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USE OF HISTORICAL AND GEOSPATIAL DATA TO GUIDE THE RESTORATION OF A LAKE ERIE COASTAL MARSH

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Abstract: Historical and geospatial data were used to identify the relationships between water levels, wetland vegetation, littoral drift of sediments, and the condition of a protective barrier beach at Metzger Marsh, a coastal wetland in western Lake Erie, to enhance and guide a joint federal and state wetland restoration project. Eleven sets of large-scale aerial photographs dating from 1940 through 1994 were interpreted to delineate major vegetation types and boundaries of the barrier beach. A geographic information system (GIS) was then used to digitize the data and calculate the vegetated area and length of barrier beach. Supplemented by paleoecological and sedimentological analyses, aerial photographic interpretation revealed that Metzger Marsh was once a drowned-river-mouth wetland dominated by sedges and protected by a sand barrier beach. Extremely high water levels, storm events, and reduction of sediments in the littoral drift contributed to the complete destruction of the barrier beach in 1973 and prevented its recovery. The extent of wetland vegetation, correlated to water levels and condition of the barrier beach, decreased from a high of 108 ha in 1940 to a low of 33 ha in 1994. The lack of an adequate sediment supply and low probability of a period of extremely low lake levels in the near future made natural reestablishment of the barrier beach and wetland vegetation unlikely. Therefore, the federal and state managers chose to construct a dike to replace the protective barrier beach. Recommendations stemming from this historical analysis, however, resulted in the incorporation of a water-control structure in the dike that will retain a hydrologic connection between wetland and lake. Management of the wetland will seek to mimic processes natural to the wetland type identified by this analysis.

Key Words: barrier beach, coastal marsh, geographic information system, GIS, historical, Lake Erie, littoral drift, management, restoration, *Typha,* water levels

INTRODUCTION

Most of the original coastal wetlands in western Lake Erie have been destroyed either by draining for agriculture or by shoreline development, and many of the remaining wetlands have been hydrologically isolated from the lake by dikes. Lake Erie coastal wetlands are important ecosystems that provide habitat for many types of wildlife, fish, amphibians, reptiles, invertebrates, and over 300 species of aquatic and wetland vascular plants (Herdendorf 1987, Stuckey 1989). The loss of these wetlands negatively impacts the biotic communities that depend on them for food and shelter. In addition to reducing shoreline erosion and filtering pollutants, these coastal wetlands are highly valued for recreational opportunities such as hunting, trapping, fishing, and bird watching (Herdendorf 1987). Therefore, proper management of the few remaining coastal wetlands in western Lake Erie is necessary to maintain or renew their natural functions and values. The governments of the United States and Canada recognized the importance of preserving and restoring wetlands across the continent when they created the North American Waterfowl Management Plan (USFWS 1986) and its update (USFWS 1994) that require the protection and restoration of waterfowl habitat. This legislation is just one of the many forces driving the desire to protect, manage, and restore Lake Erie coastal wetlands.

Historical conditions must be examined to understand how a wetland once functioned naturally and thus how it might best be restored (Steedman et al. 1996). The historical record provides a path for the restoration effort by giving clues about what to restore or what natural conditions to mimic. An historical analysis can also show factors that contributed to the degradation and what physical conditions need to be recreated during the restoration process. Once identified, these factors can be addressed in the restoration process to allow the site to restore naturally once the degrading influences have been removed (Bradshaw 1996). Although some degraded sites can be restored naturally if given enough time or the proper conditions, highly degraded ecosystems often need human design and intervention to improve their condition and functionality in a timely manner (Steedman et al. 1996).

The historical analyses can often take many forms and produce information that adds to the overall understanding of the study site. Discussions with local residents and historical maps can provide insight into the past vegetative cover in the area, land use on surrounding upland, and previous human uses of the wetland. Paleoecology and seed-bank analyses provide information on past vegetation types and can help characterize the potential vegetation. Aerial photos have been used widely to create wetland vegetation maps (Schneider 1968, Anderson and Wobber 1973, Seher and Tueller 1973, Brown 1978, Gammon and Carter 1979, Welch et al. 1988, Carmel and Kadmon 1998), identify vegetation boundaries (Naesset 1997), conduct shoreline-change assessments (Gorman et al. 1998), and measure lake-level effects on wetlands and beaches (Lyon and Drobney 1984, Shay et al. 1999). Multiple photograph sets that cover different time periods can be used to identify and date physical changes at a site (Lyon and Drobney 1984, Williams and Lyon 1995, Zellmer and Eastman 1997).

Most geospatial data collected, including delineations from aerial photographs, can be entered into a geographic information system (GIS) to facilitate data manipulation and wetland analyses (Welch et al. 1992, Remillard and Welch 1993, Welch et al. 1995). Results of these analyses may then be used to guide restoration projects. The Metzger Marsh restoration project in western Lake Erie is an example of how current and historical analyses provided the information necessary to design and guide a restoration project to mimic original conditions. Those analyses are described here along with interpretation of pre-settlement conditions, interactions of wetland and lake level, and management applications.

