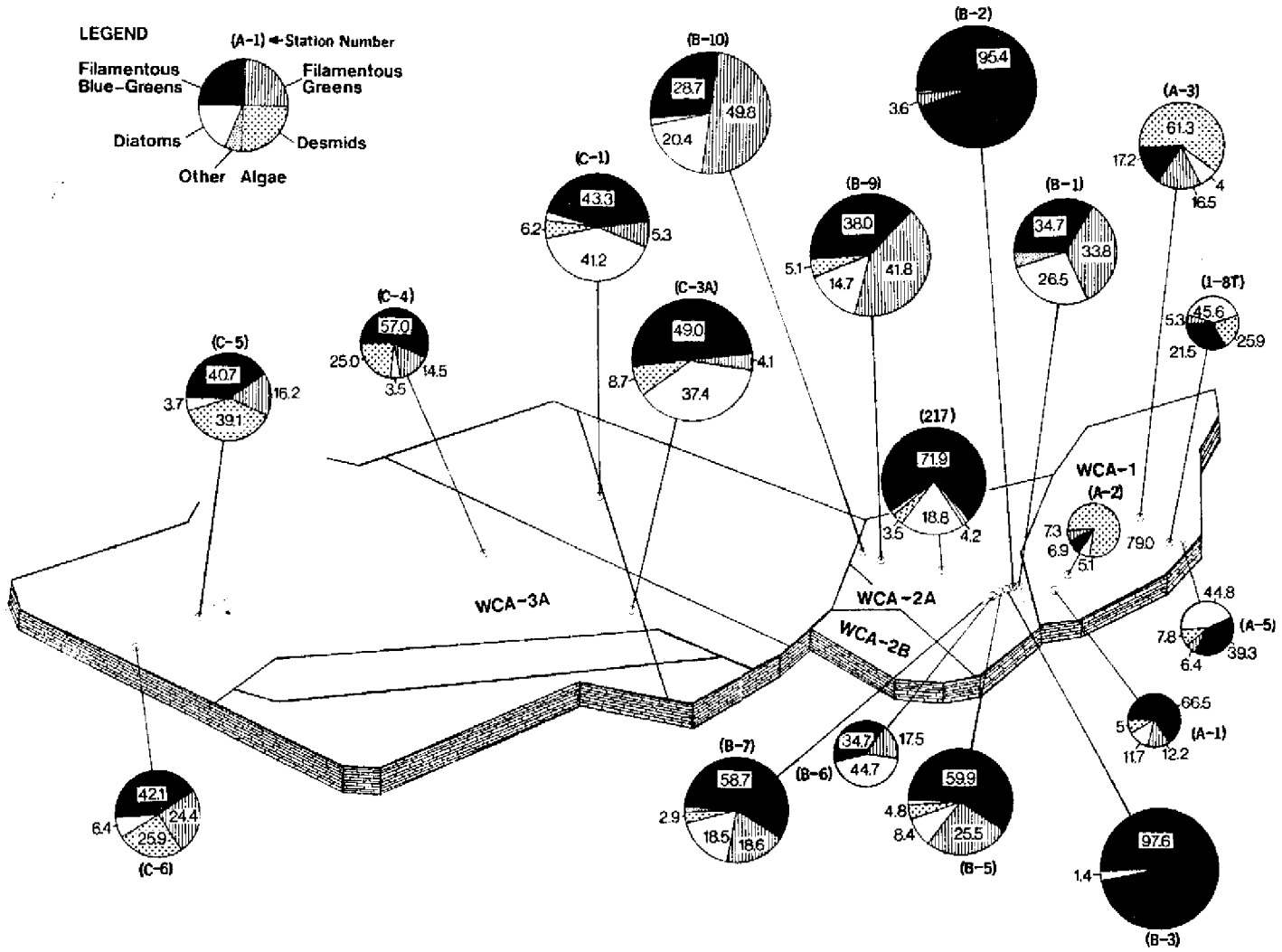


FIGURE 10. PERCENTAGE COMPOSITION BY VOLUME OF THE FOUR MAJOR PERIPHYTON GROUPS COLONIZING ARTIFICIAL SUBSTRATES IN THE WCA, JULY-AUGUST 1978. RELATIVE BIOMASS DIFFERENCES BETWEEN SITES ARE SHOWN BY DIAMETER OF CIRCLE.

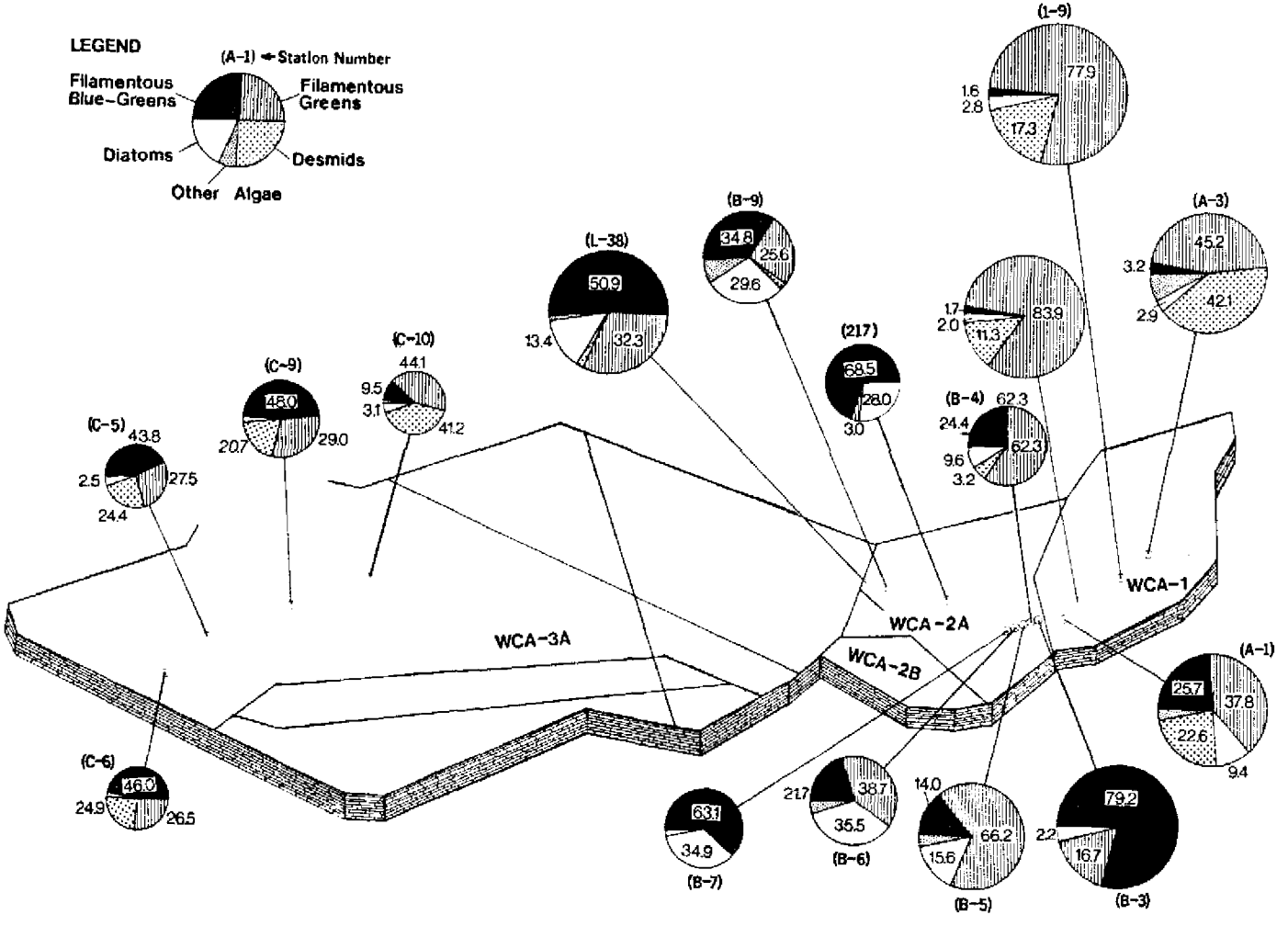


FIGURE 11. PERCENTAGE COMPOSITION BY VOLUME OF THE FOUR MAJOR PERIPHYTON GROUPS COLONIZING ARTIFICIAL SUBSTRATES IN THE WCA, JUNE-AUGUST, 1979. RELATIVE BIOMASS DIFFERENCES BETWEEN SITES ARE SHOWN BY DIAMETER OF CIRCLE.

Scytonema hofmannii Ag. and Microcoleus lyngbyaceus (Kutz) Crouan, were quantitatively important. Schizothrix calcicola was the most common species collected throughout the study area and was present in every sample collected. In summer 1978, S. calcicola was most prevalent at interior WCA-2A sites comprising 23.0 to 51.7 percent of the population by volume. Lowest concentrations of S. calcicola occurred at Stations A-2 and A-3 (interior of WCA-1) and Stations C-5 and C-6 (south end of WCA-3A) comprising only 1.4-5.0 percent of the population. In summer 1979, Mougeotia spp. (filamentous green) became a co-dominant species with Schizothrix calcicola at interior WCA-2A sites.

Microcoleus lynbyaceus was the dominant algae at peripheral marsh sampling sites during both surveys comprising 22-75 percent of periphyton biomass. Largest populations of M. lyngbyaceus occurred at sites located near the S-10 discharge structure. In summer 1979, peripheral sites in WCA-2A were dominated by M. lyngbyaceus and two filamentous green algae, Spirogyra spp. and Oedogonium spp.

Scytonema hofmannii was the dominant algae at stations located in the southern portion of WCA-3A (Sites C-5, C-6 and C-9) occurring in association with filamentous green algae, desmids and diatoms. S. hofmannii comprised 34-40 percent of the total periphyton biomass at these three southern WCA-3A sites. S. hofmannii was not common on artificial substrates in WCA-2A or WCA-1.

Filamentous green algae (Chlorophyceae) were important components of the WCA periphyton community. Four filamentous green algae were numerically important: Mougeotia spp., Oedogonium spp., Spirogyra spp., and Bulbochaetae sp. . Mougeotia spp. was the most common filamentous green occurring in

WCA's and was a co-dominant species in the interior of WCA-1 and WCA-2A during both surveys. Largest populations of Mougeotia occurred at Site 1-9 in WCA-1 where it comprised 64.0 percent of the population by volume.

Interior WCA-1 marsh sites (A-2, A-3, and 1-9) supported a highly diverse periphyton community dominated by desmids and filamentous green algae. In 1978 desmids represented 61-79 percent of the community by volume (Figure 10). Forty-seven species of desmids were recorded from the interior WCA-1 sites during 1978 and 1979. Common desmid genera included Arthrodesmus, Closterium, Cylindrocystis, Cosmarium, Desmidium, Euastrum, Genicularia, Gonatozygon, Hyalotheca, Micrasterias, Netrium, Penium, Spaherozosma, Staurastrum and Xanthidium. During summer 1979, desmids were replaced in importance by three species of filamentous green algae, Mougeotia spp., Oedogonium spp., and Spirogyra spp. (Figure 11).

Although diatoms (Bacillariophyceae) were common species of the Everglades periphyton, they were less important in terms of their total biomass (volume basis) contribution to the community (Figures 10 and 11). However, several diatoms were present as co-dominant species at six marsh sites (Anomoeonies vitrea at Station 1-8T; Mastogloia smithii v. lacustris at Stations A-5, B-6, B-9 and C-3A; and Nitzschia amphibia at Station C-1). Diatoms were more abundant at peripheral canal sites where populations ranged from 20.4 - 44.8 percent by volume. (Diatom distribution and ecology is treated in more detail in a later section of this report).

Periphyton Chlorophyll *a* Production

Mean areal periphyton chlorophyll *a* production rates for each of the four seasonal surveys are presented in Figures 12 through 15. Table C-1 provides the results of Tukey's multiple comparison procedure [84] for these data.

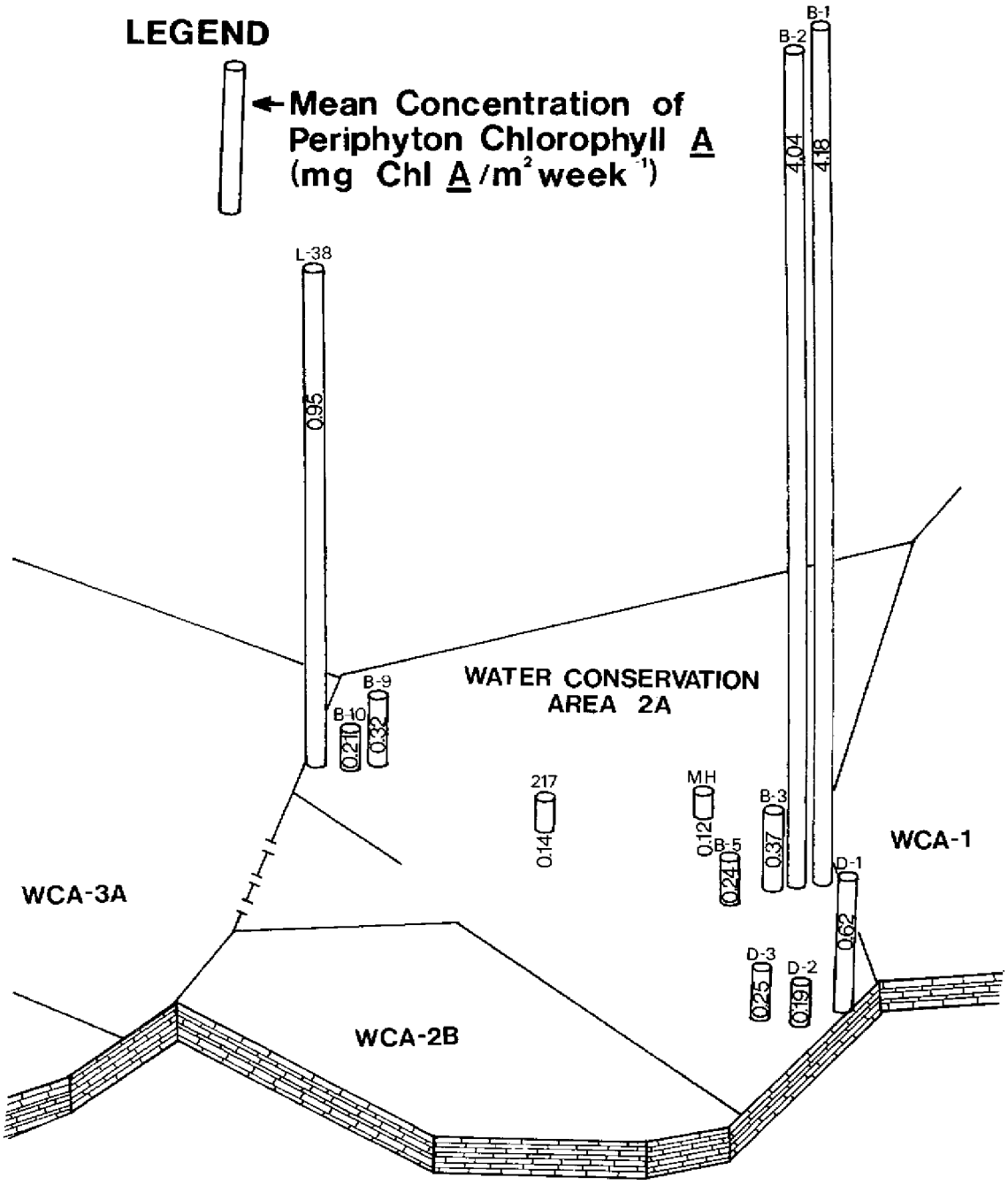


FIGURE 12. **MEAN PERIPHYTON CHLOROPHYLL A PRODUCTION RATES AT 12 WCA SITES, FEBRUARY- APRIL 1978**

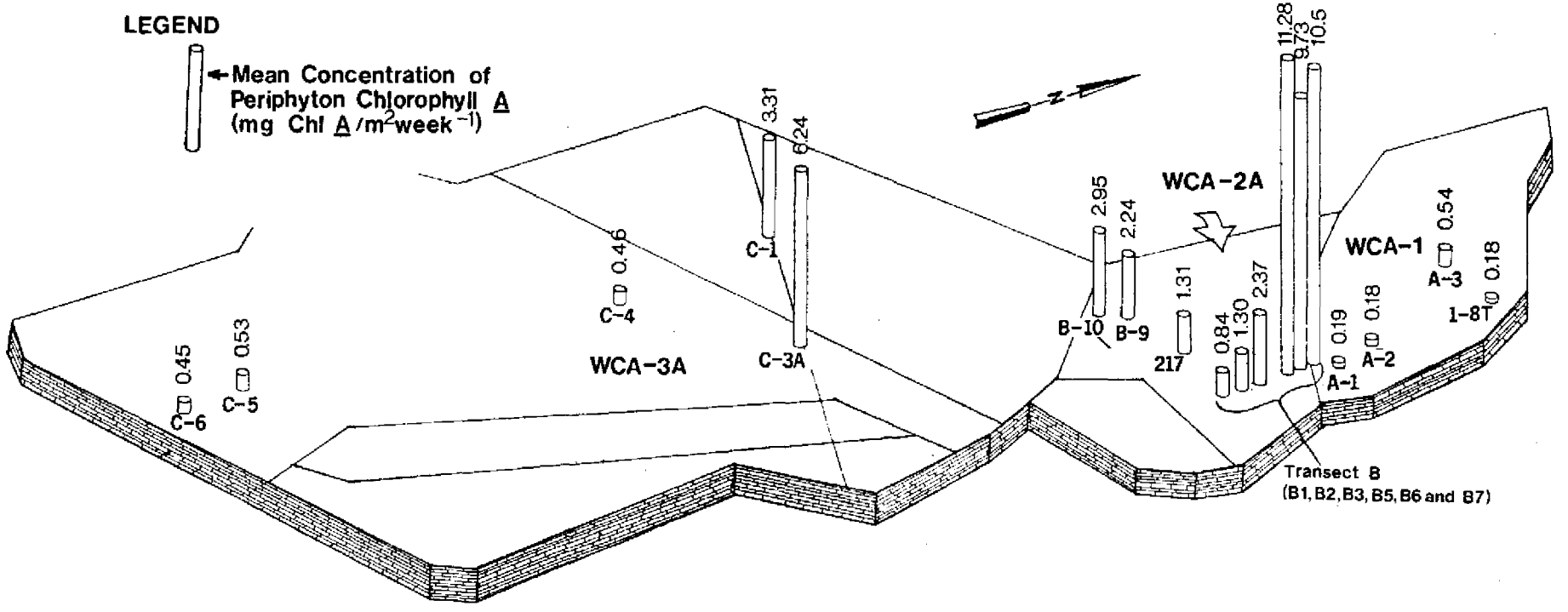


FIGURE 13. MEAN PERIPHYTON CHLOROPHYLL A PRODUCTION RATES AT 18 WCA SITES, JULY-AUGUST 1978.

