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PERIPHYTON AND WATER QUALITY RELATIONSHIPS IN THE EVERGLADES WATER CONSERVATION AREAS 1978-1982

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DRE 233

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ACKNOWLEDGEMENTS

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EXECUTIVE SUMMARY

Submerged and floating mats of periphyton algae are a conspicuous feature of the Everglades Water Conservation Areas. These microscopic plant communities not only represent a major component of the marsh food chain, but also influence dissolved oxygen concentrations, calcium carbonate (marl) deposition, and nutrient cycling in the marsh. Although periphyton are recognized as an important component of the Everglades ecosystem, little information exists regarding their ecology, population dynamics, or relationship to chemical or physical parameters in the Water Conservation Areas. This is the second technical publication of a four year study (1978-1982) conducted by the SFWMD Environmental Sciences Division concerning algal research in the Water Conservation Areas. Results of the initial 1978-1979 study are available in Technical Publication 81-5 (Swift, 1981). Primary research questions studied in this project were: (a) how do environmental variables such as light, temperature, hydroperiod, or water quality factors affect periphyton species composition and growth in the marsh, (b) what effects do short term variations in water level or water quality have on periphyton community structure, and (c) how do present water management practices impact WCA periphyton populations? Results of this work will be useful in measuring rates of ecological change in the marsh over time and should serve as a baseline for assessing future water management alternatives within the study area.

A total of 333 species of algae representing 107 genera from 8 divisions (including 4 newly described species) were identified from glass slide substrates incubated in the three Water Conservation Areas. Water quality was the predominant factor which controlled periphyton species composition and growth. Hydroperiod and water level fluctuations played less important roles. Algal species composition and distribution at interior marsh sites were closely linked to ionic content and surface water origin. In contrast, peripheral marsh algal communities were strongly affected by nutrient enriched canal water inflows.

Surface water origin was the predominant factor regulating the mineral content of each marsh. Seasonal variations in mineral content were weakly correlated with rainfall and evapotranspiration. Surface waters within WCA-2A, WCA-3A, and the peripheral marsh of WCA-1 were highly mineralized (calcium carbonate) and dominated by filamentous blue-greens (Schizothrix calcicola, Scytonema hofmannii) and an assemblage of hardwater diatoms (Mastogloia smithii v. lacustris, Cymbella ruttneri, Anomoeneis vitrea, and Synedra pahokeensis sp. nov.). Results indicate these algae are biological markers of calcium rich, low nutrient water quality conditions at interior marsh sites. In contrast, acidic, low ionic content waters (characteristic of interior WCA-1) supported a rich desmid-filamentous green (Mougeotia spp. and Spirogyra spp.) microflora.

Inorganic nitrogen and phosphorus concentrations at interior marsh sites were low in comparison to Florida lakes and peripheral marsh sites impacted by canal water inflows. Inorganic N and P remained low (near or below detection limits) when the marsh was flooded. During periods of marsh drawdown, inorganic nitrogen increased rapidly as waters receded. Phosphorus showed only minor increases in concentration during marsh drawdown and reflooding.

High concentrations of nitrogen and phosphorus were consistently recorded from two marsh sites (B-2 and B-5) located south of the S-10C structure in WCA-2A. These nutrient enriched sites supported a "specialized" periphyton community dominated by filamentous greens (Oedogonium spp. and Stigeoclonium sp.) in early summer, filamentous blue-greens (Microcoleus lynbyaceus) in late summer and fall, and diatoms during winter. The diatom flora present at these sites were pollution "indicator" species characteristic of nutrient enriched waters (eg. Gomphonema parvulum, Nitzschia amphibia, Navicula disputans, Navicula confervaceae, and Nitzschia palea).

Interior marsh periphyton communities showed a clear seasonal pattern of maximum growth from August through early October (end of wet season), and a period of diminution from January-March. Algal growth rates at interior marsh sites were low and were more affected by seasonal variations in light and temperature in comparison to seasonal changes in nutrient concentration. Highest growth rates recorded in the study occurred at nutrient enriched marsh sites (B-2 and B-5). Maximum and minimum growth rates at these sites were highly correlated with surface water phosphorus content.

Water quality and periphyton biomonitoring studies conducted in the northeast section of WCA-2A during 1980-82 showed nutrients to penetrate the marsh deeper than reported in the 1978-79 survey.

Supplies of elemental phosphorus in periphyton cell tissue from interior WCA-2A and WCA-3A sites were low in comparison to "critical concentrations" required for normal growth. Low supplies of phosphorus within marsh surface waters, periphyton cell tissue and low algal growth rates suggest nutrient limiting conditions at interior WCA-2A and WCA-3A sites. Elemental P concentrations at site A-3 (interior WCA-1) were 2-3 times higher than those recorded in WCA-2A and WCA-3A. Co-precipitation of phosphorus in calcium carbonate rich waters may partially explain the low concentration of elemental P observed in algal cell tissues collected from interior WCA-2A and WCA-3A marsh sites. Periphyton elemental P concentrations at peripheral marsh sites were significantly correlated with concentrations of phosphorus in marsh surface waters and high algal growth rates. Highest concentrations of elemental P in periphyton cell tissue occurred at sites B-2 and B-5, located south of the S-10C structure in WCA-2A.

Low ionic content waters (interior of WCA-1) were correlated with high algal species diversity and an abundant desmid flora. Periphyton species diversity in the interior of WCA-1 were significantly higher than those recorded in WCA-2A, WCA-3A, and the peripheral marsh of WCA-1. Lowest diversity indices occurred in nutrient enriched waters (Site B-2).

Comparison of Everglades peatland water chemistry with European peat forming marshes classified Water Conservation Areas 2A and 3A as minerotrophic fens. Water quality in the interior of WCA-1 compared well with reported "transitional" stages of ecological succession from minerotrophic fen to the classic ombrotrophic "raised bog" community.

Changes in periphyton species composition as a result of pumping nutrient enriched canal waters across the marsh will increase algal biomass and reduce algal species diversity at the primary producer level. Changes in the base of the marsh food web may have far reaching impacts on the species composition and biomass of higher trophic level herbivores. Such effects might include: changes in food item size, nutritive value, or selection choices available to grazing invertebrates and fish. Simplification of the marsh food chain may ultimately reduce ecosystem stability. Discharging highly mineralized (calcium rich) canal water across marshes that historically contain low concentrations of dissolved minerals could significantly alter the algal flora and water quality characteristics of the marsh.

SUMMARY OF RELATIONSHIPS BETWEEN ENVIRONMENTAL VARIABLES AND PERIPHYTON COMMUNITY STRUCTURE

	Water Quality Conditions		
	Hard Water, High N & P	Hard Water, Low N & P	Soft Water, Low N & P
AREA	Peripheral Marsh, WCA-2A, and WCA-3A	Interior Marsh, WCA-2A, WCA-3A, Peripheral Marsh WCA-1	Interior WCA-1
Dominant Periphyton Flora	Pollution tolerant species:e.g., *Microcoleus lyngbyaceus*, (blue-green); *Oedoginium spp.*, *Spirogyra spp.* and *Stigeoclonium spp.* (greens); *Gomphonema parvulum, Nitzschia amphibia, Navicula disputans, Nitzschia palea* (diatoms)	Calcareous blue-green algae: *Schizothrix calcicola, Scytonema hofmannii* Hardwater diatoms: eg. *Mastogloia smithii v. lacustris, Cymbella ruttneri, Anomoeneis vitrea*	Desmids and filamentous greens; eg. *Mougeotia spp. Oedogonium spp.*; Diatoms indicative of acid, soft water; eg. *Cymbella amphioxys, Frustulia rhomboides v. saxonica, Anomoeoneis serians v. brachysira*
Seasonal Periodicity	Filamentous greens, spring/early summer; blue-greens, late summer and fall; diatoms, winter	Blue-greens; peak growth rates late summer and fall; diatoms winter/spring	Filamentous greens, summer; desmids, late summer, fall
Periphyton Growth Rates	High	Very low-low	Low
Algal Species Diversity	Low	Moderate	High
Cell Tissue Phosphorus Content	High (Luxury consumption of P)	Very Low (P Limited)	Low-moderate
Cell N:P Ratio	Low	High	Moderate-high
Effects of Light and Temperature	High water temperature and nutrients favor development of blue-greens (*Microcolues sp.*); low water temperature and nutrients favor filamentous green algae/diatom community	Light and water temperature important seasonal growth factors at interior WCA-2A and WCA-3A sites	Light and water temperature important seasonal growth factors at interior WCA-1 sites

INTRODUCTION

Submerged and floating mats of calcium carbonate encrusted algae, commonly referred to as periphyton, are a conspicuous and ecologically important element of south Florida wetlands. Periphyton are defined as an assemblage of attached microorganisms (primarily algae) which form living biofilms on the free surface of submerged substrates. As primary producers, periphyton potentially represent a major component of the marsh food chain. Periphyton mats provide both habitat and organic matter for grazing invertebrates and small forage fish which, in turn, are consumed by wading birds, sport fish, and reptiles (Tabb et. al., 1967; Carter et. al., 1973). Wood and Maynard (1974) estimate that a significant, if not greater, portion of the total primary production of the lower Everglades marsh is derived from the 200+ species of periphyton rather than from vascular plants. Similarly, Hunt (1961) estimated that nearly all the daily production and respiration of Everglades open water prairies is due to periphyton photosynthesis and respiration. Periphyton represent a primary food source for Everglades crayfish (Schomer and Drew, 1982 and references cited therein). Kolipinski and Higer (1969) report that filamentous blue-greens, desmids, and diatoms comprise a major portion of the diet of a number of Everglades forage fish.

In south Florida, periphyton mats seasonally cover large areas of the Everglades Water Conservation Areas. Periphyton photosynthesis and respiration markedly influence diel dissolved oxygen and carbon dioxide levels within the Everglades marsh (Hunt, 1961; Wilson, 1974). Periphyton growth and metabolism also influence nitrogen fixation (Goldstein et. al., 1980), marl deposition, soil building, and nutrient uptake processes within the marsh (Craighead, 1971; Gleason, 1972; Gleason and Spackman, 1974). Periphyton may also play an important role in the survival of aquatic organisms during drought. The formation of thick algal coatings on submerged substrates provides a moist microhabitat that prevents the dessication of eggs and larvae of insects, invertebrates, and fish during the dry season. As water levels rise, these organisms rapidly repopulate the reflooded marsh (Schomer and Drew, 1982 and references cited therein).

Until recently, studies of Everglades periphyton ecology have been largely restricted to Everglades National Park (Hunt, 1961; Brock, 1970; Van Meter-Kasonof, 1965, 1973; Gleason, 1972; Gleason and Spackman, 1974; Wood and Maynard, 1974; Wilson, 1974; Browder, 1981). Comparatively little data exists concerning the ecology of algal communities within the three Everglades Water Conservation Areas (Gleason and Spackman, 1974; Swift, 1981). Specific questions investigated in this study were: (a) Do Water Conservation Area periphyton communities demonstrate periodic or seasonal changes in their community structure, growth rates, or nutritional requirements, (b) Are observed changes (if any) related to environmental variables such as light, temperature, hydroperiod, nutrients, pH, or major ion concentrations, (c) What effects do short term variations in water levels or water quality have on periphyton community structure, and (d) How do present water management practices impact Water Conservation Area periphyton?

This is the second phase of a program initiated in 1978 to study periphyton/water quality relationships within the three Water Conservation Areas. During 1978-1979, 18 periphyton/water quality sites were monitored. Water chemistry samples were collected concurrently with the growth of algae communities on glass slides over a sixty day incubation period (Swift, 1981). Results of these initial investigations suggested:

(1) The distribution of major ions and nutrients varies greatly among sites and among Water Conservation Areas.
(2) Nutrients are present in very low concentrations at interior marsh sites, suggesting nutrient limiting conditions.
(3) Nutrient concentrations at marsh sites near canal water inflows were high in comparison to nutrient concentrations at interior marsh sites.
(4) Periphyton species composition and growth rates on glass slides were significantly influenced by site differences in major ion content, pH, and phosphorus concentrations.
(5) Calcareous blue-green algae and diatoms, characterized by low growth rates and low concentrations of elemental P, were the dominant algae at low nutrient, hard water interior marsh sites within WCA-2A, WCA-3A, and the peripheral marsh of WCA-1. Desmids and filamentous greens were the dominant algae within the acid, soft water interior marsh of WCA-1.
(6) Periphyton communities exposed to nutrient enriched canal waters developed a "specialized" community of pollution-tolerant algae characterized by high growth rates and high concentrations of elemental P within algal cell tissues.
(7) Phosphorus was shown to be the major water quality factor that controlled periphyton growth rates. Major ion concentration and pH appeared to heavily influence periphyton species composition at low nutrient, interior marsh sites.

Results of these preliminary efforts showed that further studies directed toward quantifying seasonal aspects of marsh water quality and periphyton ecology were warranted.

STUDY AREA

The three Everglades Water Conservation Areas (WCA) encompass almost a million acres (3500 km^2) of native south Florida wetlands covering parts of Dade, Broward, and Palm Beach Counties. These fresh water marshes represent a little more than a third of the original 10,000 km^2 Everglades ecosystem that once covered most of south Florida, extending from south of Lake Okeechobee 100 miles to the mangrove estuaries of Florida Bay and the Gulf of Mexico (Figure 1). Today, the Water Conservation Areas represent a modified wetland ecosystem with a network of canals, levees, pumps and gates which enclose the marsh allowing manipulation of water levels for flood control, water storage, groundwater recharge, wildlife management and recreational benefits. Water levels within the WCA are managed by the South Florida Water Management District.

The Everglades region has been described as a vast sawgrass (Cladium jamaicense) marsh dotted with tree islands and interspersed with wet prairies and aquatic sloughs (Davis, 1943, 1946). Poor drainage and decomposition of marsh vegetation in this lowland region have produced muck and peat deposits up to 4 m in depth that overlie calcareous limestone formations (Stephens, 1956; Gleason et. al., 1974). South Florida has a subtropical climate with generally frost free winters and long, hot, humid summers. More than 75 percent of the annual rainfall occurs during the June through October wet season. Water levels within the Water Conservation Areas fluctuate on a seasonal basis in response to rainfall and water management practices. Maximum water depths within the marsh typically range from 0.5-0.9 m during the late wet season (September-October) while some areas of the marsh are dry during March-April.

The majority of water that flows into the WCA's is derived from agricultural lands (sugarcane, rice, vegetable and sod farming, improved pasture). Canal waters, which drain agricultural lands, are rich in organic and inorganic forms of nitrogen and phosphorus and are highly mineralized due to mixing with ground water inflows (Gleason, 1974; Waller and Earle, 1975; McPherson et. al., 1976; Lutz, 1977; Millar, 1980).

Water Conservation Area 1, (WCA-1) also known as the Loxahatchee National Wildlife Refuge, is the northernmost pool of this modified wetlands system and occupies an area of 572 km^2 in western Palm Beach County. Wildlife and recreational resources of WCA-1 are managed by the U.S. Fish and Wildlife Service. WCA-1 is a relatively shallow marsh encircled by a rim canal that is 3 to 4 meters deep. Nutrient enriched canal waters derived predominantly from the Everglades Agricultural Areas and grazing lands to the north are pumped into WCA-1 via S-5A and S-6 (Figures 1 and 2). During low water periods, these waters generally flow south along perimeter canals and do not penetrate the interior marsh due to slightly higher ground level elevations at the center of WCA-1. Under these conditions water quality within the marsh interior reflects that of rainfall. In the wet season, marsh stage levels rise in response to rainfall and increased pumping activities. High stage levels allow canal waters to penetrate the peripheral marsh to a much greater extent (Millar, 1980).

Water Conservation Area 2A (WCA-2A), the smallest of the three areas, lies to the southwest of WCA-1 and covers an area of 547 km^2 in southern Palm Beach and northern Broward Counties. WCA-2A receives large quantities of nutrient enriched canal water derived from the Everglades Agricultural Areas through the three S-10 discharge structures located on the Hillsborough Canal (Figure 2). The absence of interior canals along the north and east levees of WCA-2A forces this nutrient enriched water to sheet flow across the marsh. Since construction of canals in 1961, nutrient enriched S-10 water has impacted approximately 2,400 ha of marsh in the northeast portion of WCA-2A, producing significant changes in the species composition of aquatic macrophytes and periphyton (Gleason, 1974; Davis and Harris, 1978; Swift, 1981).

Water Conservation Area 3A (WCA-3A), located in western Broward and northwestern Dade Counties, is four times (2,400 km^2) larger than WCA-2A. WCA-3A is bisected by interior canals so that the north end receives surface water runoff from agricultural lands (L-3, S-8, S-150). The S-9 structure pumps predominantly urban runoff into WCA-3A from the South New River Canal. The L-28E and S-140 drainage basins derive water from grazing lands and wetland communities located to the west of WCA-3A.

METHODS AND MATERIALS

In the first phase of this study, water chemistry samples were collected during the wet and dry seasons of 1978-79 concurrently with the growth of periphyton communities on glass slides at 18 sites located throughout the WCA system (Swift, 1981). During 1980-82, seven of these original 18 sites were sampled on a monthly basis (Figure 2).

Field data (temperature, dissolved oxygen, specific conductance, and pH) were recorded using a Hydrolab^R electronic recording instrument. Water quality samples were filtered in the field (Millipore^R membrane filter, pore size 0.45 microns) and stored in polyethylene bottles on ice. Major ions (sodium, potassim, calcium, magnesium, silicate, and total

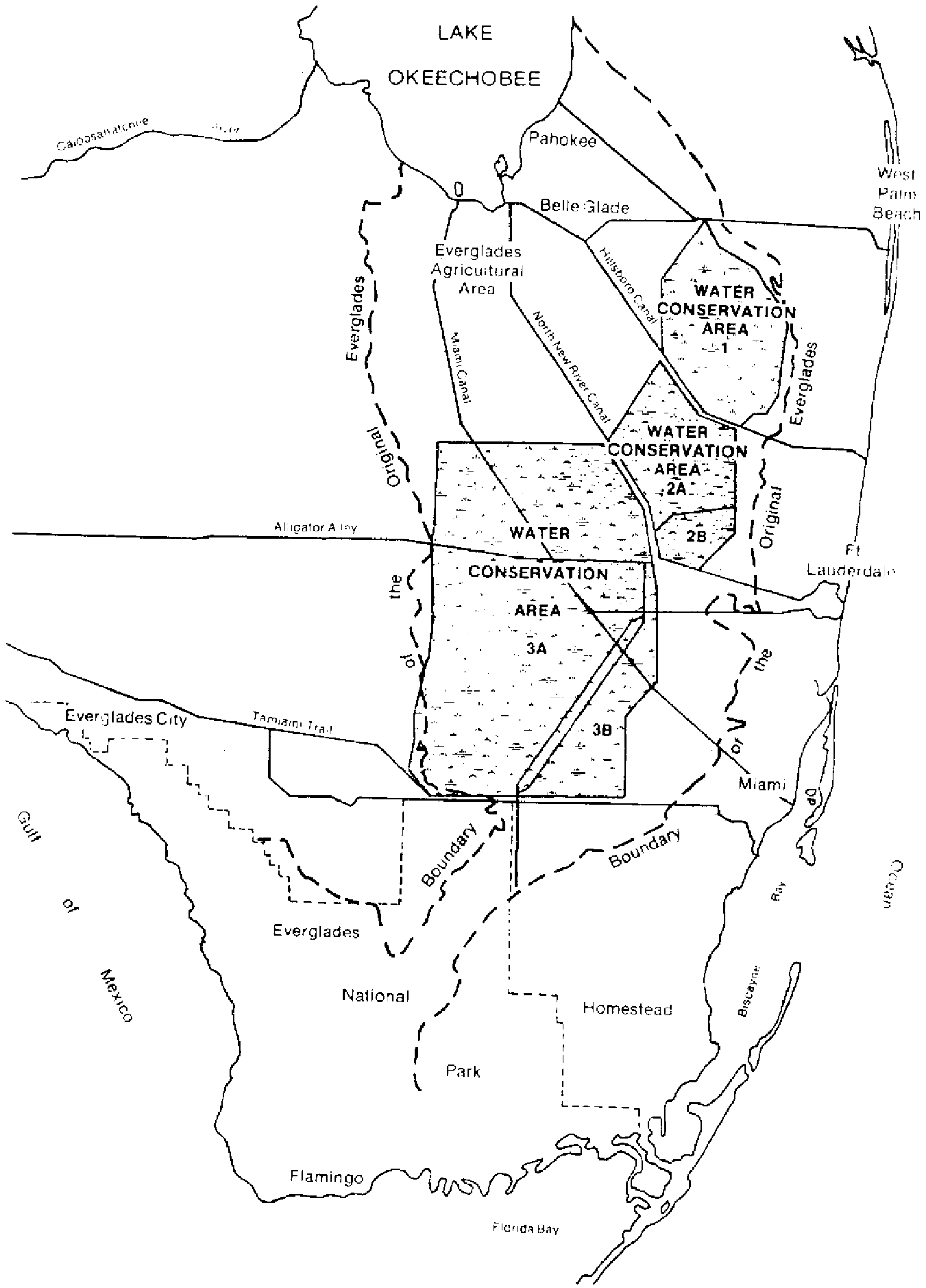

FIGURE 1. LOCATION OF EVERGLADES WATER CONSERVATION AREAS AND BOUNDARY OF ORIGINAL EVERGLADES IN SOUTH FLORIDA (Adapted from Smith, 1968).

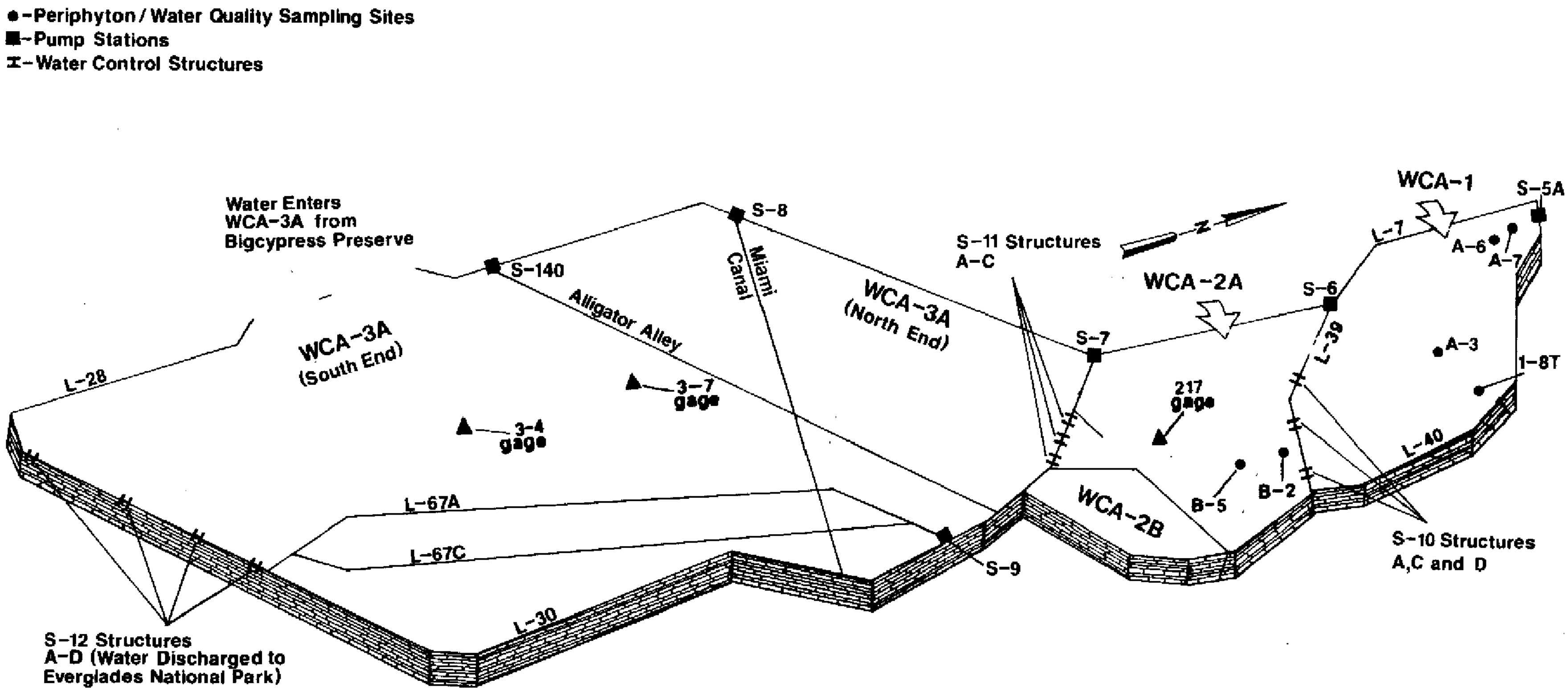

FIGURE 2. LOCATION OF LONG-TERM PERIPHYTON/WATER QUALITY SAMPLING SITES IN THE EVERGLADES WATER CONSERVATION AREAS, 1978-1982.

iron) were determined using flame atomic emission, while major nutrients (Total N, NH_4^+, NO_3, NO_2, Total PO_4, total dissolved PO_4, and ortho-PO_4), chloride, sulfate, and alkalinity were measured using Technicon[R] AutoAnalyzer methods. These chemical methods were recommended or approved by the Environmental Protection Agency (EPA, 1976) or the American Public Health Association (APHA, 1975).