STUDY AREA

Metzger Marsh is a 300-ha coastal wetland located along the southern shore of western Lake Erie approximately 25 km east of Toledo, Ohio, USA (Figure 1). Two-thirds of the marsh is managed by the Ohio Department of Natural Resources, Division of Wildlife; the remaining one-third is managed by the U.S. Fish and Wildlife Service, Ottawa National Wildlife Refuge. Earthen dikes border the marsh on the south side, and a road separates the marsh from a marina and canal on the west and northwest sides, respectively (Figure 2). Open water up to 2 m deep covered the marsh in 1994, and emergent wetland vegetation was dominated by cattails (*Typha* spp.). The cattails, clustered in a few small raised islands, were only found in the western, most protected portion of the marsh. Submersed aquatic vegetation was negligible. Woody species including willows (*Salix* sp.) and cottonwoods (*Populus deltoides* Marshall) dominated the surrounding dikes and upland areas.

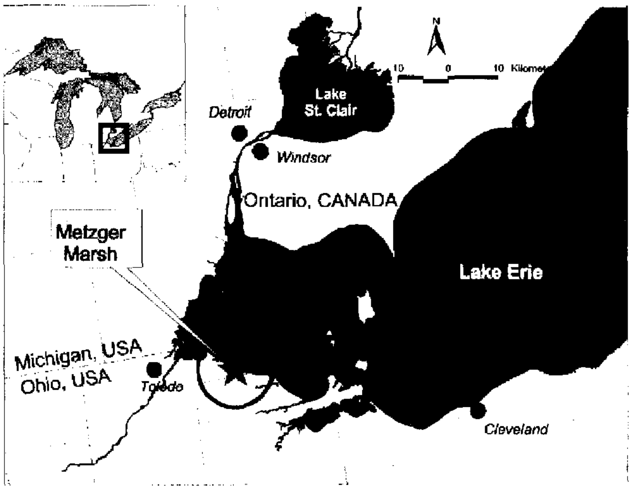

Figure 1. Map showing geographic location of Metzger Marsh in western Lake Erie.

Most coastal wetlands in western Lake Erie have been isolated by earthen dikes to protect them from wave attack (Herdendorf 1987) and promote management as migratory waterfowl habitat (Campbell and Gavin 1995). Even though Metzger Marsh was flanked by a shoreline heavily armored with rock revetments, in 1994 it was one of the few remaining hydrologically connected coastal marshes in western Lake Erie.

Historical maps (Lamson 1877, Towar 1877) and pre-1973 photographs (Figure 2) showed both the presence of a barrier beach on the lakeward side of Metzger Marsh and a significant amount of vegetation in the wetland. The barrier beach was lost to erosion in 1973 (S. Mackey, pers. comm.), and the marsh was then fully exposed to the waters of Lake Erie and the full impact of storm events. The storm events were most destructive during extended periods of high water levels, such as from the mid-1960s to 1994 (Figure 3). The historical record shows large variations in annual lake levels, with some extreme highs (e.g., 1973) and lows (e.g., 1936) (NOAA 1992a). Annual highs normally occur in June and lows in February. Short-term wind tides or seiche fluctuations of up to 5 m have been recorded (Herdendorf 1987).

Prior to the 1860s, Metzger Marsh and the surrounding landscape were relatively undeveloped sections of

