DIKED AND UNDIKED FRESHWATER COASTAL MARSHES OF WESTERN LAKE ERIE

A Thesis

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by

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"the lessons as well as the beauties of marshes await the perceptive, as do the lessons and beauties of the skies, of the seas, of the mountains, and of the other places remaining where man can still reflect upon lessons and beauties that are not of human making"

(Errington 1957)

To Rick

ACKNOWLEDGEMENTS

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CHAPTER I

INTRODUCTION

The wetlands fringing the southwestern Lake Erie shoreline are a fragment of the once extensive, contiguous wetland ecosystem known as the "Black Swamp." These wetlands, located in a former glacial lake bed, at one time covered an estimated 4,000 km^2; but now, only 150 km^2 remain (Herdendorf 1987). As a dynamic interface between upland and open water, they receded with high water levels and extended into the lake with low levels.

Due to the high shoreline energy produced in western Lake Erie, wetlands cannot exist there without natural or artificial protection of some type, whether barrier beaches, natural isolation, or man-made dikes (Herdendorf 1987). Geis (1979) found that the occurrence and extent of marshes in Lake Ontario was dependent upon the degree of protection afforded from the full force of wind and waves.

Lake Erie wetlands, fringing the shallowest of the Laurentian Great Lakes, are vulnerable to two principle types of water level fluctuations: seven to ten year long period fluctuations that occur in the Great Lakes and can change lake levels as much as 1.75 meters for extended periods; and, short period fluctuations caused by seiches (Kelley et al. 1985, Herdendorf 1987).

As the interface between land and water, yet being neither land nor water, wetlands are particularly vulnerable to changes in the water regime around them (Mitsch and Gosselink 1986). Gosselink and Turner (1978) stated that the hydrologic regime is the "primary determinant of all wetland systems." The patterns of water movement define the vegetational structure of the marsh and modify the chemical and nutrient behaviors and levels within the marsh (Geis 1985).

As development pressures increase in coastal areas around the country, diking has become a viable alternative to protect and restore coastal wetlands. Existing natural marshes are filled and new marshes are created by diking to mitigate those losses. In Louisiana, marshes are being diked and managed for waterfowl to protect them from losses due to saltwater intrusion, subsidence, dredging, and flood control levees (U.S. EPA and LGS 1987). Geis (1985) states that the "water regime is the overriding environmental factor which regulates the occurrence of wetland communities and modifies the relative significance of other variables." We have an understanding of the effects of diking and marsh management on vegetation (Meeks 1969, Weller 1978); however, we do not understand how this modification of the water regime affects the other components and functions that natural marshes provide.

Montague et al. (1987), in a review of impacts of coastal marsh impoundments on nutrient and organic matter exchange, productivity, and access by fish and invertebrates, attempted to address these concerns for salt marshes. They found that diking substantially affected vegatation diversity and composition. Net export of organic matter was generally reduced, but was dependent upon the specific management regimes (many salt marsh impoundments are kept flooded as a method of mosquito control). Nutrients were recycled in the marsh rather than imported or exported, thereby enhancing primary production. Overall, Montague et al. (1987) stressed that the variability in these processes were so high among the diked marshes that generalization was difficult.

Lake Erie Marshes

At the turn of the century, with increasing development pressures for agricultural land and waterfront property, Lake Erie marshes were drained and filled and dikes were constructed around them to protect the new agricultural fields from fluctuating lake levels. The remaining natural marshes can no longer migrate inland with rising lake levels due to the barriers imposed behind them by development. As a result, during high water years the marshes are inundated and disappear.

Those first to notice and react to wetland loss were waterfowl hunters who were concerned that if the marshes disappeared, ducks would disappear also. In an attempt to preserve waterfowl habitat, waterfowl hunting clubs bought large expanses of marshes [and previously drained marshes turned farmland] and built large earthen and rip-rap dikes to insulate them from the vagaries of fluctuating water levels. Eighty-five percent of the marshes that remain on Ohio's southern shore of Lake Erie are now diked and many of those are privately owned (Bookhout et al. 1989). They are maintained by a series of gates and pumps, and water levels within the marshes are manipulated to encourage the growth of aquatic vegetation for waterfowl. Dikes restrict the flow of water, nutrients, fish, and invertebrates. The once dynamic ecosystems that filtered nutrients and trapped sediments from surrounding upland habitats are now hydrologically isolated.

Previous Studies

Weller (1978), who discusses the proper use of water level control to influence vegetation, discourages artificial management practices and stresses the importance of patterning water level fluctuations after "natural successional patterns." He emphasizes that marshes are in constant change and that stability is deadly to a marsh system. Lyon et al. (1986) equated this continual change caused by water level fluctuations in a Lake Michigan marsh to the way a prairie is maintained by fire.

Herdendorf (1987) further states that "within those marshes where natural processes are allowed to take place, zonation and succession in response to changing environmental conditions are among the important community processes. Water level fluctuations, and the resultant plant and animal response, are often the most significant driving force."

The biota of Lake Erie marshes have been extensively studied. Floristic analyses and vegetation (Lowden 1969, Stuckey 1975, 1976a, 1989, Bartolotta 1978, Balogh 1986, Balogh and Bookhout 1989, Reeder and Mitsch 1989a), waterfowl (Andrews 1952, Barclay 1970, Kroll 1979, Hoffman 1983), invertebrates (Riley 1989), and fish (Owen et al. 1983, Navarro 1988, Johnson 1989) have all been studied. Nutrient transport and cycling studies, however, are less common (Heath 1987, Krieger 1984 and 1989, Reeder and Mitsch 1989b).

With the exception of Johnson (1989), these previous works did not directly compare diked and undiked marshes. Johnson (1989) compared fish community structure and diversity of a diked and undiked marsh, and found less diversity and unique species in the diked marsh. Although Stuckey's (1989) work was not a direct quantitative comparison between the two types of marshes, he concluded, after many years of study, that diked marshes are degraded due to a decreased diversity of native vegetation.

Mudroch (1981) included both types of marshes as sites within her study, but a comparison between them was not the focus of the study. Six marshes in the Great Lakes, three of which were diked and three undiked, were chosen to determine the effects of selected marshes on water quality. She concluded that all of the marshes demonstrated a high retentive capacity for nutrients and metals; however, this capacity was dependent upon hydrologic regime and species composition within each marsh.

Several authors in an edited volume (Prince and D'Itri 1985) focused on the effects of lake level fluctuations on processes in coastal marshes fringing the Great Lakes. These have provided much of the context for discussions on the impact of water level fluctuations on nutrient cycling (King 1985), species composition (Keddy and Reznicek 1985) and wetland distribution (Geis 1985). Other pertinent works include MacCrimmon (1980), who studied a natural marsh with a large agricultural watershed on the shores of Lake Huron and found that Wye marsh was a sink for nutrients and sediment. Klarer (1988) studied the impact of Old Woman Creek wetland, bordering Lake Erie, on mitigating stormwater runoff and concluded that the marsh trapped 35 to 80% of the nutrients and 10 to 50% of the metals passing through it. Preliminary results of hydrologic, phosphorus cycling, and productivity studies conducted at Old Woman Creek wetland are summarized in Mitsch (1989).

Study Objectives

Both upland watershed impacts and lake level fluctuations influence the hydrologic regime of natural coastal marshes. Diked marshes are not influenced in this way. A comparison of diked and undiked wetlands is a true comparison of the effects of hydrologic isolation (diking) upon the chemical constituents and vegetational components of a marsh. This study compares the impacts of diking on selected parameters of Lake Erie coastal marshes.

I am testing the null hypothesis that diked and undiked marshes in my study (local population or scale) are the same in terms of measured water chemistry and vegetation (function and structure). A second question asked is what inferences can I make from my data about all of the diked and undiked marshes in the western basin of Lake Erie. Therefore, my second null hypothesis is: diked and undiked marshes in western Lake Erie (lakewide or regional scale) are the same for the measured parameters. The third objective of my study is to provide information about selected Lake Erie marshes which can be used to direct further studies.

CHAPTER II

METHODOLOGY

In the early 1900s, when the marshes on the southern shore of Lake Erie were not diked, they were still a population of natural marshes. For the purposes of testing the hypothesis presented in this study, I assume a researcher at the turn of the century decided to test the effects of diking on marshes. Several marshes were chosen at random and dikes were constructed around them. Sixty to eighty years later, this study was conducted to assess whether changes had occurred by measuring parameters and comparing the mean of the diked marshes with the mean of the undiked marshes. A measure of the variance among marshes is the basis for assessing the significance of differences between the means. The experimental unit in this study is the marsh and the treatment on the experimental unit is diking. The diked marshes are experimental units treated alike and the undiked marshes are control units. This study tests for the effects of diking on marshes.

SITE DESCRIPTIONS

Eleven marshes were chosen bordering southwestern Lake Erie in Erie, Sandusky, and Ottawa counties (Fig. 1). All the marshes, except Old Woman Creek, border Sandusky Bay. Specific locations of the sampled marshes are presented in Table 1. Six marshes are diked and their water levels are regulated. The remaining five marshes are undiked and their water levels fluctuate with changing Lake Erie water levels. Herdendorf and Hartley (1981) summarized much of the existing information on Lake Erie's coastal wetlands providing a good general overview of the

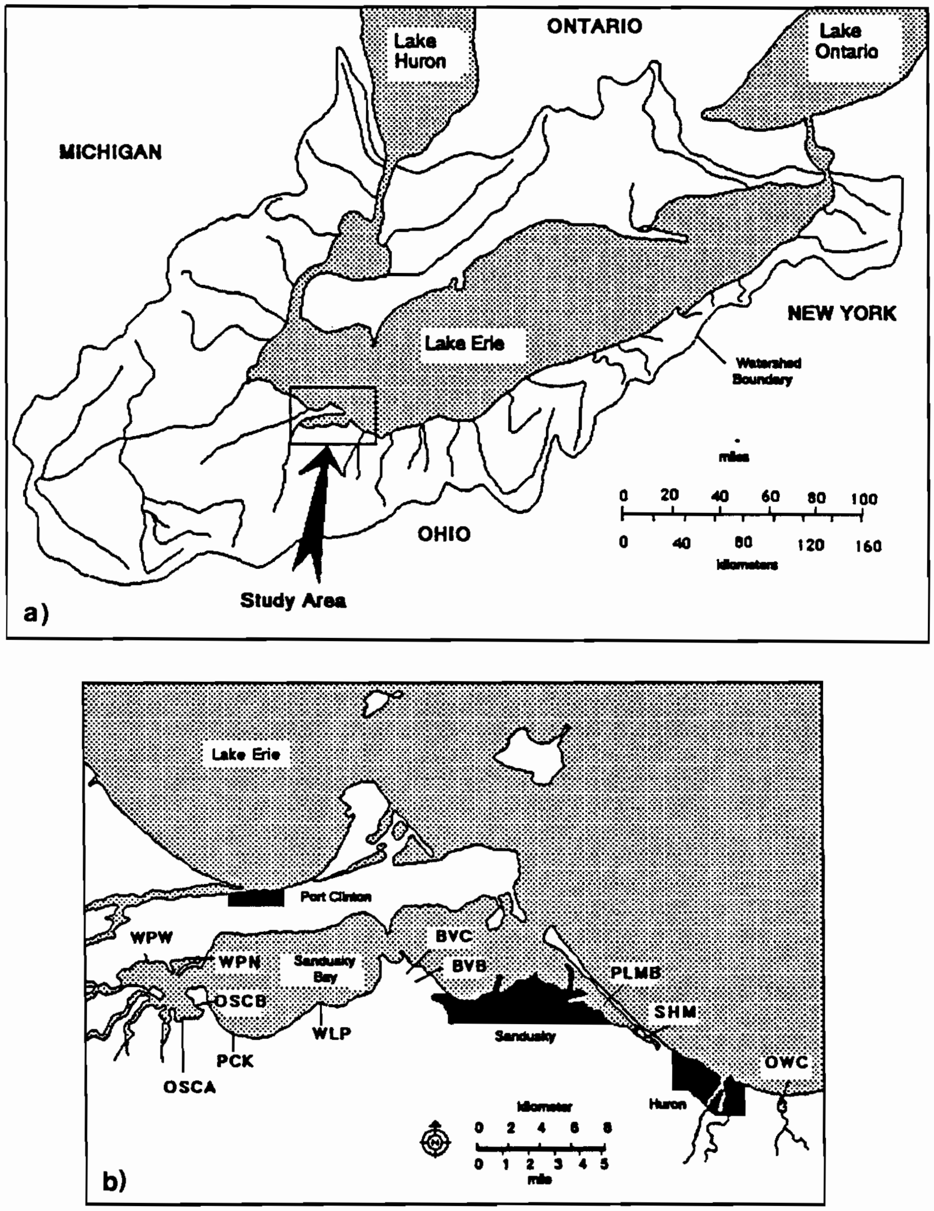

Figure 1. a) Regional view of study area depicting Lake Erie watershed, and b) Marsh site locations in Sandusky Bay and surrounding area.

Table 1. Locations and abbreviations of marsh study sites.

Marsh Site and Abbreviation	Longitude	Latitude
Diked Marshes		
Bay View "B" Marsh (BVB)	82°48'30"	41°27'30"
Bay View Center Marsh (BVC)	82°48'49"	41°27'30"
Ottawa Shooting Club Allen Pond (OSCA)	82°58'15"	41°26'40"
Ottawa Shooting Club Big Pond (OSCB)	82°58'30"	41°26'45"
Winous Point North Marsh (WPN)	82°59'30"	41°28'0"
Winous Point West Marsh (WPW)	83° 0'30"	41°28'0"
Undiked Marshes		
Pickerel Creek (PCK)	82°57'46"	41°25'38"
Plum Brook (PLMB)	82°38'40"	41°25'52"
Willow Point (WLP)	82°52'49"	41°26'12"
Sheldon Marsh (SHM)	82°36'40"	41°25'20"
Old Woman Creek (OWC)	82°30'40"	41°22'30"

topography, geology, climate, soils, and hydrology of these wetlands, including some biological information.

The regional geology is underlain and influenced by glacial till (Herdendorf 1987). West of PLMB, the area is underlain by Silurian and Devonian limestones and dolomites. Extending eastward, including PLMB, SHM, and OWC, the basin is underlain by shale. This causes a stratification that affects water chemistry and vegetation differently, according to differences in bedrock.

Sampling stations were established by placing metered stakes in the major vegetational communities within each marsh. The stations were chosen in April and were based on vegetational patterns of the previous year. Since the stations were chosen prior to the sampled growing season and vegetation patterns vary from year to year, some of the stations did not have the vegetation expected. Therefore, in some marshes, additional stations were established later in the study to adequately reflect current vegetation. The number of stations varied from three to six per marsh, depending on the marsh size and vegetation diversity. For example, a small marsh with many vegetational types might have more stations than a larger marsh with a monotypic community.

Diked Marshes

Water levels in diked marshes are manipulated through a series of gates and pumps to promote optimum vegetative growth, primarily for waterfowl use. Unless otherwise stated, diked marshes have drainage ditches surrounding them on the landward side to prevent upland drainage from entering the marsh. The drainage ditches empty directly into the nearest body of water. In general, diked marsh managers follow a regime of lowering water levels in the spring, maintaining them at low levels to encourage vegetation, then raising them again in the fall to flood seed-bearing vegetation in order to attract migrating waterfowl. The soil types of the diked marshes in the study area are classified as Toledo silty clay loam, ponded (Musgrave and Derringer 1985, Ernst and Hunter 1987) with the exception of the Bay View marshes which are classified as marsh (Redmond et al. 1971).

Bay View Marshes - The Bay View marshes, located in Erie county, are part of a privately owned marsh complex with a total of 273 ha of diked marshes (Bookhout et al. 1989) (Fig. 2). Kroll (1979) provides a good description of the geology, history, and land use of the Bay View marshes and the surrounding landscape. BVB and BVC marshes are approximately 14 and 40 ha, respectively. Due to an extensive drought in 1988 and decreasing water levels in Lake Erie, the channels by which the water level is controlled for Bay View silted in and the marsh manager was unable to maintain optimum water levels. Consequently, BVB had only one sampling station remaining by September 10 and BVC had one site that retained water throughout the study. Between June 24 and July 15, the manager opened an alternative pipe from upper Sandusky Bay into the Bay View marshes to add water.

Ottawa Shooting Club Marshes - OSCA and OSCB are located in the Ottawa Shooting Club complex in Sandusky county (Fig. 3). Ottawa Shooting Club was founded in 1871 as a waterfowl shooting club and before that was known as Hones Point Fishing Club. Ottawa comprises 526 ha of diked marshes (Bookhout et al. 1989) and OSCA and OSCB are approximately 10 ha and 121 ha, respectively. The marshes are managed primarily for millet and submerged aquatics (Larry Davis personal communication). Raccoon Creek is both the source and outlet for water level manipulations. Raccoon Creek, however, mixes with Sandusky Bay upstream of the water control structures, so the marshes are influenced by a mixture of both bodies of water. The individual marshes are serially connected with Raccoon Creek; therefore, water passes through two marshes before reaching OSCA and through a total of five marshes before reaching OSCB. Consequently, each marsh is biogeochemically influenced by the

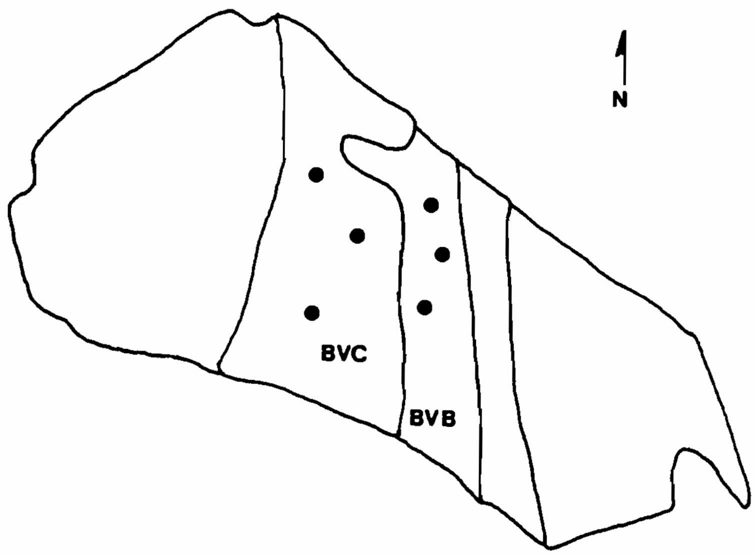

Figure 2. Study site maps indicating sampling stations for Bay View "B" and Bay View Center marshes.

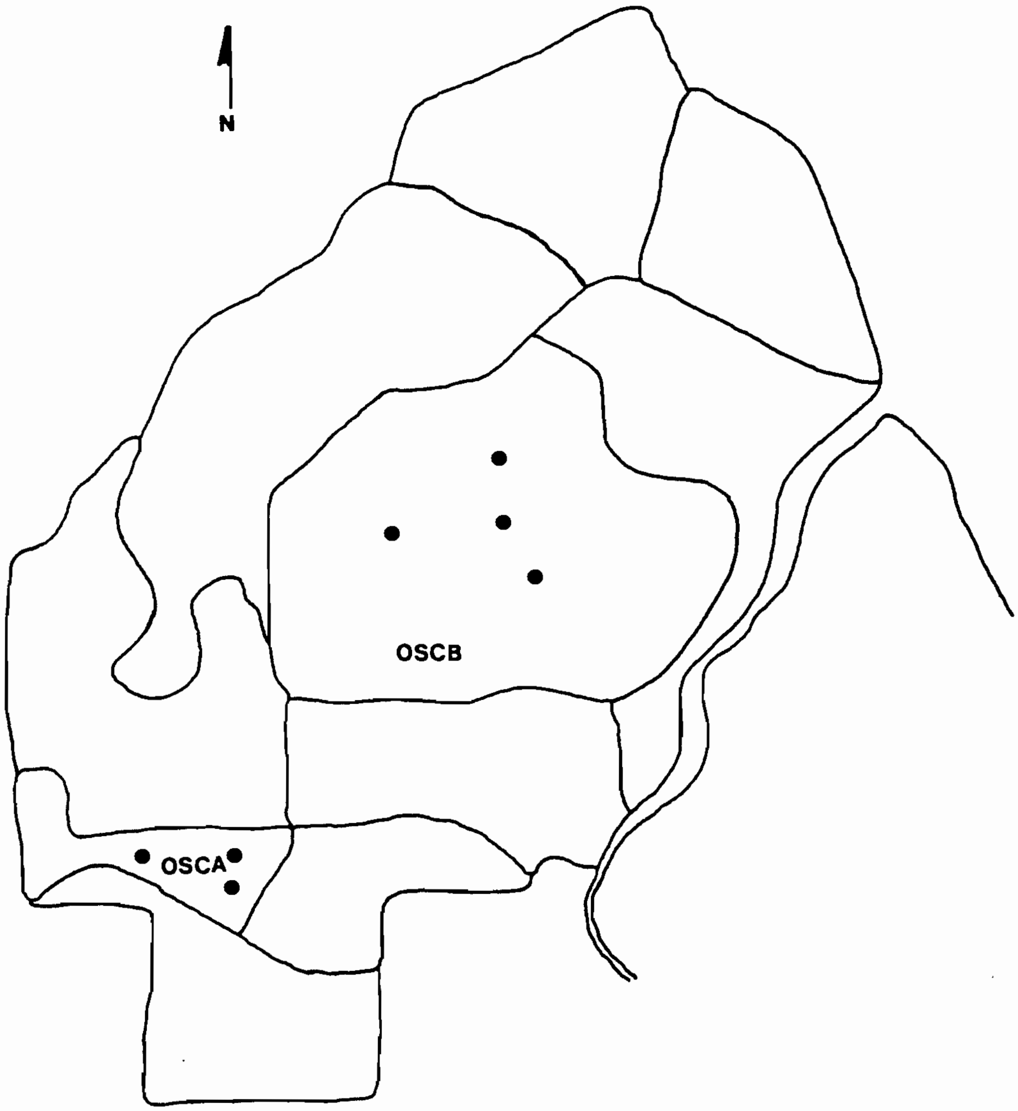

Figure 3. Study site maps indicating sampling stations for Ottawa Shooting Club marshes, Allen Pond and Big Pond.

marshes between it and Raccoon Creek. OSCB water chemistry is affected by the water chemistry of OSCA. The management objectives for Ottawa include a complete drawdown for each marsh every five to seven years. The last drawdown for OSCA was in 1987 and for OSCB was 1983. Spring drawdown for 1988 occurred mid-March during which OSCA was lowered approximately 30 cm and OSCB was lowered approximately 38 to 46 cm.

Winous Point Marshes - Winous Point North Marsh (WPN) and Winous Point West Marsh (WPW) are located within the Winous Point Shooting Club marsh complex in Ottawa County (Fig. 4). Winous Point has a long and rich history of waterfowl protection and research in Lake Erie marshes. Established in 1852, Winous Point began diking its marshes in 1900 to hold water for muskrats (*Ondatra zibethicus*) and currently has 617 ha of diked marsh (Bookhout et al. 1989). Andrews (1952) describes the geology of the Lake Erie marshes in general and provides a historical and ecological perspective for the Winous Point marshes. Winter drawdown for the 1988 growing season occurred during the end of December 1987 and beginning of January 1988.

WPN, approximately 263 ha, is the only diked marsh in this study having a watershed. The land use in this watershed is primarily agricultural crops of soybeans and corn (Musgrave and Derringer 1985). Beginning in 1985 through 1986, WPN was drained dry for the first time in its history. The management goals for WPN encourage *Polygonum* spp., *Bidens* spp., and *Echinochloa* spp. in upland areas and *Typha* spp. in the remaining areas (Roy Kroll personal communication).

WPW is approximately 142 ha and was reclaimed from Muddy Creek Bay in 1978 after storms in 1973 broke through the existing dikes. Drainage ditches surrounding the marsh drain the local farmlands directly into Muddy Creek Bay. WPW was drained dry in 1987 for the first time since 1978 and seeded for *Echinochloa*

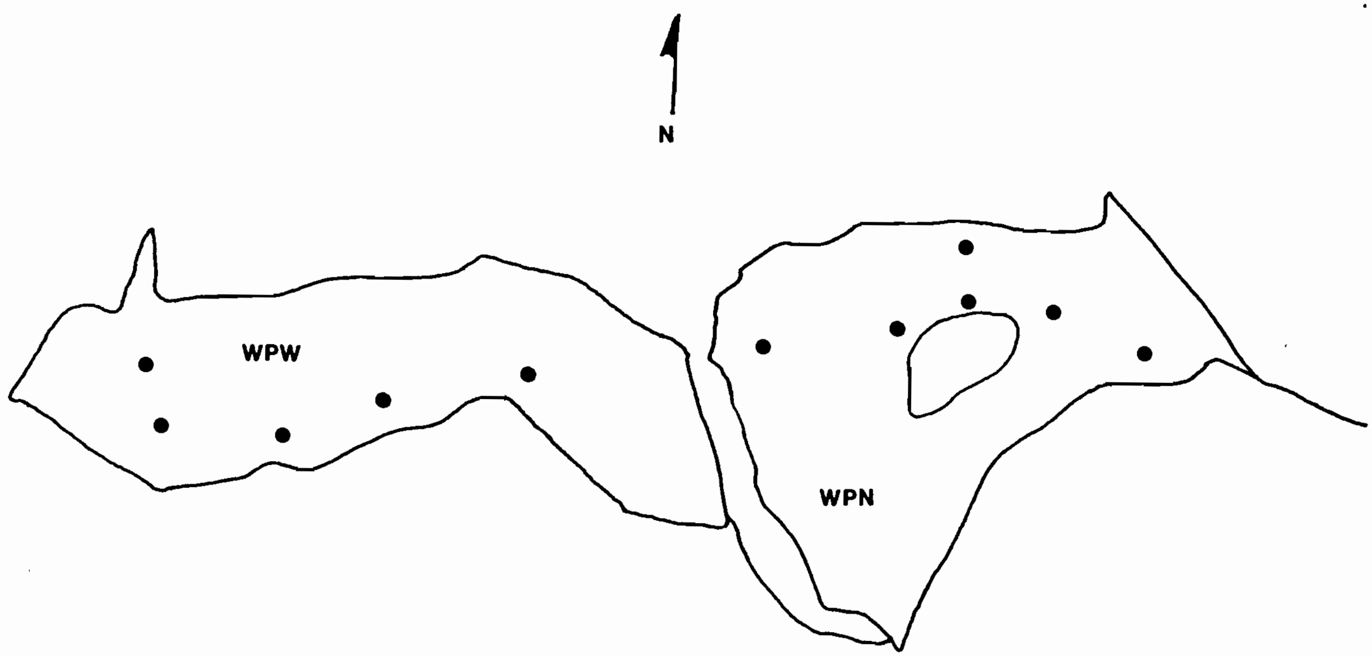

Figure 4. Study site maps indicating sampling stations for Winous Point Shooting Club, North and West marshes.

crusgalli var. *frumentacea* in its two large shallow basins. By the third week of June 1988, a combination of lowered water levels and evaporation left both basins dry again and caused germination of the *E. crusgalli* var. *frumentacea* seeded from the previous year.

Undiked Marshes

The hydrologic regime of natural, undiked marshes is directly dependent upon fluctuations in Lake Erie water levels and on runoff from their own watersheds. However, with the drought occurring during this study, marshes were not greatly affected by water from watershed sources. Only Old Woman Creek was able to be sampled throughout the duration of the study (Table 2). The soil for each study site is classified as marsh (Redmond et al. 1971), except Pickerel Creek, which is classified Toledo silty clay loam, ponded (Ernst and Hunter 1987).

Pickerel Creek - Pickerel Creek (PCK) is a state-owned wildlife management area in the lower half of Sandusky Bay in Sandusky County (Fig. 5). The marshes bordering the creek are exposed to a mixing of waters from the creek's upland watershed and the waters of Sandusky Bay. Agricultural crops of corn and soybeans, and open grassland predominate in the watershed.

Plum Brook Marsh - Plum Brook marsh (PLMB) is located in the eastern inlet of Sandusky Bay in Erie county (Fig. 6). Herdendorf (1987) defines it as a coastal lagoon protected by a sand barrier or spit called Cedar Point. The spit protects the wetland vegetation from open lake wave action while still providing access to the lake via Sandusky Bay. The land use in the watershed is urban/rural with some agriculture consisting of corn, soybeans, and orchards. Decreasing water levels prevented access after June 23 (Table 2).

Willow Point - Willow Point (WLP) is a state-owned fisheries management area in Sandusky county (Fig. 7). The marsh area chosen was previously a diked marsh until

Table 2. Sampling dates for each study site and times when stations could not be sampled due to lack of standing water.

Site/Station		May	June	July	Aug.	Sept.	Oct.
BVB	1	12/26	11/D	30	D/27	D	D
	2	12/26	D/D	D	D/D	D	D
	3	12/26	11/25	30	12/27	10	D
BVC	1	12/26	11/25	30	12/27	10	28
	2	12/26	11/25	30	12/27	10	D
	3	12/26	11/D	30	12/27	10	D
OSCA	1	14/28	9/23	27	3/14	10	28
	2	14/28	9/23	27	3/14	10	28
	3	14/28	9/D	27	3/14	10	28
OSCB	1	14/28	9/23	27	3/14	10	28
	2	14/D	D/23	27	3/14	10	28
	3	14/28	D/23	27	3/14	10	28
	4	14/28	9/23	27	3/14	10	28
WPN	1	9/23	6/20	25	11	11	26
	2	9/23	6/20	25	11	11	26
	3	9/23	6/20	25	11	11	26
	4	9/23	6/20	25	11	11	26
	5	9/23	6/20	25	11	11	26
	6	9/23	6/20	25	11	11	26
WPW	1	9/23	6/20	25	28	11	26
	2	9/23	6/D	25	28	11	26
	3	9/23	6/20	25	28	11	26
	4	9/23	6/D	25	28	11	26
	5	9/23	6/D	25	28	11	26
PCK	1	14/28	11/D	D	D/D	D	D
	2	14/28	11/D	D	14/D	D	D
	3	14/28	11/25	30	14/27	D	D
PLMB	1	12/26	11/23	D	D	D	D
	2	12/26	11/23	D	D	D	D
	3	12/26	11/23	D	D	D	D
	4	12/26	11/23	D	D	D	D
	5	*/26	11/23	D	D	D	D
WLP	1	14/28	11/25	D	D	D	D
	2	14/28	11/25	D	D	D	D
	3	14/28	11/D	D	D	D	D
SHM	1	12/26	9/23	27	3/14/28	11	D
	2	12/26	9/23	27	3/14/28	11	D
	3	12/26	9/23	27	3/14/28	11	D
OWC	1	9/23	7/20	27	3/14/29	11	8/26
	2	9/23	7/20	27	3/* /29	11	8/26
	3	9/23	7/20	27	3/14/29	11	8/26
	4	*/*	*/*	27	3/* /29	11	8/26
	5	*/*	*/*	27	3/* /29	11	8/26

D = dry during sampling time; no water sample taken
* = no water sample taken for reasons other than lack of water

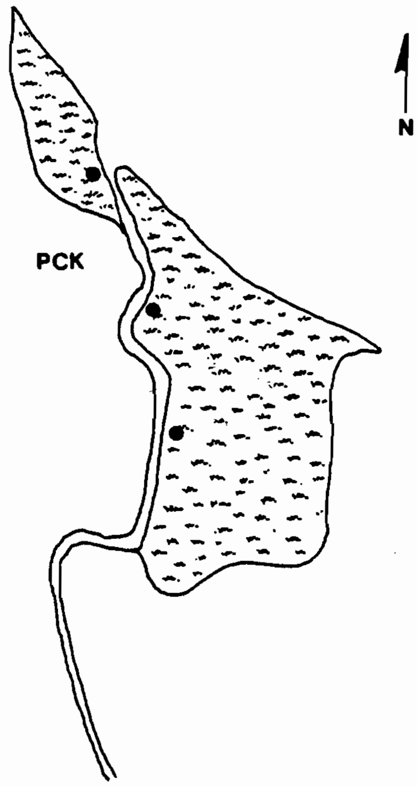

Figure 5. Study site map indicating sampling stations for Pickerel Creek wetland.

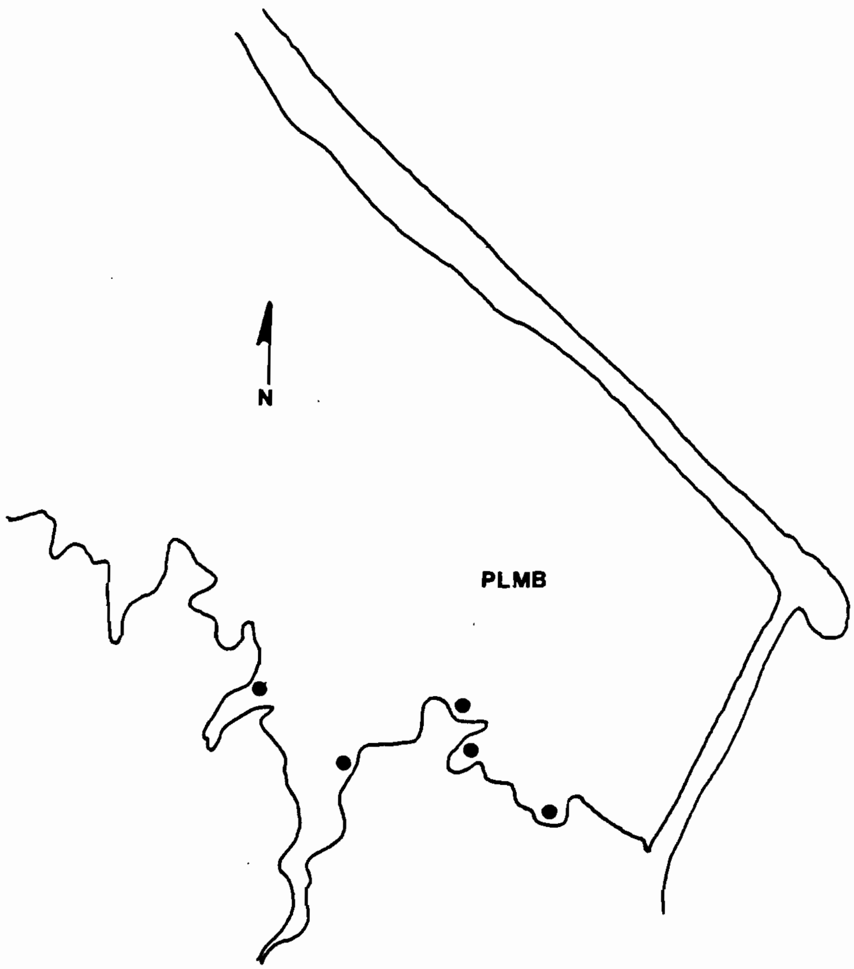

Figure 6. Study site map indicating sampling stations for Plum Brook marsh.

