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GREAT LAKES EDUCATION:
A Manual for Aquatic Ecology Studies at Franz Theodore Stone Laboratory

by

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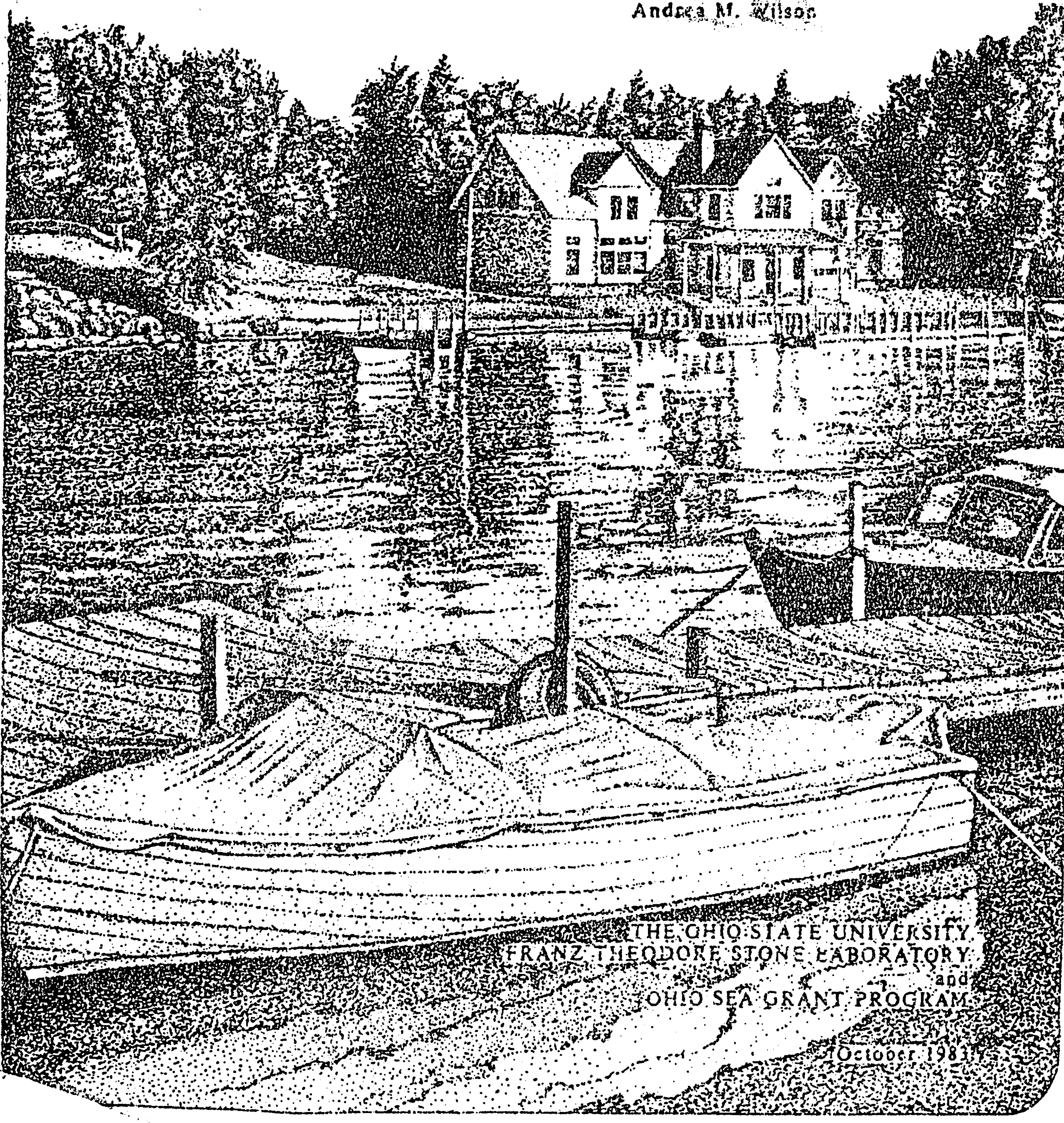

THE OHIO STATE UNIVERSITY
FRANZ THEODORE STONE LABORATORY
and
OHIO SEA GRANT PROGRAM

October 1983

PREFACE

Welcome to the Franz Theodore Stone Laboratory! Whether you are a first time visitor to the Lake Erie Islands or a seasoned investigator, it is hoped that this manual will provide you with information to make your stay more interesting and profitable.

In 1895, the Lake Laboratory (as it was then known) was founded by Professor David S. Kellicott as a place where he and his students could study the natural environment of western Lake Erie and its bays and shorelines. From the beginning, he encouraged other instructors to bring their students to the Laboratory to share the excitement of Great Lakes field studies.

Today we are keeping this tradition alive by offering a Visiting Class Program for elementary, secondary and college students and for professional groups. This manual is intended to introduce the Lake Erie Islands environment and to describe the facilities and activities available to visiting classes.

I hope your visit to the Lake Erie Islands is pleasant and that you will return again and again as many before you have done.

Charles E. Herdendorf, Director
Franz Theodore Stone Laboratory
The Ohio State University
Put-in-Bay, Ohio

October 26, 1983

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INTRODUCTION

INTRODUCTION

The Ohio State University has fostered a program of Great Lakes research and education for nearly a century. In 1895, the University opened a Lake Laboratory in Sandusky, Ohio. To accommodate a growing interest in aquatic sciences, the program was moved to Put-in-Bay, Ohio where the Franz Theodore Stone Laboratory was dedicated on Gibraltar Island in 1929. With the goal of expanding research opportunities, the Center for Lake Erie Area Research (CLEAR) was created in 1970 with facilities at Stone Laboratory and on the Columbus Campus. As a member of a national network, the Ohio Sea Grant Program was established in 1977 within the university to support education, research and advisory services directed toward the wise utilization of Great Lakes and marine resources. Today, all three components are administered by the Center for Lake Erie Area Research as the Lake Erie Programs within the College of Biological Sciences.

The visiting class and workshop program at the F. T. Stone Laboratory provides an opportunity for researchers, teachers, and students to study Great Lakes ecology and limnology. This includes hands-on collecting experience with marine and limnological equipment, as well as exercises in identification, enumeration, and interpretation of organisms and the collected data.

Several research vessels are available for educational programs with the 40-foot Biolab utilized as the primary research boat. This vessel is well-equipped for various limnological investigations including sampling the water quality, collecting of plankton and benthos, and trawling for fish. The Biolab can accommodate up to 20 people for transportation and 15 for a research cruise, which is approximately 2 hours long.

