Fish and Wildlife Resources of the Great Lakes Coastal Wetlands within the United States

VOLUME ONE: OVERVIEW

CLEAR Technical Report No. 170:1

Prepared for U.S. Fish and Wildlife Service, Division of Ecological Services-Region 3
Twin Cities, Minnesota. Project Officer: Herbert W. Hyatt. Grant No. 14-16-0009-77-076

The Ohio State University, Center for Lake Erie Area Research,
and Ohio Sea Grant Program. Columbus, Ohio

in cooperation with

Indiana University, Environmental Systems Application Center. Bloomington, Indiana

PREFACE

This volume was prepared as an overview to the five lake volumes. This volume contains an acknowledgement section listing all agencies and individuals contacted during the study. A methods chapter explains the techniques used in the study and in the preparation of the five lake volumes. The remaining chapters are written as overviews of the physiographic, biotic, and cultural resources of the Great Lakes basin. The volume concludes with a master list of common and scientific names of the vegetation, fish, avifauna, reptiles and amphibians, and mammals mentioned in the five lake volumes. Also included in these appendices are the life histories of wetland species of fish, reptiles and amphibians, avifauna, and mammals. A glossary and bibliography are the final items in this volume.

The authors would like to acknowledge the Office of Water Resources and Technology, U.S. Department of the Interior for the use of the study "Impact of Great Lakes Water Level Fluctuations on Coastal Wetlands", Contract No. 14-0001-7163 prepared by the Department of Geography/Geology, Eastern Michigan University, Ypsilanti.

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INTRODUCTION

The coastal wetlands of the Great Lakes, as identified in this report, include all wetlands located entirely or partially within 1,000 feet of the U.S. shore of the Great Lakes and their connecting waters. These include wetlands directly contiguous to the lakes (i.e. at the water's edge), as well as wetlands lying inland (i.e. not contiguous) but located at least partially within 1,000 feet of the lakeshore. Also, wetlands located entirely or partially within 1,000 feet of bays, harbors, estuaries, or coastal lakes and ponds having direct surface water connections to any of the Great Lakes are considered coastal wetlands. For this report, a total of 1,370 coastal wetlands were identified along the U.S. shores of the five Great Lakes and their connecting waters, comprising a total wetland area of 466 square miles (Table 1). The U.S. shoreline of the Great Lakes has a length of nearly 4,000 miles, and a Great Lakes water surface area of 61,000 square miles lies within U.S. jurisdiction.

Table 1

Comparison of U.S. Coastal Wetlands for the Five Great Lakes

Lake	No. of Wetlands	Percent of Total No.	Square Miles of Wetlands	Total No. of Acres	Percent of Total Area
Lake Superior and St. Marys River	348	25	103	66,175	22
Lake Michigan	417	30	189	121,230	40
Lake Huron, Lake St. Clair, and St. Clair River	197	14	110	70,245	24
Lake Erie and Niagara River	96	8	32	20,038	7
Lake Ontario and St. Lawrence River	312	23	32	20,797	7
TOTAL	1370	100%	466	298,485	100%

In recent years there has been an increasing awareness of the valuable resources of our Great Lakes coastal wetlands and of the urgent need to protect and conserve these ecosystems. Traditionally, wetland conservation efforts along the Great Lakes have been aimed at protecting waterfowl breeding, or to a lesser degree, fish spawning and nursery habitat. More recent efforts toward

Table 2. Shore Length and Ownership of U.S. Great Lakes Coast (in miles)

Lake	Federal	Public Non-Federal	Private	Total
LAKE SUPERIOR AND ST. MARY'S RIVER				
Minnesota	20.1	35.8	150.3	206.2
Wisconsin	56.6	36.1	119.3	212.0
Michigan	15.7	52.5	512.6	580.8
Total	92.4	124.4	782.2	999.0
LAKE MICHIGAN				
Michigan	13.0	100.2	731.8	845.0
Wisconsin	0.0	75.2	331.8	407.0
Illinois	3.1	35.8	26.1	65.0
Indiana	9.3	8.7	27.0	45.0
Total	25.4	219.9	1116.7	1362.0
LAKE HURON, ST. CLAIR RIVER, LAKE ST. CLAIR, AND DETROIT RIVER				
Michigan	9.5	65.0	604.5	679.0
LAKE ERIE & NIAGARA RIVER				
Michigan	0.0	5.0	26.7	31.7
Ohio	6.1	42.5	216.5	265.1
Pennsylvania	0.0	11.6	36.7	48.3
New York	0.0	12.8	58.1	70.9
Total	6.1	71.9	338.0	416.0
LAKE ONTARIO AND ST. LAWRENCE RIVER				
New York	0.0	31.9	258.1	290.0
GRAND TOTAL	133.4	513.1	3099.5	3746.0

Data Source: U.S. Army Corps of Engineers, 1971 preservation are based on the knowledge that wetlands provide additional benefits, including flood control, shore erosion protection, water management, control of nutrient cycles, accumulation of sediment, and supply of detritus for the aquatic food web. Although some of the values of these wetland areas have now been recognized, no comprehensive studies have been undertaken to map, enumerate and characterize them, or to catalog the physical, biological, and cultural data base available for each wetland. The present study attempts to do these things. Specifically, our four objectives are to:

1. delineate and describe all wetland areas along the Great Lakes shorelines
2. inventory the fish and wildlife resources of these wetlands
3. describe the physiographic and cultural .setting in which these wetlands are situated, and
4. determine the voids in knowledge pertaining to the fish and wildlife resources of the Great Lakes coastal wetlands.

This study is being published in six volumes, the first to provide an overview and introduction to the Great Lakes wetlands; the remaining five will each cover one major lake and its connecting channel. The subject areas included in each are:

Volume 1: Overview of Great Lakes Coastal Wetlands
Volume 2: Lake Ontario and the St. Lawrence River Wetlands
Volume 3: Lake Erie and Niagara River Wetlands
Volume 4: Lake Huron, St. Clair River, Lake St. Clair, and Detroit River Wetlands
Volume 5: Lake Michigan and Mackinac Straits
Volume 6: Lake Superior and St. Mary's River.

The purpose of the volumes is the compilation of information concerning the fish and wildlife resources and other environmental factors of the United States coastal wetlands of the Great Lakes in such a manner that it is readily available to professional biologists, environmental scientists, engineers, and planners as well as to the interested general public.

The information in these volumes is based on an extensive literature search undertaken by the Ohio State University's Center for Lake Erie Area Research and the Indiana University's Environmental Systems Application Center. Major sources of information used included referee journals and various technical and popular publications of the state departments of natural resources, libraries, universities, federal, state, and local agencies, multi-agency commissions having Great Lakes responsibilities, and private groups and individuals possessing knowledge of Great Lakes coastal wetlands. In some cases unpublished open file data of various agencies and individuals were used. The sheer volume and the unfinished nature of unpublished information precluded its extensive use. Many agencies, institutions, and individuals were contacted by letter, telephone, or personal visit and provided valuable assistance in the acquisition and interpretation of published information. A complete listing of agencies, institutions, and individuals contacted appears in this volume.

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Nevin Fish Hatchery (Donald Thompson)
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METHODS AND PROCEDURES

PHYSIOGRAPHIC SETTING

Setting

Individual wetlands are identified by name, reference number, location (latitude and longitude), acreage, and classification. This information appears in the tables included in the Introduction section for each lake section chapter. The acreage of each wetland has been determined using a modified acreage grid. Measurements are reported to the nearest acre and are based on the area delineated by wetland symbols on the most recent U.S.G.S. quadrangle maps. Classification of the wetlands is based upon the latest version (April, 1977) of the U.S. Fish and Wildlife Service National Wetland Classification System. Sources of information for determining wetland type include U.S.G.S. quadrangle maps, existing aerial photographs, and aerial surveys of the coastal wetlands conducted by The Ohio State University's Center for Lake Erie Area Research and Indiana University's Environmental Systems Application Center. These sources were used to determine sizes of wetlands and their locations relative to the lakeshore and tributary streams. This data permitted wetlands to be classified only to the "system" level as specified in the National Wetland Classification System.

Distances to the shoreline of the Great Lakes and to the nearest urban center are provided for each wetland. Distance to the shoreline is determined using a straight-line measurement from the lakeward edge of the wetland to the closest point on the lake. Straight-line distance to the nearest urban center is measured from the nearest edge of the wetland to the closest portion of the urban corporation line. All distance measurements are reported in miles or in feet.

Topography

The elevation of each wetland is determined from the most recent U.S.G.S. quadrangle maps. When a wetland extends beyond a contour line on the quadrangle map, or otherwise appears to have some variation in relief, the highest and lowest wetland elevations are recorded. Total relief of the wetland is then determined. Elevations are given in feet above sea level as well as feet above lake level.

The topography section provides a brief description of the terrain in the wetland and surrounding areas, including the type of shoreline (e.g., low bluff, low plain) in the vicinity of the wetland as specified by the Great Lakes Basin Commission (1975). Topographical information is gathered from the most recent U.S.G.S. quadrangle maps, aerial photographs, and other available sources of information.

Surficial Geology

Descriptions of the major surficial formations which characterize the area in which the wetland is situated are based upon available state and federal geologic maps. Other sources of information, such as U.S. Geological Survey bulletins, have been used when available. The extent of the surficial formation in the vicinity of the wetland is specified.

Soils

Information pertaining to soils has been taken from existing county soil surveys prepared by the U.S. Department of Agriculture, Soil Conservation Service. Soil surveys are available for most of the coastal counties along the Great Lakes shoreline. Soil associations present in the individual wetlands are described in terms of water capacity, fertility, and the nature of soil material present. Soil associations are also described in terms of where they are commonly found (e.g., along streams and rivers, drainage ways, and depressions).

Hydrology

Water level influences, groundwater drainage patterns and runoff, water quality, depth, and seasonal changes are described for each wetland, when wetland-specific data exist. Groundwater information includes the depth of the water below the surface of the wetland, the high and low readings, as well as the sampling dates. Water quality data are presented for representative dates and include any of the following parameters: nitrogen, phosphorus, temperature, dissolved oxygen, suspended solids, pH, salinity, and hardness. Where information on other parameterrs (e.g., pesticides, minerals) is available, reference to the data source is made, but specific measurements are not included in the text.

Surface water present in the wetland is also discussed. This includes a description of any stream entering the wetland, its location, and whether the stream is perennial or intermittent. The elevation of each stream at the mouth and as it enters the wetland is noted. Information such as drainage area, channel slope, maximum and minimum discharge, and stream flow is included, when available, for each stream. Lentic water present in the wetland is also noted.

Climate

Climatological data are compiled and published by the National Oceanic Atmospheric Administration. Data from the weather station closest to each wetland are used in the study. Mean temperatures and precipitation figures are based on thirty year normals; mean temperatures and precipitation are figured by either adding or subtracting the deviations from normal. Mean annual and monthly (January and July) data for temperature and precipitation are usually given. Information is also presented on growing seasons, using 28^{o}F as the temperature for a killing frost. When the appropriate data from a given climate station are not available, the format is adjusted to reflect as much pertinent information as possible.

Special Features

Natural features which are of special significance (e.g., baymouth bars, sandspits, and abandoned meanders) are identified and described. This information is taken primarily from the most recent U.S.G.S. quadrangle maps, existing aerial photos, and aerial surveys of the coastal wetlands.

BIOTIC SETTING

Sources of information used in the biotic setting narratives were located using computerized literature searches, personal contacts, and bibliographies.

Computerized literature searches included: Enviroline, National Technical Information Service, Mechanized Information Center (OSU), Smithsonian Science Information Exchange, and Water Resources File.

Personal contacts via telephone, letter, or personal interview were established with persons in federal and state agencies, colleges and universities, international and interstate commissions, and museums to locate additional published sources of information. These included the U.S. Fish and Wildlife Service, U.S. Environmental Protection Agency, U.S. Army Corps of Engineers, Sea Grant offices, state universities, state departments of natural resources, the Great Lakes Fisheries Commission, International Joint Commission, and Great Lakes Basin Commission. A list of all individuals, agencies, and institutions contacted is presented earlier in this volume.

All authors also searched professional bibliographies and abstract series pertaining to their particular specialty. Major bibliographies include U.S. Fish and Wildlife Service, State Fish and Wildlife , Sport Fishery Abstracts, Wildlife Review, and indices to technical journals.

Since wetland-specific information was found to be scarce, information regarding areas immediately adjacent to coastal wetlands was often utilized to extrapolate biotic characteristics of the wetland. When such indirect information was used, its use was clearly stated in the narrative in order not to confuse it with site-specific information.

Federally-listed endangered and threatened species have been extracted from the latest lists (1977, 1978) appearing in the Federal Register. Species that are being considered for inclusion on the Federal Endangered Species List have been drawn from the Endangered Species Technical Bulletin, published by the U.S. Department of the Interior. Species endangered or threatened in a particular state have been selected from lists obtained from state departments of natural resources.

CULTURAL SETTING

Population

Population information has been compiled for the county and township in which the wetland is located. Population characteristics considered include: (1) density, (2) estimated population in 1975, (3) estimated percent change in population, 1970-1975, and (4) projected population for 1990. Density is expressed in number of persons per square mile. All counties in which wetlands are situated are described as either sparsely populated (0-99 persons per square mile), moderately populted (100-999 persons per square mile), or densely populated (1,000 or more persons per square mile).

The national population growth rate for the period 1976-1990 is expected to be .94% annually. In order to provide a basis of comparison to this national growth rate, the following terminology has been used to describe estimated percent change in population, 1970-1975, and projected percent change in population 1975-1990 for the township and counties in which wetlands are situated:

Estimated 1970-1975	Classification	Projected 1975-1990
over +5.0	rapid growth	over +15.0
+3.1 to +5.0	moderate growth	+9.1 to +15.0
+1.1 to +3.0	slow growth	+3.1 to + 9.0
-1.0 to +1.0	stable	-3.0 to 3.0
-1.1 to -3.0	slow decline	-3.1 to - 9.0
-3.1 to -5.0	moderate decline	-9.0 to -15.0
over -5.0	rapid decline	over -15.0

Land Use and Ownership

Existing land use within and adjacent to the wetland is classified as either (1) residential, (2) commercial/industrial, (3) institutional (public), or (4) agricultural/open space. These four categories include the following land uses:

1. Residential
   - 1.1 Single family unit
   - 1.2 Multi-family unit
   - 1.3 Second home (recreational)
   - 1.4 Trailer park
   - 1.5 Hotel or motel
   - 1.6 Abandoned residences

2. Commercial/Industrial
   2.1 Retail trade
   2.2 Manufacturing
   2.3 Mineral extractions
   2.4 Industrial harbor facilities
   2.5 Warehousing

3. Institutional (Public)
   3.1 Educational establishments
   3.2 Government offices
   3.3 Churches
   3.4 Hospitals

4. Agricultural/Open Space
   4.1 Cropland
   4.2 Pasture
   4.3 Orchards
   4.4 Parks/recreation areas
   4.5 Wildlife refuge
   4.6 Marina
   4.7 Forest

Wetland ownership is classified as either public (federal, state, or local), private, or mixed. Information sources for ownership as well as existing land uses include county and regional land use maps and plans, county plat maps, existing aerial photographs, and U.S.G.S. quadrangle maps.

Development pressures on the wetland are described as either minimal, low, moderate, high, or severe. These estimations are primarily based upon existing land use patterns and future land use plans. In those situations where plans are not available, an attempt has been made to estimate possible development based on information relating to present land use, suitability for residential, commercial, or industrial development, ownership patterns, and the potential for resource development.

Recreation

Recreational usage (e.g., hunting, fishing, camping, hiking, and wildlife observation) of the wetland is described when existing literature is available. Wetlands lying within federal, state, or local parks are discussed in terms of recreational use of the entire park. Recreational opportunities available in wetlands situated within national or state forests are also described.

Mineral, Energy, and Forest Resources

Mineral (sand, gravel, salt, clays, shales, and limestone), energy (gas, oil, and coal), and forest resources are identified for each wetland. Where these resources are present, an attempt has been made to ascertain whether active resource extraction industries are in operation. Primary sources for this information include the publications of the various state geological survey divisions, U.S.G.S. quadrangle maps, and existing aerial photographs.

Public Utilities and Facilities

Public utilities and facilities located within a half-mile radius of the wetland are identified. Facilities considered include (1) water treatment plants, (2) sewage treatment plants, (3) electric generation plants and power lines, and (4) gas and oil pipelines. Where possible, the type (fossil fuel, nuclear) and capacity (megawatts) of the electric generation plants are noted. Major information sources have included U.S.G.S. quadrangle maps, existing aerial photographs, and various publications of the Federal Energy Regulatory Commission (formerly the Federal Power Commission) and the Federal Energy Administration.

Pollution Sources

National Pollution Discharge Elimination System (NPDES) permits identify discharge limitations for each pollutant covered under the Federal Water Pollution Control Act regulations, and the location of outfalls. These permits, available for public inspection at state environmental control agencies, are used to locate point sources discharging into or in the vicinity of the wetland. The discharger and the type of discharge (e.g., wastewater) are noted. Non-point sources of pollution are not covered under the NPDES permit program, and information on non-point sources is not widely available. Where a special study has been done on the wetland, the information is summarized.

Historical and Archaeological Features

Significant historical sites within 500 feet of the wetland have been identified primarily through federal and state historical registers. While these registers do not identify all of the existing sites, they do provide the most comprehensive listing that is readily available. The information obtained from the registers has been supplemented by contacts with state historical preservation commissions.

Archaeological sites in the vicinity of the wetland have been identified primarily through existing archaeological inventories prepared by state historic preservation divisions. Discussion of individual sites is limited to a description of where the site is located in relation to the wetland (where available) and a short summary of the archaeological significance of the site.

RESEARCH PROJECTS

Current and impending research projects are identified for each wetland. The following information is described, when available: (1) the objectives of the project, (2) the funding sources and the level of funding, and (3) the expected duration of the project and time of implementation. Research projects have been identified through selective contact of federal, state, and local agencies as well as public institutions (e.g., universities, research institutes). Published reports of research projects, such as the International Joint Commission's Directory of Great Lakes Research, have also been consulted.

PHYSIOGRAPHIC OVERVIEW

DISTRIBUTION AND ORIGIN OF COASTAL WETLANDS

The Great Lakes are located within the highly industrialized northcentral United States. The Great Lakes drainage basin covers only four percent of the United States land area, but it has 15 percent of the nation's population and produces 50 percent of the nation's steel. The basin consists of land and water areas of 183 counties in eight states (Figure 1). The coastal resources of the Great Lakes, including their wetlands, are invaluable assets to the region and to the nation as a whole. This section describes the general physiographic setting of the coastal region as it relates to wetlands formation. Figures two through six show the distribution of coastal wetlands along each of the Great Lakes and connecting channels. Much of the information summarized in this section was obtained from the Great Lakes National Shoreline Study (U.S. Army Corps of Engineers, 1971).

Origin of Coastal Wetlands

The basin occupied by the Great Lakes was created by glaciation, and its physical features and hydrology differ greatly from regions not exposed to Pleistocene ice sheets. In terms of earth history, the construction of the basin has recently been completed. The five Great Lakes, with their outlets and approximate lake levels as they are today, probably date back less than 5,000 years (U.S. Army Corps of Engineers, 1971). The processes of stream and shoreline erosion/accretion have made moderate changes in the original topography, but these slight changes are significant in the origin and development of coastal wetlands.

Prior to the Pleistocene Ice Age, the Great Lakes were non-existent; the area was dissected by well-developed valleys and several major streams. When the continental ice cap developed to a thickness of several thousand feet in northeastern Canada, it spread southward into the present Great Lakes region. Tremendous amounts of bedrock were eroded and the debris entrained in the ice mass. As the ice sheets slowly melted and retreated progressively northward, this entrained debris was released and vast irregular deposits of till were laid down on the scoured bedrock surface. Occasionally blocks of ice were also entrained in the till and eventually formed the kettle or bog lakes of the upland areas adjacent to the Great Lakes.

Once the lakes became established, stream and shoreline processes provided favorable sites for wetlands. The most significant processes included 1) delta formation, 2) estuary formation, and 3) sand bar/dune formation creating coastal lagoons. Although the gross configuration of the Great Lakes have been little altered since their glacial development, the above processes have established many favorable sites for wetlands. Except where bedrock is exposed or protective works constructed, the glacial or lacustrine overburden comprising the shores is still vulnerable to changes which can work to the benefit or destruction of coastal wetlands.

Kettle Lake Wetlands. One of the most characteristic types of lakes in the glaciated upland areas adjacent to the Great Lakes was formed by the

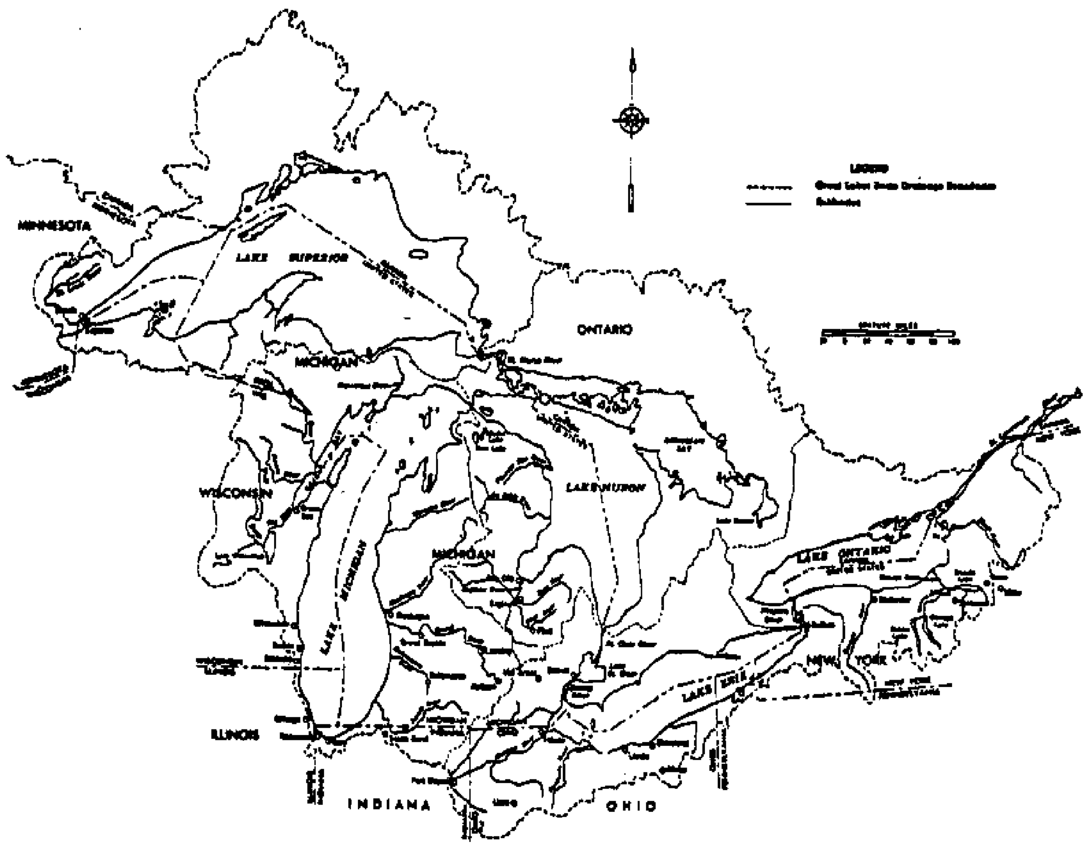


Figure 1. Great Lakes Basin

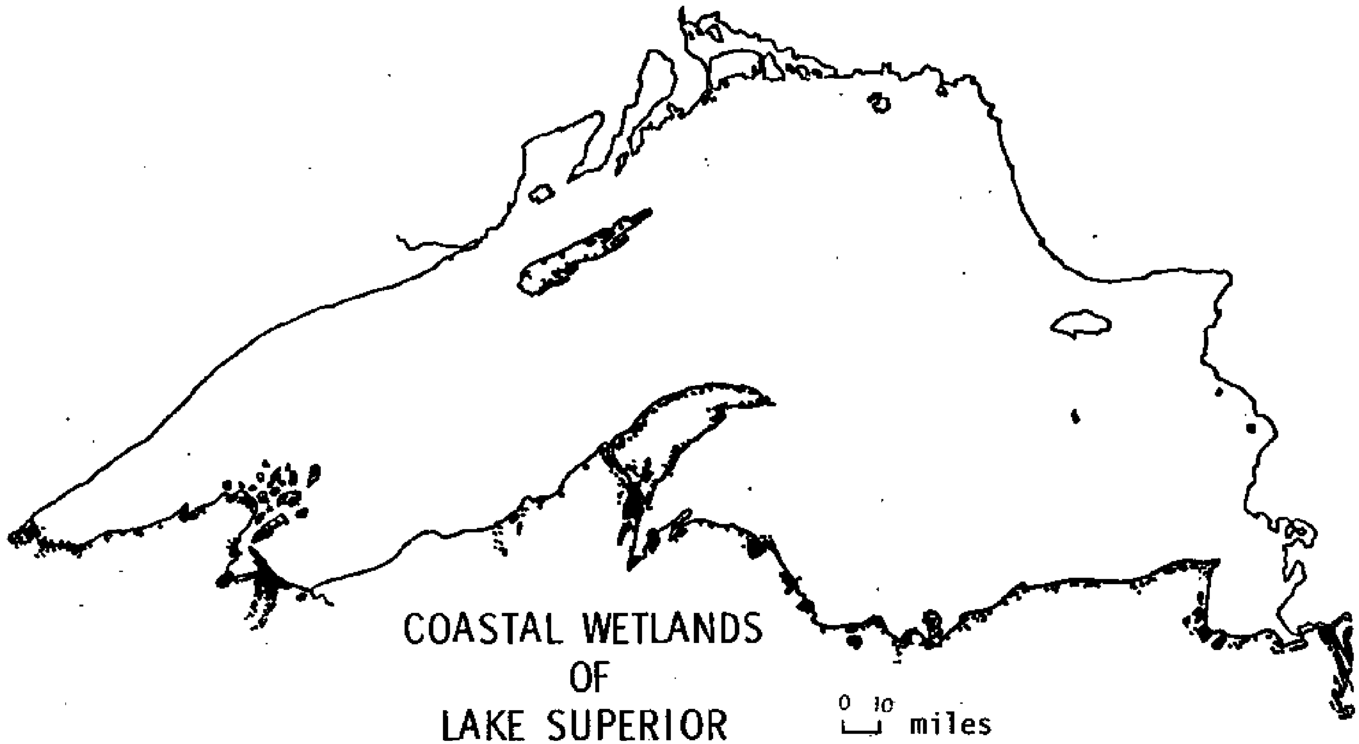


Figure 2. Coastal Wetlands of Lake Superior

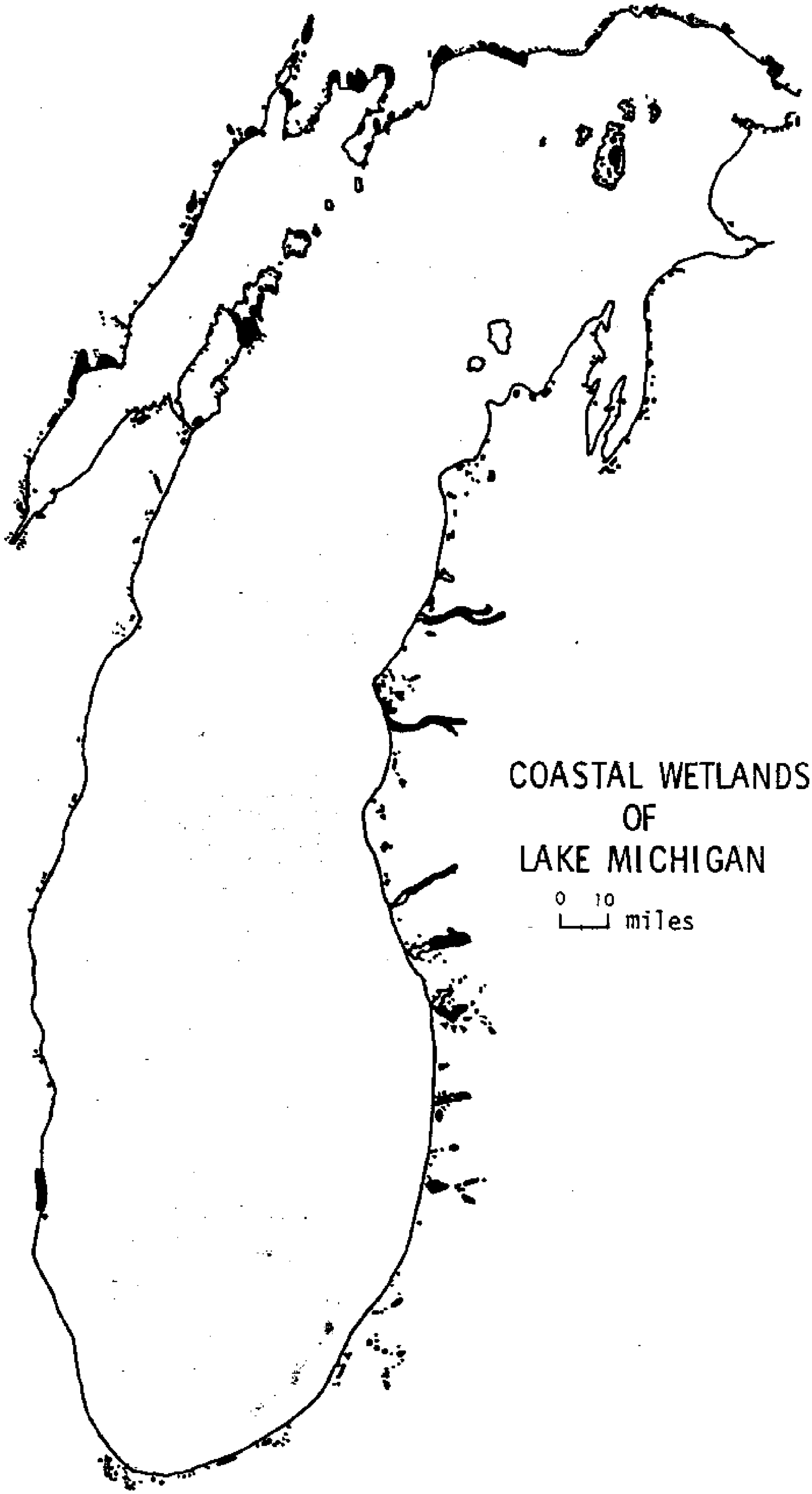


Figure 3. Coastal Wetlands of Lake Michigan

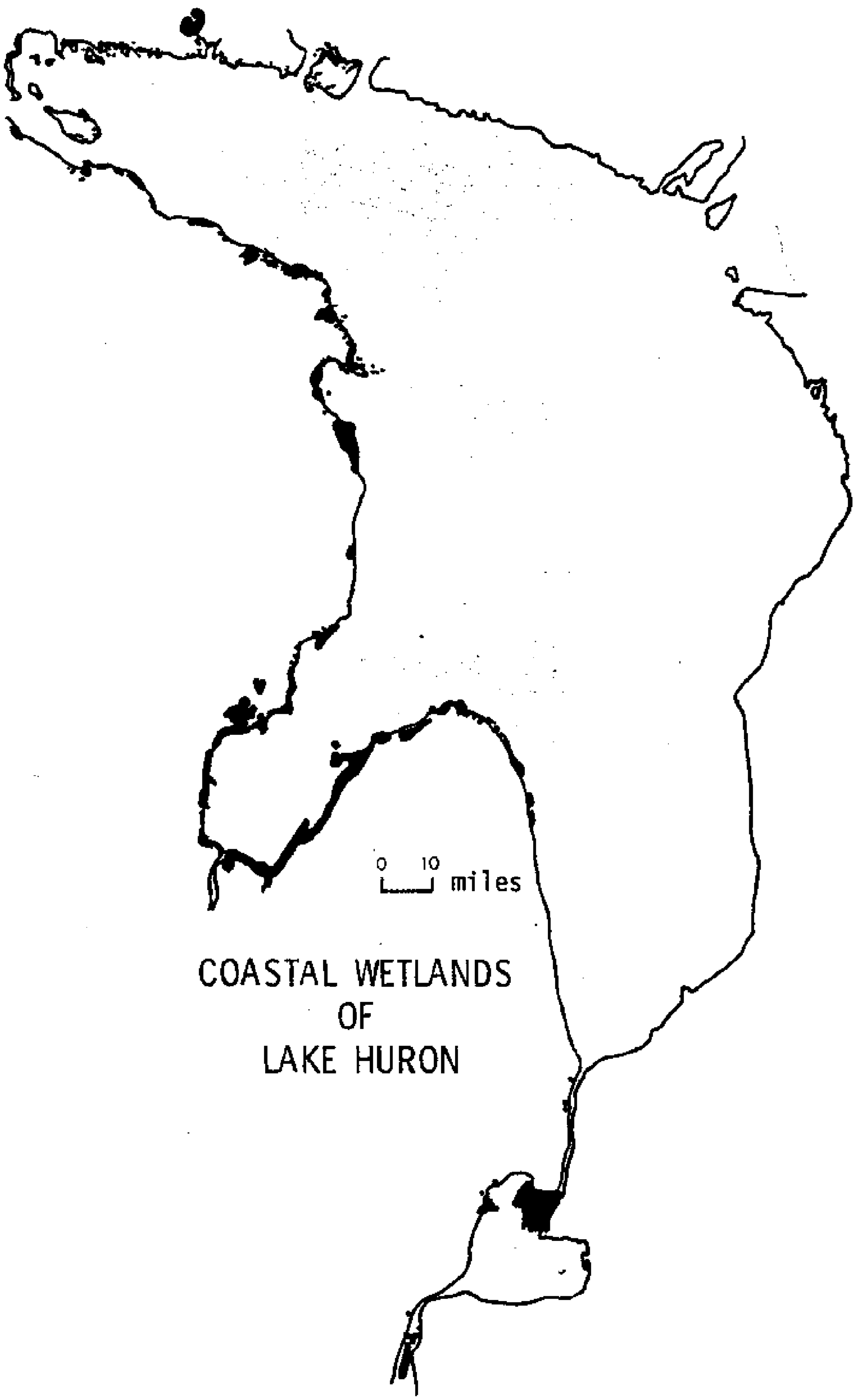


Figure 4. Coastal Wetlands of Lake Huron

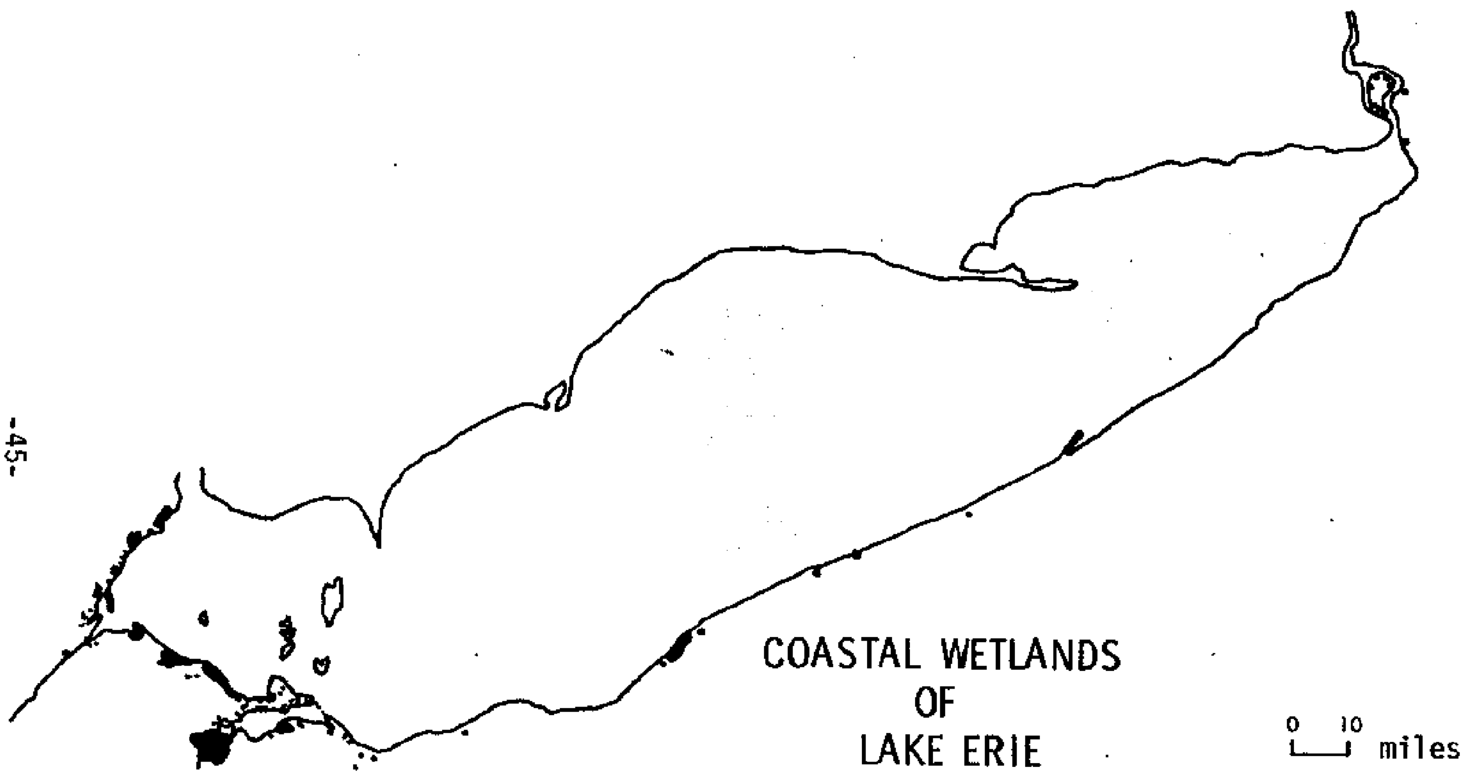


Figure 5. Coastal Wetlands of Lake Erie

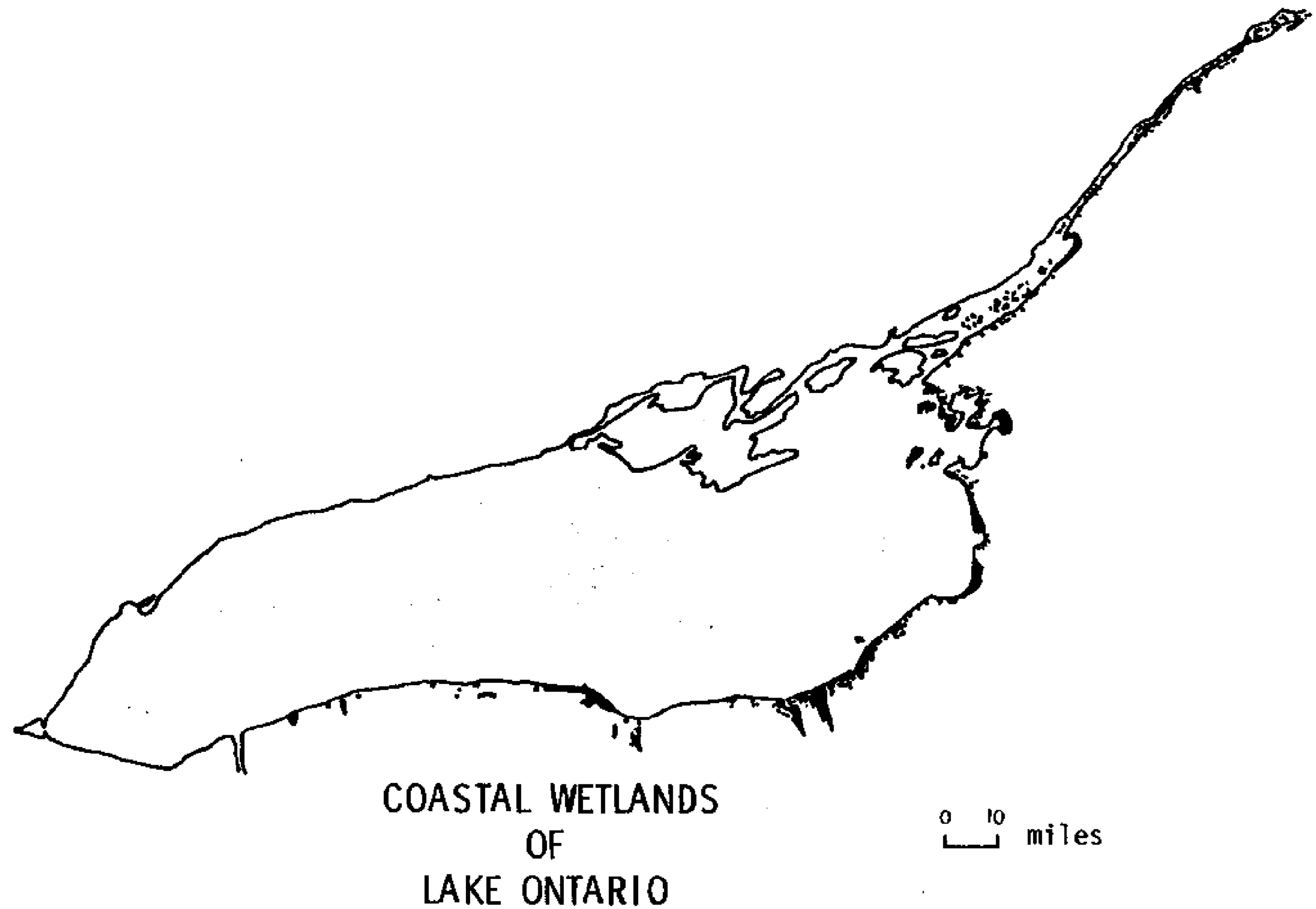


Figure 6. Coastal Wetlands of Lake Ontario

incorporation of ice blocks in the material that washed out from a melting ice front. The glacial outwash, consisting of sand, gravel, and silt, was derived from the drift or moraine underlying or bordering the ice. As the mass of ice melted, a basin was left in the drift, and if the basin penetrated below the water table a body of water known as a kettle lake came to occupy the site of the original ice block. The kettles are extremely variable in shape and size; some are less than 100 feet across while others, such as Trout Lake, Wisconsin, have a diameter of nearly three miles (Hutchinson, 1957). In general, the depth of kettle lakes does not exceed 165 feet (Flint, 1957). Bogs are the most common wetlands in kettle lakes.

Kettle lakes and other northern basins, protected from wind and poorly drained, may become bog lakes. They first become fringed by floating mats of sedge vegetation growing inward to encroach upon the open water; this change is accompanied by a drop in pH. The succession then continues as the mat covers the lake surface and sphagnum moss and ericaceous shrubs, such as leatherleaf and Laborador tea, become established. When growth exceeds decomposition, the lake basin begins to fill and peat deposits are formed. Ultimately a sequence of tree species, commonly tamarack followed by spruce, leads to a climax forest association.

Delta Wetlands. A stream reaching a body of standing water, such as the St. Clair River flowing into Lake St. Clair, at times builds a deposit or delta, composed of the stream's sediment load. These deposits are commonly the site of extensive wetland development. Not all rivers build deltas; deltas may be lacking at the mouths of streams which enter the Great Lakes because their mouths are so exposed to wave and current action that sediments are removed as rapidly as they are deposited. Some streams also lack deltas because they carry so little load. Although each delta has its own individual form, Strahler (1971) has recognized four basic outlines for deltas: 1) arcuate, triangular outline, 2) digitate, bird-foot type, 3) cuspate, tooth-shaped form and 4) estuarine, drowned valley.

The typical arcuate delta originates at an upstream apex and radiates lakeward by means of branched distributary channels to form a triangular shape. Sediments reaching the lakes from the distributary mouths are swept along the coast by wave-induced currents to form curved bars enclosing shallow wetland lagoons; the delta shoreline is thus arcuate in plan, bowed convexly outward. The digitate or bird-foot delta contains long extensions of its branching distributaries into open water. This type of delta requires a gently sloping lake bottom in front of the river mouth, such as Lake St. Clair, on which natural levees can be built up quickly. The cuspate or tooth-shaped delta is normally formed when the stream has a single dominant mouth. Sediment from this mouth builds the delta forward into deeper water while wave action sweeps the sediment away from the discharge to form a curving beach on both sides of the mouth, concave toward the lake. An estuarine delta commonly fills a long narrow estuary that resulted from drowning of the lower part of the river valley because of a rise in lake level. Estuarine deltas are characterized by depositional islands containing wetlands.

Delta growth occurs when a stream enters a standing body of water as a jet or plume. The jet velocity is rapidly checked and sediment is deposited in lateral embankments (natural levees) in zones of less turbulence on either side of the jet, thus extending the stream channel into the lake. The stream repeatedly breaks through the embankments to occupy different radii (distributary channels) and in time produces a deposit in semi-circular form, closely analogous to the alluvial fans found at the base of mountain ranges. The natural levees serve to isolate shallow interdistributary pond and marshes containing fine muds and organic detritus or peat (Stanley and Swift, 1976). The sediment structure of most deltas on the Great Lakes is produced by three sets of beds: 1) bottomset, 2) foreset, and 3) topset. Bottomset beds consist of fine-grained materials (silt and clay) carried farthest offshore and laid down on the bottom of the lake embayment into which the delta is being built. Foreset beds are somewhat coarser (fine sand) and they represent the advancing front of the delta and the greater part of its bulk; they usually have a distinctly steeper slope (dip) than the bottom set beds over which they are slowly advancing. Topset beds lie above the foreset beds and are in reality a continuation of the alluvial plain of which the delta is the terminal portion. It is on the foreset beds that delta wetlands normally develop. Unlike deltas formed along the ocean, freshwater deltas do not contain aggregates of fine particles induced by electrolite flocculation (due to the dissolved salts in the sea). Therefore, fine particles are carried offshore in lakes and are not incorporated into the delta sediments.

Delta wetlands form a significant portion of the coastal wetlands in the Great Lakes region. Delta wetlands are gradational to embayment, estuary, river, and floodplain wetlands.

Freshwater Estuary Wetlands. The lower courses of several tributaries to the Great Lakes, particularly the more southerly lakes, are characterized by estuarine-type or drowned stream mouths. The flooded flat areas adjacent to these estuaries afford ideal sites for wetland development. The lower 15 miles of the Maumee River, which flows into Lake Erie at Toledo, Ohio and posesses the largest drainage of any Great Lakes tributary, is an excellent example of a freshwater estuary. The formation of this estuary on Lake Erie is the result of a series of geologic events related to Pleistocene glaciation. The flow of the Maumee River was reversed from its southwestern direction when the glacial lakes drained from the Erie Basin as the ice sheet melted, exposing a lower Niagara River outlet. At that time, river velocities were accelerated by the base-level lowering, and the Maumee Valley was cut deeply into lacustrine deposits, glacial tills, and bedrock. With the weight of the ice removed, the outlet eventually rebounded and produced a rise in lake level. The lake encroached up the valley and formed the present drowned stream mouth which is analogous in many ways to a marine estuary. Virtually all of the tributaries entering Lake Erie on the Ohio shore have estuarine-type lower reaches and attendant wetlands, where lake water masses affect water level and quality for several miles upstream from traditional mouths (Brant and Herdendorf, 1972).

The Maumee River estuary begins near Perrysburg, Ohio, at the most downstream bedrock riffle. As the water enters the estuary from the river, its velocity abruptly diminishes except during major runoff events, causing sedimentation of suspended particles. The deposits have formed a series of elliptical islands which foster wetland formation. Similar deposits are found in the Sandusky River estuary and in the tributaries along the Michigan shore of Lake Michigan.

Coastal Lagoon Wetlands. In large bodies of water such as the Great Lakes, the shifting of sediments by nearshore currents can form basins where wetlands eventually develop. If sediments are deposited across the mouth of an embayment, a tributary outlet or a freshwater estuary, the blockage may result in the formation of a new pond or lagoon. Wave activity, too, has formed bars of sand and gravel, which likewise have closed off the mouths of embayments.

The usual way in which a lagoon capable of supporting a wetland is formed is by accretion of a bar across some irregularity or indentation of the coastline. The term bar is used here in a generic sense to include the various types of submerged or emergent embankments of sand and gravel built on the lake bottom by waves and currents. One of the most common types of bars associated with wetlands in the Great Lakes is a spit. This feature is a sand ridge attached to the mainland at one end and terminating in open water at the distal end. Spits that have extended themselves across or partially across embayments are termed baymouth or barrier bars. Commonly the axis of a spit will extend in a straight line parallel to the coast, but where currents are deflected landward or unusually strong waves exist, growth of a spit may be deflected landward, resulting in the creation of a recurved spit or hook. Several stages of hook development may produce a compound recurved spit with a series of ponds separated by beach ridges. The ponds have provided excellent sites for wetland development along the Great Lakes.

Kormondy (1969) described wetland succession in beach ponds on a four mile long spit in Lake Erie known as Presque Isle near Erie, Pennsylvania. Owing to a combination of its sandy shore and exposure to violent lake storms, this spit developed as a series of hooks with the establishment of numerous, fingerlike beach ponds over the past several thousand years. The ponds are created when an elevated bar of sand develops, thereby isolating a small portion of the lake; the ponds are seldom more than 330 to 660 feet long, 33 to 66 feet wide, and three feet deep. Some of the ponds are destroyed in a few days, months, or years by subsequent storms which either breach the sand bar or blow enough sand to fill in the depression. The better protected ponds survive these geological processes only to be subject to a biological fate, wetland succession. A four-year-old pond is characterized by sparse pioneer vegetation, such as stonewort algae, bulrushes, cattail, and cottonwood seedlings. At 50 years, filling has occurred in the basin and encroaching vegetation has reduced the open water portion to about half of its former area. The major vegetation then consists of water milfoil, cattail, bulrushes, bluejoint, willow, bayberry, and cottonwood. After 100 years the open water portion is almost obliterated and the vegetation has increased in complexity. The dominant forms then include water milfoil, pondweed, yellow water lily, bulrushes, bluejoint, spikerush, bayberry, and cottonwood. Sparseness of distribution and limitation of plant species mark the early ponds; increased density and heterogeneity characterize the older ponds, and the contrast is striking. From this analysis of succession, Kormondy concluded that the ponds or lagoons at the northeast end of Presque Isle are the youngest and that the spit has growth from the southwest because the ponds are increasingly older in that direction.

PHYSIOGRAPHY OF GREAT LAKES COASTS

Physiography of the Lake Superior Coast

The Minnesota shore of Lake Superior is characterized by steep, rocky bluffs in the northernmost reaches, ranging to low-lying clay and gravel covered banks near Duluth. Minnesota Point, a narrow, baymouth sand bar about five miles long, separates the Duluth-Superior Harbor from Lake Superior. The protection of this bar permits the development of wetlands within the harbor area. Bank heights vary from about 3 to 30 feet within the harbor, to 30 feet along the shoreline just north of Duluth and over 100 feet along the rock cliffs near the Pigeon River. The steep, exposed shore north of Duluth precludes significant wetland development.

The Wisconsin mainland shoreline of Lake Superior has widely differing physical features, including the excellent sand beach at Kakagon Slough in Ashland County, the steep, erodible clay bluffs along the Douglas County shore and the low sand bluffs and spits at Port Wing, Cornucopia and Sand Bay in Bayfield County. Bluffless slough reaches along Cheguamegon Point, at the tip of Cheguamegon Bay, and scattered along the eastern shore of Bayfield County are characterized by significant wetlands. The Apostle Islands, a group of 22 islands containing 175 miles of shoreline, have sandstone bluffs, sand and gravel beaches and wetland shores. The bluffs along the Wisconsin shore range up to 100 feet along the clay banks in Douglas County.

The Michigan coast of Lake Superior includes the rugged Keweenaw Peninsula, Isle Royale, the Pictured Rocks of Alger County, and the shore of Whitefish Bay. Heights of the Precambrian rock banks vary from 6 to 160 feet along the Keweenaw Peninsula and rise to 200 feet at the precipitous Cambrian sandstone cliffs on the Pictured Rocks reach. Wetlands are most evident along the Keweenaw waterway and at tributary mouths in Marquette and Chippewa Counties. The Isle Royale shoreline and the islands and mainland shores of the St. Marys River are dotted with wetlands.

Physiography of the Lake Michigan Coast

The Wisconsin shoreline of Lake Michigan north of Green Bay consists of low sand banks up to five feet high, fronted by wetland along most of the reach. The shoreline along the eastern side of Green Bay, including Door County Peninsula, consists of sand and gravel beaches backed by bluffs up to 100 feet high. The bluff material is composed of glacial till and lacustrine sediments. The Lake Michigan shore of Door County consists of a mixture of ledge rock cliffs with numerous narrow beaches and shallow bays. Behind the upper reaches of many of the bays are low wetland areas. A red clay bluff ranging from 10 to 70 feet in height characterizes the shore of southern Door County, Kewaunee County and northern Manitowoc County. Narrow sand beaches and red clay bluffs extend from Two Rivers south to Sheboygan. Wetlands are scarce along this reach of the lake. The southern Wisconsin shore has areas of gently sloping, low sand banks fronted by wide beaches. Between Port Washington and Milwaukee glacial till bluffs reach 140 feet and decrease to 25 feet near Kenosha. The high bluffs normally have narrow beaches and few wetlands.

The Illinois portion of the Lake Michigan shoreline consists of unprotected sandy beaches and glacial till bluffs in the northern part of the state. From Glencoe south to Indiana, the shoreline consists mostly of protected areas. These include artificial fills, wide beaches and navigation structures. Wetlands are very limited along this reach except for an area north of Waukegan.

The Indiana shoreline of Lake Michigan generally consists of well protected artificial industrial lake fills west of Gary. East of the industrial area the shore is lined with sand dunes fronted by sandy beaches. Minor wetlands are associated with the dunes and the Calumet River.

Generally the Michigan shoreline of Lake Michigan from Indiana north to Grand Haven is almost continuous sand beach, bordered by occasional clay bluffs and sand dunes. High dunes, up to 240 feet above lake level, form a series of sand hills parallel to the shoreline and up to a mile in width. The shore from Muskegon north to Empire contains clean sand beaches, with low and high dunes behind them. Wetlands are most often associated with estuarine-type tributary mouths that extend inland for several miles. The offshore islands (Beaver, North and South Fox, and North and South Manitou) have sand beaches backed by dunes. Beaver Island has extensive wetlands. The shoreline from Empire to the Straits of Mackinac, including Grand Traverse Bay, is characterized by narrow, cobble beaches, backed in some stretches by high bluff. Wetlands are less common along this reach. The Upper Peninsula shore of Lake Michigan is generally irregular and contains many small bays. Typically the points and headlands are rocky and the bay heads are sandy or marshy. This reach of shoreline contains many excellent wetlands.

Physiography of the Lake Huron Coast

The entire United States shoreline of Lake Huron, as well as the St. Clair River, Lake St. Clair, and the Detroit River lie within the state of Michigan. The northern shore of Lake Huron from the Straits of Mackinac east to Drummond Island generally consists of alternating erodible low plains of clay and marshes, with occasional non-erodible outcrops of limestones and dolomites. The Lake Huron shoreline from Mackinaw City to Harrisville is mainly a rock and boulder shore, with high bank beaches extending back into hills. From Harrisville to northern Saginaw Bay, the beaches are mostly sand, usually low, and with some high bluffs directly behind the beach. In the southern part of this reach the sand beaches are occasionally interrupted by wetlands. Much of the southeastern side of Saginaw Bay is marshy, with shallow water inshore and without a noticeable bluff. Sand Point is a long narrow peninsula that juts westward into Saginaw Bay. From this point to Port Austin the shore is composed of sand beaches with a bluff of uneven sand ridges having wetlands between them. From Port Hope southward to the St. Clair River the shore is mostly boulder-strewn to the north and sandy to the south. There are few wetlands along this reach. The shorelines of Lake St. Clair, the St. Clair River, and the Detroit River have been intensively developed for residential, industrial, and recreational use. The only extensive natural areas are on the St. Clair River delta wetlands and the wetlands on the islands at the mouth of the Detroit River.

Physiography of the Lake Erie Coast

The Michigan shoreline of western Lake Erie consists of low-lying marshes and sand beaches. At Stony Point on the shoreline of Brest Bay, a brecciated dolomite forms a rocky shoreland with boulders and sand.

The Ohio shore of western Lake Erie in its natural state is generally a marsh area fronted by low barrier beaches. Earthen and rock dikes now protect most of the shore except for the rock-bound Erie islands. East of Port Clinton the ground elevation rises and at the headlands known as Catawba Island the shore material is ledge rock which stands over 30 feet high. To the east, a strip of high ground connects to another headland known as Marblehead. Northeast of this crescent-shaped strip are three open water marshes called West, Middle, and East Harbors which are fronted by a sandy barrier beach. The Bass Island-Kelleys Island group of 12 bedrock islands have shores similar in nature to the headlands. Small embayments on the larger islands contain wetlands. Sandusky Bay is separated from Lake Erie by two sand spits: Sand Point projects south from Marblehead and Cedar Point extends northwest from near Huron. These spits protect extensive wetlands throughout the bay. One of the largest concentrations of wetlands on Lake Erie is found at the head of Sandusky Bay.

East of Cedar Point, the shore characteristics change abruptly; the low marshy backshore typical of most of the coast from Toledo to this point disappears and is replaced by low bluffs or glacial till, lacustrine sediments and block shale. The bluffs rise from 10 feet near Vermilion to 50 feet near Cleveland and 70 feet at Ashtabula. The only wetland development along this reach of shoreline is found at the estuary mouths of the tributaries. The best wetland occurs at Mentor Marsh, the abandoned valley and delta of the Grand River which now enters Lake Erie several miles east of the marsh. Beaches along this reach are narrow except where affected by large navigation structures at the major harbors.

The Pennsylvania shore of Lake Erie contains bluffs ranging from 50 to 100 feet high and is composed of silt, clay, and shale bedrock with moderate-width sandy beaches. However, the most prominent feature of the coast is Presque Isle Peninsula, a four-mile-long sand spit which encloses Erie Harbor. As discussed earlier under Coastal Lagoon Wetlands, the natural construction of this spit has created numerous ponds where wetlands have developed.

The New York shoreline of Lake Erie is characterized by bluffs ranging from 40 to 100 feet high. The lower part of the bluffs, generally well above the limit of wave uprush, is shale which has resulted in narrow shingle beaches. A few sand beaches occur, mainly between Silver Creek and Cattaraugus Creek. Because of the nature of the coast, wetlands are sparse along this reach. Several small wetlands have formed along the Niagara River, particularly on Grand Island.

Physiography of the Lake Ontario Coast

The entire United States shoreline of Lake Ontario and the St. Lawrence River lies within the state of New York. The shoreline of western Lake Ontario varies from 60 foot high glacial till bluff near the mouth of the Niagara River to low marshy shore near Rochester. Irondequoit Bay has a low marshy shore; barrier sand and gravel beaches separate the marshes and open lagoons from Lake Ontario. The shore east of Rochester to Sodus Bay has a continuous bluff from 10 to 70 feet high composed mainly of silt and clay. Between Sodus Bay and Little Sodus Bay, there are a series of prominant drumlins (low, narrow hills of glacial till) separated by wetlands that extend several miles inland along small streams that enter the lake (U.S. Army Corps of Engineers, 1971). Narrow sand and gravel barrier beaches have formed across the low marsh areas or open water between the drumlins. East of the drumlins to the head of the St. Lawrence River the shore is very uneven and contains several deep bays and prominent headlands, particularly in Jefferson County. Long stretches of coast are barrier beaches and sand dunes extending in nearly a straight line and separating marsh areas in the embayment from the open lake. Northward, there are outcrops of rock at the water's edge which rise gradually to a height of 75 feet at Stony Point and then falls gradually toward Henderson Bay. From this bay to the Tibbett's Point, at the head of the St. Lawrence River, there is generally shale or limestone rock for several feet above lake level with a few pockets of sand, gravel, or shingle beach. Marsh areas occur at the inner end of most of the deep bays.

The mainland shoreline and islands of the St. Lawrence River contain some of the best wetland development in the Great Lakes region. Eastern Jefferson County and St. Lawrence County have low marshy shores with numerous embayments and low gradient tributaries which contribute to wetland formation. The Thousand Islands are mainly rock-bound, but embayments provide sites for marshes. The valley of Crooked Creek is one of the best examples of wetland development along this reach.

OVERVIEW OF FISH AND WILDLIFE RESOURCES
and
RELATED ABIOTIC FUNCTIONS OF GREAT LAKES COASTAL WETLANDS

In this chapter an overview of the fish and wildlife resources of Great Lakes coastal wetlands is presented. Included are discussions of the economic values of commercial and sport fishing, waterfowl hunting, furbearer trapping, and nonconsumptive activities carried out in the coastal wetlands. Also discussed are abiotic values which are related to the biological values of coastal wetlands. As a result of natural and cultural modifications, many of which are permanent, wetland values are in constant change. Because of this dynamic situation, an historical view is presented so that current values may be assessed more accurately and future values better perceived.

Related to consideration of fish and wildlife habitat are selected abiotic functions which also vary over time and space. Topics such as sediment trapping, the occurrence of toxic substances, and nutrient uptake are receiving increased attention in the Great Lakes Basin, in part because of their impact on water quality, recreation, and fish and wildlife resources. Other functions, such as nonconsumptive recreation, which make significant economic and aesthetic contributions to wetland values will be discussed also.

Environmental literature suggests that wetlands have a multiplicity of functions, but seldom is any distinction made between inland and coastal wetlands in terms of functions. As research proceeds, it is becoming increasingly clear that values identified in inland wetlands are not always applicable to coastal wetlands. Based on consideration of the selected biotic and abiotic values suggested above, general recommendations for the development of wetland strategies are included in this overview.

HISTORICAL PERSPECTIVE

Definition and Classification of Wetlands

Wetlands can be defined "as land where the water table is at, near, or above the land surface long enough to promote the formation of hydric soils or to support the growth of hydrophytes" (Cowardin et al., 1977). The upper limit of wetlands is normally the transition into mesophytic or xerophytic vegetation communities, or into non-hydric soils, or into lands not flooded periodically. The lower limit, effectively the limit of aquatic plant growth, is usually considered to be a water depth of 2 meters (Messman et al., 1977).

Because wetness is part of the definition of wetlands and is essential to their maintenance, wetlands should be perceived as a sequence of specific environmental types existing along a water gradient. Using vegetation to reflect these environmental types, Figure 7 illustrates the continuum of wetland types along this gradient from a well-drained upland to open, deep water.

Note that two wetland classifications are employed in Figure 7. The new national wetlands classification system, as described in detail by Cowardin et al. (1976) is currently being widely publicized by the Office of Biological Services, U.S. Fish and Wildlife Service. The national inventory of wetlands, scheduled for completion in 1979 by the Fish and Wildlife Service, will employ the new wetlands classification. However, many users, particularly game managers and field biologists, have been accustomed to using Circular 39 (Shaw and Fredine, 1956) to identify wetland types. Moreover, many states (e.g., Michigan) utilize state-wide land cover/land use classifications which incorporate land use concepts in addition to cover types (Michigan Land Use Classification and Referencing Committee, 1976).

Perhaps the best descriptive publication concerning the vegetation of the glaciated Midwest was provided by Golet and Larsen (1974). In addition to a discussion of species composition, water depth, and substrate type associations, black and white photographs of deep marshes, shallow marshes, seasonally flooded flats, meadows, shrub swamps, and wooded swamps were presented. Kuchler's (1964) map of potential natural vegetation provided a regional view of the distribution of wetland plant communities in the United States. Important source materials on inland wetlands, by state or region, are:

Indiana	Deam (1940)
Michigan	Voss (1972)
Minnesota	Cowardin and Johnson (1973)
Missouri	Steyermark (1963)
Ohio	Braun (1967)
Prairie Potholes	Stewart & Kantrud (1972)
Wisconsin	Curtis (1959)

CONTINUUM OF WETLAND TYPES

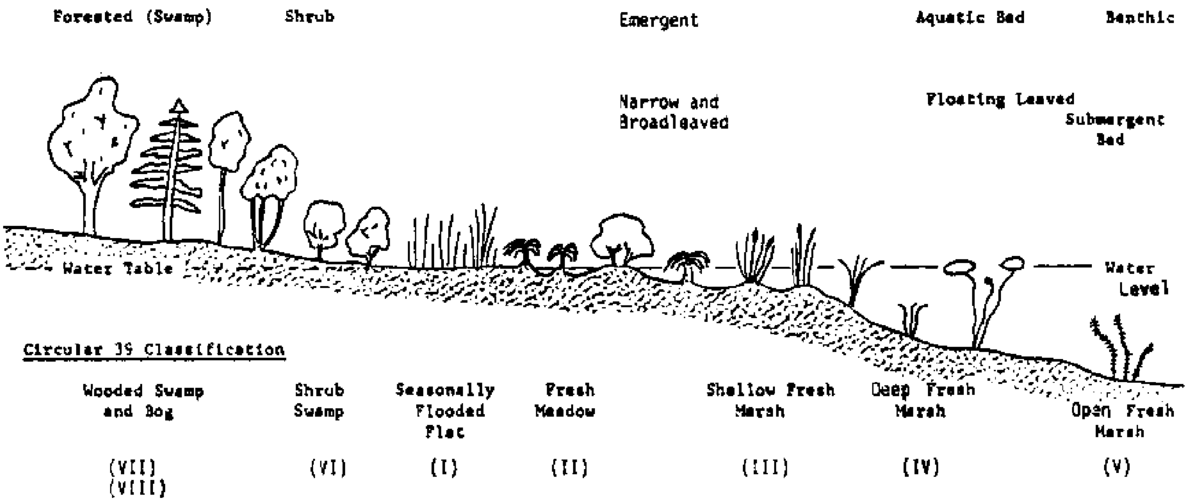


Figure 7. Diagram of Wetland Types Along a Continuum from the Upland Environment to Deep Water. Vegetation not to Scale. (Cowardin et al., 1976)

For introductory purposes, a list of common wetland plant species, by wetland type, is presented in Table 3. In a recent report, G. Wilhelm (1977) provided a comprehensive list of wetland plant species. The untrained plant taxonomist may discover that the photographic cover key by the U.S. Army Corps of Engineers (1977) is very useful to identify common species. Other popular pictorial keys have also been prepared by Hotchkiss (1970, 1967, and 1965). Important taxonomic manuals include Gleason (1952) and Fasset (1957).

Importance of Coastal Wetlands

The coastal wetlands of the Great Lakes differ in several ways from inland wetlands. The coastal wetlands are subject to temporary short-term water level changes. Seiches affect the wetlands adjacent to shorelines and commonly occur in the coastal zones in Lake Erie, Lake St. Clair, and Green Bay. Long-term cyclic water level changes, related to water budgets of the lake basins, also affect the coastal wetlands. Such fluctuations, occurring over a period of approximately seven to ten years, may cause vegetation dieback, erosion of the wetlands, or lateral displacements of the vegetative zones of wetlands. Many coastal wetlands, such as those in Tuscola County, Michigan (along Saginaw Bay) and Oconto County, Wisconsin (along Green Bay), are exposed to relatively high wave energy.

Coastal wetlands along the Great Lakes do not appear to exhibit the aging process associated with inland freshwater wetlands. Because of the fluctuating water levels of the Great Lakes, constant rejuvenation of wetland communities occurs. As a consequence, diagrams in textbooks illustrating the gradual senescence of freshwater wetlands are more applicable to inland wetlands of the glaciated Midwest than to the Great Lakes coastal wetlands. As outlined by Moore and Bellamy (1974), many inland freshwater wetlands undergo senescence and terrestrialization as a result of the formation of secondary and tertiary peat deposits. Peat mining, an economic activity in which Michigan leads in annual production, is centered primarily in senescent, inland wetlands.

Coastal wetlands often display a diversity of landforms not normally encountered in other wetland environments. Owing to changes in the water levels of the Great Lakes since the retreat of the Pleistocene ice sheets, landforms such as coastal barriers, deltas, and natural levees have been deposited, and represent the geomorphological heritage of the Great Lakes wetlands. The fluctuation of water levels in the Great Lakes is an important variable in determining many of the distinguishing characteristics and diversity of coastal wetlands, as well as the landforms the wetlands occupy.

Wetland Alteration and Destruction

Within the Great Lakes Basin, increased concern for wetland preservation may be related to wetland alterations and losses. For example, it has been estimated that Wisconsin had approximately ten million acres of wetlands prior to the heavy influx of European immigrants. Today this resource has dwindled to about 2.5 million acres (Wisconsin Department of Natural Resources, 1976). In

Table 3

Common Wetland Plant Species, by Wetland Type, in the Glaciated Midwest

Forested Wetland	
Red Ash	*Fraxinus pennsylvanica*
Tamarack	*Larix laricina*
Trembling Aspen	*Populus tremuloides*
Shrub Wetland	
Black Willow	*Salix nigra*
Red Osler Dogwood	*Cornus stolonifera*
Speckled Alder	*Alnus rugosa*
Meadow Wetland	
Bluejoint Grass	*Calamagrostis canadensis*
Reed Canary Grass	*Phalaris arundinacea*
Sedges	*Carex stricta* and others
Swamp Loosestrife	*Decodon verticillatus*
Broadleaved Emergents	
Arrowhead	*Sagittaria latifolla*
Pickerel Weed	*Pontederia cordata*
Smartweed	*Polgonum* spp.
Narrowleaved Emergents	
Bulrushes	*Scirpus acutus*, *S. americanus*, *S. validus*
Bur-reed	*Spargangium* spp.
Cattails	*Typha glauca* and *T. angustifolia*
Floating Leaved Aquatics	
Duckweed	*Lemna minor*
Floating Pondweed	*Potamogeton natans*
White Water Lily	*Nymphaea odorata*
Submersed Aquatics	
Muskgrass	*Chara* spp.
Sago Pondweed	*Potamogeton pectinatus*
Water Milfoil	*Myriophyllum* spp.
Wild Celery	*Vallisneria americana*

Michigan, similar historical losses have taken place. Originally, the state contained about 11.2 million acres of wetlands. Today approximately 3.2 million acres of wetlands remain, of which 105,855 acres (3.3 percent) occupy the coastal zone (Jaworski and Raphael, 1978).

In the 1850's the Swamp Acts were enacted for the general purpose of eliminating wetlands. Marshes and swamps were to be drained and diked to provide flood protection for adjacent communities and to reduce mosquito breeding habitat (Reitze, 1974). Moreover, the low, flat wetlands, with their generally fertile organic soils, encouraged cultivation, especially during periods of low water. As rural migration into the Great Lakes Basin increased in the 19th century, increasing numbers of wetlands were drained and cleared for agriculture. The wet prairie zone along Lake Erie from Port Clinton to Detroit was permanently lost, according to Bednarik (1975), while Langlois (1954) estimated that 1,800 miles of ditches had been dug in northern Ohio by 1950 to drain most of what had been known as the Black Swamp.

A substantial amount of alteration and loss of coastal wetlands can be directly attributed to the impact of human activity, as in the drainage schemes noted above. However, losses may also be related to such natural events and processes as storm waves, high water levels, or isostatic instability of the coastal zone. Whether changes are induced by human or natural factors, a common element of change is a readjustment of wetland hydrology. In a diked wetland, for example, hydrologic regimes are controlled in order to manage the vegetation. It is quite likely that if a particular wetland were not diked, the open hydrologic system would produce a vegetational cover very different from that of the managed system. Furthermore, the vegetation of the open system would be continually altered with changing lake levels.

Another factor which may cause loss or alteration of wetland vegetation is the sediment supply. This factor is perhaps more critical in coastal than in interior wetlands. Many coastal wetlands in the Great Lakes Basin occur in deltas (e.g., the St. Clair delta) or behind protective sand barriers; classic examples of the latter occur in eastern Lake Ontario and western Lake Erie. As long as these depositional features are nourished with sediments and other chemical and biological factors remain constant, the barrier and the wetlands will be maintained.

Specific causes of wetland alteration are many and varied. Perhaps the most evident are related to private and public dredging activities. To maintain harbors to authorized depths, federal agencies have commonly dredged harbors and in many cases filled adjacent wetlands with dredge spoils. Similar activities have also been undertaken by power companies and other private, industrial and commercial contractors.

Another cause of wetland alteration is the rechannelization of rivers. Bosley (1976) traced the historical changes in the Oconto River delta in Wisconsin. Originally, the coastal wetlands of the delta consisted of meandering rivers behind a coastal barrier. In the early 1900's the river was channelized and groins were constructed to protect the harbor entrance. As a result of littoral current patterns, erosion of the barrier and a loss of wetlands have occurred immediately south of the river. Thus, both modifications of hydrology and changes in sediment distribution have led to wetland losses at Oconto. Channelization also increases river flow, which in turn appears to increase turbidity in the immediate nearshore zone. This turbidity alters or degrades nearshore floral and faunal communities, biological diversity, and associated economic values and aesthetic appeal.

Coastal wetlands are often affected by transportation corridors, including pipelines, roads, and railroads. Many of the coastal wetlands along the eastern shore of Lake Michigan are crossed by roads and railroads which serve as barriers prohibiting complete communication between the wetlands and Lake Michigan. Residential developers have frequently contributed to the dissection of wetlands by developing housing and canal communities.

Other wetlands appear to have been affected by subsidence of the land. The coastal zone of western Lake Erie (Forsythe, 1975) is characterized by drowned river valleys, and some investigators have suggested that a relative rise in the level of Lake Erie has drowned or eroded wetlands in the western basin. These isostatic flexures of the lake basin itself may justify the diking of remaining wetlands; an action which occurs in coastal western Lake Erie.

Additional wetlands have been lost as a result of coastal erosion. For example at the mouth of the Huron River in southeastern Michigan, approximately 900 acres of wetlands were lost to Lake Erie through destruction of the coastal barrier lakeward of Pointe Mouillee between 1940 and 1972 (Sellman et al., 1974). Increased storm activity, especially during higher water levels, may account for destruction of the barrier. An alternative explanation, which is more speculative, is that dams constructed on the Huron River may have deprived the system of its sediment supply, thus leading to shoreline erosion.

Figure 8 depicts historical changes in land use at Monroe, Michigan. A pattern common to many wetlands in the Great Lakes Basin is seen here (i.e., development beginning on the margins of the wetland and proceeding toward the center). At Monroe this is most evident north of the Raisin River. In 1915, agricultural activity occupied the area west of the marsh. By 1975, development had taken place on the coastal barrier and had spread northward from the Raisin River, fragmenting and isolating smaller parcels of marsh. Identifiable causes of wetland alteration over the 59-year period include river channelization, private development, and public filling. At Sterling State Park the barrier was modified for recreational activities which are largely oriented toward Lake Erie, rather than toward the wetlands to the west. According to Hanink (1979) coastal Monroe County lost approximately 7,000 acres of wetlands between 1912 and 1975. In addition to actual loss of wetland acreage, the quality of remaining wetlands has been seriously degraded.

Table 4 summarizes wetland losses in selected areas. Included are wetlands in urban districts (e.g.: Lake St. Clair), agricultural areas (e.g.: Saginaw Bay), and more isolated regions (e.g.: Les Cheneaux Islands, Lake Huron).

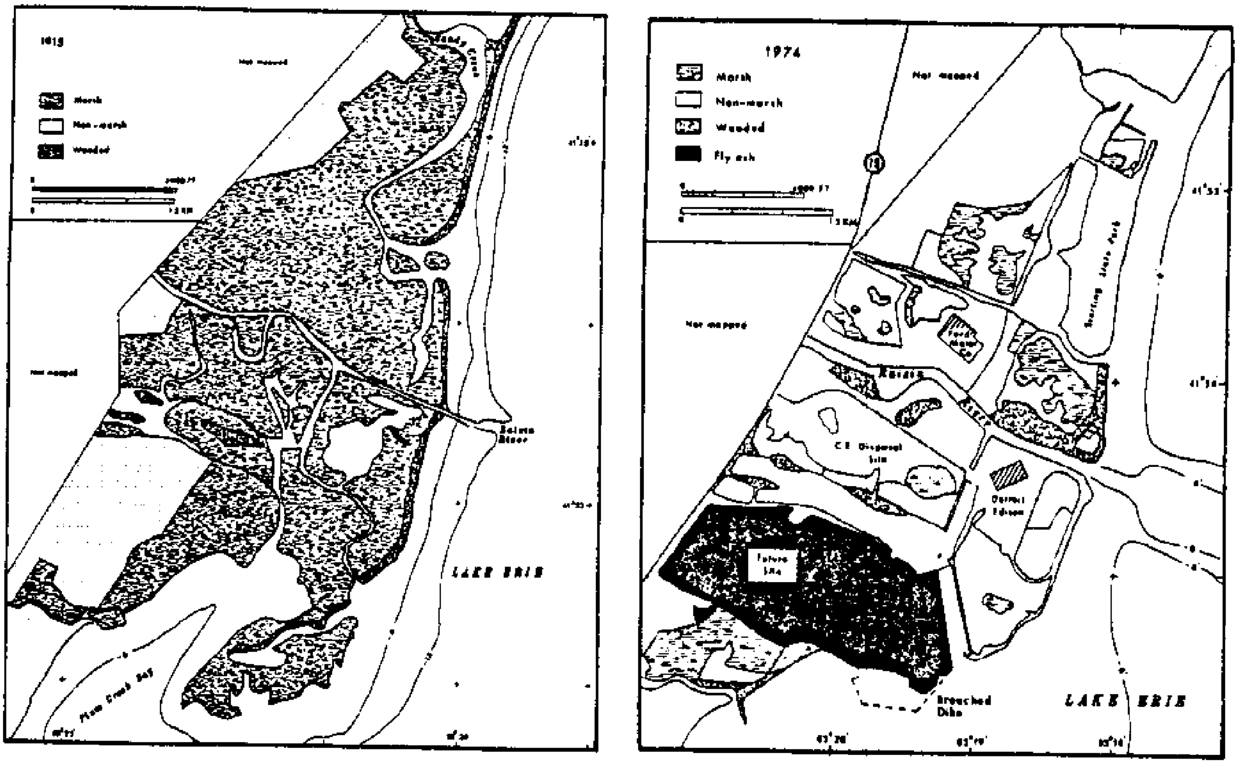


Figure 8. Alteration and Destruction of the Coastal Wetlands at Monroe, Michigan Between 1915 and 1974 (Jaworski and Raphael, 1976)

Table 4

Probable Causes of Coastal Wetland Losses in Selected Great Lakes Areas[a]

Wetlands	Acres Lost	Probable Causes
Lake Erie and Detroit River	6,240	Draining, Commercial/ Residential Growth, Erosion, Flooding.
Lake St. Clair	12,999	Draining, Local Commercial/ Urban Expansion, Coastal Flooding.
Saginaw Bay	19,620	Draining, Coastal Erosion, Local Commerical/Residential Growth.
Bay de Noc	1,423	Coastal Flooding, Local Draining, Local Urban Expansion.
Les Cheneaux Islands	1,278	Erosion, Local Draining.
TOTAL:	41,550	

[a] Jaworski and Raphael (1978)

A common pattern with regard to wetland loss begins with draining for agricultural use. Agricultural land is then overtaken by urban, residential, or industrial users. Figure 9 documents a loss of approximately 21 percent of the wetland habitat in Maumee Bay from 1877 to 1940. The pattern clearly suggests that agricultural, woodland, and wetland losses are inversely related to urban and industrial expansion. Under such circumstances the impact is irreversible and losses are permanent.

Future coastal wetland losses are difficult to project because of a changing public perspective on wetlands. In recent years the public and their legislators have recognized that wetlands have intrinsic values and that their preservation ought to be encouraged. Recent federal legislation (P.L. 92-500 Sec. 404) and an executive directive (Executive Order 11990) discouraged indiscriminate wetland destruction. On state levels, and to some degree county levels, wetland protection bills and ordinances are being designed and discussed (e.g., Michigan's pending Wetland Protection Bill).

Table 5 summarizes shoreland use in 1970 and projected use to the year 2020 for the U.S. Great Lakes shoreline.

Table 5

Existing and Projected Great Lakes Shoreland Use in Linear Miles[1,2]

Use	1970	1980	2000	2020
Industrial/Commercial	231	258	290	321
Residential	1,246	1,862	1,440	1,538
Public Park/Recreation	351	358	391	404
Fish and Wildlife	57	55	55	55
Agriculture/Forest/ Undeveloped	1,801	1,608	1,425	1,283

[1] Modified after Great Lakes Basin Commission (1975)
[2] Includes only U.S. shore. Lake St. Clair, St. Clair River, and Detroit River data are included only in the 1970 column.

If future coastal land use trends follow historical patterns, wetland losses can be anticipated. Industrial and residential growth is expected to increase along the Great Lakes' shorelines over the next 40 years, whereas agricultural, forest, and undeveloped uses are expected to decline. The latter category probably includes wetlands which will decrease as industrial and residential growth continues. Possible mitigating factors include a public awareness of wetland values and encouragement of wetland preservation, as well as future energy restrictions, which may retard urban and industrial growth. Based upon recent legislative activity, there is cause to anticipate increased preservation efforts.

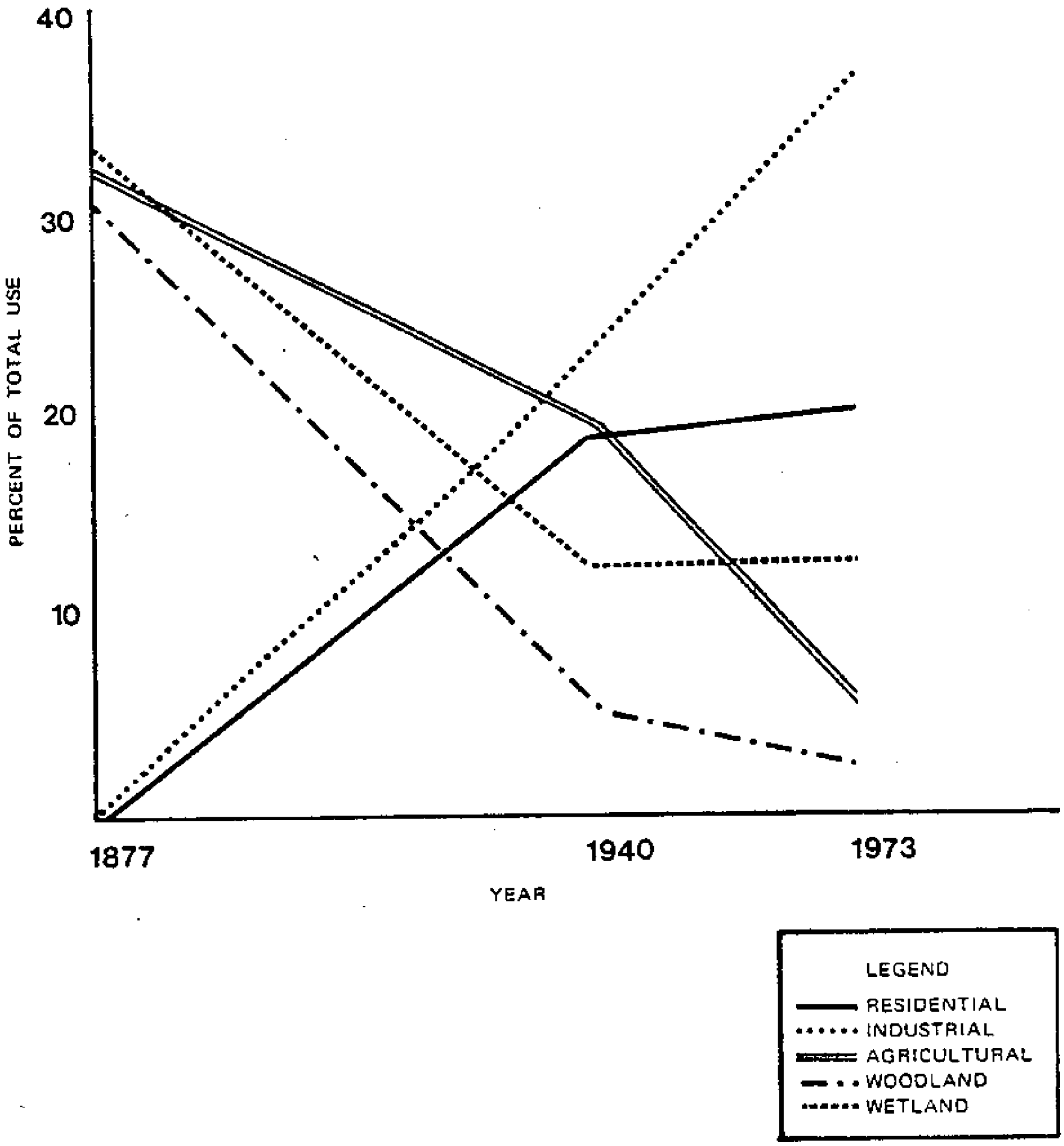


Figure 9. Maumee Bay Shoreline Land Use Changes[a]

[a] Great Lakes Basin Commission, 1977

WETLANDS AS HABITATS

Food Chain Production, Ecosystem Energy Relationships

The ultimate source of energy for all natural ecosystems is the sun. Only a small fraction of the total available energy from the sun enters the food chain of living organisms. Even when light falls where vegetation is abundant, as in a marsh, only 1 or 2 percent of that light is used in photosynthesis. Yet this fraction, small as it is, may result in the production - from carbon, oxygen, water, and minerals - of several thousand grams (dry weight) of organic matter per year in a single square meter of marshland (Russell-Hunter, 1970).

The passage of this energy from one organism to another takes place along a particular food chain, which is made up of trophic levels. In most communities, food chains form complex food webs involving many different types of organisms, especially on the lower trophic levels.

The first step in the food chain is always a primary producer, which in freshwater aquatic ecosystems may be one of three basic tyes: 1) macrophytes (marsh grasses, macroalgae, and terrestrial plants), 2) benthic microalgae, and 3) phytoplankton. Odum et al. (1973) cite several studies indicating that the macrophytes are the most important primary producers and the phytoplankton the least important. These photosynthetic organisms use light energy to make carbohydrates and other compounds, which then become sources of chemical energy. Producers far outweigh consumers: 99 percent of all organic matter in the biosphere is made up of plants, including algae. All other organisms (i.e., heterotrophs) combined account for only one percent.

Food chain production is measured by the amount of energy (in calories) stored in chemical compounds or by the increase in biomass in a particular length of time. Net productivity represents the amount of light energy converted to organic matter less the amount of glucose and other compounds used in respiration.

Energy enters the animal world largely through the activities of the herbivores: animals that eat plants and algae. Of the organic material consumed by herbivores, much is excreted undigested. Some of the chemical energy is transformed to other types of energy -heat or motion - or used in the digestive process itself. A fraction of the material is converted to animal biomass.

The next level in the food chain, the secondary consumer level, involves carnivores. Only a small part of the organic substance present in the body of the herbivore becomes incorporated into the body of the carnivore. Some chains have third and fourth consumer levels, but five links are usually the limit, largely because of the waste involved in the transfer of energy from one trophic level to another.

The decomposers, which are primarily bacteria and fungi, break down dead and discarded organic matter, completing the oxidation of the energy-rich compounds formed by photosynthesis. As a result of the metabolic work of the decomposers, waste products - detritus, feces, dead plants, and animals -are broken down to inorganic substances that are returned to the soil or water to enter once more into the tissues of plants and begin the cycle again.

The flow of energy through a food chain is often represented by a graph of quantitative relationships among the various trophic levels. Because large amounts of energy and biomass are dissipated at every trophic level, these diagrams nearly always take the form of pyramids (Figure 10). Such a pyramid may be: (1) a pyramid of numbers, showing the numbers of individual organisms at each level; (2) a pyramid of biomass, based either on the total dry weight of the organisms at each level or on the number of calories at each level; or (3) a pyramid of energy flow, showing the productivity of the different trophic levels. The shape of any particular pyramid tells a great deal about the ecosystem energy relationship it represents. It must be noted that pyramids of numbers and pyramids of biomass indicate only the quantity of organic material present at any one time; they do not give the total amount of material produced or, as do pyramids of energy, the rate at which it is produced.

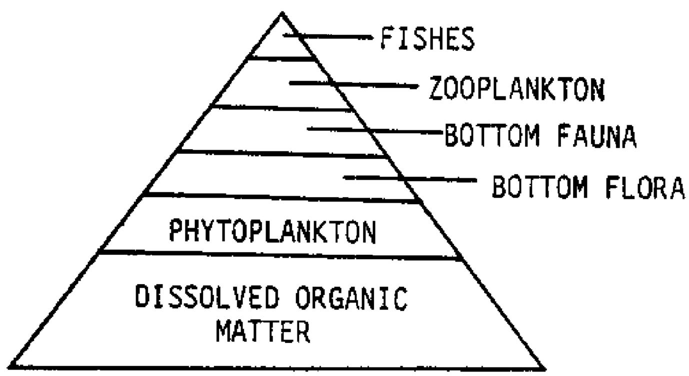


Figure 10. Pyramid of aquatic life (Redrawn from Juday, 1943)

The studies which first introduced the concepts of trophic levels were, to a large extent, worked out in freshwater wetlands. Among these should certainly be mentioned Lindeman's (1942) classic analysis of the events within a food complex in terms of energy, and Juday's (1943) "pyramid of aquatic life" which determined the various components of the aquatic population in Weber Lake, Wisconsin, as they existed in midsummer. For this particular lake, Juday found that the dissolved organic matter composed about 60 percent of the total pyramid; the fish, only one-half of one percent; and the other animals, slightly less than 5 percent of the total pyramid.

In freshwater systems there are often 3 major sources of energy for aquatic consumers: (1) marsh detritus, (2) phytoplankton production, and (3) detritus from terrestrial sources brought in by drainage. However, the contribution of marsh detritus to freshwater ecosystems has not been determined (Keefe, 1972).

Although much research remains to be done on food chain production and ecosystem energy relationships, particularly of freshwater wetlands, there are biological conclusions which seem to have a certain validity. For example, (1) food cycles rarely have more than five trophic levels; (2) the greater the separation of an organism from the basic source of energy (solar radiation), the less the chance that it will depend solely upon the preceding trophic level for energy; (3) at successively higher levels in the food cycle, consumers seem to be progressively more efficient in the utilization of food supply; and (4) in lake succession, productivity and photosynthetic efficiency increase from oligotrophy to a prolonged eutrophy and then decline in lake senescence (Welch, 1952). Clark (1974) noted that in terms of primary production, estuarine water bodies may produce 20 times as much as the deep sea and 10 times as much as either nearshore waters or deep lakes.

The majority of current research into food chain production and ecosystem energy relationships in wetlands centers around marine coastal marshes, estuaries, and mangrove and cypress swamps. Although these studies deal with the marine environment, they contain concepts and factual materials which are important to, and in many cases directly applicable to, freshwater wetlands systems. Among the more recent and useful works to investigators in freshwater wetlands are Chabreck (1972), Clark (1974, 1977), Odum (1961), Odum et al. (1974), and Waits (1967), which deal with aspects of coastal ecosystems in general; Grosselink et al. (1973), Keefe and Boynton (1973), Keefe (1972), Kirby (1972) and McIntire and Dunstan (1975), which deal with coastal salt marshes; Lauff (1967) and Odum (1970), which deal exclusively with estuaries; and Kuenzler (1974), Lugo and Snedacker (1974), Odum et al. (1975) and Snedaker and Lugo (1973), which deal with cypress and mangrove swamps.

Considerably less research has been done on food chain production and ecosystem energy relationships in freshwater wetlands than in marine systems. However, some recent and important studies have been conducted on inland marshes and lake systems (e.g.: Jervis, 1969; and Day et al., 1975).

Fish Production and Spawning

The fisheries productivity of marine wetlands (i.e., estuaries and salt-water marshes) are widely recognized, particularly with regard to spotted sea trout, croakers, crayfish, shrimp, oysters, and blue crab (Messman et al., 1977). In contrast, inland wetlands are much less well documented, but may also be relatively productive, with the possible exception of shellfish. Wetlands are productive partly because they function as sinks for nutrients and organic detritus. Like marine estuaries, inland wetlands receive nutrients and organic material from land drainage. Through the stimulation of primary producers and the activity of herbivores, as well as that of shredders and decomposers, these inputs are transformed into living biomass which, in turn, supports the food web of the wetland ecosystem.

In general, there is a paucity of data regarding the abundance and density of the fish species inhabiting inland wetlands. Important published materials include general sources such as Odum (1971) and Perkins (1974). Environmental impact statements and ecological surveys provide some data concerning local wetland areas. For example, the fisheries of southwestern Lake Erie in the vicinity of Navarre Marsh, Ohio, were studied as a result of the construction of the Davis-Besse Nuclear Power Plant (Reutter and Herdendorf, 1975). Although some regional studies were sponsored by the Tennessee Valley Authority (TVA) and by other agencies during the preconstruction phase of various public water projects, an overview of the productivity of inland wetlands has yet to be published.

A technical source of data on fish abundance and density over a wide area is contained in fish entrainment investigations of power plant intakes and other cooling water influents. These fish entrainment studies have enabled the Fisheries Division, Michigan Department of Natural Resources, to estimate fingerling production per wetland acre for walleye, northern pike, and other fish species in selected coastal wetlands of Michigan (Bill McClay, personal communication, Fisheries Division, Michigan Department of Natural Resources, Lansing). Using the Thompson-Bell method of projecting the annual recruitment of fingerling fish to various year classes (Ricker, 1975), it is possible to estimate the annual per acre production of various important species.

Most of the fish fauna inhabiting inland wetlands appears to consist of non-salmonid, warmwater or coolwater species such as carp, northern pike, bullheads, and buffalos. Because of the predominance of clayey and organic-rich substrates in wetlands, there is a prevalence of bottom feeders (e.g., bullheads, channel catfish, carp, and buffalo). Greenwood (1971) suggested that often as much as 90 percent of the standing fish crop of inland wetlands, which commonly ranges from between 250 and 500 pounds per acre, consists of forage species such as carp and freshwater drum. Large predator fish, such as northern pike, rely on visual contact for locating their prey. Minnows, such as emerald shiners, prefer clear waters with sandy bottoms, whereas some wetland species, including carp, bullheads, and buffalo are tolerant of turbidity and siltation (Pinsak and Meyer, 1976).

Wetlands are important to fish production because they provide spawning and nursery habitat for wetland-dependent species, cover for juvenile and forage fish, and feeding areas for predator fish. Horrall (1977) stated that the spawning grounds of important fish species occupying the Great Lakes have been poorly documented. Jaworski and Raphael (1977) surveyed the values of Michigan's coastal wetlands as fish spawning sites, and the Ohio Department of Natural Resources has prepared a report (Hartley and Van Vooren, 1977) on spawning areas in relation to future dredged spoil operations. Three general sources of material on fish spawning in inland wetlands are Pflieger (1975), Eddy and Underhill (1974), and Trautman (1957).

Fish species that commonly spawn in the inland wetlands of the glaciated Midwest are listed in Table 6. Northern pike usually broadcast their eggs in shallow sedge marshes or in flooded fields (Priegel and Krohn, 1975; Williams and Jacob, 1971). Carp also broadcast their eggs over vegetation and debris in warm, shallow embayments and marshes (Trautman, 1957). Because many fish species spawn only on specific substrate types, modification of wetlands through direct habitat loss, addition of suspended solids, and alteration of flow regime may result in the elimination or degradation of existing wetland spawning environments (Darnell, 1976).

Table 6

Fish Species Which Commonly Spawn in Wetlands of the Glaciated Midwest[a]

Northern Pike	Buffalo
Muskellunge	Bullheads
Yellow Perch	Carp
Smallmouth Bass	Spottail Shiner
Largemouth Bass	Blacknose Shiner
Bluegill	Goldenshiner

[a] Pflieger, 1975; Trautman, 1957.

The introduction of externally-derived detritus, including particulate organic matter, along with algae, duckweeds, and aquatic plants such as water hyacinth provide food for herbivorous fish and other forage species. In turn, the abundance of these forage fish, as well as large numbers of juvenile fish resulting from spawning activities cited above, attract predator fish to wetlands for feeding. Predator fish, such as northern pike, may feed at dusk and at dawn in shallow waters, but usually return to somewhat cooler or deeper waters for resting during the day. Thus, links between open waters and the shallow wetlands are essential. Spring floods and other high-water periods provide access to the wetlands for feeding and spawning fish. In contrast, during periods of low or obstructed flow, links to adjacent wetlands are broken and the isolated wetland populations may suffer from higher water temperatures, reduced dissolved oxygen, and a concentration of incompatible chemical effluents.

Waterfowl Wintering and Migration

Bellrose (1968) provides an excellent reference on the migration corridors which comprise the Central, Mississippi, and Atlantic Flyways. As illustrated by Figure 11, a flyway is a complex of corridors. Each corridor, in turn, is a web of routes as opposed to a single, narrow band rigidly followed by the waterfowl. In general, fall movements of dabbling ducks (e.g., common mallard (Anas platyrhynchos) and blue-winged teal, are from the northwest, across the Great Plains, to the Gulf Coast of Texas and Louisiana. Diving ducks and redheads exhibit a more east-west migration pattern but may winter in either the Gulf or Atlantic coasts. Pirnie (1935) and Miller (1943) have documented the arrival and departure of main waterfowl flights in Michigan for both the fall and spring migrations.

As waterfowl migrate between breeding grounds and wintering areas, they stop to rest and feed in wetlands referred to as concentration areas. Concentration areas are characterized by an abundance of waterfowl foods as well as by low wave energy and low human disturbance (Jaworski and Raphael, 1977). Canvasbacks, redheads, American widgeon, ring-necked ducks, and coots feed extensively on submersed plants, whereas shovellers, oldsquaw, goldeneye, and

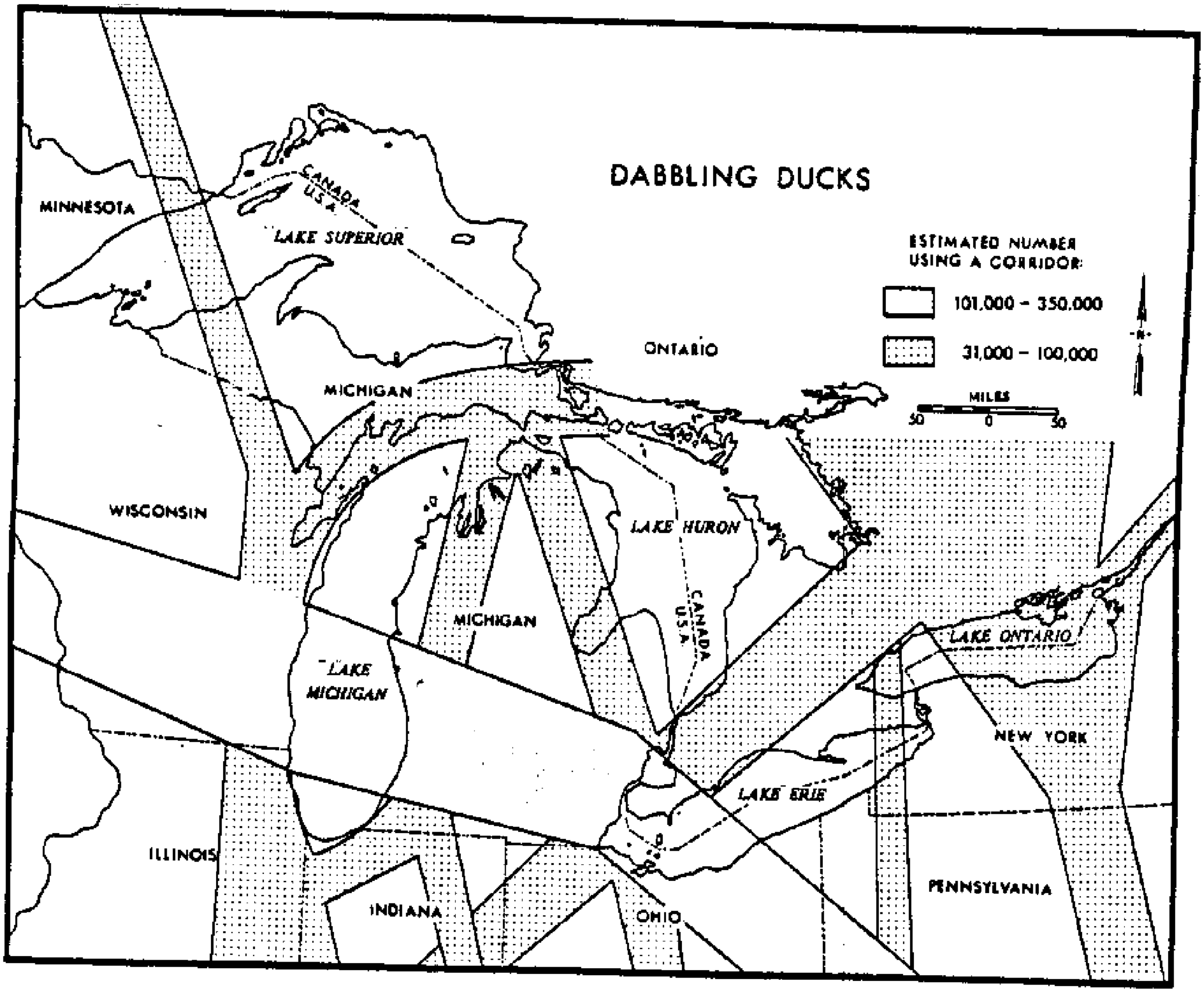


Figure 11. Migration Corridors of Dabbling Ducks in the Great Lakes region (after Bellrose, 1968)

mergansers appear to prefer crayfish, small fish, and other animal foods (Pirnle, 1935). Black ducks, common mallard, pintail, teal, scaup, and bufflehead, select from both plant and animal foods. Canada geese and common mallard also feed heavily on waste grains in agricultural fields (Jaworski and Raphael, 1977). Food availability may be more important than food preference, especially during the spring migration when food supplies are less abundant.

Concentration areas should be mapped and the waterfowl foods inventoried so that waterfowl migration may be managed more effectively. Hunt and Mickelson (1976) suggested that food availability in the wetlands of concentration areas was reduced by extreme high and low water levels, heavy siltation, turbidity, heavy hunting pressure, and other disturbances. Bednarik et al. (1975) reported that preferred natural foods of diving ducks, such as wild celery, appeared to be more adversely affected by turbidity and siltation than foods of dabbling ducks or geese.

The wintering areas for ducks, geese, swans, coots, and other waterfowl have been mapped in detail by Bellrose (1976) and Johnsgaard (1975). The Rockefeller Refuge in southwest Louisiana is a well known wintering area for migratory waterfowl. Like concentration areas, quality wintering habitat must provide abundant food and protection from waves and human disturbance. Over the years, certain waterfowl (e.g., Canada geese) have modified their wintering activity by stopping at sites somewhat north of their former winter areas. In general, most state conservation agencies do not encourage the creation of resident wintering flock because of the problem of waterfowl starvation during severe winters (Hunt, 1957). Waterfowl that reach the spring breeding grounds in good condition tend to exhibit greater nesting success than those which are undernourished.

Nesting of Migratory Waterfowl

The dependency of waterfowl on wetlands for breeding purposes is probably more crucial to their survival than their use of wetlands for wintering, resting, and feeding areas during migration, since the former involves the production of young. There are 46 species of ducks, geese, brant, and swans native to North America, 39 of which are normally hunted. Since 1934, using funds derived primarily from the sale of migratory bird hunting stamps, the U.S. Fish and Wildlife Service has purchased approximately 5.4 million acres of wetlands in the United States for waterfowl breeding and other purposes (U.S. Department of Agriculture, 1977).

Two recently published texts regarding waterfowl nesting are Bellrose (1976) and Johnsgaard (1975). These publications contain detailed maps of breeding grounds by species, as well as population estimates, description of migration corridors and general ecological data. General maps of waterfowl nesting in the Great Lakes region are contained in the Great Lakes Basin Commission Report (1975). Waterfowl nesting in the coastal wetlands of Michigan has been reviewed by Jaworski and Raphael (1977).

Generally, many North American waterfowl species nest in Canada or in the Dakotas and Alaska, and winter in the southern portion of the United States (U.S. Department of Agriculture, 1977). The prime breeding grounds extend from

South Dakota northward through the Prairie Provinces of Canada to the Mackenzie River delta and adjacent Alaska (Johnsgaard, 1975). However, significant numbers of waterfowl breed elsewhere as well.

The value of the various wetland types to waterfowl breeding, as reviewed by Shaw and Fredine (1956) are listed below:

Type 1 - Seasonally Flooded Flats.	Provides additional area for territories of breeders.
Type 2 - Inland Fresh Meadows.	Some nesting of blue-winged teal; not very significant.
Type 3 - Inland Shallow Fresh Marsh.	Used for nesting and feeding. Prime breeding environment.
Type 4 - Inland Deep Fresh Marsh.	Best breeding habitat in USA for dabbling and pochard ducks. With Type 3, constitutes the principal type of production area.
Type 5 - Inland Open Fresh Water.	Breeding areas in late summer. Concentration areas during migration.
Type 6 - Shrub Swamp.	Light use for nesting and feeding. Black duck nesting.
Type 7 - Wooded Swamp.	Wood duck nesting habitat.
Type 8 - Bogs.	Has lowest value for waterfowl nesting of inland fresh types.

Based on the maps of breeding grounds contained in Johnsgaard (1975) and Bellrose (1976), the following generalized nesting areas of several important species are summarized below:

Common Mallard.	Broad, triangular-shaped area, from Pennsylvania to Colorado and Alaska.
Blue-winged Teal	Breeding area similar to Common Mallard.
Black Duck	Northeastern U.S. and eastern Canada, Including the James Bay region.
Wood Duck	Eastern half of U.S. from Louisiana to Minnesota to New York.
Ring-necked Duck	Broad belt from New Brunswick, across Great Lakes and adjacent Ontario, to northern Alberta.
Redhead	Primarily in Prairie Provinces of Canada and Dakotas, with outliers in southeastern Michigan, etc.

The publication by Shaw and Fredine (1956) represents the results of the wetlands inventory conducted by the U.S. Fish and Wildlife Service in 1955. Based on this inventory, a summarial report was prepared for each state, to include a report on wetlands of particular importance to waterfowl. With regard to Michigan, these reports are by Panzner (1955) and Miller (1958). Since the 1955 inventory, wetlands which serve as important waterfowl breeding grounds have been lost to competing land uses. For example, since 1964 approximately

350,000 acres of prime prairie pothole wetlands have been drained for agriculture (U.S. Department of Agriculture, 1977). At present, 27 percent of Michigan's coastal wetlands, which produce an estimated 0.31 ducks per acre annually, will be threatened by development from the private sector within the next five years (Jaworski and Raphael, 1977).

Other Wildlife

Primary emphasis in appraising values of wetlands is traditionally placed on waterfowl because of the great interest in the sport of wildfowling and because waterfowl populations are often more affected by wetland changes than are populations of other game species. However, many wetlands are recognized on the basis of their values as habitat for wildlife other than waterfowl.

Wetlands serve as general habitat for many aquatic, terrestrial and avian species in that they provide all the needs of a particular species for completion of its life cycle. Cattail marshes provide excellent food and building material for furbearers such as muskrats. Conversely, many species occupy multiple habitats, of which wetlands may function only as one; various animals, such as raccoons and deer, may use wetlands as feeding areas, resting areas, or shelter. The use of wetlands by game animals is often not so obvious. Many a hunter has stalked a white-tail deer for hours, only to have it seek the thick cover of an impenetrable cedar swamp. Woodcock hunters prefer alder swamps for their shooting, while pheasant hunters find good hunting along the wild, grassy cover of local marshes where fall and winter cover is available to the birds.

In the glaciated Midwest other common game and fur animals occupying wetlands include the rabbit, moose, mourning dove, snipe, grouse, and gray and fox squirrels. The value of marshes and swamps for such fur animals as muskrats, mink, and raccoons is well known because of the cash value of wild furs. According to Shaw and Fredine (1956), the pelt value of furbearers was 50 million dollars annually in the United States at that time. In the Midwest, high muskrat production occurs in Illinois, Ohio, Iowa, and Minnesota (Niering, 1966). In the 2000-acre Magee Marsh of northern Ohio, 40,000 muskrats were harvested in a single year (U.S. Department of Interior, 1967).

Raccoons and muskrats occupy wetlands at the headwaters and wetlands at the mouths of rivers, whereas the otter and beaver occupy intermediate areas. The beaver deserves special mention because of its beneficial influence on waterfowl, other wildlife, and water conservation. Beaver dams often impound water-deficient wetlands such as meadows, shrub swamps, and wood swamps, converting them into wetlands with shallow surface water of more value to waterfowl, especially black ducks and wood ducks.

A wide diversity of aquatic birds, passerines, shorebirds, and raptors are closely associated with wetlands. Many wetlands provide vital nesting sites, feeding areas, and migratory resting sites for such species as the osprey, eagle, rails, cranes, gulls, and terns. The Lake Erie marshes are known for large assemblages of shorebirds (Butsch, 1954). Shorelands such as Whitefish Point are important staging areas for birds of prey, including several threatened species such as the peregrine falcon, osprey, and double-crested cormorant (Kelley, 1972). With regard to birds which occupy the perimeter of wetlands, Welty (1975) notes that small marshes may be more important in terms of nest density than larger marshes because of the greater edge effect. The marsh itself is important as a supplier of amphibians, reptiles, and insects to the diet of the birds.

ECONOMIC VALUE OF WETLANDS

It is generally accepted that the Great Lakes coastal wetlands contribute to the "public good", particularly with regard to fish, wildlife, and recreational use. However, a lack of quantitative and site-specific data, as well as methodological limitations, render the task of establishing dollar values for specific wetland resources, or for wetland complexes as a whole, problematic.

Two approaches may be employed to determine the economic value of wetlands. One approach is to calculate the annual economic return as determined from participant expenditures related to hunting, sport fishing, and nonconsumptive recreation as well as from the dollar value of products (e.g., pelts, commercial fish, and waterfowl carcasses) harvested from a wetland (Jaworski and Raphael, 1978; Leitch and Scott, 1977). Using this approach, it has been determined that Michigan's 105,855 acres of coastal wetlands are worth $51.8 million, or approximately $490/wetland acre/year (Table 7).

Table 7

Average Annual Return from Michigan's Coastal Wetlands For Fish, Wildlife, and Recreation 1977[a]

Use/Activity	Economic Value
Sport Fishing	$286.00/wetland acre/year
Nonconsumptive Recreation	138.24
Waterfowl Hunting	31.23
Trapping of Furbearers	30.44
Commercial Fishing	3.78
TOTALS	$489.69/wetland acre/year

[a] Jaworski and Raphael (1978)

Because few economic value assessments of wetlands have been undertaken, it is difficult to compare the results in the table to those of other studies. Nonetheless, the estimate appears to be within the range of other research. Benson and Perry (1965) reported that an average acre of marsh in New York state has an annual net value of $20 per acre. However, if gross economic values are employed, as in the Table 7, an average annual value of $400 is obtained (as the net value was 0.05 of the gross). Moreover, if the 1965 value is adjusted for cost-of-living to 1977, then an average value of $780 per marsh acre is attained.

Another method is to evaluate the investment and operating cost of a replacement ecosystem. A natural wetland which is diked and managed for commercial fish production may be worth $331/acre/year, whereas a wetland constructed artificially for commercial fish production may be valued at $849 per acre/year (Tilton et al., in press). Since only northern pike production and its cost have been adequately researched in Great Lakes wetlands, this strategy has limited application to fish and wildlife production in the wetlands in general. As renewable resources of coastal wetlands become more scarce, it may be necessary to establish critical areas for each coastal wetland type and to attach a finite economic value to these areas (Tilton et al., in press).

Agricultural Values

Compared to inland wetlands, coastal wetlands of the Great Lakes do not support much agricultural activity. Very little economic return derives from forestry, peat extraction, crop cultivation (e.g., blueberries and cranberries), or wild rice gathering in coastal wetlands. Although lumber mills were historically located in river mouths (e.g., in the lower Betsie River, near Frankfort, Michigan), the adjacent wetlands, if present, generally did not supply much of the harvested timber or lumber. Cattle were once pastured in the coastal meadows and sedge marshes along western Lake Erie and Saginaw Bay, but today pasturing is less widespread and generally restricted to improved pastures. Some wild hay (probably sedge) used to be collected from coastal wetlands along the Wisconsin coast of Lake Michigan for use in packing iced beer for shipping from Milwaukee (Johnson and King, 1975).

However, agriculture has been encroaching upon the Great Lakes coastal wetlands. Aided by the Swamp Acts of the 1850's and 1860's, most of the 300,000-acre Black Swamp of western Lake Erie has been cleared, drained, and tiled for row crop agriculture (Kaatz, 1955). Most of the 30,000 acre remnant of the Black Swamp now consists of shallow- and deep-water marshes within private or public waterfowl shooting areas. Similarly, during the period from 1857 to 1973, approximately 20,000 acres, or 52 percent, of the coastal wetlands along Saginaw Bay were drained for agriculture (Jaworski and Raphael, 1978).

Agricultural encroachment on coastal wetlands may be limited by seiche activity, particularly along Lake Erie, and by long-term water level fluctuations which exhibit a general hydroperiod of 8 to 12 years. Because Great Lakes water levels fluctuate approximately 2 to 4 feet (0.6 to 1.2 m) above the historical mean levels (U.S. Department of Commerce, 1977), the landward limit of coastal wetlands, and hence the lakeward limit of agriculture, is generally delimited by the 5-foot (1.5 m) contour. Current policies of the Soil Conservation Service provide that wetland types 3, 4, 5, and perhaps 6 (see Shaw and Fredine, 1965 for wetland types) are not to be drained under federally-subsidized programs. In some states, notably Michigan, all land located lakeward of the ordinary high-water mark (OHM) is owned by the public, so most development, including agriculture, is excluded by a permit process.

Commercial and Sport Fishing

The economic value and total landings of commercial fish from Great Lakes wetlands appears to be very low. Based on wholesale prices paid to fishermen (approximately 22 cents per pound in 1977), Michigan's commercial fish landings generated a value of $3.78/wetland acre/year (Jaworski and Raphael, 1978). The landings, by fish species, which can be attributed to Michigan's coastal wetlands are indicated in Table 8. Although the wetland catch has not been separated from open water catch for the other Great Lakes states or in the province of Ontario, it is believed that the fish which are either caught in wetlands or which spawn there are primarily low value, warmwater species. The fishing for walleye and northern pike by the Walpole Indians in the St. Clair delta wetlands is an exception to this generalization.

Table 8

Commercial Fish Landings from Michigan's Coastal Wetlands by Species, in Saginaw Bay and Western Lake Erie, 1977[a]

Species	Pounds Landed Saginaw Bay	Pounds Landed W. Lake Erie	Total Value
Carp	626,398	422,204	$ 68,923
Channel Catfish	282,148	13,950	115,651
Yellow Perch	257,203	1,799	92,875
Black Crappie	85,451	0	56,354
Bullheads	37,354	3,221	4,853
Buffalo	16,468	33,965	10,078
Quillback	16,468	0	2,525
Freshwater Drum	15,937	2,218	1,846
White Bass	117	4,558	1,515
Bowfin	2,331	0	58
Suckers, Redhorses	0	1,964	49
Gizzard Shad	440	0	23
TOTALS	1,323,847	483,879	$354,750

[a] Jaworski and Raphael (1978)

There are several reasons why the Great Lakes coastal wetlands no longer support a significant commercial fishery. In general, the coastal wetlands are difficult to fish with modern gear, and most of the wetland-dependent fish species are low-value, warmwater species or have been designated as sport fish and are protected from commercial harvest. High-value fish (e.g., the lake whitefish) no longer spawn in coastal wetlands (Regier and Hartman, 1973). Destruction of wetlands along the Lake Erie coast of Ohio contributed to the decline of the lake sturgeon and the muskellunge, two species formerly of commercial importance in Lake Erie (Trautman, 1957). According to Trautman, those species which require clear and/or vegetated waters have been replaced by small species tolerant of more turbid waters.

In many coastal wetlands (e.g., along western Lake Erie, Saginaw Bay, and Green Bay) an important factor in the fishery decline is habitat deterioration. Excessive turbidity, substrate alteration (hence, loss of spawning habitat), and toxic substances may be significant factors in this decline (Stern and Stickle, 1978; Great Lakes Basin Commission, 1975). To mitigate the historical loss of suitable habitat, critical fish habitats should be preserved much in the same manner as waterfowl refuges and breeding areas were preserved. The state of Ohio has taken the initiative in this respect (Hartley and Van Vooren, 1977). However, with regard to Lake Erie the loss of wetlands, the introduction of new species, and the emphasis on salmonid fishing suggest that restoration of a commercial fishery in the coastal wetlands is unlikely (Regier and Hartman, 1973).

In contrast, sport fishing in wetlands exhibits a high economic value. Based on annual fisherman expenditures or angler day values (see U.S. Department of Interior, 1977), the value of Michigan's coastal wetlands with respect to sport fishing is $286/wetland acre/year (Jaworski and Raphael, 1978). Lake St. Clair exhibits the highest sport fishery value for Great Lakes coastal wetlands (Figure 12) because of its proximity to Detroit and high quality of angling for walleye, smallmouth bass, and yellow perch. Current estimates indicate that the St. Clair delta wetlands average 20 to 40 angler days/wetland acre/year.

Creel censuses indicate that yellow perch probably generate more angling demand along the Great Lakes shorelines than any other species (Jamsen, 1976). However, in degraded wetlands the catch may consist largely of bowfin, carp, or bullheads. Unless northern pike, largemouth bass, channel catfish, yellow perch, or other higher-value species are abundant, sport fishing in coastal wetlands may not continue to be attractive.

The demand for Great Lakes sport fishing in 1980, in United States waters only, has been projected at 29.8 million angler days (Table 9). Approximately 45.5 percent of the angling demand derives from Lake Erie and Lake St. Clair. Note that participant demand must be exported out of five Great Lakes subareas, including southwest Lake Michigan, southeast Lake Michigan, Saginaw Bay-southern Lake Huron, Detroit River-western Lake Erie, and southeast Lake Erie. In general, these five areas are characterized by urbanization and by severe loss of coastal wetlands. Much of the unsatisifed participant demand is being redirected to quality inland lakes or to remote coastal reaches of the Great Lakes (Great Lakes Basin Commission, 1975).

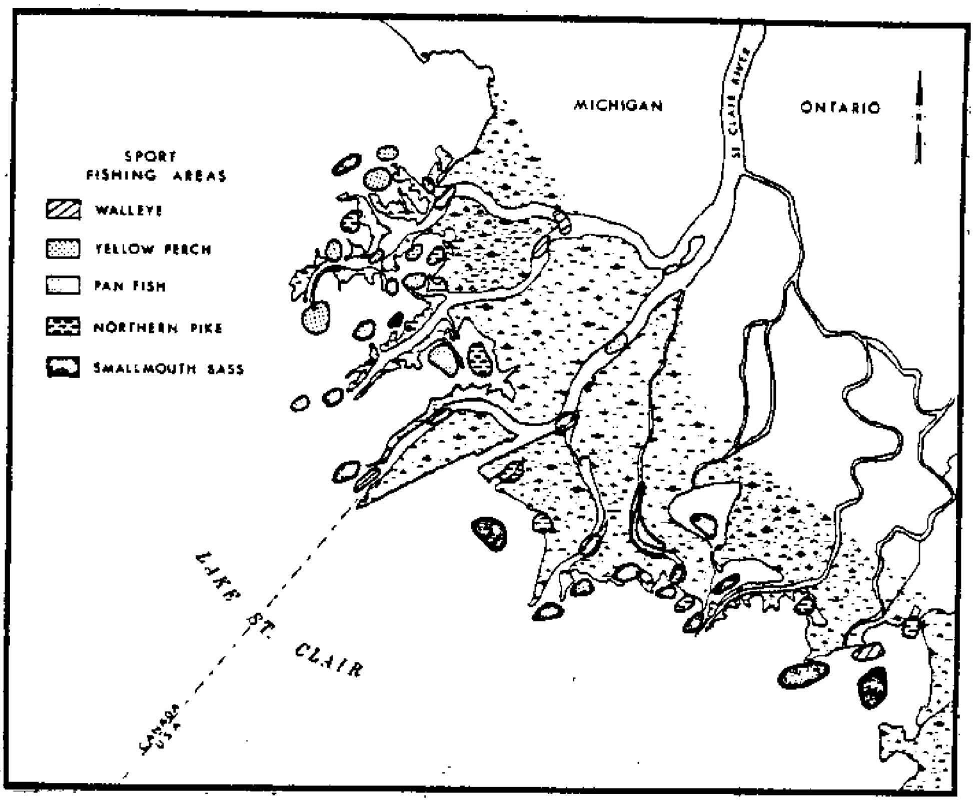


Figure 12. Location of Sport Fishing Areas, by Species, In and Adjacent to the St. Clair Delta Wetlands, Lake St. Clair (Lake St. Clair Advisory Committee, 1975)

Table 9

Great Lakes Sport Fishing Demand by Lake Subarea, 1980, United States Waters Only[a]

Lake	Subarea	Total Demand For Subarea	Demand Transferred Out of Subarea
SUPERIOR	1.1	137,000	0
	1.2	600,000	0
MICHIGAN	2.1	1,030,000	0
	2.2	3,419,000	869,000
	2.3	1,600,000	300,000
	2.4	1,300,000	0
HURON	3.1	1,400,000	0
	3.2	1,350,000	150,000
*ST. CLAIR	4.1	2,900,000	700,000
ERIE	4.2	4,250,000	0
	4.3	4,455,000	0
	4.4	1,965,000	215,000
ONTARIO	5.1	1,500,000	0
	5.2	2,900,000	0
	5.3	1,000,000	0
	TOTALS	29,806,000 man-days	2,234,000 man-days

* Includes Detroit River and western Lake Erie

[a] Great Lakes Basin Commission (1975)

Trapping of Furbearers

Although mink, otter, weasel, and skunk may be taken on occasion from coastal wetlands, the main furbearers, in terms of total pelt value, are muskrat and raccoon. When food resources are limited in winter, red fox may prey on muskrat and thus be vulnerable to local harvesting by muskrat trappers. Muskrat densities and pelt quality are generally highest in cattail marshes, which occur principally along southern Lake Huron, Lake St. Clair, Lake Erie, and Lake Ontario. Raccoons commonly inhabit wooded bottomlands, near streams and inland lakes, but may build dens and forage for food in coastal wetlands.

Table 10 indicates that muskrat and raccoon generate a value of $30.44/wetland acre/year in Michigan's coastal wetlands. Given an average annual harvest of three muskrats per wetland acre and a combined pelt and carcass value of $8.70 per animal ($7/pelt and $1.70/carcass), this furbearer yields an average annual dollar value of $26.10/wetland acre. If 0.11 raccoons are harvested per wetland acre and given a combined pelt-carcass value of $39.40/animal ($31.40/pelt and $7.90/carcass), raccoons generate an annual economic return of $4.34/wetland acre. The current demand for natural furs has resulted in exceedingly high pelt prices and intense trapping activity.

Table 10

Pelt and Carcass Value of Muskrat and Raccoon in Michigan's Coastal Wetlands, 1977[a]

	Average Yield Per Wetland Acre	Pelt Value	Carcass Value	$ Value Per Wetland Acre/Yr
Muskrat	3.0	$ 7.00	$ 1.70	$26.10
Raccoon	0.11	31.40	7.90	4.32
			TOTAL	$30.42

[a] Jaworski and Raphael (1978)

The historical modification of coastal wetlands, particularly as a result of agricultural encroachment, may have affected the raccoon differentially, since clearing of the swamp and shrub margins of wetlands may have eliminated potential breeding and hibernation habitat. In contrast, the muskrat continues to be abundant in the extant shallow- and deep-water marshes which are usually considered too wet for agriculture. Moreover, the hybrid cattail, Typha glauca, a principal food item of the muskrat, may in fact be extending its range (Stuckey, 1971), whereas crayfish and other aquatic foods of the raccoon may be decreasing in abundance owing to water pollution and siltation. Both muskrat and raccoon may benefit from wetland diking and water level management for waterfowl breeding and feeding.

