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**WATER-COLUMN SEDIMENT NUTRIENT  
INTERACTIONS AS A FUNCTION OF HYDROLOGY  
(HOPKINS PRAIRIE)**

**FINAL REPORT, 1989-90**

**Prepared for:**

**St. Johns River Water Management District  
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## EXECUTIVE SUMMARY

The St. Johns River Water Management District has undertaken a research project to investigate the effects of fluctuating water levels on the ecological functions of wetlands. Hopkins Prairie, a relatively pristine, herbaceous wetland, located in the Ocala National Forest, Florida, has been chosen as a long-term ecological research site for this purpose. The University of Florida, Department of Soil Science, was contracted by the District to evaluate the effects of hydrology, particularly fluctuating water levels, on soil water (interstitial porewater) chemistry in Hopkins Prairie. Soil and porewater sampling was conducted during the period of August, 1989 through November, 1990.

The objectives of this research were: 1) to characterize the wetland soil to a depth of 60 cm; 2) to characterize the porewater chemistry; 3) to relate the changes in porewater chemistry to season and fluctuating water levels; and 4) to evaluate the effects of fluctuating water levels on water-column/ soil porewater nutrient interactions.

Four sampling sites were selected within the prairie to correspond with ongoing research by the District and other contractors. Three replicate sites were located in an open water marsh, dominated by the macrophytes Rhynchospora inundata, Eriocaulon compressum, Eleocharis elongata, and Nymphaea odorata. A fourth site was selected within the nearby sawgrass community (dominated by Cladium jamaicense and Cephalathus

occidentalis). This site was selected to conduct a pilot project to investigate whether sediment characteristics and nutrient levels were sufficiently different to justify additional future research in this type of community.

Characterization of the soil profile to a depth of 60 cm showed that the physical and chemical characteristics of the soil in Hopkins Prairie is typical of a highly organic wetland soil. The soils of both sites were comprised primarily of organic material with very little mineral matter.

The electrochemical property that serves to distinguish an unsaturated soil from a saturated soil is the redox potential or electron activity in the soil. Redox potential provides an indirect measure of the aeration status of the soil which in turn, is affected by water table depth. Redox measurements were made at soil depths of 2, 15, and 45 cm during the study period. Flooded conditions existed during the first seven months of the study but the water table dropped below the soil surface for the latter six months of the study. As the water table moved downward in the soil profile, redox values increased indicating movement of air into the unsaturated pores above the water table.

Sediment porewater equilibrators, devices used to obtain stratigraphic information with regard to porewater chemistry, were used to monitor porewater nutrient concentrations monthly. Equilibrators consist of a series of vertically arranged discrete cells milled in a solid acrylic bar at 1 cm intervals. The cells are filled with pure water and covered with a permeable

membrane. The equilibrators are then driven into the soil. The constituents of the soil porewater come into equilibrium with the water in the cells; thus, the nutrient concentration in the cells, after a 7 to 10 day equilibration period, equals the nutrient concentration of the soil porewater.

Nitrate and phosphate concentrations were, with a few exceptions, similar in the overlying water as compared to the soil porewater. However, ammonium concentrations were significantly lower in the overlying water compared to porewater concentrations. Porewater ammonium concentrations also tended to increase with soil depth. Ammonium and nitrate concentration profiles suggested that nitrification/denitrification was occurring at the soil surface resulting in loss of nitrogen from the system. In contrast, sulfate concentrations were significantly higher in the overlying water suggesting that sulfate was being reduced to sulfide in the anaerobic soil zone. Overall, all nutrient concentrations were low. They were generally comparable to nutrient concentration values observed in the Florida Everglades Water Conservation areas, but much lower than similar measurements made in agricultural areas of the Everglades.

The effect of hydrology, i.e., water table depth, on porewater constituents was particularly evident with ammonium, nitrate, and sulfate concentrations. As the water table depth decreased, the porewater concentrations of these nutrients increased in the soil above the water table. This was particularly evident in the upper 10 cm of soil. However, it is not

clear that the water of the equilibrators cells accurately reflects soil water when the equilibrators cells are above the water table. No previous research exists to indicate the extent of equilibration taking place between moist, unsaturated soil and the equilibrators cell water. At a minimum, data obtained from above the water table should be treated with caution. This suggests that alternate methods of sampling should be considered when the water table drops below the soil surface. Sampling of the soil profile and either water extraction or porewater extrusion would appear to be viable alternatives to equilibrators when the water table drops below the soil surface.

Differences existed between the soil's physical and chemical characteristics, redox potential, and porewater nutrient levels of the open water and sawgrass communities. In particular, redox potentials were generally higher in the sawgrass community than in the open water community. The differences between the two communities was due to soil surface elevation differences and possibly to the ability of sawgrass to transport oxygen downward through its root system.

The effect of hydrology on soil physical, microbial and chemical characteristics has implications for both the rate of organic matter accumulation in the soil and aquatic plant productivity. As the water table depth decreases, the soil above the water table is exposed to air and the decomposition rate of organic matter increases. This increases the

availability of plant nutrients which subsequently will increase plant productivity.

## TABLE OF CONTENTS

	<u>Page</u>
LIST OF FIGURES .....	viii
LIST OF TABLES .....	ix
1.0 INTRODUCTION .....	1
1.1 Objectives .....	2
2.0 MATERIALS AND METHODS .....	2
2.1 Study Site .....	2
2.2 Field Procedures .....	4
2.2.1 Soil sampling .....	4
2.2.2 Redox potential .....	4
2.2.3 Porewater sampling .....	5
2.3 Laboratory Procedures .....	6
2.4 Statistical Analysis .....	7
3.0 RESULTS .....	8
3.1 Soil Characterization .....	8
3.2 Hydrology .....	13
3.3 Redox Potential .....	16
3.4 Porewater Chemistry .....	19
4.0 DISCUSSION .....	33
5.0 CONCLUSIONS .....	39
6.0 REFERENCES .....	41

## LIST OF FIGURES

<u>Figure</u>		<u>Page</u>
1	Location of Hopkins Prairie and the sampling site within the prairie . . . . .	3
2	Water table depths in the open water and sawgrass sites of Hopkins Prairie (October, 1989 to November, 1990) . . . .	15
3	Soil redox potential measured at depths of 2, 15, and 45 cm at open water sites within Hopkins Prairie . . . . .	17
4	Soil redox potential measured at depths of 2, 15, and 45 cm in a sawgrass community within Hopkins Prairie . . . . .	18
5	Porewater pH profiles for open water and sawgrass communities of Hopkins Prairie (Error bars = $\pm 1$ std. deviation). . . . .	20
6	Porewater ammonium-N profiles for open water and sawgrass communities of Hopkins Prairie (Error bars = $\pm 1$ std. deviation). . . . .	22
7	Porewater nitrate-N profiles for open water and sawgrass communities of Hopkins Prairie (Error bars = $\pm 1$ std. deviation). . . . .	25
8	Porewater phosphate-P profiles for open water and sawgrass communities of Hopkins Prairie (Error bars = $\pm 1$ std. deviation). . . . .	27
9	Porewater sulfate-S profiles for open water and sawgrass communities of Hopkins Prairie (Error bars = $\pm 1$ std. deviation). . . . .	28



## LIST OF TABLES

<u>Table</u>		<u>Page</u>
1	Moisture content and bulk density of soil samples collected from open water and sawgrass areas of Hopkins Prairie (n=6 for open water site and 2 for sawgrass site) . . . . .	9
2	Total carbon, nitrogen and, phosphorus contents of soil samples collected from open water and sawgrass sites of Hopkins Prairie (n=6 for open water site and 2 for sawgrass site) . . . . .	10
3	Soil pH and water-extractable ammonium and soluble reactive phosphorus (SRP) of soil samples collected from open water and sawgrass sites of Hopkins Prairie (n=6 for open water site and 2 for sawgrass site) . . . . .	11
4.	Soil redox potentials of open water and sawgrass communities of Hopkins Prairie (n=2) . . . . .	14
5.	Porewater nutrient concentration and pH averaged for overlying water and sediment depth increments for each sampling date. Zones A, B, C, and D represent overlying water and sediment depth increments of 0-10, 11-20, and 21-30 cm, respectively. . . . .	31
6.	Comparison (orthogonal single degree of freedom contrasts) of porewater nutrient concentrations and pH in the presence and absence of overlying water . . .	32

## APPENDIX TABLES

A1.	Sediment characterization of raw data. . . . .	A1
A2.	Redox readings from two sites in each sampling area . . . . .	A2
A3.	Concentrations of selected species in porewater samples from three open water sites (A-C) and one sawgrass site . .	A4

## 1.0 INTRODUCTION

Wetlands provide many functions which benefit our overall environment. Among these functions is a wetland's capacity to filter nutrients from overlying water (Hammer and Bastian, 1989; Best, 1987; Mitsch and Gosselink, 1986). As such, wetlands have often been called the earth's kidneys. It is important to characterize the various chemical and microbial activities which take place at the soil-water interface and within the soil in order to quantitatively evaluate the role of wetlands as a nutrient filter and to understand the overall functioning of a wetland.

Wetland soils generally exist under saturated or flooded conditions for considerable periods of time. Oxygen diffusion through the flooded water is greatly reduced compared to a nonflooded soil. Thus, the flooded soil quickly becomes anaerobic due to rapid oxygen consumption by microbial respiration and chemical reactions. The biogeochemical cycling of elements such as C (carbon), S (sulfur), and N (nitrogen) and the chemistry of P (phosphorus) are greatly influenced by the aeration status of the soil (Mitsch and Gosselink, 1986; Faulkner and Richardson, 1989). This, in turn, is reflected in the concentration of these elements in the soil porewater.

The St. Johns River Water Management District (SJRWMD) has undertaken a research project to investigate the effects of fluctuating water levels on the ecological functions of wetlands. Hopkins Prairie, a relatively pristine, herbaceous wetland, located in the Ocala National Forest, Florida, has been chosen as a long-term ecological research site for this purpose. The University of Florida,

Department of Soil Science, was contracted by the District to evaluate the effects of hydrology, particularly fluctuating water levels, on soil water (interstitial porewater) parameters in Hopkins Prairie.

### **1.1 Objectives**

The objectives of this research were: 1) to characterize the wetland soil to a depth of 60 cm; 2) to characterize the porewater chemistry; 3) to relate the changes in porewater chemistry to season and fluctuating water levels; and 4) to evaluate the effects of fluctuating water levels on water-column/ soil porewater nutrient interactions.

## **2.0 MATERIALS AND METHODS**

### **2.1 Study Site**

Hopkins Prairie is located in the Ocala National Forest in central Florida (Figure 1). The District operated a research platform in the prairie during this study, which was equipped to collect weather data (rainfall, temperature, relative humidity, solar radiation, and wind speed direction) and continuous water level recordings. Sediment cores and porewater samples were collected in the general vicinity of this platform.

Four sampling sites were selected within the prairie to correspond with ongoing research by the District and other contractors. Three replicate sites were located in an open water marsh area, dominated by the macrophytes, Rhynchospora inundata, Eriocaulon compressum, Eleocharis elongata and

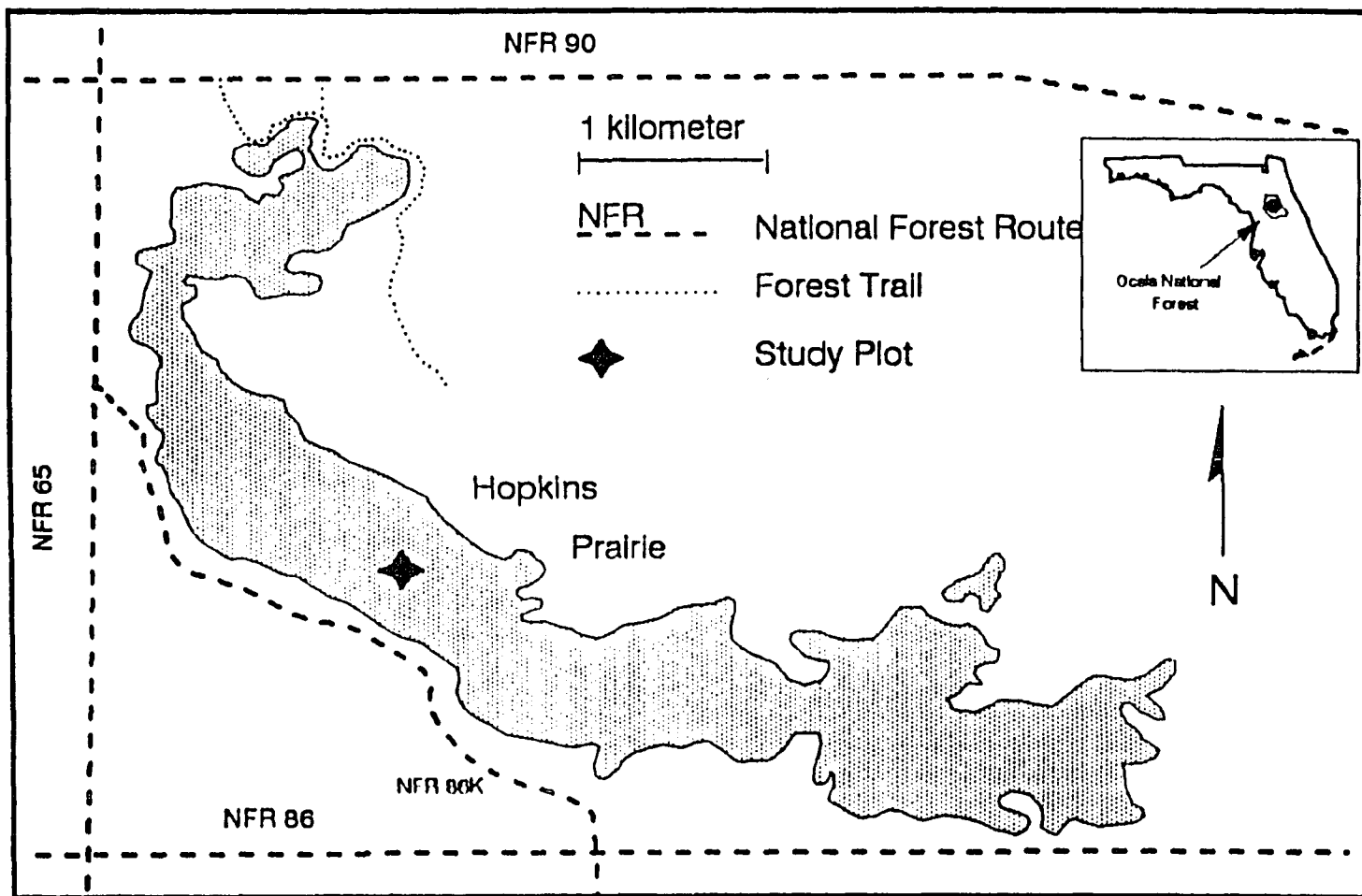


Figure 1. Location of Hopkins Prairie and the sampling site within the prairie.

Nymphaea odorata. A fourth site was selected within the nearby sawgrass community (dominated by Caladium jamaicens and Cephalathus occidentalis). This site was selected to conduct a pilot project to investigate whether sediment characteristics and nutrient levels were sufficiently different to justify additional future research in this type of community.

## **2.2 Field Procedures**

### **2.2.1 Soil sampling**

Two soil cores were taken to a depth of 60 cm at each of the four sampling sites. Intact soil cores were obtained by driving a PVC pipe to a depth of 60 cm. Compaction during the sampling process was less than 2 cm per core due to water-saturated conditions. The bottoms of the cores were sealed with PVC caps and transported to the laboratory. Each core was sectioned at intervals of 0-5, 5-10, 10-20, and 20-60 cm. Samples were analyzed for moisture content, bulk density, pH, water-extractable ammonium, nitrate and phosphate, and total carbon, nitrogen and phosphorus.

### **2.2.2 Redox potential**

Redox potential of the soils was measured on a monthly basis at depths of 2, 15, and 45 cm. Redox electrodes were constructed following the procedure described by Faulkner et al.(1989). Platinum electrodes were inserted at the respective depths for the duration of the study. The Eh (electron activity) measurements were made using a millivolt meter and a standard calomel reference

by 245 mV to express values in reference to a standard hydrogen electrode.

### **2.2.3 Porewater sampling**

Porewater samples were to be originally obtained via solution samplers placed at 2.5, 7.5, 20, and 45 cm depths in the soil. However, it was observed in other studies conducted by the University of Florida Soil Science Department (See Graetz, D.A. Evaluation of porewater equilibrators, Report to the St. Johns River Water Management District, December, 1989) that under anaerobic conditions such as occur in the soils of Hopkins Prairie, soluble iron may oxidize on the surface of the soil solution samplers due to the presence of air within the sampler. This oxidized iron would act as a barrier to phosphorus and possibly other elements as the porewater is drawn into the sampler. Thus, it was decided to use porewater equilibrators as a substitute sampling technique.

Porewater equilibrators, or peepers, are devices which obtain stratigraphic information with regard to porewater chemistry. Peepers used in this study were similar to a design suggested by Hesslein (1976). They consisted of three parts: a solid bar of acrylic with cavities milled out at appropriate intervals, a permeable membrane, and a cover to hold the membrane in place. The configuration we used was a 80 cm x 10 cm x 2 cm block of acrylic with cavities milled at 1 cm intervals. Each cavity has an internal volume of approximately 8 cm<sup>3</sup>. The membrane consisted of a layer of polycarbonate with a pore size of 0.22  $\mu\text{m}$  overlaid with a protective nylon sheet.