Rainfall and surface water elevations were obtained from U.S. Army Corps of Engineers gauging stations located near the field sampling sites. 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. Solar radiation data were obtained from the Agricultural Research and Education Center located near Belle Glade, Palm Beach County, Fla. (Lat. 26°40', Long. 80°38'). Data were reported in langleys (gram calories per cm^2) measured by a solar pyranometer (Allen, 1978-82).

Periphyton communities were grown on glass slides suspended in redwood slide racks 3 cm below the water surface. Slides were collected from the wood racks every 30-35 days. Samples were analyzed for chlorophyll a content, species composition, relative abundance of major algal groups, cell density, cell volume, and species diversity based on the Shannon-Weaver equation (Shannon-Weaver, 1963). Periphyton communities growing on natural substrates were collected from each site and analyzed for elemental concentrations of N and P according to methods outlined by Black (1965). Each of the above methods are described in detail in an earlier report (Swift, 1981). Algal species identifications were performed by the authors. New species were confirmed by Dr. Charles Reimer, Academy of Sciences of Philadelphia.

Factor analysis was used as a screening technique to uncover underlying factors which account for the majority of variance contained within the data matrix. The method of factoring used was a principal component solution with Varimax-rotation with a minimum acceptable eigenvalue of 1.0. Tests of relationships between variables were also conducted using a stepwise multiple regression statistical package (Systems/360 IBM Subroutine Package). Percent relative abundance data based on cell volume estimates were arcsin transformed (Snedecor and Cochran, 1967) for use in the factor and multiple regression analyses.

RESULTS

Solar Insolation and Water Temperature

Maximum water temperatures reached 35.5°C on July 7, 1978 with the lowest temperature of 13.2°C recorded on February 28, 1978 and January 10, 1979. The highest single daily solar radiation value was 716 langleys recorded on May 11, 1982, and the minimum value, 37 langleys, occurred on December 28, 1978 (Allen, 1982). Water temperature and averaged biweekly solar radiation showed typical, seasonal bell-shaped curves with maximum values occurring in June-August and minimum values occurring from December-February (Figure 3). Seasonal maximum water temperatures appeared to lag behind maximum light intensities by 1-3 weeks.

Hydrology

Marsh hydrology played an important role in determining seasonal variations in mineral and nutrient content of marsh surface waters at interior marsh sites (Figures 4-7).

In WCA-1, station A-3 experienced the most prolonged hydroperiod. Water levels remained above ground level except during one brief dry period in April 1981 (Figure 4). Highest water levels occurred in September 1982 with a depth of 70 cm. Water levels generally decreased during winter and spring months (dry season) with rising stages occurring from mid-summer through fall (wet season).

Water levels in WCA-2A remained well above ground from 1978 until April 1981. Figure 5 reflects the storage of water in WCA-2A (217 gauge) during 1978-79 with minimum and maximum depths of 0.36 and 1.10m, respectively. The experimental drawdown of WCA-2A during the 1981 drought caused water levels to fall well below ground level during April-May of that year. A less severe drying of the marsh occurred during January-April of 1982 (Worth, 1983).

Water level fluctuations in WCA-3A were more typical of south Florida wetlands with distinct seasonal wet and dry cycles occurring each year (Figures 6 and 7). During 1981 and 1982, water levels in the northern portion of WCA-3A (3-7 gauge) fell to 0.8 m below ground level for periods of 5-6 months. Due to the low water table, numerous fires swept the area. Many of these burns were peat fires that caused extensive soil subsidence and loss of tree island communities.

Major Ions

Interior marsh surface waters differed greatly in specific conductivity and mineral content among the three WCA's (Table 1). Lowest values of conductivity and major ion concentration occurred in the acid, soft water interior marsh of WCA-1, while highest conductivity and major ion values occurred in the highly mineralized waters of WCA-2A (Figures 8 and 9).

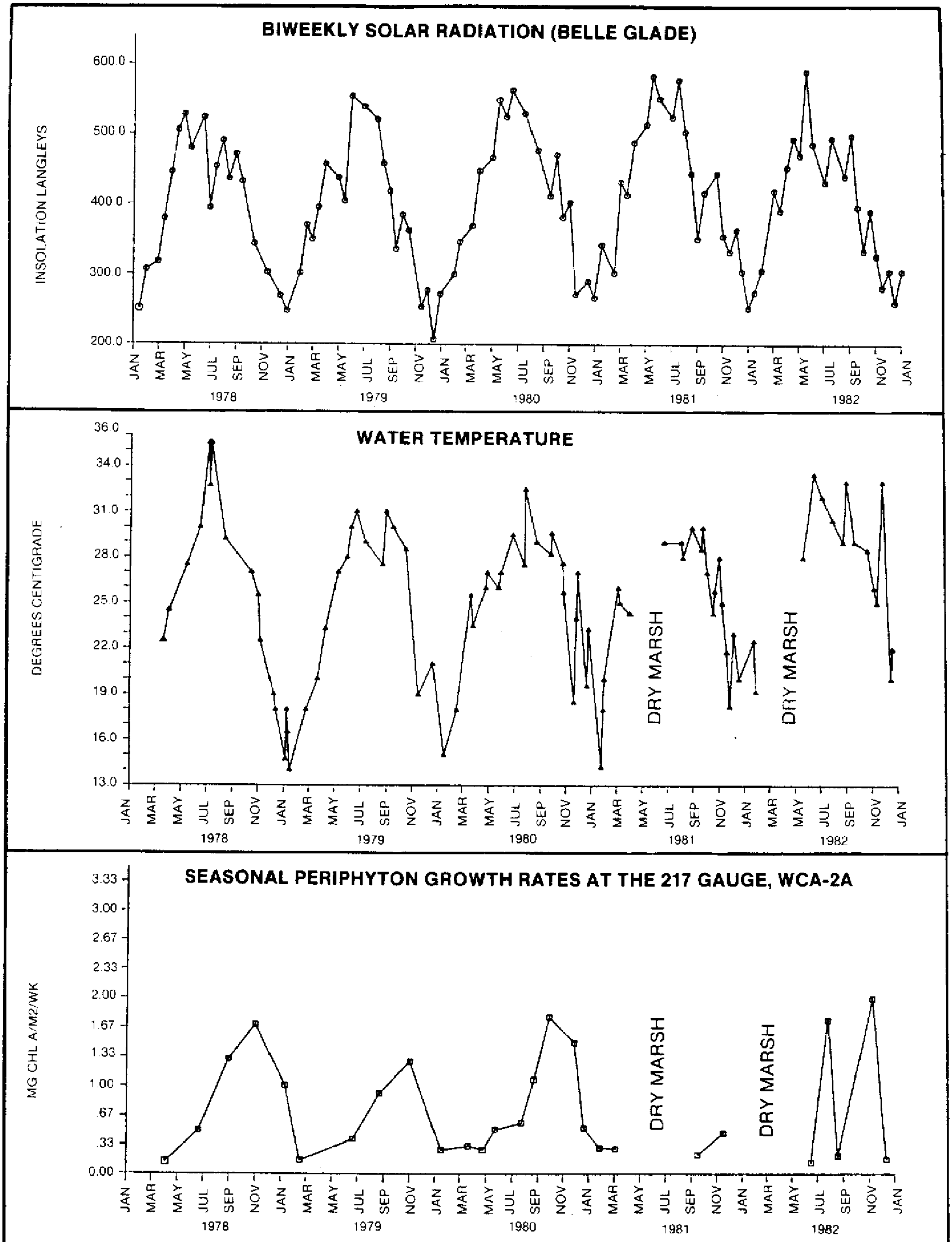

FIGURE 3. LIGHT, WATER TEMPERATURE, AND PERIPHYTON GROWTH RATES AT THE 217 GAUGE, WCA-2A, 1978-1982.

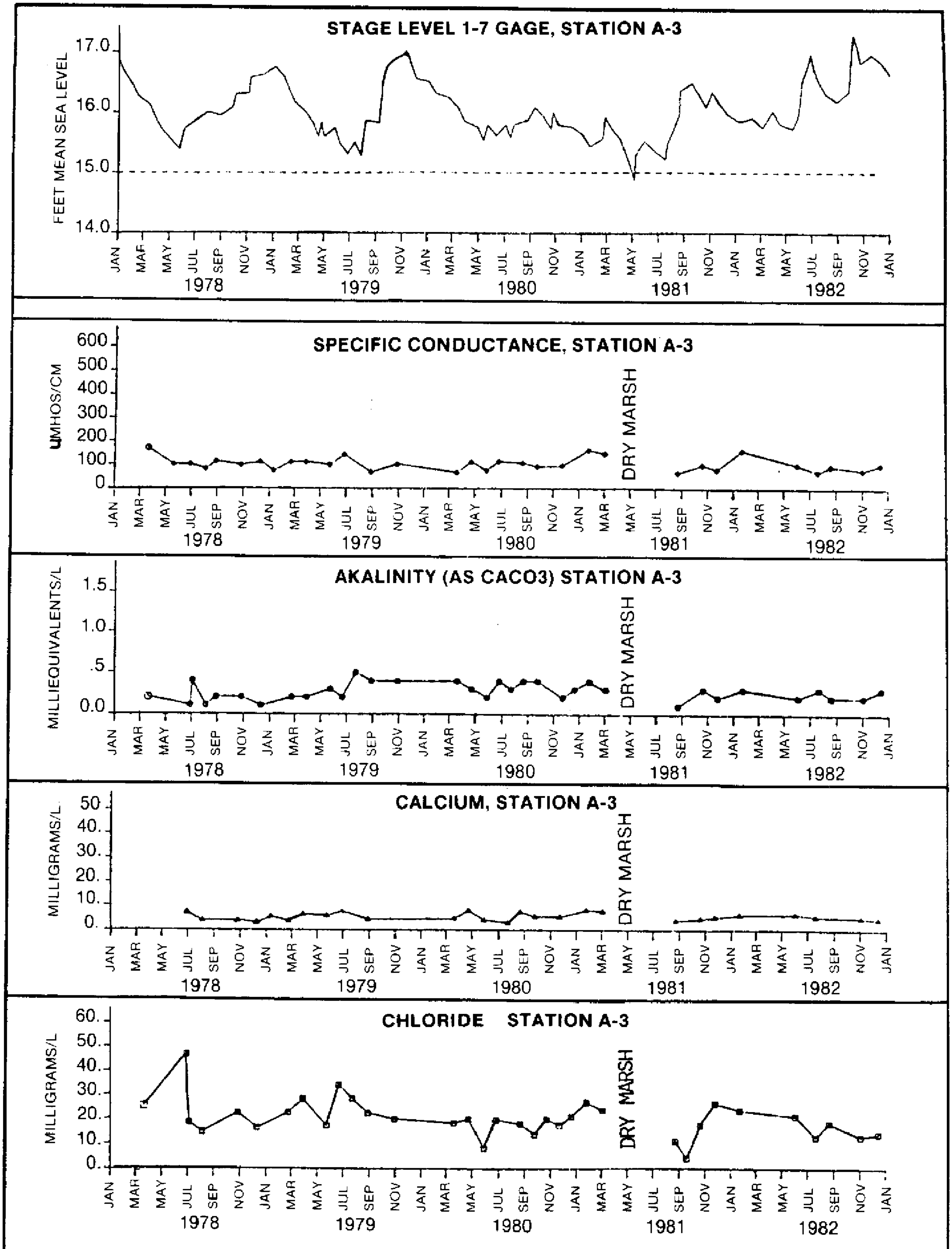

FIGURE 4. WATER LEVELS, CONDUCTIVITY, AND ALKALINITY, CALCIUM AND CHLORIDE CONCENTRATIONS AT SITE A-3, INTERIOR WCA-1 MARSH, 1978-1982.

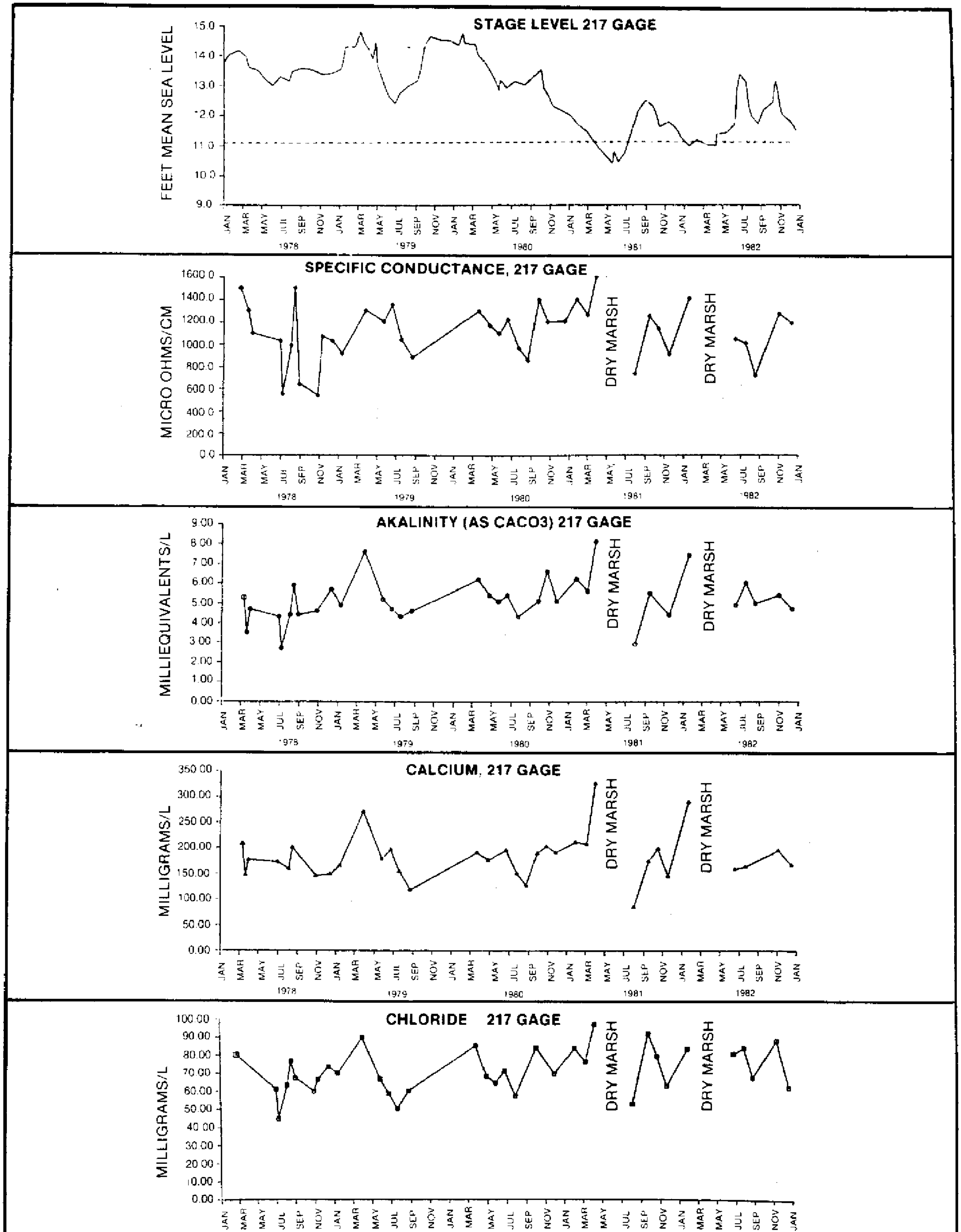

FIGURE 5. WATER LEVELS, CONDUCTIVITY, AND ALKALINITY, CALCIUM AND CHLORIDE CONCENTRATIONS AT THE 217 GAUGE, INTERIOR WCA-2A MARSH, 1978-1982.

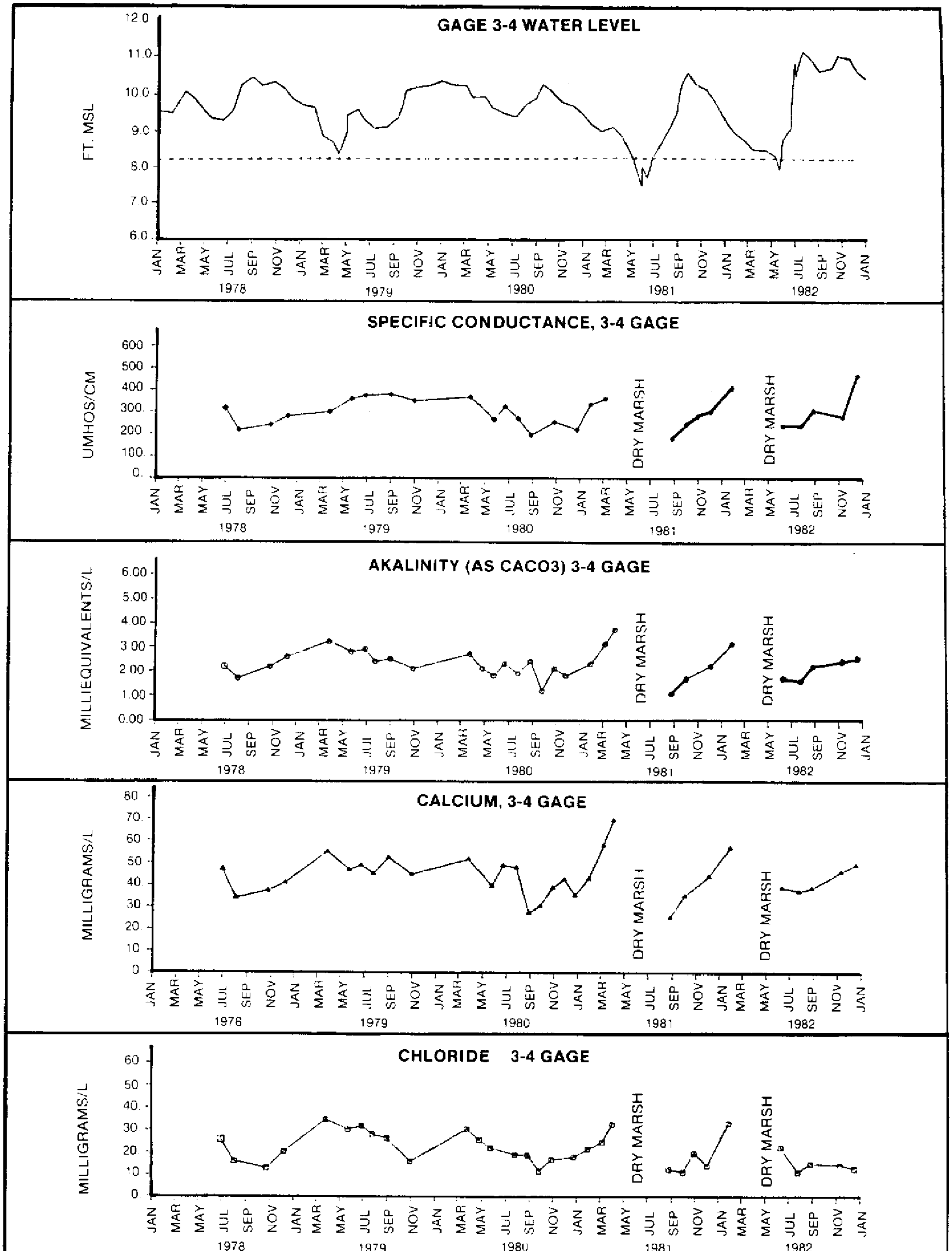

FIGURE 6. **WATER LEVELS, CONDUCTIVITY, AND ALKALINITY, CALCIUM AND CHLORIDE CONCENTRATIONS AT THE 3-4 GAUGE, INTERIOR WCA-3A MARSH, 1978-1982.**

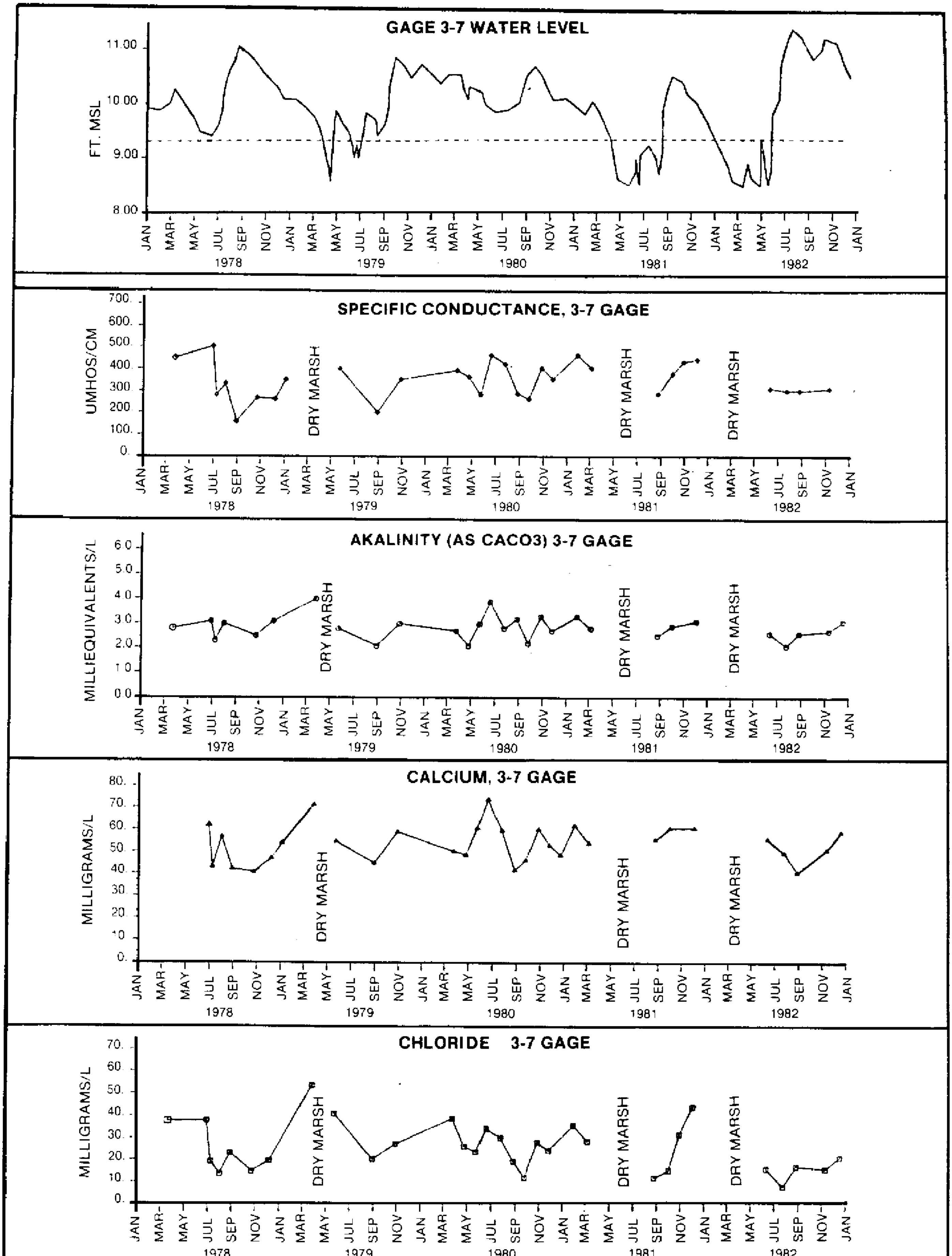

FIGURE 7. WATER LEVELS, CONDUCTIVITY, AND ALKALINITY, CALCIUM AND CHLORIDE CONCENTRATIONS AT THE 3-7 GAUGE, INTERIOR WCA-3A MARSH, 1978-1982.