Waterfowl Hunting

In 1976 over 2.1 million waterfowl hunters in the continental United States expended 15.237 million hunter-days and harvested 15.24 million ducks, 1.69 million geese, and 0.96 million coots (Sorensen et al., 1977). The mallard accounted for one-third of the total national duck harvest. Of the four continental flyways, the Mississippi and Central Flyways exhibit somewhat higher waterfowl harvests because of slightly greater waterfowl use of these routes (Bellrose, 1978). The Mississippi Flyway accounts for 40 percent of the national duck harvest, 63 percent of the total coot harvest, and 28 percent of the annual goose harvest. States which exhibit the highest waterfowl harvests in the Mississippi Flyway include, (in decreasing order) Louisiana, Minnesota, Wisconsin, Arkansas, Illinois, and Michigan (Carney et al., 1975). Except for New York and Pennsylvania, which are part of the Atlantic Flyway, most Great Lakes states and the Province of Ontario are included in the Mississippi Flyway.

Waterfowl which provide most of the hunting opportunities in the Great Lakes region include dabbling ducks, diving ducks, coots, and Canada geese. However, waterfowl harvested from coastal wetlands *per se* consist primarily of dabbling ducks and coots. With respect to Michigan's coastal wetlands, the most common species harvested is the mallard, along with lesser percentages of black duck, pintail, green-winged teal, blue-winged teal, baldpate, and ring-necked duck (Michigan Department of Natural Resources, Wildlife Division files). Along the Lake Erie coast in Ohio, 75 percent of the annual duck harvest is comprised of mallard, black duck, wood duck, and blue-winged teal (Bednarik, 1976). Because diving ducks prefer open-water or deep marshes for feeding and resting, most divers are harvested by boat in open water. Although 77 percent of the Tennessee Valley population of Canada geese are taken in Michigan, Ontario, Pennsylvania, and Ohio (Bednarik and Lumsden, 1977), only a small percentage of the total Canada goose harvest derives from Great Lakes coastal wetlands.

The total harvest of waterfowl along a given coast consists of resident waterfowl (i.e., state-reared birds) or immigrants from other regions. In general, hunting success increases as the proportion of state-reared birds increases (Goldstein, 1971). In Michigan, between 25 and 40 percent of the annual waterfowl harvest is comprised of ducks produced within the state (Jaworski and Raphael, 1978). Banding data suggest that 40 percent of all mallards (Greis, 1971) and 82 to 95 percent of all wood ducks (Bowers and Martin, 1975) shot annually in Michigan are state-reared. Based on these data, approximately one-third of all waterfowl harvested in the Great Lakes region as a whole may consist of birds locally produced.

Nevertheless, a majority of the waterfowl harvested annually in the Great Lakes region migrate into the area from outside breeding grounds, especially from the prairie pothole region of North America. As waterfowl migrate through Great Lakes corridors, the birds accumulate in sites referred to as concentration areas. Along the coastal zone, concentration areas are characterized by an abundance of preferred food items, relatively low water energy, and by low hunting pressure or disturbance from boats and other traffic (Jaworski and Raphael, 1978). Sanctuaries and refuges are often located within concentration areas. Lake St. Clair and the lower Detroit River, including their associated wetlands, are perhaps the two most intensively utilized concentration areas in the Great Lakes coastal zone (Table 11). In Ohio, a coastal wetland is considered of high value to migratory waterfowl if the waterfowl use exceeds 39 bird-days/acre/year (Weeks, 1974).

Table 11

Waterfowl Day Use of Lake St. Clair and Lower Detroit River Averages from 1948-1966, September-December Only[a]

	Lake St. Clair	Lower Detroit River	TOTAL
Ducks	10,250,000	10,197,000	20,447,000
Geese	200,000	4,000	204,000
Coots	900,000	200,000	1,100,000
Subtotals	11,350,000	10,401,000	21,751,000 days

[a] Michigan Department of Natural Resources, Wildlife Division Files

The economic value of waterfowl hunting in the coastal wetlands may be estimated from the average annual waterfowl hunter's expenditures, or it may be based upon the value of a hunting day. Using the Michigan data base, it has been determined that Michigan's 105,855 acres of coastal wetlands generate an average of $31.23/wetland acre/year (Jaworski and Raphael, 1978). Approximately 21 percent of Michigan's total annual duck harvest derives from counties with extensive coastal wetlands. For each wetland acre, an average of 0.81 waterfowl are harvested annually and each bird is valued at $38.45. Although average values are not site specific, this approach does provide an estimation of the potential economic return from waterfowl hunting in the coastal wetlands.

The species composition of the waterfowl harvest in the Great Lakes region is changing, as indicated in Table 12. Michigan was selected as a case study because it lies along corridors of both the Mississippi and Atlantic Flyways. Comparison of the species composition of the 1966 harvest with that of 1976 shows that a reduction in the percentage of black ducks taken, as well as a general decline in the harvest of most divers, is evident. Although some species of divers are not esteemed by hunters, the change in species composition probably reflects waterfowl abundance as well as hunting effort motivated by a species point system. Because long-term lake level fluctuations influence waterfowl food availability by causing plant community succession and retrogression, this and other factors should be examined in future studies of harvest trends.

Table 12

Change in Species Composition of Ducks Harvested in Michigan[a]

	Percent of Total 1966	Percent of Total 1976	Change
DABBLERS:			
*Mallard	24.5	39.29	+
Black	8.0	3.71	0
Gadwall	0.6	0.79	+
Baldpate (Am. wigeon)	3.6	2.38	0
Green-winged Teal	3.9	7.4	+
Blue-Winged Teal/ Cinnamon Teal	2.4	5.7	+
Northern Shoveler	0.7	0.25	0
Pintail	1.2	1.19	0
Wood duck	8.3	12.92	+
DIVERS:			
Redhead	9.1	1.88	0
Canvasback	4.4	0.18	0
Greater Scaup	5.4	2.63	0
Lesser Scaup	10.2	8.77	0
Ring-necked duck	4.8	3.68	0
Goldeneyes	4.1	2.85	0
Bufflehead	5.0	4.00	0
Ruddy duck	0.8	0.65	0
Oldsquaw	0.2	0.18	0
All Others	2.8	1.55	0
	100.0 %	100.00 %	

* Includes mallard X black duck hybrid

[a] Sorensen et al. (1977) and Michigan Department of Natural Resources, Wildlife Division Files

At present there is not sufficient high-quality coastal wetland acreage for waterfowl hunters to utilize. A comparison of the number of applications for reservations at three public game areas in Michigan with the number of blinds or hunting sites available determined that only 26 percent of the potential hunters could be accommodated. Even though some hunters apply for reservations at more than one public game area, there appears to be a large unsatisfied demand for waterfowl hunting, especially on opening day and for the first and second weekends of the hunting season in selected wetland areas. In fact, current projections indicate that unsatisfied participant demand for hunting will prevail by 1980 within all subareas of the Great Lakes Basin (Great Lakes Basin Commission, 1975).

A lack of accessible, high-quality waterfowl hunting sites along the Great Lakes increases hunting pressure on existing public game areas, including national refuges. The best hunting opportunities may exist at private shooting clubs (e.g., Erie Shooting and Fishing Club and Toussaint Marsh in western Lake Erie) because the number of hunters is strictly limited and continuous daily hunting is not permitted. Along the Mississippi Flyway, 22 percent of the medium-to high-value waterfowl shooting grounds are located within private hunting clubs (Barclay and Bednarik, 1968). In the Great Lakes, perhaps as much as 40 percent of the wetland resource base which affords quality waterfowl hunting is owned by private individuals, private clubs, or local sportsmen's groups.

As the huntable land resource base diminishes, and as the human population increases, a latent or unsatisified demand for hunting will continue. Many states are responding to this situation by purchasing additional coastal acreages and by artificially increasing waterfowl food production through diking and the growing of small grains at public game areas. Certain species of waterfowl, especially the mallard and Canada goose, and perhaps the black duck and blue-winged teal, rely on waste grains in agricultural fields or on plant foods produced in managed wetlands. Restoration of the natural productivity of coastal wetlands along Green Bay, Saginaw Bay, and western Lake Erie, especially with regard to submersed aquatics such as wild celery and Sago pondweed, may also increase the retention of migratory waterfowl, particularly diving ducks, and thereby provide additional hunting as well as nonconsumptive recreational opportunities.

Nonconsumptive Recreation

Because of their unique ecological character, wildlife concentrations, and high viewing quality, many Great Lakes coastal wetlands are playing an important role in outdoor recreation. For example, the visitor center at Magee Marsh Wildlife Area in Ohio attracts over 50,000 people per year (Bednarik, 1975). In Michigan, an interpretive center has been developed at Tobico Marsh and another is planned for Pointe Mouillee. Urban fishing and non-motorized boating are two activities frequently underdeveloped in coastal wetlands.

Assessing the economic value of nonconsumptive activities is difficult, since it has traditionally been easier to assign quantified values to consumptive pursuits such as hunting and fishing (e.g., value of pelts, number of hunting licenses sold, etc.) than to birdwatching, nature study, and other nonconsumptive forms of recreation. However, many parks, visitor centers, and state game areas are beginning to collect data on numbers of visitors (or cars present) which, in turn, may be translated into numbers of recreation days. Based on an average recreation day value of $25.50, it was determined that Michigan's coastal wetlands generate a mean nonconsumptive value of $138.24/wetland acre/year (Jaworski and Raphael, 1978).

Projections for the Great Lakes Basin indicate that nonconsumptive use of wildlife and wildlife lands (including wetlands) will increase more rapidly than hunting use and will compensate for decreases in consumptive uses wherever they occur (Great Lakes Basin Commission, 1975). The projections also estimate that, in the United States, the 1980 demand for nonconsumptive use of wildlife habitat in the Great Lakes Basin will exceed the supply by 7.5 million man days (Table 13). The Chicago and Detroit urban areas already exhibit large deficiencies. In Michigan, 72 percent of the public use of state game areas is for nonhunting activities (Belyea and Lerg, 1976). However, increased use of coastal wetlands may generate conflicts between new users and traditional users, particularly waterfowl hunters and muskrat trappers.

Table 13

Unsatisified Participant Demand for Nonconsumptive Use of Wildlife Habitat in the USA Portion of the Great Lakes Basin, projected for 1980[a]

Lake	Planning Subarea	Man-Days of Unsatisfied Demand
Superior	1.1	26,000
	1.2	15,000
Michigan	2.1	330,000
	2.2	2,507,000
	2.3	504,500
	2.4	202,300
Huron	3.1	16,100
	3.2	396,600
*St. Clair and Vicinity	4.1	1,596,400
Erie	4.2	581,000
	4.3	896,700
	4.4	169,200
Ontario	5.1	83,800
	5.2	138,300
	5.3	23,200
		7,486,100 man-days

* Includes lower Detroit River and western Lake Erie

[a] Great Lakes Basin Commission (1975)

Recreational use of the coastal wetlands of Lake St. Clair may result in conflicts between consumptive and nonconsumptive users as participant demand increases in the future. Because of the St. Clair delta's unique hydrology and productivity, the quality of waterfowl hunting and sport fishing is exceedingly high, and proximity to Detroit facilitates public access. At present much of the delta's marsh fringe, on both sides of the international boundary, is managed for waterfowl hunting. However, current data indicate that less than 10 percent of the available waterfowl food is being utilized by waterfowl (Dawson, 1975) because of hunting pressures and disturbance by sport fishermen and boaters. If trails, boardwalks, and other improvements were made in the wetlands of Dickinson Island, the only pristine portion of the wetland complex which remains, conflicts would develop between traditional users and canoeists, birdwatchers, and other nonconsumptive users.

NONCONSUMPTIVE VALUES

At present, 75 percent of the population of the U.S. lives in a coastal zone (Shepard and Wanless, 1971). Archaeological and historical data suggest that in the past the distribution of man was also intimately related to coastal zones. Man has used coastal areas, flood plains, and wetlands for settlement as well as for arteries of transport and commerce.

Archaeological and Historical Sites

Early man probably originated in a riparian environment (Sauer, 1965), where the prerequisites for his survival were available. Earliest man apparently was not specialized for predation. He was inept at flight or concealment; he was neither very strong nor very fast. Within a wetland environment there was fresh water to drink. Ancient campsites at Olduvai Gorge in present-day Tanzania, East Africa, contain bones of rodents, frogs, reptiles, birds, and fish, all creatures that are dependent on wetlands and that could have been taken by man without complex traps or social organization.

Man's attraction to a wetland environment is understandable, and artifacts discovered are often related to topographical features such as flood plains, terraces, and beach barriers. Campsites or middens were most often located on topographical highs rather than in marshes per se. However, the wetlands were the providers of food and water, according to the evidence of kitchen middens. Regional site exploration in the mid-Mississippi valley has revealed the remains of many animals which were wetland dependent. The most notable species were raccoon, fish, migratory waterfowl, beaver, and turtle (Smith, 1975). A well-investigated site on the floodplain of the Tibbabawassee River, Michigan, indicates that muskrat, beaver, and raccoon accounted for 14 percent of the animals utilized by the Early Woodland people of that area (Cleland, 1966).

Ratiher than occasional sites randomly dispersed through time, entire chronological sequences are found in many wetland regions. In the coastal zone of Els, Greece, the chronology suggests uninterrupted occupation of floodplain, wetlands, and coast since 1500 B.C., despite natural and cultural changes (Raphael, 1973). In coastal Louisiana a similar pattern has been recorded, in spite of the changing coastline and wetland habitat and the constant shifting of the Mississippi River over the past 2000 years (McIntyre, 1971).

Archaeological resources represent not only part of the cultural heritage of man but are valuable clues to changing limnological, geological, and climatic conditions. Molluscs were an important source of food for coastal Indians. In the wetlands of Louisiana different shells are often associated with a single shell mound (e.g.: Ostrea, Unio, and Rangia). If two or more types of mollusc are found on one site, a change in water salinity is indicated. Fresh water mussels collected from a Hopewell site in Illinois revealed changes in pH, sediments, and river regime (Matteson, 1966). Archaeological sites beneath flood plains and marshes are useful in determining rates of sedimentation and subsistence. Such data are useful in interpreting paleogeographic settings (Kraft et al., 1977). The occurrence and rates of sedimentation based on archaeological site distributions have been used as clues to past climatic conditions in the eastern Mediterranean (Vita-Finzi, 1968). According to Quimby (1971) some of the earliest archaeological sites in the Great Lakes (the Aqua-Plano tradition) commonly occurred on ancient glacial and post glacial beaches in Michigan. The density of prehistoric archaeological sites is highest in the counties having major floodplains draining into the Great Lakes, and near the Straits of Mackinac (Peebles and Black, 1976). Graves (1977) has reconstructed the paleogeography of North Maumee Bay, based partly on archaeological sites in the area.

The examination of archaeological sites, with respect to information they yield concerning the food habits and tools used by early man, may elucidate the environmental setting of the time. Table 14 indicates continuous occupation of the upper Great Lakes over a 2100-year period. Other cultures occupied the region prior to 500 B.C. (e.g., Boreal Archaic Culture). Fitting (1975) notes that Great Lakes shorelines were very rich environments to be exploited by late Paleo-Indian groups. However, the Great Lakes were as much as 400 feet lower than present day lake levels and many of the richest sites are under several feet of water. With European contact after 1600 A.D., tribes such as the Chippewa, who hunted beaver, muskrat, and mink, fished for sturgeon, and harvested wild rice, occupied the Great Lakes and upper midwest. Common foods of all cultures in Table 14 indicated the Indians' dependence on wetlands. Several fishes and other animals use the wetlands for at least parts of their life cycles. Known spawners in wetlands or adjacent waters include the northern pike and walleye, lake sturgeon, and largemouth bass. Table 14 also reveals the wide diversity of animals which are supported in wetlands. With the appearance of the Hopewell Culture came the beginnings of agriculture; corn, squash, perhaps beans, and probably tobacco were cultivated. Although agriculture became more important by Late Woodland times, the dependence on wetlands remained. A late Woodland site in southeastern Michigan has revealed that muskrats, ducks, and some fishes such as channel catfish, largemouth bass, and yellow perch were significant food sources (Fitting, 1965).

Table 14

Common Foods and Tools of Prehistoric Upper Great Lakes Cultures[a]

Culture	Food	Tools
Late Woodland 800-1600 A.D.	Beaver, Raccoon, Otter, Muskrat, Deer, Walleye, Northern Pike, Channel Catfish, Freshwater Drum	Mussel-shell scrapers, shell lures for fishing
Hopewell 100B.C.-800 A.D.	Deer, Muskrat, Mussels Painted turtle, Largemouth bass, Channel catfish	Beaver Incisors, Mussel shell spoons
Early Woodland 500 B.C.-1000 B.C.	Beaver, Lake sturgeon, Suckers, Pickerel (Northern Pike)	Fish spears, Shell
Old Copper pre-500 B.C.	Ducks, Swans,Cranes Fish, Beaver	Bird bone

[a] Quimby (1971)

Natural Landmarks

Concern for the preservation of natural and archaeological resources can be traced back to the early 1900's, with the establishment of the Antiquities Act of 1906 (PL 34-209). This act empowered the President to designate national monuments to protect sites of archaeologic, historic, or scientific interest. Through the years additional policy was legislated to recognize the value of such sites, specifically the Historic Sites Act of 1935 (PL 74-292) and the National Historic Preservation Act of 1966 (80 Stat. 915, 16 U.S.C. 470). More recently the 1969 National Environmental Policy Act (PL 91-190) encouraged the preservation of important historic, cultural, and natural aspects of our heritage (Section 101 [6] [4]).

When evaluating the possibility that a wetland has archaeological, historical, or important natural values, one should consult the National Register of Historic Places and the National Registry of Natural Landmarks. The latter agency strives to preserve sites of geological and ecological character to enhance the scientific and educational value of the sites, to strengthen cultural appreciation of natural history, and to encourage the preservation of the nation's natural heritage. Goodwin and Niering (1975) collected data on 358 wetlands in the conterminous U.S. and have noted those which are registered natural landmarks. The most recent available listing of sites in the National Register of Historic Places appears in the Federal Register, Vol. 42, No. 21, Feb. 1, 1977.

Natural and Unique Areas

In the assessment of a wetland, its natural values, some of which influence wildlife diversity and production, ought to be given consideration. Larson (1976) suggests the following as important criteria for identifying wetlands which especially merit preservation:

(1) The presence of rare, restricted, endemic, or relict flora or fauna.
(2) The presence of flora of unusually high visual quality and infrequent occurrence.
(3) The presence of flora or fauna at, or near, the limits of their range.
(4) The juxtaposition, in sequence, of several seral stages of hierarchical succession.
(5) High production of native waterfowl species.
(6) Use by great numbers of migrating waterfowl, shorebirds, marshbirds, and wading birds.
(7) The presence of outstanding or uncommon geomophological features in, or associated with, a wetland.
(8) The availability of reliable scientific information concerning the geological, biological, or archaeological history of a wetland.
(9) The known presence of outstanding archaeological evidence in a wetland.
(10) Wetlands that are relatively scarce in a given physiographic region or that provide distinct visual contrast.
(11) Wetlands that are integral links in a system of waterways or are so large that they dominate the landscape of a region.

A significant portion of the public would be in favor of preserving wetlands which have some of the above characteristics. However, one cannot expect each decision maker to search every wetland thoroughly for outstanding natural and cultural characteristics. Perhaps through the efforts of amateur and professional naturalists such data can be compiled and outstanding wetlands identified.

ENDANGERED, THREATENED, AND RARE SPECIES

One approach in determining the value of a wetland is to document certain unique characteristics identified in the field and in the literature. The most significant criterion for wetland evaluation, according to Larson (1976), is the presence of rare, restricted, endemic, or relict flora or fauna. Included under rare species are endangered, threatened, and rare plants and animals. Some states (e.g., Wisconsin) have expanded or added categories such as a list of Animals With Changing Status to make their programs more comprehensive.

Most states have definitions which distinguish the status of their unique flora and fauna. Generally the following definitions are appropriate for most states' flora and fauna:

Endangered - A species of animal or plant which is in danger of extinction throughout all or a significant part of its range.

Threatened - A species which is likely to become endangered within the foreseeable future throughout all or a significant portion of its range.

Rare - A species or lower taxa that, while not "endangered" or "threatened", is uncommon enough to deserve further study and monitoring.

The federal government and each state government have developed substantial and far-reaching programs to conserve flora and fauna for the benefit of future generations. Some species, such as the American lotus and the peregrine falcon now face difficult survival problems. They may always have been scarce, or they may have low reproductive rates, or be highly intolerant in habitat selection, or may be especially sensitive to man's presence.

Based on the federal list, about 101 species and subspecies of wildlife have been identified and are now threatened with extinction in the Great Lakes area. Threatened wildlife include the bald eagle and the peregrine falcon, both of which utilize most of the Great Lakes region. Fishes on the federal list include the short-nose sturgeon, the longjaw cisco, and the blue pike which utilize wetlands during some part of their life cycles.

The states contiguous to the Great Lakes have implemented measures to preserve endangered and threatened flora and fauna. In Michigan, for example, an Endangered Species Program was organized under the authority of the Endangered Species Act of 1973 (P.L. 93-205). The first state lists were presented to the Michigan Natural Resources Commission in February 1976. Numerous endangered, threatened, and rare species of vascular plants have been proposed for inclusion (Wagner et al., 1977). According to Beaman (1977), 38 percent of these rare flora occur in wetland and aquatic environments.

A related parameter with regard to unique wetland values is the occurrence of flora and fauna at or near the limits of their range. Preservation of habitat provides both unusual educational and scientific research opportunities which ought to be considered in an environmental impact assessment. The northern habitat limit of the Indiana bat, for example, is northern Ohio (U.S. Army Corps of Engineers, 1976). This mammal, which is on both state and federal protection lists, is known to frequent the western Lake Erie wetlands. Several important migratory shorebirds are also at the limits of their range in the basin of the Great Lakes (Sanderson, 1977). The eastern limit of coot breeding is western Lake Erie. The northern boundary breeding limit of common gallinule is the south shore of Lake Superior. Although these shorebirds are not endangered or threatened in the Great Lakes basin, they ought to be considered in any comprehensive wetland evaluation.

Goodwin and Niering (1975) have identified wetlands in the conterminous U.S. which have unique characteristics (i.e., important for waterfowl migration, threatened fauna or flora, unique morphological features, etc.).

The Lakeview Marsh in eastern Lake Ontario consists of 3400 acres and is being recommended for dedication as a Natural Area by New York State. Pennsylvania and Ohio have gone a step further and have established some wetlands as Registered Landmarks (e.g. Browns' Lake Bog, Cedar Swamp, Cranberry Bog, and Presque Isle).

Threatened flora and fauna in Michigan have been identified and mapped by Wagner et al., (1977). Jaworski and Raphael (1977) have documented threatened flora, fauna, and shorebirds for Michigan's coastal wetlands.

Additional sources which are useful in documenting threatened flora and fauna are Environmental Impact Statements (EIS). Many EIS's have been prepared by the U.S. Army Corps of Engineers Districts in the Great Lakes basin, particularly with regard to dredging and filling of commercial and recreational harbors. Private consulting firms have also prepared EIS's for power plant siting. Most EIS's are specific and include threatened species as well as the occurrence of other fish and wildlife values. Field data sheets of the Mississippi Flyway Waterfowl Habitat Reconnaissance, housed in offices of state Departments of Natural Resources, in many cases document the nesting of threatened birds, particularly birds of prey which frequent wetlands or nest in them.

A useful source for documenting the occurrence of threatened birds is the nesting report of Scharf (1977), in which shorebirds as well as threatened species (e.g. red-shouldered hawk, bald eagle) have been identified and migration sites mapped from Lake Superior to eastern Lake Ontario. Local periodicals such as The Jack-Pine Warbler and the Wilson Bulletin, which document staging and migration areas, are also useful. Some data are available through universities, particularly those with sea grant programs. The piping plover, which is on Wisconsin's list of Animals With Changing Status is discussed by Harris and Matteson, (1975). In a thesis, Koechlein (1971) idendified 72 mute swan nests in northern Michigan wetlands. Rare and endangered molluscs of the United States have been documented by Jorgensen and Sharp (1971). On a state level, Van der Schalle (1975) has identified threatened snails and mussels in Michigan.

Unpublished inventories with limited distribution are a valuable source of data for threatened species as well as other wetland values. Species diversity of shorebirds has been noted in the wetlands of northern Ohio (Bednarik, 1975). Thobaben (1974) documented 77 animal species occurring in the 96-acre Cheboygan marsh. Such data are valuable in determining wetland values but usually occur only in mimeograph form at state Department of Natural Resources offices or in private collections.

RECREATIONAL VALUES OF COASTAL WETLANDS

Two of the overriding themes of modern American society are (1) an increasing awareness of and appreciation for the values of various ecosystems and man's role in them and (2) a more urgent need for recreation and creative use of leisure time. The interaction of these themes has meant that recreational activities of a non-consumptive nature have grown at an exponential rate in recent years, challenging the traditional image of hunting and fishing as the major American outdoor pastimes (U.S. Department of Agriculture 1977, p. 53). By virtue of their unique character, high productivity, and often unspoiled character, the wetlands of the United States have come to play a major role in this process, with particular reference to certain types of activities. Assessing the relative value of these activities, however, is more difficult, since it has traditionally been easier to assign quantified values to such consumptive recreational pursuits as hunting and fishing (value of pelts and meat, weight of catch, license sales, etc.) than to birdwatching, hiking, canoeing, and other non-consumptive forms of recreation. Moreover, those practicing these various forms of recreation are devoted, almost by definition, to informality, spontaneity, and lack of an organizational structure.

In recent years, efforts have been made to utilize sociological and economic theory in assessments of recreational quality. Talhelm (1973) attempted to expand fishing experience data into general models of recreation resource utilization, while Smardon (1972, 1973) undertook a rigorous analysis of the aesthetic values of wetlands and Shaw (1974) considered the American perception of wildlife. The different types of non-consumptive recreational activities which should be considered in assessments of relative wetland values are summarized below. It should be kept in mind that these categories are not exclusive: a canoeist may also be birdwatching, and may even inadvertently become a swimmer. The list of activities is derived from U.S. Department of Agriculture (1977).

Wildlife related recreational activities

As discussed elsewhere in this summary, the wetlands of the glaciated midwest represent a uniquely productive ecosystem which concentrates wildlife of all sorts to an extraordinary degree. This means that the region's wetlands have an enormous appeal, beyond hunting and fishing, for those interested in such wildlife related activities as birdwatching, nature walks, photography, and sketching. Horvath (1974) has estimated that there were seven million birdwatchers and over four million wildlife photographers in the United States in 1970; it seems logical to suppose that a number proportionate to the regional population was found in the Great Lakes region. By way of further perspective, Payne and DeGraaf (1975) estimated that the direct expenditure attributable to the enjoyment of non-game birds in the United States in 1974 was $500,000,000 or about 1.7 times the amount spent directly by waterfowl hunters.

Recognizing the significance of this trend, as well as the compatibility of this type of use with other basic wetland values (e.g., wildlife habitat, flood control, nutrient recycling, water quality maintenance, aesthetic considerations), the Michigan Department of Natural Resources has proposed creation of the St. Johns Marshland Recreation Area in St. Clair County, at the doorstep of the Detroit metropolitan area (Michigan Department of Natural Resources, 1976). Although limited fishing, hunting, and picnicking are envisioned, the major activities will be interpretive and educational programs and the viewing and photographing of wildlife. A new interpretive center has also been opened at Tobico Marsh, Bay County, Michigan; and under the Marine Sanctuary Act, the first wetland sanctuary in the Great Lakes was established by the Ohio Department of Natural Resources at Old Woman's Creek in 1978. Finally, some 15,000 visitors annually utilize the Crane Creek Wildlife Area on Lake Erie (Ohio) to observe waterfowl, particularly during migration seasons.

Water related recreational activities

Human affinity for water and water-related recreational activities is well known. Periodic surveys (e.g., U.S. Department of the Interior, 1973) document the significance of water in the overall recreational scene, and tend to show that swimming, canoeing, sailing, other boating, water skiing, and certain winter activities such as ice skating and snowshoeing have an impressive recreational dollar value and often put considerable pressure on facilities. Moreover, recent projections envision that demand for certain water-related recreation activities (particularly sailing and water skiing) will expand at a more rapid rate than that of any other form of outdoor recreation (U.S. Department of Agriculture, 1977). The position of wetlands in this scenario is an ambiguous one. On one hand, they tend to be highly prized and intensively utilized for certain of these recreational pursuits, particularly where they are contiguous to areas of open water and where they are within easy reach of metropolitan populations (Kapp, 1969). On the other hand, the very success of water bodies as recreational areas, and the fact that wetlands may inhibit access to open water, means that the wetlands themselves may be subjected to intense developmental pressures in the form of filling, construction of marinas and boat storage areas, access dredging, and other measures designed to "improve" water-related recreation.

Other outdoor recreational activities

In addition to recreational activities specifically identified with wetland environments, many other forms of outdoor recreation are enjoyed equally in wetlands and other types of areas. This category of activity includes camping, picnicking, horseback riding, hiking, and walking for pleasure, particularly when dry conditions prevail. It is extremely difficult to differentiate the comparative value of wetlands here; but it seems reasonable to assume that the same characteristics that make them attractive for other purposes (wildlife abundance and diversity, scenic and aesthetic qualities, the presence of water) also enhance their attractiveness for these uses. Boardwalks through wetlands or along artificial levees, as at Magee Marsh in Northwest Ohio or in the Sarett Nature Center, Berrien County, Michigan, increase the attractiveness of these areas and at the same time channel visitor access. Camping is an activity closely associated with water proximity (U.S. Department of Agriculture, Forest Service, 1977) and provision of adequate camping facilities may pose additional problems for the maintenance of wetland quality

(Lime and Cushwa, 1969). Moreover, as areas peripheral to wetlands become more densely occupied, these benefits become more important. As noted by Clark (1974), the need to preserve wetlands increases with increasing development pressure.

PHYSICAL FUNCTIONS

GROUNDWATER RECHARGE AND FLOOD STORAGE

Wetlands exert influence on surface and subsurface water flow, especially during extreme wet and extreme dry periods. During periods of high precipitation many wetlands absorb and store water. According to Niering (1966), if the water level of a 10-acre wetland is raised just six inches, 1.5 million gallons of water are placed into storage. Such absorption capability is seen as an important value of wetlands in terms of flood mitigation. Conversely, during drier periods, water stored in wetlands is diffused to stressed subsurface water bodies. O'Brien (1977) noted that wetlands in Massachusetts underlain by peat deposits recharged the regional groundwater body in late summer when dry periods occurred.

Field studies by Walton (1970) of 109 drainage basins in Illinois and 38 drainage basins in Minnesota demonstrated the character of groundwater runoff. During years of less than normal precipitation more than half of the apparent groundwater runoff was slowly released from storage within lakes and wetlands to the adjacent subsurface areas. Basins with lake and wetland areas covering more than five percent of the total watershed area had twice as much groundwater discharge as watersheds with a smaller proportion of lakes and wetlands. However, in years of greater than normal precipitation, lake and wetland cover had no appreciable effect on groundwater.

It is important to note that, although the ground water resource in the Great Lakes area is essentially untapped, the contribution of coastal wetlands to groundwater recharge and flood control is probably less significant than that of inland wetlands. The Great Lakes basin receives approximately 30 inches of precipitation annually. This relatively high precipitation, coupled with low relief and gentle slopes, facilitates surface water infiltration and groundwater recharge. However, because of the abundant precipitation and the amount of water from flowing rivers and from the Great Lakes themselves, the groundwater recharge potential of wetlands and bottomlands in the Great Lakes basin is not significant in the recharging of local aquifers (Jaworski and Raphael, 1978). In western Ohio, the principal groundwater recharge areas for the bedrock aquifers are located in the higher glacial terrain, whereas the principal groundwater discharge areas are the streams and lowlands along the Lake Erie coast (Norris, 1974). Thus, the coastal wetlands of the Great Lakes are probably receivers of groundwater rather than donors.

Because of the low-lying nature of many coastal wetlands, even small changes in water level may lead to flooding. Coastal flooding in such areas occurs because of intense low pressure systems and strong onshore winds. When periods of high water levels like those which occurred in the early 1970's prevail, the flood potential is significantly increased. During a storm on 8-9 April 1973, strong north-northeast winds raised western Lake Erie water levels 1.5 to 2.5 feet above already higher than average lake levels (Bryan, 1973). The town of Detroit Beach, Michigan, had 18 inches of water in its streets, and in Monroe County most of the 10,000 beach-front residents had to be evacuated from their homes.

Several studies suggest that wetlands have the capacity to store flood waters (e.g. Niering, 1966) and thus reduce flood hazards in nearby developed areas. However, such studies only consider riverine wetlands and inland bogs rather than coastal wetlands. The role of coastal wetlands in relation to flood protection is poorly documented, but the example cited above clearly suggests that flooding can occur along the shoreline in spite of extensive wetlands.

SEDIMENTATION AND POLLUTION CONTROL CAPABILITIES OF GREAT LAKES COASTAL WETLANDS

The role of Great Lakes coastal wetlands in sediment and pollution control is not well known. However, data from other regions suggest that wetlands act as nutrient sinks and filters which reduce turbidity and mitigate related problems. The source of sediments and pollutants, including toxic substances and nutrients, is primarily from land runoff and to a lesser degree from atmospheric fallout and the nearshore zone.

Non-point pollution is a particularly significant problem in areas of intensive land use and in areas where clay and organic soils predominate. Runoff from urban landscapes varies from 60 to 100 percent of the precipitation input; runoff from agricultural land varies from 60 to 90 percent of the water input. In many instances coastal wetlands are located at the mouths of rivers draining ancient lacustrine plains which are now intensively utilized by man. Clay, silt, and organic sediments from such lands adsorb nutrients and toxic substances, which are then transported downstream. For example, the suspended solids load of the Maumee River and its tributaries is predominantly surficial in origin, presumably from the upper parts of the soil profile (A horizon), which consists largely of clay and probably an organic fraction (Jones et al., 1977; Wall and Wilding, 1977). Nutrients are usually adsorbed to the smaller-sized particles, especially the clay fraction. In the heavily agricultural Black Creek watershed, over 80 percent of the phosphorus and over 70 percent of the nitrogen in surface runoff was attached to sediments (Karr and Schlosser, 1978). Besides transporting nutrients, clay sediments are responsible for turbidity along the shorelines of the Great Lakes. Turbidity reduces light penetration through the water and inhibits the growth of submersed plants and biotic communities associated with them.

The ability of a stream to transport suspended sediments is dependent on particle size and current velocity. As a current flows through a wetland its flow velocity may be impeded by emergent and submergent vegetation, resulting in increased sedimentation. Table 15 lists critical transport velocities for sediment particles of various sizes. Clay particles have the smallest mean diameter and require the lowest current velocity (0.08 m/sec.) for transport and thus are likely to be the most abundant form of suspended sediment in coastal zones.

Table 15

Critical Transport Velocities for Particles of Various Sizes[a]

Particle	Mean Particle Diameter, mm	Current Velocity, m/sec.
Clay	0.004	0.08
Sand	0.5	0.28
Granule	4.0	0.63
Pebble	7.0	0.86
Gravel	54.0	1.62
Boulder	409.0	4.87

[a] modified from Ruttner (1963) and Twenhofel (1932)

The sediment yield of the Great Lakes basin has been studied in some detail. In general, sediment yields in the Great Lakes region are relatively low compared to other basins in the United States and amount to approximately 1 ton/2.5 acres or 0.4 ton/acre (100 ton/km^2) (Walling, 1977). Stichling (1973) suggested that levels of 0.2 to 1.0 ton/2.5 acres or 0.08-0.4 tons/acre (20 to 100 tons/km^2) were characteristic of Ontario waters of the Great Lakes. Rainwater (1962) revealed that the area of the United States tributary to the Great Lakes has a sediment yield of approximately 0.36 tons/acre (90 tons/km^2). Although the sediment yields may not be excessive, the sediments are often clays, which are biologically more degrading to the aquatic environment than coarser sediments.

The sediments entering coastal wetlands are derived from several sources. Perhaps the most common source is erosion from upland areas of drainage basins. Fluvial erosion also introduces clastic sediments into wetlands. Another source of sediment is the organic detritus produced within the wetlands themselves. Coastal wetlands of the Great Lakes with high organic sediment content are often protected by coastal barriers and subjected to low wave energies, so that dispersal of accumulating sediments is minimal; the protected embayments of eastern Lake Michigan are good examples of wetlands with high peat content. Sediments are also introduced into coastal wetlands by storm and flood activity. As waves break over barriers during severe storms, sediment washes over barrier crests into the wetlands. Such washover deposits often consist of coarse sand and fine gravel. Washover processes appear to be most prevalent on exposed coasts with low, narrow barriers, such as the coast of North Maumee Bay. Anthropogenic materials have been identified as a localized source of sediment in coastal wetlands. For example, dredged spoil at Thunder Bay, Ontario, has been found to consist primarily of sawdust removed from the embayment (Raphael et al., 1974). At Lake Macatawa, Michigan, dredged detrital materials have included cinder and ash from coal burning power plants and animal hair from early tanning operations (Anderson et al., 1978).

The role of Great Lakes wetlands in the interception of sediments from upland sources requires more complete investigation. Verduin (1969) and Stuckey (1978) suggested that the loss of the coastal wetlands of western Lake Erie (Black Swamp) appeared to be related to a decrease in submerged aquatic plants because of turbidity. When water levels in coastal wetlands fluctuate cyclically, sediment interception appears to be greatest at times of low or receding water levels. In Lake Macatawa, Michigan, water flow velocities through wetlands during periods of receding water levels decrease; the increase in residence time of water promotes sedimentation (Greij, 1976). Conversely, during higher water periods sediments appear to be exported from wetlands. The wetlands along Saginaw Bay (e.g. Tobico Marsh) released large quantities of organic detritus during the period of high lake levels between 1972-1976, which littered many beaches along the shoreline. At Sterling State Park on western Lake Erie, examination of sediment cores extracted from a wetland suggested that the marsh is an efficient trap for fine-grained sediments (Jaworski and Raphael, 1978).

The rate at which sediments accumulate in coastal wetlands of the Great Lakes has not been studied. Data from marine coastal areas, although somewhat limited in applicability because of different environmental conditions, may be used to gain some insight into the magnitude of deposition. For example, Harrison and Bloom (1977) found that the rate of sedimentary accretion in five tidal salt marshes in Connecticut over a ten-year period ranged from 2.0 mm/year to 6.6 mm/year. It is interesting to note that the highest sedimentation rates are correlated with the greatest tidal range. Thus, the greater net flooding that occurs with greater tide ranges may cause the observed high accretion rates. Conversely, in Saginaw Bay higher water levels suggest sediment export. A small _Spartina alterniflora_ marsh on the north shore of Long Island, New York, yielded an average accretion rate of 2.5 mm/year and a maximum rate of 4.7 mm/year (Flessa et al., 1977). Niering et al. (1977) took core samples of salt marshes in Connecticut and determined that sediment rates were as great as 16.5 mm/year in areas of human impact, whereas less disturbed areas of marsh had acretion rates of 3 to 6 mm/year. More recently, Richard (1978) determined the following accretion rates on coastal flats exposed at different elevations between mean low tide and slightly below mean high tide level:

Bare Mud Flats (low elevation)	20.5 to 45.5 mm/yr
Intermediate _Spartina_ Area (intermediate elevation)	9.5 to 37.0 mm/yr
High _Spartina_ Marsh (high elevation)	2.0 to 4.25 mm/yr

The highest average sedimentation rates appeared to be related to areas nearest the mean low water level, whereas the lowest average was related to the higher _Spartina_ marsh located slightly below the mean high water level.

The application of these data to Great Lakes coastal wetlands is limited because of several dissimilar factors such as vegetation type, tides, water level changes, and land use practices. Based on geological investigations, the materials deposited and the rate at which deposition occurs in Great Lakes coastal wetlands are extremely variable. The sediments accumulating in the wetlands along the eastern shore embayments of Lake Michigan are often composed of thick peat layers. Fluvial sands are dominant near channels and point bars. The sediments of the St. Clair River delta are approximately 20 feet in thickness and underlain by lacustrine clay. Assuming the delta was deposited in the last 5000 to 6000 years, the rate of accretion was an inch of deltaic sediment/20 to 25 years. In Saginaw Bay and Green Bay, the lacustrine wetlands in the nearshore zone colonize sand bars. The bars and organic substrate are estimated to be approximately two feet in thickness. If one assumes that Lake Huron stabilized its level about 4000 years ago, sedimentary accumulation in the coastal zones and wetlands of this lake has been much lower than that documented elsewhere.

The sediment trapping capabilities of coastal wetlands have been documented on a few marine wetlands, and there is general agreement that wetlands are effective sediment traps. It may be assumed that Great Lakes wetlands are also trapping sediments since the principles of deposition are similar and involve currents which can be influenced by emergent and submergent wetland plants. However, detailed sedimentation rates have not been determined in the Great Lakes wetlands.

NUTRIENT LOADING, HEAVY METALS, AND TOXIC SUBSTANCES

The rate of uptake, storage, and release of nutrients, heavy metals, and toxic substances in Great Lakes coastal wetlands has not been adequately determined. The processes appear to be complex and seasonally variable. However, wetlands in general are known to act as nutrient sinks and thus can be important in water quality management of the Great Lakes. In addition to the sediments discussed in the previous subsection, inputs of nitrogen, phosphorus, and potassium from agricultural lands in the Great Lakes basin contribute to the degradation of water quality. It has been determined that northern Indiana, Ohio, and southeastern Michigan have the highest fertilizer application rate in the Great Lakes basin. In 1964, for example, 62,719 tons of nitrogen, 37,073 tons of phosphorus, and 62,613 tons of potassium were applied to the southeastern agricultural region of Michigan (U.S. EPA, 1971). This tonnage was expected to increase 5 percent annually.

The growing volume of literature regarding nutrient uptake and biogeochemical cycling in wetlands suggests these functions are an important wetland asset. Spangler, et al. (1976) reported an improvement in sewage effluent quality as it flowed through a Wisconsin marsh. Phosphorus was reduced 13%, nitrate reduced 15% and coliform bacteria reduced 86%. More recently, Windon (1977) determined that salt marshes colonizing dredged materials removed 50% and 70% of the phosphorus and nitrogen, respectively, from effluents. Furthermore, mean heavy metal uptake (i.e. manganese, cadmium, copper, nickel, and zinc) ranged between 15% and 32%. As an example of this phenomenon after 10 million gallons of secondary sewage effluent was discharged onto a 10-acre wetland in Michigan, total dissolved phosphorus, nitrate nitrogen, and nitrite nitrogen in the overland flow through the marsh had returned to background concentrations within 129 feet (39 meters) of the discharge (Tilton, 1979). Furthermore, element budgets showed that 99%, 95%, and 71% of the total input of nitrate nitrogen and nitrite nitrogen, total dissolved phosphorus, and NH_4 nitrogen, respectively, were immobilized within 98 feet (30 meters) of the sewage discharge site. Fetter et al. (1978) recorded a significant improvement of all parameters measured in a stream passing over a *Typha* and *Sparganium* marsh in Wisconsin, including total phosphorus, ammonia nitrogen, nitrate nitrogen, and coliform bacteria. Also, Greij (1976) found an improvement of water quality due to the reduction of nitrates and phosphates in a cattail (*Typha*) marsh in Lake Macatawa, which flows into Lake Michigan.

Care must be taken in extending these data to coastal wetlands and viewing the numerical outputs as averages. Loucks et al. (1977) found that the efficiency of phosphorus trapping in Lake Wingra, Wisconsin, changed seasonally. During the summer, there were periods when the marsh retained 83% of the phosphorus, but in the fall it retained only 16%, and in winter only 1%. According to Spangler et al. (1977) phosphorus retention in marshes is highly variable. A general overview that emerges is that wetlands are always good to excellent nutrient traps during the growing season (van der Valk et al., 1978), but in the spring and fall their efficiency declines. These investigators suggested that the major underlying causes for the variation in nutrient trapping capacity seemed to be differences in hydrology and seasonal fluxes of nutrients within a wetland.

The plant species in a wetland also determine nutrient uptake efficiency. Seidel and Kickuth (1967) observed that bulrushes (*Scirpus*) absorbed industrial wastes. More recently Tilton et al. (in prep.) noted that emergent wetlands had a greater capacity to absorb nitrogen and phosphorus than submergent wetlands. Generally, the amount of phosphorus and nitrogen in plant tissue varies depending on species composition and site conditions. Tilton et al. (in prep.) have calculated that if all the plants on one hectare (2.47-acres) of wetland area in the St. Clair delta were to die off, approximately 114 to 150 pounds of phosphorus and about 1009 to 1584 pounds of nitrogen would flow into Lake St. Clair and its connecting channels.

Phosphorus loadings are of particular concern to the International Joint Commission (1978). Agricultural, livestock, and urban contributions of total phosphorus to the total phosphorus loadings of streams have been estimated and mapped. Estimated agricultural contributions of phosphorus are highest (2.01 - 2.50 kg P/ha/yr) in the northern Ohio counties, so it may be anticipated that the coastal wetlands east of Maumee Bay receive phosphorus inputs from this source. Significant agricultural contributions of phosphorus also occur in streams tributary to Green Bay (1.01 to 1.50 kg P/ha/yr). Other major wetland areas which may feel the impact of agricultural phosphorus, but to a lesser degree, are located in eastern Lake Ontario, the northern Lake Erie shoreline, Lake St. Clair, northeastern Saginaw Bay, and the coastal zones of Muskegon and Ottawa Counties on Lake Michigan.

Inputs of phosphorus from livestock sources appear to be locally significant. Wetlands which may be affected are those in Lake St. Clair, in Green Bay, and in Ottawa County, Michigan. Localized wetlands in Lake Ontario along southern Georgian Bay, and in southeastern Lake Huron, may also receive phosphorus loadings from this source. Urban contributions of total phosphorus to coastal wetlands are most apparent in Saginaw Bay (0.11 - 0.25 kg/ha/yr), Lake St. Clair, and the south shore of Lake Erie. Stream loadings in the latter area have ranged from 0.11 to 2.00 kg/ha/yr; the greatest contributions are from the Detroit metropolitan area.

Toxic substances, including heavy metals, present a serious water and sediment quality problem in the Great Lakes basin. Many metals found in small amounts in the basin are from natural sources, but levels of some metals (e.g., mercury and lead) have risen to high levels as a result of industrial activity and growth. Pesticides and industrial organic chemicals (e.g., PCB's, Mirex) are of major concern to the International Joint Commission (IJC, 1978) and the Great Lakes Basin Commission (1978).

According to Neil et al. (1978) toxic substances can be classified as follows:

(a) Industrial Organic Chemicals
Halogenated organics (i.e., organics with halide groups, primarily chlorine and bromine)
(b) Radioactive substances
(c) Pesticides (insecticides, herbicides, fungicides)
(d) Heavy metals such as lead and mercury
(e) Petroleum products
(f) Others (e.g., asbestos)

The regional occurrence and significance of heavy metals and toxic materials in coastal wetlands is not well known. However, primary sources of entry of toxic substances in the Great Lakes Basin include urban and agricultural runoff, domestic and industrial waste disposal, sewage, precipitation, automobile emissions, and animal wastes (Rutherford, 1977). Because of the sources of the materials and sedimentation patterns, it may be assumed that these materials enter coastal wetlands.

Tributary data suggest that several coastal wetlands may contain toxic substances, heavy metals, and nutrients derived from upland sources. Non-point sources of pollutants include subbasins of Lake Erie, southern Lake Huron, and several areas adjacent to Lakes Ontario and Michigan. According to the International Joint Commission (1978) several factors affect non-point pollution sources and include soil types, land use intensity, climate, and degree of industrialization. Based on these factors, drainage basins with high clay contents associated with a high degree of urbanization and industrialization would probably have the greatest pollutant loadings. In such areas nutrient uptake and sediment trapping functions of coastal wetlands would be most beneficial.

COASTAL PROTECTION

A problem confronting many Great Lakes shorelines is erosion. Over the years considerable attention has been given to this problem by the U.S. Army Corps of Engineers and the International Joint Commission, as well as state and provincial agencies (e.g. Seibel et al., 1976; Great Lakes Basin Commission, 1975; U.S. Army, 1971; Quigley and Tutt, 1968). Coastal erosion is particularly acute during higher lake levels. Along inadequately protected portions of shoreline, waves erode bluffs, beaches, and barriers. The problem is not limited to coastal areas dominated by bluffs and cliffs composed of erodible glacial sediments; low-lying shorelines composed of barriers, beach ridges, or spits are also influenced by rising water levels and wave stress. Coakley (1978), for example, concluded that Point Pelee, Ontario, had retreated landward at a rate of seven feet per year. Furthermore, Lake Erie littoral currents at Point Pelee flow to the west, and these currents have caused a nearly one foot per year westward displacement of the Point.

Coastal wetlands of the Great Lakes are most often associated with low and protected shorelines. The major wetlands in the basin occur along shorelines which have low-angle offshore profiles. Often subdued barriers characterize the shoreline (e.g. Lakeview Marsh, New York; Tobico Marsh, Michigan; Kakagon Sloughs, Wisconsin). Other coastal wetlands are located lakeward of the shoreline (Tuscola County, Michigan; Georgian Bay, Ontario; Oconto County, Wisconsin) and are thus exposed to more wave action. Wetland vegetation may decrease wave energy and contribute thereby to coastal stabilization. A few studies have illustrated the effectiveness of wave energy/wetland relationships, but more research is required before the overall impact can be evaluated.

Waves are generated by winds blowing over a water surface; the longer the water surface (fetch) the higher the waves. Waves move over an open water surface until their paths are interrupted by a shore or some obstacle such as a shoal, sand bar, or an artificial structure such as rip-rap or a sea wall. As a wave moves into shallower water, its steepness may increase, causing it to eventually break on the shoreline. Two important variables with regard to wave energy are the height (H) and length (L) of the wave. Wave energy may be expressed as $E = 1/8\ H^2L$ (Zenkovich, 1967). Another common expression of the amount of energy a wave delivers to a beach is conveniently described as wave steepness (H/L). Steep waves with values greater than 0.03 remove sediments from beaches and deposit offshore bars and higher berms. Less steep waves (less than 0.03) bring sand ashore. In either case the important parameters are the height and length of the waves. Some data on wave parameters are available. For example, hindcast data have been determined by Cole and Hilfiker (1970) for Lakes Michigan, Huron, and Superior. Some direct wave observations have been summarized by Bruno and Hiipakka (1970). However, these data are not from wetland areas, and to our knowledge the relationships between wetlands and wave characteristics have not been investigated in the Great Lakes.

Relationships between wetlands and wave action in marine environments have been investigated in some detail, however, Stoddart (1971) noted that bays covered with natural vegetation remained intact after the passage of Hurricane Hattie in Belize. Teal and Teal (1969) also found that marshes in Lincolnshire, England were not severely damaged by North Sea storms. Chabreck and Palmisano (1973) reported the uprooting and removal of wetlands in the Mississippi River delta following the passage of Hurricane Camille; nevertheless, within a year the vegetation was reestablished to pre-hurricane abundance.

In the Great Lakes, Hall and Ludwig (1975) concluded that while several emergent plant species may have special use in low-energy areas, the Great Lakes shorelines are not conducive to establishment of aquatic plants. A site investigation in northern Lake Huron revealed that bluejoint grass (Calamagrostis canadensis), great bulrush (Scirpus acutus) and rush (Juncus balticus) would not withstand high wave energy and hence were not recommended as suitable for wave attenuation. However, the authors also observed that at Cecil Bay (Lake Michigan), great bulrush and spike rush were very effective in dampening waves. Other investigations have also produced variable results. Webb and Dodd (1978) found that Gulf cordgrass (Spartina spartinae), marshhay cordgrass (S. patens) and salt cordgrass (Distichlis spicata) were more favorable stabilizers of the Galveston Bay shoreline than smooth cordgrass (S. alterniflora).

Process-oriented experiments reveal that wave attenuation does occur as waves pass over wetlands. In a laboratory experiment, Ahrens (1976) found that wave periods and wave heights were affected by artificial seaweed. There was a measurable level of wave attenuation for only the shortest wave period (2.6 sec.), and for this wave period the reduction of wave height amounted to about 12%. Wave periods in the Great Lakes commonly exceed 2.6 seconds. Random observations suggested that breaker wave periods average between 2.5 and 6.8 seconds in Lakes Michigan, Superior, and Huron during the summer months (Bruno and Hiipakka, 1973). A field experiment by Wayne (1976) indicated that smooth cordgrass reduced wave heights by 71% and wave energy by 92% in coastal Florida. Common seagrass (Thalassia testudinum), a submerged plant, reduced wave heights by a maximum of 42.2% and wave energy by 66.6%.

The impact of coastal wetlands on wave energy is not clear from the literature. Characteristics such as wave parameters, bottom topography, and vegetation types appear to be important variables. Observations on many coastal zone wetlands suggest that they provide protection from low and moderate energy waves. However, storms especially during high water conditions such as the mid-1970's reveal that many coastal wetlands in the Great Lakes are subject to erosion. At the mouth of the Huron River in western Lake Erie for example, the barrier has been eroded and the marsh exposed to wave action; between 1940 and 1972, approximately 900 acres of emergent marsh were lost (Selman et al., 1974). In Saginaw Bay an extensive offshore marsh parallels the coast of Tuscola County. However, the shoreline is characterized by transgressive beaches and washover deposits. Along many sectors of this shoreline, erosion has swept away the modern beach, exposing clayey till and higher post-glacial shorelines to wave attack. Along the western shore of Green Bay (e.g., Oconto County), storm berms and washover deposits commonly occur adjacent to emergent macrophytes. On the north shore of Lake Michigan isolated bays are often colonized by rushes. The beach deposits at the heads of the bays often consist of coarse gravels, suggesting that high wave energy environments do occur even in protected embayments.

The wave-dissipation capabilities of wetlands require further investigation. The field data from the Great Lakes suggest that some wave protection does occur in areas of emergent macrophytes as well as areas where submersed aquatic plants colonize the nearshore zones. However, the coastal areas adjacent to lacustrine wetlands reveal that over time wave erosion will occur and erosional landforms will be deposited despite the occurrence of wetland communities offshore.

IMPACT OF GREAT LAKES WATER LEVEL FLUCTUATIONS

INTRODUCTION

In recent years the nation's wetlands have received much attention. Acceptance and recognition of wetland values, supported by increased knowledge of wetland ecology and hydrology, have led to preservation efforts at the federal and state levels. Furthermore, several state agencies, particularly in Wisconsin (Wisconsin Coastal Management, 1977), Michigan (Jaworski and Raphael, 1978) and New York (Geis and Kee, 1977) have begun to develop base line wetland data on the coastal zone of the Great Lakes. Regional studies of this kind have suggested that our knowledge of coastal wetlands in the Great Lakes is only beginning to emerge.

Investigations regarding the effects of water level fluctuation on freshwater wetland cover a wide spectrum of wetland habitats. However, most of these studies have involved inland wetlands where water levels are managed within a confined system. For example, the investigations of Mathiak (1971), Harris and Marshall (1963), and Kadlec (1962) focused on managed marshes where summer drawdowns and fall reflooding were used to encourage the growth of selected aquatic plants which are most beneficial to waterfowl.

The coastal wetlands of the Great Lakes differ in several ways from inland wetlands, especially with regard to marine and littoral processes. The coastal wetlands are subject to temporary short-term water level changes. Seiches, which impact the wetlands adjacent to the shorelines, commonly occur in the coastal zones in Lake Erie, Lake St. Clair, and in Green Bay. Longer-term water level changes, related to water budgets of the lake basins, also impact on the coastal wetlands. Such fluctuations, occurring over a period of approximately seven to ten years, may cause vegetation dieback, erosion of the wetlands, or lateral displacements of the wetlands. Coastal wetlands, such as in Tuscola County, Michigan (along Saginaw Bay) and in Oconto County, Wisconsin (along the Green Bay), are exposed to wave action, a condition not normally occurring in inland wetlands.

Coastal wetlands along the Great Lakes do not appear to exhibit the aging process associated with inland freshwater wetlands. Because of the fluctuating water levels of the Great Lakes, constant rejuvenation of wetland communities occurs. Diagrams in textbooks illustrating the gradual senescence of freshwater wetlands are more applicable to inland wetlands of the glaciated Midwest than to Great Lake wetlands. As outlined by Moore and Bellamy (1974), many inland freshwater wetlands undergo senescence and terrestrialization as a result of the formation of secondary and tertiary peat deposits. Peat mining, an economic activity in which Michigan leads in annual production, is centered primarily in senescent, inland wetlands.

Coastal wetlands often display a diversity of landforms normally not found in other wetland environments; owing to changes in the water levels of the Great Lakes since the retreat of the Pleistocene ice sheets, landforms such as coastal barriers, deltas, and natural levees have been deposited. These features represent the geomorphological heritage of the Great Lakes wetlands. The fluctuating water level of the Great Lakes is an important variable in determining many of the distinguishable characteristics of the coastal wetlands as well as the landforms the wetlands occupy.

In the Great Lakes area, some data have been gathered as to the economic value of the coastal wetlands. However, the ecological and hydrological functions of wetlands are yet to be determined so that more complete values may be documented. For example, Table 16 reveals that the economic value of Michigan's coastal wetlands with regard to fish, wildlife, and non-consumptive recreation uses totals $489.60 per acre of wetland per year. Benson and Perry (1965) reported that an average acre of marsh in New York state had an annual net value of $20 per acre per year. However, if these data are brought up to date with a cost-of-living factor, an annual value of $780 per marsh acre is attained.

Table 16

Fish, Wildlife, and Recreational Value of
Michigan's Coastal Wetlands, 1978

Sport Fishing	$286.00/acre/year
Non-consumptive Recreation	138.24
Waterfowl Hunting	31.23
Trapping of Furbearers	30.44
Commercial Fishing	3.78
Total	$489.69

Jaworski and Raphael (1978)

A wetland inventory of the coastal wetlands in Michigan (Michigan Department of Natural Resources 1973) has revealed that the state has 105,855 acres of coastal wetland. Therefore, the value of Michigan's coastal wetlands, with regard to fish, wildlife, and recreation, is $489.69 x 105,855 acres, or $51.8 million annually. However, the areal extent of the wetlands changes with fluctuating water levels and consequently economic values and functions for fish and wildlife change as well. It is widely known that optimum waterfowl habitat requires approximately 50 percent marsh and 50 percent open water (Weller and Spatcher, 1965). If the marsh/open water ratio increases, the value of the wetland as waterfowl habitat will probably decrease. other functions, such as nutrient uptake, sediment trapping and coastal protection, may also vary as the water levels of the Great Lakes fluctuate.

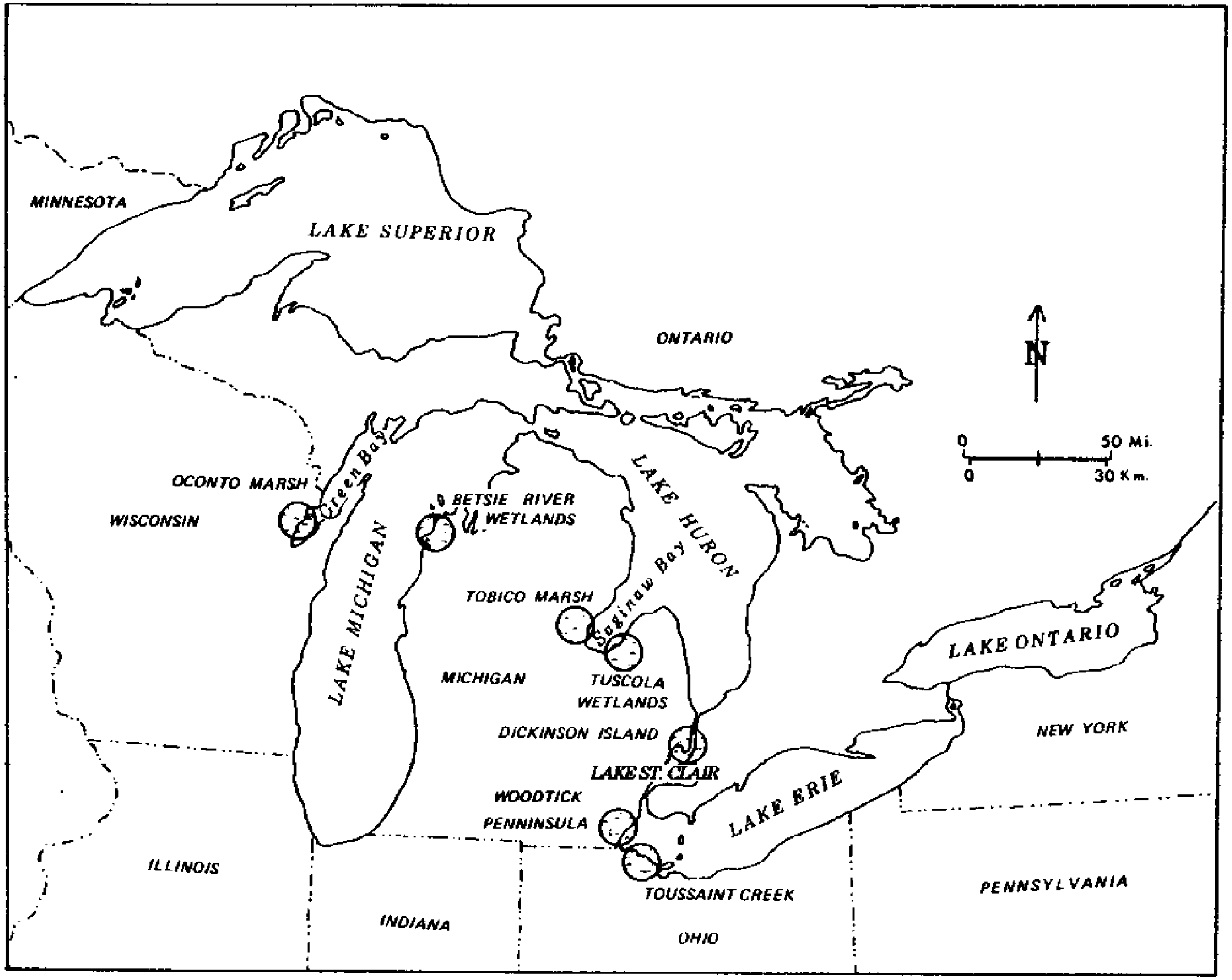


Figure 13. The Great Lakes and the Location of the Selected Study Areas

Objective

The objective of this study was to document changes in the areal extent and plant community composition of coastal wetlands of the Great Lakes in response to periodic water level fluctuations. More specifically, field bisect and aerial photograph techniques were tested with regard to understanding long-term hydrarch successional trends in the coastal wetlands. Particular attention was given to water depth, wave energy, and substrate type in an effort to develop a simple graphic model for predicting the extent of plant community type of coastal wetlands at any lake level. Because coastal environments are slowly changing in a geologic sense and are subject to wave action, the geomorphic trend and the wave climate of the wetlands were also investigated.

Specific objectives of the study are listed below.

1. To describe the geologic features and trends in the recent geomorphic history of each of seven wetland study areas.

2. To survey a field bisect across the environmental gradient of each wetland study area, with particular attention given to documentation of plant community types, water depth, and substrate type.

3. To map the distribution of the wetland communities at low, average, and high-water level conditions and to determine the areal extent of each community at each of these selected lake-level conditions.

4. To prepare photo transects, representing each of the time periods under investigation, for each wetland study area which will document the dieback and re-establishment of wetland communities in response to lake level fluctuations.

5. To review the effect of lake level fluctuations on the coastal wetlands with regard to:

a. the geologic frame work (coastal types) of the coast.
b. the area of coastal wetlands temporarily lost or gained as a result of lake level fluctuations.
c. changes in the plant community types during periodic water level fluctuations.
d. future management of the coastal wetlands.

Study Areas

Seven wetland study areas in three of the five Great Lakes were selected for investigation (Figure 13). An attempt was made to choose wetlands which exhibited a diversity of landform types and plant communities. Table 17 indicates the wetlands which were selected for field investigation. In some cases two wetlands were selected from one lake. However, there was enough geomorphic and biogeographical diversity to justify that selection.

Table 17

Location of Great Lakes Coastal Wetlands Selected as Study Areas

Wetland	County/State	Local Water Body	Great Lake
Oconto River Marsh	Oconto/Wisconsin	Green Bay	Michigan
Betsie River Wetlands	Benzie/Michigan	Betsie Lake	Michigan
Tobico Marsh	Bay/Michigan	Saginaw Bay	Huron
Tuscola County Wetlands	Tuscola/Michigan	Saginaw Bay	Huron
Dickinson Island Wetlands	St. Clair/Michigan	Lake St. Clair	St. Clair
Woodtick Peninsula Wetlands	Monroe/Michigan	Lake Erie	Erie
Toussaint Marsh	Ottawa/Ohio	Lake Erie	Erie

Included in the study are deltaic coastal wetlands (Dickinson Island), barrier/lagoon complexes (Tobico and Toussaint Marshes), and nearshore wetlands (Tuscola County). The Betsie River wetlands were also investigated. Coastal wetlands along eastern Lake Michigan per se are less abundant and appear atypical compared to those found else-where in the Great Lakes. In a strict sense, the Betsie River wetlands are estuarine and associated with river floodplains rather than with coastal landforms. However, this type of wetland is common in the Lake Michigan basin. Because the embayments are hydrologically connected to Lake Michigan by rivers and the wetland vegetation does respond to changing lake levels, the Betsie River wetlands were included in this study.

Methods

This investigation is primarily a field-oriented project. Since there is a general lack of wetland and landform mapping, considerable effort was devoted to acquiriing data from the field. Two field seasons were scheduled, one from June through August, 1977, and the other from May through July, 1978. During these times the wetland vegetation and the landforms were identified, mapped and investigated in detail.

The landforms of the coastal wetlands were mapped in the field with the aid of U.S. Geological Survey (U.S.G.S.) topographic maps and black and white aerial photographs. A significant constraint on landform mapping was the quality of the aerial photography. The date and scales (which varied from 1:6000 - 1:25,000) were of primary importance. After the landforms were mapped, selected features were surveyed with a transit level and borings were taken. After these data were developed, stratigraphic cross sections were constructed and the geomorphic framework of the selected wetland discussed.

Concurrently, with the aid of aerial photographs, the wetland vegetation was mapped. Vegetation bisects were taken, often along the same line as the landform survey. The plant species, water depth or depth to ground water, elevation, and substrate types (based on megasopic field examination) were noted and recorded. To determine wetland vegetation changes over time, older aerial photography was used and the vegetation pattern interpreted.

An attempt was made to characterize the wetland vegetation distribution during high, low, and "average" lake level conditions. However, available aerial photography did not exactly coincide with high and low water levels. For example, the record low lake level in Lake Erie was in 1935 (567.62 ft.). The only available photography of western Lake Erie which may have reflected the low-water vegetation of 1935 was, in fact, a flight made in August, 1937. Therefore, slight offsets between specific water levels and period of wetland mapping do occur in this report. Once the mapping was completed and the field bisect surveyed, two additional transects, representing higher and lower water levels, were constructed. The constructed transects follow the path of the field-generated bisect when the field bisect and the two photo transects are presented together, so that dieback and re-establishment of wetland plant communities in response to fluctuating lake levels can be analyzed.

GEOMORPHIC FRAMEWORK OF SELECTED GREAT LAKES WETLANDS

The occurrence, distribution, and diversity of coastal wetlands is, in part, determined by the morphology of a coast. Perhaps in no other geographical environment is the relationship between landforms and vegetation so evident. With the use of aerial photographs, which depict a vegetated coastal landscape, subdued landforms and slight variations in slope can be identified. A theme emphasizing vegetation and landform or physiographic-ecologic relationships is not new and can in fact be traced back to at least 1901 (Cowles). In the coastal ocean, particularly in tropical zones, interrelationships between wetland vegetation and landforms have been mapped and studied (Godfrey and Godfrey, 1973; Thom, 1967; Vann, 1959). However, compared to these marine studies, landform/vegetation associations in the Great Lakes basin have largely been ignored.

Black (1973) formulated a geologic framework of the wetlands of Connecticut with the aim of placing the state's wetlands in a physical perspective. All wetlands occur in depressions created by nature or more recently by man. These topographical lows may be erosional in origin, such as depressions found in the glaciated areas of the United States (including the Great Lakes). Other examples include wetlands of depositional origin. The St. Clair River delta is being deposited in a depression and is one of the finest wetlands in the Great Lakes. In either case, wetlands are initiated by some geomorphic or geologic process. Other detailed studies suggest that wetland occurrence is related to sediment types. Black (1973) notes that wetlands in which swamp deposits are underlain by glacial outwash or alluvium consisting mostly of sand or a mixture of sand and gravel are more widespread than wetlands underlain by glacial till and bedrock, or by silt and clay.

There has been little concern and appreciation, until recently, for the physical framework of coastal wetlands. One reason for this is the emphasis upon wetland vegetation *per se*, or the growing interest in productivity as viewed by biologists. The boundaries or margins of wetlands, for example, are often looked upon as taxonomic breaks and not very often related to changes in sediment and/or slope.

A second reason is that the geomorphology of the coastal areas of the Great Lakes has yet to be undertaken. Primary research efforts, especially during the high water levels of the early 1970's, has been directed towards bluff erosion and coastal flooding (Seibel et al., 1976; Bryan, 1976). Additional investigations concentrate on the nearshore zone. Fox and Davis (1976), for example, studied the relationship of storm patterns to waves and longshore currents in Lake Michigan. Landform investigations have generally been confined to unraveling the problems of the glacial history of the region, but there are a few exceptions to this trend (Larson, 1976; Fraser, et al., 1974; Pezzetta, 1968; and Pincus, 1960). Additional geomorphic studies are cited throughout the text. It may be concluded however, that considering that the Great Lakes have 3,400 miles of mainland shoreline, coastal investigations have been few.

The pending National Wetland Classification (Cowardin et al., 1977) does recognize a need to integrate pertinent landform and wetland vegetation data. The ecological systems (Estuarine, Palustrine, Lacustrine, and Riverine) of the new classification consider the nature of the wetland base (i.e., bedrock or unconsolidated sediment). Furthermore, the character of the wetland bottoms are subdivided into two subclasses and include geologic terms such as sand, mud, and boulders. Also, the Lacustrine System includes all habitats where a wave deposited feature (beach or barrier) or bedrock shoreline feature forms all or part of the wetland boundary. Other similar subcategories may be cited; however, what is significant is that the classification considers the physical framework of the landscape.

The geomorphic framework (sediments, slopes, and landforms) of the coast contributes to an understanding of the areal extent, type, and seasonal flooding of a wetland. The distribution of landforms in a given wetland determines the boundaries of the wetland. The upland limit of a wetland may be designated as a boundary or contact between soil that is predominantly hydric and soil that is predominantly nonhydric; hydration is a factor determined largely by elevation and slope.

The boundaries of a wetland are its greatest weakness in terms of definition. Greulich (1975) emphasizes that it is at the wetland boundary where most arguments will develop and where it is most difficult to enforce legislation. As noted in southeastern Michigan (Jaworski and Raphael, 1976) industrial/urban encroachment in coastal wetlands develop from the edges inward; a wetland is most susceptible to disturbance at its perimeter.

Flooding is not uncommon in Great Lakes wetlands (Bryan, 1976). Inundation of coastal zones in southeastern Michigan (U.S. Army, 1976) and in Green Bay (Wells, 1977) prompted an awareness of the problem. Niering (1973) refers to flood plains as "geomorphic safety valves" which are an integral part of the river system. The Great Lakes wetlands provide a similar service. As topographic depressions, the coastal wetlands and connected floodplains serve as temporary water-storage areas, especially during storms. In fact, the coastal lagoons are often looked upon as "coastal flood plains" and function like river flood plains during short higher-water periods.

This report illustrates that the vegetation communities of a given wetland may be diverse (St. Clair River delta) or somewhat monotypic (Oconto River). The diversity at St. Clair is related to a variety of landforms associated with the complex geomorphic history of the area. North of the Oconto River, on the other hand, the wetland surface is composed of fewer landform types and is predominantly characterized by grasses, sedges and willows. The natural diversity of wetland habitat is dependent upon topographical diversity, so a knowledge of landforms and related physical elements such as sediment types is essential to an understanding of wetland distributions. This is highly significant in the Great Lakes Basin where such factors as tides and salinity play a minor role.

Wetland occurrence in some areas is related to seasonal or periodic flooding which, in turn, is related to slopes, hydraulic character of streams, soil, porosity, and so forth. In fact, limits of annual flooding may be considered for a wetland boundary. The upland limit of a wetland may be designated as the boundary between land that is flooded at some time and land that is never flooded during years of normal precipittion (Cowardin et al., 1977).

Another useful relationship between wetlands and the morphology of a coast is related to the stability of the shoreline. Shorelines may possess similar topographical features (barriers and lagoons). However, when viewed in cross section, barriers which are topographically similar may have been formed by different coastal processes. A thin barrier beach underlain by organic sediments usually represents a shoreline which is dominated by a history of erosion or is transgressive. Conversely, a thicker barrier-sand sequence interfingered with the adjacent sediments is usually indicative of a more stable shoreline. If the coastal barrier remains intact over several years, the possibility of maintaining an adjacent coastal wetland is greatly increased.

Many Great Lakes wetlands are dependent upon barriers for protection. The barrier and associated beach in a broad sense is ecologically an integral part of the wetland. Not only does it protect the adjacent wetland but supports wildlife which is wetland dependent. This is particularly the case with avifauna which rest and nest on barriers and feed in the wetlands. Further, the Conservation Foundation (Clark, 1976) concluded that barriers contain extraordinary high natural values for fish and wildlife habitat and for outdoor recreation, and are often places of rare beauty as well. LaRoe (1976) concludes that wetlands are among the most important benefits of coastal barriers. Although the coastal barrier is a landform entity, it does play a significant biological role in terms of wetland protection and wetland function.

Wave Processes

The transport, deposition, and removal of organic and inorganic sediments in coastal zones are fundamentally determined by wave energies which are dictated by the wind. Furthermore, the severity of wave energy input at a given location depends on the prevalence of strong onshore winds, open water fetch, submarine topography, and the amount of natural and artifical protection present ((Brater and Seibel, 1973). An integral factor related to wave energy is the height of waves, which is principally governed by the fetch. As waves arrive at the shoreline, the wave energy is decreased due to shoaling.

Normally, as waves arrive at the shoreline wave parameters, including wave energy, are modified by changes in bottom topography. The depth to which a wave is effective (wave base) is dependent upon its wave length. In general, the wave base is approximately equal to one-half of the wave length. As waves move into shallow coastal water or pass over sand bars; the depth is less than one-half of the wave length and several modifications occur. The velocity and wave lengths decrease. Wave height first diminishes as the ratio of water depth to wave length falls below 0.5, but when this ratio becomes less than 0.06 the crest of the wave rises (Bird, 1969). With a corresponding decrease in wave length and increase in height, the wave steepness (H/L) increases to a point where a wave can no longer support itself; the wave crest then breaks and falls forward.

Deep water energy/wave height relationships in the Great Lakes reveal that as wave height increases the wave energy increases geometrically (Seibel, 1972). Thus a wave height of two feet has a wave energy of 40 foot pounds per square foot. If the wave height is doubled (four feet) the expected wave energy is 130 foot pounds per square foot. These modifications are governed by water depth-wave length relationships. Owing to changing water levels in the Great Lakes, the point at which waves break is not constant. If we assume no changes in bottom topography, during higher lake levels waves will break closer to the shoreline, whereas during lower lake levels waves will break farther offshore or several lines of breakers will occur, gradually diffusing the energy of the waves over a greater linear distance. Higher water levels, such as in the early 1970's, a long fetch, and storm surges appear to be principal factors related to coastal erosion in the Great Lakes.

Most wetlands in the Great Lakes occupy protected environments. In the investigated areas, all wetlands are either protected by a coastal barrier (Tobico), occur in protected embayments (St. Clair Delta), and/or are characterized by gently sloping and shallow bottom topography (Tuscola County). It has been suggested that the nearshore wetlands protect the shorelines from erosion. A study in the Gulf coast of Florida suggests that Spartina alterniflora reduced wave heights by as much as 71 percent and wave energy by 92 percent over a distance of 60 feet (Wayne, 1976). Common sea-grass (Thalassia testudinum) reduces wave heights by a maximum of 42 percent and wave energy by 67 percent. Other field studies summarized by Jaworski et al. (1977) tend to support the idea that wetlands afford some coastal protection. Conversely, wave tank tests reveal that only with very short period waves are plants significant in attenuating wave action (Ahrens, 1976). For a 2.6 second period, the reduction in wave height on passing through the artificial seaweed field was about 12 percent.

Nearshore wetlands, such as those in Tuscola County, may offer some coastal protection to the adjacent shoreline. However, our investigation of coastal landforms suggests that erosion is the dominant process even when wetlands are present in the nearshore zone. There is an absence of depositional features such as well-developed beaches and recent fore-dunes. In fact, the landforms on many barriers investigated are a product of high wave energies (e.g., washover deposits).

Pre-modern Lake Level Changes

Beaches and barriers occur at the land/lake interface. In the geologic past, the level and consequently the shorelines of the Great Lakes occupied positions which are quite different from the present. Owing to changing outlets, a complex of shorelines was established above as well as below the present levels of the Great Lakes. Each lake basin has a unique history, so the location and elevation of shorelines in the Michigan-Huron Basin do not necessarily conform to location and elevations of the shorelines in the Erie Basin.

With the retreat of the ice during the Pleistocene Epoch, a series of sediments was deposited. These deposits include glacial tills deposited directly by the late Wisconsin ice, as well as water-laid sediments such as lake clays and glacial outwash sediments which were deposited by water. These Pleistocene sediments were deposited directly upon geologically older bedrock.

The thickness of the deposits is extremely irregular. In the Great Lakes basin, drift thicknesses range from 0 to at least 223 feet (Flint, 1971). Seibel (1976), however, reports glacial drift as thick as 1,100 feet in Michigan. In the St. Clair River delta, bedrock is 150 feet beneath the delta. Savoy (1956) suggests that the lake clays and glacial till have a thickness of about 51 feet, but in western Lake Erie and in Oconto, bedrock and large igneous cobbles respectively are exposed at the shoreline during lower water years, suggesting that the glacial deposits there are thin or absent. In most of the investigated sites, however, the shoreline features and wetlands are resting upon variable thickness of lacustrine clays and/or glacial till.

The Pleistocene geology of the Great Lakes is complex. However, the studies of Leverett and Taylor (1915), Hough (1958) and more recently Dorr and Eschman (1970), present a regional overview of the history of the ice age. Numerous, more detailed studies are noted by Black (1973), Thwaites (1959), Flint (1971), and Wright and Frye (1965). The proglacial lake levels listed in Table 18 are based largely on the investigations of Leverett and Taylor (1915). More recent investigations have refined the chronology (Bretz, 1955; Hough, 1958); however, it remains fundamentally unchanged.

Table 18

Lake Stages of the Michigan, Huron, and Erie Basins*

Years Before the Present	Michigan 580'	Huron 580'	Erie 573'
3,000	Algoma 595'		Erie 573'
4,000	Nipissing 605'		Erie 560'
9,500	Chippewa 230'	Stanley 190'	Erie 573'

* Data in feet above mean sea level

Lakes Michigan and Huron are presently joined at the Straits of Mackinac and are therefore at the same elevation, 580 feet above mean sea level (MSL). During the Algoma postglacial lake stage, lake levels were approximately 15 feet above their present levels. During the Nipissing postglacial lake stage, present-day Lakes Huron and Michigan were about 25 feet above present lake level. Levels of presumed Nipissing and/or Algoma age have been noted on the landward side of the investigated wetlands at Oconto, Tobico, and Tuscola County. A terrace at approximately 605 feet occurs on the perimeter of the Betsie River wetlands.

The configurations of Lake Erie's wetlands (i.e., Woodtick and Toussaint) appear to be less significantly affected by postglacial lake levels than the investigated areas in the upper Great Lakes. Detail mapping in southeastern Michigan reveals the most lakeward mappable shoreline (Elkton or Lundy shoreline at 620 feet) is at least four miles inland from the present Lake Erie shoreline (Bergquist and MacLachlan, 1951). In northern Ohio (Ottawa County) the most lakeward premodern beach deposit is pre-early Lake Erie in age (Lake Lundy) and is located several miles inland at an elevation of 620 feet (Forsyth, 1959; Conrey, 1929).

The western shore of Lake Erie appears to have been drowned, as many river mouths have an estuary-like appearance. The submergence may be related to tilting of the Erie basin, as a result of either glacial rebound or isotactic adjustments of the earth's crust (Sparling, 1967; Pincus, 1959). Moseley (1905) notes that the rate of crustal subsidence is rapid and has had a profound impact on the coastal vegetation of Lake Erie and the offshore islands. Near Sandusky Bay several square miles of what in 1820 was forest and prairie, had been transformed into marsh by 1905. An alternative explanation is that the drowned stream mouths are due to the rising of the level of Lake Erie from 560 to 573 feet over the last few thousand years, accompanied by synchronous down tilting of the south shore of the lake.

Lake St. Clair has also experienced lake level oscillations in the geologic past. As with the other coastal wetland sites discussed above, the changing lake levels accompanied by shifts in the position of the delta have combined to create landforms which, in part, dictate the wetland morphology of the delta. A more detailed analysis of the wetland/landform/lake level relationships of this area is discussed in the St. Clair River delta subsection.

Such estuarine environments contain wetland habitat which is zoologically and botanically diverse. The first estuarine sanctuary under the Coastal Zone Management Act (P.L. 92-583, Sec. 315) in the Great Lakes has been recently approved. Old Woman Creek Estuarine Sanctuary between Huron and Erie, Ohio appears to be geomorphologically similar to the river valleys discussed above. The estuary is considered important for fish spawning, for waterfowl migration and for wetland plants. Pinkweed (Polygonum pennsylvanicum var. eglandulosum), which is included in the proposed federal endangered plant species list, also occurs in the area (U.S. Department of Commerce, 1977).

Another significant relationship between pre-modern lake level changes and coastal wetlands is the age of the wetlands. Most of the Lower Peninsula of Michigan and adjacent areas (Ohio, Wisconsin) were exposed by the glacial ice some 12,000 years ago (Lake Calumet and Lake Lundy Stages), but the Great Lakes reached their present levels less than 3,000 years ago (Table 18). This means that the coastal wetlands are geologically young compared to the inland wetlands which established themselves several thousands of years earlier. Therefore, thick peats and plant succession are as a general rule limited to inland wetlands.

Modern Lake Level Changes

All the Great Lakes, as well as Lake St. Clair, experience changes in water levels due to short-term and long-term weather and climatic conditions. Steep barometric gradients may produce brief changes in water level (seiches), particularly in Lake Erie (Hough, 1958). Wind set-up and storm surges also cause sudden periodic changes in lake level (U.S. Army, 1975). Although storm-related changes of lake level may be spectacular, their impact on wetland distribution is less significant than seasonal or longer period fluctuations.

The short-term level of the lakes is determined by the inputs of water derived from runoff or river flow of connecting channels and precipitation within the drainage basin of each lake, and the outputs resulting from evaporation. Long-term lake level fluctuations are usually thought of as volumetric changes, predominantly climatic in origin (Duane et al., 1975). Changes in the storage of a lake may be summarized as follows:

$$S = (P-E) + (I-O)$$

Where: S = change in storage volume
P = Precipitation in the drainage area
E = Evaporation
I = Inflow
O = Outflow

Although non-cyclic, the water levels appear to have a high water period and a low water period every seven to ten years (Figure 14). These non-cyclic water level changes cause displacement of shorelines and changes in vegetation.

Reliable records of water levels for all of the Great Lakes date back to 1860. Since 1898, continuous data have been recorded for Lake St. Clair. A detailed analysis of levels and flows of the Great Lakes was compiled in 1975 (Great Lakes Basin Commission, 1975). Annual high lake levels normally occur in mid-summer (June, July), and seasonal lows occur during the winter months. With regard to the investigated areas the historical maximum high water and minimum low water period occurred between 1934 and 1974 (Table 19).

Table 19

Record Maximum and Minimum Monthly Lake Levels Since 1900*

	High (year)	Low (year)	Range	1900-1977 Average
Lake Michigan/ Huron	581.1 (July, 1974)	575.4 (March, 1964)	5.7	578.71
Lake St. Clair	576.2 (June, 1973)	569.9 (Jan., 1936)	6.3	573.87
Lake Erie	573.5 (June, 1973)	567.5 (Dec., 1934)	6.0	570.96

* Data in feet above mean sea level
Source: National Oceanic and Atmospheric Administration, 1976

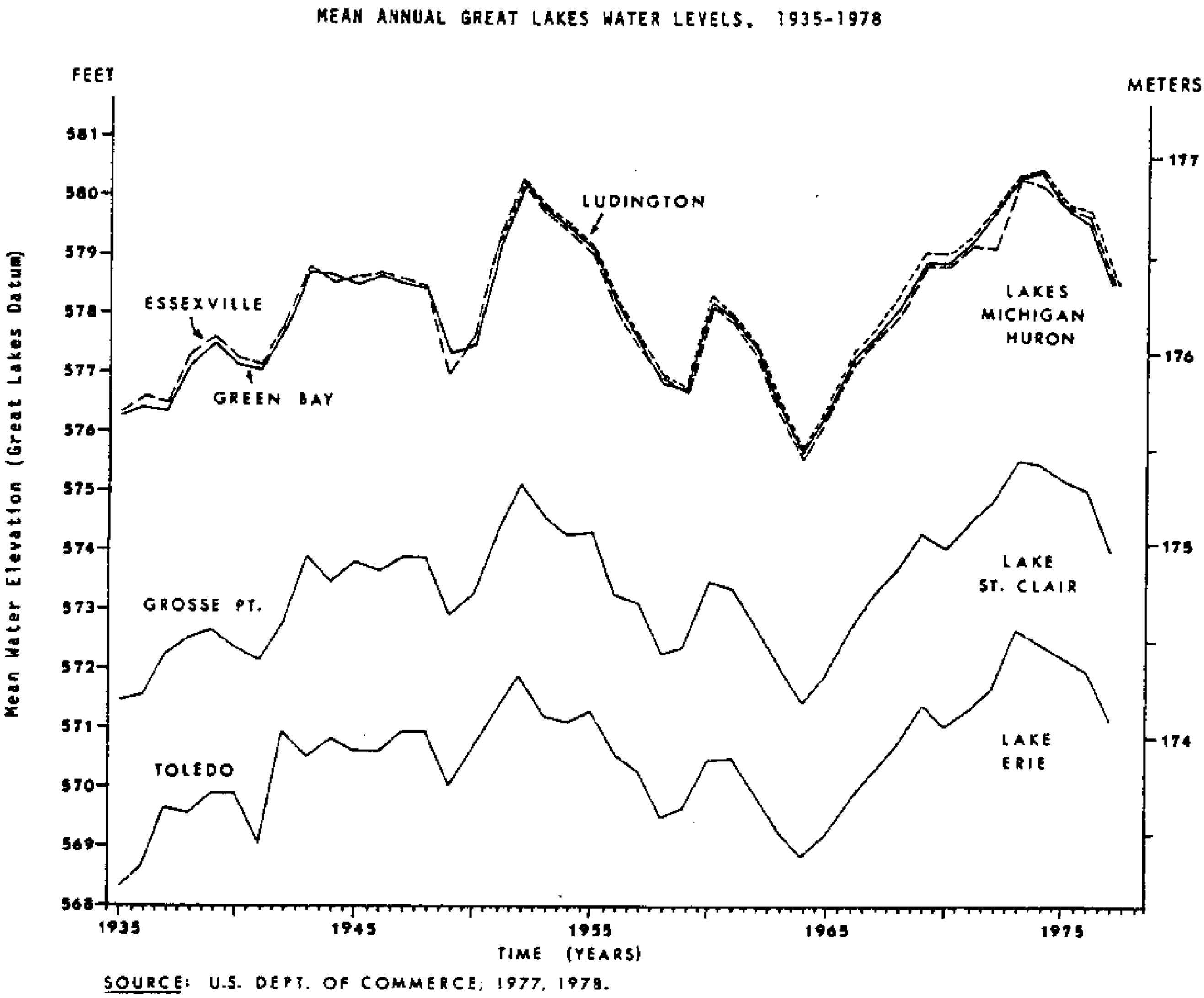


Figure 14. Lake Level Elevations of Lakes Michigan, Huron, St. Clair, and Erie, from 1935 through 1978

Aerial photography became availale after about 1935. Photography at that time in Lake St. Clair and Lake Erie reflected record low lake levels and maximum lakeward extent of the shorelines. The record low in the Michigan/Huron basin was in 1964 (575.4 ft.). The aerial photography of the 1973-1974 period reflected record high lake levels for all the coastal wetlands investigated. Within a range of 40 years (1934 to 1974) the coastal sites investigated have been exposed to extreme historical lake level changes.

Geomorphic Analysis of Selected Sites

In this subsection the coastal framework of each study area is discussed. An attempt has been made to select wetlands which exhibit a diversity in their physiography and wetland communities. Low-lying coasts generally consist of a barrier and lagoon such as those at Tobico, Woodtick, Toussaint, and Oconto. The Betsie River wetlands and the wetlands of Tuscola County are somewhat unusual. The Betsie River wetlands occur within a river valley, but since they are affected by changing levels of Lake Michigan they are included in our survey. Many of the wetlands of Tuscola County are not protected by a sand barrier. The seventh site, the St. Clair River delta, is the largest active delta in the Great Lakes and has a unique framework as well.

To adequately describe each coastal wetland area, the landforms were identified and mapped. All landforms have topographical or horizontal as well as vertical expression. Therefore, the investigated sites were bored so that landform boundaries and stratigraphic relationships could be determined. In a few areas, recorded data were available from the U.S. Army Corps of Engineers, state geologic agencies or consulting firms, which contributed to the geomorphic framework.

Oconto Marsh

Wisconsin's coastal wetlands total 34,088 acres, of which 18,349 acres are on Lake Michigan and Green Bay (Bedford et al., 1976). The remaining 15,819 are scattered in small embayments on Lake Superior. In terms of area the wetlands to the immediate north and south of the Oconto River total 6,489 acres or approximately 20 percent of the state's coastal wetland acreage (Bedford et al., 1976). The Oconto Marsh and other wetlands in Green Bay, including Peshtigo and Ridges Sanctuary, are unique wildlife areas visited by over 30,000 people each year (U.S. Department of Commerce, 1977). All of Oconto Marsh and its shoreline has been classified as outstanding with respect to fish and wildlife habitat (Wisconsin Coastal Management Program, 1977).

Prior to the ice age, the Oconto River joined the Peshtigo and Menominee Rivers to the north. The three preglacial rivers drained across Door Peninsula at Sturgeon Bay and into an ancient river in the present-day Lake Michigan Basin (Martin, 1932). Approximately 6700 years ago (during Lake Chippewa time) Green Bay was completely drained (Bertrand et al., 1976). During this time the rivers, including the Oconto, extended outward, joining other rivers, and flowed northward along the axis of Green Bay. With the subsequent rise in lake level during and since the Lake Nipissing Stage (5000 years B.P.) the ancient channels have been drowned. However, bathymetry (U.S.G.S. quadrangle map, Oconto, Wisconsin, 1956) does reveal a sinuous channel extending offshore from the mouth of the Oconto River eastward towards the center of Green Bay.

In more recent time the river has shifted its channel several times due to sedimentation and a decrease in channel gradient. Modifications to the mouth of the Oconto River began as far back as 1879. Prior to that time the natural outlet of the river was approximately one-half mile south of the present outlet. The old sinuous meander is still evident in the field and on aerial photographs (Figure 15). The natural mouth of the river split into three channels, forming a small delta at the shoreline. The U.S. Army Corps of Engineers straightened the river and continuous flow through the original channel was abandoned (Bosley, 1976). With the construction of jetties there appears to have been a decrease of sediment supply to the shoreline of the Oconto River. Historical maps (Bosley, 1976) indicate that the shoreline became more irregular and old meander channels were truncated at the shoreline as coastal erosion proceeded.

The distribution of wetlands in lower Green Bay is related to the regional geology of the area. The bedrock surrounding the basin is part of the Michigan Basin. The rocks dip to the southeast and trend or strike northeast/southwest. Because of the regional dip of the rocks, the east shore of Green Bay (Niagara Dolomite) is steep, the rivers are short, and the drainage basins are small. Sedimentation is not abundant on the east shore of the bay. In contrast, the rivers (Little Suamico, Pensaukee, Oconto, Peshtigo) on the west shore flow down the dip of the sedimentary rocks of Cambrian Sandstone, Prairie du Chien Dolomite, Platteville-Galena Dolomite, or Limestone. The gradual slope of these rocks out into the bay and the larger drainage area (hence greater sediment source) have been important determinants for wetland establishment along the western shore of Green Bay.

The wetlands of the Oconto River as well as all other wetlands in Green Bay are located within the Eastern Ridges and Lowlands Province of Wisconsin. Topographically the area is flat to gently rolling. The soils of the wetland are mapped as "Marsh" (U.S. Department of Agriculture, 1972). However medium-size sands occur at shallow depths. Although no bedrock is exposed in the area, wells in the vicinity have encountered dolomite bedrock between 34 and 38 feet (Wills, personal communication, Director of Public Works, Oconto, Wisconsin). Coarse sediments which include gravels and igneous boulders of granite are exposed on the shoreline. This suggests that glacial till, at least along the present shoreline, occurs at a shallow depth. The landforms of the Oconto wetlands are mapped and identified on Figure 15. Basically the wetlands occupy the interface of a fluvial and a marine environment. That is, the occurrence of wetlands is directed by marine landforms such as lagoon/barrier distribution as well as riverine landforms such as abandoned channels. The Oconto River forms a delta with one distributary channel which is artificially maintained for navigation. According to traditional deltaic classification the Oconto River forms a cuspate delta (Strahler and Strahler, 1976). The depositional feature is widest between the city of Oconto and the mouth of the Oconto River. To the north and south the delta becomes narrower and eventually pinches out where the higher surface meets the shoreline.

The landward limit of the wetland and delta is the higher terrain to the west. The contact is delimited by the contrast in land cover (i.e. agricultural

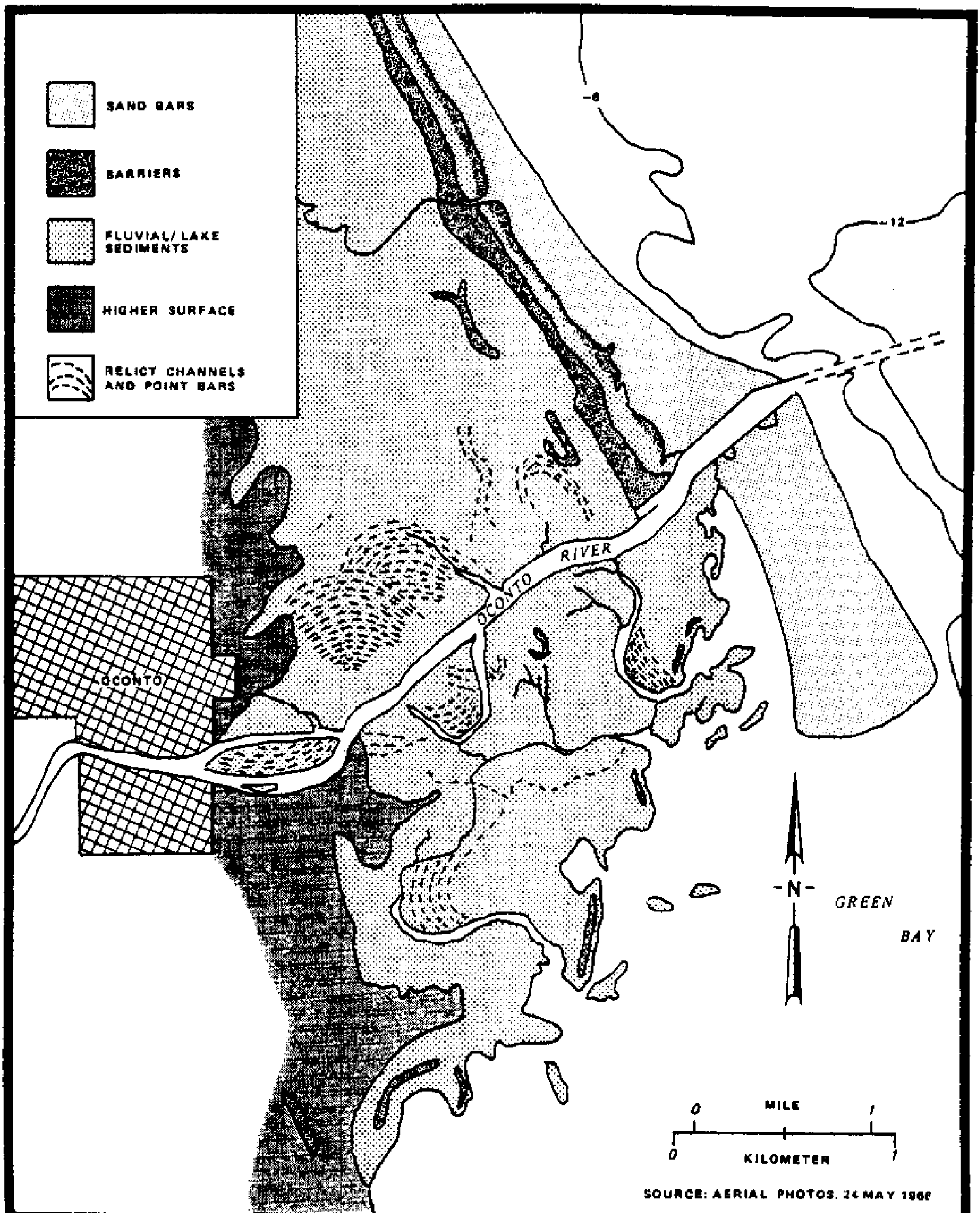


Figure 15. The Coastal and Fluvial Landforms of the Oconto Marsh

fields on a terrace and pasture or marsh on lower land). A slight break in topography also separates the two surfaces. Based on a detailed topographic map, the difference in elevation between the marsh surface north of the Oconto River and the adjacent upland at the city of Oconto is three feet (Wills, 1977). However, as one proceeds westward four to five miles, elevations rapidly increase to over 660 feet above mean sea level. The higher surface is composed of ancient beaches and glacial till. Existing beaches which represent Lake Algonquin and Lake Nipissing have been reported in the county (Leverett and Taylor, 1915; Goldthwait, 1906). The data have been synthesized and the shorelines mapped in Green Bay by Martin (1932). The Algonquin shoreline is 40 feet above Lake Michigan (ca. 620 feet above MSL) at Oconto and parallels the present shoreline. The abandoned beach of the Nipissing stage is approximately 20 feet above Lake Michigan (ca. 600 feet above MSL) at Oconto and also parallels the present shoreline. Both ancient shorelines appear to consist of multiple ridges.

The consistency of the sediment is sand or loamy sand and is identified as the Tedrow loamy fine sand association (U.S. Department of Agriculture, 1972). North and northwest of Oconto, isolated areas of glacial till consisting of loamy to clayey soil occur and can be distinguished from the sandier soil by slightly higher elevation and gravelly surface.

The actual contact of the wetland and higher surface is at an elevation lower than the Nipissing lake level. The crest of the higher surface at Oconto is at approximately 586 feet above MSL, considerably lower than the Nipissing beach which has been identified at an elevation of 600 feet above MSL. According to Willman (1971), the Algoma Lake stage is the lowest terrace level above present Lake Michigan, and Paull and Paull (1977) have suggested that the Algoma surface is 10 to 15 feet above the present level of Lake Michigan. Quite possibly the higher surface on Figure 15, at an elevation between the Nipissing level and the present Lake Michigan levels, represents the Algoma level.

As can be seen on Figure 15, the modern surface is composed of riverine landforms such as point bar topography and broad meanders as well as coastal landforms (beaches and barriers) commonly observed on coastlines. Two cross sections were constructed north of the Oconto River (Figure 16). The most northerly cross section, which is more detailed, reveals a series of unique barriers lakeward of a broad lagoon. A second cross section parallels the left bank of the Oconto River. The intent of the latter cross section is to illustrate, in overview, the relationship of the higher surface to the modern surface. The elevation of the higher surface is based upon a topographic map compiled by Wells (1977); the topography of the modern surface was determined with a barometer. A dumpy level was used to determine the elevations of the barrier and lagoon cross section to the north.

Casual inspection of the mapped shoreline reveals a smooth and straight coast north of the Oconto River. South of the river the shoreline is ragged and interrupted by embayments and abandoned channels. The immediate nearshore topography is characterized by at least seven well-developed sand bars. The bars are continuous north of the Oconto River, but they extend less than one mile south of the river. The generalized surface currents of lower Green Bay

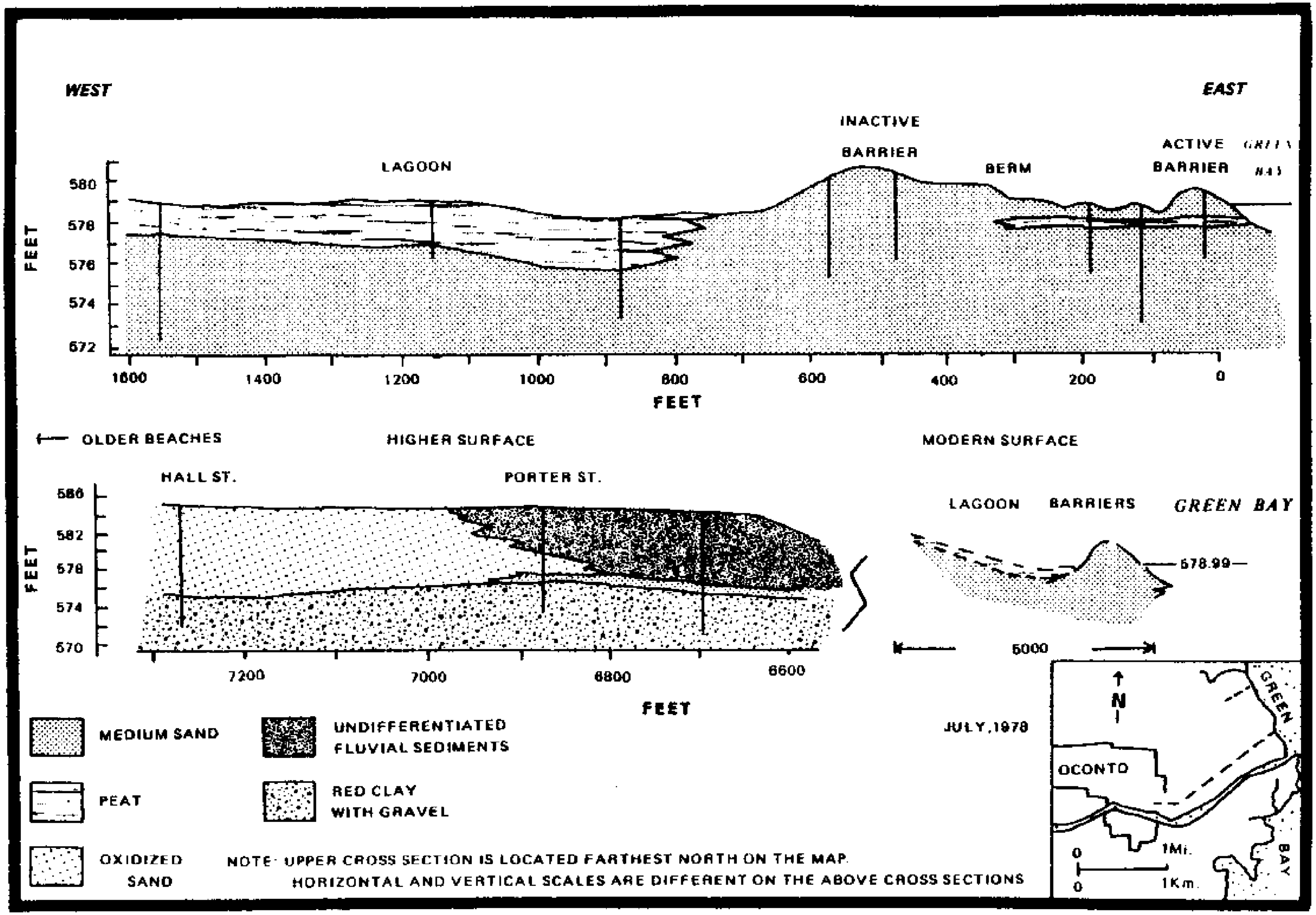


Figure 16. Selected Stratigraphic Cross Sections of the Oconto Marsh

circulate in a counterclockwise direction (Schrufnagel, 1966). The well-developed barriers and the continuous sand bar development north of the Oconto River jetties indicate that the prevailing littoral currents are moving from north to south. The distribution of sand bars is important to the contrasting character of the shoreline. The shoreline north of the Oconto River is protected from direct wave attack by nearshore sand bars, but south of the Oconto River less sediment is available to maintain the shoreline. Hence, sand bars are less extensive and the shore is exposed to direct wave attack. In this area beaches are discontinuous, narrow, and subdued compared to the barrier to the north.. As a result, the wetland is exposed to constant wave attack and has deteriorated over time.

As noted in the cross section, the shoreline north of the Oconto River is composed of an active and inactive barrier, and a lagoon. The active barrier is apparently ephemeral since it does not appear on 1973 aerial photographs. Beach studies on Lake Michigan (at Terry Andrae State Park, Wisconsin) indicate that as lake levels rise beach erosion occurs, and approximately 25 percent of the loss is due to the drowning effect of rising water level (Dubois, 1975). North of the Oconto River, the active barrier will be occasionally inundated and eroded during periods of higher water levels.

Borings into the active barrier reveal a series of peats between layers of medium sand (Table 20). The barrier, composed of medium brown sands, stands less than two feet above lake level. Although poorly vegetated, the depositional feature is barely visible because of marsh vegetation to the east and to the west. Along some areas of the shoreline, the low barrier has been recently overtopped by waves and displaced landward 30 to 40 feet. Remnants of older barriers or exposed bars occur between the active barriers and the inactive barrier to the west. These features are subdued sand deposits now colonized by wetland vegetation. Each may possible represent a barrier which was active during a higher water level.

Table 20

Sediment Profile on Oconto Shoreline

Inches	Sediment Types
0-16	Medium brown sand
16-18	Black peat; loose rafted organic remains
18-23	Brown root mat; fibrous
23-42	Medium brown sand

Beneath the active barrier are peat deposits. The organic layers extend from the nearshore zone landward under the active barrier, a distance of at least 300 feet. Although not noted in Figure 16, probes in the nearshore zone suggest that the peat extends more than 50 feet beyond the beach. In the immediate nearshore zone the fibrous peat is exposed approximately one foot below present water level.

Table 20 indicates that two organic textures were identified. Directly beneath the active barrier, rafted loose organic sediments overlie a firmer peat. What is exposed at the shoreline and occurs landward is only the firmer peat; no rafted fragments have been identified. The peat is largely composed of Scirpus roots, indicating that this organic deposit represents an emergent wetland. Since the deposit is at 578 feet above MSL and is composed of Scirpus it may represent a nearshore emergent wetland maintained during higher water levels. At the toe of the inactive barrier a well-defined berm has been noted at an elevation of 580 feet above MSL. Characterized by clastic sediments, driftwood, and large uprooted trees, the berm was probably created during the higher lake levels of the early 1970's. During this higher-water period, the zone east of the berm was drowned and perhaps colonized with the Scirpus marsh. With subsequently falling lake levels a series of small beaches and barriers (or bars) were deposited lakeward of the berm.

What is evident is a distinct pattern of distribution of landforms and vegetation. An active barrier occurs on the shoreline; lakeward is the emerging wetland. In the past with higher lake level, the shoreline was at the foot of the now inactive barrier and the berm developed. Lakeward of the berm an emergent wetland colonized the nearshore zone. As lake levels continue to drop the emergent vegetation will probably migrate lakeward.

To the west is the more prominent inactive barrier. The elevation and extent of the sandy deposit is not entirely natural. On Figure 15 it is represented by a broad continuous sand ridge. However, its natural configuration has been modified and portions of it are mapped as "Made Land" by the U.S. Department of Agriculture (1972). Borings indicate the barrier is at least five feet in thickness and composed primarily of brown medium-size sands. The surface has a grass litter zone six to ten inches in thickness. The occurrence and thickness of the litter zone is unusual since it has not been noted on other barriers in the Great Lakes. Occasionally, six to 36 inches down, black organic sand or sandy-silt layers one to two inches thick are encountered, which probably represent either a surface buried by washover deposits or the result of wind action which buried the vegetation on a lower barrier crest. Landward, the barrier is topographically and sedimentologically terminated by a broad lagoon, which is delineated on the west by the higher surface. The barrier plays an important role in that it separates two distinct wetland types. Eastward of the inactive barrier a narrow emergent wetland occurs. Westward the wetland is composed of sedges, willows, and other plants and has a meadow-like morphology.

The lagoonal areas north of the Oconto River are approximately one mile wide and are characterized by peaty surface sediments. Adjacent to the barrier the peat is 34 inches thick; it is non-woody and becomes more fibrous with depth. Westward the peat horizon decreases in thickness.

The lagoon was leveled for a distance of 800 feet. From the inactive barrier west, the elevation of the lagoon floor increased from 578.25 feet to 579.0 feet. Data from Wills (1977) reveal that the mean elevation of the lagoon is ± 582 feet above MSL. Therefore even during high water periods this wetland is seldom completely inundated by Green Bay. Since the surface extends well above many Lake Michigan water levels, most of the wetland is probably sustained by groundwater (Bedford et al., 1976).

The eroded delta south of the Oconto River is not protected by barriers and is characterized by gentle slopes at least one-half mile from the shoreline. A significant portion of the area is now colonized by cattail. This is a contrast to the wetland north of the river, which is at a higher elevation.

Flanking the north and south bank of the Oconto River are sloughs or relict channels of the river. The scars are in various stages of deterioration and represent successive stages of abandonment by the meandering river. The older, more subtle riverine features are difficult to observe in the field but are readily visible on aerial photographs. The features are sinuous to arcuate in shape.

Since the meander scars are in various stages of decay their channel fills vary in depth and hence support a variety of vegetation. The oldest meanders appear to be the clusters north of the river since they are less discernible, even on aerial photography. The large natural channel just to the south of the river was the main channel a century ago. Relict landforms of this kind increase the accessibility of the wetland, particularly to fish for spawning, and also represent maintenance-free natural access ways for recreational activities. A unique aspect of the Oconto River meanders is that they occur at or very close to the shoreline. Normally such features occur farther inland or within the confines of a valley. However, due to the erosion of the coast, the abandoned meanders continue to communicate with Green Bay, even during lower water periods. Along the north bank the land has been filled (U.S. Department of Agriculture, 1972) and communication with open water is less common there.

The landward side of the wetland is terminated by higher terrain which is composed of ancient shorelines and glacial till. In August, 1978, excavations on Main Street in Oconto exposed several feet of sediment. The sediment data were recorded and extrapolated along the north bank of the Oconto River (Figure 16). The surface of the higher terrain was composed of oxidized sand approximately 12 feet in thickness. Thin clay lenses (1-2 inches) occurred in the sand, but coarse to medium sand was the principal sedimentary component.

East of Porter Street, at least seven feet of organic silts were noted. Within the black sediment large tree stumps occurred, suggesting a swampy rather than a marshy environment in the geologic past. These sediments are a distinct contrast to the oxidized sand to the west. Although the sedimentary sequence here is complex, the sediments are probably fluvial in origin. This conclusion is suported by the fact that the sediments are in an area of point bar topography and are underlain by coarse grey sand. The lack of organics and the coarseness of the sand deposit suggests fluvial or marine deposition.

Underlying the surficial deposits is a red stiff clay mixed with gravels, at an average depth of eight feet. It probably extends eastward beneath the lagoon and the barrier complexes at the shoreline and is probably a glacial till deposited by the Green Bay Ice Lobe during the late Wisconsin ice age.

In summary, the wetlands of lower Green Bay are generally confined to the shorelines and river mouths of the western side of the Bay. Because of the dip or attitude of the bedrock, coastal lowlands are prevalent along the western shoreline compared to the cliffy shoreline of the Door Peninsula. In the Oconto River area, a wide diversity of geomorphic features, some of which are longer lasting than others, support wetland vegetation. The most extensive wetlands are located between barriers of the shoreline and the higher surface to the west. Barrier development is more continuous north of the river; the barrier coupled with an artificial levee on the north bank results in less frequent inundation of the area. Another important geomorphic determinant of wetland distribution is the deposition of an active barrier at the present shoreline. The barrier is now protecting a linear wetland just to the west of it. Finally, the shifting Oconto River channel has created a complex of relict channel and point bar topography. These features, in various stages of decline, support diverse wetland communities.

Betsie River Wetlands

Along the west coast of Michigan several rivers flow towards Lake Michigan, but instead of debouching directly into Lake Michigan they flow into smaller lakes separated from Lake Michigan by large coastal sand dunes. Morphologically the mouths of the rivers appear to be drowned, not unlike the river valleys entering western Lake Erie. Since these lakes and rivers are joined to Lake Michigan, they are affected by changing lake levels. The Michigan Department of Natural Resources (1973) regards these embayments as coastal and includes them in their coastal wetland inventory. Many wetlands in these embayments support a diversity of wildlife and are important for fish spawning, muskrat trapping and duck nesting (Jaworski and Raphael, 1978). The Betsie River valley was selected for our embayed wetland type because it was less altered than bays farther south (Muskegon, Pere Marquette, Kalamazoo Rivers).

The Betsie River embayment is delineated by landforms constructed by marine, fluvial, and glacial processes (Figure 17). The wetland is not situated on an extensive lake plain as are the other coastal sites but is confined to a linear depression between glacial moraines.

The terrain of Benzie and the surrounding counties is a result of late Wisconsin glaciation. Glacial moraines in the area were derived from the Lake Michigan lobe and represent the last advance (Valders stadial) of the Wisconsin Glacier (Dorr and Eschman, 1970). The terrain is hilly and elevations in excess of 900 feet above MSL are commonly attained. Sediments on the periphery of the basin are typical sand and gravel deposits associated with direct ice deposition (Waterman, 1917). The glacial sediments are reddish in color which is indicative of the Valders drift. The red color is due to red silt and clay sediments transported from the Upper Peninsula of Michigan by the glacier.

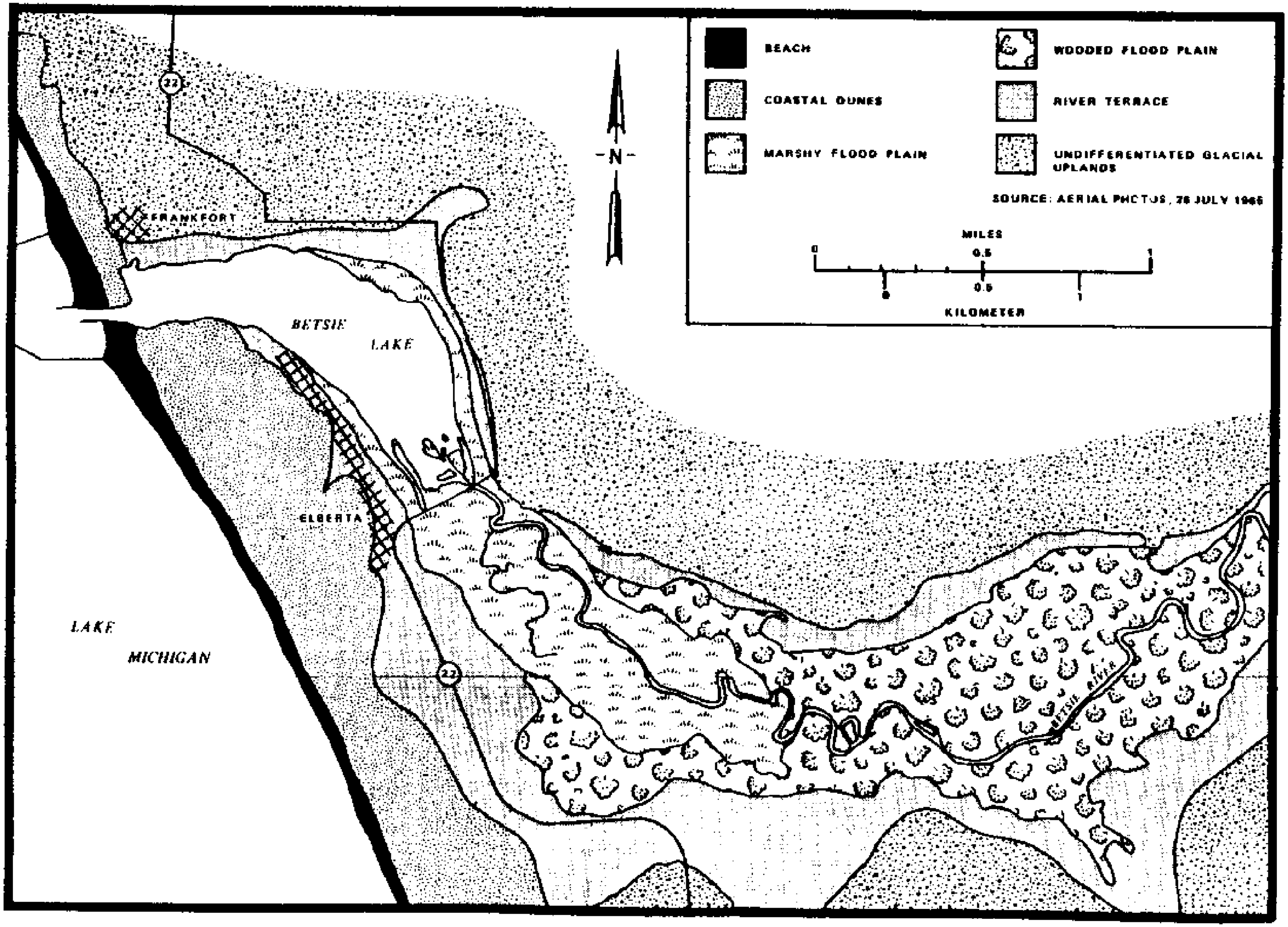


Figure 17. The Coastal and Fluvial Landforms of the Betsie River Wetlands

The lakeward (west) side of the wetland is confined by dunal topography and a sandy beach. The dunes are parabolic in shape and are actively migrating, since unvegetated blowouts are evident. Sand for the active dunes is derived from the beaches (Olsen, 1958). During lower-water stages the exposed wider beach provides sand for the formation of foredunes. Such foredunes are significant, since prior to harbor maintenance they effectively blocked the outlet of Betsie Lake and helped maintain the wetlands. The established dunes are in excess of 800 feet above MSL and are related to wind and marine activity of Algonquin and Nipissing time (Scott and Dow, 1937).

The Betsie River meanders on its flood plain which has a width of about one-half mile. The flood plain can be sub-divided into two units, marshy flood plain and wooded flood plain, on the basis of wetland differences rather than geomorphological variations. The river has many of the characteristics of an old age river, including well developed meanders and the creation of ox-bows. Where Highway 22 crosses over the flood plain a delta has been deposited, probably during the lower water period of the 1960's. However, with changing Betsie Lake water levels the focus of deltaic deposition shifts dramatically.

The principal sediments in the flood plain are peat and sands. The peats are locally accumulated organic deposits although some organics are transported by the Betsie River onto the flood plain. The sand is probably derived from the drainage basin (glacial deposits). During periods of low river flow the sands are exposed on point bars. A bore in a point bar on the flood plain reflects the changing sediment, and hence variable flow of the river. Table 21 reveals alternating layers of sand and organic remains. Point bars are approximately at river level and hence subject to flooding. The peat, 18 to 28 inches below the surface, probably represents a once-vegetated point bar which was submerged; it contains bulrush remains. Through time however, sand was deposited on the point bar and the organic horizon was subsequently buried and preserved. Since the river regime varies, the deposits exhibit variable texture. As point and bar deposition continues the river channel is gradually displaced away from the bar. Wetlands may colonize the expanding point bars, but on the opposite side (cut bank) of the channel wetlands are being eroded by the migrating river.

Table 21

Sediment Profile of a Betsie River Point Bar

Inches	Sediments
0- 2	Clean sand
2- 6	Organic stained sand
6-18	Reddish sand - rootlets
18-28	Fine textured peat, wood fragments and bulrush remains
28-33	Medium sand, traces of cattail roots but mainly Scirpus root fragments

Location: First point bar east of Highway 22. August 4, 1977

Between the low, flat flood plain and the glacial and dune topography a flat or terrace occurs. The terrace parallels and extends beyond the flood plain into Elberta and Frankfort. The width of the terrace is highly variable (Figure 18). Its elevation is approximately 585 to 595 feet above MSL. Profiles of the Stony Lake shoreline north of Muskegon reveal a similar surface at an elevation of 600 feet above MSL (Berg, 1974).

The terrace represents a higher level of Betsie Lake and Lake Michigan. In effect the surface is an older plain which has been dissected as the water level dropped from the approximate level of the terrace to its present level. According to Martin (1955) only one terrace occurs in the Betsie valley. Goldthwait (1908) reported that a shoreline of Algonquin age was evident in the Betsie valley at an elevation of 604 feet above MSL. The terrace discussed in this subsection is probably shoreline.

Figure 18 more clearly illustrates the relationship between the different earth materials and surfaces and puts the geomorphic framework in a linear and vertical perspecitve. Two profiles were constructed from the approximate center of the flood plain (in an approximate north-south direction) across the terrace. The datum for elevation determinations was the Betsie River; it was assumed that the elevation of the Betsie River at the point where the profiles were made was 580 feet above MSL. The landforms were bored along the traversed profile and two cross sections were constructed.

The flood plain is very flat and varies less than a foot in relief. The higher relief of the flood plain on the south margin of the profile may represent human disturbance or downslope movement of soil, since two feet of relief on narrow flood plains is unusual. The flood plain surface exhibits no natural levees, a feature common to most flood plains (Thornbury, 1969). However, Butzer (1976) notes that flat flood plains occur where lateral migration and point bar development are dominant processes and deposition on the flood plain is not significant. A second possible cause of flat flood plains is related to deposition by streams transporting an abnormally high load of sediment. The sediment of the Betsie River wetlands is with minor exceptions sand and peat.

Where sandy landforms occur, they are altered quickly because sand is the easiest sediment size to erode (Hjulstrom, 1935). The absence of finer river transported sediments or less sediment variation may account for the lack of land form diversity. Normally natural levees are composed of silts and clays. The clarity of the water, the sediments on the flood plain, both vertically and horizontally, and the active point bar deposits reveal that silt and clay are not abundant sediments in the Betsie River valley.

The surface of the flood plain is composed of a fibrous peat mat. Except where river channels occur, the peat extends across the entire flood plain. The peats with depth are more compacted and have a greasy feel and the consistency of coffee grounds. In most instances the peats appear to be partly composed of sedges and grasses. Localized cattail (Typha sp.) colonies exist on the flood plain surface but cattail fragments are not particularly abundant in the peats examined.