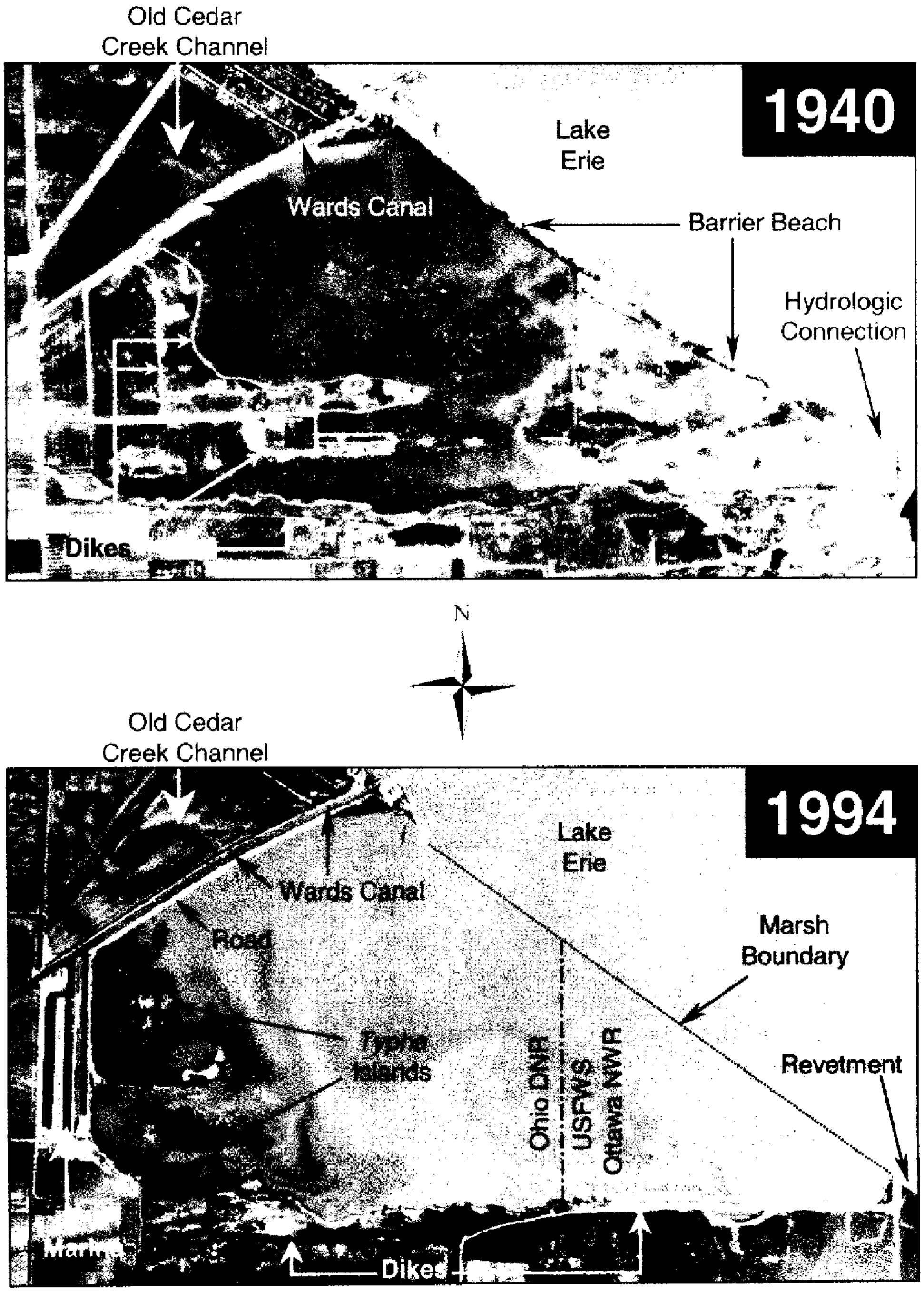

Figure 2. Vertical aerial photographs of Metzger Marsh. The top image derived from a black-and-white panchromatic photograph taken May, 1940, and the bottom image from a true color photograph taken September 1994.

the Black Swamp, a large wetland complex approximately 48 kilometers wide that extended southwest from the Lake Erie shore to New Haven, Indiana (Kaatz 1955). The arrival of the logging industry in the 1860s resulted in wetland drainage, construction of private residences and sawmills, and dredging of canals to transport logs. Wards Canal was excavated on the north side of Metzger Marsh to service a nearby sawmill and carry the flow of water diverted from Cedar Creek directly to Lake Erie (Campbell and Gavin 1995). By the early 1870s, Metzger Marsh was partially drained for agricultural purposes. Although early agricultural ventures failed and the lake reclaimed much of the marsh, some interior dikes remained and allowed intermittent farming through 1940. Hunters and trappers also used the wetland during the early 1900s.

High water levels and storm events followed the

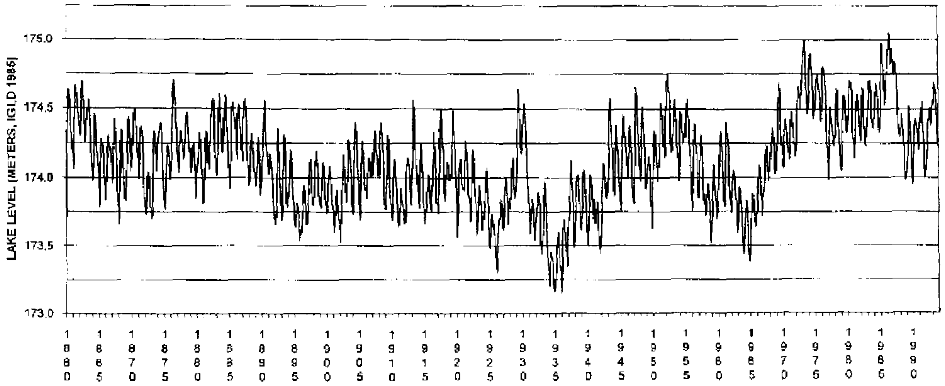

Figure 3. Changes in Lake Erie water-level elevations (IGLD 85) from 1860 to 1994.

dust-bowl years of the mid-1930s, began eroding the Lake Erie shoreline, and prompted shoreline armoring to protect developed areas. Since net littoral drift for the Metzger Marsh area is from east to west (Herdendorf 1975), the increased shoreline armoring at nearby Magee Marsh in 1954 (Savoy 1956) and at other updrift areas reduced the amount of littoral sand reaching Metzger Marsh (Mackey and Foye 1998). Without a plentiful supply of sand and low water levels, the barrier beach at Metzger Marsh was unable to rebuild itself naturally after being destroyed during the 1973 high water levels (Mackey and Foye 1998). As a result, a reduction in area dominated by wetland vegetation seemed to occur in Metzger Marsh. Other Lake Erie barrier-beach wetlands were affected similarly (Stuckey 1989).