TABLE 1. AVERAGE MAJOR ION CONCENTRATION AND FIELD MEASUREMENTS AT INTERIOR WCA SITES, FEBRUARY 1977 - JUNE 1983

Parameter	All Sites Combined (Mean)	WCA-1 (Site A-3)	WCA-3A (3-4 and 3-7)	WCA-2A (217 Gauge Gauges
Field Measurements:				
pH	6.8 (.7)	5.7 (.5)	7.0 (.5)	7.1 (.4)
Conductivity µmhos cm^{-1}	535 (403)	112 (39)	333 (115)	1050 (269)
D.O. (mg/l)	5.3 (2.7)	4.7 (2.3)	6.1 (2.2)	3.7 (2.3)
Major Ions				
$HCO_3^=$	177 (115)	19 (8)	161 (34)	299 (61)
Alkalinity (as $CaCO_3$)	145 (94)	16 (7)	132 (28)	245 (50)
Hardness	155 (103)	21 (9)	137 (30)	284 (57)
CL^-	76 (72)	22 (8)	28 (19)	174 (49)
Na^+	49 (54)	12 (4)	18 (10)	121 (30)
Ca^+	45 (26)	6 (2)	47 (9)	67 (14)
Mg^{++}	11 (11)	1.5 (.7)	4 (2)	28 (6)
K^+	2.7 (2.6)	.6 (.4)	1.1 (.9)	6.5 (2.1)
SiO_2	10 (7)	4 (3)	7 (4)	19 (5)
$SO_4^=$	18 (25)	9 (5)	12 (27)	39 (19)
TOTAL-Fe	.3 (.6)	.2 (.2)	.5 (.6)	.1 (.1)
Cl:Ca Ratio	1.7	3.7	0.6	2.6

Upper value = avg; lower value in parentheses = standard deviation

The high ionic content of these waters are the result of highly mineralized agricultural water discharged into WCA-2A via the three S-10 structures located on the Hillsborough canal (Figure 1).

In contrast, surface waters in the interior of WCA-1 (Site A-3) were low in dissolved minerals, poorly buffered, acid and soft (Table 1). Specific conductivity at Site A-3 averaged 112 µmhos/cm with pH in the acid range (4.6-6.8). Chloride (avg. = 22 mg/l), bicarbonate (avg. = 19 mg/l), and sodium (avg. = 12 mg/l) were the dominant ions. Major ion concentrations in these waters were only 2-3 times higher than south Florida rainfall (Table 2) and suggest that rainfall is the primary source of water for the interior WCA-1 marsh.

Alkalinity and hardness of surface waters in the interior of WCA-3A were roughly one half the mineral content of WCA-2A. Specific conduc-tance ranged between 300-450 µmhos/cm. Bicar-bonate (avg. = 161 mg/l) and calcium (avg. = 47 mg/l) were the dominant ions.

Seasonal variations in marsh water mineral content were more closely related to the origin of each marsh's water supply in comparison to factors such as rainfall.

Water quality within the interior of WCA-2A was highly mineralized with bicarbonate (avg. = 299mg/l) and chloride (avg. = 174 mg/l) being the principal cations. Sodium, calcium, sulfate, and magnesium were the primary anions. Specific conductance ranged from 800-1300 µmhos/cm and pH was within the circumneutral to basic range (6.8-7.5).

Linear regression results showed only weak correlations between water levels and marsh water conductivity or hardness over time. However, highest major ion concentrations were usually recorded during low water periods, while minimum concentrations occurred near the peak of the wet season (Figures 4-7).

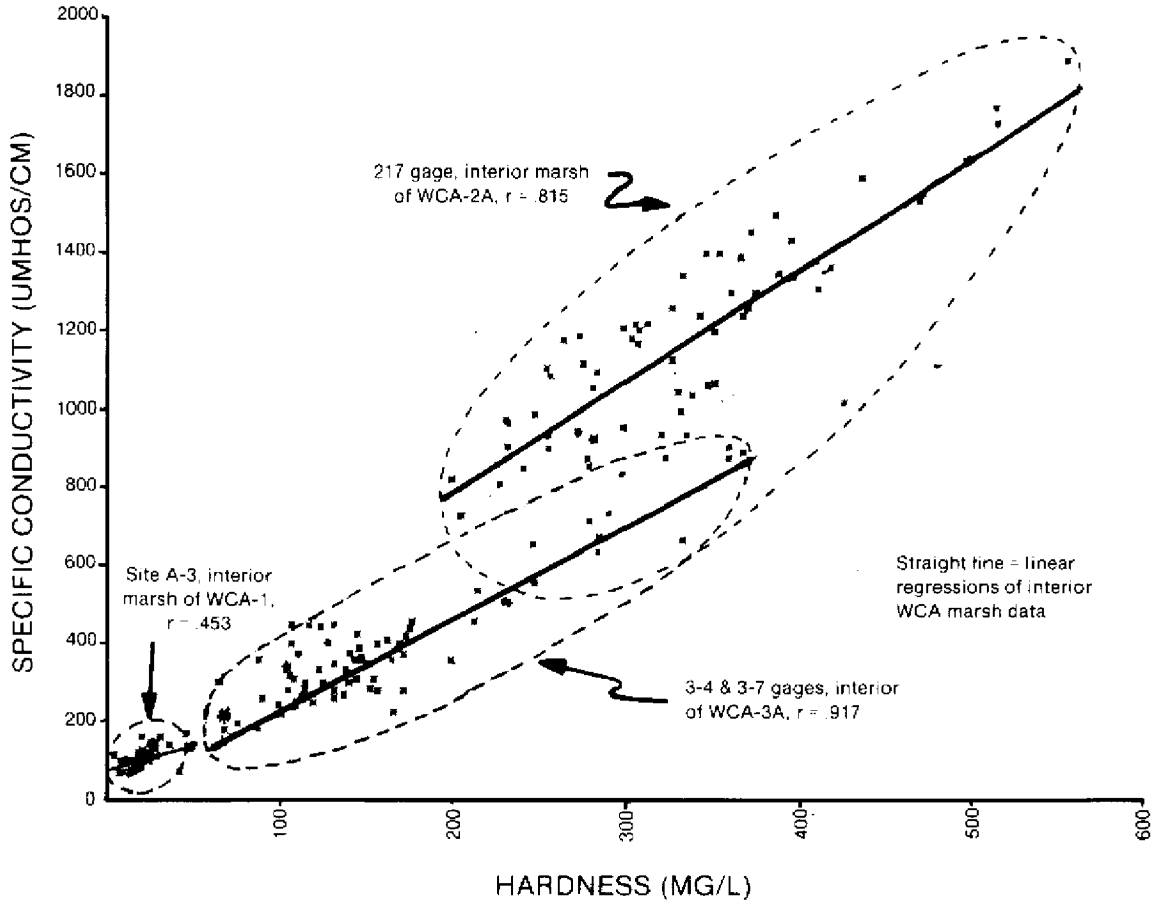

FIGURE 8. CONDUCTIVITY VS. HARDNESS IN WCA SURFACE WATER, 1978-82

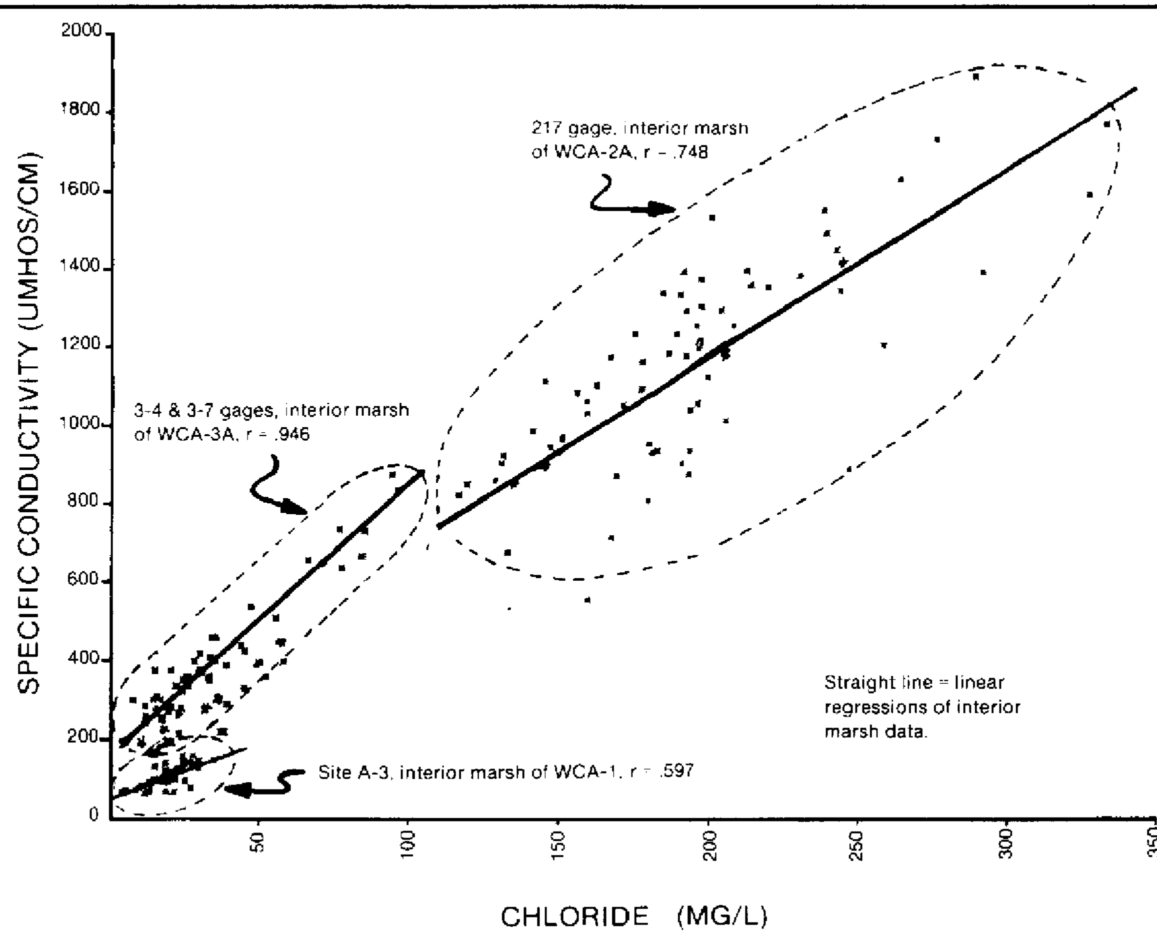

FIGURE 9. CONDUCTIVITY VS. CHLORIDE IN WCA SURFACE WATERS, 1978-82.

TABLE 2. COMPARISON OF WCA-1 MARSH SURFACE WATERS WITH SOUTH FLORIDA RAINFALL

Rainfall Collection Site	pH (Range)	Spec. Cond	Ca^{++}	Cl^-	Na^+	K^+	Mg^{++}	$HCO_3^=$	$CaCO_3$ Hard-ness	Total N	Total P
Florida State-wide*Average	4.7 - 8.8	32	2.1 (0.8)	3.2 (2.0)	1.7 (1.3)	-	-	-	-	1.1 (.52)	.10 (.08)
S-5A at Loxa-hatchee*Florida	5.6- 6.4	41 (31)	3.4 (2.0)	3.9 (2.9)	2.3 (2.2)	.4 (.3)	.6 (.5)	5.6 (4.2)	11 (6)	.97 (.45)	.09 (.13)
S-9, Andytown* Florida	4.7- 6.6	66 (37)	2.9 (1.2)	7.9 (5.3)	4.4 (2.8)	.6 (.6)	.6 (.2)	4 (4)	9 (4)	2.4 (1.5)	.10 (.08)
Surface Water WCA-1 Interior Marsh											
Average of ThreeSites (A-3, A-2, 1-9)	4.6- 7.1	112 (39)	6.3 (2.2)	22.1 (8.3)	12.3 (4.2)	.6 (.4)	1.5 (.7)	19.5 (9.1)	21 (9)	2.79 (3.95)	.015 (.029)

*Source: Irwin and Kirkland, 1980, U.S. Geological Survey

Upper value = mean; value in parentheses = standard deviation

All values mg/l with the exception of pH and specific conductivity (µmhos/cm)

Seasonal variations in major ion content at peripheral WCA-2A marsh sites were significantly influenced by canal water inflows from the S-10 structures. Sites B-2 and B-5 showed significant correlations between rising water stages, chloride content, and nutrient concentrations (R=.690) as a result of their close proximity to the S-10 structures.

Nitrogen and Phosphorus

Average total PO_4, total dissolved PO_4, ortho-PO_4 and inorganic nitrogen concentrations at interior marsh sites were low in comparison to Florida lakes (within the oligotrophic range) and various lake trophic state classification schemes (Tables 3 and 4). Seasonal changes in inorganic nitrogen concentrations at interior marsh sites were closely related to marsh hydrology and, as a result, varied from year to year (Figures 10-13). Concentrations of inorganic nitrogen were at, or very near, detection limits when the marsh was flooded. Inorganic N concentrations increased markedly in the late dry season as water levels receded in the marsh. These increases were most likely due to decomposition of organic matter and release of ammonia and nitrates into the shallow water column.

In contrast, total organic nitrogen concentrations at both background and peripheral marsh sites were comparable to eutrophic Florida lakes with background sites averaging between 2.04-2.90 mg/l (Table 3). The origin of these higher total organic N levels is not well understood; however, possible sources include rainfall, decomposition of leaf litter or peat soils, and leaching from living plants. Data collected from south Florida agricultural sites show significant amounts of total N present in rainfall ranging from 0.6-1.1 mg/l and undoubtedly represent a major source of N to interior marsh sites (Shannon, 1978, see also Table 2). High total N concentrations within marsh surface waters commonly occur in temperate and south Florida wetlands (Davis, 1981 and references cited therein).

Total dissolved PO_4 concentrations at interior marsh sites showed little change over time, remaining near detection levels during high and low water periods. Phosphorus concentrations were highest just prior to marsh drying, and after reflooding due to the mineralization of organic matter. However, these higher concentrations were of short duration, and returned to background levels within a month after the sites were flooded (Figures 10- 13). Similiar trends of low nutrient availability were also encountered at the 1-8T gauge located on the eastern peripheral marsh of WCA-1 (Figure 14).

In contrast, peripheral marsh sites (B-2 and B-5) located near the S-10 discharge structure in WCA-2A showed a positive correlation with high water levels, phosphorus, and chloride content (R=.690). Concentrations of dissolved nutrients were highest at

TABLE 3. A COMPARISON OF AVERAGE NUTRIENT CONCENTRATIONS AT INTERIOR WCA MARSH SITES WITH FLORIDA LAKES AND SELECTED LAKE TROPHIC STATE CLASSIFICATION SCHEMES

	Total P (mg/l)	Total N (mg/l)	Total Org-N (mg/l)	Inorganic N (mg/l)
INTERIOR MARSH SITES				
WCA-1	.014	2.86	2.72	.09
	(.024)	(3.39)	(2.89)	(.29)
WCA-2A	.011	3.05	2.90	.12
	(.023)	(1.91)	(1.70)	(.43)
WCA-3A	.009	2.15	2.04	.09
	(.017)	(1.27)	(1.11)	(.28)
"CLEAR" NORTH FLORIDA LAKES (Brezonik and Shannon, 1972)				
Oligotrophic	.013	---*	.25	---
	(.003)		(.08)	
Mesotrophic	.023	---	.75	---
	(.014)		(.30)	
Eutrophic	.306	---	1.98	---
	(.251)		(1.10)	
GENERALIZED LAKE TROPHIC STATE CLASSIFICATION (Likens, 1975)				
Oligotrophic	<.001-.010	<.001-.60	---	---
Mesotrophic	.010-.030	.50-1.10	---	---
Eutrophic	>.300	>1.00	---	---
EUROPEAN LAKE TROPHIC STATE CLASSIFICATION (Vollenweider, 1968)				
Ultra-oligotrophic	.005	---	---	<.20
Oligotrophic	.005-.010	---	---	.20-.40
Mesotrophic	.010-.030	---	---	.30-.65
Eutrophic	.030-.100	---	---	.50-1.50
Hypereutrophic	>.100	---	---	>1.5

Upper value represents mean, lower value in parentheses = standard deviation
*---Parameter not reported

peripheral marsh sites which received nutrient enriched canal water inflows from the three S-10 structures (Figures 15 and 16). Site B-2, located 0.6 km south of S-10C in WCA-2A, exhibited consistently high concentrations of both inorganic N and total dissolved PO_4 from 1978-1981 (B-2 was not monitored during 1982). During 1978-1980, Site B-5 (located 4.2 dominant species in most natural substrate collections

substrate collections (i.e., submerged periphyton mats, km south of S-10C) had N and P concentrations that were at or near background levels. Nutrient concentrations at Site B-5 increased dramatically following reflooding of the marsh after the 1981 drought (Figure 16). These data indicate that nutrients have penetrated the WCA-2A marsh much further than previously reported in our 1978-79 study (Swift, 1981).

Periphyton Species Composition

Water Conservation Area periphyton communities grown on glass slides contained a total of 333 taxa (including species and varieties) of epiphytic algae representing 107 genera and eight divisions (Appendix A, Table A-1).

1. Myxophyceae (Blue-greens). In terms of cell volume, biomass (as measured by chlorophyll a) and areal coverage, filamentous blue-greens were the most abundant algal group colonizing both glass slides and natural substrates in WCA-2A, 3A, and the peripheral marsh of WCA-1. These blue-green communities closely resemble the "calcareous periphyton" flora described by Van Meter (1965, 1973) and Gleason and Spackman (1974) as the dominant algae of the Everglades region. Of the fifteen blue-green taxa identified, only three were numerically important in terms of cell volume: Schizothrix calcicola (Ag.) Gom., Scytonema hofmannii Ag. ,and Microcoleus lyngbyaceus (Kutz) Crouan.

The most widely distributed and most frequently encountered alga observed in the study was Schizothrix calcicola, occuring in every sample collected. This blue-green represented the bulk of periphyton biomass grown on glass slides in shallow, low nutrient, calcium rich waters, and was also a dominant species in most natural substrate collections.,(i.e., submerged periphyton mats, and as epiphytes of Utricularia spp., Eleocharis spp. and sawgrass stems, etc.). Appendix B "Taxonomic Notes" provides a more detailed description of the morphological variations associated with the identification of S. calcicola from our collections.

The second most abundant filamentous blue-green was Scytonema hofmannii, occurring at times as a co-dominant species in association with Schizothrix calcicola at calcium rich interior marsh sites. Scytonema hofmannii was a relatively slow growing species and was not as commonly encountered in our glass slide collections as compared to periphyton mat cores collected from marsh sediments. This filamentous blue-green accounted for a maximum of 45 percent of the total periphyton community (by volume) on glass slide substrates whereas S. hofmannii accounted for 50-80 percent of the algae collected from periphyton mat cores. Scytonema hofmannii and Schizothrix calcicola were the dominant periphyton flora in waters containing high concentrations of dissolved minerals (bicarbonate and calcium) and low concentrations of inorganic nutrients.

The filamentous blue-green, Microcoleus lyngbyaceus, was the most common algae reported from nutrient enriched peripheral marsh sites. In the presence of high concentrations of inorganic nitrogen and phosphorus, this species was responsible for some of the largest biomass increases reported in this study.

Other common (but rarely abundant) filamentous blue-green species included Spirulina subsalsa, Johannesbaptista pellucida, Oscillatoria lutea, Oscillatoria cf. tenius, and Stigomena sp.

TABLE 4. AVERAGE NUTRIENT CONCENTRATIONS AT INTERIOR WCA SITES, FEBRUARY 1977 - JUNE 1983

Element (mg/l)	All Sites Combined	WCA-1	WCA-2A	WCA-3A
Inorganic N (as NO_3-N, NO_2-N, NH_4-N)	.10 (.33)	.09 (.29)	.12 (.43)	.09 (.28)
Total N (TKN + Inorganic N)	2.53 (2.35)	2.86 (3.39)	3.05 (1.91)	2.15 (1.27)
Total Organic N (TKN-NH_4)	2.41 (1.91)	1.71 (2.89)	2.90 (1.70)	2.04 (1.11)
Total PO_4	.011 (.021)	.014 (.024)	.011 (.023)	.009 (.017)
Total Dissolved PO_4	.005 (.007)	.006 (.004)	.006 (.011)	.005 (.006)
Ortho-PO_4*	.003 (.004)	.003 (.002)	<.002 (.001)	.004 (.007)
Number of Analysis	390	121	125	117

Upper value represents mean, lower value in parentheses is standard deviation

*Average ortho-PO_4 is an artificially high value. Limits of detection were changed from less than .002 mg/l to less than .004 mg/l midway through the study. Average ortho-PO_4 values are probably less than .002 mg/l at most interior sites.

Coccoid blue-greens were not important components of the WCA periphyton and usually represented less than one percent of the community by volume. The most common coccoid blue-greens present were Anacystis dimidiata, Anacystis montana, and Coccochloris elabens.

2. Bacillariophyceae (Diatoms). Diatoms were the second most important group of algae colonizing glass slides. Diatoms included 134 species represented by 25 genera (Table A-1, Appendix). Diatom communities from hardwater (calcium rich), low nutrient, interior marsh sites were characterized by the following species: Anomoeneis vitrea, Cymbella ruttneri, Mastogloia smithii v. lacustris, Cymbella minuta v. psuedogracilis, Synedra pahokeensis sp. nov., Gomphonema cf. affine v. insigne, Nitzschia storchii sp. nov., and Amphora venta.

The most unique diatom assemblages occurred in the interior WCA-1 marsh (Site A-3). Surface waters at Site A-3 were acidic (pH 5-6) and low in ionic content (soft water) with moderately low concentrations of nutrients present. Characteristic diatoms of the interior of WCA-1 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 naegelii, Synedra tenera, Pinnularia biceps, Navicula subtilissima, and Stenopterobia intermedia.

Peripheral marsh sites influenced by nutrient enriched canal water also supported a unique diatom flora. Common diatoms occurring at nutrient enriched marsh sites were Nitzschia amphibia, Gomphonema parvulum, Nitzschia palea, Nitzschia tarda, Nitzschia sigmoidea, Nitzschia sp. 7, Navicula confervacea, Navicula disputans, and Navicula cuspidata.