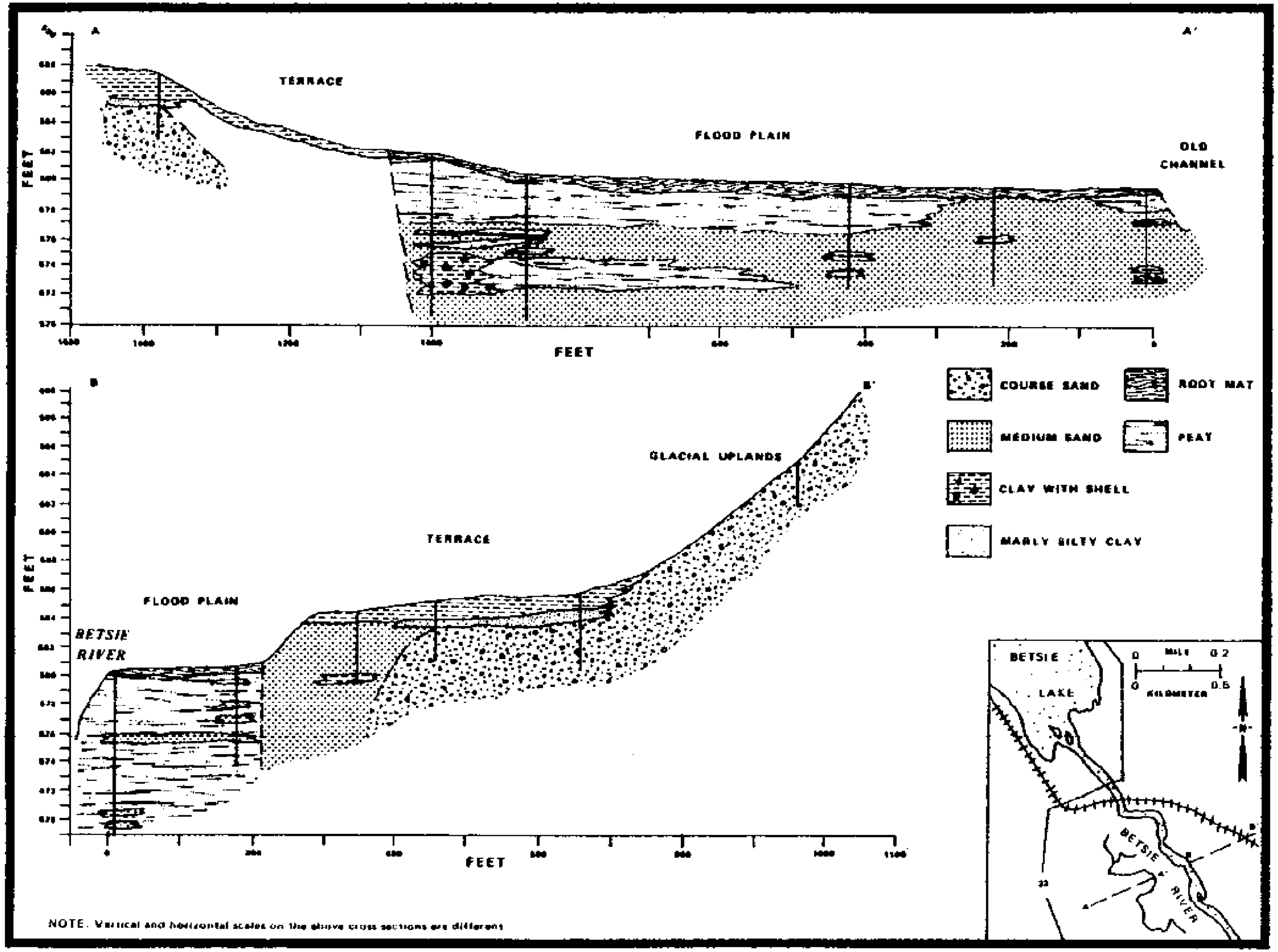


Figure 18. Selected Stratigraphic Cross Sections of the Betsie River Flood Plain. The Terrace Surface Consists of Silty Sand.

Although not visible in the transect, tree stumps (probably cedar) are exposed at river level on the north bank. The stumps are approximately three feet in diameter, and are in situ. Stratigraphically they are rooted in the peat and covered by the root mat. The trees probably represent a lakeward extension of the wooded flood plain (Figure 17). It appears that the woody flood plain vegetation was replaced by marshy vegetation; subsequently a root mat concealed the tree roots.

The distribution of the sediments of the flood plain surface provide a model for what has occurred in the immediate geologic past. Surficially, sands are concentrated on point bars and within the channel of the flood plain, and the organic mat represents the remaining flood plain sediments. At greater depth, the peat deposits are more abundant and thicker on the flanks of the flood plain; medium and coarase sands with thin peat lenses are more common towards the center of the flood plain. One possible reason for the fewer organic deposits is that the Betsie River might have filled the central part of its valley with clastic or mineral sediments. If the valley was a lake, the wetlands were confined to its margins. As alluviation continued, the valley filled with sediments to its present elevation (± 580 feet); when the level of the flood plain stabilized, a wetland, represented by the organic mat, was created.

A second possibility for the lack of peats is that the river might have migrated laterally, completely eroding the peat deposits in the middle of the flood plain. What is clear is that wetlands did occupy the Betsie River when its flood plain was at a lower level. As the flood plain was built upward by the addition of sediments, the wetlands on the flanks of the landform managed to keep pace with the upward growth and thick peat deposits were created. The sediment data also reveal that only in recent times have the wetlands extended over the entire flood plain surface.

Flanking the floodplain is the terrace, with a surface of black silty clay. Beneath this horizon a coarse, shelly sand is encountered. The contact between the terrace and flood plain is more abrupt on the north side of the valley. Because of human disturbance the break is less distinct on the south side of the valley so the boundary is more transitional but, based on the vegetation and sediments, is clearly mappable.

Beyond the terrace the glacial terrain or sand dunes are encountered. At the contact of the terrace and glacial upland, a marly silty clay capped with a thin layer of organic silty clay has been identified. Usually less than a foot in thickness, the whitish-gray deposit is consistently found at the contact between the two landforms. In Oceana County, Michigan, Bergquist (1927) has identified similar marly deposits on sandy soils. The marls discussed here appear to be equivalent to Bergquist's "Upland Marls", which are found in the terraces of former lakes and "in the upper flats, terraces and old meander channels of streams and rivers". A variety of Potentilla is commonly associated with the marl in southern Michigan. In the Betsie River area the unique deposit is an excellent stratigraphic marker between the terrace and glacial upland.

In summary, the Betsie River wetlands are geomorphologically related to a flood plain which lacks well developed levee flank depressions and natural levees. Due in part to changing water levels, the west side (down river) of the wetland border advances and retreats over short-time periods. The northern boundary of the flood plain is rather abrupt and the change from wetland vegetation to upland vegetation is rapid. On the south side of the valley, however, the slope from the flood plain to the terrace is more subtle and a broader vegetative transition was observed. Based on the distribution of peat in the subsurface, the wetlands today are perhaps more extensive than in the past, although they appear to have occupied the flanks rather than the center of the floodplain. Furthermore, as alluviation continued to build up the floodplain, the wetlands were able to build up and survive as well. The identification of buried cedar stumps in an area now colonized by marsh indicates that cedar swamps were perhaps more extensive in the past, especially near the flood plain/terrace contact.

Tobico Marsh

Tobico Marsh is an enclosed lagoon bordered on the east and west by sand ridges. The only outlet is a small creek at the south end of the marsh in the vicinity of Bay City State Park. Most of the wetland is within the Tobico Marsh State Game Area. This wetland has a diversity of avifauna and is also attractive to waterfowl during migration (Jaworski and Raphael, 1978).

The principal landforms of the Tobico Wetland are illustrated on Figure 19. On the east, the wetland is bordered by a long, straight continuous beach and barrier. Due to longshore current direction and long-term oscillating lake levels, the beach width is variable but generally widens to the south. During the 1977 summer field season the beach averaged 30 to 50 feet in width at Brissette Beach.

Based on elevations and surface expression, two distinct sets of beach ridges are evident. Highway 13 is on an elevated bluff overlooking the plain to the east, consisting of an elongated ridge at an elevation of 600 to 605 feet above MSL. According to Leverett and Taylor (1915), the altitude of the highest Algonquin beach at Kawkawlin (on Highway 13 south of Beaver Road) is 607 feet above MSL and this probably corresponds to the beach along Highway 13. However, more recently Martin (1955) has suggested that the Algonquin shoreline was even further west and the beach along Highway 13 is Nipissing in age. Since Hough (1953, 1958) has shown that the Nipissing stage in the Huron basin stood at an altitude of 605 feet, the beach ridge along Highway 13 east of Tobico Marsh is presumably Nipissing in age.

Between Highway 13 and Tobico Marsh is a cluster of beach ridges which roughly parallel the present shoreline. The sandy ridges are well defined on topographic maps, on aerial photography and on soil maps of the area. At least 26 ridge crests are evident west of Tobico Beach. However, farther to the north the ridges become less numerous and more dispersed. In all probability the multiple ridges were deposited at a level slightly higher than present Lake Huron (Lake Algoma?). The crests of the ridges are at an approximate altitude of 585 feet and are post-Nipissing in age. It is interesting to note that these ridges represent a large influx of sand, probably from farther to the south. Beach ridge deposition appears to have been more common in the immediate

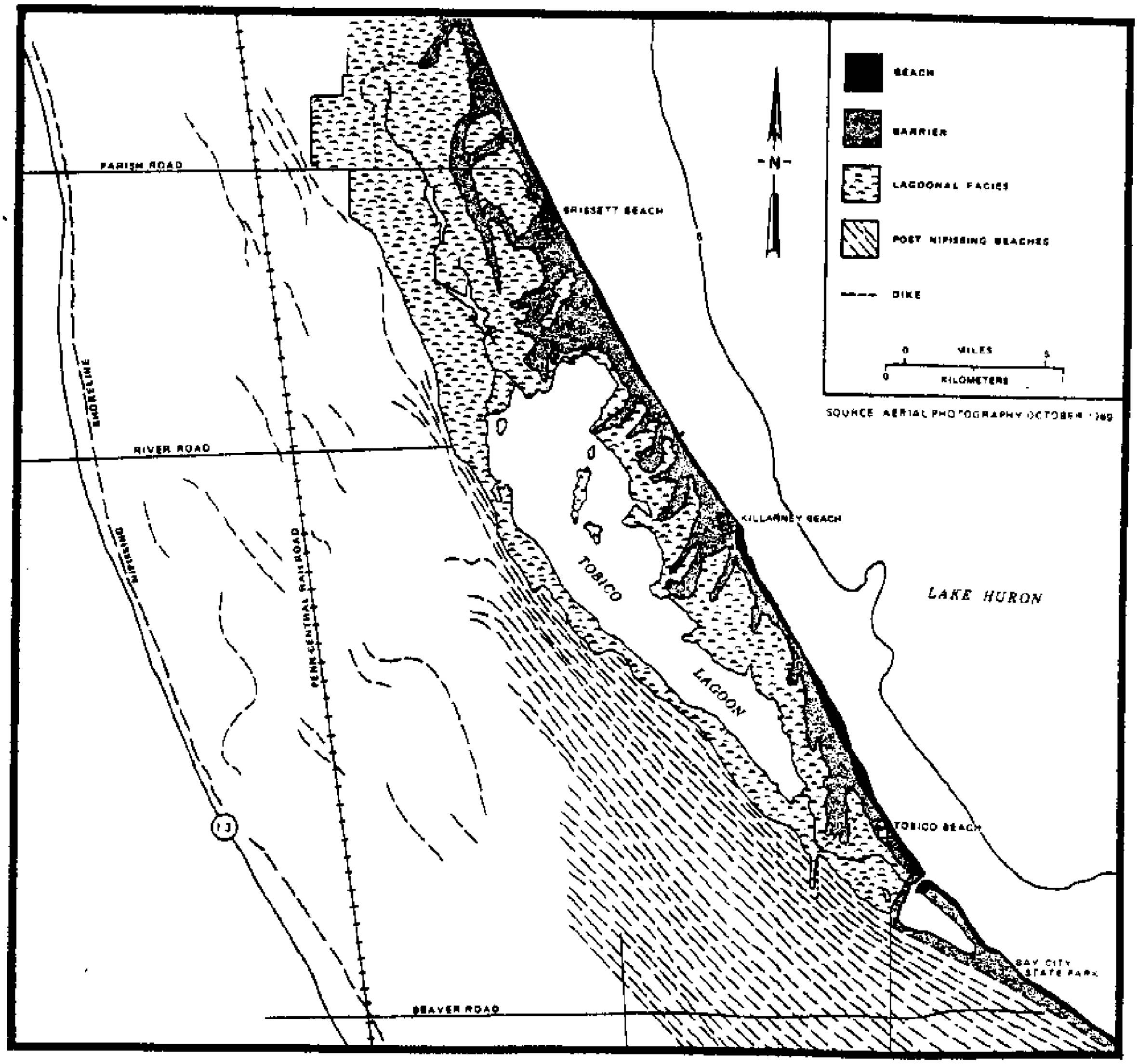


Figure 19. The Landforms of the Tobico Marsh Area

geologic past than at present. Figure 19 indicates that Tobico Marsh occupies a depression between a geologically older and wider beach-ridge complex to the west and a more narrow coastal barrier at Lake Huron.

Two east-west cross sections were constructed in Tobico Marsh. One cross section paralleled Parish Road (Figure 20) and the second cross section traversed the lagoon at the east end of River Road northwest of Killarney Beach (Figure 21).

The sediment distribution and barrier, lagoon and beach ridge relationships become evident upon examination of the bore data. Basically, the sediments fall into three categories: sand, peat, and clay. The coastal barriers are composed of fine sand (Pipestone fine sand) and interfinger with the clay and peat deposits. The sediments in the lagoon where emergent and submergent wetlands are present are composed of peats of variable consistency or a mixture of peat with fine sand. Clay underlies the lagoon and barriers.

The map (Figure 19) suggests that the barrier is being eroded and sand deposits are being thrown back into the wetland as washover deposits. However, the cross section paralleling Parish Road (Figure 20) suggests that the sand deposits west of the active barrier are probably a series of spits which were deposited by waves as the barrier extended itself from north to south, and are not washover deposits. As the barrier extended southward the tail of the spit was abandoned and the barrier, now inactive, was sheltered and ultimately sealed from Saginaw Bay and hence perserved. Occasionally the barriers in the wetlands coalesce and form isolated marshes within Tobico Marsh. Such a process was responsible for the isolated marsh north and south of Parish Road west of Brissette Beach.

Borings in the inactive barrier and in the modern barrier reveal that the barrier sands are unusually thick, at least six feet in the inactive barrier. Several borings made on the modern barrier (Cooper, 1906) recorded 16 to 19 feet of sand, underlain by 30 to 62 feet of clay. Underlying the sediments is Upper Paleozoic bedrock. The significance of the thickness of the barrier sands is that the barrier is a landform created by a depositional process associated with coastal buildout. An absence of peats or clays in the barrier reveals that the shoreline is stable and not transgressive. Based upon our investigation, such barriers are less common in the Great Lakes than the transgressive type observed at Woodtick, Toussaint, and elsewhere. The origin of such depositional features is discussed by Zenkovitch (1969) and Schwartz (1973). Komar (1976) notes that other barrier spits occur in the Great Lakes (e.g., Presque Isle). At Nayanquing Point nine miles to the north near Pinconning, similar barrier spit development is now occurring, and there is no evidence to indicate that the barrier is eroding significantly. The ridge is densely populated with homes, many of which are occupied year around. Washover deposits are not evident on the barrier, suggesting that storm waves rarely overtop the sandy deposit. Furthermore, cores extracted from the peat deposits landward of the modern and inactive barrier reveal few sand lenses, indicating that washover activity is not a frequent coastal process in this area. The significance of the barrier with regard to Tobico Marsh is that since the barrier is stable compared to other Great Lakes' coastal barriers, future protection of the wetland from Lake Huron appears to be assured.

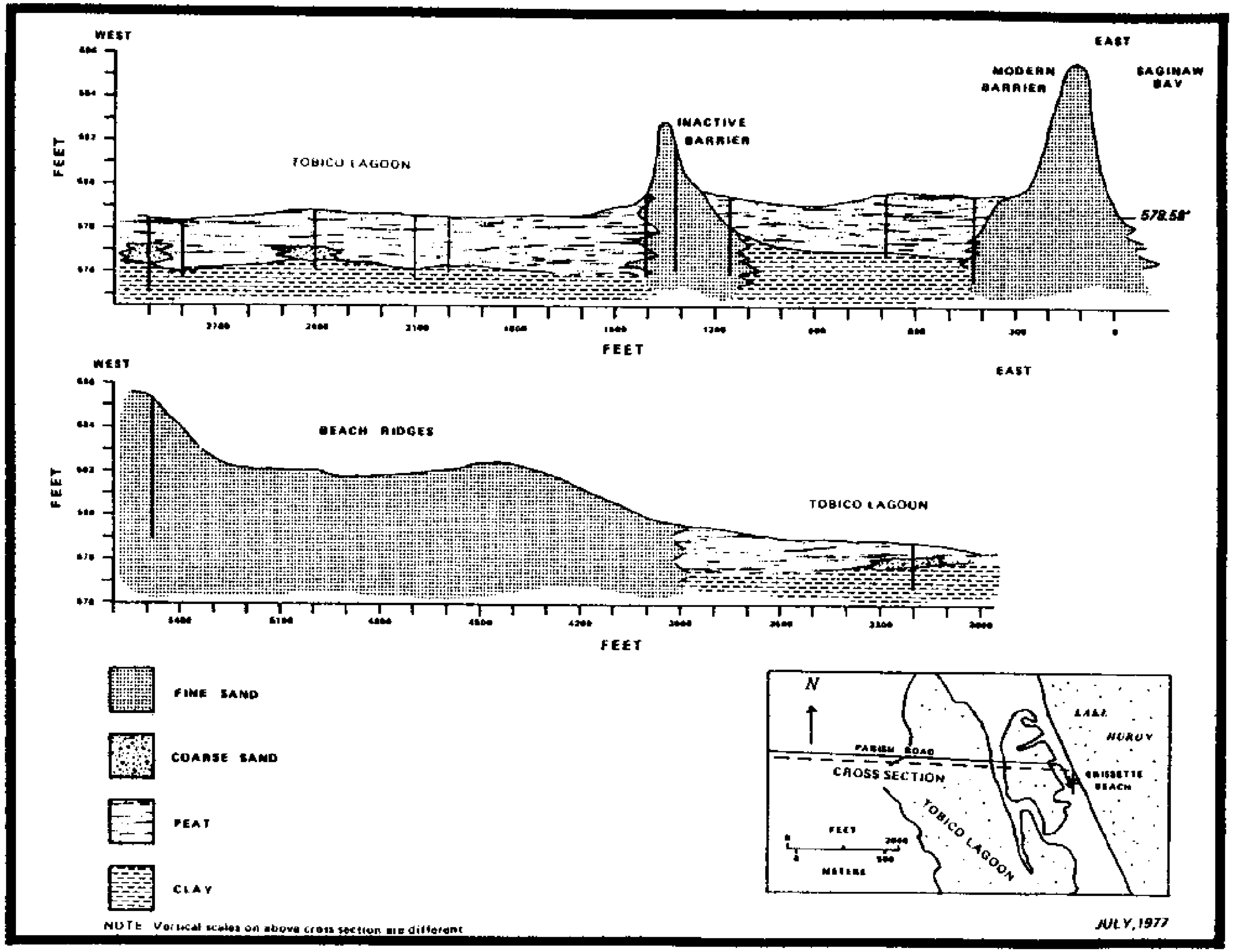


Figure 20. A Stratigraphic Cross Section Parallel to Parish Road in Northern Tobico Marsh

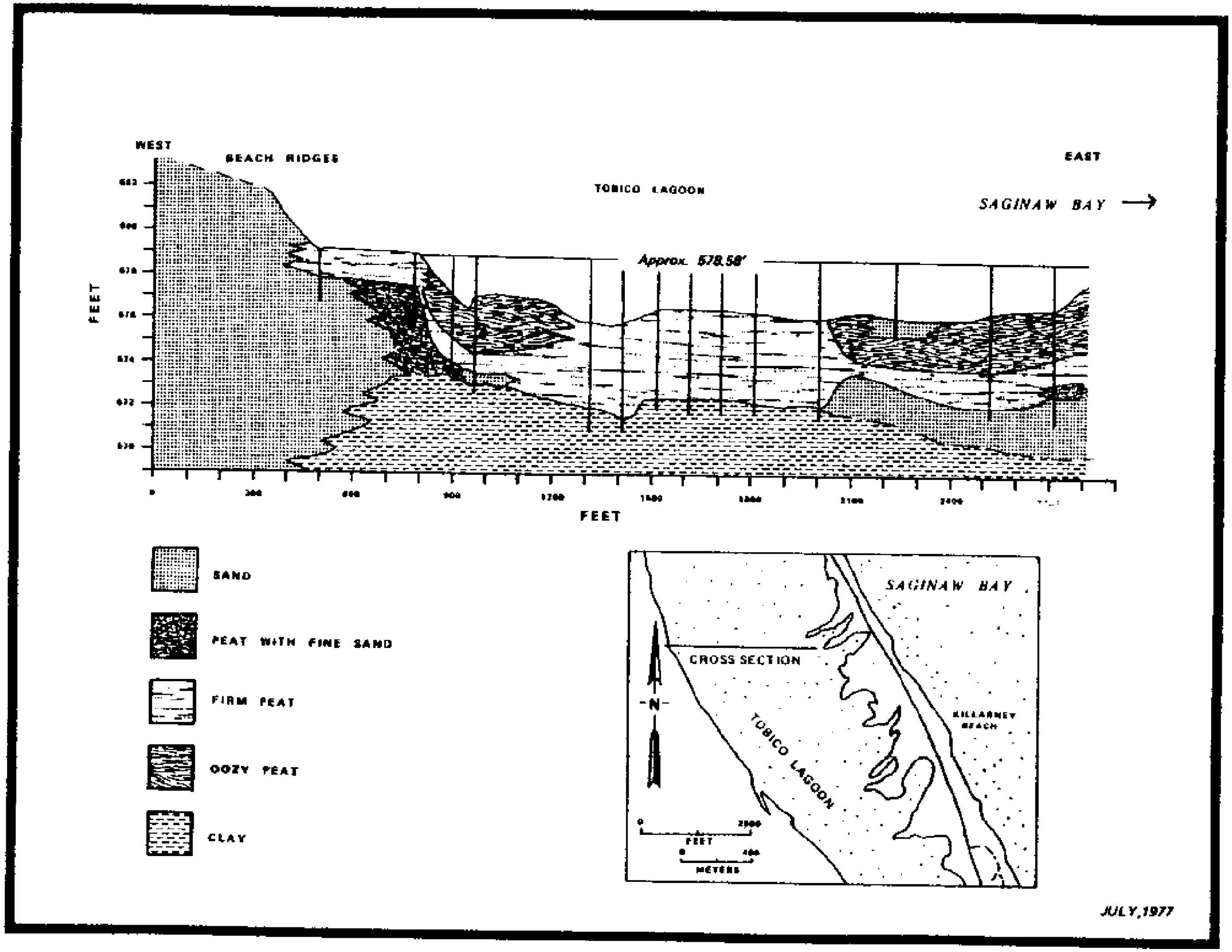


Figure 21. A Stratigraphic Cross Section North of Killarney Beach, Tobico Marsh

A comparison of Figure 20 and Figure 21 reveals that the lagoon floor is near present lake level (578 feet) in the vicinity of Parish Road and decreases in elevation towards the south. The elevation of the marsh surface between the modern and inactive barrier is higher (580 feet) than the floor west of the inactive barrier (± 579 feet). The higher lagoon floor is isolated from the main lagoon by sand barriers; such isolation encourages the deposition of an organic substrate.

The cross section one-half mile north of Killarney Beach (Figure 21) reveals that organic sedimentation of Tobico Marsh is an active ongoing process. Two distinct peat deposits are evident in the profile. Towards the center of the lagoon, firm brown peat occurs in two to three feet of water. To the east and west on the lagoon flanks, oozy peat colonized by submergent aquatics is accumulating. The peat is mucky and loosely compacted compared to the peat beneath it. The cross sections point out one of the disadvantages of well protected coastal wetlands. With the passage of time, Tobico Marsh may evolve into a peat bog owing to the lack of flushing action that occurs in more open coastal wetlands. The problem is compounded during lower water levels because a water control structure at the south end of the lagoon in effect seals the lagoon from Saginaw Bay.

Beneath the peat deposits, sand and clay are encountered. The sand on the west represents the older beach ridges which rise abruptly from the lagoon floor to form the landward boundary of the lagoon. The sand above the clay to the east on Figure 21 probably represents the toe of the active coastal barrier along Saginaw Bay.

In summary, the geomorphic framework of the Tobico Marsh consists of a barrier spit. The curved configuration of each deposit has isolated or nearly separated portions of Tobico Marsh into smaller wetland units. The landward side of the wetland is straight and abuts on the ancient beach ridges. The substrate of the wetland is peat and clay which probably extends at least 40 feet to bedrock. The stratigraphy reveals that the modern barrier has not eroded significantly in the past, so the viability of the wetland is assured from a geomorphic standpoint.

Tuscola County Wetlands

The shoreline of Tuscola County is approximately 16 miles in length and trends in a southwest-northeast direction. The area investigated and discussed in this report extends from the Quanicassee River northeastward to Fish Point. The northern portion is within the Fish Point Wildlife Area.

The present wetlands are confined to a relatively thin coastal and nearshore zone. Prior to European settlement, swamps and marshes were much more extensive. According to Davis (1909) wetlands occupied most of coastal Wisner and Akron Townships which comprise the study area, and extended three to four miles inland to approximately the 610-foot contour. Since the 1850's, approximately 9,420 acres of wetland have been lost on the southeast coast of Saginaw Bay (Jaworski and Raphael, 1978).

The coastal zone of the study area is composed of a linear series of beaches which parallel the present shoreline. The beaches are at elevations of 610 above mean sea level near Akron, seven miles inland, and descend in elevation to the present Saginaw Bay shoreline (± 580 above MSL). Chronologically the oldest and highest beach ridges represent an Algonquin shoreline. Also identified in the area is the Nipissing shoreline (Bergquist and MacLachlan, 1951); both of these shorelines are landward of Highway 25. Lakeward of Highway 25 is a series of shorelines at an elevation of about 585 feet (Figure 22). The shorelines are sinusoidal and occasionally have semi-circular depressions which enclose wetlands. Some of the ridges merge with the modern shoreline, but others run parallel with it or diverge from it at various angles. Where the premodern ridges have not been cleared for agricultural use and plowed, they are irregular and have a hummocky appearance. Lakeward of the premodern ridges, narrow sand, or exposed red clays and gravel deposits prevail. In the nearshore zones multiple sand bars have been deposited.

The wetland communities in coastal Tuscola occupy a variety of geomorphic habitats including depressions within the premodern shoreline, clay flats, lagoons at present lake level, and sand bars in the nearshore zone. Figures 23 and 24 represent cross sections constructed for an area in the southwest reach of the study area and in the northeast reach of the study area near the community of Thomas. Even a casual inspection of the cross sections reveals a diversity of modern and premodern landforms.

Figure 22, near Bradford Road, is a continuous profile subdivided into a subaerial and a submarine unit as determined by the July, 1977 Lake Huron level. The subaerial profile reveals a narrow lagoon occupying a topographical low between two barriers. The premodern barrier, approximately six feet above Saginaw Bay, is composed of fine sand and does not appear exceptionally thick (± 4 feet). The modern barrier is even thinner (± 3 feet).

The cross section suggests that the modern barrier is an ephemeral deposit formed during high water associated with longer-term high lake levels such as were the case in the early 1970's, and/or storms. The thinness of the barrier suggests that sand supplies along the shorelines are volumetrically low. Within the barrier are coarser washover deposits separating peat layers; the washover sands on the surface extend back into the lagoon and the lakeward perimeter of the lagoon has been buried by the encroaching sands. Alternating peat and sand sediments indicate that washover of barrier sands into the lagoon has repeatedly occurred in the past. Beneath the peats of the lagoon is a layer of nine to twelve inches of sand and gravel overlying finer sand and clay deposits. Since the premodern barrier is devoid of gravel, a logical source for the sandy gravel is the beach, where gravels are now abundant. The coarse sediment may have been deposited onto the lagoon by waves from Saginaw Bay during high energy conditions. An alternative possibility is that the deposit represents a submarine nearshore zone of the premodern barrier which was deposited at a slightly higher lake level. However, the lack of continuity of the feature along other sectors of the shoreline suggests that the latter concept is speculative.

From the shoreline lakeward is a series of sand bars of variable width, underlain by clay. At the shoreline the clay is often exposed due to the

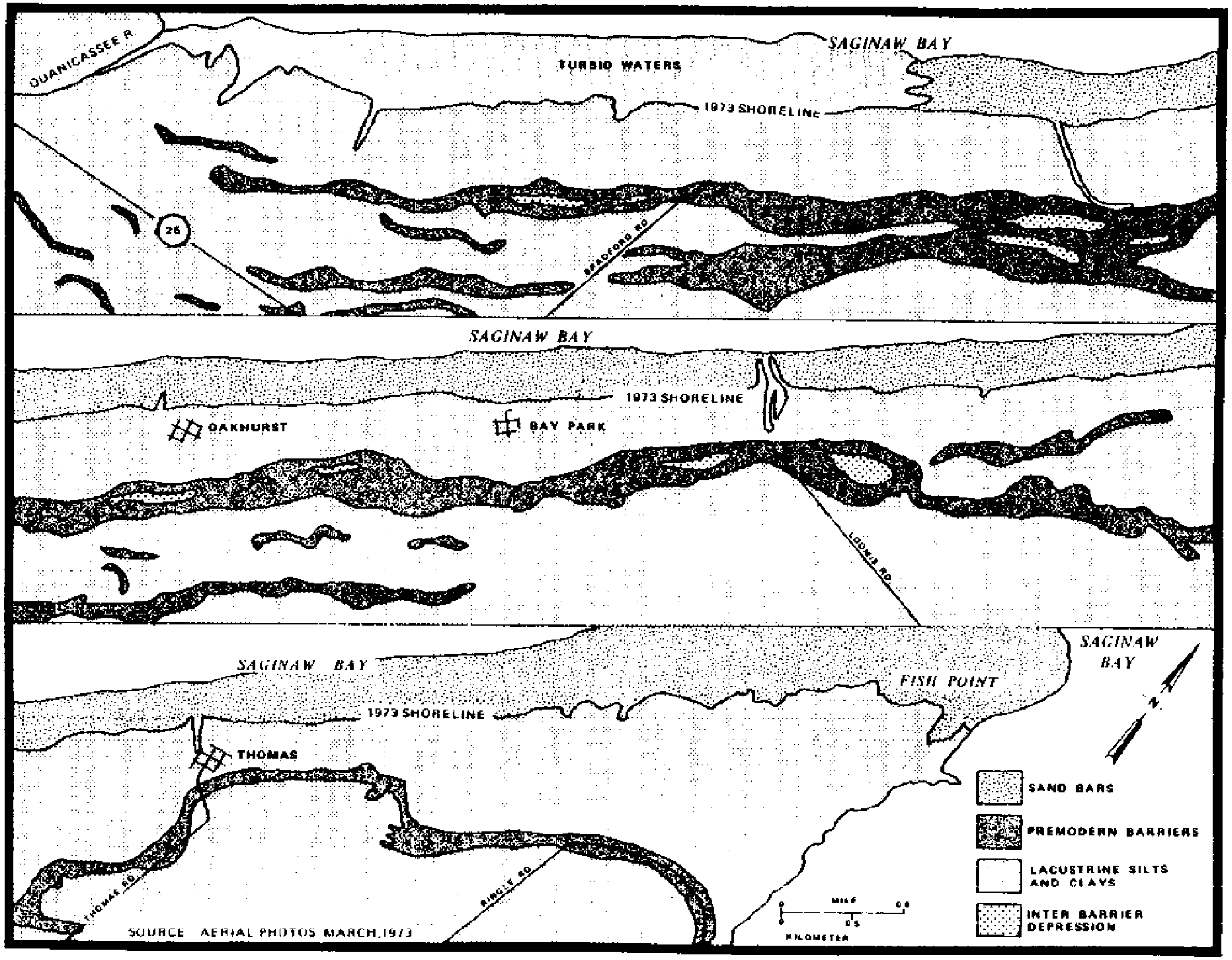


Figure 22. The Coastal Landforms from Fish Point to the Quanicassee River Tuscola County, Michigan

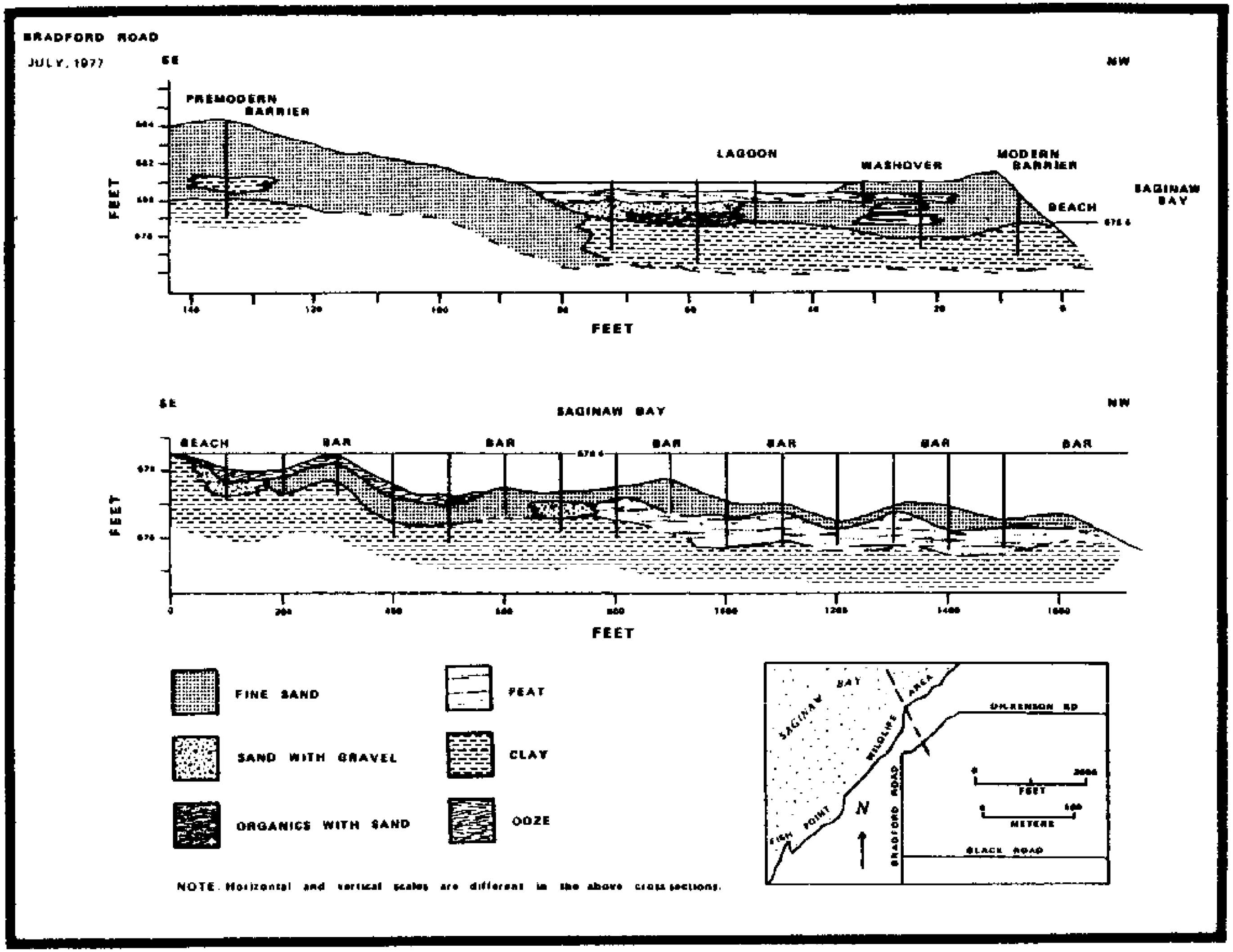


Figure 23. A Stratigraphic Cross Section of the Coastal Landforms Near Bradford Road, Tuscola County, Michigan

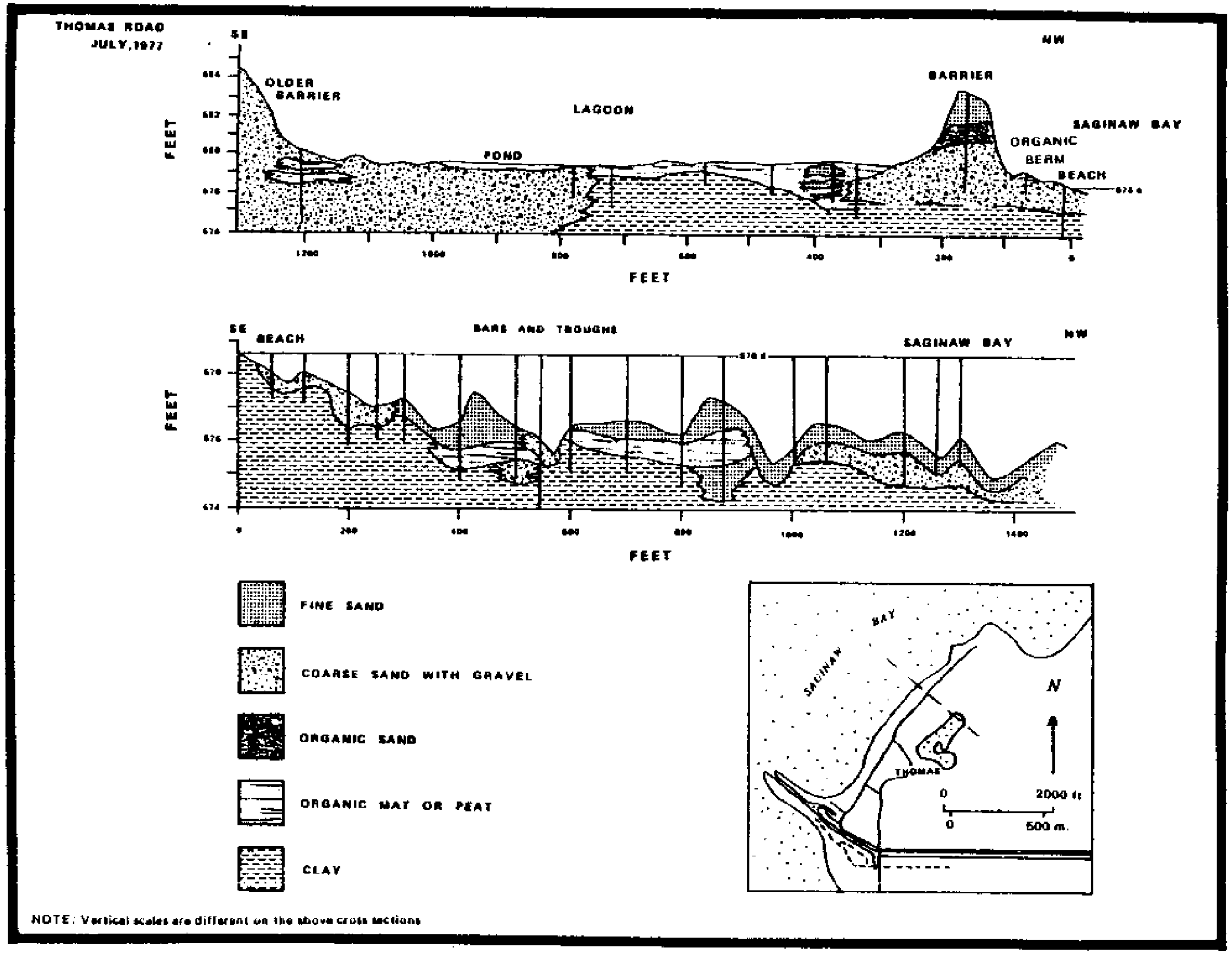


Figure 24. A Stratigraphic Cross Section of the Coastal Landforms Near Thomas Road, Tuscola County, Michigan

absence of sand beaches. However, as one proceeds into the lake the substrate becomes sandier. Based on 1963 aerial photography, the nearshore zone from the Quanicassee River northwest for approximately four miles has much suspended sediment debouching from the Quanicassee River. Skylab photography suggests that the turbidity pattern originates at the mouth of the Saginaw River and coalesces with turbid water from the Quanicassee River (Smith et al., 1977). The sand bars extend from this point to Fish Point where they are abruptly terminated. Figures 23 and 24 represent nearshore cross sections; Bradford and Thomas Roads, because of their similarities, are discussed together.

Sedimentologically the submarine topography of Tuscola County consists of sand overlying peats and/or clay. One interesting exception to this widespread pattern is at Bradford Road. There, from the beach lakeward for 550 feet, a layer of ooze was at some time draped over the coarser sediments. The sediment is very fine grained and appears to be calcareous in composition. The source of the deposit is not known but it extends laterally approximately a mile towards Fish Point.

The sand bars of Tuscola County extend one-quarter to one-third mile from the shoreline, according to 1963 aerial photography. Within 200 feet of the present shoreline, sand and gravel troughs and crests characterize the topography. However, as one proceeds lakeward, sand is the most widespread surficial sediment. Beneath the sands either clays, peat, or sandy gravel is encountered.

The most significant deposit with regard to the nearshore wetlands are the peat deposits recorded in both cross sections. The peat is composed of dense mats and includes cattail (Typha sp.) rhizomes as well as other floral remains. More lakeward, very dense living organic mats about four inches thick overlie a darker, less fibrous peat. The peat, with some local exceptions, overlies the extensive clay deposits of the nearshore zone.

A common distribution pattern of the peat deposits is that their linear extent appears to be associated with water depth. On both cross sections the organic deposits occur at an approximate average depth of 576.5 feet. As water depths increase and decrease the peat deposits are less abundant. This suggests that water level is an important variable controlling nearshore wetland distributions in coastal Tuscola County. Further lakeward, increasing water depths, increased wave heights, and higher wave energy may discourage the establishment of wetlands.

A second subaerial cross section was constructed near Thomas (Figure 24). This shoreline consists of two well-developed premodern barriers separated by a lagoon. The present shoreline is represented by a thin beach deposit of gravelly sand. Basically the shoreline is the base of the barrier. Adjacent to the barrier is a high water strand line or berm composed of rafted organic debris.

Stratigraphically the barrier is composed of three sand units and appears to be thin. The lower part of the barrier is composed of coarse sand and occasional pebbles. A middle unit, approximately one foot thick, is a deposit of black organic sand. The barrier crest is capped with fine sand and is similar in composition to the barrier near Bradford Road. The base of the barrier in the lagoon is at approximatley the same elevation as the present beach, suggesting that the feature is perhaps no thicker than five feet. Beneath the barrier a yellow-brown clay is encountered.

An examination of the sedimentary sequence suggests that the barrier was probably formed as the shoreline eroded. The organic sand represents an old vegetated surface which was buried by fine sand. The occasional sand stringers within the lagoon sediments immediately inland of the barrier may represent a series of washovers which were deposited on the lagoon surface. The conspicuously thin deposit (compared to Tobico for example) and flat contact with the clay below suggests a transgressive barrier.

The lagoon floor, partially enclosed between two barriers, is composed of two well-defined substrates. The lakeward half of the lagoon is composed of a peat which thickens lakeward and is underlain by clay. Landward, the lagoon floor, including the pond, is composed of sands which basically are a lakeward extension of the older barrier. Based on one bore, the older barrier appears to be much thicker than the barrier at the Saginaw Bay shoreline, suggesting a different process for its origin. More and deeper boring would be required to substantiate this conclusion. The lagoon and its diverse wetland represents a depression located between two premodern barriers slightly above lake level.

In summary, a diverse geomorphic framework has contributed to a diversity of wetland habitats. Fundamentally, the occurrence of coastal wetlands is determined by the distribution of modern and premodern barriers and of nearshore conditions. Where active barriers have been deposited lakeward of an older barrier, wetlands which include swamps have developed. Depressions of thin, curved, and irregular configuration in the higher and older barriers are also occupied by wetlands. The nearshore wetlands are anchored to the clay bottom of Saginaw Bay and occupy troughs and crests of the sand bars.

It has been suggested in the literature that wetlands reduce wave energy (Wayne, 1976), particularly in the case of emergent vegetation (e.g., *Spartina*). However, the shorelines of Tuscola County exhibit coastal features such as washover deposits and thin barrier sands which are normally associated with erosional shorelines. The coastal geomorphology indicates that the nearshore wetlands do not provide enough protection to completely prevent coastal recession.

Dickinson Island Wetlands

Located on the international boundary between Ontario and Michigan, the St. Clair delta is the largest delta in the Great Lakes Basin (Figure 25). Considering its recreational significance and commercial importance with regard to Seaway navigation, geographic literature on the area has not been abundant. The first significant investigation was done several decades ago by Cole (1903) who determined that the delta was being deposited atop deepwater, proglacial lake clays. Leverett and Taylor (1915) using Cole's data, briefly discussed postglacial activity of the area and speculated on its origin. More recently, Wightman (1961) attempted to establish a Late Quaternary chronology for the

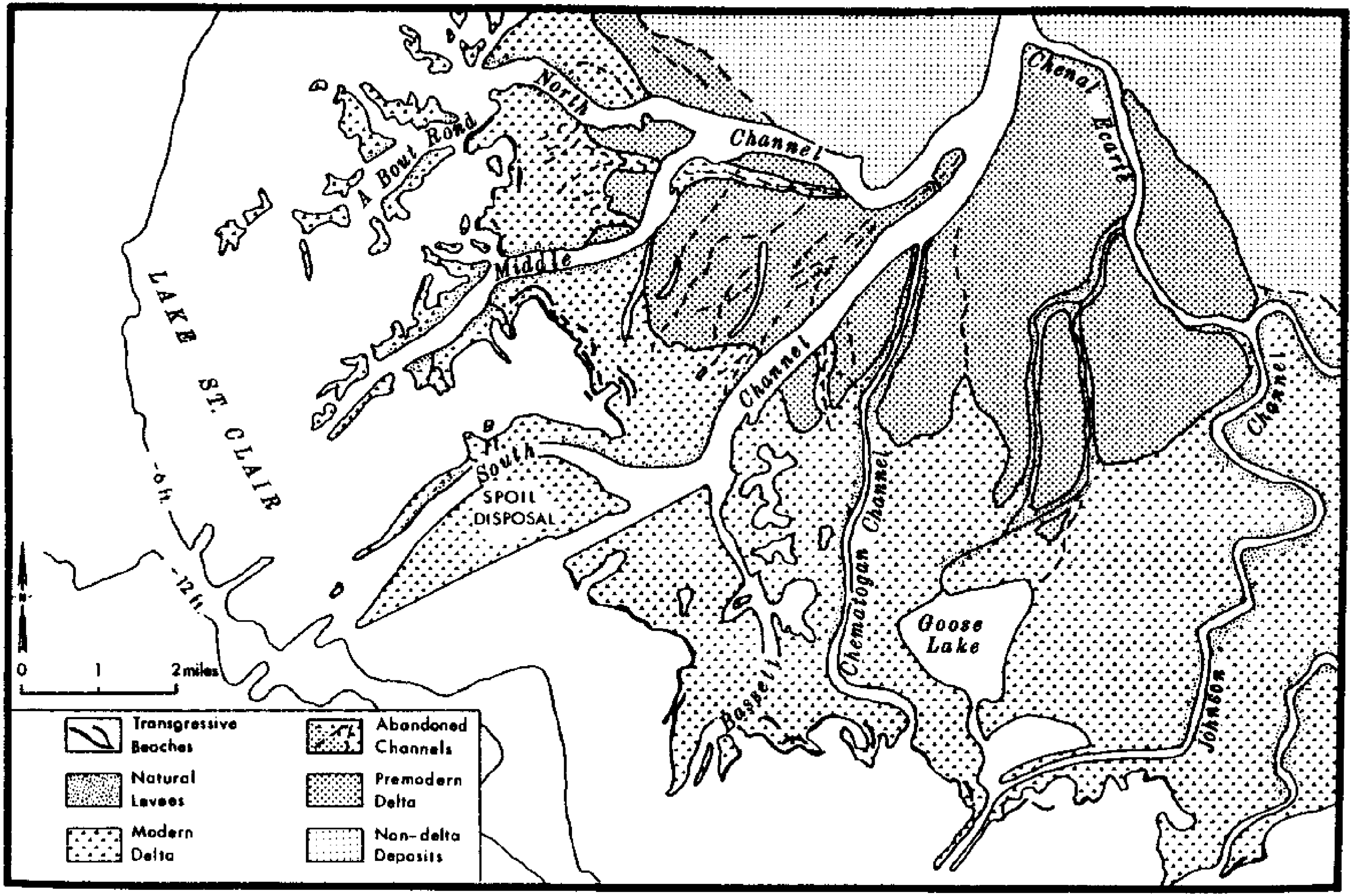


Figure 25. The Landforms of the St. Clair River Delta

delta formation. Detailed investigations by geologists have partially documented the sedimentological composition of the delta's surface, particularly in Muscamoot and Goose Bays (Mandelbaum, 1969; Pezzetta, 1968). During the 1950's, engineering studies by the U.S. Army Corps of Engineers preceded construction of the 27-foot Seaway channel through the delta. Although not published, much of these data, in the form of bore records, are on file at the Detroit District Office. Recent environmental studies associated with flooding problems on the shores of Lake St. Clair and dredged spoil disposal site locations have also contributed some useful data for this subsection (U.S. Army, 1973).

Based on flow distribution, it is clear that the most active portion of the delta is presently confined to the western side of Lake St. Clair. Much of the flow of the St. Clair River is carried by the large distributaries on the American side of the delta. North, Middle, and South Channels account for approximately 95 percent of the flow volume, and the principal Canadian distributary, Chenal Ecarte, accounts for the other five percent (U.S. Army, 1968). Although North Channel appears to have been the main channel a century ago, construction and continual dredging of the St. Clair Cutoff channel has increased the flow of South Channel.

Because the St. Clair River has few tributary streams, the source for delta sediments is not solely fluvial. Rather, the principal source appears to be the shoreline of Lake Huron; the sediment load is directly related to waves impinging upon lower Lake Huron beaches (Duane, 1967). It has been determined that 21,700 cubic yards of sediment, primarily sand size, is transported by littoral currents from the southeastern shore of Lake Huron annually (Korkigian, 1963). An undetermined amount of sediment is also derived from moraines and ancient beaches along the western shore of Lake Huron. Size and mineral composition of Muscamoot Bay sediments are similar to the glacial sediment of the southern Lake Huron coastal zone (Sachdev and Furlong, 1973).

The unusual transparency of the river water suggests that most of the material is being carried as bed load, not in suspension. It has been estimated (Pezzetta, 1968) that the total sediment load of the St. Clair River is about 20,000 cubic yards annually. Not only is the sediment load very low, but much of it may be transported through the delta into Lake St. Clair, accounting for the lack of present subaerial delta extension. In addition, over the past 55 years maintenance dredging by the Corps of Engineers in The St. Clair River has averaged 80,000 cubic yards annually (Raphael et al., 1974). Private dredgers have also been extracting sand and gravel for many years, particularly from North Channel. Because dredging removes much of the bed load and since little material is carried in suspension, little subaerial delta extension and wetland expansion are occurring.

As a lake delta, the St. Clair exhibits several of the landform characteristics of marine deltas, such as active and inactive distributaries, interdistributary bays, and crevasses or breaches which lead into interdistributary bays. However, although the St. Clair River delta has a classical bird-foot morphology, as does the Mississippi River delta, significant landform differences are also apparent. Atypical landforms include a premodern surface located at the apex of the delta and unusually wide distributary channels which are illustrated in Figure 25.

Dickinson Island (Figure 26) was selected as the site for our vegetation analysis. The island is composed of the landforms noted above and is one of the few remaining natural areas in the delta. The physiography of Harsens Island to the east, including its vegetation, has been modified; the natural levees have been urbanized and the interdistributary bays diked. Therefore from the standpoint of natural vegetation studies, Dickinson Island is more representative of natural conditions. Much of the geomorphic data, however, are derived from Harsens Island and its immediate area; the geomorphic framework extends beyond Dickinson and considers the delta as a whole.

The active distributaries, North, Middle, and South Channels, average 1,500 feet in width and 35 feet in depth. However, widths of 2,000 feet and depths of 80 feet are not uncommon. At the mouths of the distributaries, channel depths decrease abruptly, indicating the presence of river mouth bars six to twelve feet below mean lake level. As a depositional basin, Lake St. Clair is relatively small, with a maximum depth of 21 feet and a length of 25 miles.

North, Middle, and South Channels exhibit submerged river shoals along both the cutbank and point-bar sides. A similar morphology has been attributed to periodic cut and fill associated with slight base level oscillations (Butzer, 1971). These features may be caused by lateral erosion of the fine, sandy deltaic sediments which overlie the lacustrine clays. On the inside bank, especially along Middle Channel, point bar deposits characterized by ridge and swale topography are conspicuous. Here the distributary shoulders probably represent fill deposits which are colonized by emergent vegetation during low-water periods.

Because of the water level fluctuates only 1.5 to 2 feet seasonally, spring floods are not a normal occurrence within the delta, so natural levees adjacent to modern distributaries are scarcely discernible. Even though levees are poorly developed, averaging a few inches to 1.5 feet in elevation, flooding does occur, associated with breaching of levees in abnormally low areas along a levee. As a levee is breached, crevasse deposits are introduced into the interdistributary bays (Goose and Muscamoot Bays) at right angles to the channels. With continued deposition, the openwater bay will be filled with crevasse deposits and colonized by sedges and emergent aquatics.

Crevasse channels, locally known as "highways", are operative for several years but deposition into the bays is not rapid. A comparison of navigation maps reveals that such features may be part of the delta landscape for over a century. This suggests that crevasse channels are active intermittently and transport little sediment into the interdistributary bays.

During the winter and early spring when Lake St. Clair is frozen, pack ice accumulates at the mouths of distributaries. Channel flow is then diverted into crevasses. However, because the dominant grain size is sand, little suspended

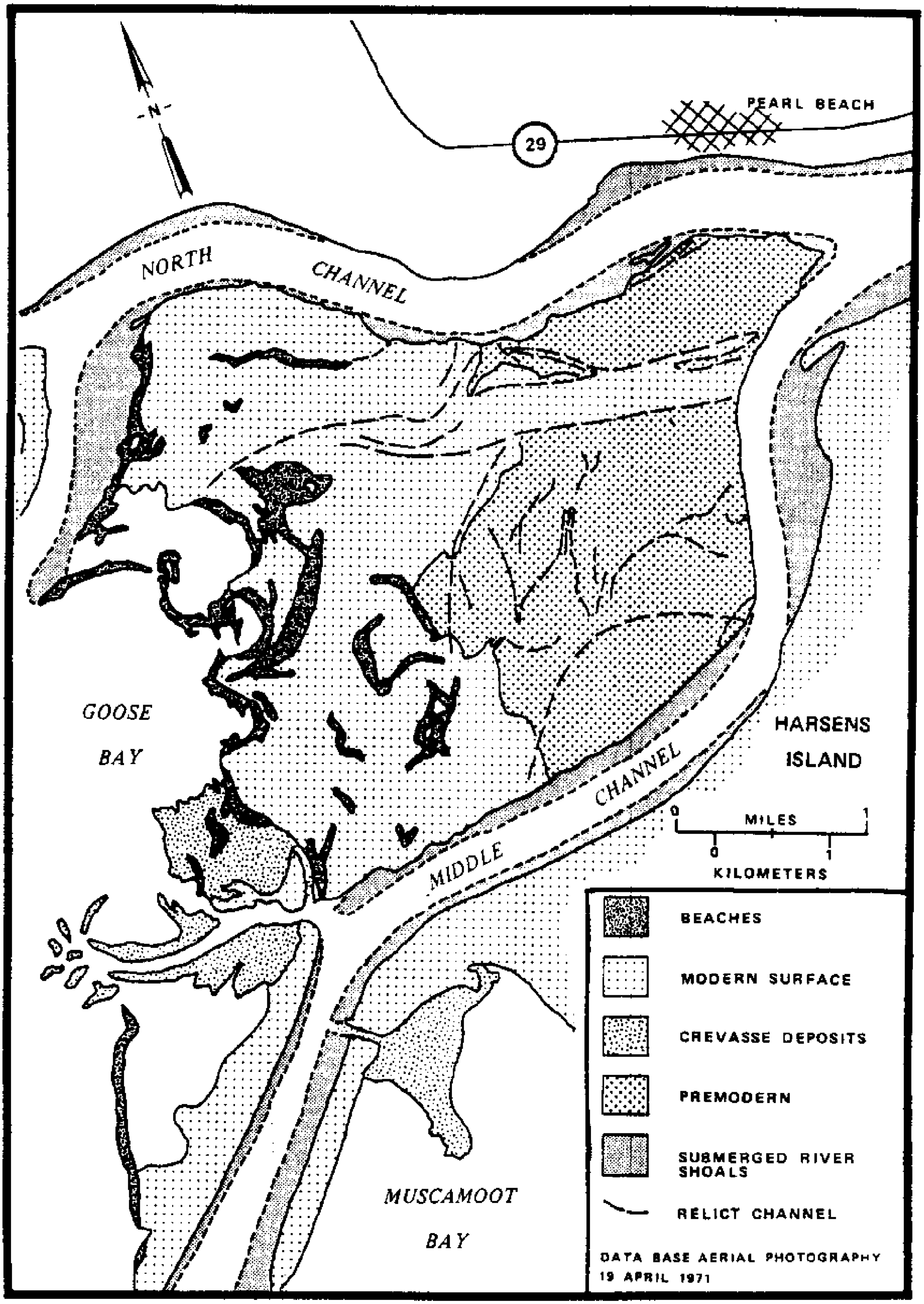


Figure 26. The Deltaic Landforms of Dickinson Island, St. Clair County, Michigan

sediment is transported from the deep distributaries into the interdistributary bays. Thus, in the St. Clair delta the filling of interdistributary bays and delta growth is a slow process. In the Mississippi delta, in contrast, crevasse deposits rapidly convert open interdistributary bays into mud flats which are subsequently colonized with marsh grasses. During flood stage, the crevasse channels are scoured deep enough to be maintained and rapid deposition occurs. In the past 135 years, crevasse deposits have transformed the open inter distributary bays of the modern delta of the Mississippi River into a complex of marshy subdeltas (Coleman and Gagliano, 1964).

Beaches on the present St. Clair delta shoreline are poorly developed and appear transgressive in origin. On the Canadian side, where the beaches are somewhat better developed, the berms may reach three to four feet in height and are colonized with sumac and small trees. Our borings reveal that the principal constituents of these beaches are coarse sand or fine gravel separated by layers of organic sediments. On the American side, the beaches consist of alternate layers of sand and organic materials including rafted logs, bulrush stems, and other debris. Coarse sands and fine gravels are not as evident, and storm berms seldom exceed two feet in elevation. Characteristic vegetation of these shoreline features consists of either sedge marsh or a complex community of grasses, thistles, and other non-woody species.

Within the interdistributary marshes, especially on lower Dickinson and Harsens Islands, are arcuate-shaped features resembling beach ridges. Our borings through one of these ridges have revealed up to ten feet of fine sand. The absence of washover deposits and organic sediments indicates that these features may be regressive beaches and represent changing shorelines as delta accretion took place.

A comparison between the eastern and western portions of the St. Clair delta illustrates two other distinct differences. On the Canadian side Chenal Ecarte and Johnson Channel are narrow, shallow distributaries which do not carry a significant portion of the volume of the St. Clair River. Moreover, open interdistributary bays are few and are colonized by marsh vegetation. Delta extension has ceased and maximum delta accretion is now occurring to the west as evidenced by the active digital distributaries of North, Middle, and South Channels and Chenal a bout Rond. In the past, Chematogan and Bassett Channels were approximately 1500 feet in width, comparable to the modern distributaries, but they have been alluviated and colonized with aquatic plants as abandonment occurred. According to Leverett and Taylor (1915), sedges and rushes slacken the current and induce sedimentation in channels.

A series of borings, cores, and exposures indicates that in cross section the St. Clair delta is a thin and sandy deposit. An east-west cross section reveals that above the shale bedrock, lacustrine clays have been deposited over a thin deposit of glacial till (Figure 27). The coarse deltaic deposits, having a maximum thickness of 20 feet, rest upon blue lake clays.

The north-south cross section from the apex of the delta into Lake St. Clair illustrates the near-surface stratigraphy (Figure 28). Topographically, however, this cross section reveals two distinct levels, a modern and the equally obvious premodern surface. The premodern surface, standing about five

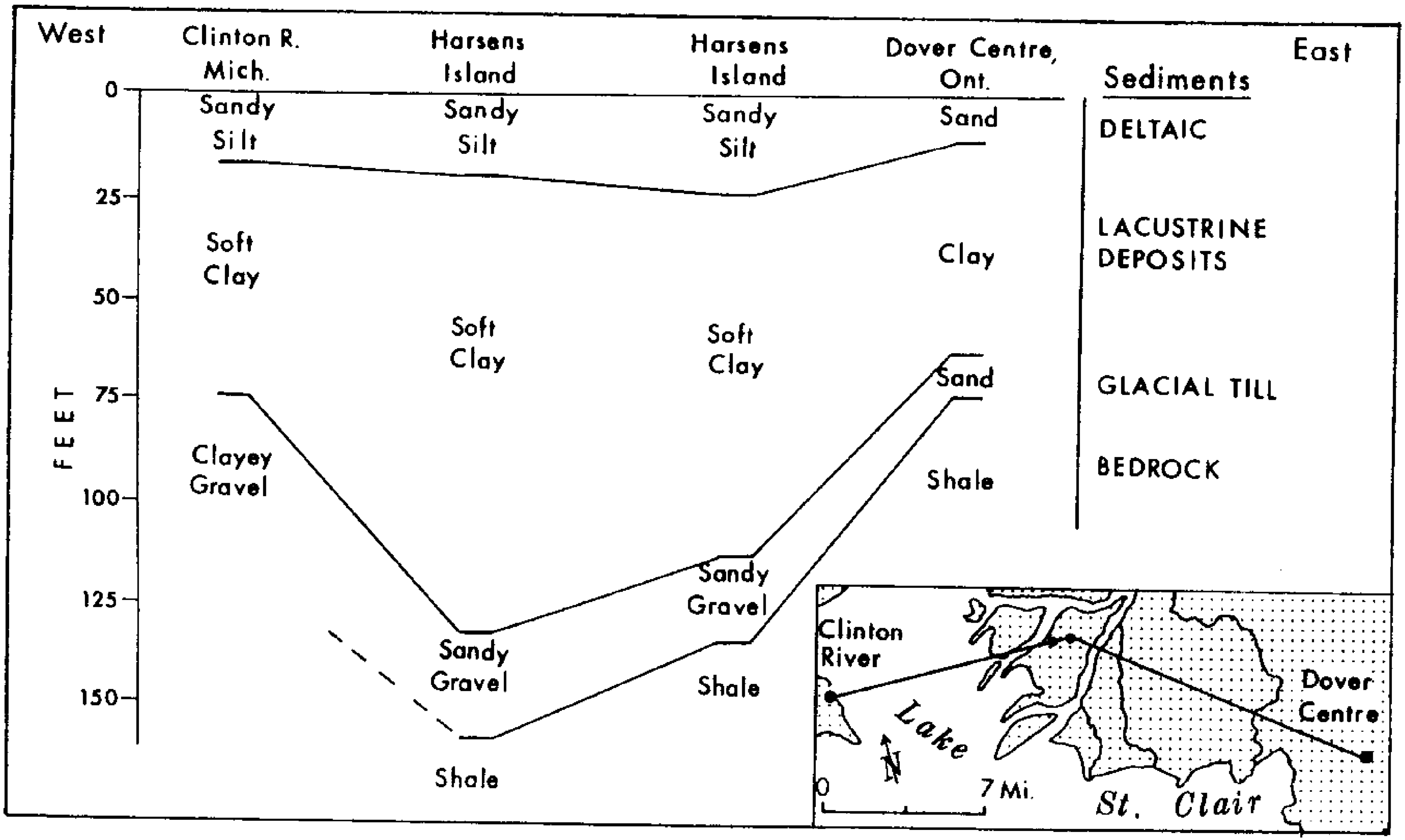


Figure 27. A Stratigraphic Cross Section of Lake St. Clair and the St. Clair River Delta

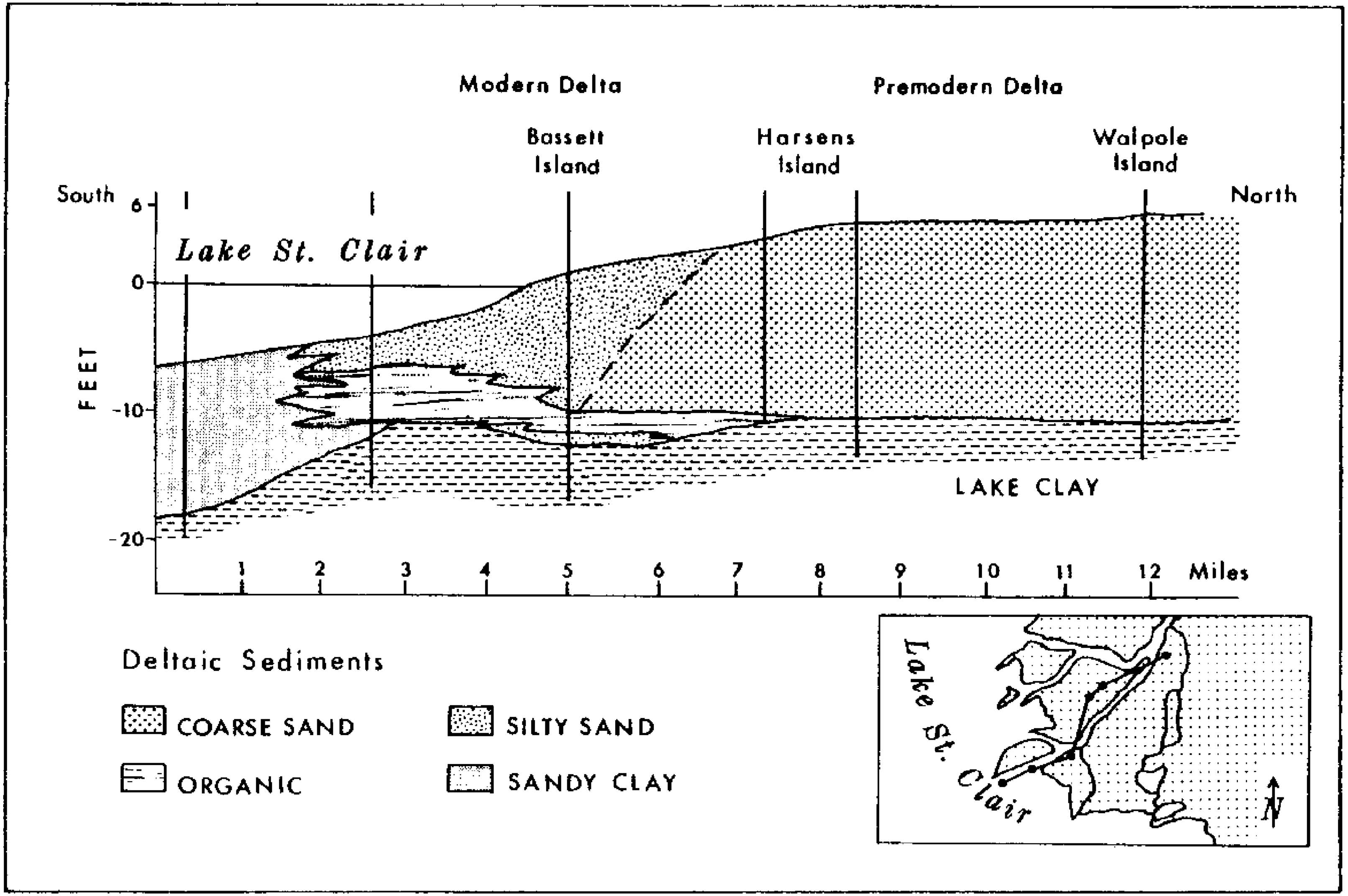


Figure 28. A Near-surface Stratigraphic Cross Section of Harsens Island, St. Clair River Delta

feet above Lake St. Clair, consists of coarse, oxidized sand and is confined to the apex of the delta complex. It has been dissected by long, sinuous channels which have been alluviated. Occasionally during high lake levels these channels have been reoccupied, particularly in areas such as Dickinson Island, where human interference has been minimal. As this higher surface is topographically and sedimentologically distinct, it is a surface which was deposited during a pre-existing higher lake level. The modern delta with its finer sediment is located at present mean lake level and is represented by the active crevasses and interdistributary marsh deposits (Pezzetta, 1968; Mandelbaum, 1969).

Since the retreat of the glacial ice, the southerly flow of the St. Clair River into Lake St. Clair was interrupted only once (Prest, 1970). The river flowed south during the existence of Lake Algonquin (12,500 to 11,500 years ago). Due to the establishment of outlets through what is now Georgian Bay, the level of Lake Huron dropped and flow through the St. Clair River ceased. This period of lower water is equated with Lake Stanley or Lake Stanley-Nipissing and occurred between 11,200 to 7,500 years before the present, an incredibly long time by post-glacial standards. A subsequent rise of water level about 6000 years ago created Lake Nipissing (ancestral Lake Huron) at approximately 605 feet above MSL which flowed south and communicated with lake St. Clair via the St. Clair River.

As noted previously, the St. Clair River delta has a premodern and a modern level. The premodern delta was probably deposited during the existence of Lake Algonquin or Lake Nipissing. According to Leverett and Taylor (1915), during the time of the highest Algonquin beach the elevation of Lake St. Clair was 595 feet above MSL; at the time of the Nipissing beach its altitude was 587 feet. Assuming no subsidence of the beaches, the premodern delta was deposited during the establishment of the Nipissing level. Leverett and Taylor seem to concur:

> The delta head near Algonac, with surface six feet above the present river, seems related more nearly to the time of the Nipissing Beach (transition phase), which was the beginning of the modern lake.

Both Wightman and Mandelbaum have obtained Carbon 14 dates from organic material in the delta. Mantelbaum's dates (1969) range from 6100 $\pm$ 200 years before the present whereas Whightman's data (1961) suggests that the delta surface is less than 7,300 $\pm$ 80 years B.P. Pezzetta also has radiogenic data that reveal that the minimum age of the delta sediments is about 4,300 years B.P. Obviously more research is required to unravel the complexities of the delta.

Abandoned channels appear to be mainly confined to the premodern surface. They vary in width from a few feet to widths comparable to the modern channels. As lake level dropped to its modern level the channels dissected the premodern surface. During this time the present channels were established and the modern delta was deposited lakeward of the premodern surface.

Vegetation provided the first evidence for the existence of a premodern and a modern delta. On Dickinson Island hardwoods dominate the oxidized sands, whereas on the modern delta a complex of wetland environments includes abandoned channels, river shoulders, crevasses, and interdistributary bays. The contact between the premodern and modern delta is generally a broad gentle slope and is well marked with a shrub/grass meadow.

Woodtick Peninsula Wetlands

The coastal zone of southeastern Michigan has been a significant outdoor recreation area for the Toledo/Detroit metropolitan area for many years. Because of urban pressure, land use in North Maumee Bay is diverse and of questionable compatibility. Included are areas of ecological importance as well as areas of industrial and residential uses (U.S. Army Corp of Engineers, 1976). Physically the area is subjected to severe flooding and many sectors of the coast in Monroe County are recognized as high risk erosion areas (U.S. Army Corps of Engineers, 1976). The coastal hazards have led to the diking of many private and public wetland tracts in southeastern Michigan as well as in northern Ohio where similar problems occur.

The landforms of North Maumee Bay include a barrier spit (Woodtick Peninsula) and lagoon, and are indirect products of the ice age. The shoreline is physiographically sited on the Eastern Lake Plain which is composed of lake clays. The lacustrine clays were deposited in ancestral lakes of present-day Lake Erie (Feldman et al., 1977). Several lake stages have been identified as the Erie ice lobe gradually retreated and new outlets for premodern Lake Erie were created. At least 15 lake stages have been identified which span a 14,000-year history (Feldman et al., 1977). Unfortunately the beach lines of the ancestral lakes are not as prominent as those observed elsewhere, as at Green Bay or at the Betsie River. The topography is low, the gradients are gentle, and few of the ancient beaches are prominently displayed near the modern shoreline. In fact, of the 15 lake stages noted, only five shorelines, including the present, have been identified with any precision (Feldman et al., 1977). These are Maumee I, Maumee III, Whittlesey, and Warren III. Of these, Warren III is the youngest and most lakeward beach. It is located 13 miles west of the present shoreline.

Another general characteristic of the shoreline is the drowned appearance of the many river mouths. Within Monroe County, La Plaisance and Otter Creeks as well as rivers entering North Maumee Bay (e.g. Ottawa River, Halfway Creek) all have wide river mouths indicative of coastal drowning due to rising lake levels or downwarping of the landscape (Erie and Oregon U.S.G.S. quadrangle maps).

Moore (1948) determined from 106 stations in the Great Lakes Basin that with the exception of northern Lake Superior, the basin is subsiding with respect to sea level. A gage at Toledo subsided 0.72 feet between 1877 and 1944. At Monroe a gage went down by 0.63 feet from 1859 to 1937. Moore concludes that greater subsidence and encroachment of Lake Erie on the land is in the western end of its basin.

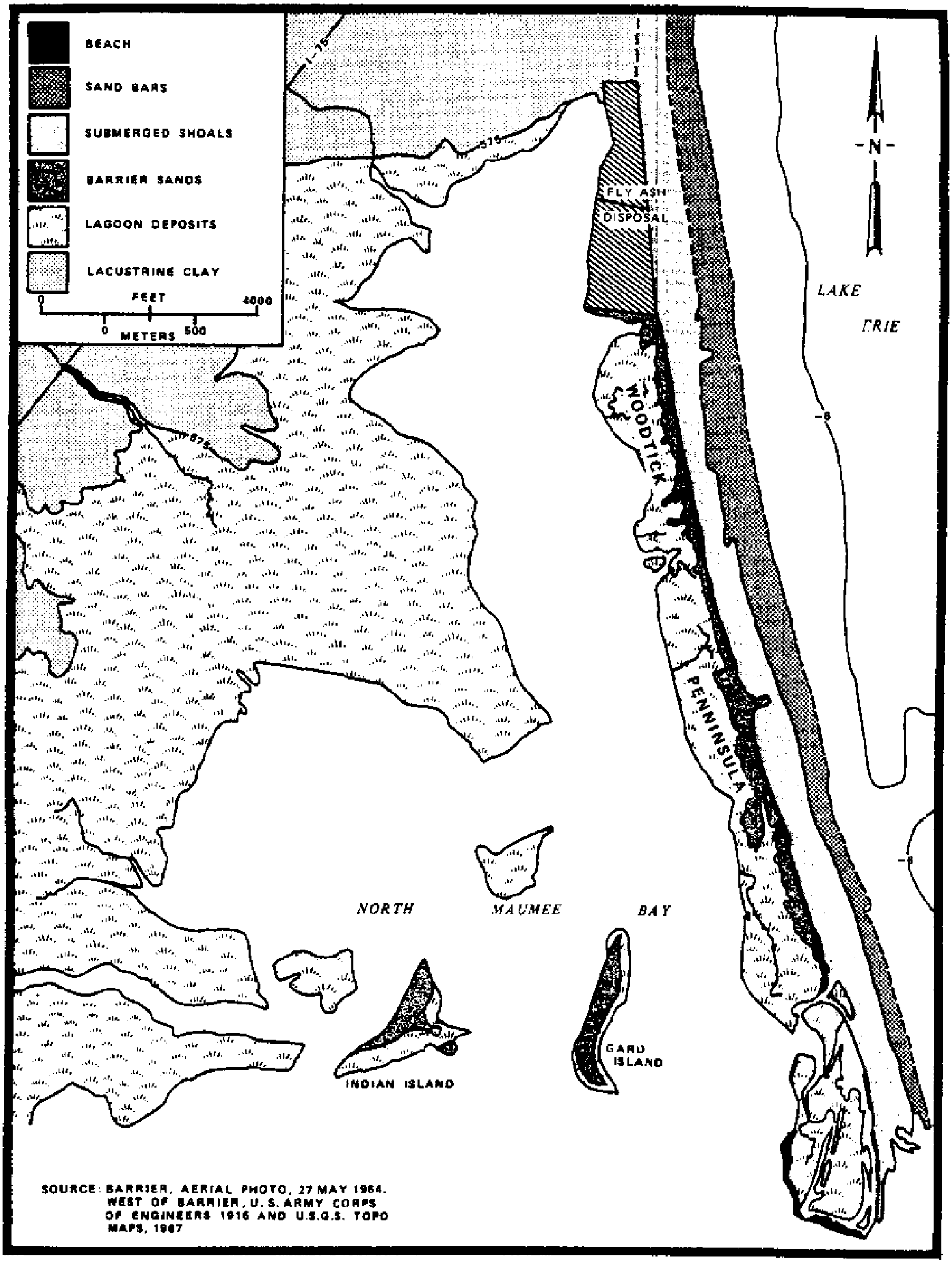


Figure 29. The Coastal Landforms of the Woodtick Peninsula Wetlands

Subsidence of the Lake Erie shoreline has been noted in more detail by many investigators (Sparling, 1976; Pincus, 1959; Shaffer, 1951) and is further discussed in the Toussaint Marsh subsection. Drowning of the shoreline may lead to the further destruction of the barriers and spits in western Lake Erie. This in turn would lead to wave exposure and erosion of adjacent wetlands. Thus, diking of coastal Lake Erie wetlands does have some geological justification.

Figure 29 illustrates the landforms of the Woodtick Peninsula and North Maumee Bay. Many of the wetlands are now diked. However, to present an unaltered view of the natural features, aerial photographs (1964) and other maps were used to compose this map. The average water level of Lake Erie at Toledo in 1964 was 568.90, somewhat lower than the long-term average which was 569.86 between 1900 and 1976. However, because of these lower levels nearshore features such as sand bars become more evident.

According to Forsyth (1973) and Lewis et al. (1966) lake Erie was about 35 feet below its present level 4,000 years ago, so during that time the shoreline was located more lakeward. According to Graves (1977), 2,500 years ago the shoreline was approximately five miles to the east. Coastal dunes developed on the exposed flats which were occupied by Woodland Indians. Gard and Indian Islands are dunes deposited on the exposed flats which were occupied during early and middle Woodland times (1,950 B.P. - 1,340 B.P.). As lake level rose the flats were drowned and the dunes became islands. The Woodtick Peninsula, according to Graves, was formed as a spit extending to the south at a much later time. A relative rise in lake level would also explain the drowned appearance of many river mouths debouching into western Lake Erie.

The Woodtick Peninsula technically is a recurved spit. As one proceeds from north to south the beach and barrier curves or exhibits a "recurved" shape. The development and growth of the deposit is in the predominant direction of the littoral current which in this case is to the south. The recurved ridges are formed either by the interplay of sets of waves approaching the shore from different directions or by wave refraction around their ends (Evans, 1942). Between the ridges of the spit linear semi-impounded wetlands have established themselves during lower water periods. During higher water periods these troughs are flooded.

The barrier spit was leveled and bored 5,000 feet south of the fly ash disposal sites (Figure 30). The barrier is composed of sand and occasional lenses of peat, and it stands approximately four to five feet above Lake Erie. As a result of the severe erosion and breaching which occurred during the higher lake levels of the early 1970's, its width has varied.

The variability of the barrier width is evident on aerial photographs between 1937 and the present. During lower lake levels such as those in the late 1930's, the width of the barrier sands was estimated to average 60 feet. The landform was colonized by large trees but occasionally unvegetated areas and washover deposits were evident, particularly on the northern part of the spit. A trail allowed access onto the barrier for a distance of 8000 feet south of the area now occupied by the fly ash disposal sites. Since the 1930's, there has been a net decrease in the width of the spit. As noted at the profiled locality, the present width of the barrier is approximately 85 feet. Due to severe

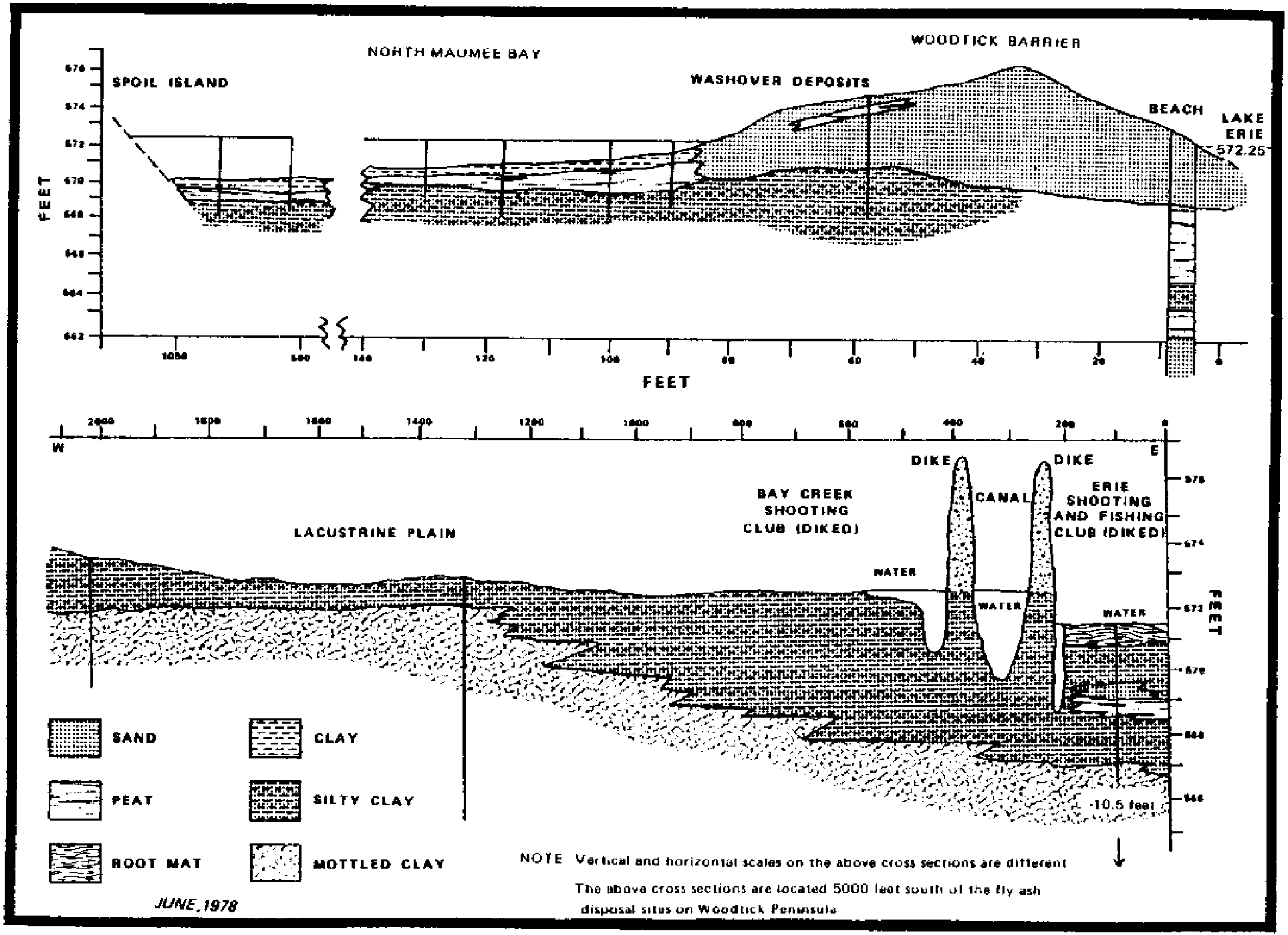


Figure 30. Stratigraphic Cross Sections of the Woodtick Peninsula Wetlands

erosion associated with storms coincident with higher lake levels, in places the barrier is less than 10 feet in width and breaches appear as common features. large willow and aspen trees have been uprooted and now litter the beach and barrier. Approximately 150 feet east of the present shoreline a distinct line of partially submerged trees litters the nearshore zone.

Based on 1964 aerial photography, the nearshore zone exhibits two distinct submarine landforms lakeward of the beaches. Immediately east of the beach are what appear to be obscure submerged shoals extending along the length of the spit. At the south end of the peninsula the features continue to parallel the shore but thin out. Elsewhere a less distinctive pattern is evident; lakeward of some beaches, the shoals are discontinuous but they more or less parallel the shoreline. Elsewhere the deposits are semi-circular and are aligned obliquely to the shoreline.

Lakeward of the submerged shoals a complex of sand bars occurs; four bars are evident near the south end of the spit. However, to the north the zone increases in width and at least seven well-defined bars are discernible by aerial photography.

It is not improbable that the lakeward side of Woodtick Peninsula once extended eastward to the lakeward side of the submerged shoals. This does not imply that the barrier was much wider than at present, but its position has shifted landward. As the spit was eroded, washover sands were deposited and the feature was gradually redeposited westward onto the North Maumee Bay wetlands. The contact between the barrier sands and existing marsh is well defined, suggesting washover activity (Figure 29). In many localities along the barrier spit, fresh sand deposits overriding cattail stands have been observed.

The stratigraphy at the shoreline (Figure 30) clearly suggests a marshy environment (silty clay; peat) which has been overridden by a transgressive barrier. The uprooted trees in the nearshore zone also dramatically point to recent coastal erosion. Aerial photographs made in July, 1937 reveal a narrow spit vegetated with trees; no trees were then evident east of the spit. The uprooted trees in the present nearshore zone are probably trees which colonized Woodtick Peninsula in 1937. More recent photography by the U.S. Army Corps of Engineers (April, 1973), which surveyed the damage of the March 1973 storms (Bryan, 1976) on Lake Erie, clearly shows breaches in the barrier and large trees littering the nearshore zone. Since the trees were present on 1964 photographs, it may be concluded that severe erosion of the spit has occurred since then, most likely during the winter storms of 1972-1973.

Although erosion is a significant process, the Woodtick barrier has maintained itself for at least 700 years. At North Cape, Indian pottery identified and classified as Middle Woodland occurs on the ridges and on the present beaches. The stamped clay artifacts found on the surface of the ridges were not wave washed or abraded, suggesting that they were not transported there by waves but rather are in situ. The intricate designs reveal that the sherds were manufactured between ca. 1100 to 1300 A.D. Depsite the coastal erosion which has occurred, the archaeology suggests that at least sectors of the spit are exceedingly resistant to change.

Landward of the spit the barrier sands interfinger with the organic and inorganic sediments of the lagoon. The landward extent of the lagoon is the 575-foot contour line. This boundary is based on soil types and land use rather than topography, since higher than present shorelines of Lake Erie are obscure in this area.

The soils east of the 575-contour are with the exception of the Woodtick Peninsula mapped as Lenawee silty clay loam, ponded (U.S. Department of Agriculture, in preparation). Landward of the 575-foot contour are two soil types, the Lenawee Series and the Del Rey Series. Both series are poorly drained silty soils and are considered lacustrine deposits of ancient Lake Erie.

In 1901 detailed navigation charts indicated the 575-foot contour approximated the landward boundary of the lagoon (Jaworski and Raphael, 1978). To the west of this contour were agricultural fields. It is not unlikely that prior to 1901, the wetlands extended farther inland. However, since then cultural modifications have occurred eastward to the 575-foot contour. East of this point the diked wetlands of the Bay Creek Shooting and Erie Shooting and Fishing Clubs are encountered. Thus, the land use east of the 575-foot contour is characterized by diked wetlands whereas to the west agriculture is the dominant activity, and the landward limit of the lagoon is determined by cultural change as well as physical change.

The surfical lagoonal sediments are composed of clays and silty clays. Immediately west of the barrier the clays are gray to black in color and are oozy rather than compacted. Beneath the soft clays a peat is encountered which extends at least 550 feet to the west. It probably represents the surface of the more extensive development of the North Maumee Bay wetlands during lower lake levels.

An east-west cross section constructed on the west side of the lagoon reveals sediments derived from a variety of processes. The surface is composed of a wedge of organic-rich greasy clay which thins to the west. Beneath the dark clay a mottled and reddish clay is encountered. The contrast between the silty clay and mottled clay is not sharp. The reddish clay increases in depth lakeward. Samples of the mottled clay have been dredged by the hunting clubs to reinforce their dikes, and small pebbles commonly have been encountered in this sediment. The mottled surface is probably glacial till (Sherzer, 1900) which is widespread throughout the county and underlies the lacustrine clays.

Within the diked area of the Erie Shooting and Fishing Club two peat layers are encountered. A dark brown to black root mat occurs at the surface (571 feet) and has a thickness of approximately eight inches. A second peat was encountered at 569 feet and has approximately the same thickness as the peat at the surface. The deeper peat is fine grained and consists of four inches of brown peat over four inches of darker peat. The horizontal extent of the peats is at best speculative. The rootmat appears to be the continuation of the surface peat landward of the coastal barrier, suggesting that North Maumee Bay wetlands were much more extensive in the recent past. The lateral extent of the lower peat (569 feet) is not known. However, based on its elevation, it may be the landward extension of the peat encountered beneath the active beach.

Overlying this peat are clastic sediments, suggesting that the old marsh surface was buried by a shoal or perhaps by washover beach deposits.

In summary, the North Maumee Bay wetland is a classic example of a barrier spit and lagoon complex. The geomorphic framework here is quite similar to the barrier/lagoon (or sound) complexes observed on the east coast of the United States. The barrier has been severely eroded, particularly over the past decade. However, the archaeological data suggests that the feature has maintained itself over several centuries. In fact in the summer of 1978 exposed shoals began to appear in the area mapped as submerged shoals on Figure 29. The sand shoals which were linear in shape are now located 250 feet offshore at the southern boundary of the fly ash disposal sites. As water levels recede it is anticipated that the barrier spit will prograde lakeward.

Another significant factor which is important to wetland distribution here as well as at Toussaint is the subsidence documented in western Lake Erie. If the shoreline is sinking because of glacial unloading or isostacy, coastal erosion and flooding can continue to be important processes in these coastal areas.

The landward limit of the lagoon is not as well defined as in other wetlands we investigated. The limit is the 575-foot contour which coincides with a soil boundary and the lakeward limit of agriculture. A distinct change in landforms, is difficult to perceive in the coast of western Lake Erie.

Toussaint Marsh

Some of the most continuous coastal wetlands in the Great Lakes were formerly located on the western end of Lake Erie. From Detroit southward to Toledo and along the south coast of the lake to Port Clinton, Ohio, the extensive wetland was part of the Black Swamp (Kaatz, 1955). However, drainage projects since the 1850's and subsequent urban growth have converted many of the wetlands to agricultural and urban/industrial land uses.

Several beaches of the Ohio shoreline have been investigated, particularly in the 1950's (Christopher, 1955; Saville, 1956; Richards, 1957) during higher water period. Much of this body of geomorphic data has been summarized by Pincus (1960). More recently Herdendorf (1973) summarized the physical aspects of the Lake Erie shoreline in Ohio.

Of all the coastal sites described in the present study, this shoreline exhibits the least diversity of landforms. The coast is composed of a low barrier and lagoon complex (Figure 31). Toussaint Creek and its tributary Rusha Creek drain 180 square miles of lake plain. The average discharge of Toussaint Creek (76 cubic feet per second) is the lowest of the principal streams which drain northern Ohio (Herdendorf, 1973). Toussaint Creek enters Lake Erie to the east of the newly constructed Davis-Besse Nuclear Power Plant. As the narrow river approaches the shoreline it widens and forms an estuary approximately one-third of a mile in width. Other rivers flowing into Lake Erie, such as the Portage and Sandusky Rivers, exhibit a similar morphology. The widened mouths are attributed to subsidence of the Lake Erie shoreline due to isostatic

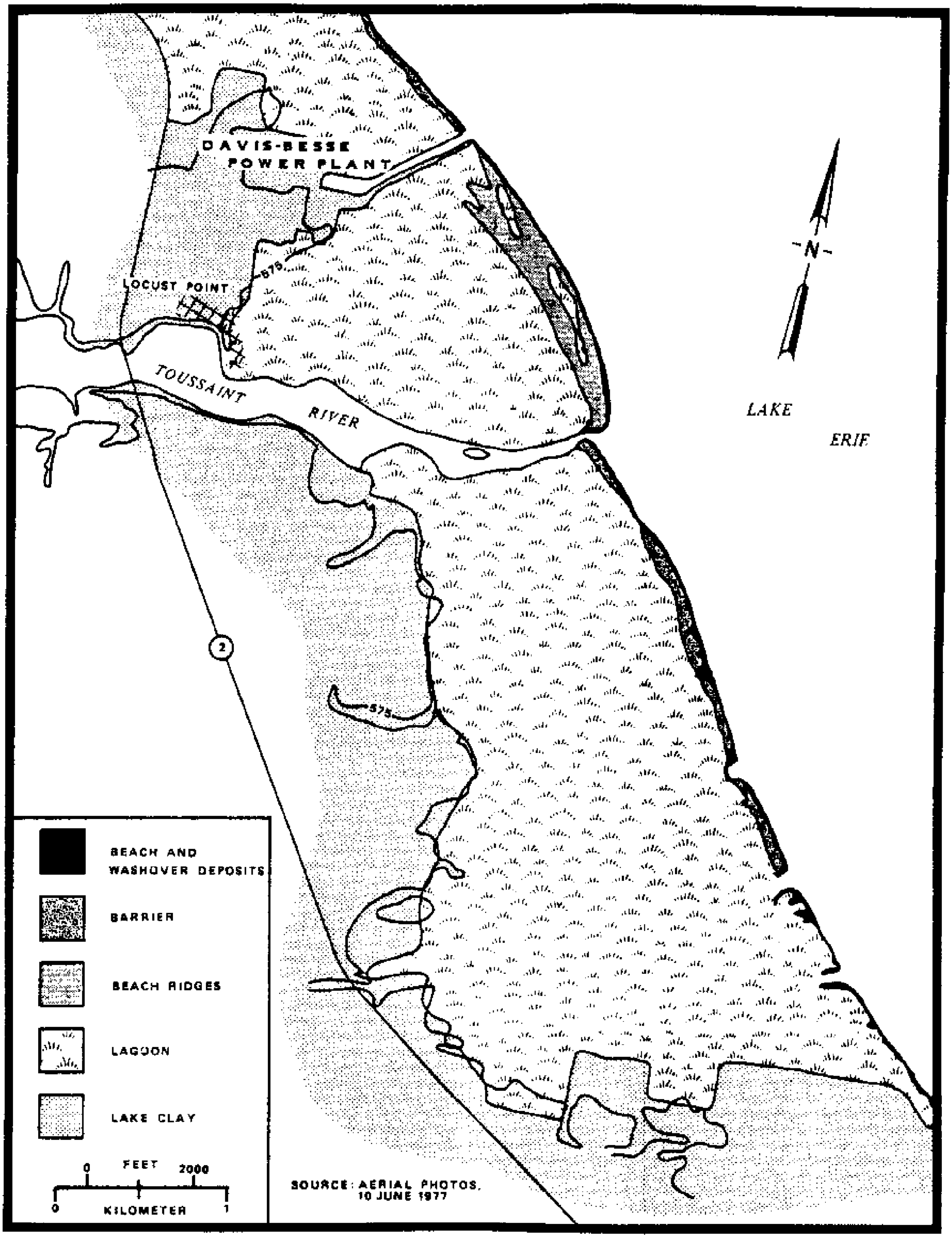


Figure 31. The Coastal Landforms of the Toussaint Wetlands

adjustments since the retreat of the Wisconsin ice sheet (Sparling, 1967; Pincus, 1959; Shaffer, 1951). As the shoreline subsides the mouths of the rivers are drowned and resemble long linear lakes or drowned valleys.

In the Erie basin the greatest measured subsidence is at Port Clinton, about seven miles east of Toussaint River. Moore (1948) determined that the Portage River at Port Clinton is drowned to a depth of six feet. As noted in the Lake Levels subsection, many investigators concur that the western Lake Erie coast has submerged; they generally agree that glacial unloading (isostatic adjustment) contributed to the morphology of the coast. Moore's data, which are more comprehensive, do not discount post-glacial adjustment but suggest that crustal movement is a continuation of movement which has been manifest since before the Ice Age.

An alternative explanation for the submergence of the shoreline is related to the outlet of Lake Erie. A bedrock sill at the Niagara River was depressed by as much as 90 feet under glacial ice (Lewis et al., 1966). Following the retreat of the ice, the outlet gradually rebounded and the level of the lake rose, drowning the existing river valleys. According to Forsyth (1973) the rate of isostatic uplift of the Niagara outlet was initially very rapid (30 feet/century) and then much slower. Currently, the rate of uplift is one-half inch per century. It is this rise of the outlet which has led to a rise in water level and to the drowned river mouth morphology of many streams emptying into the western Lake Erie basin.

The coastal barrier west of the Toussaint River is composed of five to seven beach ridges parallel to the shoreline. The beach ridges are colonized with aspens and separated from one another by grasses. Lower troughs, however, do support some linear wetlands. The barrier appears to have withstood the high water levels of the early 1970's, as no evidence of breaching or fresh washover deposits has been observed.

It is interesting to note that this is the only active barrier composed of beach ridges encountered in our study areas. The ridges represent accretion of the shoreline over time; this is unusual in this area for two reasons. Beach ridges are most likely to develop where the coast is stable, not on a coast where subsidence or rising water levels are active. Secondly, such a barrier complex reflects a sediment surplus. Most barriers of the modern Lake Erie shoreline reveal sediment deficiencies, as is the case east of the Toussaint River.

During our study, the shoreline east of the Toussaint River was investigated in some detail and a cross section was constructed (Figure 32). The barrier was profiled with a dumpy level and cored in two locations. The lagoon, which is completely diked, is managed as a private shooting club and hence is not in a natural state. However, based on topographical maps (U.S.G.S. quadrangle map, Lacarne, Ohio, 1967), exposed dredgings, and discussion with the club manager, enough information is available to determine a geomorphic framework for the lagoonal portion (southwest of the profile).

The coastal barrier separating Lake Erie from the diked marsh is a long linear ridge paralleling the full extent of the wetland. The barrier is

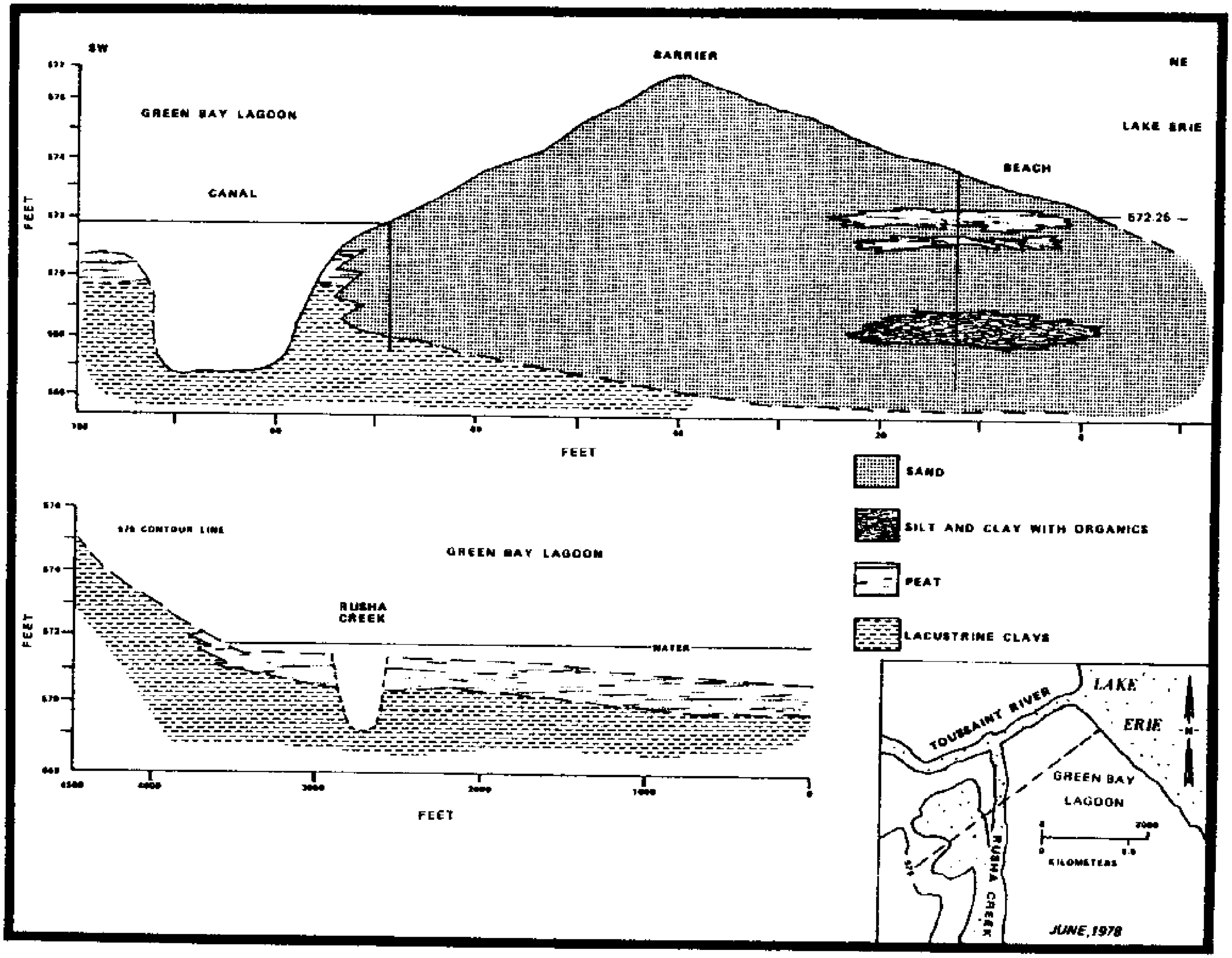


Figure 32. Stratigraphic Cross Sections of the Toussaint Barrier and of Green Bay Lagoon

approximately 70 feet in width and only four to five feet high. Large toppled aspens litter the narrow beach, indicating that erosion is currently active; breaching of the narrow barrier and washover by waves is a common occurrence along this shoreline. In June, 1977, five breaches were identified on aerial photographs. Tinker (1960) classified the beaches of Ohio and determined that Toussaint Beach is in constant change and hence unstable. Despite the current erosion activity, however, the Ohio shoreline from Toledo (Lucas County) eastward to Erie County, Ohio had minimum erosion rates in terms of volumetric contribution along the Lake Erie shoreline between 1877 and 1973 (Seibel et al., 1976).

Stratigraphically, the barrier along the shoreline at Toussaint Marsh is at least seven feet thick at the beach face. Compared to other barriers investigated, its sediments are variable in composition and size and consist predominantly of medium sands (Figure 32). Lenses of shell a few inches in thickness, occasional coarse sand and black sand layers, as well as thicker organic layers, also occur. The layers of black sand are natural concentrations of dark heavy minerals common along the Ohio shoreline (House Document No. 177, 1945). A boring on the leeward side of the barrier penetrated through the coarse sands of the barrier to a depth of three and one-half feet. Here, the barrier is deposited upon silty organic sediment which presumably underlie the entire barrier.

Despite its unusual thickness and sediment diversity, the barrier is transgressive in origin. The variability of the sediment attests to variable wave energy conditions, and the instability of the shoreline as noted by Tinker (1960) is verified in the wave-deposited sediments. The upper two organic layers, separated by clastic sediments, represent vegetated surfaces which have been buried by sands in alternating coarse and fine layers. The coarseness of some deposits is evidence that the sediments were probably deposited by wave action rather than by the wind. Furthermore, washover deposits and breaching of the barrier also confirm that the shoreline has receded.

Barriers elsewhere along the Ohio shoreline appear to by typically transgressional in origin. Saville (1950) investigated a barrier on the coast at Magee Marsh seven miles to the west and found it to be four to seven feet thick and underlain by marsh deposits approximately two feet in thickness and exposed at the beach. Richards (1957) noted that at East Harbor near Sandusky, a barrier had migrated landward with the relative rise in lake level.

As subsidence continues in the western basin, increased erosion and coastal drowning will proceed. Shaffer (1951) has summarized the rates of subsidence calculated by other researchers, which are as follows:

Gilbert (1908) 8 or 9 inches/100 years
Mosley (1905) 2.14 feet/100 years
Gutenberg (1933) 0.5 feet/100 miles/100 years.

As noted previously, several investigators have recognized that the morphology of the coast is related to the stability of the land. Maintainance of a coastal barrier under subsiding conditions is difficult, especially if the sediment budget is low. If the barrier is lost, a loss of wetlands now colonizing the lagoons may be anticipated.

Landward of the Toussaint Barrier,Green Bay Marsh is encountered, which is canalized and diked. The lagoon floor is composed of peat deposits a foot or two thick, a feature apparently consistent with other wetlands to the west. Cores taken by Pincus (1960) indicate that surface peats from Magee Marsh to Reno Beach range in thickness from two to four feet. Underlying the peats are lake clays. The landward edge of Green Bay is approximately the 575-foot contour. As noted by Forsyth (1959), Sparling (1965), and others, ancient shorelines in coastal Ottawa County are not visible. Therefore, the landward terminus of the wetland is determined by the gradual slope of the lake clays. Where the dipping lake clays meet the horizontal marsh sediments is the landward boundary of the lagoon (575 feet above MSL). The 575-foot contour also demarcates the marsh soils from the "upland" soils. The soil survey of Ottawa County (Paschall, 1928) reveals that landward of the 575-foot contour the surface soils are black silty clay (Bonosilty clay) or silty clay loams (Danbury silty clay loam). Lakeward of the 575-foot contour, marsh soils with characteristic surface peat are encountered. Thus, the landward boundary is not demarcated by sharp breaks as in other coastlines in this study, but a slight increase in the elevation of the lake clays and by a change in soil types especially with regard to the upper layer (A horizon).

In summary, the Toussaint Wetland is protected from Lake Erie by a narrow sandy barrier and dikes. The landward side of the marsh is not well marked in the field, but based on topography and on soil surveys the wetland boundary is at or near the 575-foot contour. A significant geologic factor which will continue to have an impact on the marshes along this shoreline is crustal subsidence. As subsidence continues shoreline breaching and retreat may be anticipated. Coupled with the landward migration of the barrier, a higher coastal flooding frequency may justify the need for more diking. It must also be noted that the lagoon sediments consist of peat; flow through the lagoon under present conditions is poor, and probably has been poor in the past, which may account for the accumulation of the organic deposits.

Conceptual Models of Great Lakes Wetlands

The wetlands discussed in the preceding subsections exhibit a diversity of form, but their distribution can be related to fundamental geomorphic features. On a broad regional scale for example, the distribution of wetlands in Green Bay is related to bedrock structure. Conversely, on a microscale the Betsie River wetlands occupy a floodplain devoid of topographical variation. The forms expressed by the coastal areas investigated include deltas, embayments and a variety of barriers and spits. It is interesting to note that coastal build out does not appear to be active in any of the sites investigated. Rather, the coastal areas either exhibit geomorphic stability as in the St. Clair delta or (more commonly) are erosional in character.

Models have been designed to aid in a better understanding of the geomorphic framework of the areas investigated. The models in Figure 33 represent, in composite form, the morphologic framework of some Great Lakes wetlands. Other geomorphic coastal types do occur. The wetlands of the Les Cheneaux Islands and the wetlands in the St. Lawrence River are probably morphologically different from the wetlands discussed in this report, but the coastal types we have investigated appear to represent the most common morphologies in the Great Lakes. Furthermore, the models in Figure 33 are applicable to many marine shorelines as well. It must be emphasized that the models are aerial views, and not necessarily related to preconceived cross sections. They represent topographic distributions and relationships of uplands (e.g., terraces) and lowlands (e.g., lagoons). As noted previously, similar topographical expression may represent dissimilar stratigraphic expression. Figure 33e, for example, is aerially representative of Tobico as well as the wetlands of the Woodtick Peninsula. However, the barriers and uplands in the two areas have quite different geomorphic expression.

The seven coastal wetlands discussed fall into five geomorphic settings. Figure 33a represents a model of a delta similar to that associated with Oconto Marsh. The delta is unique because the lagoon is isolated or protected on all sides. Around the inland perimeter of the marsh, upland sediments are encountered; they may represent older and higher terraces of Green Bay or may represent glacial till. In places the perimeter is composed of rock outcrops. Lakeward the wetland is enclosed by a sand barrier whose continuity is interrupted by rivers flowing through the lagoon. A smooth coastal outline characterizes the barrier, which protrudes lakeward at the rivermouth. The morphology of the landforms represents a classic cuspate delta; such a configuration appears to be related to high wave energy. As determined by Coleman (1976), a significant factor in delta morphology is wave power which is governed by several factors including offshore submarine slopes. The shape of this model indicates that the wave power is relatively high. During lower water levels, however, the wave energy appears to diminish, allowing wetlands to colonize the nearshore zone.

A significant difference between the model and the Oconto wetlands is the erosion and removal of the barrier south of the river. Possibly, marine engineering activities coupled with higher water levels may have been in part responsible for this modification.

Figure 33b is also a delta, but of a different type. The shape of the St. Clair delta is like that of a bird foot with long distributary channels and adjacent natural levees forming talons which extend into the lake. A digitate delta shape such as this is indicative of a landform deposited by low wave energy (Coleman and Wright, 1973). Normally, active deposition and extension of the delta occurs under such conditions. However, deltaic deposition and erosion have not been significant over the past century, which is unusual. In coastal Louisiana, the Atchafalaya Delta added 33 square kilometers of new land in three years (Rouse et al., 1978). The active river channels in the St. Clair delta are flanked by natural levees and crevasse deposits which stand higher than the general marsh surface. Over the years they have been dredged and filled for riverside housing. Parallel to the levees are river shoulders which extend upriver to the upland sediments. Wetlands, especially at river bends where

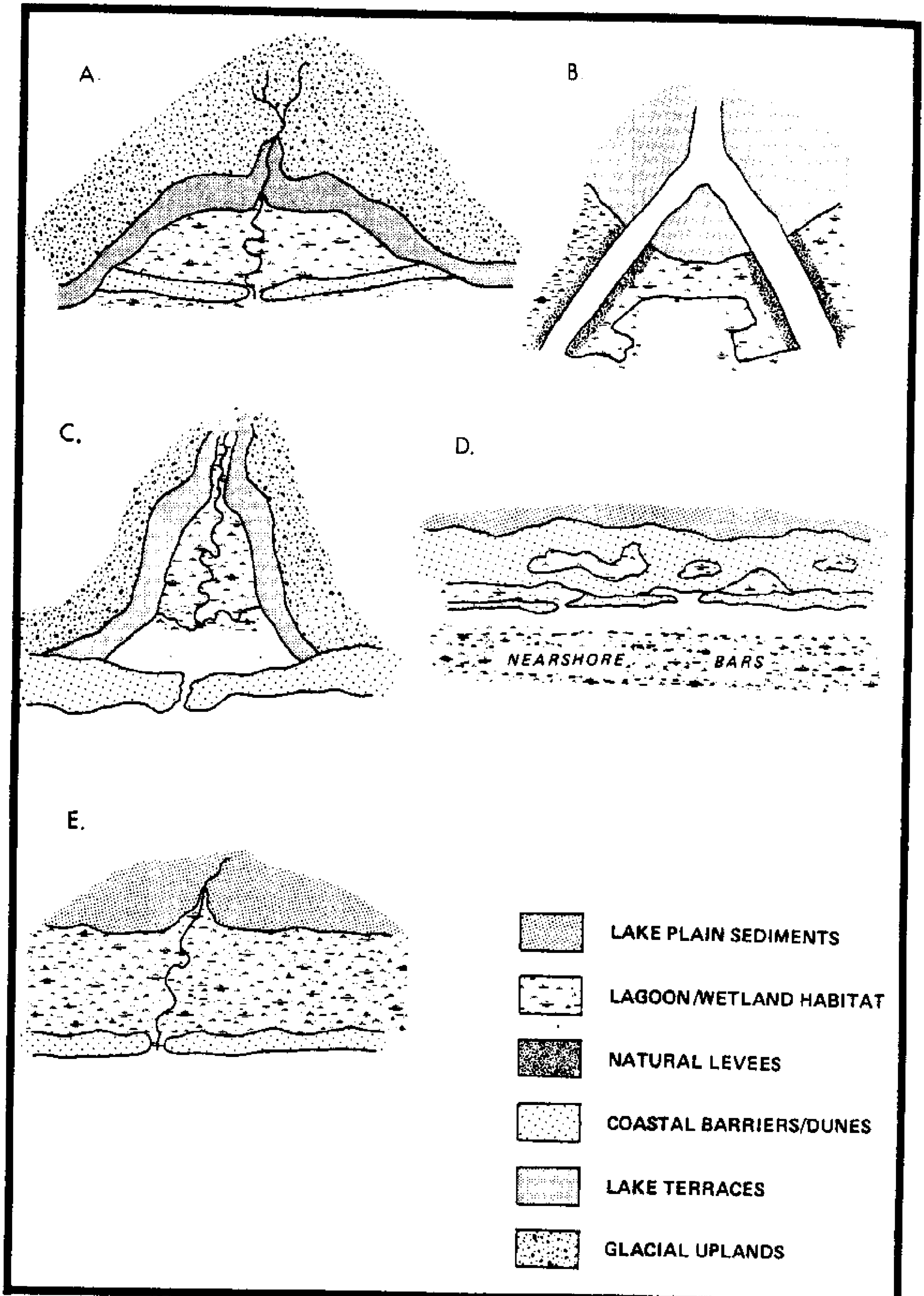


Figure 33. Geomorphic Models of the Coastal Wetlands in the Great Lakes

point bars have developed, colonize these clayey shallows. Wherever deltas have been deposited in the Great Lakes, the landward sides of the wetlands are delimited either by terraces deposited during higher lake levels, or by higher terrain. The similar geomorphic framework identified in Figure 33a and in Figure 33b is also evident in Figure 21c which is an estuarine-like delta and actively expanding.

An apparent difference between the St. Clair and the Oconto delta is that the wetlands in Figure 33a are isolated and normally well protected. Conversely, the St. Clair wetlands located within interdistributary basins are normally exposed to wave action since barriers are discontinuous and narrow, particularly during higher lake levels. In spite of the barrier at Oconto, severe coastal erosion and wetland losses have occurred. In the wetlands of the St. Clair delta, temporary changes associated with changing lake levels have occurred but a net wetland loss has not taken place regardless of the great exposure to wave action.

The contrasting conditions to which the wetlands are subjected to is in part associated with sediment supply and sediment movement which in turn are related to nearshore currents. The protective barrier in Figure 33a derives its sediments from littoral currents flowing parallel to the shore, whereas the sediments introduced into the distributaries in Figure 33b are derived from the river (crevasse deposits). As long as the littoral currents are undisturbed, the barrier will maintain itself. However, if littoral currents are altered by construction activities and if high lake levels occur, the barrier and the adjacent wetland may be eroded. The St. Clair delta is in a quasi-equilibrium state and few morphological changes have occurred over the past century. Furthermore, the shape of the delta indicates that wave energies are low. Although the wetlands are exposed directly to Lake St. Clair, wetland losses are less likely to occur here.

Figure 33c in overview is a lagoon impounded by a coastal barrier. The morphologic condition illustrated in Figure 33c commonly occurs where there is a great deal of topographical variability or change. Along many sectors of the east coast of Lake Michigan glacial moraines, lake terraces representing former shorelines, and sand dunes abut on the shore. In these aras, rivers excavated deep valleys during lower stillstands of the lake. As Lake Michigan approached its present water level, the valleys were filled with organic and inorganic sediments. Linear flood plains, colonized by elongated wetlands and protected by barriers or sand dunes, were subsequently deposited. Presently the wetlands are well protected from wave action and wave erosion. However, since they communicate with the Great Lakes, the changing water levels dramatically affect the distribution of wetland communities.

Figure 33d is a shoreline fundamentally colonized by nearshore wetlands. The shoreline is represented by premodern hummocky barriers. Modern beaches are not well developed and are frequently pushed up the slopes of the older adjacent barrier during storms or high water periods. The sand budget of such shorelines appears to be low, since clay, gravel, and small boulders are common in the littoral zone. Nearshore sand bars are thin and underlain by similar sediments. Also, foredunes are not begin deposited. Depressions in the hummocky topography of the older ridges frequently support wooded wetlands.

The nearshore zone has a series of thin sandbars which support emergent vegetation. The clay beneath the sand bars is tenacious and difficult to erode, so a relatively stable platform has been maintained as in the case of Saginaw Bay. The clayey surface attenuates waves, encouraging the growth of nearshore wetlands. During lower water levels less wave energy is expended upon the shoreline and wetlands attain broader distributions. Since coastal barriers are at best poorly developed, during higher lake levels coastal erosion characterized by washover deposits and thin sandy beaches is evident. Also, during higher lake levels the nearshore vegetation may be uprooted and the wetland area decreased.

Figure 33e is a plan outline which characterizes many shorelines and wetland habitats in the Great Lakes as well as the east coast of the United States and the Gulf of Mexico. The lagoon is located between upland sediments and some type of coastal barrier. As noted in the preceding models, the immediate upland surface is often a terrace, often of Algonquin, Nipissing, or Algoma lake stage. This characteristic holds true for many barrier and lagoon complexes, especially in the upper Great Lakes. Conversely, the inland limit of present-day coastal wetlands associated with the Erie Ice Lobe is geomorphologically obscure. Well-defined older and higher post-glacial beaches often are to be found many miles inland from the present shoreline, so, the landward limit of the lagoon is more closely related to the dipping slope of the lacustrine clays. Under these circumstances the 575-foot contour appears to be the break between "upland" and lagoon in western Lake Erie. This limit is further delimited by changes in soils as well as by land use.

The barrier depicted in Figure 33e may represent one of many more specific landforms, including recurved spits, beach ridges, and transgressive sand barriers. Only by probing the barrier with cores and bores can the mode of deposition and the character of the feature be determined.

Stratigraphic Variability of Selected Coastal Areas

As noted in the preceding subsection, the geomorphic expression of the selected wetlands areas may be represented by five map models. The models represent aerial views of wetlands within a geomorphic context. All landforms have three dimensions: length, width, and thickness. The map models reveal the length and width (i.e. areal extent) of the geomorphic entities of the coastal landscape. The purpose of the stratigraphic models is to illustrate the third dimension and subsurface relationships. As more field data are collected on Great Lakes' coastal zones such models can be further refined.

It has been determined that landforms such as coastal barriers appear on maps to be similar from one model to the next. However, the stratigraphic relationships which include barrier occurrence, barrier thickness, and the nature of the contact between the barrier and the adjacent subsurface may vary from one wetland to the next. Therefore, to present a more complete view of the geomorphic framework of the Great Lakes' coastal wetlands six stratigraphic models have been developed. Figure 34 illustrates the stratigraphic models which represent wetlands associated with the study areas.

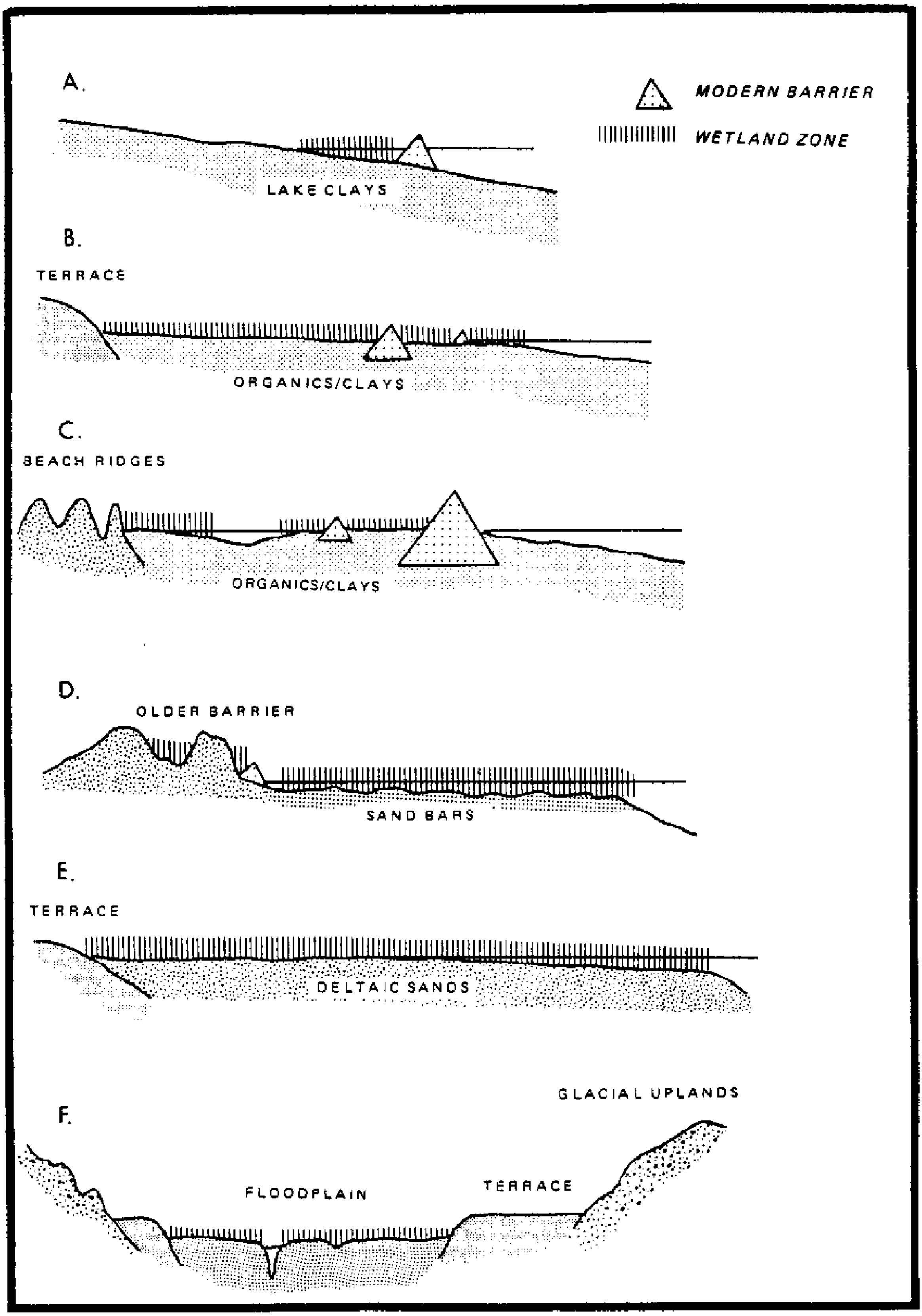


Figure 34. Conceptual Stratigraphic Framework of Great Lakes Wetlands

The least complex barrier and lagoon complexes are in western Lake Erie (Figure 34a). Sand barriers such as the recurved spit of the Woodtick Peninsula and the foredune of Toussaint Creek are ridges of sand resting directly on marsh or on silty organic deposits. The transgressive barrier is unstable and subject to erosion, breaching and laterial displacement during higher lake levels. As noted in the figure, the landward limit of this type of wetland is geomorphologically poorly defined. The remaining cross sections do exhibit an obvious break in slope at the landward boundary of the lagoon.