Prior to placing the equilibrators, the cells were filled with distilled water. The equilibrators were then placed in storage containers filled with distilled water maintained under oxygen-free conditions until inserted into the soil. Upon placement in the soil, overlying water and porewater constituents were allowed to reach equilibrium with the deionized water in the cells for a period of 10 to 14 days. After this period, the equilibrators were removed from the soil and rinsed with distilled water. Porewater samples were immediately withdrawn from each cell at either 1 or 2 cm depth intervals (depending on the sampling date) with a disposable syringe. A 5 ml volume was transferred into a 20 ml vial and placed in an ice-filled cooler for transport to the laboratory. Samples were stored at 4 °C and analyzed within 48 hours. A 3 ml sample was stored in the syringe stuck in a rubber stopper to prevent degassing for pH determination within 24 hours after sample collection. Samples were analyzed for ammonium nitrogen (EPA Method 351.2), nitrate nitrogen (EPA Method 353.2), soluble reactive phosphate (EPA Method 365.2)(USEPA, 1979), sulfate (APHA Method 4110, APHA 1989) and pH (glass electrode).

### **2.3 Laboratory Procedures**

Bulk density was determined by weighing each depth increment of the soil cores (0-5, 5-10, 10-20 and 20-60 cm), determining the soil moisture content of a subsample by drying at 70 °C, and relating dry weight to the volume of the depth increment. Soil pH was measured with a combination glass electrode. Water-extractable elements were obtained by weighing a known amount of wet soil (2.5

g dry weight equivalent) into a 50-mL centrifuge tube and adding distilled water to obtain a soil to liquid ratio of 1:10 on a dry weight basis. After shaking for one hour, the soil suspensions were centrifuged at 5000 rpm for 15 minutes and filtered through Gelman 0.45  $\mu\text{m}$  membrane filters. Extracts were analyzed for ammonium, nitrate, and soluble reactive phosphorus using autoanalyzer methodology (EPA Methods 351.2, 353.2 and 365.2, respectively) (USEPA, 1979).

Total P was determined by heating a subsample to a white ash (450-500 °C) for a period of 5 hours (Anderson, 1976). Phosphorus in the extract from the above ash was determined by autoanalyzer methodology (Method 365.2, USEPA, 1979). Finely-ground oven-dried samples were analyzed for total N and total C using a Carlo-Erba NA-1500 CNS Analyzer (Haak-Buchler Instruments, Saddlebrook, New Jersey).

#### **2.4 Statistical Analysis**

All statistics were performed using the Statistical Analysis System (SAS, 1988). Analysis of variance was carried out with the PROC GLM procedure. Separation of means was accomplished by Duncan's Multiple Range test for all parameters. Soil pH and C/N ratio were first ranked by PROC Rank. Linear correlation analysis was used to test for correlation between water depth and redox potential. Differences between porewater nutrient concentrations in the presence and absence of overlying water were analyzed by orthogonal single degree of freedom contrasts.



## 3.0 RESULTS

### 3.1 Soil Characterization

Soils were sampled at depth increments of 0-5, 5-10, 10-20, and 20-60 cm on August 29, 1989. All soils were saturated at time of sampling with overlying water present at all sites.

#### Open water site

Soil water content decreased with depth with values ranging from 92.5% in the surface increment to 88.2% in the 20-60 cm depth increment (Table 1). In contrast, bulk density values increased with depth ranging from 0.0909 g.cm<sup>-3</sup> at the surface to 0.1276 g.cm<sup>-3</sup> at the lowest depth increment (Table 1).

Soil carbon content increased with depth while nitrogen content decreased (Table 2). These trends are reflected in the C/N ratio which ranged from 13.3 for the surface soil to 22.7 for the 20-60 cm depth increment (Table 2). Total phosphorus content decreased from 261  $\mu\text{g.gm}^{-1}$  in the surface soil to 55  $\mu\text{g.gm}^{-1}$  at the 20-60 cm depth increment.

All of the water extractable inorganic nitrogen existed as ammonium (Table 3). Nitrate was not measurable in any of the depth increments. Ammonium values ranged from 50.4  $\mu\text{g.gm}^{-1}$  at the surface to 27.6  $\mu\text{g.gm}^{-1}$  at the 20-60 cm depth interval. There were no significant differences between the three upper depth intervals; however, ammonium-N level for the 20-60 cm depth increment was significantly lower than the increments above. Soluble reactive phosphorus (SRP)

Table 1. Moisture content and bulk density of soil samples collected from open water and sawgrass areas of Hopkins Prairie (n=6 for open water site and 2 for sawgrass site).

Sample depth	Moisture content	Bulk density
cm	---%---	g m <sup>-3</sup>
<u>Open Water</u>		
0- 5	92.5 (0.58) <sup>†</sup> a <sup>‡</sup>	0.0909 (0.008) a
5-10	90.5 (0.76) b	0.0887 (0.011) a
10-20	89.2 (1.38) c	0.1122 (0.016) b
20-60	88.2 (1.41) c	0.1276 (0.016) b
<u>Sawgrass</u>		
0- 5	93.2	0.0826
5-10	93.6	0.0542
10-20	92.5	0.0771
20-60	90.3	0.1141

<sup>†</sup>Numbers in parenthesis = standard deviation.

<sup>‡</sup>Means within a column followed by the same letter do not differ significantly, P<0.05, based on Duncan's Multiple Range Test.

Table 2. Total carbon, nitrogen, and phosphorus contents of soil samples collected from open water and sawgrass areas of Hopkins Prairie (n=6 for open water site and 2 for sawgrass site).

Sample depth	Carbon	Nitrogen	C/N	Phosphorus
cm	-----gm kg <sup>-1</sup> -----			µg gm <sup>-1</sup>
<u>Open Water</u>				
0- 5	468 (11) <sup>†</sup> a <sup>‡</sup>	35.1 (1.41) a	13.3 (0.5) a	261 (17) a
5-10	480 (17) a	34.6 (1.31) a	13.9 (0.8) a	218 (35) b
10-20	497 (6) b	31.4 (2.79) b	15.9 (1.4) b	133 (22) c
20-60	535 (3) c	23.8 (2.90) c	22.7 (2.6) c	55 (6) d
<u>Sawgrass</u>				
0- 5	466	26.1	17.9	270
5-10	483	26.2	18.4	183
10-20	494	27.6	17.9	109
20-60	530	27.1	19.6	48

<sup>†</sup>Numbers in parenthesis = standard deviation.

<sup>‡</sup>Means within a column followed by the same letter do not differ significantly, P<0.05, based on Duncan's Multiple Range Test.

Table 3. Soil pH and water-extractable ammonium and soluble reactive phosphorus (SRP) of soil samples collected from open water and sawgrass areas of Hopkins Prairie (n=6 for open water site and 2 for sawgrass site).

Sample depth	pH	Ammonium	Soluble reactive phosphorus
cm		----- $\mu\text{g gm}^{-1}$ -----	
<u>Open Water</u>			
0- 5	5.08 (0.07) <sup>†</sup> a <sup>‡</sup>	50.4 (16.9) a	0.84 (0.55) a
5-10	4.80 (0.10) b	61.3 (14.5) a	0.60 (0.35) a
10-20	4.90 (0.15) b	58.1 (15.9) a	0.45 (0.33) a
20-60	5.19 (0.17) a	27.6 (6.7) b	0.86 (0.88) a
<u>Sawgrass</u>			
0- 5	4.81	25.3	1.15
5-10	4.66	44.5	1.65
10-20	4.60	58.3	1.07
20-60	5.13	73.0	0.89

<sup>†</sup>Numbers in parenthesis = standard deviation.

<sup>‡</sup>Means within a column followed by the same letter do not differ significantly,  $P < 0.05$ , based on Duncan's Multiple Range Test.

values were less than  $1 \mu\text{g gm}^{-1}$  for all depth increments (Table 3). There were no significant differences between depth increments. Soil pH values showed only small variation with depth with values ranging from 5.19 to 4.80.

### **Sawgrass site**

Soil characterization parameters for the soil samples from the sawgrass site in general followed the same trends as in the open water site. Soil water content was highest in the top 20 cm ranging from 93.6% to 92.5% and decreased to 90.3% in the 20-60 cm depth increment (Table 1). Bulk density was highest in the top 20 cm with values ranging from  $0.0542 \text{ gm cm}^{-3}$  to  $0.0826 \text{ gm cm}^{-3}$  in the 20-60 cm depth increment (Table 1).

Soil carbon content increased with depth with values ranging from  $466 \text{ gm kg}^{-1}$  at the surface to  $530 \text{ gm kg}^{-1}$  at the lower depth increment (Table 2). Small differences were observed between depth increments for total nitrogen with values ranging from  $26.1 \text{ gm kg}^{-1}$  at the surface to  $27.1 \text{ gm kg}^{-1}$  at the 10-20 cm depth increment (Table 2). Carbon/nitrogen ratios also were relatively constant, ranging from 17.9 to 19.6 with no trends associated with sample depth (Table 2). Total phosphorus content decreased from  $270 \mu\text{g.gm}^{-1}$  in the surface soil to  $48 \mu\text{g gm}^{-1}$  at the 20-60 cm depth increment (Table 2).

Water-extractable ammonium concentrations increased from  $25.3 \mu\text{g gm}^{-1}$  at the surface to  $73.0 \mu\text{g gm}^{-1}$  at the 20-60 cm depth increment (Table 3). Soluble reactive phosphorus was highest at the 5-10 cm depth increment and lowest at the 20-60 cm depth increment.

### 3.2 Hydrology

Mean monthly rainfall during the study period ranged from 20 to 130 mm although considerable higher rainfall amounts occurred during July to September, 1990 (Best, 1991). At the beginning of the porewater sampling, October, 1989, both the open water and sawgrass sites were flooded with overlying water reflecting the high amounts of rainfall of the previous months (Table 4 and Figure 2). Water levels in the prairie began to drop during April and May and by June had decreased to below ground elevation (Table 4 and Figure 2). Although the water table depth fluctuated considerable between June, 1990 and November, 1990, it never reached the soil surface beyond June, 1990.

Initial water depth measurements were made only in the open water site; however as the water levels began to decrease, it was noted that the water levels decreased more in the sawgrass area than in the open water area. Subsequently, measurements of water table depths were made for both sites. It was also visually noted that the differences in water table depth were related to differences in ground elevation between the two areas.

Table 4. Soil redox potentials of open water and sawgrass communities of Hopkin's Prairie (means of 2 replications).

Date	Water table depth	OPEN WATER			Water table depth	SAWGRASS		
		Sediment Depth (cm)				Sediment Depth (cm)		
		2	15	45		2	15	45
	cm	-----millivolts-----			cm	-----millivolts-----		
Oct. 89	+40	94	-6	-36	N.D.	75	16	24
Nov. 89	+33	-25	-33	-9	N.D.	-67	1	31
Jan. 90	+26	-29	-76	-74	N.D.	152	134	93
Feb. 90	+26	-17	-129	-93	+10	105	97	172
Mar. 90	+23	21	-132	11	0	-47	-41	-11
Apr. 90	+18	85	-153	-120	0	150	-27	-47
May 90	+5	116	-24	-76	-33	464	76	245
June 90	-5	188	-23	-46	-20	502	414	147
July 90	-15	338	-35	-46	-30	514	355	171
Aug. 90	-2	113	-25	-81	-18	538	499	80
Sep. 90	-4	271	-76	-82	-28	554	503	424
Oct. 90	-30	318	82	-81	-41	485	300	190
Nov. 90	-41	359	383	-87	-56	527	362	221

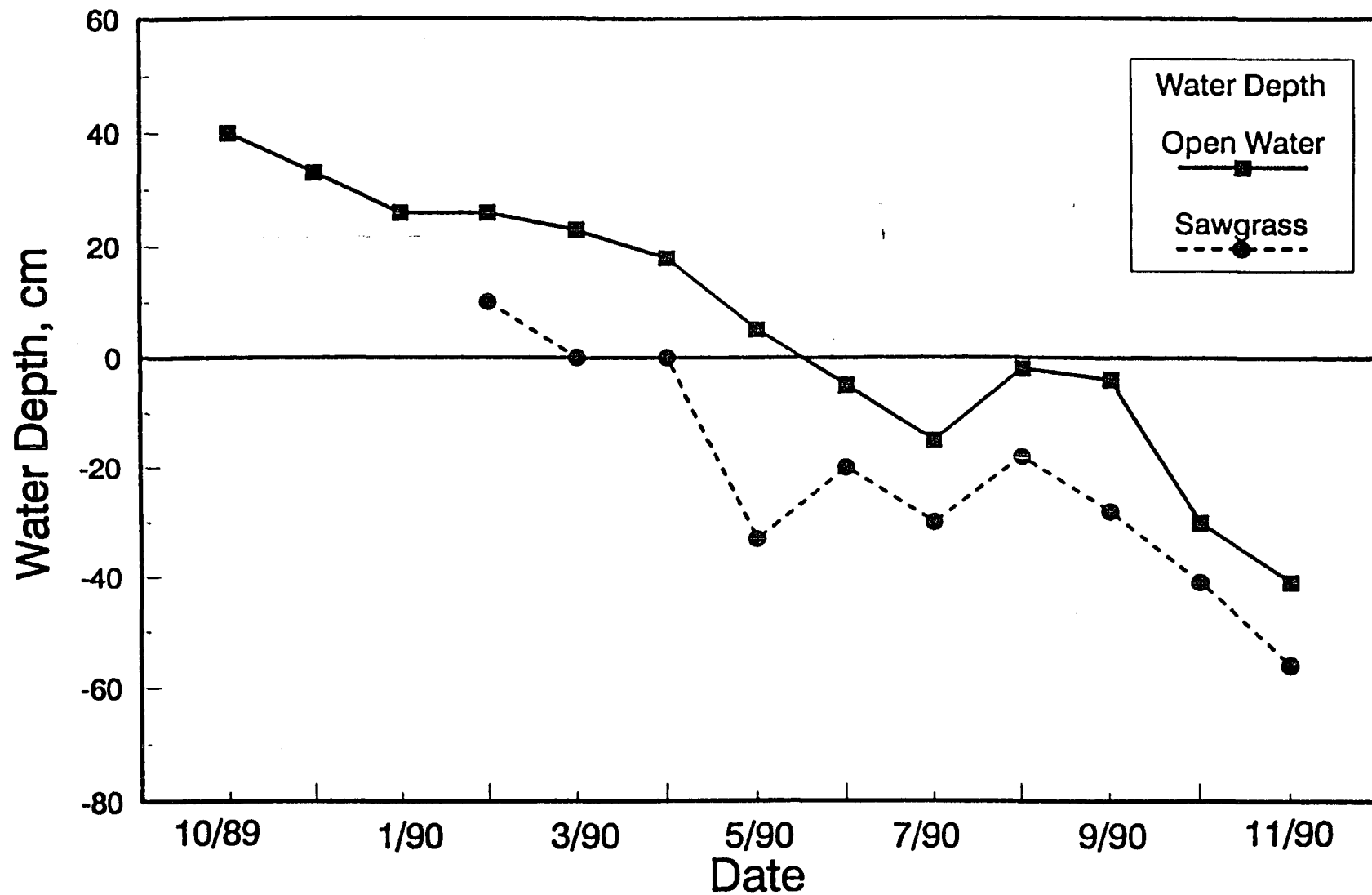


Figure 2. Water table depths in the open water and sawgrass sites of Hopkins Prairie (October, 1989 to November, 1990).



### 3.3 Redox Potential

The redox potential at the 2 cm depth in the open water area began to reflect decreasing water depth ( $R^2 = 0.807$ ;  $p = 0.0001$ ) during April as it steadily increased through the summer months (Table 4 and Figure 3). Between June and September, the water table depth fluctuated but was generally above 15 cm. The redox potential at both 15 and 45 cm remained below 0 mV. During October and November, 1990, the water table depth decreased to 30 cm and below. This change in water table depth was reflected by an increase in redox potential at 15 cm but not at 45 cm. Although the redox potential at a depth of 15 cm responded to water table depth late in the study period, redox potential at 15 cm was not significantly correlated to water table depth. Since the water table remained above 45 cm during the entire study period, there was also no significant correlation between water table depth and redox potential.

In the sawgrass site, the redox potential was affected by water table depth at all three electrode depths (Table 4 and Figure 4). The redox potential increased at all three depths during January and February, 1990 and then decreased to below 0 mV during March and April. The water table fluctuated near the soil surface during March and April and then decreased to levels generally below 15 cm for the rest of the study period. The redox potential increased at all three electrode depths for all dates subsequent to April 1990. Greatest increases were observed with the electrodes at the 2 and 15 cm depths.

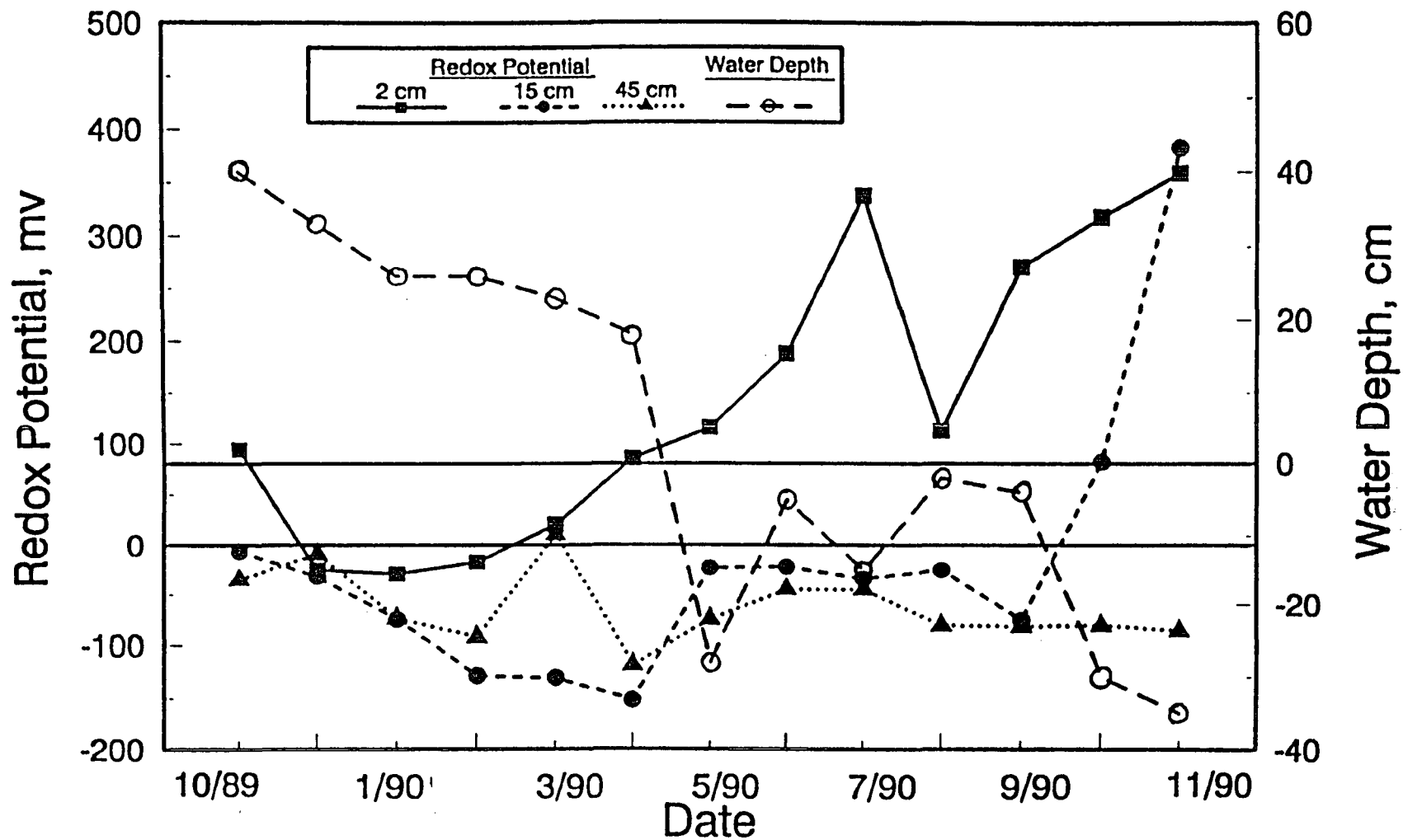


Figure 3. Soil redox potential measured at depths of 2, 15, and 45 cm at open water sites within Hopkins Prairie.