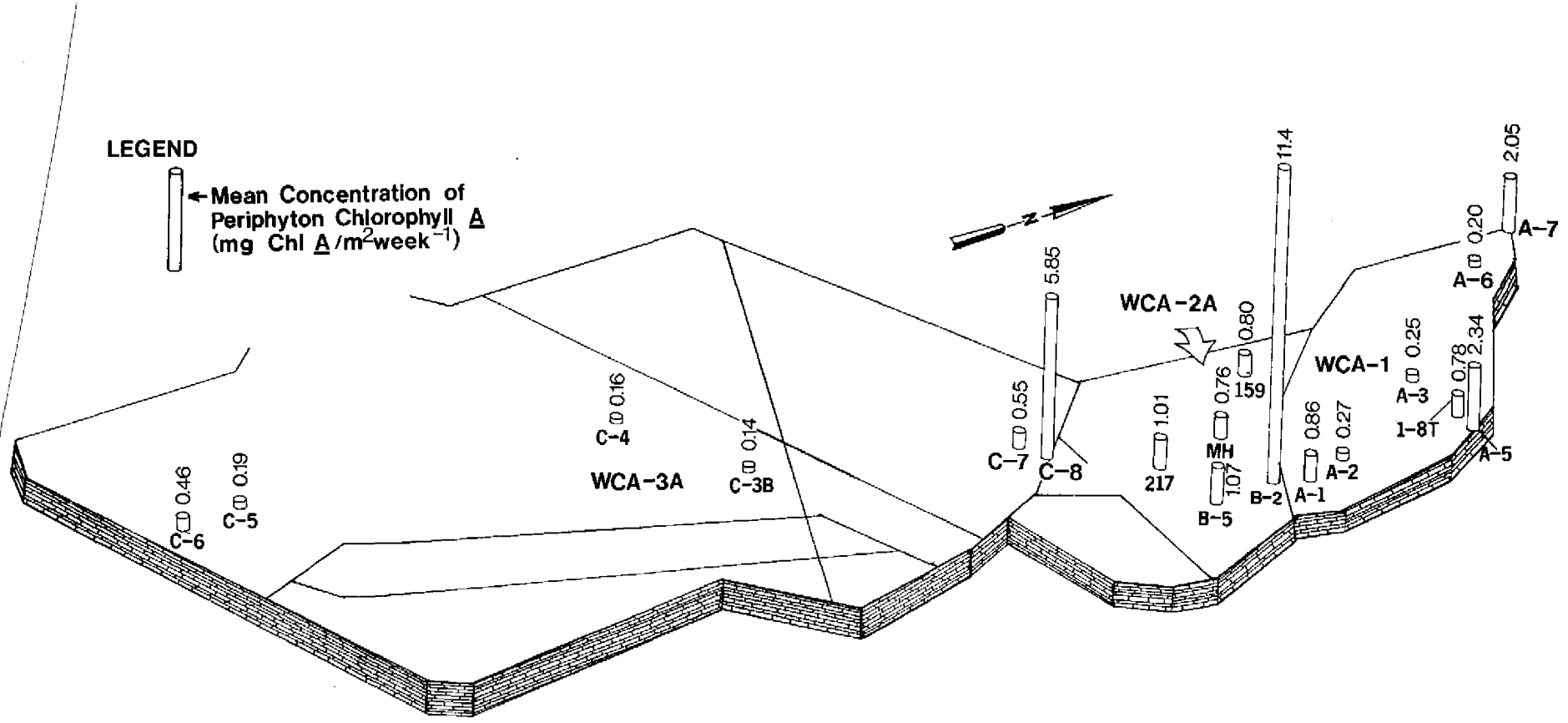


FIGURE 14. MEAN PERIPHYTON CHLOROPHYLL A PRODUCTION RATES AT 18 WCA SITES, NOVEMBER 1978-JANUARY 1979.

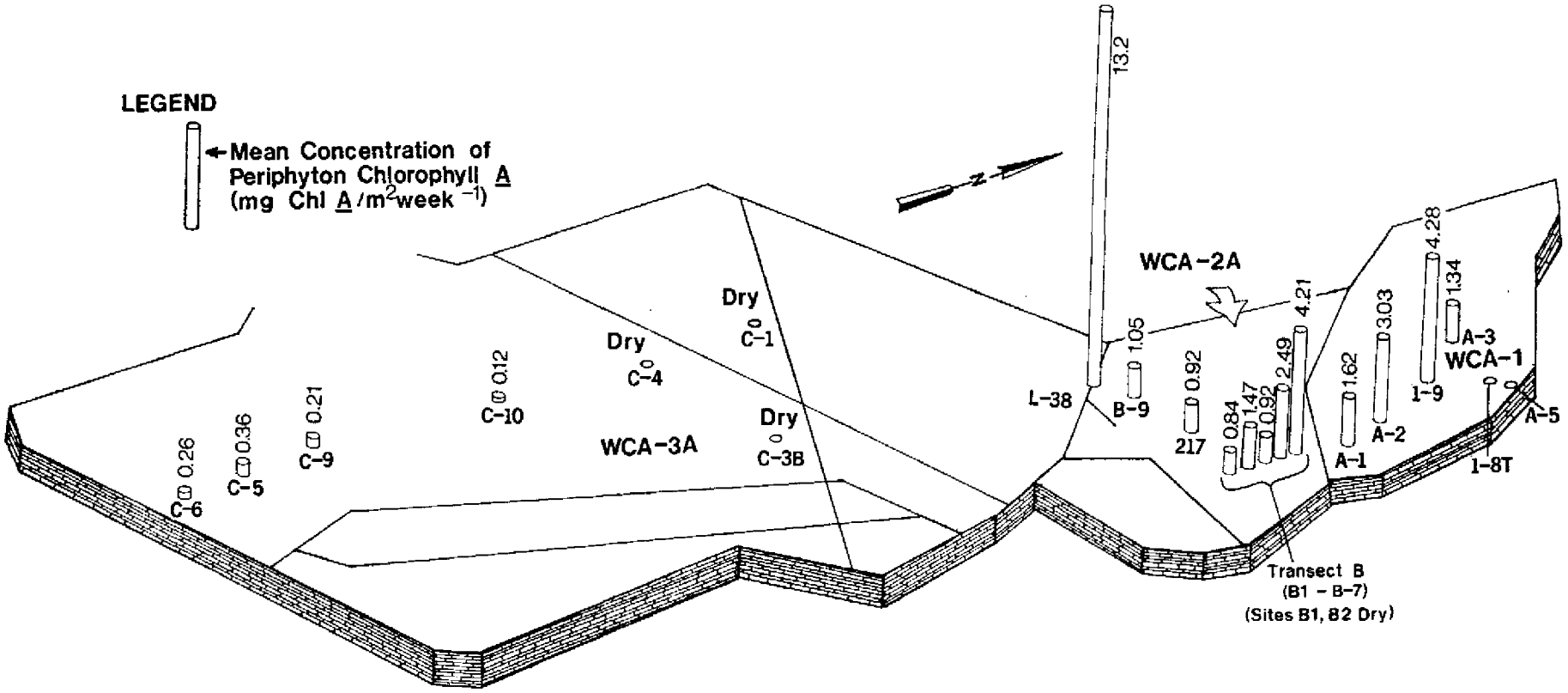


FIGURE 15. MEAN PERIPHYTON CHLOROPHYLL A PRODUCTION RATES AT 16 WCA SITES, JUNE-AUGUST 1979.

Analyses of variance techniques and Tukey's procedure showed significantly higher chlorophyll a concentrations present at peripheral marsh sites as compared to interior sites. Periphyton pigment concentrations were consistently high at sites located immediately south of the S-10 structures in WCA-2A (Sites B-1, B-2, and B-3) where mean chlorophyll a production ranged from 4.0 - 11.4 mg m^{-2} wk^{-1}. Other significantly high production rates were observed at the L-38 canal site in WCA-2A (13.2 mg m^{-2} wk^{-1}), and C-8 located west of S-11 in WCA-3A (6.24 mg m^{-2} wk^{-1}).

Chlorophyll a production at interior WCA-2A and WCA-3A sites were 5-100 times lower than levels recorded from peripheral marsh sites. Average chlorophyll a concentrations for the interior of WCA-3A ranged from 0.06 - 0.53 mg m^{-2} wk^{-1}, while averages for WCA-2A interior sites ranged from 0.12 - 2.37 mg m^{-2} wk^{-1}.

Periphyton chlorophyll a production rates were also low in WCA-1 during the July-August 1978 and November 1978-January 1979 sampling periods with values ranging from 0.18 - 0.25 mg m^{-2} wk^{-1}. However, during low water conditions in June - August of 1979, the WCA-1 sites produced significantly higher accumulations of chlorophyll a ranging from 1.34 - 4.28 mg m^{-2} wk^{-1} (Figure 15).

Nutrient Content of the Periphyton

Gerloff and Skoog [25] proposed that concentrations of nitrogen and phosphorus in algal cell tissue may be used to measure the availability of these elements in surface waters. The nutrient status of surface waters in the WCA's were examined by analysis of the nutrient content of the periphyton during the summers of 1978 and 1979. This was an attempt to define relationships that may exist among (a) concentrations of dissolved nutrients in marsh water; (b) concentrations of nutrients in

periphyton plant tissue; and (c) the effects of (a) and (b) on periphyton chlorophyll a production.

Tables A-5 and A-6 present the average nutrient content of marsh water and periphyton plant tissue along with corresponding periphyton chlorophyll a production rates for the summers of 1978 and 1979. Table C-2 provides regression analysis for the phosphorus and nitrogen content of the marsh, periphyton cell tissue and associated chlorophyll a production rates.

The phosphorus content of natural substrate periphyton was very low (<0.01 - 0.03% P) at interior WCA-2A and WCA-3A sites and high at peripheral sampling sites located near canal water inflows. Highest periphyton tissue P content was at Stations B-1, B-2, and B-3 (0.19 - 0.33% P) located south of the S-10 structures; Sites C-1 and C-3A located on the Miami Canal; and the L-38 site located on the L-38 canal in WCA-2A (Tables A-5, A-6).

The nitrogen content of the periphyton ranged from 0.8 and 3.5% N among all sampling sites. The nitrogen content of algae was higher at peripheral sampling sites and lower at interior WCA-2A and WCA-3A sites (Tables A-5, A-6).

Comparisons of periphyton tissue nitrogen to phosphorus (N:P) ratios across the WCA's are presented in Figures 16 and 17. Nitrogen: phosphorus ratios were significantly lower at peripheral sampling sites receiving agricultural surface water runoff. Lowest N:P ratios were encountered at sites located south of the S-10 structures. Nitrogen: phosphorus ratios were significantly higher at interior WCA-2A and WCA-3A sites in both surveys. Overall average N:P ratios for interior WCA-2A sites in both surveys were 116 ± 41.6, while interior WCA-3A sites had an overall N:P ratio of 128 ± 28.9.

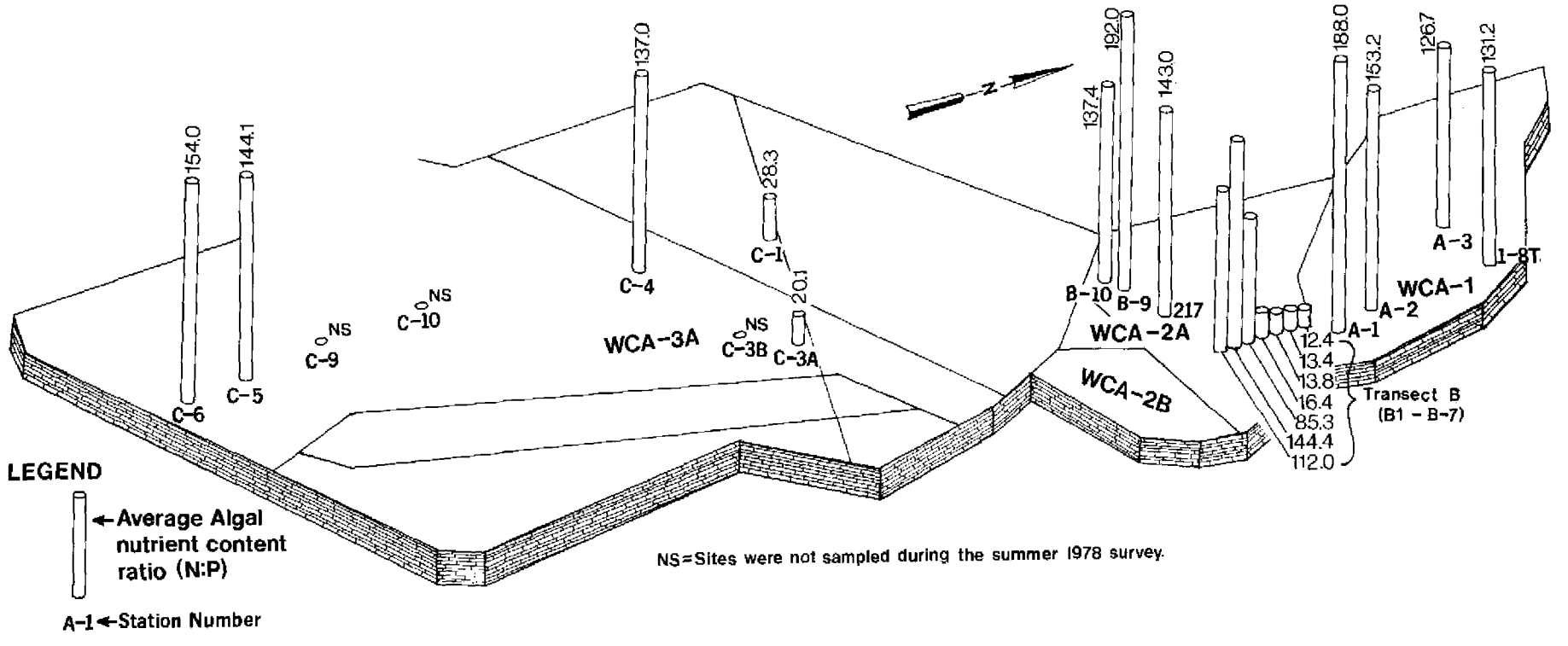


FIGURE 16. AVERAGE NITROGEN: PHOSPHORUS RATIOS FOR PERIPHYTON PLANT TISSUE AT 20 WCA SITES, JULY-AUGUST 1978.

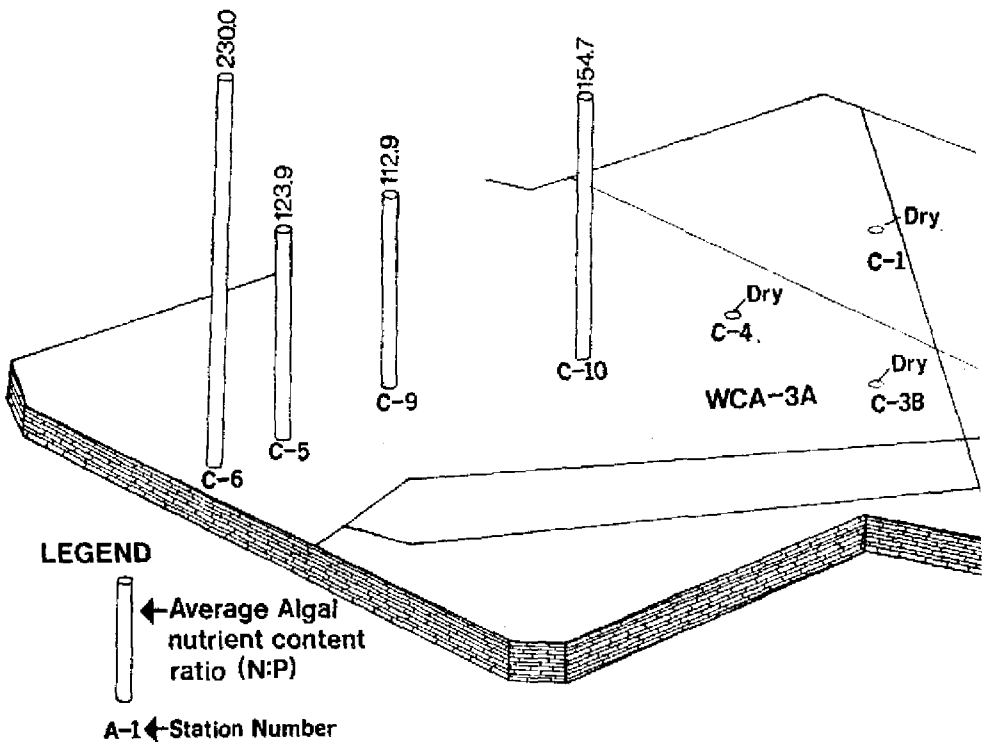
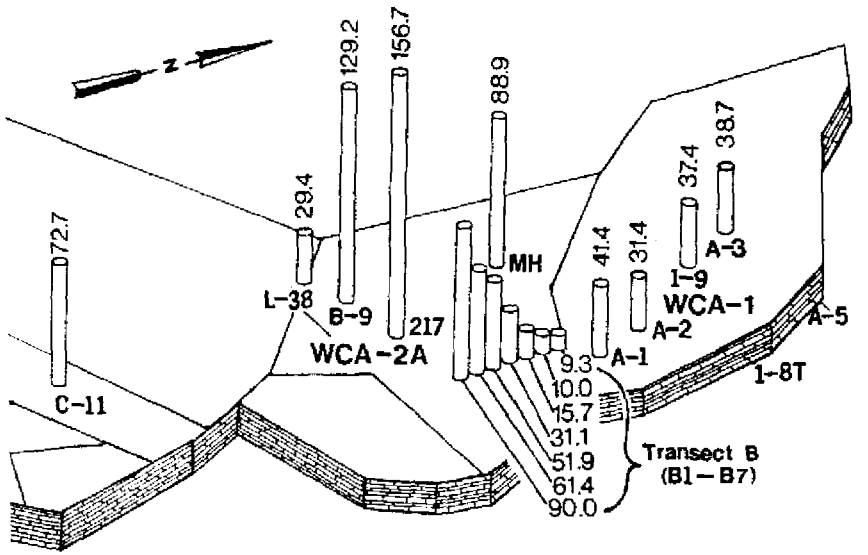


FIGURE 17. AVERAGE NITROGEN: PHOSPHORUS RATIOS FOR



PERIPHYTON PLANT TISSUE AT 20 WCA SITES, JULY-AUGUST 1979.

A departure from this trend was noted in WCA-1. In summer 1978, N:P ratios from the interior of WCA-1 (149 ± 28.3) were much higher than those reported during the 1979 survey (37 ± 4.2).

Concentrations of total dissolved P in marsh water were highly correlated with supplies of P in periphyton plant tissue (Table C-2). Relationships between concentrations of inorganic nitrogen in marsh water and the nitrogen content of the algae were weak and nonsignificant.

Marsh water P was significantly correlated with the N:P content of the algae (Table C-2). As the phosphorus content of the marsh water increased, periphyton tissue N:P ratios decreased exponentially as illustrated in Figure 18a. A similar exponential relationship existed between periphyton chlorophyll a production and the N:P content of the algae. As chlorophyll a concentrations increased, the cell tissue N:P ratio decreased exponentially (Figure 18b). A significant linear relationship was noted between the concentrations of total dissolved P in marsh water and periphyton chlorophyll a production (Table C-2).

Linear relationships between the nitrogen content of the marsh water and periphyton chlorophyll a production were weak and significant just above the 0.05 probability level. Relationships between the nitrogen content of the marsh water and periphyton tissue N:P ratios were also weak and nonsignificant (Table C-2).

Diatom Community Analysis

Although diatoms did not represent the dominant algal flora of the interior marsh, this group of algae was chosen for intensive study because of their wide use as water quality indicator organisms [8, 65, 104, 106].

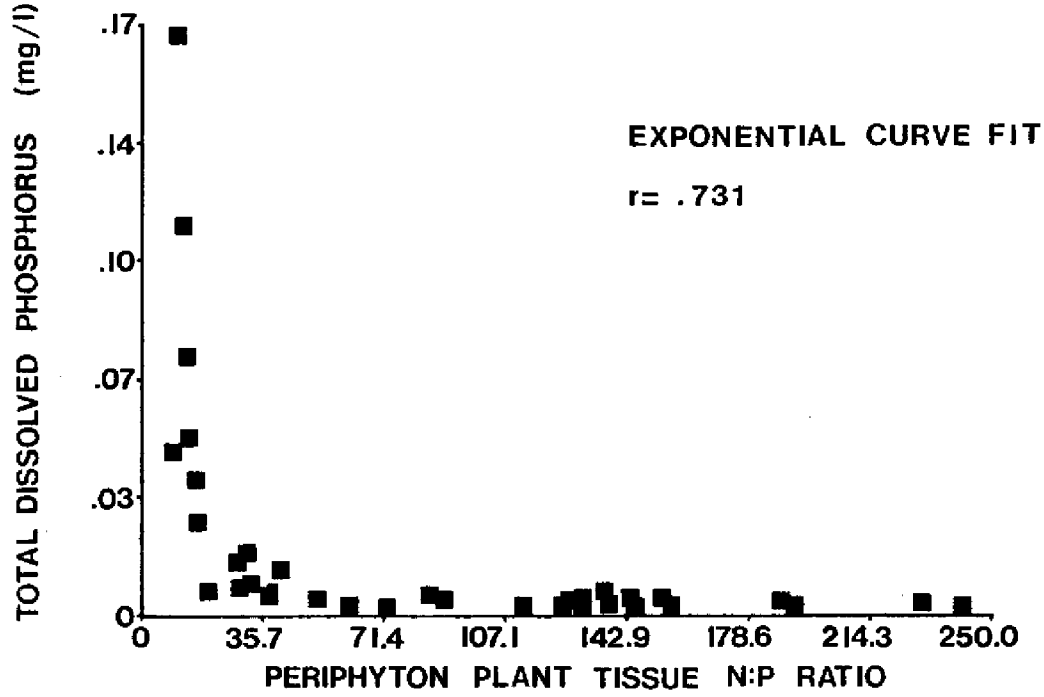


FIGURE 18a. MARSH WATER PHOSPHORUS VS. PERIPHYTON TISSUE N:P RATIO.