Oconto Marsh (Figure 34b) has two barriers near the shoreline. The landward barrier represents the shoreline during higher water levels. During lower water levels a small incipient barrier is deposited. A linear depression between the two barriers is created which may be rapidly colonized by emergent marsh plants. Our investigations reveal that the landward barrier is "rooted" in the lagoon sediments and was deposited as a prograding feature. The lower barrier at the shoreline is thin, less stable, more ephemeral, and more strongly affected by changing lake levels. Although Oconto Marsh is deltaic in nature, the viability and distribution of the wetlands are related to barrier development and maintenance as in the other coastal types; the only exception is the St. Clair delta.

The coastal barrier in Figure 34c is representative of a stable shoreline. The sand barrier at the shoreline is interfingered with the adjacent lagoon sediments. Thick barrier sequences are ususally indicative of coast stability and hence a protected wetland. Since the stable barrier developed as a spit, portions of it will also be interfingered in the adjacent sediments. The landward boundary is well defined by a higher surface consisting of beach ridges.

A fourth barrier and lagoon relationship is illustrated in Figure 34d. The active barrier is transgressive in nature and its lateral distance with respect to the higher terrain is variable. In Tuscola County, one mile northeast of Thomas at Fish Point, the active barrier is 1500 feet lakeward of the higher terrain. As one proceeds southwest the active barrier is located closer to the shoreline. At Vanderbilt State Park east of Quanicassee the modern barrier is abutting against the higher and older barrier.

Generalized stratigraphic models of Dickinson Island (St. Clair River delta) and the Betsie River wetlands are also included in Figures 34e and 34f for comparative purposes. The landward limit of the wetlands on Dickinson Island is a higher deltaic surface or terrace. The wetlands occupy interdistributary basins between natural levels. As filling of the bays continues the marshes will prograde lakeward. However, deposition is not rapid in the St. Clair River delta.

The geomorphic framework of embayed wetlands (Figure 34f) is represented by a featureless floodplain wedged between a terrace and/or high bluffs. The sediments are peats and sands which have alluviated the valley. The flatness of the terrain is broken by occasional abandoned channels. Because of the flatness of the floodplain the contact with the adjacent terrace is normally distinct.

In summary, a variety of coastal types occurs in the Great Lakes, which includes barrier and lagoon complexes, deltas, and coastal embayments. The barrier complex is perhaps the most familiar type of coast. However, barriers although similar in shape may form in different ways, and they reflect varying degrees of coastal stability and wetland viability. Perhaps the least secure wetlands are those adjacent to simple transgressive barriers (Figure 34a). In western Lake Erie where such wetlands occur, subsidence of the land and coastal flooding make these wetlands even less tenable. Conversely, wetlands and barriers exposed to lower wave energies such as the types depicted in Figures 34c, 34e, and 34f are usually well protected and from a geomorphic point of view more viable.

WETLAND VEGETATION CHANGES

Changes in the wetland plant communities in response to Great Lakes water level fluctuations have been documented by two methods. First, vegetation bisects across the environmental gradient of the coastal wetlands (from the open water of the lakeshore to the upland community) were surveyed. These bisects, which were surveyed during the summer of 1977 or 1978, provided the elevation and substrate base for the preparation of photo transects representing the low water- and high water-time periods. The second method involved the compilation of maps of plant community distributions for three time periods which represented low water, high water, and falling stage conditions of the Great Lakes water levels. Aerial photography, obtained from the Soil Conservation Service, U.S. Department of Agriculture, provided data on the wetland vegetation.

In this section wetland vegetation changes in the seven study areas are examined. First, a list of plant species, by environmental type, for each study area is presented, followed by a detailed vegetation bisect. Vegetation maps of selected time periods, representing various lake level conditions, are presented. Next, a tabular analysis of wetland losses and gains, with changing lake levels, is presented. Finally, comparative photo transects of each study area are examined and the relationship of plant community shifts to water level fluctuations are described.

Oconto River Mouth Wetlands

Comprising an area of approximately 1,650 acres, the Oconto wetlands represent one of several river mouth wetlands located along the western shore of Green Bay. Basically these wetlands are backbarrier marshes which form on the landward side of a protective barrier beach. The Oconto River essentially divides the wetland into two functional units.

Wetland Plant List Identification of the plant species was accomplished by means of walkthroughs the wetland wherever roads and trails permitted and on the basis of a vegetation bisect surveyed south of the river and a geomorphic profile which was surveyed north of the river. Plant collections were taken of plants not familiar to the field investigators. Because County Y and Bayshore Drive trend parallel to the coast north of the Oconto River, these wetlands are regarded as culturally disturbed. Moreover, diking and water level management of the Oconto Wildlife Area, which is located immediately west of County Y, also disrupts the natural plant succession and retrogression patterns. Therefore, the wetland area south of the Oconto River was selected for the vegetation bisect. However, the Oconto Sportsmen Club has dredged some canals, burned the marsh in the past, and constructed a number of duck potholes in the wetlands south of the river.

The following are the common and scientific names of the plant species generally abundant in the Oconto River mouth wetlands. The plant list is presented by environment type, beginning with the shore environment and ending at the upland boundary.

Nearshore Marsh. Located between the open water of the Green Bay (Lake Michigan) and the modern transgressive beach.

Three square *Scirpus americanus*
Hardstem bulrush *Scirpus acutus*
Hybrid bulrush *S. validus* X *S. acutus*
Sweet flag *Acorus calamus*
Sago pondweed *Potamogeton pectinatus*
Watermilfoil *Myriophyllum* sp.

Transgressive Beach. Located along the wetland shore of the Green Bay.

Willows *Salix fragilis* and others
E. cottonwood *Populus deltoides*
Thistle *Cirsium* sp.
Joe-pye weed *Eupatorium maculatum*
Freshwater rush *Juncus balticus*
Golden rod *Solidago* sp.
Nodding smartweed *Polygonum lapathifolium*
Several grasses

Artificial Earth Dikes. Vegetation variable, depending on length of colonization period.

Willows *Salix* spp.
E. cottonwood *Populus deltoides*
Sumac *Rhus* sp.
Gray dogwood *Cornus racemosa*
Timothy grass *Muhlenbergia* sp.
Brome grass *Bromus* sp.
Canary grass *Phalaris arundinacea*
Cinquefoil *Potentilla* sp.

Canals, Channels, and Open-Water Areas

Yellow pond lily *Nuphar advena*
Sago pondweed *Potamogeton pectinatus*
River bulrush *Scirpus fluviatilis*
Watermilfoil *Myriophyllum* sp.
Waterweed *Elodea canadensis*
Duckweed *Lemna minor*
Arrowhead *Sagittaria latifolia*
Softstem bulrush *Scirpus validus*
Coontail *Ceratophyllum demersum*

Emergent Marsh

Softstem bulrush *Scirpus validus*
Hybrid bulrush *S. validus* X *S. acutus*
Sweet flag *Acorus calamus*
Broadleaved cattail *Typha latifolia*
Hybrid cattail *Typha glauca*
Arrowhead *Sagittaria latifolia*

Grassy-Sedge Meadow. This wetland type may be invaded during low water by woody shrubs and wind-dispersed forbs.

Sedge *Carex stricta*
Bluejoint grass *Calamagrostis canadensis*
Canary grass *Phalaris arundinacea*
Morning glory *Convolvulus sepium*
Reed grass *Phragmites australis*
Boneset *Eupatorium perfoliatum*
Jewel weed *Impatiens* sp.

Willow Shrub

Willows *Salix sericea* and Others
Sedge *Carex stricta*
Jewel weed *Impatiens* sp.
Smartweed *Polygonum* sp.
Morning glory *Convolvulus sepium*
Bluejoint grass *Calamagrostis canadensis*

Shrub Ecotone. Sometimes the term shrub carr is employed.

Service berry *Amelanchier bartramiana*
Gray dogwood *Cornus racemosa*
Red ash *Fraxinus pennsylvanica*
Speckled alder *Alnus rugosa*
Meadow-sweet *Spiraea alba*
Swamp rose *Rosa palustris*
Royal fern *Osmunda regalis*
Sensitive fern *Onoclea sensibilis*
Dock *Rumex* sp.

Upland Hardwoods

Black oak *Quercus velutina*
Red oak *Q. rubra*
Hybrid oak *Q. velutina* X *Q. rubra*
White birch *Betula papyrifera*
Trembling aspen *Populus tremuloides*
Red maple *Acer rubrum*
American elm *Ulmus americana*

Wetland Bisect On July 3-4, 1978, when the level of the Green Bay was approximately 579.1 feet above International Great Lakes Datum, a wetland bisect was surveyed. Water depth and depth to water table served to establish elevations along the bisect. Beginning along the bay margin at an island in the Oconto Sportsmen Club Marsh, which is located about 5,000 feet south of the river, the bisect trends landward toward the west-northwest. An east-west canal was located immediately south of the bisect. A large segment of the emergent marsh was not surveyed due to difficulty in traversing the wetland surface on foot.

As shown in Figure 35, the bisect transected the entire wetland complex, extending from the Green Bay to the upland environment. Beginning with the bay shore, a sequence of wetland zones were encountered along the bisect. The plant communities within each of these zones are described below.

Nearshore Bar Communities In the low troughs between the first nearshore bar and the modern transgressive beach, and in places between the first and second bars, some submersed vegetation exists. This vegetation appears as linear strips perpendicular to the shoreline. Most of the aquatics were Sago pondweed, but some watermilfoil and waterweed were also represented. Water depths in these troughs ranged from 20 to 30 inches. Grab samples revealed the substrate type to be fine-textured, consisting of organic-rich silts and clays. Several nearshore bars occur along this stretch of the coast and afford considerable wave protection for these submersed plants.

Barrier Beach Communities Along many areas of the shoreline, including the area north of the river along Bay Shore Drive, there exists a zone of three-square. This zone, which is variable in width, appears to be confined to the lower face of the modern beach in water depths ranging from 0 to 18 inches. Up to three feet in height, three-square is tolerant of surf processes, even in sandy substrates. The extensive rhizome mat may be rooted in a buried clayey peat which was probably deposited during the recent low water period.

Where the clayey peats are exposed at the shoreline and where wave action is not intense, a number of other species tend to colonize the upper beach face. These species include hardstem bulrush, a hybrid bulrush (*S. acutus* X *S.*

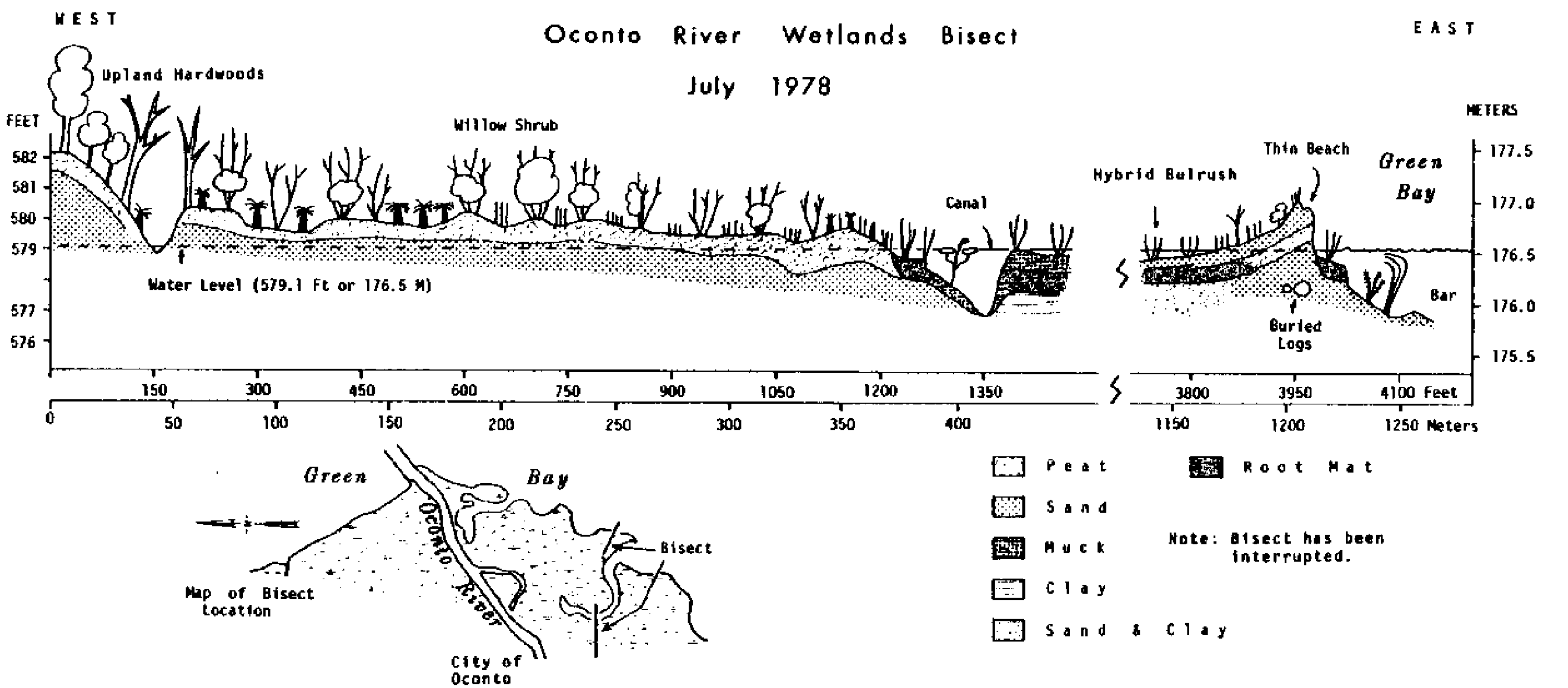


Figure 35. Bisect Across the Oconto River Wetlands, Wisconsin, Surveyed July 1978

validus), and sweet flag. Occasionally dead willows are observed protruding through this exposed clayey peat.

A diversity of plants colonize the landward side of the modern beach ridge. These species include small eastern cottonwood, young willows thistles, Joe-pye weed, nodding smartweed, jewel weed, goldenrods, as well as several grasses. Smartweed and jewel weed appear more common where organic debris is incorporated into the stormberm beach sediments.

The height of the cottonwood and willow trees is dependent on the length of time of colonization of the beach ridge. Where islands and other beach ridge environments have been stabilized by sand accumulations which may attain 3 to 4 feet in height, large cottonwood and willow trees are common. Many of these large trees on the island, where the bisect was initiated, were dead and uprooted. These uprooted trees document the drowning and the subsequent undercutting by wave erosion which occurred during the recent high lake level period.

North of the Oconto River, these large trees appear on an older beach ridge which is located somewhat landward of the modern beach. Where these large cottonwoods and willows are in close proximity, washover processes are retarded as indicated by the beach sand accumulation as well as by the trapped flotsam and organic debris. Partial die-back and some uprooting of the beach ridge trees document the impact of the former high water period. Evidence of ice gouging (removal of the bark at the base of the trees by iceshove process) was not readily apparent.

Landward of the modern beach ridge is a community of mixed grasses, sedges, and freshwater rushes. Washover processes have produced a sandy surface which dips gently away from the modern shoreline. Elevations of this surface near the beach average about 18 inches above the water table. At the emergent marsh boundary water depths of 6 inches are common. Species colonizing this sandy surface include hybrid bulrush (Scirpus validus X S. acutus), several freshwater rushes, several grasses, several sedges, as well as boneset, hardstem bulrush, and sticktights. The colorful loosestrife (Lythrum salicaria) is also common. Grasses, sedges, and freshwater rushes appear dominant near the beach ridge. Hybrid bulrush covers much of the surface near the emergent marsh where standing water occurs.

Emergent Marsh Depending on the water level of the Green Bay, the emergent marsh zone may vary in width from a few hundred feet to nearly 3,000 feet. On July 3-4, 1978, water depths in this wetland type ranged from 0 to 12 inches, with 4 to 8 inches representing the general average depth. During high water periods, storms introduce washover sands into the emergent marsh. Associated with this somewhat sandier substrate are the following plant species: hybrid bulrush (Scirpus validus X S. acutus), spike-rushes, and arrowhead along with some broadleaved cattail and grasses. The spike-rushes and grasses may have colonized this surface last year as water levels continued to drop following record high levels of 1972-1974. Hybrid cattail (Typha glauca) was observed in somewhat deeper marsh areas, and softstem bulrush tended to replace the hybrid bulrush where sediments appeared more clayey or peaty as opposed to being sandy.

The substrate and plant communities of the emergent marsh are not homogeneous. Along the landward margin of this wetland type, the investigators observed alternating layers of clay-peat and sand, while the sand layers were relatively thin. A root mat approximately 6 to 8 inches thick, and comprised largely of grass and sedge-like macrofragments, was encountered beneath the present surface. Abundant plant species along the landward margin included softstem bulrush, sweet flag, and broadleaved cattail. Softstem bulrush and sweet flag are particularly abundant along the channel and canals or where organic-rich clays occur. Whereas the broadleaved cattail is widely dispersed, the hybrid cattail was observed in scattered, but dense colonies in this wetland type.

Canals, Channels, and Embayments Abandoned river channels and artificial canals are fairly common in the Oconto wetland complex. Sediments at the bottom of these hydrologic features consist of several inches of organic-rich ooze underlain by grayish-tan sand which is medium to fine textured. In general the water color appears to be brownish probably due to staining by humic acids. Except where carp and storms raise turbidity levels, it is often possible to see the bottom of these waterways which average two to three feet (0.6 to 0.9 m) in depth. The movement of water in and out of the wetland as a result of wind setup activities was observed.

Along the southeastern margin of this wetland complex where large embayments are common, large colonies of three-square and hardstem bulrush can be observed. In smaller embayments, which are protected from wave action, patches of hybrid cattail (*Typha glauca*) are common. Other aquatics found in these embayments and in large channels as well include Sago pondweed, watermilfoil, and river bulrush.

In the canals and smaller channels the yellow pond lily is abundant along with duckweed, Sago pondweed, watermilfoil, and waterweed. Growing along the channel banks is a mixture of sweet flag, softstem bulrush, and broadleaved cattail. In places this mixed, emergent marsh actually forms a floating mat over the canal or channel edge. A buried root mat comprised of grass-sedge fragments was encountered by borings under this emergent marsh, suggesting a recent low-water stage when a meadow type wetland flourished.

Grass-Sedge Meadow Because of water level changes, this wetland type consists of several vegetation zones. The zones extend from the emergent marsh (discussed previously) to the shrub zone situated on the landward side. Although elevations generally range from 0 to 14 inches above the water table, excessive precipitation or high evapotranspiration probably cause fluctuations in the local water table. Infiltration of surface water appears to be facilitated not only because of the relatively flat topography, but also due to the substrate which consists of porous peats underlain by medium-fine sands.

Immediately west of the canal and the emergent marsh (Figure 35) is a small ridge which may represent a high-water strandline. This ridge is presently colonized by several grasses including canary grass and bluejoint grass. Where rafted organics were deposited, jewel weed, reed grass, morning glory, and boneset are common.

Between this ridge and the canal are two grassy surfaces. Next to the ridge is a meadow which is comprised of well established grasses, including canary grass and bluejoint grass, as well as some boneset and unidentified young sedges. A number of dead sedge tussocks, which were 6 to 12 inches in height, were found in this wetland type along with a few dead willow stumps and branches. In contrast, next to the emergent marsh was another grassy meadow, but which appeared less well established. About 18 to 24 inches in height, most of the vegetation was young grasses and sedges mixed with some sticktights and smartweeds. Field observations taken last summer (August 28, 1977) revealed this zone to be an exposed flat with a discontinuous cover of small grasses and sedges only a few inches tall.

Landward of the ridge the well-established meadow with canary grass and bluejoint grass exhibits dominance. Elevations averaged about 6 inches above the water table. As illustrated in the bisect, some live sedge tussocks appear near the ridge along with partially dead willow shrubs. The sedge tussocks, which average 6 to 12 inches in height, are produced by the sedge Carex stricta. Bluejoint grass commonly grows within the tussocks and may have a commensal relationship with the sedge as it provides organic matter for the buildup of the stools which provide a habitat for the grass above the water table.

Willow Shrub Zone This very extensive wetland type overlaps the meadow and extends landward into the shrub ecotone or "carr". Along the bisect, this wetland type stretches across a distance in excess of 800 feet. Elsewhere in the wetland complex even greater widths have been mapped. Elevations in this willow zone generally range from 2 to 12 inches above the water table. Basically the substrate consists of 6 to 10 inches of black, sandy peat over lying brown, medium-textured sand. Charred willow branches and grass stems indicates that burning was a common practice in the recent past.

Near the meadow boundary, the vegetation of the willow shrub type consists of dead or partially dead willow shrubs along with second or third-year growth grasses. Bluejoint grass was very abundant, with some morning glory, smartweed, and a few live Carex stricta tussocks. The willows often sprouted new shoots from the base which appeared to be slightly elevated above the general wetland surface. Shrub heights appeared to be 6 to 10 feet. The most abundant willow was tentatively identified as silky willow (Salix sericea).

Further landward the willow shrubs tended to be somewhat taller and the die-back less complete. Under the shaded portions, jewel weed were common. Between the willow clumps were mature grasses including canary grass and bluejoint grass.

In the willow shrub zone north of the Oconto River, near the Oconto Wildlife Area, the vegetation changed character dramatically approximately 750 feet west of County Y. At that distance, one abruptly encounters live Carex stricta tussocks where none were found closer to the meadow wetland type. The stools averaged 12 inches in height, whereas the stems of the sedge and commensal bluejoint grass attained a height of 3 feet or more. Also, evidence of dieback among the willow shrubs was nearly absent as fully leaved shrubs were observed. Another plant species in the community included meadow-sweet, morning glory, and stinging nettles. Another unique feature of this wetland type was the presence of several dead tamarack or eastern larch trees. It is possible that in the historical past, tamarack was once more abundant in these coastal wetlands along the Green Bay Shore.

Shrub Ecotone or Carr Located between the willow shrub zone and the upland vegetation is a transition zone referred to as the shrub ecotone. This ecotone is best established along the boundary between Markey muck soils and Wainola or Deford sandy loam soils. Elevations above present water level averaged 1 to 3 feet, while the soils were generally brown sands overlain by shallow sandy peats.

As shown on the bisect, the shrub ecotone has been divided by an old ditch which trends along the upland fringe. Immediately east of the ditch are a few dead red ash trees, numerous dead speckled alder shrubs, dying-back red dogwood, as well as live meadow-sweet, swamp dock, sensitive fern, and various grasses. Although the presence of red as, speckled alder and other shrubs suggests an ecotone, the extensive die-back indicates this area to be a transition zone.

Immediately west of the old ditch is a slope where the ecotone is well established. Of particular importance is the presence of numerous service berry or mountain june berry shrubs which form a thicket-like zone along with the other vegetation. Other abundant species are speckled alder, gray dogwood, meadow-sweet, swamp rose, as well as an understory of royal fern, and various grasses. A few dead American elm and black oak in this ecotone indicate that at least infrequent flooding eliminates the tree species requiring well-drained soils.

Upland Hardwoods At the western end of the bisect the soils have been mapped as Wainola fine sandy loams. Beneath the leaf litter and black, sandy organic-rich loam layers is a subsurface of well-oxidized orange sand. Field testing revealed a pH of 5.5 in the A horizon and a pH of 6.0 in the incipient B horizon. Elevation above the water table at the time of the bisect was 36 inches.

Although somewhat culturally disturbed, the upland vegetation consisted primarily of oaks, including black oak, red oak, and hybrid oak (*Q. velutina* X *Q. rubra*). Other common trees were red maple, white birch, and trembling aspen. Although a few tamarack or eastern larch were observed in the vicinity of Oconto, this species was not encountered in the bisect. The understory consisted of young hardwood trees, as well as service berry shrubs and small aspen trees.

Wetland Distribution at Various Lake Levels Using black and white aerial photography, maps of the wetland plant communities were compiled for the years 1938, 1966, and 1973. The 1938 photography was the earliest aerial imagery for this study area. Whereas the 1966 photography provided data on the wetland distribution during low-water conditions, the 1973 imagery was used to map the vegetation at high water. Because photography more recent than 1975, when lake levels began to descend, was not available from federal sources, a map reflecting falling stage or average lake level conditions could not be prepared.

Wetland Vegetation in 1938 As illustrated in Figure 36, the wetlands in the Oconto River mouth marsh were most extensive in 1938. Water level of the

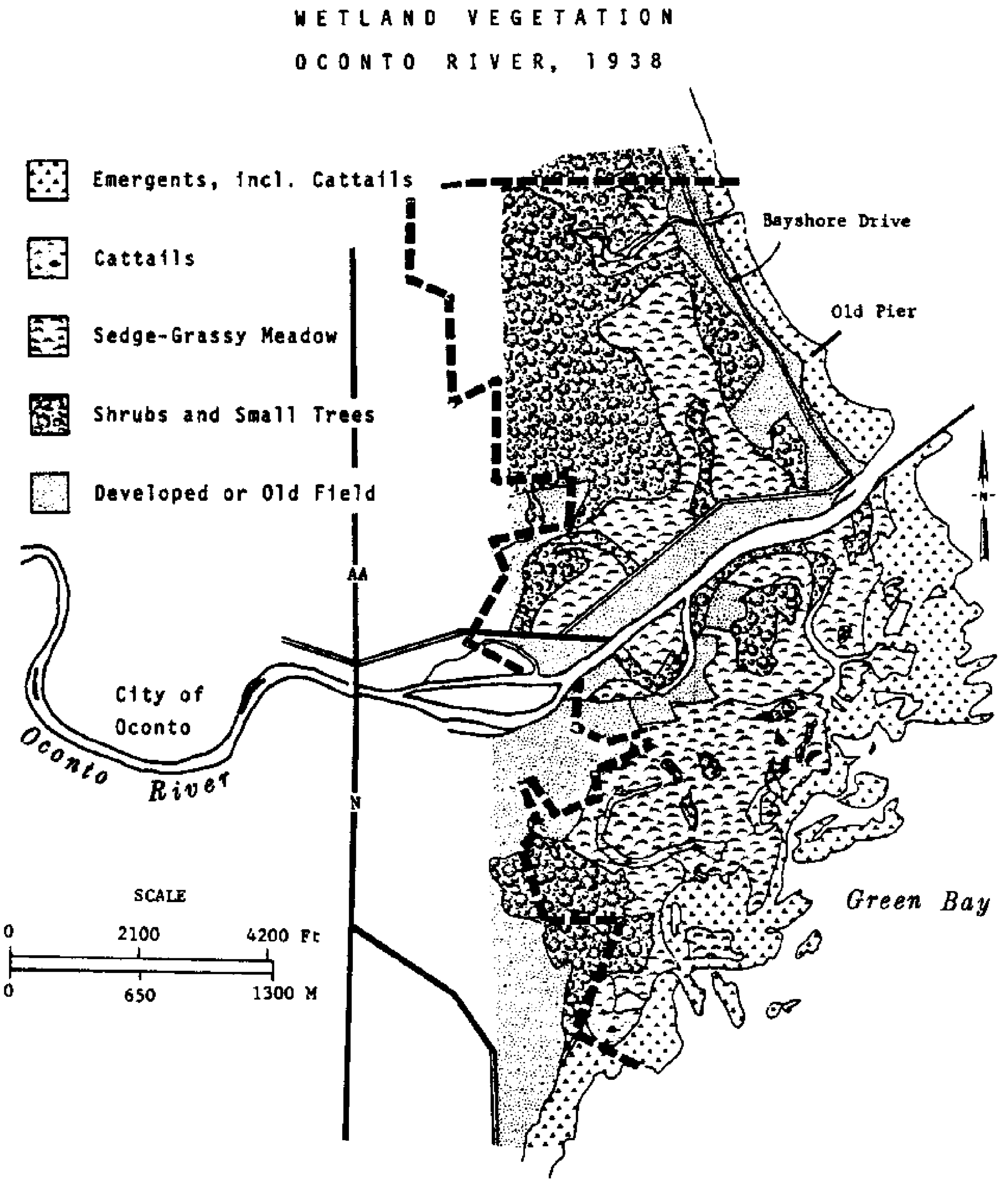


Figure 36. Distribution of Wetland Vegetation in Oconto River Wetlands in 1938. Dashed Line Indicates Limit of Wetland Soils

Green Bay at the time of the photograph was 577.6 feet, which is slightly below the long-term mean for October of 578.6. Long-term lake level data reveal that during the period 1932 to 1937 water levels were low, averaging around 576.5 feet. Therefore, even though a small increase ocurred in 1938, the vegetation would reflect low-water conditions.

An examination of the 1938 vegetation map indicates broad zones of shrubs and meadow, as well as an extensive emergent marsh. North of the Oconto River, willow shrubs appear widespread and were probably invading the meadow vegetation. Although the scale of the photography did not permit detailed interpretation, the meadow community probably consisted of a dense cover of canary grass and bluejoint grass along with some sedge. Along the shoreline near Bayshore Drive, a mixed emergent community of cattails, bulrushes, and freshwater rushes as well as grasses and forbs may have been present. Residential development and filling along Bayshore Drive and the other coastal streets resulted in the conversion of some wetlands to developed uses.

The wetlands south of the Oconto River were also extensive, indicating a bayward succession of communities during low-water conditions. Although cultivation and other land usages resulted in the disturbance of the upland vegetation and some of the shrub communities as well, willow shrub covered fairly large tracts. Most widespread, however, was the meadow vegetation which probably included canary grass, bluejoint grass, and sedges. Along the shoreline, in zones 500 feet or more in width, was emergent marsh. The photography and field experience suggest cattails, bulrushes, sweet flag, and probably arrowhead, yellow water lily, and Sago pondweed as well.

<u>Wetland Distribution in 1966</u> The vegetation map for 1966, though somewhat more detailed, resembles the map for 1938 (Figure 37). Water level at the time of the 1966 photography was the same as that during the 1938 flight, (577.6 feet). Although a low-water period preceeded the 1966 photography, as was true for the 1938 imagery, the time period was much shorter and relatively high-water conditions had preceded before that. Thus the 1966 wetland distribution does not represent stable low-water conditions, but rather a more dynamic situation which is common to the Great Lakes.

With regard to the wetland distribution north of the Oconto River, willow shrubs interspersed with meadow covered approximately two-thirds of the surface area. Along the shoreline there appears to be meadow-type vegetation, probably canary grass along with freshwater rushes and sedges. Dark colorations on the photography suggest a coastal strip of either three-square or hardstem bulrush.

With regard to the southern portion of the Oconto wetland, the meadow type wetland covers over half of the total area. Burning by the Oconto Sportsmen Club to stimulate the nesting of game birds may have retarded the colonization of the meadow by willows and other woody plants. Tussock sedge along with canary grass and bluejoint grass were probably the dominant meadow grasses. Other wetland types, but of limited extent, include willow shrub, cattails, mixed emergents, as well as developed-fill areas. Except for the shoreline edges and in the large channels, open water areas were limited. Approximately 20 potholes were constructed for waterfowl during this low-water period.

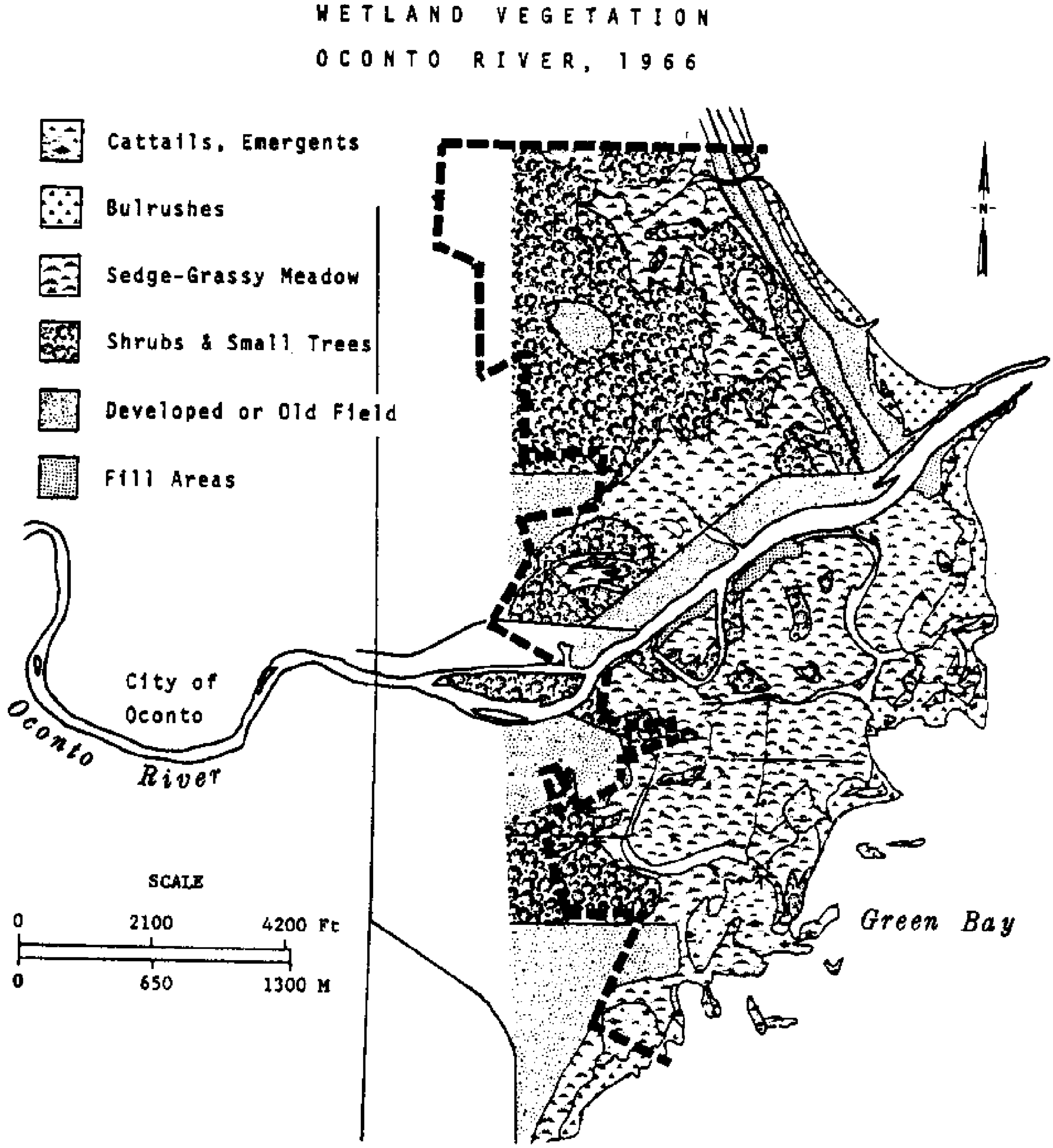


Figure 37. Distribution of Wetland Vegetation in Oconto River Wetlands, 1966

1973 Wetland Distribution The 1973 photography was flown when the water level of the Green Bay was at a near record high level (580.3 feet). Shoreland recession, erosion of the emergent marsh, and die-back of the willow shrub characterized this wetland complex at this time. Area measurements indicate a temporary loss of approximately 40 percent of the vegetated wetland area. Other major wetland changes include the construction of a new coastal highway, County Y, and the diking of the Oconto Wildlife Area north of the river.

With regard to the wetland vegetation north of the Oconto River, wooded swamp and willow shrub types cover over 50 percent of the surface area (Figure 38). Although willow die-back was very extensive, the October 1973 photography did not permit discrimination between dead shrubs and partial die-back areas. Thus the shrub zone is more extensive on the map than actual field experience supports. In contrast, the meadow wetland was of limited extent, and the emergent marsh largely disappeared. Although several open-water areas were present, particularly along canals and channels, the total extent was probably underestimated. Wherever dead willow shrub or meadow grasses remained upright in drowned areas, the area of open water was underestimated during photo interpretation. According to local residents, extreme high water levels during fall and spring storms produced extensive flooding which occasionally inundated portions of the coastal highway (County Y).

The wetland extent south of the river contrasts sharply to that north of the river due to the lack of a protective barrier beach. Whereas the beach along Bayshore Drive has been stabilized by filling and other structural modifications along the highway, the wetland areas south of the river were protected only by a thin, transgressive beach. As shown in Figure 26, the high water levels have resulted in the complete destruction of the beach and erosion of the emergent marsh. Although the shrub zone appears to have decreased in extent only slightly, both the emergent marsh and meadow were drastically reduced. In many places, shoreline recession exceeded 2,000 feet (610 m).

Wetland Area Measurements Based on polar planimeter measurements taken from the three wetland distribution maps presented earlier the areal extent of each wetland type corresponding to the three time periods was determined (Table 22). To coincide with the map legends, only four general wetland types were utilized as categories. The inland boundary of the wetland complex was delimited on the basis of wetland soils, i.e., the boundary between marley Mucks (as well as other saprists and aquents) and upland soils such as Wainola and Deford fine sandy loams. As observed on the 1938 photography, the lakeward limit of the wetland was marked by the maximum advance of the emergent marsh into Green Bay. In order to establish a common base, the 1938 wetland area of 1,650 acres was employed as the total area of the Oconto wetlands.

During low-water conditions the Oconto wetlands have an areal extent of 1,650 acres. The woodedshrub and the meadow wetland types each occupied about one-third of the total area. The remaining one third consisted primarily of the emergent marsh and of developed areas, with open-water sites (excluding the Oconto River) covering less than five percent of the total area. Thus low-water conditions are associated with the invasion of the meadow by willow shrub and the displacement of the emergent marsh by meadow grasses. Emergents (cattails and softstem bulrushes) tend to persist only along large channels and in lagoons

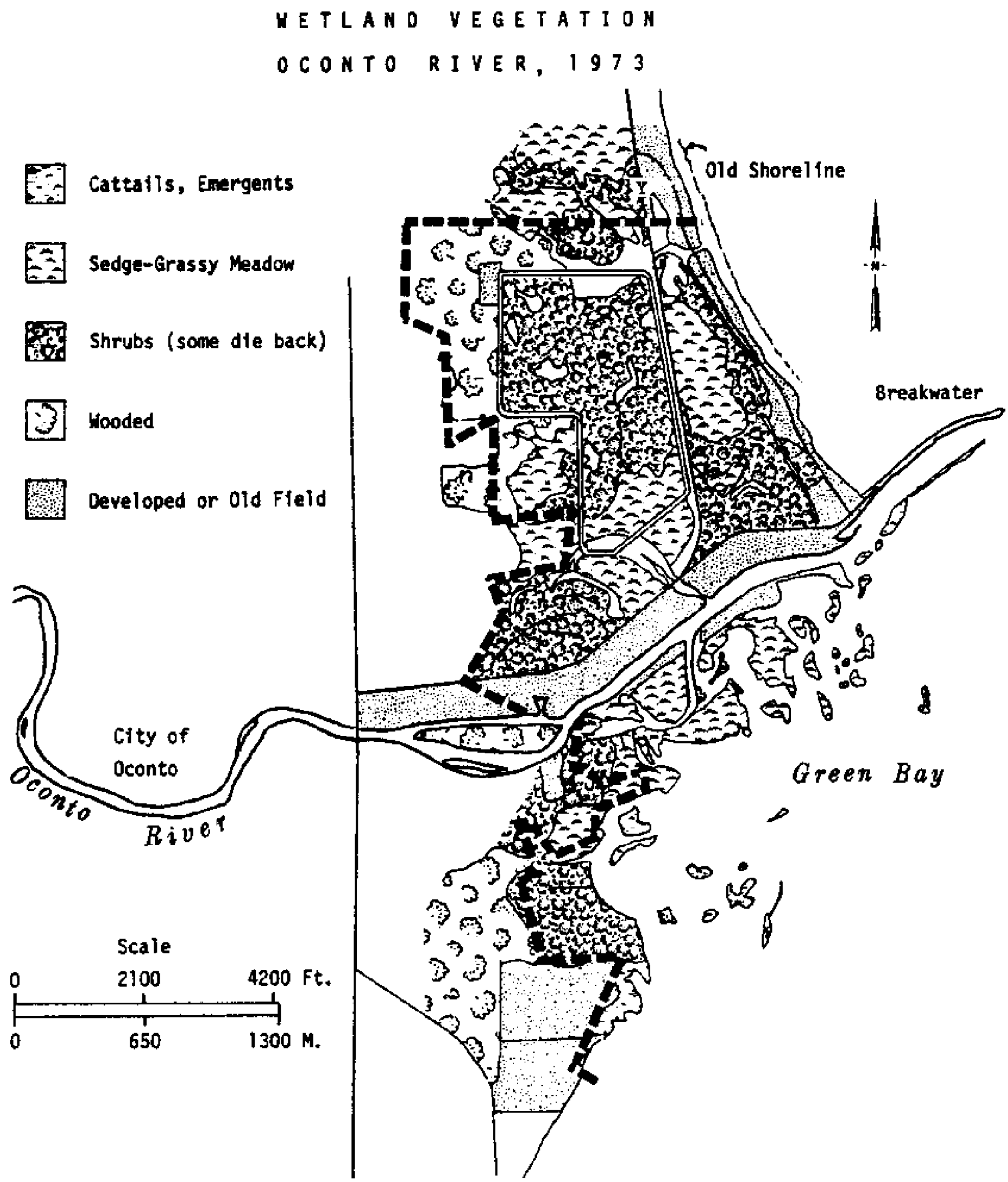


Figure 38. Distribution of Wetland Vegetation in Oconto River Wetlands, 1973

Table 22

Areal Extent of Wetlands, by Vegetation Type Oconto River Mouth Wetlands, 1938, 1966, 1973

1938 Distribution (Low Water)

Wetland Type	Acres	Hectares	Percent of Total
Wooded and Shrubs	561	227	34
Meadow	479	194	29
Emergents	346	140	21
Developed and Disturbed	231	94	14
Open Water	33	13	2
	1,650	668	100

1966 Distribution (Low Water)

Wetland Type	Acres	Hectares	Percent of Total
Wooded and Shrubs	547	221	33
Meadow	595	241	36
Emergents	225	91	13.5
Developed and Disturbed	209	85	13
Open Water	74	30	4.5
	1,650	668	100.0

1973 Distribution (High Water)

Wetland Type	Acres	Hectares	Percent of Total
Wooded and Shrubs	493	199.5	30
Meadow	195	79.0	12
Emergents	46	18.5	3
Developed and Disturbed	172	70.0	10
Open Water	744	301.0	45
	1,650	668.0	100

where protected from direct wave action by barrier beaches and islands. In the nearshore environment where wave energy is attenuated by nearshore bars and through wave diffraction, three-square, hardstem bulrush, and certain submersed aquatics may exist under these low-water conditions. It should be pointed out that the wetland area north of the river, which is protected from shoreline recession and has not been periodically burned as in the Oconto Sportsmen Club marsh south of the river, exhibits a much broader willow shrub zone, but a less extensive emergent marsh.

In contrast, during high lake level conditions the vegetated area of the Oconto wetland decreases to approximately 1,000 acres as much of the emergent marsh and meadow are inundated. South of the Oconto River, where this transgressive beaches occur, washover processes eliminate the protective beaches and many islands as well. Destruction of huge tracts of the emergent and meadow wetland types occurs, and the willow shrub zone is subjected to drowning and die-back. These changes are most evident when the 1966 area measurements are compared to the 1973 data. Note that little areal change has taken place in the acreage of wooded-shrub and developed areas, but losses of emergent and meadow wetlands are several fold. In contrast, the extent of open water increased substantially and accounted for 45 percent of the total wetland area.

Since no distribution map of wetland vegetation representing average lake level conditions was compiled, mean area measurements are not available. However, the mean extent of each wetland type can be estimated by averaging the 1966 and 1973 areal data from Table 22. Estimated mean areas for each wetland type are listed below.

Wetland Type	Acres	Hectares	Percent of Total
Wooded and Shrub	520	210	31
Meadow	395	160	24
Emergent	135	55	8
Developed and Disturbed	190	77	12
Open Water	410	166	25
TOTALS	1,650	668	100

Comparative Photo Transects As shown in Figure 39, three transects across the Oconto wetland complex have been prepared. Essentially the July 1978 (falling stage) transect is identical to the bisect discussed above. The July 1978 bisect served as the base for the landscape profile (elevations) and substrate type of all the transects. Vegetation data for the other transects derived from aerial photography, and water levels were obtained from Great Lakes gauging stations.

Although the photo transects are arranged by water level, with the highest level at the top and the lowest at the bottom, the discussion herein will proceed in chronological order. Beginning with May 1966 (low water), the transect reveals broad zones of willow shrub and sedge-grassy meadow. Emergents

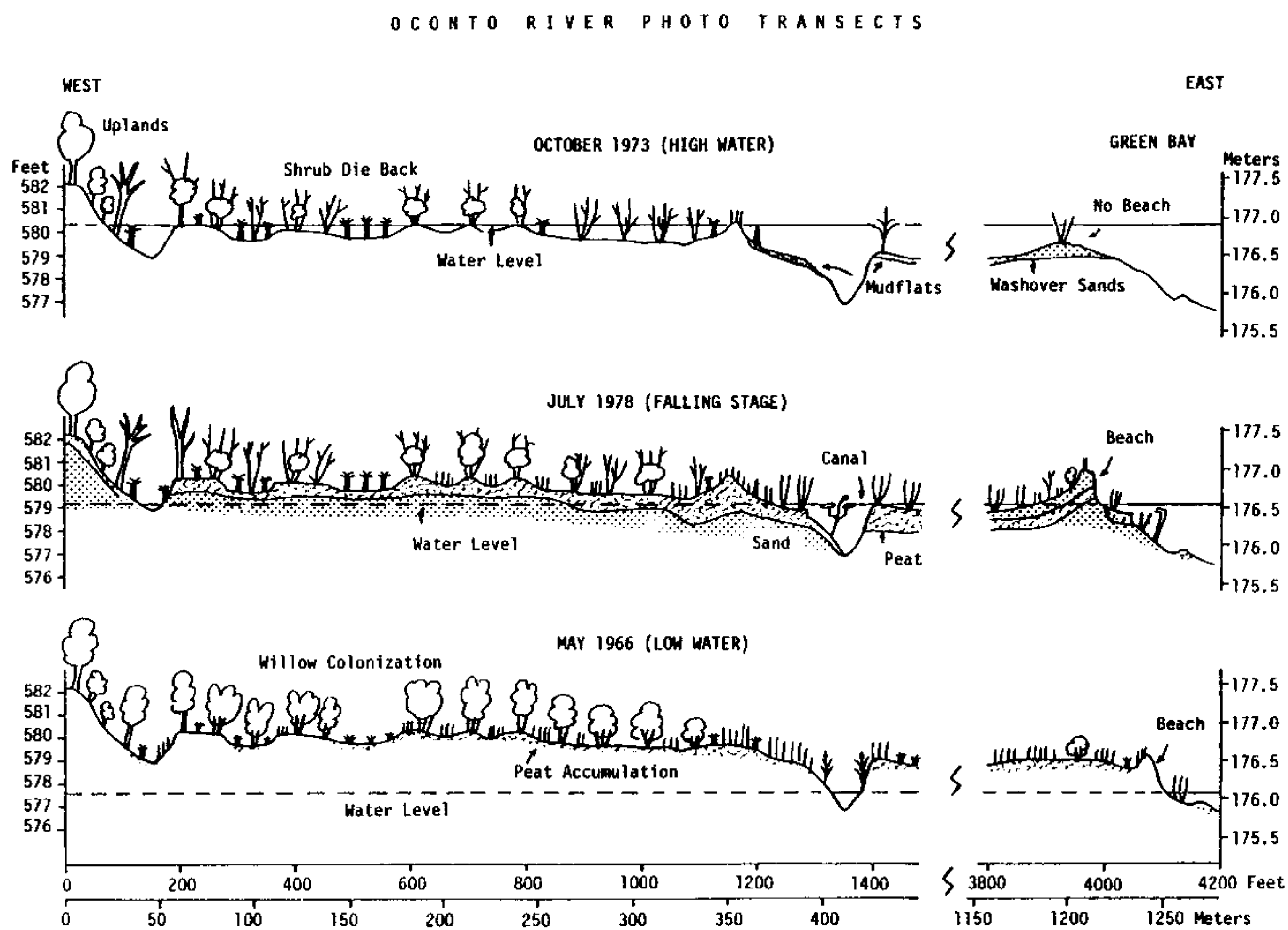


Figure 39. Photo Transects of the Oconto River Wetlands, Wisconsin

appear in the nearshore zone as well as in channels and depressions where standing water occurs. Because of the dense wetland vegetation and lack of inorganic deposition, a blanket peat accumulates.

Following the low-water conditions of the early 1960's, record high lake levels were experienced during the period 1972-1975. As indicated by the October 1973 photo transect, high water was accompanied by erosion of the transgressive beach, drowning the emergent and meadow wetland, and die-back of large areas of willow shrub. Sandy sediments are introduced into the former emergent marsh as a result of washover processes, and fine-grained organics and/or clays are deposited over much of the inundated areas due to erosion and redeposition. Most of the emergents appear intolerant of the greatly increased water depths and higher wave energies. A new shoreline or strandline usually forms landward of the previous beach as indicated by a thin sand ridge and/or the deposition of organic debris. The tops of surviving sedge tussocks mark the mean high water level along with the upper limit of die-back of the pioneering ecotone shrubs.

As water levels drop to more average conditions, the retrogressive pattern is reversed and plant succession occurs. A barrier beach forms in the nearshore zone which reduces wave energy in the backbarrier marsh. Recolonization of large tracts of marsh by emergents appears to proceed primarily by means of seeds rather than by sprouting of viable rhizomes and other vegetative parts. This recolonization mechanism also prevails in the meadow zone where falling water levels expose formerly drowned areas. Willow shrubs which were not continuously inundated for a year or more typically re-establish themselves by sucker growth from basal meristems. The tag alder appears to be less capable of such regeneration as evidenced by nearly complete dieback of alders in the willow shrub zone.

Betsie River Wetlands

The Betsie River wetland area includes the lower Betsie River floodplain and adjacent marshlands of Betsie Lake. Although directly connected to Lake Michigan via Betsie Lake and its outlet, the Betsie River mouth wetlands are situated 0.5 miles or more inland in Benzie County, Michigan. As defined in this study, the wetland area consists of approximately 373 acres. The boundaries of the study area: Highway 22 on the south, Betsie Lake and the Ann Arbor Railroad on the north, developed lands and the city of Elberta on the west, and an arbitrary 200-foot transition zone across the floodplain on the east side. Elsewhere the 590 foot contour delimits the wetland area. Much of the wetland consists of a swampy floodplain with a meadow and emergent marsh at the extreme lower end where the Betsie River empties into Betsie Lake.

Wetland Plant List Identification of common species was based on a vegetation bisect and a geomorphic profile which crossed the floodplain from east to west. Walkthroughs across the environmental gradient from the edge of the Betsie River landward into the swamp forest were conducted at four sites along the wetland perimeter. Unknown plants were collected and pressed, with proper identification taking place later in the lab. The wooded floodplain did not receive emphasis as water level changes appeared to affect the emergent and meadow marsh more directly.

Listed below, by environmental type, are the common plant species.

Canals and Abandoned River Channels

Softstem bulrush Scirpus validus
Sweet flag Acorus calamus
Yellow pond lily Nuphar advena
Sago pondweed Potamogeton pectinatus
Floating pondweed Potamogeton natans
Watermilfoil Myriophyllum spicatum?
Wild celery Vallisneria americana
Waterweed Elodea canadensis
Coontail Ceratophyllum demersum
Filamentous green algae

Emergent Marsh on Lower Floodplain (A mix of communities).

Softstem bulrush Scirpus validus
Hybrid bulrush S. validus X S. acutus
Nodding smartweed Polygonum lapathifolium
Broadleaved cattail Typha latifolia
Hybrid cattail Typha glauca
Spikerush Eleocharis obtusa?
Arrowhead Sagittaria latifolia
Burreed Sparganium eurycarpum?
Freshwater rush Juncus sp.

Sedge-Grass Meadow

Canary grass Phalaris arundinacea
Bluejoint grass Calamagrostis sp.
Kentucky bluegrass Poa pratensis
Canada bluegrass Poa compressa
Swamp rose Rosa palustris
Sedge Carex stricta
Sedge Carex hystericina
Boneset Eupatorium sp.
Smartweed Polygonum careyi or P. coccineum

Shrub Ecotone (with sedge-grass understory)

Red ash Fraxinus pennsylvanica
Speckled alder Alnus rugosa
Arbor vitae Thuja occidentalis
Dwarf birch Betula pumila
Willows Salix spp.
Sweet gale Myrica gale
Swamp rose Rosa palustris
Marsh fern Thelypteris palustris
Swamp buttercup Ranunculus sp.
Sedge Carex stricta
Sedge Carex lacustris
Sedge Carex hystericina
Kentucky bluegrass Poa pratensis
Canada bluegrass Poa compressa

Old Field and Disturbed Sites

Arbor vitae Thuja occidentalis
Red dogwood Cornus stolonifera
Gray dogwood Cornus racemosa
Willows Salix spp.
Sedge Carex stipata
Goldenrods Solidago spp.
Orange Hawkweed Hieracium aurantiacum
White daisy Chrysanthemum leucanthemum

Wooded Floodplain (Swamp Forest)

Red ash Fraxinus pennsylvanica
Black ash Fraxinus nigra
Eastern hemlock Tsuga canadensis
Trembling aspen Populus tremuloides

White birch Betula papyrifera
Tamarack Larix laricina
Arbor vitae Thuja occidentalis
Red maple Acer rubrum
Gray birch Betula sp.
Basswood Tilia sp.

Wetland Bisect The bisect across the Betsie wetlands was conducted on August 4, 1977, when the water level of Lake Michigan was at 578.6 feet. This level approximates the long-term mean level of Lake Michigan for August, but it follows a period of record high levels. Located about 2,000 feet south of the Highway 22 bridge (Figure 40), the bisect extends in an east-west direction across the lower portion of the floodplain.

Plant communities, substrate type and depth of water table along this bisect are described starting from the Betsie River and proceeding upslope. Beginning with the right side (east) of the river, the first wetland zone along the river was an unvegetated peat flat approximately 15 feet in width and 6 to 8 inches in elevation above the water table. Based on the general appearance, including an incipient growth of sedge and grasses, it is believed that this peat flat was recently exposed by a small drop in water level during the past year. The substrate consisted of layered peats, the surface layer of which supported dead sedge tussocks that ranged from 5 to 8 inches in height. Several dead arbor vitae trees were noticed along the river's edge; these small trees were rooted in peat approximtely one foot beneath the surface peat and may reflect former low-water vegetation.

The next wetland type encountered along the bisect was a sedge meadow which extended for 75 feet. Although the substrate was similar to the peat flat and depth to the water table increased only slightly (from 10 to 14 inches), live sedge (Carex stricta) tussocks were present. The distance from the surface up to the base of the sedge stems in the tussocks averaged 8 to 10 inches, while the top of the stems ranged from 2.5 to 3 feet in height. Kentucky bluegrass and Canada bluegrass commonly grew commensally in the sedge tussocks. Scattered throughout this sedge meadow were dead red dogwood bushes as well as a few dead speckled alder shrubs, especially near the upland margin of this zone. At the upland end of this zone an abandoned channel of the Betsie River was traversed. An unvegetated peat flat within this abandoned channel, which was less than 25 feet in width, exhibited the same general characteristics as the flat adjacent to the present river.

As illustrated on the bisect, the next vegetation zone lies between two abandoned river channels and extends for a horizontal distance of 110 feet. Peaty substrates continue, but depth to water table increases somewhat (from 12 to 15 inches) beneath the surface. The vegetation consists of live and rather densely spaced sedge tussocks with an overstory of live shrubs. Comprised of red dogwood and sweet gale as well as a few swamp rose, the shrubs average only 6 to 8 feet in height. Near the landward end of this vegetation zone speckled alders replace the low shrubs. Many of these alders, which attained heights up to 20 feet and exhibited trunk diameters up to 6 inches, had succumbed to drowning. Beneath the alder overstory were scattered sedge tussocks and various grasses including canary grass.

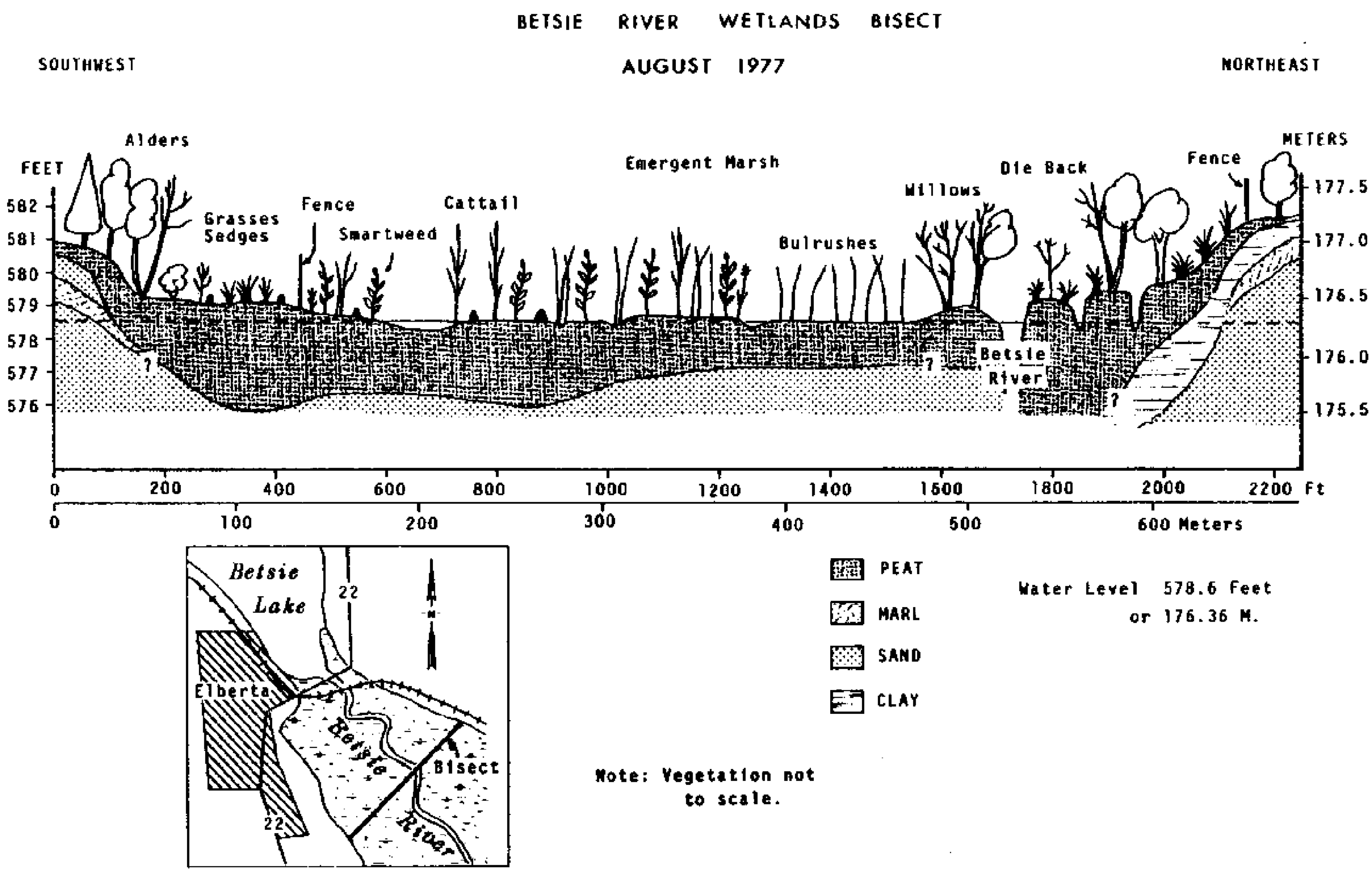


Figure 40. Bisect Across the Betsie River Wetlands, August 1977

East of the second abandoned channel, the speckled alder shrub zone continues its dominance. However, dwarf birch and white birch as well as sweet gale are also present. The understory of sedge tussocks and grasses is also present, along with an occasional marsh fern. The sedge tussocks continue to be present until surface elevations are approximately 3 feet above the water table.

At 378 feet east of the Betsie River, a decrepit fence was traversed. The land beyond the fence was previously cultivated as evidenced by the vegetation which included apple trees, young trembling aspen, red dogwood, goldenrods, and various old field grasses and sedges (especially Carex stipata). The substrate changed significantly at this point also. Beneath a 10-inch layer of black, sandy clay was a 4-inch clay layer which, in turn, was underlain by sand and marl.

Switching now to the west side of the Betsie River, the bisect description continues from the stream's edge toward the city of Elberta. Immediately west of the river is a strip of willow shrubs which probably have colonized an old spoil bank. Although the Betsie River is transporting sand as bed load, point bar deposits and natural levees are poorly developed.

Emergent marsh occupies a wide zone in this bisect as it extends from the patch of willow shrubs west to the sedge meadow, a distance of 1,250 feet. Water depths in this marsh generally range from +6 to -6 inches. The substrate of the floodplain generally consisted of 3 to 4 inches of organic-rich clayey ooze underlain by a buried root mat which contains sedge and grass macrofragments.

The emergent marsh is dominated by a hybrid bulrush (Scirpus validus X S. acutus), which closely resembles softstem bulrush except that the forescence is larger, more compact, and darker brown in coloration. Other abundant emergents include broadleaved cattail, spikerush, burreed, sweet flag, and duckweed.

Softstem bulrush appears to be restricted to the shallow waters of abandoned channels and embayments where the substrate is either clayey or organic rich. Where mud flats have exposed for a year or more, softstem bulrush is replaced by nodding smartweed, which may grow in rather pure stands. On drier sites within the emergent marsh a mix of sedges, grasses, and rushes are present. Plant species on these somewhat elevated sites include canary grass, sedge (Carex hystericina), boneset, freshwater rush, and smartweed.

Three old channels were crossed during the surveying of the bisect in the floodplain. Although the channel edges were difficult to traverse because of unconsolidated peats and organic-rich clays, the channel bottoms were generally filled with sand. Aquatics present in the channels included softstem bulrush, hybrid cattail, burreed, and arrowhead. Sago pondweed was particularly abundant in the water, along with watermilfoil and waterweed. Yellow pond lily was the common floating-leaved aquatic.

At 1,250 feet west of the Betsie River an old fence was crossed. The water table at this point lay 4 to 5 inches below the peat surface which extended downward for at least three feet. The surface peat had the appearance of an old root mat which supported sedges, grasses, and a few shrubs prior to being drowned. A number of dead sedges averaging 6 to 8 inches in height were observed on the surface. Colonizing this formerly drowned surface were various grasses and sedges which were too immature to key out. Spike rushes and a smartweed were also present.

At approximately 100 feet west of the old fence, the tussock sedge meadow began to show less evidence of drowning. Many of the sedge (Carex stricta) tussocks were alive and contained inflorescences. The commensal Kentucky bluegrass and Canada bluegrass were present in the stools which averaged 6 to 8 inches in height.

The next major vegetation change encountered along the bisect was the presence of dead red dogwood and dead willow shrubs. The change occurred 160 feet west of the old fence line or 1,410 feet west of the Betsie River. Depth to water table averaged 6 to 8 inches and the substrate continued to be peaty. Both live and dead sedge tussocks were common as were a mix of grasses. Many of the dead sedge tussocks appeared to be rooted above the roots of the dead shrubs. Thus the shrubs may have drowned first, followed by the tussock-forming sedges.

Within 100 feet, the dogwood-willow die-back zone merges into an alder thicket. All along the floodplain margin, the speckled alder exhibited die-back. Where depths to water table were 12 inches or more, the alder exhibited less die-back as evidenced by more complete leaf cover. In addition to alders, the shrub thicket included willows, dwarf birch, red dogwood, and sweet gale. The understory was comprised of tussock sedges, along with various grasses and swamp rose. The grasses included Kentucky bluegrass, Canada bluegrass, and a grass closely resembling bluejoint grass (Calamagrostis canadensis?). The substrate consisted of 15 inches of a black, woody peat underlain by peat with small sand stringers. Because of the presence of woody fragments, this wetland must have been colonized by woody vegetation for some time.

As the bisect continues westward, the elevation increased and the alder shrub ecotone changed into a swamp forest. Depth to present water table at the transition was approximately 22 inches. Although disturbed by logging, cultivation and other cultural activities, the wooded vegetation consists of speckled alder, arbor vitae, choke berry, trembling aspen, and a few red ash. In places, the arbor vitae was quite dense and grew in rather pure stands. The arbor vitae (or white cedar) may be associated with a marly substrate. Field borings reveal the following sedimentary sequence with depth: black, woody peat, 16 inches thick; underlain by tan sand, medium-textured, 10 inches thick; underlain by whitish-gray marl, coarse-textured, with numerous snail carapaces.

Beyond this forested swamp margin, marked by the presence of arbor vitae, the landscape, which generally consists of a terrace flat, has been impacted by cultural disturbances. Elevations above the present water level exceeded 3 feet and the substrate consisted of 2 to 4 feet of orange-colored sand over marl. The vegetation is largely disturbed, with common species including domestic apple trees, arbor vitae, red dogwood, gray dogwood, willows, as well as orange hawkweed, white daisy, goldenrods, and a sedge.

Wetland Distributions at Selected Lake Levels Aerial photography flown in July 1938, July 1965, and July 1973 provided the data base for mapping the wetland vegetation of the Betsie River mouth. The 1938 photography was the earliest available imagery, while the 1965 and 1973 photography reflected low-water and high-water conditions, respectively.

Wetland Vegetation in 1938 Because low lake level conditions prevailed in July 1938, large areas of the distal portion of the Betsie River were exposed and consequently colonized by wetland vegetation (Figure 41). The water level on July 7, 1938--the date of the photograph, was 577.9 feet, which is nearly one foot below the 1900-1976 long-term average of 578.6 feet for July. However, for the previous six years (1932-1937) water levels had not exceeded 577 feet.

The 1938 wetland map reveals only four general categories because of the quality of the contact prints and the historical studies. As expected, the upper portion of the floodplain was covered by a swamp forest. It is the extent of the meadow and emergent marsh, however, which is so impressive on this map. The sedge-grass meadow extended from the shrub ecotone, near the swamp forest, to beyond the Ann Arbor Railroad and Highway 22 bridges. Unless burning was routinely practiced, various shrubs should have been actively invading this meadow vegetation. An old channel of the Betsie River was noted in the meadow zone west of the present channel. Emergent marsh, as noted by darker tones on the photographs, occupied only the deltaic portion of the river mouth where it emptied into Betsie Lake. Common emergent marsh species probably included both the softstem and hybrid bulrush, as well as broadleaved cattail and other species.

Along the wetland perimeter, the encroachment of agricultural usages is obvious, particularly immediately north of Highway 22 which trends along the southern margin of the wetland. It is likely that cattle were pastured in the meadow wetlands.

Wetland Vegetation in 1965 Because of higher quality contact prints, the map for 1965 is more detailed as compared to that for 1938 (Figure 42). However, a comparison of the two vegetation maps reveals only small changes in the wetlands. The water level recorded for July 1965 was 576.85 feet, nearly one foot lower than 1938.

The floodplain vegetation appeared to be a mix of deciduous and evergreen species. In places, mature trees are absent, including on the river point bars where small, densely spaced deciduous trees (willows?) can be observed. Along the wetland margins and extending into the cultivated fields on both the northern and southern margins, is a concentration of arbor vitae. The marly substrate of the flanking terraces may be a factor in the arbor vitae distribution.

The transition from the swamp forest to the meadow is marked by the shrub ecotone zone. As shown on the map for 1965, the shrub zone extends along the flanks of the swamp forest and the terraces in a northwesterly direction. The width of the shrub zone is variable, but commonly ranges from 100 to 200 feet (30 to 70 m). The only place where this transition zone is abbreviated is on the floodplain immediately south of the Betsie River where the swamp forest

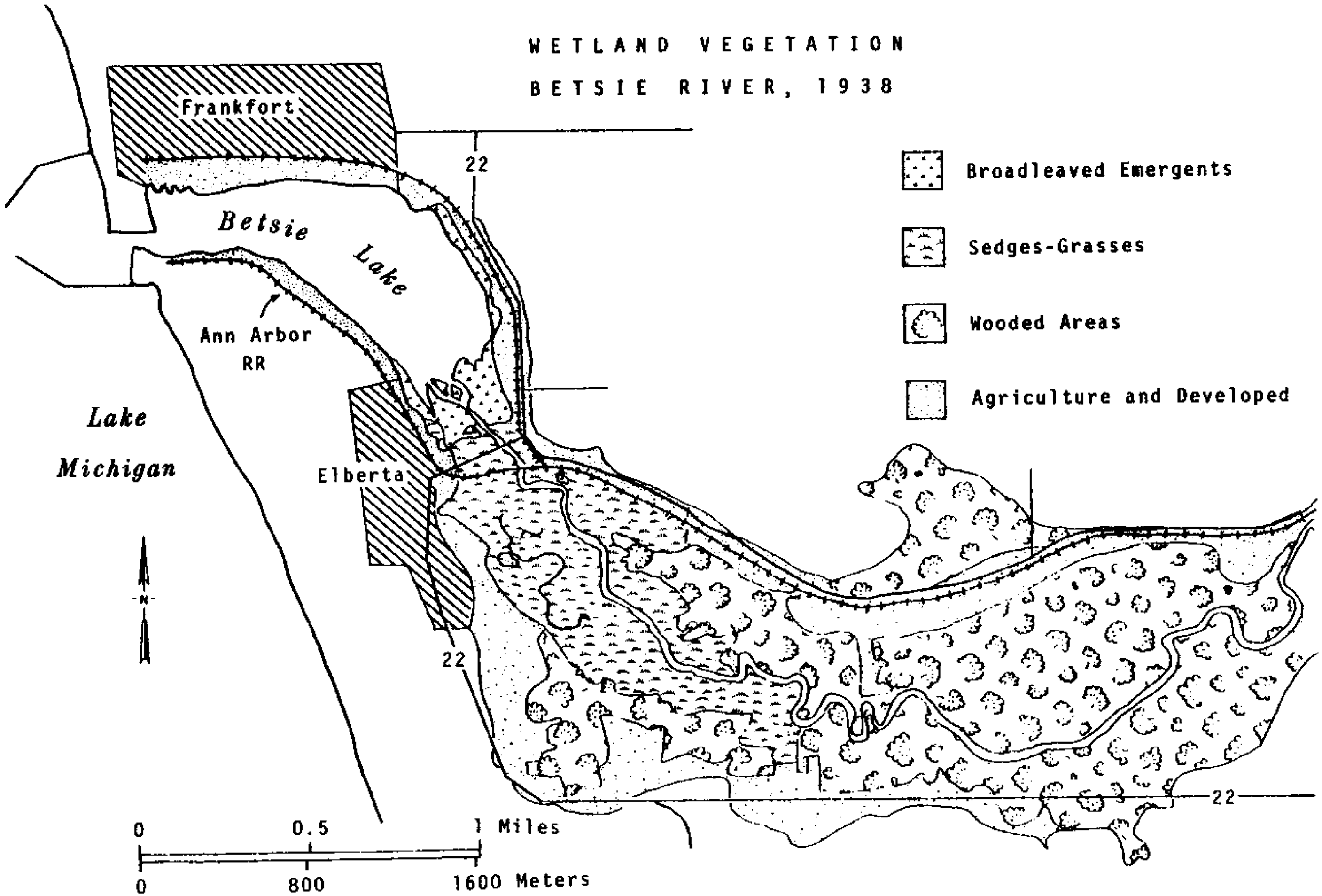


Figure 41. Distribution of Wetland Vegetation in Betsie River Wetlands, 1938. Dashed Line Indicates Limit of Wetland Soils

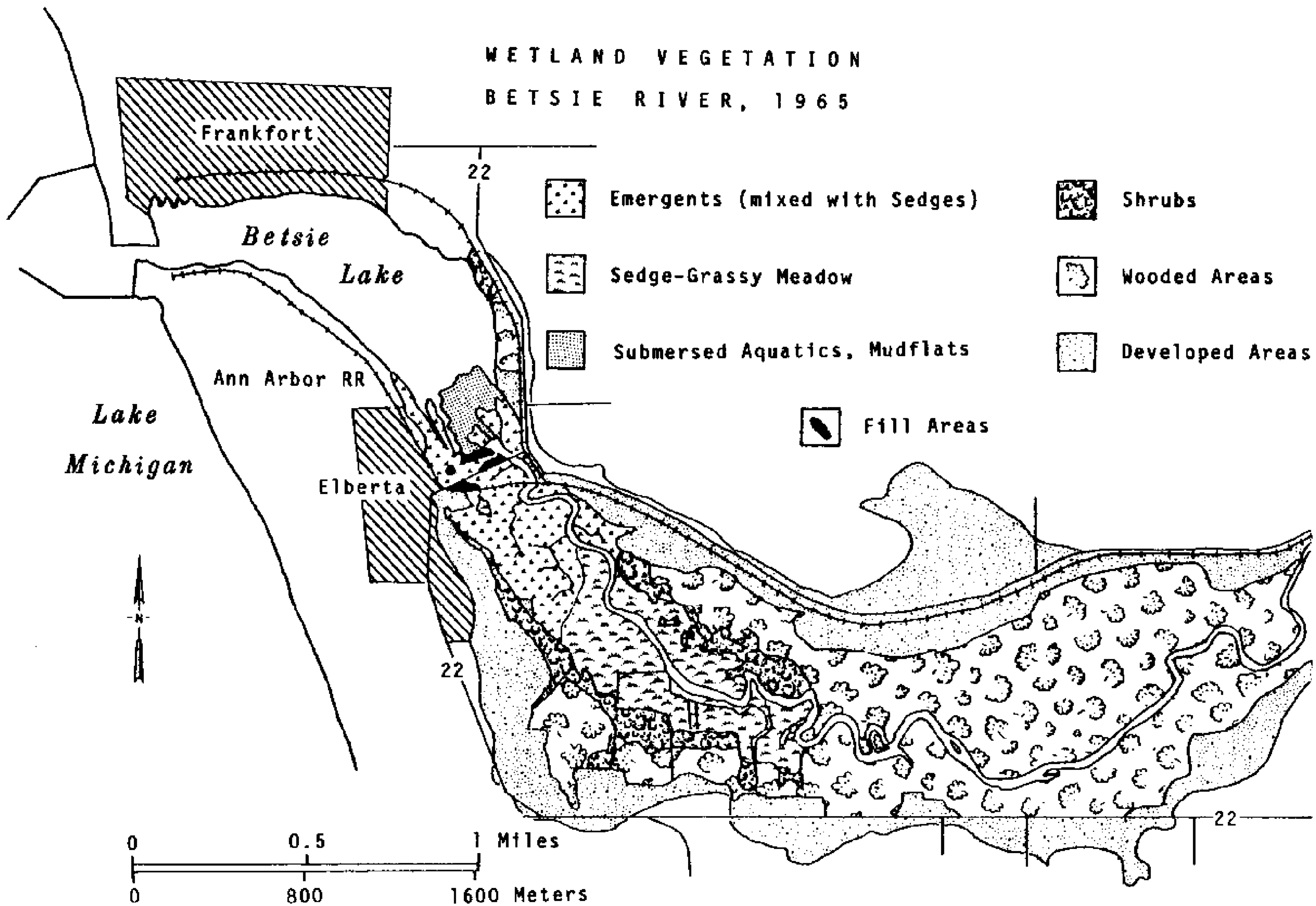


Figure 42. Distribution of Wetland Vegetation in Betsie River Wetlands, 1965

abruptly changes to meadow. Along the western flank of the wetland, i.e., east of the city of Elberta, the shrub zone has been impacted by canals and ditch activity. Artificial pumping and other water level management practices, as well as burning and shrub removal, were probably employed to keep the shrubs from invading some of the meadow wetlands.

The meadow was a well-established wetland type in 1965. Extending for nearly a mile along the central portion of the lower floodplain, the sedgegrass meadow has a width of approximately one-quarter mile. In the meadow north of the Betsie River, various shrubs, possibly willow and dogwood, can be observed invading the meadow. South of the river, however, where canals and human disturbance is evident, there is less shrub invasion.

Though sedges probably occur in the marsh located immediately southeast of the Ann Arbor Railroad bridge (which crosses the floodplain), this area has been mapped as emergent marsh. Darker tones and small patches on the aerial photography suggest the dominance of bulrushes and cattails, with open water showing through. A ditch separates the meadow from the emergent marsh, thus human interference may also be influencing wetland zonation.

The emergent marsh occupies a fairly large area at the mouth of the Betsie River. Here water depths probably range up to a foot or more in depth and the substrate is largely unconsolidated clays or sandy peats. Aerial photography reveals a complete marsh cover south of the Highway 22 bridge, whereas north of the bridge the emergent marsh is discontinuous. At the point where the main river channel bifurcates, the emergent marsh changes into an open-water environment. Though not clear on the aerial photography, the deltaic portion may be colonized by very small patches of emergent bulrushes, as well as by submersed plants such as Sago pondweed. Unvegetated mudflats and a few scattered wave-formed sand bars also appear to be present along the delta front.

Wetland Vegetation in 1973 On July 7, 1973, when the photograph was done, water depths along Lake Michigan rose to 581 feet. This high water level was 2.4 feet above the long-term average for July. When the 1973 map of wetland vegetation (Figure 43) is compared to that for 1965, the drowning of the emergent marsh and large tracts of the meadow is obvious. In 1973 open water extended for over one-half mile south of the Ann Arbor Railroad bridge. Although some of the open water has since been recolonized as modern lake levels have receded somewhat, much evidence of die-back still exists in this wetland system.

The effect of high-water conditions on the swamp forest of the floodplain was not fully investigated. Analysis of the aerial photography reveals the Betsie River to exhibit a bankfull stage and standing water appears to be more common in the backswamp areas. Field observation near the meadow-swamp forest boundary on the floodplain did reveal die-back of the shrub ecotone as well as of some of the pioneering swamp trees. In addition to the willow-dogwood-alder die-back, a number of the following trees were observed to have died very recently from drowning: red ash, tamarack, white cedar, trembling aspen, white birch, and red maple. Along the upper portion of the floodplain, where gray birch and basswood were observed along with red ash, some die-back was observed, particularly of the basswood, except where elevated above the standing water by root platforms or by topographic irregularities.

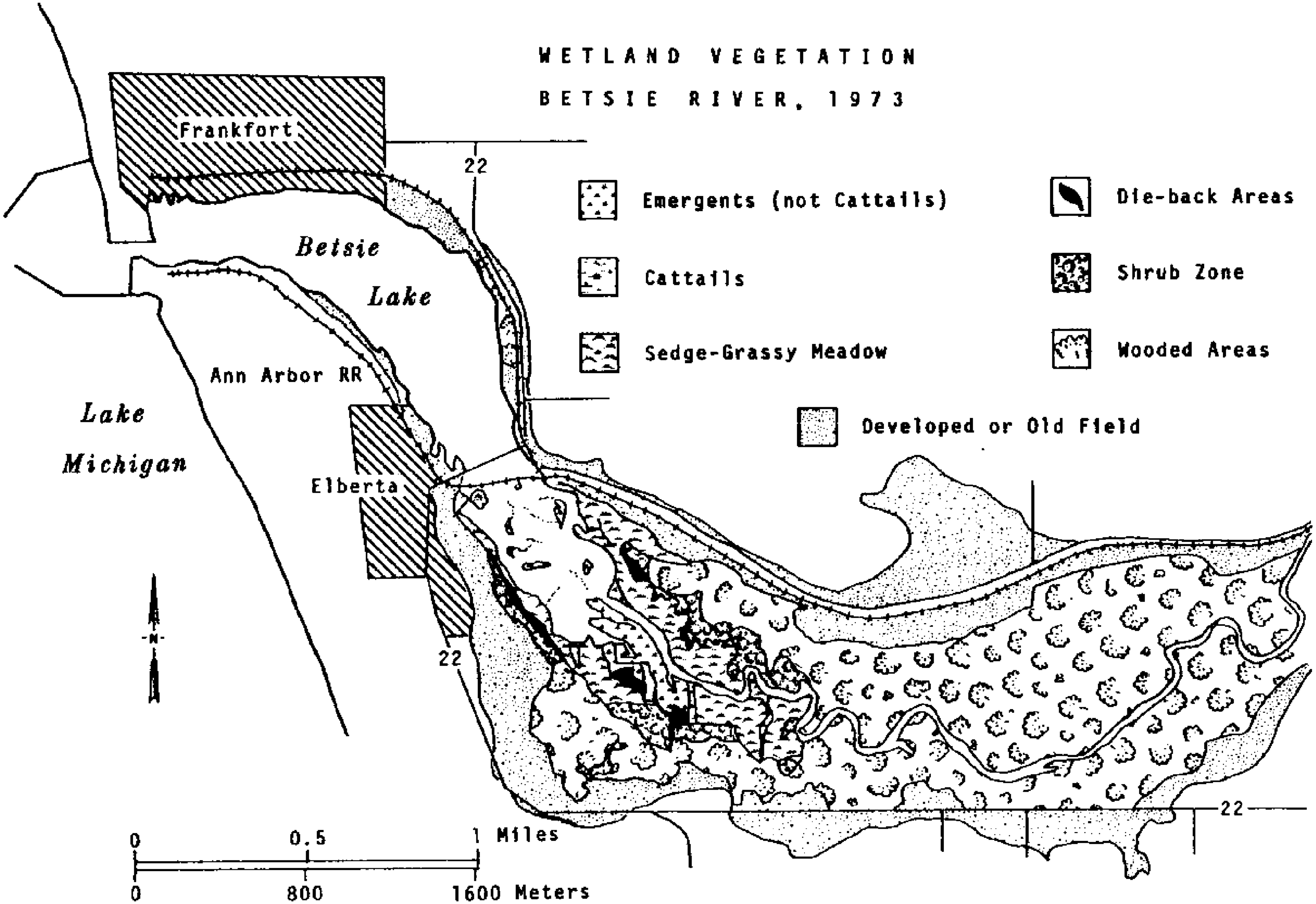


Figure 43. Distribution of Wetland Vegetation in Betsie River Wetlands, in 1973

As illustrated by the 1973 map, the meadow wetland type was dramatically affected by the high water. As a result of drowning, over half of the meadow reverted to open water or to emergent marsh. Without mechanisms for tolerating continuous submergence, the grasses succumbed except where the sedge tussocks provided habitat above the water level. Field observations indicate that in most areas the rate and magnitude of the water level increase during the late 1960's exceeded the capacity of the tussock-forming sedge to create stools.

It should be emphasized that either the meadow vegetation drowned out completely and reverted to open water, or survived on slightly higher sites as tussock sedge. South of the Betsie River where canals and water level management practices were evident, the meadow reverted to cattail and other emergents which, in turn, underwent eventual dieback.

With regard to the emergent vegetation, the change initiated by the high water was widespread. By comparing the 1965 map to the 1973 map, the nearly complete loss by 1973 of the former emergent marsh can be visualized. Although some small islands and thin patches of emergent marsh persisted in the open water areas, most of this wetland type was to be found in the former meadow areas which had been diked.

Wetland Area Measurements The maximum vegetation advance into Betsie Lake, as mapped from the 1938 aerial photographs, served as the lakeward limit of the wetlands. Because data regarding wetland soils were not available for Benzie County, the inland wetland boundary could not be based on soils. Rather, the interpolated 590-foot contour from the 1:62,250 Frankfurt topographical map, as further delimited by the Ann Arbor Railroad line and Highway 22, formed the boundaries. On the floodplain, the boundary was marked by an arbitrary 200-foot wide transition zone from coastal wetland swamp to floodplain swamp. Field observations indicated that lake level effects were not detectable, in many places, beyond 200 feet. Because it represents a historical base from which acreage changes can be measured, the 1938 wetland area of 373 acres was adopted as the standard area for the Betsie River wetlands (Table 23).

No shrub zone acreage appears in the table for the period 1938 because poor print quality did not permit mapping of that wetland type. As a result, the wooded, and perhaps the meadow category as well, exhibit slightly larger acreage values. Nevertheless the areal data for 1938 indicates the dominance of the wooded vegetation (over 50 percent of the total area), and the small areal extent of the emergent marsh and open water. The river channel appeared to account for much of the open water category.

When the 1965 area measurements are compared to 1938, little difference is evident, even though a shrub category was added. Both the wooded and the meadow types occupy somewhate smaller areas. The map data suggest that a mixed community emergent marsh in 1965 was present where meadow prevailed in 1938. It is felt that the tussock-forming sedges and meadow grasses did not have sufficient time to invade the emergent marsh during the short, but relatively low-water period of 1963-1965. However, the low-water conditions were conducive to clearing and other development along the wetland margins.

Table 23

Areal Extent of Wetlands, by Vegetation Type Betsie River Mouth Wetlands, 1938, 1965, 1973

1938 (Historical Base, Low Water)

Wetland Type	Acres	Hectares	Percent of Total
Open Water	40.0	16	10.5
Emergent	34.5	14	9.0
Meadow	185.5	74.5	50.0
Shrub/Swamp	63.0	25.5	17.0
Developed Lands	50.0	21.0	13.5
TOTAL	373.0	151.0	100.0

1965 (Low Water)

Wetland Type	Acres	Hectares	Percent of Total
Open Water/Submersed	46	18.5	12.5
Emergents	74.5	30.5	20.0
Meadow	126	51	33.5
Shrub/Swamp	72	29	19.5
Developed/Fill	54.5	22	14.5
TOTAL	373.0	151.0	100.0

1973 (High Water)

Wetland Type	Acres	Hectares	Percent of Total
Open Water	160.5	65	43.0
Emergents	40.0	16	11.0
Meadow	69.0	28	18.5
Shrub/Swamp	69.0	28	18.5
Developed/Old Field	34.5	14	9.0
TOTAL	373.0	151	100.0

With the extremely high water conditions of 1973, retrogression of the plant communities took place. Although the shrub die-back was sufficiently extensive to map, as were small patches of cattail die-back, basically the high water resulted in reversion to open water. South of the two bridges an open-water embayment of approximately 75 acres appeared. The complete drowning and reversion to open water occurred throughout nearly all of the former emergent marsh, and over half of the meadow marsh either reverted to open water or regressed to cattail which, in turn, subsequently drowned. With regard to developed areas, during the high period some of the agricultural fields were abandoned.

Because a wetland distribution map representing average lake level conditions was not prepared for the Betsie wetlands, mean area measurements for each wetland type are not available. However, the mean areas were estimated by averaging the areal data for 1965 (low water) and 1973 (high water). Estimated mean areas for the Betsie wetlands, as defined in this study, are listed below. The standard area of 373 acres was utilized as the total wetland area.

Wetland Type	Acres	Hectares	Percent of Total
Open Water/Submersed	103	41.5	27.5
Emergents	57	23	15.5
Meadow	108	44	29.0
Shrub/Swamp	70.5	28.5	19.0
Developed/Fill Lands*	34.5	14	9.0
TOTAL	373.0	151.0	100.0

* The 1973 data were utilized for this category. Some adjustment of the other categories was necessary.

Comparative Photo Transects Using the August 4, 1977, bisect as a base transects across the same environmental gradient were redrawn (Figure 44). Water level data was taken from the Ludington (Michigan) station, whereas the vegetation data were derived from the 1965 and 1973 aerial photography.

Beginning with the 1965 low-water stage, the drop in water level (to 576.9 feet) lowered the water table in the Betsie River wetlands to nearly two feet below the general surface. Although there were a few wet depressions, the only standing water was in the Betsie River channel. Based on the photography, the central portion of the transect contained dense meadow vegetation. Grasses and sedges established a thick root mat and a blanket peat was produced. Unless burning was a factor or the length of the low-water period is relatively short, woody shrubs, including willows, dogwood and swamp rose, would slowly invade the tussock sedge and grass communities. All ditch and spoil areas showed enhanced shrub growth, which was also evident in the ecotone between the meadow and swamp forest.

As illustrated by the 1973 transect, high water conditions (up to 581 feet) resulted in widespread inundation and drowning of the floodplain vegetation. Although some floating-leaved and submersed aquatics were undoubtedly present, no continuous vegetation was evident on the photographs in the open water areas.

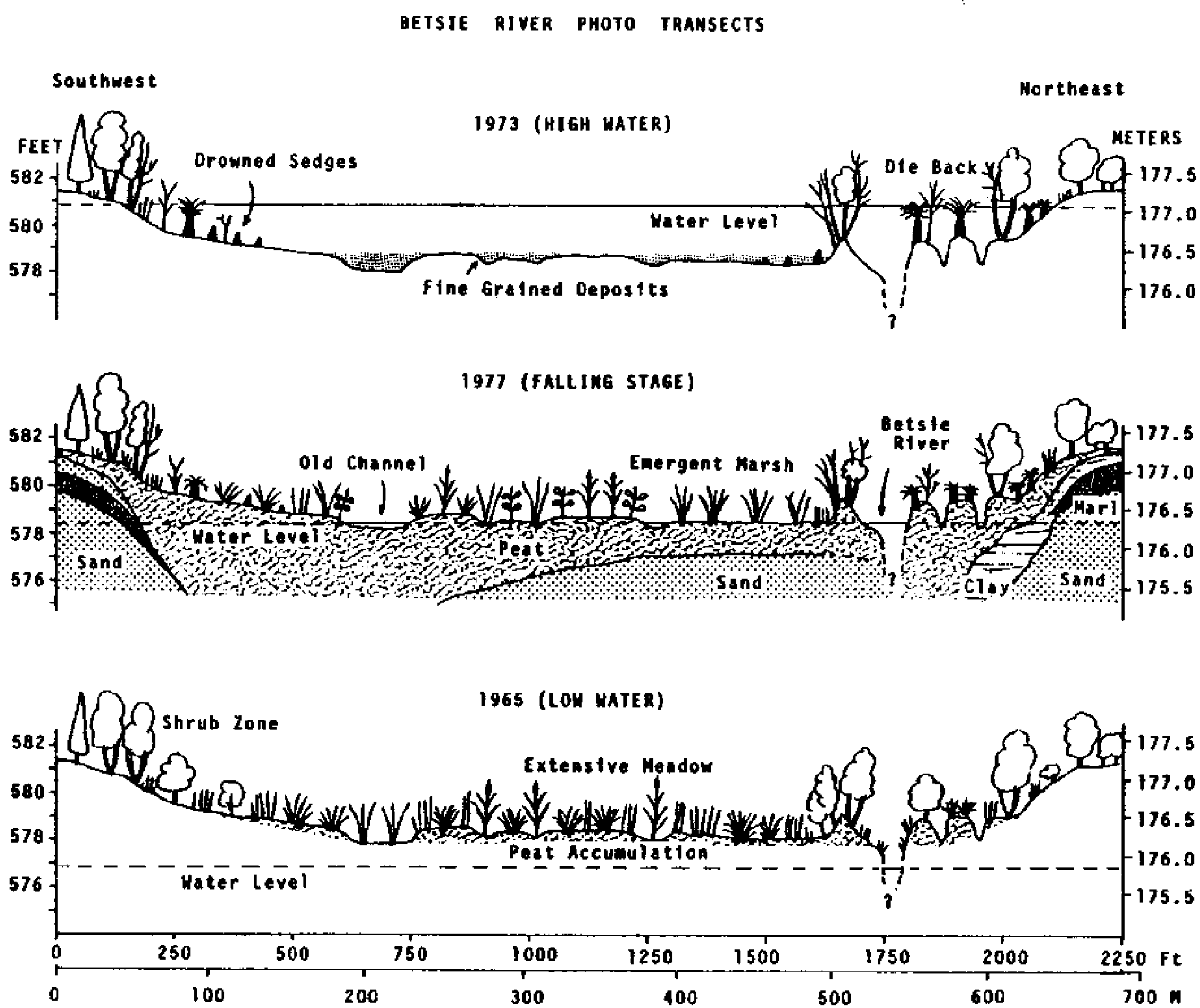


Figure 44. Photo Transects of the Betsie River Wetlands, Michigan

Year-round inundation caused the shrub ecotone to die back, and in the meadow only on the highest sites were the sedge tussocks of sufficient height to prevent drowning. Wave action, associated with increased area of open water, caused erosion of the shorelines as well as of the stressed islands of extant vegetation. Deposition resulting from this erosion process, coupled with siltation caused by overbank flow of the Betsie River, could have generated the 3 to 4 inches of organic-rich, clayey ooze which presently covers the lower flood plain surface.

From 1973 to 1977 the water level of Lake Michigan dropped a total of 2.4 feet. During the interim July 1976 to July 1977, the decrease amounted to 1.7 feet. On August 4, 1977, at the time of field bisect, the water level was at 578.6 feet. Based on the complete cover of vegetation on the 1977 surface, recolonization of the emergent marsh and sedge-grass meadow was spectacular. Because little of the emergent community survived the high-water period, the primary mechanism of regeneration appears to have involved seeds and perhaps some re-sprouting of viable rhizomes. Nodding smartweed was observed actively colonizing mudflats along with softstem bulrush. When portions of the meadow were exposed, dense seedling growth of grasses was observed amid the dead sedge tussocks. Farther landward, field observations revealed surviving tussock sedges under dieback shrubs. Thus, a mixed community of grasses borders the emergent marsh, instead of tussock sedges as one might expect, while live sedge tussocks are found on somewhat higher sites.

Other patterns include the "stump regeneration" of the partially dead willows, red dogwood, dwarf birch, and speckled alder. Based on the species composition of the leading edge of the pioneer shrubs, willows and red dogwood appear to exhibit somewhat greater regeneration capability than dwarf birch, speckled alder, and red ash. After the shrub ecotone has fully re-established itself, the thicket-like canopy will probably shade out the tussock sedges and grasses which now commonly occur as an understory in the open-canopy shrubs. As water levels drop, the stress on the marginal edge of the swamp forest would be diminished as well.

Tobico Marsh

Located in Bay County, Michigan, the Tobico Marsh consists of approximately 1,260 acres of wetlands. Basically the wetland includes a protective barrier beach and a backbarrier lagoon-marsh complex which supports much of the wetland vegetation. Only during extremely low water levels (of Saginaw Bay) will bulrushes and other emergents colonize the nearshore zone on the bay side of the barrier beach. The barrier is generally sandy and further characterized by intense residential development. On the landward side, the bottomland hardwoods which border Tobico Marsh on the west have been cleared for potato farming and other agricultural pursuits. The Tobico Marsh Interpretive Center, formerly the Tobico State Game Area, includes the southeast portion of the wetland system. Water within the elongate lagoon complex generally flows southward toward the outlet which is situated immediately north of the Bay City State Park.

Plant List The following list of common wetland plant species is based on two vegetation traverses, a geomorphic profile, and walkthroughs wherever roads and trails provided access. Most of the identification was accomplished in July 1977 with some minor collecting taking place in June-July 1978. The list is presented by environmental type, beginning at the Saginaw Bay shoreline, then ending at the upland hardwoods along the western margin of the wetland.

Beach Ridge (along Brissette and Killarney Beaches)

Black oak *Quercus ellipsoidalis?*
E. cottonwood *Populus deltoides*
Wild columbine *Aquilegia* sp.
Solomon's Seal *Polygonatum biflorum*
Silverweed *Potentilla* sp.
Sedge *Carex stricta*
Various unidentified grasses
Horsetail *Equisetum* sp.

Shrub Fringe of Beach Ridge (on lagoon side)

Red ash *Fraxinus pennsylvanica*
Black ash *Fraxinus nigra*
Trembling aspen *Populus tremuloides*
Sumac *Rhus* sp.
Willows *Salix* spp.
Red dogwood *Cornus stolonifera*
Understory sedges and grasses

Open Water of Lagoon

Hardstem bulrush *Scirpus acutus*
Softstem bulrush *Scirpus validus*
Yellow pond lily *Nuphar advena*
White water lily *Nymphaea odorata*
Water smartweed *Polygonum* sp.
Muskgrass *Chara* sp.
Duckweed *Lemna minor*
Naiad *Najas flexilis?*
Curly pondweed *Potamogeton* sp.
Sago pondweed *Potamogeton pectinatus*
Watermilfoil *Myriophyllum* sp.
Filamentous blue-green algae
Filamentous green algae

Mudflats (recently exposed mud or peat flats)

E. cottonwood *Populus deltoides*
Willows *Salix* spp.
Smartweed *Polygonus* sp.
Cattails *Typha glauca* and Others
Jewel weed *Impatiens* sp.
Boneset *Eupatorium* sp.
Several grasses and sedges

Cattail Marsh

Hybrid cattail *Typha glauca*
Narrow-leaved cattail *T. angustifolia*
Sweet flag *Acorus calamus*
Arrowhead *Sagittaria* sp.
Jewel weed *Impatiens* sp.
Mud Lettuce (Unidentified species)
Buttonbush *Cephalanthus occidentalis*

Sedge Meadow

Meadow sweet *Spiraea alba*
Sedge *Carex stricta*
Wire sedge *Carex* sp.
Boneset *Eupatorium* sp.
Marsh fern *Thelypteris palustris*

Shrub Ecotone (between sedge meadow and upland hardwoods)

Red ash *Fraxinus pennsylvanica*
Trembling aspen *Populus tremuloides*
Speckled alder *Alnus rugosa*
Willows *Salix* spp.
Red dogwood *Cornus stolonifera*
Wild raspberry *Rubus* sp.
Jewel weed *Impatiens* sp.
Nightshade *Solanum* sp.
Sedges incl. *Carex stricta*
Marsh fern *Thelypteris palustris*

Upland Hardwoods

White oak *Quercus alba*
Black oak *Quercus ellipsoidalis*
Red maple *Acer rubrum*
White birch *Betula papyrifera*
Trembling aspen *Populus tremuloides*
Cherry *Prunus* sp.
Solomon's seal *Polygonatum biflorum*

Wetlands Bisect The bisect for Tobico Marsh extends from the barrier beach to the upland hardwoods, a distance of approximately 4,000 feet (Figure 45). At the time of the bisect survey, water level in the lagoon was 579.5 feet. Beginning at the shoreline near Killarney Beach, the investigation revealed the general absence of emergent vegetation in the nearshore zone. Only at the extreme north end of the study area (north of Brissette Beach) was a patch of three-square (*Scirpus americanus*) observed. Although evidence of shoreline recession was evident, the modern beach profile reflected some shoreline progradation and nearshore bar development. The beach sediment consisted of medium to coarse textured, tan-colored sands along with occasional clumps of filamentous bluegreen algae (*Oscillatoria*).

Trending along the shoreline is the Tobico barrier beach which appears to be a double ridge system. Over 250 feet in width, the barrier has been culturally modified by residential development as well as by the coastal highway and Detroit-Mackinac Railroad line. Tall eastern cottonwood trees provide shade for the homes and cottages, while along the transportation arteries, sumac with a sedgegrass understory is common.

Between the bimodal-shaped barrier beach and a back-barrier spit (sand ridge) is a depression approximately 200 feet in width. The substrate generally consists of 6 to 12 inches of black, fibrous peat overlying coarse sand. A pH of 5.0 was determined in the field at a depth of 6 inches. This depression is further characterized by tussock sedge die-back, particularly near the center. Measurements indicate the dead sedge tussocks to be 8 to 10 inches in height. In areas subaerially exposed, a carpet of seedlings were observed colonizing the surface between the stools. Colonizing this peaty surface by means of seeds were several unidentified grasses as well as sedges, cattails, smartweed, and eastern cottonwood. Along the flanks of the depression, live sedges tussocks were encountered along with dead sumac shrubs which ranged from 4 to 5 feet in height. Most of the sedge appeared to be *Carex stricta*, but an unidentified thin-bladed, wire-like tussock-forming sedge (*Carex lasiocarpa*?) was also present.

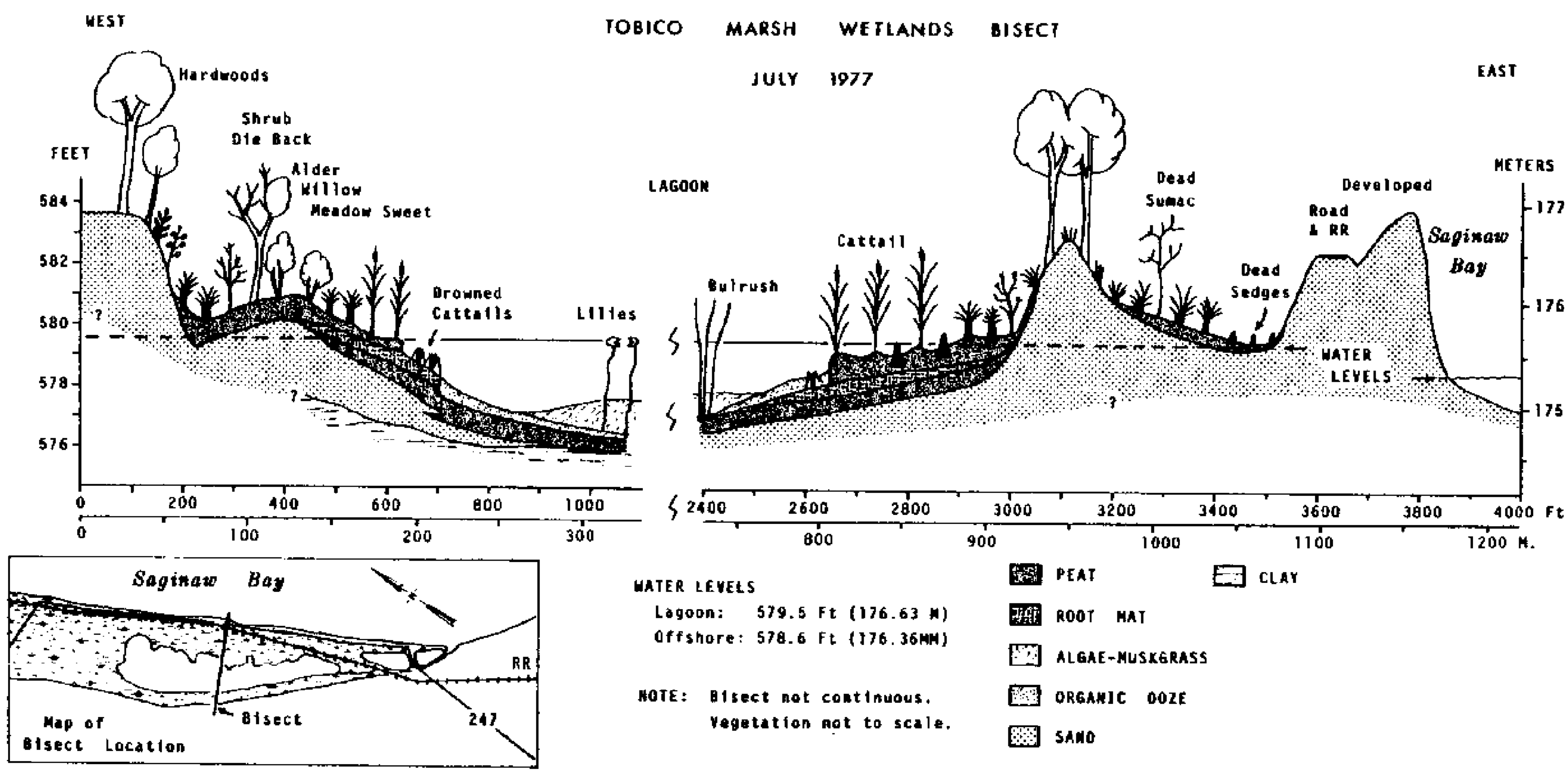


Figure 45. Bisect Across the Tobico Marsh Wetlands, July 1977

The sand ridge of the spit is located nearly 800 feet from the present shoreline and ranges 3.5 to 4 feet above the present water table. This ridge, which averages one foot lower in elevation than the modern barrier beach, consists of coarse sand, with organic layers near the surface and shell fragments increasing with depth. At a depth of 6 inches a pH of 5.0 was determined, whereas at 18 inches the pH ranged between 5.5 and 6.0. Black oak, which is tolerant of well-drained and somewhat acid environments, was the most abundant canopy species. Shrubs included sumac, red dogwood, and trembling aspen, along with a mixed understory of wild raspberry, horsetail, wild columbine, Solomon's seal, and several unidentified grasses.

On the landward side of this spit or sand ridge, the vegetation grades from a dogwood meadow into a live tussock sedge marsh. On the lagoon side of other spits in the study area, red dogwood forms a thicket 20 to 30 feet across. Depths to water table under the thicket commonly averaged 1 foot or more below the present surface. Along the lagoon margin of this thicket, the dogwood thicket may be replaced by open willow shrubs with tussock sedges as the understory. Die-back of both the red dogwood and willow shrubs was observed. Under the partially dead willows, live sedge stools ranging 8 to 12 inches in height were observed.

Farther along the bisect, the water table intercepted the surface and a zone of dead sedge marsh was encountered. These dead sedge stools appeared to be rooted in a buried root mat located beneath the present peat surface. Cattails are colonizing this former sedge marsh by means of rhizome extension as well as by seeds wherever mudflats occur. The height of the cattails, which were identified as *Typha glauca*, ranged from 3 to 5 feet.

The cattail marsh has a width of approximately 250 feet. Relatively short in height and widely spaced, the cattails are growing amid a soft, unconsolidated layer of organic debris. Fragments of cattail stems and rootstalks constitute the debris. Beneath this unconsolidated layer of peat is a root mat which was comprised of sedge and grass remains. In pools of open water within the cattail marsh several submersed aquatics were observed, including bladderwort and curly pondweed. At the lagoon margin, the cattails appear to be floating. Wave action has truncated the edge of the floating emergent marsh and floating clumps of cattails were observed in the lagoon.

Beyond the cattail marsh, the lagoon becomes an open water environment. Water depths are generally 2 to 3 feet deep. Near the cattail marsh a layer of organic ooze covers the lagoon bottom. Similar in nature to false bottom sediments of a bog, these ooze-like sediments may be derived from erosion of the cattail marsh, particularly during high water periods. Beneath the ooze, near the truncated cattail marsh, are drowned cattail rootstalks which are still rooted in a buried root mat. These drowned cattails may have been decomposing for at least two to three years.

Little emergent or floating-leaved vegetation exists in the openwater lagoon. Small patches of hardstem bulrush were encountered, especially where sandy sediments covered the lagoon bottom. Colonies of yellow pond lily were abundant, whereas a few white water lily patches were observed only in the extreme southern end of the lagoon adjacent to a weir. This weir was constructed by the Michigan Department of Natural Resources during the mid-1960's in an effort to retain water in the lagoon at times of low water.

In contrast, considerable submersed vegetation exists along the lagoon bottom. However this submergent vegetation is limited primarily to muskgrass, a naiad, and a dense layer of filamentous green algae. The algae cover most of the central portion of the lagoon where less organic ooze is being deposited. The widespread occurrence of muskgrass may be unusual in that this aquatic is often associated with calcareous substrates or hard water. A sticky bluish-gray clay, with a pH ranging between 8.0 and 8.5, was encountered within 18 inches of the lagoon bottom along the western side of the lagoon. The same clay was located at a depth of 8 feet, 2 inches beneath a spit which crosses Parish Road. Another possible source of soluble carbonates may have been Saginaw Bay which would have flooded these wetlands during the recent high water period of the early 1970's.

In patches along the eastern side of the lagoon, floating scums of bluegreen algae were common. This algae may be associated with improperly functioning private septic drain fields of residents living along the Tobico barrier beach. Along the western margin of the lagoon, duckweeds and algae were abundant in the vicinity of canals and drainage ditches. These canals presumably transport nutrient-rich, minerotrophic waters from the surrounding farmlands into the Tobico Marsh.

Along the western side of the lagoon complex a sequence of emergent marsh, sedge meadow, and shrub communities, similar to that of the eastern side, were surveyed. Drowned cattails were encountered in water depths which exceeded 12 inches. A root mat was noted beneath the present cattail marsh which may have formerly supported the now-drowned cattails. The leading edge of the cattail marsh was also floating, which made walking difficult. Borings along the cattail margin revealed coarse sand beneath the peat, with clay at considerable depth.

Nearer the lagoon the cattails appeared to grow only in clumps on somewhat elevated sites. (This growth habitat may reflect an adaptation to higher water levels of the early 1970's). Where the present water table was at or below the surface, the cattail community was more dense, the stalks taller, and florescences more common. On recently exposed mudflats, mud lettuce and a variety of seedlings were observed including young sedges and cattails.

Adjacent to the cattail marsh is the sedge meadow. Along the eastern side of the Tobico Marsh, the sedge meadow occupies a rather narrow strip between the cattail marsh and the shrub ecotone. As indicated in the bisect, the sedge meadow was even narrower because of the presence of a sand ridge which supported meadow sweet, as well as some red dogwood, speckled alder, and willows. The tussock sedge (Carex stricta) extended under the shrubs as an understory and exhibited little evidence of drowning. As suggested by the buried root mat, which contains in situ sedge and grass roots, the sedge meadow was probably more extensive in the past.

Irregular in width, the shrub ecotone consists of red ash, speckled alder, willows, red dogwood, and meadow sweet. Red ash was common only along the northwest and southwest margins of the lagoon. Tussock sedge, accompanied by jewel weed, marsh fern, and nightshade, formed the understory. Much die-back, particularly among the red ash and speckled alder was observed. The substrate consisted of a foot or more of black peat underlain by mottled, coarse sand.

West of a small depression, which may be a topographic low between two beach ridges, the vegetation undergoes transition to upland hardwoods. Along this rather sharp wetland boundary, trembling aspen are abundant. Sedges, goldenrod, jewel weed, wild raspberry, and morning glory comprised the understory.

The canopy vegetation of the upland hardwoods consists of black oak, red maple, and white birch. White oak appears to be one of the dominants farther inland. Some trembling aspen and cherry was also present, in additiion to Solomon's seal on the forest floor. Field testing of the pH at depths of 6 inches revealed the sandy soil to have a pH of 5.0. The excessive drainage and low pH may be factors explaining why red ash and other wetland shrubs do not colonize the edge of the upland hardwoods.

Wetland Distribution at Various Lake Levels Using black and white aerial photography flown in June 1938, July 1963, and in May 1975, maps were prepared of the Tobico Marsh wetland vegetation. Because photograph scales were 1:20,000 or smaller, only five or six general vegetation types could be recognized. Water levels of Saginaw Bay at the time of the photographs were as follows: 1938 - 577.6 feet; 1963 - 576.9 feet; and, 1975 - 580.15 feet.

Wetland Vegetation in 1938 In 1938, Tobico Marsh was characterized by extensive cattail marshes and relatively small areas of open water in the lagoon (Figure 46). Because of the relatively low water level, emergent vegetation had completely overgrown the channel leading to the outlet on Saginaw Bay. Two bodies of open water exist in the lagoon, separated by cattails as well as what appears to be yellow pond lily and floating algal scums. Throughout much of the central portion of the lagoon, cattail marsh predominates because low water levels during the period 1932-1937 have allowed the cattail to colonize an extensive area.

Another extensive wetland type at this time period was the sedge meadow. The meadow is well established on the flanks of the lagoon and on the backside of the barrier beach ridge. Sedge has also invaded low-lying areas near Parish Road as well as along the channel which leads to the outlet at the extreme southern end of the study area.

The shrub vegetation also appears to be well established on both the beach ridges and along the margin of the upland hardwoods. Some of the shrub vegetation along Parish Road may have been cleared by local farmers who drained wetlands for agriculture. However, on isolated sand ridges and along the southeast side of Tobico Marsh, the shrub and small tree extension was not impeded. Similarly, black oak and other hardwood trees probably extended their dominance in the well-drained environments.

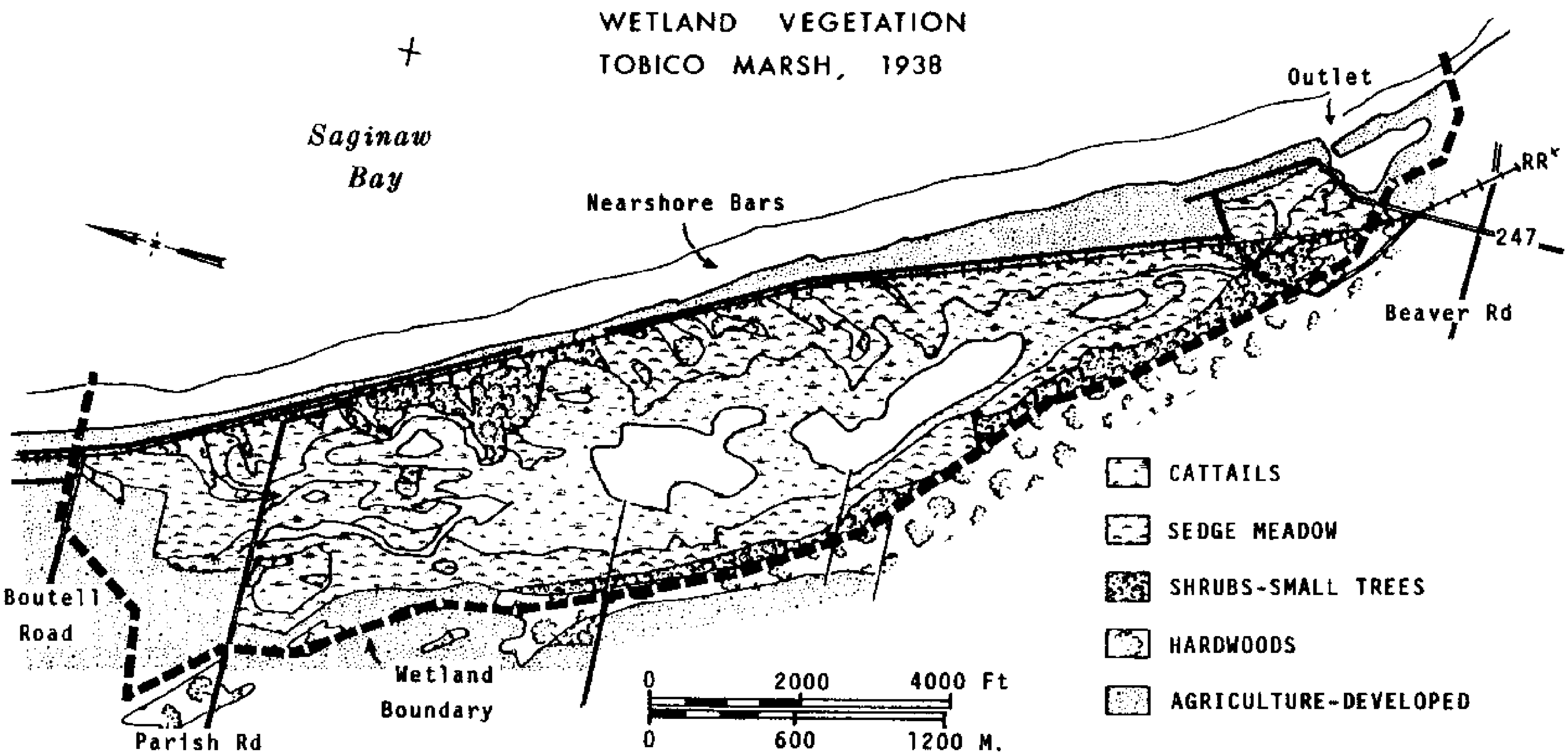


Figure 46. Distribution of Wetland Vegetation in Tobico Marsh, 1938. Dashed Line Shows Limit of Wetland Soils

Along the shoreline, wide beaches and a broad zone of nearshore bars are evident. Lower lake levels reduce wave energy which, in turn, is associated with shoreline progradation. Although no emergent vegetation was visible on the photographs, thin patches of bulrushes may have colonized some areas of the nearshore zone.

Wetland Distribution in 1963 Water levels in 1963 were relatively low as in 1938. In fact, as the time of the photograph Saginaw Bay was at 576.9 feet, which is 1.72 feet below the 1900-1976 average for July. As expected, therefore, the wetland vegetation map for 1963 (Figure 47) closely resembles the distribution map for 1938. The major differences appear to be in the open water and cattail categories. Because the year 1938 was preceded by a relatively long low-water period, cattails had colonized more of the open waters of the lagoon than in 1963.

In 1963 a large, isolated open-water body occupied the central lagoon area. Large patches of floating algae, particularly on the beach side, were common in the lagoon. The channel leading to the outlet was overgrown with vegetation, and the outlet was relocated due to modification of the Bay City State Park.

In addition, the cattail marsh at this time was most extensive, particularly in the area immediately north of the lagoon. Some cattail, and perhaps bulrushes as well, have even colonized the nearshore zone near the outlet. Although the cattails tolerated the low-water conditions along Parish Road, dark tones on the imagery suggested that the vegetation was sparse and peaty soil was visible amid the cattail colonies. Sedge and other meadow vegetation was probably invading some areas of the cattail marsh.

Another feature of the 1963 vegetation map is the curtailing of agricultural activity in some of the low-lying areas. Apparently the high water of the 1950's caused local farmers to abandon much of the land between Parish Road and Boutell Road and reclamation during the low-water period of the early 1960's did not occur. As a result, sedge and cattail communities have colonized areas which were formerly drained and cultivated. Shrub communities also appear more widespread than in 1938, suggesting that not only is low water conducive to woody invasion, but perhaps marsh burning has been discontinued as well.

1975 Wetlands Distribution Water levels in 1975, though slightly lower than in 1973, exceeded 580 feet. As a direct result of increased water levels, vegetation regression occurred and open-water areas expanded (Figure 48). The lagoon increased in size, especially along the eastern flank and in the extreme southern portion. Near the outlet, ponds appeared and the outlet channel is clearly discernible. Elsewhere small ponds opened up within the cattail marsh, particularly near Parish Road and immediately west of the railroad tracks at Killarney Beach.

Although the lagoon has increased in size, primarily at the expense of the cattail marsh, a large area of dead cattails exists north of the open-water area. Ice rafting and wave action had not yet uprooted the old stalks which probably succumbed during the record high lake levels. The cattail zone has

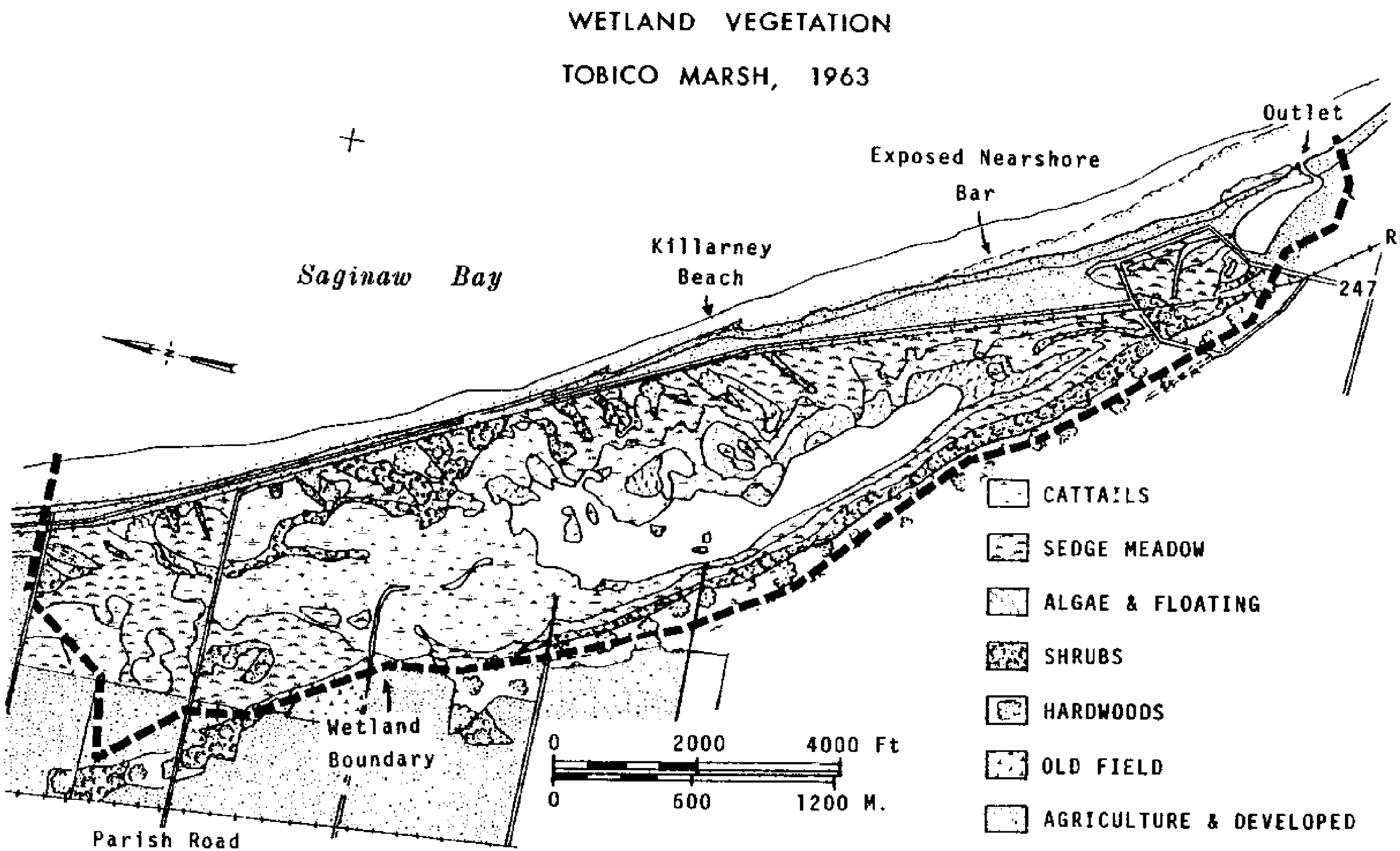


Figure 47. Distribution of Wetland Vegetation in Tobico Marsh, 1963

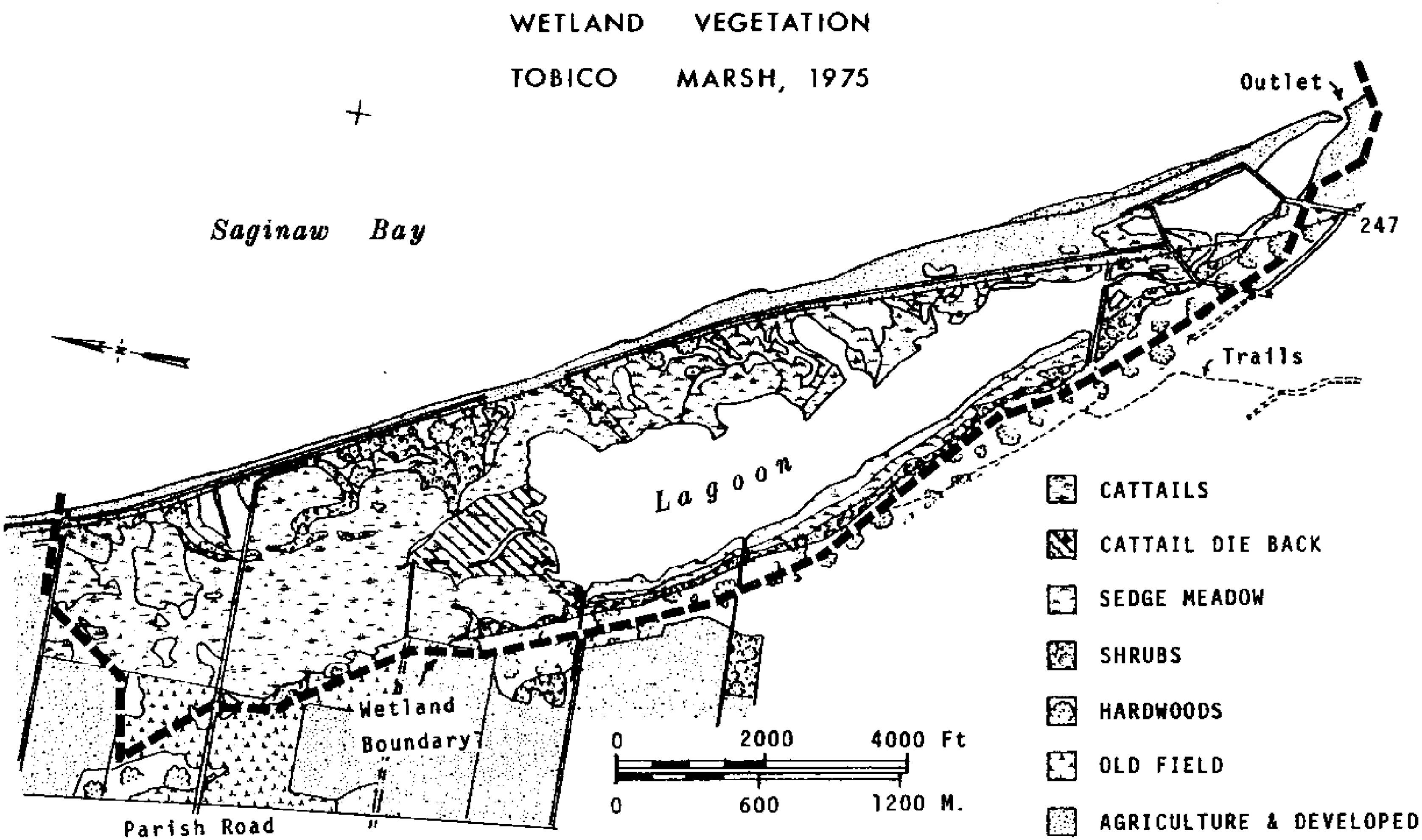


Figure 48. Distribution of Wetland Vegetation in Tobico Marsh, 1975

shifted into the sedge meadow near Parish Road and along the flanks of the lagoon. Higher water levels and subsequent anaerobic conditions probably stimulated rhizome extension of this emergent.