Stone Laboratory is well-equipped to suit the needs of aquatic research and instruction. The research lab on South Bass Island and the classroom-laboratory building on Gibraltar Island provides classrooms, a lecture hall, office and research space. Both buildings provide immediate access to Put-in-Bay Harbor and open Lake Erie and are equipped with running lake and well water. The laboratory is well-stocked with research apparatus for limnological and biological studies including standart laboratory equipment, field sampling and measuring devices for environmental factors, fisheries gear and a scale reading machine, flow through tanks and aquaria for holding and observing aquatic organisms, and basic chemical supplies and apparatus. Any specialized equipment should be supplied by the visiting class. The Laboratory library specializes in books, reprints, and periodicals relating to aquatic environments and Island history and ecology.

Housing is available on both South Bass and Gibraltar Islands for groups of up to 100 persons. Cooking facilities are located within several housing units, and a large dining hall (100-person capacity) is available on Gibraltar Island. The housing facilities which are available on South Bass Island are Sycamore Cottage and Rogick House. They house 12 and 8 persons respectively. Facilities on Gibraltar Island are Cooke Castle, Barney Cottage and Gibraltar House which will accommodate 45, 22 and 8 persons respectively.

Other attractions on South Bass Island are: Perry's International Peace Memorial, South Bass Island State Park, Village of Put-in-Bay, Heineman Winery and Crystal Cave, Perry Cave, Viking Longhouse, State Salmon Fish Hatchery and various other places of interest. The North Coast of Ohio also offers a variety of habitats and ecological areas that are easily accessible from Stone Laboratory by boat or vehicle.

The Great Lakes Education program is available to groups who are interested in the aquatic ecology of the Great Lakes region. It provides an opportunity for groups to participate in field and laboratory studies in an aquatic environment.

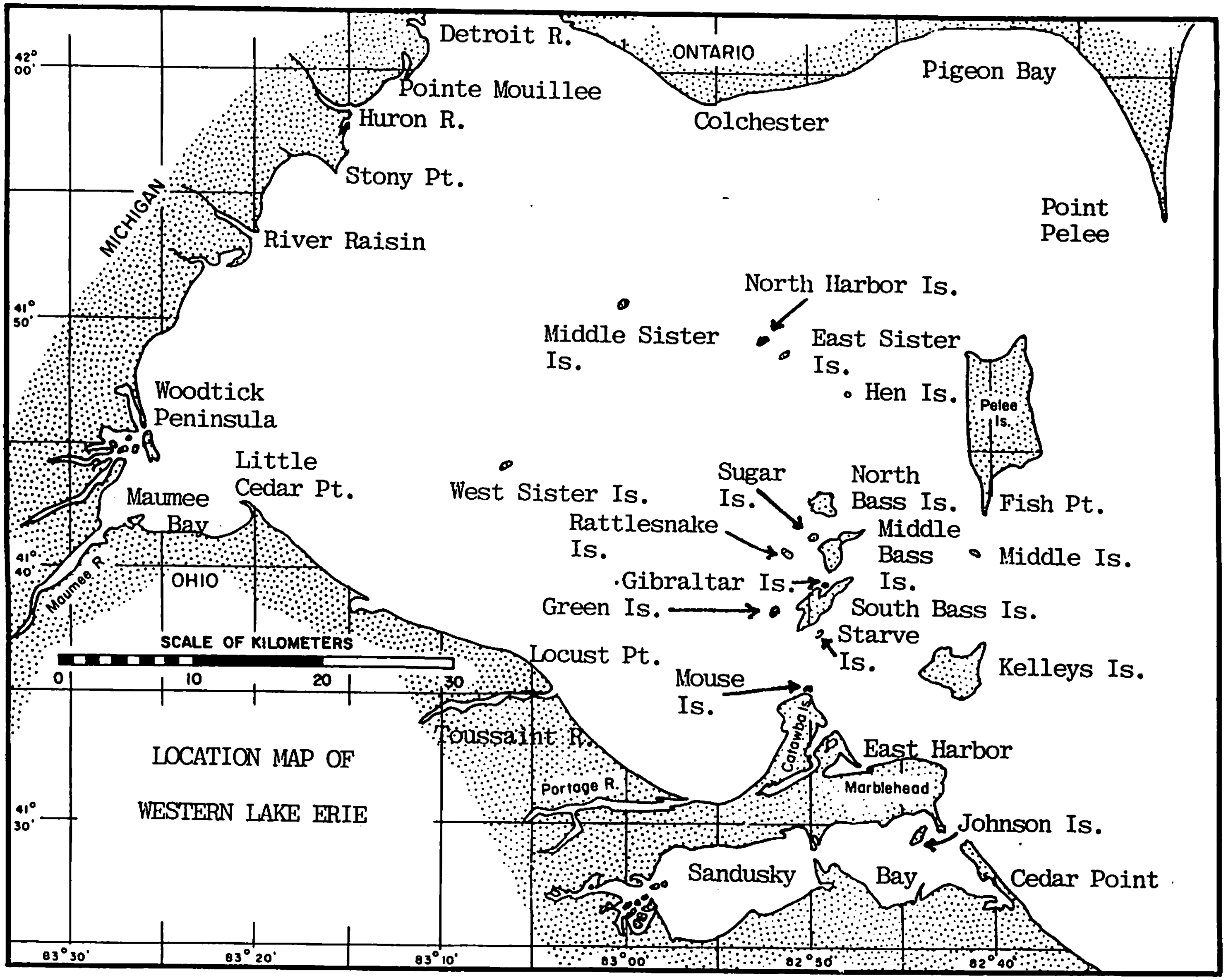
Visiting class and workshop programs are available from mid-April to mid-

October. Summer workshop programs (mid-June to the end of August) are limited to small groups due to the Ohio State University instructional program which utilizes most of the facilities during this period.