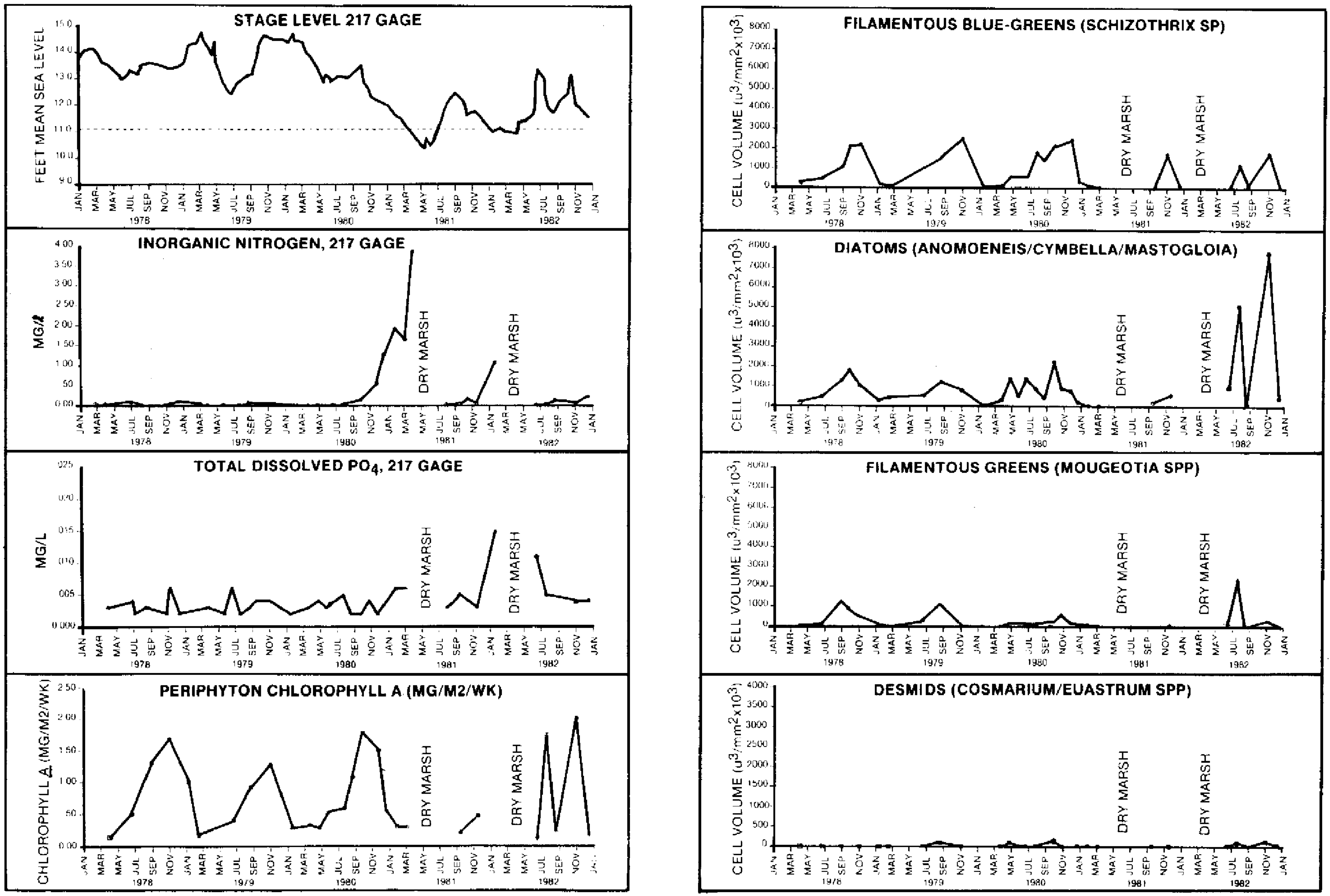

FIGURE 10. SEASONAL VARIATIONS IN WATER LEVEL, NUTRIENTS, PERIPHYTON GROWTH RATES AND SPECIES COMPOSITION AT THE 217 GAUGE, INTERIOR WCA-2A MARSH, 1978-1982.

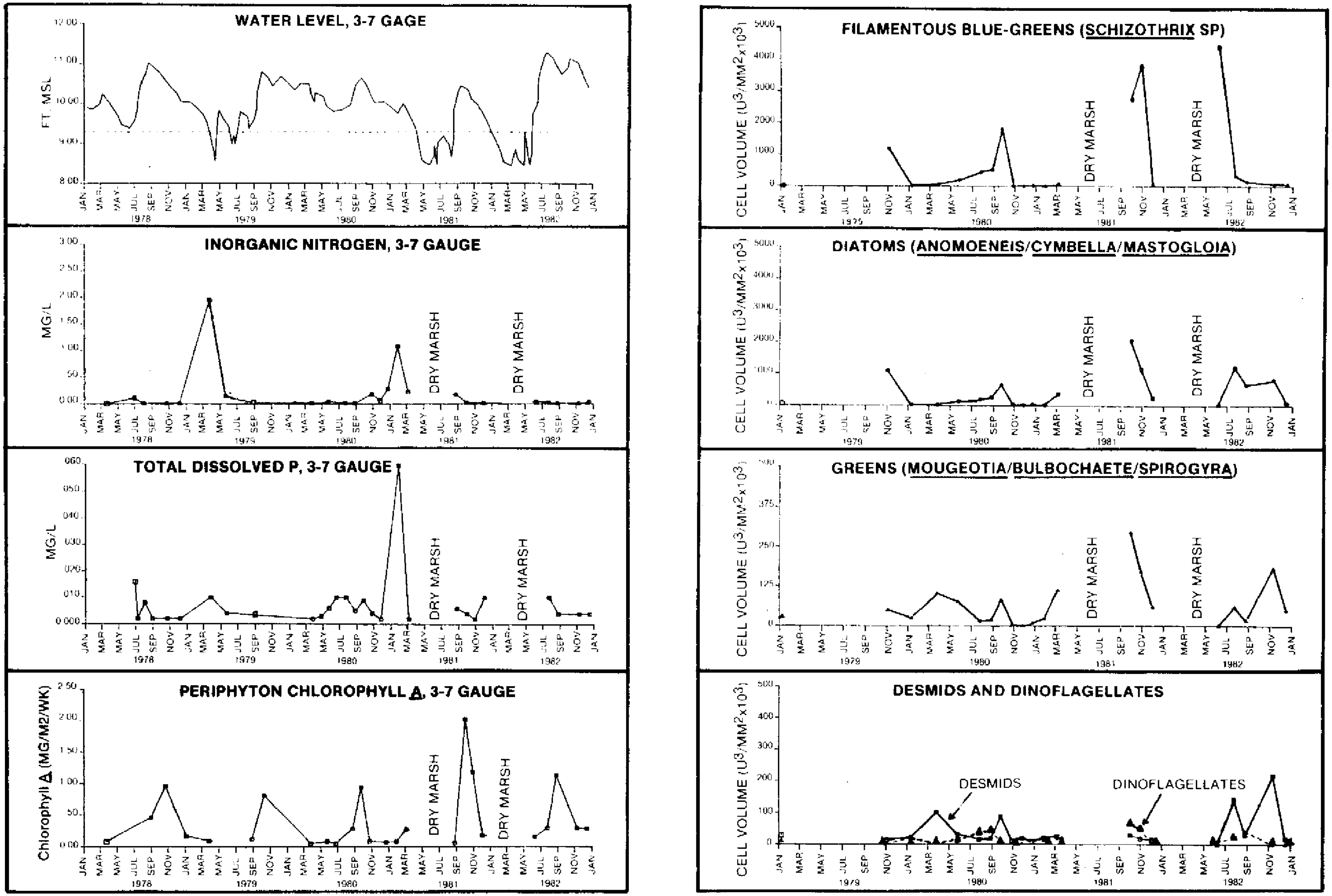

FIGURE 11. SEASONAL VARIATIONS IN WATER LEVEL, NUTRIENTS, PERIPHYTON GROWTH RATES AND SPECIES COMPOSITION AT THE 3-7 GAUGE, INTERIOR WCA-3A MARSH, 1978-1982.

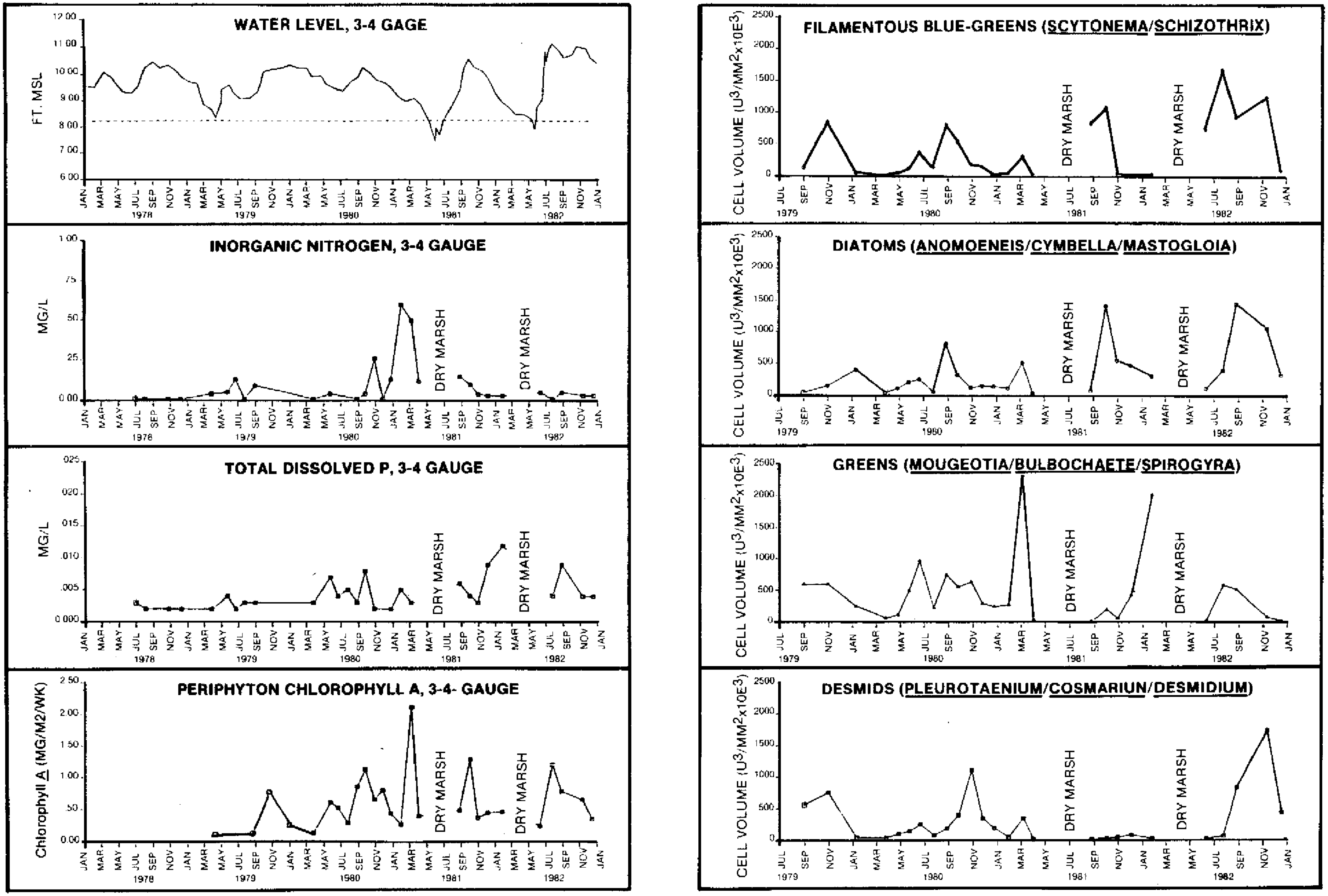

FIGURE 12. SEASONAL VARIATIONS IN WATER LEVEL, NUTRIENTS, PERIPHYTON GROWTH RATES AND SPECIES COMPOSITION AT THE 3-4 GAUGE, INTERIOR WCA-3A MARSH, 1978-1982.

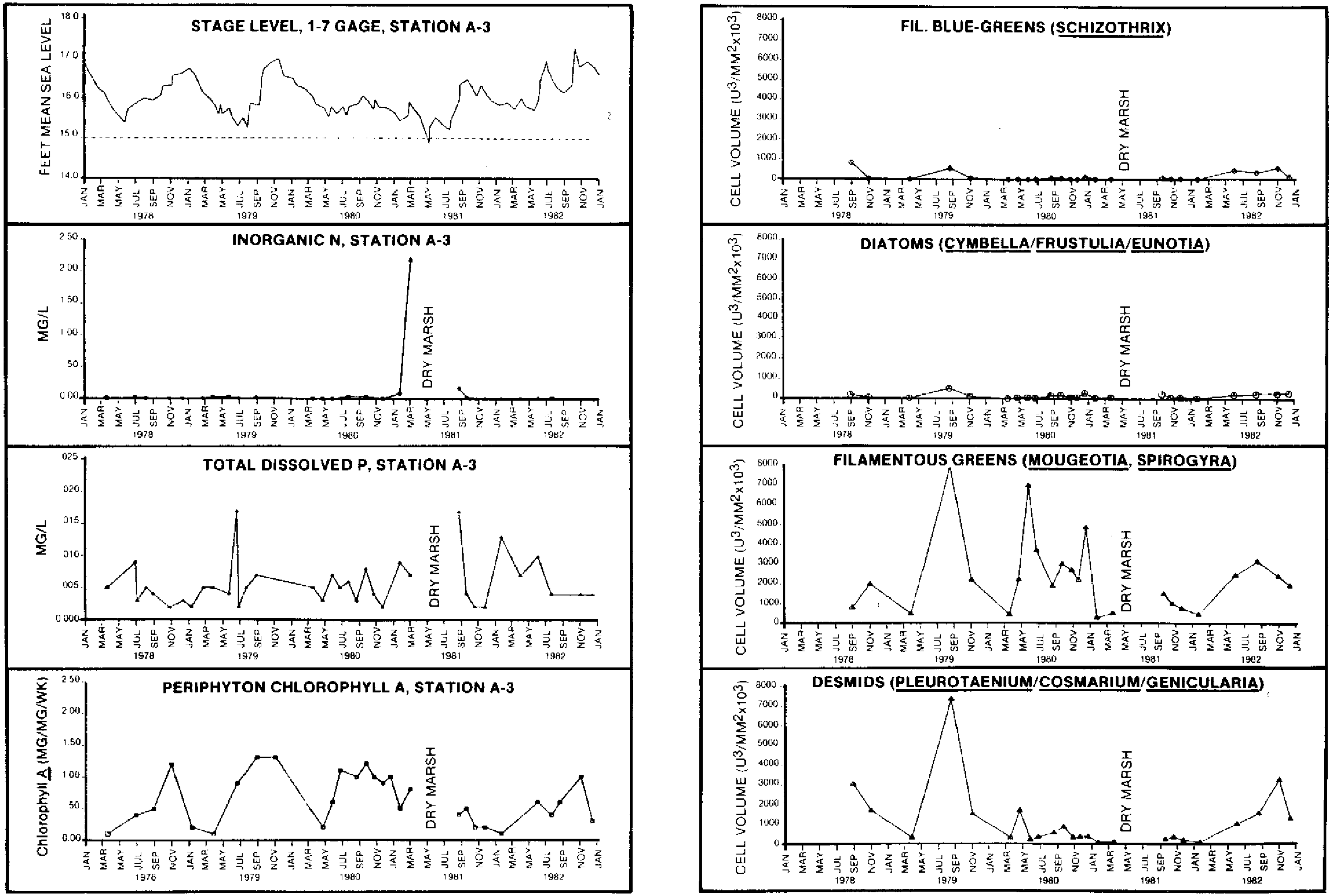

FIGURE 13. SEASONAL VARIATIONS IN WATER LEVEL, NUTRIENTS, PERIPHYTON GROWTH RATES AND SPECIES COMPOSITION AT SITE A-3, INTERIOR MARSH, WCA-1, 1978-1982.

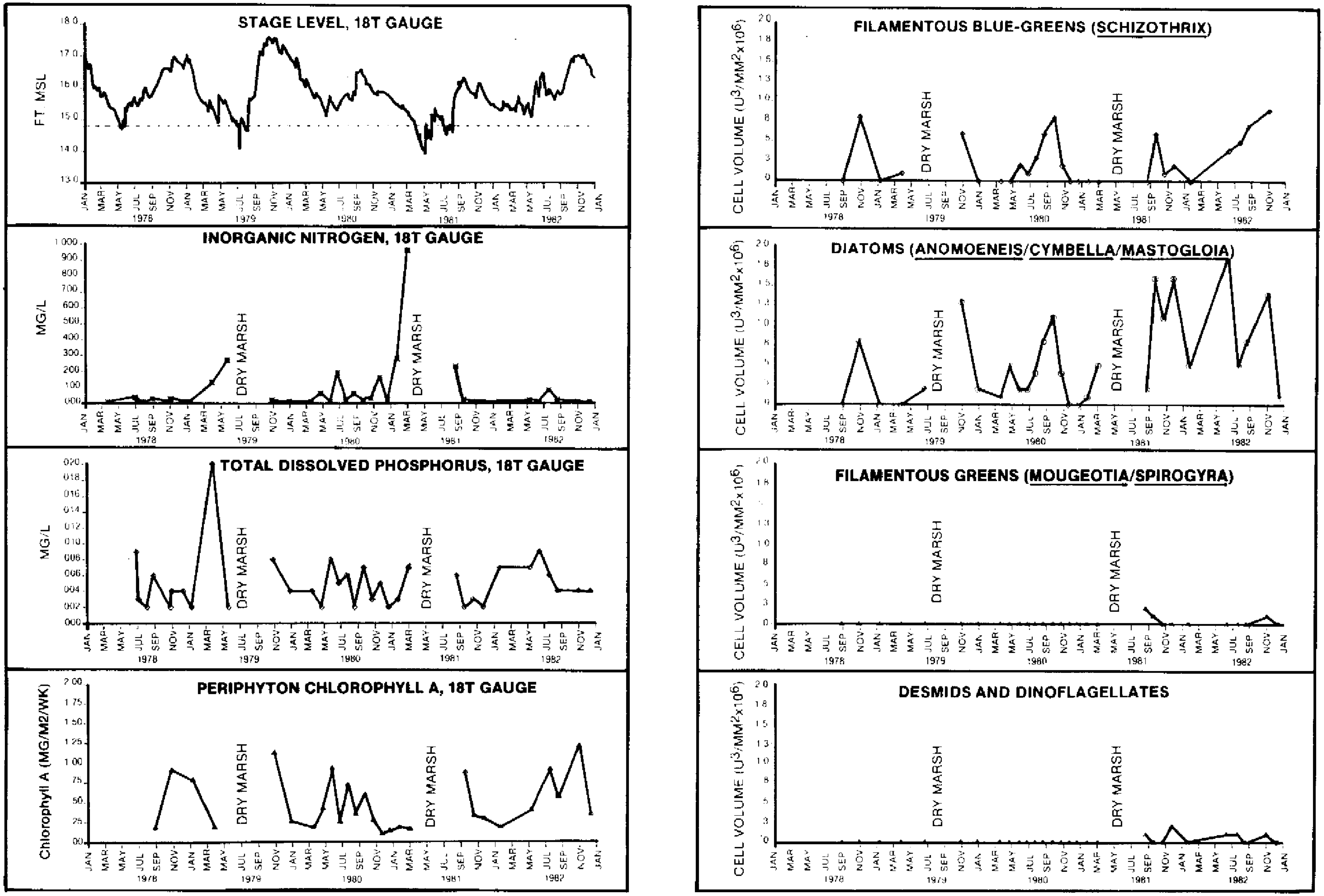

FIGURE 14. SEASONAL VARIATIONS IN WATER LEVEL, NUTRIENTS, PERIPHYTON GROWTH RATES AND SPECIES COMPOSITION AT THE 1-8T GAUGE, PERIPHERAL MARSH, WCA-1, 1978-1982.

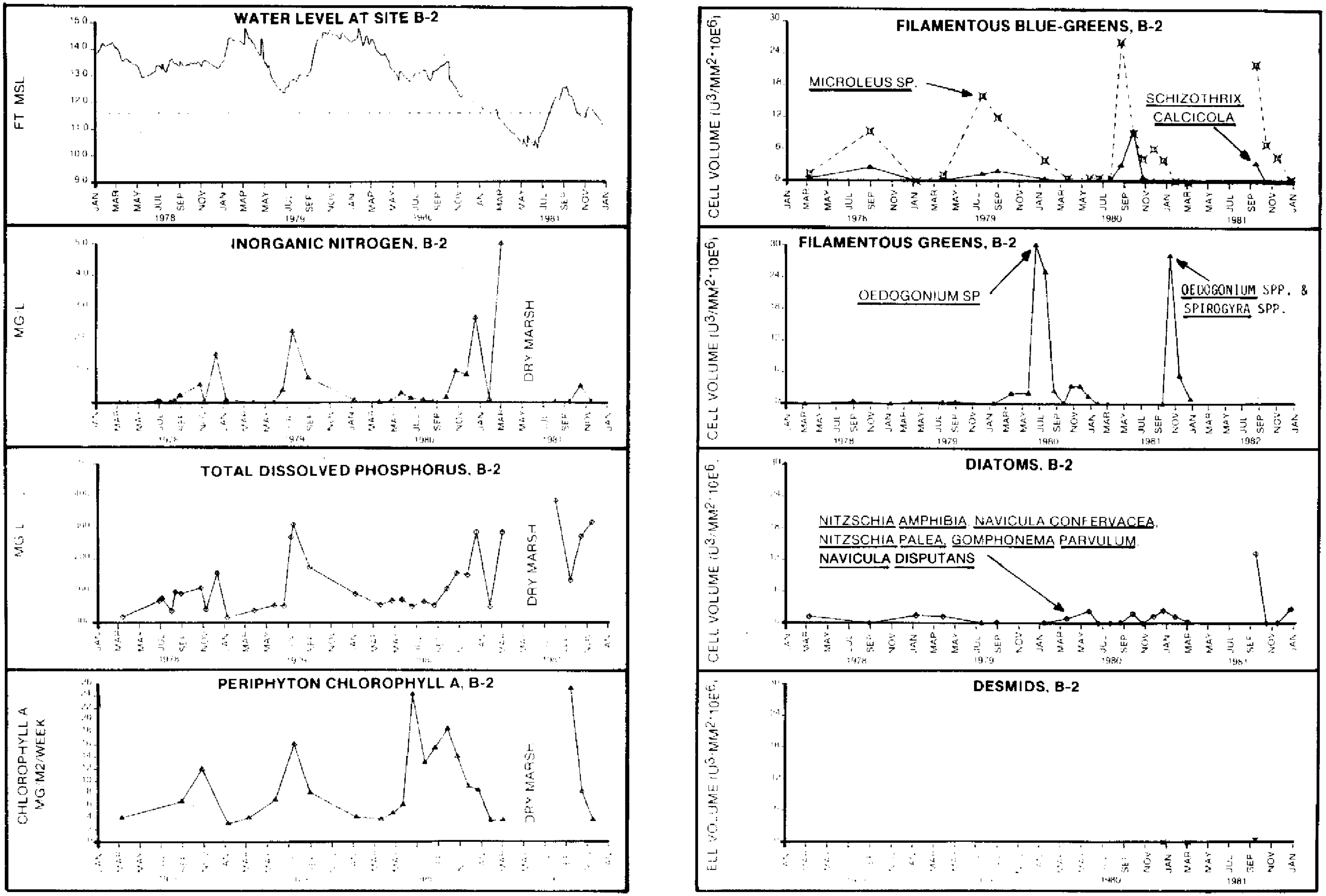

FIGURE 15. SEASONAL VARIATIONS IN WATER LEVEL, NUTRIENTS, PERIPHYTON GROWTH RATES AND SPECIES COMPOSITION AT SITE B-2, PERIPHERAL WCA-3 MARSH, 1978-1982.