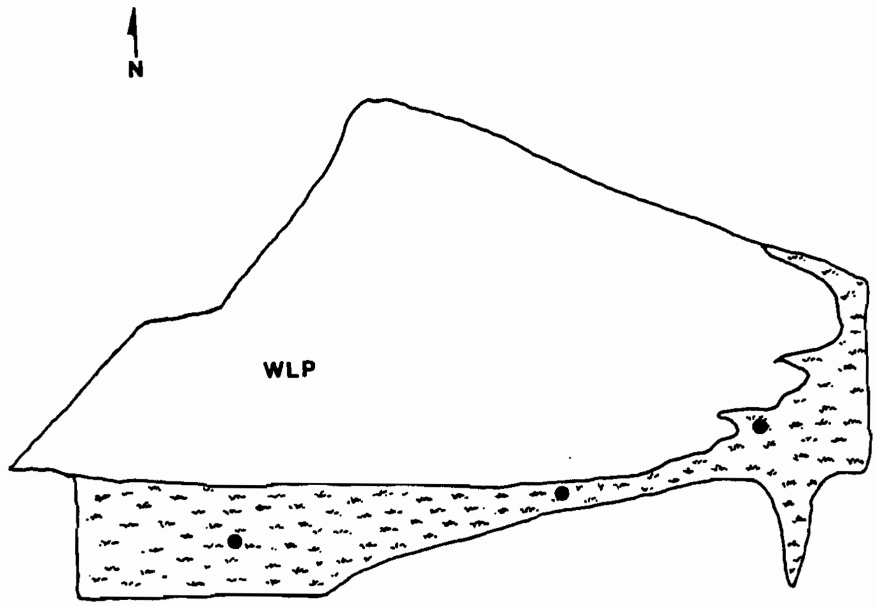

Figure 7. Study site map indicating sampling stations for Willow Point marsh.

1972 when high water broke through the dikes. The marsh is now open to Sandusky Bay, although there are future plans to rebuild the dikes. The watershed is mainly agricultural, primarily corn, soybeans, and open grassland. Water samples could be collected through June 25, by which time sampling locations were dry due to the drought.

Sheldon Marsh - Sheldon Marsh (SHM) is a State Nature Preserve in the eastern inlet of Sandusky Bay (Erie county) (Fig. 8). This marsh is also a coastal lagoon with a beach bar that protects the marsh from open lake wave action. The western end of the marsh is bounded by a roadway that was built in the early 1900s, effectively dividing PLMB and SHM. The watershed land use is primarily agricultural with crops of corn and soybeans. An adjacent golf course also contributes to runoff. The marsh area, as defined by the beach bar barrier, has decreased from 146 ha to 16 ha since 1937, mainly due to inward migration of the beach bar (D. Robb unpublished data).

At the beginning of the season, the beach bar was open at both ends; however, between June 9 and 23, the easternmost end reattached to the shore, greatly reducing the turbulence from wave action. Water samples were collected through early September when low water prevented further access (Table 2).

Old Woman Creek - Old Woman Creek (OWC) is a State Nature Preserve as well as a National Estuarine Research Reserve located near Huron, Ohio, in Erie county (Fig. 9). The estuary is open to Lake Erie intermittently throughout the year based on fluctuations of a barrier beach. Due to the lack of flow in OWC in 1988, the beach closed in mid-April and with the exception of a brief period May 9 through 14, it remained closed for the remainder of the season. The land use in the watershed is predominately agricultural with row crops and orchards. Old Woman Creek is another site with an extensive history of research and education.

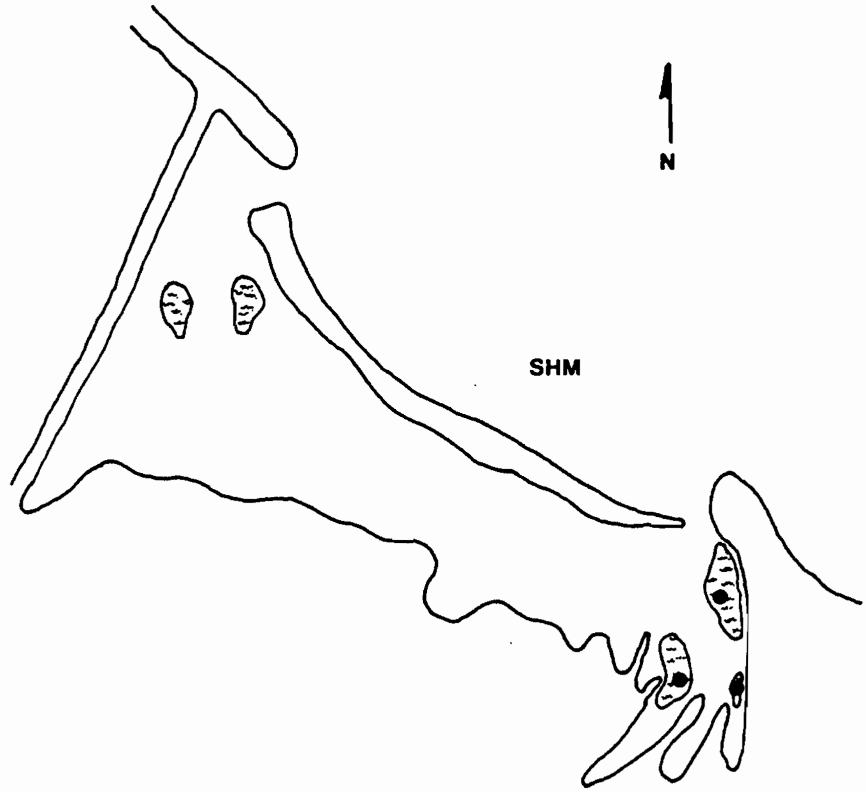

Figure 8. Study site map indicating sampling stations for Sheldon Marsh.

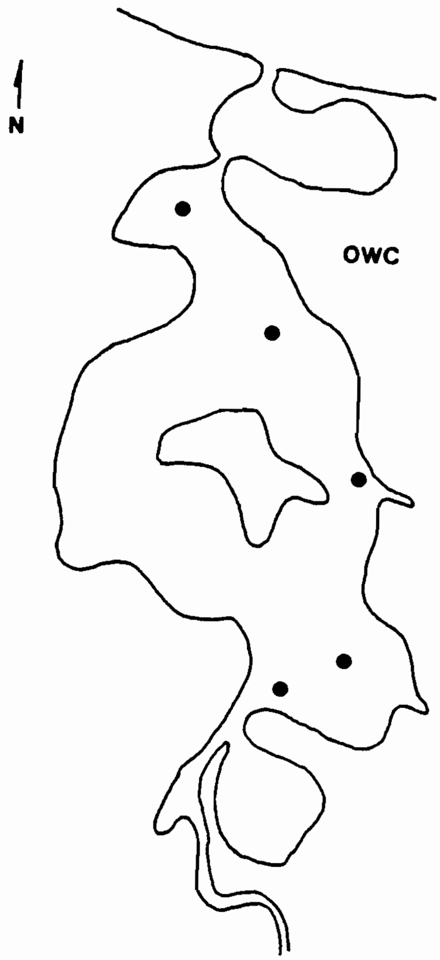

Figure 9. Study site map indicating sampling stations for Old Woman Creek wetland.

WATER CHEMISTRY

Sampling

Water samples for chemical analyses were collected at each station over a six month period in 1988. Samples were collected twice a month during May, June, and August and monthly during July, September, and October. A drought prevailed during the study causing low water levels that prevented water sampling at some of the marshes for the duration of the study. Table 2 presents sampling dates and indicates when low water prohibited sampling at each station..

One-liter polyethylene bottles were acid washed with concentrated hydrochloric acid and rinsed with distilled water between sampling periods. They were also rinsed twice with marsh water prior to collecting the samples. Water was collected within 1 meter of each sampling station. I developed a sampling tool (Fig. 10) based upon a modification of Hill (1983), which enabled me to sample 2.5 meters from the boat. At this distance, I was able to collect my sample without stirring up the sediment and subsequently contaminating the sample. The samples were chilled to $4^{o}C$ until chemical analyses were performed.

As each water sample was collected, water levels and weather conditions were recorded for each station. Rainfall data were collected by the staff at Old Woman Creek State Nature Preserve in Huron, Ohio. Temperature, dissolved oxygen (YSI Model 54 meter) and pH (Orion Research Model 231 meter) were also measured at each station at the time of collection. A Radiometer Model PHM 84 meter was used to measure pH in the lab during May until a field pH meter could be obtained.

Approximately 20% of the samples were collected in duplicate to determine the natural heterogeneity in the water mass. Identical chemical analyses were performed, and the standard deviations were determined by a formula outlined by Youden (1967, cited in U.S. EPA 1979) for a single analyst. The coefficient of

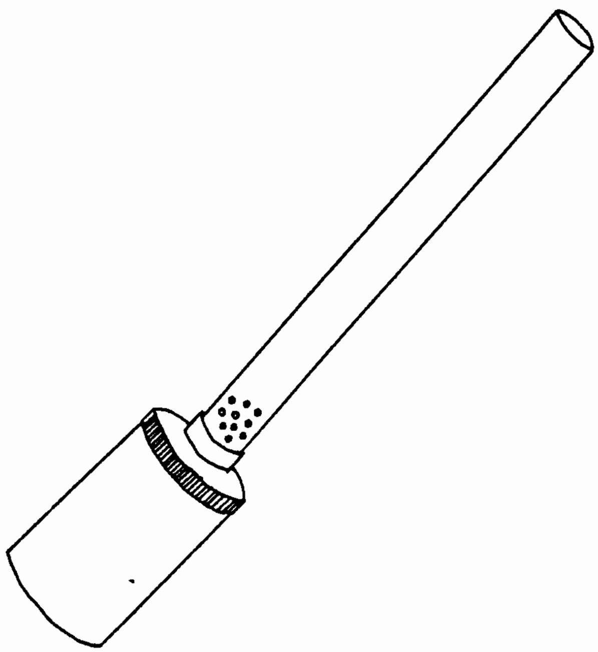

Figure 10. Water sampling tool used in this study (adapted from Hill 1983).

variation for the replicate pairs presented in Table 3 show that total phosphorus, orthophophate, ammonia, and nitrate all vary more than 10 percent. These tend to indicate the high natural variation (patchiness) present in the system and also caution against broad generalizations and conclusions based on one or two numbers.

Analysis

All chemical analyses were performed at Old Woman Creek National Estuarine Research Reserve laboratory within the time frame required by the analytical method. Unfiltered sample water was used to measure pH, alkalinity, conductivity, and turbidity. Alkalinity was determined by titrating to a pH 4.5 endpoint using a Radiometer End Point Titrator. Conductivity (micromhos/cm corrected to 25^{o}C) and turbidity (NTUs) were determined electrometrically using a YSI Model 32 Conductance meter and a Sargent Welch Turbidimeter, respectively. The remaining sample water was filtered through Fisher GS-4 glass microfiber filters for subsequent nutrient analyses. Table 4 lists the methods and sources for the analyses.

Initially, 125 ml unfiltered subsamples were removed from each sample and acidified (APHA 1985) for later total phosphorus analysis. The analysis was performed six to eight weeks after collection. Tests to determine whether the time lag affected absolute total phosphorus values did not reveal differences beyond the normal variation in the samples.

Duplicate subsamples (approximately 20% of total) were analyzed for each chemical method to determine the precision of the methods. Standard deviations were determined by a formula outlined by Youden (1967, cited in U.S. EPA 1979) for a single analyst. The coefficients of variation for the replicate pairs are presented in Table 5. Large replicate differences deleted from the analysis did not exceed 3% of the total number for any parameter.

Table 3. Analysis to determine field sample reproducibility (variability) in water of wetlands.

Parameter	Sets of Duplicates	Mean	Standard Deviation	Coeff. of Variation
pH	22	7.96	0.2	2.4%
Alkalinity (mg CaCO3/l)	21	137	10.8	7.9%
Conductivity (µmhos)	22	789	11.2	1.4%
Turbidity (NTU)	22	33	1.9	5.9%
Nitrate (mg N/l)	22	0.12	0.1	52.7%
Nitrite (µg N/l)	17	4	0.4	9.6%
Ammonia (mg N/l)	21	0.01	0.0	62.8%
Orthophosphate (µg P/l)	20	43	22.7	52.9%
Total Phosphorus (µg P/l)	21	127	19.4	15.2%

Table 4. Methods used for the chemical analysis of water samples.

Analysis	Method	Citation
Alkalinity	pH 4.5 endpoint	APHA, 1985
Conductivity	electrometrically	-----
Turbidity	electrometrically	-----
Nitrate	Cadmium Reduction	APHA, 1985
Nitrite	-----	APHA, 1985
Ammonia	-----	Zadorojny et al., 1973
Orthophosphate	Ascorbic Acid	APHA, 1985
Total Phosphorus	Persulfate Digestion/ Ascorbic Acid	APHA, 1985

Table 5. Analysis to determine precision in chemical analyses of water samples.

Parameter	Sets of Duplicates	Mean	Standard Deviation	Coeff. of Variation
pH	74	7.96	0.05	0.6%
Alkalinity (mg CaCO3/l)	82	153	1.7	1.1%
Turbidity (NTU)	50	52	0.6	1.2%
Nitrate (mg N/l)	80	0.20	0.05	25.4%**
Nitrite (µg N/l)	61	5	0.15	2.8%
Ammonia (mg N/l)	314 (1)*	0.04	0.02	40.2%**
Orthophosphate (µg P/l)	165 (5)*	54.6	8.1	14.8%
Total Phosphorus (µg P/l)	75 (1)*	184	1.2	6.1%

* Number of replicate pairs deleted
** Readings approaching lower limits of detection

VEGETATION

Vegetation was harvested between August 11 and 28 to coincide with peak above-ground biomass according to methods outlined in Westlake (1969). Three randomly placed 0.5 m^2 quadrats were harvested at each station regardless of whether standing water was present at the station throughout the duration of the study. PLMB was not sampled because of inaccessibility. WPN had one 1 m^2 quadrat harvested at each station before 0.5 m^2 quadrats were chosen as a better alternative for heavily vegetated stations. SHM stations 2 and 3 and all Old Woman Creek stations had three 1 m^2 quadrats harvested due to the broad-leaved nature of the vegetation. Where three quadrats were sampled per station, results were averaged.

The vegetation rooted within each quadrat was clipped at the sediment interface and sorted according to species. Species types and number of stems per species per quadrat were recorded. Plant species were identified using Fassett (1957). The plants were rinsed in marsh water and stored in plastic bags at $4^{o}C$ until they were weighed.

All excess water was removed from the plants, which were separated and weighed by species to the nearest 0.1 gram on an Ohaus top loading balance. The SHM vegetation, however, was weighed only to the nearest gram. The plants were then stored in a freezer to prevent decomposition until they could be dried. They were dried at $105^{o}C$ until a constant weight was maintained and re-weighed when cool. The number of stems per species and the dry weight per species were converted (where applicable) to values per meter squared.

STATISTICAL ANALYSES

Parametric statistics were used as the basis for conclusions. Levene's test for homogeneity of variance was applied to each water chemistry and vegetation parameter (Milliken and Johnson 1984) and alkalinity, nitrite, orthophosphate, and stem count were heterogenous. These parameters were analyzed using generalized least squares (GLS) models to account for heterogenous variances (Aitken 1934 as cited in Johnston 1972).

For the remaining water chemistry and vegetation parameters, ANOVA models were constructed to test the hypothesis H_O: diked and undiked marshes are the same. The water chemistry model was designed to answer five questions: (1) whether diked and undiked marshes were different for each parameter tested in my study area [$Diked_s$ vs. $Undiked_s$], (2) whether the diked and undiked marsh groups change the same way over time [Diked*Date], (3) whether each parameter significantly changes over time [Date], (4) whether all diked and undiked marshes in Lake Erie are different with respect to the parameters [$Diked_t$ vs. $Undiked_t$], and (5) whether the individual marsh replicates are different within each group [Marsh(Diked)].

Differences among marshes in this study were tested using residual variation within each marsh as an error term while the differences among Lake Erie marshes were tested using variation among marshes as an error term. Vegetational differences were tested with a model designed to answer whether diked and undiked marshes were different for each parameter reported in the study, when extrapolated to all Lake Erie marshes, and whether the individual marsh replicates were different within each group.

R^2 values are reported to indicate the proportion of the total variation accounted for by the ANOVA and GLS models. Pearson product moment correlation coefficients were also computed among the measured chemical parameters.

CHAPTER III

RESULTS

WATER LEVEL FLUCTUATIONS

Figures 11 and 12 present water level changes for each marsh site on a relative scale. Precipitation data and Lake Erie water level data are presented in Figure 13. The Great Lakes region experienced unusual weather conditions during this study as the 1988 summer was declared one of the hottest and driest on record by the National Oceanic and Atmospheric Administration (U.S. Dept. of Commerce 1988b). The precipitation for the months of June through August was only 75% of the normal rainfall for that time of year (equivalent to less than 20 cm below normal). Above normal temperatures were also recorded during this time. A moderate to severe drought was declared and streamflow was also much below normal (U.S. Dept. of Commerce 1988a). Lake Erie water levels dropped approximately 0.76 m in 1988 from the record high recorded in 1986.

Diked Marshes

Due to an inability to regulate water in the Bay View marshes, they were affected by drought conditions similar to the undiked marshes; loss of water throughout most of the study. BVB water levels decreased 14 cm by June 11 when the meter sticks marking the center of the stations were no longer in standing water (Fig. 11). An alternate water supply provided June 24 through July 15, however, increased water levels 10 cm in both marshes. The additional water raised water levels at BVB but not enough to register on the meter sticks. As a result, an accurate determination

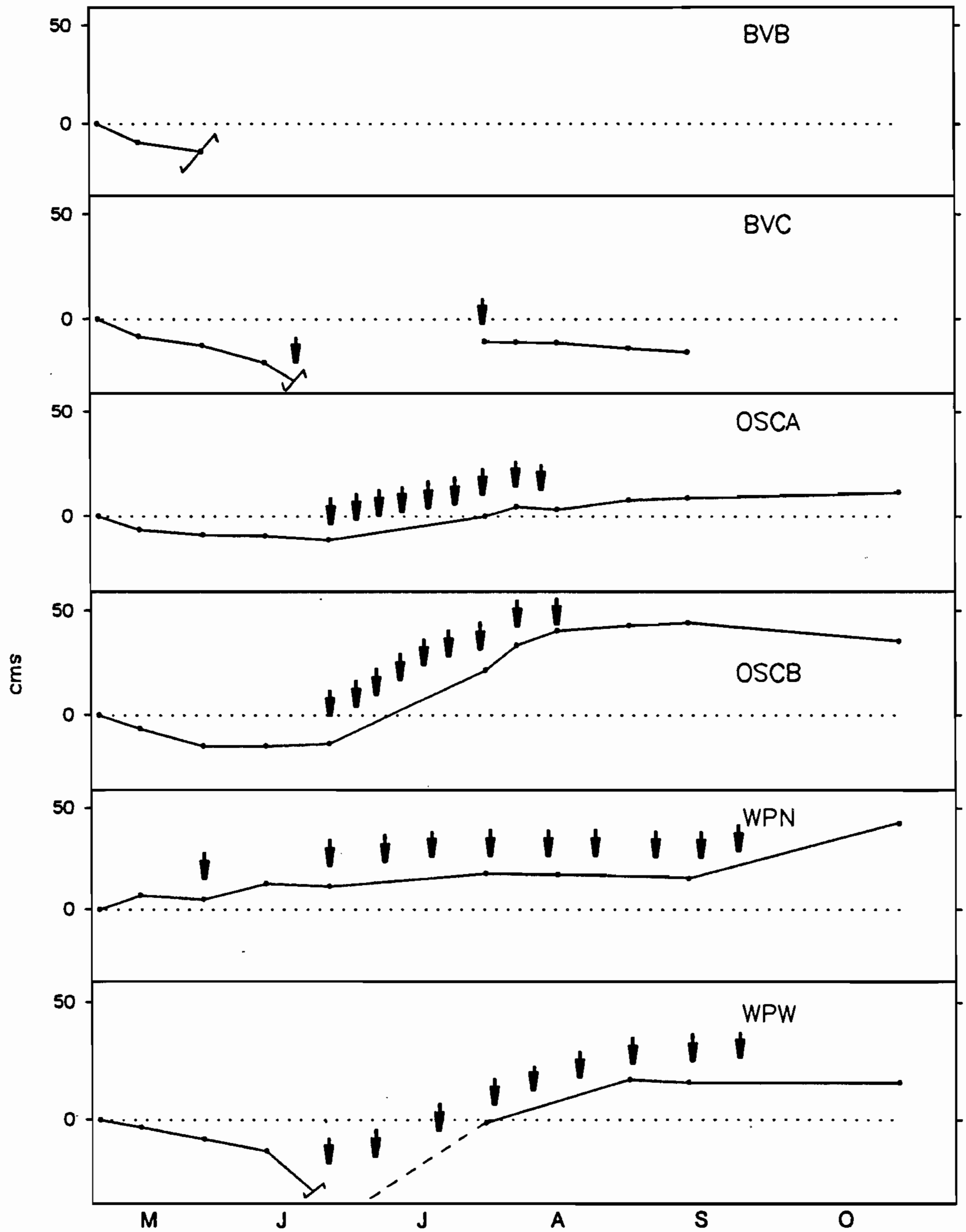

Figure 11. Water levels (relative to initial readings) for six diked marshes in western Lake Erie. Arrows indicate pumped water additions. In BVC, water additions began at the first arrow and ended with the second arrow.

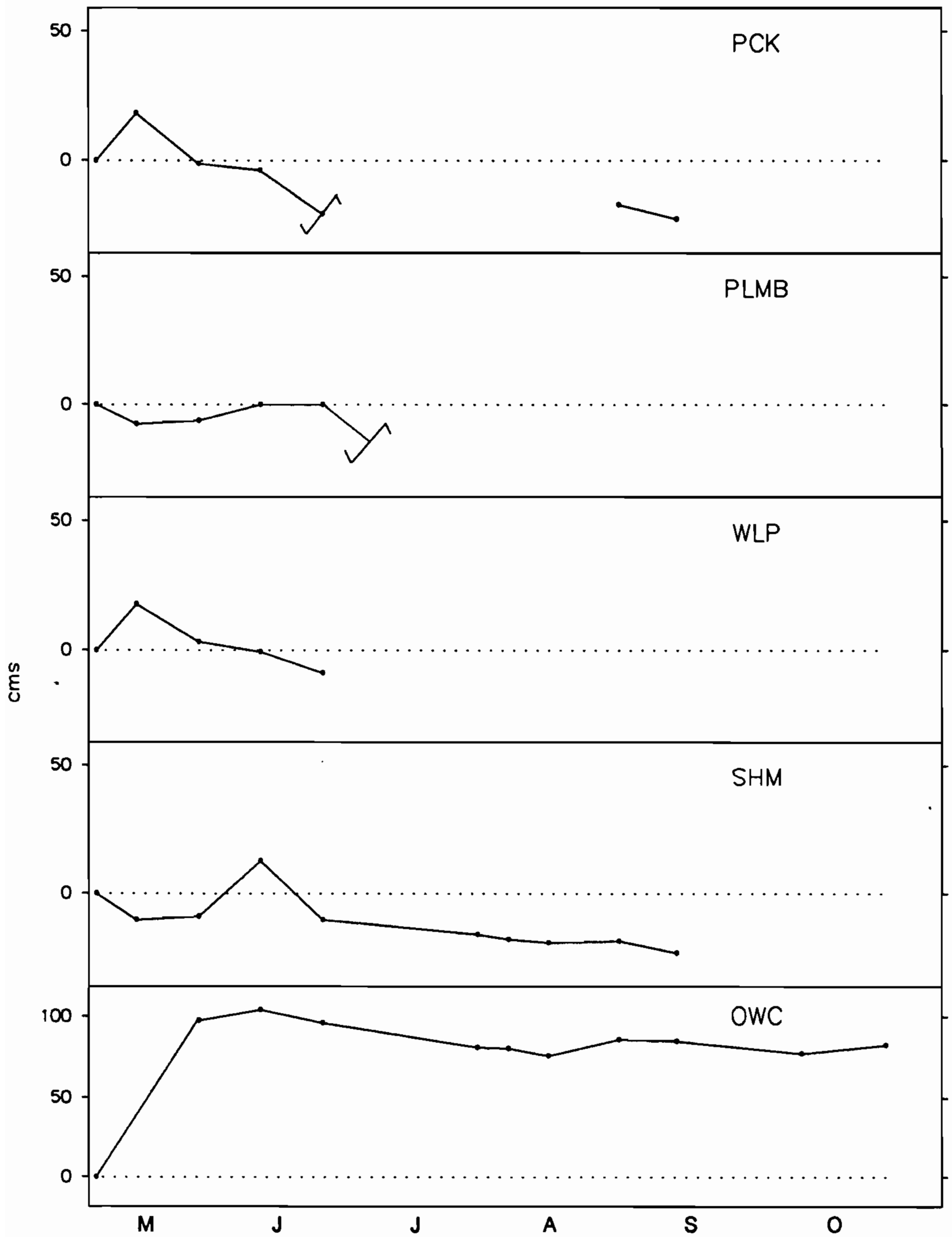

Figure 12. Water levels (relative to initial readings) for five undiked marshes in western Lake Erie.

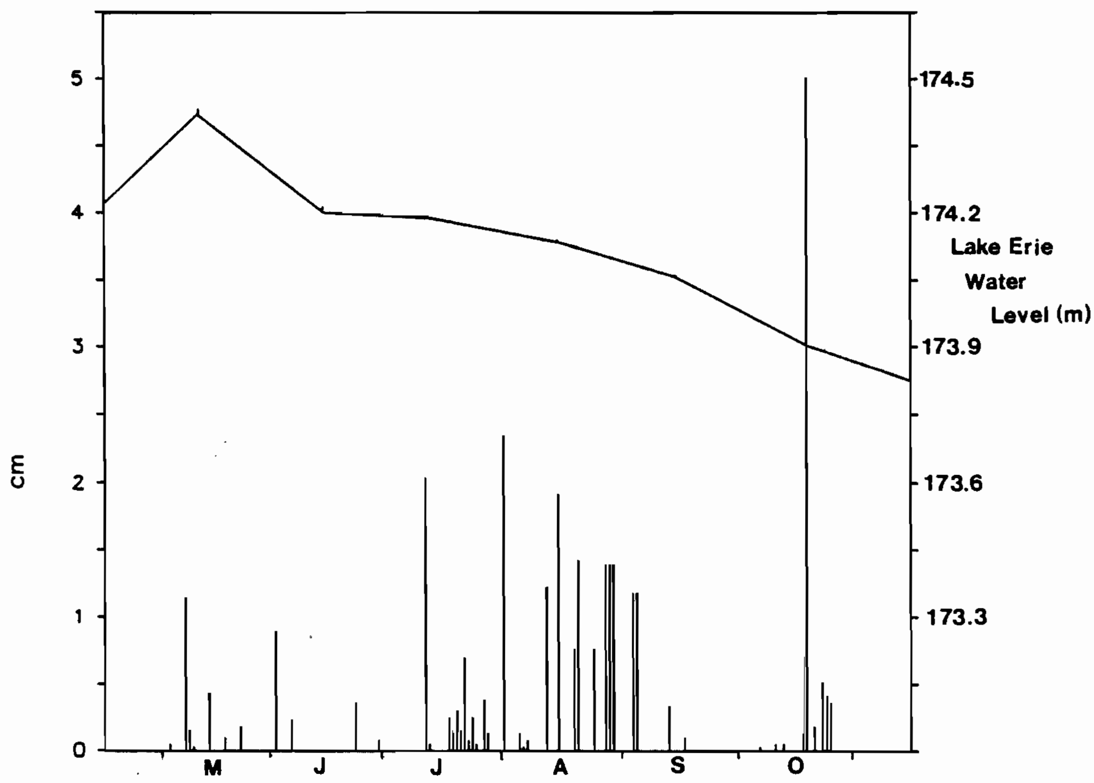

Figure 13. Precipitation at Old Woman Creek and Lake Erie water levels at Cleveland during study period (adapted from U.S. ACE 1989).

of depth could not be made. The water level in BVB continued to decline throughout the remainder of the study. There was still standing water within the arbitrary one meter distance defining the station boundary, however, from which to collect water samples from some of the stations. The pattern of BVB water fluctuations appeared to parallel BVC. The water levels in BVC decreased more than 20 cm by the June 25 sample date, rose 10 cm by July 30, and then decreased throughout the remainder of the season to have a net decrease of 15 cm (Fig. 11).

The marsh water levels for the Ottawa marshes parallel the pumping regime. Beginning June 19, 10 cm were pumped into the marshes and 10 cm were added every week thereafter until the third week of July. At that time, approximately 25 cm were added to OSCA and 33 to 36 cm to OSCB. Water level in OSCA decreased 13 cm from the beginning of this study until June 23, then increased until the end of the study to have a net increase of 11 cm (Fig. 11). OSCB water level decreased 14 cm until reaching a low point June 6, then gradually increased and peaked in early September. By the end of October, the water level decreased another 8 cm giving a 38 cm net increase (Fig. 11). OSCB exhibited larger changes than OSCA.

At the end of May, water was pumped from Sandusky Bay to WPN raising the water level approximately 15 cm. Beginning mid-June, approximately 5 cms were added to both WPN and WPW every two or three weeks for the remainder of the season. WPN experienced increasing water levels throughout the study with a net increase of approximately 43 cm (Fig. 11). The water level in WPW decreased approximately 18 cm until mid-June, increased correspondingly as water was pumped in from Sandusky Bay, continuing to increase until the last week of August (Fig. 11). At that time, the water level stabilized through the end of October, causing a net increase of approximately 15 cm over the study period.

Undiked Marshes

PCK water level had increased approximately 18 cm when measured May 14 and was back at slightly less than initial water level by May 28 (Fig. 12). This was likely caused by a seiche as WLP, which was sampled the same day, exhibited the same pattern; while SHM and PLMB, which were sampled two days before, exhibited inverse patterns to PCK and WLP. The water decreased to below registered levels for PCK by the end of June, and continued to decline. Rains at the end of August raised the water level enough to register a reading on August 27, but then declined again prohibiting further water collection.

PLMB water level decreased approximately 8 cm by May 12, then increased throughout June. This decrease may be the result of seiche activity. Water levels decreased enough during July to prohibit further sampling by the end of July.

WLP water levels exhibited the same general pattern as PCK (Fig. 12). An initial increase of 18 cm was followed by a steady decline until the end of June, after which time water levels could no longer be measured. A net decline of 9 cm was measured in the first two months of the study.

SHM water level decreased approximately 10 cm in May, then increased 20 cm by the end of July (Fig. 12). The water level subsequently dropped 20 cm again by August 3 and declined the remainder of the study for a net loss of 23 cm.

OWC water levels are greatly influenced by the barrier beach that alternately blocks the only outlet, depending on hydrologic conditions. The beach had been closed for two weeks prior to the first sample date on May 9 but re-opened during a rain storm that day. However, it closed by May 14 and remained closed for the remainder of the study. The water level rose a total of 104 cm until early June as water flowed into the closed system from the watershed; however, as the drought increased and base flow of the creek was reduced to a minimum, the water level decreased until the end of August (Fig. 12). The water level increased slightly due to the end of August rain.

WATER CHEMISTRY

Water chemistry data for each parameter are presented in two ways. To answer the initial hypothesis of diked versus undiked marshes, the marsh data are averaged together within each group to get overall diked averages and undiked averages per sample date. R^2 values reported in the tables for each parameter indicate that a large proportion of the total variation in the system was accounted for by the ANOVA and GLS models. The stations within marshes are then averaged to obtain marsh averages and examine temporal changes for each parameter for each marsh. Individual station data are presented in Appendix A.

pH - The pH values for the undiked marshes were significantly higher than the diked marshes at 8.10 and 7.67, respectively, and also changed differently over time (Table 6). The diked marshes showed a general decreasing pH trend over time while the undiked marshes fluctuated more and increased over time. The high variability among the six diked marshes and among the five undiked marshes resulted in insignificant differences when extrapolated to all Lake Erie marshes.

Figures 14 and 15 show pH values for each marsh during the study. With the exception of OSCB which averaged 8.06, the undiked marshes all averaged higher pH values (7.87 to 8.10) than the diked marshes (7.30 to 7.83). In general, the diked marshes had fairly consistent pH readings exhibiting an overall decline, while the undiked marshes fluctuated more. SHM showed a definitive increase by the end of October.

Alkalinity - Table 7 shows significantly higher alkalinity measured in the diked marshes compared to the undiked marshes in this study. On a lakewide basis, however, diked and undiked marshes were not significantly different. The two types of

Table 6. pH least square means and ANOVA[a] values for diked and undiked marshes.

Sample Date	Diked	Undiked	Overall
May 9-14	8.23	7.98	8.11
May 23-28	7.70	7.93	7.82
June 6-11	7.88	7.98	7.94
June 20-25	8.04	7.65	7.85
July 25-30	7.72	8.13	7.96
August 3	7.41	8.39	7.90
August 11-14	7.76	7.83	7.85
August 27-29	7.60	7.84	7.74
Sept. 10-11	7.63	8.47	8.11
October 8	----	7.85	7.85
October 26-28	7.32	8.15	7.79
MEAN	7.67	8.10	

ANOVA Values For Study

Source	df	Type III SS	F-value
Diked$_s$ vs. Undiked$_s$	1	1.51	15.05**
Marsh(Diked)	9	3.34	3.70**
Date	10	1.57	1.57
Diked*Date	9	2.49	2.76**
Residual	58	5.81	

ANOVA Values For Lake Erie

Diked$_t$ vs. Undiked$_t$	1	1.51	4.06

a $R^2 = .59$
** $p < .01$

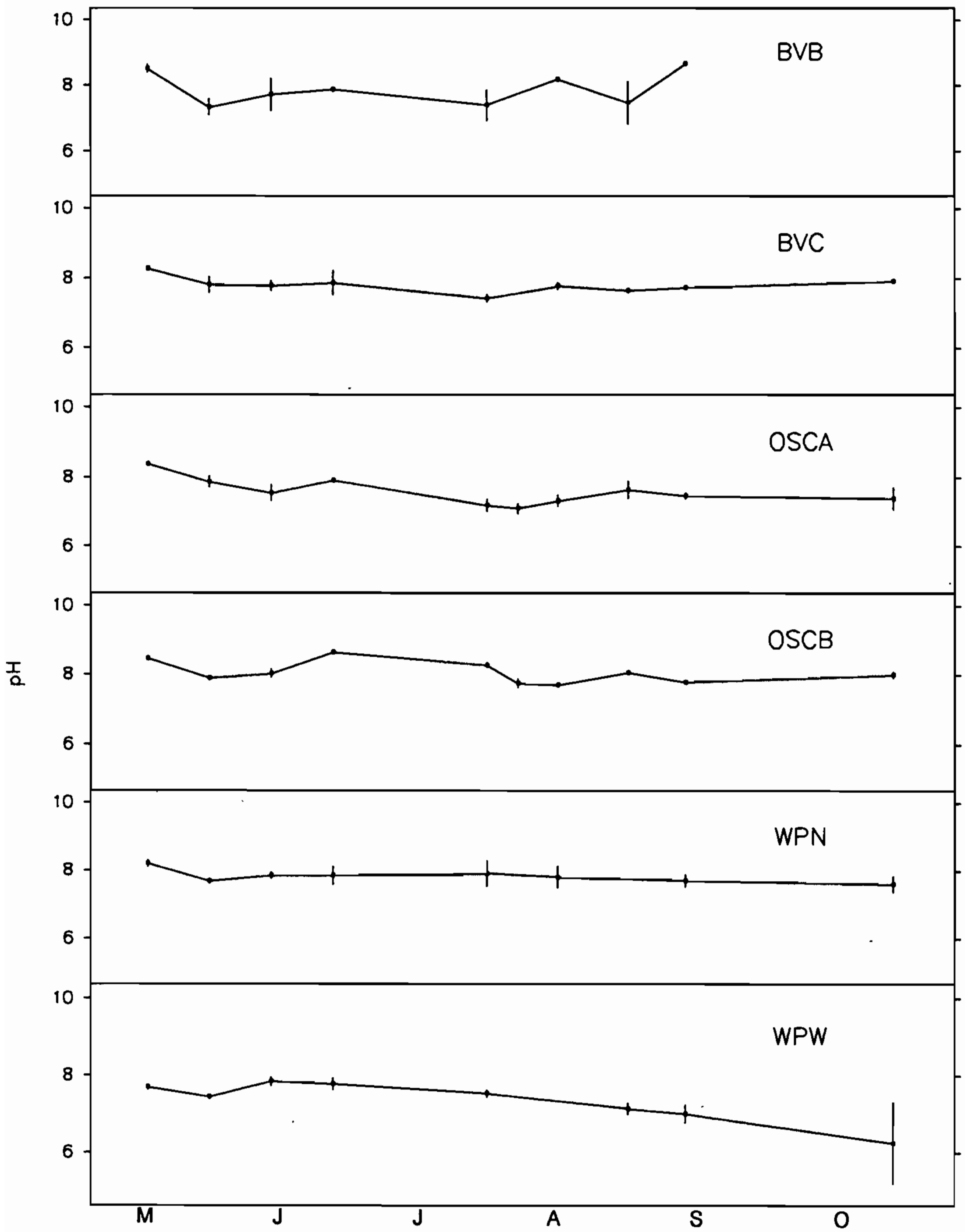

Figure 14. pH means and standard error bars for six diked marshes in western Lake Erie.