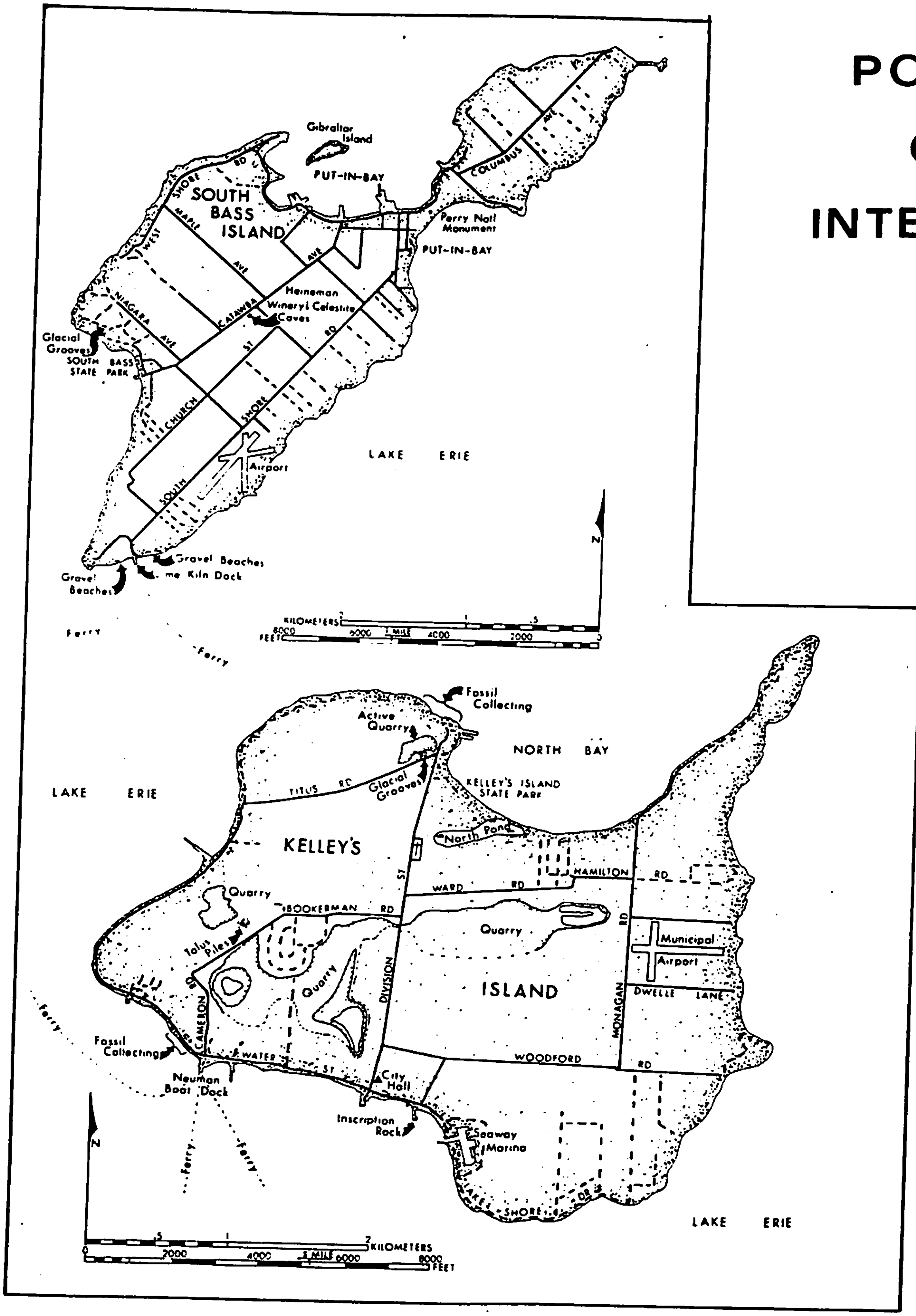
Activities for individual groups may be based on independent projects formulated by the group prior to their arrive at Stone Laboratory and/or a program of scheduled activities presented by the Stone Laboratory staff. Each visiting class and workshop program is tailored to fit the individual needs of the group.

Housing accommodations and research facilities for scientists working on individual projects are also available on a year-round basis.

For detailed information about scheduling and application procedures, please refer to the Visiting Class and Workshop Programs section of this manual.


LOCATION MAP OF
WESTERN LAKE ERIE
Detroit R.
ONTARIO
Pointe Mouillee
Huron R.
Colchester
Pigeon Bay
Stony Pt.
MICHIGAN
River Raisin
Point
Pelee
North Harbor Is.
Middle Sister
Is.
East Sister
Is.
Hen Is.
Pelee
Is.
Woodtick
Peninsula
Little
Cedar Pt.
West Sister Is.
Sugar
Is.
North
Bass Is.
Fish Pt.
Maumee
Bay
Rattlesnake
Is.
Middle
Bass
Is.
Middle Is.
OHIO
Maumee R.
Gibraltar Is.
Green Is.
South Bass Is.
Starve
Is.
SCALE OF KILOMETERS
0
10
20
30
Locust Pt.
Mouse
Is.
Kelleys Is.
Toussaint R.
Catawba Is.
East Harbor
Portage R.
Marblehead
Johnson Is.
Sandusky
Bay
Cedar Point
42°
00'
41°
50'
41°
40'
41°
30'
83°30'
83°20'
83°10'
83°00'
82°50'
82°40'

POINTS OF INTEREST



GEOLOGY

GEOLOGY

Lake Morphometry

The morphometry of a lake refers to its shape or form and is usually expressed as a series of dimensions (Table 1). Such information is useful in understanding how a large lake was formed and how it will respond to environmental stresses.

TABLE 1

MORPHOMETRY OF LAKE ERIE

	Western basin	Central basin	Eastern basin	Entire lake
Maximum length (miles)	50.0	132.5	85.0	241.0
Maximum breadth (miles)	40.0	57.2	47.5	57.0
Maximum depth (feet)	67.0	84.0	210.0	210.0
Mean depth (feet)	24.2	60.7	79.9	60.7
Maximum depth/mean depth	2.8	1.4	2.7	3.4
Area (square miles)	1,265.0	6,246.0	2,408.0	9,919.0
Volume (cubic miles)	5.8	71.8	36.4	113.0
Shoreline (miles)	268.3	373.3	263.3	844.9
Percent of area	12.8	62.9	24.3	100.0
Percent of volume	5.1	63.0	31.9	100.0
Percent of shoreline	31.7	37.1	31.2	100.0
Development of volume[2]	1.2	2.2	1.1	0.9
Development of shoreline[3]	2.3	1.3	1.7	2.1
Longitudinal axis bearing	N 67°W	N 67°E	N 67°E	N 67°E

1. Modified from Verber (1960, p. 6)
2. Development of volume is the ratio of the volume of the lake to that of a cone of basal area equal to area of the lake and a height equal to the maximum depth of the lake (Hutchinson, 1957, p. 166).
3. Development of shoreline is the ratio of the length of the shoreline to the length of the circumference of a circle of area equal to that of the lake (Hutchinson, 1957, p. 166).