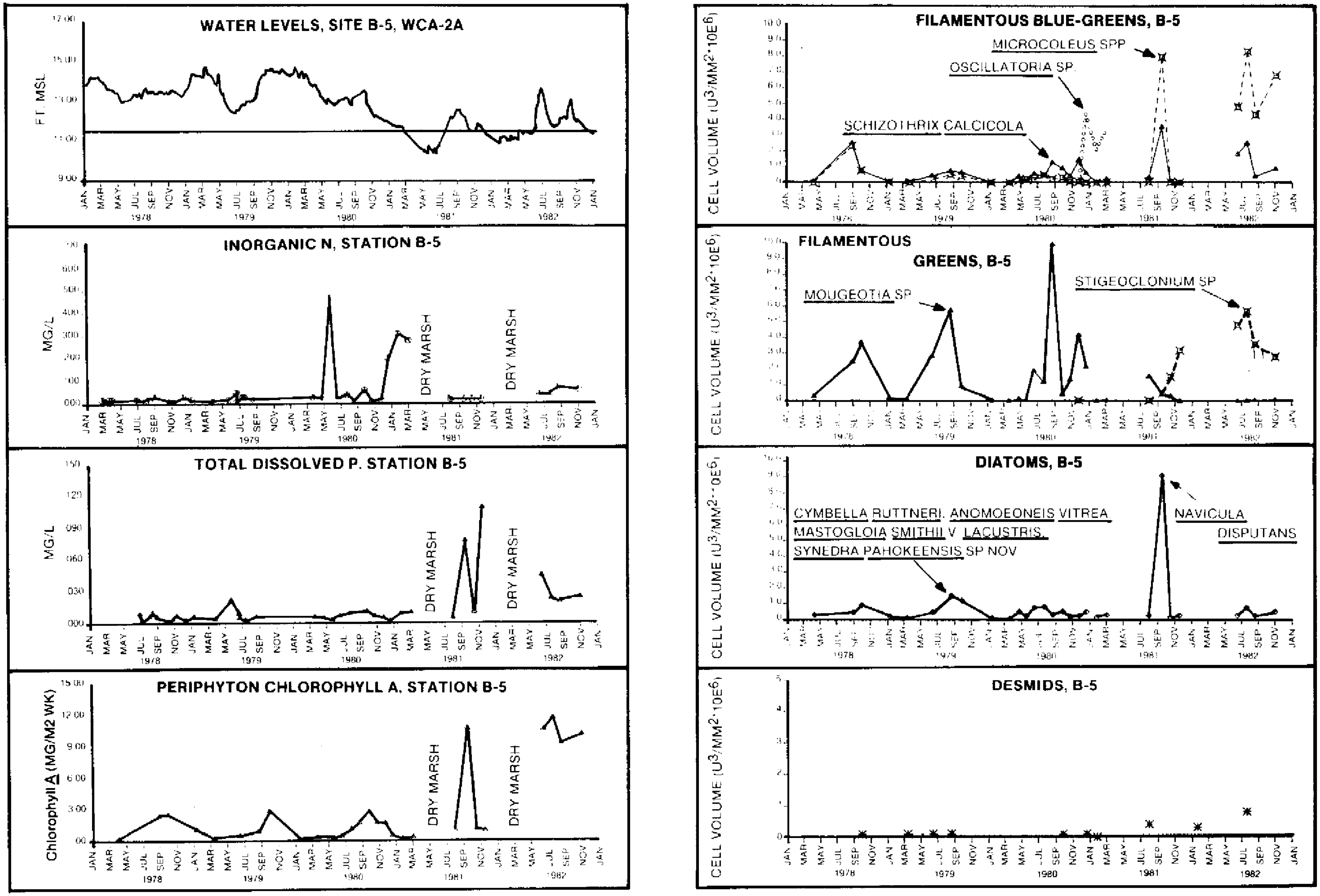

FIGURE 16. SEASONAL VARIATIONS IN WATER LEVEL, NUTRIENTS, PERIPHYTON GROWTH RATES AND SPECIES COMPOSITION AT SITE B-5, PERIPHERAL WCA-2A MARSH, 1978-1982.

Four diatom species recorded in this study represent new species to the literature (pers. comm. Dr. Charles Reimer, Academy of Natural Sciences of Philadelphia). Tentative names given to these new species are: Synedra pahokeensis sp. nov., Synedra sp. 2, Nitzschia storchii sp. nov., and Nitzschia sp. no. 7.

3. Chlorophyceae (Green Algae). Filamentous green algae and desmids were the two most important chlorophycean groups present. The five most important genera of filamentous greens were Mougeotia, Spirogyra, Bulbochaete, Oedogonium, and Stigeoclonium. Mougeotia was the most common and widely distributed of these genera.

Two families, Mesotaeniaceae and Desmidiaceae (collectively known as desmids), were important members of the periphyton community in the interior marsh of WCA-1 and WCA-3A. The acid, soft water marsh of interior WCA-1 supported a highly diverse periphyton community of desmids and filamentous green algae. The desmids included 122 species recorded from Site A-3 (Table 5). The six most common desmid genera were as follows (listed in descending order of importance): Pleurotaenium, Cosmarium, Genicularia, Desmidium, Euastrum, and Staurastrum. Other common genera included Arthrodesmus, Bambusina, Closterium, Cylindrocystis, Gonatozygon, Hyalotheca, Micrasterias, Netrium, Sphaherozosma, Spondylosium, Triploceras, and Xanthidium.

4. Dinophyceae. Although dinoflagellates are most often associated with marine plankton, two motile, "armored" (cells covered with interlocking plates) fresh water species, Peridinium inconspicum and Peridinium sp. 2, were common components of the WCA periphyton. Dinoflagellates were never present as dominant or co-dominant species but were intermittantly observed as rare species.

5. Chrysophyceae. The majority of chrysophytes identified were epiphytes on filamentous green algae. Although this group includes a large variety of plant forms, the most commonly encountered chrysophyte consisted of a naked cell enclosed within a lorica or "shell". Chrysophytes were widely distributed throughout the WCA, but represented only a minor fraction of the periphyton community (usually less than 1%). Six genera were recorded: Derepyxis, Dinobryon, Epipyxis, Lagynion, Mallomonas, and Synura.

6. Euglenophyceae, 7. Cryptophyceae, and 8. Charophyceae. These three remaining divisions were not important components of the WCA periphyton community and represented only a minor fraction of the periphyton assemblage (Table A-1).

Geographical and Seasonal Distribution of Major Algal Groups

Comparisons of the spatial and seasonal distributions of the dominant taxa were made between interior and peripheral marsh sites and among the three Water Conservation Areas.

Water Conservation Area 2A. One peripheral site (B-2), one transitional site (B-5), and one interior marsh site (217 gauge) were monitored. Sites B-5 and the 217 gauge were monitored from 1978-1982; site B-2 was sampled from 1978-1981.

Interior marsh (217 gauge): In terms of cell volume and chlorophyll a content, filamentous blue-greens (Schizothrix calcicola) and an assemblage of hardwater diatoms (Anomoeneis vitrea, Mastogloia smithii v. lacustris, Cymbella ruttnerii, and Synedra pahokeensis sp. nov.) represented the dominant periphyton flora at the interior 217 gauge site from March 1978-March 1981. Filamentous blue-greens and diatoms were most abundant during September and October (end of wet season) and least abundant during January and February (Figure 10). After reflooding of the marsh in June 1982, diatom populations at the 217 gauge increased rapidly and replaced filamentous blue-greens as the dominant flora. Filamentous greens (primarily Mougeotia sp.) were the third major group present. Peak abundance of Mougeotia occurred in September and October of each year, with the exception of 1982 when largest populations were recorded in July (Figure 10). Total numbers of algal species present at the 217 gauge were low in comparison to other interior marsh sites and included only blue-greens, greens, and diatoms. Desmids, dinoflagellates, and chrysophytes were absent or only present as rare components of the 217 gauge microflora.

Peripheral and transitional marsh sites B-2 and B-5: Periphyton species composition and biomass at these two sites were markedly different from those recorded at the 217 gauge. Site B-2, located 0.6 km south of S-10C, was dominated by the filamentous blue-green Microcoleus lyngbyaceus in association with an assemblage of diatoms and two genera of filamentous green algae (Oedogonium and Spirogyra). Seasonal maximum abundance of Microcoleus occurred in the late summer months (August-September) during periods of high water levels and high concentrations of dissolved nutrients (Figure 15). Lowest populations generally occurred during January and February.

Filamentous green algae (Oedogonium spp. and Spirogyra spp.) showed no clear seasonal trends at Site B-2. However, these two genera represented the dominant flora and the highest cell volumes recorded (51×10^6 microns^3/mm^2) during June and July of 1980

(Figure 15). Diatom communities at Site B-2 also showed no clear seasonal pattern. The majority of diatom species recorded at Site B-2 were species that are most often associated with nutrient enriched waters (Lowe, 1974). The most common diatom species at Site B-2 included Nitzschia amphibia, Nitzschia palea, Gomphonema parvulum, Navicula confervacea, and Navicula disputans.

From 1978-1980, two filamentous greens (Mougeotia spp. and Spirogyra spp.) were the dominant algae at Site B-5 located 4.2 km south of the S-10C structure. Filamentous greens were most abundant during the late summer months, while sparse populations of filamentous blue-greens and diatoms dominated this site during winter months (Figure 16).

After the 1981 drought and subsequent reflooding of the marsh via discharges from the S-10 structures, Site B-5 experienced major changes in periphyton species composition in response to increases in the phosphorus content of marsh surface waters. From 1981-1982, Site B-5 was dominated by heavy growths of the filamentous blue-green (Microcoleus lyngbyaceus), the filamentous green (Stigeoclonium spp.), and the pollution indicator diatom Navicula disputans (Figure 16).

Water Conservation Area 3A. Two interior marsh sites (3-4 and 3-7 gauges) were sampled from 1978-1982. Filamentous blue-greens (Schizothrix calcicola and Scytonema hofmannii) were the dominant algae at the 3-7 gauge (Figure 11), while filamentous blue-greens and diatoms (Anomoeneis vitrea, Cymbella ruttneri, Mastogloia smithii v. lacustris, and Synedra pahokeensis sp. nov.) were the two most abundant periphyton groups at the 3-4 gauge (Figure 12). Filamentous green algae (Mougeotia, Bulbochaetae, and Spirogyra) and desmids (Pleurotaenium spp. and Cosmarium spp.) were also important seasonal components of the 3-4 gauge periphyton.

Maximum abundance of Schizothrix and Scytonema occurred from late August through October of each year at both the 3-4 and 3-7 gauges with lowest populations present in January and February. Maximum diatom abundance generally coincided with maximum filamentous blue-green abundance. Filamentous greens (Mougeotia sp.) at the 3-4 gauge reached peak abundance during low water conditions (just before the marsh dried) and suggests a response to increased inorganic nitrogen levels. Desmids reached peak abundance at the 3-4 gauge during August-October in the years 1979, 1980, and 1982. During 1981, desmids were not important components of the 3-4 gauge periphyton. Populations of desmids and filamentous green algae at the 3-7 gauge remained low throughout the study.

Water Conservation Area 1. One peripheral and one interior marsh site were monitored from 1978-1982 (1-8T gauge and Site A-3).

Peripheral marsh (1-8T gauge): Water quality at the 1-8T gauge was high in dissolved minerals due to its close proximity to the L-40 Canal (0.6 km) but had low concentrations of nutrients (comparable to sites 3-4 and 3-7 in WCA-3A). Diatoms dominated the periphyton community at the 1-8T gauge site with filamentous blue-greens (Schizothrix calcicola) representing the second most important group (Figure 14). The most common diatom species encountered at the 1-8T gauge were Mastogloia smithii v. lacustris, Anomoeoneis vitrea, Cymbella ruttneri, Synedra pahokeensis sp. nov., and Cymbella minuta v. psuedogracilis. Seasonally, peak abundance of both diatoms and S. calcicola occurred in September of each year in association with rising water levels (Figure 15). Minimum abundance occurred during January through March. The maximum standing crop of diatoms occurred in September 1982 when the marsh was reflooded after an extended drought. Filamentous greens, desmids, and dinoflagellates were not important components of the periphyton at the 1-8T gauge.

Interior marsh (site A-3): Periphyton communities collected from the acid, soft water interior marsh of WCA-1 (Site A-3) represented the most unique and diverse algal flora encountered in the study. Algal communities at Site A-3 were dominated by the Chlorophyceae (green algae) represented by two major groups, filamentous greens (Mougeotia spp. and Spirogyra spp.) and desmids. Filamentous greens reached maximum abundance during June-August of 1979, 1980, and 1982, with lowest populations occurring during winter months. Filamentous greens were also low in abundance after reflooding of the marsh in 1981 (Figure 13). Desmids were most common during the months of August 1978 and 1979 and September 1982. The desmid population remained low throughout 1980 and 1981 (Figure 13). The most common desmid genera encountered were Pleurotaenium, Cosmarium, Genicularia, and Desmidium. Populations of filamentous blue greens and diatoms remained low at Site A-3 throughout the four years of study. Site A-3 supported an association of diatom species which have been reported as reliable indicators of acid, softwater environments (Patrick and Reimer, 1966; Round, 1965; Lowe, 1974; Patrick, 1977).

Periphyton Growth Rates

Active chlorophyll a extracted from algal pigments and corrected for phaeophytin degradation products (Strickland and Parsons, 1968) was used as an indicator of periphyton growth rates or biomass accumulation over a specified time period. Periphyton growth rates are reported as mg chlorophyll a per square meter per week (mg chl $a.m^{-2}.wk^{-1}$).

Periphyton growth rates at interior marsh sites ranged from 0.1-2.3 mg chl $a.m^{-2}.wk^{-1}$ and were low in comparison to nutrient enriched peripheral marsh sites (Figures 10-16). Maximum growth rates at interior marsh sites occurred during September and early October (end of wet season). Maximum growth rates at interior sites in WCA-2A and WCA-3A and the peripheral marsh of WCA-1 were primarily due to the abundance of filamentous blue-greens (Schizothrix calcicola and Scytonema hofmanii) and an associated diatom flora. In the interior marsh of WCA-1, filamentous greens (Mougeotia spp. and Spirogyra spp.) and desmids were responsible for peak chlorophyll a concentrations.

Periphyton growth rates at nutrient enriched marsh sites B-2 and B-5 were more than 10 times those recorded from interior marsh sites (Figures 15 and 16). Periphyton growth rates at Site B-2, located 0.6 km south of S-10C, were consistently high throughout the study, reaching a maximum rate of 25.0 mg chl $a{\cdot}m^{-2}{\cdot}wk^{-1}$ during June 1980 and September 1981. Peak growth rates during June 1980 were due to the abundance of Oedogonium spp., while Microcoleus lyngbyaceus dominated Site B-2 during the fall of each year.

Seasonal periphyton growth rates at interior marsh sites were relatively independent of surface water levels and nutrient concentrations. On an annual basis, interior marsh periphyton growth rates responded more closely to seasonal variations in light and water temperature than to variations in nutrients or water depth (see Figure 3). Chlorophyll a levels were generally lowest during January-March. These low values corresponded with low seasonal water temperature and light levels experienced each winter. As water temperatures and light levels increased during April-June there was a corresponding increase in periphyton growth rates. Growth rates continued beyond the period of maximum light and temperature so that peak seasonal concentrations of chlorophyll a occurred during September and early October of each year. These values occurred approximately four to six weeks out of phase, with maximum water temperature and two months lag time behind maximum solar radiation levels.

Periphyton Nutrient Content

Gerloff and Skoog (1954) demonstrated that concentrations of nitrogen and phosphorus in algal cell tissue can be used to measure the availability of these elements in surface waters.

The phosphorus content of periphyton communities collected from interior marsh sites in WCA-2A and WCA-3A were very low (0.01-0.04% P) in comparison to samples collected from the interior of WCA-1 and nutrient enriched peripheral marsh sites (Figures 17 and 18 a, b). Highest elemental P concentrations were observed at sites B-2 and B-5. From 1978-1980, phosphorus levels in the water at B-5 were very low, averaging about 7 µg P/l. Algae growth rates were also low and had low concentrations of elemental P in cell tissues. After the 1981 drought, increased sheet flow across WCA-2A, as a result of heavy autumn rains and high discharges through the S-10 structures, caused nutrient enriched canal water to penetrate the marsh much further than previously recorded. Consequently, marsh water nutrient content, periphyton growth rates, and elemental P content of algae at site B-5 showed dramatic increases during 1981 and 1982 (Figure 17).

Periphyton elemental P concentrations at Site A-3 (WCA-1) ranged from .048 - 0.094 percent. Periphyton communities in the interior of WCA-1 were dominated by filamentous green algae and desmids and contained roughly 2-3 times as much phosphorus as the blue-green dominated periphyton communities of the interior of WCA-2A and WCA-3A (Figure 18a).

Seasonal variations in the elemental P content of interior marsh periphyton were not distinct. However, maximum periphyton phosphorus content generally coincided with maximum periphyton growth rates which occurred during late summer and early fall (end of wet season).

In WCA-2A and WCA-3A linear correlations between the elemental N content of the algae and marsh water inorganic nitrogen concentrations were not readily apparent. Periphyton elemental N levels were generally highest during August-early October coinciding with maximum algal growth rates (Figures 17, 18a, 18b). However, there were several exceptions. After reflooding of the marsh in 1981, periphyton elemental N concentrations at Site B-5 rapidly increased in response to elevated surface water nutrient concentrations. During March 1981, elemental N concentrations at sites A-3 and the 1-8T gauge (WCA-1) increased rapidly in response to high levels of inorganic nitrogen during low water conditions (Figure 18a).

Comparisons of average periphyton nitrogen to phosphorus mass (N:P) ratios among the seven sites are presented in Figure 19. High N:P ratios were typical of interior marsh sites in WCA-2A, WCA-3A, and the peripheral marsh of WCA-1 with average mass ratios ranging from 101:1-107:1. Lowest N:P ratios (average 8.6:1) were encountered at the peripheral marsh site (B-2) located south of S-10C in WCA-2A. Nitrogen:phosphorus mass ratios at Site A-3 (avg. = 51.5:1) located within the interior of

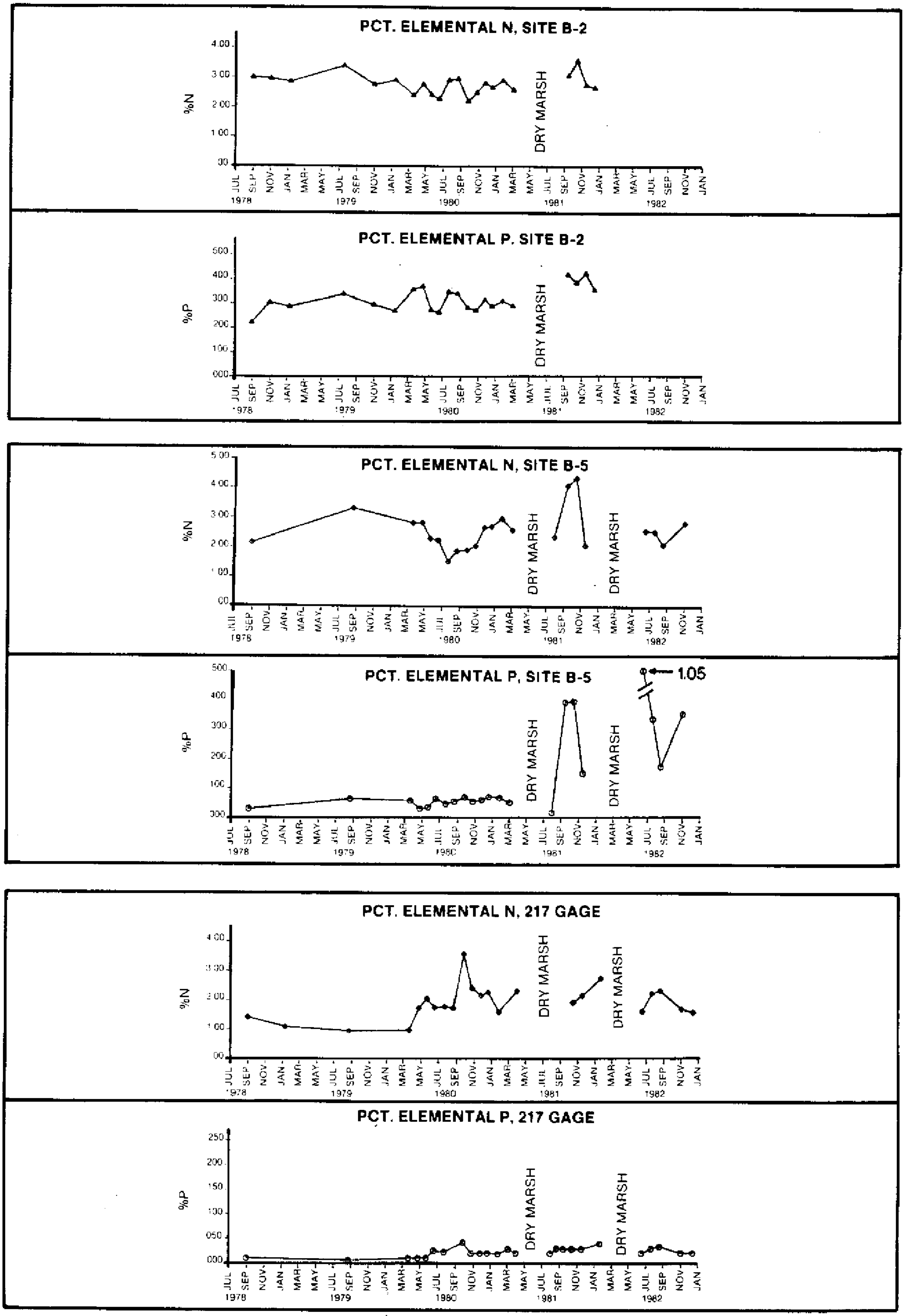

FIGURE 17. PERIPHYTON ELEMENTAL N AND P CONTENT AT SITES B-2, B-5 AND THE 217 GAUGE, WCA-2A.

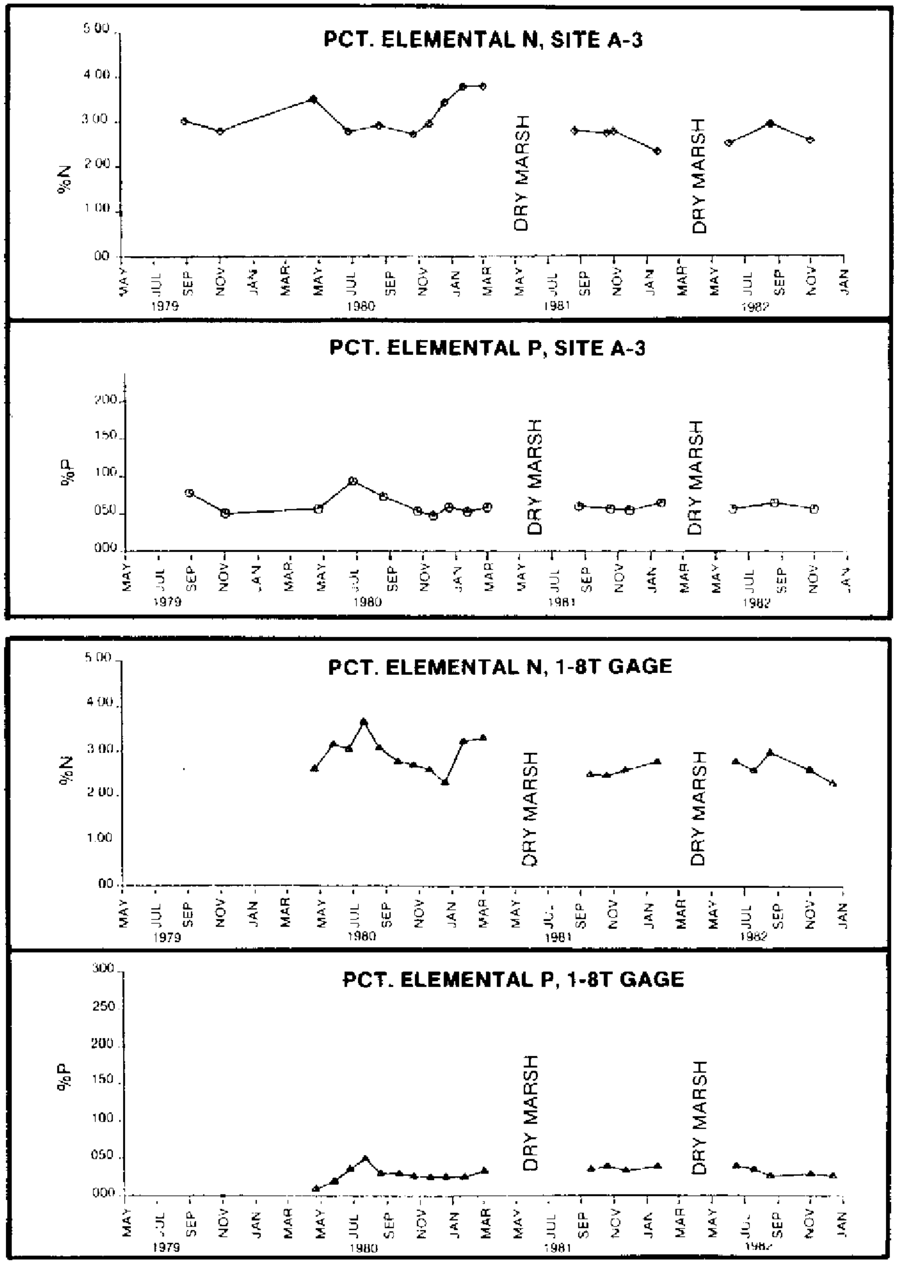

FIGURE 18a. PERIPHYTON ELEMENTAL N AND P CONTENT SITES A-3 AND THE 1-8T GAUGE, WCA-1.