METHODS

Black and white panchromatic aerial photographs dating back to 1940 and ranging in nominal scale from 1:4800 to 1:40000 were obtained from many different sources (Table 1). From a total of 22 different sets of black and white photos collected, only 10 sets were of adequate quality and completeness to be used for photointerpretation in this study. The 12 photo sets not interpreted for this study served as supplemental data sources for intervening years. Preparation of all complete photo sets was conducted following the procedures described in Owens and Hop (1995); study-area boundaries, end-match lines, and side-match lines were delineated on clear acetate overlaying the photos to create closed polygons that cover the center portion of each photo. Identification information for vegetation types was first acquired from a 1994 photo set and used to guide the interpretation of historical photos (Table 2). Ground-truthed vegetation types were then followed back in time until the link between known vegetation types and photographic signatures was lost. A more generalized vegetation description was then applied.

Over 18 color-infrared (CIR) vertical aerial photographs were taken in August 1994 at a nominal scale of 1:5000. Complete stereo photo coverage of the marsh was achieved using 60% frontlap and 30% sidelap between photos (Lillesand and Kiefer 1987, Teng

Table 1. Summary of aerial photographs interpreted for Metzger Marsh analyses. The number of ground control points (GCPs) used and the output root-mean-square-error (RMSE) of each GIS transformation are provided for the photo sets.

Month	Year	Nominal Scale	Film Type	# Photos	Source	# of GCPs	RMSE (m)
May	1940	1:20000	B/W	2	Ohio Dept. of Natural Resources	9	6.60
November	1950	1:20000	B/W	1	Ohio Dept. of Natural Resources	4	7.98
April	1957	1:4800	B/W	14	Ohio Dept. of Natural Resources	15	10.05
May	1963	1:20000	B/W	3	Ohio Dept. of Natural Resources	4	6.91
May	1964	1:20000	B/W	1	Ohio Dept. of Natural Resources	4	3.54
September	1970	1:40000	B/W	1	Ohio Dept. of Natural Resources	4	8.78
June	1973	1:24000	B/W	3	Ohio Dept. of Transportation	6	7.90
June	1978	1:24000	B/W	3	Ohio Dept. of Natural Resources	4	7.56
September	1980	1:40000	B/W	3	U.S. Dept. of Agriculture	4	11.40
April	1988	1:40000	B/W	2	U.S. Geological Survey, NAPP	4	2.63
July	1994	1:5000	CIR	18	U.S. Geological Survey	14	8.19

Table 2. Summary of plant, land, and water classifications identified during interpretation of aerial photographs of Metzger Marsh.

Name
Agriculture/Other
Baresoil
Calamagrostis
Calamagrostis/Other
Calamagrostis/Phragmites
Calamagrostis/Typha
Cyperus
Dike
Diked Wetland
Echinochloa
Emergent Vegetation
Farm
Hibiscus
Impatiens
Jetty
Lemna/Pond
Mature *Salix/Populus*
Mudflat
Mussel Beach
Open Water-Lake Connected
Open Water-Lake Isolated
Parking Lot
Phalaris
Phalaris/Hibiscus
Phalaris/Typha
Phragmites
Sagittaria
Sand/Pebble Beach
Sandbar
Scattered *Typha* Clumps
Scirpus fluviatilis/ Sparganium
Semiwooded
Short Emergent Mosaic
Sparganium/Sagittaria
Structure/Building
Submersed Aquatic (*Potamogeton*)
Submersed Aquatic (*Myriophyllum*)
Typha
Typha/Hibiscus
Typha/Impatiens/Solanum
Typha/Lythrum
Typha/Other
Typha/Sagittaria
Typha/Urtica
Upland Grass
Urtica
Vegetated Beach
Young *Salix*

et al. 1997). The CIR contact prints were also prepared following the methods outlined by Owens and Hop (1995). A magnifying mirror stereoscope and a hand lens were used for all photointerpretation. Boundary information for major vegetation types, land features, and control points was delineated on clear acetate sheets overlaying the photos using a 0.30-mm drafting pen. Unique vegetation codes, based on the dominant plant taxa present, were created to identify the major vegetation types present in the marsh and delineated on the individual photos (Table 2).

A global positioning system (GPS) receiver was used to guide ground-truthing in September 1994 and to collect positional data for 31 different ground-control points such as road and dike intersections, trees, and buildings that were identified in current and historical photographs. The same control points were used for each photo set whenever possible, but additional control points were necessary for some photo sets. The GPS data were differentially corrected to achieve a root mean square error (RMSE) of less than ±2 m (Trimble Navigation Limited 1997) using synchronized measurement data collected with a base station located at the U.S. Geological Survey (USGS), Great Lakes Science Center, Ann Arbor, Michigan.

The number and geographic distribution of control points identifiable in each photo made it impossible to georeference individual photos because of the small field-of-view of large-scale photographs, the lack of identifiable features in open water areas, and the inability to calculate coordinates for temporary features only identifiable in the historical photos. The boundary delineations and vegetation codes, therefore, were mosaicked and copied to a large piece of acetate. The resulting uncontrolled mosaic was digitized into the PC ARC/INFO GIS software package (ESRI, Redlands, California) using a high-resolution digitizer. The GIS vector coverages for each date were edited and transformed into a ground-coordinate system (Universal Transverse Mercator, Zone 17, NAD27) using GPS-derived data for the ground-control points. The coverages were overlaid on a USGS digital raster graphic (DRG) to identify the least warped transformation of each coverage. A DRG is a scanned image of a USGS 7.5" topographic map and meets the U.S. National Map Accuracy Standards (NMAS) for maps of 1:24000 scale (RMSE ± 7.2 m). Distortions inherent in aerial photographs, variations in quality of aerial photos, photointerpretation omission and commission errors, digitizing errors, and transformation errors were identified and minimized when possible (see Table 1 for RMSE values). Changes in the marsh boundaries and minor distortions in the geospatial data caused differences in total area mapped between years. Those differences were calculated to be 1.3% using a coefficient of variation ($V = \sigma/\mu \cdot 100\%$) to express the sample variability relative to the mean of the sample (Zar 1984). Since the total area mapped was approximately 300 hectares, the coefficient of variation translates into 3.1 hectares.