Lake Erie is geologically the oldest of the Saint Lawrence Great Lakes. It is by far the shallowest, with its entire water mass above sea level, and has the smallest volume of water with the shortest water retention time (Figure 1). The water temperatures of Lake Erie have the widest seasonal fluctuations of

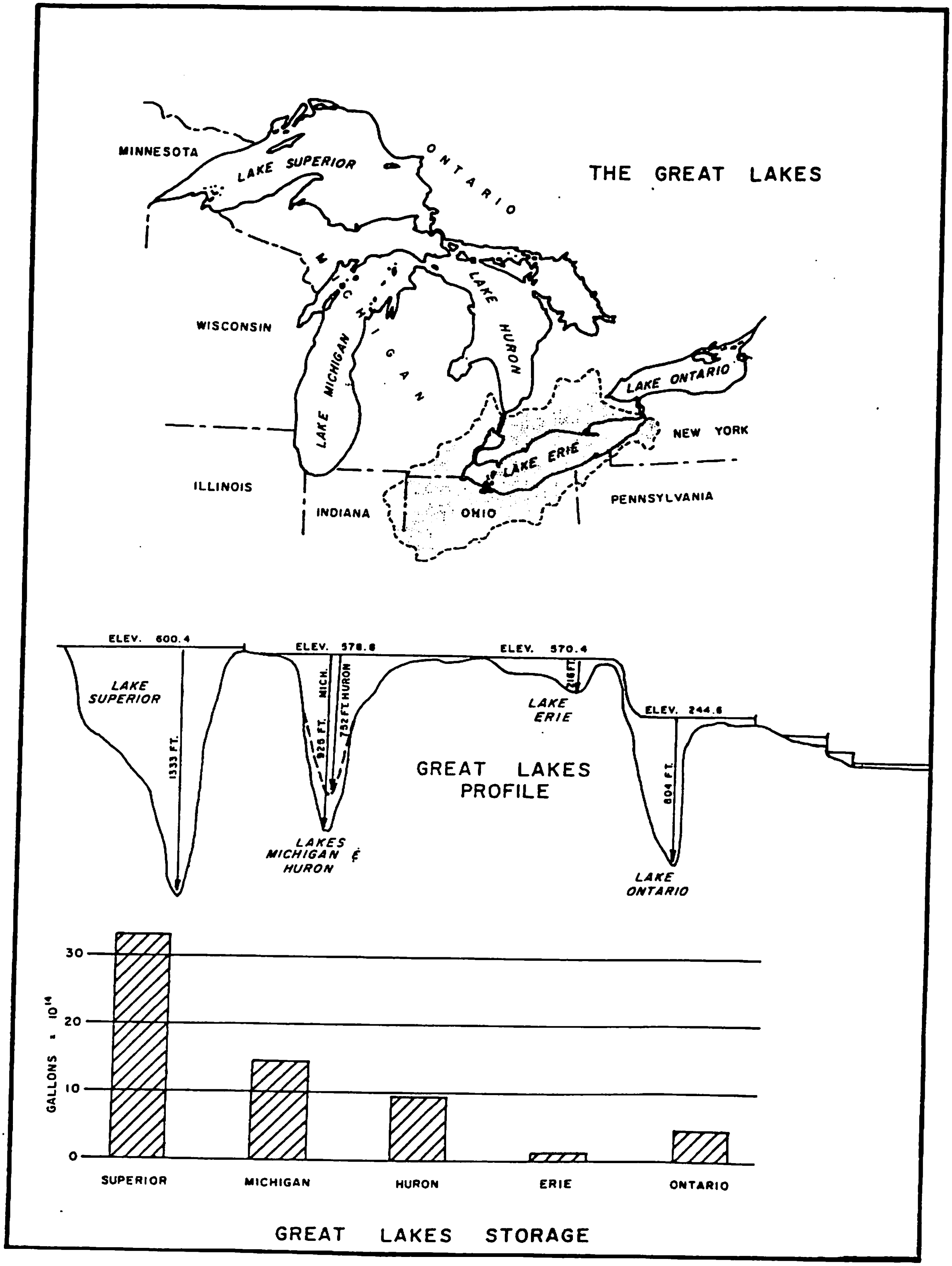


Figure 1. Comparison of Lake Erie and the other Great Lakes.

of any of the Great Lakes, and it is the only lake that typcially freezes from shore to shore. In comparison to the other Great Lakes, Lake Erie is also the southernmost, warmest, most turbid, most biologically productive, and most eutrophic of all.

Lake Erie lies between 41° 20' N to 42° 50' N latitude and 78° 50' W to 83° 30' W longitude. It is a relatively narrow lake, with its long axis oreinted southwest-northeast. This axis parallels the prevailing wind direction which subjects the lake to violent storms, with waves over 12 feet (4 meters) high, and wide fluctuations in water level over 15 feet (5 meters) between record high and low levels at Toledo, Ohio). Lake Erie is approximately 240 miles (384 km) long and 57 miles (91 km) wide, with a mean depth of 60 feet (18 meters). The water covers an area of 9,919 square miles (25,690 square km), and has a volume of 113 cubic miles (463 cubic km). Lake Erie has three major physiographic divisions: western central and eastern basins (Figure 2).

The western basin, lying west of a line from the tip of Cedar Point, Ohio northward to Point Pelee, Ontario, is the smallest and shallowest basin with most of the bottom at depths between 25 and 35 feet (8 and 11 meters). In contrast with the other basins, a number of bedrock islands and shoals (locally called reefs) are situated in the western basin and form a partial divide between it and the central basin. The bottom is flat except for the steep-sided islands and shoals. The deepest sounding is 62 feet (19 meters) in a small depression north of Starve Island Reef. The western basin possesses only 12.8 percent of the area and 5.1 percent of the volume of Lake Erie.

The central basin is separated from the western basin by the island chain and Point Pelee, and from the eastern basin by a relatively shallow sand and gravel bar between Erie, Pennsylvania and the base of Long Point, Ontario. The central basin has an average depth of 61 feet (19 meters) and a maximum depth of 84 feet (26 meters). Except for the rising slopes of a low morainal bar