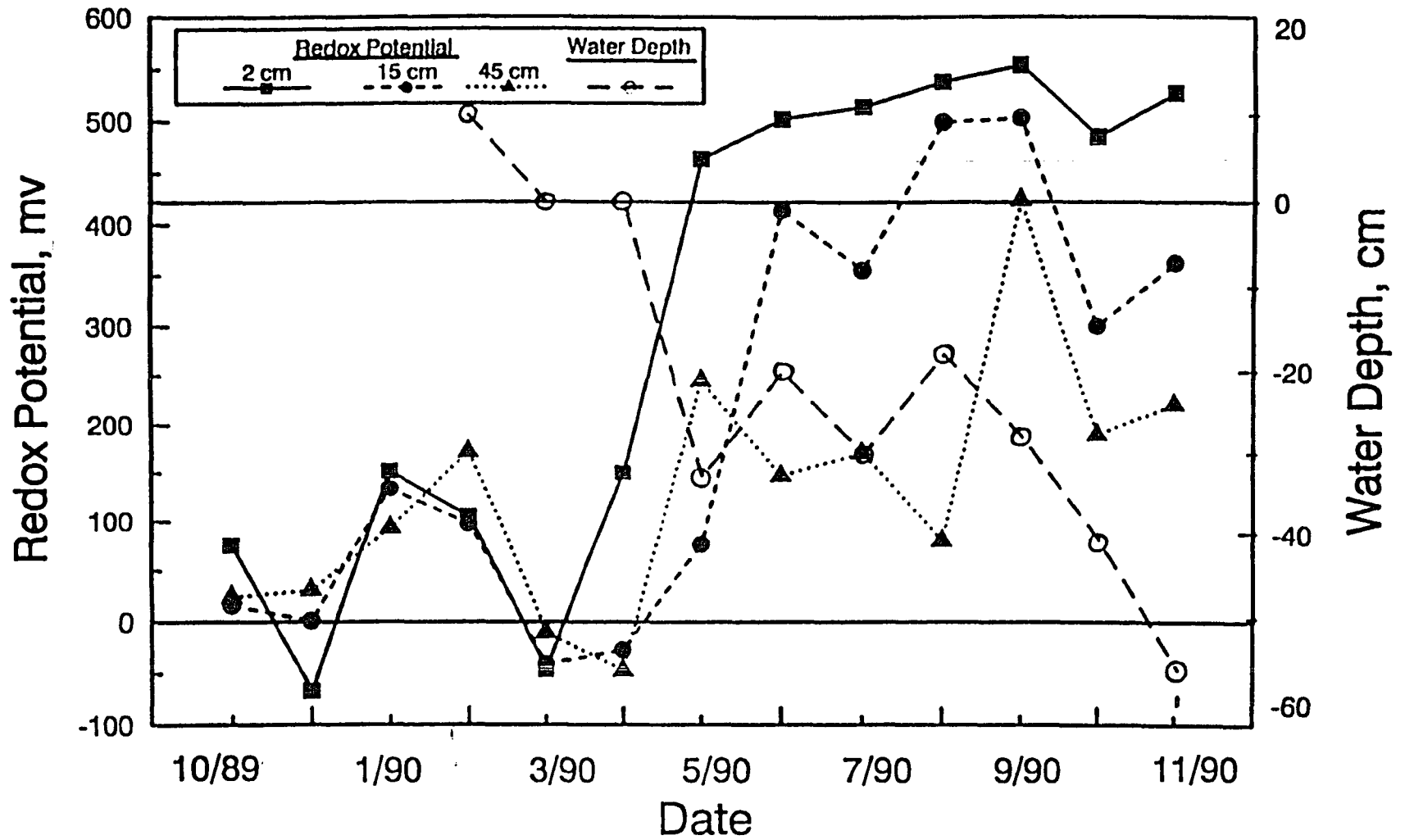


Figure 4. Soil redox potential measured at depths of 2, 15, and 45 cm in a sawgrass community within Hopkins Prairie.

### 3.4 Porewater Chemistry

Porewater pH was relatively uniform with depth for both the open water and sawgrass communities through April of 1990 (Figure 5). During this period, the pH of the sawgrass community soil was consistently lower than that of the open water community soil. However, this difference was generally less than 0.5 pH unit. In the measured pH range of 5 to 6, this difference is not likely to have any biological or chemical effect in either soil. As the water table depth dropped below the soil surface, the pH of the water in the equilibrator cells from the upper 10 cm of the soil of the sawgrass community tended to increase to a point where it was greater than that of the equivalent open water community.

Ammonium concentrations in the porewater throughout the soil profile were less than 1  $\mu\text{g N/mL}$  in November 1989 (Figure 6) for both sampling sites. Subsequent sampling dates showed higher ammonium concentrations for both sampling sites with concentrations generally in the 2 to 3  $\mu\text{g N/mL}$  range. The variability in pore water ammonium concentration noted throughout the study period likely reflect variability in microbial activity in the soil as well as localized effects of uptake by plant roots. Concentrations in the sawgrass community were generally slightly less than concentrations in the open water sites.

The ammonium concentration profiles with depth for the February, March, and April sampling dates show a concentration increase with depth (Figure 6). Ammonium concentration profiles during the period of time where there was no overlying water (May 1990 and beyond) show considerable variation and did not

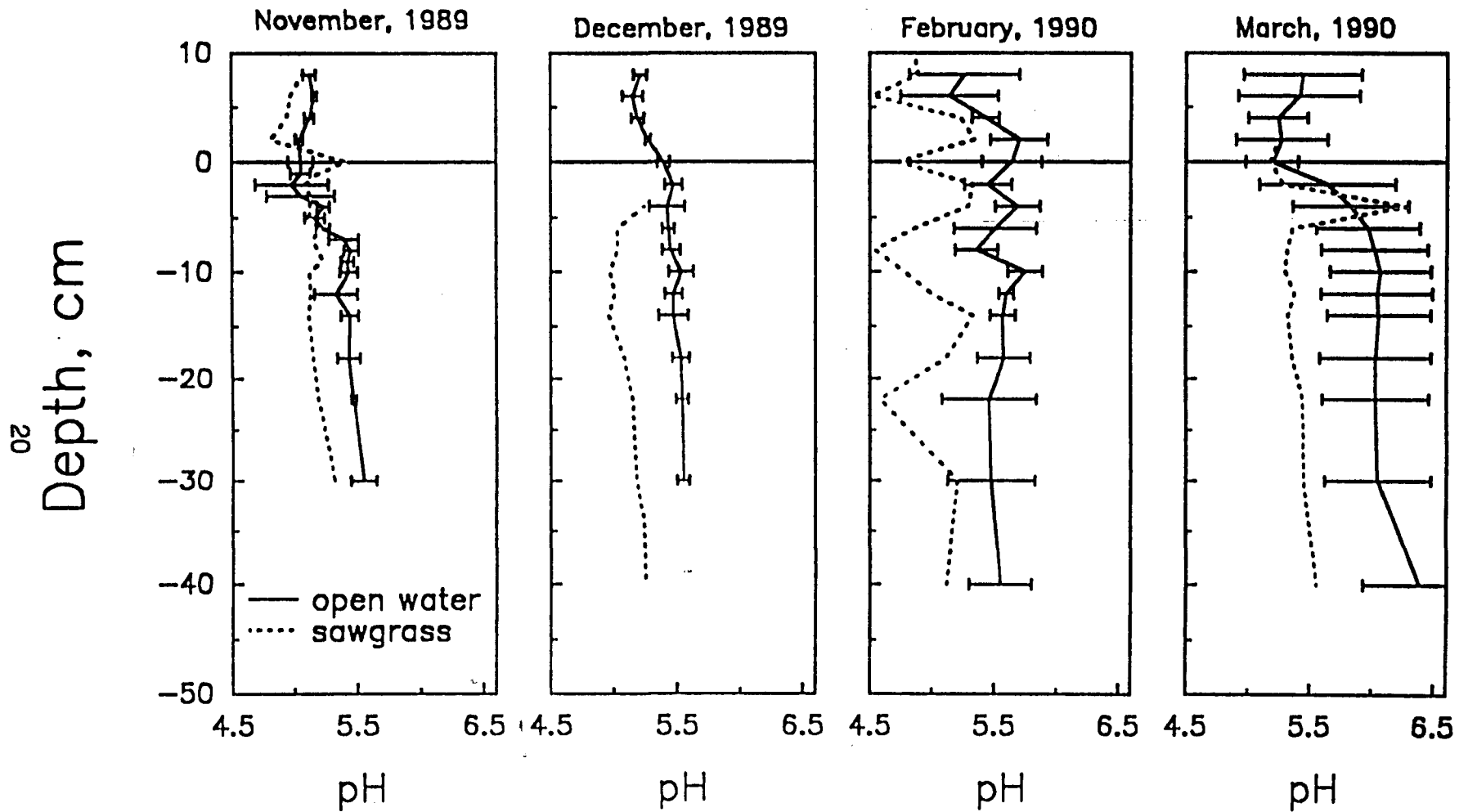


Figure 5. Porewater pH profiles for open water and sawgrass communities of Hopkins Prairie (Error bars =  $\pm 1$  std. deviation).

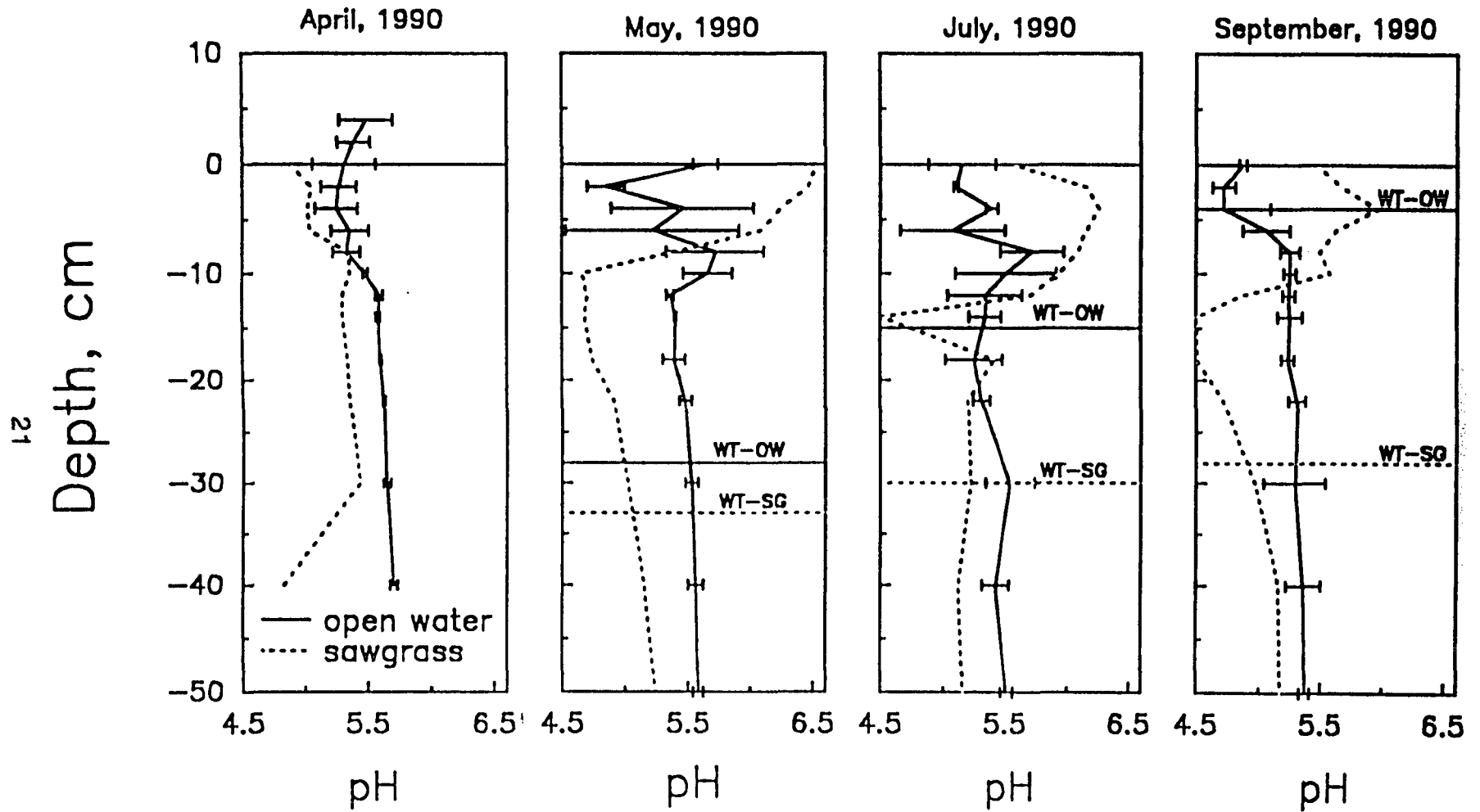


Figure 5. Continued. WT-OW = water table depth - open water; WT-SG = water table depth - sawgrass.

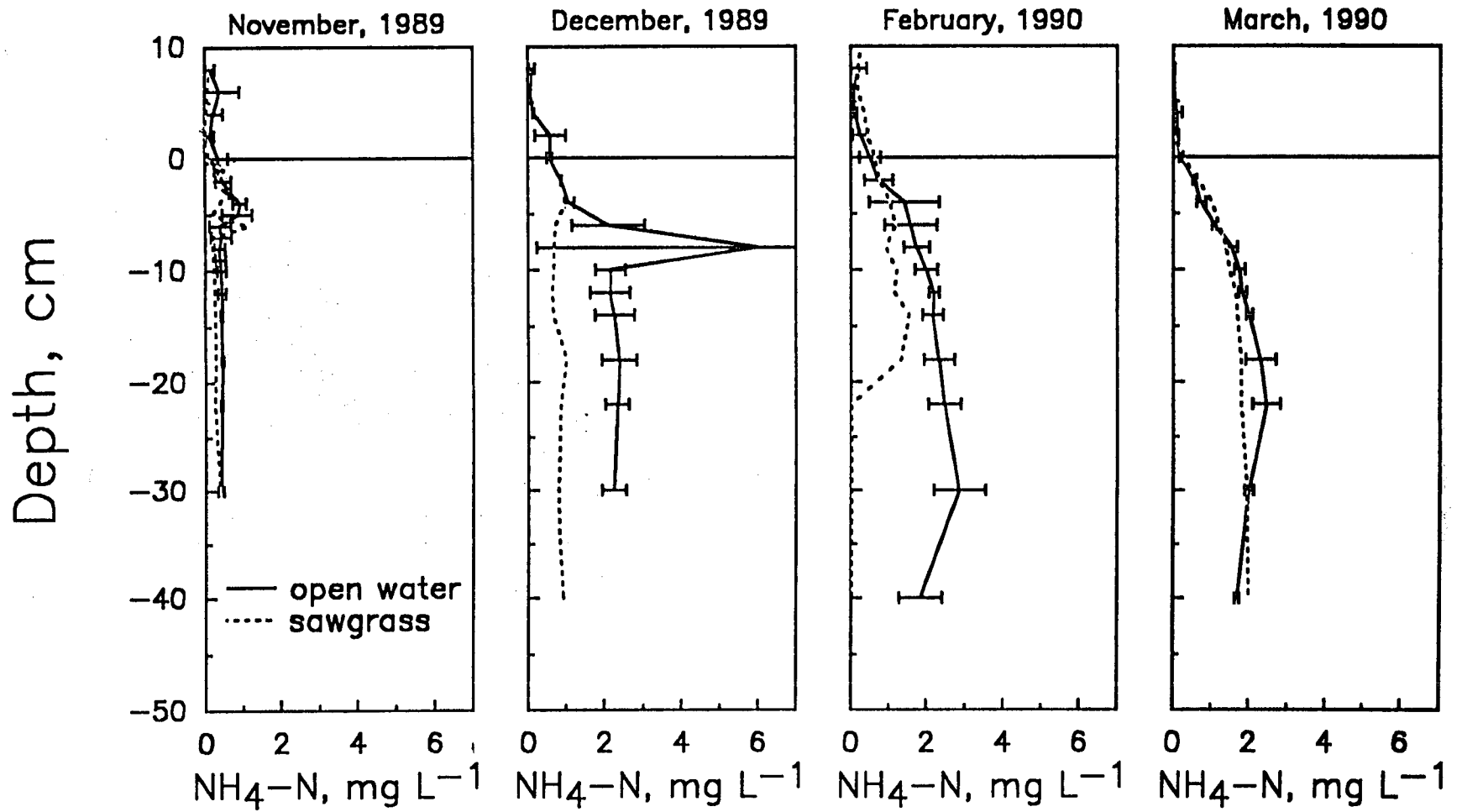


Figure 6. Porewater ammonium-N profiles for open water and sawgrass communities of Hopkins Prairie (Error bars =  $\pm 1$  std. deviation).