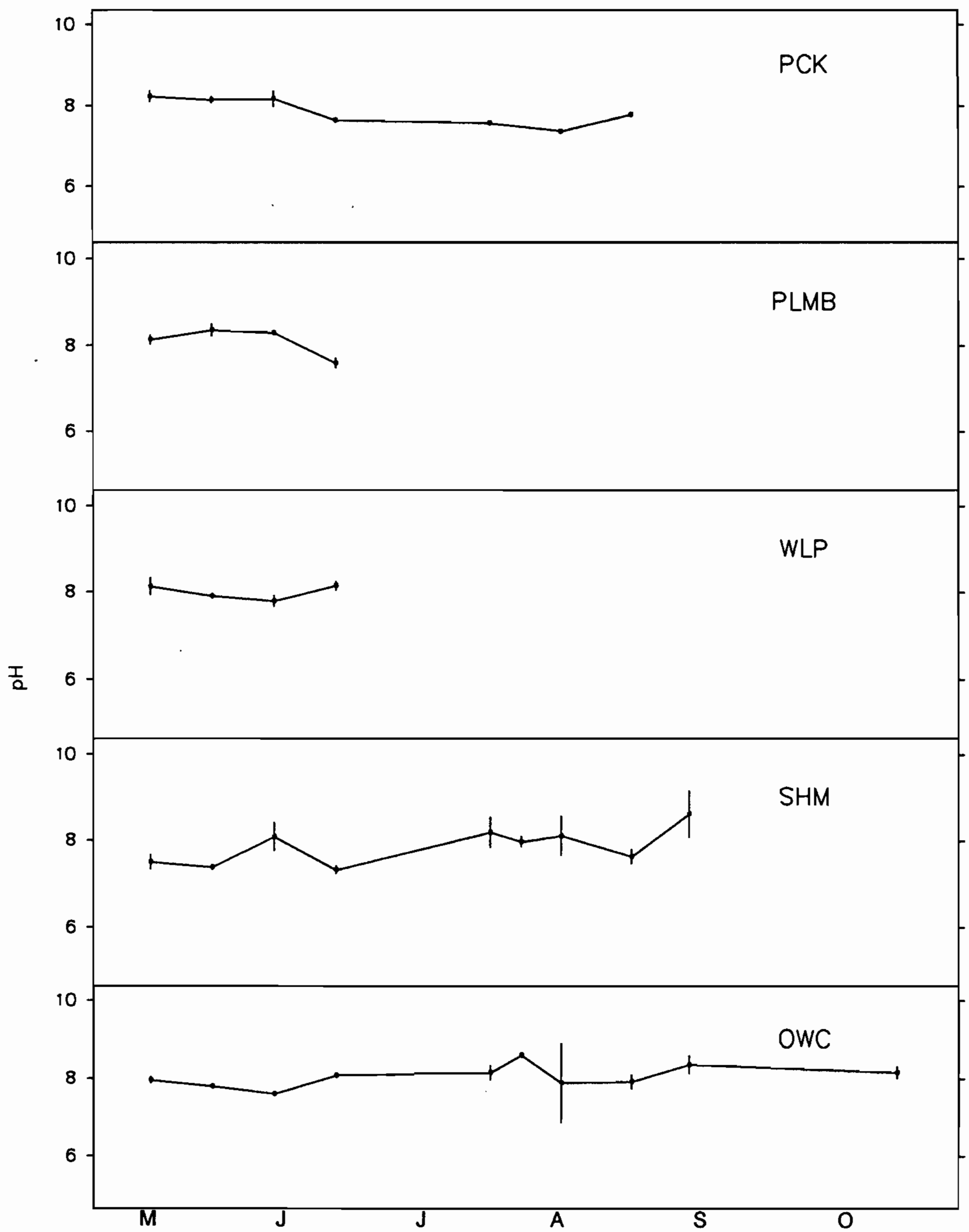

Figure 15. pH means and standard error bars for five undiked marshes in western Lake Erie.

Table 7. Alkalinity least square means (mg $CaCO_3$/l) and GLS[a] values for diked and undiked marshes.

Sample Date	Diked	Undiked	Overall
May 9-14	197	123	160
May 23-28	190	123	156
June 6-11	177	112	144
June 20-25	181	142	161
July 25-30	139	168	150
August 3	147	165	156
August 11-14	161	152	155
August 27-29	149	130	138
Sept. 10-11	156	124	137
October 8	128	156	128
October 26-28	155	141	144
MEAN	161	131	

GLS Values For Study

Source	df	Type III SS	F-value
$Diked_s$ vs. $Undiked_s$	1	14	19.78**
Marsh(Diked)	9	134	20.51**
Date	10	33	4.61**
Diked*Date	9	53	8.13**
Residual	275	199	

GLS Values For Lake Erie

$Diked_t$ vs. $Undiked_t$	1	14	0.96

[a] $R^2 = .70$

** $p < .01$

marshes also changed differently over time, with the diked marshes beginning high, decreasing to a low at the end of July, then becoming variable. Undiked marshes started out low, peaked the end of July, and decreased to a mid-point between the high and low.

Alkalinity ranged from 127 to 232 mg $CaCO_3$/l for diked marshes and from 112 to 145 mg/l for undiked (Figure 16 and 17). The highest readings occurred either the second week in May or the third week in June for nine out of the eleven marshes. Some trends for individual marshes were evident. BVC and WPN both behaved similarly with a gradually decreasing trend. OSCA and WPW also had a similar curve. WLP had a decreasing trend, while PCK had an increasing trend.

<u>Conductivity</u> - Conductivity differences between diked (ave.=1,053 µmhos) and undiked (ave.=766 µmhos) marshes were statistically significant (Table 8). Diked marshes were not significantly different from undiked marshes in the lakewide population due to the high variability between the marshes within each group. Conductivity did not show the same seasonal trend for the diked marshes as for the undiked marshes. The diked marshes increased from 1,062 to 1,409 µmhos by the third week in June, decreased to a low of 880 µmhos by the second week of September, and increased to 1,056 µmhos by the end of October. The undiked group had erratic swings throughout the study with no apparent pattern.

All diked marshes except WPN and WPW exhibited the same general pattern, with the highest conductivity the third week in June and the lowest during the second week in September (Fig. 18). Conductivity values measured in WPN and WPW remained consistent, but conductivity for WPW increased dramatically in late October (reflecting a reading of 3,984 µmhos for station 1). Conductivity levels remained fairly constant at PLMB, SHM, and OWC through the study period (Fig. 19). Levels at these three marshes were considerably lower than those recorded at the other undiked

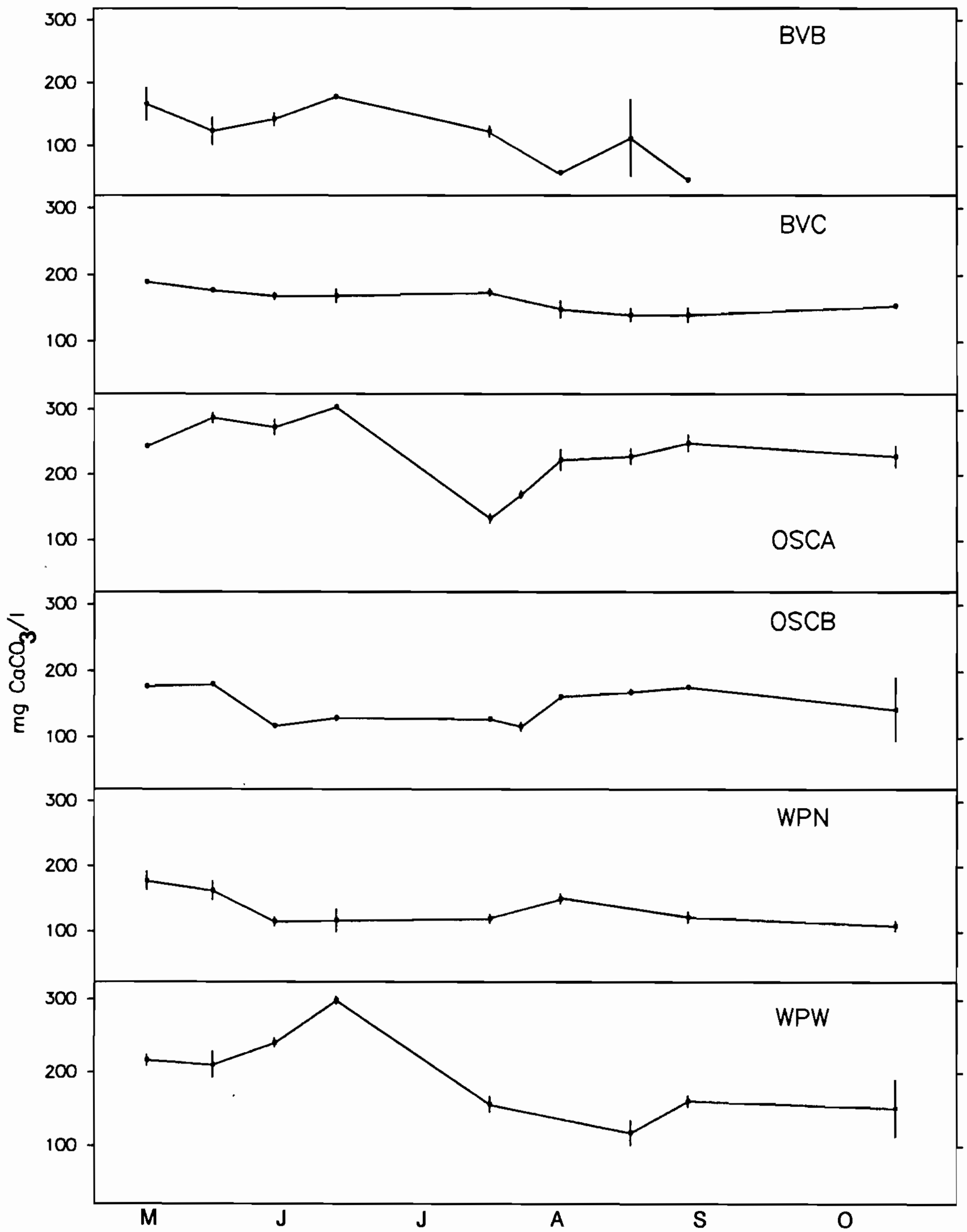

Figure 16. Alkalinity means and standard error bars for six diked marshes in western Lake Erie.

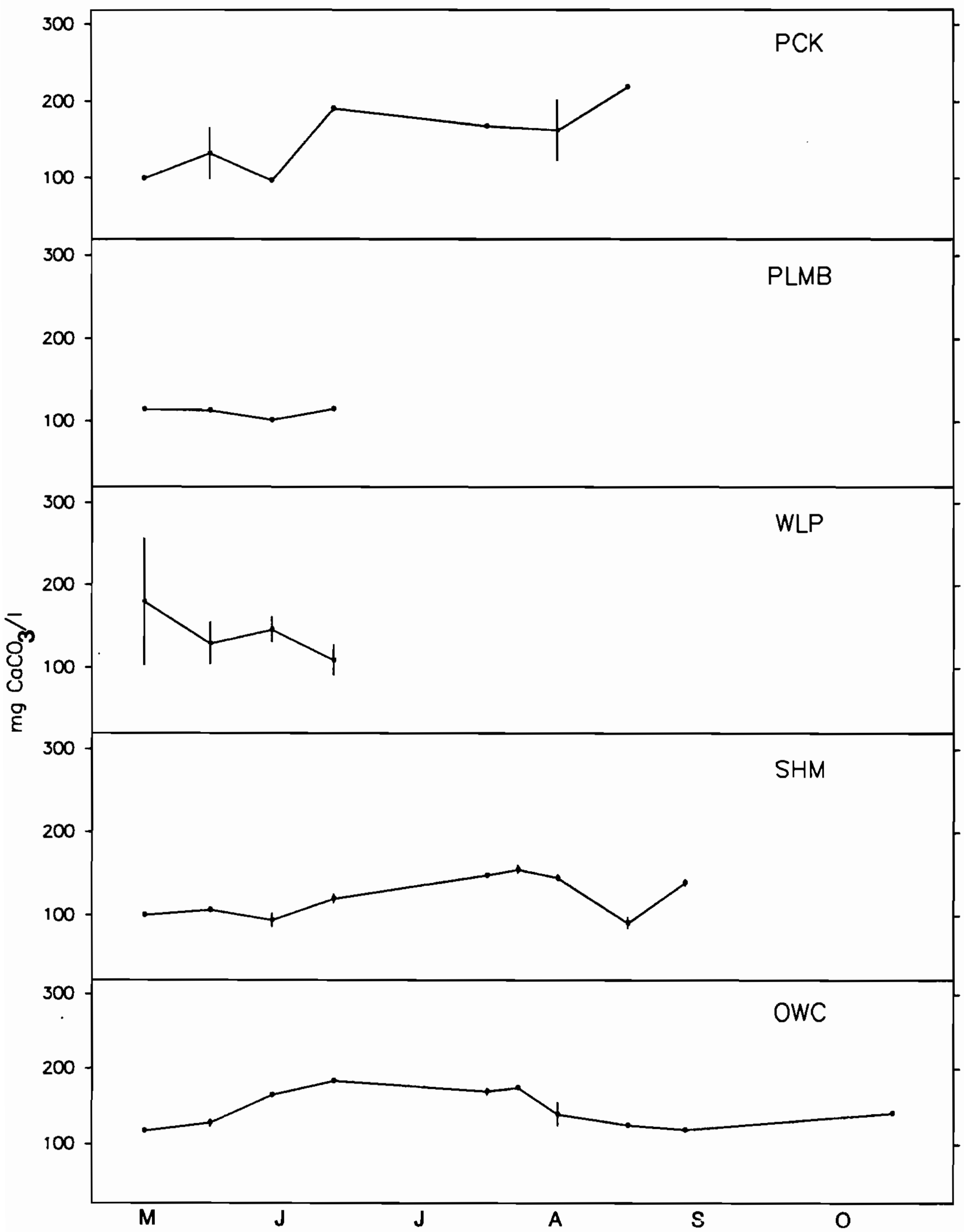

Figure 17. Alkalinity means and standard error bars for five undiked marshes in western Lake Erie.

Table 8. Conductivity least square means (µmhos/cm corrected to 25 °C) and ANOVA[a] values for diked and undiked marshes.

Sample Date	Diked	Undiked	Overall
May 9-14	1062	638	845
May 23-28	1129	724	923
June 6-11	1220	609	912
June 20-25	1409	744	1076
July 25-30	1046	942	972
August 3	978	462	720
August 11-14	1008	960	992
August 27-29	995	848	915
Sept. 10-11	880	406	717
October 8	---	586	586
October 26-28	1056	528	835
MEAN	1053	766	

ANOVA Values For Study

Source	df	Type III SS	F-value
Diked$_s$ vs. Undiked$_s$	1	557162	8.81**
Marsh(Diked)	9	10573837	18.58**
Date	10	684301	1.08
Diked*Date	9	1348291	2.37*
Residual	58	3666956	

ANOVA Values For Lake Erie

Diked$_t$ vs. Undiked$_t$	1	557162	0.47

a $R^2=.81$
** $p < .01$
* $p < .05$

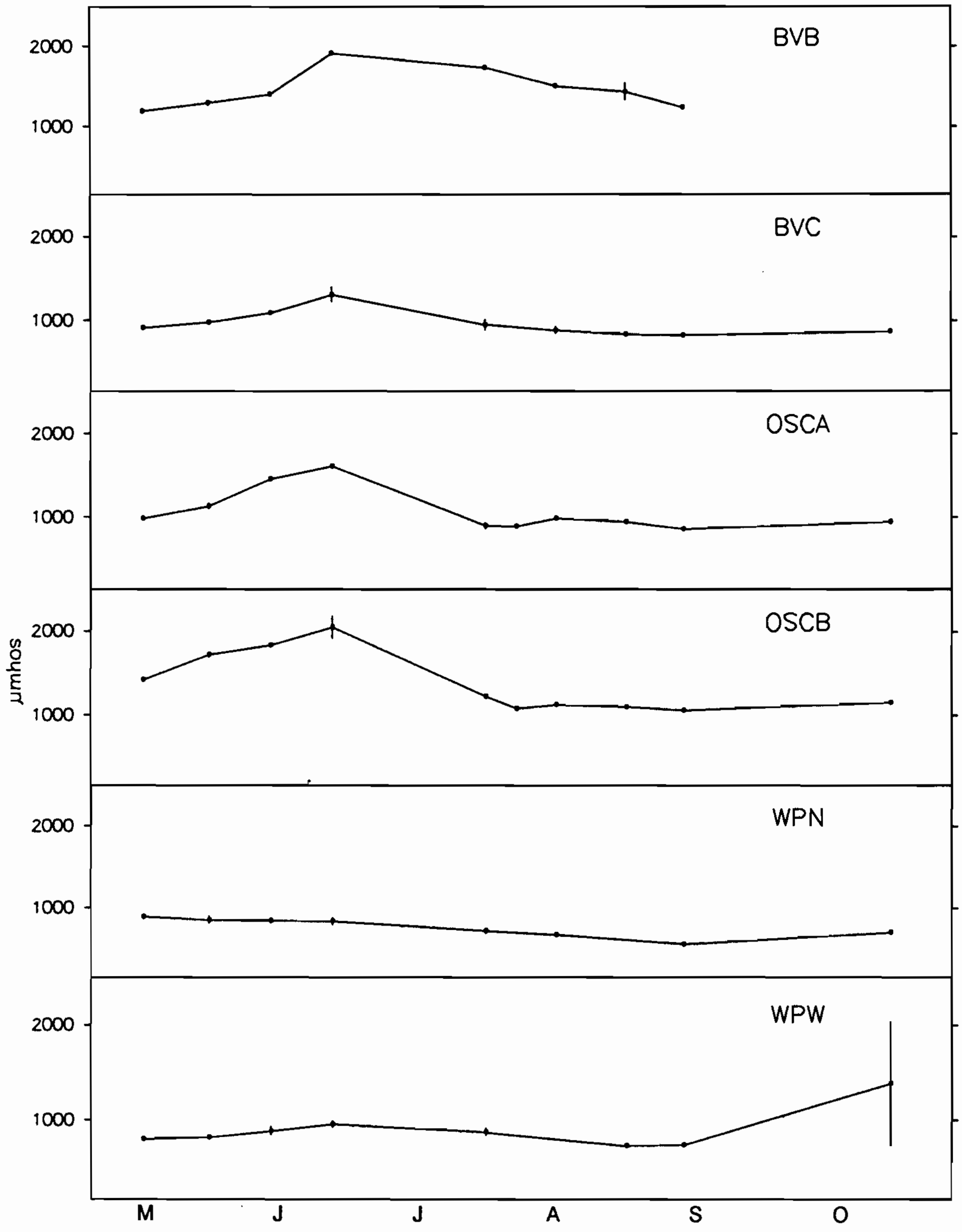

Figure 18. Conductivity means and standard error bars for six diked marshes in western Lake Erie.

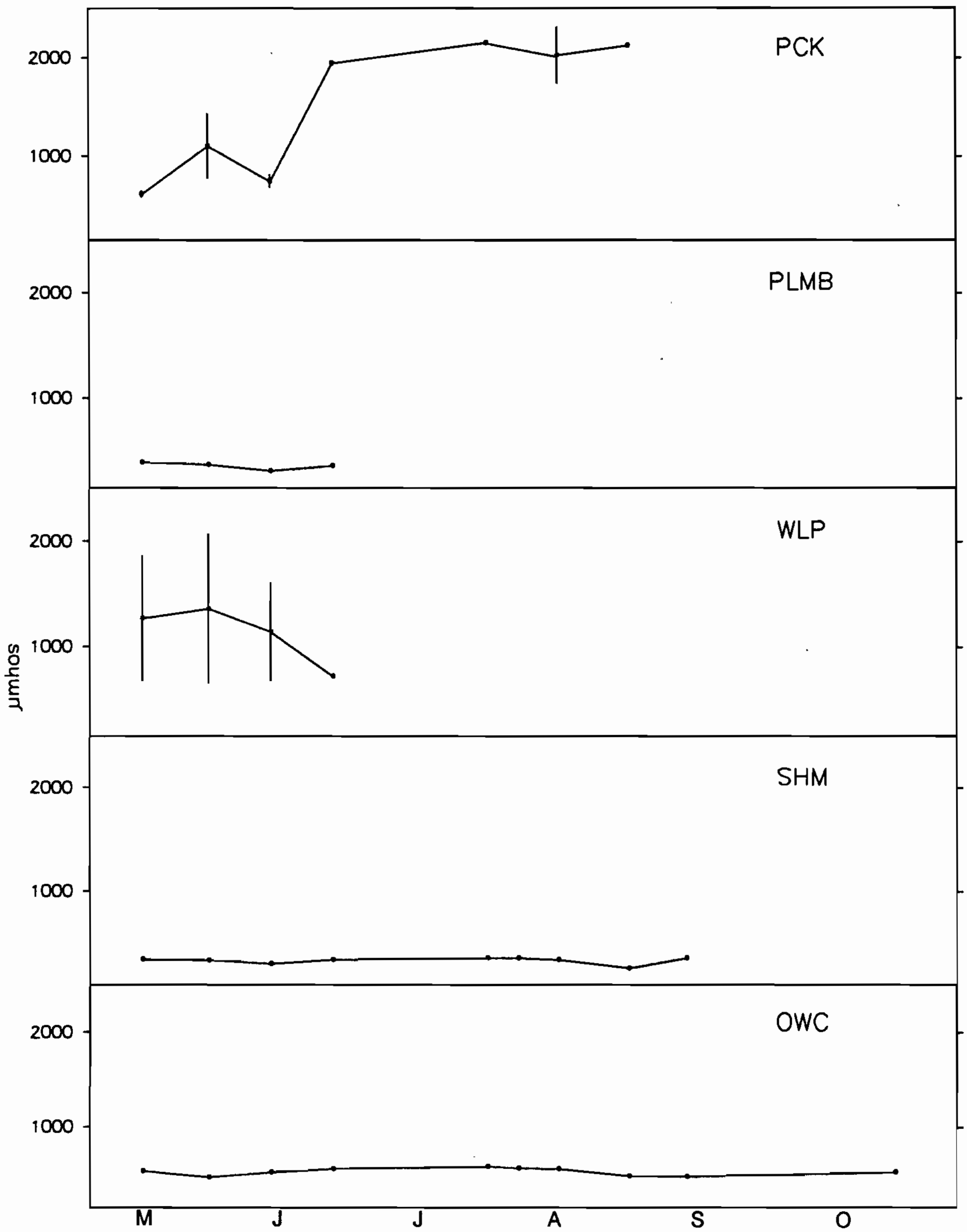

Figure 19. Conductivity means and standard error bars for five undiked marshes in western Lake Erie.

and diked marshes. Conductivity increased dramatically at Pickerel Creek (619 to 2,157 µmhos) throughout the study and decreased at Willow Point.

Turbidity - Turbidity was significantly higher for the undiked marshes in the study than for the diked marshes (Table 9). Again lakewide, diked and undiked marshes were not different. Turbidity significantly decreased over time, and both diked and undiked marshes followed that general trend.

Figures 20 and 21 show the turbidity trends for each marsh. In general, BVB and BVC had the lowest averages of all the marshes, with readings of 12 NTU and 13 NTU, respectively. WPN and WPW both averaged 25 NTU, and OSCA and OSCB were the highest of the diked marshes, with 60 and 42 NTU each. SHM had the lowest average of the undiked marshes, with 55 NTU, and PLMB had the highest average, 77 NTU. Diked marshes had fairly consistent trends with the exception of OSCA (the highest), which stayed high for four sampling periods and then declined. Except for OWC, where turbidity levels remained somewhat constant, the undiked marshes were variable throughout the study.

Nitrate + Nitrite - Diked marshes and undiked marshes were not different at either the study level or the Lake Erie ecosystem level for nitrate + nitrite (referred to as nitrate in the text) (Table 10). Measured nitrate values, however, were at the lower limits of detection. Nitrate decreased significantly during the study, and undiked marshes paralleled that decline. Diked marshes varied differently from the undiked, peaking during the end of May before decreasing throughout the remainder of the study.

The highest nitrate reading occurred during the last week in May for eight out of the eleven marshes (Fig. 22 and 23). In the other three marshes, the high occurred the second week in May. For the undiked marshes, the low value occurred either the third week in June or the last week in July. Nitrate in the diked marshes ranged from

Table 9. Turbidity least square means (NTU) and ANOVA[a] values for diked and undiked marshes.

Sample Date	Diked	Undiked	Overall
May 9-14	42	69	58
May 23-28	31	73	53
June 6-11	38	59	50
June 20-25	44	109	78
July 25-30	23	46	41
August 3	31	45	38
August 11-14	20	50	40
August 27-29	23	49	42
Sept. 10-11	22	45	42
October 8	--	50	50
October 26-28	23	37	38
MEAN	26	57	

ANOVA Values For Study

Source	df	Type III SS	F-value
$Diked_s$ vs. $Undiked_s$	1	6791	15.49**
Marsh(Diked)	9	18462	4.68**
Date	10	17288	3.94**
Diked*Date	9	1808	0.46
Residual	58	25433	

ANOVA Values For Lake Erie

$Diked_t$ vs. $Undiked_t$	1	6791	3.31

[a] R^2=.69
** $p < .01$

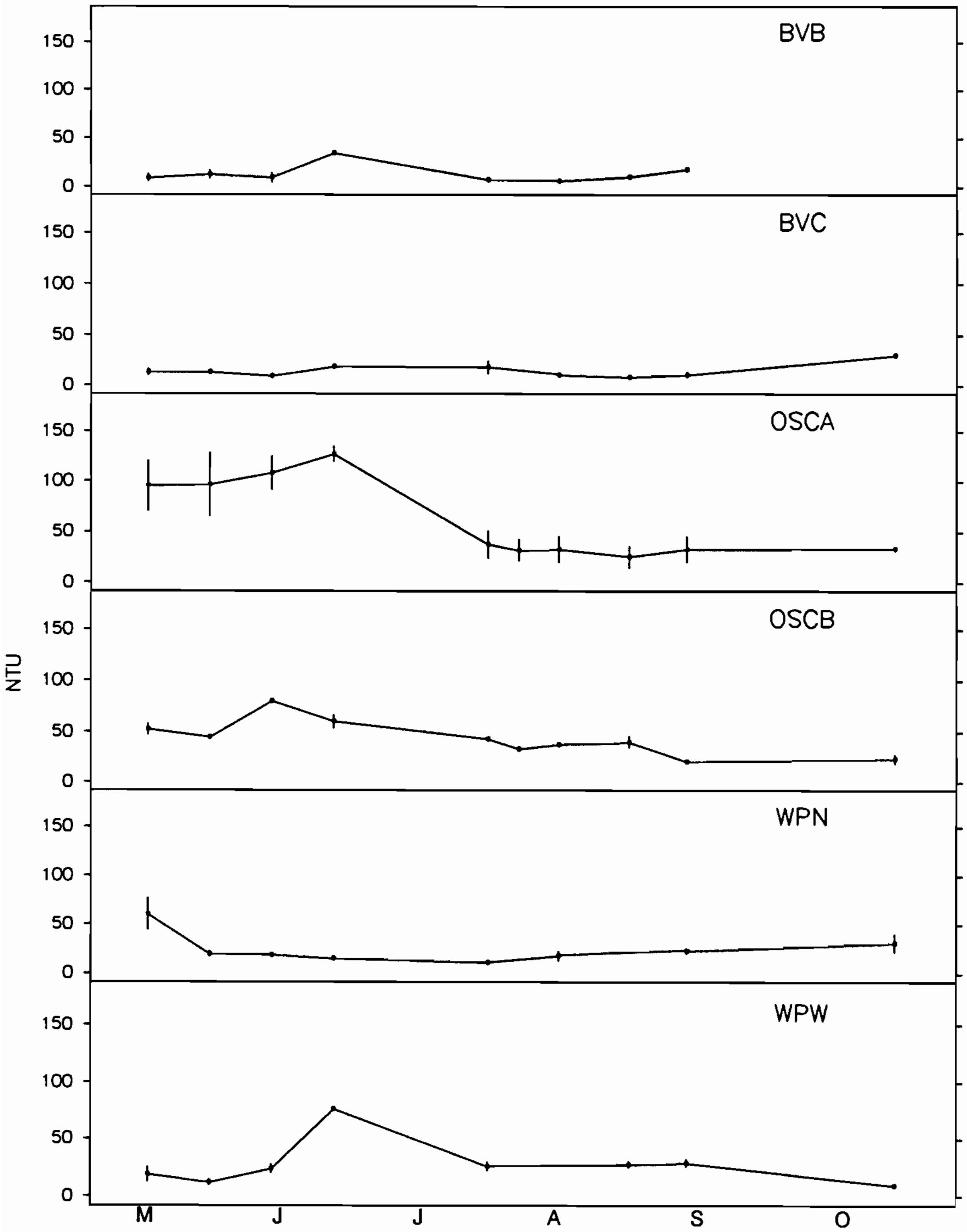

Figure 20. Turbidity means and standard error bars for six diked marshes in western Lake Erie.

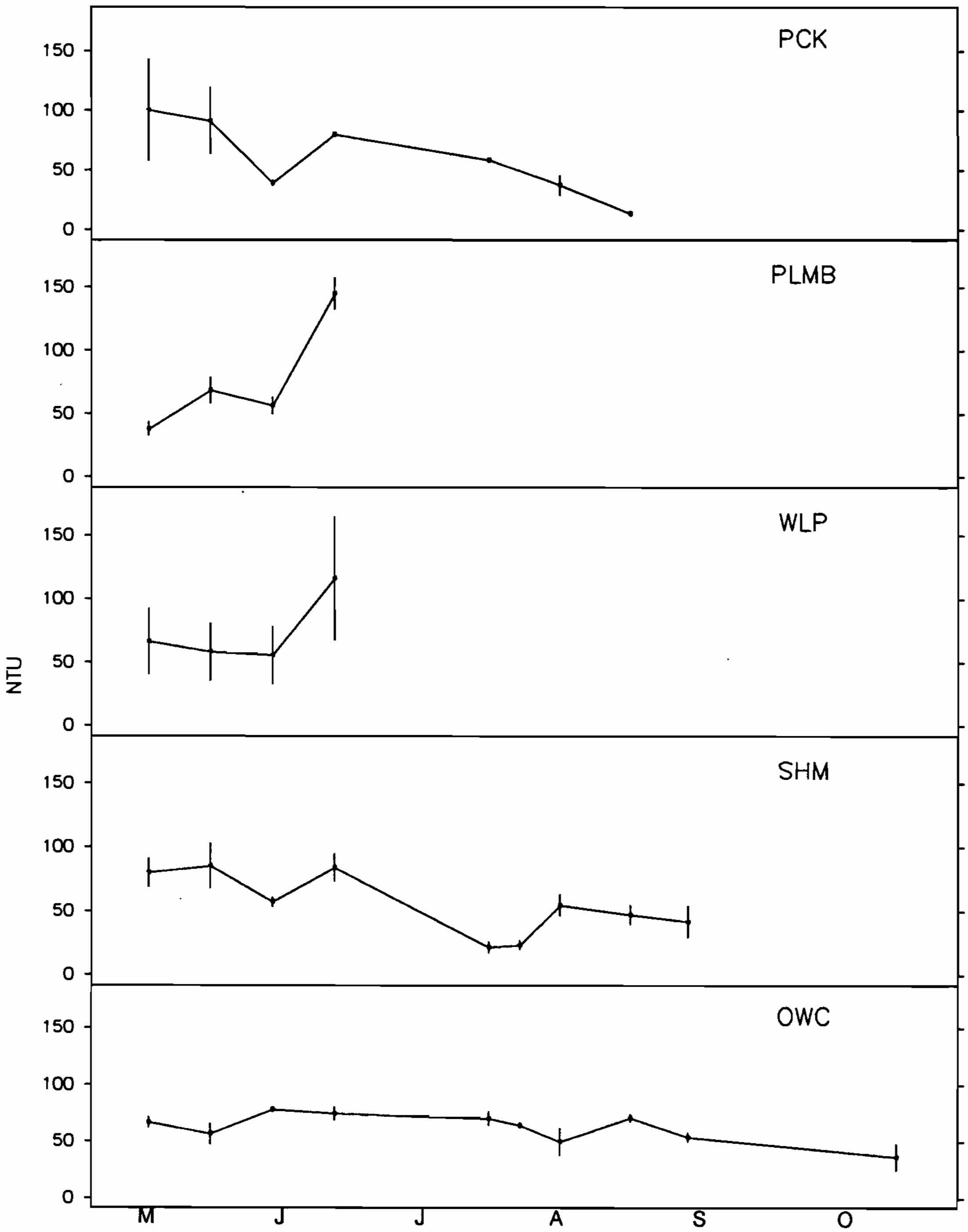

Figure 21. Turbidity means and standard error bars for five undiked marshes in western Lake Erie.

Table 10. Nitrate least square means (mg N/l) and ANOVA[a] values for diked and undiked marshes.