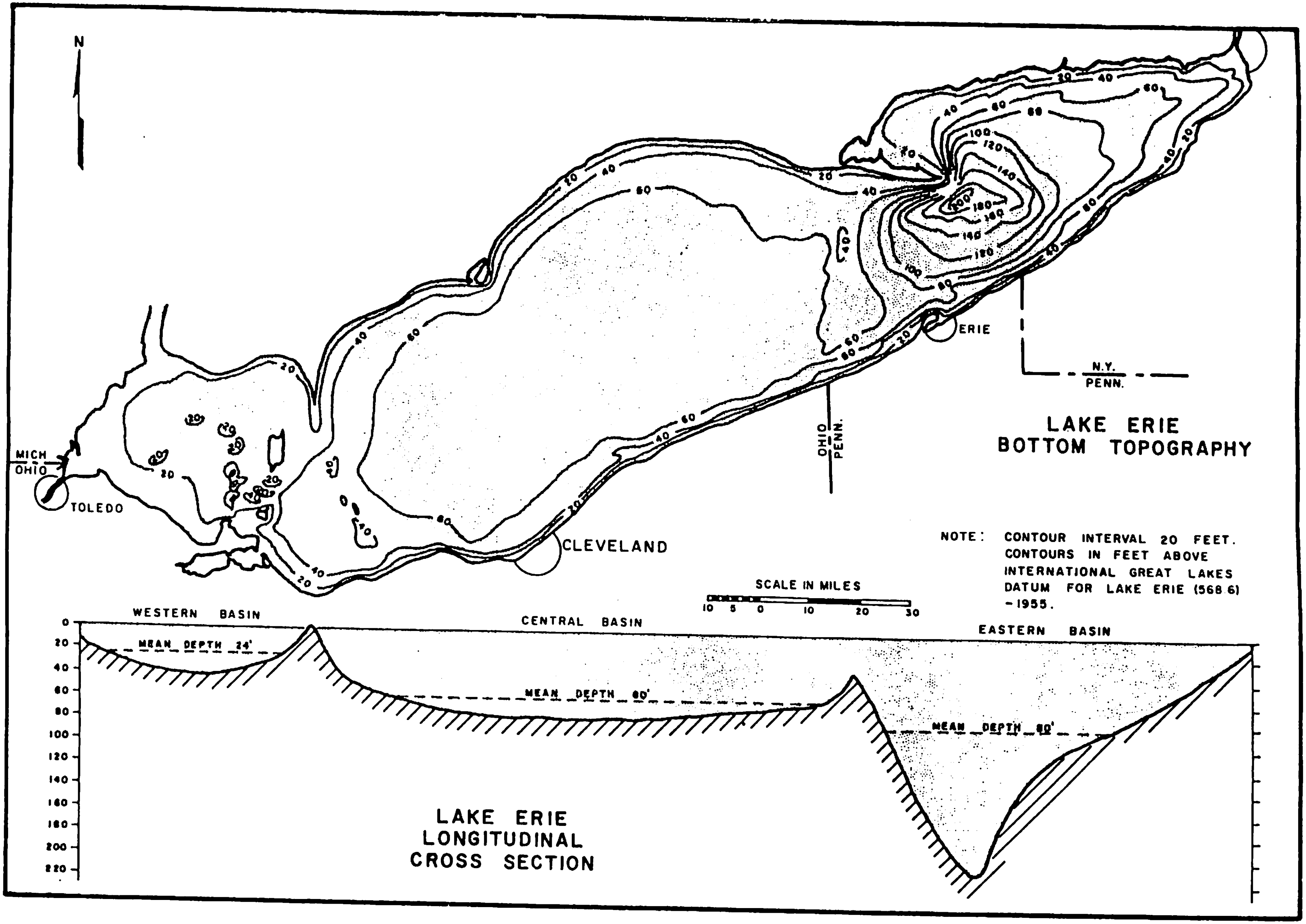


Figure 2. Lake Erie Bathymetry.

extending south-southeast from Point Pelee, Ontario, the bottom of the central basin is extremely flat. This basin is the largest, containing 62.9 percent of the area and 63.0 percent of the volume.

The eastern basin is relatively deep and bowl-shaped. A considerable area lies below 120 feet (37 meters), and the deepest sounding of 210 feet (64 meters) is about eight miles (13 km) east-southeast of Long Point, Ontario. This basin comprises 24.3 percent of the lake's area and 31.9 percent of its volume.

Lake Erie Physiography

Physiography refers to the regional topography of a large section of the earth's surface. The Lake Erie basin lies in the Central Lowlands physiographic province near where it wedges out between the Appalachian Plateau and Laurentian Upland. The southeastern part of the drainage basin is in the Appalachian Plateau. The boundary between the Central Lowlands and the Appalachian Plateau in the Erie basin is a sharp rise of 200 to 300 feet (60 to 90 meters) in elevation called the Portage Escarpment. From Cleveland eastward the escarpment parallels the lake shore and lies generally less than five miles from it. At Cleveland the escarpment turns southward across Ohio (Figure 3).

The part of the Central Lowlands in the Lake Erie basin is called the Lake Plain and is for the most part the very flat former lake bottom. East of Cleveland it is narrow and lies between the Portage Escarpment and the present lake shore. West of Cleveland it widens quickly and in western Ohio, it is more than 50 miles (80 km) wide. It narrows again in Michigan to about 20 miles (30 km) wide. In Canada, it is 20 to 30 miles (30 to 50 km) wide but is not so well defined because of the complexity of glacial features. The lake plain is characteristically low and comprised of poorly drained silt and clay with occasional sandy ridges formed as beaches and bars in older lakes.