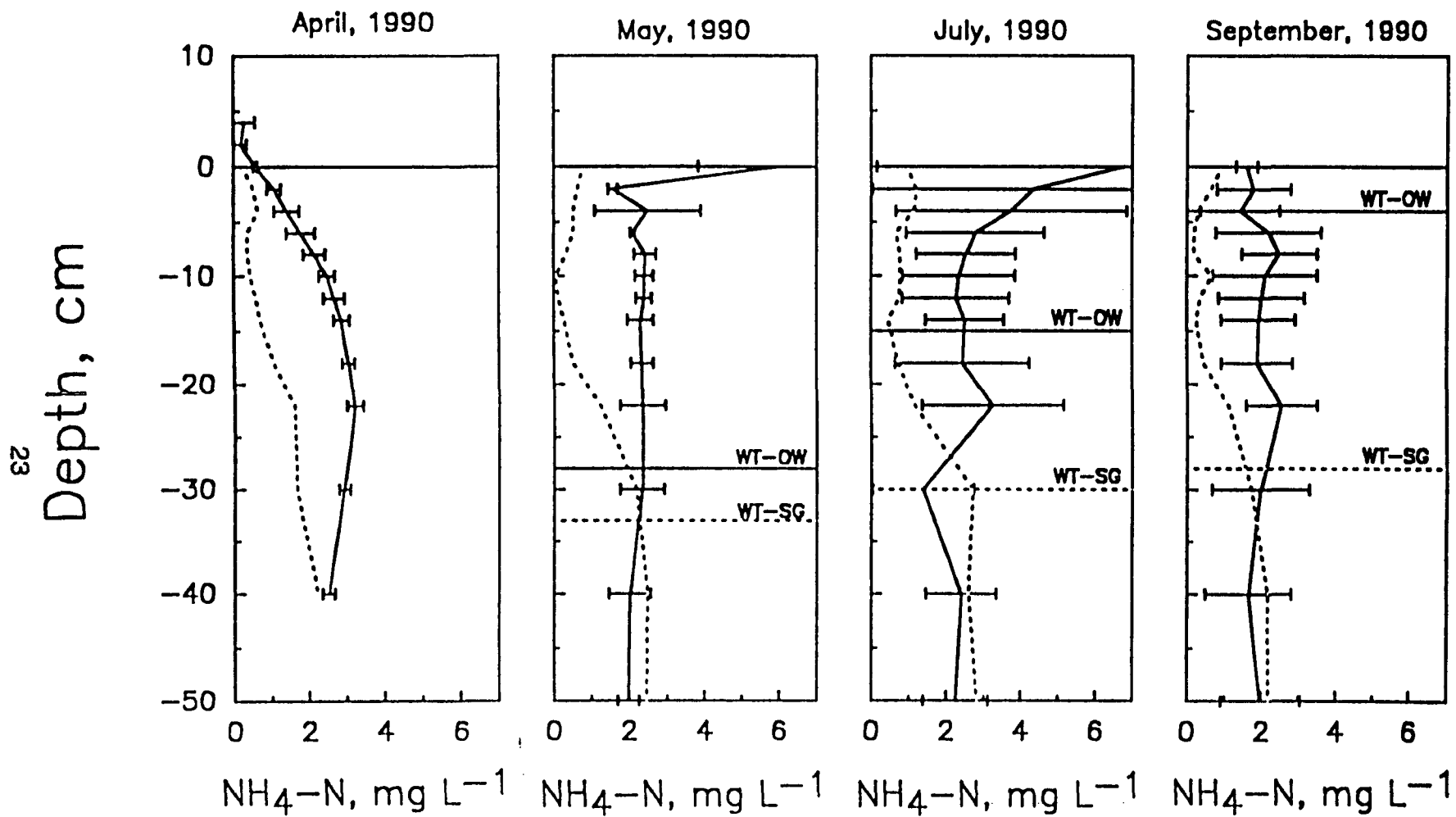


Figure 6. Continued. WT-OW = water table depth - open water; WT-SG = water table depth - sawgrass.



show the pronounced concentration decrease near the soil surface as exhibited for the previous sampling dates. The fact that some ammonium was detected in the equilibrators cells located above the water table suggests some interaction between the moist soil and the equilibrators cells.

Nitrate concentrations in the overlying water and pore water were extremely low (less than  $0.2 \text{ mg L}^{-1}$ ) during November, 1989 to March, 1990 (Figure 7). Concentrations increased in the pore water during April 1990 through September, 1990 (Figure 7). All the increases were observed above the water table and particularly in the sawgrass area.

Soluble reactive phosphate (SRP) concentrations in the porewater were extremely low and were often below detection limits (Figure 8). In fact, during most of the latter part of the sampling period (March-November, 1990), SRP concentrations were below detectable levels.

One of the more interesting observations from the porewater data is the profile of sulfate concentrations with depth (Figure 9). Sulfate was not determined for the November and December, 1989, samples because the samples were preserved with sulfuric acid. Subsequent to these dates, samples were preserved with hydrochloric acid. During the period when overlying water was present, sulfate concentrations were extremely low, being generally less than  $0.2 \text{ mg L}^{-1}$  (Figure 9). As the water table began decreasing below the soil surface, sulfate concentrations began increasing with time in the pore water in the upper part of the soil profile. This was particularly evident in the sawgrass site (Figure 9). Sulfate concentrations began increasing at the

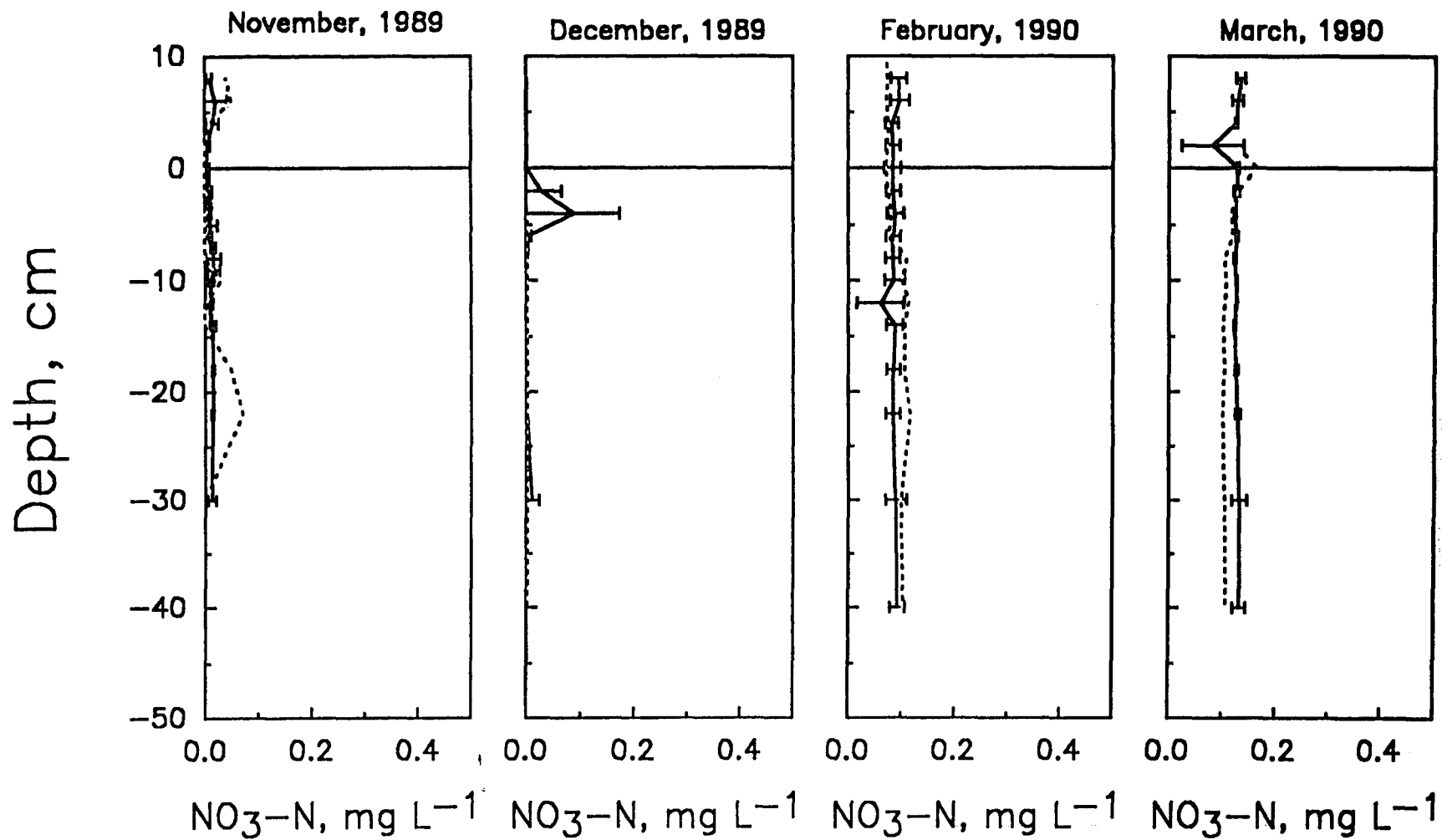


Figure 7. Porewater nitrate-N profiles for open water and sawgrass communities of Hopkins Prairie (Error bars =  $\pm 1$  std. deviation).

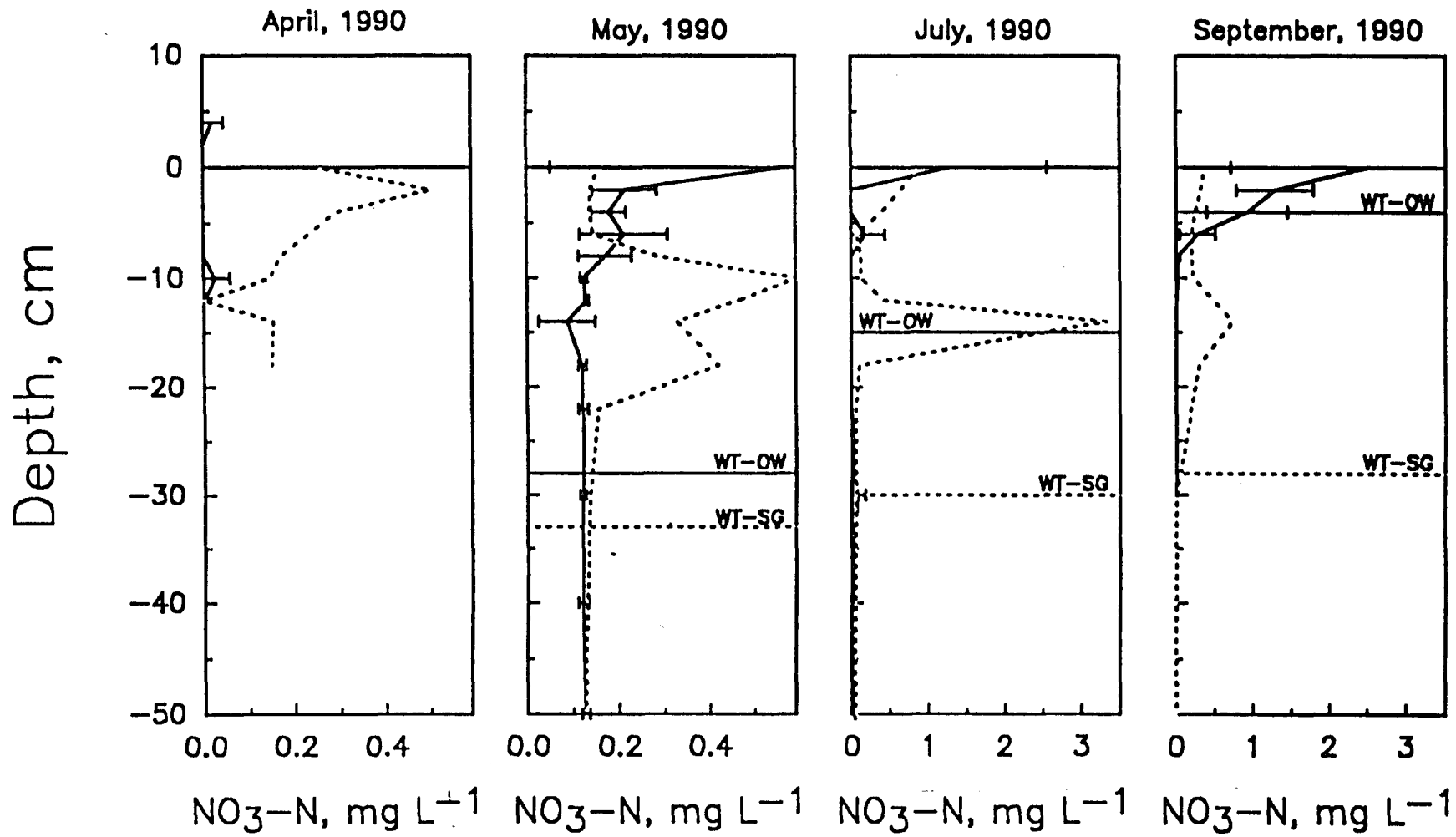


Figure 7. Continued. WT-OW = water table depth - open water; WT-SG = water table depth - sawgrass.

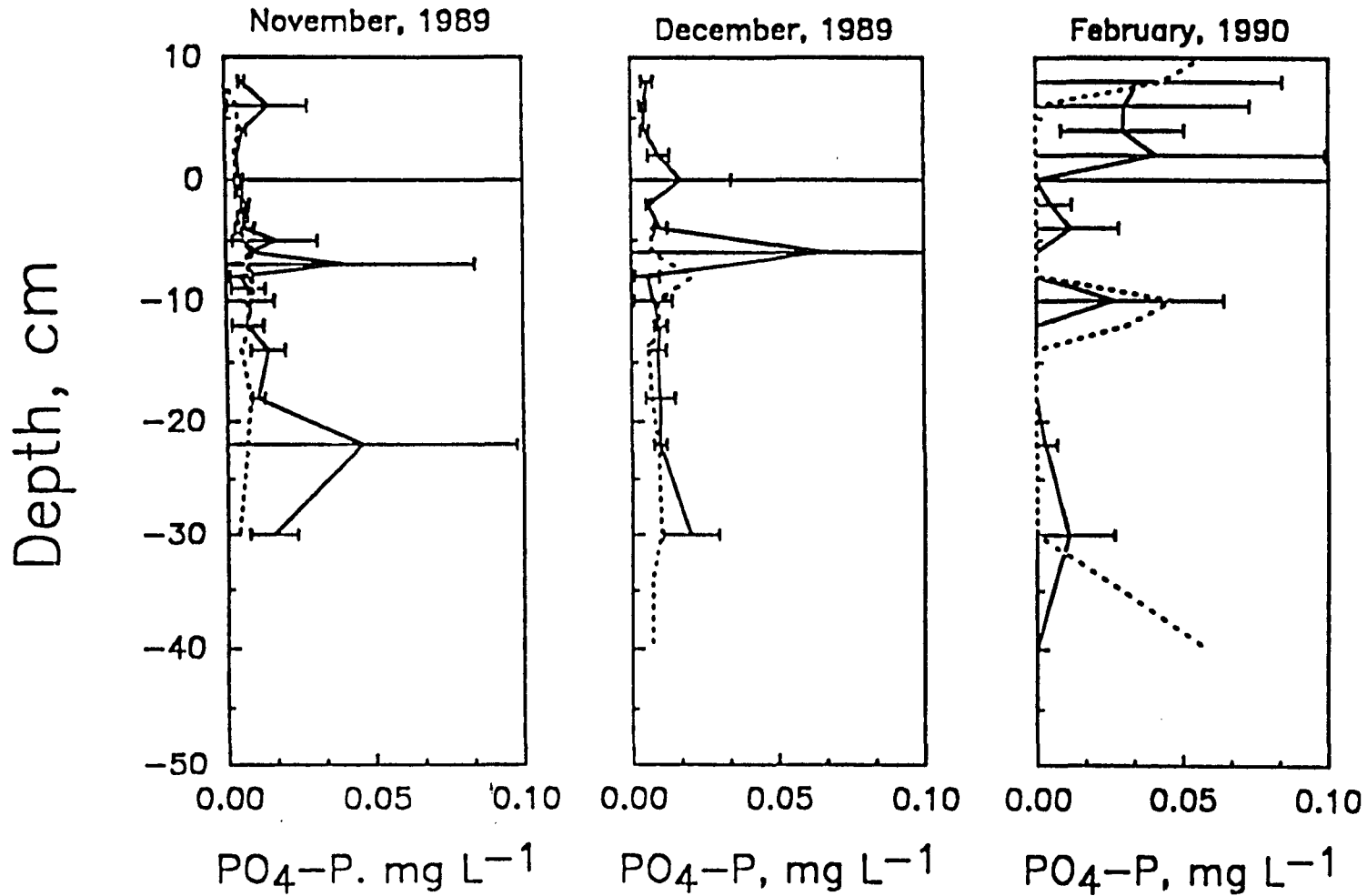


Figure 8. Porewater phosphate-P profiles for open water and sawgrass communities of Hopkins Prairie (Error bars =  $\pm 1$  std. deviation).