Sample Date	Diked	Undiked	Overall
May 9-14	0.29	0.79	0.54
May 23-28	0.82	0.72	0.77
June 6-11	0.51	0.48	0.49
June 20-25	0.34	0.13	0.23
July 25-30	0.18	0.14	0.15
August 3	0.17	0.12	0.15
August 11-14	0.21	0.22	0.21
August 27-29	0.20	0.26	0.23
Sept. 10-11	0.13	0.09	0.13
October 8	----	0.08	0.08
October 26-28	0.20	0.07	0.17
MEAN	0.33	0.36	

ANOVA Values For Study

Source	df	Type III SS	F-value
$Diked_s$ vs. $Undiked_s$	1	0.11	2.62
Marsh(Diked)	9	1.09	3.00**
Date	10	3.38	8.39**
Diked*Date	9	1.10	3.02**
Residual	58	2.34	

ANOVA Values For Lake Erie

$Diked_t$ vs. $Undiked_t$	1	0.11	0.87

[a] R^2=.75
** $p < .01$

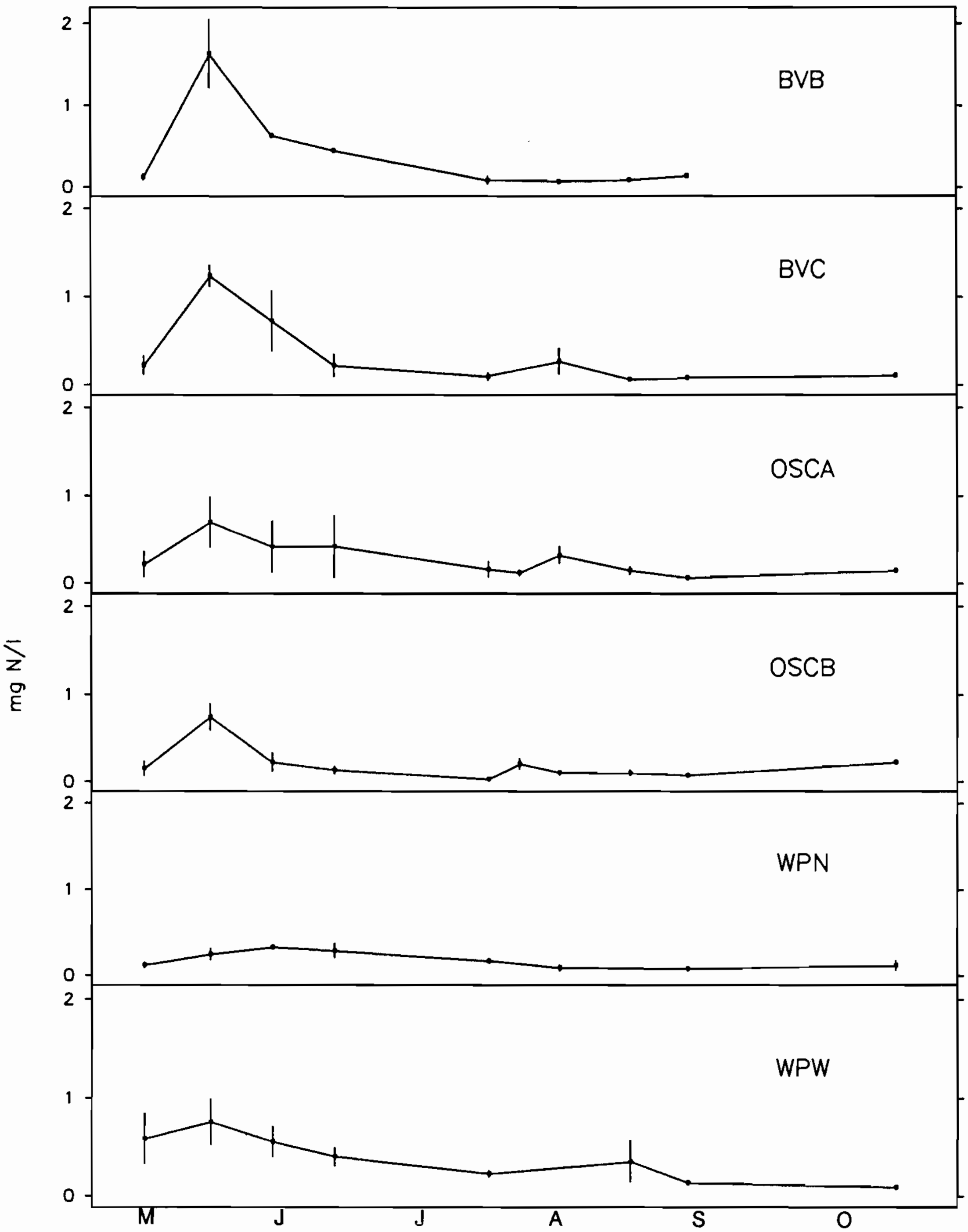

Figure 22. Nitrate means and standard error bars for six diked marshes in western Lake Erie.

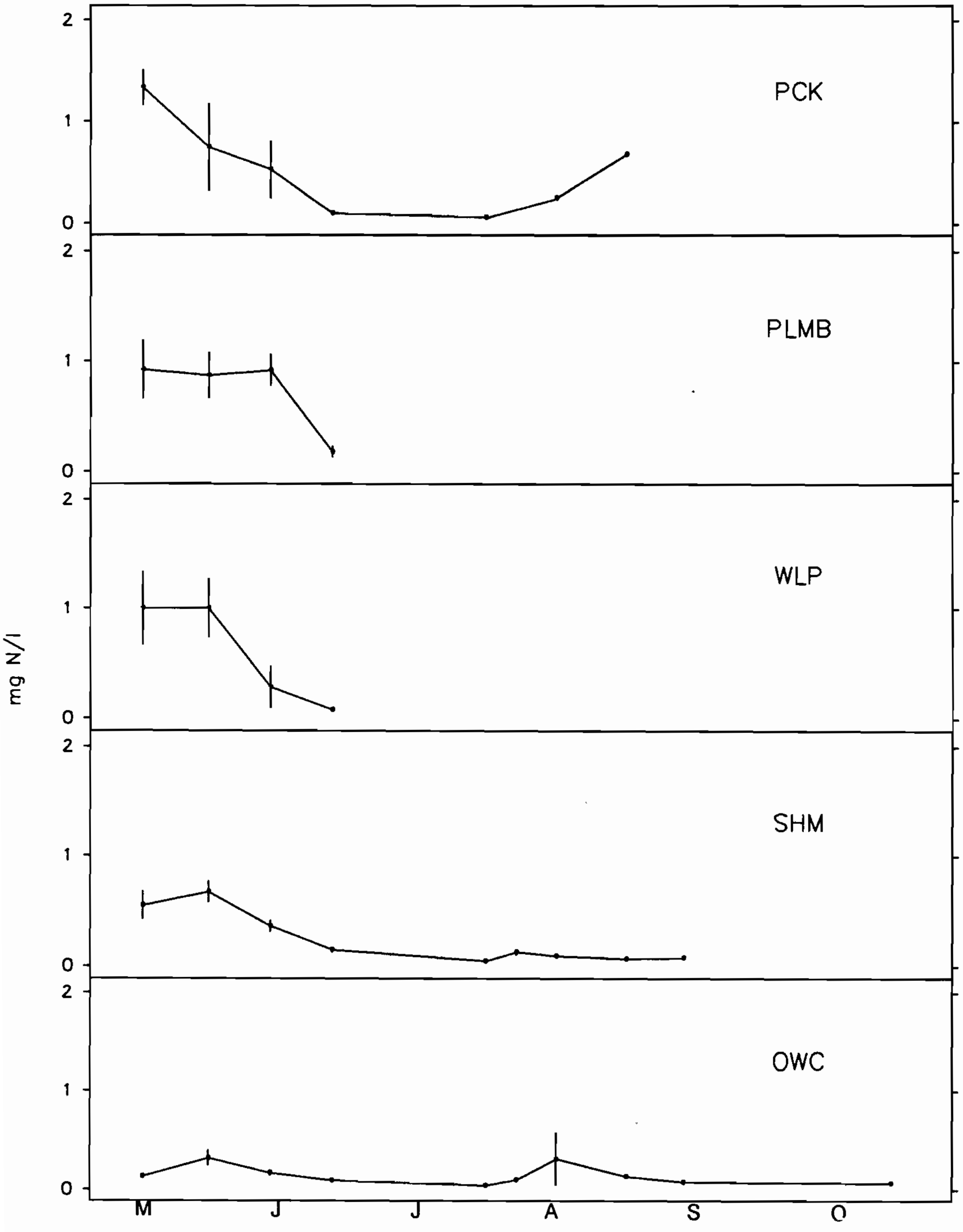

Figure 23. Nitrate means and standard error bars for five undiked marshes in western Lake Erie.

0.18 (WPN) to 0.51 mg N/l (BVB). SHM and OWC had the lowest nitrate averages for the undiked marshes, with 0.25 and 0.12 mg N/l, respectively. The other undiked marshes ranged from 0.59 to 0.73 mg N/l. In general, the most variation in nitrate levels occurred in May and June and after that remained low and consistent. Pickerel Creek nitrate, however, did increase the first two weeks of August and OWC had a slight increase the second week of August.

Nitrite - Undiked marshes in the study had significantly higher nitrite values than diked marshes (Table 11). The undiked marshes had two sampling dates, one during the second week of May and the other the last week of August, in which nitrites were considerably above average. Nitrites were also higher for the undiked marshes through the end of July, after which time they were more consistent with the diked marshes. Nitrite values for diked and undiked marshes in western Lake Erie were not significantly different.

Nitrite averaged between 2 and 4 µg N/l for diked marshes and 5 to 11 µg N/l for undiked marshes (Fig. 24 and 25). The highest nitrite values occurred the second week in September for half of the diked marshes. In three of the five undiked marshes and one of the diked marshes, the highest nitrite reading occurred the second week in May, during which time, conversely, the lowest values occurred for three of the diked marshes. Nitrite had an increasing trend for OSCB, BVB, and BVC, and had no discernable trend for the other diked marshes. The undiked marshes generally started out high and then decreased throughout the study period, with the exception of PLMB and OWC, both of which peaked the end of August.

Ammonia - Ammonia values for diked and undiked marshes in this study showed the same seasonal decreasing trends (Table 12). They were not significantly different in the study nor when extrapolated regionally. Ammonia values were at lower limits of detection and exhibited the same trends as nitrate.

Table 11. Nitrite least square means (µg N/l) and GLS[a] values for diked and undiked marshes.

Sample Date	Diked	Undiked	Overall
May 9-14	3	15	9
May 23-28	2	7	5
June 6-11	3	7	5
June 20-25	3	6	5
July 25-30	2	9	4
August 3	4	4	4
August 11-14	3	4	4
August 27-29	3	17	10
Sept. 10-11	6	4	6
October 8	-	3	3
October 26-28	5	3	5
MEAN	3	6	

GLS Values For Study

Source	df	Type III SS	F-value
$Diked_s$ vs. $Undiked_s$	1	4	4.95*
Marsh(Diked)	9	37	5.45**
Date	10	29	3.78**
Diked*Date	9	49	7.14**
Residual	248	188	

GLS Values For Lake Erie

$Diked_t$ vs. $Undiked_t$	1	4	0.91

[a] R^2=.48
** $p < .01$
* $p < .05$

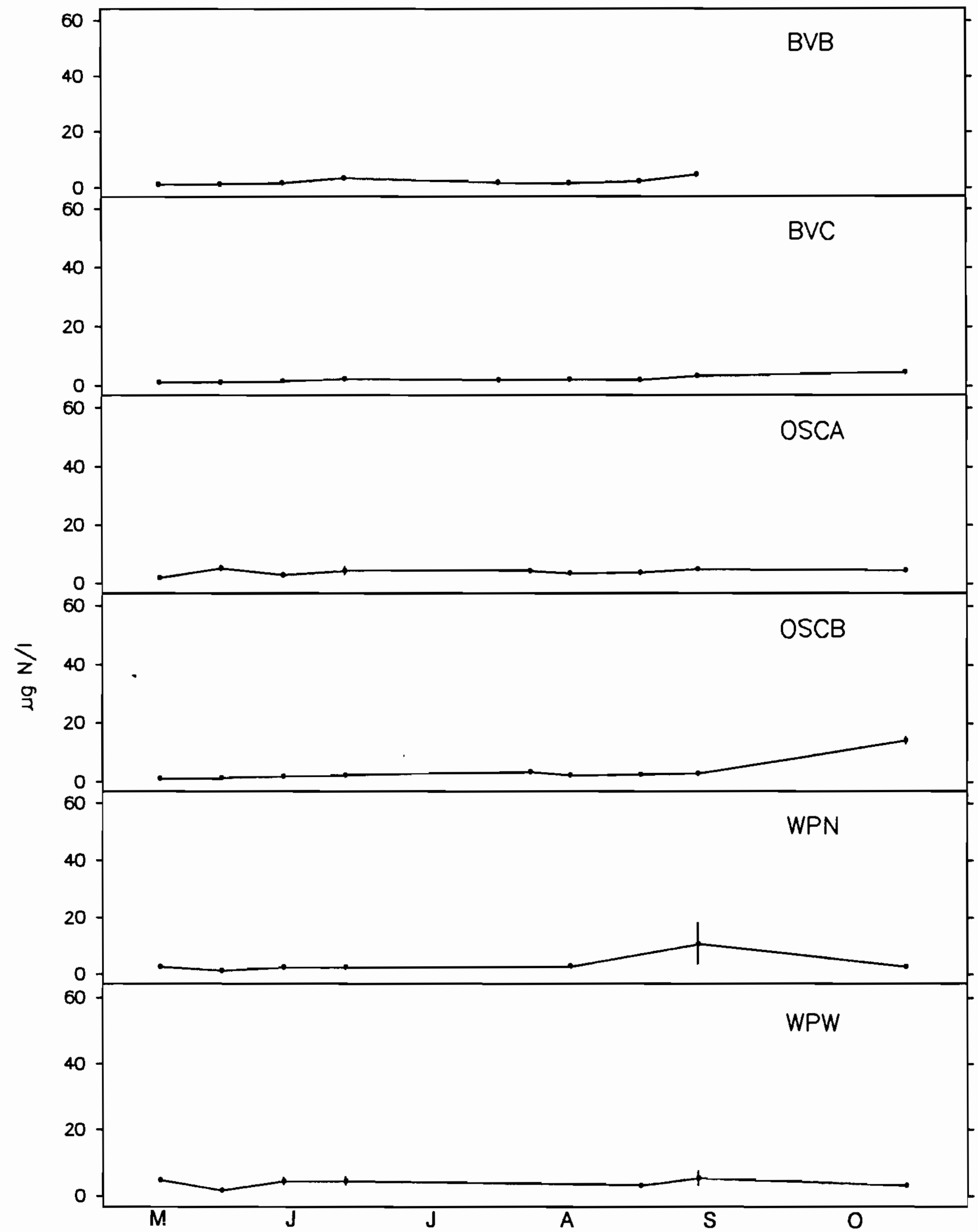

Figure 24. Nitrite means and standard error bars for six diked marshes in western Lake Erie.

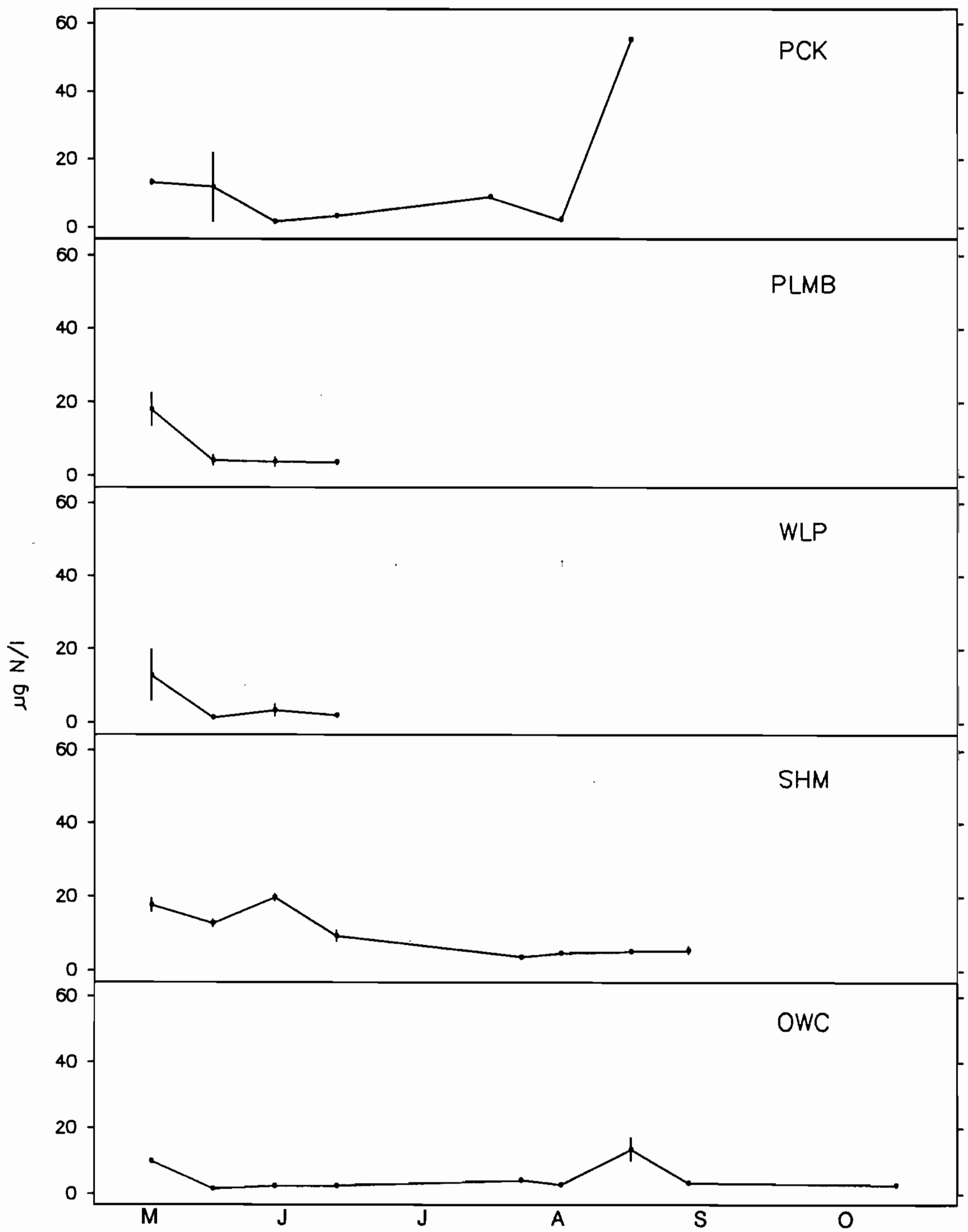

Figure 25. Nitrite means and standard error bars for five undiked marshes in western Lake Erie.

Table 12. Ammonia least square means (mg N/l) and ANOVA[a] values for diked and undiked marshes.

Sample Date	Diked	Undiked	Overall
May 9-14	0.08	0.13	0.11
May 23-28	0.14	0.15	0.15
June 6-11	0.04	0.09	0.07
June 20-25	0.03	0.03	0.03
July 25-30	0.01	0.00	0.01
August 3	0.01	0.00	0.00
August 11-14	0.02	0.02	0.02
August 27-29	0.01	0.05	0.03
Sept. 10-11	0.03	0.02	0.02
October 8	----	0.00	0.00
October 26-28	0.04	0.02	0.03
MEAN	0.05	0.04	

ANOVA Values For Study

Source	df	Type III SS	F-value
Diked$_s$ vs. Undiked$_s$	1	0.00	0.00
Marsh(Diked)	9	0.04	2.02*
Date	10	0.18	9.01**
Diked*Date	9	0.02	1.28
Residual	58	0.12	

ANOVA Values For Lake Erie

Diked$_t$ vs. Undiked$_t$	1	0.00	0.00

[a] $R^2=.68$
** $p < .01$
* $p < .05$

Generally, the ammonia readings for most of the marshes were higher in May, decreased through July and then some of the marshes increased slightly in September (Fig. 26 and 27). Eight of the eleven marshes peaked the last week in May and the other three peaked the second week in May. Ammonia readings declined to levels at or near the lower limits of detection for the remainder of the study. Diked marshes ranged from 0.03 mg N/l to 0.05 mg/l with the exception of BVB, which had an average ammonia reading of 0.11 mg/l (primarily from station 1, which increased to 0.55 mg/l the last week in May) (Appendix A). Undiked marshes ranged from 0.06 mg/l to 0.16 mg/l, with the exception of OWC, which averaged 0.04 mg/l.

Orthophosphate - Diked marshes had significantly higher orthophosphate values than undiked marshes in this study, but were not found to be significantly different in all Lake Erie marshes due to the high variability among marshes (Table 13). Both types of marshes showed the same seasonal trend and high values (double their mean) were measured the week of August 11.

Individual marshes exhibited some unusual patterns for orthophosphate (Fig. 28 and 29). Diked marshes fell into three groups: BVC was low with an average value of 15 µg P/l, BVB and OSCB were in the middle range with averages of 43 and 41 µg/l, respectively, and the others had higher ranges (84 µg/l to 139 µg/l). Undiked marshes divided into two groups: SHM and WLP were higher with averages of 81 µg/l and 83 µg/l, respectively, while the other marshes were lower with ranges of 11 µg/l to 27 µg/l.

Orthophosphates peaked during May in four diked and one undiked marsh and peaked the second week of August in three undiked and one diked marsh. OSCB, BVC, PCK, PLMB, and OWC remained low and consistent throughout the study. Orthophosphate readings for OSCA and SHM stayed low through the end of July then increased in August before declining again.

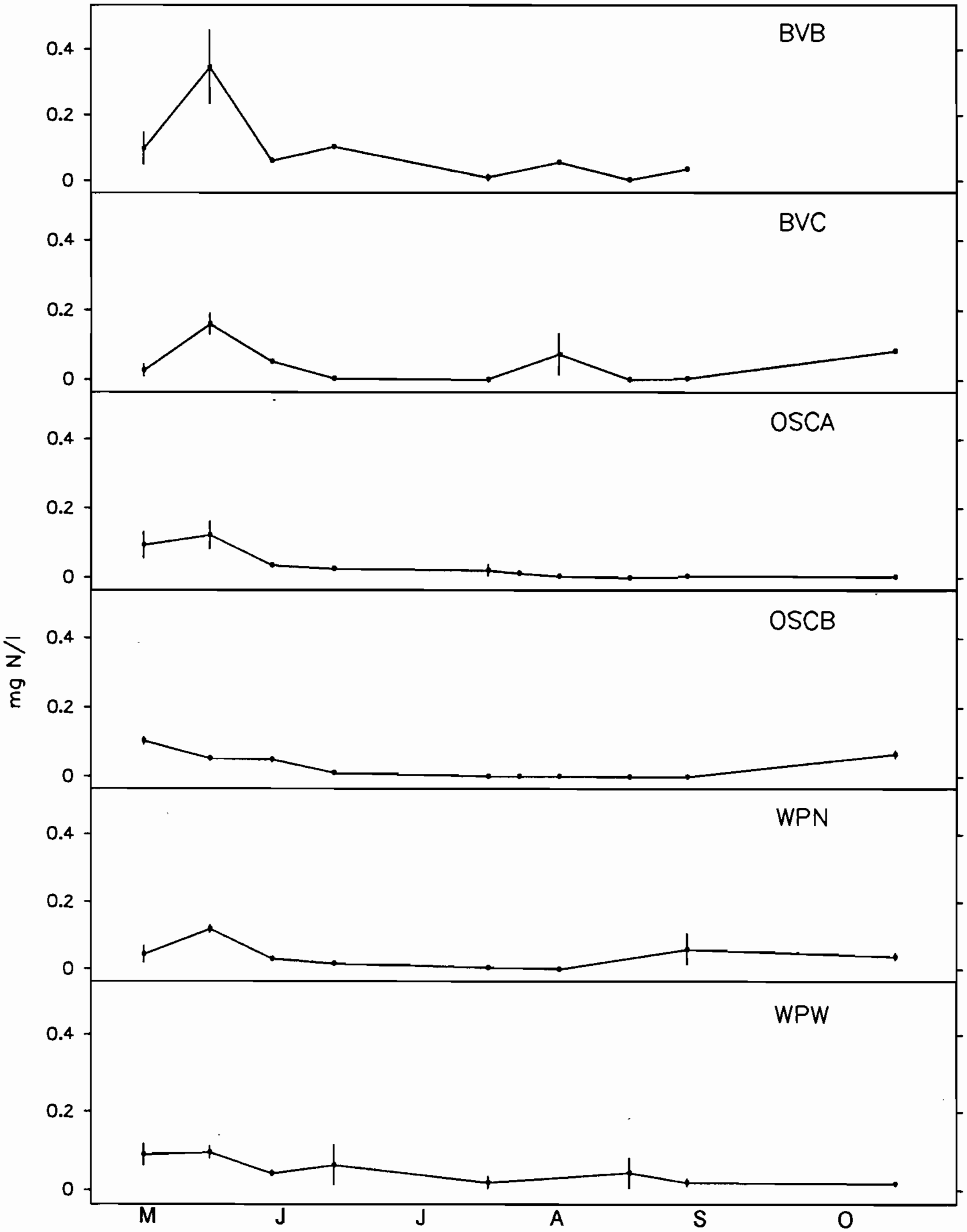

Figure 26. Ammonia means and standard error bars for six diked marshes in western Lake Erie.

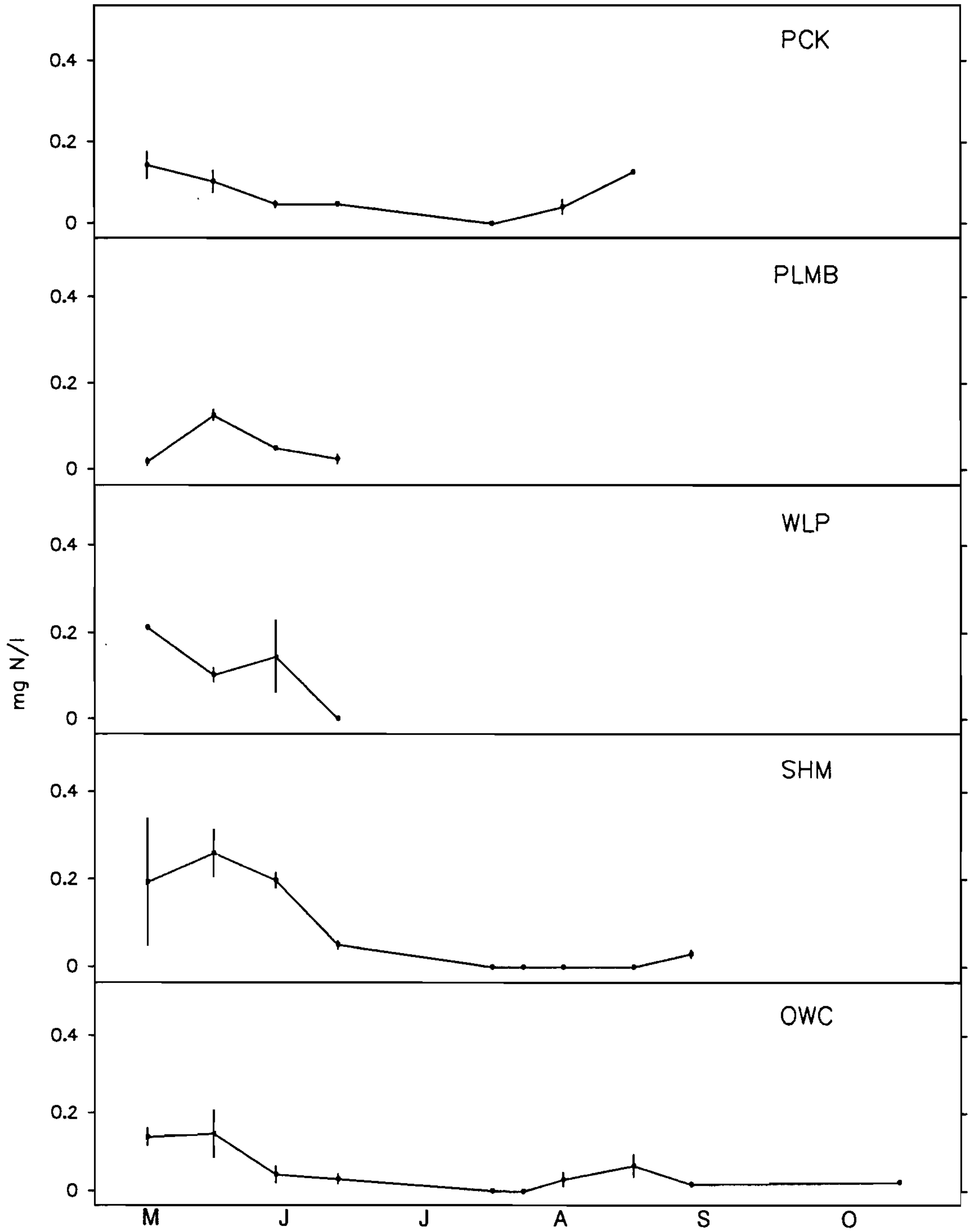

Figure 27. Ammonia means and standard error bars for five undiked marshes in western Lake Erie.

Table 13. Orthophosphate least square means (µg P/l) and GLS[a] values for diked and undiked marshes.

Sample Date	Diked	Undiked	Overall
May 9-14	70	36	51
May 23-28	95	17	54
June 6-11	52	27	38
June 20-25	73	23	47
July 25-30	60	57	57
August 3	30	33	33
August 11-14	132	128	124
August 27-29	80	71	75
Sept. 10-11	69	66	64
October 8	--	12	12
October 26-28	75	7	49
MEAN	73	55	

GLS Values For Study

Source	df	Type III SS	F-value
$Diked_s$ vs. $Undiked_s$	1	5	5.32*
Marsh(Diked)	9	88	10.35**
Date	10	19	1.95*
Diked*Date	9	10	1.21
Residual	275	261	

GLS Values For Lake Erie

$Diked_t$ vs. $Undiked_t$	1	5	0.51

[a] R^2=.37
** $p < .01$
* $p < .05$

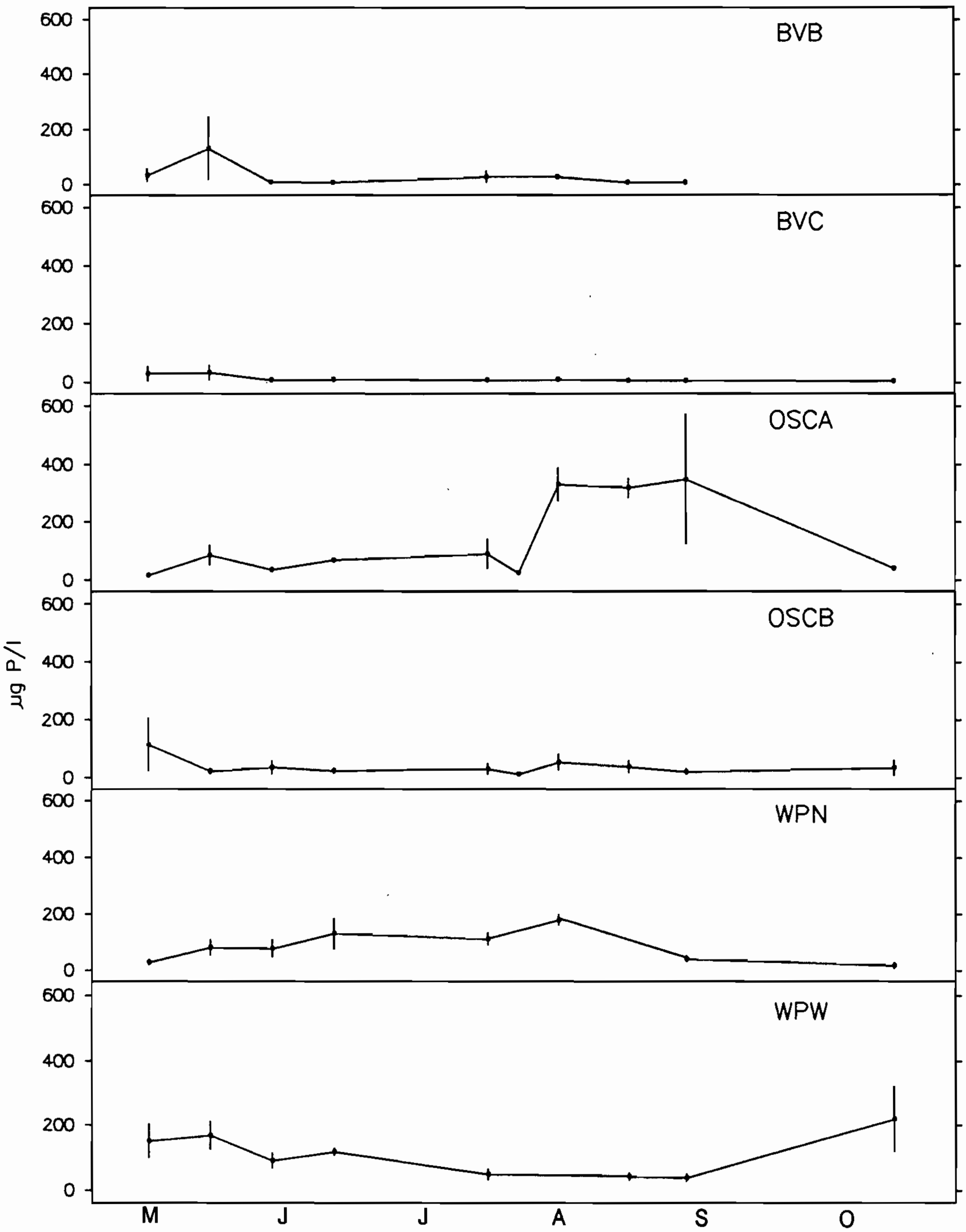

Figure 28. Orthophosphate means and standard error bars for six diked marshes in western Lake Erie.

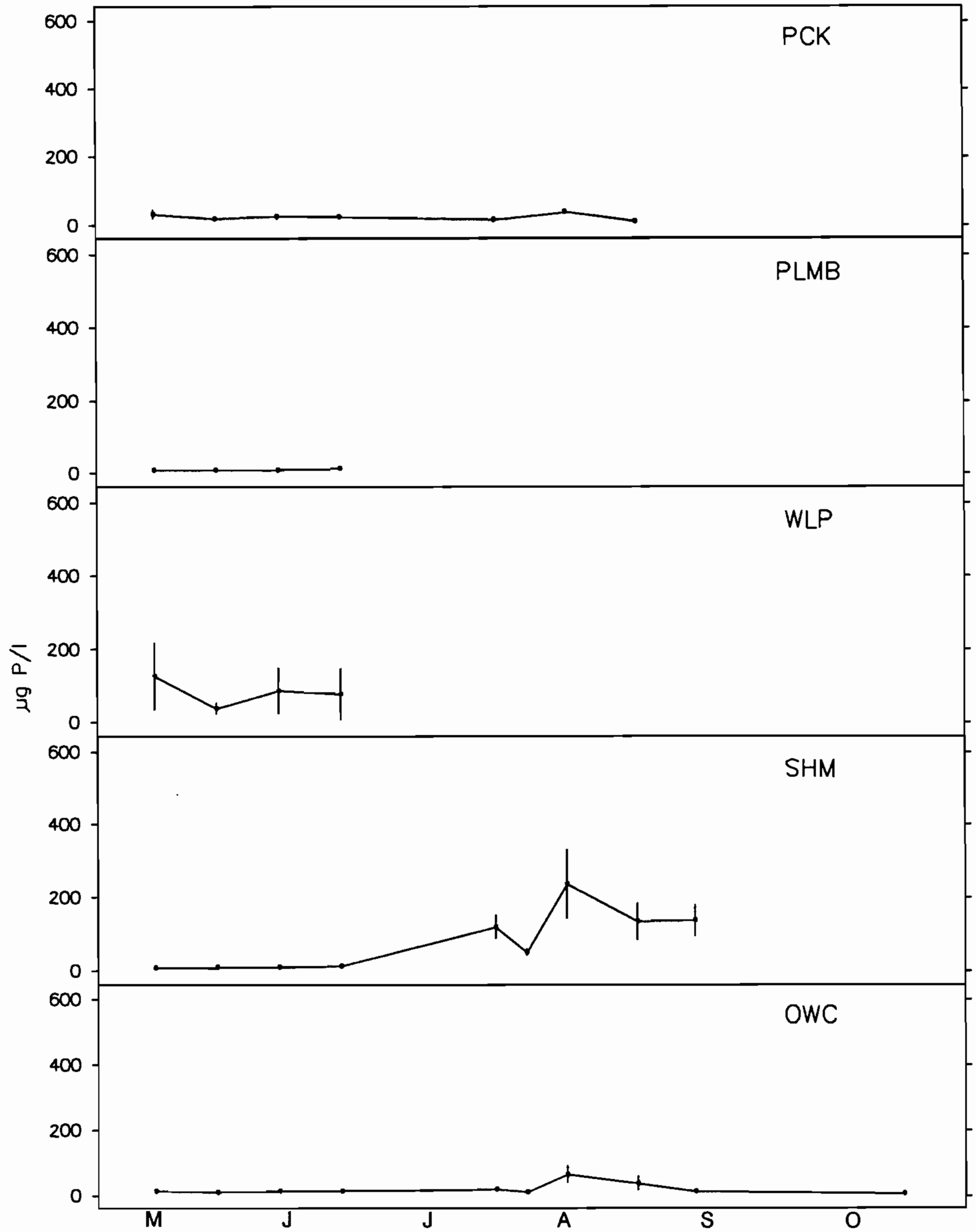

Figure 29. Orthophosphate means and standard error bars for five undiked marshes in western Lake Erie.