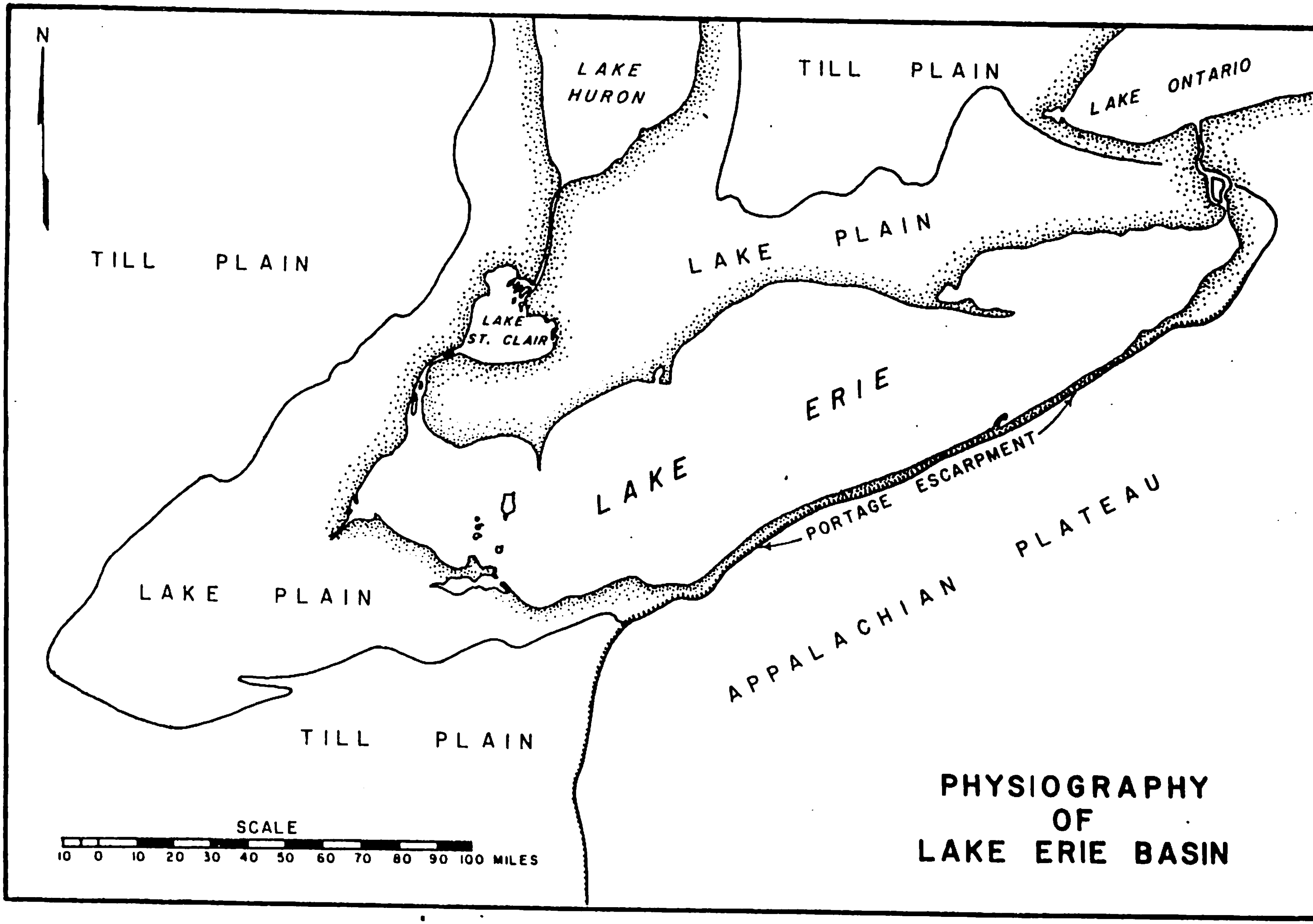


Figure 3. Lake Erie Basin Physiography.

The streams (except the Detroit River) entering Lake Erie originate either within or just outside the boundaries of the Lake Plain. The valleys are generally narrow and winding with steep to vertical walls. The shapes indicate that most of the valleys are in a youthful stage of maturity, having been cut rapidly since the Ice Age in a flat region but high relative to the lake.

The landscape of the Lake Erie basin is characterized by thousands of square miles of flat terrain, borken only by occasional ancient beach ridges and the relatively steep valley walls in many of the major tributaties. Even these features are subdued in the western part of the basin. The terrain is less monotonous from Cleveland eastward, along the south shore, where the basin reaches into the northwestern perimeter of the Appalachian uplands with their rolling hills. However, the basin there is relatively narrow between the lake and the drainage divide.

Soils in the extensive flatlands of the Lake Erie basin are characteristically dominated by poorly drained and relatively impervious clays, derived from old lake and glacial drift (Figure 4). These soils are fertile and, because of this, have been artificially drained to a great extent. The uplands along the southeast edge of the basin are well-drained, rock-derived, and less fertile. Old beach rdiges throughout the basin are extensively used for highways and farming.

Streams entering Lake Erie are generally low-gradient and winding but with steep-walled valleys. They carry large silt loads where they traverse easily eroded clay flatlands and smaller loads in the rocky hilly areas. Excluding the Detroit River input, only streams, the Maumee and Sandusky Rivers in Ohio and the Grand River in Onatario, supply significant quantitites of water (> 1,000 cubic feet/sec) to the lake (Figure 5).

Bedrock Geology

The varying depths of the Lake Erie basins are attributed to differential

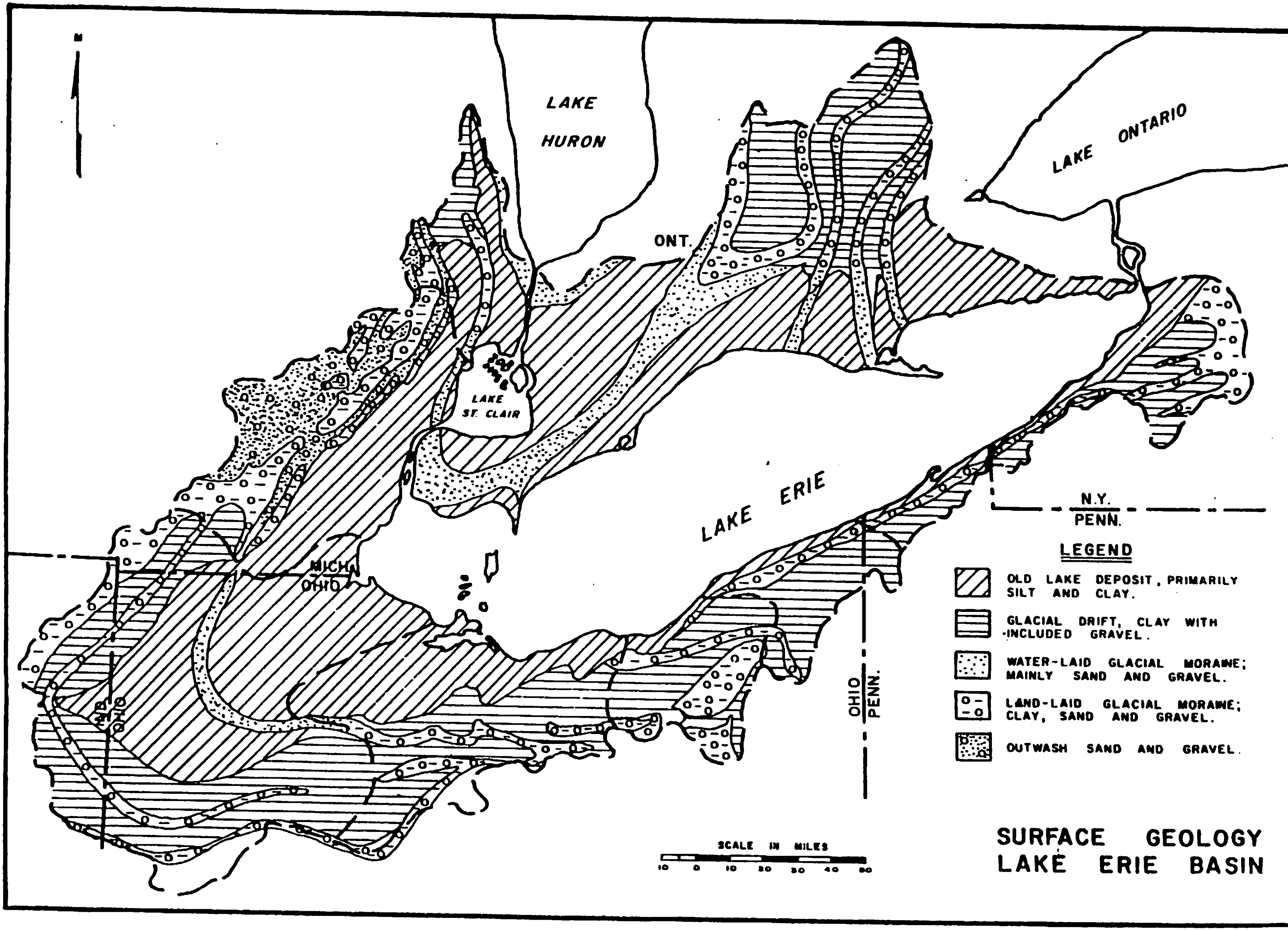


Figure 4. Lake Erie Basin Surface Geology.