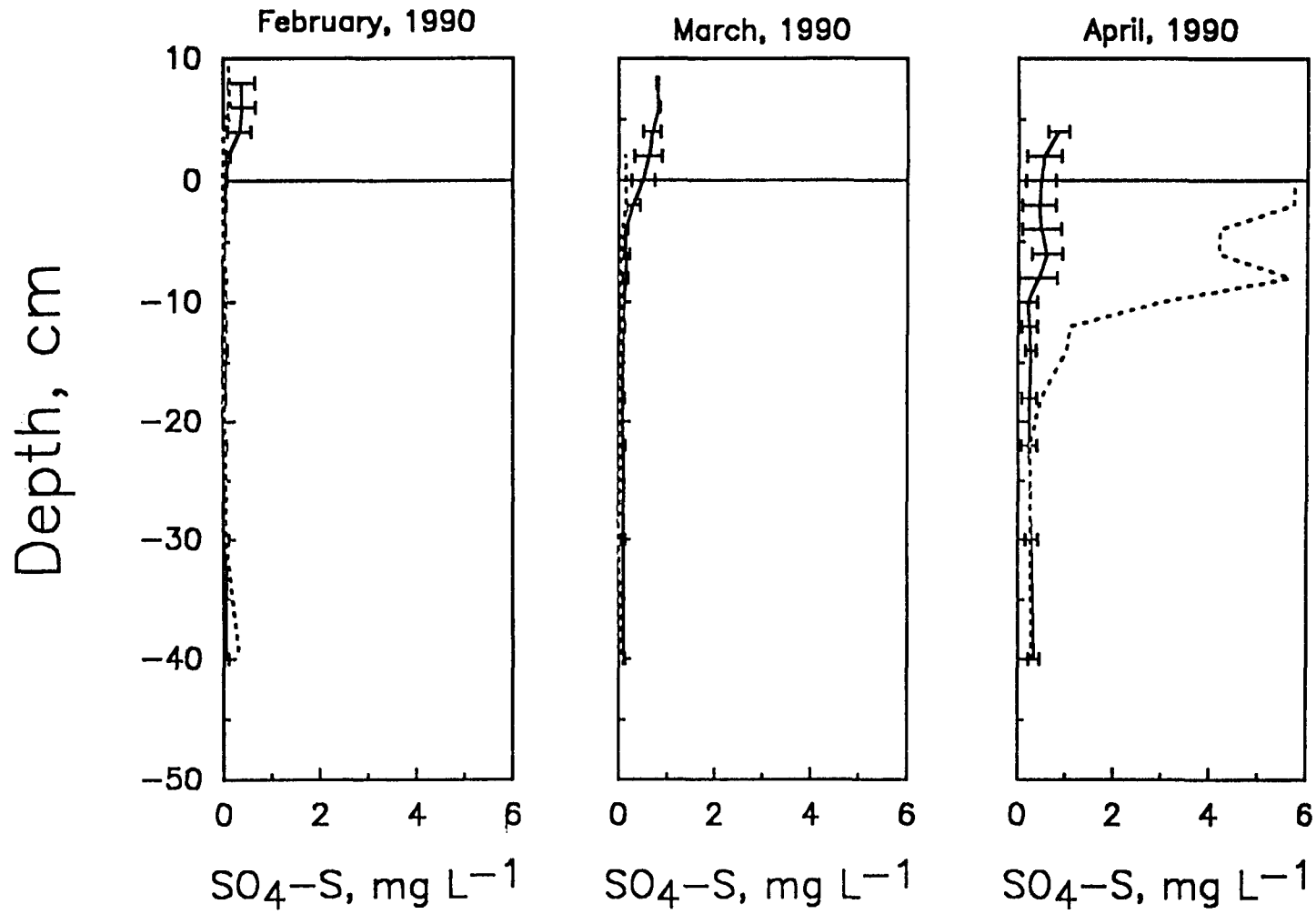


Figure 9. Porewater sulfate-S profiles for open water and sawgrass communities of Hopkins Prairie (Error bars =  $\pm 1$  std. deviation).

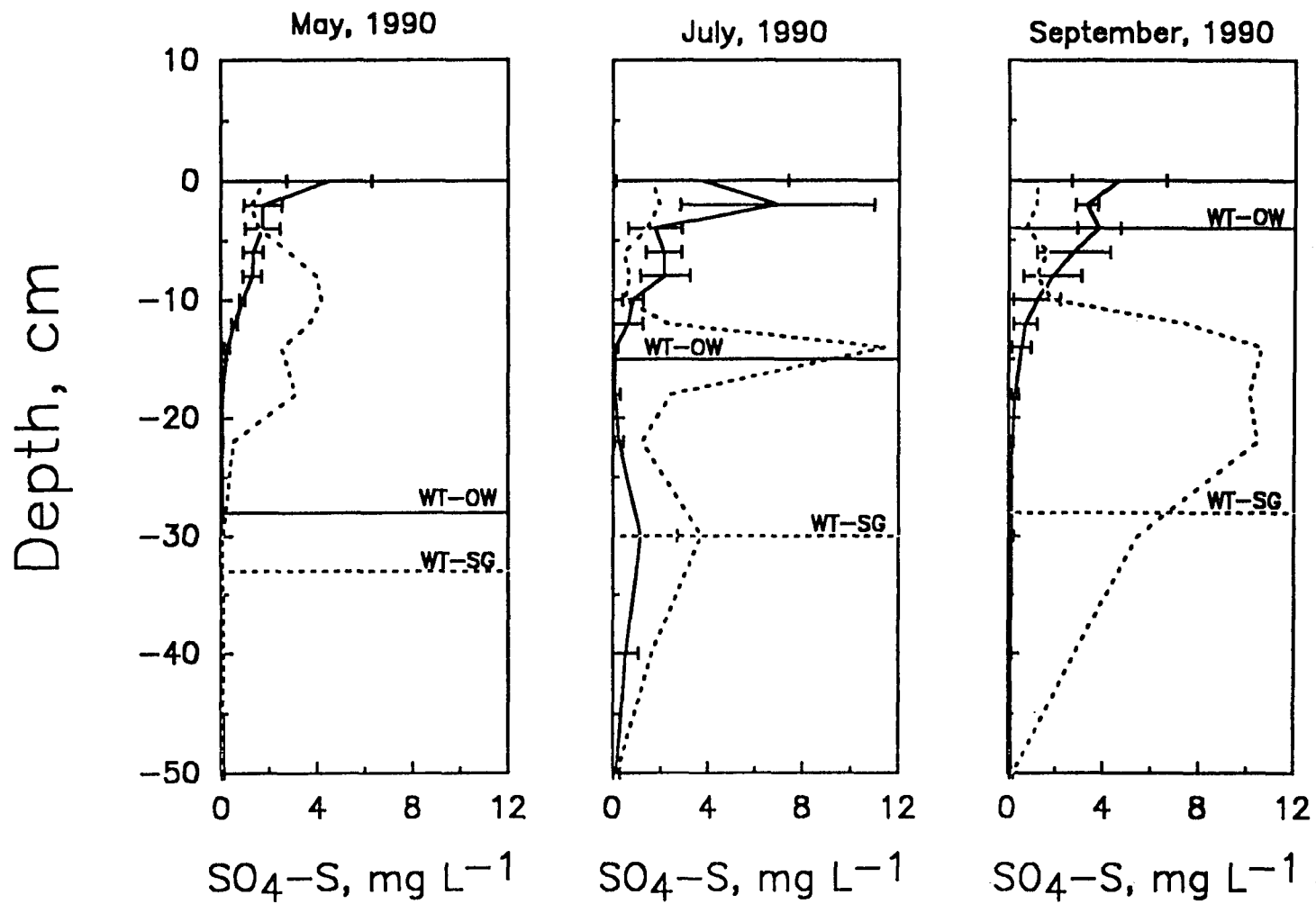


Figure 9. Continued. WT-OW = water table depth - open water; WT-SG = water table depth - sawgrass.

soil interface in the open water site and this trend continued with depth. In the sawgrass site, sulfate concentrations began to decrease near and below the water table. For both sites, this decrease in sulfate concentration likely reflects the microbial reduction of sulfate to sulfide under anaerobic conditions.

Porewater nutrient concentrations and pH at each sampling date were further evaluated by dividing the overlying water and soil into four zones, i.e., overlying water and 0-10, 11-20, and 20-30 cm soil depth increments. Ammonium concentrations were lower in the overlying water than in the three soil depth increments (Table 5). For three sampling dates (February, March, and April, 1990) ammonium concentrations were significantly higher in the 11-20 and 21-30 cm depth increments than in the 0-10 cm depth increment. Nitrate and phosphate concentrations, with a few minor exceptions, were not significantly different between the overlying water and any of the soil depth increments (Table 5).

Sulfate concentrations were significantly higher in the overlying water than in the porewater (Table 5). In the absence of overlying water, sulfate concentrations increased in the 0-10 cm depth increment and were significantly higher in that zone than in the lower two zones. The pH of the overlying water was generally slightly less than that of the porewater. Porewater pH also tended to be slightly higher for the 0-10 cm depth increment than for the 11-20 and 21-30 cm depth increments.

The effect of overlying water on porewater nutrient concentration and pH was further evaluated by comparing these parameters in the presence and absence of overlying water (Table 6). The effect of overlying water was most evident in the 0-10 and 11-20

Table 5. Porewater nutrient concentration and pH averaged for overlying water and sediment depth increments for each sampling date. Zones A, B, C, and D represent overlying water and sediment depth increments of 0-10, 11-20, and 21-30 cm, respectively.

Parameter	Zone	Sampling Date							
		11-08-89	12-15-89	2-05-90	3-13-90	4-24-90	5-31-90	7-12-90	9-04-90
-----mg L <sup>-1</sup> -----									
NH <sub>4</sub>	A	0.22a <sup>¶</sup>	0.23a	0.16a	0.06a	0.27a	---	---	---
	B	0.51b	2.13b	1.33b	0.98b	1.57b	2.91	3.52	1.93
	C	0.45b	2.26b	2.24c	2.05c	2.87c	2.36	2.40	1.93
	D	0.42b	2.29b	2.40c	2.05c	2.90c	2.18	2.32	2.04
NO <sub>3</sub>	A	0.011	0.002	0.088	0.117	0.038a	---	---	---
	B	0.011	0.021	0.085	0.125	0.004b	0.242	0.207	0.841a
	C	0.014	0.002	0.077	0.125	0.000b	0.112	0.000	0.000b
	D	0.012	0.006	0.088	0.131	0.000b	0.121	0.023	0.000b
PO <sub>4</sub>	A	0.007a	0.006	0.034a	0.000	0.035	---	---	---
	B	0.010b	0.019	0.007b	0.000	0.005	0.000	0.000	0.000
	C	0.011a	0.010	0.000b	0.000	0.000	0.000	0.000	0.000
	D	0.031b	0.015	0.047b	0.016	0.000	0.000	0.144	0.000
SO <sub>4</sub>	A	---	---	0.425a	0.731a	0.776a	---	---	---
	B	---	---	0.022b	0.221b	0.438b	2.060a	2.704a	2.919a
	C	---	---	0.030b	0.091b	0.288b	0.295b	0.299b	0.516b
	D	---	---	0.049b	0.102b	0.254b	0.059b	0.509b	0.132b
pH	A	5.11a	5.21a	5.38	5.34a	5.38a	---	---	---
	B	5.22a	5.45b	5.57	5.79b	5.33a	5.38	5.35	4.98a
	C	5.40b	5.49ab	5.58	6.04b	5.59b	5.49	5.31	5.24b
	D	5.51b	5.54c	5.50	6.16b	5.66b	5.54	5.45	5.33b

<sup>¶</sup> Means within a column followed by the same letter do not differ significantly, P<0.05, based on Duncan's Multiple Range Test.



Table 6. Comparison (orthogonal single degree of freedom contrasts) of porewater nutrient concentrations and pH in the presence and absence of overlying water.

Sediment Depth	Overlying water		P > F
	Present	Absent	
-cm-	-----mg L <sup>-1</sup> ----		
	-----NH <sub>4</sub> -----		
0-10	1.30	2.79	0.0001
11-20	1.97	2.23	0.1550
21-30	2.01	2.18	0.4293
	-----NO <sub>3</sub> -----		
0-10	0.049	0.430	0.0001
11-20	0.044	0.037	0.1664
21-30	0.048	0.048	0.8940
	-----PO <sub>4</sub> -----		
0-10	0.008	<0.001	0.0135
11-20	0.004	<0.001	0.0001
21-30	0.022	0.048	0.4362
	-----SO <sub>4</sub> -----		
0-10	0.226	2.56	0.0001
11-20	0.136	0.37	0.0037
21-30	0.135	0.23	0.4289
	-----pH-----		
0-10	5.43	5.27	0.0001
11-20	5.59	5.35	0.0001
21-30	5.65	5.43	0.0001

cm depth increments. Ammonium and nitrate concentrations were significantly higher in the absence of overlying water in the 0-10 cm depth increment. Sulfate concentrations were significantly higher in both the 0-10 and 11-20 cm depth increments.

In contrast, phosphate concentrations were significantly lower in the porewater in the absence of overlying water for the 0-10 and 11-20 cm depth increments. However, porewater phosphate concentrations were extremely low in both the presence and absence of overlying water. Soil pH significantly decreased (about 0.2 pH units) for all three depth increments.

#### **4.0 DISCUSSION**

Characterization of the soil profile to a depth of 60 cm showed that the physical and chemical characteristics of the soil in Hopkins Prairie is typical of a highly organic wetland soil (Mitch and Gosselink, 1986; Reddy and Graetz, 1991). The soils of both sites were comprised primarily of organic material with very little mineral matter. The lower carbon values at the soil surface suggest that the surface increment has undergone more decomposition than the underlying material. This is also reflected in the C/N ratios which increased with depth. The C/N ratio of soils generally approaches that of the microbial population (10/1) as CO<sub>2</sub> is respired and nitrogen is retained during the decomposition process (Brady, 1984). Organic matter in a well-decomposed mineral soil will have a C/N ratio of about 10/1 while that of an organic soil will be approximately 13/1 (Brady, 1984). The carbon/nitrogen ratio will affect the amount of nitrogen released by microbial activity in the soil. The potential for inorganic nitrogen formation during microbial decomposition of the organic matter increases with decreasing carbon/nitrogen ratio.

This is evident in the higher water-extractable ammonium concentrations from the open water site compared to those of the sawgrass site (Table 3).

Redox potential is a measure of the electron activity in a system, i.e., the tendency of a given system to oxidize or reduce susceptible substances, and is used as an aid in the interpretation of nutrient transformation data (Ponnamperuma, 1972). It is also an indicator of the degree of anaerobiosis existing in a soil. A redox potential of +300 mV indicates the presence of oxidizing conditions (presence of oxygen), while below 300 mV the system is devoid of oxygen. In the range of 0 to 300 mV, nitrate, ferric iron and manganic manganese are likely controlling the redox potential while below 0 mV, carbon and sulfur species generally are controlling factors (Reddy, 1987).

The oxygen content of wetland soils is generally controlled by the degree of water saturation. Under flooded conditions, all soil pores are filled with water and oxygen diffusion into the soil is very slow. The rate of diffusion of both O<sub>2</sub> and CO<sub>2</sub> in water is over 10,000 times slower in water than in air. Any oxygen entering the soil is quickly utilized by the microbial population. Therefore, flooded soils are generally devoid of oxygen except possibly in a very thin zone (a few millimeters) at the soil-water interface (Ponnamperuma, 1984).

When the water table depth moves below the soil surface as it did in this study in June, 1990, air (oxygen) starts to fill the soil pores and the redox potential becomes more positive. As oxygen becomes available to the soil microbial population, the microbes switch from anaerobic to aerobic respiration. The amount of energy released during

decomposition of organic matter is much greater for aerobic than anaerobic respiration. Thus, organic matter decomposition and resultant release of plant nutrients is much faster in an aerobic system (Gambrell and Patrick, 1978). Conversely, organic matter decomposition in an anaerobic system is generally less than organic matter productivity from plant biomass and organic matter readily accumulates in anaerobic systems.

A redox potential of about +300 mV or above indicates an aerobic system (Reddy, 1987). In this study, the soil at the open water site was aerobic at the 2 cm depth during most of the period from July to November, 1990 when there was no overlying water (Table 4 and Figure 3). By October, 1990, the water table depth dropped to -30 cm and by November, the redox potential at a depth of 15 cm indicated the presence of aerobic conditions. The water table depth did not reach the 45 cm depth during the study period which is reflected in the redox potential as it remained below 0 mV for the entire study period.

Soil redox potential in the sawgrass site also reflected water table depths (Table 4 and Figure 4). Soil at the sawgrass site was aerobic at a depth of 2 cm from May through November, 1990, at a depth of 15 cm from June through November and at the 45 cm depth during September, 1990. Soil redox potential in the sawgrass site was generally higher than that in the open water site, even under flooded conditions. The difference between the two sites is difficult to explain at this time. Sawgrass roots may be capable of pumping oxygen into the soil. Many aquatic plants have this capacity although sawgrass has not been evaluated in this regard.

These data show that the soil becomes aerobic above the water table soon after unsaturated conditions occur. During the period when the soil is aerobic, microbial respiration increases resulting in a more rapid rate of organic matter decomposition (not measured in this study) and more rapid rate of nutrient release from the organic matter.

The presence of oxygen also affects the nutrient end-products of organic matter decomposition (Patrick, 1981). Under anaerobic conditions, ammonium is the only inorganic nitrogen species formed during organic matter decomposition. Thus, under flooded conditions ammonium was the only nitrogen species observed in the porewater (Figure 6). In response to a concentration gradient, the ammonium diffused upward in the soil profile to the overlying water. Under aerobic conditions, ammonium is oxidized by aerobic bacteria to nitrate. This apparently occurred as the ammonium diffused into the overlying water at Hopkins Prairie. Then, in response to higher nitrate concentrations in the overlying water a diffusion gradient for nitrate was established downward into the soil. As the nitrate diffused into the anaerobic soil it was converted to nitrogen gas through a microbial process termed denitrification. The ammonium profile under flooded conditions suggests that nitrification/denitrification was occurring at the soil surface resulting in loss of nitrogen from the system (Reddy and Graetz, 1988).