Other changes include the temporary abandonment of some agricultural fields with old field succession or emergent marsh colonizing these former cultivated areas. The shrub communities, though slightly less extensive than in 1963 due to some die-back, are still well represented. Loss of the wide, sandy beach and some shoreline recession has also taken place. Because of the prevailing high lake levels, the wave base shifts landward and the nearshore bars are less effective in attenuating wave energy.

Wetland Area Measurements Using a polar planimeter and the three wetland distribution maps discussed above, the area of each wetland type was determined (Table 24). The 1938 wetland distribution map was employed to delimit the wetlands because not only is that map the oldest historically, water levels were relatively low and thus the maximum wetland limit in the nearshore zone could be established. The inland wetland boundary was based on the 585 foot contour of the 1:24,000 Kawkawlin quadrangle and the limit of the ponded Belleville loamy sand soil. By utilizing the 585-foot contour, the shrub ecotone was included in the wetland complex. The wetland soil, which would have delimited the wetland more conservatively, was employed only in the northwest corner of the wetland where the 585-foot contour was displaced landward. Boutell Road on the north and the swamp fringe along the artificial lake near the outlet on the south completed the boundary.

In 1938, the Tobico Marsh, as defined in this study, included 1,260 acres (Table 24). The cattail marsh and sedge meadow each occupied one-quarter of the wetland and together accounted for 54 percent of the entire acreage. Because low water had persisted for several years, agriculture and other developments were extensive. In contrast, little open water remained in the lagoon area. Shrubs and hardwood vegetation should have attained their maximum extent, except where marsh burning, if any, precluded shrub invasion of meadow environments.

By adopting the areal extent of the wetlands in 1938 as the standard area, comparisons with the 1963 and 1975 tabular data sets can be made. In 1963, the combined cattail and floating-leaved marsh constituted 35.5 percent of the total wetland area, whereas the sedge meadow occupied only 21 percent of the area. Inclusion of the floating-leaved vegetation, as well as the algal scums, in the cattail marsh category inflated that category somewhat. Because patches of cattails were mixed with the water lilies and algae, these areas were combined into the cattail category instead of placing them in the open water category. Although 1963 reflected low-water conditions, it is felt that the sedge meadow had not yet displaced all of the cattail marsh it would if low water levels persisted for several more years. Both the open water and shrub-hardwood areas changed very little since 1938. The agriculture-developed area did decline, reflecting the abandonment of agriculture along Parish Road during the 1950's.

Table 24

Areal Extent of Wetlands, by Vegetation Type
Tobico Marsh, 1938, 1963, 1975

1938 Distribution (Low Water)

Wetland Type	Acres	Hectares	Percent of Total
Shrubs and Hardwoods	189	76.5	15.0
Sedge Meadow	321	130.0	25.5
Cattail Marsh	359	145.5	28.5
Open Water	126	51.0	10.0
Agriculture and Developed	265	107.0	21.0
	1,260	510.0	100.0

1963 Distribution (Low Water)

Wetland Type	Acres	Hectares	Percent of Total
Shrubs and Hardwoods	189.0	76.5	15
Sedge Meadow	264.5	107.0	21
Cattail and Floating Leaved	447.5	181.0	35.5
Open Water	138.5	56.0	11.0
Agric., Developed, Old Field	220.5	89.5	17.5
	1,260.0	510.0	100.0

1975 Distribution (High Water)

Wetland Type	Acres	Hectares	Percent of Total
Shrubs and Hardwoods	189	76.5	15
Sedge Meadow	107	43.5	8.5
Cattails, incl. die-back	378	153.0	30
Open Water	391	158.0	31
Agriculture and Developed	195	79.0	15.5
	1,260	510.0	100.0

The area measurements for 1975 clearly document the effect of record high lake levels. Perhaps the most significant change from 1963 to 1975 is the dramatic increase in the extent of open water. Drowning and loss of large tracts of cattail marsh, as well as of sedge meadow, account for most of the increase in open water. Some loss of beach environment also occurred. Although the cattail marsh continued to represent a large portion of the total area, extensive areas of die-back can be identified on the 1975 photographs. Another feature of the area measurements is the contraction of the sedge meadow from 21 percent in 1963 to 8.5 percent of the total area in 1975. Large areas of the sedge were inundated by the high water and either reverted to open water or were invaded by cattails. Little change, however, occurred in the shrub-hardwood zone because shrub die-back areas were included within the shrub-hardwood category. In contrast, the agriculture-developed category did exhibit a decrease in area because of loss of beach environments in front of the shoreline residences and temporary abandonment of low-lying fields by farmers during this high-water period.

In order to generate area figures for normal lake level conditions, the measurements for 1963 (low water) and 1975 (high water) were averaged. The average area of each vegetation type is indicated below. The 1938 wetland area of 1,260 acres was adopted as the standard area.

Wetland Type	Acres	Hectares	Percent of Total
Wooded and Shrub	189	76.5	15
Meadow	189	76.5	15
Emergent	403	163.0	32
Open Water	265	107.0	21
Developed	214	87.0	17
	1,260	510.0	100

Comparative Photo Transects By juxtaposing vegetation transects pertaining to three different lake level conditions, the succession or regression of the plant communities can be illustrated (Figure 49). The July 1977 bisect served as the base for the profile elevations and substrate type for all three transects. Water level data were taken from the gauging station at Harbor Beach, Michigan. Photo interpretation provided the vegetation data as well as the shoreline changes.

During the low-water period of 1963, the lagoon was approximately 850 feet wide along the transect survey line. Patches of scum algae and floating-leaved aquatics were present along the eastern side and southern end of the lagoon. Relatively wide zones of cattail marsh and sedge meadow flanked the eastern (or lakeward) side of the lagoon, whereas on the western flank these zones were much narrower. Field borings in 1977 revealed that a thick root mat and a peat layer were being established at this time beneath the emergent and meadow vegetation. Although shrubs and small trees occupied the sand ridges and other higher topography, invasion of the sedge meadow by shrubs was not widespread. Along the shoreline, a wide, sandy beach was evident as the shoreline was displaced lakeward approximately 200 feet.

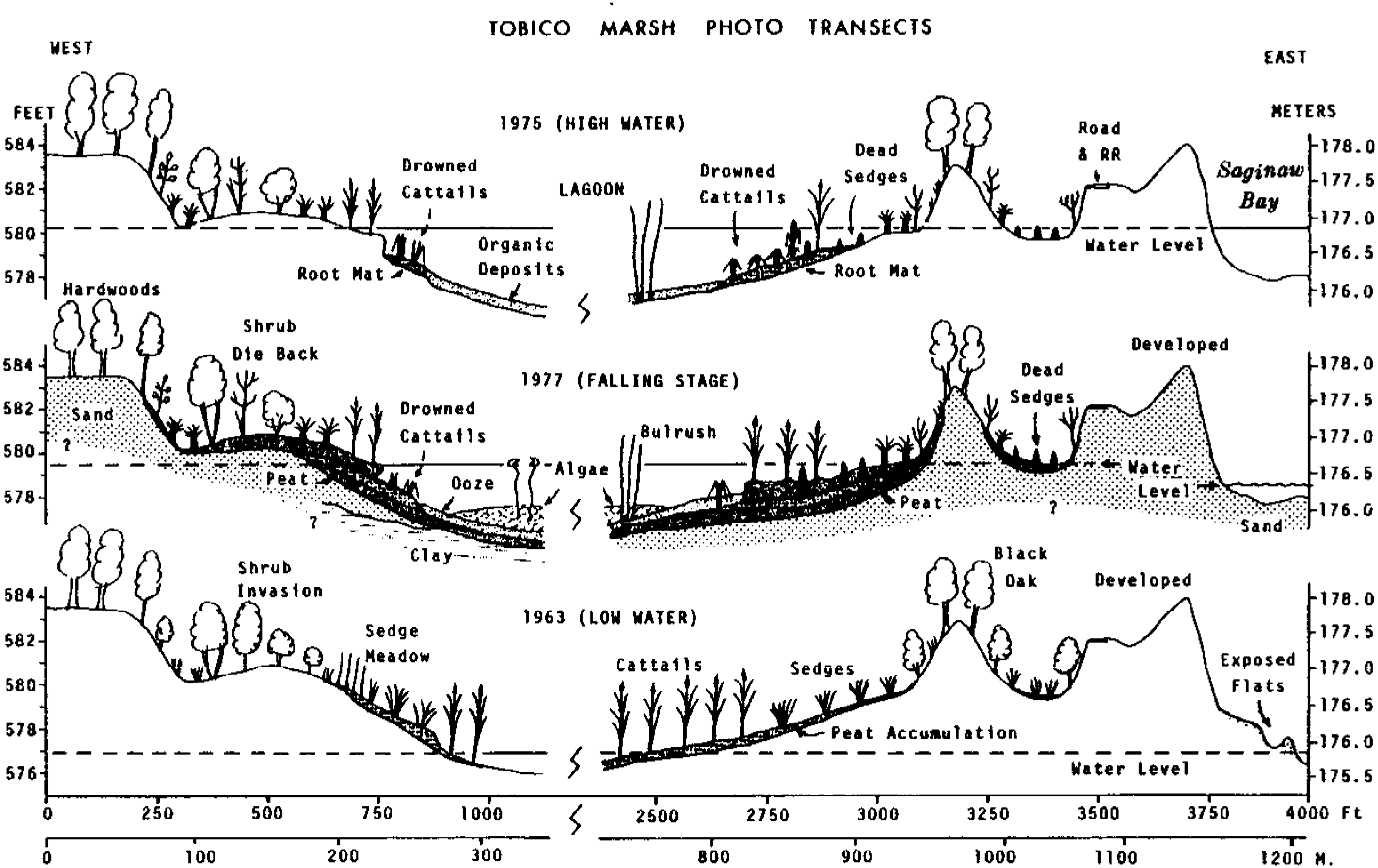


Figure 49. Photo Transects of the Tobico Marsh Wetlands, Michigan

As represented by the 1975 transect, highwater was associated with the shifting of the cattail zone into the sedge meadow zone and by the drowning of extensive areas of tussock sedge. The lagoon expanded at the expense of both the cattail marsh and the sedge meadow. Organic deposits were deposited in the lagoon or transported to the outlet as the emergent marsh was subjected to increased wave action and ice rafting. Rhizome extension probably allowed the cattails to successfully colonize the inundated sedge margins, whereas the tussock mechanism enabled the sedge to survive where permmanent water depths did not exceed approximately 10 inches. Although the black oak and other hardwoods exhibited little die-back, the shrub communities on the backside of the Tobico occurred on the eastern flank of the lagoon, but it appeared to be limited to the margin of the shrub ecotone.

From July 1974 to July 1977, the level of Saginaw Bay dropped 2.62 feet. The lowering of the water levels diminished the size of the lagoon by exposing formerly drowned areas along the flanks. Stressed cattail colonies then began to expand by means of rhizome extension, and re-establishment of drowned sedge meadow occurred by seedling growth. Partially dead shrubs, including speckled alder and willow, are now sprouting new sucker growth as the water table drops to more optimum levels. In short, the successional trend has switched from retrogression to succession. As water levels within the lagoon continue to fall, less organic material will be transported into it from the adjacent emergent marsh. In addition, less exportation of suspended material to Saginaw Bay will occur. The development of extensive submersed algal growths as well as the floating algal scums suggests that lower lake levels at Tobico Marsh may result in reduced flushing and consequent eutrophication.

Tuscola County Wetlands

Located in Tuscola County, Michigan, the Thomas Road wetlands are situated along the southeastern coast of Saginaw Bay. The wetlands include the emergent marshes in the nearshore zone as well as various wetland types in the intra-beach ridge depressions and lake plain lowlands. Because the topography gently slopes bayward, water level changes of Saginaw Bay can drastically affect the extent of both the nearshore and inshore wetlands. Although most water movement appears surficial and toward Saginaw Bay, during high water and storms the bay water inundates portions of the coastal lake plain including the coastal wetlands.

Former shorelines are marked by the presence of sandy beach ridges which trend parallel to the coast. During the past 100 years, agriculture has encroached upon the inshore wetlands and beach ridges, and in some places the wooded beach ridges have been leveled by the local farmers. However, part of this coastal plain, including an artificial lake, is part of the publicly owned Fish Point Wildlife Area.

Plant List This area has been visited annually by the principal investigators since 1975. Much of the species identification was accomplished during the July 1977 vegetation transect and geomorphic profiling. The plant list below is presented by environmental type, beginning with the nearshore emergent marsh and ending in the inshore wetlands near the agricultural fields.

Nearshore Emergent Marsh

Hardstem bulrush Scirpus acutus
Softstem bulrush Scirpus validus
Hybrid bulrush S. acutus X S. validus
Narrow-leaved cattail Typha angustifolia
Hybrid cattail Typha glauca
Three square Scirpus americanus
Spikerushes Eleocharis spp.
Sago pondweed Potamogeton pectinatus
Curly pondweed P. crispus
Watermilfoil Myriophyllum sp.
Muskgrass Chara sp.

Modern Beach Ridge

Red ash Fraxinus pennsylvanica
E. cottonwood Populus deltoides
Trembling aspen Populus tremuloides
Willows Salix spp.
Red dogwood Cornus stolonifera
Wild grape Vitis sp.
Jewel weed Impatiens sp.
Sow Thistle Sonchus sp.

Washover Deposits of Modern Beach Ridge

Willows Salix spp.
Red dogwood Cornus stolonifera
Horsetail Equisetum sp.
Staghorn sumac Rhus typhina
Jewel weed Impatiens sp.
Smartweed Polygonum sp.
Morning glory Convolvulus sepium
Virginia creeper Parthenocissus sp.

Wet Depressions between Beach Ridges (Lagoon-like features)

Red ash Fraxinus pennsylvanica
Willows Salix spp.
Water plantain Alisma plantagoaquatica
Joe-pye weed Eupatorium dubium
Boneset Eupatorium perfoliatum
Smartweed Polygonum sp.
Swamp milkweed Asclepias incarnata
Golden rods Solidago spp.
Spikerushes Eleocharis spp.
Duckweed Lemna minor

Old Beach Ridges (Inland of Modern Beach Ridge)

Pin oak Quercus palustris
Bur oak Quercus macrocarpa
Hybrid aok Q. palustris X Q. macrocarpa
Swamp white oak Quercus bicolor
Chokeberry Pirophorum sp.
Sumac Rhus sp.
Wild grape Vitis sp.
Black Raspberry Rubus sp.
Horsetail Equisetum sp.
Solomon's seal Polygonatum biflorum

Shrub Meadow on Lake Plain (Landward of Old Beach Ridges)

Red dogwood Cornus stolonifera
Gray dogwood Cornus racemosa
Reed canary grass Phalaris arundinacea
Sedge Carex stricta
Goldenrods Solidago spp.
Morning glory Convolvulus sepium

Sedge-Grass Meadow on Lake Plain

Reed canary grass P. arundinacea
Cut grass Leersia orysoides?
Reed cane Phragmites australis
Tussock sedge Carex stricta
Unidentified sedges C. lasiocarpa?
Morning glory Convolvulus sepium

Emergent Marsh on Lake Plain (near Artificial Lake)

Buttonbush Cephalanthus occidentalis
Hybrid cattail Typha glauca
Hardstem bulrush Scirpus acutus
Sedges incl. Cares stricta
Mint Mentha sp.
Smartweed Polygonum sp.
Purple loosestrife Lythrum sp.

Disturbed Meadow (south of Artificial Lake)

Sedge Carex lasiocarpa?
Wild iris Iris sp.
Black-eyed susan Rudbeckia sp.
Shrubby cinquefoil Potentilla fruticosa
Lady-slipper Cypripedium sp.?

Wetlands Bisect The wetlands bisect covers a distance of 2,400 feet (Figure 50). At the time of the bisect survey on July 17,1977, the water level of Saginaw Bay was 578.6 feet in elevation. Although the water table appeared to be horizontal, tiling and pumping by local farmers as well as slowly permeable subsoils can produce either perched or lower water levels in the inshore zone.

The first part of the bisect description begins at the shoreline and proceeds lakeward into Saginaw Bay. Along the eroded shoreline, uprooted red ash and eastern cottonwood were observed along with scattered cobble-and boulder-sized rocks. The beach sediments at the shoreline consisted of 18 inches of gravelly sand over a pebbly, yellowish-brown clay which resembled a dense glacial till. Field measurements revealed this dense clay to have a pH of 8.0. Little vegetation was present except for scattered patches of spikerushes and of an unidentified Cyperus as well as some deformed three square.

At 100 feet, the water depth measured 9 inches. The sediment consisted of 3 to 4 inches of gravel overlying yellowish-brown clay which contained some Scirpus roots. However, in many places, a thin layer of fine-grained clay and particulate organic matter covered the surface, especially during quiet-water periods when sedimentation occurs. Little vegetation was observed, except for filamentous algae attached to the scattered cobbles.

At 110 feet from shore, the first nearshore sand bar was encountered at a water depth of 4 to 6 inches. Here some Sago pondweed and muskgrass were observed in the rather turbid water. Patches of peat and shrub roots were also noted in scattered locations.

Approximately 300 feet from shore the first line of emergent vegetation was encountered. At this point, hardstem bulrush was observed growing through a few inches of coarse sand. Beneath the sand was a dense rhizome mat which was rooted in the clay or in compact sands. In general, the bulrushes tended to

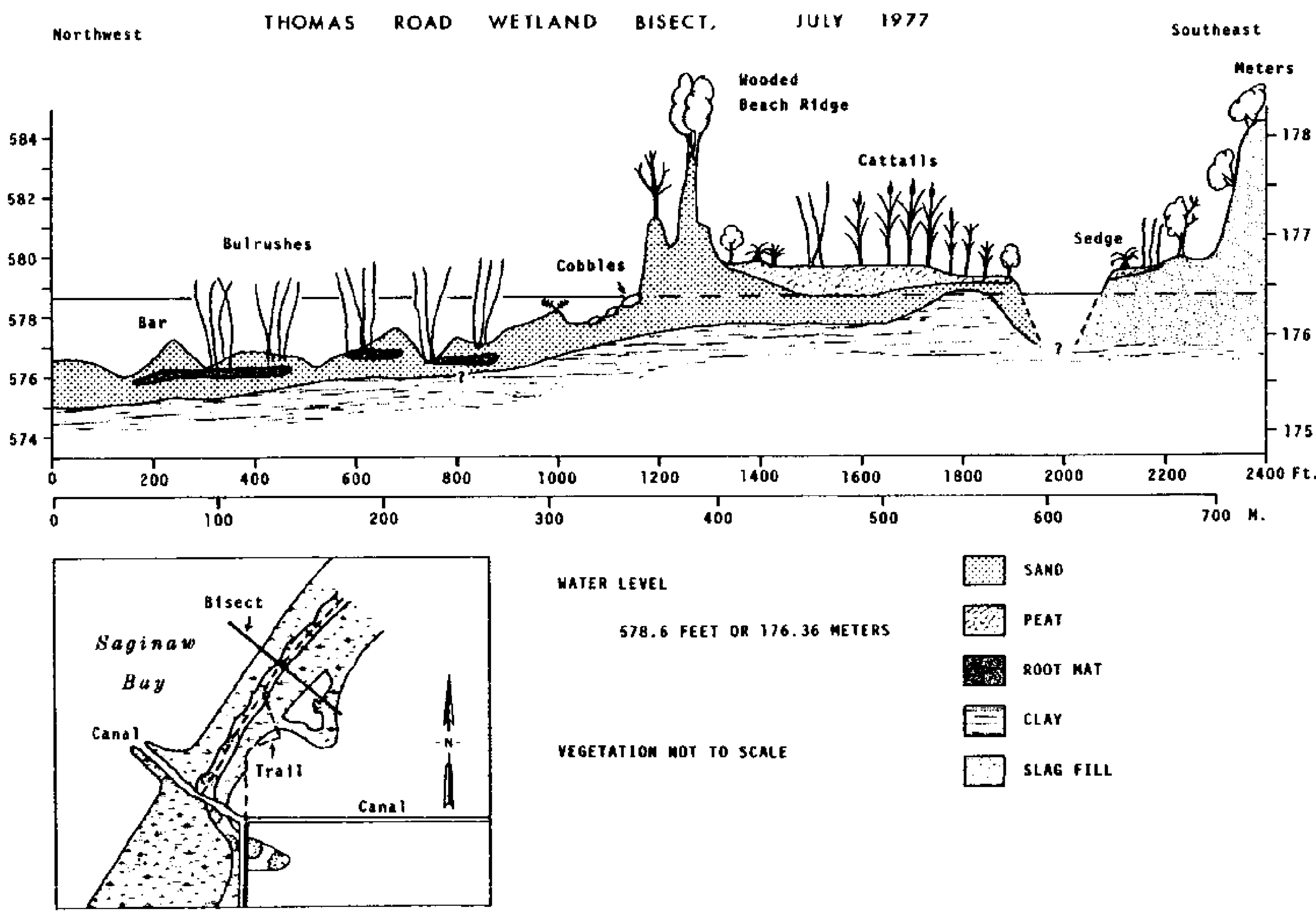


Figure 50. Bisect Across the Thomas Road Wetlands (Tuscola County), July 1977

exhibit linear patches parallel to the coast and were associated with the presence of viable rhizome mats in the subsurface sediments. Although the nearshore bars appeared to protect the rhizome mats from wave erosion, in some places the tenacious rhizomes resisted erosion in the troughs. However, the bulrush communities were less well-established in these topographic lows and frequently one noticed broken stems.

Farther out along the bisect, the wave energy continued to increase. Generally, wave energy levels were highest near the troughs and nearshore bars as evidenced by firm sands and ripple-marked bottoms. In contrast, in between the trough-bar complexes are flats which may be subjected to fine-grained deposition. No Sago pondweed or other submersed aquatics were observed beyond approximately 800 feet from shore where water depths exceeded 2 feet. In comparison, the bulrush communities extended out to beyond 900 feet where water depths were 2.5 feet. Patches of Scirpus rhizome root mats were encountered beyond this point, but partially eroded roots were not supporting emergent vegetation.

The actual traverse extended to 1,700 feet from shore. Water depth at this point was approximately 3 feet. No vegetation was observed. Basically the sediments consisted of fine sand that was extensively ripple-marked. No pebbles or cobbles were noticed. Occasional sediment probes revealed that the pebbly clay surface may underlie the surface sands which may be 1.5 feet thick.

The next segment of the bisect extends from the modern shoreline landward to the artificial lake and agricultural fields. Beginning with the modern beach ridge, this feature was found to crest at 3 to 4 feet above the bay level. Based on the diameters of the nearly mature red ash and eastern cottonwood trees, the ridge appears to be approximately 50 years old. An understory of red dogwood, small willows, wild grape, jewel weed, and sow thistle further characterizes the modern beach ridge.

On the landward side of the modern beach, particularly where the beach-ridge trees are either uprooted or absent, washover sand deposits were common. Based on the vegetation colonizing these features, the washovers appeared to be only 2 to 4 years old. Most of the washover appeared to consist of coarse sand which accumulated up to 2 to 3 feet in thickness. Horsetail and willows were common colonizers of this surface, except where rafted organic matter stimulates the growth of sumac, red dogwood, morning glory, jewel weed, vines, and small trees.

If depressions are present between the modern beach and the older ridges, or between sets of older ridges, a lagoon-like feature may develop. These lagoonal wetlands are dry during low levels of the Great Lakes, but during high water periods these lagoons may exhibit water depths of 1 to 2 feet. Although no depression was encountered along this particular transect, lagoons are common along the southeastern coast of Saginaw Bay. Whereas most lagoons exhibit an overstory of drowned red ash and willows, a mix of herbaceous plants including water plaintain, Joe-pye weed, duckweeds, etc., comprised the understory. During the late summer of 1975, the investigators noticed large numbers of dabbling ducks feeding in these lagoons.

At approximately 150 feet from the modern shoreline was a beach ridge which was considerably higher in elevation and older than the modern beach ridge. Well-oxidized soils, including yellowish-orange subsurface sands, suggest that this ridge may be several thousand years old. Most of the vegetation on this well-drained ridge consisted of pin oak along with some bur oak. A hybrid oak (Quercus palustris X Q. macrocarpa) was also abundant, and in some places the swamp white oak was observed. The understory, which was not dense where the canopy was complete, consisted of sumac, chokeberry, wild grape, black raspberry or blackcap, horsetail, and Solomon's seal.

At approximately 175 feet from the modern shoreline, a dirt trail parallels the landward side of the old beach ridge. This road, which lies at about 581 feet above mean sea level, may be inundated during extreme high lake levels, particularly if ponding occurs behind the beach ridges. Rafted debris and flotsam, however, does not wash up onto the road, but this debris was noticed in the lagoons behind the modern beach ridge and on the bayward flank of the older beach ridge.

The vegetation betwen the dirt road and the artificial lake consists of a continuum of shrub meadow, sedge meadow, and emergent marsh. Along the landward margin of the dirt road was a relatively narrow zone of red dogwood and wild grape with an understory of sedges and grasses. The sediment or soil was generally peaty and the water table lay approximately 1.5 feet below the surface.

A strip of sedge meadow comprised the next vegetation type. Less than 50 feet in width, this zone was dominated by the tussock-forming sedge Carex stricta. Tussocks begin to appear at the upper boundary next to the red dogwood shrubs and attained 6 to 10 inches in height at the lower limit of the community. At the time of the traverse, the water table was one foot or more below the surface.

Located between the sedge meadow and the emergent marsh are poorly vegetated, low-lying depressions and swales. These depressions appear to store water following intense precipitation and probably during high lake level periods as well. Borings reveal the following sedimentary sequence with depth: brown, fibrous peat; coarse, gravelly sand; and dense, mottled clay. Calcium carbonate crusts and pulmonate snails were commonly observed along the surface of the peats. Although in some places stressed colonies of hardstem bulrush were observed, in most depressions a mix of herbaceous plants were seen including smartweeds, spike rushes, Boneset, and milkweeds.

The emergent cattail marsh occupied a broad area which exceeded 300 feet in width. Generally the sediment consisted of 6 to 12 inches of peat overlying dense, mottled clays. Water depths averaged 10 to 12 inches below the surface as evidenced by crawfish chimneys. Most of the cattail was the hybrid cattail (T. glauca), except along the margins of the marsh where the shorter, narrow-leaved cattail was dominant. In places the cattail appeared stressed, perhaps undergoing some physiological drought. The relatively dry, peaty surface revealed pulmonate snails and crawfish chimneys as well as patches of smartweeds and mint. Trails made by white-tailed deer were also observed.

The shoreline of the artifical lake was located 770 feet landward from the modern shoreline. Some buttonbush along with stressed hybrid cattail and reed canary grass colonized the lake shore. Sediments along the lake shore consisted of 6 inches of brown, cattail peat overlying a clayey sand which was mixed with marl. An organic-rich marl appears to be flocculating out of the water at present. Some evidence of the recession of the lake shore during the past year or two was clearly visible in strand deposits. The depth of the lake was not determined; this water body did support breeding populations of mallards and blue-wing teal.

South of the artificial lake, the vegetation appears disturbed due to excavation of the lake at some earlier time period and perhaps due to the deposition of waste slag. The vegetation consisted of several sedges, wild iris, shrubby cinquefoil, black-eyed susan, and lady slipper (?). A ridge which is located some 1,200 feet from the modern shoreline marks the landward limit of this wetland complex. Sumac, wild grape, and other shrubs have colonized this artificial ridge.

<u>Wetland Distribution at Selected Lake Levels</u> Aerial photographs taken in June 1941, August 1963, and March 1973 provided the data base for mapping the wetland communities of the Thomas Road area. The 1941 imagery was the earliest available photography.

<u>Wetland Distribution in 1941</u> Water level of Saginaw Bay at the time of the June 1941 photography was 557.3 feet. Because this level is approximately one foot below the long-term average level for June, the shoreline of Saginaw Bay was displaced bayward and emergent marsh colonized extensive areas of the nearshore zone (Figure 51). Water levels had been below mean level since 1932, thus the photography reflects relatively stable low-water conditions.

With regard to the nearshore vegetation, three borad zones were identified on the imagery. The first zone is the unvegetated sand flats which support little plant life because of sun scalding as well as excessively drained conditions or physiological drought. Beyond this zone is a broad extent of emergent bulrushes and cattails approximately 850 feet in width. The cattails probably occupied the more shallow areas where peats accumulated. Bulrushes, in contrast, are often more tolerant of somewhat deeper water and sandy substrates with higher wave energies. Farther bayward, the emergent marsh gives way to open-water conditions. At least 5 to 6 nearshore bars can easily be counted in this nearshore environment where wave attenuation is occurring. Some thin patches of hardstem bulrush and perhaps Sago pondweed as well were colonizing the lower energy habitats of the bar and trough topography.

The inshore wetlands (inland of the coastal dirt road) also exhibit zonal patterns. The modern beach ridge and the landward side of the older beach ridge support woody shrubs and small trees. It is likely that some of the trees uprooted during the record lake levels of the early 1970's became established during the low water of the 1930's. In the lagoon between the modern beach and the older beach ridge, woody shrub vegetation was frequently dominant.

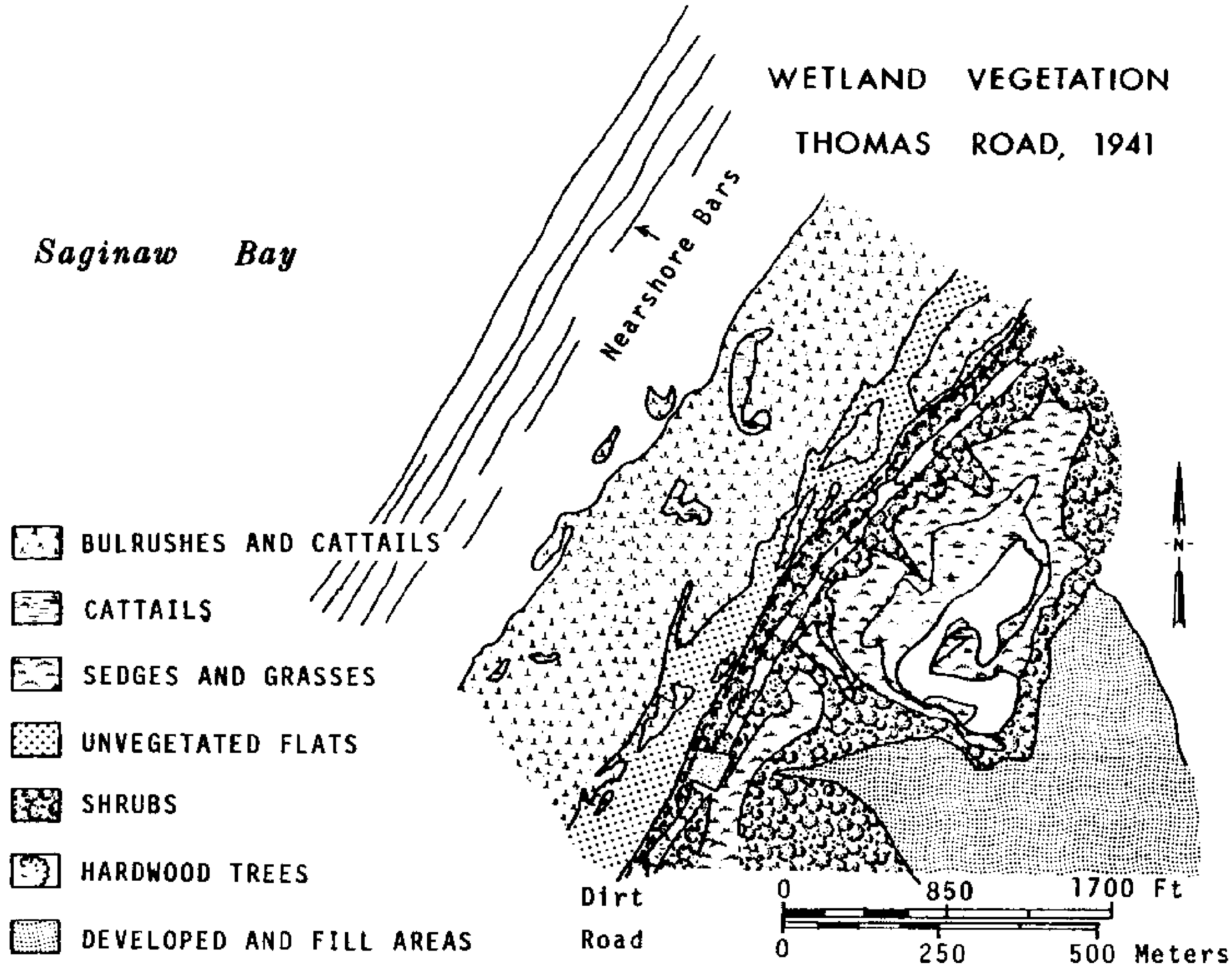


Figure 51. Distribution of Wetland Vegetation at Thomas Road (Tuscola County), 1941

Near the lake, a broad zone of meadow graminoids and emergent cattail marsh was mapped. Most of the cattail was confined to a zone immediately bayward of the lake. Much of the higher terrain along the margin of this wetland complex supported woody shrubs.

Wetland Vegetation in 1963 In August 1963, the level of Saginaw Bay was 576.9 feet, or 5 inches lower than in June 1941. Thus the shoreline and nearshore bars were displaced bayward somewhat more so than in 1941 (Figure 52). Better print contrast enabled a more detailed interpretation of the vegetation communities for the 1963 survey.

A comparison of the 1963 map with the 1941 map reveals little significant difference. Basically, the nearshore vegetation exhibited the same pattern during both time periods. With regard to the inshore vegetation, there are a few differences. First, the beach ridge vegetation appears more mature, thus much of it has been mapped as trees as opposed to shrubs. Second, more cattail communities were identified within the marly lake. Finally, increased land development pressure has eliminated much of the shrub fringe and other vegetation in the coatal area west of the lake.

Wetland Vegetation in 1973 In March 1973, water levels attained 580 feet in Saginaw Bay. During this record high lake level period, erosion of the modern beach ridge began to occur and most vegetation communities regressed to more aquatic seral stages (Figure 53).

In the nearshore zone, the nearshore bars largely disappeared as a result of a higher wave base level. Wave energy levels increased dramatically which resulted in the uprooting of the cattail rootstalks. Debris from the cattails and the non-ersistent bulrush stems provided material for organic beach ridges, washovers, and flotsam deposits. In comparison to 1941, the bayward edge of the emergent marsh receded 400 to 500 feet. Nearly all the cattail colonies were eliminated in the nearshore zone, and hardstem bulrush and three-square exhibited dominance. Although we expected that the sand flats in front of the modern beach ridge would be colonized by emergent marsh during high water, this successional change did not occur because wave energy was now being expended in the nearshore zone.

The most significant change in the inshore wetlands was the expansion of the cattail marsh near the artificial lake. In response to higher water levels, the cattails invaded and displaced large areas of graminoid meadow and shrubs. Patches of bulrushes were also identified amid the cattails. The presence of muskrat lodges throughout the cattail marsh indicated that conditions for this wetland herbivore were optimum.

Another change in these wetlands during the high water period was the drowning of the lagoon between the modern beach and the older beach ridge. Although the scale of the map did not permit mapping of this inundation, one could easily identify open water sites on the photography. Strand lines from flotsam and organic debris were visible in the lagoons. During the summer of 1974, the authors noticed waterfowl breeding in these lagoons. However, pumping

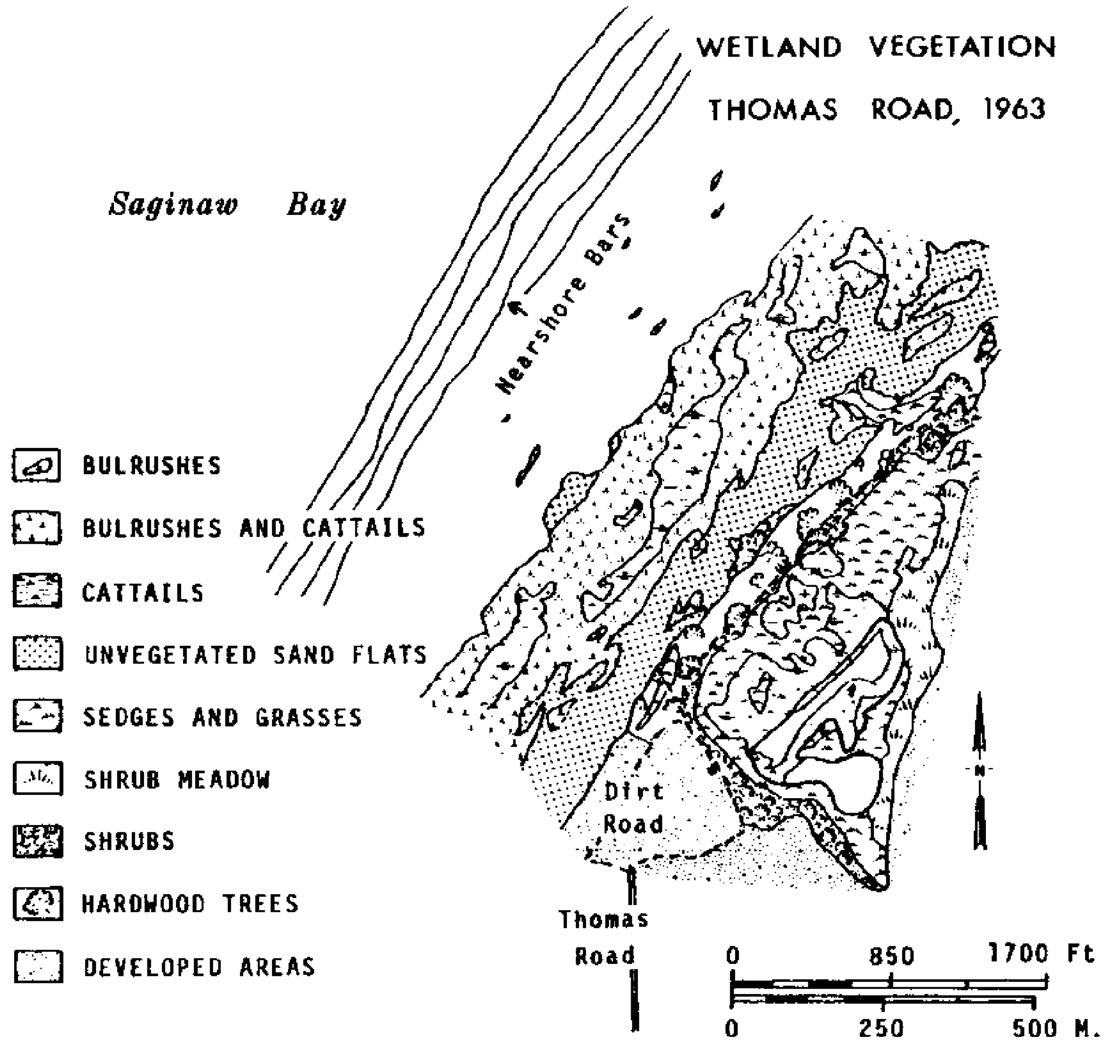


Figure 52. Distribution of Wetland Vegetation at Thomas Road (Tuscola County), 1963

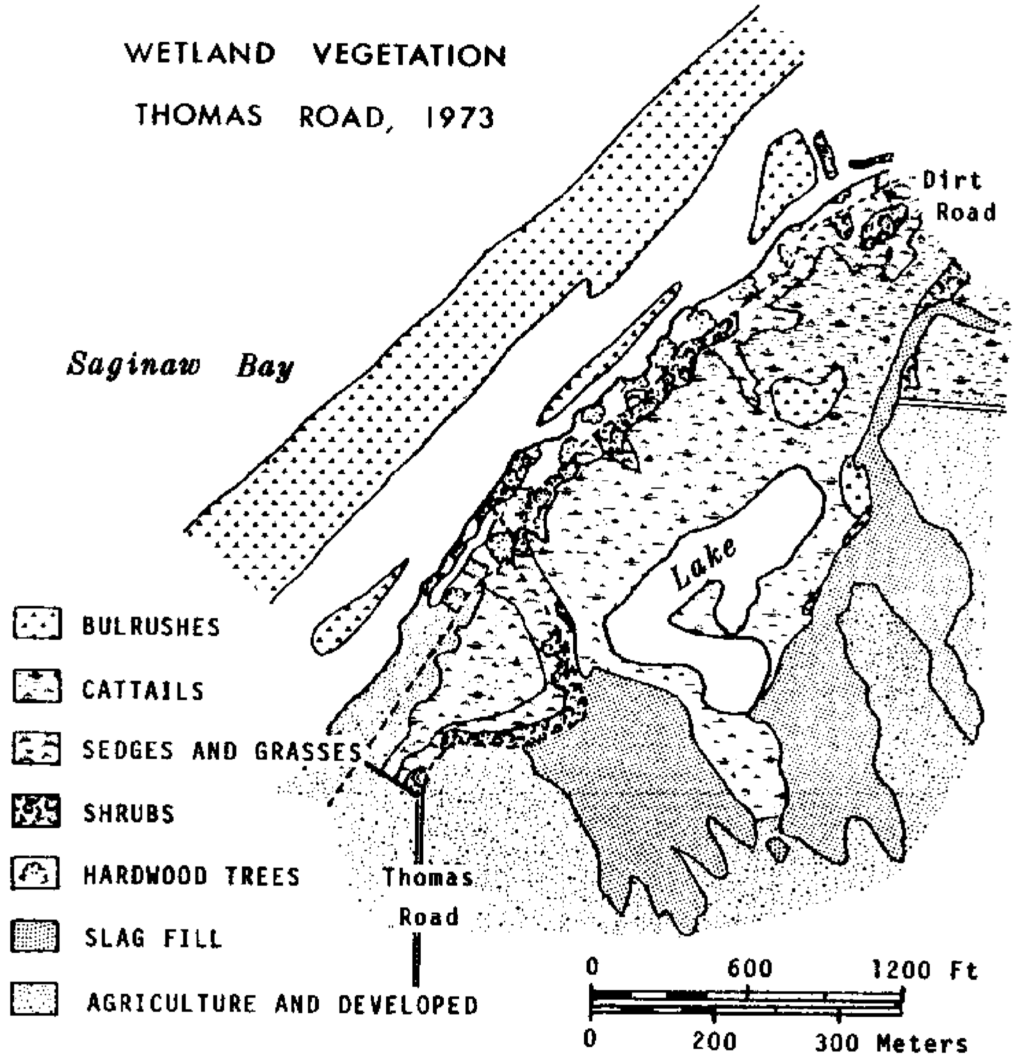


Figure 53. Distribution of Wetland Vegetation at Thomas Road (Tuscola County), 1973

and water level management by area farmers eliminated some of the inshore wetlands which were temporarily restored during high-water conditions.

Wetland Area Measurements As indicated in Table 25, water level fluctuations of Saginaw Bay do affect the areal distribution of wetland types. Using the 1941 map as a data base, the wetland area under investigation consists of a rectangular area which is 60 acres in extent. This area was delimited by drawing lines perpendicular to the coast along both margins of the artificial lake. The offshore boundary is the bayward limit of emergent vegetation on the 1941 imagery which is situated at 1,250 feet from the modern shoreline. With regard to the inland boundary, the farthest landward extent of the artificial lake was used to establish the wetland limit. Thus, the rectangular study area is representative of wetland zones along this portion of the Saginaw Bay coast.

Soil series descriptions from the Tuscola County soil survey data support the wetland delimitation above. Three soil series, including Cb (flooded portions of Saginaw Bay), Es (Essexville Sands), and Tl (Tappan Loam) comprise the soils of the Thomas Road site. Basically these soils are poorly drained and consist of calcareous sands 20 to 40 inches thick over slowly permeable, calcareous silty clay loams.

As indicated in Table 25, in 1941 the 60-acre Thomas Road wetland complex was comprised of 48 percent nearshore wetlands and 52 percent inshore wetlands. Because of the low-water conditions, emergent marsh communities occupied 69 percent of the nearshore wetlands. In addition to the strip of unvegetated sand flats, open-water wetlands are also present, but primarily bayward of the emergent vegetation. A thin regressive beach along the bayward edge of the emergent communities separates the Lacustrine wetlands from the Palustrine wetlands according to the new U.S. Fish and Wildlife Service classification. In comprison, inshore wetlands consist of tree-shrub, graminoid meadow, emergent marsh, and open-water types. What is significant here is the relatively similar areal extent of the meadow and the marsh vegetation.

Although the level of Saginaw Bay was somewhat lower in 1963, there is little difference in the areal distribution of wetland types in 1963 as compared to 1941. Slightly lower water levels have resulted in the bayward displacement of the shoreline and an increase in the width of the unvegetated sand flats. No significant change was noted in the nearshore wetlands.

In contrast, the high water of the 1973 period generated considerable change in the wetland distribution. In the nearshore zone, high water resulted in the complete elimination of the unvegetated sand flats and reduction in the extent of the emergent marsh. In the inshore zone, the effect of high water was also very evident. The increased extent of the emergent marsh and the nearly complete elimination of the meadow wetlands are obvious. More open-water habitat resulted from the expansion of the lake as well as due to inundation of the intra-beach ridge lagoons. In general, during high water periods much of the emergent marsh disappears from the nearshore zone, but it is reestablished in the inshore wetland zone.

Table 25

Areal Extent of Wetland, by Vegetation Type
Thomas Road Wetlands, 1941, 1963, 1973

Wetland Type	Acres	Hectares	Percent of Total
1941 (Historical Base, Low Water)			
Nearshore Emergent	20.0	8.1	33.0
Nearshore Flats	4.45	1.8	7.5
Nearshore Open-water	4.45	1.8	7.5
Inshore Trees and Shrubs	9.7	3.9	16.0
Inshore Meadow	7.8	3.2	13.0
Inshore Emergents	8.4	3.4	14.0
Inshore Open-water	5.2	2.1	9.0
	60.0	24.3	100.0
1963 (Low Water)			
Nearshore Emergent	16.1	6.5	27.0
Nearshore Flats	8.1	3.3	13.5
Nearshore Open-water	3.7	1.5	6.0
Inshore Trees and Shrubs	8.6	3.5	14.5
Inshore Meadow	9.4	3.8	15.5
Inshore Emergents	9.4	3.8	15.5
Inshore Open-water	4.7	1.9	8.0
	60.0	24.3	100.0
1973 (High Water)			
Nearshore Emergents	11.0	4.5	18.5
Nearshore Flats	0.0	0.0	0.0
Nearshore Open-water	16.5	6.7	28.0
Inshore Trees and Shrubs	7.5	3.0	12.0
Inshore Meadow	1.0	0.4	1.0
Inshore Emergents	16.0	6.5	27.0
Inshore Open-water	8.0	3.2	13.5
	60.0	24.3	100.0

In an effort to approximate the areal extent of the wetland types at Thomas Road during mean lake level conditions, the average of the 1963 and 1973 data was calculated as indicated:

Wetland Type	Acres	Hectares	Percent of Total
Nearshore Emergents	13.6	5.5	22.7
Nearshore Flats	4.0	1.6	6.6
Nearshore Open-Water	10.1	4.1	16.8
Inshore Trees and Shrubs	8.0	3.2	13.3
Inshore Meadow	5.2	2.1	8.7
Inshore Emergents	12.7	5.2	21.2
Inshore Open-Water	6.4	2.6	10.7
TOTALS	60.0	24.3	100.0

Comparative Photo Transects Using the July 1977 bisect as a base, transects across the same environmental gradient were redrawn (Figure 54). Water level data was taken from the Harbor Beach, Michigan, gauging station, and the vegetation distribution was obtained from the 1963 and 1973 aerial photography.

Beginning with the August 1963 low-water period, when the water level of Saginaw Bay was 576.9 feet much nearshore vegetation was evident. More favorable water levels and protection from wave energy enabled the bulrushes to develop very extensive rhizome root mats. In the somewhat more shallow areas, cattails established dense communities, probably by means of seeds. A thin beach approximately 900 feet from the present shoreline marked the bayward extent of the continuous marsh cover. Some wave-tolerant bulrushes grew beyond this thin beach, out to perhaps 1,250 feet from the present shoreline. In the inshore zone, tussock sedges colonized extensive areas with dogwood and other shrubs on somewhat elevated sites. Cattails continued to survive in low-lying environments, but physiological drought brought about by alkaline edaphic conditions was probably a stress factor.

As exemplified by the 1973 transect, high water conditions generated water depths and wave energy levels in excess of the tolerance of the nearshore emergent marsh. The cattails were easily uprooted, but the tenacious rhizomes of the bulrushes offered considerable resistance. Cobbles on the beach face indicated the location of wave energy dissipation and some erosion of the clayey glacial till along the coast. Pumping and other water-level management practices by area farmers which were designed to eliminate ponding and to lower water tables allowed the cattail marsh in the inshore zone to colonize extensive areas. If water levels were not artificially lowered in the inshore zone, it is felt that more open-water habitat would be present in the cattail marsh.

Accompanying the drop of water levels during the 1975-1977 period, the emergent vegetation re-established itself in the nearshore zone. Although little cattail is present at this time, hardstem bulrush and three-square are currently extending their range by means of rhizomes. In the inshore zone, the emergent marsh communities are exhibiting stress, particularly physiological

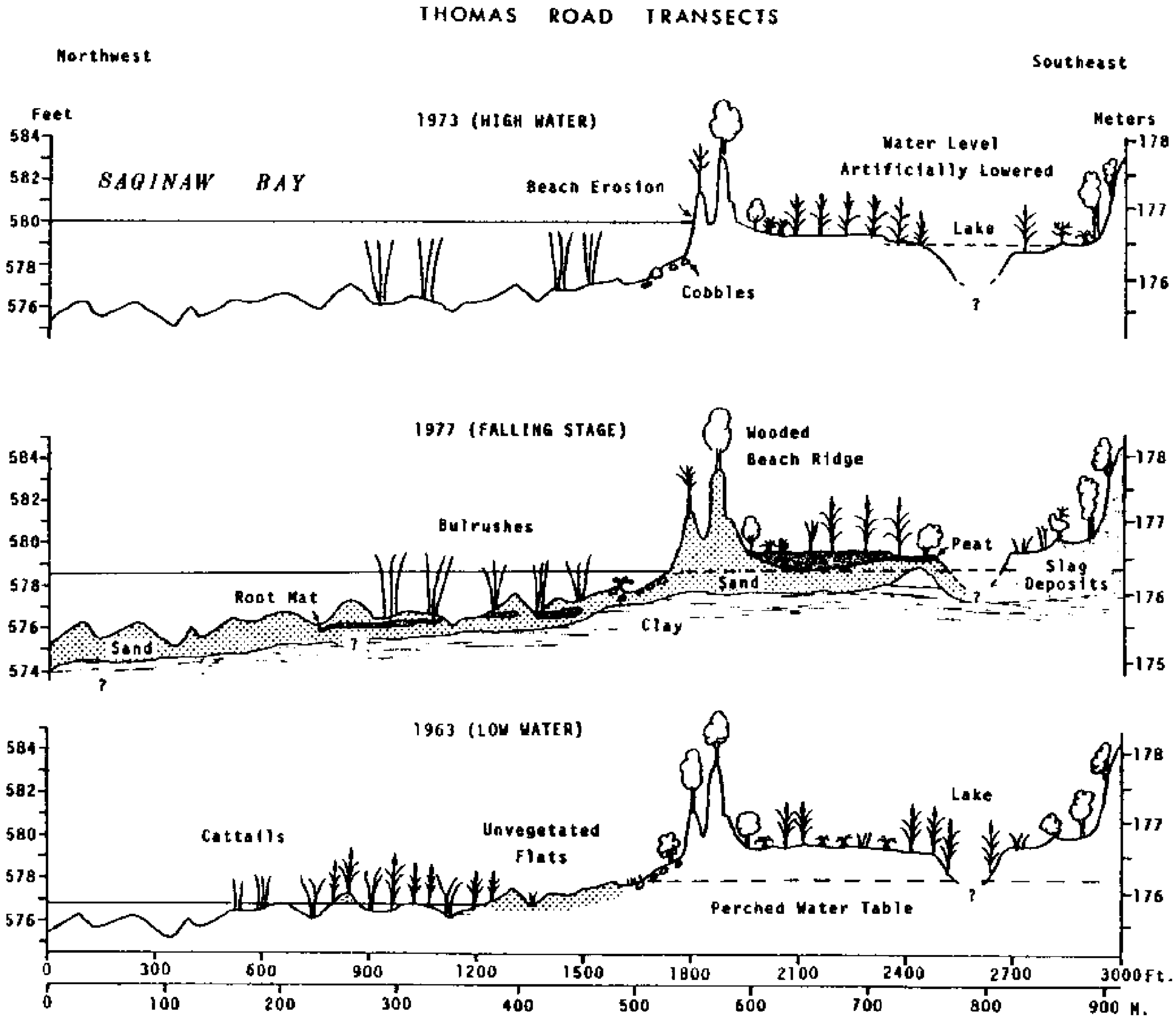


Figure 54. Photo Transects of Thomas Road (Tuscola County) Wetland, Michigan

drought. Field measurements of the pH of the clayey glacial till revealed readings of 8.0 to 8.5. Both the cattails and hardstem bulrush are exhibiting firing of the leaves and stems. Sedges, smartweed, mint, and other herbaceous plants are beginning to invade the marsh vegetation. Partially dead red ash and willows are re-establishing their dominance on the modern beach ridge, and shrub communities will probably extend their range into the sedge meadow.

Dickinson Island Wetlands

Dickinson Island is part of the St. Clair River delta wetland complex located in northeastern Lake St. Clair. Though the international boundary bifurcates the delta, Dickinson Island is totally on the United States' side. Approximately 2,800 acres or 4.37 sq. miles in area, Dickinson Island is largely a natural system because human impacts (residential development and land filling) have been restricted to the northeastern end of the island. The inland character is a result of North Channel on the north, Middle Channel on the east, and Lake St. Clair on the south. A vegetation continuum is present as the plant communities grade from upland hardwoods in the northeast to cattail marsh along the southwest. The hydrology is dominated by lake level fluctuations and by surface drainage of precipitation which falls directly onto the island.

Plant List The following list of common plant species was developed during the survey of bisects in July and October 1977. When linked together, the bisects extend from the shoreline (from Gooseneck Pond along Lake St. Clair) to the hardwoods at the northeast end of the island where elevations of 580 feet are encountered. The plant list is presented by environmental type.

Coastal Embayments (Gooseneck Pond of Fisher Bay, Goose Bay)

Three square *Scirpus americanus*
Hardstem bulrush *Scirpus acutus*
Hybrid cattail *Typha glauca*
Water smartweed *Polygonum amphibium*
Muskgrass *Chara* sp.
Bur-reed *Sparganium chlorocarpum*?
Sago pondweed *Potamogeton pectinatus*
Pickerel weed *Pontederia cordata*

Transgressive Beaches and Island Shorelines

E. cottonwood *Populus deltoides*
Staghorn sumac *Rhus typhina*
Willows *Salix* spp.
Canary grass *Phalaris arundinacea*
Bluejoint grass *Calamagrostis canadensis*
Sedge *Carex stricta*
Jewel weed *Impatiens* sp.
Thistle *Cirsium* sp.
Stinging nettle *Urtica dioica*
Morning glory *Convolvulus sepium*

Bulrush and Open-Water Marsh

Hardstem bulrush *Scirpus acutus*
Buttonbush *Cephalanthus occidentalis*
Muskgrass *Chara* sp.
Various emergents and submergents

Cattail Marsh

Hybrid cattail *Typha glauca*
Narrow-leaved cattail *T. angustifolia*
Jewel weed *Impatiens* sp.
Seedlings of grasses and sedges
Mud lettuce (Unidentified species)
Duckweed *Lemna minor*
Watermilfoil *Myriophyllum* sp.
Common bladderwort *Utricularia vulgaris*

Tussock Sedge Marsh

Tussock sedge *Carex stricta*
Dead shrubs *Salix, Populus*
Smartweed *Polygonum* sp.
Scattered cattails and bulrushes
Nightshade *Solanum dulcamara*
Common comfrey *Symphytum officinale*
Bluejoint grass *Calamagrostis canadensis*

Canals and Ponds

Yellow pond lily *Nuphar advena*
White water lily *Nymphaea tuberosa*
Green algae (unidentified)
Duckweed *Lemna minor*
Pickerel weed *Pontederia cordata*
Muskgrass *Chara* sp.
Waterweed *Elodea canadensis*
Water smartweed *Polygonum amphibium*
Curly pondweed *Potamogeton crispus*
Other pondweeds *Potamogeton* spp.
Buttonbush *Cephalanthus occidentalis*

Abandoned Channels

Buttonbush *Cephalanthus occidentalis*
Arrowhead *Sagittaria latifolia*
Hardstem bulrush *Scirpus acutus*
Three-square *Scirpus americanus*
Yellow pond lily *Nuphar advena*
White water lily *Nymphaea tuberosa*

Meadow Zone

Trembling aspen *Populus tremuloides*
Red ash *Fraxinus pennsylvanica*
Red dogwood *Cornus stolonifera*
Gray dogwood *Cornus racemosa*
Swamp rose *Rosa palustris*
Goldenrods *Solidago* spp.
Bluejoint grass *Calamagrostis canadensis*
Fowl meadow grass *Poa palustris*
Rattlesnake grass *Glyceria canadensis*
Cut grass *Leersia oryzoides*
Panic grass *Panicum* sp.
Sedge *Carex stricta*
Freshwater rush *Juncus* sp.
Silverweed *Potentilla anserina*
Swamp milkweed *Asclepias incarnata*
Morning glory *Convolvulus sepium*

Shrub Ecotone or Swamp Margin

Red ash *Fraxinus pennsylvanica*
E. cottonwood *Populus deltoides*
Trembling aspen *P. tremuloides*
Red osier dogwood *Cornus stolonifera*
Gray dogwood *Cornus racemosa*
Wild grape *Vitis* sp.
Understory plants (see Meadow)

Deciduous Hardwoods

Pin oak Quercus palustris
Swamp white oak Quercus bicolor
Bur oak Quercus macrocarpa
Shagbark hickory Carya ovata
Silver maple Acer saccharinum
American elm Ulmus americana

Wetlands Bisect On July 26 and October 7, 1977, a two-segment bisect was surveyed across Dickinson Island (Figure 55). The location of the bisects are shown on Figure 55. Because of the density of the wetland vegetation, surveying instruments could not be used, thus a 100-foot tape and water level controls were employed instead. Water level of Lake St. Clair during these two time periods was 574.3 feet and 574.1 feet, respectively. Because the average level of Lake St. Clair for July during the 1900-1976 period was 573.82 feet the bisect water levels are just slightly above the long-term average. However, because of the record high levels of the 1972-1975 period, the vegetation patterns of the bisect may reflect high-water conditions. In order to document the relationship of the plant communities to the water level, the bisect is described below in considerable detail.

The coastline of lower Dickinson Island along Lake St. Clair is highly irregular due to embayments and poorly-developed beaches. The transect begins in Gooseneck Pond (of Fisher Bay) where shallow water and wave diffraction reduce wave energy (Figure 55). At approximately 75 feet from shore, the water depth was 22 inches and the bottom sediments consisted of soft, clayey ooze 2 to 3 inches thick over sand. The water was surprisingly free of turbidity and the calcareous substrate supported muskgrass and Sago pondweed. Ten feet from shore, a live bulrush rootmat was encountered which was supporting a sparse three-square colony.

The present shoreline consisted of rafted plant macrofragments and a root mat which was 3 to 4 inches thick. Sedge tussocks grew out of the root mat, but only some of the tussocks supported live sedges. The beach ridge, which was about 10 to 12 inches above the lake level at that time, consisted of fine, gray sand with rootlets. This sand extended down to approximately 24 inches and exhibited alternating layers of clean sand and organic-rich sands or peat.

Between the modern shoreline and a small, isolated island, which formerly supported large eastern cottonwood trees, was an open-water marsh. Hard-stem bulrush colonized the sandy substrate of the washover area near the modern beach and was found in scattered locations where water depths exceeded 8 to 10 inches. Other common emergents included pickerel weed and bur-reed. Dabbling ducks (e.g., blue-winged teal) were observed making forage trails through the submersed aquatics which consisted primarily of muskgrass as well as some water smartweed and several pondweeds including floating-leaved pondweed. A dead sedge rootmat covered the bottom of this open-water area, but few dead sedge tussocks were noted.

At approximately 600 feet from the modern shoreline, a zone of hybrid cattail was encountered. Along the open-water margin, the cattails averaged 4

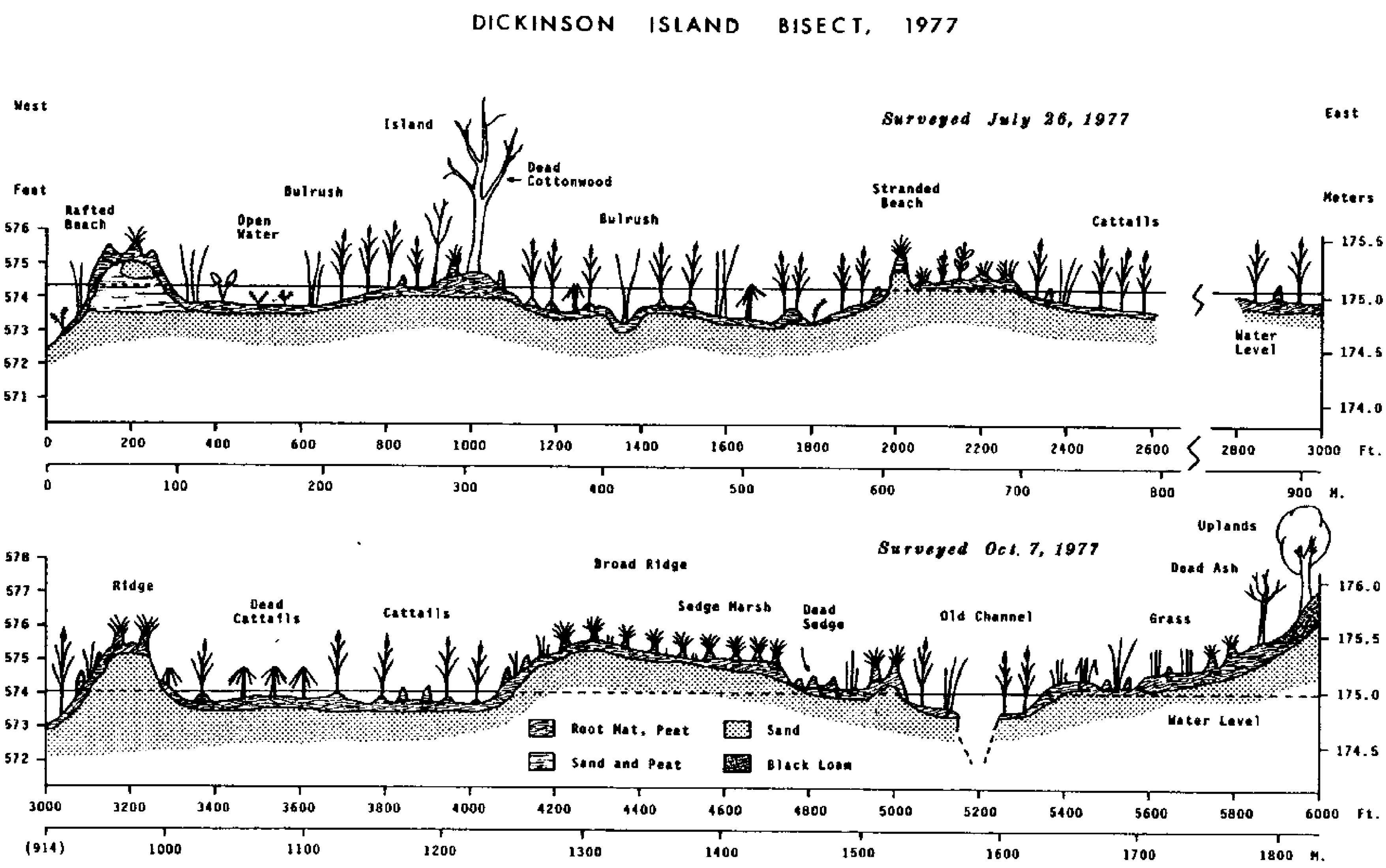


Figure 55. Bisect Across Dickinson Island (St. Clair Delta), July 26 and October 7, 1977

to 6 feet in height and exhibited few inflorescences. The lack of mature cattails and the presence of muskgrass suggest that the cattails were actively invading the open-water area. Water depths averaged 4 to 6 inches in the cattail marsh. Farther landward, a small, isolated island was encountered. A mature eastern cottonwood, which apparently drowned during the high water of the 1972-1975 period, occupied the center of the island. A few dead willow shrubs were noted near the base of the cottonwood. Most of the sedge (Carex stricta) tussocks were also dead, except for a few which were on higher sites. Basically the sediment consisted of a foot of rootmat, including both graminoid and woody fragments, underlain by clean, fine sand. In the subsurface sands, numerous $CaCO_3$ concretions and greenish-brown stains along rootlets were noted.

In between the small island and a stranded beach ridge, a distance of approximately 1,000 feet, was an emergent marsh. Water depths generally ranged from 6 to 12 inches while the substrate was largely a marsh rootmat underlain by sand. Most of the emergent marsh consisted of Typha glauca colonies which grew 6 to 10 feet in height. In general, the cattail shoots emanated from rootstalks which were somewhat elevated or were partially floating. Water depths above the rootstalks averaged 6 to 8 inches, whereas between the rootstalks the water depths ranged from 8 to 12 inches. Mud lettuce and duckweeds were common where the cattails were sparsely distributed, whereas short-billed marsh wren nests were numerous in the dense cattails.

Where water depths in the cattail communities exceeded about 12 inches, colonies of dead cattail were noted. Because the dead stalks were still upright in many places, it was surmised that these communities had succumbed to drowning within the past two to three years.

Where water depths were even greater, as in scattered pools and in abandoned distributary channels, hardstem bulrush was present. Along the margins of channels, occasional patches of buttonbush shrubs were observed. The adventitious roots and lenticels of the buttonbush were most conspicuous just below the water line. Open-water pools which were not directly connected to Lake St. Clair not only exhibited higher water temperatures, but also contained watermilfoil, common bladderwort, and green algae. At the time of the survey, the boundary between the cooler lake water mass and the warmer marsh water was approximately 1,600 feet from the shoreline.

The stranded beach ridge feature measured 250 feet in width, but averaged only 2 to 6 inches above the water level at that time. Dead sedge tussocks, ranging in height from 6 to 8 inches, were noted on both sides of the beach ridge. Live sedge (Carex stricta) tussocks were encountered atop the highest ridge which exceeded 575 feet in elevation. Eastward (more inland) of the highest ridge, the old beach was relatively flat. Young seedlings of tussock sedge (Carex stricta), bur-reed, smartweed, and other unidentified graminoids were colonizing this recently exposed flat. Although no sedge tussocks were observed on the central portion of this flat, at depths of 2 to 6 inches beneath the peaty surface a dead sedge rootmat was encountered. Beneath the surface organics, was light gray-colored, fine sand with abundant $CaCO_3$ concretions.

The remainder of the July 26 bisect consisted of a cattail marsh with drowned sedge tussocks. (As indicated on Figure 55, a short segment of the bisect was not surveyed). Water depths generally ranged from 4 to 10 inches. As in other areas, the substrate was comprised of an organic layer 2 to 6 inches thick underlain by fine sands. Much of the organic layer appeared to be sedge macrofragments. Because of the absence of clastic (inorganic material) sediments within these surface peats, it may be assumed that deposition of inorganic material did not occur during the recent high lake level period.

On October 7, 1977, the second segment of the bisect was surveyed. Beginning with the lakeward-most end, which does not quite match the July 26, 1977, termination point exactly because of a small compass error in the traverse direction, another ridge-like feature was encountered. This ridge exhibits biogeographic patterns noted elsewhere along the bisect. For example, live sedge tussocks were observed only atop the higher ridges where elevations exceeded 575 feet, but were dead (or drowned) below that elevation. Cattail colonies grew along the ridge margins where the water table rose above the ground surface. As an aside, the field investigators noticed that marijuana had been planted earlier in the year on this beach ridge.

In between the ridge described previously and another very broad ridge (which was located 4,400 feet from the shoreline) was a cattail marsh nearly 800 feet in width. Although water levels averaged only 2 to 6 inches in depth, patches of dead cattail were observed amid the live hybrid cattail colonies. Although the cause of the cattail die-back was not evident, the old stalks were still upright, suggesting recent drowning. In contrast, the live cattail clumps appeared to be associated with hummocks formed by cattail rootstalks. Toward the landward margin of this vegetation zone, a number of dead sedge tussocks were also noted.

The broad ridge was nearly 600 feet in width and ranged from 12 to 18 inches above the water table at that time. Live tussocks of the sedge <u>Carex stricta</u>, which were 6 to 8 inches in height, further characterized the ridge. In between these tussocks, which were widely spaced in places, a carpet of grass and sedge seedlings was observed. A few scattered patches of freshwater rush and of cordgrass were also observed. Basically the substrate consisted of 0 to 7 inches of live sedge rootmat which, in turn, was underlain by 6 inches of black, organic-rich sand. Farther down, fine sand with oxidation stains were encountered. A path of a tracked vehicle was also noted on this ridge.

Immediately east (landward) of the broad sedge-covered ridge was a zone of dead tussock sedge. What may be significant here is that the dead sedge was at an elevation below 575 feet, whereas the live tussocks were restricted to sites situated above that critical elevation. Some graminoids and other herbaceous plants were colonizing this recently "uncovered" surface by means of seeds.

An abandoned channel of a former distributary of the St. Clair River was encountered 800 feet from the east end of the bisect. Although the water depth at the time of the survey averaged only 11 inches, the channel was probably much deeper several centuries ago. Hardstem bulrush, hybrid cattail, and an unidentified <u>Cyperus</u> were noted along the channel margins. Some bur-reed and <u>Cyperus</u> were also observed in the channel, but very little submersed vegetation could be seen.

East (landward) of the abandoned channel the vegetation becomes meadow-like. Several white-tailed deer were observed in this zone during the field survey. In depressions, dead sedge tussocks were encountered along with live hardstem bulrush. On slightly higher sites the investigators observed stressed water smartweed and patches of live softstem bulrush. The water table ranged from 6 to 15 inches below the surface. The sediments consisted of fibrous marsh plant macrofragments which, in turn, were underlain by fine, mottled sand.

However, much of the meadow was comprised of a 180-foot wide zone of bluejoint grass. Dead sedge tussocks were observed among the bluejoint grass along with dead or stressed smartweed. Some eastern cottonwood seedlings less than one foot tall were also noted. Only a few small red osier dogwood bushes and other woody shrubs were present in the meadow. Presumably, high water conditions eliminated some of these shrubs which appeared to be more common on the photographs taken during low-water periods. In general, the substrate of the meadow consisted of a surface layer of black, greasy, organic-rich clay which was underlain by oxidized, fine sand.

At approximately 225 feet from the eastern end of the bisect, a zone of live tussock sedge was noted. The sedge was identified as (Carex stricta). The field investigators did not anticipate finding a sedge zone at slightly higher elevations than the meadow. As observed elsewhere along the bisect, the live sedge tussocks were approximately six inches in height and the tops of the stools were generally above 575 feet. The water table at the time of the survey lay 10 to 25 inches below the surface.

At 160 feet from the end of the bisect a dead red ash tree approximately 15 feet in height was encountered. The depth to the water table near this dead ash tree was 18 inches. This ash tree, which may have become established in a low-water period (the early 1960's), probably drowned during the high water of the 1972-1975 period.

The end of the traverse represents a transition into upland hardwood vegetation. Deciduous hardwood trees (pin oak, swamp white oak, and silver maple) were observed among the canopy specimens. Along the woodland margins, an understory of red osier dogwood, wild grape, bluejoint grass, and various non-tussock forming sedges were noted. In places, a shrub ecotone of red osier dogwood, gray dogwood, red ash, and eastern cottonwood was mapped. At the very end of the bisect, the depth to the water table was 37 inches. Also at this location the surface layer of soil consisted of 10 inches of black, sandy, decomposed organic matter. Beneath the organic soil was moist, mottled, fine sand which contained large tree roots. A pH of 7.6 was measured at a depth of one foot under the hardwood vegetation, while a pH of 7.8 was measured at a similar depth in the sedge marsh located on the broad ridge.

Wetland Distribution at Selected Lake Levels Black and white aerial photography flown in late April-early May 1949, early July 1964, and in early June 1975 were utilized to map the wetland vegetation at three time periods. The water levels of Lake St. Clair at the time of the photographs were as follows: late April 1949 -- 573.4 feet, July 1964 -- 572.0 feet, and June 1975 -- 575.6 feet. According to the gauging station at Grosse Point Shores (on Lake St. Clair), the 1900-1976 average level for Lake St. Clair in July is 573.3

feet. The lowest levels recorded for the lake was 569.9 feet in January 1926 and again in January 1936. In contrast, the record high of 576.2 feet occurred in June 1973.

Because it is the oldest photograph generally available, the 1949 imagery provides base line distribution data. Although water levels averaged near 572.0 feet in the 1932-1941 period, during the 1940's the levels approached the long-term mean. Thus the 1949 wetland distribution reflects average to low-water level conditions. During the 1952 to 1964 period, water levels dropped approximately 3 feet. Thus the 1964 photography should indicate low water, or at least falling stage conditions. In contrast the 1975 imagery clearly reflects high-water level conditions.

Distribution of Wetlands in Spring 1949 As indicated in Figure 56, the wetlands of Dickinson Island were extensive in late April-early May 1949. At that time, the level of Lake St. Clair averaged 573.4 feet, which is approximately the long-term mean for July. Because water levels during the period 1931 to 1941 were below normal (at 572 feet), many of the shrub, meadow, and sedge communities were well established. Although water levels somewhat above normal prevailed during the period 1943-1948, the levels apparently were not sufficiently high to induce community retrogression.

Beginning with the hardwoods along the eastern end of the island, these oaks and other deciduous trees are restricted to land elevations in excess of 577.5 feet. Immediately east of the largest area of woodland (along Middle Channel) is a strip of vacation camps and summer homes which can only be accessed by boat. At the extreme northeast tip of the island, much of the land about the scattered oak-hickory stands has recently been cultivated or mowed for hay. The aerial photography also revealed evidence of cultivation and hay cropping along the west and east sides of the large wooded area located at the southern side of the island.

As illustrated in Figure 56, the meadow vegetation west of the hardwoods covers a large semi-circular area. Although it was most difficult to distinguish between the grass communities of the meadow and the sedge marsh on the photography, the presence of small shrubs and water levels for the period 1931 to 1949 aided in the determination of vegetation boundaries. Whereas some tussock sedge (Carex stricta) may be present in the meadow, it is felt that bluejoint grass, fowl meadow grass, and panic grass, along with red osier dogwood, swamp rose, silverweed, and so forth, probably dominated the communities.

Where water tables were at or slightly below the surface, particularly if the substrate was inorganic (along beaches, atop former shorelines now stranded in the cattail marsh, and along the levees of the distributary channels), tussock sedge (Carex stricta) and other sedges appeared to be dominant. On Dickinson Island, sedge usually comprises the ecotone between the meadow and the cattail marsh. Sedges generally colonize the narrow beaches and washovers along the shoreline. Ridges stranded in the cattail marsh, which have irregular shapes similar to that of the modern shoreline, are also colonized by sedges.

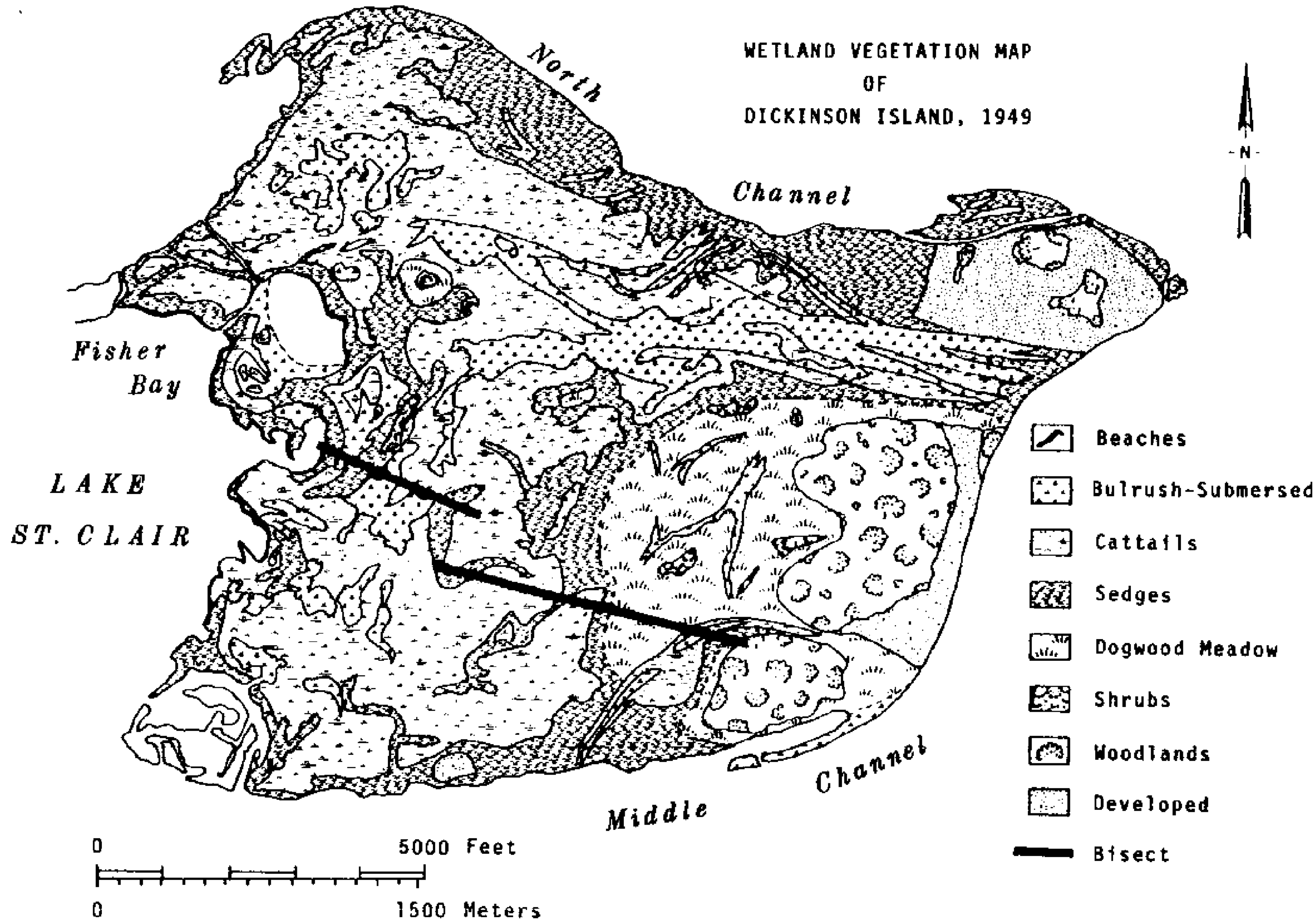


Figure 56. Distribution of Wetland Vegetation at Dickinson Island (St. Clair Delta), 1949

Much of the western half of the island is covered by emergent marsh. As interpreted from the photography, cattail, especially the hybrid Typha glauca, covered extensive areas between the shoreline and the graminoid wetlands of the interior. Where water depths exceed 1 to 2 feet, cattail may be replaced by hardstem bulrush along with a diversity of floating-leaved and submersed aquatics. Where abandoned channels occur, there is usually some water flow and thus the substrate may be sandy as opposed to peaty or ooze-like. Hardstem bulrush and buttonbush are common in such channels. Very little unvegetated open-water areas were apparent in 1949, with the possible exception of Mud Lake which is located immediately landward of Fisher Bay. In the embayments, which are protected by direct wave action, scattered colonies of three-square and of submersed aquatics were presumed to be present.

Distribution of Wetlands in July 1964 Because water levels in July 1964 averaged only 572 feet it may be anticipated that the plant communities would reflect low-water conditions. Although water levels in July 1964 were 1.3 feet below the long-term mean for July, as corroborated by the extensive beaches (Figure 57), previous water levels were higher and did affect the successional trend of the wetland. Except for the years 1948 to 1950 and 1957 to 1960, summer water levels in Lake St. Clair since 1943 generally averaged over 573.5 feet. Thus, although water levels in 1964 were quite low, the plant communities may not have had time to fully colonize the available sites.

A comparison of the 1964 vegetation map with the 1949 map reveals only small differences in wetland distribution. Because less cultivation was practiced in 1964, some encroachment of the woodlands, meadow and sedge communities on former farmland is evident. Perhaps the main difference is an increase in the extent of the sedge, particularly at the expense of the shallow, emergent marsh. Extensive sedge marshes were mapped along both North and Middle Channels. Because water levels were generally above average during the 1943 to 1962 period, it is felt that the western margin of the meadow communities still included much tussock sedge. However, much of the island, particularly the marshes, appeared to have been burned during the Fall of 1963 to Spring of 1964. The burning hampered the interpretation between sedge and meadow (grass) communities, and may have retarded shrub invasion of the meadow zone.

Another difference is a decrease in the extent of the bulrush-submergent communities within the emergent cattail marsh. It is felt that hardstem bulrush, and perhaps the hybrid cattail as well, undergo physiological drought stress when falling lake levels lower the water table in the mildly alkaline sediments of the island. The bulrush-submersed aquatic communities appeared to have shifted to a zone along the shoreline where sandy beaches were present. The decrease in water level also cut off water circulation through the abandoned distributary channel which trends across Dickinson Island from the northeast to the southwest. Because cattails and other broad-leaved emergents were apparent on the 1964 photography, the channel vegetation was mapped as mixed emergents. As in 1949, very little open-water could be identified in the emergent marsh or in Mud Lake.

Distribution of Wetland in June 1975 As indicated in Figure 58, the 1975 distribution map clearly reflects high-water conditions. During the early 1970's, water levels in the Great Lakes rose and reached record highs in 1973.

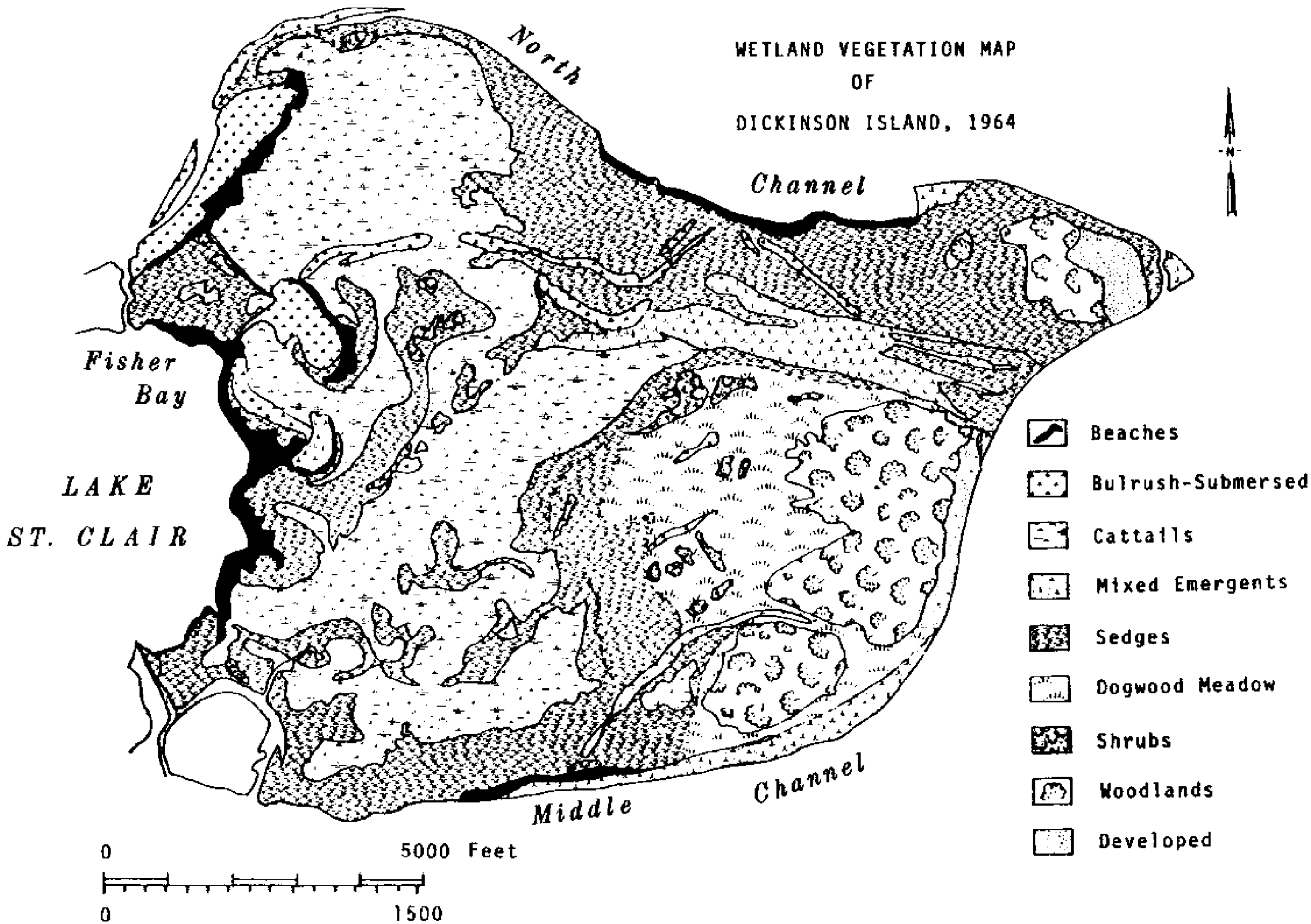


Figure 57. Distribution of Wetland Vegetation at Dickinson Island (St. Clair Delt), 1964

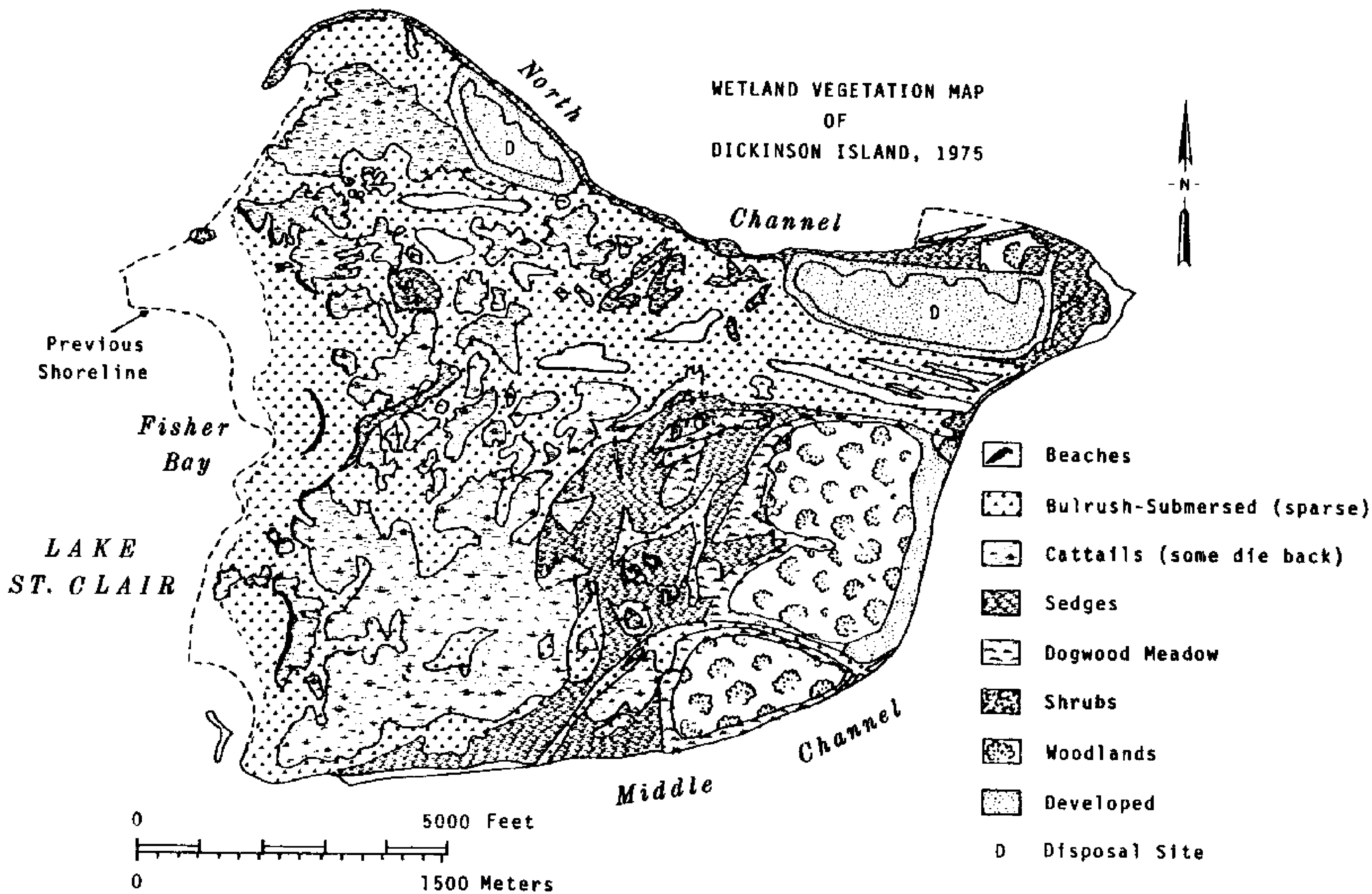


Figure 58. Distribution of Wetland Vegetation at Dickinson Island (St. Clair Delta), 1975

By June 1975, the water level in Lake St. Clair had decreased slightly from a record level of 576.2 feet in June 1973 to 575.6 feet. Even though widespread die-back and drowning of plant communities had occurred, some of the rhizomes and rootstalks of the aquatics remained viable. Relatively low turbidities and relatively high oxygen levels of the marsh water, which was dominated by Lake St. Clair water masses, may have been a factor in the survival and reestablishment of some of the stressed communities.

By comparing the 1975 map with the earlier vegetation maps, the changes become evident. First, the most significant change accompanying high-water conditions is the displacement of the shoreline several hundred feet landward. Most of the former beach ridges were washed over by storm waves and extensive drowning of the cattail marsh occurred. Bulrush and other aquatic communities expanded throughout the cattail marsh. However, although there was considerable cattail die-back and opening up of the cattail marsh, some of the cattail rootstalks did survive the high-water period of the early 1970's.

In addition, high water resulted in widespread sedge die-back, except where land elevations enabled the tussock-forming sedges to remain above the water level. Much of the mixed grass and shrub communities of the meadow appeared to have been invaded by sedges. The meadow was restricted to higher surfaces near the woodlands which did not undergo much die-back. The area of the developed category increased because of the construction (by the U.S. Army Corps of Engineers) of two dredged material disposal sites which cover 166 acres.

During the high water, cooler and probably better oxygenated water masses from Fisher Bay can penetrate the emergent marsh when onshore winds prevail. Perhaps more important, during high water stages water from the St. Clair River (water flowing down North and Middle Channels) can move into abandoned channels and canals. Thus, the water quality of the wetlands during high-water periods may reflect the river and lake properties because the effect of land drainage is diluted.

<u>Wetland Area Measurements</u> Using a polar planimeter and the 1949, 1964, and 1975 distribution maps of Dickinson Island discussed previously, the areal extent of each wetland vegetation type corresponding to each of the three time periods was determined (Table 26). The entire mapped area shown on the 1964 vegetation map was adopted as the standard area of the Dickinson Island wetlands. For the purpose of this study, the woodlands and developed lands were included as wetlands, but the littoral environments in the St. Clair River and in Lake St. Clair were excluded. As indicated in Table 26, an area of 2,800 acres was adopted as the standard area.

In 1949, during low to somewhat average water levels, 40 percent of the island was covered by emergent marsh (cattail). Sedge marsh was also widespread and occupied 23 percent of the total area. Three wetland types, submersed/floating-leaved, meadow, and wooded (including shrubs), each covered approximately 10 percent of the wetland area. In contrast, open water (unvegetated) and developed lands together accounted for only 7.5 percent on the total area.

Table 26

Areal Extent of Wetlands, by Vegetation Type Dickinson Island Wetlands, 1949, 1964, and 1975

1949 Distribution (Low to Average Water Level)

Wetland Type	Acres	Hectares	Percent of Total
Wooded and Shrubs	252	102	9
Meadow (Grassy)	252	102	9
Sedge Marsh	644	260.5	23
Emergents (Cattail)	1,120	453.5	40
*Submersed-Floating	322	130.5	11.5
Developed Lands	154	62.5	5.5
Open Water	56	23	2
SUBTOTALS	2,800	1,134.0	100.0

1964 Distribution (Low Water)

Wetland Type	Acres	Hectares	Percent of Total
Wooded and Shrubs	280	113.5	10
Meadow (Grassy)	252	102	9
Sedge Marsh	1,022	414	36.5
Emergents (Cattail)	1,036	419.5	37
*Submersed-Floating	140	56.5	5
Developed Lands	56	22.5	2
Open Water	14	6	0.5
SUBTOTALS	2,800	1,134.0	100.0

1975 Distribution (High Water)

Wetland Type	Acres	Hectares	Percent of Total
Wooded and Shrubs	280	113.5	10
Meadow (Grassy)	112	45.5	4
Sedge Marsh	364	147.5	13
Emergent (Cattail)	784	317.5	28
*Submersed-Floating	840	340	30
Developed Lands	210	85	7.5
**Open Water	210	85	7.5
SUBTOTALS	2,800	1,134.0	100.0

* Includes scattered colonies of hardstem bulrush and three-square.

** This category may be underestimated because some open water was included in the submersed floating-leaved wetland category.

Accompanying the extremely low water of 1964 were several changes in the areal extent of the wetland communities. In general, the sedge and wooded-shrub categories increased; the emergent marsh, submersed/floating-leaved marsh, developed, and open-water categories decreased; and, the meadow exhibited no change. Although the emergent (cattail) marsh decreased slightly to 37 percent of the land area, the sedge marsh expanded its range considerably by displacing either cattail or bulrush-submersed aquatics. It is likely that hybrid cattail, hardstem bulrush, and some of the other aquatic species experienced physiological drought stress during the low-water period. In contrast, the shrub and hardwood tree communities appeared to expand their range, particularly in areas formerly cultivated. However, because much of the marsh was burned prior to the date of the photography, shrub invasion of the meadow communities may have been inhibited.

The record high water of the 1970's caused extensive changes in the areal extent of all the wetland categories, except for the wooded-shrub category. Although considerable die-back of the scattered shrub communities, which were located within the meadow and sedge marsh, did occur, the hardwood tree stands were generally not adversely affected by the higher water table. In contrast, the meadow communities were subjected to drowning and were displaced to a large extent by sedges.

Perhaps the most dramatic impact of the high water was to increase the extent of the submersed/floating-leaved communities at the expense of the emergent (cattail) marsh and sedge marsh. Even though sparse colonies of hardstem bulrush were probably scattered throughout the submersed/floating-leaved category, this area was not considered to be emergent marsh because of the presumed abundance of muskgrass, pondweeds, and other aquatics. Moreover, since there appeared to be some vegetation present, the photo interpreter could not classify these areas as open water. Patches of open water were present in the old channels, along the drowned shoulders of North and Middle Channels as well as along the shoreline of Fisher Bay.

Although the 1949 map does reflect near average water level conditions, it was felt that Dickinson Island has changed considerably since 1949. Therefore, in order to derive the areal extent of each wetland type for mean water level conditions, the areal data for 1964 and 1975 were averaged. As indicated below, some adjustment of the data was necessary because of the diking of some of the wetlands for dredged material disposal sites.

Wetland Type	Acres	Hectares	Percent of Total
Wooded and Shrub	280	113.5	10.0
Meadow (Grasses)	182	73.5	6.5
Sedge Marsh	643	260.5	23.0
Emergent (Cattail)	883	357.5	31.5
Submersed/Floating-Leaved	490	198.5	17.5
Open Water	112	45.5	4.0
*Developed Lands	210	85.0	7.5
TOTALS	2,800 a.	1,134.0 ha.	100.0 %

* The 1975 figure was utilized because the development appears to be permanent, i.e., disposal sites and residences.

Comparative Photo Transects In an effort to comprehend the processes of plant communicty succession and of retrogression, photo transects of Dickinson Island were prepared (Figure 59). The July-October 1977 bisect, specifically the land elevations and substrate types, was adopted as the base for transects representing July 1964 and June 1975. The vegetation data were derived principally from interpretation of aerial photography, but some interpretation of peat fragments and of long-term water levels was also included. Water level data were taken from the U.S. Lake Survey gauging station at Grosse Point Shores, Michigan.

Beginning with the July 1964 transect, when water levels were 1.3 feet below the long-term mean level for July, a dense vegetation cover was evident. Shrub and woodland resumed optimum growth and may have invaded new sites by means of seeds. Meadow grasses, along with a mix of forbs and shrubs, dominated a wide area immediately west of the woodlands. Throughout much of the lower-lying wetlands, sedge and cattail marshes were extensive. Sedge generally occupied the somewhat elevated, inorganic soil sites where physiological drought may stress cattails and other broadleaved emergents. In contrast, hybrid cattail tolerated the low-water conditions only in depressions and in sites where the water table lay within approximately 1.5 feet of the surface.

Low water is generally accompanied by peat accumulation and by water movements through the sediments as opposed to surface water flow. These water level conditions are also associated with wider beaches which tend to be colonized by sedges, reed canary grass, and sometimes by shrubs.

As exemplified by the June 1975 transect, high water levels produce community retrogression. Although much die-back of the cattail marsh occurred as a result of excessive water levels, in some colonies the cattail rootstalks survived but did not produce inflorescences nor dense stem growths. It is possible that some of the cattail rootstalks were buoyed up by the higher water levels and that this mechanism enabled some of the rootstalks (Typha glauca) to resist drowning.

On the aerial photography, some of the drowned cattail marsh appeared very dark in tone. This tonation indicates that either the organic-rich bottom sediments are visible through the semi-transparent water, or the dark-colored

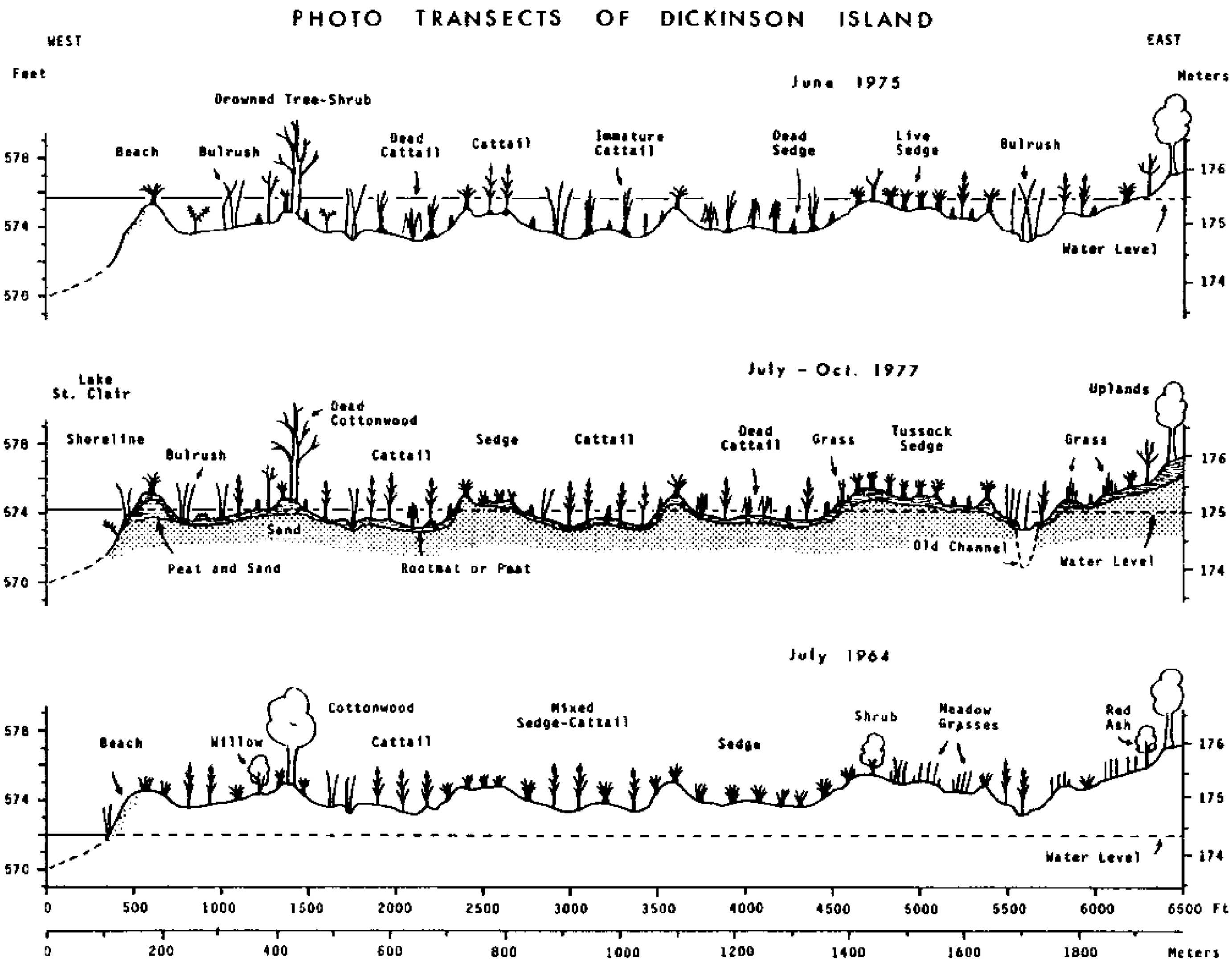


Figure 59. Photo Transects of Dickinson Island (St. Clair Delta), Michigan

hardstem bulrush is abundant. The 1977 bisect suggests that the former interpretation is more likely and that much of the open cattail marsh is actually dominated by submersed aquatics (e.g., muskgrass) as well as scattered floating-leaved and emergent species. Because very little inorganic sediment was encountered within or atop the root mat and peat deposits, it is concluded that high water is not accompanied by excessive turbidity or siltation as in many other Great Lakes coastal wetlands.

The sedge marsh and the meadow communities were also subjected to die-back and displacement. The field data suggest that tussock sedge (Carex stricta) survived if the tussocks developed height to an elevation equal to or greater than 575 feet. Throughout much of the emergent marsh, the investigators observed dead sedge tussocks and peat deposits which were comprised of sedge macrofragments. Except for the margins of the deciduous hardwoods and the understory of the shrub communities, the meadow grasses were displaced by sedges. Paradoxically, within a year or two after the drowned sedge marshes were "uncovered" by falling water levels, many grasses, including bluejoint grass, appeared to colonize these surfaces more quickly than sedges.

The rise of lake levels was also accompanied by the recession of the relatively thin beaches along Lake St. Clair. when storms occur, the waves push sand and flotsam on top of the sedges and other plants which are colonizing the beach ridge. Thus alternating layers of in situ peat and sand characterize many of the beaches. However, because record lake levels were attained, most of the beaches were eventually washed over. Nevertheless, the loss of protective beaches did not contribute to the wave erosion of the cattail marsh because the wave climate in the shallow wetlands was relatively low.

As the water levels began to recede (see July-October 1977 transect), community succession takes place again. Tussock sedge communities are initially located only where the stools survived the previous high water period. In many places where the sedges succumbed to high water, grasses have recolonized the bare sites by means of seeds. Thus, for a few years following a high water period, tussock sedges may be observed on sites somewhat more elevated than those occupied by meadow grasses. Because meadow grasses, forbs, and shrubs may eventually shade out the sedge tussocks, this paradoxical juxtaposition should be eliminated after several years of succession. Sedges, in turn, may displace cattails and other stressed emergent communities.

With the decline of water levels, the cattail marsh will re-establish itself where the rootstalks are still viable. Field observations revealed that the surviving rootstalks were characterized by rootstalk mounds or by partially buoyed root mats. As the cattails spread vegetatively and perhaps by means of seeds as well, cattail die-back areas are re-vegetated and the submersed communities are displaced. During the 1977 field survey, hardstem bulrush and other open-water species were encountered only in the abandoned channels or in depressions.

Falling water levels are also accompanied by the redevelopment of the beach ridges along the shoreline. Although the beach ridges do afford some protection from wave action, wave heights in these shallow interdistributary bays are relatively low. It is felt that during low-water periods the beach ridges and other elevated sites impede the exchange of water masses between the emergent marsh and Fisher Bay. Reduced connectivity also adversely affects the spawning of wetland-dependent fish as well as the movements of waterfowl broods.

Woodtick Peninsula Wetlands

Located in southeastern Monroe County, Michigan, along the western coast of Lake Erie, the Woodtick Peninsula Wetland Complex consists of a barrier island (Woodtick Peninsula), a backbarrier embayment (North Maumee Bay), and a coastal marsh situated at the margin of the lakeward dipping lake plain. The wetland is bounded by Lake Erie on the east, Maumee Bay on the south, Highway I-75 on the west, and Consumer's Power Whiting Plant on the north. The Erie Shooting and Fishing Club Marsh, a private club founded in 1857, encompasses 1,000 acres of diked marshland. Although Bay Creek and a few other small tributaries and artificial canals input into North Maumee Bay, the hydrology of this backbarrier wetland complex is controlled by long-term lake level fluctuations as well as by short-term wind-generated circulation and seiches.

Plant List The list of common wetland plant species was derived during the survey of a vegetation bisect on June 8-9 and June 23, 1978. The bisect was surveyed perpendicular to Woodtick Peninsula, beginning at approximately 0.5 mile south of Consumer's Power Whiting Plant and ending in a cultivated field west of the Bay Creek Shooting Club. Listed below, by environment type, are the abundant plant species.

Barrier Beach (Woodtick Peninsula)

E. cottonwood *Populus deltoides*
Willows *Salix fragilis* and Others
Box elder *Acer negundo*
Wild grape *Vitis* sp.
Jewel weed *Impatiens capensis*
Smartweed *Polygonum* sp.

Backshore of Barrier Beach (Washovers on barrier beach)

Bur-dock *Arctium* sp.
Canary grass *Phalaris arundinacea*
Bluejoint grass *Calamagrostis canadensis*
Sweet clover *Melilotus* spp.
Small willows *Salix* spp.

Emergent Marsh (landward side of Woodtick Peninsula)

Arrowhead *Sagittaria latifolia*
Narrow-leaved cattail *Typha angustifolia*
Hybrid cattail *Typha glauca*
Softstem bulrush *Scirpus validus*
Three-square *Scirpus americanus*

Open-Water of North Maumee Bay

Sago pondweed *Potamogeton pectinatus*

Emergent Marsh (inside Erie Shooting and Fishing Club)

Softstem bulrush *Scirpus validus*
Spike rush *Eleocharis* sp.
Arrowhead *Sagittaria latifolia*
Spiked loosestrife *Lythrum salicaria*

Narrow-leaved cattail Typha angustifolia
Hybrid cattail Typha glauca
Canary grass Phalaris arundinacea
Smartweed Polygonum sp.
Jewel weed Impatiens capensis

Emergent Marsh (of Bay Creek Shooting Club)

Narrow-leaved cattail Typha angustifolia
Hybrid cattail Typha glauca
Spiked loosestrife Lythrum salicaria
Arrowhead Sagittaria latifolia
E. cottonwood seedlings Populus deltoides
Willows Salix spp.
Jewel weed Impatiens sp.

Old Field - Abandoned Farmland

Canary grass Phalaris arundinacea
Jewel weed Impatiens sp.
Sedge Carex stipata
Sedge Carex lanuginosa
Sedge Carex vulpinoidea

Wetland Bisect In June 1978, the Woodtick Peninsula and the North Maumee Bay Wetlands were surveyed in the field. The water level of Lake Erie in June 1978 averaged 572.25 feet, which is 1.32 feet above the long-term average for June. As indicated in Figure 60, the bisect consists of two segments with an unsurveyed section in the middle. The central portion was not surveyed because of the diked Erie Shooting and Fishing Club Marsh is a managed wetland and immediately east of the Big Dike is the water intake canal of Consumer's Power Whiting Plant.

The bisect description will proceed from east to west, beginning at the Lake Erie shore of Woodtick Peninsula. At about 325 feet from shore a well-developed nearshore bar was encountered. This sandy, ripple-marked bar was nearly 50 feet in width and at the crest extended upward to 1.95 feet from the lake surface. A few scattered Sago pondweeds were noted on this bar. Farther offshore, other nearshore bars were apparent as indicated by parallel lines of breaking waves in this shallow, nearshore environment.

Another bar was encountered at 124 feet from the shore. In general, soft, fine sands or sticky clay sediments were found in between the nearshore bars. As indicated by uprooted trees and by roots in the substrate, large cottonwood trees once colonized a beach ridge which is now 100-125 feet from the modern transgressive shoreline. Near the uprooted trees the field investigators found clayey peats averaging 6-12 inches in thickness. At approximately 50 feet from the shoreline the sediments became extremely soft and consisted of organic-rich ooze. Gray, silty clays underlie all the nearshore sediments.

At the time of the field survey, Woodtick Peninsula averaged only 90 feet in width and attained 3-4 feet in elevation above lake level. The total thickness of the barrier island sands averaged 5-6 feet and were underlain by gray, silty clays. Although the beach face was unvegetated, near the crest of the barrier the investigators noted young cottonwood and small willow trees as well as sweet clover, wild grape, and jewel weed. Coarse sand and shell fragments, along with some gravel, characterized the beach ridge sediments,

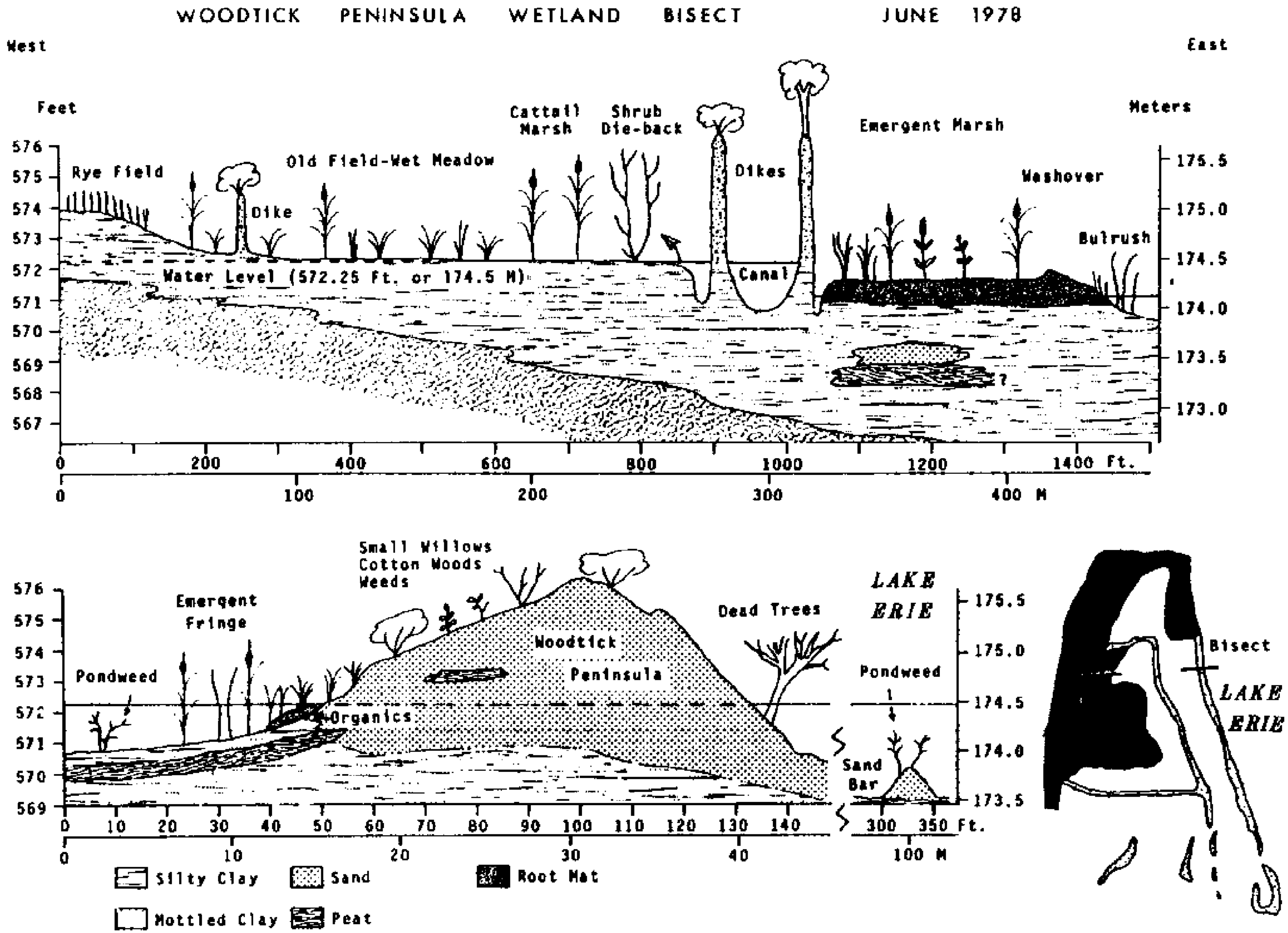


Figure 60. Bisect Across the Woodtick Peninsula Wetlands, June 1978

including the washovers which, in places, extended across the eroding peninsula. Cottonwood seedlings and willow brush were colonizing the sandy washovers along with canary grass, sweet clover, and bur-dock.

On the landward side of the barrier island, a narrow band of canary grass and bluejoint grasses colonized the back shore. A layer of peat 6-8 inches thick was associated with this plant community, but may have been formed by cattails and sedges during the 1972-1975 high-water period. Beyond this grassy zone was an emergent marsh which extended for a width of approximately 30 feet. Cattails, three-square, and some arrowhead comprised this marsh. Water depths ranged from 8 to 24 inches and the substrte consisted of soft, silty clays. In the deeper portions, some Sago pondweed colonized the soft bottoms. American lotus had been identified here in previous years, but this endangered species was not observed during the bisect survey.

The open-water area of North Maumee Bay from the edge of the emergent marsh (described above) to the Consumer's Power intake canal near the Big Dike was not surveyed in detail. A walkthrough from Woodtick Peninsula to a small, wooded island located immediately east of the intake canal revealed water depths which ranged from 2-3 feet. Almost no vegetation was noted in this somewhat turbid and soft-bottom, lagoonal environment. Generally the sediment consisted of soft, organic-rich clays underlain by a blanket peat. The blanket peat, which may have formed under a cattail marsh or sedge meadow during the low-water period of the mid-1960's, was underlain by gray, silty clay.

The second segment of the bisect begins within the diked wetlands of the northern portion of the Erie Shooting and Fishing Club Marsh. Water level within this enclosure was 1.16 feet lower than that of Lake Erie because of water level management. Along the shoreline a narrow zone of softstem bulrush was encountered which graded into a mixed softstem bulrush and spikerush community. Farther landward, an unvegetated washover of cattail-bulrush macrofragments was surveyed. This washover appears to have been deposited during the high lake level period of the early 1970's.

Across the remainder of this diked wetland (over a distance of 300 feet), peat flats and emergent marsh were noted. Generally the water table lay 6 to 12 inches below the surface, and the substrate consisted of 12 to 18 inches of root mat and marsh peat.

Separating the Erie Shooting and Fishing Club and Bay Creek Shooting Club marshes are two earthen dikes with a canal in between. The dikes were 4 to 5 feet in height and were colonized by small cottonwood trees, gray dogwood, sumac, wild grape, and smartweeds. The canal, which averaged 100 feet in width, contained turbid, gray-colored water. In contrast, the water inside the Erie Shooting and Fishing Club marsh appeared to be somewhat less turbid and more brownish in color. Erosion of the silty clay dikes may explain the turbidity of the canal water. However, in a nearby canal hundreds of carp were trapped by low water levels. These fish create turbidity by their feeding and swimming activities as well as by attempting to leap out over the poorly vegetated banks of the dikes.

West of the second earthen dike, a shrub die-back was encountered. Most of the dead shrubs were young eastern cottonwood and willow trees which probably drowned during the record high water levels of the 1972-1975 period. Under the dead shrubs were arrowhead, jewel weed, and patches of cattail. The sediments, though somewhat peaty at the surface, were generally silty clays which became quite dense at depths of 3 feet or so.

The next vegetation zone encountered was a cattail marsh. This zone, approximately 175 feet in width, was dominated by hybrid cattail with an understory of arrowhead and jewel weed. As the cattail marsh graded into a field meadow, narrow-leaved cattail became the dominant emergent. Along with the narrow-leaved cattail, a number of other species were found here including canary grass, arrowhead, and dock.

Between the cattail marsh (described above) and a small earthen dike was an old field-wet meadow wetland type. The substrate generally consisted of black, blocky clays and silty clays. Field pH measurements revealed alkaliine conditions as the pH ranged between 7.0 and 8.0. Although the water table lay only a few inches below the surface, during lower lake levels this field was planted in corn and other waterfowl-attracting grains by the Bay Creek Shooting Club. At present the vegetation is quite diverse and includes scattered cattails, canary grass, arrowhead, jewel weed, dock, and several sedges.

West of the small dike, which was colonized by gray dogwood and other shrubs, was an uncultivated old field. This old field was poorly vegetated, but did support cattails in the low-lying areas. Beyond the old field was a cultivated rye field. The water table under the rye field averaged about 22 inches below the surface. At the surface the substrate consisted of black, blocky clay which became more compact and more mottled with depth. At approximately 26 inches below the surface, the substrate graded into a compact, gray silty clay which contained numerous orange- and brown-colored concretions. Some of the concretions were calcareous and fizzed when acid was applied.

Wetland Vegetation at Various Lake Levels Using black and white aerial photography flown on July 27, 1937; May 27, 1964; and, on August 8, 1975, vegetation maps were generated of the Woodtick Peninsula wetlands. Water levels of Lake Erie at the time of the photography were as follows: July 1937: 570.6 feet; May 1964: 569.7 feet; and, August 1975: 572.4 feet. Whereas the 1937 photography provides base line data, both the 1937 and the 1964 imagery reflects low-water conditions, and the 1975 photography is indicative of high lake level conditions.

Vegetation in 1937 Although the water level in July 1937 was at 570.6 feet, lake levels for the period 1934-1936 averaged below 569 feet. In fact, the historical record low-water levels of Lake Erie for the months of March through December were recorded in 1934. Thus the 1937 imagery reflects both the base line and extreme low lake level conditions.

Perhaps the most striking aspect of the wetland vegetation distribution in 1937 is the zones of emergent marsh located lakeward of Woodtick Peninsula (Figure 61). In places, this emergent marsh is 800 feet or more in width. Much

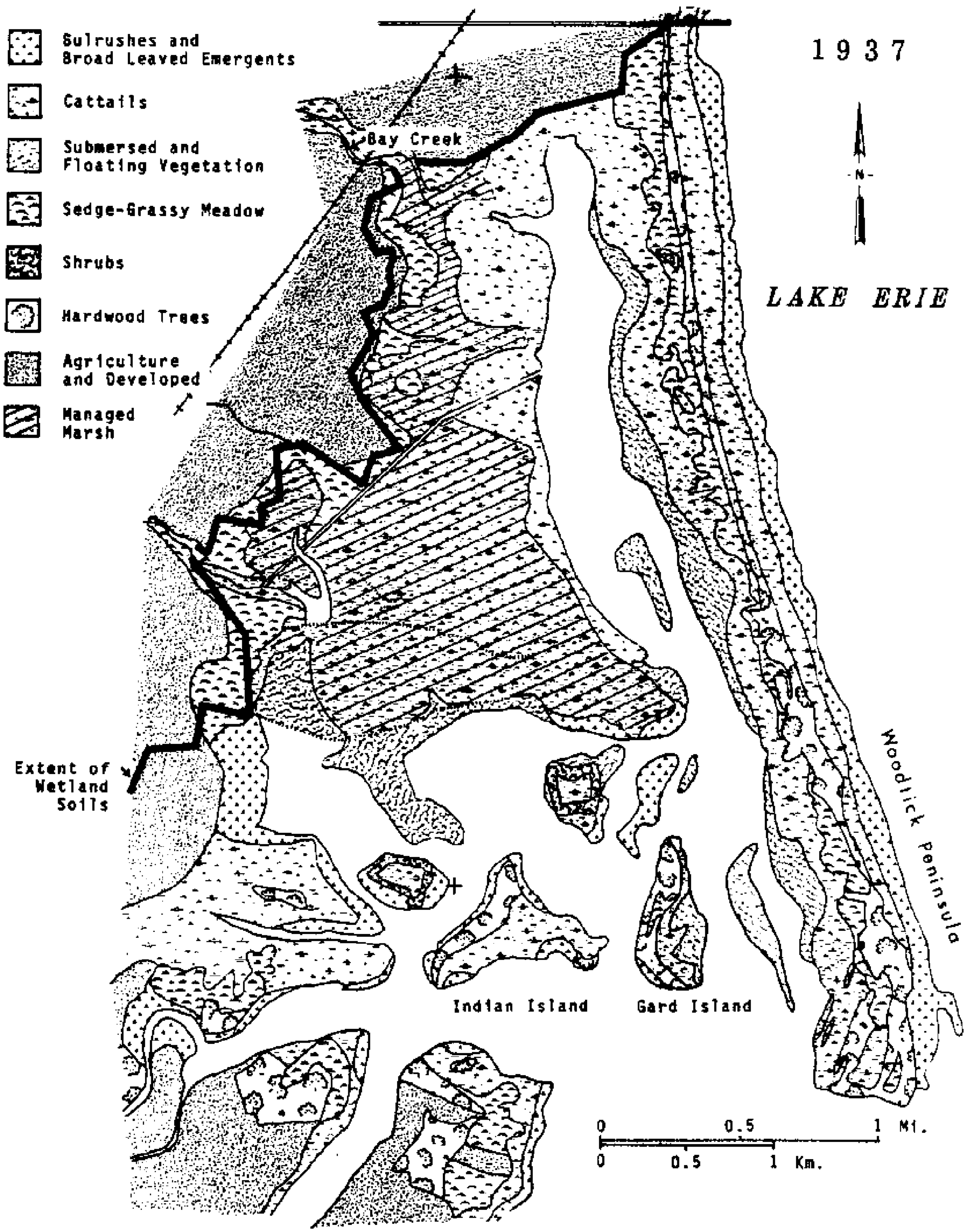


Figure 61. Distribution of Wetland Vegetation at Woodtick Peninsula, 1937, Monroe County, Michigan

of the vegetation appears to be cattail along with a fringe of bulrushes (possibly hardstem bulrush) and perhaps some Sago pondweed as well. Although the barrier beach had not exhibited much lakeward accretion, shoaling resulting from lower lake levels during the 1930's permitted the emergent vegetation to colonize the nearshore zone. At least 6 nearshore bars could be identified on the photography of the nearshore environment.