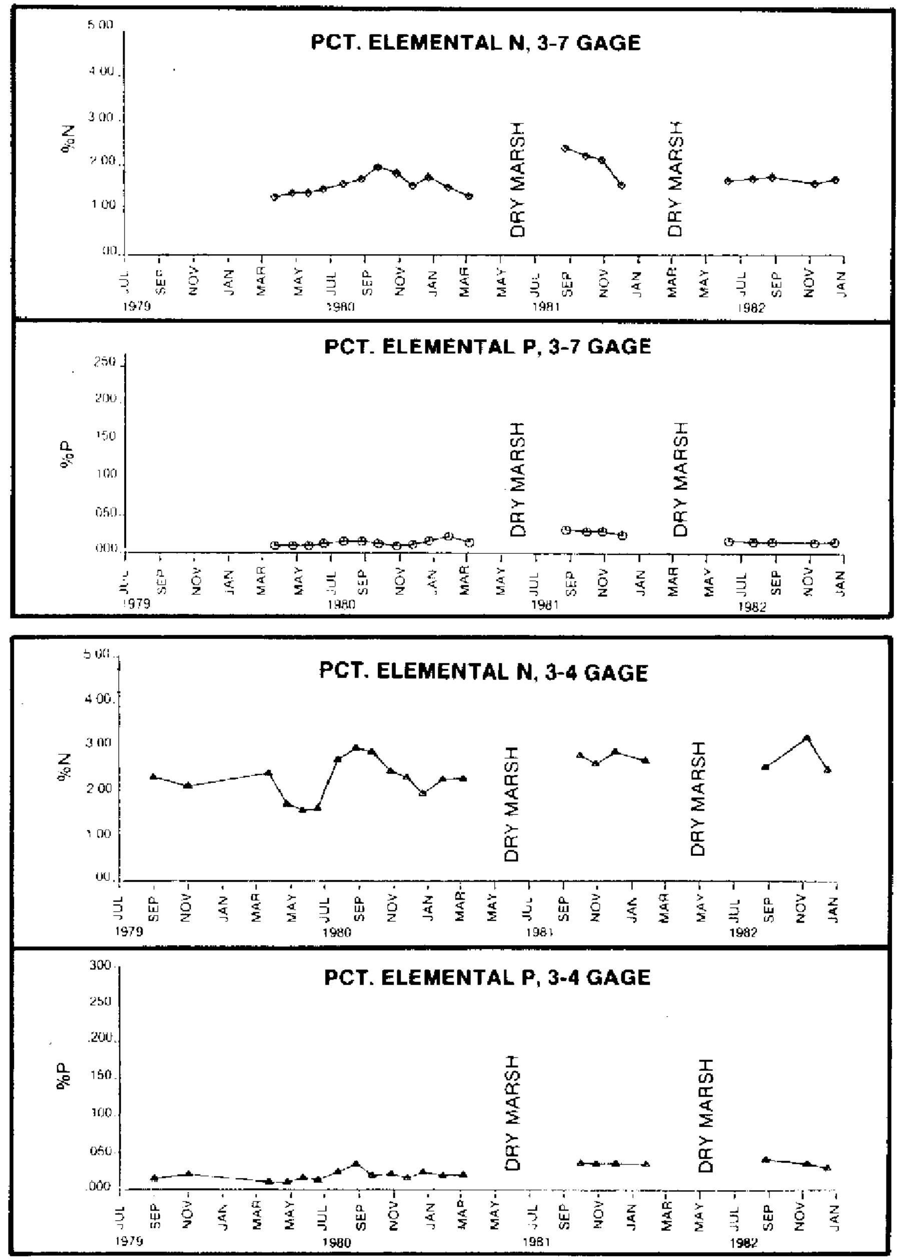

FIGURE 18b. PERIPHYTON ELEMENTAL N AND P CONTENT AT THE 3-4 AND 3-7 GAUGES, WCA-3A.

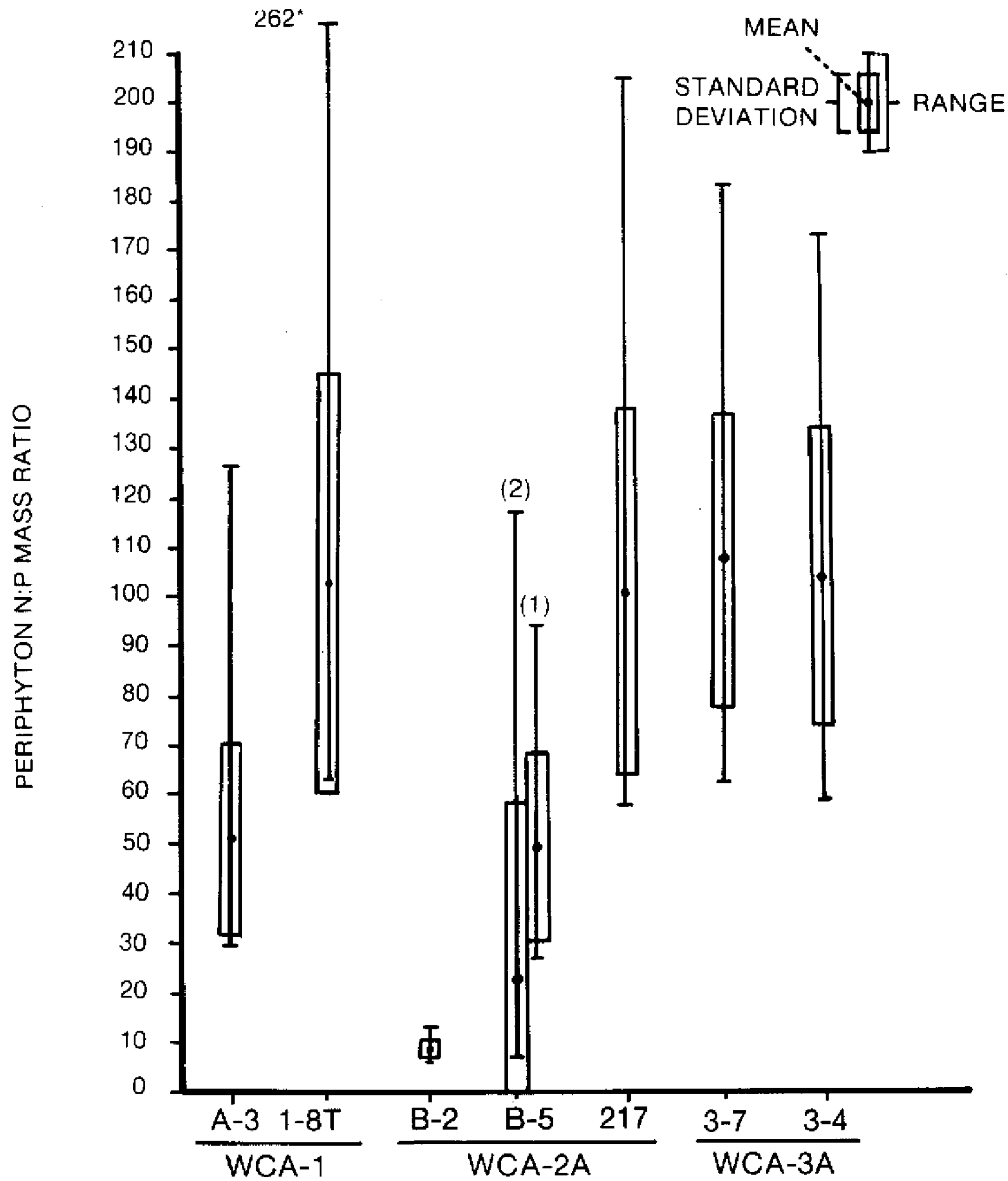

FIGURE 19. **PERIPHYTON N:P RATIO AVERAGES, STANDARD DEVIATIONS AND RANGES AT SEVEN LONG TERM WCA MONITORING SITES.**
(1) AVERAGE N:P RATIO PRIOR TO 1981 DROUGHT (1978-MARCH 1981)
(2) AVERAGE N:P RATIO AFTER 1981 DROUGHT AND REFLOODING OF MARSH JULY 1981 - DECEMBER 1982 (showing impact of nutrients on Site B-5)

WCA-1 were generally lower than interior WCA-2A and WCA-3A sites.

Marsh water phosphorus showed a significant inverse correlation with the N:P content of the periphyton. As the phosphorus content of the marsh water increased, algae N:P mass ratios decreased exponentially (Figure A-1, Appendix A). A similar relationship also existed between periphyton growth rates and the N:P content of the algae. As chlorophyll a concentrations increased, algae N:P mass ratios decreased logarithmically. Maximum algae growth rates in the Water Conservation Areas occur at N:P mass ratios of less than 15:1 (Figure A-2, Appendix A).

Species Diversity

Periphyton species diversity at Site A-3 was significantly higher (Tukey's test, $p < .05$) than all other sites sampled (Figure 20). This was a result of the rich and varied desmid flora (i.e., rich in terms of total number of species) that were present at Site A-3 throughout the study. High species diversity, and high relative abundance of desmids, were closely linked to the mineral content of marsh surface waters (Tables 5 and 6). An inverse relationship exists between periphyton species diversity and calcium carbonate alkalinity of WCA marsh waters (Figure A-3, Appendix A). Highest species diversity and high desmid relative abundance occurred primarily in soft water, with lower diversity indices occurring in hard water.

Lowest species diversity indices were recorded at nutrient enriched Site B-2 as a result of the dominance of Microcoleus lyngbyaceus and Oedogonium spp. The filamentous blue-green M. lyngbyaceus reached maximum abundance in the late summer and fall, while the filamentous green, Oedogonium spp., dominated Site B-2 during the early summer months (Figure 15). No significant differences in algal species diversity were noted among the remaining five sites (i.e., Sites B-5, 1-8T, 217, 3-4, and 3-7 gauges).

Relationship Between Periphyton Species Composition and Environmental Factors

Factor analysis reduced 30 variables to 5 biologically interpretable factors that accounted for 74% of the variance within the data set (Table 5). The primary factor (Factor 1) was closely related to the following variables: chlorides, conductivity, hardness, silicon, alkalinity, Microcoleus relative abundance, and (-) desmid relative abundance. Factor 1 might be labeled "periphyton response to surface water major ion concentration." Factor 1 shows that waters containing low concentrations of dissolved minerals were highly correlated with the development of a desmid dominated periphyton community; while marsh waters containing high concentrations of major ions favored periphyton communities that were dominated by the filamentous blue-green, Microcoleus spp.

Factor 2 shows a significant correlation between periphyton species diversity and the occurrence of filamentous greens, desmids, dinoflagellates, and a group of diatom species indicative of acid, soft water conditions (i.e., Cymbella amphioxys, Frustulia rhomboides v. saxonica, Anomoeoneis serians v. brachysira, etc.). These correlations are a result of the unique and varied periphyton assemblage that occurs in the acid, soft water interior marsh of WCA-1. The desmid flora of the interior of WCA-1 was exceedingly rich and contained over 120 species (Table A-1). As a result, desmids were significantly correlated with high species diversity indices. Desmids were typically found in close association with filamentous greens (Mougeotia and Oedogonium), acid water diatoms, and dinoflagellates (Peridinium spp.). As a result, these algae groups were also correlated with high species diversity.

Factor 3 was related to the following variables: Schizothrix calcicola, and Scytonema hofmannii relative abundance, "alkaline" water diatoms (i.e. Mastogloia smithii v. lacustris, Cymbella ruttneri, Synedra pahokeensis sp. nov., Anomoeoneis vitrea) and the calculated mass ratio of elemental N:P within periphyton cell tissue. Factor 3 shows that Schizothrix-Scytonema- alkaline water diatom communities reach maximum abundance under conditions of low phosphorus supply (which results in a high N:P ratio). These results suggest these algal species may be used as biological markers of calcium rich, low nutrient, water quality conditions in the Water Conservation Areas.

Factor 4 is related to Stigeoclonium relative abundance, eutrophic indicator diatoms (i.e., Nitzschia amphibia, Navicula disputans, Navicula confervaceae, Gomphonema parvulum, Nitzschia palea) relative abundance, marsh water total dissolved PO_4 concentration, and periphyton elemental P content. The relationship within factor 4 shows that Stigeoclonium and eutrophic diatoms reach maximum abundance under phosphorus enriched conditions and suggests that these algae may serve as useful indicator species of nutrient enrichment.

The final factor (Factor 5) is related to water depth, periphyton elemental P content, Microcoleus relative abundance, periphyton growth rates, and marsh water total dissolved PO_4 content. Factor 5 relates primarily to the deep water, nutrient enriched environment that was prevalent at Sites B-2 and B-5. These sites were unique because they produced the highest periphyton biomass (as chlorophyll a) of all sites studied and were seasonally dominated by the

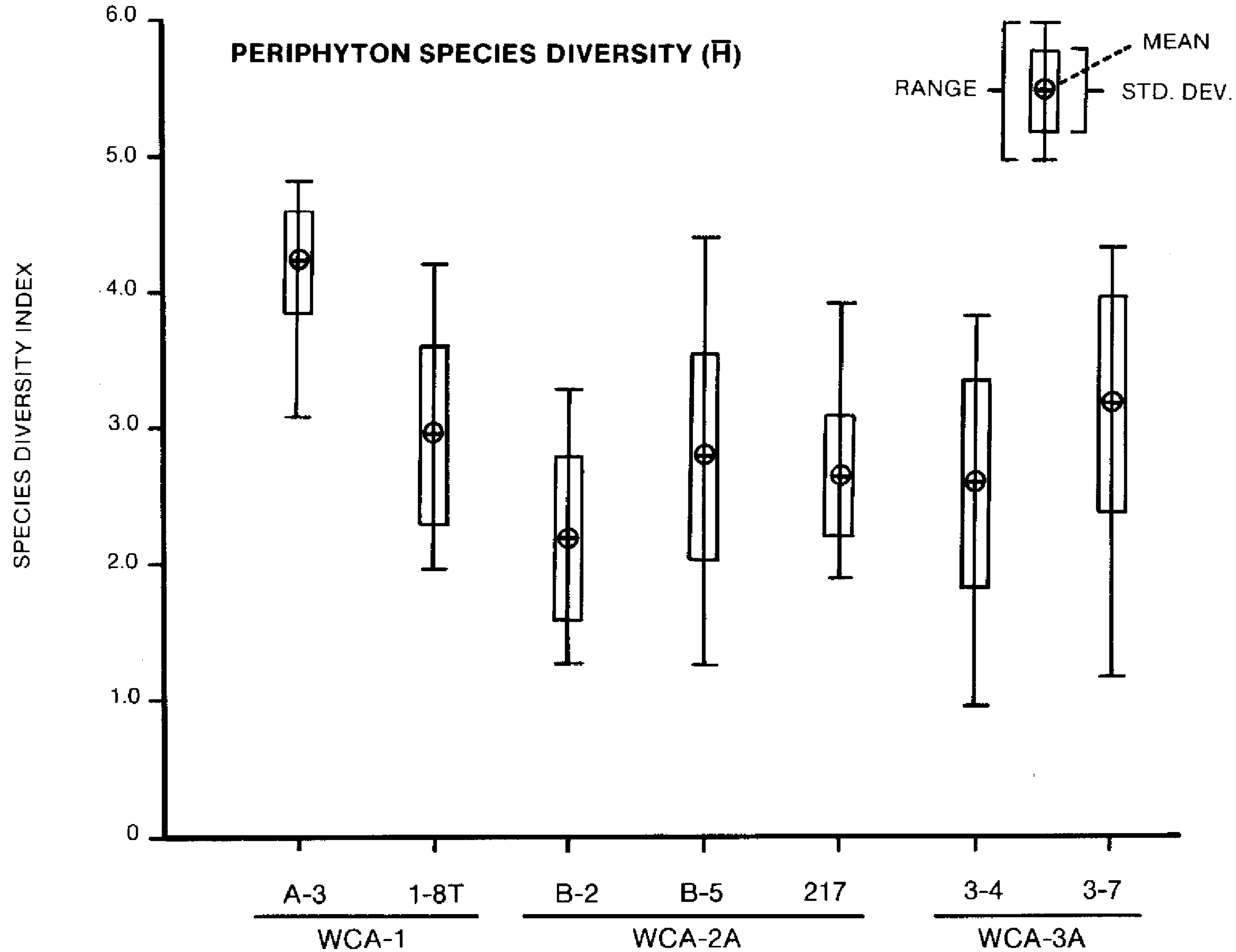

FIGURE 20. PERIPHYTON SPECIES DIVERSITY MEANS, STANDARD DEVATION, AND RANGES AT SEVEN LONG-TERM WCA MONITORING SITES.

TABLE 5. VARIMAX ROTATED FACTOR LOADINGS FOR 30 BIOLOGICAL AND PHYSIO-CHEMICAL VARIABLES,* 1978-1982

Variable	R +
FACTOR 1	
CL**	.927
Conductivity	.919
Hardness	.901
SiO_2	.753
Alkalinity	.708
% Microcoleus	.497
% Desmids	-.478
Variable	**R**
FACTOR 2	
Species Diversity(H)	.926
% Mougeotia/Oedogonium	.684
% Desmids	.630
% Acid Water Diatoms	.472
% Dinoflagelletes	.431
FACTOR 3	
% Schizothrix calcicola/ Scytonema hoffmanni	.939
% Alkaline Water Diatoms	.894
Periphyton Cell N:P Ratio	.847
FACTOR 4	
% Stigeoclonium	.762
%.Eutrophic Indicator Diatoms	.733
Total Dissolved PO_4	.721
Periphyton Elemental P Content	.450
FACTOR 5	
Water Depth	.819
Periphyton Elemental P Content	.777
% Microcoleus	.560
Periphyton Chlorophyll a	.542
Total Dissolved PO_4	.483

Legend:

* Of the 30 variables tested, only % cell N content was not significantly correlated with another parameter.

** Because of the high degree of correlation between a number of major ion species and chlorides (r = .90) the following ions were omitted from the above analysis to overcome problems of multicollinearity. These ions were: Na, K, Mg, and Ca.

\+ Coefficient (R) values represent both regression weights and correlation coefficients (Nie et. al. 1970, SPSS).

n = 198 observations, significant values of R at 5% level = 0.431 at 1% level = .460.

filamentous blue-green Microcoleus spp. These relationships suggest that Microcoleus may also be a useful marker species of phosphorus enrichment in the Water Conservation Areas.

In summary, factor analysis shows the importance of major ions, phosphorus concentrations, and water depth on periphyton species composition, cell nutrition and algal growth rates in the Water Conservation Areas.

Stepwise multiple regression analyses closely paralleled results of factor analysis (Table 6). Marsh water phosphorus content and water depth were highly correlated with increases in periphyton growth rates (as measured by chlorophyll a) and increases in elemental P content of periphyton cell tissues. Low concentrations of elemental P in periphyton cell tissues were highly correlated with the dominance of interior marsh filamentous blue-greens (Schizothrix calcicola and Scytonema hofmannii) and "alkaline" water diatoms (i.e., Mastogloia smithii v. lacustris, Cymbella rutnerii, Anomoeoneis vitrea and Synedra pahokeensis). The filamentous blue-green Microcoleus spp., the filamentous green Stigeoclonium sp., and the diatoms, Nitzschia amphibia, Navicula disputans, Navicula confervaceae, Gomphonema parvulum, and Nitzschia palea were highly correlated with marsh waters containing high concentrations of major ions, inorganic phosphorus, and nitrogen. Desmid relative abundance and periphyton species diversity indices were highest under acid, soft water conditions and high concentrations of elemental N in periphyton cell tissue (Table 6).

DISCUSSION

Major Ions, Algal Species Composition, and Diversity

Differences in the mineral content of WCA surface waters were closely related to the source of water for each marsh. Highest concentrations of major ions (bicarbonate, chloride, and calcium) occurred in WCA-2A which receives mineralized canal water inflows primarily from the three S-10 structures (See Figure 2). Due to the lack of interior perimeter canals, these waters are directly discharged across the northeast section of the marsh. Surface water inflows into WCA-2A represent a mixture of highly mineralized ground water and nutrient enriched canal water that drains the Everglades Agricultural Area south of Lake Okeechobee. Ground waters derived from this region are high in chloride and sodium, in contrast to calcium carbonate dominated ground water of WCA-3A and Everglades National Park (Flora and Rosendahl, 1981; Waller and Earle, 1975). Consequently, rainfall mixing with ground water derived from the Everglades Agricultural Area results

TABLE 6. CORRELATION COEFFICIENTS (R) FROM A STEPWISE MULTIPLE REGRESSION ANALYSIS OF DEPENDENT BIOLOGICAL VARIABLES VS. INDEPENDENT PHYSIO-CHEMICAL VARIABLES, WATER CONSERVATION AREA PERIPHYTON SURVEYS, 1978-1982

Dependent Variable (Biological)	Independent Variable (Physio-chemical)	R	% Variance Accounted	F Value
Periphyton elemental P content	Periphyton growth rates, water depth, marsh water PO_4	.83	73%	98.0
% Schizothrix-Scytonema rel. abund.	Periphyton N:P ratio, -periphyton elemental P content, -water depth	.806	65%	87.8
% Eutrophic diatom relative abundance: (Nitzschia amphibia, Navicula disputans, Navicula confervaceae, Gomphonema parvulum, Nitzschia palea)	Marsh water PO_4, periphyton elemental P content, inorganic N, -Magnesium, hardness	.728	54%	36.8
% Alkaline diatom relative abundance: (Mastogloia smithii v. lacustris Cymbella ruttneri, Anomoeoneis vitrea, Synedra pahokeensis, Cymbella minuta v. psuedogracilis)	Periphyton N:P ratio, -periphyton elemental P, -solar radiation	.714	51%	67.0
% Microcoleus relative abundance	Periphyton elemental P content, periphyton growth rates, marsh water inorganic nitrogen alkalinity	.690	48%	42.9
% Desmid relative abundance (Pleurotaenium, Cosmarium, Genicularia)	-Potassium, -magnesium, periphyton elemental N content	.513	26%	34.0
% Stigeodonium relative abundance	Marsh water PO_4	.427	18%	42.7

in ratios of chloride:calcium that are relatively high (greater than 2.0) in WCA-2A (Table 1).

In contrast, surface waters in the interior of WCA-1 were low in dissolved minerals, poorly buffered, acid, and soft. The low mineral content of these waters are a result of three factors: (1) WCA-1 is encircled by three levees (L-7, L-39, and L-40) which direct the majority of canal waters around the marsh perimeter. (2) Peat subsidence in the vicinity of these perimeter canals have created slightly lower ground level elevations around the peripheral edges of WCA-1 in comparison to ground levels in the interior marsh (Stephens and Johnson, 1951). The presence of perimeter canals, differences in ground level elevations, and the restriction of flow across the marsh to a large extent limits interior WCA-1 marsh water from mixing with mineralized canal water. (3) The high water holding capacity and capillary action of the deeper WCA-1 peat soils (up to 4 meters in depth) effectively holds large volumes of surface water (rainfall) above the main ground water mass. Together these factors effectively isolate interior WCA-1 marsh water from mineralized canal and ground water influences with the majority of its surface water being obtained directly from rainfall. Since rainfall contains relatively low concentrations of dissolved minerals, surface waters in the interior of WCA-1 are also low in electrolyte concentrations.

Surface water alkalinity and hardness in the interior of WCA-3A was roughly one half that of WCA-2A. Water in this region of the Everglades has been described as the "calcium carbonate type" (calcium is the dominant anion) and is influenced primarily by rainfall and dissolution and weathering of the Biscayne Aquifer (Gleason, 1972; Gleason and Spackman, 1974; Flora and Rosendall, 1981). Typically these waters have low ratios (less than 1.0) of chloride:calcium (Table 1).

Seasonal variations in the mineral content of interior marsh surface waters were weakly correlated with marsh hydrological variables such as water depth, concentration of ions by evapotranspiration, dilution by rainfall, or hydroperiod length. The ionic character and volume of each marsh's source water appear to be the most important factors influencing seasonal major ion concentrations in the WCA.