The effect of hydrology, i.e., water table depth, on porewater constituents was particularly evident with nitrate and sulfate concentrations. As the water table depth increased and the soil became aerobic, the porewater concentrations of these two species increased in the soil above the water table (Table 5, Figures 7 and 9).

However, nitrate concentrations even under aerobic conditions, generally remained below

1 mg L<sup>-1</sup>. Low concentrations of nitrate may be attributed to either plant uptake or the occurrence of denitrification in isolated anaerobic pockets within the soil profile. Sulfate concentrations decreased below the water table suggesting that sulfate reduction was occurring in the anaerobic part of the soil profile. Sulfate concentrations were much higher in the oxidized zone of the sawgrass soil than in the oxidized zone of the open water soil. Further research is needed with regard to sulfur transformations in these soils to ascertain the reason(s) for these differences.

Phosphorus is not directly affected by changes in redox potential (Mitch and Gosselink, 1986). In Hopkins Prairie, porewater phosphorus concentrations were generally less than 0.05 mg L<sup>-1</sup> under flooded conditions and undetectable when the water table was below the soil surface (Figure 8). The change in phosphorus concentrations between aerobic and anaerobic conditions likely reflects the increased microbial activity, and thus demand for phosphorus, under aerobic conditions.

The effect of hydrology on pore water constituents was difficult to evaluate using porewater equilibrators due to the water table dropping significantly below the soil surface. When the equilibrator cells are above the water table, the extent of interaction between the equilibrator cell water and the moist, but unsaturated soil is not clearly defined. There is no previous research to indicate the quantitative effect of unsaturated conditions on equilibration between the soil and the equilibrator cell water. The fact that both nitrate and sulfate was detected in the cells above the water table indicates that some interaction between porewater and equilibrator cells did occur.

All porewater nutrient concentrations were low during most of the study period. Low nutrient concentrations would be expected in an oligotrophic wetland such as Hopkins Prairie (Mitch and Gosselink, 1986). Only a limited amount of data are available with regard to porewater nutrient concentrations in freshwater wetlands. However, recent studies indicate that the porewater nutrient concentrations in Hopkins Prairie are similar to those in the Water Conservation Area of the Florida Everglades and considerably lower than porewater nutrient concentrations in the agricultural fields of the Everglades area (Reddy and Graetz, 1991).

Although overlying water and porewater nutrient concentrations were low in Hopkins Prairie, these data indicate that the interaction between overlying water and soil porewater can have a significant effect on the nutrient budget of this wetland prairie. This was particularly evident for nitrogen and sulfur. Ammonium in the overlying water is taken up by plants or oxidized to nitrate. The nitrate is then taken up by plants or diffuses back to the anaerobic soil zone where it is converted to nitrogen gas and lost from the system. In either case, a diffusion gradient for ammonium is established from the soil to the overlying water and the soil becomes a nitrogen supply for both floating and rooted aquatic plants.

The sulfur cycle is also active in the water-soil complex of Hopkins Prairie. Sulfate in the overlying water and aerobic soil zone from rainfall, surface runoff, and soil oxidation diffuses downward in the soil until it reaches an anaerobic zone where it is converted to sulfide. The sulfide then reacts with metals such as iron to form metal sulfides or forms hydrogen sulfide gas which diffuses upward to the atmosphere and is lost from the

system. Metal concentrations were not determined in Hopkins Prairie soils or porewater, however similar oligotrophic marshes generally have low levels of metals (Mitch and Gosselink, 1986). Thus, in Hopkins Prairie, much of the sulfide will likely be volatilized to the atmosphere and lost from the system.

Differences exist between the soil characteristics of the open water and sawgrass communities. The primary difference observed was with regard to the total nitrogen content of the soils, i.e., open water soils had greater total nitrogen content than sawgrass soils. This difference was also reflected in the carbon/nitrogen ratio of the soils with higher ratios observed in the sawgrass soils. The open water soils should have a greater tendency to release inorganic nitrogen during decomposition which was reflected in the extractable ammonium levels. It appears that sufficient differences exist between the open water and sawgrass sites to warrant additional study in the sawgrass area.

Differences in soil surface elevations may partially explain the differences in redox potential between the two communities. In addition, sawgrass roots may be involved in downward oxygen transport into the soil although this possibility needs to be more clearly established with further research.

## **5.0 CONCLUSIONS**

Hydrology of Hopkins Prairie, particularly as it relates to water table depths, had significant effects on soil redox potential. However, a more intensive evaluation of redox changes with regard to time and soil depth increments would allow a more clear interpretation of water table effects on both redox potential and porewater nutrient



concentrations. Water table depths appear to be quite responsive to rainfall events as well as periods of intensive evapotranspiration. These short term fluctuations in water table depth were not detected in the monthly sampling interval used in this study. Monitoring water table depth and redox potential intensively over shorter time periods would provide additional valuable information for understanding the relationship between hydrology and nutrient transformations in Hopkins Prairie.

Porewater equilibrators are designed to measure the concentrations of nutrients and other elements in water-saturated systems. Quantitative interpretation of data from porewater equilibrators used under unsaturated soil conditions is difficult because the extent of equilibration between the porewater and equilibrator cells is not well-defined. Alternate methods of sampling should be considered when the water table drops below the soil surface. Sampling of the soil profile and either water extraction or porewater extrusion would appear to be viable alternatives to equilibrators when the water table drops below the soil surface.

Porewater nutrient concentrations in Hopkins Prairie were similar to those found in native sawgrass wetlands of the Everglades Water Conservation Areas which are also not affected by man's activities. Water table fluctuation affected concentrations of nutrient species such as ammonium, nitrate and sulfate even though nutrient concentrations in the porewater of Hopkins Prairie were generally quite low. The effect of water table depth was most evident in increased concentrations of the oxidized species of nitrogen (nitrate) and sulfur (sulfate) in the soil above the water table. Phosphorus concentrations in the porewater decreased under aerobic conditions although concentrations were low, even

under anaerobic conditions. The decrease in phosphorus concentration under aerobic conditions was likely due to increased microbial uptake which suggests that phosphorus limiting conditions may exist in Hopkins Prairie.

The nutrient budget for Hopkins Prairie, especially for nitrogen and sulfur, is affected significantly by the environmental conditions existing at the soil-water interface. Both the nitrogen and sulfur cycles are controlled by the interaction of aerobic/anaerobic processes which affect the accumulation or loss of these elements in the prairie ecosystem. Changes in soil aeration caused significant increases in concentrations of ammonium and sulfate in the soil porewater. These increased concentrations of nitrogen and sulfur may result in increased plant growth or enhanced loss of these elements from the prairie. Additional studies of nitrogen and sulfur transformations are needed to quantify loss of these nutrients from the ecosystem.

Differences existed between the soil physical and chemical characteristics, redox potential, and porewater nutrient levels, especially for sulfate, of the open water and sawgrass communities. Redox potentials were generally higher in the sawgrass community than in the open water community. It was speculated that differences between the two communities was due to soil surface elevation differences and possibly to the ability of sawgrass to transport oxygen downward through its root system.

The effect of water table depth fluctuation on soil physical, microbial and chemical characteristics has implications for both the rate of organic matter accumulation in the soil and aquatic macrophyte productivity. Soil organic matter decomposition rate is enhanced by aerobic conditions which results in the release of greater amounts of plant nutrients.

Drying of the soil also tends to increase the decomposability of soil organic matter upon rewetting which also results in an initial flush of nutrient release similar to that which occurs during lake drawdown and reflooding. Thus, when overlying water returns to Hopkins Prairie, there should be a noticeable, but likely temporary increase in plant productivity.

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APPENDIX TABLES

Table A1.

Sediment characterization raw data. Sample designation is as follows: Numbers 1-3 are sampling locations within the open water area and location number 4 is within the sawgrass area. Letters A and B at each sample location represent replicates at that site.

Sample	Hori	Depth water		Dry B.D. g.cm-3	pH	soil NH4 ug/g	SRP ug/g	Carbon %	TN %	C/N	TP ug/gm
		cm	%								
HP1A	1	0-5	92.91	0.080	5.06	80.9	1.31	46.5	3.66	12.7	295.0
HP1A	2	5-10	91.02	0.083	4.97	70.0	0.74	45.9	3.54	13.0	225.0
HP1A	3	10-20	89.96	0.110	5.05	74.4	0.77	48.8	3.39	14.4	150.0
HP1A	4	20-54	88.13	0.125	5.03	34.0	1.13	53.4	2.19	24.4	52.5
HP1B	1	0-5	92.90	0.088	4.96	49.7	1.11	46.1	3.46	13.3	250.0
HP1B	2	5-10	90.07	0.107	4.68	48.2	0.78	47.5	3.32	14.3	180.0
HP1B	3	10-20	90.33	0.088	4.88	57.2	0.83	49.5	3.19	15.5	117.5
HP1B	4	20-58	88.97	0.116	5.08	30.7	0.74	53.7	2.18	24.6	54.2
HP2A	1	0-5	92.81	0.091	5.04	45.0	1.06	45.8	3.33	13.8	250.0
HP2A	2	5-10	91.85	0.080	4.77	61.3	0.96	46.4	3.51	13.2	263.7
HP2A	3	10-20	90.26	0.104	4.71	51.0	0.21	50.6	3.43	14.8	145.0
HP2A	4	20-60	89.68	0.112	5.05	31.3	0.15	53.3	2.80	19.0	59.4
HP2B	1	0-5	91.61	0.100	5.12	52.2	0.16	46.3	3.53	13.1	273.6
HP2B	2	5-10	90.07	0.081	4.84	54.5	0.14	49.1	3.51	14.0	195.0
HP2B	3	10-20	89.72	0.115	4.98	46.7	0.09	49.9	3.24	15.4	121.9
HP2B	4	20-56	89.24	0.119	5.38	31.6	0.08	53.4	2.70	19.8	52.5
HP3A	1	0-5	92.79	0.086	5.14	45.2	0.12	47.9	3.41	14.0	267.3
HP3A	2	5-10	90.05	0.086	4.77	85.6	0.16	49.6	3.28	15.1	171.6
HP3A	3	10-20	87.19	0.133	4.73	79.7	0.16	49.6	2.75	18.0	97.0
HP3A	4	20-52	86.14	0.152	5.15	19.7	2.46	53.2	2.14	24.9	42.5
HP3B	1	0-5	91.87	0.100	5.13	29.4	1.25	48.5	3.69	13.1	262.3
HP3B	2	5-10	90.05	0.097	4.80	48.1	0.80	50.0	3.61	13.9	185.6
HP3B	3	10-20	87.69	0.124	5.03	39.5	0.64	49.7	2.86	17.4	99.5
HP3B	4	20-58	86.84	0.142	5.43	18.5	0.58	54.1	2.29	23.6	44.1
HP4A	1	0-5	92.95	0.087	4.83	8.5	0.95	47.0	2.63	17.9	390.0
HP4A	2	5-10	93.37	0.059	4.61	52.7	2.00	48.3	2.66	18.2	322.5
HP4A	3	10-20	92.55	0.076	4.56	11.9	1.05	49.9	2.69	18.6	226.6
HP4A	4	20-60	90.68	0.115	5.06	26.5	0.95	52.9	2.78	19.0	97.5
HP4B	1	0-5	93.49	0.078	4.80	42.2	1.34	46.1	2.58	17.9	358.9
HP4B	2	5-10	93.89	0.050	4.72	36.3	1.29	48.2	2.58	18.7	437.5
HP4B	3	10-20	92.53	0.078	4.63	104.7	1.09	48.9	2.82	17.3	253.7
HP4B	4	20-60	89.94	0.113	5.21	119.5	0.82	53.1	2.64	20.1	81.7

Table A2. Redox readings from two sites in each sampling area. Readings have been corrected for the hydrogen reference electrode by adding 245 mV to each reading obtained in the field.

Date	Location	Repl.	Corrected Eh (mV)		
			2 cm	15 cm	45 cm
Oct. 89	Open	A	92	-24	-13
		B	95	12	-58
	Sawg.	A	15	1	9
		B	134	31	39
Nov., 89	Open	A	-7	-69	-37
		B	-43	4	19
	Sawg.	A	-105	-11	-10
		B	-29	12	72
Jan., 90	Open	A	-56	-78	1
		B	-2	-73	-149
	Sawg.	A	267	242	54
		B	36	26	132
Feb., 90	Open	A	-16	-137	-29
		B	-18	-121	-156
	Sawg.	A	150	189	245
		B	60	5	99
Mar., 90	Open	A	21	-121	43
		B	21	-142	-21
	Sawg.	A	-104	-15	18
		B	11	-67	-39
Apr., 90	Open	A	46	-150	-70
		B	123	-155	-169
	Sawg.	A	173	-28	-7
		B	127	-26	-87
May, 90	Open	A	56	-48	-40
		B	175	1	-111
	Sawg.	A	611	26	245
		B	317	126	245
Jun., 90	Open	A	168	-28	-22
		B	208	-17	-69
	Sawg.	A	395	455	38
		B	608	372	255
Aug. 3, 90	Open	A	383	-45	-36
		B	293	-24	-55
	Sawg.	A	452	355	355
		B	575	355	-13
Aug. 22, 90	Open	A	302	-85	-31
		B	-77	35	-131
	Sawg.	A	665	392	-15
		B	410	605	175
Sept. 4, 90	Open	A	311	-40	-19
		B	231	-112	-145

	Sawg.	A	665	396	490
		B	443	610	357
Oct. 12, 90	Open	A	325	-25	-42
		B	310	188	-120
	Sawg.	A	485	300	190
		B	245	245	245
Oct. 30, 90	Open	A	353	443	-40
		B	364	323	-133
	Sawg.	A	381	373	383
		B	673	350	58

Table A3. Concentrations of selected species in porewater samples from three open water sites (A-C) and one sawgrass site (D).

Date	Rep	Depth	pH	NO3-N	PO4-P	SO4-S	NH4-N
		--cm--	-----mg/L-----				
1	11/08/89	A +8	5.11	0.00	0.004	--	0.31
2	11/08/89	A +6	5.15	0.05	0.033	--	1.14
3	11/08/89	A +4	5.12	0.00	0.008	--	0.03
4	11/08/89	A +2	5.04	0.00	0.003	--	0.02
5	11/08/89	A -0	4.98	0.01	0.003	--	0.00
6	11/08/89	A -1	5.03	0.01	0.004	--	0.38
7	11/08/89	A -2	4.78	0.01	0.005	--	0.29
8	11/08/89	A -3	4.78	0.01	0.004	--	0.70
9	11/08/89	A -4	5.20	0.01	0.004	--	1.18
10	11/08/89	A -5	5.14	0.03	0.037	--	0.31
11	11/08/89	A -6	5.17	0.02	0.009	--	0.81
12	11/08/89	A -7	5.23	0.02	0.102	--	0.81
13	11/08/89	A -8	5.36	0.02	<0.001	--	0.60
14	11/08/89	A -9	5.36	0.02	<0.001	--	0.60
15	11/08/89	A -10	5.33	0.02	<0.001	--	0.60
16	11/08/89	A -12	5.09	0.02	<0.001	--	0.60
17	11/08/89	A -14	5.37	0.02	0.022	--	0.48
18	11/08/89	A -18	5.31	0.02	0.010	--	0.50
19	11/08/89	A -22	5.49	0.02	0.119	--	0.41
20	11/08/89	A -30	5.50	0.01	0.011	--	0.32
21	11/08/89	B +8	5.07	0.01	0.006	--	0.02
22	11/08/89	B +6	5.19	0.01	0.005	--	0.02
23	11/08/89	B +4	5.17	0.01	0.005	--	0.03
24	11/08/89	B +2	5.01	0.01	0.003	--	0.10
25	11/08/89	B 0	5.19	0.01	0.006	--	0.41
26	11/08/89	B -1	5.16	0.01	0.006	--	0.38
27	11/08/89	B -2	5.39	0.01	0.008	--	0.79
28	11/08/89	B -3	5.42	0.01	0.006	--	0.63
29	11/08/89	B -4	5.30	0.01	0.005	--	0.77
30	11/08/89	B -5	5.08	0.01	0.007	--	1.19
31	11/08/89	B -6	5.23	0.01	0.009	--	0.21
32	11/08/89	B -7	5.52	0.01	0.006	--	0.23
33	11/08/89	B -8	5.48	0.03	0.007	--	0.26
34	11/08/89	B -9	5.44	0.03	0.009	--	0.30
35	11/08/89	B -10	5.48	0.01	0.006	--	0.32
36	11/08/89	B -12	5.46	0.01	0.010	--	0.35
37	11/08/89	B -14	5.43	0.01	0.007	--	0.41
38	11/08/89	B -18	5.50	0.01	0.009	--	0.41
39	11/08/89	B -22	5.44	0.01	0.010	--	0.41
40	11/08/89	B -30	5.46	0.00	0.009	--	0.41
41	11/08/89	C +8	5.18	0.01	0.007	--	0.09
42	11/08/89	C +6	5.15	-0.00	0.005	--	0.00
43	11/08/89	C +4	5.07	0.03	0.005	--	0.59
44	11/08/89	C +2	5.08	-0.00	0.004	--	0.27
45	11/08/89	C 0	4.98	-0.00	0.004	--	0.63
46	11/08/89	C 1	4.96	-0.00	0.004	--	0.21



Table A3. Concentrations of selected species in porewater samples (Cont.).