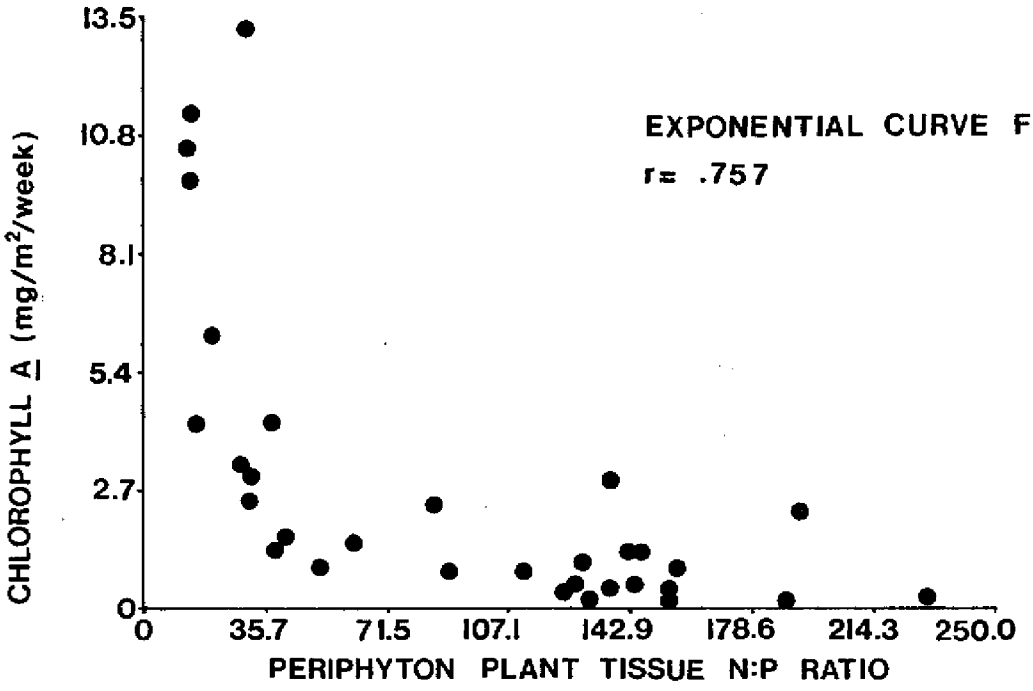


FIGURE 18b. PERIPHYTON CHLOROPHYLL A VS. PERIPHYTON TISSUE N:P RATIO.

A total of 118 species of diatoms representing 25 genera were identified from glass slide substrates. Table A-2 presents a detailed list of all diatom species recorded, while Table 6 presents a list of the more common diatom species characteristic of each WCA.

Diatom community structure differed between the three WCA's and also between interior and peripheral sites within each area. The most unique diatom assemblages encountered were those species collected from the interior of WCA-1. These sites were low in ionic content, acid, soft water marsh habitats with low to moderate concentration of nutrients present. Characteristic diatom species of the interior WCA-1 sites were Cymbella amphioxys, Anomoeoneis serians v. brachysira, Anomoeoneis serians, Anomoeoneis vitrea, Frustulia rhomboides v. saxonica, F. rhomboides v. crassinervia, Cymbella minuta v. silesiaca, Nitzschia sp. 7 sp. nov., Eunotia naegeli, Synedra tenera, Pinnularia biceps, Navicula subtillisima, and Stenopterobia intermedia.

Cymbella amphioxys, Anomoeoneis serians v. brachysira, Anomoeoneis vitrea, Synedra tenera, and Eunotia naegeli were the four most abundant diatoms present at these sites appearing as dominant or co-dominant species in the summers of 1978 and 1979. Table 6 lists a number of these species as reliable indicator organisms of acid, soft water environments, low in calcium and bicarbonate content [32, 62, 66].

In contrast, diatom communities at interior WCA-2A and peripheral sites located around WCA-1 were dominated by the following diatom species: Mastogloia smithii v. lacustris, Rhopalodia gibba, Synedra pahokeensis sp. nov., Anomoeoneis vitrea, Cymbella microcephala, C. ruttneri, C. minuta v. pseudogracilis, and Nitzschia sp. 7 sp. nov. These sites were characterized

TABLE 6. CHARACTERISTIC DIATOM FLORA AT WCA SAMPLING SITES WITH GENERAL NOTES AS TO THEIR WATER QUALITY PREFERENCES

Interior WCA-1
(Sites A-3, 1-9)

Cymbella amphioxys*-A

Anomoeoneis serians v. brachysira-A

Anomoeoneis serians-A

Anomoeoneis vitrea-I

Cymbella minuta v. silesiaca-I

Eunotia spp.

Frustulia rhomboides v. saxonica-A

Navicula subtillisima-A

Pinnularia spp.-A

Stenopterobia intermedia-A

Peripheral WCA-1
(Sites A-5, A-1, 1-8T)

Mastogloia smithii v. lacustris*-H

Anomoeoneis vitrea*-I

Rhopalodia gibba-H

Cymbella minuta v. psuedogracilis

Cymbella ruttneri

Synedra pahokeensis sp. nov.

Nitzschia sp. 7 sp. nov.

Interior WCA-2A
(Sites B-5, B-6, B-7, 217, B-9)

Mastogloia smithii v. lacustris*-H

Rhopalodia gibba-H

Synedra pahokeensis sp. nov.

Anomoeoneis vitrea-I

Cymbella microcephala-I

Cymbella ruttneri

Cymbella minuta v. psuedogracilis

Nitzschia storchii sp. nov.

Peripheral WCA-2A
(Sites B-1, B-2, B-3, L-38)

Achnanthes exigua v. heterovalve-H

Gomphonema parvulum*-E,I

Nitzschia amphibia-E

Nitzschia sp. 7 sp. nov.

Nitzschia palea-E,I

Nitzschia subtilis

Nitzschia tarda

Navicula rhyncocephala v. germani-E,H

Navicula confervaceae-E,I

Navicula tripunctata v. schizomoides-H

Synedra radians-H

Interior WCA-3A
(Sites C-3B, C-4, C-5, C-6, C-10)

Cymbella ruttneri*

Cymbella minuta v. psuedogracilis-MH

Anomoeoneis vitrea-I

Mastogloia smithii v. lacustris-H

Interior WCA-3A
(Sites C-3B, C-4, C-5, C-6, C-9, C-10)

Cymbella ruttneri*

Cymbella minuta v. psuedogracilis

Anomoeoneis vitrea-I

Mastogloia smithii v. lacustris-H

Peripheral WCA-3A
(C-1, C-3A)

(No clear dominant assemblage)
Common Species:

Nitzschia obtusa

Nitzschia amphibia-E

Cyclotella meneghiniana-E,I

Mastogloia smithii v. lacustris

Amphora veneta-H

KEY:

A = acid, soft water indicator species

H = alkaline, hard water species

E = indicator species of eutrophic water quality

I = indifferent to calcium and hydrogen ion (pH) concentrations

* = dominant species in the Water Conservation Areas

Literature References: Patrick and Reimer, 1966, 1973; Hustedt, 1930; Lowe, 1974.

as hard water, alkaline habitats with high concentrations of bicarbonate, chloride, calcium, and sodium ions. Nitrogen and phosphorus concentrations were very low at these sites.

Diatom community structure at the WCA-3A sites were generally similar to those found in WCA-2A and peripheral WCA-1 sites. However, a shift in diatom dominance was observed in WCA-3A where the Mastogloia - Rhopalodia - Synedra complex of WCA-2A was replaced by Cymbella ruttneri and Cymbella minuta v. psuedogracilis. Concentrations of major ions at the WCA-3A sites were moderately high with respect to calcium and bicarbonates and low in chloride concentrations. Nitrogen and phosphorus concentrations were at or below detection limits in each survey. Common taxa shared by all the interior WCA-3A sites were Cymbella ruttneri, Cymbella minuta v. pseudogracilis, Mastogloia smithii v. lacustris, Anomoeoneis vitrea, Cymbella muelleri, Cymbella microcephala, Gomphonema affine v. insigne, and Gomphonema intricatum v. vibrio.

Diatom species occurring at peripheral sites around WCA-2A and WCA-3A were also unique. Common species occurring at Station B-1, located south of the S-10C structure were Gomphonema parvulum, Navicula rhyncocephala v. germanii, Nitzschia palea, Nitzschia amphibia, and Achnanthes exigua v. heterovalva. Peripheral WCA-2A sites (B-2 and B-3) located further south of the S-10 structures into the marsh showed a shift in dominance to the genus Nitzschia. The characteristic diatom flora at these sites during both summer surveys were Nitzschia amphibia, N. sp. 7 sp. nov., N. sigmoidea, N. cf. spiculoides, N. brevirostris, N. congelensis, N. palea, N. cf. subtilis, N. tarda, and Gomphonema parvulum. Peripheral sites in WCA-3A shared a number of common taxa with the peripheral sites of WCA-2A. Characteristic species at these sites were Nitzschia obtusa, Cyclotella meneghiniana, Nitzschia amphibia, and Mastogloia smithii v. lacustris.

Periphyton Species Diversity

Periphyton assemblages were compared utilizing the Shannon index of general diversity [59]. Figures 19 and 20 present the spatial distribution of periphyton species diversity in the WCA, while Table C-3 presents the results of Tukey's multiple comparison procedure for periphyton species diversity indices in 1978 and 1979. Periphyton species diversity was lowest in WCA-2A at Sites B-2 and B-3 located south of the S-10 discharge structure (mean range of 1.3 - 1.4) and highest at Sites A-2, A-3 and 1-9 located in the interior of WCA-1 (mean range of 3.8 - 4.2).

In 1978, algal species diversity at Sites B-2 and B-3 were significantly lower than all other sites sampled due to the dominance of the filamentous blue-green, Microcoleus lyngbyaceus. In 1978 and 1979, interior WCA-1 sites had significantly higher algal species diversity when compared to the remaining WCA sites due to the high numbers of desmid and green algal species present.

In WCA-1, algal species diversity was higher at interior sites and lower at peripheral sites. With the exception of Sites B-2 and B-3 in WCA-2A, interior sites in WCA-2A had lower indices of diversity in comparison to peripheral WCA-2A sites. There were no significant differences in algal species diversity between sites located in the interior of WCA-3A, the interior of WCA-2A, and the periphery of WCA-1 (Table C-3).

Statistical Results

Three statistical methods (linear regression, factor analysis, and stepwise multiple regression) were used to assess underlying relationships between biological and physiochemical variables. Due to the skewed distribution of three variables it was necessary to normalize these

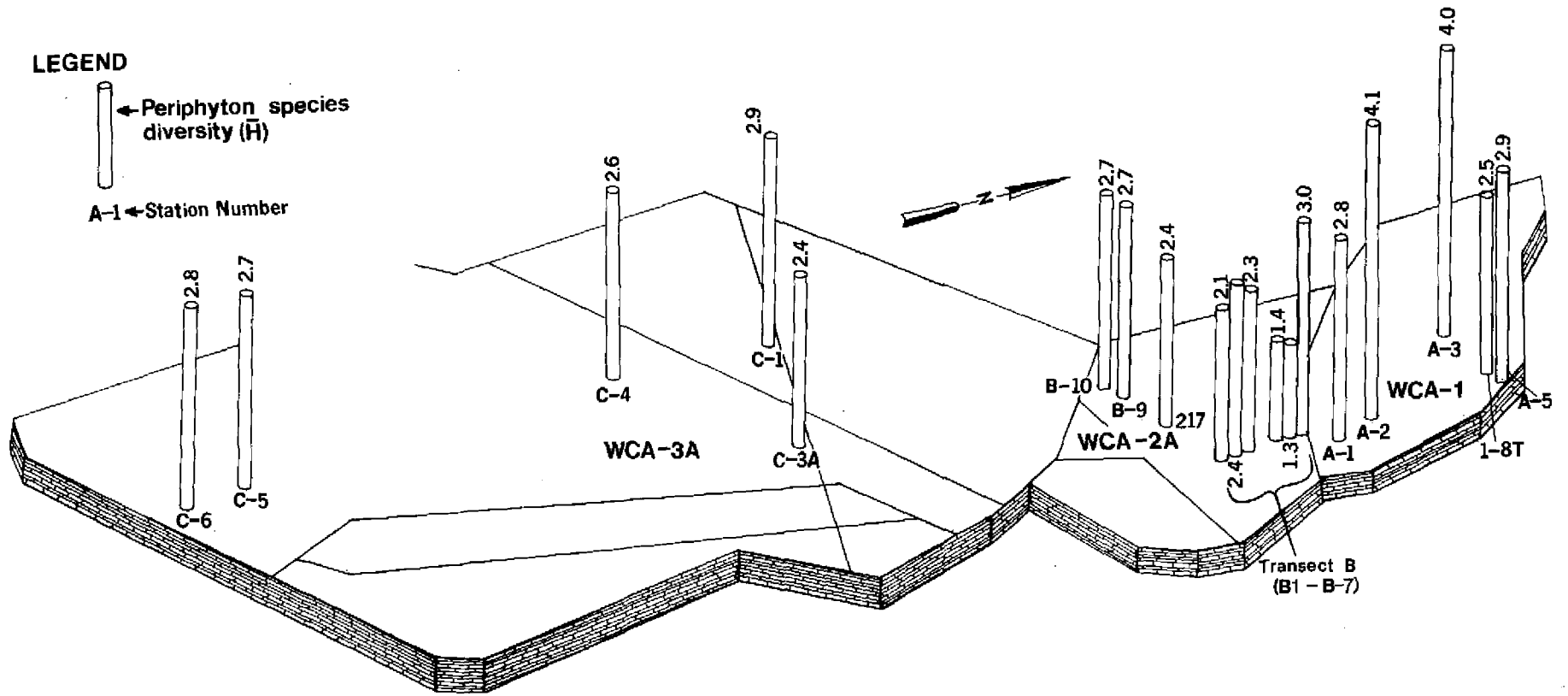


FIGURE 19. PERIPHYTON SPECIES DIVERSITY INDICES IN THE WCA, JULY-AUGUST 1978.

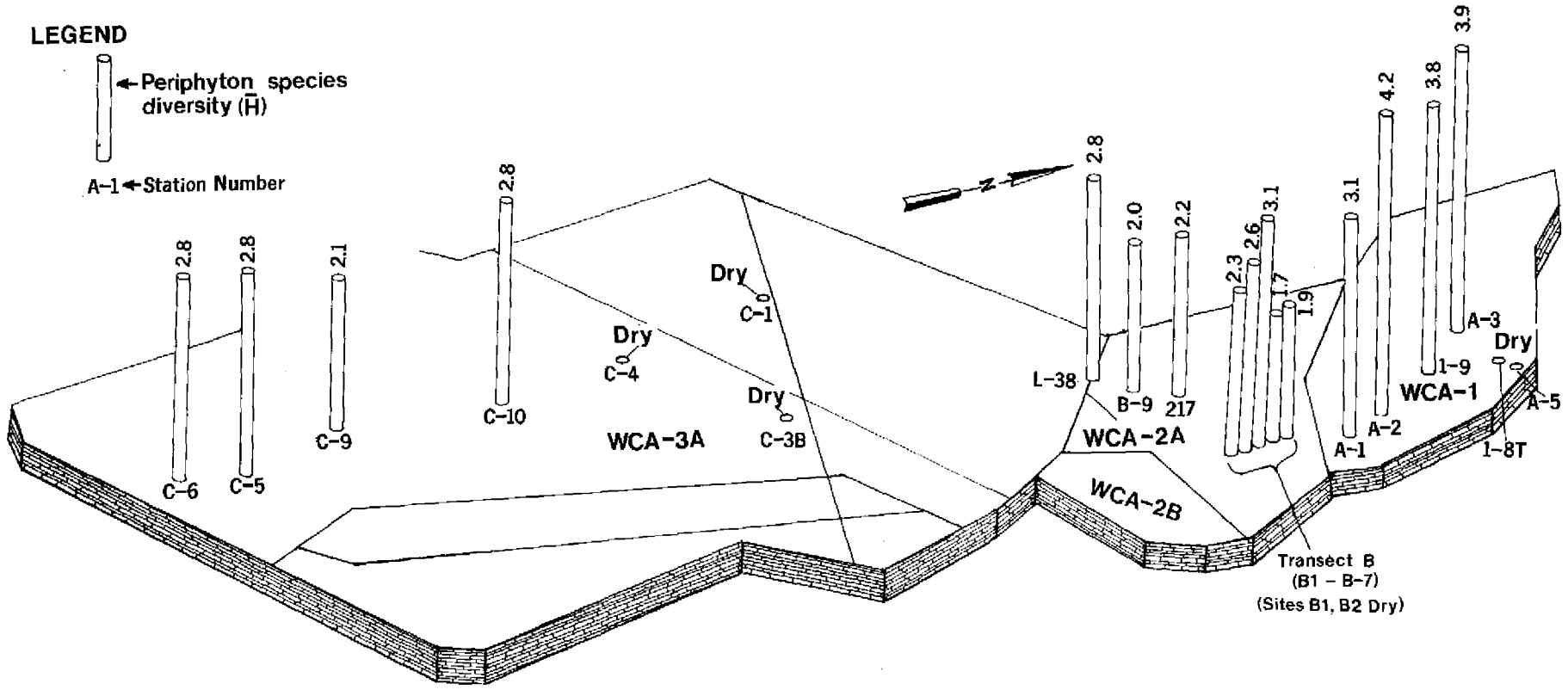


FIGURE 20 PERIPHYTON SPECIES DIVERSITY INDICES IN THE WCA, JUNE-AUGUST 1979.

data for use in regression and factor analysis models [85]. Periphyton population percentages were converted to arcsines, while cell volume and cell density data were transformed to logarithms (Log_{10}).

Linear correlation coefficients (r) between major ions (Ca, Mg, Na, K, Cl, SiO_2) and related parameters (alkalinity, specific conductance, and pH) were highly correlated (Table C-4). Results indicate that measurement of any one of the six major ions could easily be used to predict concentrations of the other five with a high degree of accuracy. Field measurements of specific conductance were also shown to be a reasonable predictor of major ion concentration (Table C-4). Highest correlations between variables were:

	r		r
Na vs. Cl	.979	Na vs. conductivity	.901
Mg vs. K	.978	Mg vs. conductivity	.897
Na vs. Mg	.974	Cl vs. conductivity	.888
Mg vs. Cl	.954	Na vs. SiO_2	.876
Ca vs. alkalinity	.946	Na vs. alkalinity	.872

Factor analysis was used to reduce the data matrix down to a relatively small number of common factors which account for the majority of variance in the data. Factor analysis reduced 26 variables to three biologically interpretable factors which accounted for 73 percent of the total variance (Table C-5).

The primary factor (Factor 1) contained in Table C-5 represents the variables Na, Cl, K, Mg, conductivity, TOC, SiO_2, alkalinity, Ca, desmid percent relative abundance, total numbers of algae species present, and periphyton species diversity. Factor 1 could be called

"periphyton response to major ion concentrations"; waters containing low concentrations of major ions were highly correlated with the development of desmid dominated periphyton communities, high total numbers of algae species present, and high periphyton species diversity. Factor 1 accounted for over 50 percent of the total variance contained within the data set.

The second factor (Factor 2) contained the variables marsh water total dissolved P, marsh water inorganic N, periphyton tissue phosphorus, periphyton tissue nitrogen and periphyton chlorophyll a production (Table C-5). Factor 2 might be termed "periphyton response to increased nutrient concentrations"; it showed significant correlations between increases in marsh water phosphorus and increases in both periphyton biomass (as measured by chlorophyll a) and the phosphorus content of the algae. In combination, Factors 1 and 2 accounted for over 65 percent of the total variance.