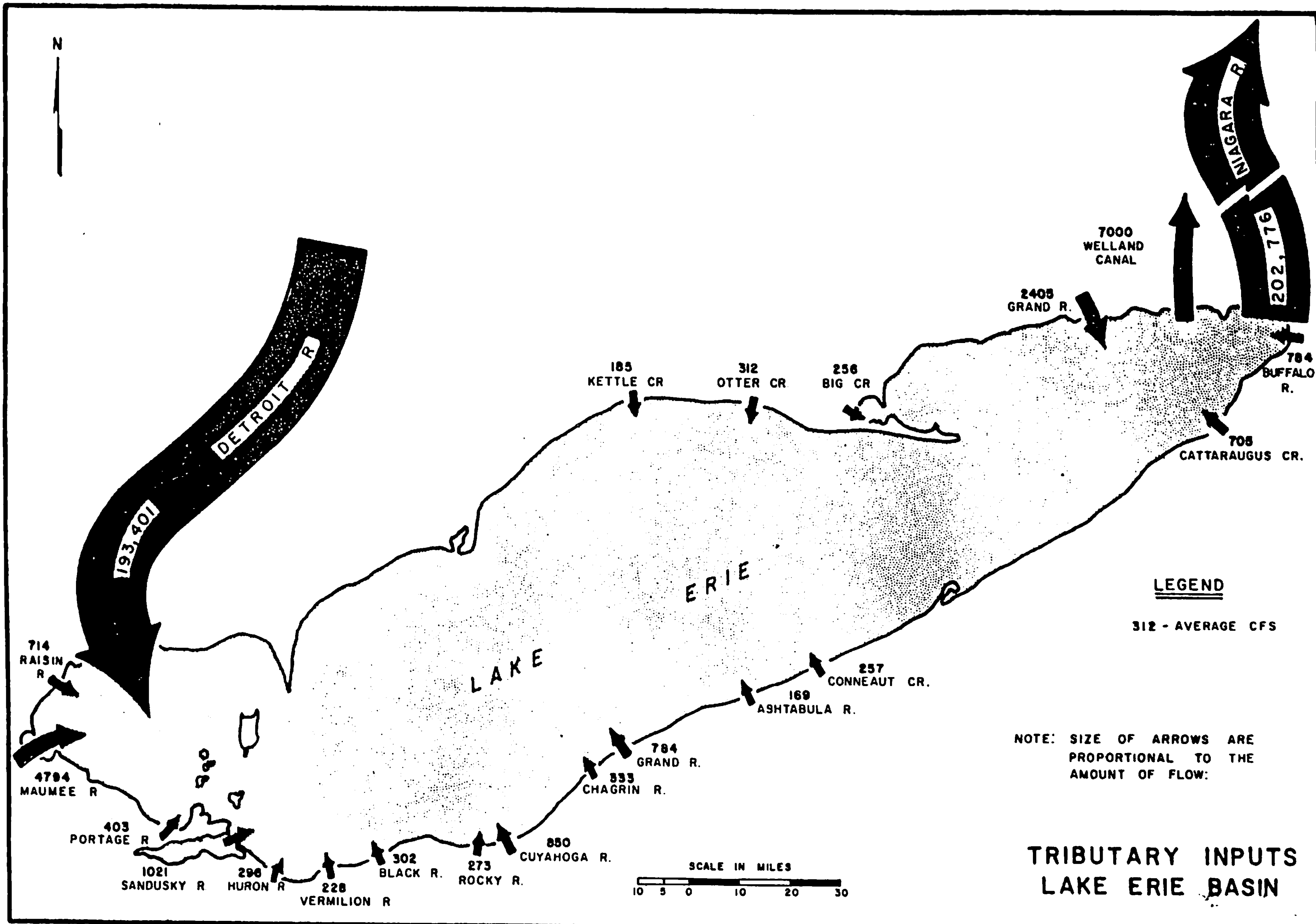


Figure 5. Lake Erie Tributary Flow.

erosion by preglacial streams, glaciers, and postglacial lake processes. The rock strata of the central and eastern protions of Lake Erie dip slightly to the southeast. Lake Ontario is separated from Lake Erie by resistant Silurian limestones and dolomites of the Niagara Escarpment. The central and eastern basins of Lake Erie are underlain by nonresistant shale, shaly limestone, and shaly sandstone of Upper Devonian Age. Inland along the south shore, eastward from Cleveland, the Portage Escarpment, composed largely of Mississippian sandstone, rises several hundred feet above the level of the lake and forms the northwest front of the Appalachian Plateau (Figure 6).

The outcrop belt of Devonian shales swing inland between Cleveland and Sandusky and continues southward through central Ohio (Figure 7). The shallow western basin is underlain by Silurian and Devonian limestones and dolomites on the northward plunging end of the Findlay Arch (Cincinnati Anticline) or Alonquin Arch as it is known in Ontario (Figure 8). Glacial erosion had relatively slight effects on these resistant rocks other than to form impressive grooves such as those found on Kelleys Island and the Bass Islands. The glacial scour was probably controlled by the pre-glacial stream valleys, resulting in the shallow basin and the island chains.

The bedrock in the island region of western Lake Erie is sedimentary in origin and was deposited as lime muds in shallow, warm Silurian (Figure 9) and (Figure 10) Devonian seas, which covered the region from 410 to 375 million years ago (Table 2). The warm, clear conditions of the sea can be inferred from the abundant fossil corals and other invertebrates found in the rocks on Kelleys and Johnson Islands. The abandoned limestone quarries in Kelleys Island State Park are excellent sites for fossil collecting and have yielded over 70 species of marine organisms (Figures 11 and 12). While a shallow sea occupied the present islands region, the Appalachian mountains were built to the east, resulting in the deposition of deltas which nor form the sandstones and shales