To quantify changes in the size of the barrier beach through time, ArcView GIS software (ESRI, Redlands, California) was used to calculate the length of the barrier beach in each of the georeferenced coverages. Length measurements were taken in a straight line from an identifiable static location on the northern point near Wards Canal (313660.80 N 4613246.96 W, UTM Zone 17, NAD27) to the southeastern-most tip of visible sand beach. During years when the barrier beach was not continuous across the opening, the lengths of the individual sections were measured and summed. The total length of beach across the marsh opening, calculated in meters, provided a measure of the amount of protection offered to the marsh by the barrier beach. To facilitate analyses, the length measurements were converted to a percentage of the marsh opening protected by the barrier beach. The GIS software was also used to quantify the amount of each vegetation type delineated in the aerial photos. This area measurement was converted into a percentage of total mapped area specific to each year.

In addition to aerial photographs, we also used historical maps, books, and water-level records to identify early conditions in the marsh. Towar's 1877 map provided insight into the conditions of Wards Canal, marsh vegetation, and status of the barrier beach during the late 19th century. Documentation of landscape characteristics by early settlers also added to the understanding of pre-settlement conditions. Monthly water-surface elevations dating back to 1860 were obtained from NOAA (1992a, 1992b, 1993, 1994, 1995). These data were compared to the length of the barrier beach and the amount of vegetation to identify patterns or relationships. Quantifying the changes in the beach length and the amount of vegetated area during different time periods allowed characterization of historic conditions. Once identified, the historic conditions provided insight and guidance for the restoration efforts.

RESULTS

Changes in Vegetation

Analyses and subsequent digitizing of 1994 CIR and historic aerial photographs resulted in 11 vegetation maps showing a general reduction in vegetated area since 1940 (Table 3, Figure 4, Figure 5). The largest amount of wetland vegetation was mapped in 1940 (108.0 ha) and did not include the 33.6 ha, or 11.2% of the marsh, that was temporarily diked for agricultural purposes (Figure 4). *Typha* spp. was the most prevalent vegetation type mapped. Dikes protecting the agricultural area in the center of the marsh were fully breached between 1940 and 1950. By the time the 1950 photos were taken, the amount of vegetated area had decreased to 95.9 ha, with the reduction appearing on the lakeward side of the dikes (Figure 5). This loss reflected an over-50% reduction of *Typha* spp. vegetation type (Table 3). Vegetated area, mostly *Typha* spp., expanded in the early 1960s (Table 3, Figure 5) but greatly decreased during the early 1970s. The amount of vegetated area observed in 1980 (54.8 ha) was sustained through 1994 (Figure 5). No expansion of vegetation occurred on the north and west borders, but a small portion of the southern boundary dike was breached in 1973, allowing the marsh to reclaim approximately 12 ha of farmland. *Typha* spp. was the most prevalent vegetation type mapped from 1940 through 1994, with young *Salix* spp. greatly increasing in area after 1980.

Changes in Barrier Beach

The longest continuous beach, observed in 1940 (Table 3), was breached in many places by 1950 (Fig-

Table 3. Vegetated area (ha) and length (m) of barrier beach at Metzger Marsh interpreted from multi-year aerial photographs and calculated with GIS analyses.

	1940	1950	1957	1963	1964	1970	1973	1978	1980	1988	1994
Typha/Other (ha)[1]	84.1	32.7	12.3	72.1	75.9	61.1	40.2	30.0	38.5	14.0	9.9
Total (ha)[2]	108.4	95.9	21.6	89.4	98.4	82.1	50.4	50.9	54.8	33.2	33.0
Barrier Beach Length (m)	2273	1765	718	1165	1257	1507	190	436	157	355	304

[1] Sum of vegetation types mapped as *Typha*, *Typha*/*Hibiscus*, *Typha*/*Impatiens*/*Solanum*, *Typha*/*Lythrum*, *Typha*/Other, and *Typha*/*Sagittaria*.
[2] Sum of all vegetation types mapped from aerial photos.