Total Phosphorus - Diked and undiked marshes were also significantly different in measured total phosphorus values. In this instance, however, undiked marshes were higher than diked marshes with respective means of 237 and 149 µg P/l (Table 14). Lake Erie diked and undiked marshes were not significantly different. For diked marshes, the orthophosphate to total phosphorus ratio was 1:2, and for undiked marshes, the ratio was 1:4.3. Consequently, diked marshes had a higher fraction available for uptake than the undiked marshes.

With a range of 45 to 333 µg P/l, the lowest total phosphorus values for diked marshes were 57 and 45 µg/l for BVB and BVC, respectively (Fig. 30 and 31). The other diked marshes started at 142 µg/l. Undiked marshes ranged from 127 µg/l to 370 µg/l. A trend for five of the eleven marshes was to start low, peak the third week in June, then decrease until the end of October with the ultimate low occurring either the second week in May or the end of October. The other marshes had no obvious trend, except for SHM which remained low through the end of July then rose steadily through the second week in September when sampling ceased.

PHYSICAL PARAMETERS

Temperature and Dissolved Oxygen - Temperature and dissolved oxygen fluctuate diurnally; and, since the marshes were sampled at different times of the day throughout the study, marsh types and individual marshes cannot be compared with each other. The data are presented as reference conditions for other water chemistry parameters. However, since individual marshes were sampled at approximately the same time throughout the study, temporal trends can be examined. ANOVA tests revealed seasonal trends of decreasing temperature and increasing oxygen (Tables 15 and 16). Higher dissolved oxygen measured at the end of October corresponds to lower water temperature illustrating the higher oxygen saturation capacity of cold

Table 14. Total phosphorus least square means (µg P/l) and ANOVA[a] values for diked and undiked marshes.

Sample Date	Diked	Undiked	Overall
May 9-14	146	159	154
May 23-28	165	176	170
June 6-11	205	202	204
June 20-25	265	269	268
July 25-30	125	190	170
August 3	184	238	211
August 11-14	164	330	252
August 27-29	122	238	190
Sept. 10-11	128	292	225
October 8	---	152	152
October 26-28	96	111	141
MEAN	149	237	

ANOVA Values For Study

Source	df	Type III SS	F-value
$Diked_s$ vs. $Undiked_s$	1	88977	11.57**
Marsh(Diked)	9	775018	11.19**
Date	10	188600	2.45*
Diked*Date	9	136439	1.97
Residual	58	446179	

ANOVA Values For Lake Erie

$Diked_t$ vs. $Undiked_t$	1	88977	1.03

a $R^2=.72$
** $p < .01$
* $p < .05$

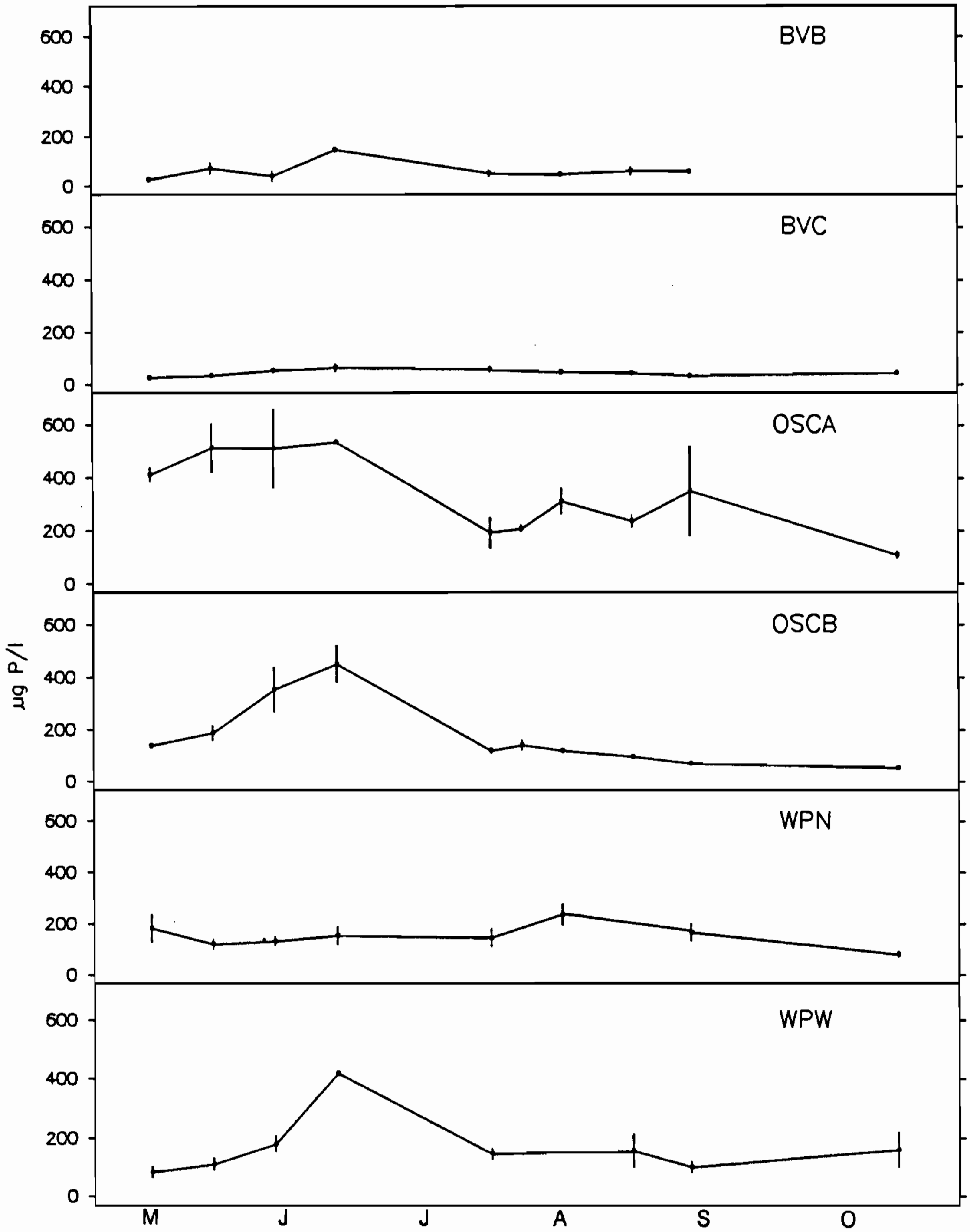

Figure 30. Total phosphorus means and standard error bars for six diked marshes in western Lake Erie.

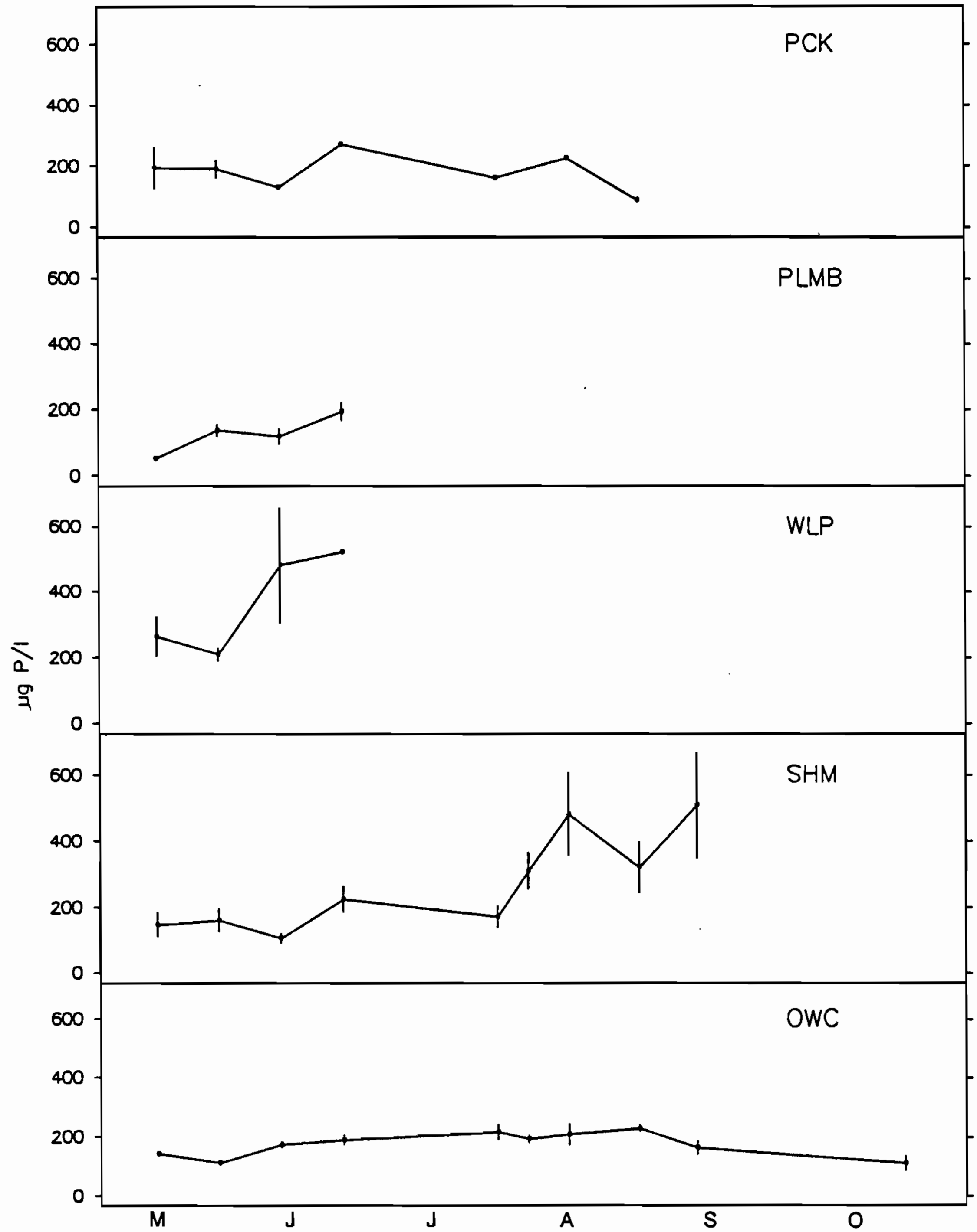

Figure 31. Total phosphorus means and standard error bars for five undiked marshes in western Lake Erie.

Table 15. Temperature least square means (°C) and ANOVA[a] values for diked and undiked marshes.

Sample Date	Diked	Undiked	Overall
May 9-14	17	18	7
May 23-28	17	23	20
June 6-11	21	19	20
June 20-25	23	28	26
July 25-30	24	29	27
August 3	26	28	27
August 11-14	28	24	26
August 27-29	21	19	20
Sept. 10-11	19	23	21
October 8	--	10	10
October 26-28	3	--	3
MEAN	20	22	

ANOVA Values For Study

Source	df	Type III SS	F-value
Diked*Date	8	183	2.51*
Date	10	1788	19.67**
Residual	49	445	

[a] $R^2=.87$
** $p < .01$
* $p < .05$

Table 16. Dissolved oxygen least square means (mg O_2/l) and ANOVA[a] values for diked and undiked marshes.

Sample Date	Diked	Undiked	Overall
May 9-14	9.5	9.5	9.2
May 23-28	9.4	10.0	9.5
June 6-11	10.1	9.5	9.5
June 20-25	9.0	8.5	8.7
July 25-30	7.2	11.8	9.5
August 3	3.9	12.8	7.7
August 11-14	6.4	6.7	5.5
August 27-29	8.1	8.3	8.0
Sept. 10-11	7.5	11.7	9.7
October 8	---	12.2	12.2
October 26-28	12.1	13.9	13.2
MEAN	8.4	11.0	

ANOVA Values For Study

Source	df	Type III SS	F-value
Diked*Date	8	90.7	2.99**
Date	10	165.8	4.92**
Residual	78	165.0	

[a] R^2=.73
** $p < .01$

water versus warm water. Figures 32 through 35 represent the individual marsh values for dissolved oxygen and temperature during the study.

WATER CHEMISTRY CORRELATIONS

Pearson product moment correlations were calculated to determine if relationships existed between the measured water quality parameters for all of the wetlands (Table 17). Alkalinity was found to have a highly significant correlation ($p < 0.01$) with conductivity, orthophosphate, and total phosphorus and an inverse correlation ($p < 0.01$) with dissolved oxygen. Orthophosphate had a highly significant correlation ($p < 0.01$) with dissolved oxygen and total phosphorus and a significant inverse correlation ($p < 0.05$) with pH. Ammonia was correlated with nitrate and nitrite ($p < 0.01$) and inversely correlated with temperature ($p < 0.05$). Turbidity was correlated with total phosphorus ($p < 0.01$). Nitrite and nitrate were significantly correlated ($p < 0.05$), and dissolved oxygen had a highly significant correlation with pH ($p < 0.01$).

VEGETATION

A total of 35 species of aquatic plants were collected and identified at the water sampling stations. References for each species are presented in Appendix B. Thirty-two species were collected in the diked marshes and seventeen in the undiked marshes (Table 18). Of those collected, three species were found only in undiked marshes, and eighteen species were found only in diked marshes (Table 18). Appendix C lists plant species collected at each marsh and each individual quadrat per sampling station. The number of species collected per marsh was highly variable ranging from one to sixteen species. Sixteen species were collected at WPW, a diked marsh, and fourteen species (the next highest) were collected at WLP, an undiked marsh. The most species per quadrat were eleven collected at both BVB and WLP. Three monotypic marshes were sampled including OSCB, SHM, and OWC.

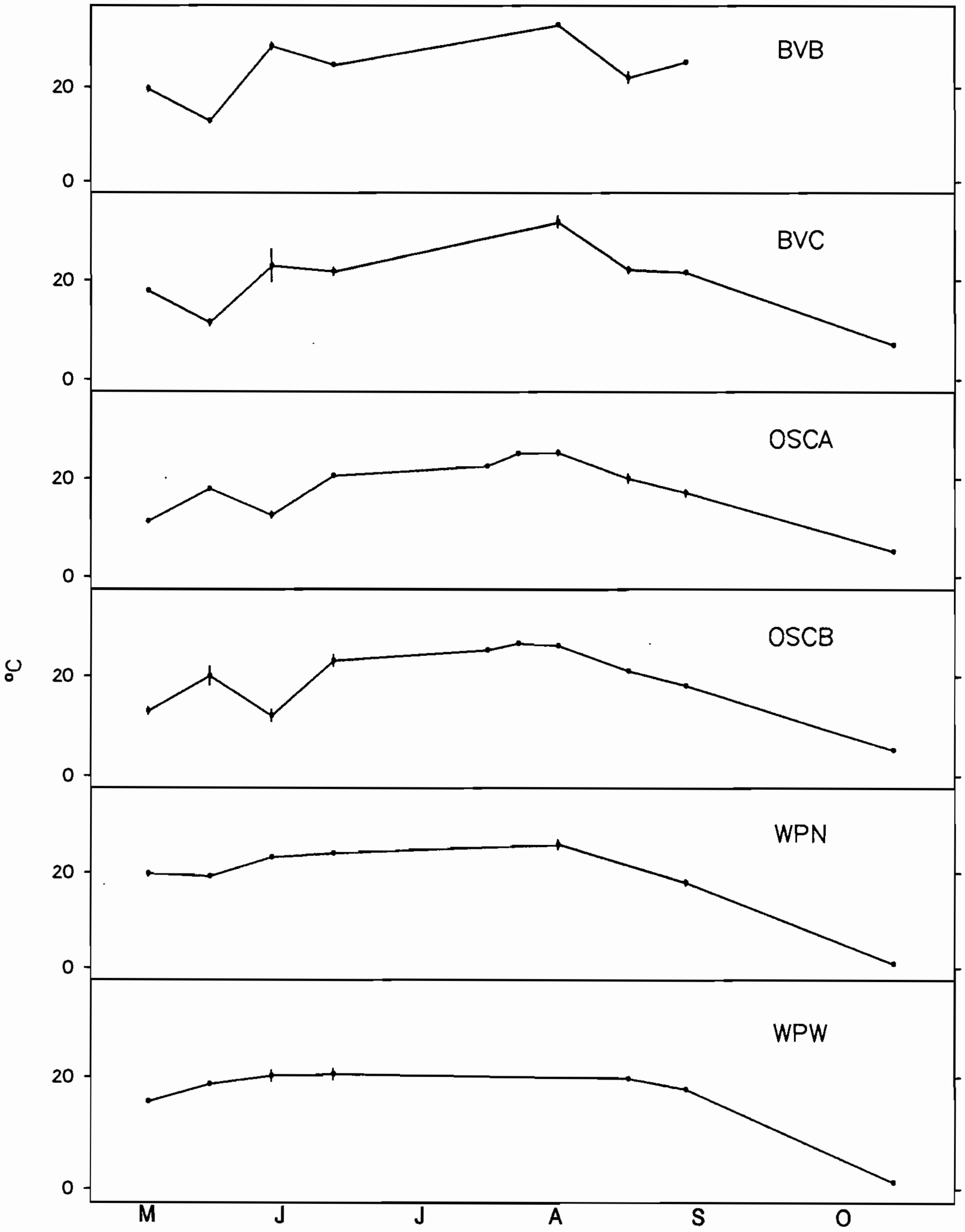

Figure 32. Temperature means and standard error bars for six diked marshes in western Lake Erie.

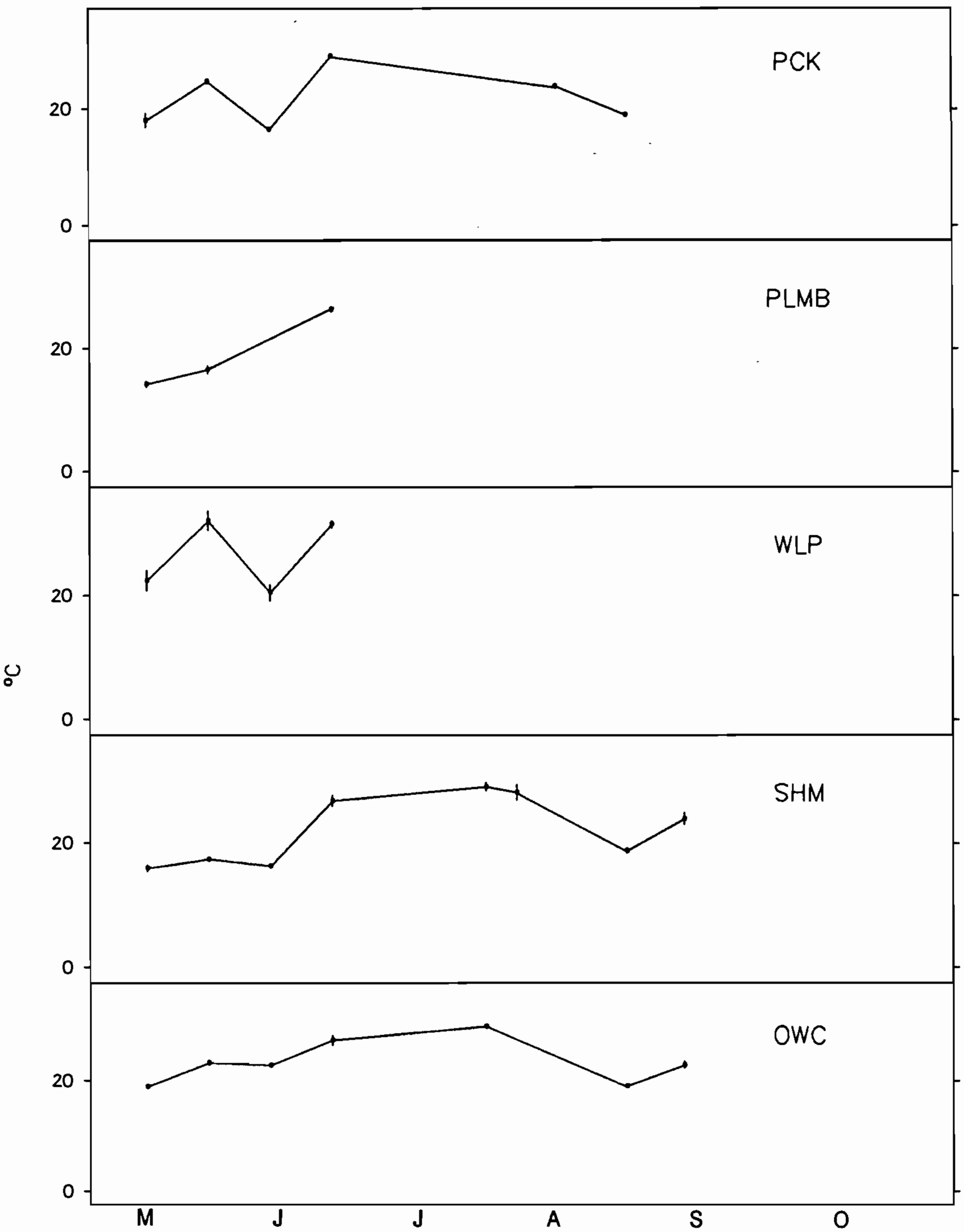

Figure 33. Temperature means and standard error bars for five undiked marshes in western Lake Erie.

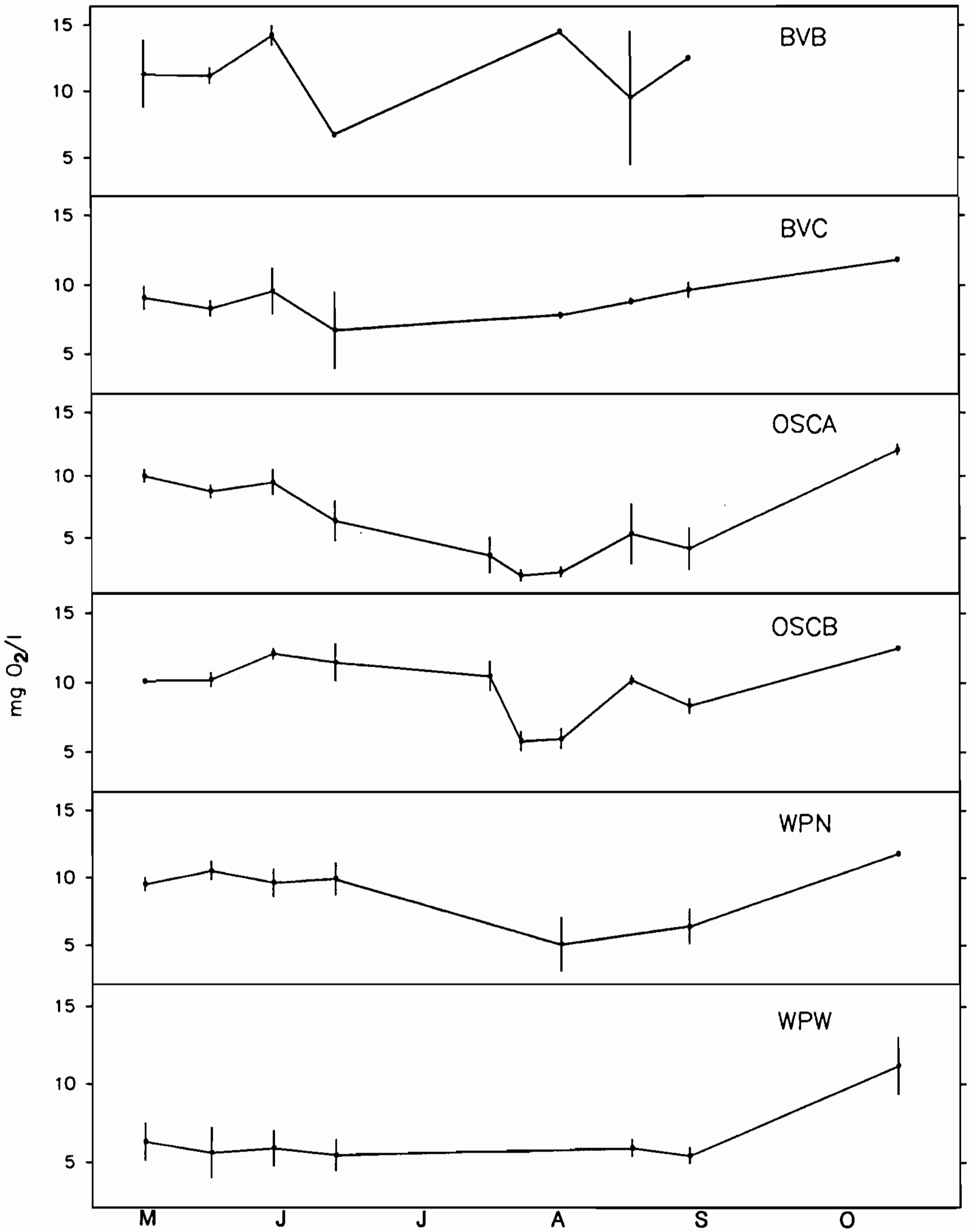

Figure 34. Dissolved oxygen means and standard error bars for six diked marshes in western Lake Erie.

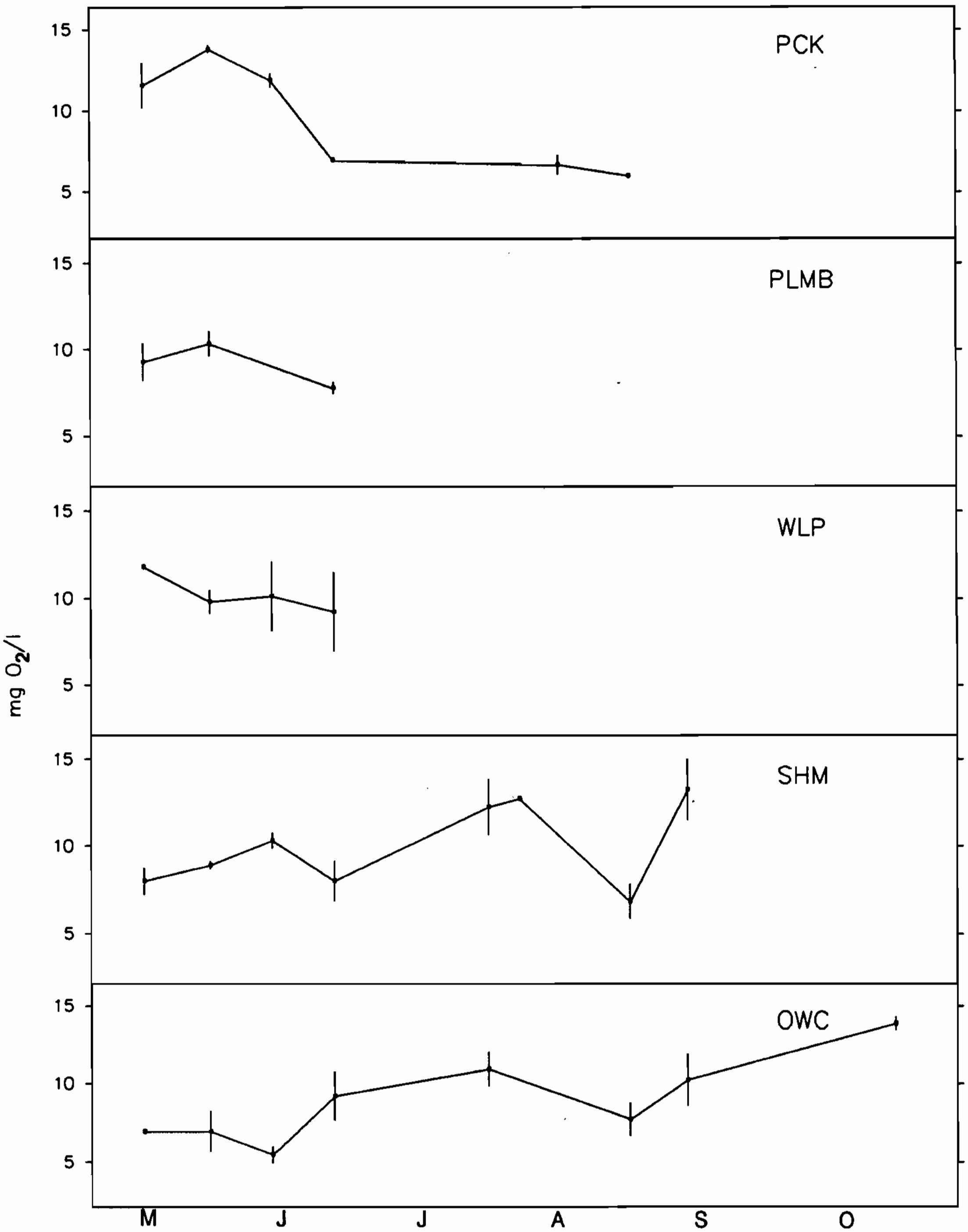

Figure 35. Dissolved oxygen means and standard error bars for five undiked marshes in western Lake Erie.

Table 17. Pearson product moment correlation coefficients among water quality measurements.

	Alkalinity	Conductivity	Turbidity	Orthophosphate	Nitrate	Nitrite	Ammonia	Dissolved Oxygen	Temperature	pH	Total Phosphorus
Alkalinity	1.000										
Conductivity	0.270**	1.000									
Turbidity	0.145	-0.123	1.000								
Orthophosphate	0.330**	-0.066	-0.152	1.000							
Nitrate	0.038	0.055	0.094	-0.028	1.000						
Nitrite	-0.005	0.031	0.087	-0.117	0.209*	1.000					
Ammonia	-0.094	-0.007	0.152	-0.092	0.684**	0.298**	1.000				
Dissolved Oxygen	-0.373**	0.039	-0.027	-0.327**	0.065	-0.077	0.115	1.000			
Temperature	-0.143	0.027	0.055	-0.064	-0.132	-0.128	-0.206*	-0.141	1.000		
pH	-0.144	-0.092	0.195	-0.241*	0.022	0.014	0.013	0.458**	0.200	1.000	
Total Phosphorus	0.367**	0.039	0.624**	0.355**	-0.082	-0.063	-0.085	-0.122	0.093	0.106	1.000

** $p < 0.01$
* $p < 0.05$

Table 18. Plant species collected in diked and undiked marshes.

Species Name	Diked	Undiked
Abutilon theophrasti	X	
Amaranthus tuberculatus		X
Ceratophyllum demersum	X	
Cyperus diandrus	X	
C. erythrorhizos	X	X
C. ferruginescens	X	
Echinochloa crusgalli	X	
E. crusgalli var. *frumentacea*	X	
E. pungens	X	
E. walteri	X	X
Eleocharis sp.	X	X
Hibiscus palustris	X	X
Leersia oryzoides	X	X
Ludwigia palustris	X	
Lythrum salicaria	X	X
Myriophyllum spicatum	X	
Nelumbo lutea		X
Nuphar advena		X
Panicum dichotomiflorum	X	
Phragmites australis	X	
Polygonum lapathifolium	X	X
P. pensylvanicum	X	
Pontederia cordata	X	
Populus deltoides	X	X
Potamogeton crispus	X	
Rorippa palustris	X	
Rumex maritimus	X	
Sagittaria latifolia	X	X
Salix sp.	X	X
Scirpus acutus	X	
S. fluviatilis	X	X
S. validus	X	X
Sparganium eurycarpum	X	X
Typha angustifolia	X	X
Utricularia vulgaris	X	
TOTAL NUMBER OF SPECIES	32	17

A listing of dry weight above-ground biomass and species percentage at each station is found in Table 19 along with the major species collected at each marsh. The predominate species in diked marshes was *T. angustifolia*, which represented the majority by weight in three out of six marshes. No single species was prevalent at the undiked marshes. In general, diked marsh plants had a higher dry/wet ratio. Table 20 lists stem counts and species percentages at each station as well as the major species by stem count at each marsh. The stem counts had more variable species representation across all marshes. Appendix D includes above-ground biomass and stem counts per species measured for each quadrat at each sampled station.

Table 21 lists least square means for diked and undiked marshes for the measured parameters: total wet weight, total dry weight, and stem count per m^2. The diked marshes were significantly higher than the undiked marshes in all measured parameters. Due to the high variability among the diked and undiked marshes, when making inferences to the Lake Erie population of marshes, the two were not significantly different in the measured parameters.

Table 19. Vegetation dry weight means for above-ground biomass (g/m^2) per station and major species composition by dry weight. Collection occurred in August.