Another feature of this time period is the extensive colonization of the North Maumee Bay area by wetland vegetation, including the landward side of Woodtick Peninsula. The open-water portion of the bay was only 1,640 feet in width. In the southern portion of Maumee Bay, the wooded islands (Indian and Gard Islands) exhibited fringes of cattails and floating-submersed aquatics.

A large segment of the marsh, which is now contained in the Erie Shooting and Fishing Club and Bay Creek Shooting Club marshes, exhibited dark tones on the photography. This tonal pattern suggests disturbance resulting from some management practice, such as burning or mowing. Although it was not possible to key out the plant communities, it is believed that the disturbed marsh contained sedges and grasses (canary grass and bluejoint grass) as well as mint, swamp rose mallow, and annual weeds. Because of the encroachment by agriculture along the upland margin, little shrub or wooded swamp remained in 1937.

Vegetation in 1964 Although the level of Lake Erie in May 1964 was at 569.7 feet, or 0.9 feet below the 1937 level, the 1964 photography does not reflect low-water conditions as completely as the 1937 imagery. This is because the years previous to 1964 were associated with lake water levels that averaged between 570 and 571 feet. Moreover, during the early 1950's, near record high levels were measured.

The 1964 map reveals that the very little emergent marsh lakeward of Woodtick Peninsula was present (Figure 62). However, patches of bulrushes or cattails too small to map did appear on the photography. The photographic analysis also revealed exposed peats along the peninsula shoreline. Farther south along the peninsula, near North Cape, a breach in the beach ridge was evident.

Landward of the barrier island, the major change since 1937 involve the Erie Shooting and Fishing Club Marsh. In 1951 dredging by Consumer's Power of the water intake canal generated the spoil necessary for the construction of the Big Dike. Water level management of all the sections within the diked complex was possible in 1960 (Hunt and Mickelson, 1976). Thus, vegetation changes within the diked enclosure, as observed on the 1964 photography, can not be directly associated with water level fluctuations of Lake Erie.

Whereas very little floating-leaved or submersed vegetation was evident on the 1964 imagery, open-water environments are widespread. Likewise, bulrush communities could not be located in 1964. Much of the wetland vegetation consisted of cattail marshes along with some sedge-grass meadow. Except for Indian Island, most of the wooded islands tended not to exhibit a fringe of emergent or submergent marsh. As in 1937, little shrub or swamp vegetation existed along the upland margin due to the encroachment of agricultural and other land uses. However, except for the construction of the Whiting Plant by

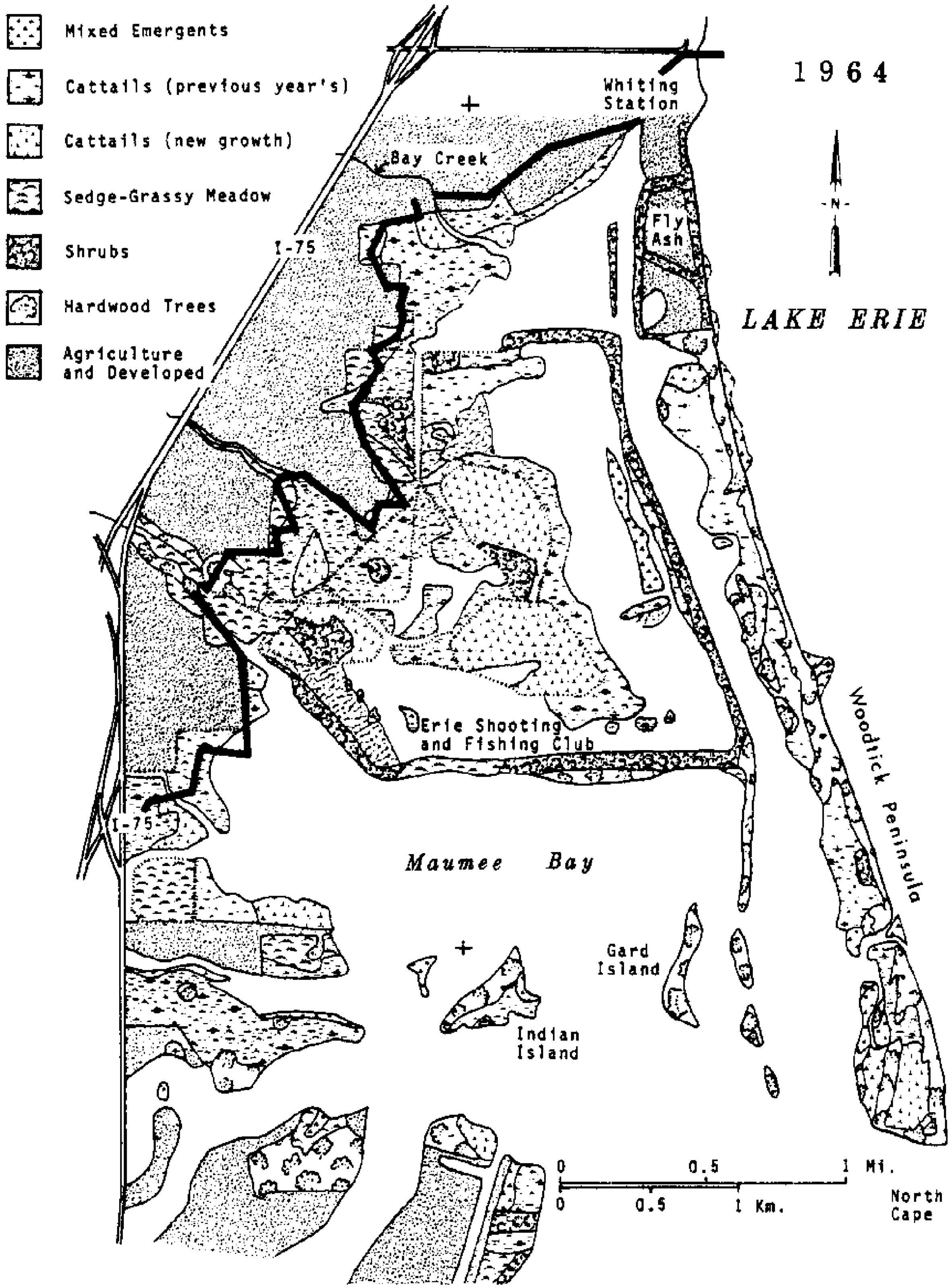


Figure 62. Distribution of Wetland Vegetation at Woodtick Peninsula, 1964, Monroe County, Michigan

Consumer's Power during the 1950's and continual development along Maumee Bay near Toledo, Ohio, little change in the limit of agriculture-developed lands occurred.

Prior to the construction of the Whiting Plant, the State of Michigan's Department of Conservation leased a large area of northern Maumee Bay. The leased area was a waterfowl refuge until about 1955 when the property owner, Consumer's Power, initiated plans for the construction of the fossil-fuel power station. The Michigan Department of natural Resources now maintains a public hunting area (Erie State Game Area) south of the Erie Shooting and Fishing Club Marsh.

Wetland Vegetation in 1975 During the period 1972-1975 the coast of Lake Erie was subjected to extensive erosion and flooding as a result of record high water levels. In June 1973, Lake Erie attained a record level of 573.5 feet and levels in 1974 continued to be relatively high. However, in 1975 the water level began to drop, and by August 1975 (the date of the photography used for mapping) Lake Erie averaged 572.4 feet.

Woodtick Peninsula, in 1975, reflects high-water conditions as it is breached in three places (Figure 63). Not only is the beach ridge discontinuous, in many places the barrier island has receded 150 feet and the established beach ridge trees have been uprooted. Even the dikes enclosing the fly ash pits of the Whiting Plant underwent erosion and some fly ash sediment was noted as far south as North Cape. Washover deposits were pushed by waves across the eroding barrier island, particularly during fall and spring storms.

Compared to the 1964 map of vegetation, the main difference is the loss of cattail and sedge-grass meadow wetland types. Open-water environments are more predominant in 1975 than in 1964. In many places, open water extended into agricultural fields and developed lands. Highway I-75 as well as flood-control dikes in the fields acted as barriers to the flooding and erosion processes. Only in the diked wetlands and in protected embayments did cattail and meadow communities survive. The extensive flooding caused die-back of shrub communities, including those along the dikes and on the wooded islands.

Wetland Area Measurements Using a polar planimeter and the 1937, 1964, and 1975 wetland vegetation maps discussed previously, the area of each plant community was determined during the three time periods (Table 27). The 1937 wetland distribution map, because it represented extremely low-water conditions, served to delimit the wetland boundary along Lake Erie. With regard to the inland boundary of the Woodtick Peninsula wetlands, the boundary of the Lenawee Silty Clay Loam (Ponded) soil series was utilized. The southern limit of the wetland complex is a line drawn along the southern perimeter dike of the Erie Shooting and Fishing Club Marsh. This line was temporarily drawn on the three vegetation maps, but was erased after the planimetering was completed.

In 1937, the Woodtick Peninsula wetland complex included an area of 2,395 acres (Table 27). This area has been adopted as the standard area for the 1964 and 1975 time periods as well. Because of low-water conditions, the emergent

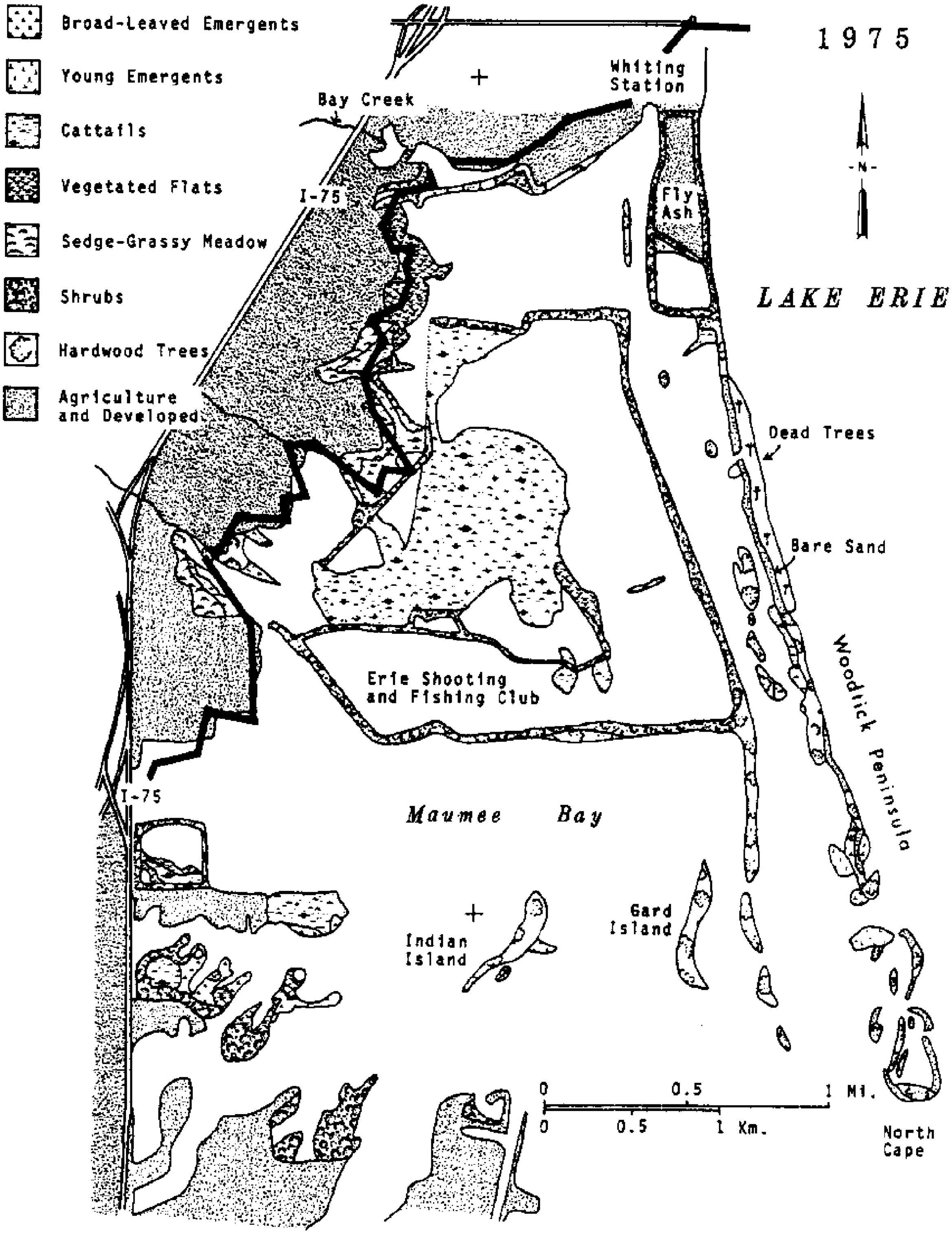


Figure 63. Distribution of Wetland Vegetation at Woodtick Peninsula, 1975

Table 27

Areal Extent of Wetlands, Woodtick Peninsula
By Vegetation Type, 1937, 1964, and 1975

1937 (Historical Base, Low Water)

Wetland Type	Acres	Hectares	Percent of Total
Open Water	407	165	17
Floating and Submersed	191	77.5	8
Emergents	1,461	591.5	61
Meadow	240	97	10
Shrub-Swamp	72	29	3
Developed-Agriculture	24	10	1
TOTAL	2,395	970.0	100

1964 Distribution (Low Water)

Wetland Type	Acres	Hectares	Percent of Total
Open Water	1,061.5	430	44.0
*Floating and Submersed	69	28	3.0
Emergents	610	247	25.5
Meadow	67	27	3.0
Shrub-Swamp	265	107.5	11.0
**Developed-Ag.-Fill	322.5	130.5	13.5
TOTAL	2,395.0	970.0	100.0

1975 Distribution (High Water)

Wetland Type	Acres	Hectares	Percent of Total
*Open Water	1,645	666	68.5
Floating and Submersed	0	0	0.0
*Emergents	357	145	15.0
Meadow	15	6	0.5
Shrub-Swamp	156	63	6.5
**Developed-Ag.-Fill	222	90	9.5
TOTAL	2,395	970	100.0

* Includes managed wetland within diked areas.
** Vegetation within diked wetlands not included.

marsh was very extensive and covered 61 percent of the total wetland area. However, this marsh exhibited very dark tonal parterns on the July 1937 photography. The tonal patterns suggest some management of the marsh, possibly winter burning, mowing, or spraying.

Other features of the 1937 wetland area measurements include the relatively low percentage of open water (only 17 percent) and floating-leaved/submersed aquatic beds of sufficient distribution to map and planimeter. It is likely that wild celery, Sago pondweed, and American lotus were among the aquatic species present. Although the sedge-grassy meadow exhibited considerable distribution, this category may be underestimated slightly because the managed marsh category could not be interpreted with sufficient detail to permit identification of meadow areas. Very little shrub-swamp vegetation was present because of agricultural encroachment. Though some dikes were in place as early as 1920, it was not until 1960 that water level regulation was possible at the Erie Shooting and Fishing Club Marsh.

The year 1964 was also indicative of low-water conditions. However, area measurements reveal several important changes. First, the extent of open water increased, perhaps due to the high-water during the 1950's and because of increased turbidity and siltation. Second, the beds of floating-leaved and submersed aquatics largely disappeared. Third, the emergent vegetation, particularly the cattail marsh, decreased markedly in area. Completion of the outer dike and establishment of a partially closed circulation system may have prevented elimination of some of the emergent, floating-leaved, and submersed vegetation within the Erie Shooting and Fishing Club Marsh. In contrast, the diking of the shooting club marsh and of the fly ash pits resulted in the creation of islands and of diked sites for shrub growth.

Comparison of the 1975 (high water) and the 1964 (low water) area measurements reveals surprisingly little difference in the wetland vegetation. The main change was a sharp increase in the extent of open water (from 44 to 68.5 percent of the total area). However, it should be pointed out that within the 1,000 acre diked marsh of the Erie Shooting and Fishing Club, nearly two-thirds of the enclosed wetland consists of open-water environments. Another important difference is the decrease in the extent of the emergent marsh, particularly of cattails. The sedge-grass meadow was also reduced in extent, as was the shrub-swamp, principally because of the erosion of the Woodtick Peninsula.

In order to approximate the mean area and percent of total area of the various plant communities at Woodtick Peninsula during average lake level conditions, the area measurements for 1964 (low water) and 1975 (high water) were averaged as indicated below. A total area of 2,395 acres was adopted as the standard area. In order to estimate the areal extent of each vegetation type the plant communities within the Erie Shooting and Fishing Club Marsh were also planimetered. Therefore, the developed/fill category is comprised of agricultural fields, power plant complex, and fly ash sites, but not diked wetlands. The undiked portion of this wetland may exhibit less floating-leaved/submersed and emergent vegetation than diked areas because of excessive turbidity and substrate changes. To cause the 1964-1975 average to total 2,395 acres, the open-water category was adjusted.

Wetland Type	Acres	Hectares	Percent of Total
Open Water	1,300	525.6	54.0
Floating/Submersed	35	14.0	1.5
Emergents	484	196.0	20.0
Meadow	42	17.0	20.0
Shrub/Swamp	211	85.5	9.0
*Developed/Fill	323	131.0	13.5
TOTAL	2,395	790.0	100.0

* Does not include the Erie Shooting and Fishing Club diked wetlands.

Comparative Photo Transects When the three time periods are studied in profile, by reconstructing the 1978 bisect for the 1964 and 1975 periods, the plant community successional trends are evident (Figure 64). The June 1978 bisect served as the base for the other two time periods. Except for obvious beach changes, it was assumed that little change in elevation took place. Some substrate changes near the surface were surmised on the basis of short cores taken during the bisect survey and by associating known sediment processes with lake level conditions. Water level data were taken from the Cleveland, Ohio, and Monroe, Michigan, gauging stations.

Beginning in May 1964, when Lake Erie was at 569.7 feet, low-water conditions prevailed (Figure 64). At this time, a very shallow nearshore environment in excess of 750 feet was evident. Although nearshore bars and low-wave energy permitted the growth of a few scattered emergents in the nearshore zone, the emergent vegetation was not as extensive nor as dense as in the 1937 low-water period. In 1964 the barrier beach was in excess of 300 feet in width and probably was 7 feet or more in elevation above lake level at that time. On the back-barrier side, cattails and other emergents established dense colonies and some peat accumulated. Along the upland margin of the wetland complex, shrubs extended their range and may have displaced some of the graminoid forms.

The 1975 bisect reveals the extensive drowning and die-back which accompanied the high-water conditions. Although water levels in August 1975 were 572.4 feet, in 1973 the water level reached a record level of 573.5 feet. High water levels raise the base level of Lake Erie which, in turn, allows storm waves to pass unattenuated over the nearshore environment. Thus the waves break and expend their energy on the easily erodable beach sands. The uprooting of the beach ridge trees, recession of the beach, and washover of sand into the backbarrier side accompanies high water level conditions.

The high water conditions also increased wave action in the lagoon. This more intensive wave action in the lagoonal environments of North Maumee Bay appears to have been associated with the blanket-like deposition of sticky, gray, silty clays. In addition, very little cattail or meadow survived the higher water levels and increased wave erosion. Die-back of the shrub communities also occurred.

In June 1978 water levels had dropped only to 572.25 feet. Nevertheless, the barrier beach was no longer exhibiting critical erosion as evidenced by

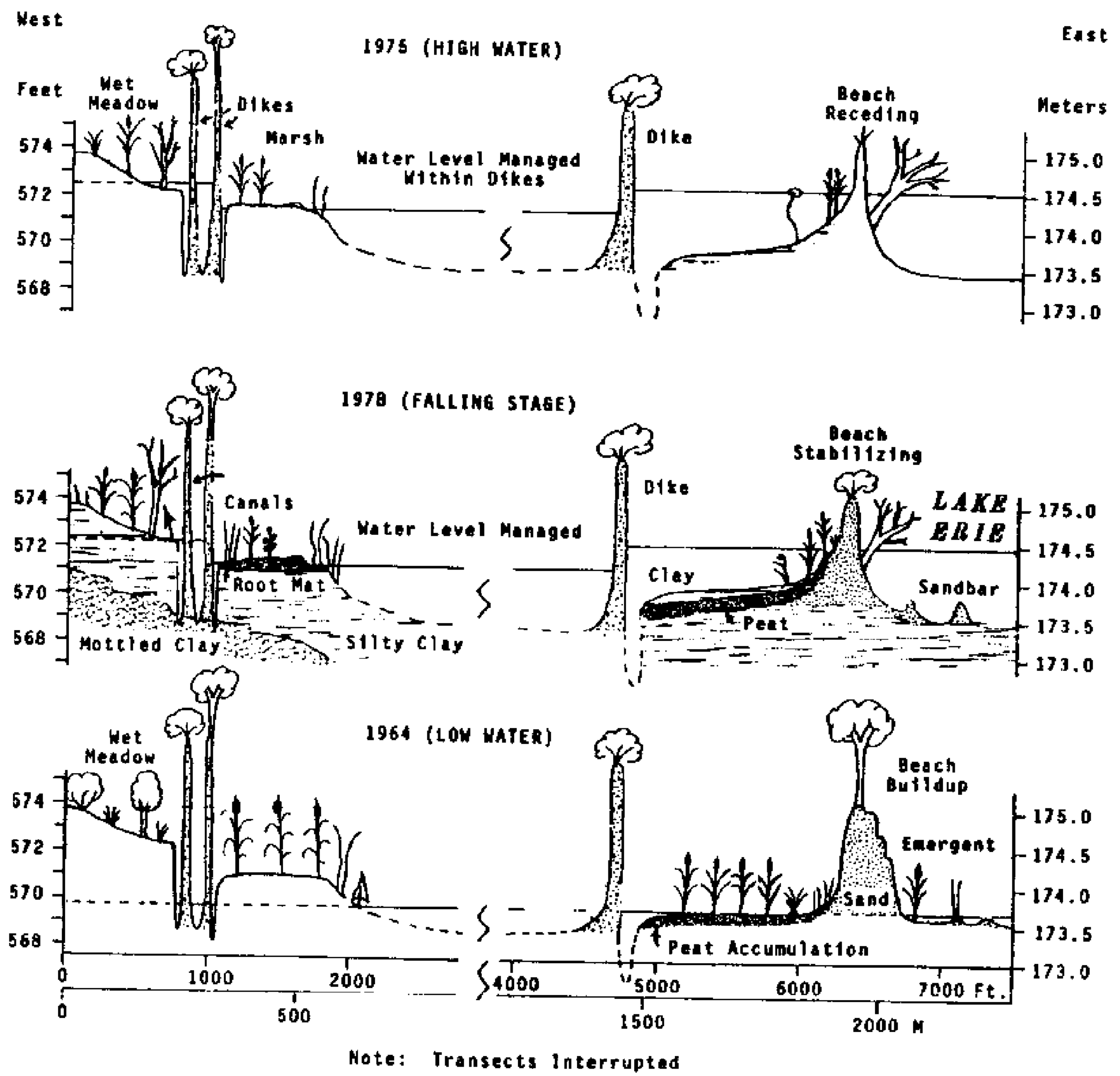


Figure 64. Photo Transects of Woodtick Peninsula Wetlands, Michigan

several nearshore bars forming in the nearshore zone. Although open water conditions persisted throughout the open marsh as well as within the diked enclosures, some expansion of the cattail colonies by rhizome extension began to occur. However, because most of the floating-leaved and submersed aquatics have been eliminated, the re-establishment of these plant communities may not take place until water levels drop considerably lower. High turbidity and clayey substrates may reduce the available habitat for many of the intolerant aquatic species. In fact, the elimination of floating-leaved and submersed vegetation in the Woodtick Peninsula wetlands may be evident in the 1964 vegetation map which exhibits a surprisingly restricted distribution of these plants.

Toussaint Marsh

This wetland complex is located in Ottawa County, Ohio, along the Lake Erie coast. Basically, the wetland is an estuary of the Toussaint River and Rusha Creek. However, many of the shallow lagoons landward of the barrier beach ridges, which flank the river mouth, have been diked and modified by human activities. Because of the flat, relatively fertile lake plain soils (Fulton and Lucas soils), agriculture has encroached upon these coastal wetlands. As a result of agricultural encroachment and ineffective non-point water management, turbidity levels are high, especially in the lower Toussaint River.

Toussaint Marsh is a backbarrier marsh located between lower Toussaint River and Camp Perry, Ohio. Agricultural fields and Highway 2 form the landward boundary. Local residents refer to the Green Bay and the Huntington marsh in the northern and southern portions, respectively. Toussaint Marsh is a private shooting club marsh which has been diked since the late 1800's. Because pumping and water level management has been practiced since at least the 1940's, this wetland can not be regarded as a natural system. Thus, a bisect was not surveyed across this wetland, nor were photo transects constructed as in the case of the other six study areas.

Plant List The plant list below was developed by walkthroughs and a boat transect through the Green Bay and Huntington Marsh on June 22, 1978. Relatively high lake levels resulted in a predominance of species tolerant to inundation.

Eroding Barrier Beach along Lake Erie.

E. cottonwood Populus deltoides
Willows Salix spp.
Gray dogwood Cornus racemosa
Wild grap Vitis sp.
Indian berry Parthenocissus sp?
Jewel weed Impatiens sp.
Morning glory Convolvulus sepium

Backbarrier Flats and Marshes (of eroding barrier beach)

Willows Salix spp.
Thistle Cirsium sp.
Canary grass Phalaris arundinacea
Sedges Carex spp.
Jewel weed Impatiens sp.
Sweet flat Acorus calamus
Pickerel weed Pontederia cordata
Smartweed Polygonum amphibium

Emergent Marsh (of Green Bay and Huntington Marsh)

Hybrid cattail *Typha glauca*
N. -leaved cattail *T. angustifolia*
Bluejoint grass *Calamagrostis canadensis*
Marsh fern *Thelypteris palustris*
Water willow *Decodon verticillatus*
Rose mallow *Hibiscus palustris*
Swamp dock *Rumex* sp.

Open-water Marsh (of Green Bay)

River bulrush *Scirpus fluviatilis*?
Sweet flat *Acorus calamus*
Flowering rush *Butomus umbellatus*
Water shield *Brasenia schreberi*
Yellow water lily *Nuphar advena*
White water lily *Nymphaea odorata*
Sago pondweed *Potamogeton pectinatus*
Curly-leaved pondweed *P. crispus*
Floating pondweed *P. natans*

Dikes and Artificial Levees

E. cottonwood *Populus deltoides*
Willows *Salix* spp.
Burdock *Arctium* sp.
Thistle *Cirsium* sp.
Canary grass *Phalaris arundinacea*

Swamp Margin (inland of Toussaint marsh)

E. cottonwood *Populus deltoides*
Red ash *Fraxinus pennsylvanica*
Red osier dogwood *Cornus stolonifera*
Gray dogwood *Cornus racemosa*
Elderberry *Sambucus* sp.
Canary grass *Phalaris arundinacea*
Various grasses *Panicum* sp., Etc.
Swamp dock *Rumex* sp.
Water smartweed *Polygonum amphibium*
Jewel weed *Impatiens* sp.
River bulrush *Scirpus fluviatilis*?

Wetland Bisect

Because this wetland, like so many other extant wetlands along Lake Erie, is diked and managed, it is felt that lake level fluctuations do not directly influence seral succession. Therefore, no wetland bisect was surveyed for this study area. Some appreciation of the substrate and plant community relationships, however, can be gained by study of the geomorphic data presented earlier (Figure 32).

Wetland Vegetation at Selected Lake Levels The wetland vegetation was mapped at selected time periods as indicated below.

Year	Date of Photography	Water Level Feet	Water Level Meters	Lake Level Stage
1950	10- 6-50	570.6	173.92	Average
1970	6- 2-70	571.2	174.10	Rising Water
1977	6-10-77	571.7	174.26	High water

Wetlands in 1950 Although the water level of Lake Erie in early October 1950 was 570.6 feet, which is just 4 inches below the 1900-1977 mean for July, previous water levels were much lower. During the period 1931 to 1936, the water level averaged 569.0 feet. Because of these relatively low levels during the 1930's and due to average levels for the period 1937-1942, the 1950 wetland distribution map (Figure 65) reflects low to average water level conditions. Only in 1943, and during 1947-1948, did the previous water levels exceed the long-term average for July.

As indicated in Figure 65, the Toussaint Marsh was extensively diked in 1950. Therefore, this wetland system is not open, and long-term lake level fluctuations may not cause succession and retrogression as in the other study areas. The 1950 vegetation map reflects the wetland communities which were being managed for at that time. Since many coastal wetlands are diked and have water level regulation, the Toussaint Marsh is representative of those systems.

In 1950, much of the Toussaint Marsh consisted of dense cattail communities, probably hybrid and narrow-leaved cattail. Because circular colonies were evident on the 1950 photography, it appears that hybrid cattail was already widespread. The other extensive emergent community, which was designated as mixed emergents, appears to be restricted to depressions and low-lying areas. Although some cattail may have been present, this emergent zone appeared to contain more broad-leaved species, perhaps pickerel weed, water smartweed, sweet flag, and river bulrush. Some dark, organic-stained water may also be showing through these mixed emergent communities.

In contrast, little open-water was evident. A section of open water, within Toussaint Marsh, was located near the Toussaint River. This open water may exist as a result of excessive turbidity, or may be a result of marsh management (water level regulation). Open-water areas were also prevalent along the lower Toussaint River, even within diked wetlands located west of the river channel. Again, it is felt that turbidity, and perhaps carp activity as well, result in the absence of floating-leaved and submersed aquatics in these sites.

The other vegetation communities were very restricted in distribution. Except for scattered patches, little meadow, or sedge marsh could be identified. Likewise, the shrub and swamp fringe zones were generally absent due to the encroachment of agriculture. It appears that many of the perimeter dikes are designed to keep water out of the agricultural fields and that farmers cultivate as close to these earthen dikes as soil moisture conditions permit. The barrier beach, in comparison, appeared to be quite stable and was covered with mature trees (probably cottonwood). Between the wooded barrier beach and the emergent marsh, a linear strip of graminoid meadow or sedge marsh may have been present, but the map scale did not permit mapping of this zone.

Along the Lake Erie shorelines (lakeward of the Green Bay) there was a discontinuous strip of vegetation which appeared to be remnants of low-water colonization. Dark tones on the photography suggest patches of bulrush and cattails, or submersed aquatics (such as Sago pondweed). Perhaps during low to

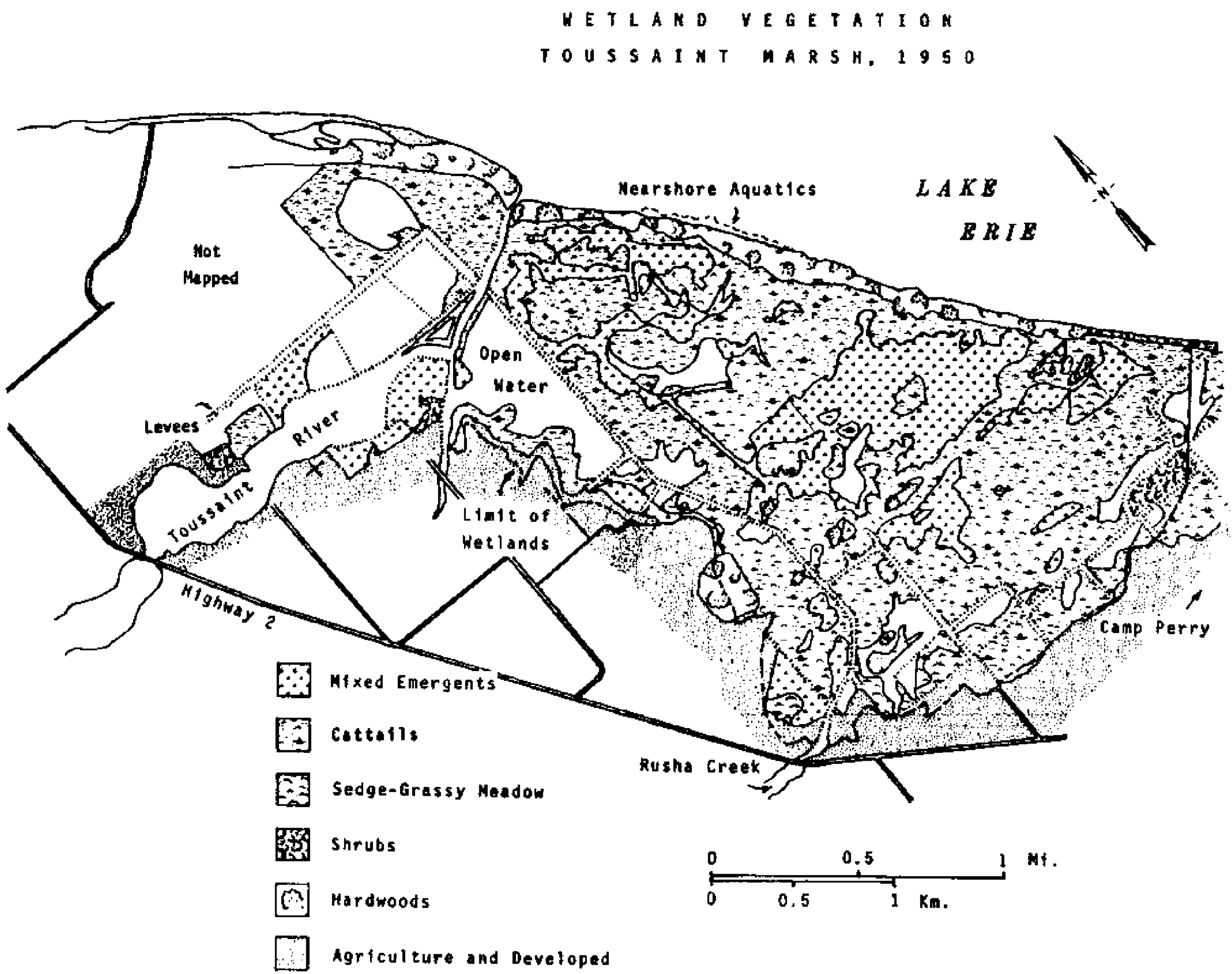


Figure 65. Distribution of Wetland Vegetation at Toussaint Marsh, Ohio, in 1950

average lake levels, when nearshore wave energies are low, some emergent and submergent vegetation colonizes selected portions of the nearshore zone. Photographs taken of this coast during the low-water period of 1964 confirm the presence of nearshore herbaceous vegetation.

Wetlands in 1970 Photographs flown on 6-2-70 were utilized to map the wetland vegetation as of 1970 when the lake level was 571.2 feet. Because levels were relatively low during the 1963-1965 period, the wetland vegetation in 1970 (Figure 66) represents rising water level conditions. However, it should be emphasized that in July 1969, water levels reached 572.5 feet. In fact, from July 1964 to July 1969, the average elevation of Lake Erie rose 2.8 feet. This consistent annual rise was accompanied by extensive cattail die-off.

As indicated in Figure 66, the extent of dead cattails exceeded that of live cattail colonies. It is believed that the Toussaint Marsh pumps either could not keep up with the rising water levels, or the lakeshore dikes began to leak. Whatever the cause, it appears that rising water levels drowned extensive sections of cattail marsh. Because the old stalks remained upright, the wetlands had not yet reverted to open water or to other aquatic communities.

In theory, cattail communities should survive only in sites where water depths do not exceed 18 to 24 inches. In the southeast portion of Toussaint Marsh, cattails invaded former meadow communities. Along an old dike, which trends east-west in Huntington Marsh, the cattails were restricted to higher sites around two island patches of shrubs.

The extent of mixed emergents appears to have diminished somewhat as a result of higher water levels since 1950. Some displacement by cattails is evident, but little reversion to open water was noted. However, after the dead cattail stalks are matted down, perhaps deep-water emergents, along with floating-leaved and submersed aquatics, will invade these inundated areas.

Otherwise there appears to be little change from the 1950 map. The meadow communities are essentially absent, but the shrub and wooded areas exhibit little departure from earlier distributions. Although some rupturing or leaking of the dikes may be occurring, the Toussaint River drainage did not flow into the Toussaint Marsh. Thus, the effect of excessive turbidity and other related factors appears to be restricted to the open portions of the lower estuary.

Wetlands in 1977 The distribution of plant communities in 1977 represents a culmination of record high lake-level conditions. In June 1973, a record high level of 573.5 feet was attained. This record level is 2.6 feet above the 1900-1977 mean level of Lake Erie in July (which is 570.9 feet). By June 6, 1977, the level of Lake Erie had dropped to 571.7 feet. Although the wetland plant communities had not sufficient time yet to recolonize much of the open-water areas in 1977, during the field survey in June 1978 the investigators noticed considerable recovery of the cattail marsh and other emergent communities.

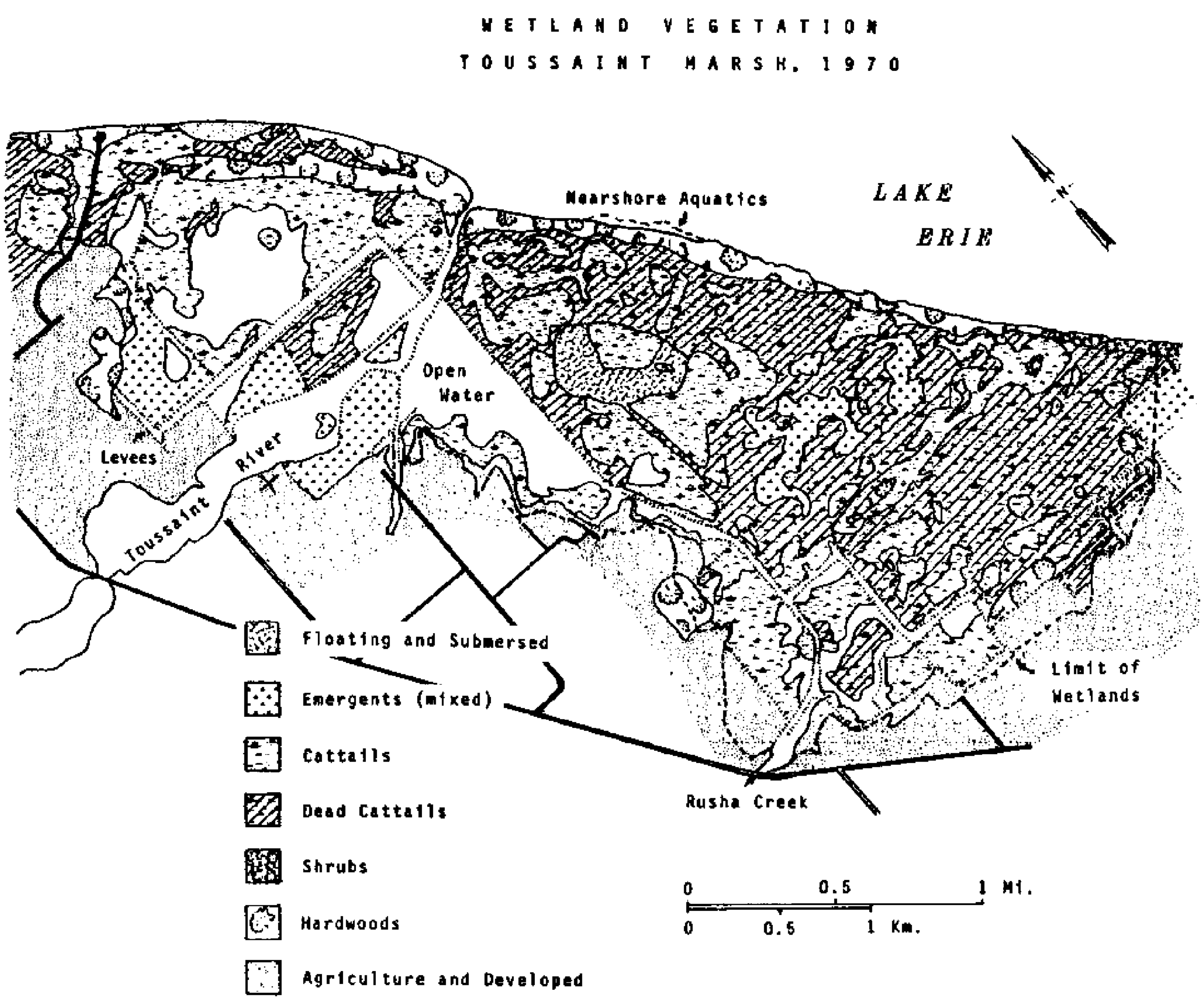


Figure 66. Distribution of Wetland Vegetation at Toussaint Marsh, 1970

In general, the 1977 vegetation map indicated a predominance of open-water environments as compared to vegetated areas (Figure 67). Open water was extensive along the landward side of the barrier beach and along lower Toussaint River where deep water and turbidity synergistically eliminated the marsh communities. Because some of the vegetation in the southern portion of Toussaint Marsh exhibited alignment, wind erosion during storms may have been a factor in the survival of cattail and other emergent communities. According to the St. Clair family who manage Toussaint Marsh, the marsh of the Green Bay occasionally floats and a false bottom 15 feet or more in thickness may underlie the flotaing mat. Although no field investigation was conducted, it is possible that during high water the cattail rootstalks do exhibit buoyancy and drift about when winds are strong.

Large areas within the Green Bay and Huntington Marsh exhibited dark tones on the 1977 photography. It was felt that these patterns were a mix of floating-leaved, submersed aquatics, and perhaps scattered emergents as well. Water lilies may have been abundant along with sweet flag, river bulrush, Sago pondweed, and floating pondweed. Because turbidity within much of the Toussaint Marsh appeared to be much lower than in the lower Toussaint River, submersed aquatics probably colonized fairly extensive areas during the high-water periods.

Breaks in the barrier beach ridge were also evident. Two large breaks near Huntington Marsh were caused by storm waves washing over the beach ridge. Attempts were apparently made to repair the dikes along the lower Toussaint River, and even along the barrier beach some levee construction was carried out in an effort to keep Lake Erie water out. However, some exchange of Lake Erie was established intermittently as indicated by the abundance of gizzard shad along with freshwater drum, and buffalo fish inside the Toussaint Marsh. Bullheads, carp, channel catfish, and bowfin are common residents of the Green Bay, even during low-water periods. A large, exotic pulmonate snail (Viviparus japonicus) was also fairly common, and local residents spoke of a "jellyfish" (freshwater sponge) but none were observed in the field.

Wetland Area Measurements Although the Toussaint Marsh does not represent an open system which responds directly to long-term lake level fluctuations, area measurements were determined for each plant community during the selected time periods. The total area of the marsh complex was set at 1,766 acres. In order to establish the lakeward wetland boundary, the outer margin of the beach ridge in 1950, including the nearshore vegetation, was utilized. In contrast, the landward limit of the Toussaint Marsh was based upon the landward margin of the Toledo soil series and the 575-foot contour as indicated on the Lacarne U.S.G.S. quadrangle map, Ottawa County, Ohio, 1967 edition (see Figures 65, 66, and 67). Because the soils were not mapped in the vicinity of Rusha Creek and Camp Perry, the 575-contour line was adopted as the landward boundary. A polar planimeter was employed to determine the total extent of the wetland, whereas a dot grid provided area measurements of the individual plant communities.

As indicated in Table 28, the areal extent of the plant communities changed considerably as lake level fluctuated. In 1950, when the water level was at an average elevation, but had been relatively low in previous years, emergent

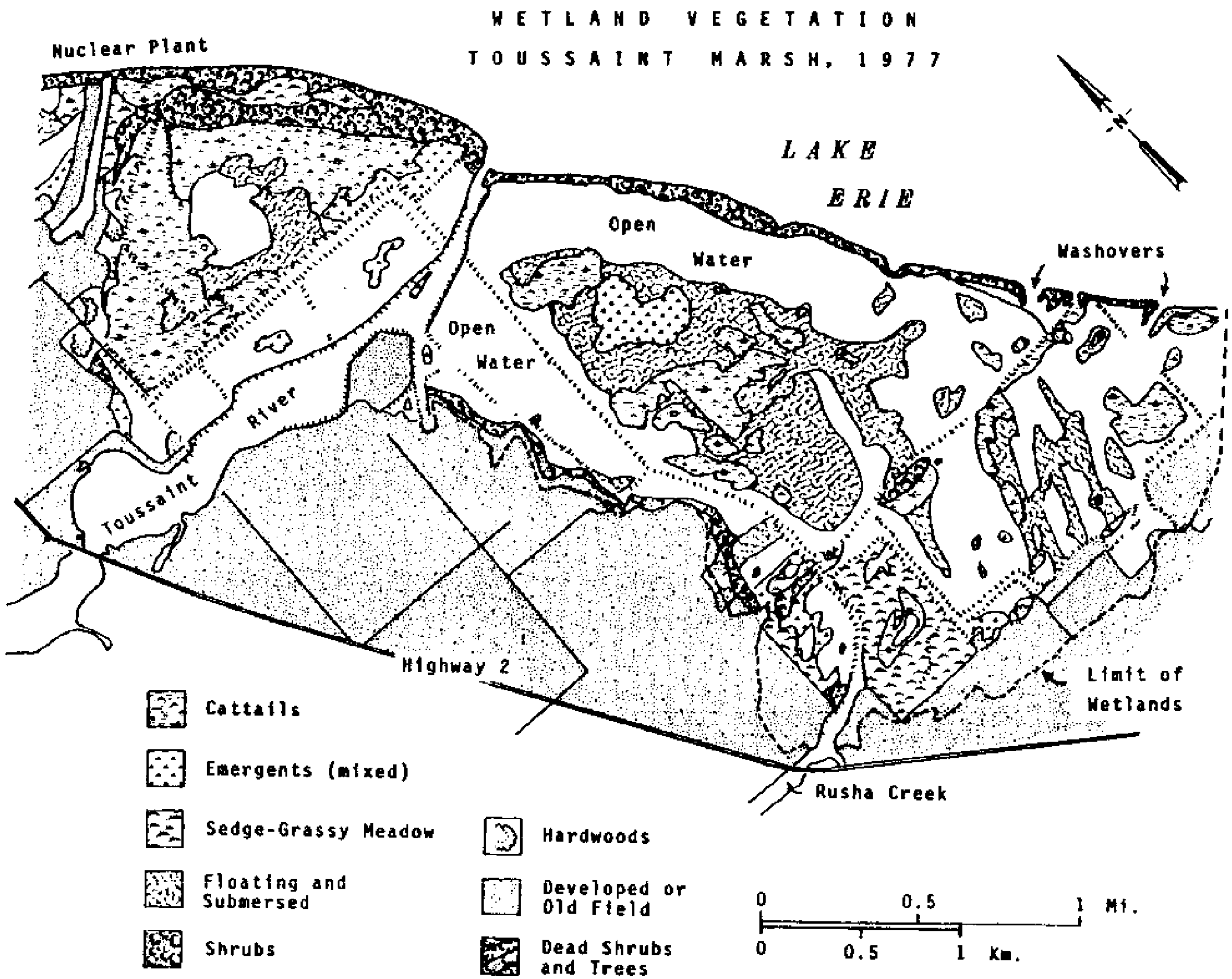


Figure 67. Distribution of Wetland Vegetation at Toussaint Marsh, 1977

Table 28

Areal Extent of the Toussaint Marsh By Vegetation Type, 1950, 1970, and 1977

1950 Distribution (Low to Average)

Wetland Type	Acres	Hectares	Percent of Total
Emergent	1,289.0	522.0	73
Graminoid Meadow	53.0	21.5	3
Shrub-Wooded	176.5	71.5	10
*Agriculture-Developed	71.0	28.5	4
Open Water	176.5	71.5	10
TOTALS	1,766.0	715.0	100.0

1970 Distribution (Rising Stage)

Wetland Type	Acres	Hectares	Percent of Total
Floating-Submersed	62	25.0	3.5
**Emergent	1,183	479.0	67.0
Shrub-Wooded	159	64.5	9.0
*Agriculture-Developed	159	64.5	9.0
Open Water	203	82.0	11.5
TOTALS	1,766	715.0	100.0

1977 Distribution (High Water)

Wetland Type	Acres	Hectares	Percent of Total
Floating-Submersed	353.0	143	20.0
Emergent	291.5	118	16.5
Graminoid Meadow	88.5	36	5.0
Shrub-Wooded	141.0	57	8.0
*Agriculture-Developed	185.5	75	10.5
Open Water	706.5	286	40.0
TOTALS	1,766.0	715	100.0

*Does not include the diked marsh
** Includes the dead cattail

communities, especially cattail, occupied 73 percent of the total wetland area. The combined shrub-wooded and the open water category each accounted for ten percent of the area, whereas agriculture-developed and graminoid meadow contributed only four and three percent, respectively.

In 1970, as water levels began to rise, the cattail marsh began to die back which, in turn, resulted in more open water as well as floating-leaved/submersed vegetation. However, because the dead cattail stalks were still standing, the drowned cattail marsh area was incorporated with the emergent marsh data. Thus, the emergent marsh still dominated the wetland cover types. Other significant changes are the loss of the meadow communities and a modest increase in the agriculture-developed category. Local farmers near Rusha Creek have drained some of the wetland margin, perhaps in response to the relatively low water of the 1963-1965 period.

The most dramatic change in the plant communities is evidenced by the 1977 area measurements. Essentially, the emergent marsh sharply decreased in extent and was replaced by open water as well as by some floating-leaved/submersed aquatic communities. A diked portion of the wetland near Rusha Creek, which contained meadow vegetation, may have been the only managed section of Toussaint Marsh during the high-water period. Erosion of the wooded barrier beach is reflected in the small decrease in the shrub-wooded category, and some additional agricultural encroachment is evident in the slightly higher percentage of agriculture-developed lands.

Photo Transects Since a bisect was not surveyed, photo transects representing selected time periods could not be constructed. However, water level management of the Toussaint Marsh renders the sequential transect analysis inappropriate regardless. It should be emphasized, nonetheless, that Toussaint Marsh does exhibit plant community shifts as the level of Lake Erie fluctuates.

No doubt during low-water periods water is retained in the marsh so that snapping turtle harvesting, muskrat trapping, and waterfowl hunting by club members may continue. Local residents reported that bluejoint grass may invade some of the drier cattail marshes during these low-water periods. In contrast, during high-water conditions, as in the 1970-1975 period, the emergent vegetation drowns and open-water communities dominate. A layer of organic detritus is probably deposited in the depressions as the cattail stalks are disintegrated. Apparently the present dike and pump system of the Toussaint Marsh can not lower internal water levels sufficiently nor prevent Lake Erie water from entering the wetland during high water.

IMPACT OF CHANGING LAKE LEVELS ON WETLAND ENVIRONMENTS

Based upon the previous discussion, the impact of lake level oscillations on the selected wetland sites can be analyzed. Included in this discussion is an analysis of wetland and wave energy relationships, as well as wetland vegetation changes resulting from various lake level conditions since the mid-1930's. Because of federal, state, and local concern over wetland protection and water-level related changes in wetland acreage, a model of plant community shifts has been developed. The dynamic wetland changes in response to water level changes modifies fish and wildlife uses as well as abiotic functions (sediment trapping and turbidity levels). These relationships are also analyzed and discussed.

Wetland and Wave Energy Relationships

It is often stated that wetlands afford protection to coastal areas with regard to wave energy dissipation and erosion. Field observations in coastal areas suggest that wetlands do provide some coastal protection to a shoreline, however, the data thus far do not appear to be conclusive. In this subsection the wetlands are examined with regard to wave energy and the selected coasts discussed in the "Geomorphic Framework of Selected Great Lakes Wetlands" section.

In the Great Lakes, Hall and Ludwig (1975) conclude that while several emergent plant species may have special use in low-energy areas, the Great Lakes shorelines are not conducive to establishement of aquatic plants. A site investigation in northern Lake Huron revealed that bluejoint grass, hardstem bulrush, and rush will not withstand high wave energy and hence are not recommended as suitable for wave attenuation. However, the authors also observed at Cecil Bay (Lake Michigan), that hardstem bulrush and spike rush were very effective in dampening waves. Other investigations have also documented mixed results. Webb and Dodd (1978) for example found that Gulf cordgrass, marshhay cordgrass and salt cordgrass were the more favorable stabilizers of the Galveston Bay shoreline than smooth cordgrass.

Process-oriented experiments reveal that wave attenuation does occur as waves pass over wetlands. In a lab experiment Ahrens (1976) found that wave periods and wave heights were affected by artificial seaweed. There was a measurable level of wave attenuation for only the shortest wave period (2.6 sec.) and for this wave period the reduction of wave height amounted to about 12%. Wave periods in the Great Lakes commonly exceed 2.6 seconds. Random observations suggest that breaker wave periods average between 2.5 and 6.8 seconds in Lakes Michigan, Superior, and Huron during the summer months (Bruno and Hiipakka, 1973). A field experiment by Wayne (1976) concluded that smooth cordgrass reduced wave heights by 71% and wave energy by 92% in coastal Florida. Common seagrass, a submerged aquatic, reduced wave heights by a maximum of 42.2% and wave energy by 66.6%.

The energy of waves is derived from winds blowing across a water surface. As the fetch or area of open water increases so does the height of the waves. Thus, the fetch and wave heights in the Tobico Marsh for example, are quite limited. However, on Lake St. Clair the fetch is greater and higher waves will be generated. Of the areas investigated, the greatest fetch is related to the wetlands bordering Saginaw Bay and western Lake Erie.

The significance of wave height is that it is one of the two parameters which is related to wave energy. The wave energy (E) is equal to $1/8\ H^2L$ where H represents wave height and L represents the length of the wave. Based on the above formula, it can be seen that as the height of the wave increases (due to the increase of the fetch) greater energy can be generated. Therefore wave energy in the lagoon at Tobico is relatively low compared to the shoreline of Tuscola County adjacent to Saginaw Bay.

Another way of viewing the impact of the amount of energy a wave delivers to a beach is conveniently described as wave steepness (H/L). Steep waves with values greater than 0.03 remove sediments from beaches and deposit bars, and sediments up the beach face in the form of storm berms (Great Lakes Basin Commission, 1975). Less steep waves (less than 0.03) bring sediment ashore and the beach is nourished.

Another factor related to wave energy and unique to Great Lakes coastal zones is the changing water levels (Figure 68). The fluctuating lake levels impact upon the wave energy in two ways. As water levels change, a change in composition and perhaps more importantly a change in vegetation density occurs. Figure 68 illustrates the changes which have occurred in the emergent macrophytes over a 12-year period in the study area at Tuscola County (Dickinson Road transect). As the level of Lake Huron rose 3.2 feet over that time period, the vegetation density of the cattails and three-square decreased and the wetland zone shifted landward.

A second factor associated with wave energy/wetland relationships is the impact of water level on the breaking waves. As waves move into shallow water, a decrease in the wave length and an increase in the height occurs. This transformation is gradual and begins to occur at a depth of about 1/2 WL. If the water level in the lake is high, it may be anticipated that the waves will move closer to the beach before breaking. In Figure 68 a wave breaking 1500 feet from the shoreline in June, 1963 may break within 100 feet of the shoreline in August, 1975. During higher water level conditions the wave energy is stored until the wave is nearer to the shoreline before breaking and expending its energy. Also the vegetation density is lower with the higher lake levels which also encourages the higher wave energies to be maintained.

The cumulative effect of wave energy/wetland relationships is reflected in the geomorphic framework of the shoreline. During lower water periods, barriers become broader as the nearshore zone becomes more and more exposed (Figure 68). The Woodtick Peninsula during the 1973-1974 high water period was breached and in many places the spit had widths of only 20 feet. However, with the lower levels since that time, exposed flats are increasing the width of the

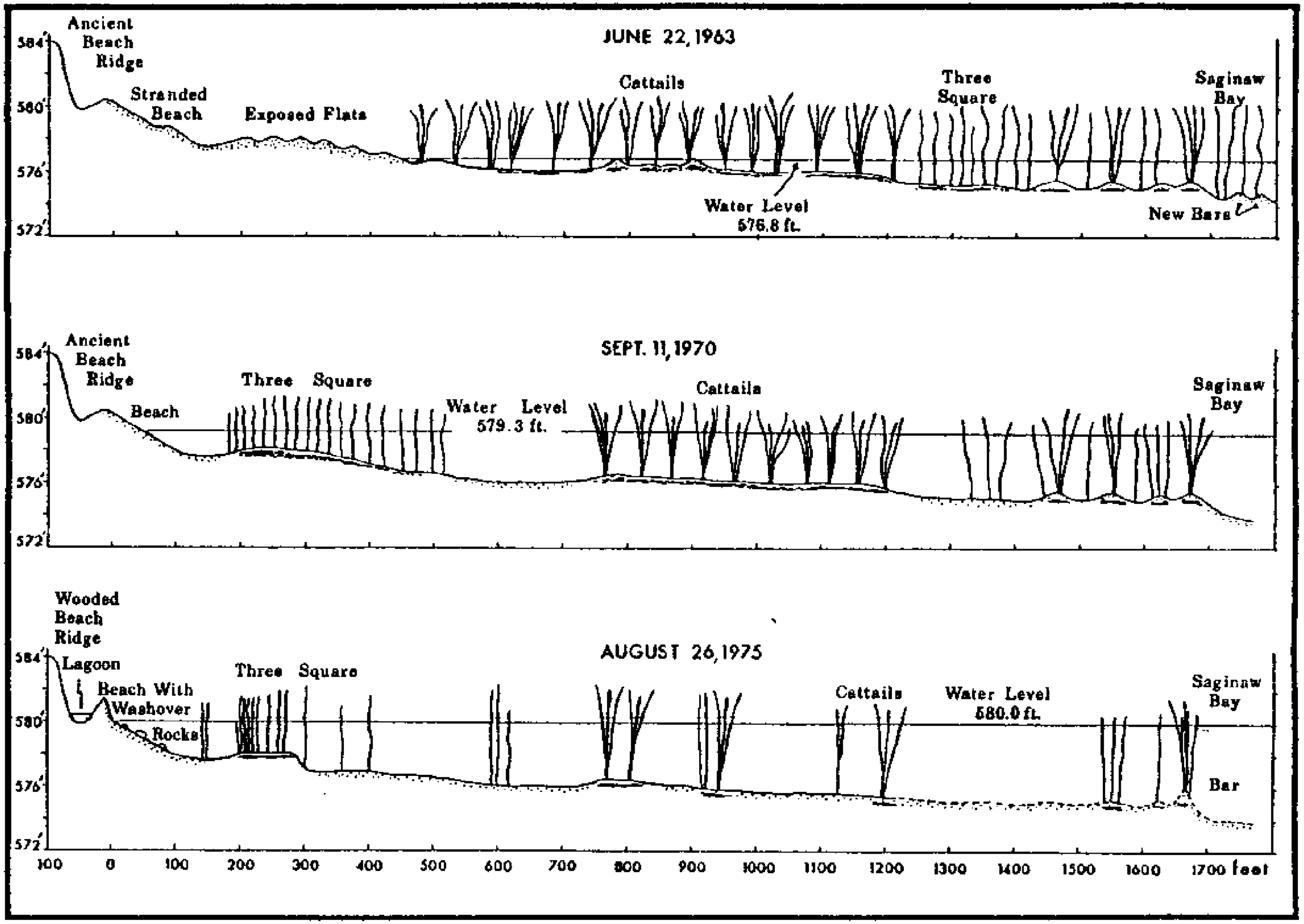


Figure 68. A Profile Illustrating Nearshore Wetland/water Level Relationships, Dickinson Road, Tuscola Co., in 1963, 1970, and 1975

peninsula. Also, assuming that the quality of the aquatic environment has not been further degraded, the nearshore wetlands will be restored and some wave energy dissipation may occur. A similar response occurred in 1963 (Figure 68).

During the higher water levels of the early 1970's, Woodtick Peninsula was almost completely destroyed. Beach deposits were reworked and storm berms developed at Woodtick and at Tuscola and Oconto. Also, coarse washover sands and fine gravels were deposited over the landward marshes. The type of barriers identified at Oconto, Tuscola, Woodtick, and Toussaint are classified as erosional or transgressive in origin. Also, many of the beaches investigated in the St. Clair Delta are transgressive features as well.

On many shorelines rafted organic deposits commonly occur. At Oconto the organics were most often incorporated in the storm berms. In Tuscola County the macrophytes littered broad zones of the shoreline and created organic beaches. Also, root mats (e.g., Typha spp.) were eroded and transported onto the adjacent premodern beach ridge and draped at the base of the woody vegetation. During higher water levels the emergent macrophytes lakeward of the Oconto and Woodtick shorelines are drowned or physically removed. This condition allows higher wave energies to be maintained and allows the creation of transgressive landforms. Although some wetland vegetation was destroyed in Saginaw Bay, a continuous zone paralleling the coast was maintained during the extreme high lake levels of the early 1970's. However, even here coastal erosion occurred in spite of the presence of nearshore wetlands.

Figure 69 is a schematic map and cross section which may represent typical shoreline/wetland relationships in the Great Lakes. The modern barrier is usually low and thin and was deposited upon a marsh as coastal recession occurred. In some coastal sectors, storm berms have been created which are juxtaposed to an older or premodern barrier. Good examples have been identified at Oconto and along the Tuscola County shoreline. The geomorphic framework of Woodtick Peninsula is composed of a transgressive barrier similar to that noted in the cross section.

Table 29 represents an overview of the investigated sites. Also, included are the nearshore wetland vegetation conditions which occur during low, average, and high lake levels. Based upon the previous discussion of the geomorphic framework, the coastal barriers may be classified as transgressive or regressive geomorphic features. The Betsie River wetlands are morphologically associated with a river rather than with a coastal system and hence the relationships noted on the table are not applicable.

As noted, during low water levels, wetlands colonize the nearshore zone of many coastal sites. At Oconto, Tuscola, Dickinson, and Woodtick broad emergent bands occur parallel to the shoreline. Quite possibly Toussaint may have supported more nearshore vegetation during low water in the historical past. However because of environmental changes (increased turbidity) the vegetation is now less abundant in this coastal zone. As lake levels rise to average levels the nearshore vegetation becomes less abundant and a decrease in density also occurs. Only at Tuscola and at Dickinson does the vegetation remain

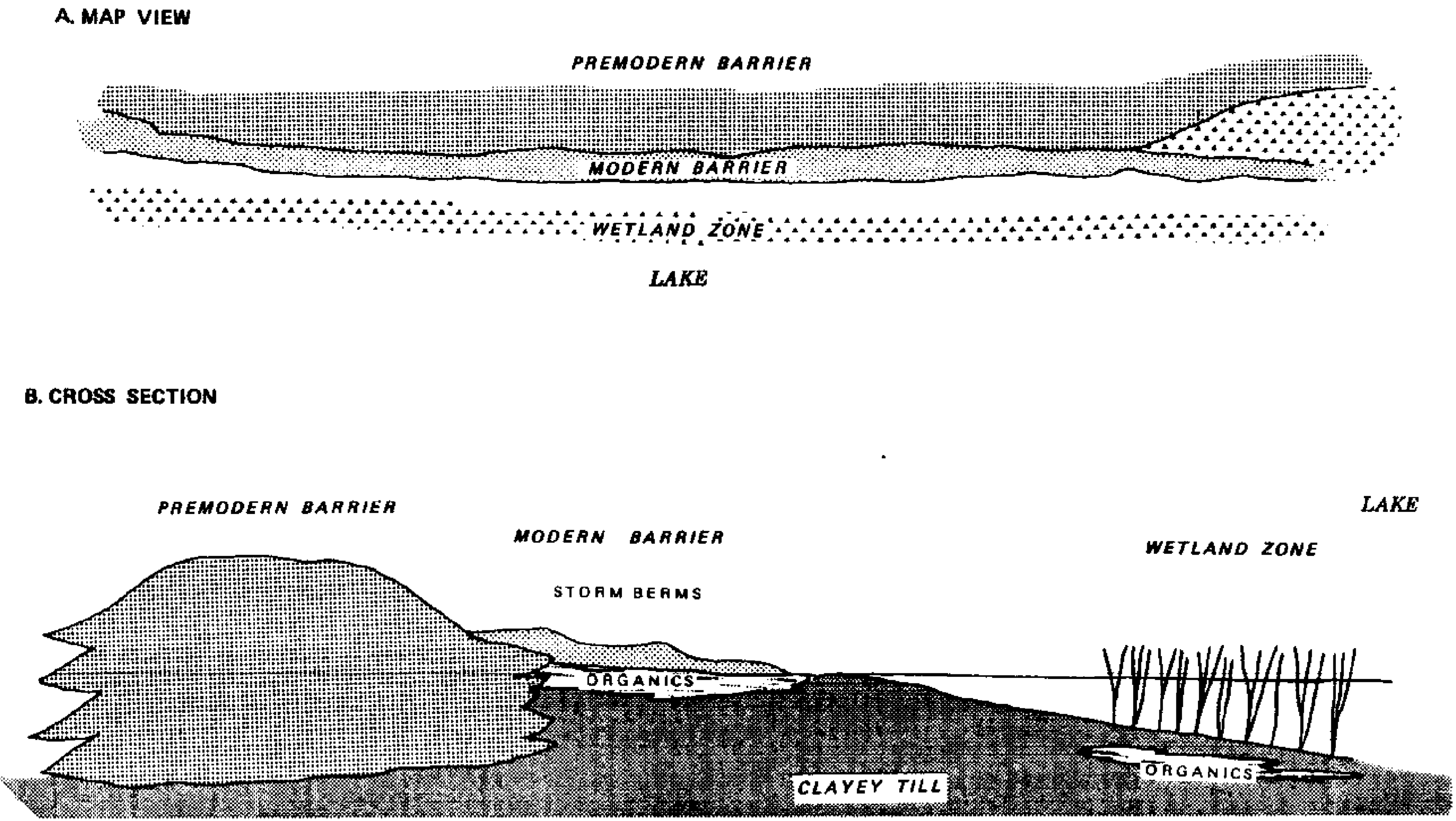
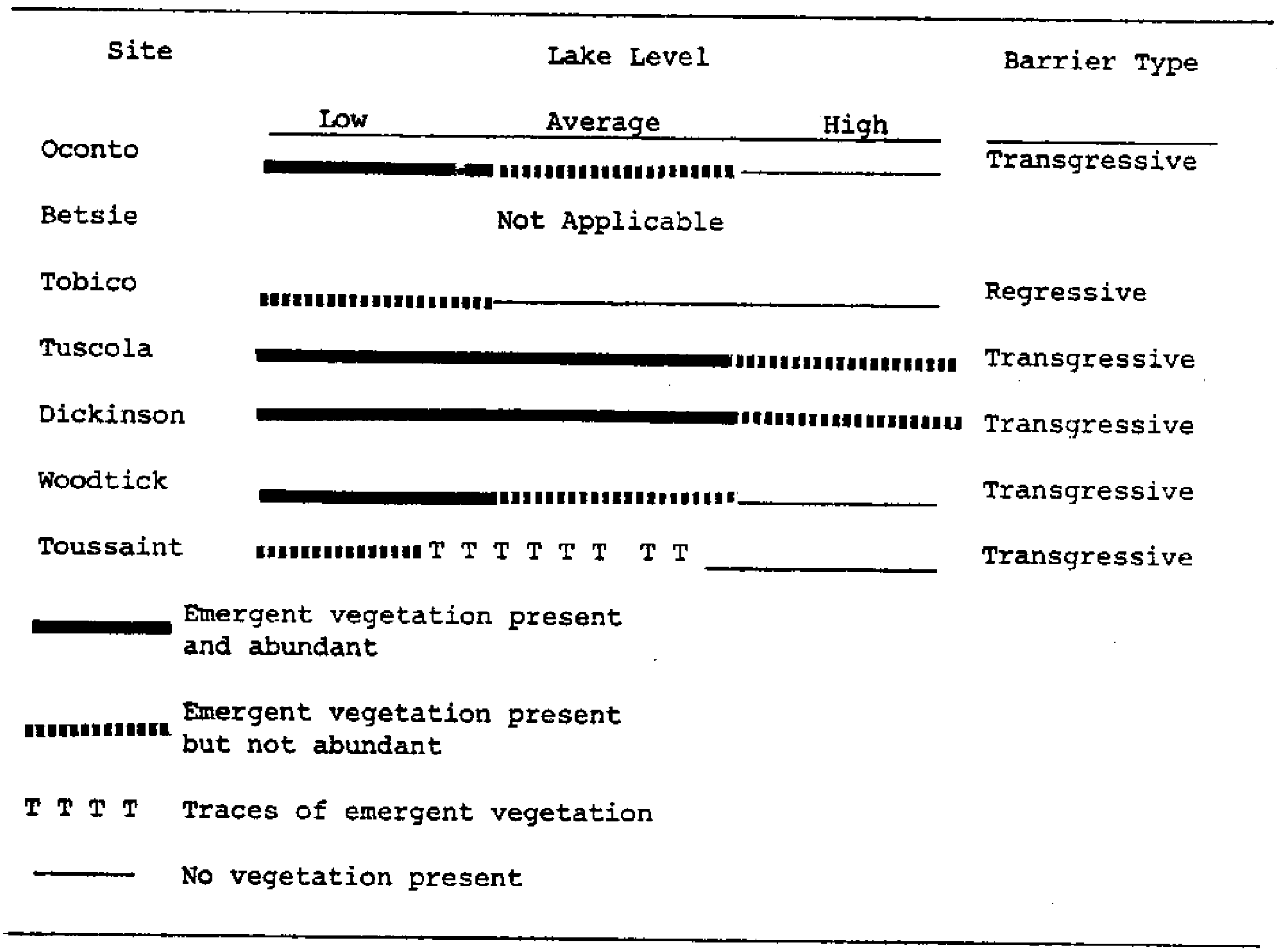


Figure 69. Schematic Map and Cross Section of Typical Great Lake Barrier and Wetland Relationships

Table 29

Occurrence of Nearshore Emergent Vegetation
and Coastal Barrier Types



continuous. As lake levels continue to rise and reach high water levels, some wetland continues to survive at Tuscola and at Dickinson whereas at the other sites the emergents have been lost.

The survival of vegetation in coastal wetlands may be related to wave power in the nearshore zone. As noted by Coleman (1976) wave power is related to the slope of the floor of the submarine basin. Where steep slopes are present, less wave dissipation or frictional attenuation occurs. However, low-angle submarine slopes are characterized by higher wave attenuation and hence lower energies occur at the shoreline.

Figure 70 represents the submarine slopes of the investigated areas except the Betsie wetlands. The information was plotted from National Oceanic and Atmospheric Administration navigation charts. Depths represent elevation below low water datum. Wave attenuation would be greatest at Dickinson and at Tobico followed by Tuscola. The remaining coastal areas would experience less difference between the offshore and nearshore wave powers. Therefore, relatively higher wave energy would be experienced at Toussaint, Oconto, and Woodtick. The submarine slopes and relatively high wave power especially during high lake levels may account for the loss of wetlands at Oconto, Woodtick, and Toussaint as indicated on Table 29. Conversely relatively lower energies in the nearshore zones at Tuscola and Dickinson may account for the survival of some wetland vegetation during higher lake levels. The nearshore emergents at Tobico are sparse during low water and lost during a rising level.

As noted in the field and reflected in the schematic diagrams, it is apparent that the Great Lakes' shorelines are not completely protected by nearshore wetlands. Erosion and coastal recession have produced shorelines which reflect relatively high waver energy. It has also been noted that higher water levels decrease emergent vegetation abundance and allow waves to come closer to the shoreline before expending their energy. During lower water levels, the macrophytes are denser and waves break farther from the shoreline.

Water levels and submarine slope appear to be factors controlling wave energy conditions in the investigated Great Lakes' shorelines. The wetlands may provide some protection to the shoreline expecially during lower water level conditions when lower wave energies and denser wetlands may be anticipated. During higher lake levels wetland vegetation is less abundant and wave energy expended at the shoreline is probably higher. Under such conditions shoreline recession occurs producing the transgressive landforms which have been identified and discussed in this report.

The viability of wetlands is dependent upon the type and condition of the barrier. Where regressive barriers occur (as at Tobico) the landward wetland (Tobico Marsh) is not likely to be eroded. However, where transgressive barriers occur, the landward wetland is not as well protected from the lake. Such barriers are often breached exposing the adjacent wetland to erosion. At Woodtick breaching of the barrier exposed the lagoon to Lake Erie and artificial dikes of the Erie Shooting and Fishing Club adjacent to the lagoon had to be reinforced because of erosion due to wave action. A second impact of barrier erosion is that the washover deposits frequently erode or bury the emergent marsh immediately landward of the barrier; this has been recorded in many of the

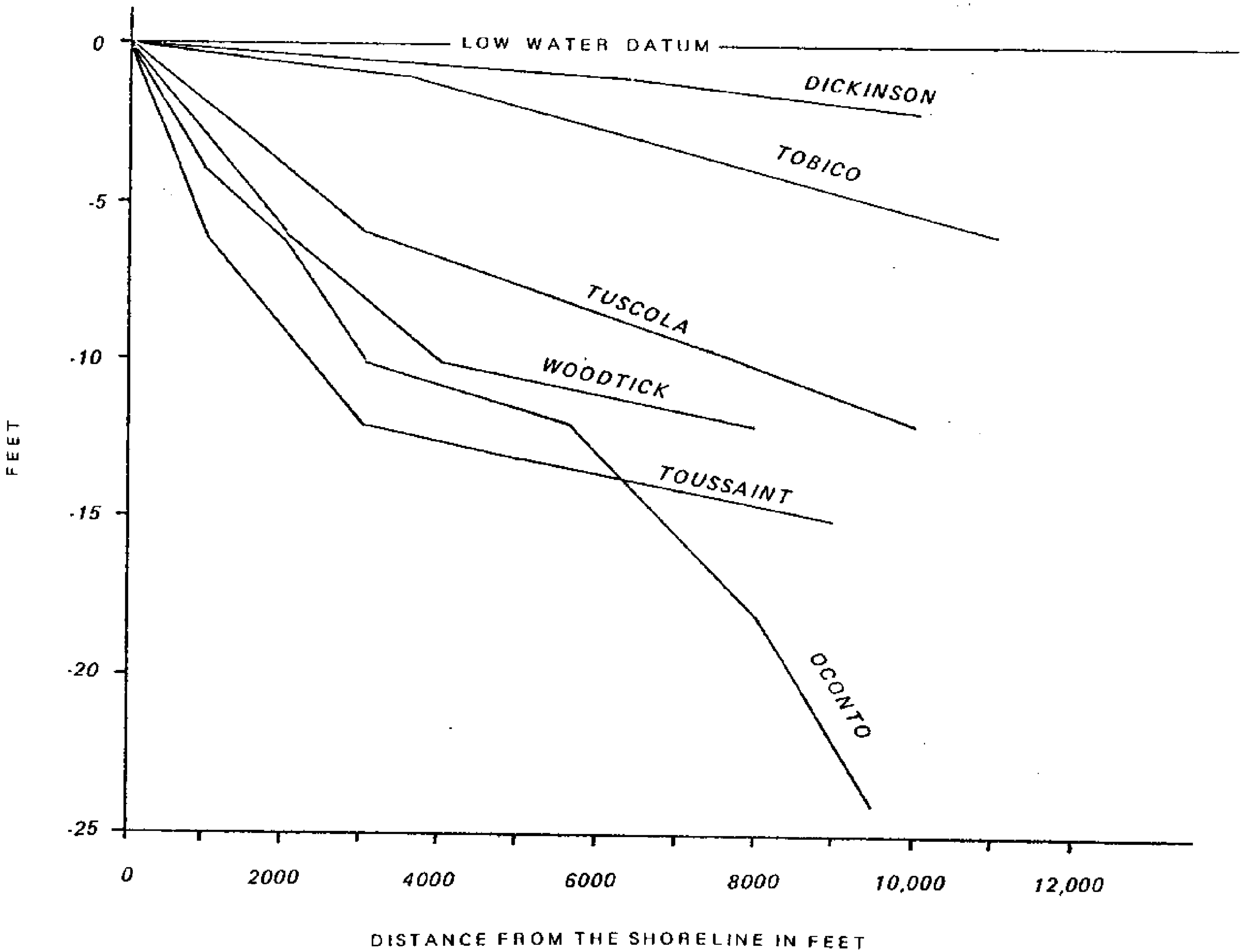


Figure 70. Submarine Profiles and Water Depths Adjacent to the Study Areas

cross sections. Based on our observations, breaching also causes increased turbidity in lagoons due to resuspension of fine sediments which inhibit wetland growth. This appears to be a problem in wetlands associated with clayey lake plains such as western Lake Erie rather than with wetlands with more sandy substrates.

Changes in Wetland Area

Based on area measurements obtained from the seven field sites, the coastal wetlands of the Great Lakes do expand and contract in concert with periodic lake level fluctuations (Table 30). As indicated in Table 30, the total area of the wetlands under investigation decreased from 10,304 acres during low-water conditions to 8,975 acres in high-water periods. This is a net change of 1,329 acres, or a 12.9 percent decrease in wetland area. Compared to its extent at mean lake level, and assuming stable water-level conditions for four to five years, a given wetland complex may increase its area by 6.7 percent during low water, but may decrease in area by 6.1 percent during high lake levels.

Table 30

Extent of the Wetlands at Various Lake Levels
by Wetland Study Area

Study Area	Low Stage (acres)	Average Stage (acres)	High Water (acres)
Oconto	1,650	1,404*	1,157
Betsie	373	307*	241
Tobico	1,260	1,243*	1,225
Tuscola	60	50	43
Dickinson	2,800	2,675	2,470
Woodtick	2,395	2,182	2,119
Toussaint	1,766	1,743*	1,720
TOTALS	10,304	9,604	8,975

* Computed by averaging the low- and high-water stage data.

As determined in this study, changes in the area of coastal wetlands occurred only in the littoral or nearshore zone. Field observations suggest that emergent and submersed vegetation tend not to colonize the nearshore zone along the Great Lakes where water depths exceed one meter. A depth of two meters is considered the lakeward limit of lacustrine vegetation according to the new U.S. Fish and Wildlife Service wetlands classification (Cowardin et al., 1976). Because the fluctuation of Great Lakes water levels is approximately three feet from the mean level for all lakes, except Lake Superior, high-water conditions can cause die-back of the lacustrine vegetation in the littoral zone. Not only are water depths increased, but the wave energy increases and the shoreline is displaced landward as beach erosion and washover ocur. Although ice rafting in spring appears not to be a major cause of wetland loss as reported by Bosley (1976), some marsh destruction may occur in spring as blocks of mudflats and cattail rootstalks float up and are blown out into deep water by offshore winds. During low-water conditions, except along high wave-energy coasts, emergent and submersed vegetation recolonizes the nearshore zone, especially where viable rhizomes and mudflats are present. The lakeward boundary of a wetland, therefore, is marked by the maximum lakeward extent of aquatic vegetation during low water (as observed on the 1937-1938 or the 1963-1966 aerial photography).

Because some wetland vegetation persists during high-water periods in areas landward of the shoreline, even in openwater sites, no areal change due to lake level fluctuations was recognized in this portion of the wetland complex. The landward margin of a wetland should be based on the boundary of hydric soils and/or on the presence of swamp or shrub trees which have lenticels or are capable of anaerobic metabolism (Fraxinus pennsylvanica). Because high-water levels, during the 1972-1975 period, cause die back of the wetland shrub margin, the leading edge of the live shrub or swamp margin marks the landward limit of flooding and/or soil waterlogging during the growing season. Grasses and sedges, (Phalaris arundinacea and Carex stricta) appear to tolerate somewhat more flooding than wetland shrubs without suffering die back, particularly if the turbidity is low and dissolved oxygen levels of the flood waters are high.

If the total area of coastal wetlands in the Great Lakes were known it might be possible to predict the areal extent of wetlands at any lake level. Utilizing data obtained in this investigation, an attempt to establish this relationship is illustrated in Figure 71. The shape of the curve which connects the acreage data points would reflect the rate at which succession or retrogression occurs as water levels fluctuate. A two to three year lag between high water and maximum die back and perhaps a somewhat longer lag between low water and maximum recolonization are suggested by the field investigation. Given additional data points, it may be possible to construct a regression line for the prediction of total wetland area on the basis of Great Lakes water levels.

Changes in Wetland Plant Communities

Coastal wetlands that are open systems, and some of those which are diked, exhibit plant community shifts in response to long-term lake level fluctuations. In this study, the areal changes of four wetland types, including open water/floating-leaved/submersed, sedge marsh and meadow, emergents (especially cattail), and shrub/forested wetland were measured in response to lake level fluctuations (Table 31). In general, as water levels increase, the percent area of sedge marsh/meadow, emergent marsh, and shrub/forested wetland decreases and the open water (and associated aquatic communities) increases. The sedge marsh/meadow exhibits the largest percent change, whereas the shrub/forested wetland changes very little.

Based on mean water-level conditions, the emergent marsh (including cattail) is the most widespread wetland vegetation type. Except for the Oconto and Betsie wetlands, where a more northerly climate and decreased dominance of

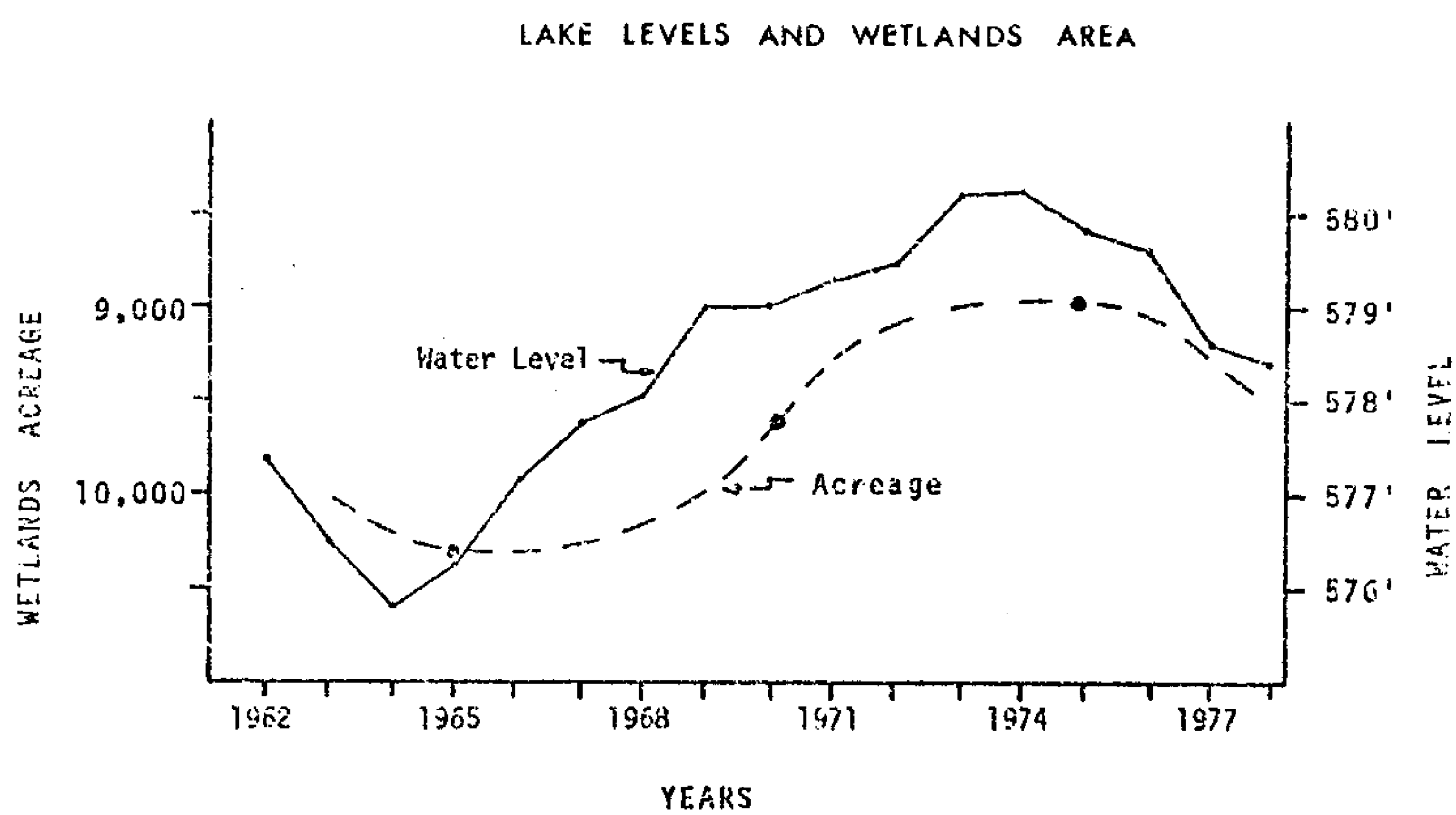


Figure 71. Relationship Between Lake Level Elevation and Change in Total Area of Wetland Study Areas. Water Level is of Lake Michigan-Huron.

Table 31

Areal Extent of Plant Communities by Lake Level Stage
All Coastal Wetlands[a]

	OPEN WATER/FLOATING/SUBMERSED			SEDGE MARSH AND MEADOW		
Study Area	Low	Average	High	Low	Average	High
Oconto	4.5	25.0	45	36.0	24.0	12.0
Betsie	12.5	27.5	43	33.5	29.0	18.5
Tobico	16.5	21.0	31	21.0	15.0	18.5
Tuscola	14.0	27.5	41.5	15.5	8.7	1.0
Dickinson	5.5	21.5	37.5	45.5	29.5	17.0
Woodtick	44.0	54.0	68.5	3.0	2.0	0.5
Toussaint	10.0	11.5	60.0	3.0	0.0	5.0
MEANS	15.3%	26.9%	46.6%	22.5%	15.5%	8.9%

	EMERGENTS (CATTAIL)			SHRUB/FORESTED WETLAND		
Study Area	Low	Average	High	Low	Average	High
Oconto	13.5	8.0	3.0	33.0	31.0	30.0
Betsie	20.0	15.5	11.0	19.5	19.0	18.5
Tobico	30.0	32.0	30.0*	15.0	15.0	15.0
Tuscola	42.5	43.9	32.0	14.5	13.3	12.0
Dickinson	37.0	31.5	28.0*	10.0	10.0	10.0
Woodtick	25.5	20.0	15.0	11.0	9.0	6.5
Toussaint	73.0	45.0	16.5	10.0	9.0	8.0
MEANS	34.5%	30.0%	19.4%	16.1%	15.2%	14.3%

* Includes die-back areas
[a] In percent of total area

the hybrid cattail (Typha glauca) may be reducing the extent of cattails, many Great Lakes coastal wetlands have 30 to 50 percent of their area in cattail and other emergents. Some of the Upper Great Lakes may be too ombrotrophic for optimum cattail growth (Phillips, 1970). The Woodtick Peninsula wetlands also have less emergents than the average, but this may be due to siltation which could smother cattail rootstalks in the dormant season and decrease the depth of the aerobic zone of the substrate for rooted aquatics. In contrast, certain mudflat species, such as softstem bulrush, have aerenchyma tissue and other mechanisms for survival in muddy substrates.

The effect of agricultural encroachment and other development on the sedge and meadow communities of the Woodtick and Toussaint wetlands is reflected in the tabular data. A paucity of graminoid communities reduces the habitat diversity, especially with regard to meadow nesting ducks and northern pike spawning. However, future agricultural encroachment on the extant graminoid communities of the western Lake Erie lake plains and in the Saginaw Bay Lowlands may be curbed by new Soil Conservation Service policies which preclude federal funding subsidy of drainage and other projects which involve wetland types three through eight (see Shaw and Fredine, 1965, for data on wetland types). Because wetland development usually proceeds from the landward margin inward, coastal wetlands which exhibit a disproportionately low area of graminoid communities also usually have little shrub or forested wetland fringe.

In an effort to highlight the percent composition of the wetlands at any lake level, the means from Table 31 were extracted and presented in Table 32. Note that even though the emergent marsh (especially cattail) may dominate, sedge marsh and grassy meadow communities are fairly widespread at low lake levels. In fact, much of the diking of coastal wetlands by private and public shooting clubs was carried out during low-water periods (1930's and 1960's) when dense cattail and widespread sedge communities reduced the quality of waterfowl and muskrat habitat. Because 80 percent of the sedge dies back naturally each year (Bernard and Gorham, 1978) and because the organic substrate beneath the tussock sedges may exhibit a high C:N ratio, relatively thick blankets of graminoid peats usually accumulate during low water.

Table 32

Change in Composition of the Wetland Vegetation by Lake Level Stage[a]

Vegetation Type	Low Water	Average Level	High Water
Open Water, incl. Submersed and Floating-Leaved	15.3	26.9	46.6
Emergent, incl. Cattail	34.5	30.0	19.4
Sedge Marsh, Meadow	22.5	15.5	8.9
Shrub/Forested Wetland	16.1	15.2	14.3

[a] In mean percent of total wetland area.
Note: Die-back areas were included in the live category.

As shown in Table 32, when lake levels rise, open water and associated plant communities increase in extent as the other communities retrogress. If the optimum wildlife habitat is a semi-marsh, (50 percent open water and 50 percent wetland vegetation; Weller and Spatcher, 1965), then higher lake levels would be preferred to maintain higher wetland wildlife diversity. The fluctuation of water levels not only precludes the formation of a dense, senescent wetland, it also enables the wetland to export organic detritus into the lake and to redistribute organic and/or fine-grained sediment within the wetland. The flux of allochthonous suspended sediments through the ecosystem as well as the resuspension of in situ clays and silts in the Woodtick Peninsula wetlands may, however, be adversely affecting the survival of floating-leaved and submersed aquatics during high water conditions. Reduced circulation and sediment trapping caused by the highway and railroad bridges at the Betsie River wetlands may also be reducing the diversity of aquatic plant species which survive the high-water periods.

In order to analyze changes in plant communities in response to lake level fluctuations, the vegetation at Dickinson Island was studied in great detail (Table 33). Dickinson Island was selected because it has an intact environmental gradient over which vegetation displacements can occur and because seiches are of small magnitude in this basin. In this case, a standard area of 2,800 acres was adopted, thus no net loss of wetlands occurs with lake level fluctuations. Only the extent of open water and of the vegetated categories changes as water levels fluctuate.

Table 33

Vegetation Changes in Response to Lake Level Fluctuations, Dickinson Island, Michigan

	Low Water		Average Level[a]		High Water	
Open Water	14[b]	(0.5)[c]	112	(4)	210	(7.5)
Floating-Leaved/Submersed	140	(5.0)	490	(17.5)	840	(30)
Emergents, incl. Cattail	1,036	(37)	883	(31.5)	784	(28)
Sedge Marsh	1,022	(36.5)	643	(23)	364	(13)
Grassy Meadow	252	(9.0)	182	(6.5)	112	(4)
Shrub/Swamp	280	(10)	280	(10)	280	(10)
Developed Lands	56	(2)	210	(7.5)	210	(7.5)
	2,800	(100%)	2,800	(100%)	2,800	(100%)

[a] These data were obtained by averaging the 1964 and 1975 data sets.
[b] Data in parentheses are percent of total (i.e., of 2,800 acres).
[c] Data in acres.

On the basis of aerial photography, it was difficult to distinguish between unvegetated open water and floating-leaved/submersed communities. Nevertheless, an attempt was made to separate the categories for the low-water period of 1964 and high water of 1975. The difference in water level between 1964 and 1975 was 3.6 feet. However, because the water level in 1973 exceeded the level in 1975, the effective water level range was 4.2 feet. Except for Lake Superior, a magnitude of 4.2 feet between low and high water levels is quite common in the Great Lakes. Notice that the emegent marsh (including cattail) dominates in area except during high water, and that the sedge marsh and grassy meadow decrease markedly as water levels rise. The shrub-swamp fringe exhibits little change largely because these communities lie above the flood limits and because the die-back of the shrub zone, if any, has been included within the shrub/swamp category.

A cross-section diagram is perhaps a better technique to show vegetation changes in response to water level fluctuations. As shown in Figure 72, an attempt has been made to model the plant community shift at Dickinson Island. Because data for the cross section were taken from the photo transects (Figure 72), similar models could be constructed for the other study areas as well (except for Toussaint Marsh). Each of the plant communities or vegetation types have been placed at the proper elevation (Table 34). Note the dashed lines (Figure 72) which have been extended downward and which indicate the extent of a given vegetation type for both low water (lakeward side) and high water (landward side).

Table 34

Elevation of Plant Communities, Dickinson Island at Low and High Water Level Stages

			Range
Floating-Leaved/Submersed/Bulrush			
Low Water:	572.0 ft.	174.3 m.	1.8 ft., 0.6 m.
High Water:	573.8 ft.	174.9 m.	
Emergent (Cattail)			
Low Water:	573.0 ft.	174.6 m.	1.8 ft., 0.6 m.
High Water:	574.8 ft.	175.2 m.	
Sedge Marsh			
Low Water:	573.5 ft.	174.8 m.	2.0 ft., 0.61 m.
High Water:	575.5 ft.	175.41 m.	
Grassy Meadow			
Low Water:	575.0 ft.	175.25 m.	1.5 ft., 0.45 m.
High Water:	576.5 ft.	175.7 m.	
Shrub/Forested Wetland			
Low Water:	576.0 ft.	175.6 m.	1.4 ft., 0.4 m.
High Water:	577.4 ft.	176.0 m.	

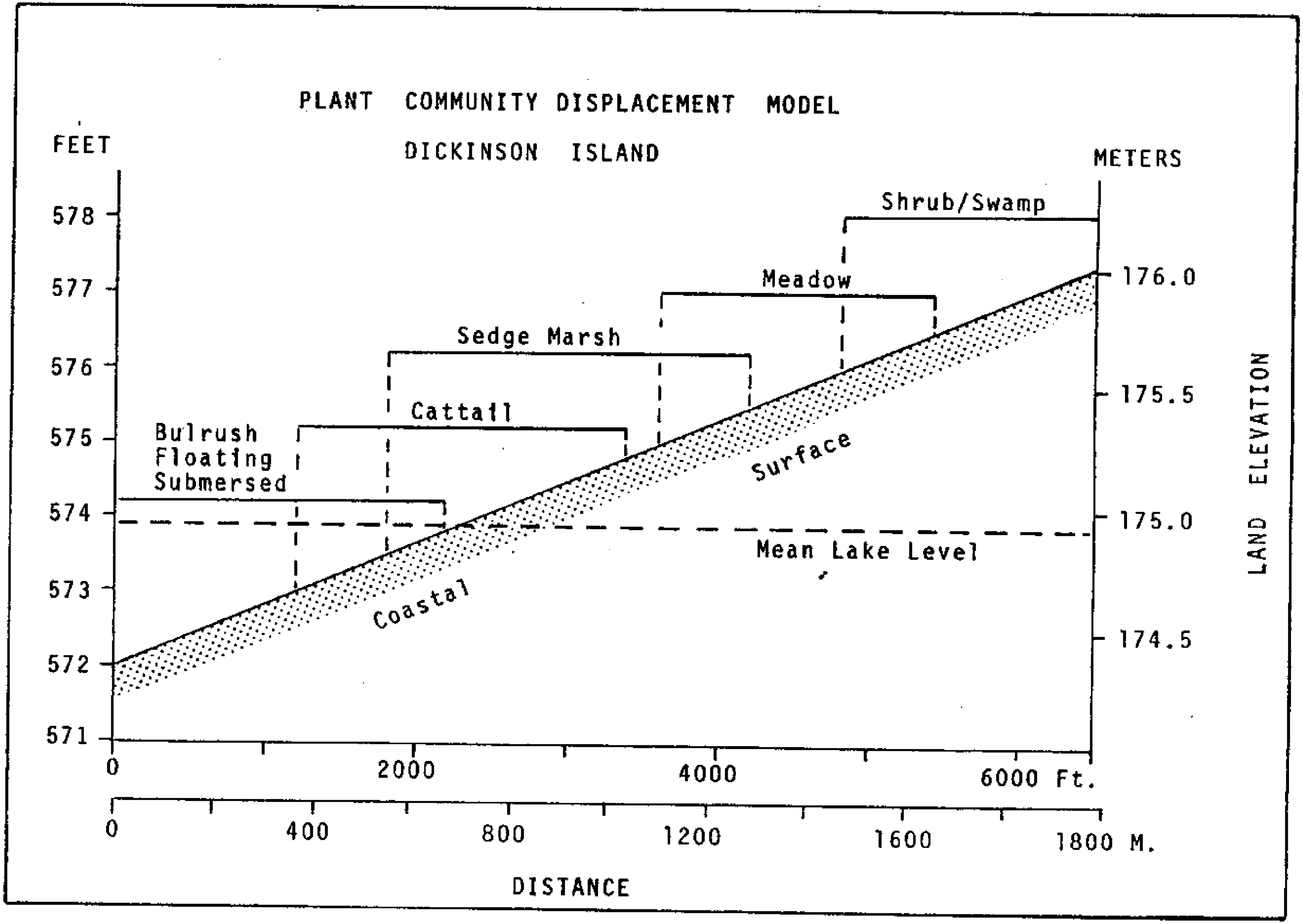


Figure 72. Plant Community Displacement Model for Dickinson Island, Michigan

The plant community displacement model can predict vegetation changes if future patterns are similar to historical changes. Notice that cattail communities are generally located near the mean water level, whereas floating-leaved/submersed aquatics/hardstem bulrush are generally restricted to levels below the average water level. Sedge communities occur in sites immediately above the mean water line, followed by grassy meadow and then shrub/forested wetland. As one moves up the vegetation gradient, the amount of community displacement is less and core areas appear to persist during both low- and high-water periods. As expected, the shrub/forested wetland zone shifts least and is overlapped the least by the adjacent community. Topographic irregularities, ponding landward of a barrier beach, as well as ditching and tiling could alter the distributions considerably.

The value of allowing coastal wetlands to shift during periodic lake level fluctuations has already been discussed by Jaworski and Raphael (1976). However, in some instances regulation of water levels in wetlands may prove to be beneficial to wildlife (Boss, 1976). On Dickinson Island there may be little need for artificial water level management because an entire gradient of habitats are available at any lake level. Moreover, the presence of active and abandoned channels in the St. Clair Delta provide connectivity and circulation. In contrast, the Toussaint Marsh and Woodtick Peninsula wetlands are boxed in by Lake Erie and agricultural encroachment. One strategy may be to acquire properties along the landward margin as well as to provide connections to Lake Erie so that an open system results.

Significance of Wetland Changes

Although an inventory of fish, wildlife, and recreational values or uses of the coastal wetlands during the various lake stages was not conducted *per se*, these relationships were regarded as very important. Given the present concern for wetlands protection and management as well as for lake level regulation (International Great Lakes Levels Board, 1973), the significance of the changing value of coastal wetlands in response to lake level fluctuations is clear. Because of the scope of this study and the authors' experience in Great Lakes wetlands (Jaworski and Raphael, 1978), an attempt was made to associate selected wetland uses and functions with lake level stages (Table 35). This preliminary table of relationships was patterned after a habitat utilization diagram by Weller and Spatcher (1965).

During low water, common wildlife users of coastal wetlands include the red-winged blackbird, short-billed wren, blue-winged teal, mallard, and the muskrat. Some feeding and breeding of dabbling ducks may occur, especially near the remaining open-water areas. White-tailed deer, cottontail rabbits, and small rodents may also utilize coastal wetlands during low water levels.

In comparison, during high water periods the wildlife diversity increases and may include several unique forms including black terns and yellowheaded blackbirds. For example, Roznik (1978) found that yellowheaded blackbirds prefer a wetland with 60 percent open water and scattered robust emergents. Increased water depths generally provide improved habitat conditions for invertebrates as well as for amphibians and reptiles which, in turn, increase the wetland use by piscivorous birds and predator fish. High water may facilitate the interchange between the lake and the wetland, and thus permit fish spawning (northern pike) as well as the wetland rearing of forage fish (gizzard shad).

Non-wildlife functions of the coastal wetlands may be more important than wildlife considerations, especially in reference to Great Lakes water quality. Though poorly researched at this time, Table 35 suggests that water level plays a major role in circulation and water quality of wetlands. In general, during low water levels sedge and cattail communities are dense and the water table usually lies beneath the marsh surface. Peat tends to accumulate and the absence of clastic sediments in the peat indicates that little allochthonous material is being transported through the system. Land drainage dominates as reflected in a lower pH and perhpas by reduced carbonate levels as well. Where perhaps much of the substrate is sandy or peaty, as in Tobico Marsh, lower lake levels may be accompanied by a tendency toward ombrotrophic conditions.

In contrast, during higher water the circulation system is improved and lake water may enter the wetland directly through creeks or breaches in the barrier beach. If the lake water has a somewhat higher pH, more dissolved oxygen, lower temperature, and higher levels of carbonates, the introduction of lake water masses may directly affect the species composition of the submersed and floating-leaved communities.

During the high water of the 1972-1975 period, the authors noticed that many of the lagoons and deltaic wetlands were exporting organic detritus from the marsh into the lake. The die back and flotation of cattail colonies may play a large role in this regard. High-water levels may result in increased turbidity levels and subsequent siltation as noticed in the deposits found in the Woodtick, Betsie River, and Tobico Marsh wetlands. In the Woodtick Peninsula wetlands, the suspension of <u>in situ</u> clays may be due to carp activity, wave erosion of artificial levees, and the introduction of sediments from terrestrial sources. In places, high water may result in the elutriation of polluted bottom sediments given sufficient wetland flushing and sediment reworking.

Water level changes are important because of human reaction to wetland losses. For example, during the 1972-1975 high water period the Pointe Mouillee marsh at the mouth of the Huron River, western Lake Erie, underwent extensive erosion after the protective barrier was destroyed by wave action (Sellman, et al., 1974). Moreover during this same period the State of Ohio lost most of its coastal wetland except for 14,372 acres which had been previously diked by private and public interests (Weeks, 1974). Ohio responded by placing boulder revetments along its public shoreline (Bednarik, 1975). Although such revetments stop additional erosion, the hydrological function of the coastal wetlands is seriously impaired and multiple use of the potential resources is not possible. In the state- and federally-owned wetlands, construction of wetland protection structures usually proceeds without an environmental impact statement. Because few states have sufficient funds for wetland protection or for shoreline improvement, states may entertain solutions that are federally funded, but which may not be compatible with the long-term ecology of the coastal wetland.

Table 35

Wildlife Use and Other Functions of Coastal Wetlands
At Low and High Water Levels

Use/Function of Wetlands	Low Water	High Water
A. Use by Wildlife:		
Blue-winged teal (breeding)	- - - ---------	
Red-winged blackbird	-----------------	- - -
Mallard (breeding)	- - ----------	------- - - -
Short-billed wren	--------- - -	
Muskrat	- - - --------	-------- - - -
Black tern		- - -------
Yellowheaded blackbird		- - -------
Great blue heron	- - -	- ------------
Belted kingfisher	- - -	- ------------
Crayfish	- - -	- ------------
Frogs and turtles		- - ------------
Fish spawning (N. pike)		- ------------
Forage fish		- ----------
Dabbling ducks (feeding)	-- - - ----------	------ - - - -
Diving ducks (feeding)		- - ----------
B. Other Functions:		
Peat accumulation	--------- - - - -	
Sediment trapping	--------- - - - -	
Hemi-marsh		- - - ----------
Water circulation		- - - ----------
Dominance of land drainage	--------- - -	
Dominance of lake water masses	-	- - ------------
Turbidity levels		- - - ----------
Export of detritus	-	- - ------------
Re-suspension of *in situ* clay		- ----------

It is estimated that 40 percent of the extant coastal wetlands along the Great Lakes are diked and/or subject to artificial water level management. Most of these diked wetlands are owned by private and public waterfowl hunting organizations who manage the wetlands for duck hunting in the fall. Barclay and Bednarik (1968) have determined that 22 percent of moderate- to high-value waterfowl habitat in the Mississippi Flyway is in private ownership.

Traditionally, diking provided protection from low water as well as from high water and enabled marsh managers to cultivate or stimulate preferred foods for migratory waterfowl and muskrats. More recently, the practice of diking and water level management of wetlands has been questioned (Stearns, 1978). Instead, emphasis is on multiple resource use and the reliance on natural processes to generate the desired management results. Moreover, the adverse effects of diking and other hydrological alterations on the natural diversity of freshwater wetlands has only recently received some attention (Jaworski and Raphael, in press).

Construction of surface drains, tiling of cultivated fields, and clearing of marginal agricultural land in the lake plain areas have fragmented and reduced the water quality of many coastal wetlands. The most eutrophic waters of the coastal Great Lakes occur where the agricultural encroachment and wetland losses have been the greatest (International Joint Commission, 1978). In fact, diking of coastal wetlands (Erie Shooting and Fishing Club Marsh and the Toussaint Marsh), may protect them from contamination by local surface runoff. The apparent lack of floating-leaved and submersed aquatic species along western Lake Erie, especially in the undiked Woodtick and Toussaint wetlands, attest to the potential adverse impact of local surface runoff on coastal wetlands. Stuckey (1971, 1978) reported that siltation and excessive nutrient loading, as well as other causes, may have eliminated several intolerant plant species from the wetlands of western Lake Erie. In contrast, a pollution-intolerant freshwater sponge exists inside the diked Toussaint Marsh where the water quality is superior to that of Toussaint Creek.

If sediments are transported through or around the coastal wetlands into the nearshore zone, storms and higher wave action during high lake levels may re-suspend these fine-grained materials (Jaworski and Raphael, 1978). Fine-grain sediments accumulate along the relatively low wave-energy Great Lakes coasts and may be associated with a reduction in preferred waterfowl foods (e.g., Vallisneria americana) and fish spawning habitat (Jaworski and Raphael, 1978). A need exists for a nonpoint water quality management strategy which provides for a "green belt" of terrestrial vegetation which could protect coastal wetlands from excessive turbidity and nutrient loadings. This filter belt may be more important during high lake levels when regional precipitation and/or runoff may be greater and water circulation in the wetlands more efficient.

CONCLUSIONS

Considering the national attention coastal zones have received within recent years (Coastal Zone Management Act of 1972) literature on the morphology of Great Lakes coastlines and wetlands is deficient. There is a lack of field-derived baseline data on historical wetland distributions, wetland functions, and shoreline geology, including studies of lake level/wetland/coastal relationships. It was, therefore, decided in the early stages of this investigation that data had to be obtained from the field and supplemented by aerial photographs and available soil data. The observations and conclusions presented here are largely based upon data gathered in the field.

The range of periodic water level fluctuations of the Great Lakes, except for Lake Superior, is 5 to 6 feet. Along the gently sloping wetland shorelines, this oscillation is approximately one meter above and below the mean water level for each lake. In recent years, two record high-water periods, which occurred in the early 1950's and early 1970's, were separated by a near record low of the mid-1960's. These lake level fluctuations not only interrupt the normal hydrarch succession, but produce the "pulse stability" and high productivity associated with freshwater wetlands.

In terms of a topographical framework, the investigated wetlands fall into four environmental settings. Wetland habitats are associated with deltaic landforms, coastal embayments, barrier/lagoon complexes, and nearshore zones. With a geomorphic perspective, wetland occurrence is related to structural geology, lacustrine topography, or to a fluvial system initiated in the geologic past. The wetlands of Green Bay, for example, are confined to the western shoreline (e.g., Oconto). Their occurrence is related to the regional dip of the sedimentary rocks of this part of the Michigan structural basin (Niagara Escarpment). The linear wetlands, which extend perpendicular to the eastern Lake Michigan shoreline, occupy river basins that are related to cut and fill processes during the oscillating lake levels of the geologic past. These wetlands occupy flood plains which are so featureless that there is even a lack of natural levees. The absence of landform diversity here contributes to a lower wetland diversity than in many barrier/lagoon wetland systems.

The most extensive wetlands are associated with clayey lake plains deposited since the retreat of the Wisconsin ice sheet. These wetlands exhibit considerable landform diversity, in terms of a geomorphic framework, since they include deltaic wetlands, wetlands protected by a diversity of coastal barriers, and wetland colonizing the nearshore zone. Of the landscapes investigated, the greatest diversity in landforms occurs on Dickinson Island. Included are landforms created by the St. Clair River (natural levees old channels, river shoulders) as well as landforms created by wave action (beaches). In addition to the diversity of landforms created by different lake levels during the geologic past, the flow-through hydrology and lack of human impact are unique. Of the seven study areas investigated, Dickinson Island has outstanding geomorphic and ecological characteristics and is most worthy of preservation.

Coastal wetlands and associated shorelines exhibit a varying degree of geomorphic stability. Many of the coastal barriers investigated and mapped are erosional (transgressional) in origin and appear to have been displaced landward, particularly during the high water levels of the mid-1970's. Such barriers are normally less than five feet above present water level, are composed of medium to coarse sands, and are stratigraphically a few feet (usually less than five) in thickness and rest on finer sediments on organic deposits normally associated with lagoons or backbarrier wetlands. The only coastal barrier identified which was not transgressional was at Tobico. Also, the St. Clair River delta (Dickinson Island) has exhibited little erosion over the past several decades. The latter coastal area exhibits the gentlest offshore slopes suggesting that wave energies here are generally low compared to the other investigated sites. Thus erosion of the barrier and marshes of these two sites is less extensive. Based upon the geomorphic framework, the Tobico and Dickinson Island wetlands appear to be stable geomorphically and biologically productive.

Isostatic movement is another physical factor which may impact the geomorphic stability of barriers, and hence wetlands, of selected localities of the Great Lakes. According to several investigators, subsidence of the western Lake Erie basin has caused a relative rise in lake level over the past several centuries. Should subsidence of the basin continue, coastal wetlands may be threatened, especially if landward displacement is prevented by competing land uses. Over a longer period, coastal wetlands may be lost and estuarine wetlands in drowned river mouths may become more extensive.

Although erosion is a process common to most of the barriers investigated, total or permanent barrier destruction is uncommon. The Woodtick Peninsula has been narrowed to a width of 20 feet during the high waters of the 1970's. However, sediments are now being redeposited and the barrier width is increasing. Furthermore the archaeology suggests that the barrier has maintained itself for at least 600 years.

A problem perhaps more serious to the wetland viability than the destruction of the barrier and exposure of the wetland to wave erosion is the degradation of wetland water quality. Many of the coastal wetlands located on lake plains appear to have been degraded by increased turbidity and fine-grained substrates. In many western Lake Erie coastal zones, diked wetlands are colonized by emergent and submergent vegetation whereas adjacent non-diked wetland areas are devoid of sumbersed and floating-leaved communities.

The geomorphic framework does exert some control over the substrate type. In general, more confined or protected wetlands are dominated by organic substrates, whereas the more open and unprotected wetlands are characterized by a higher mineral content in the soils. Peat accumulations of several feet were logged in the Betsie River embayment and at Tobico--two wetland systems completely protected from the Great Lakes. Conversely, the nearshore wetlands of Oconto and Tuscola County have accumulated very little peat. Perhaps the lack of thick peat accumulations at Woodtick Peninsula may be related to periods of high turbidity which discourages dense emergent plant growth. Moreover, the introduction of inorganic sediment, due to breaching of the coastal barrier, and exportation of the organics from the lagoons during high lake levels, may also reduce peat accumulation.

Because of the erosional character of most shorelines, the occurrence of nearshore wetlands does not seem to provide an effective buffer against coastal recession. It must be noted that as lake levels rise, emergent vegetation becomes less dense and waves break closer to the shoreline. Such conditions encourage erosional activity observed along many shorelines. In Tuscola County, the nearshore wetland vegetation has decreased, but has survived the higher water levels of the early and mid-1970's. However, even here transgressive beaches are characteristic, suggesting that the remaining wetlands are ineffective in retarding coastal erosion.

Using surveying instruments, including a dumpy level and a 100-foot tape, bisects along selected wetland environmental gradients were surveyed. Analysis of plant macrofragments (rhizomes and peat deposits) and interpretation of sedimentary sequences permitted the partial reconstruction of recent successional events. Low lake levels (mid-1960's) are generally accompanied by in situ peat accumulation, especially if sedge and cattail communities are present. During high-water periods, die back of wetland communities and redistribution of peats may occur. High water allows the introduction of Great Lakes water masses which, in turn, may result in increased wave action, higher wetland turbidity, and exportation of detritus from the wetlands into the nearshore environment. Along western Lake Erie (Woodtick Peninsula and Toussaint Marsh), high water is accompanied by the deposition of land-derived suspended sediment in undiked portions of the coastal wetlands.

Plant community maps, prepared for each of the seven study areas, revealed that as lake levels change, the wetland communities alternately undergo succession and retrogression. In general, during low-water conditions the deep-water marsh communities decrease in extent along with the total area of open water. In comparison, during high-water periods the open water and floating-leaved/submersed communities expand while all other communities (emergents, sedge marsh, grassy meadow, and shrub/forested wetland) decrease in extent. The sedge marsh/grassy meadow exhibited the greatest net change in area as this combined vegetation type accounted for 22.5 percent of the total wetland area at low lake levels, but only 8.9 percent at high levels. In contrast, the shrub/forested wetland type exhibited the least net change in response to water level changes.

The succession or retrogression of vegetation communities was illustrated by a series of photo transects which were constructed for each study area (except Toussaint Marsh). The 1977 or 1978 field bisect served as the base for redrawing transects for time periods representing other lake level conditions. By noting, for each wetland plant community, the lakeward extent at low water and the landward limit at high water, a model of plant community displacement was constructed. The distribution limits of the plant communities can be read off the photo transects which were prepared for the study areas and/or from the three vegetation maps which represent various lake level conditions.

A plant community displacement model for Dickinson Island indicates that the floating-leaved and submersed communities are generally found in sites situated below the mean water level whereas cattail (emergent marsh) is usually located approximately 15 inches above and below the mean lake level. A sedge marsh is typically located on the landward side of the emergent marsh, followed in order by a grassy meadow and then a shrub/forested wetland fringe. The model also indicates that a narrow zone of sedge marsh persists as sedge at any lake level, but that deep-marsh communities, including cattail, floating-leaved, and submersed aquatics, may be completely displaced by other communities or by open water. In contrast, the grassy meadow and shrub/forested wetland communities exhibit an even larger core area than the sedge marsh. Moreover, field observations suggest that complete die back of plant communities may lag behind the time of high water by two to three years, whereas the lag between low water and maximum recolonization is even longer, especially for woody species.

Because lake level fluctuations may determine the presence or absence of wetland vegetation in the nearshore or littoral zone, the total area of wetland changes as Great Lakes water levels oscillate. Data from our seven study areas reveal that the coastal wetlands increase in total area by 12.9 percent as water levels drop from high levels to low levels. The percent loss or gain is greatest in those wetlands, e.g., Tuscola County, where non-persistent lacustrine vegetation is present in the littoral zone. In contrast, permanent wetland loss has occurred historically as a result of agricultural and other land use encroachments along the landward margin, as well as due to dredging and filling, and to a lesser extent, due to the continual decline of lacustrine vegetation in the nearshore zone.

Although little emergent vegetation along western Lake Erie survived the record high water of the early 1970's, increased water depths and increased wave energy climates are not the only causative factors. A map comparison pertaining to Woodtick Peninsula, covering the time period 1938 to 1975, documented the steady decline in the extent of floating-leaved and submersed communities as well as the simultaneous increase in the area of unvegetated open water. Because the species diversity and percent cover of plant communities located within diked wetlands exceeds that of open wetlands, it is felt that surface runoff in the coastal zone is degrading the water and substrate quality of many open coastal wetlands. In wetlands where turbidity levels were low and where deposition of land-derived sediments did not occur, as at Oconto, Betsie, Tobico, Tuscola, and Dickinson Island, re-establishment of wetland communities following the high-water of the 1970-1975 period was most impressive. Thus, factors which influence the displacement of wetland communities in response to lake level oscillations include water depth (or depth to water table), wave energy, substrate type, and turbidity levels.

As plant communities change with the oscillation of lake levels, so does the mix of wetland uses and functions. Although each wetland is somewhat unique, certain preliminary statements can be made. During low-water periods, wildlife such as redwinged blackbirds, short-billed wrens, and muskrats are abundant. In contrast, during high lake levels, aquatic and open-water communities become more abundant including fish, frogs, turtles, piscivorous birds, and diving ducks. Because a hemi-marsh tends to exist at high lake levels, and because wildlife diversity is highest when the open water-wetland vegetation cover ratio is approximately 50:50, some wetland managers may prefer high lake levels over low levels. Dickinson Island, which has an intact environmental gradient and thus permits vegetation shifting during lake level changes, may consistently exhibit the highest habitat diversity of all coastal wetlands in the Great Lakes.

Water levels also influence other wetland functions as well. During low lake level periods, the coastal vegetation may complement streamside, floodplain, and other terrestrial "green belts" in the region which are providing some sediment trapping and nutrient uptake capacity. Land drainage may dominate the wetland hydrology at this time, and if the water table lies beneath the surficial wetland deposits, little land-derived sediment or nutrient may be transported through the wetlands into the Great Lakes. During high water, in contrast, water depths increase in the wetlands and thus influent drainage waters may be dispersed throughout the inundated wetlands. Turbidity levels may rise due to allochthonous inputs and because increased wave action may entrain some of the *in situ* organic matter. In some wetlands, where breaches in the barrier beaches permit the exchange of water between the lake and the wetland, improved circulation may facilitate redistribution and elutriation of wetland bottom sediments, as well as flushing of some detritus and suspended sediments out of the lagoon into the nearshore environment. Although diking may protect wetlands against erosion during high lake levels and prevent contamination from polluted land drainage, structural management strategies usually reduce the diversity of wetland uses and functions, particularly with regard to fish habitat and hydrologic functions.

CULTURAL SETTING

POPULATION

Tables 36 through 41 provide figures on estimated population for 1975, and changes in population from 1970 to 1975, for the coastal counties of the Great Lakes. The total population of the coastal counties is 15,304,171. As reflected in Table 41, the counties have, overall, experienced rapid population growth between 1970 and 1975, with growth averaging about 5% during the five year period. The coastal counties of Lake Michigan and Lake Huron, in particular, showed very rapid growth rates (7.7% and 9.6%, respectively) between 1970 and 1975. Lake Superior, Lake Erie, and Lake Ontario exhibited slower growth rates of 3.7%, 1.4%, and 2.7% for the same period.

Several trends can be noted for the growth that took place between 1970 and 1975. Most rapid growth generally occurred in the less populated counties along the shoreline, while stable growth or some population decline occurred most often in those counties containing urban areas. Figures 73 through 77 show the major urban areas along the shoreline of the Great Lakes. Each of these urban centers has a population of 25,000 or more.

It should be noted that the population figures provided in Tables 36 through 41 do not accurately reflect the seasonal population of the lakeshore counties, since seasonal populations are not reported in the census data. Figures that are available for Lake Michigan indicate that the relative amount of seasonal housing may be as high as 47% in some coastal counties. Thus, a number of the counties along the shoreline of the Great Lakes are likely to have summer populations in excess of what is reflected in Tables 36 through 41.

Future population projections for the coastal counties vary considerably, and in many cases, different methods of projection have been utilized. This lack of uniformity in methods makes it difficult to reach any general conclusions about future population changes in the coastal counties. However, it may be noted that some consistent projections for 1990 are available for the coastal counties of Lake Michigan. These figures indicate that the rapid population growth that has been occurring along the Lake Michigan shoreline will gradually taper off to slow growth.