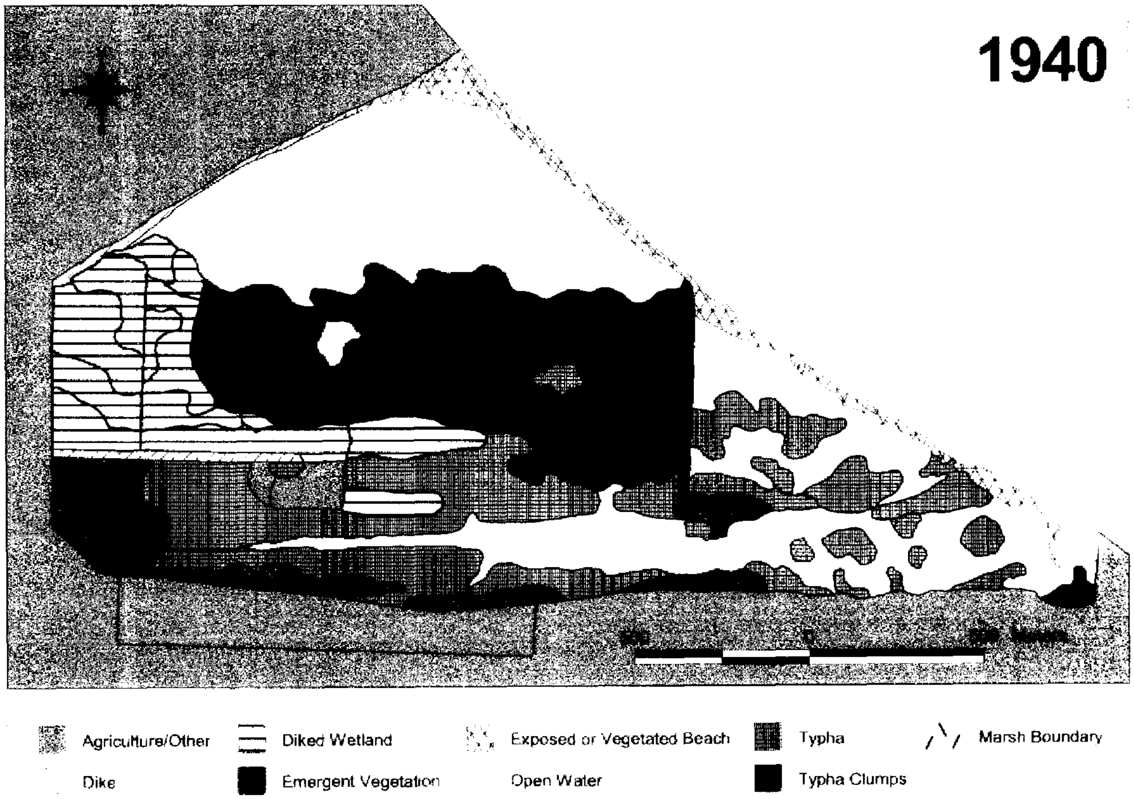

Figure 4. GIS map showing vegetation types and length of barrier beach at Metzger Marsh as derived from interpretation of a 1940 aerial photograph.

ure 5) and, except for being slightly rebuilt during the early 1960s, decreased in length until its disappearance before June 1973. The barrier beach never rebuilt naturally after 1973 (Figure 5). A small (280 m) rock revetment extending south into the marsh was constructed between 1973 and 1978 to protect the road and parking lot on the north side of the marsh. The length of this structure is included in the barrier beach data because it offers limited protection to the northern portion of the marsh.

The width and location of the barrier beach varied between years. The 1940 beach was long and narrow but contained an opening, approximately 95 m wide, that retained the hydrologic connection between the lake and wetland. Breaches in the 1950 beach were scattered along its length (Figure 5), and the whole beach migrated slightly landward. The rebuilt 1964 beach was even further landward and was much wider than appeared in previous photographs.

DISCUSSION

Description of the Pre-Settlement Marsh

Reviews of the historical maps, literature, and aerial photographs showed that Metzger Marsh once looked and operated much differently than in 1994. The map by Towar (1877) showed an extensive area of unidentified wetland vegetation in the marsh and a long barrier beach on the outer boundary. Vibracores of wetland and lacustrine sediments taken in Metzger Marsh contained fibrous peat (1.8 m deep) overlain by organic silt (0.3 m deep) (Thompson and Wilcox 1991), indicating that the barrier beach had long provided a sheltered environment before it was lost to erosion. Pollen and plant macrofossil analyses from one of those cores suggest that, in addition to emergent marsh, the wetland contained sedge meadow vegetation until the late 19th century (Jackson and Singer 1995). Many of the aerial photos also showed soil patterns on agricultural land that define the former channel of a creek near the northern border of Metzger Marsh (see Figure 2). That meandering creek bed is the path that Cedar Creek followed through the wetland until the water was diverted into Wards Canal in the early 1860s. Thus, Metzger Marsh was once a flow-through, drowned-river-mouth wetland similar in orientation to others that occur along the U. S. shoreline of western Lake Erie (e.g., Crane, Turtle, and Toussaint creeks). These drowned-river-mouth wetlands formed as differential isostatic rebound caused