The third factor (Factor 3) contained the variables blue-green algae relative abundance, green algae relative abundance, pH, periphyton species diversity, and soil (peat) depth (Table C-5). Factor 3 was generally associated with the effects of hydrogen ion concentration (pH) on periphyton community structure and species composition. Factor 3 showed high correlations between the occurrence of filamentous blue-green algae under alkaline pH conditions while green algae populations, and high periphyton species diversity predominated under low or acidic pH and deep soil (peat) conditions.

Taken together, Factors 1, 2, and 3 underline the importance of the effects of major ion and nutrient concentrations on periphyton growth and development in the WCA. Water depth, hydroperiod length,

diatom relative abundance, periphyton cell volume, and cell density were not significantly correlated with any other variable in the factor analysis.

Results of a stepwise multiple regression analysis between a single biological variable and 15 physiochemical variables are presented in Table C-6. Multiple regression analysis indicated that marsh water phosphorus concentrations, major ion content, alkalinity, and hydrogen ion concentration (pH) were the four most consistently important physiochemical variables which influenced periphyton growth rates, species composition, and species distribution in the WCA. Marsh water phosphorus content was highly correlated with increases in periphyton biomass (as measured by chlorophyll a) and the phosphorus content of periphyton cell tissues (Table C-6). Low concentrations of major ions (Mg, K) in marsh water were significantly correlated with the development of desmid periphyton communities. Periphyton species diversity and total numbers of algae species present were highest under acid, soft water (low pH, low alkalinity) conditions. Filamentous blue-green relative abundance was highest under alkaline pH conditions. Water depth and hydroperiod length were not significantly correlated with the development of periphyton communities on glass slides in the multiple regression analysis of the 1978-1979 data (Table C-6).

Comparison of Algae Communities Grown on Artificial and Natural Substrates

A pilot survey of periphyton growth on natural substrates (Typha sp. and Cladium jamaicense leaves) and artificial substrates (glass slides) was conducted in the early phases of the project to measure the potential effect of selective substrate colonization by the marsh periphyton. After 30 days incubation in WCA-2A, both natural and artificial substrates were colonized by similar species of algae. The filamentous blue-green,

Schizothrix calcicola, and a number of diatom species (Mastogolia smithii v. lacustris, Anomoeoneis vitrea, Synedra pahokeensis sp. nov.) were the predominant algae colonizing all substrates. Glass slide populations produced less chlorophyll a and lower total number of species per unit area compared to periphyton grown on natural substrates. Range and average values for chlorophyll a production rates, cell density estimates, total numbers of species, and species diversity indices for each substrate type are presented in Table 7, while results of a two-tailed t-test comparing substrate types are presented in Tables C-7 thru C-10.

Results of the t-test indicated significant differences between mean chlorophyll a concentrations on glass slides incubated at the water surface versus natural substrates (Typha and Cladium) incubated at mid-depth (Table C-7). Chlorophyll a concentrations from glass slides and Typha substrates incubated at mid-depth were similar but Cladium substrates had higher chlorophyll a levels in comparison to the mid-depth glass slides. Mean chlorophyll a production over the 30 day incubation period ranged from 0.51 mg m^{-2} wk^{-1} for slides incubated at water surface to 1.16 mg m^{-2} wk^{-1} for freshly cut Cladium substrates incubated at mid-depth (Table 7). Periphyton chlorophyll a was significantly higher on freshly cut sawgrass leaves in comparison to all other substrates tested.

Periphyton cell densities (Log_{10} cell/mm^2) showed no significant differences between populations grown on surface glass slides or natural substrate materials. Glass slides incubated at mid-depth showed no differences in cell density when compared to Typha substrates incubated at mid-depth. However, both Cladium sp. substrates incubated at mid-depth produced higher cell densities compared to glass slides incubated at mid-depth (Table C-8).

TABLE 7. MEAN AND RANGE COMPARISONS FOR PERIPHYTON CHLOROPHYLL A PRODUCTION RATES, CELL DENSITIES, TOTAL NUMBER OF SPECIES, AND SPECIES DIVERSITY INDICES FROM 5 TEST SUBSTRATES (OCTOBER-NOVEMBER, 1977)

Description of Substrate	Incubation Depth (cm)	Chlorophyll a[a] ($mg\ m^{-2}\ wk^{-1}$) Mean	Range	Cell Density[b] (log_{10} cells/mm^2) Mean	Range	Total Numbers of Species[b] Mean	Range	Species Diversity[b] (H) Mean	Range
1. Surface Glass Slides	2.5	0.51	0.35-0.96	3.11	2.97-3.21	16.2	12-19	1.72	1.60-1.86
2. Mid-depth Glass Slides	30	0.63	0.42-0.82	2.95	2.81-3.07	15.6	12-18	1.90	1.82-2.00
3. Mid-depth Typha sp. (dead leaves)	30	0.74	0.23-0.93	3.09	2.96-3.16	20.6	18-23	2.06	1.88-2.25
4. Mid-depth Cladium sp. (dead leaves)	30	0.80	0.56-1.31	3.18	3.09-3.25	21.8	20-25	2.23	2.14-2.38
5. Mid-depth Cladium sp. (freshly cut leaves)	30	1.16	0.63-1.54	3.39	3.18-3.72	20.6	17-24	2.16	2.07-2.22

[a] Mean of 15 replicates per substrate type

[b] Mean of 5 replicates per substrate type

There were no differences between the total number of species of algae colonizing surface glass slides and natural substrate materials. Glass slide communities of algae incubated at mid-depth were similar in total number of species present when compared to the Cladium substrates. However, Typha substrates had higher total numbers of species present when compared to the mid-depth glass slides (Table C-9).

Periphyton species diversity indices were significantly higher on natural substrates in comparison to communities of algae on developing glass slides incubated at the surface. No differences in species diversity were noted between glass slides and Typha substrates incubated at mid-depth; however, both Cladium substrates had significantly higher diversity indices in comparison to the mid-depth glass slides (Table C-10).

DISCUSSION

The species composition of periphyton communities in the WCA resemble those commonly encountered in lentic (standing water) environments. The majority of these algae were filamentous species having poorly developed holdfast mechanisms forming a thin gelatinous coating on submerged substrates. The delicate nature of these communities created inherent sampling problems as algae could be easily dislodged from glass slides during sample collection.

Filamentous blue-green algae were the most conspicuous feature of the WCA periphyton community. Periphyton species composition in WCA-2A, WCA-3A, and the periphery of WCA-1 closely resembled the "calcareous periphyton" described first by Van Meter [99, 100] and later by Gleason and Spackman [27] for Everglades National Park. Calcareous periphyton refer to that association of algae in which blue-green algae (Mxyophyceae) dominate and coat submerged macrophyte vegetation with a felt-like growth of algal filaments encrusted with calcium carbonate ($CaCO_3$) crystals [27]. In the deeper slough communities of WCA-2A and WCA-3A, floating mats of blue-green algae attached to Utricularia (bladderwort) plants cover the entire water surface during late summer and fall. In wet prairie communities which experience annual wet and dry cycles, calcareous periphyton may briefly form on plant surfaces and desiccate under dry conditions, returning organic matter and precipitated $CaCO_3$ to the marsh sediment. The calcareous periphyton community in this study was volumetrically dominated by two species of blue-green algae, Schizothrix calcicola (Ag) Gomont, and Scytonema hofmannii Ag.

In contrast, interior WCA-1 sites supported a rich desmid and filamentous green algae community. Interior WCA-1 periphyton were similar to the algal communities of the Okefenokee Swamp, Georgia [4, 24] and a number of temperate, acid water, peat forming bog communities [71, 112, 113]. Desmids and filamentous green algae (Mougeotia sp., Spirogyra spp., Oedogonium spp., and Bulbochaetae spp.) were the dominant periphyton of both the interior of WCA-1 and the Okefenokee Swamp.

Peripheral marsh sites adjacent to canals supported a specialized community dominated by the filamentous blue-green algae, Microcoleus lyngbyaceus, and a number of pollution indicator diatom species.

Statistical results (factor analysis, stepwise multiple regression) showed that periphyton species composition and biomass production rates on glass slides incubated at similar depths (one inch below surface) over similar time periods (6-8 weeks) were significantly affected by site differences in marsh water major ion content, pH, alkalinity, and phosphorus concentrations. These results contrast with Van Meter's [99, 100] work which suggested that water depth and hydroperiod lengths were the controlling factors regulating periphyton standing crop and species composition in Everglades National Park. Water depth and hydroperiod length did not significantly affect periphyton communities grown on glass slides in the WCA.

Differentiation should be made concerning measurements of periphyton biomass in these earlier studies and this investigation. Van Meter [99, 100] and Gleason and Spackman [27] measured periphyton biomass in terms of standing crop (amount of organic biomass present at any given time). This study measured periphyton biomass as a rate (rate of chlorophyll a production over a specific time period). Under similar

water quality conditions, hydroperiod length and water column depth could be expected to influence the amount of algal biomass accumulated (standing crop) in the marsh over time. However, these variables would not necessarily influence the rate of algal biomass production.

Major ion concentrations (HCO_3^-, Ca^{++}, Na^+, Cl^-, Mg^{++}, and K^+) were found to be the controlling factor which influenced periphyton species composition in the WCA. Results of this study showed that desmid and filamentous green algae periphyton populations, periphyton species diversity, and total numbers of algae species present were highest at interior WCA-1 sites under low salinity*, low pH (acid) water conditions. Wetzel [109] and Hutchinson [37] report that desmids are one of the few algal groups that are found primarily in low salinity water, especially from acid pH, low calcium (<10 mg Ca/l), and low magnesium environments. Many studies describe desmids as calciphobic species (i.e., intolerant of high calcium concentrations) developing best under low calcium, low pH conditions. Results of our field studies did not find such straightforward relationships. Although green algae and desmid relative abundance were correlated with low pH, calcium proved to be a relatively poor predictor of desmid dominance in comparison to the magnesium and potassium content of the marsh water (Table C-6). These data compare with Moss' [56, 57] research on desmid ecology in which he found no evidence that desmids are regulated by calcium at concentrations greater than 1 mg Ca/l.

The desmid flora of the interior of WCA-1 was exceedingly rich with over 47 species† reported (Table A-2). As a result, desmids were

*The ionic salinity of inland fresh waters are usually expressed as the concentration of the four major cations, Ca^{++}, Mg^{++}, Na^+, and K^+ and the major anions, carbonate ($CO_3^=$), sulfate ($SO_4^=$) and chlorides (Cl^-) [108].

†This preliminary study describes some of the more common desmid species present in WCA-1. There are easily more than 100 species present as indicated by an unpublished SFWMD survey carried out by Drs. P. Gleason and G.F. Prescott in 1973.

significantly correlated with high species diversity indices and high total numbers of species present (Table C-5).

In contrast, filamentous blue-green periphyton were found to dominate in waters containing moderate to high concentrations of major ions (i.e. alkaline water conditions). Although blue-greens are found in a wide variety of environments, they are most often associated with alkaline habitats [62]. Fogg's [23] review of phytoplankton dominance in temperate lakes concludes that blue-greens are indicative of well buffered, alkaline water. The dominant WCA periphyton genus Schizothrix has been associated with the formation of calcium carbonate deposits in the Everglades [27], and in a variety of other alkaline freshwater and marine environments [16, 29, 53].

Highest concentrations of major ions occurred in WCA-2A which receives mineralized canal water discharges from the S-10 structure and pump station S-7 (Table 1). Concentrations of calcium (Ca^{++}) and bicarbonate (HCO_3^-) in WCA-2A were usually found at or near saturation* levels with respect to calcite. These data suggest that this water has recently been in equilibrium with the limestone (calcium carbonate) bedrock. Water budgets computed for the area estimate that about 57 percent of the surface water which flows across WCA-2A is derived from canal water inflows and is highly mineralized before it enters WCA-2A [53].

Lowest concentrations of major ions occurred at sites located in the interior of WCA-1. Concentrations of calcium and bicarbonate at interior WCA-1 sites remained well below saturation levels throughout the study. Comparison of the ionic content of interior WCA-1 marsh water with south

*Saturation levels were derived from an equilibrium nomogram of pH, calcium, and bicarbonate activities in solution with calcite at 1.0 atmosphere and 25°C [31].

Florida rainfall suggests that these waters are derived primarily from direct rainfall (Table 3).

Concentrations of major ions at interior WCA-3A and peripheral WCA-1 sites were roughly 3-10 times higher than those recorded at interior WCA-1 sites, and one-half the values reported from WCA-2A and therefore represent intermediate ranges of major ion concentration in the WCA (Table 1).

Multivariate analysis showed significant correlations between the abundance of filamentous blue-green periphyton and the hydrogen ion concentration (pH) of the marsh water (Tables C-5 and C-6). The pH of most freshwater systems is regulated largely by the bicarbonate "buffering capacity" of the water. Highly buffered waters containing high concentrations of bicarbonate tend to have relatively stable pH values in the neutral to alkaline ranges (above 7). Poorly buffered waters (low concentrations of minerals) usually have a slightly acid pH (5-6) resulting from the disassociation of carbonic acid (dissolved CO_2) in water [31, 109]. Blue-green periphyton communities were most prevalent in WCA-2A and WCA-3A and the periphery of WCA-1 under neutral to alkaline pH conditions while desmids and filamentous green algae dominated in acid water (low pH) situations. These results are similar to previous studies of periphyton in the Everglades [27, 99, 100].

Results of this study showed that increases in marsh water phosphorus were significantly correlated with increases in periphyton biomass production (as measured by chlorophyll a) and the phosphorus content of the periphyton (Tables C-5 and C-6). High concentrations of nitrogen and phosphorus consistently stimulated periphyton growth at WCA-2A sites located south of the S-10 structures (Figures 12 thru 15). Nutrient

uptake by marsh vegetation and peat soils in WCA-2A generally reduced nutrient concentrations and periphyton growth rates to background levels within a distance of 2.5 km south of the S-10 structure. These results are similar to previous water quality studies [26, 52, 53] in WCA-2A where high levels of nutrients were found to be present in the vicinity of the S-10 structures. Agricultural surface water runoff is a major contributor of nitrogen and phosphorus in the canal systems surrounding the WCA-1 and WCA-2A marshes [26, 49, 52, 103]. Davis and Harris [13] report that high water levels and increased nutrient concentrations have increased cattail standing crop in the northeast section of WCA-2A. This study and Gleason [26] have shown that elevated phosphorus levels in the marsh south of the S-10 structures dramatically increase periphyton biomass production and foster the development of a "specialized" algal community comprised of Microcoleus lyngbyaceus and a number of pollution tolerant diatom species.

In sharp contrast, interior WCA-2A and WCA-3A sites had very low concentrations of phosphorus and nitrogen present throughout the study (Figures 5 and 6). Comparison of supplies of nitrogen and phosphorus from marsh water and local rainfall (Table 3) suggests that bulk precipitation may be a major nutrient source for the interior WCA periphyton communities. Phosphorus and nitrogen were both potentially growth limiting nutrients at interior WCA sites due to their low availability. Periphyton chlorophyll a production at these interior sites was also very low and represents some of the lowest values reported in the literature (Figures 12 thru 15).

There are few comparable studies of periphyton chlorophyll a production in marsh environments. Table 8 presents minimum and maximum

Table 8. COMPARISONS OF PERIPHYTON CHLOROPHYLL A STANDING CROP AND CHLOROPHYLL A PRODUCTION RATES FROM A VARIETY OF AQUATIC HABITATS

Community	Chlorophyll a[1] Standing Crop (mg Chl a/ M^2)	Chlorophyll a[1] Production Rate (mg Chl a/M^2. wk^{-1})	Nutrient Concentration (µg/l) $(NO_3)N$	Nutrient Concentration (µg/l) $(PO_4)P$
Laboratory Streams, Oregon				
Light Adapted	480-2010	68-240		
Shade Adapted	140-1300	5-44	0-500	50-120
(McIntire and Phinney, 1965)				
Duwamish Estuary, Washington St.				
Annual Min.-Max.	NA[2]	2-100	~180	~200
(Welch et al, 1972)				
Silver Springs, Florida				
High production station	1500[3]	20	500	50
Low production station	500	2		
(Yount, 1956)				
Hyalite Reservoir, Montana				
Ammonia Enriched Stream	62-176	15-44	6	63
Downstream Control	8-15	2-7.5	5-8	60
(Marcus, 1980)				
Ohio River, Cincinnati, Ohio				
Aug.-Nov. 1967	5-18[4]	2.1-9.7[4]	NA	20
(Weber and McFarland, 1969)				
Tennessee River Reservoir				
Waconda Bay, Chattanoga, Tenn.				
Nitrogen Impacted Sites	18-38	4.5-17.5	500	10
Control Sites	2-18	1-9.0		
(Sullivan, et al, 1977)				
Carnation Creek Estuary, B.C.	17.2	8.6	98	22
Carnation Creek, B.C.	1.6	0.4	35	1.6
Ritherdon Creek, B.C.	2.3	0.6	73	1.0
(Stockner and Shortreed, 1976)				
Arctic Sea Ice	10-12	NA	NA	NA
(Appolonio, 1965 as cited by Moss, 1968)				
Everglades Water Conservation Areas				
Peripheral Marsh	20-120	4-13.2	150	90
Interior Marsh WCA-1	1-46	0.18-4.3	4	17
Interior Marsh WCA-2A	1-15	0.12-2.4	4	12
Interior Marsh WCA-3A	0.5-4.5	0.06-0.5	7	9

[1] Author has estimated Chl.a rate data by converting literature values into one standard unit.

[2] NA = data could not be converted to these units or was not available.

[3] Younts' data as reported by Odum, 1958.

[4] Chlorophyll a data back calculated from Weber and McFarland's (1969) autrophic index and biomass data.

chlorophyll a standing crop and production rates for various aquatic habitats. Periphyton chlorophyll a levels near the S-10 structures are comparable to rates measured in several eutrophic temperate riverine systems and to maximum chlorophyll a production rates measured in Silver Springs, Florida [116]. However, these rates do not approach values derived from artificial laboratory stream communities [50, 107].

Report of low periphyton growth rates at interior WCA sites may seen unlikely since floating mats of blue-green algae are a conspicuous feature of many portions of the interior WCA's during the late summer and fall months. Previous studies of Everglades periphyton [27, 99, 100] have reported large standing crops of periphyton algae (up to 351 g/m^2) in Taylor and Shark River Sloughs (Everglades National Park) and at peripheral sites in WCA-1 (up to 449 g/m^2). These conflicting observations are explained by the fact that although algal growth in the marsh is slow, it continues year round when water is present. During 1978-1979, many sites in WCA-2A and WCA-3A supported massive standing crops of blue-green algae representing growth over three to six years of continuous inundation.

Supplies of elemental phosphorus in periphyton cell tissue from interior marsh sites were low in comparison to reported "critical concentrations" required for normal aquatic macrophyte and algae growth (Table 9). Supplies of phosphorus in periphyton tissue were comparable to levels reported from Utricularia-periphyton communities in the Okefenokee Swamp [4] and from Everglades aquatic plants and organic peat soils [13, 87, 101]. Low concentrations of periphyton tissue phosphorus, chlorophyll a, and the low nutrient content of marsh water suggest nutrient limiting conditions at interior WCA-2A and WCA-3A

TABLE 9 . COMPARISON OF ELEMENTAL NITROGEN AND PHOSPHORUS CONCENTRATIONS IN ALGAE AND AQUATIC PLANTS FROM DIFFERENT ENVIRONMENTS.