LAND USE AND OWNERSHIP

Table 42 provides information on land use along the shorelines of each of the Great Lakes. The two major land use categories along the shoreline are residential-commercial-industrial structures, and forested lands. These two categories comprise approximately 72% of the total shoreline mileage. Shoreline land use patterns tend to vary considerably from those of the Great Lakes Basin as a whole. Consideration of land use patterns of the entire basin indicates that agricultural land use is much more prominent, while urban and built-up land use is considerably less prominent. Table 42 also provides information concerning shoreline ownership by lake. Approximately 83% of the total shoreline mileage is under private ownership. States and localities are

Table 36. Population of Coastal Counties - Lake Superior[a]

County	Estimated population 1975	% Change 1970-1975
Lake, Minnesota	13,780	3.2
Cook, Minnesota	3,688	7.7
St. Louis, Minnesota	216,220	-2.0
Iron, Wisconsin	6,627	1.4
Douglas, Wisconsin	44,379	-0.6
Bayfield, Wisconsin	12,565	7.5
Ashland, Wisconsin	16,616	-0.8
Gogebec, Michigan	20,810	0.6
Ontonagon, Michigan	11,357	7.7
Houghton, Michigan	36,960	6.7
Keweenaw, Michigan	2,173	-4.0
Baraga, Michigan	8,060	3.5
Marquette, Michigan	69,467	7.4
Alger, Michigan	8,977	4.8
Luce, Michigan	7,115	4.8
Chippewa, Michigan	35,993	11.0
Total	516,787	3.7

[a]U.S. Bureau of the Census (1977)

Table 37. Population of Coastal Counties - Lake Michigan[a]

County	Estimated population 1975	% Change 1970-1975
Mackinac, Michigan	10,714	10.9
Schoolcraft, Michigan	8,659	5.3
Delta, Michigan	39,358	9.6
Menominee, Michigan	25,563	4.0
Marinette, Wisconsin	37,555	4.9
Oconto, Wisconsin	27,356	7.1
Brown, Wisconsin	169,467	7.1
Kewaunee, Wisconsin	20,138	6.2
Door, Wisconsin	22,469	11.8
Manitowoc, Wisconsin	82,560	0.3
Sheboygan, Wisconsin	99,814	3.3
Ozaukee, Wisconsin	64,519	18.5
Milwaukee, Wisconsin	1,012,335	-4.0
Racine, Wisconsin	175,781	2.9
Kenosha, Wisconsin	122,621	4.0
Lake, Illinois	407,373	6.5
Cook, Illinois	5,369,328	-2.3
Lake, Indiana	546,757	0.1
Porter, Indiana	96,327	10.6
LaPorte, Indiana	105,857	0.5
Berrien, Michigan	170,549	4.0
Van Buren, Michigan	61,734	9.9
Allegan, Michigan	71,501	7.4
Ottawa, Michigan	140,556	9.7
Muskegon, Michigan	156,971	-0.3
Oceana, Michigan	20,663	14.9
Mason, Michigan	24,517	8.4
Manistee, Michigan	21,766	6.7
Benzie, Michigan	9,870	14.9
Leelanau, Michigan	12,527	15.2
Grand Traverse, Michigan	44,875	14.6
Antrim, Michigan	15,314	21.4
Charlevoix, Michigan	18,467	11.6
Emmet, Michigan	21,211	15.7
Total	9,192,467	7.7

[a]U.S. Bureau of the Census (1977)

Table 38. Population of Coastal Counties - Lake Huron[a]

County	Estimated Population 1975	% Change 1970-1975
Cheboygan, Michigan	19,419	17.2
Presque Isle, Michigan	14,000	9.1
Alpena, Michigan	33,293	8.4
Alcona, Michigan	8,640	21.5
Iosco, Michigan	28,218	13.3
Arenac, Michigan	13,179	18.2
Bay, Michigan	120,099	2.4
Tuscola, Michigan	53,776	10.6
Huron, Michigan	35,879	5.3
Sanilac, Michigan	38,981	10.8
St. Clair, Michigan	130,749	9.6
Macomb, Michigan	669,813	7.0
Wayne, Michigan	2,517,726	-5.7
Monroe, Michigan	127,094	6.6
Total	3,810,866	9.6

[a]U.S. Bureau of the Census (1977)

Table 39. Population of Coastal Counties - Lake Erie[a]

County	Estimated population 1975	% Change 1970-1975
Lucas, Ohio	476,657	-1.4
Ottawa, Ohio	38,828	4.7
Sandusky, Ohio	63,019	3.3
Erie, Ohio	77,327	1.9
Lorain, Ohio	268,579	4.6
Cuyahoga, Ohio	1,592,613	-7.5
Lake, Ohio	206,881	4.9
Ashtabula, Ohio	101,940	3.8
Erie, Pennsylvania	273,396	3.4
Chautaqua, New York	147,156	-0.1
Erie, New York	1,089,327	-2.2
Total	4,335,723	1.4

[a]U.S. Bureau of the Census (1977)

Table 40. Population of Coastal Counties - Lake Ontario[a]

County	Estimated population 1975	% Change 1970-1975
Niagara, New York	237,521	0.8
Orleans, New York	38,328	2.7
Monroe, New York	708,642	-0.5
Wayne, New York	82,543	4.0
Cayuga, New York	77,833	0.5
Oswego, New York	109,651	8.7
Total	1,254,518	2.7

[a]U.S. Bureau of the Census (1977)

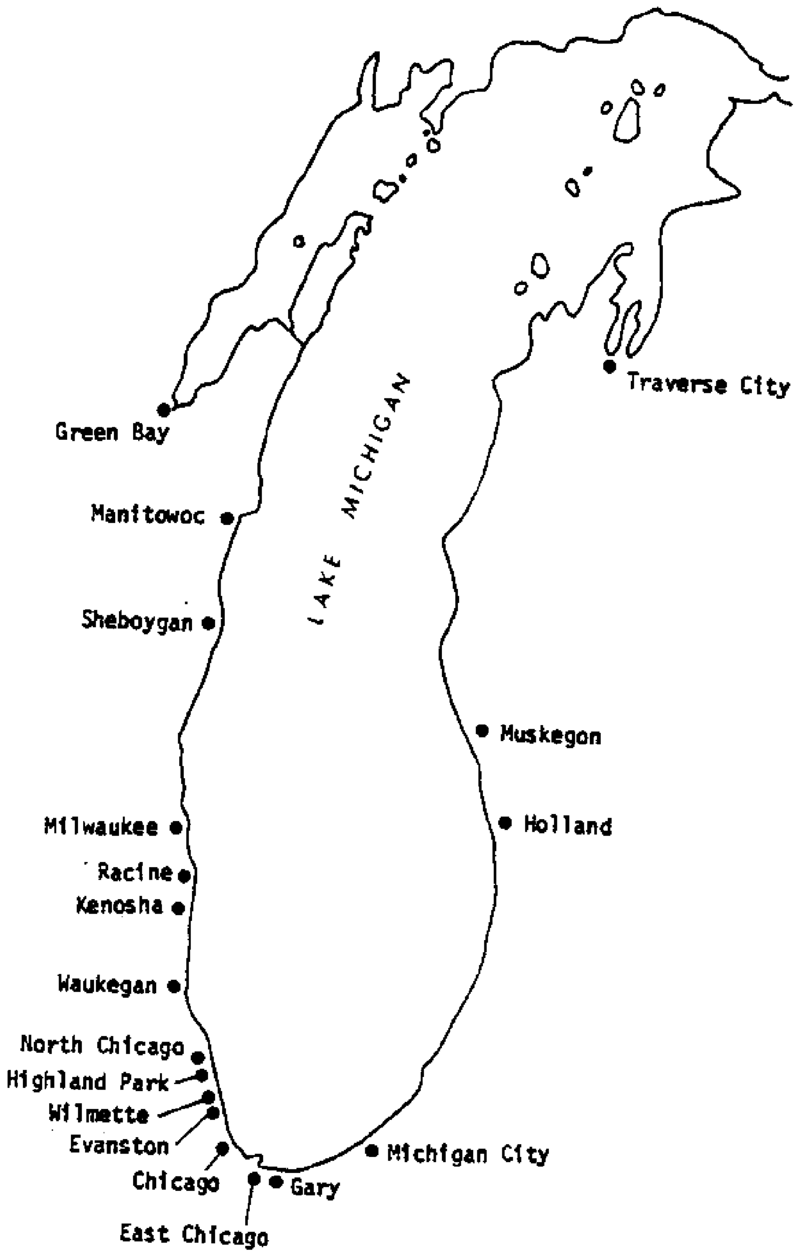
Table 41. Population of Coastal Counties - Total by Lake

Lake	Estimated population 1975	% Change 1970-1975
Superior	516,787	3.7
Michigan	9,192,467	7.7
Huron	3,810,866	9.6
Erie	4,335,723	1.4
Ontario	1,254,518	2.7
Total	15,304,171	5.0

Figure 73. Urban Areas Along the U.S. Lake Superior Shoreline Having Populations of 25,000 or More[a]

[a]Based on U.S. Geological Survey 1:250,000 scale maps

Figure 74. Urban Areas Along the Lake U.S. Lake Michigan Shoreline Having Populations of 25,000 or More[a]

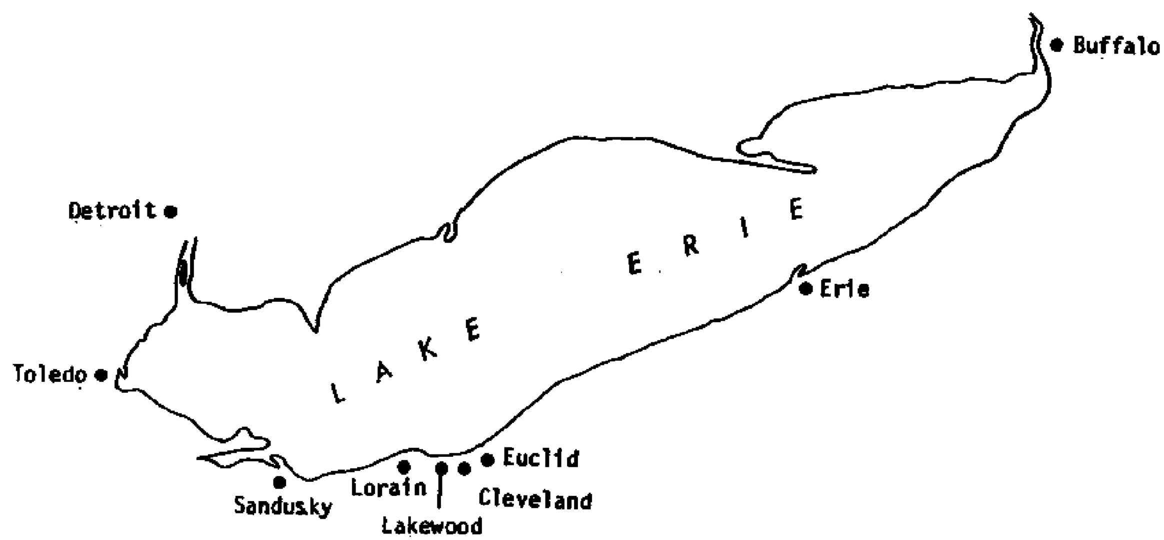


[a]Based on U.S. Geological Survey 1:250,000 scale maps

Figure 75. Urban Areas Along the U.S. Lake Huron Shoreline Having Populations of 25,000 or More[a]

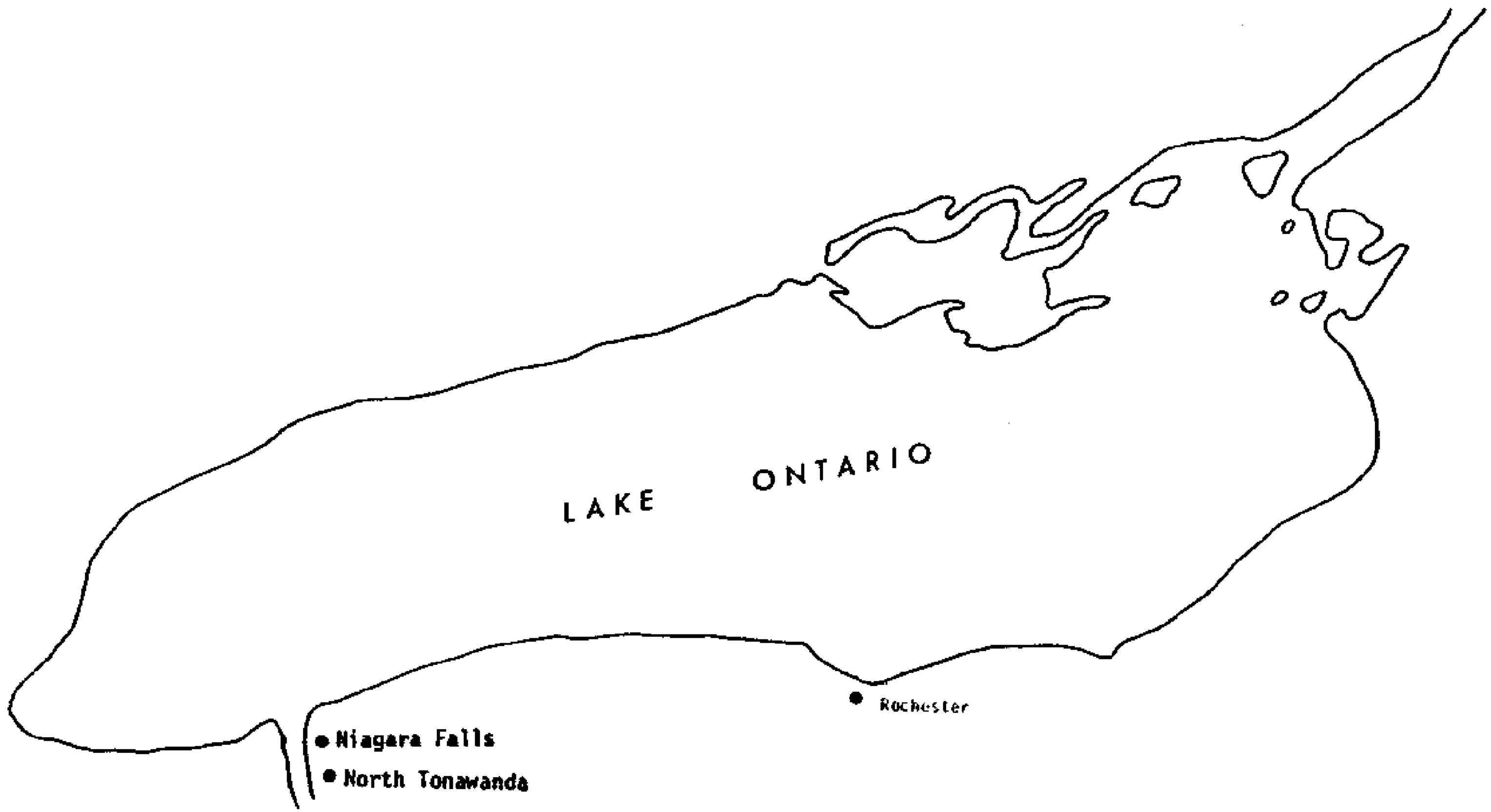
[a]Based on U.S. Geological Survey 1:250,000 scale maps

Figure 76. Urban Areas Along the U.S. Lake Erie Shoreline Having Populations of 25,000 or More[a]



[a]Based on U.S. Geological Survey 1:250,000 scale maps

Figure 77. Urban Areas Along the U.S. Lake Ontario Shoreline Having Populations of 25,000 or More[a]



[a]Based on U.S. Geological Survey 1:250,000 scale maps

the largest public holders of lakeshore mileage (13%); the federal government holds approximately 4% of the total shoreline mileage.

Table 43 provides information on shoreline land use by state. Although the states show some variance in the overall composition of land use types, the primary land use is by residential, commercial, and industrial structures. Private ownership is predominant in all of the states, followed by state and local ownership and federal ownership.

In most cases, it is difficult to obtain information relating to future land use plans for the Great Lakes coastal wetlands, particularly for wetlands which are privately owned. This lack of information makes it difficult to reach any quantitative conclusions about the developmental pressures faced by the coastal wetlands. It is possible, however, to speculate about these developmental pressures based on present land use patterns and ownership. Land use information presented in Tables 42 and 43 suggests that the greatest development threats to the coastal wetlands come from the expansion of urban areas and residential development of the shoreline. To a lesser extent, natural resource development also poses a threat, especially to those portions of the shoreline where the wetlands are in conjunction with several types of commercially exploitable resources.

A major deterrent to wetland development is public ownership. Many wetlands are located in either national or state forests, game areas, natural areas, or national, state, or local parks. In general, it might be assumed that such ownership of wetlands serves as a protective mechanism owing to the overall management goals of these units to maintain the natural environment. Although the extent of protection varies with each public agency, all of these units provide some degree of protection to wetlands. Another protective mechanism having varying levels of effectiveness is land use planning, particularly at the state and local governmental levels. Many land use plans contain provisions relating to the protection of wetlands as unique or natural environments. This is particularly true in terms of the Coastal Zone Management Programs developed by the various states.

RECREATION

Tables 42 and 43 provide information concerning the total amount of Great Lakes shoreline that is being utilized for recreational areas. This constitutes about 10% of the total shoreline.

Relatively little information was identified through the literature search pertaining to recreational usage of the coastal wetlands along the Great Lakes shorelines. In most instances, information is available only when a wetland lies within the boundaries of a federal, state, or local park. Where this is the case, available information tends to reflect recreational usage within the entire park rather than specific activities within the wetland.

A significant number of wetlands along the Great Lakes shoreline lie within state or national forests. These forested lands provide various recreational opportunities including hunting, fishing, camping, hiking, off-road vehicle trails, and nature and wildlife observation. Site-specific information on the

Table 42. Great Lakes Shoreline Land Use and Ownership by Lake - 1970[a]

	Total miles	Percent	Lake Superior	Lake Michigan	Lake Huron	Lake Erie	Lake Ontario
Shoreline Use							
Residential, commercial, and industrial; public lands and buildings	1,362.4	39%	201.4	552.4	256.6	202.5	149.5
Agricultural and undeveloped	583.6	17%	40.2	280.6	84.7	68.2	109.9
Forest lands	1,134.4	33%	599.0	350.0	181.0	4.4	0.0
Public recreation	334.6	10%	70.2	160.8	25.6	48.0	30.2
Fish and wildlife wetlands	55.4	2%	1.2	18.2	17.1	18.9	0.0
Ownership							
Federal	133.1	4%	91.4	25.4	9.5	6.8	0.0
Non-federal public	466.2	13%	87.0	219.9	56.4	71.0	31.9
Private	2,871.3	83%	733.6	1,116.7	399.1	264.2	257.7

[a]Adapted from Great Lakes Basin Commission (1975h)

Table 43. Great Lakes Shoreline Land Use and Ownership by State - 1970[a]

	Total miles	IL	IN	MI	MN	NY	OH	PA	WI
<u>Shoreline Use</u>									
Residential, commercial, and industrial; public lands and buildings	1,362.4	33.5	27.9	687.5	68.8	188.1	128.1	24.8	203.7
Agricultural and undeveloped	583.6	0.6	0.1	282.3	11.0	134.3	16.4	11.9	127.0
Forest lands	1,134.4	0.0	0.0	900.0	69.7	0.0	3.5	0.0	160.3
Public recreation	334.8	30.9	17.0	125.3	24.2	38.1	33.6	11.6	54.1
Fish and wildlife wetlands	55.4	0.0	0.0	27.3	1.2	0.0	8.7	0.0	18.2
<u>Ownership</u>									
Federal	133.1	3.1	9.3	38.2	20.1	0.0	5.8	0.0	56.6
Non-federal public	466.2	35.8	8.7	217.5	19.0	44.7	24.5	11.6	94.3
Private	2,871.3	26.1	27.0	1,767.6	135.7	315.8	150.0	36.7	412.4

[a]Adapted from Great Lakes Basin Commission (1975h)

recreational usage of wetlands lying within state and national forests is generally not available.

Recreational use and demand along the Great Lakes shoreline will undoubtedly increase in the future. In fact, the Great Lakes Basin Commission (1975) concludes that recreation requirements are expected to increase at a much faster rate than population. The population of the Great Lakes Basin is expected to increase 84 percent between 1970 and 2020. Recreational requirements during the same time period are expected to increase 193 percent. It is likely that this increase in recreational requirements will lead to greater utilization of coastal wetlands along the Great Lakes shoreline for recreational purposes.

MINERAL, ENERGY, AND FOREST RESOURCES

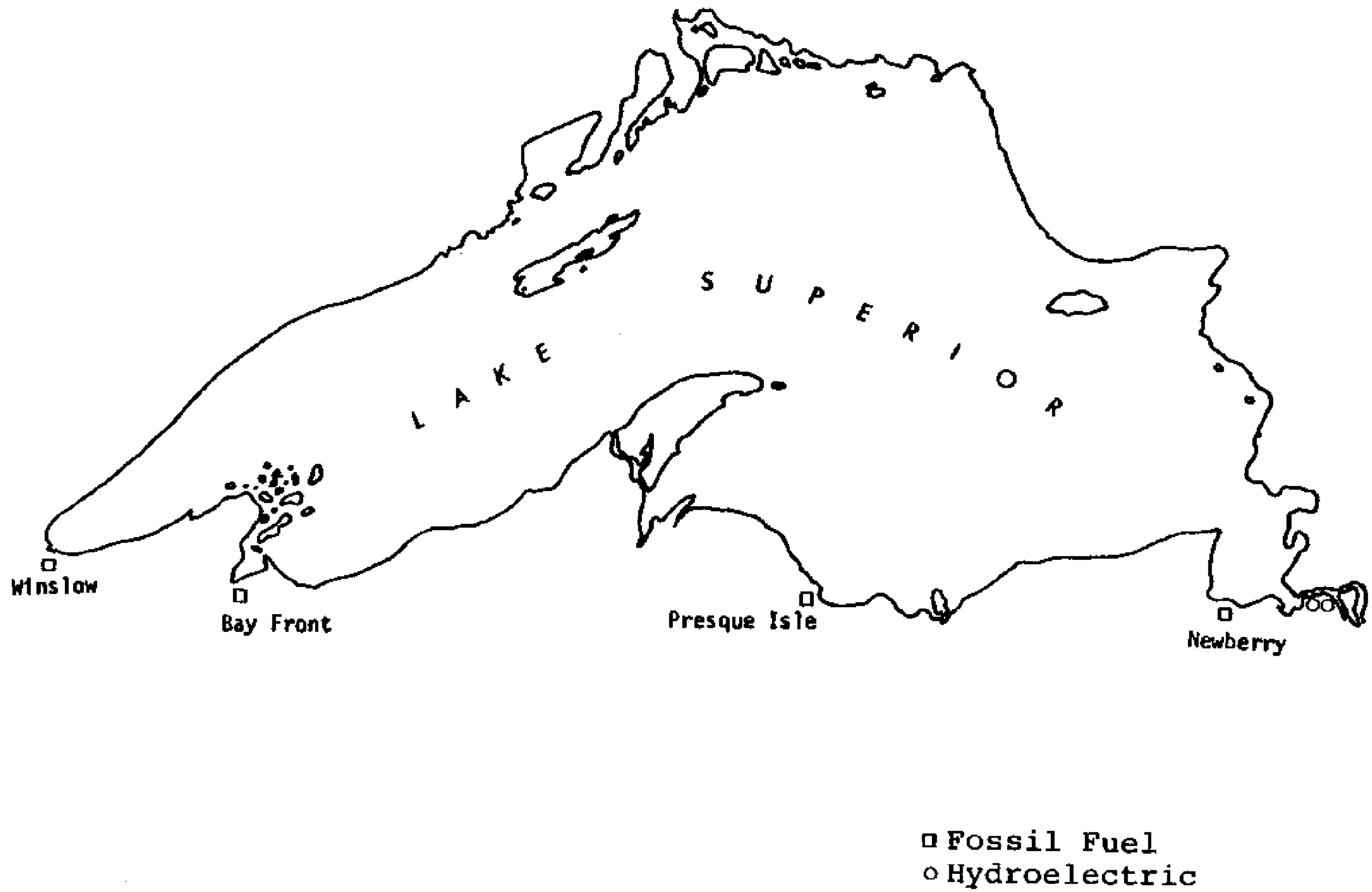
Metals, non-metals, and fuels are produced in large quantities throughout the Great Lakes Basin (Great Lakes Basin Commission, 1975), and many of the wetlands along the Great Lakes shoreline are situated within areas containing mineral deposits. Mineral resources present include sand and gravel, limestones, dolomites, Silurian and Devonian salts, clays, shales, and possibly some magnesium. Other mineral resources may also be found in the wetlands. Although many of the wetlands lie within areas of potential mineral resources, relatively few have been invaded by active resource extraction operations. For example, 360 of the 413 wetlands along the Lake Michigan shoreline are situated in areas of potential mineral resources, but only 16 of these wetlands contain active extraction operations. The number of resource extraction operations within wetlands may become greater in the future should available supplies become limited elsewhere.

A large proportion of the wetlands along the Great Lakes shoreline contain forest resources. In most instances, it was not possible to determine through the literature search whether these forest resources are of commercial value. However, the Great Lakes Basin Commission (1975) notes that almost all of the forested land in the Great Lakes Basin is capable of producing commercial crops of timber. A number of the wetlands containing forest resources are located within national or state forests, particularly along the Lake Michigan and Lake Superior shorelines. Although the official policy in regard to wetland timber varies with jurisdiction, virtually all of the policies developed for publicly owned forested areas provide protection against indiscriminate timber cutting within wetlands.

PUBLIC UTILITIES AND FACILITIES

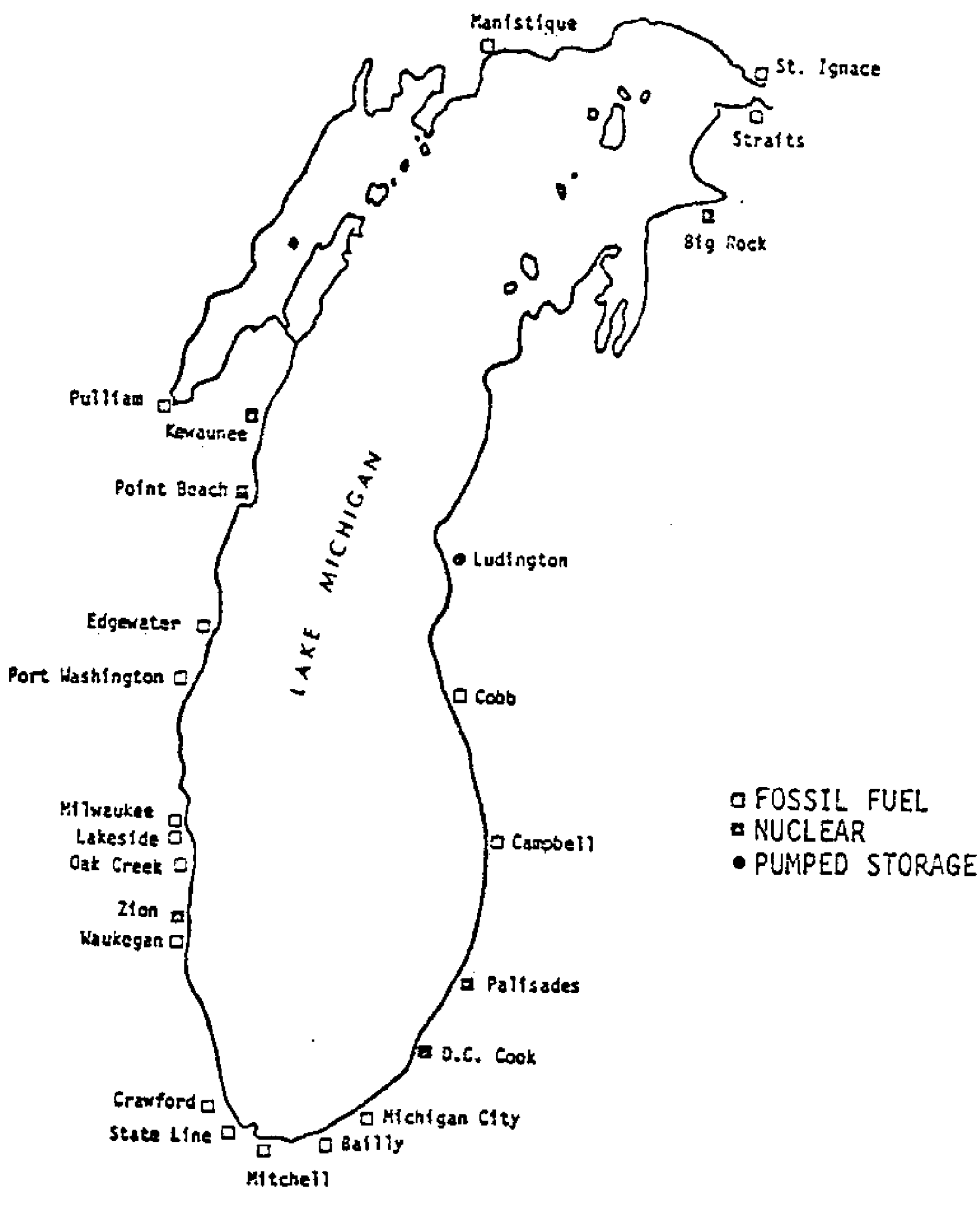
Figures 78 through 82 show the principal existing and authorized electric generating plants along the Great Lakes shorelines as of January 1978 (East Central Area Reliability Coordination Agreement Power Systems, 1978). The majority of the plants use fossil fuel. Several nuclear plants are present or are planned along the shorelines of Lake Michigan, Lake Erie, and Lake Ontario. Hydroelectric plants are relatively few in number and are limited to Lake Huron and Lake Ontario. Of the five Great Lakes, Lake Michigan has the greatest number (23) of plants along its shoreline. Several of the wetlands included in this study are situated within one-half mile of a generating plant.

Figure 78. Existing Electric Generating Plants Situated Along the U. S. Shoreline of Lake Superior June 1975



[a]Adapted from Federal Power Commission (1975)

Figure 79. Existing and Authorized Electric Generating Plants Situated Along the Shoreline of Lake Michigan - January 1978[a]

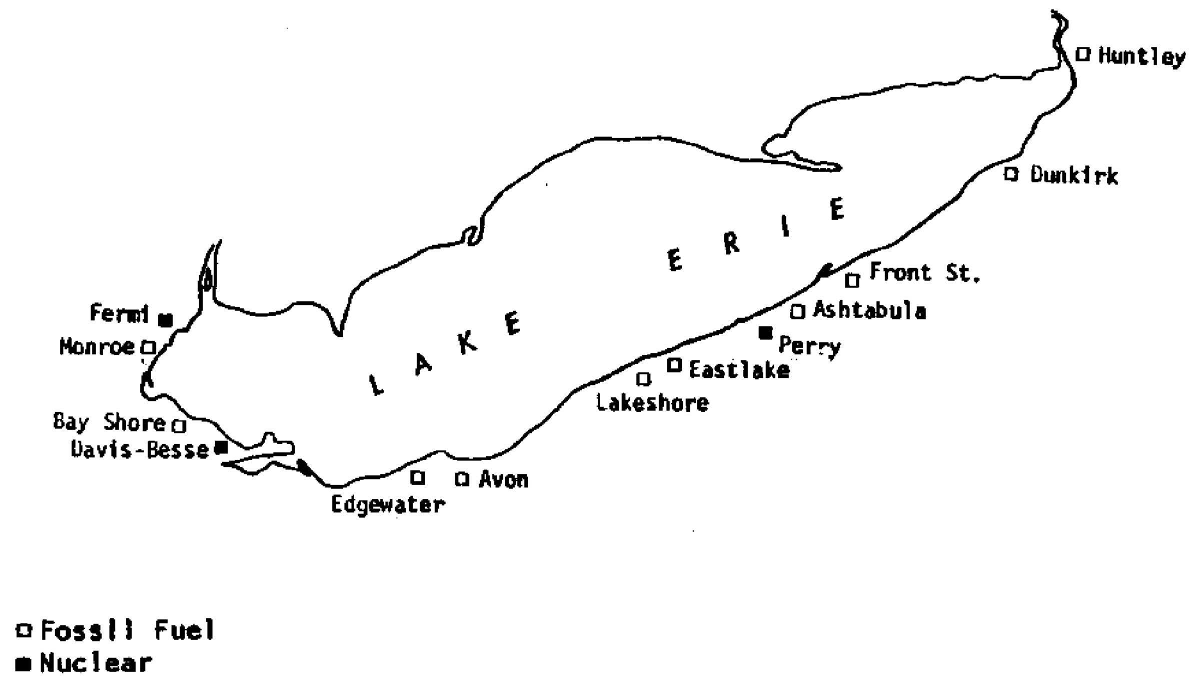


[a]Adapted from East Central Area Reliability Coordination Agreement Power Systems (1978)

Figure 80. Existing and Authorized Electric Generating Plants Situated Along the U. S. Shoreline of Lake Huron January 1978[a]

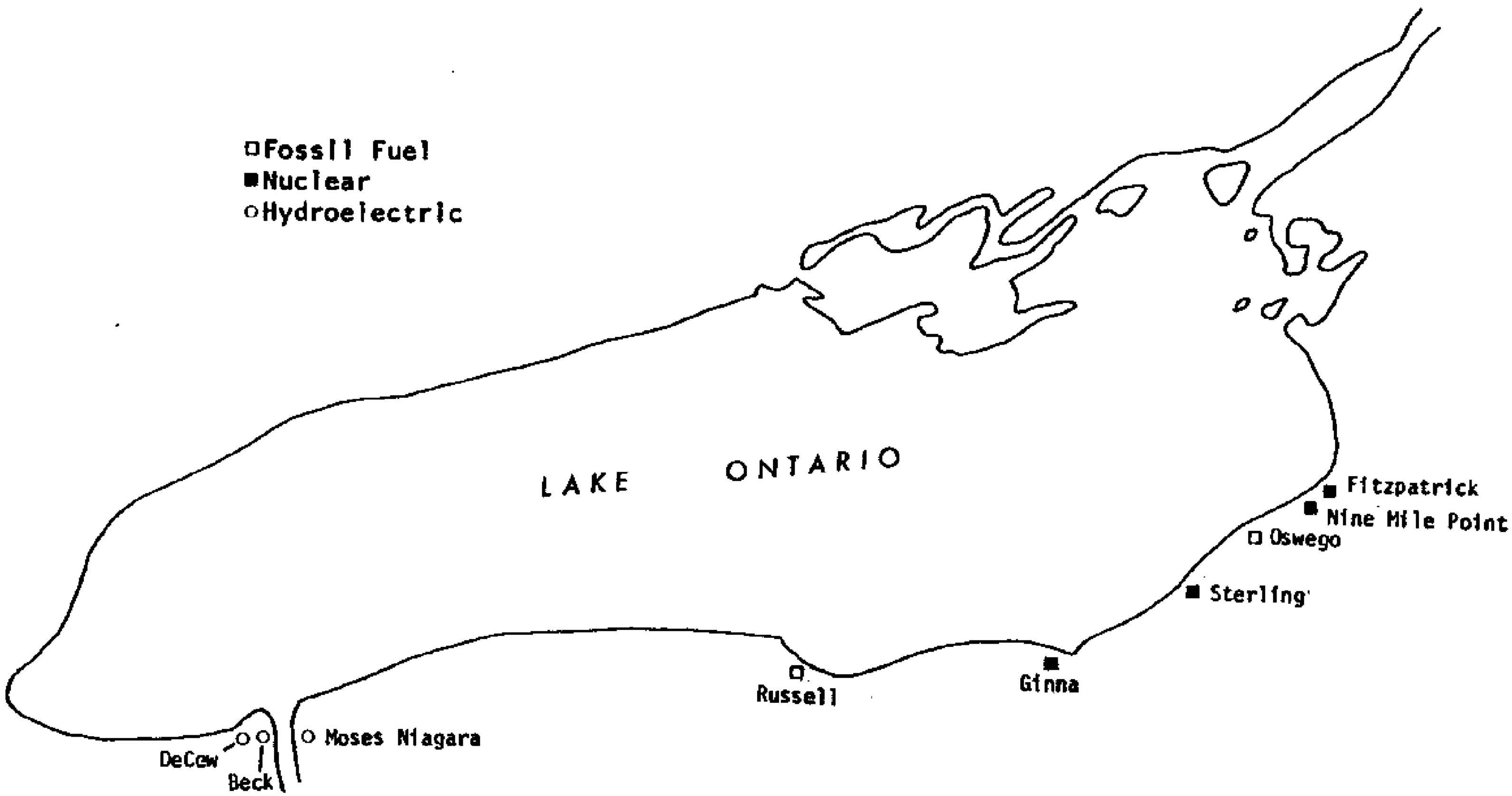
[a]Adapted from East Central Area Reliability Coordination Agreement Power Systems (1978)

Figure 81. Existing and Authorized Electric Generating Plants Situated Along the U. S. Shoreline of Lake Erie - January 1978[a]



[a]Adapted from East Central Area Reliability Coordination Agreement Power Systems (1978)

Figure 82. Existing and Authorized Electric Generating Plants Situated Along the U. S. Shoreline of Lake Ontario - January 1978[a]



[a]Adapted from East Central Area Reliability Coordination Agreement Power Systems (1978)

Information concerning ownership, installed capacity, average annual generation, and fuel type for each of the plants located along the Great Lakes shoreline is available from the Federal Energy Regulatory Commission (formerly the Federal Power Commission). Of particular value are Gas Turbine Electric Plant Construction Cost and Annual Production Expenses, Steam Electric Plant Construction Cost and Annual Production Expenses, Hydro-electric Power Resources of the United States, Developed and Undeveloped, and Hydroelectric Plant Construction Cost and Annual Production Expenses. A report prepared by the Federal Energy Administration, entitled Inventory of Power Plants in the United States, is also of particular value for identifying existing and proposed power plants.

POLLUTION SOURCES

Information concerning point sources of pollution in the wetlands along the Great Lakes shoreline is primarily available from National Pollution Discharge Elimination System (NPDES) permits. These are housed in the Michigan Department of Natural Resources, Water Quality Division, in Lansing; the Indiana State Board of Health, Water Pollution Control Division, in Indianapolis; the Illinois Environmental Protection Agency, Division of Water Pollution Control, in Springfield; the Wisconsin Department of Natural Resources, Industrial Discharge Section, in Madison; the Minnesota Pollution Control Agency, Permit Section, in St. Paul; the Ohio Environmental Protection Agency, Technical Records Section, in Columbus; the New York Department of Environmental Conservation, Pure Waters Division, in Albany; and the Erie County Department of Health, Division of Sanitary Engineering, in Erie, Pennsylvania.

The NPDES permits usually do not pinpoint the exact location of the point source discharge. As a result, it is often impossible to determine whether the polluter is discharging directly into the wetland or into an area near the wetland. Wetland-specific information on non-point sources of pollution is virtually non-existent. A strong need exists for research on both point and non-point sources of pollution as they pertain to the wetlands along the Great Lakes shorelines.

HISTORICAL AND ARCHAEOLOGICAL FEATURES

Historical sites along the Great Lakes shorelines are well documented in The National Register of Historic Places as well as in state and local historic registers. Much of the Great Lakes shoreline has not been systematically surveyed for archaeological sites. However, several extremely helpful sources of information are available for portions of the shoreline. The Wisconsin Historic Preservation Division has an on-going file of historic and archaeologic sites for the coastal counties along the Lake Michigan and Lake Superior shorelines in Wisconsin. The Illinois Department of Conservation has available records on archaeological sites, particularly in the vicinity of Illinois Beach State Park, along the Lake Michigan shoreline. The Minnesota Historical Society, Division of Historic and Archaeological Sites, and the Indiana Department of Natural Resources, Division of Historic Preservation, should be contacted regarding sites along the Lake Superior shoreline in Minnesota and the Lake Michigan shoreline in Indiana.

In Michigan, the History Division of the Michigan Department of Natural Resources has published a report entitled The Distribution and Abundance of Archaeologic Sites in the Coastal Zone of Michigan (Peebles and Black, 1976). This report summarizes existing knowledge of archaeologic sites along the Lake Michigan, Lake Superior, Lake Huron, and Lake Erie shorelines in Michigan. The Ohio Historic Preservation Center and the New York State Parks and Recreation Department, Historic Preservation Field Services, should be contacted regarding sites along the Lake Erie shoreline in Ohio and the Lake Ontario shoreline in New York.

While there are few known archaeological sites in the vicinity of many of the wetlands along the Great Lakes shoreline, there is reason to believe that more archaeological sites may be present. Sites are commonly found on barriers adjacent to the wetlands rather than in the wetlands per se. Such relationships occur, for example, on barriers in Bay, Tuscola, and Monroe Counties in Michigan. Undoubtedly, this pattern also occurs in other coastal zones of the Great Lakes. Since much of the shoreline has not been systematically surveyed, a professional archaeologist should be consulted prior to initiation of any action that might affect the wetlands.

FUTURE PROJECTIONS AND RECOMMENDATIONS

Until recently, the future of coastal wetlands around the Great Lakes was uncertain. Since they represent a transitional zone between land and water, coastal wetlands are sensitive to the pressures of change in their natural environment, as well as to modification by human activity.

The frequent and substantial variations in water level common to the Great Lakes have resulted in changes in size, character and use of many coastal wetlands, as well as the periodic loss of wetland areas. Localized short-term changes in water level, such as storm surges, are apt to have serious impacts on wetlands. This makes future projections difficult.

Historically, wetlands have had a negative image. Only the hunting/trapping function of wetlands and their potential for agriculture were considered legitimate values. Like the "forest", the "swamp" was viewed as a place to be modified, exploited, casually destroyed, or ignored if utilization was not feasible.

The Great Lakes coastal wetlands frequently occupy sites that are subject to intensive development pressure. While isolated spruce bogs and other interior wetlands of the glaciated Upper Lakes states have low development pressure, where lumbering is the only major economic value, coastal wetlands often occupy land suitable for urban expansion, siting of transportation routes and other infrastructure, or intensive market-garden agriculture for urban markets. A simple comparison of population distribution around the lakes with the locations of major areas of coastal wetlands suggests the severity of the problem. Pressure for water-oriented recreation facilities has grown steadily as urban populations, disposable income, and leisure time have increased in recent years. In their natural function as buffer zones, wetlands inhibit easy movement between land and open water and so are often viewed as inconveniences.

Most of the functions dependent on the maintenance of wetlands as integral ecosystems have either been considered trivial or have only recently acquired significance as a result of current scientific analysis. Most of the latter functions are not readily visible or comprehensible to the public.

The future picture for wetlands is not entirely negative, since the numerous values of wetlands are gaining wider and more influential recognition. The enhanced level of public environmental awareness over the past decade, successful legal challenges to environmental degradation, and increasing commitment to rational development by government agencies at various levels have changed the atmosphere in which decisions are made. Around the Great Lakes, the particularly vulnerable character of coastal wetlands has been recognized, and various steps to ensure preservation or enhancement of remaining wetlands are being taken or considered. In a study of attitudes toward wetlands in Michigan Jaworski et al. (1978) noted a direct relationship between population density, threatened wetlands, and active concern on the part of various groups. Also indicative of heightened awareness of the values and problems of wetlands is the amount of investment now being made in research on various aspects of wetland environments. For the past few years wetlands have been receiving an increasing share of available research funds.

Considerable scientific effort is being devoted to the quantification of wetland values, as awareness grows that the survival of wetlands will ultimately depend on economic competition with uses and activities that might destroy them. Thus, while substantial data now exist on hunting, fishing, and trapping activities in wetlands, identification and quantification of abiotic, biological, and aesthetic functions of great potential value may be crucial. Moreover, close quantitative attention to actual values of wetlands reveals changes in emphasis and in relative economic significance over time. Table 7 suggests that traditional activities (notably hunting) are now much less economically productive than sport fishing and non-consumptive recreation uses.

Coastal wetlands by their nature will always remain vulnerable to modification by natural elements, and it still seems doubtful that they can ever be truly cost-effective in competition with other more intensive land uses. Specifically, the preservation of wetlands as integral environmental units, not subject to any sort of selective improvement or augmented use pressures, seems unlikely. Nonetheless, increasing awareness of the unique character of wetlands, and of the incalculable losses that their total disappearance would entail, may lend sufficient urgency to various initiatives that may lead to preservation of remaining wetlands.

Two basic wetland policy objectives that might be considered are to enhance the status of wetlands in the land use hierarchy, and to optimize wetland use in the light of conflicting interests. Specific strategies that might be utilized to achieve these objectives include:

1) Enactment of significant wetland legislation in the Great Lakes states.
2) Quantify further the economic values of wetlands.
3) Improve the wetland image through educational programs.
4) Provision of data and assistance to all wetland interest groups.
5) Steps to increase community awareness of and involvement in wetland decisions.
6) Coordination of definitions and enforcement policies among various state and local agencies concerned with wetland environments.
7) Consideration of active measures to resolve problems of wetland deterioration.
8) Accumulation of site-specific data.
9) Modification of land use practices in order to minimize wetland degradation.
10) Articulation, possibly through one or more of the existing agencies concerned with the Great Lakes, of overall planning, development, and preservation strategies for wetlands based on the perspective of the Great Lakes basin as a single functional unit.

APPENDICES

The following life histories include all fish, reptiles and amphibians, avifauna, and mammals that utilize the coastal wetlands habitually. The life histories are preceeded by a list of common and scientific names. Many species often occur in coastal wetlands but are not strictly classifable as wetland species. These species have not been included.

The following sources were consulted in the preparation of life histories:

Fish - Trautman (1957), Scott and Crossman (1973, Hubbs and Lagler (1958), Smith (1979), Becker (1976), Eddy and Underhill (1974).

Amphibians and Reptiles - Conant (1951, 1975), Walker (1946), Ruthven et al. (1928), Smith (1961), Bishop (1941), Pope and Dickinson (1928), Pentecost et al.

Avifauna - Bent (1919 - 1968), Bull and Farrand (1977, Palmer (1976), Pearson (1923), Robbins et al. (1966), Sanderson (1977), Snow (1973), and Zarm (1974).

Mammals - Jackson (1961) and Burt (1972).

These sources summarize a wide range of literature. For additional information on any of the wetland species included in the appendices or non-wetland species which have not been discussed, these sources can be consulted.

APPENDIX A

Common and Scientific Names of the Vegetation of the Coastal Wetlands of the Great Lakes[a]

Common Name	Scientific Name
balsam fir	*Abies balsamea*
maple	*Acer* sp.
red maple	*A. rubrum*
silver maple	*A. saccharinium*
sugar maple	*A. saccharum*
sweet flag	*Acorus calamus*
upland bent grass	*Agrostis perennans*
water-plantin	*Alisma subcordatum*
water-plantin	*A. triviale*
alder	*Alnus* sp.
tag alder	*A. incana*
speckled alder	*A. rugosa*
pigweed	*Amaranthus* sp.
beach grass	*Ammophila arenaria*
bog-rosemary	*Andromeda glaucophylla*
little bluestem	*Andropogon scoparius*
little bluestem	*Anemone canadensis*
bearberry	*Arctostaphylos uva-ursi*
whorled milkweed	*Asclepias incarnata*
swamp milkweed	*Asclepias incarnata*
upland white aster	*Aster ptarmicoides*
small white aster	*A. vimineus*
birch	*Betula* sp.
yellow birch	*B. lutea*
paper birch	*B. papyifera*
begger's ticks	*Bidens* sp.
begger's ticks	*B. cernua*
tickseed sunflower	*B. coronata*
begger's ticks	*B. frondosa*
log-hemp	*Boehmeria cylindrica*
water shield	*Brasenia schreberi*
sea rocket	*Cakile edentula*
bluejoint grass	*Calamagrostis canadensis*
starwort	*Callitriche heterophylla*
beach reed	*Calmovilfa longifolia var. magma*
orchid	*Calopogon pulchellus*
marsh marigold	*Caltha palustris*
marsh bluebell	*Campanula aparinoides*
marsh bluebell	*Cardamine pensylvanica*
sedge	*Carex* sp.
sedge	*C. aquatilis*
golden fruited sedge	*C. aurea*
sedge	*C. comosa*

-continued-

Common Name	Scientific Name
sedge	C. crinita
sedge	C. cristatella
sedge	C. filiformis
sedge	C. lacustris
sedge	C. lanuginosa
sedge	C. lasiocarpa
sedge	C. lasiocarpa var americana
sedge	C. riparia
sedge	C. sartwellii
sedge	C. stricta
sedge	C. stricta var. strictior
sedge	C. virescens
greenish sedge	C. viridula
shagbark hickory	Carya ovata
American chestnut	Castanea dentata
hackberry	Celtis occidentalis
centuary	Centauriun pulchelbium
buttonbush	Cephalanthus occidentalis
coontail	Ceratophyllum demersum
leatherleaf	Chamaedaphne sp.
leatherleaf	C. calyculata var. angustifolia
stonewart	Chara contvaria
stonewart	C. kukensis
stonewart	C. vulgaris
water hemlock	Cicuta bulbifera
water hemlock	Cicuta maculata
thistle	Cirsium sp.
twig rush	Cladium mariscoides
goldbread	Cladophora lomerata
virgins bower	Clematis virginiana
thistle	Coptis groenlandica
lance leaved coreapsis	Coreapsis lanceoldata
dogwood	Cornus sp.
dogwood	C. amomum
bunchberry	C. canadensis
flowering dogwood	C. florida
gray dogwood	C. racemosa
red osier dogwood	C. stolonifera
hawthorns	Crataegus spp.
sedges	Cyperus diandrus
sedges	C. odoratus
umbrella sedge	C. strigosus
schweintz cyperus	C. schweinitzii
moccasin flower	Cypripedium acaule
yellow lady slipper	C. calciolus
orchid	C. canidum

-continued-

Common Name	Scientific Name
orchid	*Cypripedium arietinum var. parveflouer*
orchid	*C. arietinum var. pubescens*
swamp loosestrife	*Decodon verticillatus*
narrow-leaved sundew	*Drosera intermedia*
round-leaved sundew	*D. rotundifolia*
marsh fern	*Dryopteris thelypteris*
Walter's millet	*Echinochloa walteri*
wild cucumber	*Echinocystis lobata*
needle spike rush	*Eleocharis acicularis*
spike rush	*E. erythropoda*
spike rush	*E. intermedia*
spike rush	*E. obtusa*
spike rush	*E. smallii*
elodea	*Elodea canadensis*
fireweed	*Epilobium* sp.
purple-leaved willow herb	*E. coloratum*
heath family	*Ericaceae*
daisy fleabane	*Erigeron annuus*
duck grass	*Eriocaulon septangulare*
cotton grass	*Eriophorum* sp.
spotted joe-pye weed	*Eupatorium maculatum*
strawberry	*Fragaria virginiana*
white ash	*Fraxinus americana*
ash	*F. nigra*
red ash	*F. pennsylvanica*
bed straw	*Galium obtusum*
fringed gentian	*Gentiana virginiana*
purple avens	*Geum rivale*
manna grass	*Glyceria* sp.
grasses	*Gramineae*
clubspur orchid	*Habenaria clayellata*
orchid	*H. dilatata*
orchid	*H. hyperborea*
orchid	*H.* x *media*
witch hazel	*Hammanelis virginicana*
water-stayrass	*Heteranthera dubia*
marsh mallow	*Hibiscus palustris*
Klam's St. John's Wart	*Hypericum kalmianum*
marsh St. John's Wart	*H. virginicum*
winterberry	*Ilex* sp.
black alder	*I. verticillata*
touch-me-not	*Impatiens biflora*
jewelweeds	*I. capensis*
jewelweeds	*I. pallida*
blue flag	*Iris versicolor*

-continued-

Common Name	Scientific Name
rush	*Juncus* sp.
baltic rush	*J. balticus var. littoralis*
short-tailed rush	*J. brevicaudatus*
soft rush	*J. effusus*
common juniper	*Juniperus communis*
red cedar	*J. virginiana*
creeping juniper	*J. horizontalis*
mints	*Labiatae*
European larch	*Larix decidua*
tammarack	*L. laricina*
tammarack	*Lathyrus maritimus*
labrador tea	*Ledum groenlandicum*
rice cut-grass	*Leersia lenticularis*
cut grass	*L. oryzoides*
duckweed	*Lemna minor*
duckweed	*L. trisculca*
twin flower	*Lemna borealis*
tulip tree	*Liriodendron tulipifera*
Kalm's labelia	*Lobelia kalmii*
Loese's twayblade	*Liparis loeselii*
shining clubmoss	*Lycopodium lucidulum*
American bugle-weed	*Lycopus americanus*
loosestrife	*Lysimachia thrysifolia*
purple loosestrife	*Lythrum salicaria*
monkey flower	*Mimulus ringens*
white mulberry	*Morus alba*
sweet gale	*Myrica gale*
water milfoil	*Myriophyllum alterniflorum*
milfoil	*M. exalbescens*
milfoil	*M. heterophyllum*
milfoil	*M. verticillatum var. pectinatum*
slender niad	*Najas flexilis*
American lotus	*Nelumbo lutea*
aquatic lotus	*N. pentapetala*
mountain holly	*Nemopanthus mucronatus*
stonewart	*Nitella* sp.
yellow water lily	*Nuphar advena*
spatterdock	*Nuphar advena*
yellow pond lily	*Nuphar rubrodiscum*
bullhead lily	*N. variegatum*
white water lily	*Nymphaea odorata*
white water lily	*N. tuterosa*
evening primrose	*Oenothera biennis*
sensitive fern	*Onoclea sensibulis*
prickly pear	*Opuntia* sp.
cinnamon fern	*Osmunda cinnamonea*

-continued-

Common Name	Scientific Name
royal fern	Osmunda regalis
hop hornbeam	Ostrya virginiana
switchgrass	Panicum virgatum
arrow arum	Peltandra virginica
ditch stonecrop	Penthorum sedoides
reed canary grass	Phalaris arundivacea
reed grass	Phragmites communis
pokeweed	Phytolacca americana
spruce	Picea sp.
white spruce	P. glauca
black spruce	P. mariana
jack pine	Pinus banksiana
Austrian pine	P. nigra
red pine	P. resinosa
pitch pine	P. rigida
white pine	P. strobus
scotch pine	P. sylvestris
foul meadow grass	Poa palustris
orchid	Pogonia ophioglossoides
water heart's ease	Polygonum amphibium
water smartweed	P. coccineum
mild water-pepper	P. hydropiperoides
nodding smartweed	P. lapathifolium
smartweed	P. pennsylvanicum
smartweed	P. punctatum
arrowhead tearthumb	P. sagittatum
pickerel weed	Pontederia cordata
silverweed	Pontentilla anserina
cottonwood	Populus deltoides
bigtooth aspen	P. grandidentata
quaking aspen	P. tremuloides
thin leaved pondweed	Potamogeton alpinus var. tenuifolius
slender pondweed	P. amplifolius
pondweed	P. berchtoldii
curly leaf pondweed	P. crispus
pondweed	P. foliosus
pondweed	P. friesii
variable pondweed	P. grammineus
pondweed	P. illinaoensis
pondweed	P. natans
pondweed	P. nodosus
sage pondweed	P. pectinatus
slender pondweed	P. pusillus
red head pondweed	P. richardsoni
pondweed	P. robbinsii
pondweed	P. strictifolius

-continued-

Common Name	Scientific Name
pondweed	Potamogeton zosteriformis
marsh cinquefoil	Potentilla palustris
mermaid weed	Proserpinaca palustris
cherry	Prunus sp.
pincherry	P. pennsylvanica
sand cherry	P. pumila
black cherry	P. serotina
choke cherry	P. virginiana
crabapple	Pyrus coronaria
slender mountain mint	Pycnanthemum flexiuosum
oak	Quercus sp.
white oak	Q. alba
swamp white oak	Q. bicolor
red oak	Q. borealis
bur-oak	Q. macrocarpa
pin oak	Q. palustris
black oak	Q. velutina
white water crowfood	Ranunculus aquatilis
white water crowfood	R. flabellaris
white water crowfood	R. trichophyllus
smooth sumac	Rhus glabra
swamp rose	Rosa palustris
prarie rose	R. setigera
dock	Rumex crispus
dock	R. verticillatus
arrowhead	Sagittaria cuneata
arrowhead	S. graminae
arrowhead	S. heterophylla
arrowhead	S. latifolia
arrowhead	S. rigida
rose pink	Sabatia angularis
willow	Salix spp.
peach-leaved willow	S. amygdaloides
willow	S. candida
heart-leaved willow	S. cordata
sand bar willow	S. interior
black willow	S. nigra
willow	S. lucida
willow	S. pedicellaris
silky willow	S. sericea
willow	S. serissima
common elder	Sambuscus canadensis
pitcher plant	Sarracenis purpirea
sassafras	Sassafras albidum
lizards tail	Saururus cernuus

-continued-

Common Name	Scientific Name
hardstem bulrush	*Scirpus acutus*
American bulrush	*S. americanus*
darkgreen bulrush	*S. atrovirens*
wool grass	*S. cyperinus*
river bulrush	*S. fluviatilis*
slender bulrush	*S. heterochaetus*
bulrush	*S. torreyi*
soft-stem bulrush	*S. validus*
skullcap	*Scutellaria epilobiifolia*
water parsnip	*Sium* sp.
horse nettle	*Solanum carolinense*
cattail nightshade	*Solanum dulcamara*
tall goldenrod	*Solidago canadensis var. scabra*
Indiana grass	*Sorghasttum nutans*
American burreed	*S. americanum*
burreed	*Sparganium androcladum*
burreed	*S. eurycarpum*
grass	*Spiranthes cernua*
prarie cord grass	*Spartina pectinata*
meadow sweet	*Spirea alba*
meadow sweet	*S. latifolia*
hardhack	*S. tomentosa*
Sphagnum moss	*Sphagnum* sp.
grass	*Sphenopholis* sp.
big duckweed	*Spirodela polyrhiza*
sand dropseed	*Sporobolus cryptandrus*
common comfrey	*Symphytum officinale*
marsh fern	*Thelypteris palustris*
star flower	*Trientalis borealis*
arrow grass	*Triglochin maritima*
hemlock	*Tsuga canadensis*
hemlock	*T. occidentalis*
narrow leaved cattail	*Typha angustifolia*
cattail	*T. latifola*
cattail	*T. glauca*
elm	*Ulmus americana*
slippery elm	*U. rubra*
nettle	*Urtica* sp.
tall nettle	*U. procera*
horned bladderwart	*Utricularia cornuta*
bladderwart	*U. vulgaris*
blueberry	*Vaccinuim* sp.
large cranberry	*Vaccinuim macrocarpum*
wild celery	*Vallisneria americana*
north mullein	*Verbascum blattaria*
	Verbena sp.

-continued-

-concluded-

Common Name	Scientific Name
black haw	*Viburnum prunifolium*
witherod	*V. cassinoides*
arrow-wood	*V. recognitum*
wild grape	*Vitis* sp.
summer grape	*V. aestivalis*
wild grape	*V. palmata*
water meal	*Wolffia columbiana*
horned pondweed	*Zannichellia palustris*
wild rice	*Zizania aquatica*

[a]Gleason, 1968

APPENDIX B

Phylogenetic List of Common and Scientific Names of Fishes in the Great Lakes Basin[a]

Common Name	Scientific Name
	Class Agnatha
	Order Petromyzontiformes
	Family Petromyzontidae (Lampreys)
chestnut lamprey	*Ichthyomyzon castaneus*
northern brook lamprey	*Ichthyomyzon fossor*
silver lamprey	*Ichthyomyzon unicuspis*
American brook lamprey	*Lampetra lammotei*
sea lamprey	*Petromyzon marinus*
	Class Osteichthyes
	Order Acipenseriformes
	Family Acipenseridae (Sturgeons)
lake sturgeon	*Acipenser fulvescens*
	Family Polyodontidae (Paddlefishes)
paddlefish	*Polyodon spathula*
	Order Semionotiformes
	Family Lepisosteidae (Gars)
spotted gar	*Lepisosteus oculatus*
longnose gar	*Lepisosteus osseus*
shortnose gar	*Lepisosteus platostomus*
	Order Amiiformes
	Family Amiidae (Bowfins)
bowfin	*Amia calva*
	Order Anguilliformes
	Family Anguillidae (Freshwater Eels)
American eel	*Anguilla rostrata*
	Order Clupeiformes
	Family Clupeidae (Herrings)
skipjack herring	*Alosa chrysochloris*
alewife	*Alosa pseudoharengus*
American shad	*Alosa sapidissima*
gizzard shad	*Dorosoma cepedianum*

-continued-

Common Name	Scientific Name
	Order Osteoglossiformes
	Family Hiodontidae
mooneye	*Hiodon tergisus*
	Order Salmoniformes
	Family Salmonidae (Trouts)
longjaw cisco	*Coregonus alpenae*
lake herring (cisco)	*Coregonus artedii*
lake whitefish	*Coregonus clupeaformis*
bloater	*Coregonus hoyi*
deepwaer cisco	*Coregonus johannae*
kiyi	*Coregonus kiyi*
blackfin cisco	*Coregonus nigripinnis*
shortnose cisco	*Coregonus reighardi*
shortjaw cisco	*Coregonus zenithicus*
pink salmon	*Oncorhynchus gobuscha*
coho salmon	*Oncorhynchus kisutch*
sockeye salmon	*Oncorhynchus nerka*
chinook salmon	*Oncorhynchus tshawytscha*
pygmy whitefish	*Prosopium coulteri*
round whitefish	*Prosopium cylindraceum*
rainbow trout (steelhead)	*Salmo gairdneri*
Atlantic salmon	*Salmo salar*
brown trout	*Salmo trutta*
brook trout	*Salvelinus fontinalis*
lake trout	*Salvelinus namaycusch*
arctic grayling	*Thymallus arcticus*
	Family Osmeridae (Smelts)
rainbow smelt	*Osmerus mordax*
	Family Umbridae (Mudminnows)
central mudminnow	*Umbra limi*
	Family Esocidae (Pikes)
grass (redfin) pickerel	*Esox americanus*
northern pike	*Esox lucius*
muskellunge	*Esox masquinongy*
chain pickerel	*Esox niger*

-continued-

Common Name	Scientific Name

Order Cypriniformes

Family Cyprinidae (Minnows)

Common Name	Scientific Name
stoneroller	Campostoma anomalum
goldfish	Carassius auratus
redside dace	Clinostomus elongatus
lake chub	Couesius plumbeus
carp	Cyprinus carpio
silverjaw minnow	Ericymba buccata
cutlips minnow	Exoglossum maxillingua
brassy minnow	Hybognathus hankinsoni
silvery minnow	Hybognathus nuchalis
bigeye chub	Hybopsis amblops
streamline chub	Hybopsis dissimilis
silver chub	Hybopsis storeriana
gravel chub	Hybopsis x-punctata
hornyhead chub	Nocomis biguttatus
river chub	Nocomis micropogon
goldenshiner	Notemigonus crysoleucas
pugnose shiner	Notropis anogenus
popeye shiner	Notropis ariommus
emerald shiner	Notropis atherinoides
bridle shiner	Notropis bifrenatus
bigeye shiner	Notropis boops
ghost shiner	Notropis buchanani
ironcolor shiner	Notropis chalybaeus
striped shiner	Notropis chrysocephalus
common shiner	Notropis cornutus
bigmouth shiner	Notropis dorsalis
pugnose minnow	Notropis emiliae
blackchin shiner	Notropis heterodon
blacknose shiner	Notropis heterolepis
spottail shiner	Notropis hudsonius
silver shiner	Notropis photogenis
rosyface shiner	Notropis rubellus
spotfin shiner	Notropis spilopterus
sand shiner	Notropis stramineus
weed shiner	Notropis texanus
redfin shiner	Notropis umbratilus
mimic shiner	Notropis volucellus
suckermouth minnow	Phenacobius mirabilis
northern redbelly dace	Phoxinus eos
southern redbelly dace	Phoxinus erythrogaster
finescale dace	Phoxinus neogaeus
bluntnose minnow	Pimephales notatus
fathead minnow	Pimephales promelas
bullhead minnow	Pimephales vigilax

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Common Name	Scientific Name
blacknose dace	Rhinichthys atratulus
longnose dace	Rhinichthys cataractae
creek chub	Semotilus atromaculatus
fallfish	Semotilus corporalis
pearl dace	Semotilus margarita
	Family Catostomidae (Suckers)
river carpsucker	Carpiodes carpio
quillback	Carpiodes cyprinus
highfin carpsucker	Carpiodes velifer
longnose sucker	Catostomus catostomus
white sucker	Catostomus commersoni
creek chubsucker	Erimyzon oblongus
lake chubsucker	Erimyzon sucetta
northern hogsucker	Hypentelium nigricans
smallmouth buffalo	Ictiobus bubalus
bigmouth buffalo	Ictiobus cyprinellus
black buffalo	Ictiobus niger
harelip sucker	Lagochila lacera
spotted sucker	Minytrema melanops
silver redhorse	Moxostoma anisurum
river redhorse	Moxostoma carinatum
black redhorse	Moxostoma duquesnei
golden redhorse	Moxostoma erythrurum
shorthead redhorse	Moxostoma macrolepidotum
greater redhorse	Moxostoma valenciennesi
	Order Siluriformes
	Family Ictaluridae (Freshwater Catfishes)
white catfish	Ictalurus catus
channel catfish	Ictalurus punctatus
yellow bullhead	Ictalurus natalis
brown bullhead	Ictalurus nebulosus
black bullhead	Ictalurus melas
stonecat	Noturus flavus
tadpole madtom	Noturus gyrinus
brindled madtom	Noturus miurus
northern madtom	Noturus stigmosus
flathead catfish	Pylodictis olivaris

-continued-

Common Name	Scientific Name
	Order Percopsiformes
	Family Aphredoderidae (Pirate Perches)
pirate perch	Aphredoderus sayanus
	Family Percopsidae (Trout-Perches)
trout-perch	Percopsis omiscomaycus
	Order Gadiformes
	Family Gadidae (Codfishes)
burbot	Lota lota
	Order Atheriniformes
	Family Cyprinodontidae (Killifishes)
banded killifish	Fundulus diaphanus
blackstripe topminnow	Fundulus notatus
starhead topminnow	Fundulus notti
	Family Poeciliidae (Livebearers)
mosquitofish	Gambusia affinis
	Family Atherinidae (Silversides)
brook silverside	Labidesthes sicculus
	Order Gasterosteiformes
	Family Gasterosteidae (Sticklebacks)
brook stickleback	Culaea inconstans
threespine stickleback	Gasterosteus aculeatus
ninespine stickleback	Pungitius pungitius
	Order Perciformes
	Family Percichthyidae (Temperate Basses)
white perch	Morone americana
white bass	Morone chrysops
yellow bass	Morone mississippiensis
	Family Centrarchidae (Sunfishes)
rock bass	Ambloplites rupestris
green sunfish	Lepomis cyanellus
pumpkinseed	Lepomis gibbosus
warmouth	Lepomis gulosus
orangespotted sunfish	Lepomis humilis

-continued-

Common Name	Scientific Name
bluegill	Lepomis macrochirus
longear sunfish	Lepomis megalotis
redear sunfish	Lepomis microlophus
smallmouth bass	Micropterus dolomieui
largemouth bass	Micropterus salmoides
white crappie	Pomoxis annularis
black crappie	Pomoxis nigromaculatus
Family Percidae (Perches)	
western sand darter	Ammocrypta clara
eastern sand darter	Ammocrypta pellucida
greenside darter	Etheostoma blennioides
rainbow darter	Etheostoma caeruleum
bluntnose darter	Etheostoma chlorosomum
Iowa darter	Etheostoma exile
fantail darter	Etheostoma flabellare
least darter	Etheostoma microperca
johnny darter	Etheostoma nigrum
orangethroat darter	Etheostoma spectabile
banded darter	Etheostoma zonale
yellow perch	Perca flavescens
logperch	Percina caprodes
channel darter	Percina copelandi
gilt darter	Percina eides
blackside darter	Percina maculata
slenderhead darter	Percina phoxocephala
river darter	Percina shumardi
sauger	Stizostedion canadense
blue pike	Stizostedion vitreum glaucum
walleye	Stizostedion vitreum vitreum
Family Sciaenidae (Drums)	
freshwater drum	Aplodinotus grunniens
Family Cottidae (Sculpins)	
mottled sculpin	Cottus bairdi
slimy sculpin	Cottus cognatus
spoonhead sculpin	Cottus ricei
fourhorn sculpin	Myoxocephalus quadricornis

[a] Bailey et al., 1973; Scott and Crossman, 1973; Hubbs and Lagler, 1964; Trautman, 1957; Van Meter and Trautman, 1970; Becker, 1976.

- spotted gar (Lepisosteus oculatus)

Habitat - The spotted gar is found only in very clear, base gradient waters, with profuse aquatic vegetation, such as glacial lakes, sheltered bays, and estuaries of the Great Lakes. The species is highly dependent on vegetation, where it spawns, seeks shelter as young and adult, and feeds. It disappears entirely from waters that are devegetated.

Distribution - This species is primarily southern in range, occurring in the Mississippi and Gulf Coast drainages, and reaching its northernmost limits in the Great Lakes region. It is unreported in Lakes Superior and Ontario and rare in Lakes Erie, Huron, and Michigan.

Spawning and Migration - The spotted gar has not been intensively studied. It spawns in spring in shallow, densely vegetated margins of lakes and bays.

Food - Limited data indicate the food of this species to be primarily small fish, such as yellow perch and cyprinids.

Recreational and Commercial Value - The spotted gar has no present major recreational or commercial value. Gars in general are regarded by fishermen as a nuisance due to their alleged voracious consumption of more valuable fish and tendency to tangle nets.

● longnose gar (Lepisosteus Osseus)

Habitat - The longnose gar, like the spotted gar, prefers very clean, base gradient waters with some aquatic vegetation. However, it tolerates greater current and turbidity, as well as less vegetation than the spotted gar. In the Great Lakes it commonly occurs in sheltered bays, tributaries, and estuaries having these characteristics.

Distribution - The species occurs from Montana and Quebec to the north, throughout the entire Mississippi-Missouri-Ohio River drainage basin, the Rio Grande basin, along the eastern coastal drainage from New Jersey south, and along the Gulf Coast. The longnose gar is common in the Great Lakes except in Lake Superior, where it is restricted largely to the south shore.

Spawning and Migration - The longnose gar spawns in late spring and early summer in shallow water (usually two feet), over submerged vegetation. Upstream migrations may occur. Adults spawn in clusters, sometimes constructing crude nests, but usually broadcasting eggs randomly. Eggs adhere to vegetation, and after hatching young also adhere to vegetation using an adhesive pad near the tip of the snout.

Food - Adults are almost entirely piscivorous, utilizing a variety of small fishes.

Recreational and Commercial Value - Like the spotted gar, the longnose has no major recreational or commercial use and is regarded by fishermen as a nuisance.

● bowfin (Amia calva)

Habitat - The bowfin is almost identical in habitat with the longnose gar, preferring shallow base gradient, vegetated waters, such as the margins of glacial lakes, river backwaters, marshes, swamps, and bays and estuaries of the Great Lakes. The species tolerates some turbidity and current, and it is often found in waters lacking vegetation. However, it is common only where aquatic vegetation is relatively abundant.

Distribution - The species ranges from Minnesota to the Lake Champlain drainage on the north, throughout most of the Mississippi River basin, the eastern seaboard drainage from the Susquehanna River south, and the Gulf Coast drainage. It is relatively common in all of the Great Lakes except Lake Superior, where it is restricted to the southeastern shore.

Spawning and Migration - The bowfin spawns in nests constructed in submerged aquatic vegetation in warm shallow water, usually in late April to late May. Adult males form protective colonies guarding the young after hatching.

Food - Young feed on plankton, while adults chiefly utilize fish, crayfish, and molluscs.

Recreational and Commercial Value - The bowfin has no major recreational or commercial value in the Great Lakes, and it is generally regarded by fishermen as a nuisance.

● gizzard shad (Dorosoma cepedianum)

Habitat - The gizzard shad is found in base or low-gradient waters such as lakes, large impoundments, and large streams. It is highly tolerant of warm temperatures, muddy bottoms, and turbidity, provided phytoplankton is abundant. In the Great Lakes it occurs in almost all bays, estuaries, and shallow open nearshore waters. Although not dependent on aquatic vegetation, it is usually common in the warm shallow waters associated with coastal wetlands.

Distribution - The gizzard shad is found in larger waters throughout the eastern United States excluding New England, throughout most of the Mississippi basin, the eastern and Gulf coastal drainages, and the Rio Grande. It is common in the lower Great Lakes and southern Lakes Michigan and Huron. In the northern regions of the latter two lakes and Lake Superior it is uncommon.

Spawning and Migration - The gizzard shad spawns in early June to early July in warm shallow water, apparently broadcasting eggs at random. At this time a general concentration and inshore migration of adults occurs.

Food - Young and adults are largely planktivorous, utilizing both phytoplankton and zooplankton. Adults also utilize benthic and periphytic algae and invertebrates (including those growing on rocks, piers, pilings, and vegetation), which is harvested by long sweeping movements against such substrates.

Recreational and Commercial Value - The gizzard shad has no major recreational or commercial use in the Great Lakes, although it may be sold to rendering plants or used as animal feed or fertilizer when taken in sufficiently large quantities. Young gizzard shad are important forage for larger predators.

- redfin pickerel (*Esox americanus americanus*) and
  grass pickerel (*Esox americanus vermiculatus*)

Systematic Note - Of the two recognized subspecies of *Esox americanus*, the grass pickerel is apparently the form found in the Great Lakes. The redfin pickerel is found in the Canadian lower St. Lawrence River and will not be considered here.

Habitat - The grass pickerel is found in shallow, clear, densely vegetated waters of base or low gradient streams, lakes, and marshes. It is tolerant of some turbidity. In the Great Lakes it occurs in such areas in bays, tributary mouths, and coastal wetlands. It is generally rare or absent when aquatic vegetation or overhanging terrestrial sedges and grasses are absent or removed.

Distribution - Whereas the redfin pickerel is primarily found in the eastern coastal drainage of the United States and Canada, the grass pickerel is primarily distributed west of the Allegheny plateau, including the Mississippi River basin, Lake Erie, Lake Ontario, and southern Lakes Huron and Michigan. It is absent or rare in Lake Superior and northern Lakes Huron and Michigan.

Spawning and Migration - The grass pickerel spawns soon after ice-out in early spring, usually late March to early May. Some fall spawning may also occur. Adults migrate upstream or inshore to shallow water with submerged vegetation, often utilizing temporarily inundated flood plains, pastures, meadows, and woods. No nest is built. The eggs are broadcast, abandoned, and adhere to vegetation. Young shelter in the vegetation, apparently clinging to it in some manner.

Food - Young feed on zooplankton and small invertebrates, and adults are largely piscivorous but also consume crayfish, tadpoles, and insects.

Recreational and Commercial Value - The grass pickerel has no major recreational or commercial use in the Great Lakes.

● northern pike (*Esox lucius*)

Habitat - The northern pike prefers lakes, low gradient streams, and bays and estuaries of the Great Lakes. The species requires abundant aquatic vegetation, particularly submersed types and emergent gramminoid types, and relatively clear, cool or cold water, although the adults are moderately tolerant of turbidity. It is one of the more common fishes of Great Lakes coastal wetlands.

Distribution - The northern pike is holarctic in distribution. In North America it occurs from extreme northern Alaska and Canada, south to the Missouri and upper Mississippi River drainages, and eastward through the Great Lakes basin to the Lake Champlain and Hudson River drainages. It is relatively abundant in all the Great Lakes but Lake Erie, where it has greatly decreased in abundance due to siltation and marsh drainage.

Spawning and Migration - Like the grass pickerel, the northern pike spawns at ice-out (March to early May) in shallow vegetated waters of marshes, streams, lakes, or temporarily inundated pastures, woods, and meadows. Adults migrate upstream or inshore to such areas, where eggs are broadcast and adhere to vegetation. Highly turbid, saline, or stagnant waters are poor spawning habitat, with relatively clear waters, gramminoid vegetation, and sandy or detrital substrates preferred. Adults usually return to deeper waters after spawning and remain there during summer.

Food - Young feed on large zooplankters and small insect larvae, and adults are primarily piscivorous, although waterfowl, frogs, and snakes may also be consumed.

Recreational and Commercial Value - The northern pike is one of the more important game fishes in the Great Lakes. Prior to 1900 it was also commercially important but is of minimal commercial importance at present. The species is the primary game fish of coastal wetlands.

● muskellunge (Esox masquinongy)

Habitat - The muskellunge prefers deeper waters than the northern pike and appears to be more common in submersed aquatic vegetation in larger bays, lakes, and deep rivers. Few sympatric populations of northern pike and muskellunge exist, and it is believed the more numerous northern pike has a competitive advantage over the muskellunge in many habitats. The muskellunge also requires relatively clear, cool or cold waters, and abundant aquatic vegetation.

Distribution - The muskellunge is found primarily in the Great Lakes basin, the Ohio River drainage, and the Lake Nipigon region of southeastern Manitoba, northern Minnesota, and western Ontario. It is not common in the Great Lakes except in certain areas of intensive stocking. Relatively large native populations exist in some coastal areas such as the upper Niagara River and Lake St. Clair.

Spawning and Migration - Spawning occurs just after ice-out, usually after northern pike spawning, from early April to early May. Adults migrate upstream or inshore from deeper-water wintering areas. Eggs are broadcast without nesting activity and adhere to vegetation. Young gradually migrate to deeper water by summer.

Food - Young feed on zooplankton, fish larvae, and young fishes, and adults are primarily piscivorous, although waterfowl, frogs, snakes, or aquatic mammals may also be consumed.

Recreational and Commercial Value - The muskellunge is an important game fish in the Great Lakes region, although it is not as numerous as the northern pike and is maintained largely by supplemental stocking. Prior to 1900 it was commercially important, but such importance is currently minimal.

● central mudminnow (Umbra limi)

Habitat - Mudminnows prefer clear, generally cool waters of small ponds, marshes, lakes, acid bogs, and low gradient streams, where aquatic vegetation is relatively abundant and the bottom consists of detritus, under which the fish burrows.

Distribution - The central mudminnow is distributed much like the muskellunge. It occurs in central North America west of the Allegheny region, south to Tennessee, west to Missouri, and northwards to southeastern Manitoba, along the south shore of Lake Superior through the Great Lakes to the Lake Champlain region. It is relatively common in all the U.S. waters of the Great Lakes.

Spawning and Migration - Spawning occurs in late March to early April in aquatic vegetation along stream or lake bottoms and margins. No nests are constructed, and eggs adhere to aquatic vegetation.

Food - Young feed on small invertebrates, such as ostracods and young snails, and adults utilize larger invertebrates, such as isopods, amphipods, and molluscs.

Recreational and Commercial Value - Aside from its value as a forage fish, the mudminnow is of no current recreational or commercial value.

● goldfish (Carassius auratus)

Habitat - The goldfish prefers warmer waters in lakes, low gradient streams, and bays and estuaries of the Great Lakes. The species also prefers dense aquatic vegetation and is less tolerant of silt and cultural pollution than the closely related carp.

Distribution - The goldfish is endemic to eastern Asia and was introduced widely throughout the North America for ornamental purposes. Although present throughout the United States, it is primarily common in the Midwest and reaches its greatest abundance in western Lake Erie. It occurs sparsely in the other Great Lakes.

Spawning and Migration - Goldfish spawn in May and June in warm shallow water in submersed and emergent vegetation. Eggs are broadcast randomly and adhere to vegetation. No migration except gradual inshore movement for spawning occurs.

Food - The species is omnivorous in feeding habits, utilizing a variety of plant and animal material depending on availability.

Recreational and Commercial Value - A limited ornamental market for wild goldfish exists, but the species is largely of no economic or recreational value at present.

● carp (*Cyprinus carpio*)

Habitat - Like the goldfish, the carp prefers warmer waters of lakes, reservoirs, low gradient rivers and streams, and bays and sheltered nearshore waters of the Great Lakes. The carp prefers dense aquatic vegetation and is highly tolerant of low dissolved oxygen, silt, cultural pollution, and high temperatures. It is usually absent from cooler, clearer, higher gradient waters.

Distribution - The carp is endemic to temperate Europe and Asia and was introduced widely in North America for food. Although present throughout the continental United States, the carp is most abundant south of the Great Lakes region. It is present and locally common in all the Great Lakes, but it is most abundant in western Lake Erie.

Spawning and Migration - Carp spawn in late spring and early summer in warm, quiet water, and usually in aquatic vegetation. Eggs are broadcast randomly and adhere to vegetation. A general migration into shallow water usually occurs prior to spawning.

Food - Carp are scavengers and are omnivorous in feeding habits, utilizing a variety of plant and animal material. They do not deliberately ingest mud and sewage as is commonly believed.

Recreational and Commercial Value - Recreational fishing for carp is common throughout its range. Although the value per pound is low, the total commercial harvest of carp is sufficiently large to make it a valuable commercial fish.

● brassy minnow (*Hybognathus hankinsoni*)

Habitat - The brassy minnow is usually found in small, clear, cool- or cold-water streams and acid bogs, often in association with vegetation.

Distribution - The brassy minnow occurs from the upper St. Lawrence River and Lake Champlain region, westward through the Great Lakes region, the Missouri River basin, and southern Manitoba and Saskatchewan. It is relatively common in all the Great Lakes except Lake Erie.

Spawning and Migration - Spawning is largely undocumented but probably occurs during May in quiet pools over silt, sand, or aquatic vegetation. Eggs are adhesive and are attached to submerged substrates. No migration has been documented.

Food - The species probably feeds on algae, zooplankton, and small aquatic insects.

Recreational and Commercial Value - Other than its value as a forage fish, the brassy minnow has no economic or recreational value at present.

● goldenshiner (Notemigonus crysoleucas)

Habitat - The goldenshiner is most abundant in clear waters of lakes, ponds, marshes, and low gradient streams. The species prefers submersed aquatic vegetation or filamentous algae and substrates of sand or detritus.

Distribution - This species is restricted largely to eastern North America from southeastern Saskatchewan and the Maritime Provinces south to Florida and eastern Texas. It is common in all the Great Lakes.

Spawning and Migrations - The goldenshiner spawns in June or July in quiet shallow water over filamentous algae, submersed vascular vegetation, or among the stems of emergent vegetation. Eggs are broadcast and abandoned, apparently adhering to the vegetation. No large scale migrations have been documented.

Food - The species feeds on a variety of insect larvae and adults, microcrustaceans, and reportedly filamentous algae in late summer.

Recreational and Commercial Value - Although the goldenshiner is an important bait and forage fish, it has no current recreational or economic value.

● pugnose shiner (Notropis anogenus)

Habitat - The pugnose shiner occurs in clear, quiet, vegetated waters of glacial lakes, low gradient streams, and sheltered nearshore waters of the Great Lakes. It is strongly dependent on aquatic vegetation and requires a substrate of sand, marl, or detritus.

Distribution - The species is restricted to the Great Lakes basin except Lake Superior and is also found in part of the Red River of the North. It is uncommon and decreasing in abundance in Lakes Ontario, Erie, Huron, and Michigan.

Spawning and Migrations - Few studies of the species have been made. It presumably spawns in spring.

Food - Feeding habits are also largely unknown, although the species probably utilizes small plant and animal material.

Recreational and Commercial Value - The pugnose shiner, due to its scarcity, is of little forage importance and has no other economic or recreational value.

● pugnose minnow (Notropis emiliae)

Habitat - The pugnose minnow occurs in clearer generally warmer waters of lakes, bays, estuaries, and low gradient streams with abundant aquatic vegetation and substrates of of sand or detritus. It is highly dependent on vegetation, and its extinction in many areas is attributed to devegetation of its habitat.

Distribution - This species is primarily southern in distribution, occurring in the Mississippi basin and northwards in to the Great Lakes region only to southern Lake Michigan and Lake Erie. It is generally rare in the areas of the Great Lakes in which it occurs.

Spawning and Migration - The pugnose minnow is primarily a spring spawner, but little is known about its spawning activity or migrations, if any.

Food - The pugnose shiner feeds on microcrustaceans and small insect larvae.

Recreational and Commercial Value - Aside from its possible use as a forage fish, the pugnose minnow has no recreational or commercial importance.

● blackchin shiner (Notropis heterodon)

Habitat - The blackchin shiner prefers clear, heavily vegetated waters in glacial lakes and the bays and estuaries of larger lakes, such as the Great Lakes. It is highly dependent on aquatic vegetation and its extinction in some areas of its range (e.g., Lake Erie) has been attributed to devegetation of its habitat.

Distribution - The species occurs primarily in glaciated regions, from the pothole region of the Dakotas and Minnesota, south through the glaciated Midwest to northern Kentucky, and east through the Great Lakes region to the upper St. Lawrence region. It is absent from northern Lake Superior, which is north of its range, common in Lakes Michigan, Huron, and Ontario, and probably absent from Lake Erie due to siltation and the decline of aquatic vegetation.

Spawning and Migration - The blackchin shiner probably spawns in June, although its spawning habits and migrations, if any, have received little study.

Food - Microcrustaceans and small insects appear to comprise the majority of the diet.

Recreational and Commercial Value - Although it is important as a forage fish in many areas, the blackchin shiner has no current recreational or commercial importance.

● blacknose shiner (Notropis heterolepis)

Habitat - The blacknose shiner occurs in very clear water of glacial lakes, streams, and sheltered embayments, and estuaries of the Great Lakes. It requires profuse aquatic vegetation substrates of sand, gravel, hard mud, or detritus, and is highly intolerant of siltation.

Distribution - This is primarily a northern species occurring from central Saskatchewan to the Maritime Provinces in the north, south through the pothole regions of the Dakotas to Missouri, and northeast through Tennessee and the Ohio River drainage to New England. The species is common in Lakes Ontario, Huron, Michigan, and Superior, but is increasingly rare in Lake Erie due to marsh removal and siltation.

Spawning and Migration - The biology of the species is poorly documented, but it probably spawns in spring or summer in quiet waters over sandy bottoms. No migrations are known.

Food - Microcrustaceans, algae, and small insects are the probable diet of the species.

Recreational and Commercial Value - The blacknose shiner is probably an important forage item for predaceous fishes in its habitat. It has no present recreational or commercial value.

● redfin shiner (Notropis umbratilis)

Habitat - The redfin shiner occurs in clear, quiet waters of pools, streams, ditches, and probably small stream mouths in coastal wetlands. It often occurs around submersed aquatic vegetation and is generally intolerant of siltation.

Distribution - The species occurs in the Mississippi basin from Minnesota, south to Texas and Mississippi and northeast along the Ohio River drainage and southern half of the Great Lakes region to New York. It is largely absent from Lake Superior and northern Lakes Huron and Michigan.

Spawning and Migration - The redfin shiner spawns in slow riffles on sand or gravel substrates and often in the occupied nests of green sunfish and longear sunfish. Eggs may be broadcast over submersed vegetation. No migrations have been documented.

Food - Feeding habits of the redfin shiner have not been studied, but it probably feeds on microcrustaceans and small insects.

Recreational and Commercial Value - The redfin shiner has no present recreational or commercial importance.

● fathead minnow (Pimephales promelas)

Habitat - The fathead minnow is found in slow-flowing streams, ponds, small lakes, and marshes. It is tolerant of both clear and turbid water and extremes in pH. It is usually absent in habitats where the bluntnose minnow occurs.

Distribution - The species occurs throughout central North America from the Great Slave Lake and Hudson Bay drainage to New Brunswick in the north and south through the St. Lawrence-Great Lakes, Ohio River, and Missouri River drainages, to the Rio Grande drainage. It is common to abundant in all the Great Lakes.

Spawning and Migration - The fathead minnow spawns on the undersides of rocks, logs, vegetation, and other submerged objects, usually over a prolonged period from April to August depending on location. Adhesive eggs are deposited in a nesting site selected by a single male, often by several females consecutively. Males remain after spawning and actively defend nests. There are no true migrations.

Food - The food of the fathead minnow consists of algae, detritus, and zooplankton.

Recreational and Commercial Value - The fathead minnow is widely cultured as a bait fish, and in many coastal areas, including wetlands, it is an extremely abundant and valuable natural forage fish.

● white sucker (Catostomus commersoni)

Habitat - The white sucker prefers sandy or gravelly areas in clear streams, rivers, and lakes. It is highly tolerant of siltation, cultural pollution, and dense vegetation, and it consequently occurs in a wide variety of pristine and degraded habitats, including coastal wetlands, throughout the Great Lakes region.

Distribution - The white sucker occurs widely throughout northern North America, from the Yukon region, east to Labrador in the north and south through the Great Lakes-St. Lawrence, eastern coastal, Ohio River, Missouri River, and Mississippi River drainages as far as northern Texas and east to northern Georgia.

Spawning and Migration - The species spawns from early May to early June, usually migrating in large numbers from deeper wintering waters to sandy or gravelly areas in streams and along lakeshores. Adhesive eggs are broadcast over the sand or gravel and abandoned.

Food - Young feed on plankton and small invertebrates. Larger individuals utilize a variety of benthic invertebrates.

Recreational and Commercial Value - Angling, spearing, and dip-netting for white suckers, particularly during spawning migrations, is popular in several tributaries of the Great Lakes. Commercially, the species is not heavily utilized. Young and adult white suckers are important natural forage fishes and are often used for forage in fish culture.

● lake chubsucker (Erimyzon sucetta)

Habitat - The lake chubsucker prefers clear, well-vegetated waters of lakes and ponds and is found in sheltered, vegetated nearshore waters of the Great Lakes. It is intolerant of siltation.

Distribution - The lake chubsucker is restricted primarily to eastern North America, occurring from southern Minnesota in the west to southern New York in the east, south to southern Florida and southern Texas. It is apparently absent from Lake Superior and northern Lakes Michigan and Huron. Its abundance in the Midwest is steadily decreasing due to siltation and devegetation of its habitat.

Spawning and Migration - The species spawns in March to April, usually migrating to tributary streams. Non-adhesive eggs are scattered in a nest cleared by the male in a sand or gravel substrate, generally in association with aquatic vegetation, filamentous algae, or submersed terrestrial vegetation.

Food - Young feed on copepods, cladocerans, and chironomid larvae, and adults utilize a variety of benthic invertebrates.

Recreational and Commercial Value - The lake chubsucker has no present recreational or commercial value, although it may serve as forage for many predatory fishes.

● black bullhead (Ictalurus melas)

Habitat - The black bullhead occurs in lakes, ponds, marshes, and low-gradient streams. It prefers warm, turbid water, a muddy bottom, and aquatic vegetation, although it is not as dependent on vegetation as the brown or yellow bullheads. It is also highly tolerant of low dissolved oxygen and cultural pollution.

Distribution - The black bullhead occurs throughout central North America, including the entire Mississippi basin, the western Gulf Coast drainage, and the southern Great Lakes. It is abundant in Lake Erie and Lake Michigan but is uncommon in Lake Superior, Lake Huron, and Lake Ontario.

Spawning and Migration - The species spawns in May to June, usually in nests consisting of a shallow depression or burrow under a stream bank or among logs, stumps, and aquatic vegetation. Parents guard the eggs and young, which form dense schools, until several days after hatching. No true migrations occur.

Food - The black bullhead is primarily a benthic feeder, utilizing crustaceans, molluscs, leeches, oligochaetes, aquatic insects, plant material, and sometimes small fish.

Recreational and Commercial Value - The species is locally popular for angling in the Midwest, and it comprises a variable portion of the fish marketed as bullheads or catfish from Lake Erie. Lake Michigan, and the Mississippi River basin fisheries. It is of limited forage value except as young.

● yellow bullhead (*Ictalurus natalis*)

Habitat - The yellow bullhead requires dense aquatic vegetation in shallow, clear waters of lakes, ponds, bays, rivers, and low-gradient streams. It is not as tolerant of siltation and pollution as the black bullhead and requires a firmer substrate of clay, detritus, or gravel.

Distribution - The yellow bullhead occurs in eastern North America from North Dakota across the southern half of the Great Lakes region to New York and south to Florida and central Texas. It is common in Lake Ontario, Lake Erie, Lake Huron, and Lake Michigan but is uncommon to rare in Lake Superior.

Spawning and Migration - Spawning is similar to the black bullhead.

Food - Food is similar to the black bullhead.

Recreational and Commercial Value - Recreational and commercial use are similar to the black bullhead.

● brown bullhead (*Ictalurus nebulosus*)

Habitat - Habitat is similar to the yellow bullhead.

Distribution - The brown bullhead occurs in eastern North America along the entire Atlantic coastal drainage from New Brunswick to Florida, west through the Great Lakes to the northern tributaries of the Missouri River, and most of the eastern drainage of the Mississippi basin. It is generally more common than the yellow bullhead and black bullhead in the Great Lakes and occurs in all but Lake Superior.

Spawning and Migration - Spawning is similar to the black and yellow bullheads.

Food - Food is similar to that of black and yellow bullheads and also includes eggs of other fishes.

Recreational and Commercial Value - Recreational and commercial uses are similar to those of black and yellow bullheads.

● tadpole madtom (Noturus gyrinus)

Habitat - The tadpole madtom occurs in marshes, lakes, bays, and low gradient streams. It is highly intolerant of pollution and siltation and requires clear water, abundant aquatic vegetation, and substrates of mud, clay, or detritus.

Distribution - The species occurs only in low gradient waters of the Great Lakes basin, the U.S. eastern and Gulf coastal drainages, and extreme lowland portions of the Mississippi basin. It has been introduced, apparently with bullheads, into Oregon, Idaho, Connecticut, and New Hampshire. It occurs in lake Ontario, Lake Erie, southern Lake Huron, southern Lake Michigan, and the northwestern Lake Superior tributaries. Siltation is causing decreasing range and abundance.

Spawning and Migration - The tadpole madtom spawns in June to July in much the same manner and habitat as the bullheads.

Food - The species feeds on small aquatic invertebrates, including cladocerans, ostracods, and chironomid larvae.

Recreational and Commercial Value - Where common this species may be an important forage item for larger predaceous fishes, but it has no other recreational or commercial value.

● pirate perch (Aphredoderus sayanus)

Habitat - The pirate perch occurs in swamps, marshes, and pools of low gradient streams. It prefers some emergent vegetation and substrates of muck and detritus.

Distribution - The species is restricted to the eastern United States, occurring in the north from southeastern Minnesota along the southern edges of the Great Lakes to northern New York, south between the western Appalachians and Mississippi River to the Gulf Coast, and westward to eastern Texas and Oklahoma. It is uncommon in the Great Lakes region and apparently absent from the lakes themselves.

Spawning and Migration - The pirate perch probably spawns during May in nests built and guarded by the spawning pair. No migrations are known to occur.

Food - Aquatic insects and small fishes are apparently the primary food source.

Recreational and Commercial Value - The pirate perch may be used as forage by predaceous fishes, but it has no present economic value.

● banded killifish (*Fundulus diaphanus*)

Habitat - The banded killifish is found only in glacial lakes, ponds, marshes, and low gradient vegetated streams, primarily on substrates of marl, sand, or detritus.

Distribution - The species occurs in the pothole region of the Dakotas and Minnesota, eastward across the Great Lakes region to the Atlantic coastal drainage between the Maritime Provinces and South Carolina. It is generally common in the Great Lakes, although Lake Superior is beyond its northern range limit, and it has been virtually extirpated in Lake Erie due to siltation and devegetation of waterways.

Spawning and Migration - The banded killifish spawns in May. Males select and defend breeding areas in dense vegetation, pursuing gravid females and spawning directly against submerged plants. Adhesive threads attach extruded eggs to the vegetation. No true migration occurs.

Food - Juveniles utilize chironomid larvae, ostracods, cladocerans, and copepods, while adults utilize similar items in addition to small newly hatched Odonata, Ephemeroptera, molluscs, and Turbellaria.

Recreational and Commercial Value - Aside from limited use as bait, the banded killifish has no present economic value.

● starhead topminnow (*Fundulus notti*)

Habitat - The starhead topminnow apparently prefers densely vegetated pools and backwaters of streams.

Distribution - This prairie species occurs in the Mississippi River tributaries of Iowa and southern Wisconsin, east to the extreme southern tributaries of Lake Michigan, and south to northern Arkansas, eastern Oklahoma, and western Tennessee. It is probably absent from the Great Lakes.

Spawning and Migration - The life history of the starhead topminnow has been poorly documented, but it probably spawns in late May.

Food - The primary food items include small aquatic and terrestrial insects, molluscs, crustaceans, and delicate portions of aquatic vegetation.

Recreational and Commercial Value - The starhead topminnow may serve as forage for larger predaceous fishes, but it has no present economic value.

● brook stickleback (<u>Culaea inconstans</u>)

<u>Habitat</u> - The brook stickleback is a coldwater species occurring in small springs, brooks, ponds, and shallow margins of larger lakes with abundant submersed aquatic vegetation and substrates of marl, muck, sand, or detritus.

<u>Distribution</u> - The species occurs throughout glaciated central North America from eastern British Columbia to Nova Scotia in the north and from Montana to New York on the south, including the Great Slave Lake, Hudson Bay, Missouri River, upper Mississippi River, Great Lakes-St. Lawrence, and Ohio River drainages. It is generally common in the Great Lakes basin, but probably occurs only in tributaries.

<u>Spawning and Migration</u> - The brook stickleback spawns from April to July, depending on temperature, in shallow quiet water. Males construct and defend nests made from stems of aquatic vegetation. Females are enticed to the nests, and adhesive eggs are extruded, fertilized, and guarded by the male until hatching.

<u>Food</u> - Aquatic larvae of many insects, small crustaceans, fish eggs, snails, oligochaetes, and algae are utilized.

<u>Recreational and Commercial Value</u> - Although occassionally used for bait, the brook stickleback has no present economic value.

● brook silverside (<u>Labidesthes sicculus</u>)

<u>Habitat</u> - The brook silverside occurs in glacial lakes, ponds, low gradient streams, and bays and harbors of the Great Lakes, usually in clear water with some aquatic vegetation and substrates of sand, gravel, or muck.

<u>Distribution</u> - The species occurs in the Great Lakes basin, the Gulf Coast drainage, and the Mississippi basin from its easternmost reaches westward to southern Minnesota and south to eastern Texas. It occurs in bays of Lake Erie and Lake Ontario, is absent from Lake Superior, and probably occurs only in tributaries of Lake Michigan and Lake Huron.

<u>Spawning and Migration</u> - There are no true migrations. Spawning is prolonged and occurs in May to July, sometimes as late as August. Eggs with adhesive filaments are deposited in moderate current over gravel among vegetation, especially <u>Scirpus</u> and <u>Potamogeton</u>. Adults apparently do not guard eggs or young.

<u>Food</u> - Food of this surface feeder consists mostly of Cladocera, small flying insects, and <u>Chaoborus</u>.

<u>Recreational and Commercial Value</u> - In locations where it is abundant, the brook silverside is an ideal forage fish, but it has no other economic value.

● rock bass (Ambloplites rupestris)

Habitat - The adult rock bass is primarily an inhabitant of streams and littoral waters of lakes with rocky or gravelly bottoms and clear water (including the Great Lakes), having little dependence on aquatic vegetation. However, juveniles often utilize vegetated embayments on the Great lakes as nursery areas.

Distribution - The rock bass occurs throughout the Great Lakes basin, the Red River of the north drainage in North Dakota and Manitoba, and the Mississippi basin from its easternmost reaches west to Minnesota and south through Iowa, Arkansas, and Louisiana. It is common in all the Great Lakes.

Spawning and Migration - Spawning occurs in May to June, in gravelly areas of streams or nearshore reefs and beaches. Males construct depressional nests, spawn with females, and guard eggs and young until shortly after hatching.

Food - Rock bass feed on aquatic insects, crayfish, small fishes (especially minnows and young yellow perch), and sometimes their own young.

Recreational and Commercial Value - The rock bass is a highly popular game fish, particularly in streams and lake gravel bars, where it often occurs in abundance with the smallmouth bass. It is harvested commercially on a limited basis in some parts of the Great Lakes.

● green sunfish (Lepomis cyanellus)

Habitat - The green sunfish inhabits pools of small and large streams, lakes, and marshes. It utilizes a variety of substrates and is generally more tolerant of turbidity and siltation than other sunfishes. Although it has no strong dependence on aquatic vegetation, its versatility in habitat requirements leads to its abundance in many coastal wetlands.

Distribution - The species is restricted to east-central North America. It occurs west of the Appalachian Mountains from New York to Georgia and east to the Rocky Mountains from northern Mexico and Texas to North Dakota, throughout the southern Great Lakes region and in parts of the Red River of the North and Hudson Bay drainages. It is uncommon in Lake Superior and Lake Huron but common in the remaining Great Lakes.

Spawning and Migration - Multiple spawnings occur at 8-9 day intervals from May to August or September. Males are territorial and build shallow nests in various substrates, usually among sheltering rocks, logs, or vegetation. After courtship and spawning, males guard nests and fan the eggs for aeration until hatching. No true migrations occur.

Food - Green sunfish consume molluscs, insects, crustaceans, and small fish.

Recreational and Commercial Value - Green sunfish are among a variety of panfish that are locally popular for angling and are widely stocked, but they have no significant commercial use.

● pumpkinseed (Lepomis gibbosus)

Habitat - The pumpkinseed inhabits lakes and low gradient streams with abundant aquatic vegetation and substrates of sand, muck, or detritus. It occurs in vegetated bays and estuaries of the Great Lakes.

Distribution - The species occurs in the eastern coastal drainage of North America from Georgia to Maine, throughout the Great Lakes basin exclusive of Lake Superior, and in the northern drainages of the Ohio, Mississippi, and Missouri Rivers as far west as the Dakotas. It has been widely stocked and is locally common elsewhere in North America and Europe.

Spawning and Migration - The pumpkinseed is highly territorial, with nesting, spawning, courtship, and nest guarding behavior similar to the green sunfish. Nests are shallow depressions and are constructed among aquatic vegetation in substrates of clay, sand, gravel, or rock. Multiple spawnings occur from late spring to late summer.

Food - The pumpkinseed feeds primarily on insects and a variety of small aquatic and terrestrial invertebrates, but it will consume small fish and other small vertebrates such as salamander larvae.

Recreational and Commercial Value - The pumpkinseed is a locally popular game fish, and in some areas of the Great Lakes, particularly in Canada, it is commercially harvested on a limited scale.

● bluegill (Lepomis macrochirus)

Habitat - The bluegill occurs primarily in low or base gradient waters of streams, natural lakes, marshes, and artificial impoundments, preferring relatively clear water, substrates of sand, gravel, or muck, abundant cover, and scattered beds of aquatic vegetation. Bays and estuaries are its principal habitat in the Great Lakes.

Distribution - The bluegill occurs in eastern North America throughout the Mississippi-Ohio River drainage, the lower Missouri River drainage, the Gulf coastal drainage, the eastern coastal drainage from North Carolina to Florida, and the Great Lakes basin exclusive of Lake Superior. It is generally common in all the Great Lakes except Lake Superior. It has been stocked widely outside its natural range.

Spawning and Migration - Spawning times and behavior are similar to the pumpkinseed and green sunfish, although the bluegill is less dependent on aquatic vegetation than the former. No true migrations occur.

Food - Blugills are primarily insectivorous, but they also consume crustaceans, annelids, molluscs, and plant materials. They are very rarely piscivorous.

Recreational and Commercial Value - The bluegill is an extremely important game fish in inland waters, although it is probably locally popular in the coastal waters of the Great Lakes. It, like the pumpkinseed, is harvested commercially in the Great Lakes on a limited scale.

● smallmouth bass (Micropterus dolomieui)

Habitat - The habitat of the smallmouth bass is nearly identical with that of the rock bass, and the two species are usually found together. The smallmouth bass occurs in streams with moderate to fast current, relatively clear water, and substrates of rock, boulders, or gravel with abundant cover such as logs, undercuts, and artificial structures. It also occurs commonly on gravel bars and sheltered gravel-bottom embayments of the Great Lakes. Adults are not dependent on aquatic vegetation, although they often feed in it, but young in the Great Lakes often utilize aquatic vegetation as nursery habitat.

Distribution - The smallmouth bass occurs throughout the Great Lakes basin, the Ohio River basin, the eastern coastal drainage from Nova Scotia to Georgia, and westward as far as southern Saskatchewan to the north and central Oklahoma to the south. It is common to abundant in all the Great Lakes. It has been widely introduced outside its natural range, including Europe, Asia, and Africa.

Spawning and Migration - The smallmouth bass spawns from May to July. Males build depressional nests on bottoms of sand, gravel, or cobbles, usually near cover as described above. After courtship and spawning, males guard the eggs and young until several days after hatching. No true migrations occur.

Food - Food changes with age, usually consisting of plankton in young-of-the-year, insects, and crustaceans in yearlings, and small fish and crayfish in older adults.

Recreational and Commercial Value - The smallmouth bass is an extremely important game fish in the Great Lakes. It is also harvested commercially on a limited scale.

● largemouth bass (*Micropterus salmoides*)

Habitat - The largemouth bass occupies habitat similar to the bluegill, usually base or low gradient waters of lakes, streams, and marshes. It prefers clear water, abundant aquatic vegetation, and substrates of mud, muck, clay, sand, gravel, or detritus. It occupies sheltered areas of bays and estuaries of the Great Lakes.

Distribution - The largemouth bass occupies most of North America east of the Rocky Mountains as far north as southern Manitoba, Quebec, and Ontario and south to the Rio Grande drainage and southern Florida. It is common in the Great Lakes exclusive of Lake Superior.

Spawning and Migration - The largemouth bass spawns in late spring to mid-summer in depressional nests in shallow water, usually on substrates of sand, or soft mud among emergent vegetation. Territoriality, nesting, courtship, and nest guarding are similar to the smallmouth bass.

Food - Food habits are similar to the smallmouth bass.

Recreational and Commercial Value - Although extremely important as a game fish in inland waters, the largemouth bass is also of local recreational importance in coastal waters of the Great Lakes. It is harvested commercially on a limited scale.

● black crappie (*Pomoxis nigromaculatus*)

Habitat - The black crappie is found in low or base gradient waters of lakes, rivers, and bays, estuaries, and large marshes on the Great Lakes. It requires abundant aquatic vegetation, relatively clear water, and substrates of sand, muck, hard clay, or detritus. It is generally uncommon in waters with an abundance of white crappies.

Distribution - To the north the species occurs from North Dakota and southern Manitoba to the Lake Champlain drainage, south along the western slope of the Appalachian Mountains to the Gulf Coast in Alabama, along the eastern coastal plain from Florida to Virginia, and west to central Texas and eastern Oklahoma, Kansas, Nebraska, and the Dakotas. It is common to abundant in all the Great Lakes except Lake Erie, where loss of extensive coastal marshes and ubiquitous siltation are apparently causing a decrease in abundance. It has been widely introduced outside its natural range in North America.

Spawning and Migration - Spawning occurs in late spring to early summer. Nesting, territoriality, courtship, spawning, and protection of young are similar to other centrarchids. Nests are usually constructed among vegetation, stumps, or other protective cover. No true migrations occur.

Food - Young generally feed on plankton and small aquatic insects. Adults are largely piscivorous, but also consume crustaceans, molluscs, and insects.

Recreational and Commercial Value - The black crappie is an extremely important game fish in both inland and coastal waters of the Great Lakes. It is harvested commercially on a limited scale.

● white crappie (*Pomoxis annularis*)

Habitat - The white crappie prefers warm waters of base or low gradient in lakes, rivers, marshes, and bays and estuaries of the Great Lakes. It also prefers abundant aquatic vegetation and clear waters, but it is tolerant of a wide variety of sheltered habitats, including turbid waters, muddy substrates, and sparse vegetation. It is generally common in habitats unfavorable to the less tolerant black crappie.

Distribution - The species is largely sympatric with the black crappie in the southern part of its range, but it occurs only as far north as southern Ontario, Michigan, Wisconsin, and Minnesota. It is most abundant in Lake Erie, southern Lake Michigan, and eastern Lake Huron along the Canadian shore. In Lake Superior, northern Lake Michigan, western Lake Huron, and Lake Ontario it is less common or absent.

Spawning and Migration - Spawning time, nesting, territoriality, courtship, spawning, and protection of young are similar to the black crappie. No true migrations occur.

Food - Feeding habits of the white crappie are similar to those of the black crappie.

Recreational and Commercial Value - The white crappie is an extremely important game fish in both inland waters and coastal Great Lakes waters. It is harvested commercially on a limited scale.

● Iowa darter (*Etheostoma exile*)

Habitat - The Iowa darter occurs in cool, clear lakes and low gradient streams. It requires abundant aquatic vegetation and substrates of sand, mud, muck, or detritus, but it is highly intolerant of siltation.

Distribution - The species occurs from the Great Slave Lake drainage in the northwest, along the southernmost Hudson Bay drainage, to Vermont in the northeast, southwest through the lower Great Lakes basin, central Ohio, Indiana and Illinois, the upper Missippi River drainage, and the northern Missouri River drainage.

Spawning and Migration - The Iowa darter spawns in April to May, depending on water temperature. Adhesive eggs are deposited on fibrous root material in shallow water, often under undercut banks. Males establish spawning territories, and females move from one territory to another. Eggs and young are not guarded. Spawning adults move from deeper waters to spawning territories in shallow water, but no true migrations occur.

Food - Iowa darters feed on midge larvae, mayfly naiads, snails, amphipods, and corixid naiads.

Recreational and Commercial Value - The Iowa darter may serve as forage in localities where it is abundant, but it has no present recreational or commercial value.

● yellow perch (*Perca flavescens*)

Habitat - The yellow perch occurs in clear waters of lakes, marshes, and low gradient streams with substrates of muck, detritus, sand, or gravel. Although the degree of dependence of yellow perch on aquatic vegetation is unclear, abundant vegetation seems to be favorable, particularly for spawning. In the Great Lakes the species inhabits river mouths, bays, and both shallow and deep water in the nearshore and offshore zones, far from any aquatic vegetation.

Distribution - The yellow perch occurs in subarctic and temperate regions of eastern and central North America. To the north it occurs from Nova Scotia northwest through the southern Hudson Bay drainage to the Great Slave Lake drainage. From the latter region its range extends southeast through Alberta, most of the Missouri River drainage to southern Illinois, northeast through the northern tributaries of the Ohio River to the Hudson River drainage, and south along the eastern coastal plain to northern Florida and the extreme eastern Gulf Coast. It is abundant in all the Great Lakes.

Spawning and Migration - The yellow perch spawns from mid-April to early May but may spawn as late as July in some areas. Adults in lakes migrate inshore to bays and tributaries to spawn. Spawning occurs during night and early morning, usually among rooted aquatic vegetation, logs, stumps, submerged brush, or artificial structures (e.g. piers, pilings, boats, and fish nets), but sometimes on reefs or bars of sand and gravel. Eggs are extruded in long, adhesive, gelatinous masses which adhere to various substrates. No nests are constructed, and adults do not guard eggs or young.

Food - The young feed on a variety of small aquatic insects and zooplankton. Adults utilize larger aquatic invertebrates, primarily insects and crustaceans, as well as small fish and fish eggs.

Recreational and Commercial Value - The yellow perch is one of the most accessible, abundant, palatable, and thus one of the most important commercial and game fishes in the Great Lakes. Depending on varying year-class strengths, market prices, and other biological and climatic variables, it often dominates commercial production in one or more of the Great Lakes. It is widely popular as a game fish and it supports on intense ice-fishery during the winter.

APPENDIX C

Phylogenetic List of Common and Scientific Names of Amphibians and Reptiles Found in the Great Lakes Basin[a]

Common Name	Scientific Name
Class Amphibia	
Order Caudata (Salamanders)	
Family Necturidae (Mudpuppies)	
mudpuppy	*Necturus maculosus maculosus*
Lake Winnebago mudpuppy	*Necturus maculosus stictus*
Family Cryptobranchidae (Hellbenders)	
hellbender	*Cryptobranchus alleganiensis alleganiensis*
Family Sirenidae (Sirens)	
western lesser siren	*Siren intermedia nettingi*
Family Ambystomatidae (Mole Salamanders)	
marbled salamander	*Ambystoma opacum*
small-mouthed salamander	*Ambystoma texanum*
eastern tiger salamander	*Ambystoma tigrinum tigrinum*
Jefferson salamander	*Ambystoma jeffersonianum*
Tremblay's salamander	*Ambystoma tremblayi*
silvery salamander	*Ambystoma platineum*
blue-spotted salamander	*Ambystoma laterale*
spotted salamander	*Ambystoma maculatum*
Family Salamandridae (Newts)	
red-spotted newt	*Notophthalmus viridescens viridescens*
central newt	*Notophthalmus viridescens louisianensis*
Family Plethodontidae (Lungless Salamanders)	
northern dusky salamander	*Desmognathus fuscus fuscus*
mountain dusky salamander	*Desmognathus ochrophaeus*
northern spring salamander	*Gyrinophilus porphyriticus*
northern red salamander	*Pseudotriton ruber ruber*
slimy salamander	*Plethodon glutinosus glutinosus*
red-backed salamander	*Plethodon cinereus cinereus*
ravine salamander	*Plethodon richmondi*
four-toed salamander	*Hemidactylium scutatum*
northern two-lined salamander	*Eurycea bislineata bislineata*

-continued-

Common Name	Scientific Name
	Order Anura (Toads and Frogs)
	Family Bufonidae (Toads)
American toad	*Bufo americanus americanus*
Fowler's toad	*Bufo woodhousei fowleri*
	Family Hylidae (Treefrogs)
Blanchard's cricket frog	*Acris crepitans blanchardi*
northern spring peeper	*Hyla crucifer crucifer*
gray tree frog	*Hyla versicolor*
western chorus frog	*Pseudacris triseriata triseriata*
boreal chorus frog	*Pseudacris triseriata maculata*
	Family Ranidae (True Frogs)
bullfrog	*Rana catesbeiana*
green frog	*Rana clamitans melanota*
mink frog	*Rana septentrionalis*
northern leopard frog	*Rana pipiens*
pickerel frog	*Rana palustris*
wood frog	*Rana sylvatica*
	Class Reptilia Order Testudines (Turtles)
	Family Chelydridae (Snapping Turtles)
snapping turtle	*Chelydra serpentina*
	Family Kinosternidae (Musk and Mud Turtles)
stinkpot	*Sternotherus odoratus*
	Family Emydidae (Box and Water Turtles)
spotted turtle	*Clemmys guttata*
bog turtle	*Clemmys muhlenbergi*
wood turtle	*Clemmys insculpta*
eastern box turtle	*Terrapene carolina carolina*
map turtle	*Graptemys geographica*
red-eared turtle	*Chrysemys scripta elegans*
midland painted turtle	*Chrysemys picta marginata*
western painted turtle	*Chrysemys picta belli*
Blanding's turtle	*Emydoidea blandingi*
	Family Trionychidae (Softshell Turtles)
eastern spiny softshell	*Trionyx spiniferus spiniferus*

-continued-

Common Name	Scientific Name
Order Squamata (Lizards and Snakes)	
Family Scincidae (Skinks)	
five-lined skink	Eumeces fasciatus
coal skink	Eumeces anthracinus
Family Teiidae (Whiptails)	
six-lined racerunner	Cnemidophorus sexlineatus sexlineatus
Family Anguidae (Glass Lizards)	
western slender glass lizard	Ophisaurus attenuatus attenuatus
Family Colubridae (Colubrids)	
northern water snake	Natrix sipedon sipedon
Lake Erie water snake	Natrix sipedon insularum
northern copperbelly	Natrix erythrogaster neglecta
queen snake	Natrix septemvittata
Kirtland's water snake	Natrix kirtlandi
Graham's water snake	Natrix grahami
northern brown snake	Storeria dekayi dekayi
midland brown snake	Storeria dekayi wrightorum
northern red-bellied snake	Storeria occipitomaculata occipitomaculata
eastern garter snake	Thamnophis sirtalis sirtalis
Chicago garter snake	Thamnophis sirtalis semifasciatus
Butler's garter snake	Thamnophis butleri
short-headed garter snake	Thamnophis brachystoma
eastern plains garter snake	Thamnophis radix radix
northern ribbon snake	Thamnophis sauritus septentrionalis
western ribbon snake	Thamnophis proximus proximus
eastern hognose snake	Heterodon platyrhinos
northern ringneck snake	Diadophis punctatus edwardsi
eastern smooth green snake	Opheodrys vernalis vernalis
western smooth green snake	Opheodrys vernalis blanchardi
blue racer	Coluber constrictor foxi
northern black racer	Coluber constrictor constrictor
bullsnake	Pituophis melanoleucas sayi
eastern milk snake	Lampropeltis triangulum triangulum
eastern fox snake	Elaphe vulpina gloydi
western fox snake	Elaphe vulpina vulpina
black rat snake	Elaphe obsoleta obsoleta
Family Viperidae (Pit Vipers)	
timber rattlesnake	Crotalus horridus
eastern massasauga	Sistrurus catenatus catenatus

[a]Conant, 1975

- mudpuppy (Necturus maculosus maculosus),
  ssp. Lake Winnebago mudpuppy (N. m. stictus)

Habitat - This species is wholly aquatic, occurring in base or low gradient waters of lakes, streams, bays, and estuaries. A variety of turbidity and temperature conditions are tolerated. Bays, estuaries, and sheltered nearshore waters with logs, stumps, or submersed aquatic vegetation are the preferred Great Lakes habitat.

Distribution - N. m. maculosus occurs commonly throughout the Ohio River, upper Mississippi River, Lake Champlain, Lake-of-the-Woods, and Great Lakes basins, exclusive of northern Lake Superior. N. m. stictus occurs only in the Green Bay area.

Breeding and Life Cycle - Mating occurs in autumn, with oviposition occurring the following spring. Eggs are laid on undersides of submerged rocks and logs, and hatch in mid-summer. Mudpuppies are active throughout the year.

Food - Small invertebrates, such as crustaceans, molluscs, annelids, as well as small fishes and fish eggs, are utilized.

Recreational and Commercial Value - Aside from occasional catches by anglers and commercial fishermen, the mudpuppy has no recreational or commercial value.

- red-spotted newt (Notophthalmus viridescens viridescens), ssp. central newt (N. v. louisianensis)

Habitat - The red-spotted and central newts are similar in habitat requirements. The aquatic phase of the species inhabits small, permanent lakes, ponds, ditches, and quiet streams with clear water and abundant submersed aquatic vegetation. The terrestrial eft phase occurs in moist woodlands adjacent to the aquatic phase habitat, usually in rotten logs or under dense leaf litter. Newts probably inhabit only the more sheltered coastal wetlands, such as those behind beach ridges and barrier beaches or small ponds and tributaries.

Distribution - N. v. viridescens ranges from Lake Nipigon to Nova Scotia in the north, south along the Atlantic seaboard to North Carolina, west through northern South Carolina, Georgia, and Alabama, north through eastern Tennessee, Kentucky, Indiana, and Michigan to Saginaw Bay, and along the northern shores of Lakes Huron and Superior to Lake Nipigon. N. v. louisianensis ranges west from the westernmost range limits of N. v. viridescens to central Minnesota, eastern Iowa, Missouri, and eastern Kansas, Oklahoma, and Texas, and including Louisiana, Mississippi, southern Alabama, Georgia, South Carolina, and northern Florida. Both are common in the Great Lakes region.

Breeding and Life Cycle - Adult aquatic newts lay eggs on submersed vegetation in early spring. Eggs hatch in two to three weeks, and larvae transform into terrestrial efts in two to three months. Efts mature in two to three years and metamorphose into aquatic adults. Aquatic adults are apparently active throughout the year, whereas efts hibernate deep in logs and under leaf litter.

Food - Larvae have been observed eating green algae. Aquatic and terrestrial newts consume a variety of food items, including small crustaceans, insects, molluscs, and tadpoles.

Recreational and Commercial Value - The newts have no major economic value, although they serve as food for fish, reptiles, birds, and mammals where they are common.

- Jefferson salamander (*Ambystoma jeffersonianum*)
  blue-spotted salamander (*Ambystoma laterale*)
  Tremblay's salamander (*Ambystoma tremblayi*)
  silvery salamander (*Ambystoma platineum*)

Systematic Note - This complex of closely related salamanders consists of two diploid species, *A. jeffersonianum* and *A. laterale*, with largely disjunct ranges. Where these ranges overlap, primarily in the Great Lakes region, triploid hybrids (*A. tremblayi* and *A. platineum*), consisting almost entirely of females, have arisen.

Habitat - All four forms are similar in habitat requirements. These are primarily woodland salamanders which burrow deeply into or under logs, rocks, soil, and tree roots. They often occur in swamps and lowland woods and may utilize the waters of coastal wetlands adjacent to such wooded areas for breeding.

Distribution - *A. laterale* is the northernmost diploid form, occurring from southeastern Manitoba, east through the Great Lakes region and extreme southern Hudson Bay drainage, to New England, Nova Scotia, and southern Quebec. *A. jeffersonianum* occupies a range to the south and largely disjunct of *A. laterale*, extending from southwestern New England through southern New York, Pennsylvania, northern Virginia, West Virginia, north-central Kentucky, southeastern Indiana, and most of Ohio. *A. tremblayi* occurs in isolated concentrations in new England and in larger areas along the upper St. Lawrence River, in northwestern Ohio, southern Michigan, northeastern Indiana, and in northern Wisconsin. *A. platineum* occurs similarly in New England and in a larger area of western Ohio, southern Michigan, and eastern Indiana.

Breeding and Life Cycle - Eggs are laid singly or in small clumps attached to litter in shallow woodland ponds, usually in early spring. Eggs hatch approximately one month later, and transformation of larvae to adult form occurs in mid-summer. Hibernation occurs deep in rotten logs or in crevices among tree roots.

Food - Adults feed on small crustaceans, annelids, and insects.

Recreational and Commercial Value - Although the larvae and adults may serve as food for a variety of fishes, other amphibians, reptiles, birds, and mammals, these salamanders have no major economic value.

● spotted salamander (Ambystoma maculatum)

Habitat - This salamander occurs in damp deciduous woodlands under leaf litter, logs, and rocks. It may occur in wooded coastal wetlands along the Great Lakes or emerge from upland woods to breed in coastal wetlands.

Distribution - The spotted salamander occurs throughout eastern North America, from the Lake Nipigon region to Nova Scotia in the north, south along the Atlantic seaboard to southern Georgia, west through southern Alabama, Mississippi, Louisiana, and eastern Texas, and north through eastern Oklahoma, Kansas, central Missouri, southern Illinois, most of Wisconsin, and extreme northern Michigan. It is common throughout the Great Lakes region.

Breeding and Life Cycle - Breeding occurs in early spring in shallow woodland ponds. Eggs, which are deposited on forest litter, hatch in less than one month, and larvae transform to adult form by mid-summer. Hibernation occurs deep in or under rotten logs and crevices among tree roots.

Food - Adults feed on arthropods, molluscs, and annelids.

Recreational and Commercial Value - Aside from its value as food for other vertebrates, the spotted salamander has no major economic value.

● small-mouthed salamander (Ambystoma texanum)

Habitat - The small-mouthed salamander is primarily a lowland woodland species, although it occurs under logs, rocks, tree roots, and boards in prairies, pastures, marshes, and cultivated land as well. It may occur in the marshes of western Lake Erie.

Distribution - This is primarily a species of the central Mississippi basin, occurring in most of lowland Ohio, Indiana, Illinois, Kentucky, Tennessee, Louisiana, Mississippi, western Alabama, southern Iowa, most of Missouri and Arkansas, and eastern Kansas, Oklahoma, and Texas. It occurs in the Great Lakes basin only along the south shore of western Lake Erie.

Breeding and Life Cycle - Breeding occurs in late February and most of March, in almost any available standing water. Eggs are deposited on sticks or submersed vegetation and hatch in only a few days. Larvae transform to the adult form during late May through July. Hibernation occurs deep in or under rotten logs and the crevices among tree roots.

Food - A variety of terrestrial arthropods, molluscs, and oligochaetes are eaten by adults.

Recreational and Commercial Value - Aside from its possible value as food for other vertebrates, the small-mouthed salamander has no economic value.

• eastern tiger salamander (Ambystoma tigrinum tigrinum)

Habitat - The eastern tiger salamander occupies a variety of habitats, including woods, pastures, prairies, marshes, and cultivated or urban areas. It is fossorial and seldom encountered except under logs, rocks, boards, or other cover. It probably occurs in a variety of coastal wetland types.

Distribution - The eastern tiger salamander occurs from southeastern Manitoba to southeastern Texas in the west, east through the southern Great Lakes region to western Ohio and along the Gulf Coast to northern Florida, north from Florida along the coastal plain to Long Island, excluding most of the Allegheny uplands. It occurs along western Lake Erie, southern Lake Michigan, and the north shore of Lake Superior.

Breeding and Life Cycle - Breeding occurs early in spring, and a variety of eggs are deposited on objects in shallow water. Hatching occurs in about three weeks, and larvae transform to adult form in mid-summer. Hibernation occurs deep under matted vegetation, rotten logs, rocks, and the crevices among tree roots.

Food - This large voracious salamander consumes a variety of invertebrates and will ingest tadpoles, small frogs, and other salamanders.

Recreational and Commercial Value - Aside from its possible value as food for other vertebrates, the eastern tiger salamander has no major economic value.

• northern dusky salamander (Desmognathus fuscus fuscus)

Habitat - This salamander occurs primarily in wooded hilly areas adjacent to small springs and brooks. It generally burrows under logs and rocks. It is probably not found extensively in coastal wetlands, but it may be abundant in adjacent woods.

Distribution - This upland salamander occurs from Maine and southern Quebec, southwest through the Allegheny region to easten Tennessee and western North Carolina. It occurs in woods along the southern shores of Lake Erie, Lake Ontario, and the upper St. Lawrence River.

Breeding and Life Cycle - Eggs are deposited in nests near running water in spring and fall. Eggs are protected by the female, although they are sometimes devoured by her. Hatching occurs in one to two months, and larvae apparently overwinter in water and transform to adult form in about one year. Adults hibernate in or under rotten logs, leaf litter, or crevices among tree roots.

Food - A variety of arthropods, annelids, and molluscs are consumed, as well as other salamanders.

Recreational and Commercial Value - Aside from its value as food for other vertebrates, the northern dusky salamander has no major economic value.

● four-toed salamander (Hemidactylium scutatum)

Habitat - This salamander is restricted largely to boggy habitats, usually associated with sphagnums and found under leaves or logs. It may occur in coastal bogs in the Great Lakes region.