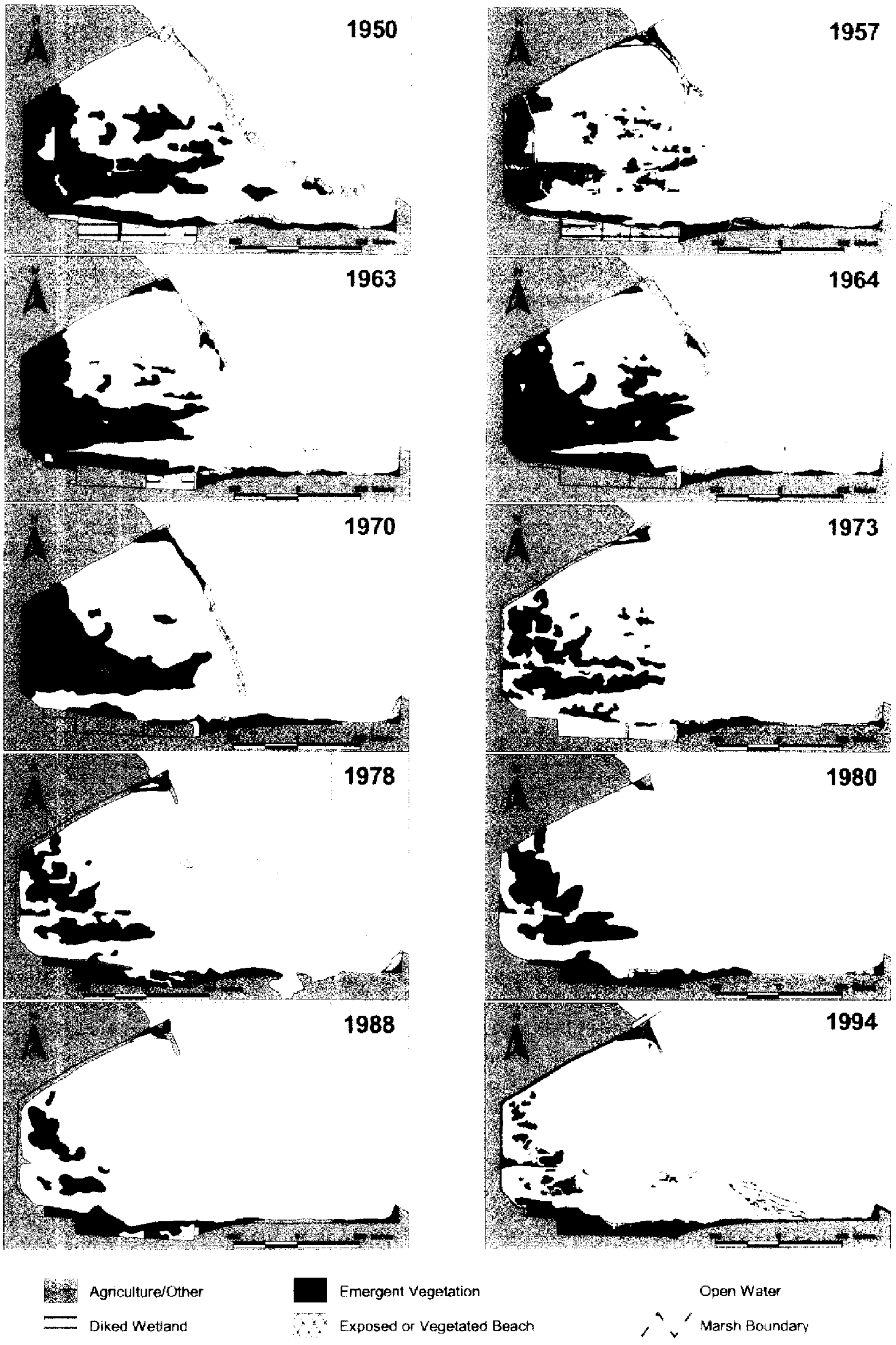

Figure 5. GIS maps showing amount of vegetated area and length of barrier beach at Metzger Marsh as derived from interpretation of aerial photographs.

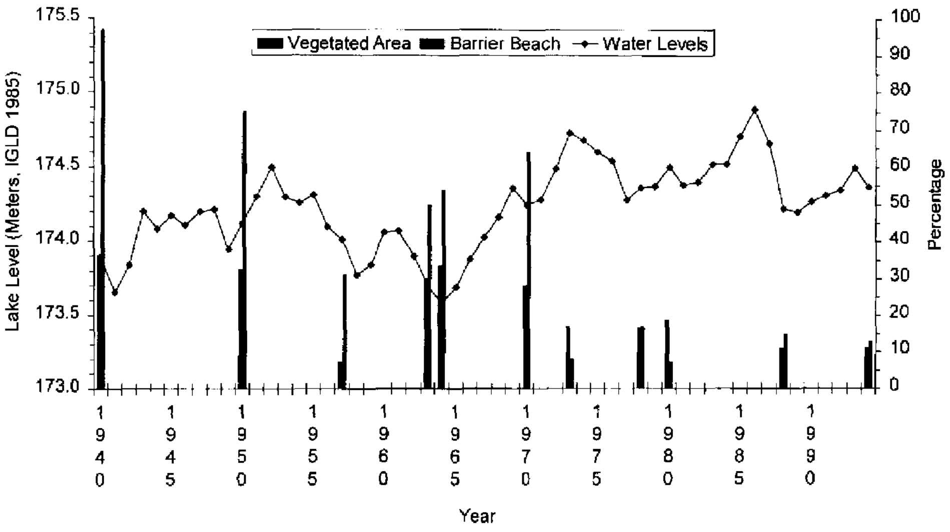

Figure 6. Comparison of Lake Erie mean annual water levels to percent vegetated area and percent barrier beach at Metzger Marsh, Ohio. Vegetation and barrier beach values are based on photointerpretation of available aerial photographs.

the elevation of the lake's eastern outlet to increase with respect to the western end, flooding lake water into the downstream portion of the river channels. The wetlands are protected from direct wave attack, but their water levels are directly affected by lake-level changes, including seiches that cause short-term river flow reversals (Maynard and Wilcox 1997). The earliest aerial photographs confirm this description of the physical characteristics of Metzger Marsh, but our analyses showed that the shift from sedge meadow to open marsh vegetation had already occurred by 1940.