Marsh Site	Biomass, g dry wt./m^2	Dry/Wet Ratio	% Species Dry Weight*	
Bay View "B"				
Station 1	327	0.16	*C. erythrorhizos*	71%
			C. diandrus	17%
2	294	0.19	*C. erythrorhizos*	94%
3	96	0.13	*L. salicaria*	62%
			E. walteri	32%
MAJOR SPECIES GROUPS FOR BVB:** *C. erythrorhizos* 72%, *L. salicaria* 11%				
Bay View Center				
Station 1	603	0.31	*T. angustifolia*	100%
2	2620	0.43	*P. australis*	100%
3	1214	0.32	*S. acutus*	100%
MAJOR SPECIES GROUPS FOR BVC:** *P. australis* 59%, *S. acutus* 28%, *T. angustifolia* 14%				
Ottawa S. C. Allen				
Station 1	604	0.26	*L. oryzoides*	40%
			P. dichotomiflorum	26%
			C. ferruginescens	14%
2	251	0.12	*L. palustris*	55%
			E. walteri	37%
3	726	0.13	*E. walteri*	98%
MAJOR SPECIES GROUPS FOR OSCA:** *E. walteri* 52%, *L. oryzoides* 16%, *P. dichotomiflorum* 10%				
Ottawa S. C. Big				
Station 1	2584	0.20	*T. angustifolia*	100%
2	1985	0.24	*T. angustifolia*	100%
4	1388	0.21	*T. angustifolia*	100%
MAJOR SPECIES GROUPS FOR OSCB:** *T. angustifolia* 100%				

Table 19. (continued)

Marsh Site	Biomass, g dry wt./m²	Dry/Wet Ratio	% Species Dry Weight*	
Winous Point North				
Station 1	467	0.20	*T. angustifolia*	47%
			S. validus	46%
2	597	0.19	*T. angustifolia*	91%
3	1216	0.15	*T. angustifolia*	95%
4	96	0.18	*M. spicatum*	71%
			Salix sp.	29%
5	240	0.09	*T. angustifolia*	81%
			P. cordata	19%
6	923	0.14	*T. angustifolia*	97%

MAJOR SPECIES GROUPS FOR WPN:** *T. angustifolia* 85%

Marsh Site	Biomass, g dry wt./m²	Dry/Wet Ratio	% Species Dry Weight*	
Winous Point West				
Station 2	311	0.14	*T. angustifolia*	46%
			P. cordata	22%
			L. oryzoides	16%
3	634	0.18	*S. validus*	44%
			S. eurycarpum	18%
			L. oryzoides	17%
			T. angustifolia	16%
4	893	0.19	*T. angustifolia*	61%
			L. oryzoides	17%
5	400	0.18	*T. angustifolia*	28%
			E. pungens	18%
			L. oryzoides	15%

MAJOR SPECIES GROUPS FOR WPW:** *T. angustifolia* 40%, *S. validus* 21%, *L. oryzoides* 17%

Table 19. (continued)

Marsh Site	Biomass, g dry wt./m²	Dry/Wet Ratio	% Species Dry Weight*	
Pickerel Creek				
Station 1	493	0.15	*S. fluviatilis*	84%
2	1294	0.28	*S. fluviatilis*	100%
3	791	0.12	*S. fluviatilis*	55%
			C. erythrorhizos	38%
MAJOR SPECIES GROUPS FOR PCK:** *S. fluviatilis* 83%, *C. erythrorhizos* 13%				
Willow Point				
Station 1	1159	0.21	*T. angustifolia*	61%
			A. tuberculatus	17%
			P. lapathifolium	12%
2	201	0.14	*C. erythrorhizos*	78%
3	438	0.16	*S. eurycarpum*	47%
			T. angustifolia	21%
			L. salicaria	16%
MAJOR SPECIES GROUPS FOR WLP:** *T. angustifolia* 45%, *S. eurycarpum* 12%, *A. tuberculatus* 11%, *C. erythrorhizos* 11%				
Sheldon Marsh				
Station 1	367	0.07	*N. advena*	100%
2	256	0.08	*N. advena*	100%
3	358	0.09	*N. advena*	100%
MAJOR SPECIES GROUPS FOR SHM:** *N. advena* 100%				
Old Woman Creek				
Station 3	212	0.16	*N. lutea*	100%
4	186	0.16	*N. lutea*	100%
5	163	0.16	*N. lutea*	100%
MAJOR SPECIES GROUPS FOR OWC:** *N. lutea* 100%				

* species >10% by weight per station, ** species <10% by weight per marsh not listed

Table 20. Vegetation stem count means (stems/m^2) per station and major species composition by stem count. Collection occurred in August.

Marsh Site	Stems	% Species Stem Count*	
Bay View "B"			
Station 1	1,468	*C. diandrus*	45%
		C. erythrorhizos	42%
2	1,089	*Eleocharis* sp.	61%
		C. erythrorhizos	28%
3	163	*E. walteri*	73%
		L. salicaria	11%

MAJOR SPECIES GROUPS FOR BVB:** *C. erythrorhizos* 34%, *Eleocharis* sp. 26%, *C. diandrus* 25%

Marsh Site	Stems	% Species Stem Count*	
Bay View Center			
Station 1	59	*T. angustifolia*	100%
2	567	*P. australis*	100%
3	795	*S. acutus*	100%

MAJOR SPECIES GROUPS FOR BVC:** *S. acutus* 56%, *P. australis* 38%

Marsh Site	Stems	% Species Stem Count*	
Ottawa S. C. Allen			
Station 1	1404	*L. oryzoides*	74%
		C. ferruginescens	11%
2	1635	*L. palustris*	75%
		E. walteri	23%
3	1388	*E. walteri*	99%

MAJOR SPECIES GROUPS FOR OSCA:** *E. walteri* 40%, *L. palustris* 28%, *L. oryzoides* 24%

Marsh Site	Stems	% Species Stem Count*	
Ottawa S. C. Big			
Station 1	164	*T. angustifolia*	100%
2	152	*T. angustifolia*	100%
4	193	*T. angustifolia*	100%

MAJOR SPECIES GROUPS FOR OSCB:** *T. angustifolia* 100%

Table 20. (continued)

Marsh Site	Stems	% Species Stem Count*	
Winous Point North			
Station 1	150	*S. validus*	78%
		T. angustifolia	11%
2	94	*T. angustifolia*	57%
		Eleocharis sp.	14%
		S. validus	13%
3	164	*T. angustifolia*	57%
		S. validus	43%
4	6	*Salix* sp.	100%
5	37	*P. cordata*	62%
		T. angustifolia	32%
6		*L. oryzoides*	59%
	100	*T. angustifolia*	37%

MAJOR SPECIES GROUPS FOR WPN:** *T. angustifolia* 38%, *S. validus* 36%, *L. oryzoides* 12%

Marsh Site	Stems	% Species Stem Count*	
Winous Point West			
Station 2	269	*L. oryzoides*	71%
		P. cordata	19%
3	773	*L. oryzoides*	46%
		S. validus	38%
4	408	*L. oryzoides*	62%
		T. angustifolia	19%
		S. validus	11%
5	400	*L. oryzoides*	38%
		E. pungens	19%

MAJOR SPECIES GROUPS FOR WPW:** *L. oryzoides* 51%, *S. validus* 25%

Table 20. (continued)

Marsh Site	Stems	% Species Stem Count*	
Pickerel Creek			
Station 1	351	*S. fluviatilis*	48%
		T. angustifolia	18%
		C. erythrorhizos	16%
2	155	*S. fluviatilis*	100%
3	395	*S. fluviatilis*	38%
		C. erythrorhizos	37%
		T. angustifolia	11%

MAJOR SPECIES GROUPS FOR PCK:** *S. fluviatilis* 52%, *C. erythrorhizos* 22%, *T. angustifolia* 12%

Marsh Site	Stems	% Species Stem Count*	
Willow Point			
Station 1	125	*T. angustifolia*	55%
		C. erythrorhizos	21%
		L. salicaria	15%
2	571	*C. erythrorhizos*	57%
		S. validus	12%
		L. oryzoides	11%
3	424	*S. validus*	26%
		S. eurycarpum	18%
		T. angustifolia	16%
		C. erythrorhizos	16%
		Eleocharis sp.	13%

MAJOR SPECIES GROUPS FOR WLP:** *C. erythrorhizos* 38%, *S. validus* 16%, *T. angustifolia* 13%

Table 20. (continued)

Marsh Site	Stems	% Species Stem Count*	
Sheldon Marsh			
Station 1	75	*N. advena*	100%
2	62	*N. advena*	100%
	393	*N. advena*	100%
MAJOR SPECIES GROUPS FOR SHM:** *N. advena* 100%			
Old Woman Creek			
Station	316	*N. lutea*	100%
4	10	*N. lutea*	100%
5	17	*N. lutea*	100%
MAJOR SPECIES GROUPS FOR OWC:** *N. lutea* 100%			

* species >10% by stem count per station, ** species <10% by stem count per marsh not listed

Table 21. Vegetation least square means for diked and undiked marshes by group and individually and ANOVA and GLS comparisons. Wet and dry weight above-ground biomass are measured in g/m^2 and stem count is measured in $stems/m^2$.

	Wet	Dry	Stem
Diked	4277	897	596
Undiked	3190	493	191
<u>Diked</u>			
Winous Point North	3945	590	92
Winous Point West	3289	560	461
Ottawa S. C. Allen	3767	527	476
Ottawa S. C. Big	9224	1986	170
Bay View "B"	1667	239	907
Bay View Center	3767	1479	473
<u>Undiked</u>			
Pickerel Creek	4312	859	300
Willow Point	3303	599	373
Sheldon Marsh	4003	327	77
Old Woman Creek	1142	187	14

Group ANOVA and GLS Comparisons

DRY $R^2=.59$

Source	df	Type III SS	F-value
$Diked_s$ vs. $Undiked_s$	1	3460998	15.00**
Marsh(Diked)	8	23179079	12.56**
Residual	80	18454137	

STEM $R^2=.86$ (GLS)

Source	df	Type III SS	F-value
$Diked_s$ vs. $Undiked_s$	1	48	48.12**
Marsh(Diked)	8	280	35.09**
Residual	80	80	

LAKE ERIE

Source	df	Type III SS	F-value
D_t vs. UD_t-Dry	1	3460998	1.19
D_t vs. UD_t-Stem	1	48	1.37

** $p < .01$
* $p < .05$

CHAPTER IV

DISCUSSION

Two levels of examination were conducted in this study: as a local population of marshes and as a subsample of the broader lakewide population. The differences tested in the locally applicable study were determined based on the variability present among sampling stations **within** individual marshes. The differences tested on the regional Lake Erie scale were determined based on the variability **among** individual marshes within the two types of marshes. Individual marshes are highly diverse, and it is precisely this high level of variability among marshes within groups that suggests that diked marshes in Lake Erie are not different from undiked marshes for the sampled parameters. A large part of the variability within and among marshes is represented by the statistical models designed to help define the ecological relationships (represented by R^2). The large number of samples (marshes) within each type of marsh taken from the Lake Erie population make this study particularly applicable for drawing inferences to the larger lakewide population because replicate samples are drawn from the population as well as replication across time.

An important point to remember is that this study was a synoptic survey measuring "snapshots" of parameters in time and does not examine specific processes that are occurring in the marshes. This study measures the impacts of diking upon marshes and does not measure the impacts of diking on the surrounding water body. The effect of diking on the localized population of eleven marshes in this study was large and although throughout the discussion these differences will be discussed, keep in mind that overall no differences were measured lakewide. The inherent variability among marshes (background noise) throughout the Lake Erie region masked the impacts of diking on the larger scale.

Hydrology of Lake Erie Wetlands

Diked and undiked marshes have different hydrologic patterns. Diked marshes are typically hydrologically isolated from their watersheds by surrounding drainage ditches that lead runoff and surface flow away from the marshes (with the exception of WPN in this study). They are also isolated from external lake level fluctuations by dikes. The changes in water level that diked marshes do have are contrary to natural patterns. In general, peak Lake Erie water level occurs in June and decreases to a low in February with seasonal variations between 0.3 to 0.6 meters (Herdendorf 1987). In diked marshes, however, water is usually lowered in the spring, kept at a minimum level throughout the summer, and then raised in the fall (Weller 1978).

Undiked, natural coastal marshes are connected with a watershed. They also generally have a free and open connection with the lake (except Old Woman Creek, which is separated from Lake Erie by a barrier beach for most of the growing season). Although in any given year these marshes are influenced by their watersheds, the drought in the Great Lakes region reduced this effect during this study.

Two types of lake level fluctuations are common in Lake Erie: long-term water level changes driven by precipitation in the Great Lakes basin and short-term seiche events. Diked marshes do not benefit from the flushing and the import and export of chemical constituents that occur via this mechanism. Farney and Bookhout (1982) studied a Winous Point marsh after storms broke through the dikes and determined that the long term fluctuations provided by Lake Erie helped to maintain the fertility of the marsh through nutrient enrichment. Simpson et al. (1978) found that periodic inundations provided nitrogen and phosphorus to the wetlands in their study area in the Delaware River estuary. Based on his studies of Lake Michigan wetlands, Kadlec (1979) concluded that the two critical parameters hydrologically for wetlands are seasonal variations of water level and flushing or turnover rate.

The wetland water levels measured during this study illustrate differences in hydrology between the two types of marshes over the six-month study period. The water level graphs of OSCA, OSCB, and WPW depict a "typical" managed marsh water regime. If the Bay View marshes had not had difficulties in maintaining water they would have also more closely paralleled that schedule. Initial water additions began the same approximate time in June for all the marshes. WPN never dropped below its initial water level, partly because water was added a month before the other marshes. Also, since WPN is hydrologically connected to a small watershed, the increases beginning the first of September can be explained by 6 cm of rainfall the previous week. Further rain in October continued the trend. Since the water had no outlet, the increase was more pronounced.

All the undiked marshes showed a general decline in water levels with the exception of OWC, which for most of the study had no surface water outlet because the barrier beach was closed. The influence of short term fluctuations is reflected for undiked marshes by highs and lows which occured during different sampling times. Sager et al. (1985) measured 269 seiches during their 1984 sampling of a Great Lakes coastal marsh. Herdendorf and Braidech (1972 as cited in Herdendorf 1987) found that seiches occur about 44% of the year and generally have an amplitude less than 0.7 m and a period of 12 hours.

Seasonal Water Chemistry Trends and Differences

These hydrologic differences alter water chemistry and cause different trends and processes to dominate in the two types of marshes. Within the localized population, many differences in seasonal water chemistry trends were reported. These trends were not tested for regionally so no inferences can be made lakewide. Other differences in water chemistry parameters are discussed in relation to the effects on the local population and were not significant lakewide. During a normal rainfall year, a larger separation of mean values for the water chemistry parameters would be expected as a result of increased watershed runoff flowing through the undiked marshes without an analogous change to the diked. This would probably not result in significant lakewide differences because increased flow should not should not have an effect on variability among marshes within groups. The variable effect of regional geologic differences could also be intensified from increased flow through several of the undiked marshes.

One method of examining the effect of hydrologic isolation on diked marshes is to determine if differences exist in seasonal water chemistry trends. One part of the ANOVA and GLS models tested for seasonal differences between the two groups for each of the parameters. The results indicated that pH, alkalinity, conductivity, nitrate, nitrite, dissolved oxygen, and temperature all changed differently over time between diked and undiked marshes. Changing the seasonal patterns of water flux possibly influenced seasonal trend differences for these parameters. Turbidity, ammonia, orthophosphate, and total phosphorus exhibited enough variability across time that hydrology did not appear to affect seasonal trends.

pH - Over time, pH was more variable in undiked wetlands than in diked, however, pH averaged across all marshes showed no seasonal trend. MacCrimmon (1980) also did not find a seasonal trend for pH in his study. King (1985) stressed that pH is very dependent upon water movement through a marsh; therefore, pH variability in undiked marshes may relate to fluctuating water levels. Mudroch (1981) found pH ranges of 7.8 to 8.4 in six Great Lakes wetlands and attributed the high values to the influence of the carbonate bedrock. MacCrimmon's (1980) narrower range of 6.9 to 7.4 over the same time period was measured in one Lake Huron coastal marsh. Averaged pH values for each marsh in this study ranged from 7.3 to 8.1. I would also ascribe these higher values partly to substrate. Mitsch et al. (1989) reported high soil calcium levels in several of the marshes in the study. Limestone is quarried in the region.

Generalizations between marshes are made with caution since pH fluctuates diurnally in response to photosynthesis and respiration, and marshes were sampled at different times throughout the day. Undiked marshes for the local population had significantly higher pH values. This could be attributed to higher water column productivity in these wetlands (Wetzel 1983), although the buffering capacity, as measured by the alkalinity appears to be high.

Alkalinity and Conductivity - I observed a seasonal alkalinity trend averaged across marshes but not one for conductivity. Within the sampled marshes, both parameters were significantly lower in the undiked marshes. MacCrimmon (1980) found no seasonal trends in alkalinity or conductivity in a study of a Lake Huron wetland, although he found lower alkalinity and conductivity values in the spring that he attributed to runoff and associated dilution. Klarer (1988), in a study documenting the effects of storm water on the chemical and nutrient components of Old Woman Creek, also found that alkalinity and conductivity were diluted by watershed runoff. I found alkalinity values lower in the spring for undiked marshes resulting from the watershed influence, but did not find the same tendency for conductivity.

Conversely, diked marshes had higher alkalinity and conductivity in spring which decreased dramatically with water additions from the Bay in mid-June. Consistently higher alkalinity and conductivity in diked marshes can also be attributed to lack of flushing by Sandusky Bay. During the summer, the only water outflow for diked marshes is through evapotranspiration, which tends to concentrate the ions in the system. MacCrimmon (1980) measured a range of 153-177 mg/l for alkalinity, while the diked marshes in this study ranged from 128-197 mg/l, and the undiked marshes ranged from 112-168 mg/l. Krieger (1984) measured a much lower range of alkalinity for OWC, which decreased to 46 mg/l at one station. This lower alkalinity may be a result of measuring directly after rain storms.

MacCrimmon (1980) measured much lower conductivities of 254-282 µmhos, compared to diked marsh values of 880-1,409 µmhos and undiked marshes values of 406-960 µmhos. The higher values in this study can be partially attributed to the drought and decreased flushing. Overall, alkalinity and conductivity were significantly correlated ($p < 0.01$). Krieger (1984) also found a weak correlation between the two parameters at Old Woman Creek.

Turbidity - When comparing measured turbidity ranges with previous studies (MacCrimmon 1980, Krieger 1984, Klarer 1988), the turbidities in this study appear low. Lack of precipitation would cause a decrease in particle resuspension in diked marshes and a decrease in the sediment load in undiked marshes. The previous studies were also conducted directly after storm events, which would cause higher readings. Turbidity did not change seasonally between marsh types because it is affected intermittently by the unpredictable effects of wind action, waves, water fluctuations, and biotic influences (such as carp, *Cyprinus carpio*). Undiked marshes had turbidities that varied more than diked marshes, probably due to fluctuating water levels.

Diked marshes are protected from changing water levels and the dikes also diminish wind and wave influences on turbidity. Turbidity in diked marshes seemed to decrease with increasing water depth, which could be due to the greater wind needed to stir bottom sediments in deeper water. Other factors are responsible for reducing turbidity in diked marshes. Vegetation in the form of higher stem density measured in the diked marshes was another possible factor in reducing turbidity by dampening wind induced flow (Lee et al. 1975). Carp in the Winous Point marshes had recently been poisoned removing that disturbance from those marshes. Carp were also regularly observed stirring up bottom sediments in the undiked marshes, while they were seldomly seen in the diked marshes.

Akhurst and Breen (1987) studied two lakes and reported a negative correlation in shallow water systems between ionic content and turbidity. They concluded that high ionic content would lead to decreased turbidity. Krieger (1984) also found a highly significant negative correlation between conductivity and turbidity at OWC. I found a negative correlation although it was not significant.

Nutrients - Nitrogen and Phosphorus - Water movement through a wetland affects every aspect of the marsh. The patterns of nutrient flux and nutrient load are dependent upon the pattern, amount, and source of water movement (Gosselink and Turner 1978, King 1985). Lee et al. (1975) found that during the growing season, a marsh reduces stream fluctuations based on the resistance encountered by vegetation and the storage capacity provided. Similarly, the density and vegetational patterns and species of a fringing coastal marsh are made up of microhabitats of various substrate types, volume and flow of water, and movement of organisms. These microhabitats contribute to the natural heterogeneity of the water mass within and among marshes. This is demonstrated by the high variability in field replications where two samples were taken in the same spot within minutes of each other, and the chemistry was at times markedly different.

The nutrient cycles of a marsh can be altered quite dramatically through diking and the subsequent drawdown and re-addition of water. Lack of water movement resulting from increased retention time from diking can cause accumulation of organic matter (Gosselink and Turner 1978). King (1985) reported that both water temperature and pH increase with increased retention time of water, leading to volatilization of ammonia. Simpson et al. (1978) reported that areas of "pond-like" water were depleted of ammonia and orthophosphate throughout the year. In most cases, marsh managers allow the marshes to lose water through evaporation to save on pumping costs. When water evaporates or is transpired, the water is removed from the marsh, but the dissolved chemicals are not. This causes a concentration of chemical constituents. Nutrients can be transformed into more or less bioavailable forms or may be removed from the marsh through various chemical or biological processes such as denitrification. Klopatek (1978) found that drainage of marsh soils increased organic decomposition which released more nitrate into the system. Lee et al. (1975) concluded that dranage of marsh soils resulted in a significant loss of nitrogen due to denitrification. Kelley et al. (1985) determined that the amount of nutrients cycled through a wetland is directly dependent upon water levels. Richardson et al. (1978) reported that high concentrations of ammonia and nitrate were found in oxidized areas created by water level fluctuations. King (1985) attributes this to the balance between oxidizing and reducing conditions within a wetland. In mid-June, two stations were dry at OSCB for two to four weeks, and I noted distinct changes in some parameters. Conductivity and total phosphorus both increased dramatically, and ammonia decreased. Klopatek (1978) measured high concentrations of nitrogen in a marsh during drawdown and subsequent decreases with increasing water level. He found that drawdown caused a net increase of nitrogen in the marsh. Lyon et al. (1986) found that nutrients increased with flooding and anaerobic soil conditions compared to dry, infrequently flooded sites. Phosphorus is also mobilized under anoxic conditions (Mitsch and Gosselink 1986). Although this study did not examine specific processes and cycling, these cited studies demonstrate the potential impact of diking on processes within a diked marsh.

Of the five nutrient species measured, only nitrate and nitrite demonstrated significantly different seasonal trends between the diked and undiked marsh groups. Nitrate and ammonia were not different when averaged across time for the types of marshes and were near the lower limits of detection throughout the study. Values are consistent with those reported in previous studies (Mudroch 1981, Krieger 1984, Klarer 1988, Krieger 1989). Krieger (1984) reported much higher nitrate readings in OWC than my study recorded. Klarer (1988) also reported occasional higher nitrate values in OWC.

Both diked and undiked marshes would be classified hypereutrophic based on total phosphorus concentrations (Wetzel 1983). Orthophosphate was significantly higher in the diked marshes and total phosphorus was significantly higher in the undiked marshes. Diked marshes had 49% of their phosphorus in the form of orthophosphate as opposed to the 23% measured in undiked marshes. Orthophosphate is the primary form directly utilizable by plants, which could mean that undiked marshes are uptaking more for productivity. MacCrimmon (1980) measured a decline of orthophosphate levels in early spring, and attributed the trend to macrophytic assimilation. Emergent plants, however, primarily absorb their nutrients through the roots, not from the water column. The higher biomass measured for diked marshes also does not support this hypothesis, unless above-ground macrophytic biomass is not the appropriate test of productivity for undiked wetlands.

The undiked marshes could be utilizing the phosphorus for algal production. Reeder and Mitsch (1989b) found decreased orthophosphate concentrations during periods of high planktonic production.

The lower percentage of available phosphorus in undiked marshes, may not be an indicator of increased productivity. Particle resuspension by wind and seiche effects in undiked marshes would cause more sediment to be collected in the water sample, therefore yielding a disproportionate amount of total phosphorus, as measured in the undiked marshes (237 μg/l) compared to the diked marshes (149 μg/l). Stumm and Leckie (1971) reported increased upward transport of phosphorus with high turbulence as measured by turbidity. MacCrimmon (1980) found a high correlation between turbidity and total phosphorus, and Baker (1985) also reported a correlation between total phosphorus and suspended particles. This agrees with the significant correlation ($p < 0.01$) between total phosphorus and turbidity found in this study.

Manny and Owens (1983) found high total phosphorus concentrations were correlated with periods of peak discharge. Total phosphorus measured in undiked marshes in this study also followed seasonal precipitation and watershed runoff trends. Diked marshes, however, do not receive phosphorus from the watershed. Surprisingly, North Marsh, which is connected to a small watershed, did not exhibit higher total phosphorus concentrations than the other diked marshes. Total phosphorus decreased in the diked marshes when water was pumped in. Water additions did not appear to affect orthophosphate concentrations. Mudroch (1980) reported much lower total phosphorus concentrations and MacCrimmon (1980) reported lower orthophosphate and slightly lower total phosphorus than reported in this study. Total phosphorus values were within the low end of Krieger's (1984) values. Other studies summarized by Krieger (1989) exhibited similar ranges of values.

Watershed Nutrient Contributions

Another consequence of hydrologic isolation is the absence of nutrient input from the watershed. Mitsch and Gosselink (1986) stressed the importance of hydrology in nutrient cycling as the primary pathway for nutrient input into a wetland. A major portion of the nutrient input into marshes in temperate climates occurs during peak spring discharge from the watershed (King 1985, Kadlec 1979). This is especially true in agricultural regions where fields are fertilized in the spring (Neilsen et al. 1980, Baker et al. 1985a). Krieger (1984) measured the highest nutrient concentrations during his study at OWC after the first rainstorm that followed spring planting. Mudroch (1980) attributed two peaks of nitrate concentration to watershed runoff following fertilization. Nitrate and ammonia in this study showed the highest concentrations at the end of May.

They decreased to low concentrations for most of the summer, which could be due to denitrification at high temperatures (Wetzel 1983), as well as lack of input. Richardson et al. (1978) postulated that high nitrate values measured in the spring in their study were a result of the inhibitory effect of low temperatures on denitrification. Simpson et al. (1978) and MacCrimmon (1980) found nitrogen to be incorporated into macrophytes early in and throughout the growing season, thereby causing lower concentrations during the period of biomass accumulation. It is likely that all of these processes contributed to some extent to high nitrate concentrations in spring and low concentrations in summer. Watershed contributions would be important in undiked marshes, whereas, temperature and macrophytic influences would play a larger role in diked marshes. Baker (1985) measured the highest concentrations of nitrate-nitrogen in northwestern Ohio streams between May and July. He found that 43% of nitrogen fertilizer inputs are lost from agricultural fields via streamflow to the receiving water body. This was equivalent to 19% of the total nitrogen inputs, which includes those from precipitation and nitrogen fixation. In Klarer's (1988) study of stormwater flow through OWC, he found that both orthophosphate and ammonia were strongly correlated with turbidity and that they increased during storm flow through the wetland. Nitrate and nitrite increased after storm events and were associated with the interflow period, water that percolated through the soil before entering the stream. In Sheldon Marsh, after a twenty-minute hard rain, I measured an increase in turbidity of 31 to 55 NTU, and an increase in orthophosphate and total phosphorus of 52 to 237 µg P/l and 331 to 482 µg P/l, respectively. In Pickerel Creek, after several days of rain, nitrate increased from 0.26 to 0.68 mg N/l, nitrite increased from 2 to 55 µg N/l, and ammonia increased from 0.06 to 0.13 mg N/l.

Nutrient Sources to Diked Marshes

When the watershed can no longer serve as a nutrient source because of diking, the major input sources become direct precipitation, input from pumped water, and animal input. In a study conducted in northwestern Lake Huron, Manny and Owens (1983) estimated that 43% of the nitrogen and 10% of the phosphorus in the nearshore waters were contributed by the atmosphere. Hutchinson (1957) estimated concentrations of approximately 0.2 mg/l nitrate-nitrogen and 0.6 mg/l ammonia-nitrogen, respectively, are contributed by precipitation to lakes in temperate latitudes. For diked marshes, it is possible that direct precipitation and atmospheric deposition are significant percentages of the yearly nutrient input.

Klarer (1988) discussed the variable effect of precipitation on a marsh based upon factors such as duration and intensity of a storm and conditions of the watershed before a storm. This variability is part of the dynamic nature of runoff into an undiked marsh, whereas only direct precipitation affects a diked marsh.

Another source of nutrient input, to diked marshes especially, is the large number of migratory waterfowl that pass through the system in early spring and in the fall. Manny et al. (1975 as cited in Wetzel 1983) found that waterfowl temporarily residing on a lake at numbers of one per m^2 can provide significant inputs of nitrogen and phosphorus. During migration large numbers of waterfowl are attracted to diked marshes. Therefore, in the months of September and October, an increase in nutrient input would be expected. For example, at station three in WPN in September when I arrived to collect a water sample, I noticed that a large area of *Typha* was bent over and bird defecation covered the plants. The nutrient concentrations increased from 0.07 mg N/l to 0.12 mg N/l nitrate, 3 µg N/l to 48 µg N/l nitrite and 0 mg N/l to 0.28 mg N/l ammonia since the previous sampling period. Orthophosphate and total phosphorus, however, decreased since the previous sampling time. The measured values suggest increases in some nutrients; however, it is difficult to differentiate between nutrient input from waterfowl activity or from macrophyte senescence, which also causes nutrient release during the fall.

Mudroch (1980) attributed increased total Kjeldahl nitrogen and ammonia in November to decomposition of vegetation. Kulshreshtha and Gopal (1982a, 1982b) documented the loss of nutrients from macrophytes by leaching and microbial decay and found an increase in alkalinity and conductivity in the surrounding water. They found rapid increases in orthophosphate during the first eight days and ammonia during the first 30 days. Losses of nitrogen and phosphorus in species of *Typha*, *Scirpus*, and *Polygonum* ranged from 41 to 83% within the first fifteen days (Kulshreshtha and Gopal 1982a, 1982b).

Vegetation Diversity and Water Level Fluctuations

The entire premise behind managing diked marshes for waterfowl is that through manipulation of water levels, desired vegetation can be achieved to enhance waterfowl habitat (Kadlec 1962, Meeks 1963, Meeks 1969, Weller 1978). The importance of the water regime in plant community development was emphasized by Geis (1979) who, in an earlier study, found four measures of water regime (minimum, maximum, and mean levels, and drawdown) were significantly correlated with species composition (Geis 1985). As a result of the differences in hydrologic regime between diked and undiked wetlands, vegetative patterns, stem density, productivity, and species diversity are altered.

Farney and Bookhout (1982) reported significantly altered vegetative composition when high water levels breached the dikes in a Lake Erie marsh. In Stuckey's (1989) extensive floristic studies in western Lake Erie, he found native species had decreased by half and non-indigenous flora comprised one-quarter to one-third of the vegetation in areas heavily affected by human activity. He concluded that "stabilization of water-levels through diking and ditching...creates a lower diversity of native species in the wetlands...and consequently, the quality of the marshes and swamps as a whole are degraded and lowered." This concurred with Meeks' (1969) findings that the stabilization of water levels by diking and drawdown reduces the diversity of wetland and aquatic flora.

On a lakewide basis, however, no significant differences were found for the measured vegetative parameters. And for the local population, significantly greater diversity was reported in the diked marshes. The reasons for this disparity are most likely due to sampling methodology. While Stuckey (1989) conducted detailed floristic studies designed to inventory all species, my study only measured dominant species at relatively few locations within the marshes. My purpose was to categorize diversity at the sampled stations, not to list all species within the marshes.

Lyon et al. (1986) found that species composition and distribution in a Lake Michigan wetland were directly related to flood duration. Species presence and absence in the diked and undiked marshes in this study can also be related to hydrologic regime. For example, two of the four sampled undiked marshes were dominated by single species, floating-leaved vegetation. A variety of emergent vegetation were observed fringing those wetlands, but only the dominant species were sampled. Floating-leaved vegetation such as those sampled are particularly adapted to changing water levels and able to tolerate extended periods of inundation. The lack of abundance of floating-leaved vegetation in diked marshes and relative abundance in undiked marshes reflects their various hydrologic signatures.

Stuckey (1975, 1989) reported that the vegetative diversity of the marshes has been maintained by the naturally fluctuating water levels of Lake Erie, and the zones of highest diversity occurred where water level fluctuations occurred throughout the season. Water level changes allow a greater diversity of species because different species are able to expoit the variety of habitats provided by changing depths (Keddy and Reznicek 1985). Lyon et al. (1986) studied Lake Michigan wetlands and found long-term lake level effects to be vital in determining short-term soil and plant characteristics. They emphasized the importance of water level changes as analagous to the importance of fire in maintaining a prairie ecosystem. Burton (1985) measured the effects of water level changes on wetland area and found that decreasing water levels of 1.5 m caused a reduction from 50% to 15% open water in a marsh. This phenomenom was observed in the undiked marshes as the drought caused a lakeward migration of the marshes due to vegetation colonizing newly exposed mudflats.

No submerged vegetation was observed in the undiked marshes. This could be due to higher turbidities causing decreased light penetration in these marshes. Carp were consistently abundant in the undiked marshes. King and Hunt (1967) found carp negatively impacted vegetation by uprooting and consuming plants and also caused increased turbidities. They found that the abundance of submerged vegetation was significantly altered. Marshall (1977) found diversity to be low in Old Woman Creek, which he also attributed to high turbidity caused by carp and by high water levels.

Macrophyte Productivity

Mitsch and Gosselink (1986) stressed hydrologic flux as the single most important factor in potential primary productivity. Inflow of water provides a nutrient and sediment supply or "subsidy" for plant growth (Gosselink and Turner 1978, Mitsch and Gosselink 1986). The flooding regime provides this energy and nutrient subsidy and hence contributes to productivity. Geis (1979) also found that modification in the water regime, whether natural or man-induced, would result in changes in primary productivity.

In diked marshes, resource intensive management replaces natural subsidies. Diked marshes were more productive in this study, as measured in peak above-ground biomass, but may have not been more productive when measured against costs of maintenance. Diked marshes are specifically managed to obtain high vegetative biomass, therefore, a comparison of above-ground biomass is biased against undiked marshes. Most studies report biomass and stem density according to single species and not assemblages of species. Very few sample quadrats in this study were represented by single species. Those that were single species were not often the same species as reported by other researchers. As a result, I was only able to compare a few of the monotypic stations of similar species with other studies. In comparing single species biomass and stem density values reported in Tilton et al. (1978) with diked marsh stations, this study had considerably higher readings for some stations and were average for other stations. Biomass of individual species were within the range of species measured in Mudroch's (1981) diked marshes. Montague et al. (1987) stated that "the energy subsidies accrued through active management may enhance primary productivity within impoundments above that occurring in natural marshes." Two undiked marshes with *Nelumbo* and *Nuphar*, large-leaved, high water-content species, had low peak biomass and stem densities. Simpson et al. (1983) measured a freshwater tidal wetland and found, in areas dominated by *Nuphar* sp., that this difference in composition was also reflected by a lower biomass. Emergent species exhibit a denser growth habit, which contributes both to the higher stem density and the higher biomass in diked marshes.

The higher stem density found in diked marshes on a local scale could be linked to factors observed by Lyon et al. (1986). They found that areas with a long relative duration of flooding had both increased bioavailable nutrient concentrations and a higher density of plants. This higher density in diked marshes is also directly related to species composition because different species exhibit different growth habits (eg. *Cyperus* have many more stems/m^2 than *Typha* or *Nuphar*). This is further connected to hydrology since *Cyperus*, for example, are predominately found on mudflats while *Nuphar* are found in open water. *Typha*, a fringe species between mud flat and open water, was found predominately in diked marshes. This species cannot survive the greatly fluctuating water levels found in undiked marshes (Stuckey 1976b).

Research conducted at Old Woman Creek suggests that this marsh is a plankton-dominated system (Reeder and Mitsch 1989a). If so, above-ground biomass would not be a proper representation of its productivity. Undiked coastal marshes export large quantities of organic matter to the surrounding water bodies. Diked marshes accumulate their organic matter in the substrate. Perhaps a measure of detrital organic matter production and export would more accurately represent undiked marsh productivity.

Implications of Marsh Management

Diking marshes has helped to maintain important waterfowl habitat in western Lake Erie in the face of increasing development pressures, and continued lake level fluctuations. The implications of marsh management on water chemistry, however, are not fully understood. Marshes have an ability under certain conditions to filter, retain, or transform nutrients to have a positive impact on the receiving water body. Numerous studies have examined the amount and mechanisms of these effects. Klarer (1988) demonstrated that Old Woman Creek ameliorated storm water that passed through the wetland. MacCrimmon's (1980) study found that Wye Marsh significantly lowered the levels of nitrogen, phosphorus, and turbidity passing through it. The amount of nutrient retention a marsh can facilitate is based on the hydrologic regime and the vegetation present in the marsh (Mudroch 1981). Tilton et al. (1978) postulated, based on published literature, that between 52-68 kg of phosphorus and 459-720 kg of nitrogen would enter Lake Michigan if surrounding wetland vegetation were removed. Consider the remaining marshes in western Lake Erie, of which 85% of those in Ohio are diked and restricted from normal exchange with Sandusky Bay and Lake Erie. If water were allowed to pass through these systems from surrounding agricultural watersheds rather than bypassing them, a valuable function would be restored.

The effects of hydrologic alteration upon chemical processes and upon vegetative structure are interrelated and intertwined. One of these cannot change without affecting the other. The character of the western Lake Erie landscape has been modified to enhance one ecological value at the expense of others. The result is an unbalanced, disturbed ecosystem as emphasized by Stuckey (1989). Siegley et al.