Study	Elemental Nutrient Concentration %N	%P	N:P Ratio
"Critical concentrations" Producing maximum growth response in Microcystis spp. lab culture (Gerloff and Skoog, 1954).	4.0	0.2	20:1
Essential concentrations of N and P required for growth in freshwater plants (Vallentyne, 1974)	0.7	0.08	7:1*
Ranges of nutrient concentrations for aquatic macrophytes (Boyd, 1978).	1.46-3.95	.08-0.63	ND
Ontario, Canada Average periphyton nutrient content			
oligiotrophic lake	2.59	.06	43:1
fertilized lake	2.56	.18	14:1
(Stockner and Armstrong, 1971)			
Okefenoke Swamp, Georgia Nutrient content of Utricularia periphyton mats (ranges) (Bosserman, 1979)	1.73-3.09	.045-.075	38:1-41:1
Water Conservation Areas, Fla. Nutrient content of natural substrate periphyton (range of means)			
Peripheral WCA-2A sites	2.36-4.03	.067-.339	9:1-31:1
Interior WCA-2A sites	1.12-3.01	.006-.049	61:1-230:1
Interior WCA-1 sites	2.89-3.48	.019-.093	31:1-188:1
Everglades National Park, Fla. Periphyton mat, 4 miles South of Tamiami Trail ($\bar{x}$ of three samples)	1.45	.006	242:1

ND = No data

*Based on typical plant tissues of aquatic algae and macrophytes in the ratios of approximately 40 carbon: 7 nitrogen: 1 phosphorus per 100 dry weight.

sites. Low concentrations of available phosphorus in Everglades surface waters, soils, aquatic macrophytes, and the periphyton gives evidence that phosphorus is rapidly recycled through the ecosystem.

Significant differences in periphyton tissue phosphorus concentration were noted between interior sites and three peripheral marsh sites located south of the S-10C structure in WCA-2A. Increases in the phosphorus content of the algae at these three sites were highly correlated with increases in chlorophyll a production and the nutrient content of the marsh water (Tables C-2, C-5, C-6). Periphyton tissue phosphorus was well above the 0.2 percent "critical concentration" level reported necessary for producing a maximum growth response in blue-green algae (Table 9). High phosphorus uptake by peripheral marsh periphyton indicate these algae are storing phosphorus in excess of their growth requirements (i.e., luxury consumption) in response to S-10 nutrient enrichment.

Concentrations of nitrogen in periphyton tissue were comparable to ranges reported for Utricularia - periphyton mats from the Okefenoke Swamp, and ranges reported for most aquatic macrophytes (Table 9). The nitrogen content of WCA periphyton were always above Vallentyne's [98] 0.7 percent N "lower limit" at which growth may occur in freshwater plants and algae (Table 9). This suggests that nitrogen was present in adequate supply at all sites to permit algal growth. However, the nitrogen content of the majority of samples collected was usually below Gerloff and Skoog's [25] 4.0 percent "critical concentration" necessary to produce a maximum growth response in laboratory cultures of blue-green algae (Table 9). Although Gerloff and Skoog demonstrated nitrogen storage in blue-greens, our field data showed periphyton nitrogen levels

to be only weakly correlated with periphyton chlorophyll a production and marsh water nitrogen content (Tables C-2, C-5, C-6).

The lack of published field data concerning periphyton N:P ratios derived from similar environments makes comparisons difficult. Of the limited data available, interior Everglades periphyton N:P ratios are some of the highest reported, ranging from 61:1 - 230:1 (Table 8).

Studies of hard water lakes in Florida and in temperate regions of the world have often correlated the occurrence of large standing crops of planktonic blue-green algae with high nutrient concentrations. However, several investigators [37, 68] report blue-greens commonly develop in low nutrient, alkaline waters. Schizothrix calcicola and Scytonema hofmannii were shown in this study to grow well in alkaline, nutrient limited situations. This may be explained by the ability of some species of blue-greens to fix free nitrogen (N_2) from the atmosphere, converting it to nitrate for cell growth [79, 88, 89]. Although this study did not investigate the nitrogen fixing capabilities of blue-greens in the WCA, preliminary experiments have shown that nitrogen fixation may be an important aspect of periphyton nutrition in the WCA [28]. In addition, research on algal phosphate uptake kinetics has shown that some blue-greens are phosphorus limited at much lower concentrations when compared to green algae requirements [77]. Therefore, blue-greens may competitively exclude green algae in nutrient limited situations.

Several workers suggest that algal species composition and growth may be regulated by the availability of free carbon dioxide (CO_2) dissolved within the water column [40, 77]. In freshwater systems, inorganic carbon is present in three forms as free CO_2, bicarbonate (HCO_3^-), and carbonate ($CO_3^=$) ions. The relative abundance of the

three carbon species is dependent on the pH of the water. In acid (pH 5-6) softwater systems, free CO_2 is present as the dominant ion, while the HCO_3^- ion dominates in moderately alkaline (pH 7-9) environments [30, 36, 39, 108]. Experimental studies conducted by Shapiro [77] on algal dominance in midwestern lakes showed that waters artificially enriched with free carbon dioxide stimulated a rapid shift in dominance from blue-green to green algae. King [41] presented the supposition that blue-green algae dominate in alkaline pH waters because they are more efficient in obtaining free CO_2 at low concentrations in comparison to green algae. In addition, a number of investigators believe some blue-green species may be able to utilize HCO_3^- (and possibly $CO_3^=$) as a carbon source when the supply of free CO_2 is exhausted [29, 41, 109].

Unfortunately, no direct evidence exists which supports the theory that inorganic carbon is a limiting nutrient to some algal groups in natural freshwater systems. It is generally believed that free CO_2 in the atmosphere and in water (bacterial decomposition of organic matter, plant respiration, etc.) are more than adequate in supplying the necessary carbon requirements for algal growth in nature [109].

Detailed analysis of WCA periphyton diatom populations showed that certain portions of the marsh supported a number of water quality indicator species. Nutrient enriched portions of the marsh in the vicinity of the S-10 structures supported a diatom community indicative of organically enriched conditions such as Gomphonema parvulum, Nitzschia amphibia, Nitzschia palea, and Navicula confervaceae [10, 47, 63, 67, 74].

Interior WCA-1 sites supported the following indicator diatom species: Frustulia rhomboides v. saxonia, F. rhomboides v. crassinervia, Anomoeoneis serians, A. serians v. brachysira, Navicula subtillisima,

Synedra tenera, Stenopterobia intermedia, four species of Eunotia and three species of Pinnularia. These diatoms are reported to be reliable indicators of low calcium, low bicarbonate, acid, soft water habitats [33, 47, 66, 74]. Mastogolia smithii v. lacustus was one of the more dominant diatoms found throughout WCA-2A and WCA-3A. Round [74] reports the genus Mastogolia to be indicative of highly alkaline situations. Lowe's [47] review of the nominate variety (M. smithii v. smithii) reports it as a "calciophilous" species (i.e., developing best under high calcium concentrations).

Comparisons of algae communities developing on natural and artificial substrate showed that periphyton species composition on glass slides were similar (but not identical) to those grown on natural substrates. Glass slides produced lower estimates of periphyton biomass, had lower species diversity, and fewer total numbers of species. These results are similar to the studies of Castenholz [9] and Dor [15] who found the species composition of attached communities similar on glass slides and natural substrates, with the natural substrates producing larger standing crops of algae. Stockner and Armstrong [91] reported similar communities of algae growing on glass slides and rock substrates in their study of Ontario lakes. Other investigators have reported differences in periphyton communities developing on glass slides and natural substrates. Tippett [94] concluded that the epiphytic diatom communities developing on several macrophytes differed from those on glass slides. Foerster and Schlichting [22] found that many periphyton species were not included in the glass slide community. Brown [7] and Silver [78] found compositional differences in attached algal communities on glass slides and submerged macrophyte vegetation.

Chlorophyll a accumulations on freshly cut leaves were significantly higher than those collected from dead sawgrass and cattail leaves and from glass slides. These results may indicate possible bacterial decomposition and nutrient loss from the decaying leaves with subsequent uptake by periphyton colonizing the freshly cut sawgrass leaves.

Natural substrate materials (cattail, sawgrass leaves) had higher chlorophyll a levels in comparison to glass slides. These differences may be the result of the porous nature and irregular surface areas of natural substrate materials which may afford somewhat better attachment sites for the colonizing algae.

Although glass slide substrates produced lower estimates of periphyton biomass and community diversity, these differences were relatively small. Glass slides were used as a comparative method of measuring relative differences between periphyton populations in the WCA's. The use of glass slides suspended in the water column at a standard depth minimized the effects of such variables as light, water depth, and substrate differences between sampling sites. Glass slides were much easier to handle, both in the field and in the laboratory, compared to natural substrate materials and therefore allowed additional time to sample a wider variety of habitats.

SUMMARY

1. Submerged and floating mats of periphyton algae are a conspicuous feature of the Water Conservation Areas.

2. Earlier periphyton studies in the Everglades have shown that these microorganisms are an important component of the marsh food chain.

3. In addition to their importance as a food source, periphyton photosynthesis and metabolism greatly influence marsh water diurnal dissolved oxygen concentrations and calcium carbonate (marl) deposition in marsh sediments.

4. Recent nitrogen fixation studies in the Water Conservation Areas show that periphyton may play an important role in the marsh nitrogen cycle.

5. Periphyton populations are very sensitive to changes in water quality and thus have been utilized as a monitoring tool to assess both short and long term changes in the aquatic environment.

6. Although periphyton algae are recognized as an important component of the Water Conservation Area ecosystem, little is known concerning their seasonal population dynamics, species composition, growth rates, or their relationship with water quality parameters.

7. Preliminary results of our study found a total of 225 species of algae representing 94 genera, and 9 divisions which colognized glass slide substrates in the Water Conservation Areas during 1978-1979.

8. Two filamentous blue-green algae (Schizothrix calcicola and Scytonema hofmanii) dominated periphyton communities in WCA-2A, WCA-3A and the peripheral marsh of WCA-1, while desmid and filamentous green algae (Mougeotia spp., Spirogyra spp., Oedogonium and Bulbochaetae spp.) dominated interior WCA-1 sites.

9. Peripheral marsh sites adjacent to canal water inflows supported a "specialized" periphyton community dominated by the filamentous blue-green Microcoleus lynbyaceus and a number of diatom species indicative of nutrient enrichment (Gomphonema parvulum, Nitzschia amphibia, Navicula confervaceae and Nitzschia palea).

10. Water quality in WCA-2A, WCA-3A and the peripheral areas of WCA-1 were highly mineralized, alkaline, hard water habitats. The dominant major ions at these sites were bicarbonate, chloride, sodium, and calcium. In contrast, interior WCA-1 sites were poorly buffered, soft water habitats, low in dissolved minerals with low (acid) pH.

11. Concentrations of nitrogen and phosphorus were very low at interior Water Conservation Area sites (at or near detection limits) in

comparison to peripheral marsh sites impacted by canal water inflows. Phosphorus and nitrogen were both potentially growth limiting nutrients at interior WCA-2A and WCA-3A sites due to their low availability. Highest nitrogen and phosphorus concentrations occurred at Sites B-1, B-2, and B-3 located south of the S-10C discharge structure in WCA-2A.

12. Results showed that periphyton species composition and growth rates on glass slides incubated at similar depths (one inch below surface) and over similar time periods (6-8 weeks) were significantly influenced by site differences in water quality (major ions, pH, and phosphorus concentrations). Although water depth and hydroperiod length were poorly correlated with the development of periphyton communities on glass slides during 1978-79, it is well documented that extended hydroperiod length encourages the long term accumulation of periphyton biomass (standing crop) in some portions of the Everglades.

13. Marsh water phosphorus concentrations were shown to be the major factor regulating periphyton growth rates and the phosphorus content of algae in the Water Conservation Areas during 1978-79.

14. Marsh water ionic content (major ion concentrations) was a principal factor regulating periphyton species composition in the Water Conservation Areas. Desmid and filamentous green algae dominance was significantly correlated with waters containing low concentrations of major ions, while filamentous blue-green periphyton were more prevalent under high concentrations of major ions.

15. Marsh water hydrogen ion concentration (pH) was also an important factor which influenced periphyton species composition. Filamentous blue-green populations were statistically shown to dominate under alkaline pH conditions, while desmid and filamentous green algae dominanted under acid water conditions.

16. Periphyton chlorophyll a production at interior WCA-2A and WCA-3A sites represent some of the lowest values reported in the literature and may indicate nutrient limitation at these interior sites.

17. Supplies of elemental phosphorus in periphyton cell tissue were low in comparison to reported "critical concentrations" required for normal growth and reproduction of algae. Low supplies of nutrients in periphyton cell tissue suggest nutrient limiting conditions at interior WCA-2A and WCA-3A sites.

18. Significant differences existed in marsh water nutrient content, periphyton species composition, periphyton chlorophyll a production, algal species diversity, and periphyton tissue phosphorus at sites located south of the S-10 discharge structure in WCA-2A and indicate development of a "specialized" periphyton community in response to nutrient enrichment.

19. Although diatoms were not major components of the periphyton, they served as important indicators of water quality conditions in the Water Conservation Areas. The following indicator species of low calcium, low bicarbonate, acid water conditions were present at interior WCA-1 sites: Frustulia rhomboides v. saxonica, F. rhomboides v. crassinvervia, Anomoeoneis serians, A. serians v. brachysira, Eunotia spp., Navicula subtillisima, Pinnularia spp., Synedra tenera, and Stenopterobia intermedia. Interior WCA-2A and WCA-3A supported a number of diatoms indicative of alkaline, high calcium conditions such as Mastogolia smithii v. lacustris. Nutrient enriched portions of the marsh supported the following species indicative of organic pollution: Gomphonema parvulum, Nitzschia amphibia, Navicula confervaceae and Nitzschia palea.

20. Algae populations developing on natural and artificial substrates were similar in species composition but glass slides produced lower estimates of periphyton biomass, had fewer total numbers of algae species present, and lower species diversity.

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APPENDIX A

SUPPORTING DATA

TABLE A-1. DESCRIPTION OF THE LOCATION AND VEGETATION AT WATER CONSERVATION AREA PERIPHYTON/WATER QUALITY SAMPLING SITES

Station	Location	Dominant Macrophyte Vegetation
Water Conservation Area 1		
A-1	Located 1.1 km north of S-10A in WCA-1 (peripheral WCA-1 site)	Deep water slough, Typha and Cladium stands present
A-2	4.2 km north of S-10A in WCA-1 (interior WCA-1 site)	Located at the edge of a large Cladium ridge, shallow open water slough, Nymphaea, Hymenocallis, Utricularia dominant vegetation
A-3	7.4 km due west of U.S. Wildlife Refuge Headquarters, WCA-1 (interior WCA-1 site)	Tree islands numerous, large open wet prairie community dominated by Rhynchospora spp.
1-8T	Approximately 0.6 km west of U.S. Wildlife Refuge Headquarters at the 1-8 telemetry (U.S.G.S.) water gauge (peripheral WCA-1 site)	Large open, wet prairie community, Rhynchospora, Eleocharis, Utricularia, some Nymphaea, prairie bordered by Cladium. Blue-green algae mats present seasonally.
A-5	About 200 meters west of Canal L-40, due west of U.S. Wildlife Refuge Headquarters (peripheral WCA-1 site)	Wet prairie, Rhynchospora, Eleocharis Utricularia, prairie located at the fringe of a Typha stand
A-6	1.8 km south of S-5A pump station (this station was sampled only twice during the third quarter survey)	Rhynchospora wet prairie surrounded by tree islands
A-7	0.4 km south of S-5A pump station (sampled only twice during winter of 1978-79)	Typha, Salix, and Cladium dominant marsh cover
Water Conservation Area 2A		
B-1	Open slough system, approx. 100 meters south of S-10C structure (peripheral WCA-2A)	Luxuriant growths of emergent and floating vegetation: Phragmites, Typha, Mikania, Panicum, Eichhornia crassipes, Pistia, Salvinia, and Hydrocotyle. Submergent species: Hydrilla, Ceratophyllum, and Vallisineria.

TABLE A-1. (Con't)

Station	Location	Dominant Macrophyte Vegetation
Water Conservation Area 2A		
B-2	Dense Typha stand 0.6 km south of S-10C structure (peripheral WCA-2A site)	Typha dominant; Salvinia, Lemna, Mikania, Polygonum, and Saccio-lepis, stems of Typha covered with dark green periphyton.
B-3	Edge of Typha fringe approx. 1.8 km south of S-10C located just north of the "North Trail" (peripheral WCA-2A site)	Cladium dominant, mixed with Mikania, Typha, Sagittaria, Utricularia and Nymphaea odorata. Dark green periphyton covering sawgrass stems.
B-4	Dense Cladium near a willow (Salix) head approx. 2.3 km south of S-10C structure (peripheral WCA-2A site)	Cladium dominant, Salix, Typha, Nymphaea odorata, Sagittaria, Pontederia, blue-green periphyton attached to submerged aquatics.
B-5	Dense Cladium approx. 3.7 km south of S-10C structure, approx. 400 meters south of the east-west airboat trail to "Townsend's Camp" (interior WCA-2A site)	Cladium dominant, Utricularia, some Nymphaea, attached growths of blue-green algae (Schizothrix calcicola and diatoms) present.
B-6	Open water slough, 5.8 km south of S-10C structure, due east of "Townsend's Camp" (interior WCA-2A)	Nymphaea, Utricularia; slough bordered by Cladium
B-7	Dense Cladium 6.9 km south of S-10C structure (interior WCA-2A site)	Cladium dominant, Utricularia and Nymphaea present
Water Conservation Area 3A		
C-1	Located 6.4 km north of State Road 84 (Alligator Alley) and 150 meters west of the "Swamp Buggy Bridge" located on the Miami Canal (peripheral WCA-3A site)	Typha dominant emergent vegetation, Cladium, Ludwigia, Panicum spp. also present
C-3A	Located 2.2 km south of State Road 84 and 0.25 km west of the Miami Canal (peripheral WCA-3A site)	Wet prairie, Cladium dominant, Panicum, Eleocharis, Rhynchospora also present

TABLE A-1. (Con't)

Station	Location	Dominant Macrophyte Vegetation
Water Conservation Area 3A		
C-3B	Same general vicinity as Station C-3A but located further west of the influences of the Miami Canal. Located 3.5 km south of State Road 84 and 1.3 km west of the Miami Canal (interior WCA-3A site)	Cladium wet prairie, seasonal cylindrical growths of blue-green algae found covering submerged plant stems and leaves
C-4	5.8 km south of State Road 84, located at the 3-7 gauge, north end WCA-3A (interior WCA-3A site)	Rhynchospora, Panicum wet prairie, scattered tree islands. Large bottom mats of blue-green algae present during wet season
C-5	Located at the 3-28 gauge 4.5 km north of State Road 41 (Tamiami Trail) south end WCA-3A (interior WCA-3A site)	Open water slough, Nymphaea, Hymenocallis, Utricularia, slough bordered by Cladium stands
C-6	Located 1.7 km north of the S-12C structure on State Road 41, south end of WCA-3A (peripheral WCA-3A site)	Wet prairie, Cladium, Eleocharis, scattered tree islands
C-7	1.1 km west of the S-11B water control structure, northeast corner of WCA-3A (sampled only during third quarter survey)	Dense Cladium stand
C-8	0.3 km west of S-11B, northeast corner of WCA-3A (sampled only during third quarter survey)	Dense Typha, Salix, and Cladium growth
C-9	Located just north of John Buck Island, south end, WCA-3A (10.7 km north of S-12C structure). This site was sampled only during the fourth quarter survey (interior WCA-3A site)	Rhynchospora-Cladium wet prairie
C-10	Located at the 3-4 gauge in the center of WCA-3A, 15.4 km south of State Road 84 (interior WCA-3A site)	Aquatic slough bordered by Rhynchospora wet prairie and Cladium stands

TABLE A-2. A PRELIMINARY SYSTEMATIC LIST OF PERIPHYTON SPECIES COLONIZING GLASS SLIDES IN THE WATER CONSERVATION AREAS. FEBRUARY 1978 - AUGUST 1979.