Results of this study and those of Gleason and Spackman (1974) and Swift (1981) indicate that major ion concentration is the predominant factor controlling periphyton species composition and species diversity within wet prairie communities of the interior marsh. These results contrast with Browder's (1981) work in Everglades National Park where percent soil organic matter and hydroperiod were reported as the major factors controlling the taxonomic composition of Everglades periphyton. Marsh waters of low ionic content (interior of WCA-1) favored development of an abundant desmid and filamentous green algae (Chlorophyceae) flora. These ion poor waters had a rich desmid flora, with over 120 species reported. As a result, low ionic content marsh waters were correlated with high species diversity. These results parallel earlier work in the WCA's (Swift, 1981) and compare well with previous studies of desmid ecology. Prescott (1952), Ruttner (1953), Hutchinson (1967), Moss (1972), Whitford and Schmaucher (1973), Wetzel (1975) and Woeklering (1976) report that desmids reach maximum development in waters of low ionic content; especially in acid pH, low calcium, and magnesium habitats. Ruttner (1953) suggests that the electrolytic content (especially calcium carbonate) of the water appears to be associated with cell membrane permeability. Under hardwater conditions, desmid cells may become flooded with salts that they are unable to remove. As a result, desmids are less commonly found in alkaline, hard water habitats and are generally restricted to acid, low ionic content waters.

In contrast, interior marsh sites in WCA-2A, WCA-3A and the peripheral marsh of WCA-1 supported a filamentous blue-green flora dominated by <u>Schizothrix</u> <u>calcicola</u>, <u>Scytonema</u> <u>hofmannii</u> and an assemblage of diatoms indicative of hardwater environments (i.e., <u>Mastogloia</u> <u>smithii</u> v. <u>lacustris</u>). Filamentous blue-greens were the dominant algal group colonizing glass slides in waters containing moderate to high concentrations of major ions (bicarbonate, chloride, and calcium) and low nutrient content. These algae closely resembled the "calcareous periphyton" described by Van Meter (1965, 1973) and Gleason and Spackman (1974) for Everglades National Park. Calcareous periphyton refer to blue-green algae communities which coat submerged macrophyte vegetation with algal filaments that are encrusted with calcium carbonate crystals. Floating mats of calcareous filamentous blue-greens attached to <u>Utricularia</u> (bladderwort) plants were a common feature of the WCA-2A and WCA-3A marshes during late summer and fall. In wet prairie communities, blue-green algae formed wooly, felt-like coatings or "cylinders" on submerged plant surfaces. During dry periods these algal communities desiccate and return organic matter and precipitated $CaCO_3$ to the marsh sediment.

Increased sampling frequencies during 1980-82 revealed several trends that were not evident in earlier work (Swift, 1981). Filamentous blue-greens (<u>Schizothrix</u> and <u>Scytonema</u>) showed distinct seasonal patterns of growth and species succession. Maximum periphyton growth and abundance occurred during September-October of each year, near the end of the wet season. Minimum growth and abundance occurred during January-March. In earlier work, diatoms were not considered important members of WCA periphyton due to their relatively low biomass contribution to the total community. Results of this study indicate that diatoms play a much more important role at mineralized interior marsh sites, and frequently represent one third to one half of the total community by volume. Diatoms (e.g., <u>Anomoeonis</u> <u>vitrea</u>) were important pioneer algal species at several interior sites and rapidly recolonized submersed substrates following reflooding of the marsh after an extended dry period. Four diatom species recorded in this study represent new species. The fact that these species were present as abundant or common components of the WCA periphyton community demonstrates the lack of research that has been conducted regarding algal systematics in the Everglades region. In addition, two filamentous green algae (Mougetia and Spirogyra) were much more widely distributed throughout the WCA marsh than had been previously reported, and were seasonally important at both hard and soft water interior marsh sites.

Nutrients, Algal Growth Rates, and Nutritional Requirements

Results of this study support earlier observations concerning the nutrient status of the three WCA marshes: (a) during periods of inundation, inorganic forms of N and P at interior marsh sites remain low; (b) rainfall represents a major source of nutrients for interior marsh sites; (c) periphyton growth rates and elemental P concentrations within algal cell tissues are low at interior marsh sites suggesting that phosphorus represents the growth limiting nutrient within the interior marsh; (d) highest nutrient concentrations were recorded from peripheral marsh areas that are enriched by canal water inflows (sites B-2 and B-5); (e) algal communities exposed to nutrient enriched waters developed a "specialized" community of pollution tolerant species (i.e. Microcoleus spp. Oedogonium spp.) that have high growth rates, and high concentrations of elemental P within cell tissues.

Seasonal monitoring of interior marsh sites showed that hydrological events play an important role in recycling nutrients in the Water Conservation Areas. Inorganic nitrogen concentrations increase dramatically in the late dry season as water levels decline and approach the litter zone. These increases are the result of organic matter decomposition and release of ammonia and nitrates into the shallow water. Large releases of ammonia and nitrate are a common phenomenon in marshes which experience periodic exposure of soils that are normally inundated (Klopatek, 1978; Richardson et. al., 1978; Worth, 1983). Changes in water levels may result from natural climatic fluctuations or from man-induced changes, such as a marsh drawdown to re-establish the growth of certain aquatic plants. Release of phosphorus from interior marsh sediments into the water column was low in comparison to previous investigations of marsh reflooding (Kadlec, 1978; Klopatek, 1978; Federico et. al., 1978). Although these results are not consistent with previous studies of marsh reflooding, they compare well with Worth's (1983) data (ortho-PO_4 concentrations ranging from 2-4 µg/l) collected at interior WCA-2A sites during the same time period. Interior WCA marsh sites showed no major "first flush" effects (i.e., release of phosphorus from soils after reflooding) as has been described for Chandler Slough, Florida (Federico et. al., 1978) and several other temperate marsh ecosystems (Richardson et. al., 1978).

Seasonal monitoring of periphyton growth rates at both interior and peripheral marsh sites showed contrasting results. High periphyton growth at nutrient enriched peripheral marsh sites were highly correlated with increases in the phosphorus content of marsh surface waters. Review of recent data collected from the northeast section of WCA-2A at Site B-5 clearly shows that S-10 discharges presently affect a much larger area of the marsh than previously reported in a preliminary 1978-79 survey (Swift, 1981). During 1978-1980, total dissolved P levels in water at B-5 were very low, averaging about 7 µg P/l. Algae growth rates were also low and contained low concentrations of elemental P within their cell tissues. During the drought of 1981, fire played an indirect but important role in modifying marsh water nutrient chemistry at Site B-5. Controlled burns of marsh vegetation in the northeast section of WCA-2A were conducted by the Florida Game and Fish Commission in the summer of 1981. This temporary reduction in sawgrass density permitted increased water flow across the marsh. Increased sheet flow, coupled with heavy autumn rains and high discharges through the S-10 structures allowed nutrient enriched canal water to penetrate the marsh much deeper than previously recorded. Biological response to these nutrient increases included (a) major shifts in periphyton species composition favoring development of algal communities tolerant of nutrient enriched conditions; (b) biostimulation (increased growth rates) of algal populations; and (c) increases in algal elemental P content.

Seasonal growth rates at interior marsh sites followed the classic "J" shape growth curve. Growth curves of this type are typical of algae populations which undergo rapid growth on a seasonal basis (i.e., "seasonal bloom" conditions). Kormondy (1969) indicates that the J shaped growth curve is indicative of unrestricted, rapid, exponential growth up to the limits of the environment. As these limits are exhausted (nutrients) or imposed (reduced light, temperature, or drought), the population declines to a reduced equilibrium level. Interior WCA periphyton communities exhibited low but well defined seasonal population maximums and minimums with chlorophyll a concentrations rarely exceeding 2.5 mg chl a $\cdot$ $m^{-2} \cdot wk^{-1}$. This suggests these microorganisms exist within relatively well-defined (low) limits of nutrient concentration. Seasonal fluctuations in algal growth at interior marsh sites were only weakly correlated with surface water nutrient concentrations. Seasonal growth rates were more related to variations in temperature, light, and water levels.

Periphyton elemental P concentrations at interior marsh sites were very low in comparison to reported "critical concentrations" required for normal aquatic macrophyte and algae growth (Table 7). Supplies of phosphorus in periphyton tissue were comparable to levels reported from Utricularia-periphyton communities in the Okefenokee Swamp (Bosserman, 1979) and from Everglades aquatic plants and organic peat soils (Davis and Harris, 1978; Stewart and Ornes, 1975; Volk et. al., 1975). Low concentrations of elemental P in periphyton cell tissue, low periphyton growth rates, and the low phosphorus content of marsh surface waters and soils suggest that phosphorus is the nutrient limiting element at interior WCA-2A and WCA-3A sites.

Elemental P content of periphyton communities collected from ion poor waters (interior of WCA-1) were 2-3 times higher than those recorded from calcium rich interior marsh sites. Since rainfall probably represents the major source of P to interior marsh sites, the question may be asked, "Why do acid, soft water periphyton communities contain higher levels of P when compared to algae collected from calcium rich environments?" One explanation suggested is that under conditions of high calcium carbonate precipitation, "coprecipitation" of phosphorus as hydroxylapitite $Ca_2(OH)(PO_4)^3$ may occur naturally removing available P from the water column (Wetzel, 1975). Consequently, the calcium content of marsh surface waters may have a significant effect on amounts of P available for plant growth at calcium rich interior marsh sites. In temperate marl lakes calcium carbonate precipitation is a significant factor in the regulation of algal productivity both by thispagereserved for Table 7 adsorption of liable organic substrates and through interaction with phosphate (Otsuki and Wetzel, 1972). Coprecipitation of P may partially explain the observed low P content of marsh surface waters and soils, low algal growth rates and low elemental P content of periphyton observed throughout this study at calcium rich interior marsh sites.

Increases in elemental P content of periphyton at peripheral marsh sites were highly correlated with increases in nutrient content of marsh surface waters and periphyton growth rates. Periphyton elemental P content was well above the 0.2 percent "critical concentration" level reported necessary for producing maximum growth responses in blue-green algae (Table 7). The high phosphorus content of peripheral marsh periphyton indicates 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 Okefenokee Swamp, and ranges reported for most aquatic macrophytes. The nitrogen content of WCA periphyton were always above Vallentyne's (1974) 0.7 percent N "lower limit" at which growth may occur in freshwater plants and algae (Table 7). This suggests that nitrogen was present in adequate supply to permit algal growth. However, nitrogen content of the majority of samples collected was usually below Gerloff and Skoog's 4.0 percent "critical concentration" necessary to produce a maximum growth response in laboratory cultures of blue-green algae. Although Gerloff and Skoog demonstrated nitrogen storage in blue-greens, our field data showed periphyton nitrogen levels to be weakly correlated with marsh water nutrient chemistry. Two incidences of nitrogen uptake and storage were reported during low water conditions at Stations A-3 and the 3-4 gauge during 1981. Filamentous green algae (Mougeotia sp. and Spirogyra sp.) communities showed rapid, short term increases in their biomass and elemental N content in response to increases in inorganic nitrogen concentrations (primarily ammonia) during low water periods.

Indicator Organisms

Results of this study and review of the literature show that specific assemblages of periphyton can be used as fairly reliable indicators of water quality type within the Water Conservation Areas.

Periphyton communities dominated by the blue-greens Schizothrix calcicola and Scytonema hofmannii in association with the diatoms, Mastogloia smithii v. lacustris, Anomoeoneis vitrea, Cymbella rutnerii, Synedra pahokeensis sp. nov. and Cymbella minuta v. psuedogracilis represent low nutrient, hard water (calcium carbonate dominated) water quality conditions. Conversely, algal communities dominated by filamentous greens (Mougeotia spp.) and a rich desmid flora in close association with several species of diatoms (Cymbella amphioxys, Frustulia rhomboides v. saxonica, Anomoeoneis serians v. brachysira, Anomoeoneis serians, Eunotia neageli, and Stenopterobia intermedia) represent low pH (acid), soft water marsh conditions.

Algal communities dominated by large populations of the blue-green Microcoleus lyngbyaceus or the green alga, Oedogonium spp. in close association with the diatoms, Nitzschia amphibia, Nitzschia palea, Navicula disputans, Navicula confervaceae or Gomphonema parvulum provided good evidence that these waters have recently contained relatively high concentrations of inorganic phosphorus and nitrogen (Van Landingham, 1981; Reimer, 1962; Lowe, 1974).

Comparison of Peatland Marsh Water Chemistry

Water chemistry characteristics of peat forming marshes fall within two extremes: (a) ombrotophic peatlands (bogs) which receive their water supplies directly from precipitation, and (b) minerotrophic

TABLE 7. COMPARISON OF ELEMENTAL NITROGEN AND PHOSPHORUS CONCENTRATIONS IN ALGAE AND AQUATIC PLANTS FROM DIFFERENT ENVIRONMENTS

	Elemental Nutrient Concentration		
Study %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)			
Periphyton growth in artificial streams, averages and standard deviations (Kevern and Ball, 1965)	3.29-1.63	.21-.11	16:1
Okefenoke Swamp, Georgia Ranges of N and P content for Utricularia periphyton mats (Bosserman, 1979)	1.73-3.09	.045-.075	38-41:1
Water Conservation Areas, Fl. Nutrient content of natural substrate periphyton (ranges)			
Interior WCA-1 (Site A-3)	2.32-3.79	.048-.094	29-71:1 (avg. 51:1)
Interior WCA-2A (217 gauge)	.94-3.57	.01-.042	60-205:1 (avg. 101:1)
Interior WCA-3A (3-4 and 3-7 gauges)	1.32-3.22	.01-.041	59-183:1 (avg. 105:1)
Nutrient enriched Site B-2	2.21-3.60	.224-.419	6.5-13.4:1 (avg.8.6:1)

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.

peatlands (fens) which derive the majority of their waters from ground water sources. Most peat forming marshes can be placed somewhere within these two extremes since they receive various amounts of water from both rainfall and ground water.

This classification scheme is useful to this study because the origin of the marsh's water directly affects its chemical properties and ultimately influences periphyton species composition within the marsh.

Minerotrophic fens develop in marsh systems which drain alkaline soils or overlie mineral soils. Minerotrophic fens can also develop in marshes which are influenced by mobile ground water sources (either continuous or intermittant). In either case, minerotrophic fens are characterized as alkaline, hard water environments dominated by bicarbonate and calcium ions with circumneutral to basic pH, high specific conductivity and generally low concentrations of inorganic forms of nitrogen and phosphorus (Moore and Bellamy, 1974).

Water quality within interior marshes of Water Conservation Areas 2A, 3A, and the peripheral marsh of WCA-1 can be best described as minerotrophic. The dominant major ions of these marshes are bicarbonate, calcium, chloride, and sodium. Hydrogen ion concentrations (pH) are usually within the neutral to basic range, while average specific conductivity ranges from 333-1050 µmhos/cm. Inorganic forms of N and P were generally at or near detection levels throughout the year (with the exception of the onset of the dry season). Calcium carbonate precipitating species of blue-green algae (Schizothrix calcicola and Scytonema hofmannii) and the diatom complex comprised of Mastogloia smithii v. lacustris, Cymbella ruttneri, Synedra pahokeensis sp. nov. and Anomoeneis vitrea represented the characteristic microflora of WCA minerotrophic peat forming marshes.

Ombrotrophic peatlands (bogs) typically contain an interior raised bog (interior of marsh has a higher ground level than the peripheral marsh due to peat accumulation) and an accompanying perched water table. The accumulation of peat acts as a reservoir holding large volumes of water above the ground water mass. As a result, ombrotrophic peatlands are isolated from ground water inflows and derive the majority of their water from direct rainfall. Since rainfall is ion-poor, surface water of these marshes is also ion-poor and typically contain calcium concentrations of less than 5 mg/l and specific conductance less than 15 µmhos/cm (Moore and Bellamy, 1974). Ombrotrophic peatlands are acidic with pH values ranging from 3-4.5 as a result of the cation exchange properties of various Sphagnum species of mosses which dominate ombrotrophic situations (Cylmo, 1963). Desmids represent the characteristic microflora of ombrotrophic bog communities (Wetzel, 1975).

Water quality in the interior of WCA-1 represents an intermediate or transitional stage of marsh succession from minerotrophic fen to ombrotrophic bog. Marsh waters of interior WCA-1 are ion poor and contain approximately 2-3 times the concentration of electrolytes present in local rainfall. Surface waters are typically within the acid range (pH 5.7) with specific conductance averaging about 100 µmhos/cm, and calcium concentrations averaging less than 8 mg/l. Desmids, filamentous green algae, and certain diatom species indicative of acid, soft water conditions represent the dominant microflora of interior WCA-1.

Table 8presents a comparison of the general shift in ionic components of marsh waters in the transition from minerotrophic fen to ombrotrophic bog (after Wetzel, 1975) with comparisons of averaged data collected from interior sites from each of the three Water Conservation Areas.

European minerotrophic fens compared well with WCA-2A and WCA-3A with respect to pH, calcium, bicarbonate, potassium and magnesium concetrations. However, chloride and sodium concentrations in WCA-2A exceeded the European fen average approximately tenfold. Sulfate concentrations in the WCA's were lower than the European fen average.

Water quality data from WCA-1 compared well with European transitional fen averages but had significantly higher concentrations of dissolved minerals when compared to classic ombrotrophic raised bog environments.

Effects of Water Management on Everglades Periphyton

The predominant water management practice affecting the Water Conservation Areas today is the impoundment of surface water runoff derived from the Everglades Agricultural Area for flood control and water storage purposes. Future water management plans for south Florida may call for backpumping urban stormwater runoff, presently discharged eastward to tidewater, into the Water Conservation Areas (SFWMD, 1977, 1983). Benefits of these backpumping plans include increased water storage capacity for recharge of regional ground water supplies and protection of east coast well fields against salt water intrusion. Environmental concerns of these plans focus on the impact of increasing nutrient concentrations, water levels, and hydroperiod lengths within the Water Conservation Areas. One goal of this study was to address these impacts as they affect periphyton communities in the Water Conservation Areas.

Introduction of Nutrients as a Result of Backpumping.

Results of this study indicate that increases in marsh water N and P supplies (1) promote major changes in periphyton species composition, (2) reduce algal species diversity, (3) stimulate the growth of pollution tolerant algae, and (4) increase the P content of algal cells. Changes in periphyton species composition and reduced algal species diversity as a result of nutrient

TABLE 8. A COMPARISON OF AVERAGE IONIC COMPOSITION OF WESTERN EUROPEAN/SCANDANAVIAN PEATLAND SURFACE WATERS WITH AVERAGED DATA FROM THE THREE WATER CONSERVATION AREAS

Direction of Peatland Water Chemistry Succession	Study Location	pH	Conductivity (µhos/cm)	Ca^{++} (mg/l)	$HCO_3^{=}$ (mg/l)	Na^{+} (mg/l)	Cl^{-} (mg/l)	Mg^{++} (mg/l)	K^{+} (mg/l)	$SO_4^{=}$ (mg/l)
Minerotrophic fen (surface waters influenced by ground water inflows)	Western European[(a)] mineroptrophic fens	7.6	ND	80	195	11.5	17.7	10.9	3.1	48
	WCA-2A	7.1	1050	67	245	121	174	28	6.5	39
	WCA-3B	7.4	566	54	184	57	64	9	2.4	6
	WCA-3A	7.0	333	47	132	18	28	4	1.1	12
Transitional fen (interior marsh receives direct rainfall, continued peat accumulation diverts ground water inflows around perimeter of basin)	Transitional fen[(b)] (Scandanavia)	5.8	ND	18	45	1.1	3.5	0.2	0.4	1.4
	Transitional mire[(a)] (Western Europe, Type No. 4)	5.6	ND	14	20	11.5	17	2.4	1.6	24
	WCA-1	5.7	112	6	16	12	22	1.5	0.6	9
Ombrotrophic "raized" Bog (perched water table isolated from ground water)	Ombrotrophic[(1)] Bog (Sphagnum dominated)	3.8	<15	0.8	1	2	1.4	0.6	.4	4.8

ND = No Data Available

(1) Moore and Bellamy, 1974

(2) Sjors, 1950

enrichment may have important long term effects on marsh fish and invertebrate fauna. Inasmuch as periphyton represent a significant component of the marsh food web, major shifts in species composition at the primary producer level may ultimately influence both the species composition and biomass of higher trophic level organisms. Changes in food item size, reduction in food selection choices, or changes in food nutritive value denote the possible effects of nutrient enrichment on herbivorous invertebrates and fish fauna.

Aquatic ecosystems containing high species diversity generally contain more complex pathways of energy flow between trophic levels (i.e, have more complex food webs or food chains) and represent more stable ecosystems in comparison to simpler, less diverse communities (Odum, 1971). Reduction of periphyton species diversity as a result of nutrient enrichment may ultimately reduce ecosystem stability by reducing the number of food item choices available to grazing invertebrates.

Increasing Marsh Water Ionic Content as a Result of Backpumping.

Results show that periphyton species composition at interior marsh sites are also strongly influenced by the ionic content of marsh surface waters. Discharge of mineralized canal water (high calcium carbonate content) across WCA-2A, WCA-3A, and the peripheral WCA-1 marsh will have little effect on resident blue-green/diatom communities because these marshes are already hard water ecosystems. However, discharge of mineralized canal waters across the interior of WCA-1 would significantly change the periphyton flora and water quality characteristics of the marsh interior from an acid, soft water marsh dominated by desmids and filamentous greens to an alkaline, hard water ecosystem dominated by filamentous blue-greens.

In practice, waters that could potentially be backpumped into the WCA's would almost always contain high concentrations of N and P as well as calcium carbonate. It is the author's opinion that excess N and P concentrations have had far greater impacts on the Everglades periphyton community, as a whole, in comparison to increases in the calcium carbonate content of WCA surface waters.

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APPENDIX A

SPECIES LIST

TABLE A-1. A SYSTEMATIC LIST OF PERIPHYTON SPECIES COLONIZING WCA GLASS SLIDES, 1978-1982.