(1988), in a study of a created marsh near Plum Brook marsh, noted that the trend exists to replace natural marshes with managed marshes created for single purposes. With this in mind, when evaluating marsh creation for mitigation purposes, the values lost in the natural marsh must be recognized and those values should be replaced instead of substituting other values. This would lead to a more balanced ecosystem than presently exists and would contribute more to the Lake Erie landscape.

CHAPTER V

CONCLUSIONS

In an examination of the effects of diking on marshes, no significant effect was found for the lakewide population of Lake Erie marshes due to the high natural variation which exists among diked marshes and among undiked marshes. As a result, the null hypothesis that diked and undiked marshes in western Lake Erie are the same for the measured parameters was not rejected. No differences were found on the lakewide scale.

On the local population, the effects were large. The null hypothesis that diked and undiked marshes in this study (local population) are the same in terms of water chemistry and vegetation was rejected, except for nitrate and ammonia. Diked and undiked marshes were found to be different for the other parameters.

Diked and undiked marshes were found to differ in hydrologic patterns. Diked marshes have water level trends contrary to natural fluctuations. Water flow through undiked marshes is constantly changing in volume and force from watershed runoff as well as fluctuations resulting from lake seiches.

Hydrologic differences led to different seasonal water chemistry trends between diked and undiked marshes for all measured parameters except turbidity, ammonia, orthophosphate, and total phosphorus. No significant seasonal differences could be inferred lakewide. Measured chemical parameters were not significantly different between diked and undiked marshes lakewide. Conductivity, alkalinity, and orthophosphate were significantly higher in diked marshes when compared to the undiked marshes on a local scale. Turbidity, pH, nitrite, and total phosphorus were higher in the undiked marshes on a local scale. No significant differences could be inferred lakewide for any chemical parameter.

Limited nutrient input to diked marshes was attributed to hydrologic isolation from the watershed, and to a lesser extent, isolation from lake effects. Waterfowl may be a major nutrient source to diked marshes.

Higher above-ground biomass measured in this study (not significant lakewide) is attributed to energy subsidies supplied by specific management practices and more predictable water levels. As nutrients are recycled and not flushed from the system as in undiked marshes, productivity is enhanced. Productivity in undiked marshes is possibly more tied up in plankton and detritus.

Future Implications

Perhaps the more important question is not the effect of diking on the marsh but what effect does diking have on the surrounding water body and associated ecosystem. In Lake Erie, such a small proportion of marshes now remain with respect to total lake acreage that their effect on the landscape may be negligible. But in other areas, such as Louisiana, where enormous acreages of marsh still exist and diking is encouraged as a means of wetland protection, this practice may dramatically affect ecosystem functions and values. State-owned fish and wildlife refuges in Louisiana and elsewhere are primarily managed for single-use waterfowl management (U.S. EPA and LGS 1987). As a result, fisheries have already been negatively impacted. The effects of diking on water chemistry processes needs to be conducted to quantify these effects and determine if they are significant to the ecosystem. Alternative methods of marsh management which provide for other marsh values should be explored, especially where public land is involved.

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APPENDIX A

WATER CHEMISTRY DATA FOR INDIVIDUAL SAMPLING STATIONS BETWEEN MAY AND OCTOBER, 1988

SITE/STATION	DATE •	WATER LEVEL (cm)	ALKALINITY (mg $CaCO_3$/l)	CONDUCTIVITY (µmhos)	TURBIDITY (NTU)	ORTHO-PHOSPHATE (µg P/l)	NITRATE (mg N/1)	NITRITE (µg N/1)	AMMONIA (mg N/1)	DISSOLVED OXYGEN (mg/l)	TEMPERATURE (°C)	pH	TOTAL PHOSPHORUS (µg P/l)
Bay View B /1	0	41											
/1	1	31	115	1130	4	83	0.14	1	0.16	15.0	21	8.77	20
/1	2	27	81	1251	8	358	1.06	1	0.55	11.5	1	6.87	86
/1	3		132	1418	15	15	0.62	2	0.06	13.5	30	7.24	61
/1	5		114	1764	7	51	0.04	2	0.02			6.93	67
/1	8		174	1537	12	9	0.08	2	0.00	4.5	21	6.83	78
/2	0	38											
/2	1	26	195	1228	16	16	0.19	1	0.14	12.5	20	8.45	42
/2	2	24	137	1353	22	32	2.43	1	0.34	12.0	14	7.46	105
/3	1		190	1232	8	7	0.06	1	0.00	6.5	19	8.33	18
/3	2		153	1285	9	10	1.41	1	0.16	10.0	13	7.69	24
/3	3		153	1393	5	6	0.65	2	0.06	15.0	28	8.23	20
/3	4		179	1915	35	8	0.45	4	0.10	6.8	25	7.88	146
/3	5		132	1704	8	8	0.14	2	0.00			7.87	37
/3	7		58	1503	6	30	0.07	2	0.06	14.5	33	8.18	48
/3	8		52	1330	9	8	0.10	2	0.01	14.5	23	8.12	44
/3	9		46	1237	18	8	0.14	5	0.04	12.5	25	8.67	59
Bay View Center /1	1		188	905	10	82	0.39	1	0.06	9.5	17	8.26	26
/1	2		178	972	13	85	1.12	1	0.12	9.3	12	8.18	37
/1	3		167	1070	13	18	0.99	2	0.05	9.5	20	7.90	53
/1	4		179	1225	19	18	0.36	3	0.00	4.0	21	7.52	81
/1	5		175	858	30	11	0.07	2	0.00			7.62	69
/1	7		156	828	12	14	0.14	2	0.00	7.5	31	7.98	51
/1	8		146	825	11	8	0.09	2	0.00	8.8	22	7.75	42
/1	9		143	811	12	7	0.08	3	0.00	9.0	21	7.86	28
/1	11		153	868	30	6	0.11	5	0.08	11.8	7	7.91	43
/2	0	37											
/2	1	29	189	920	10	6	0.03	1	0.00	10.3	19	8.29	28
/2	2	24	173	983	9	14	1.11	1	0.22	7.3	10	7.38	32
/2	3	16	178	1120	7	6	0.05	2	0.06	6.8	20	7.49	68
/2	4		159	1406	19	6	0.10	3	0.01	9.5	23	8.22	48
/2	5	26	164	911	18	9	0.04	2	0.00			7.45	72
/2	7	25	124	854	11	11	0.12	2	0.03	8.3	31	7.61	46
/2	8	23	121	812	8	9	0.06	2	0.00	8.5	21	7.55	52
/2	9	21	120	790	15	8	0.10	4	0.00	9.3	22	7.63	51
/3	0	36											
/3	1	27	193	919	20	7	0.27	1	0.02	7.5	19	8.26	25
/3	2	23	180	983	18	8	1.48	1	0.14	8.5	13	7.88	36
/3	3		160	1086	9	7	1.13	2	0.04	12.5	30	7.96	42
/3	5		183	1077	7	7	0.19	2	0.00			7.22	35
/3	7		166	970	9	8	0.57	3	0.19	7.8	34	7.73	50
/3	8		154	865	7	8	0.05	2	0.00	9.3	24	7.64	35
/3	9		158	863	5	7	0.08	3	0.02	10.8	23	7.71	20

SITE/STATION	DATE *	WATER LEVEL (cm)	ALKALINITY (mg $CaCO_3$/l)	CONDUCTIVITY (µmhos)	TURBIDITY (NTU)	ORTHO-PHOSPHATE (µg P/l)	NITRATE (mg N/1)	NITRITE (µg N/1)	AMMONIA (mg N/1)	DISSOLVED OXYGEN (mg/l)	TEMPER-ATURE (°C)	pH	TOTAL PHOSPHORUS (µg P/l)
Ottawa Allen													
Pond /1	0	6											
/1	1	0	244	993	145	13	0.06		0.04	9.5	12	8.32	444
/1	2	-4	277	1087	140	23	1.13	6	0.07	9.0	18	8.11	505
/1	3	-3	250	1472	137	36	1.01	3	0.04	7.5	13	7.07	796
/1	4	-8	305	1606	135	62	0.78	6	0.02	4.8	21	7.87	532
/1	5	6	127	943	63	61	0.34		0.01	6.5	23	7.48	179
/1	6	11	172	936	43	33	0.19		0.02	2.3	26	7.37	218
/1	7	19	235	1022	51	303	0.51	4	0.01	2.4	26	7.52	302
/1	8	14	252	992	42	257	0.23	4	0.00	6.5	20	7.77	264
/1	9	16	241	907	27	152	0.11	4	0.01	5.0	18	7.50	153
/1	11	18	248	935	35	37	0.20	5	0.01	12.4	6	7.93	89
/2	0	6											
/2	1	0	241	1008	77	15	0.09	2	0.07	9.5	12	8.45	435
/2	2	-3	282	1120	115	100	0.16	4	0.09	7.8	18	7.94	677
/2	3	-3	279	1447	79	51	0.12	3	0.02	10.8	11	7.82	446
/2	4	-5	304	1623	120	77	0.07	3	0.03	8.0	21	7.95	541
/2	5	6	127	830	36	192	0.03		0.00	2.0	23	7.22	299
/2	6	11	158	899	42	27	0.10	5	0.00	2.8	26	7.09	229
/2	7	10	191	975	38	248	0.19	4	0.01	3.0	26	7.45	233
/2	8	14	211	930	29	373	0.09	4	0.00	8.8	22	7.99	189
/2	9	15	232	852	57	102	0.05	5	0.00	6.5	19	7.61	213
/2	11	18	242	942	37	46	0.16	5	0.00	12.6	6	7.37	101
/3	0	17											
/3	1	10	246	971	65	22	0.51	2	0.17	11.0	11	8.38	359
/3	2	5	303	1198	36	140	0.81		0.20	9.5	19	7.56	362
/3	3	7	290	1456	110	26	0.13	3	0.04	10.3	14	7.74	293
/3	5	16	148	930	15	22	0.12		0.06	2.5	22	6.85	103
/3	6	21	179	850	10	14	0.08	5	0.02	1.3	25	6.82	181
/3	7	21	243	967	9	444	0.27	3	0.00	1.6	24	6.98	400
/3	8		222	916	5	329	0.12	3	0.00	0.8	19	7.14	255
/3	9	25	275	828	14	796	0.04	5	0.00	1.0	16	7.27	685
/3	11	29	195	967	29	42	0.10	4	0.00	11.2	5	6.83	135

SITE/STATION		DATE •	WATER LEVEL (cm)	ALKALINITY (mg $CaCO_3$/l)	CONDUCTIVITY (μmhos)	TURBIDITY (NTU)	ORTHO-PHOSPHATE (μg P/l)	NITRATE (mg N/1)	NITRITE (μg N/1)	AMMONIA (mg N/1)	DISSOLVED OXYGEN (mg/l)	TEMPER-ATURE (°C)	pH	TOTAL PHOSPHORUS (μg P/l)
Ottawa Big Pond	/1	0	14											
	/1	1	8	173	1395	53	11	0.11	1	0.10	9.8	11	8.42	121
	/1	2	-1	179	1680	47	8	0.45	1	0.04	9.3	18	7.90	169
	/1	3	-1	118	1842	81	14	0.12	2	0.06	11.8	11	7.91	438
	/1	4	1	124	1840	71	8	0.12	2	0.01	8.3	20	8.55	345
	/1	5	36	131	1214	37	11	0.03		0.00	7.8	26	8.22	92
	/1	6	48	96	1094	31	20	0.33	4	0.00	3.8	27	7.34	185
	/1	7	55	160	1113	39	16	0.15	3	0.00	4.0	27	7.75	122
	/1	8	57	174	1099	36	12	0.08	3	0.00	9.3	21	8.13	93
	/1	9	58	179	1038	18	7	0.08	3	0.00	7.0	18	7.78	66
	/1	11	50	191	1160	14	6	0.22	14	0.07	12.2	6	8.14	62
	/2	0	6											
	/2	1	-3	184	1482	38	387	0.04	1	0.14	10.5	15	8.42	136
	/2	2	0											
	/2	3	0											
	/2	4	-5	138	2287	47	42	0.08	2	0.02	12.5	24	8.65	641
	/2	5	27	129	1244	43	88	0.04		0.00	13.0	26	8.45	126
	/2	6	39	125	1105	36	18	0.31	4	0.00	6.5	27	7.89	135
	/2	7	46	165	1129	41	136	0.16	2	0.01	6.0	26	7.77	123
	/2	8	48	175	1125	35	102	0.20	3	0.00	10.3	21	7.92	117
	/2	9	50	177	1066	22	54	0.07	3	0.00	8.0	18	7.81	76
	/2	11	45	191	1164	23	11	0.23	17	0.09	12.4	5	8.02	43
	/3	0	13											
	/3	1	4	179	1434	55	15		1	0.10	10.0	14	8.46	148
	/3	2	-1	181	1780	46	22		1	0.00	11.0	24	7.84	151
	/3	3	0											
	/3	4	-1	137	2277	52	11	0.08	3	0.01	10.8	26	8.66	475
	/3	5	34	127	1234	48	14	0.03		0.00	10.5	25	8.10	144
	/3	6	47	127	1057	28	8	0.12	3	0.00	6.5	27	7.91	94
	/3	7	53	170	1150	32	47	0.09	3	0.00	7.2	27	7.58	129
	/3	8	57	154	1076	33	25	0.09	3	0.00	10.5	22	7.99	94
	/3	9	57	174	1056	25	15	0.07	4	0.00	8.8	19	7.76	72
	/3	11		189	1162	36	9	0.20	12	0.04	13.0	5	8.09	52
	/4	0	6											
	/4	1	0	172	1396	65	55	0.33	1	0.08	10.3	13	8.57	155
	/4	2	-8	181	1710	42	42	0.85	2	0.05	10.5	19	7.96	246
	/4	3	-8	119	1838	80	61	0.34	3	0.04	12.5	14	8.15	269
	/4	4	-5	122	1809	72	42	0.28	3	0.00	14.5	24	8.70	345
	/4	5	29	127	1227	45	13	0.04		0.00	10.8	25	8.33	124
	/4	6	43	121	1058	37	8	0.09	3	0.00	6.5	27	7.85	159
	/4	7	47	151	1124	40	22	0.04	2	0.00	6.8	26	7.68	115
	/4	8	52	173	1112	57	15	0.06	3	0.00	10.8	22	8.16	85
	/4	9	53	176	1082	20	13	0.09	2	0.00	9.5	19	7.80	68
	/4	11	46	0	1134	22	115	0.28			12.4	6	7.72	

SITE/STATION	DATE *	WATER LEVEL (cm)	ALKALINITY (mg $CaCO_3$/l)	CONDUCTIVITY (µmhos)	TURBIDITY (NTU)	ORTHO-PHOSPHATE (µg P/l)	NITRATE (mg N/1)	NITRITE (µg N/1)	AMMONIA (mg N/1)	DISSOLVED OXYGEN (mg/l)	TEMPER-ATURE (°C)	pH	TOTAL PHOSPHORUS (µg P/l)
Winous Point North /1	0	8											
/1	1	3	224	884	20	74	0.08	4	0.03	9.5	22	7.94	108
/1	2	8	127	638	9	118	0.14	1	0.11	12.5	21	7.63	143
/1	3	15	113	678	18	62	0.30	3	0.03	11.3	24	7.87	98
/1	4	13	133	685	16	342	0.34	3	0.00	13.8	25	7.50	279
/1	5		146	684	10	198	0.20		0.00			7.34	316
/1	7		162	638	13	201	0.04	3	0.00	2.0	31	7.35	395
/1	9		133	578	28	14	0.06	3	0.00	7.5	19	7.66	312
/1	11		120	691	15	7	0.05	4	0.08	11.5	1	7.85	62
/2	0	10											
/2	1	17	179	908	57	45	0.18	3	0.02	9.5	21	8.03	108
/2	2	15	133	860	16	95	0.56	2	0.14	10.0	19	7.43	130
/2	3	23	89	851	13	223	0.27	3	0.03	14.0	23	8.22	148
/2	4	22	180	891	15	243	0.44	3	0.01	6.5	24	7.25	151
/2	5	28	120	695	11	100	0.30		0.00			7.25	107
/2	7	27	112	676	11	134	0.27	4	0.00	2.5	25	7.06	124
/2	9	25	79	544	14	87	0.06	4	0.08	7.5	17	7.50	115
/2	11	53	70	722	23	76	0.42	3	0.06	11.5	10	6.52	95
/3	0	21											
/3	1	17	179	887	44	15	0.26	3	0.17	11.5	21	8.66	116
/3	2	17	173	875	30	61	0.25	2	0.16	11.0	19	7.82	110
/3	3	25	138	892	19	69	0.31	2	0.04	7.5	25	7.54	187
/3	4	24	114	923	23	46	0.55	3	0.04	9.5	25	7.53	213
/3	5	30	126	718	15	136	0.15		0.00			7.39	145
/3	7		159	691	41	211	0.07	3	0.00	2.0	24	7.48	322
/3	9		126	569	17	60	0.12	48	0.28	2.5	17	7.40	149
/3	11		123	692	30	7	0.06	3	0.02	12.0	1	7.94	87
/4	0	24											
/4	1	19	175	898	90	10	0.08	3	0.00	9.0	18	8.29	346
/4	2	19	158	910	25	9	0.26	1	0.11	8.3	19	7.92	72
/4	3	28	116	910	21	13	0.34	2	0.02	8.0	23	7.92	84
/4	4	26	85	901	8	22	0.34	3	0.00	11.8	23	8.50	66
/4	5	40	115	738	9	121	0.14		0.00			8.88	107
/4	7	32	156	676	22	185	0.07	3	0.00	11.3	26	8.93	218
/4	9	30	125	528	30	29	0.11	3	0.00	10.3	20	8.55	160
/4	11		122	690	18	7	0.06	3	0.01	12.5	1	7.96	60
/5	0	8											
/5	1	18	193	899	125	11	0.08	2	0.02	7.8	20	8.18	356
/5	2	18	158	896	21	19	0.20	1	0.11	9.3	19	7.75	73
/5	3	26	127	853	25	27	0.44	3	0.03	8.0	25	7.62	106
/5	4	25	56	705	18	15	0.06	2	0.02	11.5	26	8.86	57
/5	5	92		628	12	65	0.12		0.01			9.30	71
/5	7		162	650	13	236	0.05	3	0.00	11.5	26	8.70	186
/5	9		128	558	30	24	0.05	5	0.00	8.3	20	7.85	67
/5	11	30	108	704	25	7	0.06	3	0.03	11.5	1	7.41	53

SITE/STATION	DATE *	WATER LEVEL (cm)	ALKALINITY ($mg\ CaCO_3/l$)	CONDUCTIVITY (µmhos)	TURBIDITY (NTU)	ORTHO-PHOSPHATE (µg P/l)	NITRATE (mg N/1)	NITRITE (µg N/1)	AMMONIA (mg N/1)	DISSOLVED OXYGEN (mg/l)	TEMPER-ATURE (°C)	pH	TOTAL PHOSPHORUS (µg P/l)
Winous Point													
North /6	1		116	908	29	22	0.06	3	0.02	10.0	18	8.13	68
/6	2		226	942	21	187	0.09	1	0.08	12.5	19	7.58	205
/6	3		110	879	17	73	0.33	3	0.03	9.3	22	7.95	180
/6	4		134	919	15	114	0.03	2	0.04	6.8	24	7.48	161
/6	5		119	849	13	51	0.14		0.02			7.31	130
/6	7		148	709	11	112	0.05	3	0.00	1.3	25	7.37	171
/6	9		142	584	20	36	0.07	4	0.00	2.5	16	7.29	198
/6	11		111	688	76	7	0.07	3	0.03	12.0	1	7.96	129
Winous Point													
West /1	0	0											
/1	1	39	199	790	8	116	0.14	4	0.00	1.8	16	7.55	146
/1	2	35	195	803	20	185	1.24	4	0.09	0.0	20	7.36	161
/1	3	25	264	843	18	155	0.31	5	0.03	2.5	18	7.41	242
/1	4		305	919	79	106	0.31	3	0.12	4.5	20	7.62	420
/1	5	42	116	909	32	28	0.31		0.01			7.38	157
/1	8	61	50	827	37	36	1.20	5	0.20	4.5	20	6.56	93
/1	9	60	170	802	26	82	0.20	4	0.03	5.5	18	6.16	66
/1	11	60	0	3984	9	218	0.10	2	0.02	13.5	1	2.08	131
/2	0	41											
/2	1	37	211	787	15	154	1.34	5	0.11	7.5	15	7.76	29
/2	2	32	147	738	6	219	1.32	1	0.12	6.3	19	7.42	77
/2	3	23	230	864	17	135	1.05	9	0.04	4.8	18	7.75	144
/2	5	39	165	798	32	112	0.25		0.00			7.85	146
/2	8	58	137	706	24	44	0.24	4	0.00	7.3	20	7.22	109
/2	9	56	156	694	30	52	0.17	14	0.06	6.3	18	6.93	126
/2	11	56	167	677	6	276	0.12	5	0.03	12.0	1	7.08	163
/3	0	22											
/3	1	19	209	784	45	352	1.05	6	0.09	8.5	16	7.86	104
/3	2	14	248	831	19	298	0.72	1	0.04	9.5	18	7.60	168
/3	3	9	238	822	36	82	0.79	4	0.03	6.3	20	8.08	198
/3	4	9	294	988	75	131	0.50	6	0.02	6.5	22	7.94	
/3	5	21	156	790	35	65	0.21		0.00			7.65	192
/3	8	39	143	697	22	21	0.06	2	0.00	6.5	20	7.31	381
/3	9	38	175	723	35	22	0.12	3	0.01	6.5	19	7.38	155
/3	11	38	184	738	16	568	0.09	4	0.01	5.8	2	7.25	384
/4	0	9											
/4	1	4	243	825	14	78	0.09	5	0.09	6.5	16	7.77	75
/4	2	-1	234	859	9	70	0.22	1	0.10	5.0	19	7.50	78
/4	3		245	836	31	60	0.32	3	0.05	7.0	22	8.00	227
/4	5	6	172	864	20	22	0.11		0.01			7.39	161
/4	8		135	712	32	23	0.05	3	0.00	6.8	20	7.36	93
/4	9		174	709	19	27	0.09	4	0.00	5.5	18	7.45	101
/4	11	23	213	758	13	19	0.06	2	0.03	13.5	1	7.28	71

SITE/STATION	DATE *	WATER LEVEL (cm)	ALKALINITY ($mg\ CaCO_3/l$)	CONDUCTIVITY (µmhos)	TURBIDITY (NTU)	ORTHO-PHOSPHATE (µg P/l)	NITRATE (mg N/l)	NITRITE (µg N/l)	AMMONIA (mg N/l)	DISSOLVED OXYGEN (mg/l)	TEMPER-ATURE (°C)	pH	TOTAL PHOSPHORUS (µg P/l)
Winous Point													
West /5	0	10											
/5	1	5	222	826	16	62	0.32	5	0.17	7.5	16	7.50	68
/5	2	1	231	860	9	74	0.30	1	0.14	7.5	19	7.32	73
/5	3	-9	227	1062	20	30	0.31	3	0.07	9.3	24	7.97	94
/5	5	8	176	1002	14	24	0.27		0.08			7.34	72
/5	8	27	126	716	26	88	0.24	3	0.03	4.8	20	7.22	101
/5	9	25	132	746	37	14	0.12	3	0.00	3.5	18	7.11	49
/5	11	60	194	756	5	19	0.09	3	0.01		1	7.56	46
Pickerel													
Creek /1	0	15											
/1	1	32	98	583	180	14	1.31	13	0.14	11.5	26	8.31	166
/1	2	13											
/1	3	10	95	717	42	15	0.39	1	0.03	11.5	17	7.81	144
/2	0	0											
/2	1	41	100	686	34	59	1.06	12	0.09	14.0	20	8.39	87
/2	2	29	92	693	148	25	1.59	2	0.08	14.3	25	8.03	250
/2	3		94	660	42	40	0.13	3	0.05	11.5	17	8.26	121
/2	7		123	1744	30	37	0.26	3	0.02	6.1	24	7.34	230
/3	0	26											
/3	1	44	103	587	89	27	1.65	15	0.20	9.3	16	8.36	179
/3	2	25	199	1751	63	26	0.48	32	0.16	13.5	24	8.10	159
/3	3	22	104	883	36	24	1.06	1	0.06	12.8	17	8.45	129
/3	4		191	1949	80	25	0.10	3	0.05	7.0	29	7.65	273
/3	5		168	2157	59	16	0.07	9	0.00			7.57	162
/3	7		202	2312	46	44	0.26	2	0.06	7.3	24	7.40	224
/3	8	9	219	2128	14	12	0.68	55	0.13	6.0	19	7.78	88
/3	9	7											

SITE/STATION	DATE *	WATER LEVEL (cm)	ALKALINITY (mg $CaCO_3$/l)	CONDUCTIVITY (µmhos)	TURBIDITY (NTU)	ORTHO-PHOSPHATE (µg P/l)	NITRATE (mg N/l)	NITRITE (µg N/l)	AMMONIA (mg N/l)	DISSOLVED OXYGEN (mg/l)	TEMPER-ATURE (°C)	pH	TOTAL PHOSPHORUS (µg P/l)
Plum Brook /1	0	34											
/1	1	28	121	424	40	7	0.66	32	0.05	9.3	14	7.83	62
/1	2	30	113	399	46	8	0.85	3	0.13	10.5	15	8.20	111
/1	3	34	106	358	81	8	0.42	1	0.05			8.16	183
/1	4	34	116	370	185	12	0.11	7	0.03	6.5	25	7.29	275
/2	0	0											
/2	1	22	114	394	34	7	0.79	14	.00	10.7	15	8.29	57
/2	2	23	108	357	96	12	1.09	8	0.11	10.5	18	8.35	154
/2	3	30	104	297	50	7	0.90	3	0.04			8.38	103
/2	4	27	115	365	161	12	0.17	3	0.02	7.8	26	7.35	178
/3	0	29											
/3	1	23	109	393	26	15	1.70	14	0.02	11.0	15	8.33	42
/3	2	23	110	353	91	14	1.49	8	0.17	8.5	16	7.94	199
/3	3	31	97	296	57	19	0.96	7	0.06			8.25	115
/3	4	29	118	366	128	14	0.37	3	0.00	8.0	27	7.76	216
/4	0	28											
/4	1	20	117	371	52	9	0.58	13	0.01	6.3	13	8.10	55
/4	2	22	117	355	55	10	0.28	1	0.09	12.0	18	8.63	99
/4	3	28	99	299	42	10	1.12	7	0.05			8.38	76
/4	4	28	110	351	138	16	0.19	3	0.00	8.5	28	7.70	200
/5	2		119	416	55	9	0.69	1	0.14			8.72	127
/5	3		106	324	54	8	1.23	1	0.05			8.32	
/5	4		119	364	115	23	0.08	4	0.06	8.3	27	7.88	105
Willow Point /1	0	25											
/1	1	43	110	665	113	19	1.27	25	0.22	11.8	20	7.82	342
/1	2	29	136	696	70	9	0.64	1	0.07	10.5	34	7.99	228
/1	3	25	173	739	67	39	0.08	7	0.31	10.8	19	7.76	449
/1	4	17	91	707	68	147	0.07	2	0.00	11.5	32	8.27	523
/2	0	13											
/2	1	30	97	698	64	54	0.34	12	0.22	11.8	22	8.51	148
/2	2		83	620	90	47	0.85	1	0.12	8.5	29	7.80	
/2	3		120	625	89	13	0.11	2	0.05	6.5	20	7.59	196
/2	4		128	745	165	8	0.09	2	0.00	7.0	31	8.05	522
/3	0	17											
/3	1	13	334	2449	24	307	1.40	1	0.20	12.0	26	8.08	306
/3	2	17	170	2774	15	61	1.52	2	0.12	10.5	34	7.96	190
/3	3	16		2070	13	209	0.67	2	0.08	13.3	23	8.04	799

SITE/STATION		DATE *	WATER LEVEL (cm)	ALKALINITY ($mg\ CaCO_3/l$)	CONDUCTIVITY (µmhos)	TURBIDITY (NTU)	ORTHO-PHOSPHATE (µg P/l)	NITRATE (mg N/1)	NITRITE (µg N/1)	AMMONIA (mg N/1)	DISSOLVED OXYGEN (mg/l)	TEMPER-ATURE (°C)	pH	TOTAL PHOSPHORUS (µg P/l)
Sheldon Marsh	/1	0	64											
	/1	1	51	98	328	58	11	0.73	15	0.05	9.0	16	7.48	76
	/1	2	53	102	332	65	13	0.86	11	0.21	9.3	18	7.34	125
	/1	3	74	102	296	64	10	0.47	20	0.16	11.0	17	8.21	123
	/1	4	52	131	339	98	18	0.16	6	0.05	9.0	29	7.49	214
	/1	5	46	155	347	29	181	0.05		0.00	15.0	31	8.58	231
	/1	6	44	158	352	31	71	0.16	4	0.00	12.8	30	8.22	409
	/1	7	44	139	305	63	424	0.14	5	0.00			9.03	705
	/1	8	45	105	263	39	171	0.10	5	0.00	6.3	19	7.98	301
	/1	9	39	143	372	40	172	0.10	7	0.02	15.0	26	8.96	804
	/2	0	50											
	/2	1	39	99	388	94	9	0.31	21	0.48	6.5	17	7.22	192
	/2	2	41	106	331	72	9	0.54	15	0.37	8.5	18	7.32	132
	/2	3	62	79	310	58	10	0.36	18	0.23	10.5	17	7.47	76
	/2	4	39	113	356	91	14	0.11	11	0.04	9.3	27	7.15	166
	/2	5	34	146	371	22	106	0.06		0.00	9.5	29	7.50	171
	/2	6	32	163	369	23	46	0.07	3	0.00		27	7.85	307
	/2	7	30	152	364	64	166	0.08	5	0.00			7.65	463
	/2	8	31	84	261	62	197	0.06	6	0.00	8.8	20	7.47	463
	/2	9	27	133	375	64	54	0.06	3	0.03	9.8	24	7.57	454
	/3	0	48											
	/3	1	41	106	315	88	8	0.64	17	0.05	8.5	15	7.81	181
	/3	2	41	113	326	120	11	0.65	12	0.20	9.0	17	7.52	231
	/3	3	64	104	289	50	13	0.28	21	0.20	9.5	16	8.59	125
	/3	4	40	118	312	63	14	0.19	11	0.07	5.8	26	7.35	299
	/3	5	36	145	344	14	74	0.05		0.00	12.3	28	8.50	116
	/3	6	33	147	344	18	39	0.16	4	0.00			7.87	220
	/3	7	33	146	346	38	121	0.08	5	0.00			7.67	277
	/3	8	33	85	232	41	36	0.05	4	0.00	5.5	18	7.47	199
	/3	9	29	143	309	22	189	0.10	6	0.05	15.0	23	9.32	265

SITE/STATION	DATE *	WATER LEVEL (cm)	ALKALINITY (mg $CaCO_3$/l)	CONDUCTIVITY (µmhos)	TURBIDITY (NTU)	ORTHO-PHOSPHATE (µg P/l)	NITRATE (mg N/1)	NITRITE (µg N/1)	AMMONIA (mg N/1)	DISSOLVED OXYGEN (mg/l)	TEMPER-ATURE (°C)	pH	TOTAL PHOSPHORUS (µg P/l)
Old Woman Creek /1	0												
/1	1		117	536	71	17	0.14	9	0.17	7.0	19	7.80	133
/1	2	102	121	448	39	14	0.40	1	0.05	9.5	23	7.86	97
/1	3	109	166	517	77	17	0.23	3	0.02	4.5	23	7.59	176
/1	4	100	181	554	65	15	0.14	3	0.04	11.8	29	8.12	164
/1	5	84	170	598	57	16	0.13		0.00	13.8	30	8.36	166
/1	6	84	172	552	62	11	0.17	5	0.00			8.57	176
/1	7	84	156	545	39	39	0.58	3	0.05			8.90	172
/1	8	90	122	468	75	123	0.15	5	0.00	10.5	20	8.32	255
/1	9	89	118	479	49	13	0.08	3	0.02	10.8	22	8.36	83
/1	10	81	122	584	47	10	0.09	4	0.02	14.5	12	7.66	148
/1	11	86	133	527	26	6	0.09	3	0.01	14.0		7.87	94
/2	0	0											
/2	1		120	542	73	13	0.13	11	0.16			7.99	156
/2	2		138	491	70	10	0.40	2	0.26	5.5	24	7.81	116
/2	3		168	530	82	17	0.13	3	0.09	5.8	23	7.70	190
/2	4		186	569	86	18	0.07	3	0.05	6.5	26	7.98	183
/2	5		172	578	78	34	0.04		0.00	11.0	31	8.42	223
/2	6		172	555	64	14	0.08	4	0.00			8.68	151
/2	8		130	476	82	29	0.14	21	0.07	8.3	20	8.28	224
/2	9		119	470	62	21	0.08	5	0.02	14.3	24	8.92	183
/2	10		139	579	46	20	0.09	2	0.00	14.3	10	8.36	141
/2	11		144	524	21	6	0.06	3	0.04	14.3		8.42	80
/3	0	33											
/3	1		118	543	58	15	0.16	11	0.09			8.09	140
/3	2	131	126	474	62	10	0.17	1	0.13	6.0	24	7.73	125
/3	3	137	163	532	77	13	0.16	2	0.02	6.3	23	7.56	154
/3	4	130	186	570	74	15	0.08	3	0.01	9.5	27	8.12	222
/3	5	114	151	599	72	14	0.02		0.00	13.0	30	7.43	206
/3	6	114	173	570	69	11	0.08	4	0.00			8.70	227
/3	7	109	124	581	62	93	0.05	3	0.01			6.88	244
/3	8	119	122	474	73	13	0.08	11	0.02	9.0	19	7.91	229
/3	9	118	121	477	57	12	0.06	3	0.01	11.0	22	8.50	179
/3	10	110	111	602	57	9	0.08	3	0.00	12.0	10	7.75	167
/3	11	116	143	526	19	7	0.06	3	0.02	14.2		8.26	78

SITE/STATION		DATE *	WATER LEVEL (cm)	ALKALINITY (mg $CaCO_3$/l)	CONDUCTIVITY (µmhos)	TURBIDITY (NTU)	ORTHO-PHOSPHATE (µg P/l)	NITRATE (mg N/1)	NITRITE (µg N/1)	AMMONIA (mg N/1)	DISSOLVED OXYGEN (mg/l)	TEMPER-ATURE (°C)	pH	TOTAL PHOSPHORUS (µg P/l)
Old Woman Creek	/4	5		180	579	58	15	0.04		0.01	8.5	29	8.42	173
	/4	6		181	575	71	10	0.09	4	0.00			8.69	211
	/4	8		121	489	62	16	0.12	8	0.07	4.5	18	7.36	251
	/4	9		116	481	42	12	0.09	4	0.04	4.3	25	7.53	145
	/4	10		128	577	47	9	0.08	3	0.00	11.5	9	7.76	146
	/4	11		148	520	35	6	0.05	2	0.02	14.6		8.51	97
	/5	5		177	575	90	24	0.02		0.00	8.5	30	8.11	312
	/5	6		179	582	59	11	0.09	4	0.00			8.40	204
	/5	8		133	507	65	13	0.18	24	0.17	6.5	19	7.72	183
	/5	9		121	486	61	12	0.09	2	0.01	11.0	22	8.48	222
	/5	10		141	586	54	11	0.07	3	0.00	8.8	10	7.70	160
	/5	11		138	545	82	7	0.07	4	0.02	12.2		7.69	207

* Date numbers 1 through 11 correspond to the following sampling days (month/day) for each marsh.