Systematic List of Periphyton Species

Division: Myxophyceae (Blue-Greens)[a]
- Family: Chroococaceae
  - *Agmenellum quadruplicatum*
  - *Anacystis dimidiata*
  - *Anacystis montana*
  - *Coccochloris elabens*
  - *Gomphospheria spp.*
  - *Johannesbaptistia pellucida*
- Family: Oscillatoriaceae
  - *Microcoleus lyngbyaceus* (2 ecophenes)
  - *Oscillatoria lutea*
  - *Oscillatoria princeps*
  - *Schizothrix calcicola* (5 ecophenes)
  - *Spirulina princeps*
  - *Spirulina subsalsa*
- Family: Nostoceae
  - *Anabaena spp.*
  - *Scytonema hofmannii*
- Family: Stigonemataceae
  - *Stigonema panniforme*

Division: Chlorophyceae (Greens)[b]
- Order: Volvocales
  - *Carteria spp.*
  - *Chlamydomonas spp.*
  - *Eudorina elegans*
- Order: Tetrasporales
  - *Elakatothrix gelatinosa*
  - *Gleocystis gigas*
- Order: Chlorococcales
  - *Ankistrodesmus falcatus v. mirabilis*
  - *Ankistrodesmus sprialis*
  - *Characium sp.*
  - *Chlorella vulgaris*
  - *Coelastrum sp.*
  - *Crucigenia tetrapedia*
  - *Dimorphococcus lunatus*
  - *Nephrocytium lunatum*
  - *Oocystis spp.*
  - *Pediastrum boryanum*
  - *Pediastrum spp.*
  - *Scenedesmus abundans*
  - *Scenedesmus arcuatus v. platydisca*
  - *Scenedesmus bijuga*
  - *Scenedesmus brasiliensis*
  - *Scenedesmus denticulatus*
  - *Scenedesmus longus*
  - *Scenedesmus obliquus*
  - *Scenedesmus parisiensis*
  - *Scenedesmus quadricauda*
  - *Selenastrum spp.*
  - *Sorastrum sp.*
  - *Tetraedron caudatum*
  - *Tetraedron regulare*
- Order: Zygnematales
  - *Mougeotia spp.*
  - *Spirogyra spp.*
  - Families: Mesotaeniaceae and Desmidiaceae (Desmids)
    - *Arthrodesmus validus*
    - *Bambusiana spp.*
    - *Closterium spp.*
    - *Cosmarium blyttii*
    - *Cosmarium comminsurale v. crassum*
    - *Cosmarium elegantissimum v. simplicus*
    - *Cosmarium hammeri*
    - *Cosmarium isthmium*
    - *Cosmarium margaritatum*
    - *Cosmarium notabile*
    - *Cosmarium pyramidatum*
    - *Cosmarium pyramidatum v. convexum*
    - *Cosmarium regnesi montanum*
    - *Cosmarium tinctum*
    - *Cylindrocystis spp.*
    - *Desmidium aptogonum*
    - *Desmidium baileyi*
    - *Desmidium cylindricum*
    - *Desmidium grevelli*
    - *Docidium undulatum*
    - *Euastrum spp.*
    - *Euastrum affine*
    - *Euastrum binale v. gutwinskii*

Families: Mesotaeniaceae and Desmidiaceae (Con't.)
- *Euastrum lutkemulleri*
- *Genicularia elegans*
- *Genicularia sp. 1*
- *Gonatozygon spp.*
- *Hyalotheca dissiliens*
- *Hyalotheca undulata*
- *Mesotaenium sp. 1*
- *Micrasterias pinnatifida*
- *Micrasterias radiata*
- *Netrium spp.*
- *Penium spp.*
- *Penium minutum*
- *Sphaerozosma granulatum*
- *Spondylosium spp.*
- *Staurastrum alternans*
- *Staurastrum cf. leptocladium*
- *Staurastrum crytocerum*
- *Staurastrum dejectum*
- *Staurastrum paradoxum*
- *Staurastrum tetracerum*
- *Tetmemorus spp.*
- *Triploceras gracile*
- *Triploceras verticillatum*
- *Xanthidium armatum*

Division: Bacillariophyceae (Diatoms)[c]
- Order: Centrales
  - Suborder: Discineae
    - Family: Coscinodiscaceae
      - *Coscinodiscus rothii v. subsalsa*
      - *Cyclotella cf. glomerata*
      - *Cyclotella meneghiniana*
      - *Melosira granulata*
      - *Melosira varians*
      - *Thallassiosira fluviatilis*
- Order: Pennales
  - Suborder: Araphidae
    - *Fragilaria brevistriata*
    - *Fragilaria capucina v. mesolepta*
    - *Synedra pahokeensis sp. nov.*
    - *Synedra radians*
    - *Synedra tenera*
    - *Synedra ulna*
    - *Synedra ulna v. amphirhyncus*
  - Suborder: Araphidae (Con't.)
    - *Synedra ulna v. obtusa*
    - *Synedra ulna v. oxyrhynchus*
    - *Synedra sp. 2 sp. nov.*
  - Suborder: Monoraphidae
    - *Achnanthes exigua v. heterovalve*
    - *Achnanthes hauckiana*
    - *Achnanthes inflata*
    - *Achnanthes minutissima*
    - *Cocconeis placentula v. euglypta*
  - Suborder: Biraphidae
    - *Amphipleura pellucida*
    - *Amphora veneta*
    - *Anomoeoneis serians*
    - *Anomoeoneis serians v. brachysira*
    - *Anomoeoneis vitrea*
    - *Bacillaria paradoxa*
    - *Caloneis bacillum*
    - *Caloneis ventricosa v. truncatula*
    - *Cymbella amphioxys*
    - *Cymbella microcephala*
    - *Cymbella minuta*
    - *Cymbella minuta v. psuedogracilis*
    - *Cymbella minuta v. silesiaca*
    - *Cymbella cf muelleri*
    - *Cymbella pusilla*
    - *Cymbella ruttneri*
    - *Diploneis elliptica*
    - *Diploneis finnica*
    - *Diploneis ovalis*
    - *Epithemia spp.*
    - *Epithemia argus v. alpestris*
    - *Eunotia spp.*
    - *Eunotia curvata*
    - *Eunotia flexuosa*
    - *Eunotia flexuosa v. eurycephala*
    - *Eunotia formica*
    - *Eunotia naegeli*
    - *Eunotia pectinalis v. minor*
    - *Frustulia rhomboides v. crassinervia*

Suborder: Biraphidae (Con't.)
- *Frustulia rhomboides v. saxonica*
- *Gomphonema acuminatum*
- *Gomphonema affine*
- *Gomphonema affine v. insigne*
- *Gomphonema angustatum*
- *Gomphonema consector*
- *Gomphonema gracile*
- *Gomphonema intricatum*
- *Gomphonema intricatum v. vibrio*
- *Gomphonema subclavatum*
- *Gomphonema parvulum*
- *Gomphonema turris*
- *Hantzschia amphioxys v. major*
- *Mastogloia smithii*
- *Mastogloia smithii v. lacustris*
- *Navicula arvensis*
- *Navicula bicephala*
- *Navicula biconica*
- *Navicula bioculata*
- *Navicula capitata*
- *Navicula capitata v. hungarica*
- *Navicula cincta*
- *Navicula confervacea*
- *Navicula cryptocephala v. veneta*
- *Navicula exigua v. capitata*
- *Navicula geitleri*
- *Navicula luzonensis*
- *Navicula minima*
- *Navicula mutica*
- *Navicula pupula v. rectangularis*
- *Navicula pygmaea*
- *Navicula radiosa*
- *Navicula radiosa v. tenella*
- *Navicula rhynchocephala v. germanii*
- *Navicula seminulum*
- *Navicula cf. subtilissima*
- *Navicula tripunctata v. schizonemoides*
- *Neidium affine*
- *Nitzschia acuta*
- *Nitzschia amphibia*
- *Nitzschia cf. brevirostris*
- *Nitzschia cf. congelensis*
- *Nitzschia denticula*
- *Nitzschia denticula v. elongata*
- *Nitzschia fonticola*
- *Nitzschia frustulum*
- *Nitzschia kutzingiana*
- *Nitzschia linearis*
- *Nitzschia obtusa*
- *Nitzschia palea*
- *Nitzschia sigmoides*
- *Nitzschia cf. spiculoides*
- *Nitzschia storchii sp. nov.*
- *Nitzschia cf. subrostrata*
- *Nitzschia subtilis*
- *Nitzschia tarda*
- *Nitzschia vermicularis*
- *Nitzschia sp. 7 sp. nov.*
- *Pinnularia spp.*
- *Pinnularia abaujensis*
- *Pinnularia acrosphaeria*
- *Pinnularia biceps*
- *Pinnularia braunii v. amphicephala*
- *Rhopalodia gibba*
- *Stauroneis anceps f. gracilis*
- *Stauroneis phoenicenteron f. gracilis*
- *Stauroneis sp. 1*
- *Stenopterobia intermedia*

Division: Chrysophyceae
- Order: Phaeoplacales
  - *Dinobryon spp.*
  - *Mallomonas caudata*

Division: Dinophyceae
- Order: Gymnodiniales
  - *Gymnodinium sp.*
- Order: Peridinales
  - *Gonyaulax sp.*
  - *Peridinium spp.*

Division: Euglenophyceae
- Order: Euglenales
  - *Euglena spp.*
  - *Phacus spp.*
  - *Trachelomonas sp.*

Systematic List of Periphyton Species (Con't.)

Division: Cryptophyceae
    Order: Cryptomonales
        Cryptomonas erosa
        Rhodomonas spp.

Division: Charophydeae
    Order: Charales
        Chara spp.

Footnote:

[a]After Drouet's classification, Drouet and Daily (1956); Drouet, 1968, 1973

[b]After G.M. Smith (1950) 2nd Edition

[c]Hustedt's (1930) classification

TABLE A-3. PERCENT RELATIVE ABUNDANCE OF DOMINANT TO COMMON PERIPHYTON SPECIES COMPRISING MORE THAN FIVE PERCENT OF THE TOTAL COMMUNITY CELL VOLUME FROM WATER CONSERVATION AREA ARTIFICIAL SUBSTRATE SAMPLING SITES, JULY-AUGUST, 1978.

STATION	SPECIES	AVERAGE CELL VOLUME ($\mu 3/mm2x10^3$)	RELATIVE ABUNDANCE BASED ON CELL VOLUME (%)
A-1	*Microcoleus spp.*	69.8	56.9
	Mougeotia spp.	11.2	9.1
	Mastogloia smithii v. lacustris	9.2	7.5
	Schizothrix calcicola	7.7	6.3
	Other Algae	24.8	20.2
	Total	122.7	100.0
A-2	*Penium spp.*	126.2	32.1
	Genicularia sp. 1	90.1	22.9
	Cosmarium pyramidatum v. convexum	32.8	8.3
	Mougeotia spp.	19.8	5.0
	Other Algae	124.7	31.7
	Total	393.6	100.0
A-3	*Penium spp.*	1936.0	38.9
	Stigonema spp.	687.5	13.8
	Spirogyra	550.0	11.1
	Genicularia spp.	390.5	7.8
	Other Algae	1413.6	28.4
	Total	4977.6	100.0
A-5	*Microcoleus spp.*	101.4	31.1
	Mastogloia smithii v. lacustris	96.3	29.5
	Rhopalodia gibba	26.0	8.0
	Cosmarium pyramidatum v. convexum	25.4	7.8
	Schizothrix calcicola (Ecophene 1)	22.2	6.8
	Mougeotia spp.	20.8	6.8
	Other Algae	34.3	10.5
	Total	326.4	100.0
1-8T	*Anomoeoneis vitrea*	50.2	24.1
	Microcoleus spp.	28.2	13.6
	Rhopalodia gibba	27.6	13.2
	Cosmarium spp.	19.7	9.4
	Schizothrix calcicola (Ecophene 1)	13.3	6.4
	Mougeotia spp.	11.0	5.3
	Penium spp.	11.0	5.3
	Other Algae	47.3	22.7
	Total	208.3	100.0

TABLE A-3. (Con't.)

STATION	SPECIES		AVERAGE CELL VOLUME ($\mu^3/mm^2 x 10^3$)	RELATIVE ABUNDANCE BASED ON CELL VOLUME (%)
	Microcoleus spp.		742.5	22.0
	Characium spp.		613.8	18.2
B-1	*Schizothrix calcicola* (Ecophene 1)		425.7	12.6
	Stigeoclonium spp.		412.5	12.2
	Gomphonema parvulum		406.9	12.1
	Other Algae		771.4	22.9
		Total	3372.8	100.0
	Microcoleus spp.		3393.3	74.5
B-2	*Schizothrix calcicola* (Ecophene 1)		2612.9	20.7
	Other Algae		6603.5	4.8
		Total	12609.7	100.0
	Microcoleus spp.		8996.4	62.3
B-3	*Schizothrix calcicola* (Ecophene 1)		3539.0	24.5
	Anabaena spp.		1521.4	10.5
	Other Algae		382.4	2.7
		Total	14439.2	100.0
	Microcoleus spp.		3315.0	34.1
	Mougeotia spp.		2475.2	25.5
B-5	*Schizothrix calcicola* (Ecophene 1)		1458.6	15.0
	Scytonema hofmannii		884.0	9.1
	Mastogloia smithii v. lacustris		646.4	6.6
	Other Algae		932.7	9.7
		Total	9711.9	100.0
	Schizothrix calcicola (Ecophene 1)		322.9	27.0
	Mastogloia smithii v. lacustris		321.1	26.9
B-6	*Mougeotia spp.*		208.0	17.4
	Synedra pahokeensis sp. nov.		110.1	9.2
	Microcoleus spp.		78.0	6.5
	Other Algae		154.4	13.0
		Total	1194.5	100.0
	Schizothrix calcicola (Ecophene 1)		1613.6	37.8
	Mougeotia spp.		794.4	18.6
B-7	*Schizothrix calcicola* (Ecophene 2)		591.7	13.9
	Microcoleus spp.		297.9	7.0
	Mastogloia smithii v. lacustris		215.1	5.0
	Other Algae		751.1	17.7
		Total	4263.8	100.0

TABLE A-3. (Con't.)

STATION	SPECIES	AVERAGE CELL VOLUME ($\mu^3/mm^2 x 10^3$)	RELATIVE ABUNDANCE BASED ON CELL VOLUME (%)
B-9	*Mougeotia spp.*	4939.2	41.8
	Schizothrix calcicola (Ecophene 1)	1891.9	16.0
	Microcoleus spp.	1323.0	11.2
	Schizothrix calcicola (Ecophene 2)	1124.6	9.5
	Mastogloia smithii v. lacustris	688.0	5.8
	Other Algae	18455.5	15.7
	Total	11812.2	100.0
B-10	*Mougeotia spp.*	6355.2	49.8
	Schizothrix calcicola (Ecophene 1)	2442.8	19.2
	Cymbella minuta v. psuedogracilis	1390.2	10.9
	Mastogloia smithii v. lacustris	817.6	6.4
	Other Algae	1746.0	13.7
	Total	12751.8	100.0
217	*Schizothrix calcicola* (Ecophene 1)	2742.6	32.7
	Scytonema hofmannii	1986.0	23.7
	Schizothrix calcicola (Ecophene 2)	849.2	10.1
	Mastogloia smithii v. lacustris	609.4	7.3
	Anomoeoneis vitrea	428.8	5.1
	Other Algae	1770.0	21.1
	Total	8386.0	100.0

	Schizothrix calcicola (Ecophene 1)		2144.9	21.5
	Microcoleus spp.		1986.0	19.9
	Nitzschia obtusa		1032.7	10.4
C-1	*Nitzschia amphibia*		1007.9	10.1
	Cyclotella meneghiniana		820.9	8.2
	Diploneis elliptica		579.2	5.8
	Mougeotia spp.		529.6	5.3
	Other Algae		1868.2	18.8
		Total	9969.4	100.0
	Microcoleus spp.		3307.5	25.4
	Mastogloia smithii v. lacustris		3210.4	24.6
C-3A	*Schizothrix calcicola* (Ecophene 1)		2917.2	22.4
	Genicularia sp. 1		926.1	7.1
	Other Algae		2678.0	20.9
		Total	13039.2	100.0
	Scytonema hofmannii		993.6	34.0
	Penium spp.		463.7	15.9
C-5	*Genicularia sp. 1*		386.4	13.2
	Spirogyra spp.		276.0	9.4
	Mougeotia spp.		198.7	6.8
	Other Algae		604.6	20.7
		Total	2923.0	100.0

TABLE A-3. (Con't.)

STATION	SPECIES		AVERAGE CELL VOLUME ($\mu^3/mm^2 x 10^3$)	RELATIVE ABUNDANCE BASED ON CELL VOLUME (%)
	Scytonema hofmannii		772.8	36.0
	Penium spp.		331.2	15.4
C-6	*Spirogyra spp.*		276.0	12.9
	Mougeotia spp.		132.5	6.2
	Bulbochaete spp.		115.9	5.4
	Genicularia sp. 1		115.9	5.4
	Other Algae		401.9	18.7
		Total	2146.2	100.0

TABLE A-4. PERCENT RELATIVE ABUNDANCE OF DOMINANT AND COMMON PERIPHYTON SPECIES COMPRISING MORE THAN FIVE PERCENT OF THE TOTAL COMMUNITY CELL VOLUME FROM WATER CONSERVATION AREA ARTIFICIAL SUBSTRATE SAMPLING SITES, JUNE-AUGUST, 1979

STATION	SPECIES		AVERAGE CELL VOLUME ($\mu^3/mm^2 x 10^3$)	RELATIVE ABUNDANCE BASED ON CELL VOLUME (%)
A-1	*Mougeotia sp. 1*		2695.6	28.7
	Schizothrix calcicola (Ecophene 1)		1208.6	12.9
	Mougeotia sp. 2		849.7	9.0
	Microcoleus lyngbyaceus		703.2	7.5
	Genicularia sp. 1		615.3	6.6
	Other Algae		3318.5	35.3
		Total	9390.9	100.0
A-2	*Oedogonium sp. 2*		19395.0	73.4
	Mougeotia sp. 1		2401.2	9.1
	Genicularia sp. 1		1833.3	6.9
	Other Algae		2790.3	10.6
		Total	26419.8	100.0
A-3	*Mougeotia sp. 1*		3281.6	18.8
	Spirogyra spp.		2930.0	16.8
	Genicularia sp. 1		2871.4	16.4
	Genicularia elegans		1758.0	10.0
	Mougeotia sp. 2		1699.4	9.7
	Other Algae		4946.1	28.3
		Total	17486.5	100.0
1-9	*Mougeotia sp. 2*		24465.5	64.0
	Spirogyra spp.		2930.0	7.7
	Mougeotia sp. 1		2344.0	6.1
	Genicularia elegans		1758.0	4.6
	Other Algae		6699.7	17.6
		Total	38197.2	100.0
B-3	*Microcoleus sp. 1*		10548.0	60.1
	Oedogonium sp. 2		2930.0	16.7
	Microcoleus lyngbyaceus		2285.4	13.0
	Schizothrix calcicola (Ecophene 1)		1050.4	6.0
	Other Algae		746.2	4.2
		Total	17560.0	100.0
B-4	*Spirogyra spp.*		1552.5	47.5
	Schizothrix calcicola (Ecophene 1)		399.5	12.2
	Oedogonium sp. 2		345.0	10.6
	Microcoleus lyngbyaceus		289.8	8.9
	Other Algae		681.5	20.8
		Total	3268.3	100.0

TABLE A-4. (Con't.)

STATION	SPECIES		AVERAGE CELL VOLUME ($\mu^3/mm^2 x 10^3$)	RELATIVE ABUNDANCE BASED ON CELL VOLUME (%)
	Mougeotia sp. 1		2925.6	33.8
	Mougeotia sp. 2		2801.4	32.4
B-5	*Mastogloia smithii v. lacustris*		753.5	8.7
	Schizothrix calcicola (Ecophene 1)		581.7	6.7
	Microcoleus lyngbyaceus		496.8	5.7
	Other Algae		1089.7	12.7
		Total	8648.7	100.0
	Mougeotia sp. 2		1200.6	29.3
	Mastogloia smithii v. lacustris		986.7	24.1
B-6	*Schizothrix calcicola (Ecophene 1)*		621.0	15.2
	Mougeotia sp. 1		386.4	9.4
	Other Algae		903.4	22.0
		Total	4098.1	100.0
	Schizothrix calcicola (Ecophene 1)		817.7	21.8
	Mougeotia sp. 2		800.4	21.4
	Mastogloia smithii v. lacustris		681.7	18.2
B-7	*Mougeotia sp. 1*		441.6	11.8
	Rhopalodia gibba		276.0	7.4
	Mierocaleus lyngbyaceus		207.0	5.5
	Other Algae		520.4	13.9
		Total	3744.8	100.0
	Schizothrix calcicola (Ecophene 1)		1167.5	26.8
	Mastogloia smithii v. lacustris		932.9	21.4
	Mougeotia sp. 1		717.6	16.4
B-9	*Mougeotia sp. 2*		400.2	9.2
	Microcoleus lyngbyaceus		289.8	6.6
	Peridinium spp.		276.0	6.3
	Other Algae		577.1	13.3
		Total	4361.1	100.0
	Spirogyra spp.		5860.0	26.7
	Microcoleus sp. 1		5274.0	24.0
L-38	*Microcoleus lyngbyaceus*		2988.6	13.6
	Schizothrix calcicola (Ecophene 1)		2689.7	12.2
	Oedogonium sp. 1		1230.6	5.6
	Other Algae		3925.3	17.9
		Total	21968.2	100.0
	Scytonema hofmannii		576.0	34.6
	Mougeotia sp. 2		252.0	15.1
C-5	*Spirogyra spp.*		120.0	7.2
	Cosmarium pyramidatum v. convexum		96.7	5.8
	Other Algae		619.2	37.3
		Total	1663.9	100.0

TABLE A-4. (Con't.)