SYSTEMATIC LIST OF PERIPHYTON SPECIES

Division: Myxophyceae (Blue-Greens)[a]
Family: Chroococcaceae
Agmenellum quadruplicatum
Anacystis dimidiata
Anacystis montana
Coccochloris elabens
Gomphospheria spp.
Johannesbaptistia pellucida
Family: Oscillatoriaceae
Microcoleus lynbyaceus
Oscillatoria lutea
Oscillatoria princeps
Schizothrix calcicola
Spirulina princeps
Spirulina subsalsa
Family: Nostocaceae
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: Ulotrichales
Chaetopleltis obicularis
Chaetosphaeridium globosum
Stigeoclonium tenue
Ulothrix zonata
Order: Chlorococcales
Ankistrodesmus falcatus
v. mirabilis
Ankistrodesmus sprialis
Characium sp.
Chlorella vulgaris
Chlorococcum humicola
Coelastrum sp.
Crucigenia tetrapedia
Dimorphococcus lunatus
Kentrosphaera gloephila
Kirchneriella lunaris
Nephrocytium lunatum
Oocystis spp.
Pediastrum boryanum
Pediastrum sp. 1
Scenedesmus abundans
Scenedesmus acruatus
v. platydisca
Scenedesmus bijuga
Scenedesmus brasiliensis
Scenedesmus denticula
Scenedesmus incrassatus
Scenedesmus longus
Scenedesmus obliquus
Scenedesmus parisiensis
Scenedesmus quadricauda
Selenastrum spp.
Sorastrum sp.
Sphaerocystis sp. 1
Tetraedron caudatum
Tetraedron regulare
Tetraedron trigonum
Order: Oedogonales
Bulbochaetae sp.
Oedogonium species 1, 2 & 3
Order: Zygnematales
Mougeotia species 1 & 2
Spirogyra spp.
Families: Mesotaeniaceae and Desmidiaceae
Arthrodesmus incus
v. semilunatus
Arthrodesmus validus
Bambusina brebissonii
Closterium acutum
Closterium archerianum f. major
Closterium setaceum
Closterium species 1, 2 & 3

Families: Mesotaeniaceae and Desmidiaceae (con't.)
Cosmarium alpestre
Cosmarium angulosum
v. concinnum
Cosmarium bisphaericum
Cosmarium blyttii
Cosmarium circulare
Cosmarium comminsurale
v. crassum
Cosmarium cf. contractum
Cosmarium cf. costatum
Cosmarium elegantissimum
v. simplicus
Cosmarium excavatum
f. duplomajor
Cosmarium exiguum
Cosmarium cf. galeritum
Cosmarium cf. granatum
Cosmarium hammeri
Cosmarium cf. impressulum
Cosmarium margaritatum
Cosmarium cf. moniliforme
Cosmarium notable
Cosmarium orthostichum
Cosmarium cf. punctulatum
Cosmarium pyramidatum
Cosmarium pyramidatum
v. convexum
Cosmarium cf.
schliephackeanum
Cosmarium speciosum
Cosmarium cf. tenue
Cosmarium tinctum
Cosmarium tinctum
v. subretusum
Cosmarium trilobatum
v. depressum
Cosmarium cf. undulatum
v. minutum
Cosmarium variolatum
Cosmarium species #1-19
Cylindrocystis spp.
Desmidium aptogonum
Desmidium baileyi
Desmidium coarctatum
Desmidium cylindricum
Desmidium grevelli
Desmidium swartzii
Docidium undulatum
v. semiundulatum
Euastrum abruptum
f. minor
Euastrum affine
Euastrum bidentatum
Euastrum binale
v. gutwinskii
Euastrum binale
v. elobatum
Euastrum intermedium
Euastrum lutkemulleri
Euastrum cf. verrucosum
v. reductum
Genicularia elegans
Genicularia sp. 1
Gonatozygon aculeatum
Gonatozygon brebissonii
Hyalotheca dissiliens
Hyalotheca undulata
Mesotaenium sp. 1
Micrasterias foliaceae
Micrasterias pinnatifida
Micrasterias radiata
Micrasterias radiosa
v. ornata
Micrasterias species 1 & 2
Netrium digitus
Onychonema laeve
v. latum
Pleurotaenium minutum
Pleurotaenium minutum
v. elongatum
Pleurotaenium minutum
v. major
Sphaerozosma granulatum

Spondylosium planum
Staurastrum alternans
Staurastrum americanum
Staurastrum arachne
Staurastrum cf. comptum
v. pinnatiforme
Staurastrum crytocerum
Staurastrum dejectum
Staurastrum dickiei
v. rhomboideum
Staurastrum forficulatum
v. eximium
Staurastrum lativenter
Staurastrum leptocladium
Staurastrum inversenii
Staurastrum johnsonii
Staurastrum ophiura
v. cambricum
Staurastrum paradoxum
v. parvum
Staurastrum tetracerum
Staurastrum triundulatum
Tetmemorus granulatus
Triploceras gracile
Triploceras verticillatum
Xanthidium armatum
v. fissum
Xanthidium cristatum
v. unicinatum
Xanthidium f. micronatum
Xanthidium sp. 2

Division: Bacillariophyceae (Diatoms)[c]
Order: Centrales
Suborder: Discineae
Family: Coscinodiscaceae
Coscinodiscus rothii
v. subsalsa
Cyclotella cf. glomerata
Cyclotella meneghiniana
Melosira granulata
Melosira varians
Thalassiosira fluviatilis
Order: Pennales
Suborder: Araphidae
Fragilaria brevistriata
Fragilaria capucina
v. mesolepta
Fragilaria pinnata
Synedra delicatissima
Synedra pahokeensis
sp. nov.
Synedra radians
Synedra tenera
Synedra ulna
v. amphirhynchus
Synedra ulna
v. obtusa
Synedra ulna
v. oxyrhynchus
Synedra sp. 2 sp. nov.
Suborder: Monoraphidae
Achnanthes exigua
v. heterovalva
Achnanthes hauckiana
Achnanthes inflata
Achnanthes minutissima
Cocconeis placentula
v. euglypta
Suborder: Biraphidae
Amphipleura pellucida
Amphora veneta
Amphora sp. 1
Anomoeoneis serians
Anomoeoneis serians
v. brachysira
Anomoeoneis sphaerophora
Anomoeoneis vitrea
Bacillaria parodoxa
Caloneis bacillum
Caloneis ventricosa
v. truncatula

TABLE A-1 (Con't.). A SYSTEMATIC LIST OF PERIPHYTON SPECIES COLONIZING WCA GLASS SLIDES, 1978-1982.

SYSTEMATIC LIST OF PERIPHYTON SPECIES

Division: Bacillariophyceae[c] (Con't).
Order: Pennales
Suborder: Biraphidae
Cymbella amphioxys
Cymbella microcephala
Cymbella minuta
Cymbella minuta
v. pseudogracilis
Cymbella minuta
v. silesiaca
Cymbella cf muelleri
Cymbella pusilla
Cymbella ruttneri
Diploneis elliptica
Diploneis finnica
Diploneis ovalis
Epithemia spp.
Epithemia argus
v. alpestris
Eunotia arcus
v. bindens
Eunotia curvata
Eunotia flexuosa
Eunotia flexuosa
v. eurycephala
Eunotia formica
Eunotia naegelii
Eunotia pectinalis
v. minor
Frustulia rhomboides
v. crassinervia
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 truncatum
Gomphonema turris
Hantzschia amphioxys
v. major
Mastogloia smithii
Mastogloia smithii
v. lacustris
Navicula accomoda
Navicula arvensis
Navicula bicephala
Navicula biconica
Navicula bioculata
Navicula capitata
Navicula capitata
v. hungarica
Navicula cincta
Navicula confervacea
Navicula cryptocephala
v. veneta
Navicula cuspidata
Navicula disputans
Navicula exigua
v. capitata
Navicula geitleri
Navicula luzonensis
Navicula minima
Navicula mutica
Navicula paucivisitata
Navicula pupula
v. rectangularis
Navicula pygmaea
Navicula radiosa
Navicula radiosa
v. tenella
Naviucla rhynchocephla
v. germainii

Suborder: Biraphidae (Con't)
Navicula seminulum
Navicula cf. subtillissima
Navicula tripunctata
v. schizonemoides
Navicula variostriata
Neidium affine
v. amphirhyncus
Neidium cf. iridis
Nitzschia acicularis
Nitzschia acuta
Nitzschia amphibia
Nitzschia cf. brevirostris
Nitzschia closterium
Nitzschia denticula
Nitzschia denticula
v. elongata
Nitzschia dissipata
Nitzschia fonticola
Nitzschia frustulum
Nitzschia frustulum
v. perpussilla
Nitzschia hybrida
Nitzschia kutzingiana
Nitzschia linearis
Nitzschia microcephala
Nitzschia obtusa
Nitzschia obtusa
v. scalpelliformis
Nitzschia palea
Nitzschia sigmoidea
Nitzschia cf. spiculoides
Nitzschia storchii sp. nov.
Nitzschia cf. subrostrata
Nitzschia subtilis
Nitzschia tarda
Nitzschia vermicularis
Nitzschia species #5-16
Pinnularia sp. 2
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[b]
Order: Rhizochrysidales
Lagynion macrotrachelum
Order: Rhizochloridates
Stipitococcus vasiformes
Order: Phaeoplacales
Dinobryon spp.
Epipyxis sp.
Mallomonas caudata
Division: Dinophyceae
Order: Gymnodiniales
Gymnodinium sp.
Order: Peridinales
Gonyaulux sp. 1
Peridinium species 1 & 2

Division: Euglenophyceae
Order: Euglenales
Euglena spp.
Phacus spp.
Trachelomonas spp.

Division: Cryptophyceae
Order: Cryptomonales
Cryptomonas erosa
Rhodomonas spp.

Division: Charophyceae
Order: Charales
Chara spp.

Footnote:

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

[b]After G.M. Smith (1950)

[c]After Hustedt's (1930)

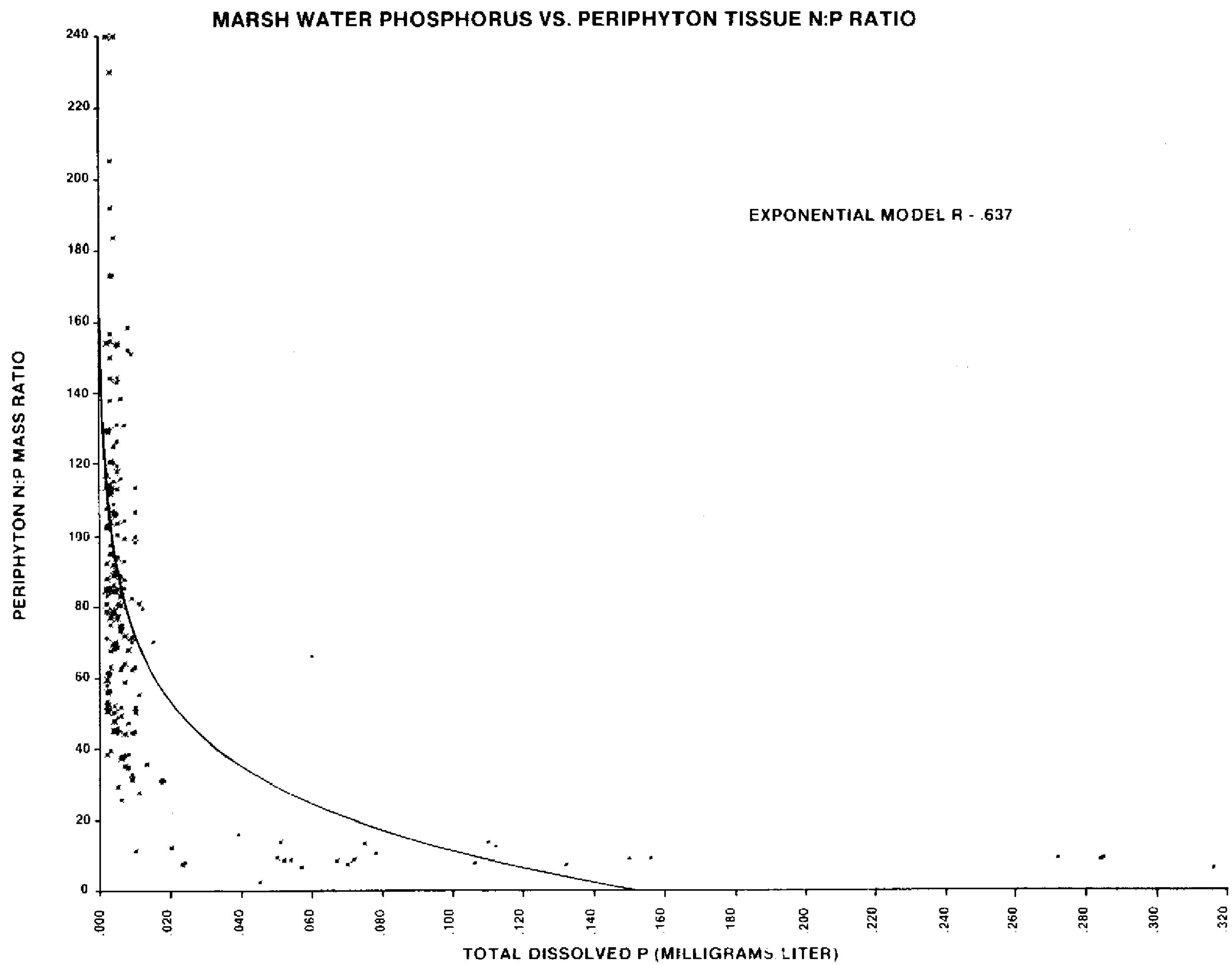

Figure A-1 MARSH WATER PHOSPHOROUS VS. PERIPHYTON N:P MASS RATIOS

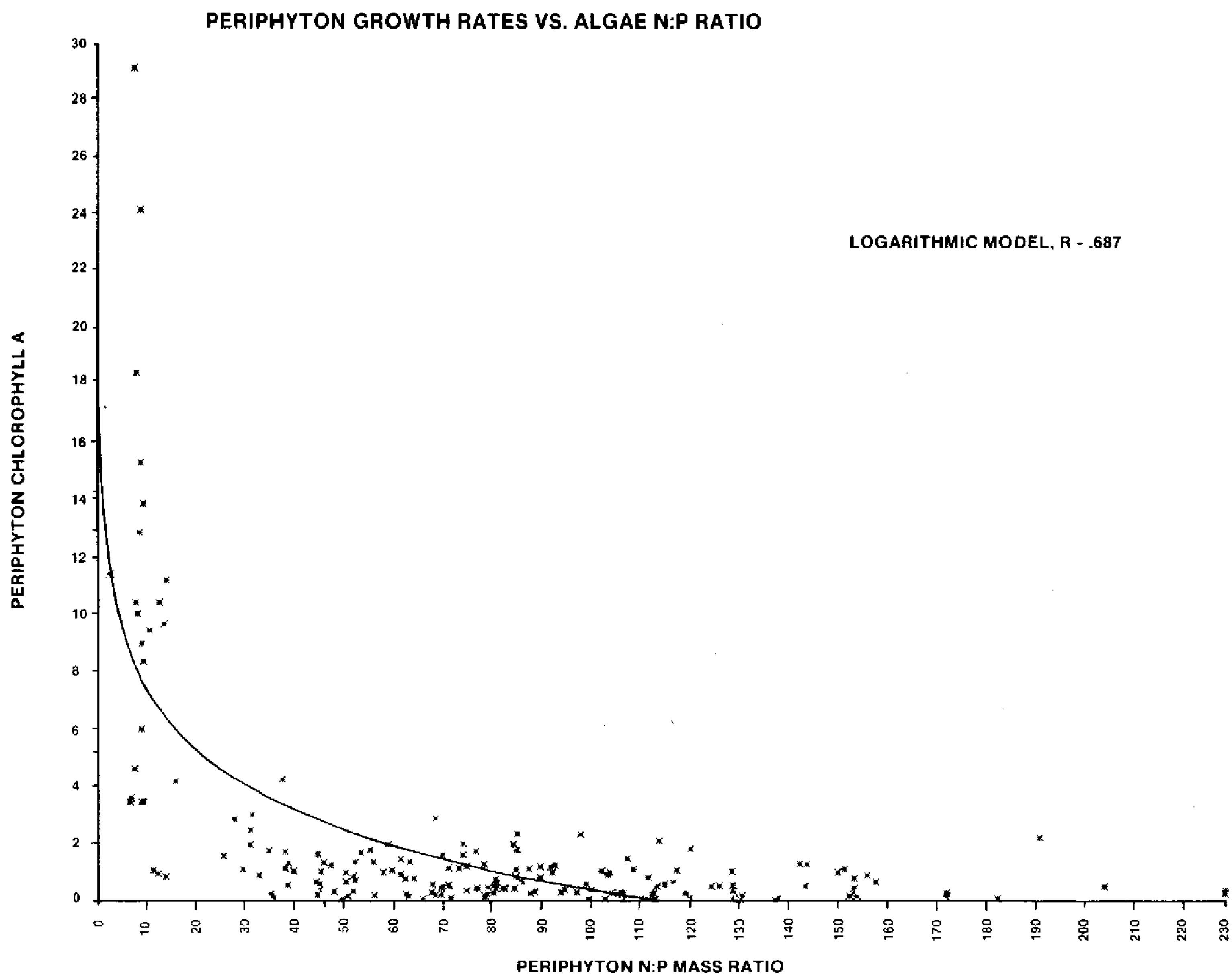

Figure A-2 PERIPHYTON GROWTH RATES (CHLOROPHYLL a) vs. PERIPHYTON N:P MASS RATIO

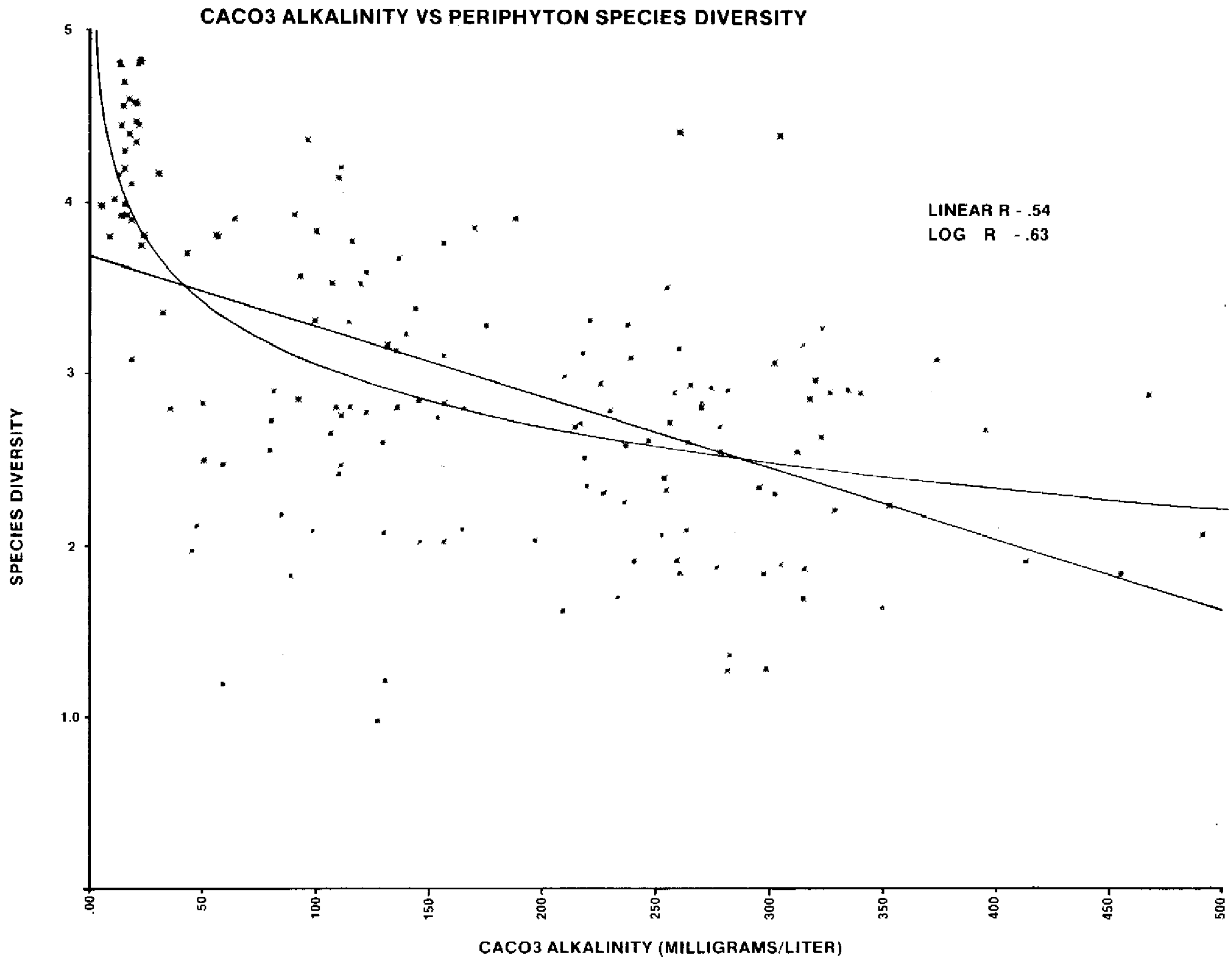

Figure A-3 PERIPHYTON SPECIES DIVERSITY VS. SURFACE WATER CALCIUM CARBONATE ALKALINITY.

APPENDIX B

TAXONOMIC NOTES

Schizothrix calcicola (Ag.) Gom. was the most widely distributed and most frequently encountered blue-green algae observed in our collections, occurring in every sample examined. S. calcicola is a small threadlike filamentous alga consisting of a trichome (usually) enclosed within a thin mucilaginous sheath. Trichome length was highly variable with trichome width averaging 1.2-1.5 (up to 3.5) microns. Average cell volume for S. calcicola ranged between 300-500 cubic microns.

Presently there exists confusion regarding the taxonomy of this alga. Drouet (1968) has reported that strains of Schizothrix can modify their cell morphology (ie. cell size or shape, degree of filament bending, presence or absence or a sheath, or color), in response to changing environmental or physiological conditions. Algae which have these characteristics have been termed "ecophenes". Drouet (1963) demonstrated these morphological variations by growing pure cultures of S. calcicola, in a wide variety of culture media under different environmental conditions. His results showed the final growth form of this one species could be classified as 54 separate species representing nine different genera using some of the most commonly used taxonomic references. Gleason (1972) reports similar "variants" of S. calcicola both in his laboratory culture work and from periphyton mats collected in Everglades National Park. Within this study five ecophenes of S. calcicola are reported.

Scytonema hofmannii was the second most abundant filamentous blue-green present occurring at times as a co-dominant species in association with Schizothrix calcicola at calcium rich interior marsh sites. Filaments of S. hofmannii were much larger in size (roughly 500 times) as compared to S. calcicola with a cell diameter typically ranging between 8-12 (up to 25) microns. Cell volumes calculated for S. hofmannii averaged between 150,000- 250,000 cubic microns. Scytonema hofmannii is identified by its false branching habit, yellow-brown colored trichomes, intercalary heterocysts, and laminated hyaline sheath that are usually heavily encrusted with calcium carbonate crystals.

S. hofmannii was a relatively slow growing species and was not as commonly encountered in our glass slide collections as compared to periphyton mat cores collected from marsh sediments. S. hofmannii on glass slide substrates accounted for a maximum of 45 percent of the total periphyton community (by volume) whereas S. hofmannii accounted for 50-80 percent of the algae collected from periphyton mat cores. S. hofmannii and S. calcicola were the dominant periphyton flora in waters containing high concentrations of dissolved minerals (bicarbonate and calcium) and low concentrations of inorganic nutrients.

Microcoleus lyngbyaceus was the most common blue-green present at nutrient enriched peripheral marsh sites. M. lyngbyaceus is a relatively large filamentous blue-green intermediate in size between S. calcicola and S. hofmanni. It is distinguished by its parallel trichomes, and highly granular cross walls. Sheath material may be present or completely lacking. Living specimens are mobile and exhibit a gliding motion under the microscope.

The taxonomy of M lyngbyaceus is also in a muddled state. Drouet's (1968) revision of this group has reduced or "lumped" hundreds of filamentous blue-green species into six genera and 23 species. As a result, taxonomists using earlier reference material (eg. Prescott, 1962; G.M. Smith, 1950) could easily key out M. lyngbyaceus as one of five different species depending upon cell diameter measurements or the presence or absence of sheath material. For example; Drouet (1968) recognizes Oscillatoria limosa, Oscillatoria tenius, Lyngbya major, Lyngbya martensiana and Lyngbya aestuarii as being merely ecophenes of Microcoleus lyngbyaceus. It is not the intention of this paper to address these problems of classical taxonomy, but rather to report that M. lyngbyaceus commonly exhibited a wide range of morphological variability within our collections. It should be noted, however, that numerous studies have cited Oscillatoria limosa and Oscillatoria tenuis (= M. lynbyaceus) as two of the most pollution tolerant algae reported in the literature. Large populations of these algae have been cited as indicators of gross organic pollution (Palmer, 1969).

Five genera of filamentous greens were quantitatively important members of the WCA periphyton community. These included: Mougeotia, Spirogyra, Bulbochaetae, Oedogonium, and Stigeoclonium. Mougeotia was the most common and widely distributed of these genera. Both Mougeotia and Spirogyra are members of the family Zygnematales. These unbranched, filamentous greens reproduce sexually by use of a conjugation tube connected between two filaments whereby gametes are exchanged to form zygospores (Smith, 1950;

Whitford and Schmuacher, 1969). Members of this family are difficult to identify to species as most manuals require the presence of fruiting bodies (ie. zygospores). The majority of filamentous greens colonizing our slides were in the vegetative stage and were only keyed to genus.

Oedogonium and Bulbochaetae were also important components of the WCA periphyton community. Oedogonium spp. is an unbranched, filamentous green algae which is identified by the presence of one or more ring-like scars (resulting from previous cell division) located at the enlarged anterior end of the cell. Oedogonium is difficult to key to species as both male and female reproductive structures are required for identification. Since the majority of filaments colonizing our slides were in the vegetative stage, no attempt was made to key these organisms lower than the generic level.