Distribution - The species has a spotty distribution from Nova Scotia to Wisconsin in the north, southern Ontario and all the Great Lakes states, the Atlantic seaboard and Allegheny states, as well as disjunct locations in the deep South and Mississippi River states. It occurs throughout the coastal regions of Lake Ontario, Lake Erie, Lake Huron, Lake Michigan, and southern Lake Superior.

Breeding and Life Cycle - Breeding apparently occurs in fall, but oviposition does not occur until the following spring. Eggs are laid in clusters near water, attached to sphagnum and roots of other vegetation. Hatching occurs in one to two months, during which time the female remains with the eggs. Larvae transform to adults in about six weeks. Hibernation occurs deep under mosses, matted vegetation, rotten logs, and tree roots.

Food - Small arthropods are apparently the primary food.

Recreational and Commercial Value - Aside from its possible value as food for other vertebrates, the four-toed salamander has no known economic value.

● red-backed salamander (Plethodon cinereus cinereus)

Habitat - The red-backed salamander is a ubiquitous woodland species, occurring in moist areas in or under rocks, logs, roots, and leaf litter. It is not a wetland form, but it is common in woodlands adjacent to coastal wetlands of the Great Lakes.

Distribution - The range is similar to that of the four-toed salamander and includes, in addition, the northern shore of Lake Superior. This species is common throughout the Great Lakes region.

Breeding and Life Cycle - Breeding occurs in late fall. Eggs are deposited in cavities of rotten logs and guarded by the female until hatching the following summer. Larvae transform rapidly to terrestrial adult form, usually within one day, without an aquatic stage. Hibernation occurs deep in or under rotten logs, leaf litter, or among corevices of tree roots.

Food - Small arthropods, particularly mites and Collembola, as well as annelids, and molluscs are the primary food.

Recreational and Commercial Value - Aside from its value as food for other vertebrates, the red-backed salamander has no economic value.

● American toad (Bufo americanus americanus)

Habitat - The American toad occurs in a variety of habitats, including woods, prairies, marshes, swamps, and cultivated or urban lands. It is primarily terrestrial and nocturnal, but occurs both as larvae and adults in virtually every coastal wetland in the Great Lakes.

Distribution - The American toad occurs from the Lake Manitoba region to New Brunswick in the north, south along the Atlantic seaboard to Virginia, west through western north Carolina, and the northern parts of Georgia, Alabama, and Mississippi, and north through Tennessee, Kentucky, Missouri, Iowa, Minnesota, and southeastern Manitoba.

Breeding and Life Cycle - Breeding and egg deposition occur in early spring in almost any type of quiet water. Long strings of eggs are attached to submersed objects and hatch in about one week. Larvae transform to adult form by early June. Adults hibernate in a variety of fossorial habitats.

Food - Insects, annelids, and molluscs are the primary food.

Recreational and Commercial Value - This species is food for a variety of other vertebrates, and its abundance is sufficient that it becomes economically important as a garden insectivore.

● Fowler's toad (Bufo woodhousei fowleri)

Habitat - Fowler's toad occurs chiefly in sandy areas of lakeshores and river bottoms and is particularly common in the Great Lakes region around wetlands associated with beach ridges, barriers, and dunes.

Distribution - This toad occurs from lower Michigan to New Hampshire in the north, south along the Atlantic coast to North Carolina, inland and westward through Georgia and the Gulf Coast states to eastern Texas, and north through eastern Oklahoma, Arkansas, Missouri, Illinois, and Indiana. It occurs along the eastern shore of Lake Michigan and the Chicago vicinity, almost all of Lake Erie, and western Lake Ontario.

Breeding and Life Cycle - Breeding occurs later than for the American toad, usually late Arpil, but otherwise the life histories are similar, with hatching and larval transformation occurring about two weeks after those of the American toad. Adults hibernate in a variety of fossorial habitats.

Food - Insects and earthworms are the primary food.

Recreational and Commercial Value - Aside from its possible value as food for other vertebrates, Fowler's toad has no major economic value.

● Blanchard's cricket frog (Acris crepitans blanchardi)

Habitat - This tree frog is largely non-arboreal and occurs near permanent or semi-permanent streams, lakes, ponds, and marshes, usually among bordering terrestrial vegetation or emergent and floating aquatic vegetation. It is probably common in many Great Lakes coastal wetlands in its range.

Distribution - This subspecies occurs from Nebraska to the Lower Peninsula of Michigan in the north, southeastward through Ohio, Kentucky, northern Tennessee, Arkansas, and Texas, and north through Oklahoma and Kansas.

Breeding and Life Cycle - Breeding and egg deposition occur in late April to July, depending on location and temperature, in a variety of quiet waters, usually as large surface films. Eggs hatch in several days, and larvae transform to adult form from July to September. Adults hibernate deep under matted vegetation, leaf litter, in or under logs, and in hollow trees.

Food - Small insects are apparently the major food item.

Recreational and Commercial Value - Aside from its value as food for other vertebrates, Blanchard's cricket frog has no economic value.

● northern spring peeper (Hyla crucifer crucifer)

Habitat - Spring peepers are primarily woodland and semi-arboreal in habitat. They frequent moist woods, clinging to the lower parts of trees and shrubs, or moving on the ground among leaves and along borders of woodland ponds. These frogs are common in wooded margins of emergent wetlands or coastal swamps of the Great Lakes.

Distribution - This subspecies occupies in most of eastern North America from the Lake Winnipeg region to Nova Scotia in the north, south along the Atlantic and Gulf Coasts (excluding most of Florida) to eastern Texas, and north through the Mississippi River states to Minnesota. It is abundant throughout the Great Lakes region.

Breeding and Life Cycle - Breeding occurs from early March to late June, depending on location and temperature. Eggs are deposited singly on submersed objects in shallow temporary or permanent woodland ponds. Hatching occurs in one to two weeks, and larvae transform to adult form in May or June, about two months after hatching in most areas. Adults hibernate under leaves, mosses, or in hollow trees.

Food - Small arthropods are the primary food.

Recreational and Commercial Value - Aside from its possible value as food for other vertebrates, the spring peeper has no economic value.

● gray treefrog (*Hyla versicolor* and *Hyla chrysoscelis*)

Systematic Note - These two species are largely sympatric and barely distinguishable, so that delineation of the separate ranges of each is incomplete due to lack of detailed field observations. Both are generally included indiscriminately under the name gray treefrog (*Hyla versicolor*).

Habitat - These treefrogs are primarily arboreal, occurring in mesic woods on trees, vines, stumps, and wooden structures. They are probably common in wooded margins of emergent coastal wetlands or in coastal swamps and bogs.

Distribution - The gray treefrogs occupy most of eastern North America from the Lake Winnipeg region to New Brunswick in the north, south along the Atlantic Coast to northern Florida, west along the Gulf Coast to eastern Texas, and north through the eastern parts of Oklahoma, Kansas, Nebraska, and the Dakotas. They are common throughout the Great Lakes region.

Breeding and Life Cycle - Breeding occurs from late April into August, depending on location and temperature. Eggs are deposited in small clusters on plant litter and vegetation in temporary or permanent pools, ponds, and streams. Hatching occurs in four or five days, and larvae transform to adult form from May into August. Hibernation occurs in hollow trees or among tree roots.

Food - Small terrestrial arthropods comprise the major food source.

Recreational and Commercial Value - Aside from its possible value as food for other vertebrates, the gray treefrog has no economic value.

● western chorus frog (*Pseudacris triseriata triseriata*), ssp. boreal chorus frog (*P. t. maculata*)

Habitat - *P. t. triseriata* is an inhabitant of wet prairies, woodlands, meadows, marshes, and a variety of culturally disturbed habitats. It is essentially terrestrial, usually occurring in dense vegetation, often far from open water. *P. t. maculata* is a far northern subspecies which inhabits heavily vegetated margins of ponds, lakes, streams, and marshes. *P. t. triseriata* occurs widely in coastal wetlands of the Great Lakes, but *P. t. maculata* is important only in western Lake Superior wetlands.

Distribution - *P. t. triseriata* occurs from South Dakota and Minnesota in the northwest, east through Wisconsin, the Lower Peninsula of Michigan, and southern Ontario, and southwest through western New York and Pennsylvania, Ohio, Indiana, Illinois, Iowa, Missouri, Nebraska, eastern Kansas, and central Oklahoma. It occurs along the coasts of Lake Ontario, Lake Erie, Lake Huron, eastern and southwestern Lake Michigan, and extreme western Lake Superior. *P. t. maculata* occurs from Alberta, south through the northern mountain states, and eastward through the prairie provinces and northern prairie states to western Ontario and northern Minnesota. Its range touches northern and extreme western Lake Superior.

Breeding and Life Cycles - Habits of these tree frogs are apparently not well known. Breeding occurs early in spring for both subspecies (early March into May). Eggs are attached in masses to aquatic or submerged terrestrial vegetation and probably to plant litter as well. Hatching occurs in about two weeks, and larvae metamorphose to adult form in about two months. Hibernation is probably similar to other hylid frogs.

Food - Small arthropods are the primary food source.

Recreational and Commercial Value - Aside from their possible value as a food source for other vertebrates, these frogs have no economic value.

● bullfrog (Rana catesbeiana)

Habitat - The bullfrog is largely aquatic and inhabits any type of permanent water, including ponds, lakes, streams, rivers, marshes, and swamps. It is one of the dominant amphibians of a variety of coastal wetlands along the Great Lakes.

Distribution - The bullfrog occurs throughout eastern North America, from Wisconsin to Nova Scotia in the north, south along the Atlantic coast to central Florida, along the entire Gulf Coast to northern Mexico, north through Texas, eastern New Mexico, eastern Colorado, southeastern Wyoming, and east again through southern Iowa and South Dakota to Wisconsin. It has been widely introduced in the mountain states and along the Pacific Coast.

Breeding and Life Cycle - Breeding occurs from late April to early August. Eggs are deposited in huge floating surface masses in quiet water. Hatching occurs in about one week, and larvae generally overwinter, metamorphosing the following July or August. Hibernation occurs in soft mud or leaves on the bottoms of streams, lakes, and ponds.

Food - The large, voracious bullfrog consumes any available aquatic or terrestrial invertebrate as well as small fishes, other amphibians, turtles, snakes, and small mammals.

Recreational and Commercial Value - The bullfrog is harvested intensively for human consumption on a commercial and recreational basis.

● green frog (Rana clamitans melanota)

Habitat - The green frog is largely aquatic and inhabits the same waters as the bullfrog. It is more often encountered in small running waters and temporary pools and ponds than is the bullfrog. It is one of the dominant amphibians in a variety of Great Lakes coastal wetlands.

Distribution - The green frog occurs from southeastern Manitoba to Nova Scotia in the north, south along the Atlantic coast to North Carolina, west through the northern parts of South Carolina, Georgia, Alabama, Mississippi, and Arkansas to eastern Oklahoma, and north through eastern Kansas, most of Missouri, and eastern Iowa and Minnesota. It is abundant throughout the Great Lakes region.

Breeding and Life Cycle - Breeding begins in late April or early May and may extend throughout the summer into September. Egg deposition is similar to that of the bullfrog. Hatching occurs in less than one week. Larvae, like those of the bullfrog, overwinter and metamorphose to adult form during the following summer. Hibernation is similar to that of the bullfrog.

Food - The green frog, like the bullfrog, feeds on a variety of aquatic and terrestrial invertebrates, as well as small vertebrates.

Recreational and Commercial Value - The green frog is harvested intensively for human consumption on both a recreational and commercial basis.

● pickerel frog (Rana palustris)

Habitat - The pickerel frog is largely aquatic and occurs in waters that are either cold or running. It is absent from warm, sluggish waters. It inhabits small springs, brooks, and streams, as well as cooler quiet waters, such as spring-fed ponds, generally lying concealed in bordering vegetation. It occurs only in coastal wetlands with cool water or associated small flowing streams.

Distribution - The pickerel frog occurs from Wisconsin and the Upper Peninsula of Michigan to New Brunswick and Nova Scotia in the north, south along the Atlantic Coast to South Carolina, west through northern Georgia and Alabama to west-central Mississippi, northern Louisiana, and eastern Texas, and north through eastern Oklahoma, southern Missouri, and eastern Iowa, to southeastern Minnesota.

Breeding and Life Cycle - Breeding occurs during April or May. Eggs are deposited in globular masses attached to sticks and hatch in one to two weeks. Larvae metamorphose to adult form from late July to August. Hibernation is similar to that of the bullfrog and green frog.

Food - Aquatic and terrestrial arthropods and molluscs are the major food.

Recreational and Commercial Value - This frog is small and is not harvested extensively for human consumption, but it probably comprises a valuable food source for other vertebrates.

● northern leopard frog (Rana pipiens)

Habitat - The leopard frog is largely aquatic and occupies habitats similar to those of the pickerel frog, but it is more tolerant of warm, sluggish waters. It often wanders far from water through open fields and prairies. It is one of the dominant amphibians of a variety of Great Lakes coastal wetlands.

Distribution - The northern leopard occurs from eastern Alberta to Labrador in the north, south through New England and the Great Lakes states, westward through the northern prairie states and mountain states as far south as northern New Mexico and Arizona, and north through Nevada and northeastern California to disjunct areas of Idaho, Washington, and Oregon.

Breeding and Life Cycle - Breeding generally occurs prior to the pickerel frog from March to early May. Egg deposition, incubation period, and larval transformation time are similar to but one to three weeks earlier than those of the pickerel frog. Hibernation is similar to the bullfrog and green frog.

Food - Earthworms, insects, and small frogs are the major foods.

Recreational and Commercial Value - Leopard frogs are extensively harvested or cultured as laboratory animals, and the larger individuals may be harvested for human consumption. It is also an abundant and important food item for other vertebrates.

● mink frog (*Rana septentrionalis*)

Habitat - This subarctic frog is largely aquatic, occurring in cold flowing water and the vegetated borders of lakes, especially at the mouths inflowing streams. It is especially common on floating leaves of aquatic plants. In the Great Lakes it occurs in a variety of the more northern coastal wetlands.

Distribution - The mink frog occurs from southeastern Manitoba to Labrador in the north, south and westward through the Maritime Provinces, northern New England and northern New York, southern Ontario, the Upper Peninsula of Michigan, northern Wisconsin, and northeastern Minnesota. It occurs along the entire St. Lawrence River, eastern and northern Lake Ontario, eastern Lake Huron, all of Lake Superior, and northwestern Lake Michigan. It is absent from Lake Erie.

Breeding and Life Cycle - The mink frog breeds in late spring or early summer. Eggs are deposited on aquatic plants and hatch in less than one week. Larvae overwinter and metamorphose to adult form the following summer. Hibernation occurs under mud and plant litter on the bottoms of lakes, ponds, and pools of streams.

Food - Aquatic insects and probably other aquatic and terrestrial invertebrates, as well as small fish, are eaten.

Recreational and Commercial Value - Aside from its possible value as food for other vertebrates, the mink frog has no major economic value.

● wood frog (*Rana sylvatica*)

Habitat - The wood frog is primarily a terrestrial woodland species. It occurs on the forest floor among mosses, moist leaf litter, and rotten logs, usually not far from permanent or semi-permanent pools. It occurs widely in lowland woods adjacent to coastal wetlands and in coastal swamps and bogs.

Distribution - This species is largely subarctic, occurring from Alaska to Labrador in the north, south along the Atlantic coast to Virginia, west and south through the mid-Atlantic states, West Virginia, western North Carolina, eastern Tennessee, most of Ohio, Kentucky, Indiana, and Michigan, eastern Illinois, most of Wisconsin and Minnesota, eastern North Dakota, Manitoba, Saskatchewan, Alberta, and northern British Columbia. It occurs throughout the Great Lakes region.

Breeding and Life Cycle - Breeding occurs primarily in March and early April. Eggs are deposited in globular masses on objects in woodland pools. Hatching usually occurs in less than one week, and larvae metamorphose to adult form by May or June. Hibernation probably occurs under leaf litter, rotten logs, hollow logs, and deep crevices among tree roots.

Food - A variety of terrestrial arthropods and molluscs are consumed.

Recreational and Commercial Value - Aside from its value as food for other vertebrates, the wood frog has no economic value.

● snapping turtle (Chelydra serpentina)

Habitat - The snapping turtle is primarily aquatic and occurs in lakes, low gradient streams, rivers, marshes, and swamps, often buried in mud or hidden in vegetation and other cover. In the Great Lakes it occurs in sheltered bays, tributary mouths, and coastal wetlands.

Distribution - The snapping turtle occurs throughout North America east of the Rocky Mountains, from southern Saskatchewan to Nova Scotia in the north and New Mexico to northern Florida in the south. It is abundant in the Great Lakes region of the United States.

Breeding and Life Cycle - Mating occurs primarily in late spring or early summer. Eggs are buried in unguarded nests on land, often far from water, and hatching occurs in September. These turtles hibernate in mud or leaves underwater, but they may be active well into winter or early in spring.

Food - Snapping turtles are both predators and scavengers, consuming almost any invertebrate or vertebrate that can be captured.

Recreational and Commercial Value - Snapping turtles are widely harvested for human consumption in the Great Lakes. The digging activities of these turtles are often destructive to earthen dikes and dams.

● stinkpot (Sternotherus odoratus)

Habitat - The stinkpot is primarily aquatic, occurring in a variety of low or base gradient waters with or without aquatic vegetation. In the Great Lakes it occurs in bays, tributary mouths, ditches, and marshes.

Distribution - The stinkpot occurs in eastern North America from southern Wisconsin to southern Maine in the north and from eastern Texas to southern Florida in the south. It occurs along southern Lake Michigan, southern and eastern Lake Huron, all of Lake Erie, and all of Lake Ontario exclusive of the extreme eastern end and the St. Lawrence River.

Breeding and Life Cycle - Mating usually occurs in early spring, but some autumn mating may occur. Eggs are buried on land in sand, matted vegetation, rotten logs, or muskrat houses during late spring or early summer, and hatching occurs in early fall. Hibernation probably occurs buried in mud or leaves under water.

Food - Molluscs, crustaceans, annelids, fish, and a variety of aquatic arthropods are utilized.

Recreational and Commercial Value - The stinkpot is a useful scavenger and predator, but it is not generally harvested for human consumption.

- midland painted turtle (Chrysemys picta marginata),
  ssp. western painted turtle (C. p. belli)

Habitat - painted turtles are primarily aquatic but often roam far on land. They occur in almost any permanent water with sufficient food, including lakes, marshes, wet meadows, large or small streams, bogs, ditches, and the bays and estuaries of the Great Lakes, often in association with aquatic vegetation.

Distribution - The midland subspecies occurs in eastern North America from the eastern parts of Illinois, Wisconsin, and the Upper Peninsula of Michigan eastward through the Great Lakes basin and Ohio River basin to the Atlantic coastal drainages of New England, New York, and Pennsylvania. It occurs along the coasts of all the Great Lakes exclusive of Lake Superior, where it is restricted to the extreme eastern end. The western subspecies occurs in western and central North America from southern British Columbia, Washington, and northern Oregon eastward through northern Idaho and the Missouri River basin to Illinois, Wisconsin, Minnesota, and the Upper Peninsula of Michigan, where its range overlaps with that of the midland subspecies.

Breeding and Life Cycle - Mating occurs in early spring, and eggs are deposited on land in nests excavated from soft soil near the water during June. Hatching generally occurs in late summer or early fall. Hibernation occurs under mud or leaves in water, but individuals may be active all winter under ice cover.

Food - Insects, molluscs, crustaceans, amphibians, small fish, carrion, and aquatic vegetation form the diet of this species.

Recreational and Commercial Value - Aside from its value as a predator and scavenger, the painted turtles have no major economic value.

● spotted turtle (*Clemmys guttata*)

Habitat - The spotted turtle generally occurs in bogs and shallow, often running, vegetated waters. In the Great Lakes it may occur in shallow marshes, tributary mouths, and coastal bogs.

Distribution - The spotted turtle occurs in eastern North America from southern Michigan and northern Indiana eastward to southern New England and south along the Atlantic coastal plain to eastern Georgia and several disjunct localities in northern Florida. It occurs along eastern Lake Michigan, eastern Lake Huron, all of Lake Erie, and southern Lake Ontario, but it is rare in many areas within its range.

Breeding and Life Cycle - Little is known of the habits of this species. Mating probably occurs in early spring. Eggs are buried on land in sand or soil during late spring or early summer and hatch in early fall. Hibernation is probably similar to that of other aquatic turtles.

Food - A variety of terrestrial and aquatic molluscs, crustaceans, insects, arachnids, diplopods, annelids, and plant material is consumed.

Recreational and Commercial Value - Aside from its value as a scavenger and predator, the spotted turtle has no major economic value.

● bog turtle (*Clemmys muhlenbergi*)

Habitat - The bog turtle prefers sphagnum bogs, swamps, and clear low gradient streams with mud bottoms. It may occur in certain coastal streams, swamps, bogs, and marshes of Lake Ontario.

Distribution - The bog turtle is rare and has a spotty distribution in eastern north America, with disjunct areas of occurrence in New York, Pennsylvania, New Jersey, Maryland, Delaware, Virginia, Tennessee, and North Carolina. In the Great Lakes it occurs only along southern Lake Ontario.

Breeding and Life Cycle - Little is known of the habits of this species. Mating probably occurs in early spring, with eggs being laid during June and hatching in early fall. Hibernation probably occurs buried under mud, leaves, or grass under water or in wet areas.

Food - A variety of terrestrial and aquatic invertebrates are probably utilized.

Recreational and Commercial Value - This turtle has no present economic value.

● Blanding's turtle (Emydoidea blandingi)

Habitat - Blanding's turtle is largely aquatic, but individuals may roam far from water. It appears to prefer shallow, quiet, vegetated waters of rivers, lakes, marshes, bogs, swamps, wet meadows, ditches, and bays and estuaries of the Great Lakes.

Distribution - Blanding's turtle occurs in central and eastern North America from eastern Nebraska eastward through northern Iowa, southern Minnesota, southern Wisconsin, northern Illinois, southern Michigan, northern Indiana, and Ohio, southern Ontario, and extreme northwestern Pennsylvania. It occurs along the coasts of northern Lake Ontario, northern Lake Erie and the Ohio and Pennsylvania shores, most of Lake Huron and Lake Michigan, and a small section of southern Lake Superior.

Breeding and Life Cycle - Little is known of the habits of Blanding's turtle. Mating appears to occur in spring with egg deposition during June or July. Nests are dug in sand near water and hatching probably occurs during August or September. Hibernation occurs under mud or debris in or near water.

Food - A variety of crustaceans, molluscs, annelids, small fish, vegetation, and carrion are utilized.

Recreational and Commercial Value - Aside from its value as a predator and scavenger, Blanding's turtle has no present economic value.

● map turtle (Graptemys geographica)

Habitat - The map turtle is largely aquatic, occurring in lakes, marshes, and low-gradient streams, generally in association with aquatic vegetation. In the Great Lakes it occurs in sheltered bays, estuaries, and coastal wetlands.

Distribution - This species occurs in eastern North America from eastern Minnesota to western Vermont in the north and from eastern Kansas and northern Arkansas to the western regions of Pennsylvania, West Virginia, Virginia, North Carolina, and Georgia in the south. It occurs along the coasts of Lake Ontario, Lake Erie, southern Lake Huron, southern and eastern Lake Michigan, and extreme western Lake Superior.

Breeding and Life Cycle - Mating occurs in early spring, and eggs are deposited on land in nests dug in soil or dry sand during June. Hatching occurs generally during late August or early September. Hibernation occurs in water under mud or leaves, but individuals may remain active under ice all winter.

Food - Molluscs and crayfish are the major foods, although a variety of other aquatic invertebrates, small fish, and carrion may be used.

Recreational and Commercial Value - Aside from its value as a predator and scavenger, the map turtle has no economic value.

● eastern spiny softshell (*Trionyx spiniferus spiniferus*)

Habitat - The eastern spiny softshell is essentially an entirely aquatic turtle, occurring primarily in large rivers but often encountered in smaller streams. It often lies buried in sand or mud under water. This species probably occurs in many estuaries and associated wetlands of the Great Lakes, although it has no particular affinity for vegetation.

Distribution - The eastern spiny softshell occurs in eastern North America from the Mississippi River eastward through Wisconsin, Illinois, Kentucky, Tennessee, southern Michigan, Indiana, Ohio, and southern Ontario to the western parts of New York, Pennsylvania, West Virginia, Virginia, and North Carolina. It occurs along the coasts southern Lake Michigan, southern Lake Huron, all of Lake Erie, and southern Lake Ontario. It is absent from Lake Superior.

Breeding and Life Cycle - Mating takes place in early spring, and eggs are laid during June in nests excavated in sand or soil near water. Hatching occurs in late August or September. Hibernation occurs in water under mud or sand.

Food - A variety of aquatic crustaceans, snails, insects, and small fish are utilized.

Recreational and Commercial Value - The eastern spiny softshell is harvested widely for human consumption.

● eastern fox snake (*Elaphe vulpina gloydi*)

Habitat - This subspecies of *E. vulpina* is almost entirely restricted in habitat to the marshes of western Lake Erie and southern Lake Huron.

Distribution - The eastern fox snake occurs only in low, marshy areas immediately adjacent to western Lake Erie, Lake St. Clair, and Lake Huron south of Georgian Bay and Saginaw Bay.

Breeding and Life Cycle - Mating occurs in early spring, and clutches of eggs are deposited under matted vegetation, logs, bark, and other loose cover. Hatching occurs in September or October. Fox snakes hibernate in burrows under logs, rocks, and similar cover.

Food - The eastern fox snake feeds primarily on small mammals, birds, and eggs, although larger invertebrates and perhaps frogs, salamanders, and snakes are also eaten.

Recreational and commercial Value - The eastern fox snake is a valuable predator in rodent control.

● Graham's water snake (Natrix grahami)

Habitat - This semi-aquatic species occurs in sluggish waters of rivers, lakes, sloughs, swamps, bayous, and marshes. It may be found in coastal wetlands of Illinois.

Distribution - Graham's water snake occurs in the lower Mississippi River basin, and in the Great Lakes it occurs only in the Illinois coastal region.

Breeding and Life Cycle - See northern water snake.

Food - Newly-molted crayfish are a primary item in the diet, but small fish and amphibians are also eaten.

Recreational and Commercial Value - Aside from its value as a predator, Graham's water snake has no economic value.

● Kirtland's water snake (Natrix kirtlandi)

Habitat - This species is primarily terrestrial, but it occurs in predominantly moist habitats in woodland pools, wet meadows, and the borders of marshes, swamps, lakes, and streams. It is probably a peripheral species in the coastal wetlands of the Great Lakes.

Distribution - Kirtland's water snake occurs only in Illinois, Indiana, Ohio, and extreme northern Kentucky and western Pennsylvania. It is found in western Lake Erie and southern Lake Michigan.

Breeding and Life Cycle - See northern water snake.

Food - Terrestrial invertebrates such as snails, slugs, insects, and earthworms, as well as small salamanders, are utilized. Earthworms appear to be the primary food item.

Recreational and Commercial Value - Aside from its value as a predator, this species has no economic value.

- northern water snake (Natrix sipedon sipedon),
  ssp. Lake Erie water snake (N. s. insularum)

Habitat - The northern water snake is largely aquatic and occurs abundantly in almost any wet habitat, including lakes, ponds, marshes, swamps, rivers, streams, ditches, wet meadows, and a wide range of coastal habitats along the Great Lakes. It has no great affinity for aquatic vegetation but is nevertheless abundant in wetlands.

Distribution - N. s. sipedon occurs in eastern and central North America from eastern Colorado eastward through the middle prairie states to Wisconsin and Illinois, through most of the Great Lakes basin and upper Ohio Rier basin to the eastern coastal drainage between southern Maine and northern North Carolina. It is abundant along the coasts of all the Great Lakes but is absent from the northern shore and Keweenaw region of Lake Superior. The Lake Erie water snake occurs only on the islands of western Lake Erie.

Breeding and Life Cycle - Mating occurs in early spring and ovoviviparous birth occurs during late August or early September. Hibernation is terrestrial, occurring in deep burrows and crevices among rocks and logs.

Food - This species is predatory, feeding on crayfish, fish, frogs, tadpoles, salamanders, other snakes, and occasionally small birds and mammals.

Recreational and Commercial Value - Aside from its value as a predator, this species has no economic value.

- northern brown snake (Storeria dekayi dekayi),
  ssp. midland brown snake (S. d. wrightorum)

Habitat - This is a very secretive species, occurring under rocks, logs, loose tree bark, and similar cover in a variety of moist locations. Moist woods, meadows, marsh and swamp borders, farmlands, urban areas, and the perimeters of lakes and streams are frequented.

Distribution - S. d. dekayi occurs in eastern North America from the Lower Peninsula of Michigan to southern Maine in the north and from eastern Indiana southeastward to South Carolina in the south. It occurs along the coasts of the upper St. Lawrence River and Lake Ontario, Lake Erie, Lake Huron, and eastern Lake Michigan. S. d. wrightorum occurs in the Mississippi River states from Wisconsin to Louisiana and eastward to overlap the range of S. d. dekayi in southern Ontario, Ohio, Kentucky, western Virginia, and the Carolinas. It occurs along the coasts of northern Lake Ontario, Lake Erie, Lake Huron, and Lake Michigan.

Breeding and Life Cycle - Mating occurs in early spring, and ovoviviparous birth takes place primarily during August. Hibernation occurs under logs, rocks, and woody debris or in deep rock crevices.

Food - Earthworms and slugs are the primary food items, but a variety of terrestrial and aquatic invertebrates are eaten.

Recreational and Commercial Value - Aside from its value as a small predator, the brown snake has no economic importance.

- northern red-bellied snake (Storeria occipitomaculata occipitomaculata)

Habitat - The northern red-bellied snake resembles the brown snakes in its habitat preferences and is very generally distributed in moist habitats.

Distribution - This species occurs in eastern North America from southern Manitoba to southern Maine in the north and from eastern Texas to Georgia in the south. It occurs throughout the Great Lakes exclusive of southwestern Lake Erie and northern Lake Superior.

Breeding and Life Cycle - See northern brown snake.

Food - See northern brown snake.

Recreational and Commerical Value - See northern brown snake.

- Butler's garter snake (Thamnophis butleri)

Habitat - Butler's garter snake is semi-aquatic and prefers open, moist habitats such as marshes, wet meadows, and the margins of lakes and streams. It occurs along the borders of coastal marshes of the Great Lakes.

Distribution - This species occurs only in southeastern Wisconsin, eastern Michigan, northeastern Indiana, northwestern Ohio, and extreme southwestern Ontario. it is found along the coasts of western Lake Erie, Lake St. Clair, southern and western Lake Huron, and west-central Lake Michigan.

Breeding and Life Cycle - Mating occurs in early spring, and ovoviviparous birth occurs during July or early August. Hibernation is terrestrial, generally in burrows under woody debris or under matted vegetation.

Food - Small frogs, earthworms, fish, and leeches are utilized.

Recreational and Commercial Value - Aside from its value as a predator, this species has no economic value.

- western ribbon snake (Thamnophis proximus proximus)

Habitat - This species is markedly aquatic and occurs around swamps, marsh edges, bogs, and small lakes and ponds, including those of Great Lakes coastal wetlands.

Distribution - The western ribbon snake occurs in the central United States from southeastern Colorado and northeastern New Mexico eastward through Texas, Oklahoma, Kansas southeastern Nebraska, southern Iowa, Missouri, Arkansas, Louisiana, western Mississippi, western Tennessee, western Kentucky, western and northern Illinois, western Indiana, and southern Wisconsin. It occurs along the southwestern coast of Lake Michigan.

Breeding and Life Cycle - Mating occurs in early spring, and ovoviviparous birth occurs in July or August. Hibernation is similar to that of other Thamnophis species.

Food - Frogs, small fish, crayfish, and other small snakes are eaten.

Recreational and Commercial Value - Aside from its value as a predator, the western ribbon snake has no economic importance.

● eastern plains garter snake (Thamnophis radix radix)

Habitat - This semi-aquatic species frequents moist, open areas such as wet meadows, pastures, prairies, floodplains, sloughs, marsh borders, and bogs. It occurs in the borders of coastal wetlands within its range.

Distribution - The eastern plains garter snake occurs in southeastern Minnesota, eastern Iowa, northwestern Missouri, southern and western Wisconsin, northern Illinois, northwestern Indiana, and disjunct locations in southern Illinois, northern Arkansas, and central Ohio. It occurs along the southwestern coast of Lake Michigan.

Breeding and Life Cycle - Mating occurs in mid-spring and ovoviviparous birth occurs in August. Hibernation is similar to that of other garter snakes.

Food - Earthworms and small amphibians are the primary food items, but a variety of invertebrates may be eaten.

Recreational and Commercial Value - Aside from its value as a predator, this species has no economic value.

● northern ribbon snake (Thamnophis sauritus septentrionalis)

Habitat - See western ribbon snake.

Distribution - The northern ribbon snake occurs primarily in the lower Great Lakes region, from the Lower Peninsula of Michigan and northern Indiana eastward through northern Ohio, southern Ontario, northern Pennsylvania, northern and western New York, and parts of Vermont, New Hampshire, and Maine. It occurs along the coasts of Lake Ontario, Lake Erie, western and southeastern Lake Huron, and eastern Lake Michigan. A record also exists for the Green Bay region.

Breeding and Life Cycle - See western ribbon snake.

Food - See western ribbon snake.

Recreational and Commercial Value - See western ribbon snake.

● eastern garter snake (*Thamnophis sirtalis sirtalis*), ssp. Chicago garter snake (*T. s. semifasciata*)

Habitat - These subspecies are similar in habitat requirements. Moist habitats are preferred, but a wide range of terrestrial and aquatic habitats are occupied. These snakes are common in virtually all Great Lakes coastal wetlands within their respective ranges.

Distribution - *T. s. sirtalis* occurs in eastern North America from eastern Manitoba and the Mississippi River states eastward to the Atlantic coast between eastern Quebec and northern Florida. It is abundant along the coasts of all the Great Lakes. The Chicago garter snake occurs only in southeastern Wisconsin and northeastern Illinois and is common along the coast of southwestern Lake Michigan.

Breeding and Life Cycle - See Butler's garter snake.

Food - A variety of terrestrial and aquatic invertebrates are eaten, as well as small vertebrates such as fish, frogs, toads, tadpoles, salamanders, other snakes, and small birds and mammals.

Recreational and Commercial Value - Aside from its value as a predator, this species has no major economic importance.

● eastern massasauga (*Sistrurus catenatus catenatus*)

Habitat - This is essentially a snake of moist prairie regions, and it occurs in bogs, wet meadows, prairie marshes, sloughs, swamps, and swales. It occurs in coastal habitats of this type in the Great Lakes region.

Distribution - The eastern massasauga occurs in midwestern North America from eastern Iowa and northeastern Missouri eastward through southern Wisconsin, Illinois, Indiana, the Lower Peninsula of Michigan, southern Ontario, northern Ohio, northwestern Pennsylvania, and central New York. It is found along the coasts of southwestern and eastern Lake Michigan, Lake Huron, northern and southwestern Lake Erie, and western Lake Ontario.

Breeding and Life Cycle - Mating occurs in early spring, and ovoviviparous birth takes place in August or September. Hibernation occurs deep in rock crevices, tree roots, and under logs or stumps.

Food - Small mammals are the primary food item, but birds, snakes, and frogs are also eaten.

Recreational and Commercial Value - Eastern massasaugas are valuable as predators of rodents, but they have no other economic importance.

APPENDIX D

Phylogenetic List of Common and Scientific Names of Birds in the Great Lakes Basin[a]

Common Name	Scientific Name
	Class Aves
	Order Gaviiformes
	Family Gaviidae
common loon	*Gavia immer*
red-throated loon	*Gavia stellata*
	Order Podicipediformes
	Family Podicipedidae
red-necked grebe	*Podiceps grisegena*
horned grebe	*Podiceps auritus*
eared grebe	*Podiceps nigricollis*
pied-billed grebe	*Podilymbus podiceps*
	Order Pelencaniformes
	Family Pelecanidae
white pelican	*Pelecanus erythrorhynchos*
	Family Sulidae
gannet	*Morus bassanus*
	Family Phalacrocoracidae
double-crested cormorant	*Phalacrocorax auritus*
	Order Ciconiiformes
	Family Ardeidae
great blue heron	*Ardea herodias*
green heron	*Butorides striatus*
little blue heron	*Egretta caerulea*
cattle egret	*Bubulcus ibis*
great egret	*Casmerodius albus*
snowy egret	*Egretta thula*
Louisiana heron	*Egretta tricolor*
black-crowned night heron	*Nycticorax nycticorax*
yellow-crowned night heron	*Nycticorax violacea*
least bittern	*Ixobrychus exilis*
American bittern	*Botaurus lentiginosus*

-continued-

Common Name	Scientific Name
	Family Ciconiidae
wood stork	*Mycteria americana*
	Family Threskiornithidae
glossy ibis	*Plegadis falcinellus*
	Order Anseriformes
	Family Anatidae
mute swan	*Cygnus olor*
whistling swan	*Olor columbianus*
Canada goose	*Branta canadensis*
brant	*Branta bernicla*
white-fronted goose	*Anser albifrons*
snow (blue) goose	*Chen caerulescens*
Ross' goose	*Chen rossii*
mallard	*Anas platyrhynchos*
black duck	*Anas rubripes*
gadwall	*Anas strepera*
pintail	*Anas acuta*
green-winged teal	*Anas crecca*
blue-winged teal	*Anas discors*
cinnamon teal	*Anas cyanoptera*
American wigeon	*Anas americana*
northern shoveler	*Anas clypeata*
wood duck	*Aix sponsa*
redhead	*Aythya americana*
ring-necked duck	*Aythya collaris*
canvasback	*Aythya valisineria*
greater scaup	*Aythya marila*
lesser scaup	*Aythya affinis*
common goldeneye	*Bucephala clangula*
Barrows' goldeneye	*Bucephala islandica*
bufflehead	*Bucephala albeola*
oldsquaw	*Clangula hyemalis*
harlequin duck	*Histrionicus histrionicus*
common eider	*Somateria mollissima*
king eider	*Somateria spectabilis*
white-winged scoter	*Melanitta fusca*
surf scoter	*Melanitta perspicillata*
black (common) scoter	*Melanitta nigra*
ruddy duck	*Oxyura jamaicensis*
hooded merganser	*Lophodytes cucullatus*
common merganser	*Mergus merganser*
red-breasted merganser	*Mergus serrator*

-continued-

Common Name	Scientific Name
	Order Falconiformes
	Family Cathartidae
turkey vulture	Cathartes aura
black vulture	Coragyps atratus
	Family Accipitridae
goshawk	Accipiter gentilis
sharp-shinned hawk	Accipiter striatus
Cooper's hawk	Accipiter cooperii
red-tailed hawk	Buteo jamaicensis
red-shouldered hawk	Buteo lineatus
broad-winged hawk	Buteo platypterus
Swainson's hawk	Buteo swainsoni
rough-legged hawk	Buteo lagopus
golden eagle	Aquila chrysaetos
bald eagle	Haliaeetus leucocephalus
marsh hawk	Circus cyaneus
	Family Pandionidae
osprey	Pandion haliaetus
	Family Falconidae
gyrfalcon	Falco rusticolus
peregrine falcon	Falco peregrinus
merlin	Falco columbarius
American kestrel	Falco sparverius
	Order Galliformes
	Family Tetraonidae
ruffed grouse	Bonasa umbellus
sharp-tailed grouse	Pedioecetes phasianellus
	Family Phasianidae
bobwhite	Colinus virginianus
ring-necked pheasant	Phasianus colchicus
	Order Gruiformes
	Family Gruidae
sandhill crane	Grus canadensis

-continued-

Common Name	Scientific Name
	Family Rallidae
king rail	*Rallus elegans*
Virginia rail	*Rallus limicola*
sora	*Porzana carolina*
yellow rail	*Coturnicops noveboracensis*
black rail	*Laterallus jamaicensis*
purple gallinule	*Porphyrula martinica*
common gallinule	*Gallinula chloropus*
American coot	*Fulica americana*
	Order Charadriiformes
	Family Charadriidae
semipalmated plover	*Charadrius semipalmatus*
piping plover	*Charadrius melodus*
Wilson's plover	*Charadrius wilsonia*
killdeer	*Charadrius vociferus*
American golden plover	*Pluvialus dominica*
black-bellied plover	*Pluvialus squatarola*
	Family Scolopacidae
ruddy turnstone	*Arenaria interpres*
American woodcock	*Philohela minor*
common snipe	*Capella gallinago*
long-billed curlew	*Numenius americanus*
whimbrel	*Numenius phaeopus*
upland sandpiper	*Bartramia longicauda*
spotted sandpiper	*Actitis macularia*
solitary sandpiper	*Tringa solitaria*
willet	*Catoptrophorus semipalmatus*
greater yellowlegs	*Tringa melanoleuca*
lesser yellowlegs	*Tringa flavipes*
red knot	*Calidris canutus*
purple sandpiper	*Calidris maritima*
pectoral sandpiper	*Calidris melanotos*
white-rumped sandpiper	*Calidris fuscicollis*
Baird's sandpiper	*Calidris bairdii*
least sandpiper	*Calidris minutilla*
dunlin	*Calidris alpina*
short-billed dowitcher	*Limnodromus griseus*
long-billed dowitcher	*Limnodromus scolopaceus*
stilt sandpiper	*Micropalama himantopus*
semipalmated sandpiper	*Calidris pusilla*
western sandpiper	*Calidris mauri*
buff-breasted sandpiper	*Tryngites subruficollis*
marbled godwit	*Limosa fedoa*
Hudsonian godwit	*Limosa haemastica*
ruff	*Philomachus pugnax*

-continued-

Common Name	Scientific Name
	Family Scolopacidae (continued)
sanderling	*Calidris alba*
red phalarope	*Phalaropus fulicarius*
Wilson's phalarope	*Phalaropus tricolor*
northern phalarope	*Phalaropus lobatus*
	Family Stercorariidae
pomarine jaegar	*Stercorarius pomarinus*
parasitic jaegar	*Stercorarius parasiticus*
long-tailed jaeger	*Stercororius longicaudus*
	Family Laridae
glaucous gull	*Larus hyperboreus*
Iceland gull	*Larus glaucoides*
great-black-backed gull	*Larus marinus*
herring gull	*Larus argentatus*
Thayer's gull	*Larus thayeri*
ring-billed gull	*Larus delawarensis*
black-headed gull	*Larus ridibundus*
laughing gull	*Larus atricilla*
Franklin's gull	*Larus pipixcan*
Bonaparte's gull	*Larus philadelphia*
little gull	*Larus minutus*
black-legged kittiwake	*Rissa tridactyla*
Forster's tern	*Sterna forsteri*
common tern	*Sterna hirundo*
roseate tern	*Sterna dougallii*
least tern	*Sterna albifrons*
Caspian tern	*Sterna caspia*
black tern	*Chlidonias niger*
	Order Columbiformes
	Family Columbidae
rock dove	*Columba livia*
mourning dove	*Zenaida macroura*
	Order Cuculiformes
	Family Cuculidae
yellow-billed cuckoo	*Coccyzus americanus*
black-billed cuckoo	*Coccyzus erythropthalmus*
	Order Strigiformes
	Family Tytonidae
barn owl	*Tyto alba*

-continued-

Common Name	Scientific Name
	Family Strigidae
screech owl	_Otus asio_
great horned owl	_Bubo virginianus_
snowy owl	_Nyctea scandiaca_
barred owl	_Strix varia_
long-eared owl	_Asio otus_
short-eared owl	_Asio flammeus_
boreal owl	_Aegolius funereus_
saw-whet owl	_Aegolius acadicus_
	Order Caprimulgiformes
	Family Caprimulgidae
whip-poor-will	_Caprimulgus vociferus_
common nighthawk	_Chordeiles minor_
	Order Apodiformes
	Family Apodidae
chimney swift	_Chaetura pelagica_
	Family Trochilidae
ruby-throated hummingbird	_Archilochus colubris_
	Order Coraciiformes
	Family Alcedinidae
belted kingfisher	_Megaceryle alcyon_
	Order Piciformes
	Family Picidae
common (yellow-shafted) flicker	_Colaptes auratus_
pileated woodpecker	_Dryocopus pileatus_
red-bellied woodpecker	_Melanerpes carolinus_
red-headed woodpecker	_Melanerpes erythrocephalus_
yellow-bellied sapsucker	_Sphyrapicus varius_
hairy woodpecker	_Picoides villosus_
downy woodpecker	_Picoides pubescens_
black-backed three-toed woodpecker	_Picoides arcticus_
northern three-toed woodpecker	_Picoides tridactylus_
	Order Passeriformes
	Family Tyrannidae
eastern kingbird	_Tyrannus tyrannus_
great crested flycatcher	_Myiarchus crinitus_

-continued-

Common Name	Scientific Name
	Family Tyrannidae (continued)
eastern phoebe	*Sayornis phoebe*
yellow-bellied flycatcher	*Empidonax flaviventris*
Acadian flycatcher	*Empidonax virescens*
willow flycatcher	*Empidonax traillii*
alder flycatcher	*Empidonax alnorum*
least flycatcher	*Empidonax minimus*
eastern wood pewee	*Contopus virens*
olive-sided flycatcher	*Nuttallornis borealis*
	Family Alaudidae
horned lark	*Eremophila alpestris*
	Family Hirundinidae
tree swallow	*Iridoprocne bicolor*
bank swallow	*Riparia riparia*
rough-winged swallow	*Stelgidopteryx ruficollis*
barn swallow	*Hirundo rustica*
cliff swallow	*Petrochelidon pyrrhonota*
purple martin	*Progne subis*
	Family Corvidae
gray jay	*Perisoreus canadensis*
blue jay	*Cyanocitta cristata*
common raven	*Corvus corax*
common crow	*Corvus brachyrhynchos*
	Family Paridae
black-capped chickadee	*Parus atricapillus*
boreal chickadee	*Parus hudsonicus*
tufted titmouse	*Parus bicolor*
	Family Sittidae
white-breasted nuthatch	*Sitta carolinensis*
red-breasted nuthatch	*Sitta canadensis*
	Family Certhiidae
brown creeper	*Certhia familiaris*
	Family Troglodytidae
house wren	*Troglodytes aedon*
winter wren	*Troglodytes troglodytes*
Bewicks' wren	*Thryomanes bewickii*
Carolina wren	*Thryothorus ludovicianus*
long-billed marsh wren	*Cistothorus palustris*
short-billed marsh wren	*Cistothorus platensis*

-continued-

Common Name	Scientific Name
	Family Mimidae
mockingbird	*Mimus polyglottos*
gray catbird	*Dumetella carolinensis*
brown thrasher	*Toxostoma rufum*
	Family Turdidae
American robin	*Turdus migratorius*
wood thrush	*Hylocichla mustelina*
hermit thrush	*Catharus guttatus*
Swainson's thrush	*Catharus ustulata*
gray-cheeked thrush	*Catharus minimus*
veery	*Catharus fuscescens*
eastern bluebird	*Sialia sialis*
	Family Sylviidae
Blue-gray gnatcatcher	*Polioptila caerulea*
golden-crowned kinglet	*Regulus satrapa*
ruby-crowned kinglet	*Regulus calendula*
	Family Motacillidae
water pipit	*Anthus spinoletta*
Sprague's pipit	*Anthus spraguei*
	Family Bombycillidae
Bohemian waxwing	*Bombycilla garrulus*
cedar waxwing	*Bombycilla cedrorum*
	Family Laniidae
northern shrike	*Lanius excubitor*
loggerhead shrike	*Lanius ludovicianus*
	Family Sturnidae
starling	*Sturnus vulgaris*
	Family Vireonidae
white-eyed vireo	*Vireo griseus*
Bell's vireo	*Vireo bellii*
yellow-throated vireo	*Vireo flavifrons*
solitary vireo	*Vireo solitarius*
red-eyed vireo	*Vireo olivaceus*
Philadelphia vireo	*Vireo philadelphicus*
warbling vireo	*Vireo gilvus*
	Family Parulidae
black and white warbler	*Mniotilta varia*
prothonotary warbler	*Protonotaria citrea*
worm-eating warbler	*Helmitheros vermivorus*
golden-winged warbler	*Vermivora chrysoptera*

-continued-

Common Name	Scientific Name
	Family Parulidae (continued)
blue-winged warbler	Vermivora pinus
Tennessee warbler	Vermivora peregrina
orange-crowned warbler	Vermivora celata
Nashville warbler	Vermivora ruficapilla
Northern parula	Parula americana
yellow warbler	Dendroica petechia
magnolia warbler	Dendroica magnolia
Cape May warbler	Dendroica tigrina
black-throated blue warbler	Dendroica caerulescens
yellow-rumped warbler	Dendroica coronata
black-throated green warbler	Dendroica virens
Cerulean warbler	Dendroica cerulea
Blackburnian warbler	Dendroica fusca
yellow-throated warbler	Dendroica dominica
chestnut-sided warbler	Dendroica pensylvanica
bay-breasted warbler	Dendroica castanea
blackpoll warbler	Dendroica striata
pine warbler	Dendroica pinus
Kirtland's warbler	Dendroica kirtlandii
prairie warbler	Dendroica discolor
palm warbler	Dendroica palmarum
ovenbird	Seiurus aurocapillus
northern waterthrush	Seiurus noveboracensis
Louisiana waterthrush	Seiurus motacilla
Kentucky warbler	Oporornis formosus
Connecticut warbler	Oporornis agilis
mourning warbler	Oporornis philadelphia
common yellowthroat	Geothlypis trichas
yellow-breasted chat	Icteria virens
hooded warbler	Wilsonia citrina
Wilson's warbler	Wilsonia pusilla
Canada warbler	Wilsonia canadensis
American redstart	Setophaga ruticilla
	Family Ploceidae
house sparrow	Passer domesticus
	Family Icteridae
bobolink	Dolichonyx oryzivorus
eastern meadowlark	Sturnella magna
western meadowlark	Sturnella neglecta
yellow-headed blackbird	Xanthocephalus xanthocephalus
red-winged blackbird	Agelaius phoeniceus
orchard oriole	Icterus spurius
northern (Baltimore) oriole	Icterus galbula
rusty blackbird	Euphagus carolinus

-continued-

Common Name	Scientific Name
	Family Icteridae (continued)
Brewer's blackbird	Euphagus cyanocephalus
common grackle	Quiscalus quiscula
brown-headed cowbird	Molothrus ater
	Family Thraupidae
scarlet tanager	Piranga olivacea
	Family Fringillidae
cardinal	Cardinalis cardinalis
rose-breasted grosbeak	Pheucticus ludovicianus
Indigo bunting	Passerina cyanea
dickcissel	Spiza americana
evening grosbeak	Hesperiphona vespertina
purple finch	Carpodacus purpureus
house finch	Carpodacus mexicanus
pine grosbeak	Pinicola enucleator
hoary redpoll	Carduelis hornemanni
common redpoll	Carduelis flammea
pine siskin	Carduelis pinus
American goldfinch	Carduelis tristis
red crossbill	Loxia curvirostra
white-winged crossbill	Loxia leucoptera
rufous-sided towhee	Pipilo erythrophthalmus
savannah sparrow	Passerculus sandwichensis
grasshopper sparrow	Ammodramus savannarum
Henslows sparrow	Ammodramus henslowii
LeContes sparrow	Ammospiza leconteii
sharp-tailed sparrow	Ammospiza caudacuta
vesper sparrow	Pooecetes gramineus
Bachman's sparrow	Aimophila aestivalis
dark-eyed junco	Junco hyemalis
tree sparrow	Spizella arborea
chipping sparrow	Spizella passerina
clay-colored sparrow	Spizella pallida
field sparrow	Spizella pusilla
Harris' sparrow	Zonotrichia querula
white-crowned sparrow	Zonotrichia leucophrys
white-throated sparrow	Zonotrichia albicollis
fox sparrow	Passerella iliaca
Lincoln's sparrow	Melospiza lincolnii
swamp sparrow	Melospiza georgiana
song sparrow	Melospiza melodia
Lapland longspur	Calcarius lapponicus
snow bunting	Plectrophenax nivalis

[a] Nomenclature source: American Ornithologists' Union Check-list of North American Birds, 1957, fifth edition through the 33rd supplement.

GREBES (Podicipedidae)

● pied-billed grebe (Podilymbus podiceps)

Habitat - Ponds with much shore and emergent vegetation, marshes with areas of open water and marshy inlets and bays are utilized for breeding by this species. Nests are usually floating, built around or anchored to dead or growing reeds, rushes, or bushes. In shallow water, nest platforms are built up from the bottom. They are generally placed at an opening in the vegetation to allow underwater approach. Grebes prefer exposed situations on lakes and rivers, or brackish and salt waters for winter habitat.

Distribution - The breeding range extends from British Columbia, Quebec, and New Brunswick southward to Texas. The northern limits of the wintering range extend from Washington state southward in an arc to Texas, then north to the Potomac Valley. The southern limits include Central America. Migration corridors are utilized.

Habits - Pied-billed grebes associate closely with marshbirds such as coots and gallinules, but otherwise are not gregarious.

Food - An animal diet consisting of fish, crayfish, other crustaceans, molluscs, insects, frogs and salamanders is consumed. Aquatic plants are occasionally eaten.

● horned grebe (Podiceps auritus)

Habitat - Ponds and marshes having areas of open water, and sheltered portions of lakes and streams are utilized for breeding. Nests are placed in shallow water, well within the fringe of vegetation. Some are exposed, but others rest on submerged plants or tussocks, or are anchored to and supported by bushes growing in the water. The horned grebe winters primarily in marine waters.

Distribution - The breeding range extends from Alaska across the United States on about parallel 45° to Maine. The species formerly nested along the Great Lakes and St. Lawrence River, but now breeds only sporadically there. The wintering range extends from southern British Columbia, southern Ontario and Maine south to the Gulf Coast, and includes the Great Lakes. The main migration routes go directly to and from the Atlantic and Pacific coasts; the Mississippi flyway is also used.

Habits - Horned grebes are usually observed as scattered singles. They feed in water 5-25 feet deep.

Food - Diet consists mainly of fish and insects but larger crustaceans, small frogs, salamanders, leeches, and tadpoles are also utilized.

HERONS, BITTERNS (Ardeidae)

● great blue heron (Ardea herodias)

Habitat - Salt and freshwater environments are used for breeding, particularly shallow waters and shores of lakes, ponds, marshes, streams, and bays. Nests are platforms of sticks, placed high in trees.

Distribution - The breeding range extends from southeastern British Columbia and northern Ontario south to California, Texas, and the south Atlantic states. The wintering range extends from Oregon through the Ohio valley and the middle states south to the West Indies. Following the nesting season the heron migrates south.

Habits - Nesting is colonial, often mixed with other heron species. The bird feeds by stalking prey in shallow waters, on shore or along watercourses.

Food - Diet consists of fish, frogs, snakes, small mammals, crustaceans, leeches, and aquatic and land insects.

● great egret (Casmerodius albus)

Habitat - Birds forage in open water situations in swamps and along streams and ponds. Nests are placed in nearby woods and thickets, either singly or in colonies. Nests are made of twigs, placed high in tall trees.

Distribution - The breeding range extends from Oregon to Wisconsin and Massachusetts, and south to southern South America. The wintering range extends north to South Carolina and south to the Gulf Coast. Post-breeding dispersal extends into the lower Great Lakes and the St. Lawrence River before birds move southward for the winter.

Habits - The species is highly gregarious and it is primarily a diurnal feeder.

Food - The great egret feeds largely in freshwater marshes and ponds on fish, frogs, salamanders, snakes, snails, crustaceans, insects, and small mammals.

● green heron (<u>Butorides striatus</u>)

<u>Habitat</u> - These birds utilize a variety of habitats along streams, swamps, or shorelines for breeding. They may nest in dry woodlands or open marshes, or build a structure of reeds and cattails on a low tussock or muskrat house. Nests are close to water.

<u>Distribution</u> - The breeding range is limited to eastern North America from South Dakota, northern Wisconsin, southern Ontario, and Nova Scotia south to the West Indies and includes the St. Lawrence River, Lake Ontario, Lake Erie, Lake Huron, most of Lake Michigan, and western Lake Superior. The wintering range extends from the West Indies southward.

<u>Habits</u> - These herons are solitary nesters, occasionally occurring in small groups. Food is obtained by stalking prey in shallow water.

<u>Food</u> - Small fish, amphibians, reptiles, crustaceans, leeches, arachnids, land and water insects, and molluscs are taken.

● black-crowned night heron (<u>Nycticorax nycticorax</u>)

<u>Habitat</u> - The type of habitat used for breeding is variable. Nests have been found in trees in wooded areas, in swamps, on the ground in cattail marshes, or in clumps of tall grass on dry land. Nests are constructed of coarse twigs, reeds, and sticks.

<u>Distribution</u> - The breeding range extends from Oregon through Wyoming, Manitoba, Quebec, and Nova Scotia, and south to Patagonia. This includes the lower Great Lakes and the St. Lawrence River region. The wintering range extends from northern California and Gulf states southward, and excludes the Great Lakes region. There is general movement southward following the post breeding dispersal.

<u>Habits</u> - This heron is highly gregarious at all seasons, but exhibits territoriality on its feeding areas. It feeds actively at night by stalking prey or agitating the water with its bill to attract prey.

<u>Food</u> - Fishes, frogs, tadpoles, snakes, salamanders, molluscs, crustaceans, insects, vegetable matter, and sometimes young birds and mammals are taken.

● yellow-crowned night heron (Nycticorax violacea)

Habitat - Tidal flats, waterless areas on islands, or lush river swamps are utilized for breeding. Nests, constructed of twigs, are placed in trees in low wet areas, in small to large colonies.

Distribution - The breeding range extends from lower California through Kansas, southern Illinois and Indiana, to South Carolina and southward to Brazil and Peru. The northern limits have recently been extended to include northern Illinois and Ohio. The wintering range extends from southern California and southern Florida southward; there is general movement southward to the Gulf Coast. Post breeding dispersal extends north to the lower Great Lakes.

Habits - This heron is shyer, less gregarious and more diurnal than the black-crowned night heron.

Food - The diet consists mainly of crustaceans, but occasionally frogs, molluscs, and aquatic insects are included.

● American bittern (Botaurus lentiginosus)

Habitat - Marshes, swamps, bogs, or areas of wetness with tall growths of cattails and bulrushes are utilized for breeding. The nest site may be on floating islands of vegetation on a lake. Birds usually nest singly.

Distribution - The range extends from central British Columbia to Newfoundland and south to California, the Ohio Valley and North Carolina, inclusive of the Great Lakes region. The wintering range extends from California, Arizona, Texas, the Ohio Valley, and Virginia south to Cuba and Guatemala.

Habits - Birds remain solitary, and feed by stalking prey. They have been observed perching on the ground or on logs or stumps, but rarely in trees.

Food - Fishes, eels, frogs, salamanders, snakes, crayfish, molluscs, land and aquatic insects, spiders, and small rodents are taken.

- least bittern (Ixobrychus exilis)

Habitat - Stands of cattails and other semi-aquatic or dense aquatic vegetation are used. The birds prefer marshes with scattered bushes or other woody growth and have been found in swamps of buttonbush, sawgrass, and smartweed. Sedge bogs and areas with tussocks of tall grass provide good habitat. Nests are located in dense stands of robust emergent vegetation, 8-14 inches above shallow water. The birds usually nest singly.

Distribution - The breeding range extends from lower California, Kansas, and southern Indiana north to Colorado, Ontario, Maine, and Nova Scotia, inclusive of the Great Lakes and St. Lawrence River. The wintering range extends from southern California through southern New Mexico and Arizona. The southern tip of Florida is also utilized.

Habits - The least bittern is a timid and retiring species which is generally solitary; it stalks its prey in pools from within the vegetation.

Food - Small fishes, frogs, tadpoles, salamanders, leeches, slugs, crustaceans, insects, and occasionally small mammals are taken.

DUCKS (Anatidae)

● mallard (Anas platyrhynchos)

Habitat - Mallards are primarily found in small, shallow waters, but will use large lakes and rivers if food is plentiful. Nests are usually built on uplands, farm lands, or in grasslands in proximity to water, but occasionally are found in marshes, on tussocks of grass or weeds.

Distribution - The species breeds throughout the Great Lakes region. The wintering and breeding ranges overlap along Lake Ontario, Lake Erie, and lower Lake Michigan. Various migration corridors are utilized.

Habits - Drakes move to larger lakes and extensive wetlands to molt in late May. Mallards feed in unharvested and harvested crop fields, and by tipping in shallow waters.

Food - The mallard diet includes stems and seeds of aquatic plants, cultivated grains, mast, aquatic insects, molluscs, tadpoles, frogs, small fish, and fish eggs.

● black duck (Anas rubripes)

Habitat - Black ducks utilize wooded areas more than other Anas spp. Nests are placed in tussocks of grass or clumps of bushes in marshes or swamps, but also occur on wooded or grassy sloping shores and banks, under cover of grasses, bushes, and conifers in proximity to water. In winter preferred habitat is brackish marshes bordering bays and estuaries. Freshwater marshes, swamps, rivers, creeks, reservoirs, and ponds are also used.

Distribution - The breeding range extends from Northwestern Alaska across to Greenland, south to lower California and across the United States on about the 37° parallel. It includes the lower Great Lakes and the St. Lawrence River. The wintering range extends from Montana and Wyoming to southern Wisconsin, Ohio, and Maryland, and south to Mexico. Black ducks use five recognizable migration corridors. Birds from eastern Ontario move southwest across the west end of Lake Erie to the confluence of the Wabash and Ohio Rivers.

Habits - The black duck apparently does not associate closely with other ducks, but it prefers to travel and assemble with its own species in small flocks. It is predominantly a surface feeder.

Food - Plant matter comprises the bulk of food items for black ducks, but the diet contains a larger percentage of animal matter than that of mallards.

● gadwall (Anas strepera)

Habitat - Uplands, grasslands, brushy areas, and coastal salt marshes are used for nesting but extensive freshwater wetlands support higher breeding densities. In winter, birds will utilize any open water which offers adequate food, including brackish and interior marshes and coastal lagoons and bays. During migration birds stop over on very shallow waters, particularly in spring.

Distribution - The breeding range extends from Alaska and Nova Scotia south to North Carolina and California. Birds winter as far north as southern New England and the lower Great Lakes.

Habits - The gadwall readily associates with other species. It feeds on floating plant material, or by diving, and rarely comes ashore.

Food - The diet is composed mainly of leaves and stems of grasses, sedges, pondweeds, and other aquatic plants. Insects, molluscs, crustaceans, amphibians, and fish are also taken.

● pintail (Anas acuta)

Habitat - Marshes, prairie ponds, and tundra provide suitable breeding habitat. The nest is located in open dry areas of short vegetation, often far from water. The pintail stops on shallow waters which are sheltered from the wind.

Distribution - The breeding range extends from Alaska and Greenland south to western Pennsylvania, Nebraska, and California. The pintail range extends south to Central America and the West Indies. Westward bound birds from the Maritime provinces and Quebec travel through the St. Lawrence region and the Great Lakes.

Habits - The species is quite wary and readily associates with other dabblers. It feeds in very shallow water, at the surface by up-ending but rarely submerging. The pintail will also fly to feed on grain fields. It rests on fairly exposed places, particularly on mud or sand at the water's edge.

Food - The diet consists largely of seeds of pondweeds, sedges, grasses, and smartweeds. Molluscs, crustaceans and insects are also taken.

● green-winged teal (Anas crecca)

Habitat - This species prefers a mixture of grassy and sedgy vegetation for nesting, with brush or scattered trees, not far from water. It winters in brackish tidal marshes, estuarine areas, and shallow inland fresh waters, and these types of habitat are also preferred during migration.

Distribution - The main breeding range includes northern Alaska, Manitoba, and Quebec and extends south to New York, Nebraska, and California. The northern wintering limits include the southern tips of Lakes Michigan, Erie, and western Ontario. Flight corridors are used for migration.

Habits - Individuals associate in small groups of family units. They feed regularly at night but are also active and mobile in daylight.

Food - The diet is composed largely of vegetable matter such as seeds of pondweeds, bulrushes, sedges, grasses, waste grain, berries, wild grapes, and mast. Insects, crustaceans, and molluscs are also taken.

● blue-winged teal (Anas discors)

Habitat - The species utilizes the shoreline of marshes, sloughs, and ponds for breeding. Nests are dry, in fairly tall coarse grasses away from water. The vegetation often forms a canopy over the nest.

Distribution - The breeding range extends from central British Columbia to Newfoundland, south to New Mexico, Indiana, Ohio, western New York, and Maine. It includes the Great Lakes and the St. Lawrence region. The northern limit for over-wintering is 36° parallel and the range extends south to the West Indies and South America. A large percentage of the breeders from the Great Lakes and upper St. Lawrence move to the Atlantic coast.

Habits - This teal is highly social, forming large assemblies along migration corridors and on the winter range. Teals readily associate with other waterfowl. They prefer to feed in very shallow water where floating and submerged vegetation and small animal life are abundant. They sometimes glean the surface but seldom dive. They favor fallen trunks, stumps, or mudflats for perching.

Food - Items are largely vegetable matter, consisting of seeds of grasses and sedges, and seeds, stems, and leaves of pondweeds. Molluscs, insects, and a few crustaceans are also taken.

● American wigeon (*Anas americana*)

Habitat - This species prefers to breed in marshes with open waterways and some exposed shoreline. The nest is usually dry, well concealed, ashore, or on an island in herbaceous or sedge cover. Inland fresh water is used in the winter until it is frozen, then the bird moves to salt water. Large inland marshes with extensive open water areas and lakes are utilized during migration. Marsh edges and sloughs are used for feeding.

Distribution - The breeding range extends from northwestern Alaska to Oregon, through Kansas and southern Wisconsin, and includes the St. Lawrence River, Lake Ontario, and eastern Lake Erie. The wintering range extends from southern British Columbia, southern Illinois and Delaware south to California, the West Indies, and Costa Rica.

Habits - This species occurs in large assemblies in the winter range, along migration corridors and when molting. It spends a considerable amount of time grazing ashore. It commonly associates with diving ducks, coots, swans, and geese.

Food - Items are largely vegetable matter, consisting of pondweeds, grasses, algae, sedges, wild celery, and other aquatic plants. A few snails and insects are also taken.

● northern shoveler (*Anas clypeata*)

Habitat - Open marshy areas with shallow waterways, abundant aquatic vegetation and surrounding dry meadows are suitable for nesting. The nest site is usually in low grass, often with little concealment early in the season.

Distribution - The breeding range extends from Alaska to southern California, New Mexico, Texas, and northern Indiana. The eastern limits include extreme western Lake Superior. The wintering range extends from southern British Columbia south to the West Indies, Colombia, and Hawaii. It does not include the Great Lakes and upper St. Lawrence region. Migration is through the main corridors as described by Bellrose (1968).

Habits - Shovelers are gregarious, but remain in small groups. They commonly associate with blue-winged teal (*Anas discors*), cinnamon teal (*A. cyanoptera*), gadwall (*A. strepera*) and American wigeon (*A. americana*). They feed most actively early and late in the day in very shallow waters. Birds seldom up-end, dive, or fly to grain fields.

Food - Plants of many families including grasses, sedges, pondweeds, waterlilies, algae, and smartweeds are consumed. Molluscs are also taken.

● wood duck (Aix sponsa)

Habitat - Shallow, quiet inland waters in or near deciduous or mixed woodlands are utilized for breeding. Preferred nest sites are natural cavities in trees, 5-40 feet above ground or water, or within 200 yards of water. Brood rearing habitat may consist of brushy understory (concealment), floating and emergent vegetation (food sources), small open-water passages (mobility) and fallen limbs and stumps (perching). In general, sheltered waters such as open to wooded swamps, flooded lowland forest, ponds, and expanses of open water in marshes are used.

Distribution - The breeding range extends from southern British Columbia eastward on about the 46° parallel to New Brunswick and Nova Scotia, and south to California, Texas, and Florida, including the Great Lakes region.

Habits - This species is often found in assemblies with black ducks (Anas rubripes) and gallinules. Females often return to the same locale to nest. The wood duck is a surface feeder with a pronounced daily feeding pattern.

Food - Seeds and vegetative parts of aquatic and land plants, aquatic insects, and crustaceans are taken. The young consume primarily insects and insect larvae.

Predators - Raccoons, fox squirrels, bull snakes and rat snakes destroy numerous eggs. Snapping turtles and bullfrogs may take ducklings.

● redhead (Aythya americana)

Habitat - Extensive wetland areas with shallow water openings bordered by emergents (bulrushes, sedges, cattail, and reed) are preferred habitat for breeding. Nests are made of dried vegetation and are placed over shallow water near the shore, or occasionally on dry ground. Vegetation is pulled over the nest for concealment.

Distribution - The main breeding range covers the western and central Canadian provinces and Alaska. There has been increased nesting in scattered localities along Lake Huron, Lake Erie, and to a lesser extent along Lake Ontario. The wintering range encompasses the continental interior from southern British Columbia to Mexico and Florida. The northern limits include Lakes Michigan, Erie, and Ontario. Migration is overland to the Gulf of Mexico.

Habits - This species is highly gregarious and associates with canvasbacks (Aythya valisineria), lesser scaup (A. affinis), and American coot (Fulica americana) during the nesting season. There is no well defined feeding period during the day. Food is obtained by diving or swimming submersed in water less than six feet deep.

Food - Items consist of vegetable or animal matter. The composition varies with the season and according to the age of the birds.

● ring-necked duck (<u>Aythya</u> <u>collaris</u>)

<u>Habitat</u> - For breeding, freshwater marshes, especially sedge marshes and bogs, with shallow water and quite dense vegetation are utilized. Small potholes, sloughs, and beaver flowages are also used for nesting if they are near a larger body of water. Nests are placed on floating islands, among hummocks or on brushy clumps. The nest foundation is dry to semi-dry but in proximity to open water. Nests are seldom placed in emergent vegetation over open water, but open water areas are used during the molting season.

<u>Distribution</u> - The main breeding range extends from northern California, North Dakota, northern Iowa, and southern Wisconsin northward. The eastward limit extends into the Great Lakes and includes Lake Superior and most of Lakes Michigan and Huron. The wintering range extends from southern British Columbia, southern Illinois, and New Jersey south to New Mexico, northern Texas, Puerto Rico, and Guatemala. Ring-necked ducks migrate north to Newfoundland, Nova Scotia, and Quebec. A minor fall corridor occurs diagonally southeast from the Great Lakes region to Chesapeake Bay and south to the wintering grounds along the Atlantic coast. Lake Erie is a minor spring migration route for birds coming north through Indiana to the Maritime provinces in Canada.

<u>Habits</u> - The species is highly gregarious, often attaining high breeding densities. Birds feed regularly in early morning, mid-afternoon, and evening.

<u>Food</u> - Items are primarily vegetative and include seeds, bulbs, succulent parts of waterlilies, pondweeds, sedges, grasses, and smartweeds. Some aquatic insects and molluscs are also included in the diet.

● canvasback (*Aythya valisineria*)

Habitat - The species breeds in marshes and sloughs. The semi-floating nests are placed in a clump of reeds, rushes, or long sedges, often in deep water. For winter habitat, canvasbacks prefer brackish or fresh water with submerged vegetation.

Distribution - The main breeding range is the prairie pothole region of the interior Northwest. The species does not breed regularly in the Great Lakes region. The overall wintering range includes the Illinois shoreline of Lake Michigan and extends north to the Straits of Mackinac. It also includes Lake Erie and the central portion of Lake Ontario. Birds tend to concentrate in a few places within these areas. Canvasbacks follow a diagonal migration route across lower Lake Michigan and southern Ontario Province to Lake Ontario before heading south to the Gulf Coast.

Habits - The species is gregarious, and associates on the water with redheads (*Aythya americana*) and lesser scaup (*A. affinis*). It feeds in shallow water areas with abundant submergent vegetation during the early morning and late evening. Resting places are on open water areas of bays and lakes.

Food - Vegetable matter in the diet of canvasbacks includes primarily pondweeds, but wild celery, water plantains, grasses, and sedges are also taken. Animal items include molluscs and insects.

Predators - Raccoons destroy numerous canvasback nests by taking eggs. The canvasback is also detrimentally affected by redheads which parasitize canvasback nests.

● lesser scaup (*Aythya affinis*)

Habitat - The lesser scaup nests, often semicolonially, along grassy margins of ponds, lakes, floating shorelines, in river deltas and on mud flats. Nests consist of a slight depression among standing or sheltering vegetation.

Distribution - The lesser scaup has been reported nesting outside of its main range in the Canadian provinces and Alaska along the shorelines of Lake Michigan, lower Lake Huron and western Lake Erie. Birds from the northwest move southeast through the Great Lakes region to the Atlantic coast. Wintering concentrations of birds head east from the Mississippi Valley to Lake Erie and proceed down the interior to Florida.

Habits - The lesser scaup is one of the most numerous divers. It feeds most actively in early morning, either in shallow water or by diving in deeper water. It rests offshore in large rafts.

Food - The diet includes both vegetable and animal matter, but its composition varies with locale and according to age of the birds.

● ruddy duck (*Oxyura jamaicensis*)

Habitat - Freshwater marshes are utilized for breeding. Nests are built over shallow water in dense stands of emergent aquatic plants such as cattails, bulrush, and reeds. Open water areas are used for display, feeding, and resting. Birds frequent sheltered, saltwater coastal areas in the winter but they are also common in ice-free inland waters. During migration birds occur in shallow fresh and brackish water where aquatic plants and small molluscs are abundant.

Distribution - The breeding range extends from central British Columbia to northern New Mexico, western Nebraska, southern Michigan, and Ontario to Maine. Scattered records exist for the lower Great Lakes. The wintering range extends from southern British Columbia to New Mexico, southern Illinois, and Maine. The upper limits of occurrence include Lakes Erie and Ontario.

Habits - The ruddy duck occurs in small groups on open water as well as weedy areas. It commonly associates with the American coot (*Fulica americana*). It usually dives and feeds on the bottom but will also surface feed.

Food - Vegetable matter such as pondweeds, sedges, wild celery, and algae are taken. Animal items in the diet are mainly insects, molluscs, and crustaceans.

EAGLES, HARRIERS (Accipitridae)

● bald eagle (Haliaeetus leucocephalus)

Habitat - Lakes, rivers, marshes, and seacoasts are utilized for breeding and wintering. The stick nest is placed in the largest tree in a nearby stand of timber. A body of water is usually within half a mile and the area must be free of human disturbance.

Distribution - The breeding range formerly extended throughout North America, but is now restricted to Alaska, northern and eastern Canada, the northern United States, and Florida. Northern birds winter south to northern Mexico, primarily in the Mississippi Valley and the northwest.

Habits - The species is highly territorial during the nesting season but roosts communally on wintering grounds. It hunts by flying low over water, by swooping from the air or a perch or by fishing in shallow water.

Food - The diet consists mainly of fish, but waterfowl and rabbits are taken depending on locale and availability. Carrion is also readily consumed.

● marsh hawk (Circus cyaneus)

Habitat - Birds are found in any open country, particularly marshes, open grasslands and shrubby meadows. Nests are placed in a mound of dead reeds and grass, in the open or under shrubs.

Distribution - The breeding range extends from Alaska to Newfoundland, and south to Virginia and northern Mexico. Birds winter as far north as British Columbia, Wisconsin, and New Brunswick.

Habits - The marsh hawk is the only North American harrier. It hunts prey by flying close to the ground, quartering wide open spaces. It seldom pursues prey in the air or from perches.

Food - Diet consists mainly of mice, rats, frogs, small snakes, and insects, but this hawk will also take small birds.

OSPREYS (Pandionidae)

● osprey (Pandion haliaetus)

Habitat - Lakes, rivers, marshes, and seacoasts are used for breeding and wintering. The nest is constructed of sticks and debris and may be placed in a dead or live tree, on rocks, flat ground, or on a telephone pole. The ideal nest site is on top of a tall dead snag surrounded by water.

Distribution - The breeding range extends from Alaska and Newfoundland south to Florida and the Gulf Coast, including Lakes Superior, Michigan, and Huron. Birds winter regularly from the Gulf Coast and California south to Argentina.

Habits - An abundant food supply must be available in suitable nesting habitat in order for ospreys to attain high breeding densities. Nest sites are chosen in proximity to perches. Ospreys hunt 15-30 meters above the water and strike the water and prey feet first. They may completely submerse themselves in the process.

Food - The diet consists primarily of fish but mammals, birds, reptiles, amphibians, and invertebrates are occasionally taken.

CRANES (Gruidae)

- sandhill crane (<u>Grus canadensis</u>)

<u>Habitat</u> - Large freshwater marshes, tundra and prairie potholes are used during the breeding season. The nest, a slight depression lined with grass, is placed in a large mound of grass on the ground. Open prairies and grainfields are used during migration and as wintering grounds.

<u>Distribution</u> - The breeding range extends from northeastern Siberia, Alaska, and the Arctic Islands south to Michigan, Minnesota, and California. The species is also found along the Gulf of Mexico from Florida to Texas. The birds winter in Texas, Mexico, and California.

<u>Habits</u> - Birds occur singly, in pairs, or occasionally in small flocks on the feeding grounds. They often feed on dry prairies and plains.

<u>Food</u> - The diet is composed of roots, bulks, and grains but insects, frogs, lizards, snakes, and mice are also taken.

RAILS, GALLINULES, COOTS (Rallidae)

● king rail (Rallus elegans)

Habitat - Freshwater marshes and roadside ditches are used for breeding. The nest is a deep bowl of grass, with surrounding marsh grass woven overhead into a dome.

Distribution - The breeding range extends from Minnesota and Massachusetts south to Florida, Texas, and northern Mexico. It includes Lakes Ontario and Erie, and the lower portion of Lakes Huron and Michigan. Birds winter from the Gulf Coast southward.

Habit - The species is nongregarious and secretive. King rails are known to return to the same marsh for several consecutive breeding seasons, where territories are established and maintained, usually by the male. They feed in very shallow water, usually no more than two to three inches deep.

Food - Main items are aquatic animal life, particularly crustaceans. Plants are sometimes taken.

● Virginia rail (Rallus limicola)

Habitat - Both salt and freshwater marshes are used. Nests are usually placed in the shallow water sedge or cattail zones. The nest is a shallow saucer woven into the surrounding plant growth.

Distribution - The breeding range extends from British Columbia, Minnesota, and Newfoundland south to Guatemala. The lower St. Lawrence River and Lakes Ontario, Erie, Huron, and Michigan are areas of high breeding density. The birds winter from Virginia south along the Atlantic coast and the Gulf of Mexico.

Habits - The Virginia rail seldom flushes but will escape easily by running through marsh vegetation. The species is readily identified by its call. Food is obtained by probing in mud.

Food - The diet consists mainly of animal matter such as coleoptera, larval diptera, and snails, but duckweeds are also eaten.

● sora (Porzana carolina)

Habitat - Freshwater marshes are preferred habitat for breeding and during migration. The nest basket is suspended several inches above water and is well hidden in clumps of grass.

Distribution - The breeding range extends from British Columbia and Newfoundland south to the Carolinas, Pennsylvania, Oklahoma, and Baja California.

Habits - Soras will not readily flush but maneuver by foot through the vegetation if disturbed.

Food - Primary items are small molluscs and insects, but soras will feed heavily upon wild rice in the autumn.

● yellow rail (Coturnicops noveboracensis)

Habitat - High margins of marshes and grassy or sedge meadows are used for nesting. The nest is cup-shaped and well-concealed in the vegetation.

Distribution - The breeding range extends from central Canada south to North Dakota, and to New Brunswick, Quebec, and Maine. Birds winter from the Carolinas, Florida, and the Gulf Coast to California.

Habits - The species is the most secretive of the rails. If approached, it will not readily flush, but prefers to conceal itself in the vegetation.

Food - Freshwater snails provide the diet of yellow rails.

● black rail (Laterallus jamaicensis)

Habitat - Inland marshes with a dense, mixed growth of rushes, sedges, or grasses and a wet ground surface are preferred breeding habitat. Rank old growth is used instead of younger stages. Nests are placed directly on the ground, and subsequently affected by fluctuations in water level. They are often reconstructed and built up, but are well concealed.

Distribution - The species is limited to the eastern United States. The breeding range extends from southern Ontario and Massachusetts south to Kansas, Illinois, and South Carolina. Birds winter from Texas east through the Gulf states to Guatemala.

Food - The diet has not been documented thoroughly; however, invertebrates and some plant materials may be important.

● common gallinule (Gallinula chloropus)

Habitat - Freshwater marshes and ponds with growths of cattails and other aquatic vegetation are utilized. Nests are shallow platforms constructed of dead cattails, rushes, and other marsh plants; they are usually built up just a few inches above water level, or may be partially floating.

Distribution - The overall range extends from southern Canada to southern South America and includes the lower Great Lakes and the St. Lawrence River.

Habits - The gallinule swims well and feeds along the edges of open water. Occasionally, it will dive for food. If disturbed it will seek cover in dense vegetation.

Food - The diet includes seeds, roots, and the soft parts of succulent water plants, as well as snails, small molluscs, grasshoppers, worms, and other insects.

● American coot (Fulica americana)

Habitat - Preferred habitat is shallow ponds and marshes with good interspersion of reeds or cattails. Nests consist of a shallow platform, usually on the water anchored to a clump of reeds.

Distribution - The overall range extends from southern Canada to northern South America. Lesser breeding densities with locally high density occur along lower Lakes Michigan and Huron, and western Lake Erie.

Habits - Movement and feeding behavior among coots is similar to that of ducks. They swim and dive for food but will also feed ashore in grain fields during the winter.

Food - The diet consists of vegetable matter such as pondweeds, sedges, algae, and grasses.

PLOVERS (Charadriidae)

● killdeer (Charadrius vociferus)

Habitat - Marshes, fields, gardens, and dry uplands are used for nesting. The nest, a shallow depression on the ground, is often away from open water.

Distribution - The breeding range extends from British Columbia, Mackenzie, and Newfoundland south to the West Indies, Mexico, and Peru. Birds winter regularly from New Jersey and Ohio southward.

Habits - This species feeds along the wet margins of open marshes and meadows, and in cultivated cropfields.

Food - The diet is composed of grubs, earthworms, mosquitoes, grasshoppers, weevils, horseflies, crayfish, diving beetles, and other insects.

WOODCOCK, SNIPE (Scolopacidae)

● American woodcock (Philohela minor)

Habitat - Moist older thickets along banks of meandering streams, spring-fed boggy runs, rich bottomlands and scrubby edges of damp, second-growth woods provide suitable nesting areas. The nest is among the litter on the ground.

Distribution - The overall range includes the eastern United States. The breeding range extends from North Dakota, southern Manitoba, northern Michigan, Quebec, and Nova Scotia south to Kansas and northern Florida. Birds winter from southern Missouri, the Ohio Valley, and New Jersey south to Texas and Florida.

Habits - The species is nocturnal or crepuscular in its habits, remaining in cover during the day. It feeds at night and during dusk and twilight.

Food - The diet consists principally of earthworms but grubs, slugs, and insects are also taken.

● common snipe (Capella gallinago)

Habitat - Freshwater marshes, ponds, flooded meadows, and fields are used for breeding and wintering. The nest consists of a grass-lined depression concealed in a clump of grass.

Distribution - The breeding range extends from Alaska, Hudson Bay, and Laborador south to Massachusetts, Indiana, and California. Birds winter north to British Columbia and Virginia.

Habits - Migration is at night, usually in flocks. Birds feed early in the morning and late in the afternoon, and are more active during days with overcast skies.

Food - The diet is made up largely of insects, earthworms, crustacea, arachnids, and molluscs.

GULLS, TERNS (Laridae)

● Franklin's gull (*Larus pipixcan*)

Habitat - Wet prairies, marshy lakes, and sloughs are utilized for breeding. Birds breed in large, dense colonies and construct nests of dead plant material on the ground, or semi-floating platforms among reeds and other vegetation.

Distribution - The breeding range extends from southern Canada to South Dakota and southwestern Minnesota. The species migrates to the Gulf Coast and winters south to Chile.

Habits - This gull is highly gregarious on the nesting and feeding grounds. The species will breed only if the colonies are large. The birds migrate in large flocks often feeding in cultivated fields.

Food - The species is primarily insectivorous, including grubs, earthworms, grasshoppers, and insect larvae.

● Forster's tern (*Sterna forsteri*)

Habitat - Salt marshes along the east coast and freshwater marshes in the interior are used for breeding. The nest is constructed of dead reeds and is placed on a muskrat house or is a floating platform. The species prefers to nest in small groups.

Distribution - The breeding range extends from Maryland to Texas along the Atlantic Coast and from Alberta and California east to Illinois in the interior. The species winters from South Carolina to Guatemala.

Habits - The species is sociable and gregarious but actively defends its nest and young.

Food - Insects are taken on the wing or from the surface of the water. Fish are taken but to a lesser extent than other tern species.

● black tern (Chlidonias niger)

Habitat - Freshwater marshes, marshy lakes, sloughs, and wet meadows are used for breeding. Nests are built of dead reeds on hummocks of mud or debris or on a mass of floating vegetation in shallow water. The black tern nests in small colonies in openings among tall, thick growths of reeds or cattails.

Distribution - The breeding range extends from Nova Scotia and Alaska south to Pennsylvania, Missouri and California. Wintering grounds are in South America. In the spring, the black tern moves up the coast across the Great Lakes to the interior.

Habits - The species is gregarious to a limited extent. Birds glean insects from grasses, reeds, flags, and bulrushes by flying over meadows, marshes, or open water.

Food - Black terns are primarily insectivorous, taking dragonflies, moths, grasshoppers, crickets, beetles, water scorpions, flies, and an occasional mollusc or crustacean.

TRUE OWLS (Strigidae)

● short-eared owl (Asio flammeus)

Habitat - Preferred habitat is in freshwater and salt marshes, but open grasslands, prairies and dunes are also used. The nest is a shallow depression on the ground in grass clumps or beneath bushes.

Distribution - The breeding range extends from Alaska and northern Canada south to New Jersey and across the northern U.S. to northern California. Birds winter in the southern part of the breeding range and south to Guatemala, and the winter range includes the entire U.S.

Habits - The species is highly gregarious in the winter and during migration. Birds commonly hunt by skimming low over the ground, by hovering, or by surprising prey from a low perch. Birds are nocturnal but may begin hunting late in the afternoon.

Food - The diet consists mainly of mice and other small mammals, but birds are occasionally taken.

WRENS (Troglodytidae)

● long-billed marsh wren (Cistothorus palustris)

Habitat - Freshwater and brackish marshes of cattails, bulrushes, sedges, or other tall grasses are utilized during the breeding season. The nest is a globular mass of reeds and cattails with a side entrance, and is anchored to vegetation.

Distribution - The breeding range includes British Columbia, Manitoba and New Brunswick south to Florida, the Gulf Coast and northern Mexico. Birds winter from New Jersey south to the Gulf and Pacific Coasts.

Habits - The species is shy and elusive.

Food - The diet is composed mainly of insects.

● short-billed marsh wren (Cistothorus platensis)

Habitat - The species is found in the drier parts of grassy freshwater marshes. Dense tufts in sedge meadows are the preferred breeding habitat. The nest is a globular mass of marsh grass with a side entrance.

Distribution - The breeding range extends from Saskatchewan, Manitoba, and New Brunswick south to Delaware, Missouri, and Kansas. Birds winter very locally as far north as New Jersey and Illinois.

Habits - The species is shy and elusive.

Food - The diet is composed mainly of insects.

WOOD WARBLERS (Parulidae)

- prothonotary warbler (Protonotaria citrea)

Habitat - The species is found in wooded swamps, flooded bottomland forests and along streams. It nests in a tree cavity, or a hole in a stump 5-10 feet high. Deserted holes of woodpeckers and chickadees are favorite sites.

Distribution - The breeding range is restricted to the south-eastern states north to Minnesota, Michigan, and New York, including the lower Great Lakes. Birds winter from southern Mexico to northern South America.

Habits - The species is highly territorial during nesting season. Food is obtained from trunks and branches of trees and shrubs, fallen logs, or on the water.

Food - The species is insectivorous, with a diet consisting of spiders, beetles, mayflies, caterpillars, and water insects.

- yellow warbler (Dendroica petechia)

Habitat - The species occurs abundantly in moist thickets of willow and alder, especially along streams and swampy areas. The nest cup is placed in an upright fork of a small sapling.

Distribution - The breeding range extends from Alaska, northern Quebec and Newfoundland south to the Carolinas, Missouri, Texas, and South America. Birds winter north to southern Mexico.

Habits - The yellow warbler is a rather tame species. Its nest is often parasitized by cowbirds.

Food - The diet consists mainly of insects.

- northern waterthrush (Seiurus noveboracensis)

Habitat - Cool bogs, wooded swamps and lake shores are used in the breeding season. Ground nests lined with moss are set in a bank, at the base of a tree or among the roots of an upturned tree in thickets bordering swamps and ponds.

Distribution - The breeding range extends from Alaska and Canada to the northern United States, including the Great Lakes and upper St. Lawrence region. Birds winter from Mexico to northern South America.

Habits - The northern water thrush is a timid bird that lives on or near the ground in the immediate vicinity of water. It feeds by turning up leaves and litter looking for food.

Food - The diet consists mainly of aquatic insects, beetles, and moths.

● common yellowthroat (*Geothlypis trichas*)

Habitat - The species occurs abundantly in moist thickets and grassy meadows. It prefers the margins of swamps and woodlands for nesting, although drier upland situations are also used. The nest is a loose mass of grass and sedges, concealed on or near the ground in tussocks of grass, reeds, cattails, or briars. The nest is often placed near shrubbery.

Distribution - The breeding range extends from Alaska, Ontario, and Newfoundland south to Florida, the Gulf Coast, and Mexico. Birds winter regularly as far north as the Carolinas, Louisiana, and central California.

Habits - These birds are secretive and shy. They do not flush readily from the nest but silently creep away. Food is gleaned from vegetation close to the ground, or on the ground.

Food - The diet consists mainly of insects such as beetles, grubs, larvae, moths, butterflies, flies, ants, spiders, caterpillars, and leafhoppers.

BLACKBIRDS (Icteridae)

- yellow-headed blackbird (Xanthocephalus xanthocephalus)

Habitat - The species is found in freshwater marshes with dense stands of cattail. Birds prefer to nest over water that is 2-4 feet deep, and form small to large colonies. A basket nest is woven around several strong stalks of vegetation.

Distribution - The species is basically a western bird extending into the prairie states and provinces. The present range includes Lake Superior and the west shore of Lake Michigan.

Habits - This blackbird is a conspicuous species which frequently engages in display flight or mobbing behavior. It often nests in association with red-winged blackbirds (Agelaius phoeniceus). It feeds close to water among plants and in mud or shallow water along the shoreline.

Food - The diet is composed of animal and vegetable matter.

- red-winged blackbird (Agelaius phoeniceus)

Habitat - The species occurs in marshes, swamps, wet and dry meadows, and pastures in proximity to water. Extensive thick stands of cattails, bulrushes, sedges, and reeds are preferred nesting habitat. This species often nests in water-loving bushes such as buttonbush, alder or willow. The nest is a well-made cup of marsh grass or reed, either attached to growing vegetation or in a bush.

Distribution - The breeding range extends from Alaska and Newfoundland south to Florida, the Gulf Coast, and central Mexico. Birds winter regularly north to Pennsylvania and British Columbia.

Habits - Individuals are highly territorial during nesting but will congregate in large flocks in late summer. They feed on the ground, often in grain fields.

Food - The diet consists of animal and vegetable matter, including small insects and weed seeds.

SPARROWS (Fringillidae)

● LeConte's sparrow (Ammospiza leconteii)

Habitat - The drier margins of wet marshes, moist meadows, and sloughs are used during the breeding season. Shrubby areas in these habitat types are also preferred. The cup nest is placed on the ground in a tuft of grass. Dry fields are utilized in the winter.

Distribution - The breeding range extends from south-central Canada to north-central United States. The species winters in the central and southern states.

Habits - The species is secretive and elusive. It will not readily flush but prefers to run through the vegetation to escape detection. It prefers to sing from an exposed perch on taller vegetation.

● sharp-tailed sparrow (Ammospiza caudacuta)

Habitat - The dry, grassy areas of coastal salt marshes and inland freshwater marshes are used for breeding. The cup-shaped nest is placed in a grassy tussock or in marsh grass above the high-water mark.

Distribution - The breeding range extends from central Canada to the middle Atlantic states. The species winters on the south Atlantic coast and along the Gulf of Mexico.

Habits - Birds spend much time down in the marsh grass foraging for food.

Food - The diet is composed of insects but grass seeds are also eaten.

● Lincoln's sparrow (Melospiza lincolnii)

Habitat - Willow and alder thickets and shrubby areas in bogs and wet meadows are used for nesting. The nest, a cup made of grass, is placed on the ground in herbaceous vegetation. Woodland thickets and scrubby pastures are used in the winter.

Distribution - The breeding range extends from Alaska, northern Quebec, Labrador, and Newfoundland south to northern New England and California. The species winters along the Gulf of Mexico and California south to Guatemala.

Habits - The species is secretive and spends much time concealed in the vegetation.

Food - The diet is composed mainly of plant seeds but insects are also eaten.

● swamp sparrow (*Melospiza georgiana*)

Habitat - The species is found in freshwater marshes, open wooded swamps, bogs, and wet meadows. Mixed stands of grasses are preferred as nesting habitat, because they offer an overhead canopy as protection. The nest is a grassy cup with a side entrance, usually well hidden in a dense clump of vegetation.

Distribution - The breeding range extends from east-central Canada south to east-central United States. Birds winter south to the Gulf of Mexico.

Habits - The species nests semi-colonially. Individuals rarely fly long distances except during migration. Birds forage on the ground singly, or wade in shallow water for insects and seeds.

Food - The diet is composed of insects including beetles, ants, caterpillars, grasshoppers, crickets. Seeds of sedges and smartweeds are often utilized during the fall.

APPENDIX E

Phylogenetic List of Common and Scientific Names of Mammals in the Great Lakes Basin

Common Name	Scientific Name
	Order Marsupialia (Marsupials)
	Family Didelphidae (Opossums)
Virginia opossum	*Didelphis marsupialis virginiana* .
	Order Insectivora (Insectivorous mammals)
	Family Soricidae (Shrews)
artic shrew	*Sorex articus*
masked shrew	*Sorex cinerus*
water shrew	*Sorex palustris*
short-tailed shrew	*Blarnia brevicauda*
	Family Talpidae (Moles)
star-nosed mole	*Condylura cristata*
	Order Chiroptera (Bats)
	Family Vespertilionidae (Common Bats)
little brown bat	*Myotis lucifugus*
Indiana bat	*Myotis sodalis*
silver-haired bat	*Lasionycteris noctivagans*
	Order Lagomorpha (Hares, Rabbits, and Allies)
	Family Leporidae (Hares and Rabbits)
snowshoe hare	*Lepus americanus*
eastern cottontail	*Sylvilagus floridanus*
	Order Rodentia (Rodents or gnawing mammals)
	Family Sciuridae (Squirrels and Allies)
woodchuck	*Marmota monax*
Franklin's ground squirrel	*Spermophilus franklini*
fox squirrel	*Sciurus niger*
red squirrel	*Tamiasciurus hudsonicus*
	Family Castoridae (Beavers)
beaver	*Castor canadensis*)
	Family Cricetidae (Deer Mice, Harvest Mice, Muskrat, Voles, and others)

Common Name	Scientific Name
	Subfamily Cricetinae (Deer Mice and Allies)
woodland deer mouse	*Peromyscus maniculatus*
white-footed mouse	*Peromyscus leucopus*
	Subfamily Microtinae (Voles and Allies)
Gapper's red-backed mouse	*Clethrionomys gapperi*
meadow vole	*Microtus pennsylvanicus*
muskrat	*Ondatra zibethicus*
	Family Muridae (Old World Rats and Mice)
Norway rat	*Rattus norvegicus*
	Family Zapodidae (Jumping Mice)
meadow jumping mouse	*Zapus hudsonius*
woodland jumping mouse	*Napaeozapus insignis*
	Family Erethizontidae (Porcupines)
porcupine	*Erethizon dorsatum*
	Order Carnivora
	Family Canidae (Wolves, Coyotes, and Foxes)
coyote	*Canis latrans*
gray wolf	*Canis lupus*
red fox	*Vulpes vulpes*
	Family Ursidae (Bear)
black bear	*Ursus americanus*
	Family Procyonidae
raccoon	*Procyon lotor*
	Family Mustelidae (Weasels, Skunks, Otters, and Allies)
short-tailed weasel or ermine	*Mustela erminea*
least weasel	*Mustela rixosa*
long-tailed weasel	*Mustela frenata*
mink	*Mustela vison*
skunk	*Mephitis mephitis*
river otter	*Lutra canadensis*
	Family Felidae (Cats and Allies)
Canada lynx	*Lynx canadensis*
bobcat	*Lynx rufus*

Common Name	Scientific Name
	Order Artiodactyla (Even-toed Hoofed Mammals)
	Family Cervidae (Deer and Allies)
white-tailed deer	*Odocoileus virginianus*
moose	*Alces alces*

- opossum (Didelphis marsupialis)

Breeding Characteristics - The breeding period extends from March to April. One to three litters, usually one, ranging from 5-25 per litter are produced. The gestation period is 12-13 days. Sexual maturity is reached at one year.

Adult Characteristics - The preferred habitat is wooded pastures adjacent to a stream, lake, marsh, or swamp. The den is typically in a wooded area near water. The home range is 15-40 acres. Life expectancy is 5-7 years. The opossum is nocturnal. Major food items are: carrion, insects, fish, amphibians, reptiles, eggs, fruits, vegetables, and nuts. The opossum is both terrestrial and aboreal. Natural enemies are foxes, hawks, and owls. The opossum is hunted and trapped for food and sport. The pelt is not highly valued.

- Arctic shrew (Sorex arcticus)

Breeding Characteristics - The breeding season extends from March to September. Three litters may be produced per year with an average of 6-7 young per litter. The gestation period is 18 days.

Adult Characteristics - The preferred habitat is tamarack and spruce swamps. The major food items are insects, vertebrates, and centipedes. The life expectancy is less than two years. Major predators are owls and hawks. The shrew is considered to be economically beneficial due to its destruction of harmful insects.

- masked shrew (Sorex cinerus)

See artic shrew.

- water shrew (Sorex palustris)

Breeding Characteristics - The breeding season extends from March to August. The gestation period is 21 days. Litter size is probably 6 or less. More than one litter is probably produced during a season.

Adult Characteristics - This shrew is nearly aquatic or at least amphibious. It inhabits marshes, logs, and borders of lakes and streams. Their life expectancy is less than two years. Major food items are insects, snails, leaches, and planarians. Natural enemies are hawks, owls, trout, bass, pickerel, and walleye.

● shorttail shrew (Blarina brevicauda)

Breeding Characteristics - This shrew breeds spring-fall. Litters range in size from 5 to 8. The gestation period is 21 days.

Adult Characteristics - The shorttail shrew inhabits heavy forests, low damp swampy areas but may be found in every land habitat in the Great Lakes area. They have a home range of ½ acre. Major food items are: insects, worms, crustacea, small vertebrates, molluscs, centipedes, arachnids, millipids, and plant material. The shrew is economically important as an insect killer.

● star-nosed mole (Condylura cristata)

Breeding Characteristics - The breeding period extends from April to June. A gestation period of 45 days produces a litter of 3-7.

Adult Characteristics - The mole's habitat is swamps and low wet meadows. The star-nosed mole lives in an established colony with a territory of 10-12 acres. It is active day and night during all seasons of the year. It is an excellent swimmer spending much time in the water. The mole eats aquatic worms and insects. The life span is from 3-4 years.

● little brown bat (Myotis lucifugus)

Breeding Characteristics - The young are born from late May to early June. One is the usual number although two are born occassionally. Sexual maturity is reached at eight months.

Adult Characteristics - The bat makes its home in hollow trees, beneath loose bark, in caves, and about buildings. It flys over lakes, fields, and forests at night. The major food item is flying insects. The bat migrates south or hibernates in late fall. The bat is a carrier of rabies but is beneficial as an insect destroyer.

● Indiana myotis (Myotis sodalis)

Little is known, but it is probably similar to the Myotis lucifugus.

● silver haired bat (Lasionycteris noctivagans)

Breeding Characteristics - It usually has two sometimes one young in June or July. There is only one litter per year.

Adult Characteristics - Habitat is wooded areas, parks, and orchards especially near streams and lakes. The bat feeds exclusively on nocturnal insects. The bat has few natural enemies although an owl catches one occassionally.

● snowshoe hare (Lepus americanus)

Breeding Characteristics - The breeding season is from April to September. The usual is 2 or 3 litters per season consisting of 3-5 young. The gestation period is 36 days.

Adult Characteristics - The preferred habitat is spruce and cedar swamps. It has a home range of ten acres. Major food items are succulent vegetation, twigs, birds, and bark. The snowshoe hare has been known to swim, however, it is considered a rare occurrence. The hare is considered a game animal. Major predators are the coyote, lynx, fox, weasel, owl, eagle, and hawk.

● eastern cottontail (Sylvilagus floridanus)

Breeding Characteristics - The breeding period extends from February to September with the greatest activity in April to May. The gestation period is 28-30 days. There are 2-5 litters (3 average) per year with an average litter size of five(2-10). Females reach maturity at three months; males at six months.

Adult Characteristics - Life expectancy is less than one year; maximum 4-5 years. The female has a home range of four acres, the male ten acres. The rabbit feeds in early morning and early evening. Typical foods are a wide variety of succulent plants such as clover, dandelion, plantain, lambs-quarter, and rag weed. Winter foods include ear corn, dry hay, and bark of tree saplings. The cottontail is a game species.

● woodchuck (Marmota monax)

Breeding Characteristics - The breeding period extends from March to May. The gestation period is from 31 to 32 days. A litter of 2-7 is produced once a year. Sexual maturity is reached at one year.

Adult Characteristics - The woodchuck burrows in bushy fence rows along creeks and in any other undisturbed cover in farming country. Dikes surrounding marshes are a favorite habitat. The woodchuck has a life expectancy of 2-3 years. The home range is 40-160 acres. The woodchuck feeds mostly in early morning and late afternoon. Major food items are grasses, clover, alfalfa, soy beans, peas, lettuce, and apples. The woodchuck may cause significant economic damage due to its fondness for farm crops and damage caused by the den holes.

● Franklin's ground squirrel (Spermophilus franklini)

Breeding Characteristics - Each female has one litter annually between the last of May and mid-June. Litter size varies from 5-8. The gestation period is 28 days.

Adult Characteristics - Preferred habitat is the edge of wooded areas, nearby marshlands and dense marsh grass. The squirrel hibernates from November to April. Major food items are seeds, green vegetation, insects, bird eggs, birds, and mammals. The squirrel is detrimental because it eats the eggs of ground nesting birds and destroys farm crops. It is beneficial because it also destroys insects and mice.

● fox squirrel (Sciurus niger)

Breeding Characteristics - The fox squirrel has two litters per season after its first breeding season. Usually four young are produced per litter. Sexual maturity is reached at age one. The gestation period is 44 days.

Adult Characteristics - Preferred habitat is open hardwood woodlands. The home range is 3-4 acreas. Life span in the wild is about four years. Major food items are nuts, fruits, birds, and seeds. Natural enemies are the hawk and owl.

● red squirrel (Tamiasciurus hudsonicus)

Breeding Characteristics - There are normally two litters (May and August) of 4-7 young. The gestation period is about 38 days.

Adult Characteristics - Preferred habitat is coniferous and hardwood forests. The red squirrel is active all year. Life expectancy is 6-7 years. It is a proficient swimmer. The home range is 200 yards. Major food items are nuts, pine cones, mushrooms, meat, and sap. Natural enemies the are hawk, owl, snake, bobcat, fox, and large fish.

● Beaver (Castor canadensis)

Breeding Characteristics - The breeding period is January to February. The gestation period is 128 days. Litter size varies from 1-8 with an average of 4. The breeding age is 2½ years.

Adult Characteristics - The adult beaver weighs from 30-70 lbs., average 35-40 lbs. Adult body length is from 25-30 inches. The life expectancy is 9-11 years with a maximum of 19 years. The beaver feeds primarily at night. Typical foods are bark and twigs of softwood trees such as aspen, poplar, birch, willow, maple, cottonwood, and alder; aquatic and marsh plants such as duckweed, cattail, sedge, and bulrush. The beaver is a valuable fur bearer. Besides man the beaver has few natural enemies. They are occasionally killed by dogs.

● Woodland deer mouse (Peromyscus maniculatus)

Breeding Characteristics - The breeding season is April to August. The usual litter size is 4-5. The gestation period is 25-27 days. Four of five litters may be raised by one female during the breeding season.

Adult Characteristics - Preferred habitat is mixed tree growth, particularly in log stream timber or along river or lake banks. The mouse is active all year around. The major food items are seeds and fruits. Major predators are the hawk, owl, and mammals.

● white-footed mouse (Peromyscus leucopus)

Breeding Characteristics - Multiple litters are born beginning in March. Litter size varies from 2 to 6. The gestation period is 21 days. Sexual maturity is reached in 10-11 weeks.

Adult Characteristics - Preferred habitat is forest and brushy areas. Major food items are seeds, nuts, and insects. The female home range is ½ acre. The male home range is 1 to 1½ acres. The average life span is 3 years. The white-footed mouse is prey for the fox, weasel, and owls.

● Gapper's red-backed mouse (Clethrionomys gapperi)

Breeding Characteristics - Three or four litters may be raised between April and October. Litter size varies from 3-8. The gestation period is 17-19 days. Sexual maturity is reached at four months.

Adult Characteristics - Preferred habitat is moist woodland and forests. Life expectancy is probably less than three years. The major food of the red-backed mouse is green vegetation. Also eaten are nuts and seeds. Economically Gapper's red-backed mouse is of little importance.

● meadow vole (Microtus pennsylvanicus)

Breeding Characteristics - The meadow vole breeds throughout the year. Litter size varies from 2-9. The gestation period is 21 days. Females are sexually mature at 25 days, males at 45 days.

Adult Characteristics - Habitat is lowland fields and meadows, grassy marshes, along rivers and lakes, and sometimes in flooded marshes or on high grasslands near water. Life expectancy is less than one year. Major food items are roots and bulbs. It is prey for predatory mammals, birds, reptiles, and fish.

● muskrat (Ondatra zibethicus)

Breeding Characteristics - The breeding period extends from February through August. Two to three litters a year are produced varing in size from 3-9 per litter (usually 6). Sexual maturity is reached at about ten months.

Adult Characteristics - The muskrat is well adapted to aquatic life. Its hind feet are slightly webbed with stiff hairs between the toes helping to propel the animal through the water. The muskrat lives in marshy areas although they are also found in streams, ponds, and drainage ditches. The muskrat den is either in a bank or a large mound of mud and vegetation. Typical food items are the stems, roots, bulbs, and foliage of aquatic plants such as cattail, bur-reed, blue-joint, needle-grass, waterlily, pondweed, and sedges. Life expectancy is two years. The muskrat is a valuable fur-bearing animal.

● meadow jumping mouse (Zapus hudsonicus)

Breeding Characteristics - The female may have from one to three litters per year. The number of young vary from 4-6. The gestation period is 18 days.

Adult Characteristics - The meadow jumping mouse is found in nearly every habitat in the Great Lakes Area. The normal life span is two years. Major food items are seeds, fruits, and insects. This mouse hibernates from October/November to April/May.

● woodland jumping mouse (Napaeozapus insignis)

Breeding Characteristics - One litter appears from June to September. Four to five young are the usual number. The gestation period is 29 days. Young-of-the-year breed the following spring.

Adult Characteristics - Preferred habitat is forests bordering lakes or streams. The woodland jumping mouse hibernates from November to April/May. Its home range is 1-2 acres. Major food items are seeds, fruits, and insects. Weasels are the major predator. Normal life span is two years.

● porcupine (Erethizon dorsatum)

Breeding Characteristics - The gestation period is not known for certain but is thought to be seven months. At this time the female gives birth to one young. Sexual maturity is reached at three years.

Adult Characteristics - The porcupine can be found in almost any kind of forest, but prefers some coniferous growth. Major food items are vegetation, bark of trees, and meat. The porcupine damages buildings, commercial lines, and trees.

● red fox (<u>Vulpes vulpes</u>)

<u>Breeding Characteristics</u> - The breeding period is January and February. The gestation period is 51 days. One litter per year with an average of 4-9 young is produced. Sexual maturity is reached at one year.

<u>Adult Characteristics</u> - Farm lands with woodlots and brushy areas near marshes and swamps are ideal habitat. The den may be a natural rock shelter or an excavation in sandy soil. The life expectancy is 6-8 years. The home range is 5-10 square miles and may increase to 20 square miles during winter. Feeds mostly at night, dusk, and dawn. Major food items are: mice, rats, rabbits, and other small mammals; birds, frogs, snakes, lizards, eggs, insects, fruits, and some grasses.

● black bear (<u>Ursus americanus</u>)

<u>Breeding Characteristics</u> - The black bear has one or two cubs in alternate years. The gestation period is 7 to 7½ months. The young are born in January or February.

<u>Adult Characteristics</u> - Preferred habitat is heavily wooded areas and swamps. The home range can extend as far as 15 miles. The black bear is omnivorous eating carrion, fresh berries, and tender roots. It is still an important game animal. The black bear hibernates from November/December to March/April.

● raccoon (<u>Procyon lotor</u>)

<u>Breeding Characteristics</u> - The breeding period extends from late January to early February. The gestation period is 63 days. One litter with 3-7 young is produced per year. Sexual maturity is reached at one year.

<u>Adult Characteristics</u> - Wooded areas near streams and lakes are excellent raccoon habitat. The raccoon seldom ranges more than one mile from the home den. It feeds primarily at night. Major food items are: nuts, fruits, grains, insects, crayfish, mice, frogs, and bird eggs. It is a valuable fur-bearing game animal.

● long-tailed weasel (<u>Mustela frenata</u>)

<u>Breeding Characteristics</u> - The breeding period is July-August. The gestation period is variable due to delayed implantation of the embryo; average is 280 days. One litter per year is produced with a litter size of 4-8; average 6. The breeding age for females is 3-4 months; males one year.

<u>Adult Characteristics</u> - The life expectancy is from 1-2 years; maximum 4-5 years. The home range is 30-40 acres. Feeding period is usually at night. Typical foods are small mammals up to rabbit size, birds, eggs, and insects. Major predetors are eagles, hawks, owls, and mink. The pelt is small but of high quality.

● mink (Mustela vison)

Breeding Characteristics - The breeding period extends from February to April. The gestation period varies from 40-75 days (average 51 days). Litter size varies from 2-17 (usually 3-6). Sexual maturity is reached at ten months.

Adult Characteristics - The mink is both terrestrial and aquatic. The den is typically under a log, in a bank cavity, or muskrat burrow. The den is always near streams, lakes, or marshes. The life expectancy of the mink is two years or less. The mink feed at night. Major food items are: mice, muskrats, fish, frogs, rabbits, crayfish, birds, eggs, and insects. The male mink has a home range of up to five miles, the female range is about 200 acres. Mink fur is valuable and eagerly sought.

● striped skunk (Mephitis mephitis)

Breeding Characteristics - The breeding period extends from February to March. The gestation period is 63 days. The skunk has one litter per year varying in size from 2-10. Sexual maturity is reached at one year.

Adult Characteristics - The skunk prefers a semi-open habitat of mixed woods, brush, and open grassland within two miles of water. The home range is ten acres. The skunk feeds at night. Major food items are: mice, lizards, frogs, fish, crayfish, insects, grubs, eggs, fruits, and carrion. Life expectancy is from 8-10 years. The skunk is an important furbearer and an effective predator of small rodents and insects. The skunk has few predators. The great horned owl takes more skunks than any other natural predator.

● river otter (Lutra canadensis)

Breeding Characteristics - The breeding period extends from January to May. The gestation period is from 11-12 months. Two young per litter is typical.

Adult Characteristics - The otter lives on rivers, larger creeks, sloughs, and lakes. It makes a burrow in the bank of a lake or stream. The entrance is below water. The otter has a home range of 15-100 miles of shoreline. Major food items are forage fish, amphibians, panfish, and crayfish. The otter is valued for its pelt and aesthetic value. It does, however, eat some forage and panfish.

● Canada lynx (Lynx canadensis)

Breeding Characteristics - Four or five young are born in March or April. The gestation period is about 62 days.

Adult Characteristics - Habitat is heavy and dense forests and woodlands. Major food items are snowshoe hare, small mammals, and birds. It is a strict carnivore. The lynx was once a valuable fur bearer but is now reduced in numbers.

● bobcat (Lynx rufus)

Breeding Characteristics - One to four young are born in late April or early May. The gestation period is about seven months. The bobcat matures in one year.

Adult Characteristics - Preferred habitat is swamps, broken country with adequate brush cover. Major food items are birds and mammals. The bobcat is nocturnal. The bobcat is considered by some hunters to be good sport. Life expectancy is 8-10 years.

● white-tailed deer (Odocoileus virginianus)

Breeding Characteristics - The breeding period extends from late October through mid-January. The gestation period is 190-210 days. The deer has one litter consisting of one or two young. Males reach sexual maturity at 1½ years; females between six and eight months.

Adult Characteristics - Marshes provide a foraging area for the deer. Typically deer feed at dawn and dusk. Typical food items are: wild crabapples, corn, sumac leaves and stems, grasses, clover leaves, and soybean leaves and beans. The white-tailed deer is a popular sport animal providing recreation for naturalist and hunter alike.

● moose (Alces alces)

Breeding Characteristics - One or two young are born in June. The gestation period is eight months. The moose is full grown when 15 to 18 months old.

Adult Characteristics - Preferred habitat is forests in the vicinity of lakes and rivers. The moose is a brouser feeding primarily on the leaves of trees and shrubs. The timber wolf is probably the only serious natural enemy.

APPENDIX F

GLOSSARY

anthropogenetic sediments - sedimentary by-products which are derived from man's activties. Examples include saw dust from past lumbering activity and fly ash from urban/industrial sources.

anticyclone - a system of winds that rotates about a center of high pressure clockwise in the northern hemisphere and counterclockwise in the southern hemisphere.

clastic - made up of fragments of pre-existing rocks.

coliform bacteria - rod-shaped bacteria found in soil, on plants and in insects, in old sewage, and in waters polluted some time in the past. Coliform bacteria should be carefully distinguished from fecal coliform bacteria which are inhabitants of warmblooded animal intestines and are indicators of recent fecal pollution and hence of dangerous contamination and pollution. The presence of other coliform organisms suggests less recent pollution or contributions from sources of non-fecal origin.

commercial fish - fish which are caught in large quantities and sold primarily for profit by licensed commercial fishermen. Common species include carp, white bass, freshwater drum, and yellow perch.

ecosystem - A unit of biological organization made up of all the organisms, plant and animal, in a given area and the environment in which they live. It is characterized by interactions between the living and nonliving components that result in a flow of energy from the sun through plants and animals and a cycling of minerals and other inorganic materials.

or: All organisms in a community plus the associated environmental factors with which they interact.

ericaceous - low much-branched evergreen shrub

fluvial - produced by stream action

food chain - A sequence of organisms, including producers (plants), herbivores (plant eaters), and carnivores, through which energy and materials move within an ecosystem.

geomorphology - a science that deals with the land and submarine relief features of the earth's surface.

ground water - wateroccurring in the spaces within sediments, soils, and rocks in the subsurface, and moving under the force of gravity heavy metals - Those metals having high specific gravity and considerable weight in relation to volume. Heavy metals are a special form of pesticide pollution. The four heavy metals of most concern are arsenic, lead, copper, and mercury. Such heavy metals are persistent, since biodegradation of arsenic, mercury, or copper does not occur.

hydric soil - A soil which exhibits chemical and/or visible signs of water-logging or seasonal inundation including gleying and mottling (alternating reduction and oxidation). Histosoils (i.e., organic soils) are generally regarded to be hydric. Hydric soils may be used to define wetlands in operational terms.

hydroperiod - The time duration between the occurrence of cyclic hydrologic events. For example, high water levels in the Great Lakes generally occur every 8 to 12 years.

littoral process - a process which includes the movement of currents and sediments adjacent to the shoreline. The process is, in general, governed by wave refraction at or near the shoreline. Included are littoral currents and beach drifting.

marine process - a process of or belonging to or caused by a water body. Included are wave action and current movements generated by waves.

mesophytic vegetation - A vegetation type found on intermediate sites, that is, in between dry (xerophytic) and wet (hydrophytic) sites. Mesophytic vegetation characteristically lacks structures and mechanisms necessary to invade dry and wet environments.

nonconsumptive recreation - Human recreational activities that do not damage or deplete natural systems. Examples include nature study, birdwatching, and photography.

nonhydric soil - a zonal soil characterized by adaquate drainage and usually colonized with mesophytic vegetation.

nutrient loading - the volume of any one of a number of inorganic or organic compounds or ions used primarily in the nutrition of primary producers. Nitrogen and phosphorus compounds are examples of essential nutrients.

ordinary high water mark - in the state of Michigan the ordinary high water mark (OHM) is a specific elevation along the Great Lakes coasts as established by the Submerged Lands Act of 1955. All lands lakeward of the OHM, except where patented, are in public ownership. Other states may have similar legislation.

photosynthesis - the process of synthesizing carbohydrates from carbon dioxide and water, utilizing the radiant energy of light captured by the chlorophyll in plant cells.

sediment - solid material both mineral and organic that has been transported and deposited within a river channel or basin.

seiche - a periodic, rapid, and often violent fluctuation in the water level within an embayment or a lake often due to onshore or offshore winds and low barometric pressure.

senescence - an ecological concept usually employed to describe a stage of wetland succession wherein dense vegetation growth occurs in otherwise semi-open wetland environments.

sport fish - fish primarily of importance for the sport they afford to anglers. They are commonly regarded as game fish, and/or have been designated by appropriate agencies as being sport fish and hence may not be harvested by commercial fishermen. Examples include northern pike, walleye, and smallmouth bass.

suspended sediment - solid material being carried by moving water or solid material in more or less still water that is suspended in a turbid or colloidal condition.

terrestrialization - an ecological concept used to describe a trend in wetland succession wherein the wetland vegetation communities are beginning to resemble terrestrial or upland communities.

toxic substances - poisonous substances which produce harmful and/or lethal effects on organisms by physical contact, ingestion, or inhalation.

turbidity - reduced water clarity resulting from the presence of suspended matter. As turbidity increases, light penetration is reduced and plant growth is inhibited.

wave energy - the capacity of a wave to erode, transport sediment or to do work. The energy of a wave is half potential and half kinetic and the amount of energy is related to the height and period of the wave

wetlands - areas which are periodically or permanently inundated and which are characterized, under normal conditions, by vegetation that requires saturated soils for growth and reproduction.

xerophytic vegetation - a vegetation type found in arid climates or in excessively drained environments. Because water is the limiting factor, these plant species possess xeric mechanisms and adaptations, including reduced leaves and stomata, a capacity to become dormant, and so forth.

APPENDIX G

ABBREVIATIONS

Abst. - abstract
Acad. - Academy, Academician
Admin. - administration
Adv. - advancement
Agri. - agriculture (-al)
Agron. - agronomy
Amer. - America (-n)
Anal. - analysis
Anat. - anatomy
Anim. - animal
Ann. - annals
Annu. - annual
Anthropol. - anthropology
Appl. - applied
Arch. - archives
Archaeol. - archaelogy (-ical)
Assoc. - association
Astron. - astronomy
Atmos. - atmosphere
Bienn. - biennial
Biochem. - biochemistry
Biol. - biology
Biophys. - biophysics
Bot. - botany (-ical)
Brit. - Britain, British
Bull. - bulletin
Bur. - bureau
Can. - Canada (-ian)
Cat. - catalog
Chem. - chemistry, chemical
Climatol. - climatology
Co. - company
Coll. - college
Comm. - commission
Conch. - conchology
Conf. - conference
Congr. - congress
Conserv. - conservation
Contrib. - contribution
Corp. - corporation
cm. - centimeter
Cult. - cultural (-ist)
Dept. - department
Dev. - development
Dir. - director
Diss. - dissertation
Dist. - district
Div. - division
Doc. - document
Ecol. - ecology
Econ. - economics
Ed. - editor
Educ. - education
Eng. - engineering
Entomol. - entomology (-ical)
Environ. - environment (-al)
Evolut. - evolution
Exp. - experiment
Ext. - extension
Fac. - faculty
Fed. - federal (-ation)
Fish. - fisheries
Found. - foundation
For. - forestry
g. - gram
gaz. - gazette
Geochem. - geochemistry
Geogr. - geography (-ic)
Geol. - geology (-ical)
Grad. - graduate
Herb. - herbarium
Hered. - heredity
Hist. - historical, history
Hort. - horticulture (-al)
Hydrobiol. - hydrobiology
Hydrogr. - hydrography
Hydrol. - hydrologic (-al)
Ichthyol. - ichthyology
Ill. - Illinois
Ind. - Indiana
Inc. - incorporated
Info. - information
Inorg. - inorganic
Inst. - institute (-tion)
Internat. - international
Invest. - investigation
J. - journal
kg. - kilogram
l. - liter
Lab. - laboratory

Let. - letter
Lib. - library
Limnol. - limnology
LWD - low water datum
m. - meter
Malacol. - calacological
Mammal. - mammalogy
Manu. - manuscript
Math. - mathmatics (-ical)
Med. - medicine (-ical)
Mem. - memoirs. memorandum
Meteor. - meteorology (-ical)
Method. - methodology
Mich. - Michigan
Microbiol. - Microbiology
u. - micron
Micros. - miscroscopy
Mineral. - mineralogy
Minn. - Minnesota
Misc. - miscellaneous
Mol. - molecule
Monogr. - monograph
Morph. - Morphology
Mus. - museum
Mycol. - mycology
Natl. - national
Natr. - natural
N. S. - new series
N. Y. - New York
Nucl. - nuclear
Observ. - ovservatory
Oceanogr. - oceanography (-ic)
Oceanol. - Oceanology
Ohio - Ohio
Ont. - Ontario
Opt. - optical
Org. - organic
Pa. - Pennsylvania
Paleontol. - paleonotology
Parasitol. - parasitology
Path. - pathogen
Pathol. - pathology
Pediat. - pediatrics
Petrol. - petroleum
Pharm. - pharmacy
Phil. - philosophy
Phys. - physics
Physiol. - physiology
Phytol. - phytology
Poll. - pollution
Proc. - proceedings
Prof. - professional
Prog. - program
Proj. - project
Prot. - protection
Pub. - publication
Publ. - publishers
Quart. - quarterly
Radiat. - radiation
Radioact. - radioactive
Radiobiol. - radiobiology
Radiol. - radiology
Rep. - report
Res. - research
Rev. - review
Sci. - science
Sed. - sedimentary
Ser. - series
Serv. - service
Soc. society
Sociol. - sociology
Spec. - special
Sta. - station
Stat. - statistics
Suppl. - supplement
Surv. - survey
Symp. - symposium
Taxonom. - taxonomy
Tech. - technical
Technol. - technology (-ical)
Topo - topography (-ic)
Toxicol - Toxicology
U. K. - United Kingdom
U. N. - United Nations
U. S. - United States
U. S. A.- United States of America
U. S. S. R. - Russia
Univ. - university
Verein.- Vereinigung
Verh. - Verhandlungen
Vol. - volume
Wisc. - Wisconsin
Zool. - Zoology
USGS - United States Geological Survey
NPDES - National Pollution Discharge Elimination System

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