STATION	SPECIES		AVERAGE CELL VOLUME ($\mu^3/mm^2 \times 10^3$)	RELATIVE ABUNDANCE BASED ON CELL VOLUME (%)
	Scytonema hofmannii		810.0	40.4
	Spirogyra spp.		250.0	12.5
C-9	*Mougeotia sp. 2*		237.5	11.8
	Schizothrix calcicola (Ecophene 1)		133.1	6.6
	Other Algae		572.5	28.7
		Total	2003.1	100.0
	Bubochaete spp.		598.6	44.1
C-10	*Genicularia sp. 1*		463.3	34.2
	Microcoleus lyngbyceus		74.7	5.5
	Other Algae		219.6	16.2
		Total	1356.2	100.0

TABLE A- 5. AVERAGE NUTRIENT CONTENT OF MARSH WATER AND PERIPHYTON PLANT TISSUE WITH CORRESPONDING PERIPHYTON GROWTH RATES - JULY-AUGUST, 1978

Station	AVERAGE NUTRIENT CONTENT OF MARSH WATER (mg/l)		AVERAGE NUTRIENT CONTENT OF PERIPHYTON TISSUE			AVERAGE PERIPHYTON GROWTH RATE
	Inorganic N	Total Dissolved P	% N	% P	N:P Ratio	(Chlorophyll a mg m^{-2} wk^{-1})
A-1	0.02[a]	0.004[a]	3.21[b]	0.017[b]	188.8	0.19[c]
A-2	0.01	0.005	2.91	0.019	153.2	0.18
A-3	0.02	0.005	3.42	0.027	126.7	0.54
1-8T	0.03	0.005	2.10	0.016	131.2	0.18
B-1	1.16	0.112	2.36	0.190	12.4	10.5
B-2	0.11	0.075	3.00	0.224	13.4	9.73
B-3	0.06	0.051	4.03	0.292	13.8	11.28
B-4	0.02	0.027	2.16	0.132	16.4	ND
B-5	0.02	0.007	2.56	0.030	85.3	2.37
B-6	0.02	0.005	2.31	0.016	144.4	1.30
B-7	0.03	0.003	1.12	<0.010	112.0	0.84
217	0.04	0.005	1.43	<0.010	143.0	1.31
B-9	0.05	0.003	1.92	<0.010	192.0	2.24
B-10	0.03	0.003	2.61	0.019	137.4	2.95
C-1	0.52	0.015	3.11	0.110	28.3	3.31
C-3A	0.53	0.007	3.56	0.177	20.1	6.24
C-4	0.04	0.007	1.37	<0.010	137.0	0.46
C-5	0.02	0.003	2.45	0.017	144.1	0.53
C-6	0.01	0.005	1.54	<0.010	154.0	0.45

[a] Average of 5 samples collected from site during July-August 1978

[b] Percent elemental N, P on a dry weight basis

[c] Chlorophyll a growth rates obtained from artificial substrates incubated from July-August 1978 (Average of 5 samples)

ND = No Data

TABLE A-6. AVERAGE NUTRIENT CONTENT OF MARSH WATER AND PERIPHYTON PLANT TISSUE WITH CORRESPONDING PERIPHYTON GROWTH RATES - JUNE-AUGUST, 1979.

Station	Average Nutrient Content of Marsh Water (mg/l)		Average Nutrient Content of Periphyton Tissue			Average Periphyton Growth Rate
	Inorganic N	Total Dissolved P	% N	% P	N:P Ratio	(Chlorophyll a mg m^{-2} wk^{-1}
A-1	0.04[a]	0.013[a]	3.23[b]	0.078[b]	41.4	1.62[c]
A-2	0.40	0.009	2.89	0.092	31.4	3.03
A-3	0.02	0.008	3.02	0.078	38.7	1.34
1-9	0.44	0.006	3.48	0.093	37.4	4.28
B-1	0.25	0.047	3.08	0.326	9.2	DRY[d]
B-2	1.42	0.167	3.40	0.339	10.0	DRY
B-3	0.42	0.039	3.29	0.209	15.7	4.21
B-4	0.12	0.018	2.61	0.084	31.1	2.49
B-5	0.03	0.005	3.32	0.064	51.9	0.92
B-6	0.04	0.003	3.01	0.049	61.4	1.47
B-7	0.03	0.005	1.44	0.016	90.0	0.84
MH	0.04	0.005	1.60	0.018	88.9	NC
217	0.04	0.003	0.94	0.006	156.7	0.92
B-9	0.03	0.002	1.68	0.013	129.2	1.05
L-38	0.08	0.008	1.97	0.067	29.4	13.20
C-5	0.02	0.003	2.23	0.018	123.9	0.36
C-6	0.06	0.003	1.38	0.006	230.0	0.26
C-9	0.03	0.003	1.58	0.014	112.9	0.21
C-10	0.10	0.003	2.32	0.015	154.7	0.12
C-11	0.06	0.002	1.60	0.022	72.7	DRY
ENP	0.01	0.002	1.45	0.006	241.7	DRY

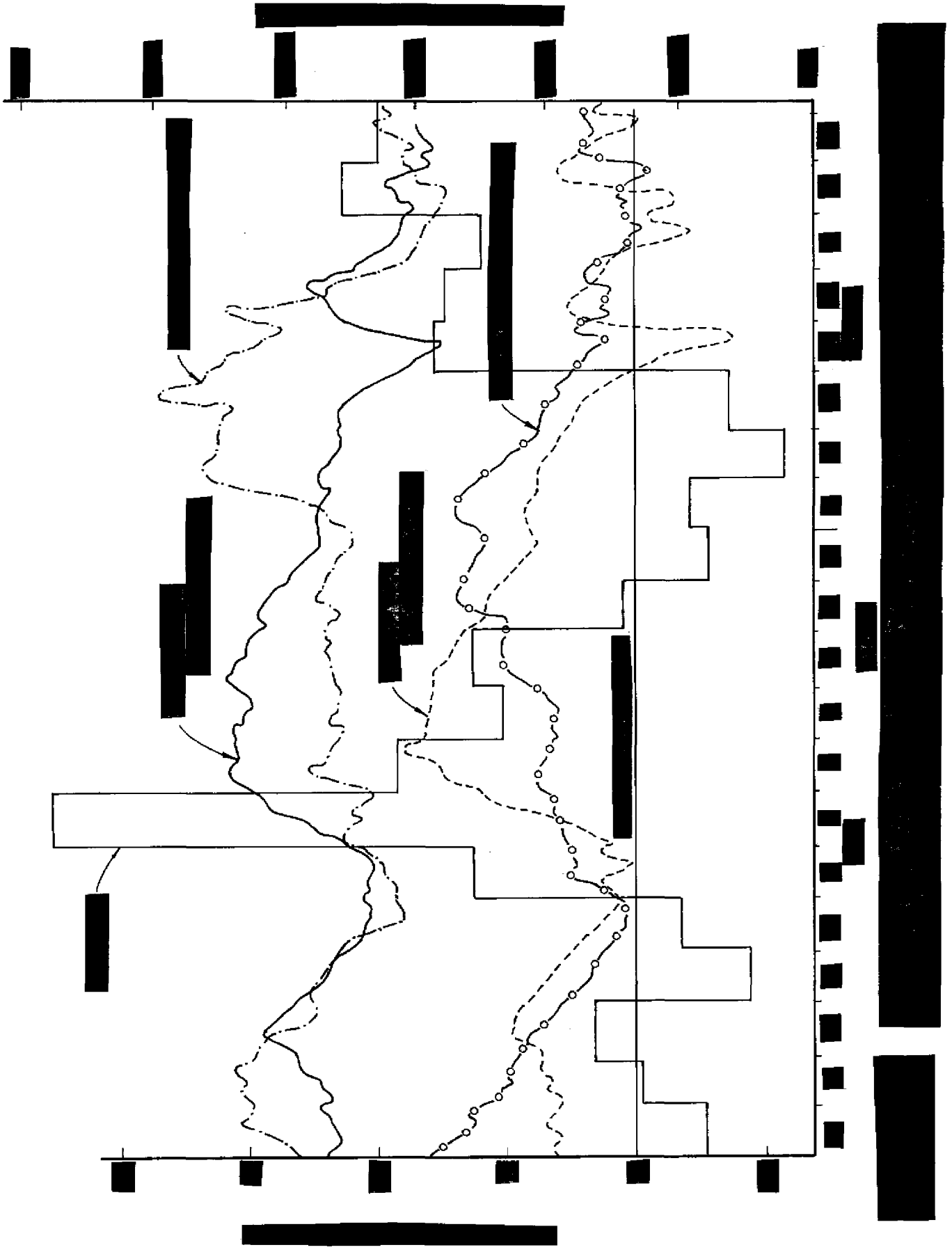
[a] Average of 5 samples collected from site during June-August 1979

[b] Percent element N, P on a dry weight basis

[c] Chlorophyll a growth rates obtained from artificial substrates incubated from June-August 1979

[d] Site dried up before slides could be collected

NC = No sample collected



APPENDIX B

CLUSTER ANALYSIS OF BIOLOGICAL DATA

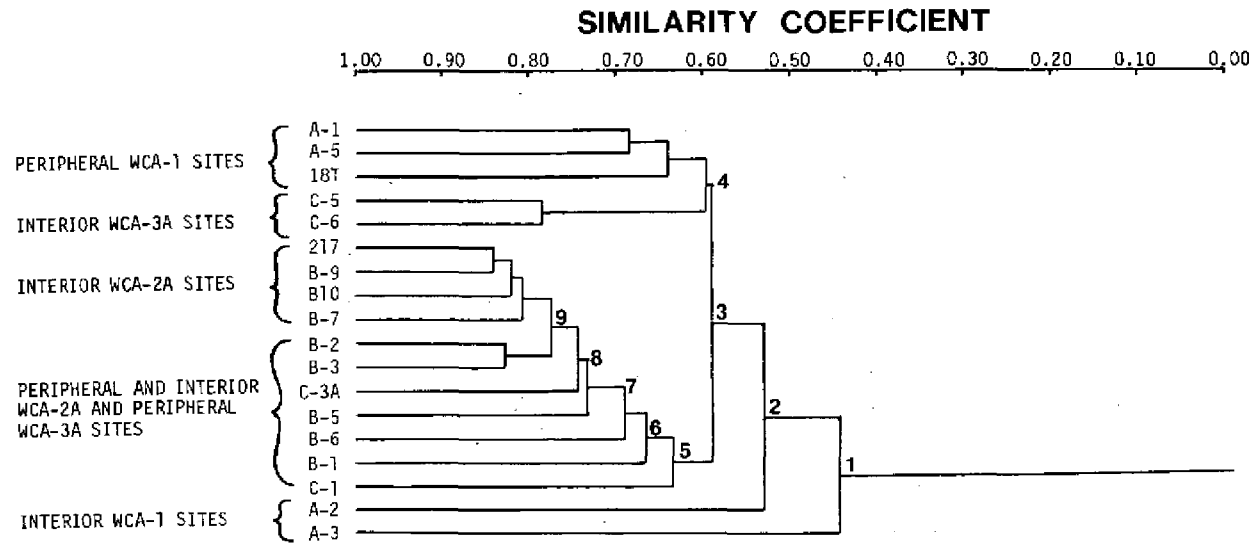
Appendix B

Cluster Analysis of Biological Data

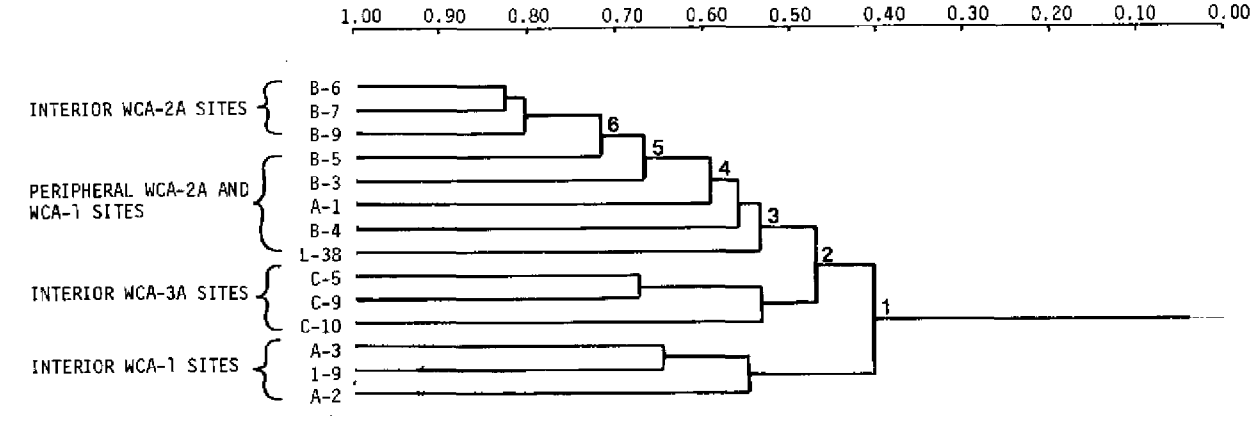
A cluster analysis program [69] was used to reduce the periphyton species abundance data (based on cell volume) into smaller subgroups based on similarities of species composition and abundance.

Figure B-1 presents the results of a cluster analysis of the summer 1978 periphyton data using the Pinkham-Pearson Biotic Similarity Index [69]. Figure B-1 illustrates five major algal groupings for the summer 1978 data. The least similar periphyton assemblage occurred at Sites A-2 and A-3 located in the interior of WCA-1 (Clusters 1 and 2 in Figure B-1). These sites exhibited low coefficients of similarity due to the presence of a desmid and filamentous green algae dominated flora. Cluster No. 3 divides the remaining stations into two groups: (a) periphyton assemblages at peripheral WCA-1 sites and interior WCA-3A sites and (b) periphyton occurring in WCA-2A and the periphery of WCA-3A. Although all sites within Cluster No. 3 were dominated by filamentous blue-green algae, differences in periphyton biomass (cell volume) were the major factors for their division. Interior WCA-3A sites (C-5 and C-6) and periphery WCA-1 sites (A-1, A-5, 1-8T) had much lower cell volume estimates compared to sites clustered in the lower half of the dendrogram.

Cluster No. 4 segregates the interior WCA-3A sites from the peripheral WCA-1 sites at a relatively low coefficient of similarity. The major difference between these sites was the occurrence of large populations of Scytonema hofmannii at Sites C-5 and C-6. Peripheral WCA-1 sites were somewhat similar to the algal flora present at WCA-3A interior sites but were dominated by Microcoleus lyngbyaceus (filamentous blue-green),



SUMMER 1978



SUMMER 1979

Mougeotia spp. (filamentous green) and the diatom, Mastogloia smithii v. lacustris. Clusters No. 5 through 8 illustrate the relative similarities between peripheral WCA-2A and WCA-3A sites and interior WCA-2A sites. Peripheral sites C-1, B-1, and C-3A clustered with interior WCA-2A sites B-5 and B-6 due to their relatively high cell volume estimates and similar algal flora (filamentous blue-greens and diatoms). Common species recorded from the peripheral WCA-2A and WCA-3A sites were Microcoleus lyngbyaceus (filamentous blue-green), Schizothrix calcicola (filamentous blue-green), Gomphonema parvulum (diatom), Nitzschia amphibia (diatom), and Nitzschia obtusa (diatom). The final dichotomy of importance was Cluster No. 9 which divided WCA-2A interior sites (217, B-9, B-10, and B-7) from two peripheral WCA-2 sites (B-2, B-3) located south of the S-10 discharge structures. Sites B-2 and B-3 clustered due to the dominance of Microcoleus lyngbyaceus which comprised 74 and 62 percent, respectively, of the total community. These sites were related to the interior WCA-2A sites at a somewhat lower coefficient of similarity. Interior WCA-2A sites (Stations 217, B-9, B-10 and B-7) clustered due to similar biomass estimates and the presence of the following common flora: Schizothrix calcicola (filamentous blue-green), Mougeotia spp. (filamentous green), Mastogloia smithii v. lacustris (diatom), Anomoeoneis vitrea (diatom), Cymbella ruttneri (diatom), and Microcoleus lyngbyaceus (filamentous blue-green).

A cluster of the summer 1979 periphyton data is presented in Figure B-2. The dendrogram divides the data into four general station groupings: The first cluster separates those sites located in the interior of WCA-1 (Sites A-3, 1-9, and A-2) from all other WCA sites. These sites had the least similar periphyton of all stations sampled due to large populations of filamentous green algae (Mougeotia spp., Oedogonium spp., and Spirogyra

spp.) and an accompanying diverse desmid flora. Cluster No. 2 separates sites located in WCA-2A from those located in the interior of WCA-3A (Sites C-5, C-9, and C-10). Interior WCA-3A sites had low estimates of periphyton cell volume and were dominated by the filamentous blue-green Scytonema hofmannii and a number of associated desmid and filamentous green algae species.

Clusters No. 3 through No. 5 generally grouped together peripheral marsh sites located in WCA-2A and WCA-1. These sites showed relatively high cell volume estimates and were dominated by filamentous blue-green and green algae: (Microcoleus lyngbyaceus, Schizothrix calcicola, Oedogonium spp., Mougeotia spp., and Spirogyra spp).

The final cluster of importance (Cluster No. 6) segregates interior WCA-2A sites from peripheral WCA-2A sites. Interior WCA-2A sites were unique due to their lower cell volumes and the shift in dominance to a filamentous algae community co-dominated by Schizothrix calcicola and Mougeotia spp.

APPENDIX C

STATISTICAL RESULTS

TABLE C-1. RESULT'S OF TUKEY'S MULTIPLE COMPARISON PROCEDURE FOR THE ACCUMULATION OF CHLOROPHYLL A ON GLASS SLIDES IN THE WATER CONSERVATION AREAS-1978-1979-(MG CHLOROPHYLL A MG M-1 WK-1)

FEBRUARY-APRIL 1978 (Data From WCA-2A Only)

STATION*	MH	217	D-2	B-10	B-5	D-3	B-9	B-3	D-1	L-38	B-2	B-1
MEAN**	0.12	0.14	0.19	0.21	0.24	0.25	0.32	0.37	0.62	0.95	4.04	4.18
n = 72												

JULY-AUGUST 1978

STATION	1-8T	A-2	A-1	C-6	C-4	C-5	A-3	B-7	B-6	217	B-9	B-5	B-10	C-1	C-3A	B-2	B-1	B-3
MEAN	0.18	0.18	0.19	0.45	0.46	0.53	0.54	0.84	1.30	1.31	2.24	2.87	2.95	3.31	6.24	9.73	10.5	11.28
n = 96																		

NOVEMBER-JANUARY 1978-79

STATION	C-3B	C-4	C-5	A-6	A-2	A-3	C-6	C-7	MH	1-8T	159	A-1	217	B-5	A-7	A-5	C-8	B-2
MEAN	0.14	0.16	0.19	0.20	0.22	0.25	0.46	0.55	0.76	0.78	0.80	0.86	1.01	1.07	2.05	2.34	5.85	11.4
n = 178																		

JUNE-AUGUST 1979

STATION	C-9	C-10	C-6	C-5	B-7	B-5	217	B-9	A-3	B-6	A-1	B-4	A-2	B-3	1-9	L-38
MEAN	0.06	0.12	0.26	0.36	0.84	0.91	0.92	1.05	1.34	1.47	1.62	2.49	3.03	4.21	4.28	13.2
n = 130																

* See Appendix for description of station locations (See also Figures 10-13)

** Means not underscored by the same line are significantly different at the .05% probability level

TABLE C-2. CORRELATION COEFFICIENTS (r) AMONG NUTRIENTS IN MARSH WATER, NUTRIENTS IN PERIPHYTON TISSUE, AND PERIPHYTON CHLOROPHYLL A PRODUCTION MEASURED IN WCA MARSHES, SUMMERS OF 1978-1979.