BVB, BVC : #1 = 5/12, #2 = 5/26, #3 = 6/11, #4 = 6/25, #5 = 7/30, #7 = 8/12, #8 = 8/27, #9 = 9/10, #11 = 10/28
OSCA, OSCB : #1 = 5/14, #2 = 5/28, #3 = 6/9, #4 = 6/23, #5 = 6/27, #6 = 8/3, #7 = 8/14, #9 = 9/10, #11 = 10/28
WPN : #1 = 5/9, #2 = 5/23, #3 = 6/6, #4 = 6/20, #5 = 7/25, #7 = 8/11, #9 = 9/11, #11 = 10/26
WPW : #1 = 5/9, #2 = 5/23, #3 = 6/6, #4 = 6/20, #5 = 7/25, #8 = 8/28, #9 = 9/11, #11 = 10/26
PCK, WLP : #1 = 5/14, #2 = 5/28, #3 = 6/11, #4 = 6/25
PLMB : #1 = 5/12, #2 = 5/26, #3 = 6/11, #4 = 6/23
SHM : #1 = 5/12, #2 = 5/26, #3 = 6/9, #4 = 6/23, #5 = 7/27, #6 = 8/3, #7 = 8/14, #8 = 8/28, #9 = 9/11
OWC : #1 = 5/9, #2 = 5/23, #3 = 6/7, #4 = 6/20, #5 = 7/27, #6 = 8/3, #7 = 8/14, #8 = 8/29, #9 = 9/11, #10 = 10/8, #11 = 10/26

APPENDIX B

PLANT SPECIES REFERENCE LIST

SPECIES *	COMMON NAME
ALISMACEAE	
19. *Sagittaria latifolia* Willd.	Common Arrowhead
AMARANTHACEAE	
22. *Amaranthus tuberculatus* (Moq.) Saver	Pigweed
CERATOPHYLLACEAE	
25. *Ceratophyllum demersum* L.	Coontail
CRUCIFERAE	
8. *Rorippa palustris* (L.) Bess	Yellow Cress
CYPERACEAE	
5. *Cyperus diandrus* Torr. **	Low Cyperus
4. *Cyperus erythrorhizos* Muhl.	Red-rooted Sedge
32. *Cyperus ferruginescens* Boeckl.	Rusty Sedge
1. *Eleocharis* sp.	Spike Rush
17. *Scirpus acutus* Muhl.	Hardstem Bulrush
14. *Scirpus fluviatilis* Torr.	River Bulrush
3. *Scirpus validus* Vahl.	Softstem Bulrush
GRAMINEAE	
30. *Echinochloa crusgalli* (L.) Beauv.	Coxspur Grass
31. *Echinochloa crusgalli* var. *frumentacea* (Link) W.F. Wight	Japanese Millet
29. *Echinochloa pungens* (Poir.) Rydb.	Barnyard Grass
9. *Echinochloa walteri* (Pursh) Nash.	Walter's Millet
20. *Leersia oryzoides* (L.) Swartz.	Rice Cutgrass
34. *Panicum dichotomiflorum* Michaux	Panic Grass
16. *Phragmites australis* (Cav.) Trin. ex Steud.	Reed Grass
HALORAGIDACEAE	
26. *Myriophyllum spicatum* L.	Eurasian Water Milfoil
LENTIBULARIACEAE	
15. *Utricularia vulgaris* L.	Bladderwort

SPECIES *	COMMON NAME
LYTHRACEAE	
2. *Lythrum salicaria* L.	Purple Loosestrife
MALVACEAE	
33. *Abutilon theophrasti* Medicus	Velvetleaf
6. *Hibiscus palustris* L.	Marsh Rose Mallow
NAJADACEAE	
27. *Potamogeton crispus* L.	Curly Pondweed
NYMPHAEACEAE	
18. *Nelumbo lutea* (Willd.) Pers.	American Lotus
21. *Nuphar advena* Ait.	Yellow Water Lily
ONAGRACEAE	
35. *Ludwigia palustris* (L.) Ell.	Water Purslane
POLYGONACEAE	
10. *Polygonum lapathifolium* L.	Nodding Smartweed
28. *Polygonum pensylvanicum* L.	Pinkweed
7. *Rumex maritimus* L.	Duckweed
PONTEDERIACEAE	
24. *Pontederia cordata* L.	Pickerelweed
SALICACEAE	
11. *Populus deltoides* Marsh.	Cottonwood
13. *Salix* sp.	Willow
SPARGANIACEAE	
23. *Sparganium eurycarpum* Engelm.	Bur Reed
TYPHACEAE	
12. *Typha angustifolia* L.	Narrow-leaved Cattail

* Numbers before species name represents coding found in Appendix D.
** Ohio threatened plant (McCance and Burns 1984)

APPENDIX C

PLANT SPECIES COLLECTED FOR QUADRAT REPLICATES AT EACH WATER SAMPLING STATION

SPECIES NAME	BVB1	BVB2	BVB3	BVC1	BVC2	BVC3	OSL1	OSL2	OSL3	OSL4
A. theophrasti										
A. tuberculatus										
C. demersum										
C. diandrus	XXX									
C. erythrorhizos	XXX	XXX	*XX							
C. ferruginescens										
E. crusgalli										
E. crusgalli var. *frumentacea*										
E. pungens										
E. walteri	*XX	XXX	XXX							
Eleocharis sp.	X**	XXX	*X*							
H. palustris	XX*	X*X								
L. oryzoides										
L. palustris										
L. salicaria	XXX	XXX	*XX							
M. spicatum										
N. advena										
N. lutea										
P. australis					XXX					
P. cordata										
P. crispus										
P. deltoides	**X	X*X								
P. dichotomiflorum										
P. lapathifolium	*XX									
P. pensylvanicum										
R. maritimus	*XX									
R. palustris	*X*	*X*								
S. acutus					*X*	XXX				
S. eurycarpum										
S. fluviatilis			*X*							
S. latifolia										
S. validus	X**	XX*								
Salix sp.		*XX								
T. angustifolia		XX*		XXX			XXX	XXX		XXX
U. vulgaris				X**						
TOTAL # OF SPECIES	11	10	5	2	2	1	1	1	0	1
TOTAL SPECIES/MARSH		BVB=14			BVC=4			OSL=1		

SPECIES NAME	OSS1	OSS2	OSS3	WPN1	WPN2	WPN3	WPN4	WPN5	WPN6
A. theophrasti	XX*								
A. tuberculatus									
C. demersum					X				
C. diandrus									
C. erythrorhizos									
C. ferruginescens	XXX								
E. crusgalli									
E. crusgalli var. *frumentacea*									
E. pungens									
E. walteri	X**	XXX	XXX						
Eleocharis sp.	**X				X				
H. palustris									
L. oryzoides	XXX		**X	X	X				X
L. palustris	**X	XXX	X**						
L. salicaria									
M. picatum							X	X	
N. advena									
N. lutea									
P. australis									
P. cordata				X	X			X	X
P. crispus							X	X	
P. deltoides									
P. dichotomiflorum	XX*	X**							
P. lapathifolium	*X*	*XX	X**						
P. pensylvanicum	*X*								
R. maritimus									
R. palustris									
S. acutus									
S. eurycarpum		*X*			X				
S. fluviatilis									
S. latifolia									X
S. validus				X	X	X			
Salix sp.				X			X		
T. angustifolia		*XX	*XX	X	X	X		X	X
U. vulgaris									
TOTAL # OF SPECIES	9	6	5	5	7	2	3	4	4
TOTAL SPECIES/MARSH		OSS=11				WPN=11			

SPECIES NAME	WPW1	WPW2	WPW3	WPW4	WPW5	OWC1	OWC2	OWC3	OWC4	OWC5
A. theophrasti										
A. tuberculatus										
C. demersum										
C. diandrus										
C. erythrorhizos										
C. ferruginescens										
E. crusgalli					X**					
E. crusgalli var. *frumentacea*					*XX					
E. pungens					X*X					
E. walteri					*X*					
Eleocharis sp.			**X							
H. palustris		*X*	*X*	*X*						
L. oryzoides		XXX	XXX	XXX	XX*					
L. palustris										
L. salicaria										
M. spicatum										
N. advena										
N. lutea								XXX	XXX	XXX
P. australis										
P. cordata		XXX	X*X	X**						
P. crispus										
P. deltoides										
P. dichotomiflorum										
P. apathifolium		*XX	XXX	**X						
P. pensylvanicum		*X*								
R. maritimus										
R. palustris										
S. acutus										
S. eurycarpum		X**	XXX	XXX						
S. fluviatilis				XX*						
S. latifolia				X*X						
S. validus		X**	XXX	XXX	X*X					
Salix sp.				XXX						
T. angustifolia		*XX	XXX	XXX	*X*					
U. vulgaris										
TOTAL # OF SPECIES	0	8	8	10	7	0	0	1	1	1
TOTAL SPECIES/MARSH			WPW=16					OWC=1		

SPECIES NAME	PCK1	PCK2	PCK3	SHM1	SHM2	SHM3	WLT1	WLT2	WLT3
A. theophrasti									
A. tuberculatus							*X*		
C. demersum									
C. diandrus									
C. erythrorhizos	XXX		XXX				X**	XXX	XXX
C. ferruginescens									
E. crusgalli									
E. crusgalli var. *frumentacea*									
E. pungens									
E. walteri							X**		
Eleocharis sp.									**X
H. palustris								XXX	XXX
L. oryzoides	**X							X*X	
L. palustris									
L. salicaria							X*X	*X*	XXX
M. spicatum									
N. advena				XXX	XXX	XXX			
N. lutea									
P. australis									
P. cordata									
P. crispus									
P. deltoides	*X*		*XX					**X	
P. dichotomiflorum									
P. lapathifolium							XXX	**X	XXX
P. pensylvanicum									
R. maritimus									
R. palustris									
S. acutus									
S. eurycarpum								*XX	XXX
S. fluviatilis	XXX	XXX	XXX					X**	
S. latifolia	XXX		XXX					*X*	X**
S. validus	*X*							XXX	XXX
Salix sp.	*X*								
T. angustifolia	XXX		XXX				XXX	XXX	XXX
U. *vulgaris*									
TOTAL # OF SPECIES	8	1	5	1	1	1	6	11	9
TOTAL SPECIES/MARSH		PCK=8			SHM=1			WLT=14	

APPENDIX D

ABOVE-GROUND BIOMASS AND STEM COUNTS
PER SPECIES FOR EACH QUADRAT

STATION/SITE		DATE	QUADRAT	SPECIES CODE *	WET WT. g/m²	DRY WT. g/m²	PERCENT WATER	STEM COUNT	STEM DENSITY
Bay View									
B	/1	8/12/88	1	1	7.6	1.6	78.95	120	5.36
	/1	8/12/88	1	2	29.2	4.0	6.30	28	1.25
	/1	8/12/88	1	3	70.0	7.6	89.14	72	3.22
	/1	8/12/88	1	4	1496.4	202.4	86.48	568	25.36
	/1	8/12/88	1	5	1094.4	110.8	89.88	1448	64.64
	/1	8/12/88	1	6	1.6	0.4	75.00	4	0.18
	/1	8/12/88	2	2	112.4	12.8	88.61	168	15.56
	/1	8/12/88	2	4	2034.8	357.6	82.43	596	55.19
	/1	8/12/88	2	5	254.4	38.4	84.91	264	24.45
	/1	8/12/88	2	6	22.0	4.0	81.82	4	0.37
	/1	8/12/88	2	7	168.4	26.4	84.32	36	3.33
	/1	8/12/88	2	8	4.0	0.4	90.00	4	0.37
	/1	8/12/88	2	9	5.2	0.4	92.31	4	0.37
	/1	8/12/88	2	10	7.2	1.2	83.33	4	0.37
	/1	8/12/88	3	2	47.6	6.8	85.72	80	7.38
	/1	8/12/88	3	4	926.0	139.6	84.93	676	62.36
	/1	8/12/88	3	5	182.4	19.2	89.47	288	26.57
	/1	8/12/88	3	7	13.2	2.8	78.79	12	1.11
	/1	8/12/88	3	9	2.4	0.8	66.67	4	0.37
	/1	8/12/88	3	10	186.8	42.0	77.52	20	1.85
	/1	8/12/88	3	11	3.6	0.8	77.78	4	0.37
	/2	8/12/88	1	1	71.2	8.0	88.77	1200	65.94
	/2	8/12/88	1	2	27.6	3.6	86.96	44	2.42
	/2	8/12/88	1	3	0.8	0.4	50.00	4	0.22
	/2	8/12/88	1	4	2911.2	430.4	85.22	544	29.89
	/2	8/12/88	1	6	0.8	0.0	100.00	4	0.22
	/2	8/12/88	1	9	1.6	0.4	75.00	4	0.22
	/2	8/12/88	1	11	8.4	1.6	80.95	16	0.88
	/2	8/12/88	1	12	4.4	0.4	90.91	4	0.22
	/2	8/12/88	2	1	22.4	4.0	82.14	400	43.67
	/2	8/12/88	2	2	167.6	18.4	89.02	100	10.92
	/2	8/12/88	2	3	74.4	8.4	88.71	64	6.99
	/2	8/12/88	2	4	1647.6	232.4	85.90	320	34.94
	/2	8/12/88	2	8	4.4	0.8	81.82	4	0.44
	/2	8/12/88	2	9	8.4	1.2	85.72	8	0.87
	/2	8/12/88	2	12	32.8			8	0.87
	/2	8/12/88	2	13	0.8	0.8	0.00	12	1.31
	/2	8/12/88	3	1	31.6	4.0	87.34	400	75.19
	/2	8/12/88	3	2	27.2	2.0	92.65	52	9.78
	/2	8/12/88	3	4	1223.6	162.8	86.70	52	9.78
	/2	8/12/88	3	6	2.4	0.0	100.00	4	0.75
	/2	8/12/88	3	9	4.0			12	2.26
	/2	8/12/88	3	11	10.0	1.6	84.00	8	1.50
	/2	8/12/88	3	13	7.2	0.8	88.89	4	0.75
	/3	8/12/88	1	9	387.2	30.4	92.15	112	100.00
	/3	8/12/88	2	1				12	5.26
	/3	8/12/88	2	2	543.6	128.4	76.38	32	14.04
	/3	8/12/88	2	4	18.4	2.0	89.13	20	8.77
	/3	8/12/88	2	9	350.8	32.4	90.76	148	64.91
	/3	8/12/88	2	14	38.8	3.6	90.72	16	7.02
	/3	8/12/88	3	2	220.0	51.2	76.73	24	16.22
	/3	8/12/88	3	4	106.0	11.2	89.43	28	18.92
	/3	8/12/88	3	9	373.6	30.0	91.97	96	64.87

STATION/SITE		DATE	QUADRAT	SPECIES CODE *	WET WT. g/m²	DRY WT. g/m²	PERCENT WATER	STEM COUNT	STEM DENSITY
Bay View									
Center	/1	8/12/88	1	12	5385.6	1532.4	71.55	144	97.30
	/1	8/12/88	1	15	33.6			4	2.70
	/1	8/12/88	2	12	269.6	54.0	79.97	4	100.00
	/1	8/12/88	3	12	487.6	221.2	54.64	24	100.00
	/2	8/12/88	1	16	4728.0	2345.6	50.39	432	100.00
	/2	8/12/88	2	16	4775.2	2284.4	52.16	460	98.29
	/2	8/12/88	2	17	95.2	24.0	74.79	8	1.71
	/2	8/12/88	3	16	6642.8	3205.2	51.75	800	100.00
	/3	8/12/88	1	17	3652.0	1184.8	67.56	736	100.00
	/3	8/12/88	2	17	3449.2	1169.2	66.10	668	100.00
	/3	8/12/88	3	17	4382.0	1288.8	70.59	980	100.00
Ottawa Allen									
Pond	/1	8/22/88	1	9	405.6	65.2	83.93	60	4.72
	/1	8/22/88	1	20	916.8	269.2	70.64	1124	88.37
	/1	8/22/88	1	32	254.4	50.8	80.03	68	5.35
	/1	8/22/88	1	33	8.0	1.6	80.00	4	0.32
	/1	8/22/88	1	34	46.0	14.0	69.57	16	1.26
	/1	8/22/88	2	0	18.0	3.6	80.00	16	1.57
	/1	8/22/88	2	10	340.4	134.8	60.40	20	1.96
	/1	8/22/88	2	20	76.0	32.4	57.37	268	26.28
	/1	8/22/88	2	28	112.0	20.8	81.43	8	0.79
	/1	8/22/88	2	32	494.8	124.0	74.94	300	29.41
	/1	8/22/88	2	33	353.2	126.0	64.33	140	13.73
	/1	8/22/88	2	34	1620.4	462.4	71.46	268	26.28
	/1	8/22/88	3	1	6.0	2.0	66.67	60	3.13
	/1	8/22/88	3	20	1438.0	428.0	70.24	1720	89.58
	/1	8/22/88	3	32	454.0	72.4	84.05	116	6.04
	/1	8/22/88	3	35	28.4	3.2	88.73	24	1.25
	/2	8/22/88	1	9	612.8	63.6	89.62	292	19.95
	/2	8/22/88	1	34	41.2	9.2	77.67	64	4.37
	/2	8/22/88	1	35	1286.0	127.6	90.08	1108	75.68
	/2	8/22/88	2	9	1937.2	204.0	89.47	744	35.57
	/2	8/22/88	2	10	88.4	16.4	81.45	16	0.77
	/2	8/22/88	2	12	8.4	0.4	95.24	4	0.19
	/2	8/22/88	2	23	144.0	12.8	91.11	4	0.19
	/2	8/22/88	2	35	1869.2	147.2	92.13	1324	63.29
	/2	8/22/88	3	9	120.4	13.6	88.71	72	5.34
	/2	8/22/88	3	10	22.8	2.8	87.72	8	0.59
	/2	8/22/88	3	12	139.6	18.0	87.11	8	0.59
	/2	8/22/88	3	35	1503.6	137.6	90.85	1260	93.47
	/3	8/22/88	1	9	8822.0	1013.2	88.52	2100	99.24
	/3	8/22/88	1	10	40.4	7.6	81.19	8	0.38
	/3	8/22/88	1	35	12.4			8	0.38
	/3	8/22/88	2	9	4401.2	537.2	87.80	860	99.54
	/3	8/22/88	2	12	129.6			4	0.46
	/3	8/22/88	3	9	5849.6	583.6	90.02	1144	96.62
	/3	8/22/88	3	12	241.2	23.6	90.22	12	1.01
	/3	8/22/88	3	20	63.2	11.6	81.65	28	3.37

STATION/SITE		DATE	QUADRAT	SPECIES CODE *	WET WT. g/m^2	DRY WT. g/m^2	PERCENT WATER	STEM COUNT	STEM DENSITY
Ottawa Big Pond	/1	8/27/88	1	12	16474.4	3339.6	79.73	160	100.00
	/1	8/27/88	2	12	10254.0	1959.6	80.89	128	100.00
	/1	8/27/88	3	12	11532.4	2454.0	78.72	204	100.00
	/2	8/27/88	1	12	8290.4	1512.0	81.76	116	100.00
	/2	8/27/88	2	12	8554.4	2120.0	75.22	188	100.00
	/2	8/27/88	3	12	8341.2	2322.4	72.16	152	100.00
	/4	8/27/88	1	12	6688.4	1489.6	77.73	164	100.00
	/4	8/27/88	2	12	6687.2	1340.8	79.95	220	100.00
	/4	8/27/88	3	12	6197.2	1334.4	78.47	196	100.00
Winous Point North	/1	8/11/88	1	3	1242.3	212.8	82.87	117	78.00
	/1	8/11/88	1	12	998.5	217.4	78.23	16	10.67
	/1	8/11/88	1	13	21.7	8.1	62.67	1	0.67
	/1	8/11/88	1	20	46.0	6.5	85.87	3	2.00
	/1	8/11/88	1	24	208.5	22.3	89.31	13	8.67
	/2	8/11/88	1	1				13	13.83
	/2	8/11/88	1	3	5.7	0.8	85.97	12	12.77
	/2	8/11/88	1	12	2752.3	540.7	80.36	54	57.45
	/2	8/11/88	1	20	8.2	1.4	82.93	2	2.13
	/2	8/11/88	1	23	30.2	13.7	54.64	4	4.26
	/2	8/11/88	1	24	176.5	18.9	89.29	9	9.57
	/2	8/11/88	1	25	441.7	21.6	95.11		
	/3	8/11/88	1	3	497.8	66.7	86.60	71	43.29
	/3	8/11/88	1	12	6861.7	1149.3	83.25	93	56.71
	/4	8/11/88	1	13	103.8	27.5	73.51	6	100.00
	/4	8/11/88	1	26	671.7	68.9	89.74		
	/5	8/11/88	1	12	1521.3	195.1	87.18	12	32.43
	/5	8/11/88	1	24	459.7	44.6	90.30	23	62.16
	/5	8/11/88	1	26	7.6	0.4	94.74	1	2.70
	/5	8/11/88	1	27	0.9			1	2.70
	/6	8/11/88	1	12	7365.2	895.3	87.85	37	37.00
	/6	8/11/88	1	19	49.0			1	1.00
	/6	8/11/88	1	20	151.5	20.5	86.47	59	59.00
	/6	8/11/88	1	24	46.8	7.5	83.98	3	3.00

STATION/SITE		DATE	QUADRAT	SPECIES CODE *	WET WT. g/m²	DRY WT. g/m²	PERCENT WATER	STEM COUNT	STEM DENSITY
Winous Point									
West	/2	8/28/88	1	3	46.4	3.2	93.10	8	2.60
	/2	8/28/88	1	20	319.6	60.4	81.10	216	70.13
	/2	8/28/88	1	23	215.2	24.0	88.85	4	1.30
	/2	8/28/88	1	24	1669.2	152.4	90.87	80	25.98
	/2	8/28/88	2	6	325.6	70.0	78.50	8	2.25
	/2	8/28/88	2	10	192.4	20.0	89.61	16	4.50
	/2	8/28/88	2	12	177.2	19.2	89.17	4	1.12
	/2	8/28/88	2	20	360.0	71.6	80.11	276	77.53
	/2	8/28/88	2	24	506.0	44.0	91.31	48	13.48
	/2	8/28/88	2	28	94.0	14.0	85.11	4	1.12
	/2	8/28/88	3	10	38.8	6.4	83.51	8	5.56
	/2	8/28/88	3	12	2400.0	413.6	82.77	32	22.22
	/2	8/28/88	3	20	100.0	20.4	79.60	80	55.56
	/2	8/28/88	3	24	129.2	12.4	90.40	24	16.67
	/3	8/28/88	1	3	1162.8	212.0	81.77	268	48.91
	/3	8/28/88	1	10	14.4	2.8	80.56	4	0.73
	/3	8/28/88	1	12	608.0	104.8	82.76	44	8.03
	/3	8/28/88	1	20	284.4	74.8	73.70	204	37.23
	/3	8/28/88	1	23	161.6	28.8	82.18	4	0.73
	/3	8/28/88	1	24	271.2	27.6	89.82	24	4.38
	/3	8/28/88	2	0	4.8	0.4	91.67	4	0.44
	/3	8/28/88	2	3	2036.0	380.4	81.32	400	44.25
	/3	8/28/88	2	6	30.4	5.6	81.58	4	0.44
	/3	8/28/88	2	10	26.8	5.2	80.60	4	0.44
	/3	8/28/88	2	12	804.0	134.8	83.23	36	3.98
	/3	8/28/88	2	20	488.0	133.6	72.62	440	48.67
	/3	8/28/88	2	23	883.2	145.6	83.52	16	1.77
	/3	8/28/88	3	1	16.4	2.8	82.93	160	18.43
	/3	8/28/88	3	3	1418.8	247.6	82.55	216	24.89
	/3	8/28/88	3	10	15.6			4	0.46
	/3	8/28/88	3	12	442.8	72.4	83.65	20	2.31
	/3	8/28/88	3	20	432.0	117.6	72.78	420	48.39
	/3	8/28/88	3	23	993.6	175.6	82.33	20	2.31
	/3	8/28/88	3	24	272.0	30.0	88.97	28	3.23
	/4	8/28/88	1	3	484.0	67.2	86.12	48	21.05
	/4	8/28/88	1	12	3866.4	724.4	81.27	120	52.63
	/4	8/28/88	1	13	16.0	4.0	75.00	4	1.76
	/4	8/28/88	1	14	158.0	38.8	75.44	12	5.26
	/4	8/28/88	1	19	296.4	22.4	92.44	8	3.51
	/4	8/28/88	1	20	40.0	11.2	72.00	20	8.77
	/4	8/28/88	1	23	360.4	60.8	83.13	8	3.51
	/4	8/28/88	1	24	24.4	2.8	88.53	8	3.51
	/4	8/28/88	2	3	622.8	77.6	87.54	48	6.52
	/4	8/28/88	2	6	283.2	66.0	76.70	8	1.09
	/4	8/28/88	2	12	2138.4	303.6	85.80	52	7.07
	/4	8/28/88	2	13	22.0	5.6	74.55	4	0.54
	/4	8/28/88	2	14	50.8	10.4	79.53	4	0.54
	/4	8/28/88	2	20	1354.4	354.0	73.86	616	83.70
	/4	8/28/88	2	23	143.6	26.0	81.90	4	0.54
	/4	8/28/88	3	3	549.2	77.2	85.94	44	16.92
	/4	8/28/88	3	10	29.6	4.4	85.14	4	1.54
	/4	8/28/88	3	12	3528.4	603.2	82.91	64	24.62
	/4	8/28/88	3	13	65.6	19.6	70.12	8	3.08
	/4	8/28/88	3	19	56.8	5.6	90.14	4	1.54
	/4	8/28/88	3	20	360.0	100.0	72.22	124	47.69
	/4	8/28/88	3	23	652.0	95.2	85.40	12	4.62

STATION/SITE		DATE	QUADRAT	SPECIES CODE *	WET WT. g/m^2	DRY WT. g/m^2	PERCENT WATER	STEM COUNT	STEM DENSITY
Winous Point									
West	/5	8/28/88	1	3	1250.0	226.8	81.86	244	35.26
	/5	8/28/88	1	20	498.8	141.2	71.69	316	45.67
	/5	8/28/88	1	29	360.0	59.2	83.56	112	16.19
	/5	8/28/88	1	30	144.4	14.4	90.03	20	2.89
	/5	8/28/88	2	9	370.4	47.2	87.26	36	15.79
	/5	8/28/88	2	12	2521.2	335.2	86.71	56	24.56
	/5	8/28/88	2	20	186.0	41.2	77.85	132	57.90
	/5	8/28/88	2	31	43.6	12.8	70.64	4	1.76
	/5	8/28/88	3	3	927.6	149.2	83.92	128	49.23
	/5	8/28/88	3	29	1008.8	156.8	84.46	116	44.62
	/5	8/28/88	3	31	116.8	16.0	86.30	16	6.15
Pickerel									
Creek	/1	8/27/88	1	4	29.2	5.2	82.19	16	5.33
	/1	8/27/88	1	12	81.2	10.0	87.69	80	26.67
	/1	8/27/88	1	14	2852.4	605.2	78.78	192	64.00
	/1	8/27/88	1	19	30.0	4.0	86.67	12	4.00
	/1	8/27/88	2	3	25.2	2.8	88.89	40	9.01
	/1	8/27/88	2	4	479.2	66.4	86.14	108	24.33
	/1	8/27/88	2	11	45.2	5.6	87.61	16	3.60
	/1	8/27/88	2	12	760.0	85.2	88.79	100	22.52
	/1	8/27/88	2	13	2.4	0.8	66.67	4	0.90
	/1	8/27/88	2	14	2402.0	385.6	83.95	156	35.14
	/1	8/27/88	2	19	81.2	6.0	92.61	20	4.51
	/1	8/27/88	3	4	62.4	7.6	87.82	40	12.99
	/1	8/27/88	3	12	20.8	1.2	94.23	8	2.60
	/1	8/27/88	3	14	1708.0	254.4	85.11	156	50.65
	/1	8/27/88	3	19	330.4	34.4	89.59	56	18.18
	/1	8/27/88	3	20	15.6	3.2	79.49	48	15.59
	/2	8/27/88	1	14	6318.8	2257.2	64.28	236	100.00
	/2	8/27/88	2	14	3656.8	866.4	76.31	116	100.00
	/2	8/27/88	3	14	3047.6	758.4	75.12	112	100.00
	/3	8/27/88	1	4	2750.8	469.6	82.93	132	36.67
	/3	8/27/88	1	12	93.2	8.4	90.99	24	6.67
	/3	8/27/88	1	14	4303.2	520.0	87.92	188	52.22
	/3	8/27/88	1	19	42.4	2.8	93.40	16	4.45
	/3	8/27/88	2	0	16.0	1.6	90.00	8	1.68
	/3	8/27/88	2	4	1720.0	196.0	88.61	160	33.61
	/3	8/27/88	2	11	102.0	18.0	82.35	84	17.65
	/3	8/27/88	2	12	932.0	92.8	90.04	84	17.65
	/3	8/27/88	2	14	2527.2	318.8	87.39	120	25.21
	/3	8/27/88	2	19	153.6	14.4	90.63	20	4.20
	/3	8/27/88	3	4	1604.4	245.2	84.72	144	41.38
	/3	8/27/88	3	11	7.2	1.2	83.33	20	5.75
	/3	8/27/88	3	12	83.2	7.2	91.35	20	5.75
	/3	8/27/88	3	14	2424.4	467.6	80.71	140	40.23
	/3	8/27/88	3	19	98.0	8.8	91.02	24	6.90

STATION/SITE	DATE	QUADRAT	SPECIES CODE *	WET WT. g/m^2	DRY WT. g/m^2	PERCENT WATER	STEM COUNT	STEM DENSITY
Willow Point/1	8/26/88	1	2	946.8	211.6	77.65	24	13.95
/1	8/26/88	1	4	121.2	27.6	77.23	80	46.51
/1	8/26/88	1	9	4.4			4	2.33
/1	8/26/88	1	10	1200.0	293.6	75.53	8	4.65
/1	8/26/88	1	12	2254.8	458.8	79.65	56	32.56
/1	8/26/88	2	10	836.4	119.6	85.70	4	12.50
/1	8/26/88	2	12	2218.0	483.2	78.22	20	62.50
/1	8/26/88	2	22	3960.8	607.2	84.67	8	25.00
/1	8/26/88	3	2	523.6	88.8	83.04	32	18.61
/1	8/26/88	3	10	2551.6			8	4.65
/1	8/26/88	3	12	3935.6	1186.0	69.87	132	76.75
/2	8/26/88	1	0	14.0	2.4	82.86	68	13.60
/2	8/26/88	1	4	840.0	112.0	86.67	256	51.20
/2	8/26/88	1	14	314.0	47.2	84.97	48	9.60
/2	8/26/88	1	20	44.0	10.0	77.27	128	25.60
/2	8/26/88	2	2	50.4	4.8	90.48	48	8.45
/2	8/26/88	2	3	178.4	17.2	90.36	192	33.80
/2	8/26/88	2	4	1384.4	182.8	86.80	260	45.78
/2	8/26/88	2	6	6.0	1.2	80.00	20	3.52
/2	8/26/88	2	12	122.8	15.2	87.62	20	3.52
/2	8/26/88	2	19	22.4	2.4	89.29	20	3.52
/2	8/26/88	2	23	42.0	3.6	91.43	8	1.41
/2	8/26/88	3	3	5.6	0.8	85.72	20	3.11
/2	8/26/88	3	4	1151.2	172.8	84.99	460	71.43
/2	8/26/88	3	6	19.2	2.4	87.50	48	7.45
/2	8/26/88	3	10	162.8	19.6	87.96	24	3.73
/2	8/26/88	3	11	12.4	2.4	80.65	24	3.73
/2	8/26/88	3	12	5.2	0.8	84.62	12	1.86
/2	8/26/88	3	20	19.6	3.6	81.63	52	8.08
/2	8/26/88	3	23	10.4	0.8	92.31	4	0.62
/3	8/26/88	1	2	1.6	0.0	100.00	8	1.87
/3	8/26/88	1	3	97.6	24.0	75.41	116	27.10
/3	8/26/88	1	4	379.6	68.4	81.98	140	32.71
/3	8/26/88	1	6	143.2	22.4	84.36	40	9.35
/3	8/26/88	1	10	17.2	2.0	88.37	8	1.87
/3	8/26/88	1	12	458.4	89.2	80.54	84	19.63
/3	8/26/88	1	19	7.6	1.2	84.21	8	1.87
/3	8/26/88	1	23	387.2	69.2	82.13	24	5.61
/3	8/26/88	2	2				4	1.47
/3	8/26/88	2	3	31.2			28	10.30
/3	8/26/88	2	4	261.2	38.0	85.45	64	23.53
/3	8/26/88	2	6	65.6	12.0	81.71	32	11.77
/3	8/26/88	2	10	50.8	6.8	86.62	8	2.94
/3	8/26/88	2	12	440.8	80.0	81.85	80	29.41
/3	8/26/88	2	23	952.0	170.4	82.10	56	20.59
/3	8/26/88	3	1	7.2	0.8	88.89	160	27.97
/3	8/26/88	3	2	896.4	208.4	76.75	16	2.80
/3	8/26/88	3	3	103.6	17.6	83.01	192	33.57
/3	8/26/88	3	4	10.4	1.6	84.62	4	0.70
/3	8/26/88	3	6	3.2	0.4	87.50	4	0.70
/3	8/26/88	3	10	84.0	16.0	80.95	8	1.40
/3	8/26/88	3	12	474.8	106.8	77.51	44	7.69
/3	8/26/88	3	23	1892.8	380.0	79.92	144	25.18

STATION/SITE		DATE	QUADRAT	SPECIES CODE *	WET WT. g/m^2	DRY WT. g/m^2	PERCENT WATER	STEM COUNT	STEM DENSITY
Sheldon Marsh	/1	8/28/88	1	21	3275.6	192.0	94.14	56	100.00
	/1	8/28/88	2	21	5608.4	440.0	92.16	84	100.00
	/1	8/28/88	3	21	6303.2	468.0	92.58	84	100.00
	/2	8/28/88	1	21	2670.7	245.0	90.83	45	100.00
	/2	8/28/88	2	21	3250.0	237.0	92.71	66	100.00
	/2	8/28/88	3	21	3298.5	287.0	91.30	75	100.00
	/3	8/28/88	1	21	3676.8	354.0	90.37	96	100.00
	/3	8/28/88	2	21	3792.2	360.0	90.51	101	100.00
	/3	8/28/88	3	21	4151.1	359.0	91.35	83	100.00
Old Woman Creek	/3	8/30/88	1	18	1230.0	209.7	82.95	15	100.00
	/3	8/30/88	2	18	1710.5	301.4	82.38	17	100.00
	/3	8/30/88	3	18	859.0	125.1	85.44	15	100.00
	/4	8/30/88	1	18	1337.2	201.2	84.95	12	100.00
	/4	8/30/88	2	18	1197.3	206.6	82.75	9	100.00
	/4	8/30/88	3	18	890.7	149.2	83.25	10	100.00
	/5	8/30/88	1	18	1022.4	168.4	83.53	16	100.00
	/5	8/30/88	2	18	1086.5	158.5	85.41	18	100.00
	/5	8/30/88	3	18	941.4	161.7	82.82	17	100.00

* Numbers assigned species are found in Appendix B.