Date	Rep	Depth	pH	NO3-N	PO4-P	SO4-S	NH4-N	
		--cm--	-----mg/L-----					
47	11/08/89	C	-2	4.78	-0.00	0.007	--	0.39
48	11/08/89	C	-3	4.94	-0.00	0.008	--	0.67
49	11/08/89	C	-4	5.18	0.00	0.011	--	0.81
50	11/08/89	C	-5	5.27	-0.00	0.006	--	1.04
51	11/08/89	C	-6	5.30	-0.00	0.008	--	0.18
52	11/08/89	C	-7	5.42	0.02	0.011	--	0.24
53	11/08/89	C	-8	5.50	-0.00	0.007	--	0.26
54	11/08/89	C	-9	5.47	0.00	0.014	--	0.31
55	11/08/89	C	-10	5.49	0.01	0.019	--	0.36
56	11/08/89	C	-12	5.43	0.00	0.012	--	0.41
57	11/08/89	C	-14	5.53	0.02	0.013	--	0.44
58	11/08/89	C	-18	5.48	0.02	0.013	--	0.46
59	11/08/89	C	-22	5.49	0.01	0.008	--	0.47
60	11/08/89	C	-30	5.69	0.02	0.027	--	0.51
61	11/08/89	D	+8	5.06	0.04	<0.001	--	0.11
62	11/08/89	D	+6	4.97	0.05	0.004	--	0.09
63	11/08/89	D	+4	4.94	0.01	0.005	--	0.03
64	11/08/89	D	+2	4.81	-0.01	0.003	--	0.00
65	11/08/89	D	0	5.41	-0.01	0.004	--	0.04
66	11/08/89	D	-1	5.19	-0.00	0.006	--	0.51
67	11/08/89	D	-2	5.08	-0.01	0.006	--	0.26
68	11/08/89	D	-3	5.13	0.02	0.004	--	0.57
69	11/08/89	D	-4	5.17	-0.01	0.004	--	0.70
70	11/08/89	D	-5	5.12	0.01	0.007	--	0.20
71	11/08/89	D	-6	5.20	-0.00	0.007	--	1.16
72	11/08/89	D	-7	5.15	0.00	0.007	--	0.19
73	11/08/89	D	-8	5.16	-0.01	0.007	--	0.19
74	11/08/89	D	-9	5.22	0.00	0.010	--	0.22
75	11/08/89	D	-10	5.12	0.03	0.007	--	0.29
76	11/08/89	D	-12	5.13	0.00	0.008	--	0.26
77	11/08/89	D	-14	5.11	0.00	0.005	--	0.27
78	11/08/89	D	-18	5.15	0.05	0.008	--	0.27
79	11/08/89	D	-22	5.19	0.07	0.007	--	0.24
80	11/08/89	D	-30	5.32	0.00	0.004	--	0.39
1	12/15/89	A	+8-7	5.23	0.002	0.003	--	0.04
2	12/15/89	A	+6-5	5.24	0.002	0.006	--	0.052
3	12/15/89	A	+4-3	5.23	0.002	0.004	--	0.129
4	12/15/89	A	+2-1	5.30	0.002	0.005	--	0.359
5	12/15/89	A	0-1	5.41	0.002	0.004	--	0.666
6	12/15/89	A	2-3	5.39	0.002	0.006	--	0.86
7	12/15/89	A	4-5	5.44	0.054	0.011	--	1.061
8	12/15/89	A	6-7	5.42	0.002	0.006	--	1.439
9	12/15/89	A	8-9	5.35	0.002	0.01	--	2.07
10	12/15/89	A	10-11	5.44	0.002	0.016	--	2.713
11	12/15/89	A	12-13	5.38	0.002	0.011	--	2.868
12	12/15/89	A	14-15	5.30	0.002	0.01	--	2.97

Table A3. Concentrations of selected species in porewater samples (Cont.).

Date	Rep	Depth	pH	NO3-N	PO4-P	SO4-S	NH4-N	
--cm--			-----mg/L-----					
13	12/15/89	A	18-19	5.43	0.002	0.017	--	3.023
14	12/15/89	A	22-23	5.46	0.002	0.012	--	2.779
15	12/15/89	A	29-30	5.49	0.028	0.023	--	2.307
16	12/15/89	B	+8-7	5.27	0.002	0.007	--	0.205
17	12/15/89	B	+6-5	5.17	0.002	0.003	--	0.092
18	12/15/89	B	+4-3	5.22	0.002	0.004	--	0.186
19	12/15/89	B	+2-1	5.27	0.002	0.01	--	1.164
20	12/15/89	B	0-1	5.44	0.002	0.006	--	0.518
21	12/15/89	B	2-3	5.55	0.08	0.007	--	0.882
22	12/15/89	B	4-5	5.23	0.204	0.012	--	0.935
23	12/15/89	B	6-7	5.37	0.012	0.18	--	3.442
24	12/15/89	B	8-9	5.48	0.002	0	--	14.109
25	12/15/89	B	10-11	5.67	0.002	0	--	1.883
26	12/15/89	B	12-13	5.53	0.002	0.012	--	1.754
27	12/15/89	B	14-15	5.55	0.002	0.012	--	1.781
28	12/15/89	B	18-19	5.58	0.002	0.007	--	2.017
29	12/15/89	B	22-23	5.57	0.002	0.01	--	2.127
30	12/15/89	B	29-30	5.60	0.002	0.03	--	2.611
31	12/15/89	C	+8-7	5.14	0.002	0.007	--	0.08
32	12/15/89	C	+6-5	5.05	0.002	0.004	--	0.052
33	12/15/89	C	+4-3	5.12	0.002	0.007	--	0.142
34	12/15/89	C	+2-1	5.24	0.002	0.014	--	0.251
35	12/15/89	C	0-1	5.33	0.002	0.041	--	0.53
36	12/15/89	C	2-3	5.46	0.002	0.005	--	0.868
37	12/15/89	C	4-5	5.58	0.002	0.007	--	1.242
38	12/15/89	C	6-7	5.50	0.002	0.009	--	1.418
39	12/15/89	C	8-9	5.51	0.002	0.007	--	1.749
40	12/15/89	C	10-11	5.49	0.002	0.007	--	1.888
41	12/15/89	C	12-13	5.51	0.002	0.007	--	1.823
42	12/15/89	C	14-15	5.57	0.002	0.005	--	2.017
43	12/15/89	C	18-19	5.58	0.002	0.006	--	2.122
44	12/15/89	C	22-23	5.58	0.002	0.007	--	2.096
45	12/15/89	C	29-30	5.57	0.002	0.007	--	1.838
46	12/15/89	D	-4-5	5.24	0.002	0.007	--	0.975
47	12/15/89	D	6-7	5.03	0.002	0.007	--	0.717
48	12/15/89	D	8-9	5.03	0.002	0.021	--	0.682
49	12/15/89	D	10-11	4.97	0.002	0.009	--	0.692
50	12/15/89	D	12-13	5.01	0.002	0.01	--	0.643
51	12/15/89	D	14-15	4.96	0.002	0.006	--	0.668
52	12/15/89	D	18-19	5.08	0.002	0.007	--	1.005
53	12/15/89	D	22-23	5.15	0.002	0.009	--	0.856
54	12/15/89	D	29-30	5.18	0.002	0.01	--	0.797
55	12/15/89	D	34-35	5.24	0.002	0.007	--	0.806
56	12/15/89	D	39-40	5.25	0.002	0.007	--	0.931
57	12/15/89	D	S.W.A	5.24	0.002	0.048	--	0.368
58	12/15/89	D	S.W.B	5.17	0.002	0.006	--	0.065
59	12/15/89	D	S.W.C	5.20	0.002	0.055	--	0.687

Table A3. Concentrations of selected species in porewater samples (Cont.).

	Date	Rep	Depth	pH	NO3-N	PO4-P	SO4-S	NH4-N
60	12/15/89	D	S.W.D	4.87	0.002	0.071	--	0.455
1	02/05/90	A	+8-7	5.58	0.103	0	0.571	0.515
2	02/05/90	A	+6-5	4.66	0.116	0	0.576	0.097
3	02/05/90	A	+4-3	5.34	0.100	0	0.551	0.127
4	02/05/90	A	+2-1	5.86	0.102	0	0.155	0.515
5	02/05/90	A	0-1	5.90	0.106	0	0.096	0.903
6	02/05/90	A	2-3	5.21	0.103	0	0.076	1.262
7	02/05/90	A	4-5	5.89	0.111	0	0.062	2.707
8	02/05/90	A	6-7	5.80	0.103	0	0.007	2.522
9	02/05/90	A	8-9	5.26	0.103	0	0.023	2.175
10	02/05/90	A	10-11	5.89	0.112	0.08	0.069	2.325
11	02/05/90	A	12-13	5.55	0.104	0	0.066	2.384
12	02/05/90	A	14-15	5.51	0.109	0	0.060	2.546
13	02/05/90	A	18-19	5.29	0.102	0	0.059	2.797
14	02/05/90	A	22-23	5.82	0.103	0	0.082	3.035
15	02/05/90	A	29-30	5.84	0.116	0	0.126	3.268
16	02/05/90	A	39-40	5.91	0.110	0	0.120	2.54
17	02/05/90	B	+8-7	5.57	0.106	0.105	0.587	0.037
18	02/05/90	B	+6-5	5.60	0.102	0.091	0.615	0.037
19	02/05/90	B	+4-3	5.59	0.073	0.042	0.448	0.025
20	02/05/90	B	+2-1	5.87	0.071	0.123	0.057	0.025
21	02/05/90	B	0-1	5.70	0.071	0	0.034	0.252
22	02/05/90	B	2-3	5.67	0.077	0	0.000	0.536
23	02/05/90	B	4-5	5.72	0.074	0	0.000	0.862
24	02/05/90	B	6-7	5.70	0.076	0	0.000	1.337
25	02/05/90	B	8-9	5.59	0.076	0	0.000	1.676
26	02/05/90	B	10-11	5.56	0.072	0	0.000	2.043
27	02/05/90	B	12-13	5.57	0.077	0	0.000	2.104
28	02/05/90	B	14-15	5.49	0.078	0	0.000	1.942
29	02/05/90	B	18-19	5.68	0.074	0	0.000	2.396
30	02/05/90	B	22-23	5.62	0.072	0.009	0.000	2.426
31	02/05/90	B	29-30	5.59	0.071	0	0.000	1.912
32	02/05/90	B	39-40	5.41	0.076	0	0.000	1.134
33	02/05/90	C	+8-7	4.63	0.072	0	0.000	0.108
34	02/05/90	C	+6-5	5.17	0.072	0	0.000	0.074
35	02/05/90	C	+4-3	5.35	0.070	0.047	0.000	0.179
36	02/05/90	C	+2-1	5.38	0.075	0	0.107	0.226
37	02/05/90	C	0-1	5.32	0.072	0	0.025	0.376
38	02/05/90	C	2-3	5.48	0.072	0.015	0.000	0.402
39	02/05/90	C	4-5	5.46	0.079	0.035	0.000	0.675
40	02/05/90	C	6-7	5.05	0.073	0	0.000	0.867
41	02/05/90	C	8-9	5.22	0.071	0	0.000	1.358
42	02/05/90	C	10-11	5.80	0.073	0	0.000	1.597
43	02/05/90	C	12-13	5.68	ND	0	0.000	2.117
44	02/05/90	C	14-15	5.72	0.073	0	0.087	1.996
45	02/05/90	C	18-19	5.77	0.075	0	0.000	1.829
46	02/05/90	C	22-23	4.92	0.075	0	0.000	1.978

Table A3. Concentrations of selected species in porewater samples (Cont.).

Date	Rep	Depth	pH	NO3-N	PO4-P	SO4-S	NH4-N	
--cm--			-----mg/L-----					
47	02/05/90	C	29-30	5.01	0.079	0.033	0.059	3.442
48	02/05/90	C	39-40	5.35	0.090	0	0.052	1.841
49	02/05/90	D	+9-10	4.86	0.072	0.057	0.109	0.268
50	02/05/90	D	+8-7	4.89	0.072	0.043	0.126	0.179
51	02/05/90	D	+6-5	4.52	0.071	0	0.133	0.192
52	02/05/90	D	+4-3	5.23	0.075	0	0.000	0.363
53	02/05/90	D	+2-1	5.34	0.073	0	0.000	0.442
54	02/05/90	D	0-1	4.73	0.070	0	0.000	0.625
55	02/05/90	D	2-3	5.33	0.075	0	0.000	0.754
56	02/05/90	D	4-5	5.29	0.080	0	0.000	1.019
57	02/05/90	D	6-7	4.86	0.075	0	0.000	1.177
58	02/05/90	D	8-9	4.44	0.105	0	0.072	0.909
59	02/05/90	D	10-11	4.78	0.101	0.047	0.038	1.211
60	02/05/90	D	12-13	5.00	0.113	0.031	0.024	1.156
61	02/05/90	D	14-15	5.33	0.106	0	0.029	1.544
62	02/05/90	D	18-19	5.12	0.105	0	0.000	1.332
63	02/05/90	D	22-23	4.28	0.116	0	0.037	0.021
64	02/05/90	D	29-30	5.21	0.099	0	0.047	0.021
65	02/05/90	D	39-40	5.12	0.103	0.059	0.321	0.021
66	02/05/90	end brdwlk		5.24	ND	0	0.612	0.021
67	02/05/90	15' inside		4.82	0.101	0	0.710	0.021
68	02/05/90	sawgrass		4.95	0.108	0	0.390	0.021
69	02/05/90	sawgrass		5.30	0.104	0	0.523	0.021
1	03/13/90	A	+8-7	5.07	0.147	0	0.771	0.035
2	03/13/90	A	+6-5	4.98	0.120	0	0.801	0.007
3	03/13/90	A	+4-3	4.99	0.122	0	0.801	0
4	03/13/90	A	+2-1	4.86	0.124	0	0.830	0.013
5	03/13/90	A	0-1	4.97	0.127	0	0.569	0.207
6	03/13/90	A	2-3	5.26	0.123	0	0.462	0.622
7	03/13/90	A	4-5	5.55	0.120	0	0.182	0.678
8	03/13/90	A	6-7	5.71	0.127	0	0.110	1.123
9	03/13/90	A	8-9	5.82	0.120	0	0.090	1.758
10	03/13/90	A	10-11	5.85	0.126	0	0.087	1.932
11	03/13/90	A	12-13	5.84	0.127	0	0.073	1.932
12	03/13/90	A	14-15	5.89	0.121	0	0.079	1.974
13	03/13/90	A	18-19	5.72	0.122	0	0.071	2.062
14	03/13/90	A	22-23	5.71	0.125	0	0.075	2.546
15	03/13/90	A	29-30	5.71	0.120	0	0.085	2.007
16	03/13/90	A	39-40	5.74	0.119	0	0.085	1.702
17	03/13/90	B	+8-7	6.12	0.128	0	0.783	0.035
18	03/13/90	B	+6-5	6.10	0.122	0	0.846	0.019
19	03/13/90	B	+4-3	5.57	0.128	0	0.433	0.29
20	03/13/90	B	+2-1	5.76	0.120	0	0.200	0.149
21	03/13/90	B	0-1	5.46	0.131	0	0.188	0.246
22	03/13/90	B	2-3	6.42	0.122	0	0.105	0.511
23	03/13/90	B	4-5	6.49	0.121	0	0.076	0.622

Table A3. Concentrations of selected species in porewater samples (Cont.).

Date	Rep	Depth	pH	NO3-N	PO4-P	SO4-S	NH4-N
		--cm--	-----mg/L-----				
24	03/13/90	B 6-7	6.55	0.125	0	0.091	0.988
25	03/13/90	B 8-9	6.62	0.125	0	0.108	1.439
26	03/13/90	B 10-11	6.65	0.127	0	0.100	1.73
27	03/13/90	B 12-13	6.66	0.125	0	0.126	1.874
28	03/13/90	B 14-15	6.64	0.122	0	0.104	2.123
29	03/13/90	B 18-19	6.66	0.130	0	0.138	2.874
30	03/13/90	B 22-23	6.64	0.137	0	0.146	2.844
31	03/13/90	B 29-30	6.66	0.152	0	0.145	1.841
32	03/13/90	B 39-40	6.69	0.147	0	0.129	1.758
33	03/13/90	C +8-7	5.14	0.127	0	0.830	0.005
34	03/13/90	C +6-5	5.16	0.143	0	0.858	0.013
35	03/13/90	C +4-3	5.17	0.125	0	0.827	0.013
36	03/13/90	C +2-1	5.18	ND	0	0.795	0.107
37	03/13/90	C 0-1	5.12	0.128	0	0.769	0.151
38	03/13/90	C 2-3	5.23	0.132	0	0.336	0.536
39	03/13/90	C 4-5	5.46	0.126	0	0.164	0.899
40	03/13/90	C 6-7	5.64	0.130	0	0.250	1.148
41	03/13/90	C 8-9	5.63	0.124	0	0.203	1.425
42	03/13/90	C 10-11	5.71	0.124	0	0.080	1.591
43	03/13/90	C 12-13	5.61	0.127	0	0.070	1.672
44	03/13/90	C 14-15	5.65	0.125	0	0.077	1.918
45	03/13/90	C 18-19	5.71	0.127	0	0.078	2.001
46	03/13/90	C 22-23	5.74	0.126	0	0.082	1.982
47	03/13/90	C 29-30	5.78	0.123	0	0.072	2.14
48	03/13/90	C 39-40	6.74	0.129	0.141	0.097	1.622
49	03/13/90	D +8-7					
50	03/13/90	D +6-5					
51	03/13/90	D +4-3					
52	03/13/90	D +2-1	5.24	0.125	0	0.125	0.007
53	03/13/90	D 0-1	5.18	0.165	0	0.155	0.262
54	03/13/90	D 2-3	5.28	0.129	0	0.146	0.636
55	03/13/90	D 4-5	6.28	0.116	0	0.075	1.032
56	03/13/90	D 6-7	5.36	0.119	0	0.058	1.204
57	03/13/90	D 8-9	5.31	0.104	0	0.016	1.398
58	03/13/90	D 10-11	5.30	0.107	0	0.064	1.483
59	03/13/90	D 12-13	5.37	0.105	0	0.074	1.65
60	03/13/90	D 14-15	5.32	0.102	0	0.052	1.697
61	03/13/90	D 18-19	5.36	0.104	0	0.024	1.791
62	03/13/90	D 22-23	5.44	0.101	0	0.026	1.791
63	03/13/90	D 29-30	5.45	ND	0	-0.021	1.949
64	03/13/90	D 39-40	5.55	0.107	0	0.051	2.004
65	03/13/90	east end	5.29	0.103	0	0.813	0.146
66	03/13/90	middle	5.11	0.107	0	0.815	0.099
67	03/13/90	near c	5.06	0.106	0	0.808	0.102
68	03/13/90	sawgrass	4.65	0.105	0	0.926	1.758
1	04/24/90	A +8-7	-				

Table A3. Concentrations of selected species in porewater samples (Cont.).