		Periphyton Tissue N	Periphyton Tissue P	Periphyton Tissue N:P Ratio	Periphyton Chlorophyll a Production
Marsh Water Inorganic N	VS:	.202 NS	.522	.409[e] NS	.494 NS
Marsh Water Total Dissolved P	VS:	.246 NS	.735	.731[e]	.676
Periphyton Tissue N	VS:	--	.632	.592[e]	.333 NS
Periphyton Tissue P	VS:	--	--	.843[e]	.776
Periphyton Tissue N:P Ratio	VS:	--	--	--	.757[e]

n = 34

All regressions significant at the 0.01 level unless otherwise indicated ($y = mx + b$)

NS = r value not significant

[e] = Exponential curve fit, ($y = ae^{bx}$), all other regressions are linear ($y = mx + b$)

TABLE C-3. RESULTS OF TUKEY'S MULTIPLE COMPARISON PROCEDURE FOR PERIPHYTON SPECIES DIVERSITY FROM ARTIFICIAL SUBSTRATES INCUBATED IN THE WATER CONSERVATION AREAS, SUMMER 1978 AND 1979.

(Species Diversity, $\bar{H}$)

JULY-AUGUST 1978

STATION	B-2[a]	B-3	B-7	B-5	217	B-6	C-3A	1-8T	C-5	B-9	B-10	C-6	A-1	C-1	A-5	B-1	A-3	A-2
MEAN[b]	1.29[c]	1.37	2.07	2.26	2.35	2.40	2.42	2.47	2.66	2.70	2.74	2.76	2.83	2.92	2.95	2.97	4.02	4.11
n = 36																		

JUNE-AUGUST 1979

STATION	B-4	B-3	B-9	C-9	B-7	B-6	L-38	C-5	C-10	A-1	B-5	1-9	A-3	A-2
MEAN	1.71	1.87	2.04	2.08	2.31	2.59	2.77	2.81	2.85	3.07	3.13	3.80	3.90	4.17
n = 28														

(a) See Figures 18-19 for station location description

(b) Means not underscored by the same line are significantly different at the 0.05 probability level

(c) Shannon-Weaver index, base 2 (Odum, 1971)

TABLE C-4. CORRELATION COEFFICIENTS (r) BETWEEN WATER CHEMISTRY PARAMETERS OTHER THAN NITROGEN AND PHOSPHORUS FOR PERIPHYTON/WATER QUALITY SAMPLING SITES, WCA, SUMMERS OF 1978-1979.

	Ca	Mg	Na	K	Cl	SiO_2	TOC	Alkalinity	Conductivity	pH
Ca	1.000									
Mg	.795	1.000								
Na	.720	.974	1.000							
K	.761	.978	.947	1.000						
Cl	.695	.954	.979	.918	1.000					
SiO_2	.638	.864	.876	.854	.878	1.000				
TOC	.618	.822	.825	.852	.795	.794	1.000			
Alkalinity	.946	.919	.872	.877	.851	.784	.704	1.000		
Conductivity	.756	.897	.901	.864	.888	.783	.798	.850	1.000	
pH	.816	.598	.539	.541	.519	.576	NS	.780	.638	1.000

All correlations noted are significant at the 0.01 level
NS = Not Significant

TABLE C-5. R-MODE, VARIMAX ROTATED FACTOR LOADINGS FOR THE 26 BIOLOGICAL AND PHYSIOCHEMICAL VARIABLES*

Factor 1		Factor 2		Factor 3	
Variable	R†	Variable	R	Variable	R
Na	.936	Total dissolved P	.892	Filamentous blue-greens (%) Rel. Abun.	.825
Cl	.914	Inorganic N	.829	pH	.757
K	.893	Periphyton tissue P	.844		
Mg	.889			Filamentous green algae (%) Re. Abun.	-.750
Conductivity	.870	Periphyton Chlorophyll *a* Production	.698		
TOC	.865	Periphyton tissue N	.521	Periphyton species - diversity (H)	-.720
SiO_2	.847				
Alkalinity	.719			Soil (peat) depth	-.685
Ca	.540				
Desmid (%) Rel. Abun.	-.689				
Total No. Algae Species	-.577				
Periphyton Species - Diversity (H)	-.552				
% of Variance Accounted By Each Factor	50.1		65.2		73.3

*The following variables: diatom (%) relative abundance, periphyton (Log_{10}) cell volume and cell density, water depth and hydroperiod length were not significantly correlated with any of the above variables.

†Coefficient (R) values represent both regression weights and correlation coefficients (Nie *et. al.*, 1970. SPSS, Statistical Package for the Social Sciences, 2nd Edition, McGraw-Hill, Inc.).

TABLE C-6. CORRELATION COEFFICIENTS (R) FROM A STEPWISE MULTIPLE REGRESSION ANALYSIS OF DEPENDENT BIOLOGICAL VARIABLES VS INDEPENDENT PHYSIO-CHEMICAL VARIABLES, PERIPHYTON SURVEYS IN THE WCA, 1978-1979.

Dependent Biological Variable	Independent Physio-chemical Predictor Variables (a)	R	F_{Value}
Periphyton Tissue P	Total dissolved P, Cond., Mg, Soil depth, Inorganic N, Na	.922	30.74
Desmid (%) Relative Abundance	Mg, K	.864	45.75
Periphyton Species Diversity ($\bar{H}$)	Alkalinity, Inorganic N	.816	30.97
Total Numbers of Algal Species Present	pH	-.725	35.54
Filamentous Blue-green Relative Abundance	pH	.677	27.02
Periphyton Chlorophyll *a* Production	Total dissolved P	.676	26.95
Periphyton Log_{10} Cell Density	Mg	.653	23.73
Diatom (%) Relative Abundance	Mg, SiO_2	.534	6.18
Periphyton Tissue N	pH, Ca	.526	5.93
Periphyton Log_{10} Cell Volumes	--	NS	--

Regression coefficients are all significant at the 0.01 probability level unless otherwise specified.

(a) Independent predictor variables included: water depth, hydroperiod length, soil (peat) depth, total dissolved P, inorganic N, specific conductance, alkalinity, pH, Ca, Mg, K, Mg, Cl, SiO_2, TOC.

NS = No significant correlation

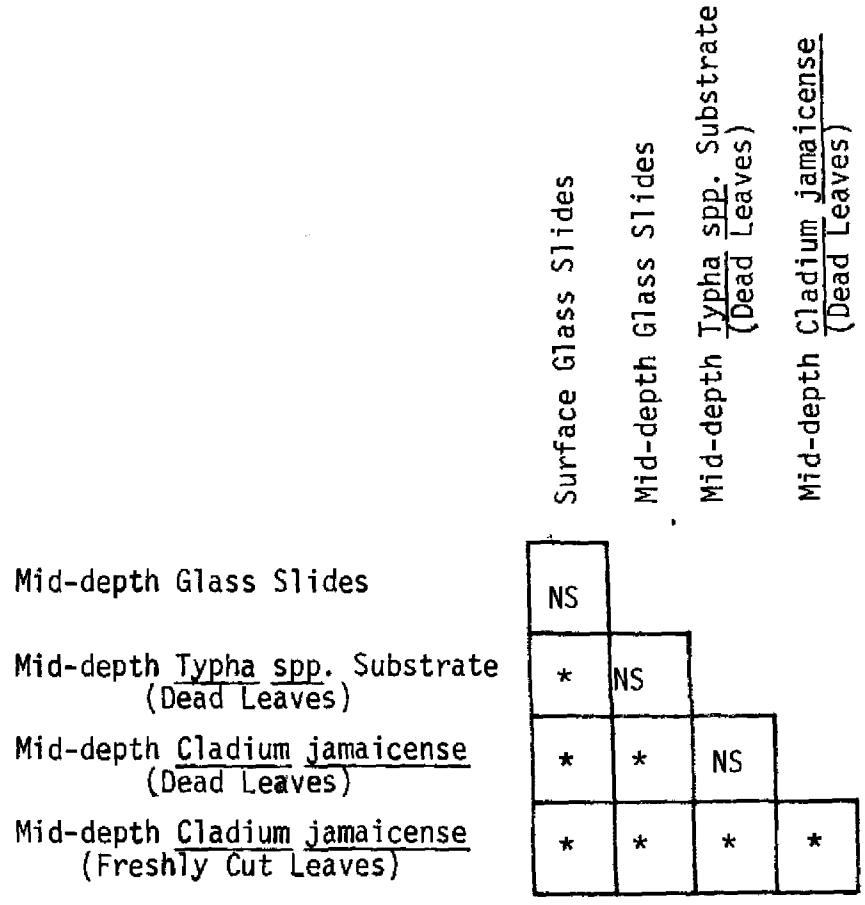


Table C-7. Results of Two-Tailed T-Statistic for Chlorophyll a Accumulated on Five Test Substrates

*Population Means are Significantly Different at P = 0.01.

NS Population Means are Not Significantly Different.

	Surface Glass Slides	Mid-depth Glass Slides	Mid-depth *Typha spp.* Substrate (Dead Leaves)	Mid-depth *Cladium jamaicense* (Dead Leaves)
Mid-depth Glass Slides	NS			
Mid-depth *Typha spp.* Substrate (Dead Leaves)	NS	NS		
Mid-depth *Cladium jamaicense* (Dead Leaves)	NS	*	NS	
Mid-depth *Cladium jamaicense* (Freshly Cut Leaves)	NS	*	NS	NS

Table C-8. Results of Two-Tailed T-Statistic for Periphyton Cell Density Estimates on Five Test Substrates

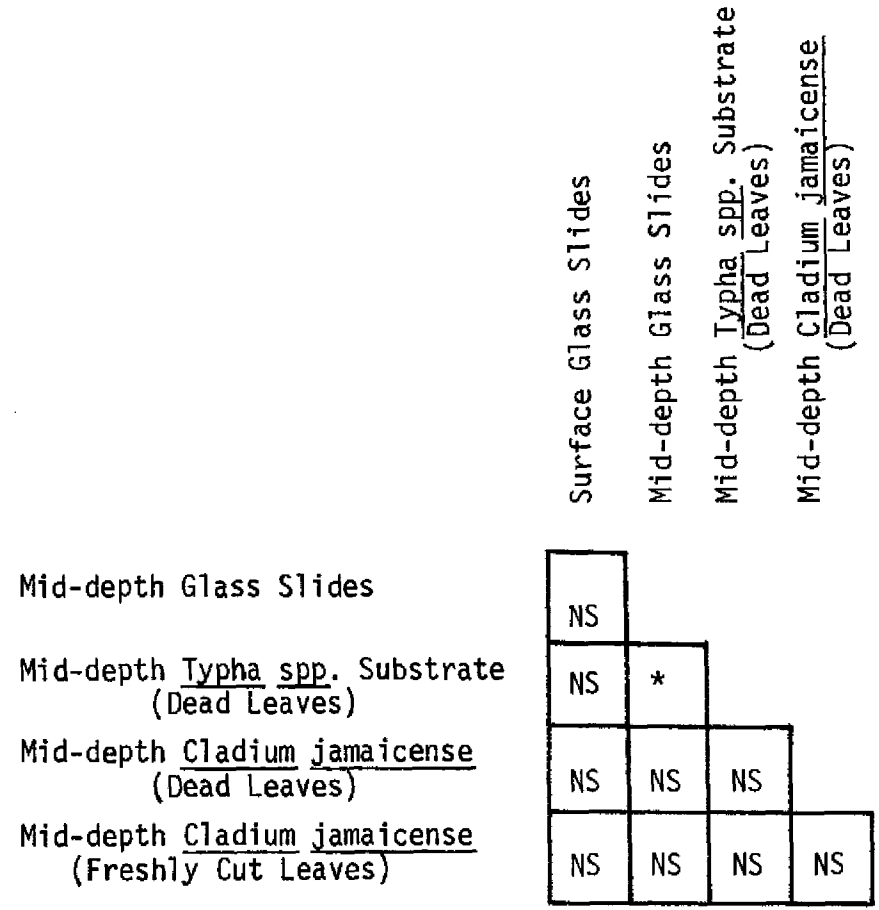


Table C-9. Results of Two-Tailed T-Statistic for Periphyton Species Numbers on Five Test Substrates

*Population Means are Significantly Different at P = 0.01.

NS Population Means are Not Significantly Different.

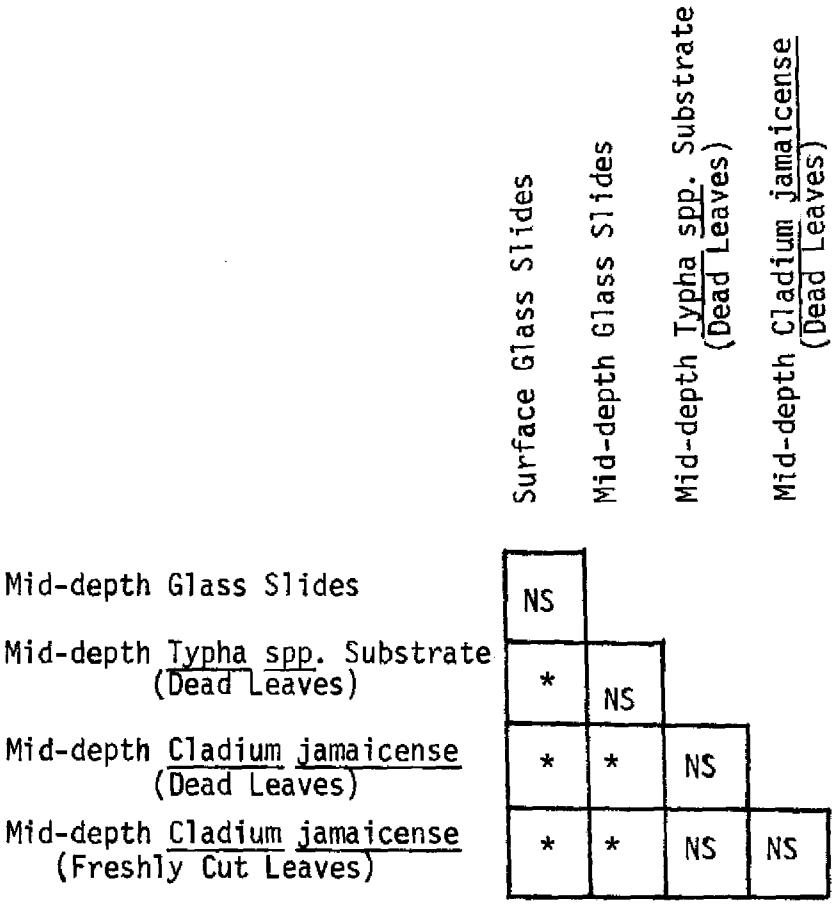
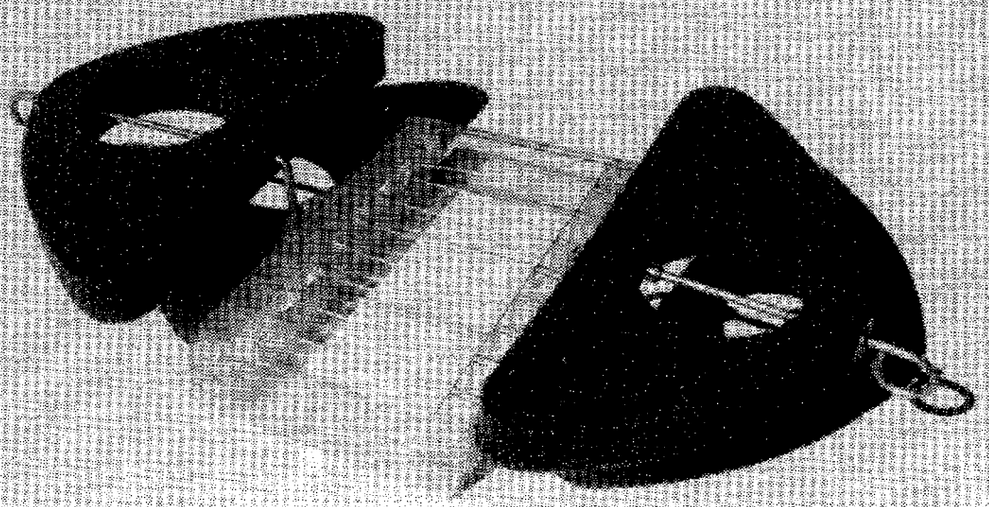
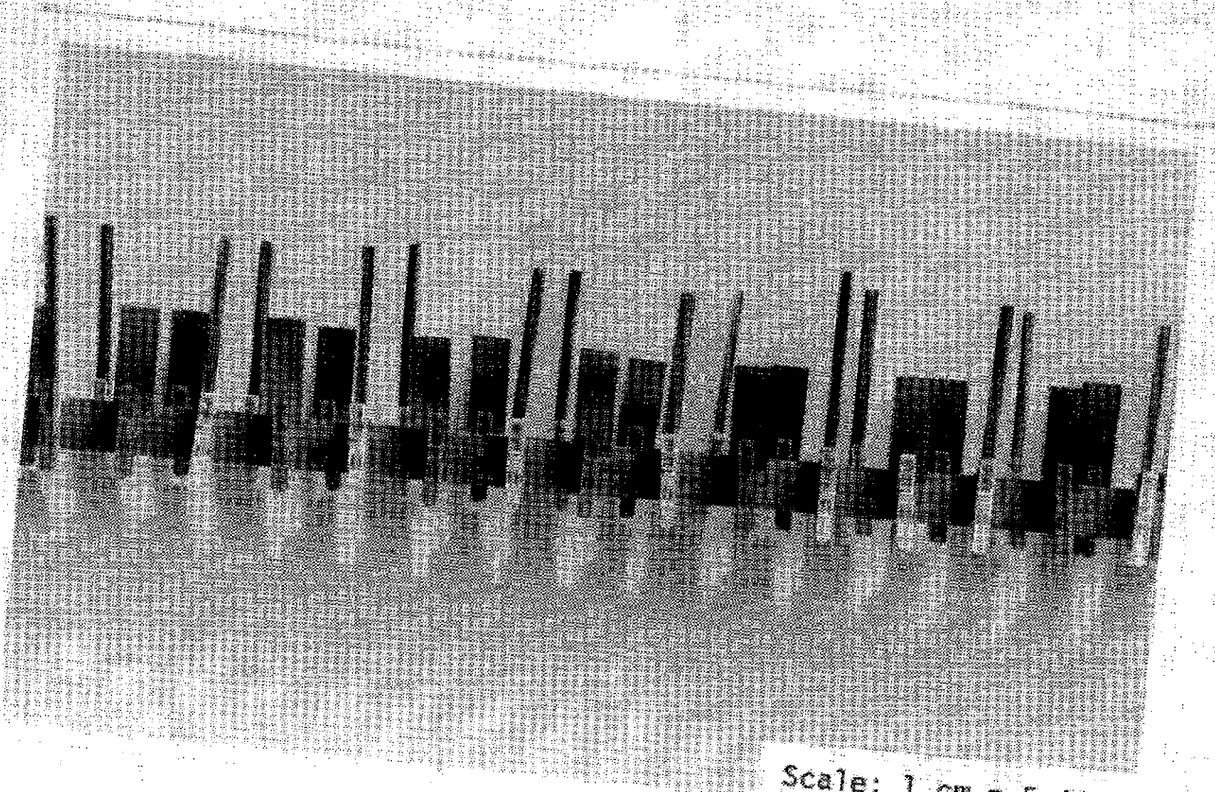


Table C-10. Results of Two-Tailed T-Statistic for Periphyton Species Diversity on Five Test Substrates



Scale: 1 cm = 2.54 cm

FIGURE 3a. PERIPHYTOMETER^{R} II SLIDE RACK, DESIGN ALLIANCE CORP., CINCINNATI, OHIO.



Scale: 1 cm = 5.44 cm

FIGURE 3b. IMPROVISED CLOTHESPIN RACK HOLDING SAWGRASS LEAVES AND GLASS SLIDE SUBSTRATES.