Wetland Vegetation, Water Levels, and Barrier Beaches

Photointerpretation and GIS analyses showed degradation of the marsh from 1940 to 1994 but gave little insight into why it occurred. The water-level history of Lake Erie, however, shows that changes in extent of the marsh were correlated to water-level changes. During periods of high water levels, storm events cause accelerated erosion of barrier beaches, thereby exposing the protected wetland to wave attack and contributing to a decrease in vegetated area. The loss of emergent vegetation due to deeper standing water and wave attack is well-documented (Harris and Marshall 1963, Spence 1982, Keddy and Reznicek 1986, Foote and Kadlec 1988, Wilcox and Meeker 1991, van der Valk et al. 1994). After high water levels and storm events, the sediments in the littoral drift can rebuild barrier beaches (Silvester and Hsu 1991). Lower water levels also expose mud flats and allow buried or floating seeds to germinate and become established (van der Valk 1981).

The 1940 photo showed the marsh with a lengthy barrier beach and extensive areas of emergent vegetation; this followed low water levels during the mid-1930s (see Figure 3). Higher water levels in the late 1940s resulted in loss of barrier beach and vegetated area, as shown in the map created from 1950 photos (Figure 5) and also portrayed in Figure 6. The timing of this vegetation response to increased lake levels parallels the response at Pointe Mouillee, a Lake Erie marsh in Michigan that was thoroughly investigated by McDonald (1955). Another high lake level in the early 1950s elicited a similar response (Figure 6). Lower water levels in 1958 and during the early 1960s then resulted in increases in beach and vegetated area. Extremely high water levels in 1973 were associated with the complete destruction of the beach and reduced vegetated area. Similar decreases in vegetated area were observed in nearby Sandusky Bay following high water in the early 1970s (Farney and Bookhout 1982, Gottgens et al. 1998). The barrier beach was not naturally rebuilt after the 1973 events primarily because of sustained high water levels and a lack of sediments in the littoral drift (S. Mackey, pers.comm.). High water levels in 1986 also resulted in loss of vegetated area, but the ensuing 0.7 m reduction in lake level by 1988 produced little increase in vegetated area because it was not enough to expose sediments and the protective barrier was gone. The armored shoreline directly contributed to the degradation of the marsh by reducing the contribution of sediments to the littoral drift in the lake and transferring wave energy downshore, thereby accelerating the erosion of unprotected shoreline (Mackey and Foye 1998). The armored shoreline also impeded the deposition of the littoral sediments required to rebuild barrier beaches and unprotected shoreline (Silvester and Hsu 1991).

Application to Management

The information generated from this study characterized the historical conditions at Metzger Marsh and the relationship between water levels, wetland vegetation, littoral drift of sediments, and barrier-beach condition. Therefore, when a joint federal and state management decision was made to restore the wetland, recommendations were made to restore it to resemble its pre-settlement condition. However, as suggested by our analyses and the work of others, restoration of the barrier beach and wetland plant communities would require an increase in the amount of sediments available in the littoral drift and a period of extremely low lake levels that would expose sediments for barrier-beach building and for seed-bank germination. The long-term water-level history of upstream lakes Michigan-Huron suggested that such extreme lows were not likely to occur soon on Lake Erie (Thompson and Baedke 1997). Sediment supply in the littoral drift of western Lake Erie had also been greatly reduced (S. Mackey, pers. comm.). Therefore, it would have been a long time, if ever, before conditions allowed the system to naturally restore itself.

Since the original physical functions of a barrier beach wetland needed to be recreated or mimicked to restore the wetland and minimize future required management (Wilcox and Whillans 1999), federal and state managers opted to construct a dike across the opening of the marsh in 1995 to mimic the protective function of the former barrier beach. Unlike other diked wetlands on the Lake Erie shore, however, this dike contains a water-control structure to mimic the natural opening that connected the marsh to Lake Erie and allowed exchange of nutrients and biota between the water bodies. The structure also allowed an initial drawdown of the marsh for two years to mimic a low water-level period and allow emergent vegetation to reestablish from the seed bank.

In conclusion, analyses of early maps, aerial photography, water levels, sediment types, and pollen and plant macrofossils provided a description of the historical conditions at Metzger Marsh. These analyses helped identify a correlation between wetland vegetation, Lake Erie water levels, and sediment supply in the littoral drift and led to the modification of the dike built to mimic the former barrier beach at Metzger Marsh. Inclusion of a water-control structure allows the marsh to be managed in a manner that mimics historical conditions. In addition, the GIS database created during this study will supplement analyses of ongoing changes in wetland plant communities at Metzger Marsh and provide spatially-referenced information upon which management actions can be based.

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