Date	Rep	Depth	pH	NO3-N	PO4-P	SO4-S	NH4-N	
		--cm--	-----mg/L-----					
2	04/24/90	A	+6-5	5.06	0.213	0.243	1.290	0.497
3	04/24/90	A	+4-3	5.20	0	0	1.060	0.692
4	04/24/90	A	+2-1	5.20	0	0	0.786	0.414
5	04/24/90	A	0-1	5.02	0	0	0.673	0.615
6	04/24/90	A	2-3	5.09	0	0	0.405	0.969
7	04/24/90	A	4-5	5.02	0	0	0.427	0.969
8	04/24/90	A	6-7	5.15	0	0	0.344	1.274
9	04/24/90	A	8-9	5.21	0	0	0.310	1.759
10	04/24/90	A	10-11	5.46	0	0	0.000	2.223
11	04/24/90	A	12-13	5.62	0	0	0.348	2.293
12	04/24/90	A	14-15	5.61	0	0	0.353	2.639
13	04/24/90	A	18-19	5.61	0	0	0.359	2.916
14	04/24/90	A	22-23	5.61	0	0	0.331	2.916
15	04/24/90	A	29-30	5.62	0	0	0.373	2.854
16	04/24/90	A	39-40	5.65	0	0	0.420	2.313
17	04/24/90	B	+8-7	-				
18	04/24/90	B	+6-5	-				
19	04/24/90	B	+4-3	5.62	0	0	0.936	0.081
20	04/24/90	B	+2-1	5.48	0	0	0.804	0.067
21	04/24/90	B	0-1	5.62	0	0	0.730	0.591
22	04/24/90	B	2-3	5.43	0	0	0.890	1.322
23	04/24/90	B	4-5	5.39	0	0	1.020	1.794
24	04/24/90	B	6-7	5.49	0	0	1.063	2.189
25	04/24/90	B	8-9	5.32	0	0	0.952	2.466
26	04/24/90	B	10-11	5.48	0	0	0.493	2.729
27	04/24/90	B	12-13	5.60	0	0	0.364	2.986
28	04/24/90	B	14-15	5.59	0	0	0.366	3.117
29	04/24/90	B	18-19	5.59	0	0	0.359	3.284
30	04/24/90	B	22-23	5.64	0	0	0.380	3.409
31	04/24/90	B	29-30	5.69	0	0	0.395	3.145
32	04/24/90	B	39-40	5.72	0	0	0.420	2.708
33	04/24/90	C	+8-7	-				
34	04/24/90	C	+6-5	-				
35	04/24/90	C	+4-3	5.65	0.055	0	0.540	0.076
36	04/24/90	C	+2-1	5.48	0	0	0.016	0.066
37	04/24/90	C	0-1	5.28	0	0	0.020	0.493
38	04/24/90	C	2-3	5.29	0	0	0.019	0.906
39	04/24/90	C	4-5	5.34	0	0	0.025	1.461
40	04/24/90	C	6-7	5.44	0	0	0.428	1.877
41	04/24/90	C	8-9	5.47	0	0	0.007	2.189
42	04/24/90	C	10-11	5.50	0.071	0.096	0.072	2.466
43	04/24/90	C	12-13	5.54	0	0	ND	2.75
44	04/24/90	C	14-15	5.55	0	0	0.111	2.861
45	04/24/90	C	18-19	5.59	0	0	0.022	2.986
46	04/24/90	C	22-23	5.64	0	0	ND	3.339
47	04/24/90	C	29-30	5.64	0	0	0.101	2.812
48	04/24/90	C	39-40	5.72	0	0	0.173	2.57

Table A3. Concentrations of selected species in porewater samples (Cont.).

Date	Rep	Depth	pH	NO3-N	PO4-P	SO4-S	NH4-N	
--cm--			-----mg/L-----					
49	04/24/90	D	0-1	4.88	0.250	0	5.738	0.249
50	04/24/90	D	2-3	5.05	0.501	0	5.721	0.513
51	04/24/90	D	4-5	5.02	0.290	0	4.197	0.644
52	04/24/90	D	6-7	5.04	0.230	0	4.181	0.355
53	04/24/90	D	8-9	5.35	0.169	0	5.647	0.35
54	04/24/90	D	10-11	5.36	0.147	0	2.994	0.43
55	04/24/90	D	12-13	5.30	0.000	0	1.103	0.592
56	04/24/90	D	14-15	5.30	0.153	0	1.026	0.681
57	04/24/90	D	18-19	5.34	0.150	0	0.482	1.059
58	04/24/90	D	22-23	5.36	ND	0	0.253	1.6
59	04/24/90	D	29-30	5.44	ND	0	0.267	1.669
60	04/24/90	D	39-40	4.83	ND	0	0.285	2.237
61	04/24/90	D	A	4.71	0.186	0	0.652	0.303
62	04/24/90	D	B	5.36	0.191	0	0.794	0.318
63	04/24/90	D	C	4.41	0.184	0	0.572	0.279
1	05/31/90	A	0-1	5.60	1.289	0	6.079	7.54
2	05/31/90	A	2-3	4.70	0.284	0	2.572	1.703
3	05/31/90	A	4-5	4.97	0.232	0	1.591	1.475
4	05/31/90	A	6-7	4.25	0.346	0	1.869	2.154
5	05/31/90	A	8-9	5.31	0.250	0	1.848	2.246
6	05/31/90	A	10-11	5.43	0.123	0	0.955	2.211
7	05/31/90	A	12-13	5.35	0.124	0	0.493	2.114
8	05/31/90	A	14-15	5.41	0.126	0	0.140	1.856
9	05/31/90	A	18-19	5.39	0.112	0	0.096	1.933
10	05/31/90	A	22-23	5.42	0.112	0	0.043	1.521
11	05/31/90	A	29-30	5.48	0.114	0	0.052	1.514
12	05/31/90	A	39-40	5.49	0.113	0	0.088	1.228
13	05/31/90	A	49-50	5.53	0.114	0	0.120	1.647
14	05/31/90	B	0-1	5.77	0.237	0	5.441	7.54
15	05/31/90	B	2-3					
16	05/31/90	B	4-5	6.26	0.155	0	2.740	4.505
17	05/31/90	B	6-7	5.59	0.128	0	1.320	2.002
18	05/31/90	B	8-9	5.60	0.115	0	0.950	2.211
19	05/31/90	B	10-11	5.92	0.114	0	0.740	2.267
20	05/31/90	B	12-13	5.35	0.127	0	0.488	2.553
21	05/31/90	B	14-15	5.38	ND	0	0.201	2.421
22	05/31/90	B	18-19	5.28	0.115	0	0.050	2.518
23	05/31/90	B	22-23	5.51	0.116	0	0.045	2.678
24	05/31/90	B	29-30	5.52	0.116	0	0.038	2.678
25	05/31/90	B	39-40	5.55	0.113	0	0.032	2.351
26	05/31/90	B	49-50	5.58	0.129	0	0.034	2.337
27	05/31/90	C	0-1	5.54	0.168	0	2.028	2.957
28	05/31/90	C	2-3	4.99	0.142	0	0.949	1.445
29	05/31/90	C	4-5	5.15	0.146	0	0.977	1.521
30	05/31/90	C	6-7	5.81	0.159	0	0.871	2.135
31	05/31/90	C	8-9	6.24	0.145	0	1.115	2.839

Table A3. Concentrations of selected species in porewater samples (Cont.).

Date	Rep	Depth	pH	NO3-N	PO4-P	SO4-S	NH4-N	
		--cm--				mg/L		
32	05/31/90	C	10-11	5.64	0.133	0	1.014	2.737
33	05/31/90	C	12-13	5.40	0.135	0	0.743	2.546
34	05/31/90	C	14-15	5.39	0.133	0	0.379	2.665
35	05/31/90	C	18-19	5.51	0.132	0	0.064	2.593
36	05/31/90	C	22-23	5.52	0.136	0	0.087	2.874
37	05/31/90	C	29-30	5.59	0.131	0	0.044	2.844
38	05/31/90	C	39-40	5.63	0.135	0	0.052	2.486
39	05/31/90	C	49-50	5.63	0.134	0	0.076	1.954
40	05/31/90	D	0-1	6.53	0.155	0	1.809	0.784
41	05/31/90	D	2-3	6.46	0.137	0	1.291	0.605
42	05/31/90	D	4-5	6.25	0.136	0	1.627	0.515
43	05/31/90	D	6-7	6.09	0.144	0	2.839	0.515
44	05/31/90	D	8-9	5.39	0.282	0	3.979	0.328
45	05/31/90	D	10-11	4.66	0.592	0	4.200	0.057
46	05/31/90	D	12-13	4.70	0.463	0	3.689	0.129
47	05/31/90	D	14-15	4.68	0.326	0	2.522	0.272
48	05/31/90	D	18-19	4.74	0.419	0	2.109	0.515
49	05/31/90	D	22-23	4.91	0.154	0	0.515	1.232
50	05/31/90	D	29-30	5.02	0.136	1.104	0.069	2.187
51	05/31/90	D	39-40	5.15	0.130	0	0.072	2.486
52	05/31/90	D	49-50	5.24	0.127	0	0.044	2.456
SWC206/27/90					ND	ND	4.44	
D2 06/27/90					ND	ND	10.29	
SWA 06/27/90					ND	ND	7.32	
SWB 06/27/90					2.01	ND	5.69	
SWB206/27/90					ND	ND	8.02	
SWA206/27/90					2.62	ND	9.07	
SWC 06/27/90					ND	ND	4.9	
SGD 06/27/90					1.99	ND	13.15	
SWC 06/27/90					ND	ND	5.32	
SGD 06/27/90					1.95	ND	12.07	
1	07/12/90	A	6-7	4.73	0.547	0	3.195	1.831
2	07/12/90	A	8-9	5.52	0	0	1.308	0.774
3	07/12/90	A	10-11	4.98	0	0	0.345	0.230
4	07/12/90	A	12-13	4.95	0	0	0.121	0.230
5	07/12/90	A	14-15	5.17	0	0	ND	1.034
6	07/12/90	A	18-19	4.93	0	0	ND	0.115
7	07/12/90	A	22-23	5.22	0	0	0.361	0.580
8	07/12/90	A	29-30	5.37	0.005	0.102	0.057	0.985
9	07/12/90	A	39-40	5.27	0	0	0.046	1.070
10	07/12/90	A	49-50	5.45	0	0	0.049	1.197
11	07/12/90	B	0-1	5.42	2.560	0	7.390	13.379
12	07/12/90	B	2-3	5.09	0	0	2.842	8.666
13	07/12/90	B	4-5	5.34	0	0	2.905	6.853



Table A3. Concentrations of selected species in porewater samples (Cont.).

Date	Rep	Depth	pH	NO3-N	PO4-P	SO4-S	NH4-N	
--cm--			-----mg/L-----					
14	07/12/90	B	6-7	5.68	0	0	1.511	5.385
15	07/12/90	B	8-9	5.55	0	0	1.626	4.037
16	07/12/90	B	10-11	5.56	0	0	0.859	3.734
17	07/12/90	B	12-13	5.39	0	0	0.282	3.136
18	07/12/90	B	14-15	5.38	0	0	0.071	3.420
19	07/12/90	B	18-19	5.38	0	0	0.392	4.508
20	07/12/90	B	22-23	5.33	0	0	0.433	4.339
21	07/12/90	B	29-30	5.44	0	0	3.347	3.185
22	07/12/90	B	39-40	5.47	0	0	1.308	3.191
23	07/12/90	B	49-50	5.53	0	0	0.345	3.330
24	07/12/90	C	0-1	4.89	0	0	0.121	0.157
25	07/12/90	C	2-3	5.12	0	0	10.970	0.049
26	07/12/90	C	4-5	5.44	0	0	0.668	0.653
27	07/12/90	C	6-7	4.84	0	0	1.756	1.148
28	07/12/90	C	8-9	6.08	0	0	3.640	2.768
29	07/12/90	C	10-11	5.98	0	0	1.421	3.070
30	07/12/90	C	12-13	5.69	0	0	1.548	3.420
31	07/12/90	C	14-15	5.48	0	0	0.277	3.070
32	07/12/90	C	18-19	5.45	0	0	ND	2.707
33	07/12/90	C	22-23	5.38	0	0	ND	4.823
34	07/12/90	C	29-30	5.82	0.217	1.627	0.160	0.000
35	07/12/90	C	39-40	5.52	0.000	0	0.261	2.937
36	07/12/90	C	49-50	5.56	0.051	0	0.107	2.236
37	07/12/90	D	0-1	5.56	0.876	0	1.645	0.955
38	07/12/90	D	2-3	6.16	0.643	0	1.954	1.197
39	07/12/90	D	4-5	6.26	0.402	0	1.447	1.136
40	07/12/90	D	6-7	6.16	0.075	0	0.462	0.647
41	07/12/90	D	8-9	6.09	0.128	0	0.684	0.774
42	07/12/90	D	10-11	5.94	0.130	0	0.536	0.774
43	07/12/90	D	12-13	5.71	0.414	0	2.320	0.756
44	07/12/90	D	14-15	4.51	3.320	0	11.430	0.447
45	07/12/90	D	18-19	5.41	0.110	0	2.470	0.725
46	07/12/90	D	22-23	5.20	0.055	0	1.237	1.148
47	07/12/90	D	29-30	5.22	0.058	0	3.719	2.707
48	07/12/90	D	39-40	5.12	0.047	0	1.652	2.598
49	07/12/90	D	49-50	5.16	0.048	0	0.190	2.822
50	07/12/90	D.Water		5.65	0.048	0	0.077	0.018
1	09/04/90	A	0-1	4.86	4.974	0	6.799	1.843
2	09/04/90	A	2-3	4.63	1.901	0	3.726	0.774
3	09/04/90	A	4-5	4.46	0.931	0	3.878	0.230
4	09/04/90	A	6-7	5.05	0.031	0	1.484	0.230
5	09/04/90	A	8-9	5.19	0	0	0.626	1.046
6	09/04/90	A	10-11	5.19	0.033	0	0.385	0.109
7	09/04/90	A	12-13	5.17	0	0	0.219	0.592
8	09/04/90	A	14-15	5.27	0	0	0.098	0.967
9	09/04/90	A	18-19	5.27	0	0	0.092	1.076

Table A3. Concentrations of selected species in porewater samples (Cont.).

Date	Rep	Depth	pH	NO3-N	PO4-P	SO4-S	NH4-N	
		--cm--	-----mg/L-----					
10	09/04/90	A	22-23	5.31	0	0	0.039	1.197
11	09/04/90	A	29-30	4.95	0	0	0.120	3.227
12	09/04/90	A	39-40	5.16	0	0	0.055	2.140
13	09/04/90	A	49-50	5.38	0	0	0.034	1.904
14	09/04/90	B	0-1	4.92	1.855	0	5.092	1.759
15	09/04/90	B	2-3	4.69	1.306	0	3.526	1.451
16	09/04/90	B	4-5	4.45	1.571	0	4.876	1.233
17	09/04/90	B	6-7	4.83	0.587	0	4.892	2.829
18	09/04/90	B	8-9	5.20	0.076	0	3.538	3.264
19	09/04/90	B	10-11	5.26	0	0	2.613	3.251
20	09/04/90	B	12-13	5.27	0	0	1.410	3.432
21	09/04/90	B	14-15	5.35	0	0	1.056	3.305
22	09/04/90	B	18-19	5.27	0	0	0.416	3.239
23	09/04/90	B	22-23	5.40	0	0	0.162	3.372
24	09/04/90	B	29-30	5.41	0	0	0.045	0.169
25	09/04/90	B	39-40	5.43	0	0	0.022	0.055
26	09/04/90	B	49-50	5.32	0	0	0.203	0.683
27	09/04/90	C	0-1	4.84	0.712	0	1.977	1.197
28	09/04/90	C	2-3	4.85	0.666	0	2.633	3.142
29	09/04/90	C	4-5	5.24	0.281	0	2.656	2.828
30	09/04/90	C	6-7	5.30	0.223	0	1.823	3.523
31	09/04/90	C	8-9	5.37	0	0	1.375	3.130
32	09/04/90	C	10-11	5.30	0	0	0.636	2.943
33	09/04/90	C	12-13	5.29	0	0	0.515	1.982
34	09/04/90	C	14-15	5.12	0	0	0.493	1.499
35	09/04/90	C	18-19	5.16	0	0	0.347	1.318
36	09/04/90	C	22-23	5.22	0	0	0.212	3.064
37	09/04/90	C	29-30	5.52	0	0	0.265	2.544
38	09/04/90	C	39-40	5.48	0	0	0.204	2.768
39	09/04/90	C	49-50	5.42	0	0	0.224	3.311
40	09/04/90	D	0-1	5.46	0.374	0	1.192	0.925
41	09/04/90	D	2-3	5.67	0.317	0	1.170	0.641
42	09/04/90	D	4-5	5.96	0.250	0	0.738	0.296
43	09/04/90	D	6-7	5.62	0.208	0	1.629	0.182
44	09/04/90	D	8-9	5.49	0.205	0	1.162	0.176
45	09/04/90	D	10-11	5.57	0.227	0	1.831	0.653
46	09/04/90	D	12-13	4.85	0.482	0	7.489	0.351
47	09/04/90	D	14-15	4.43	0.733	0	10.631	0.236
48	09/04/90	D	18-19	4.51	0.296	0	10.136	0.441
49	09/04/90	D	22-23	4.72	0.203	0	10.457	1.088
50	09/04/90	D	29-30	4.97	0	0	5.436	1.740
51	09/04/90	D	39-40	5.16	0	0	2.819	2.163
52	09/04/90	D	49-50	5.17	0	0	0.221	2.182