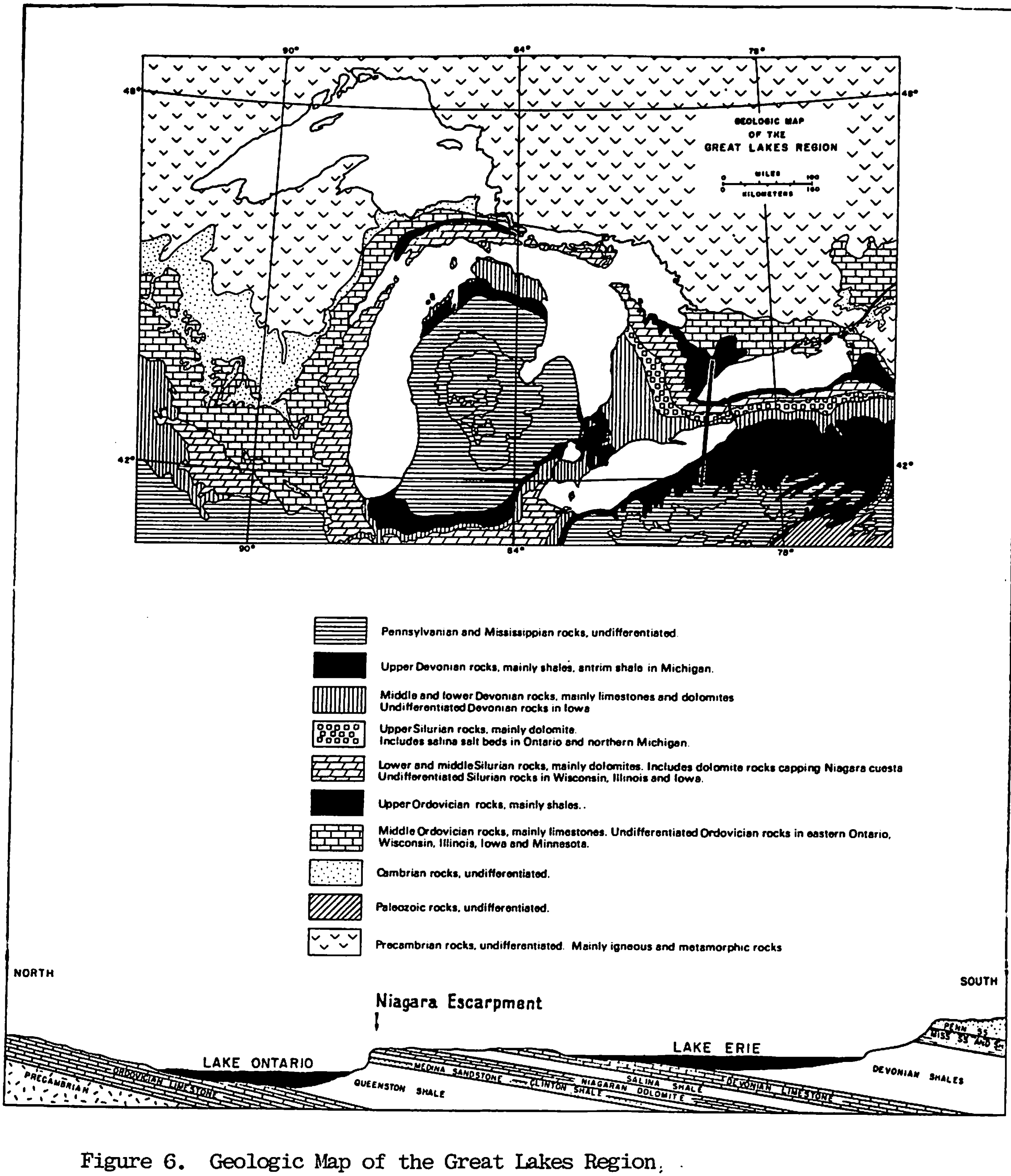


Figure 6. Geologic Map of the Great Lakes Region, and Cross-section of Lake Erie Bedrock.

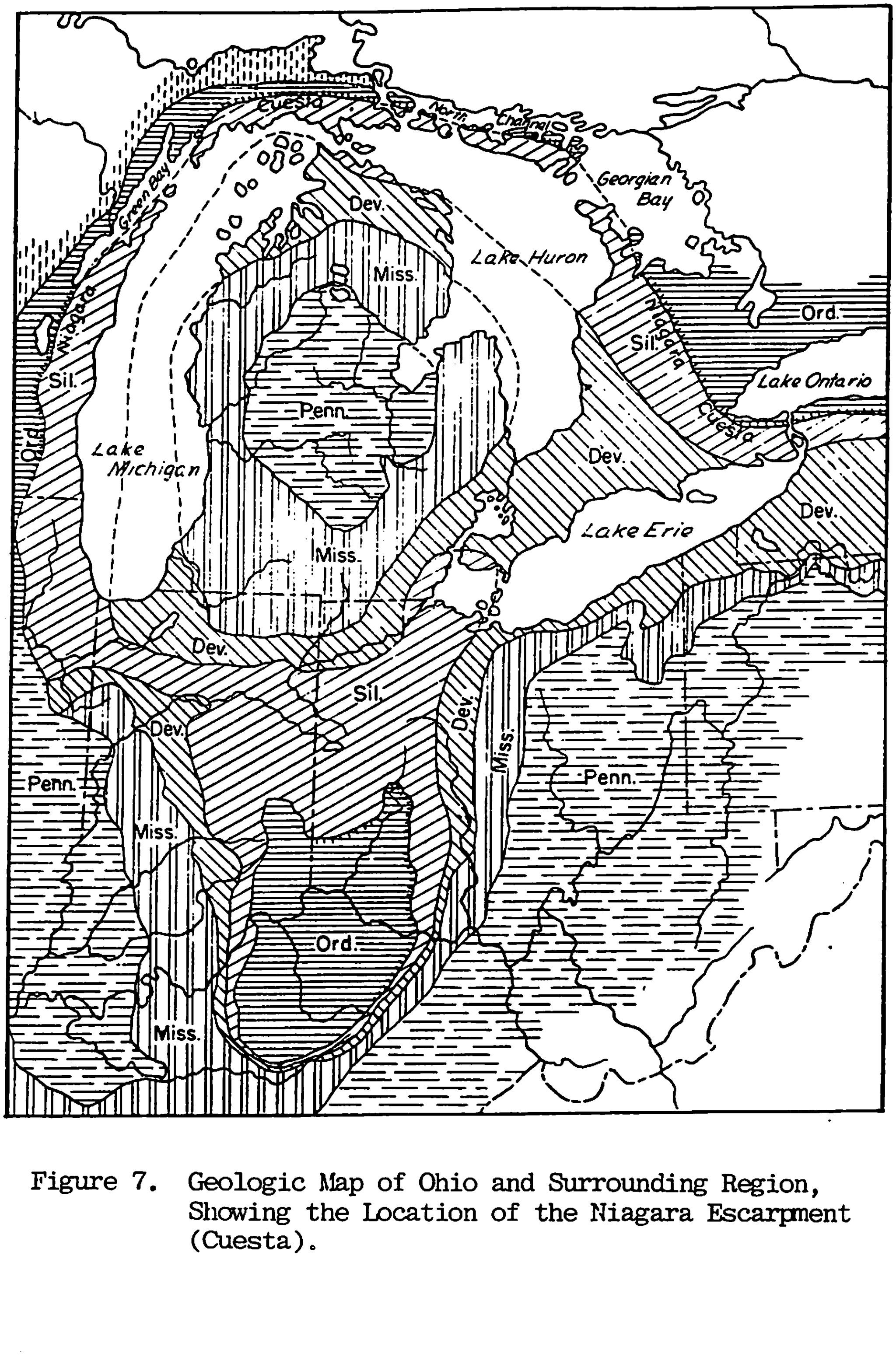


Figure 7. Geologic Map of Ohio and Surrounding Region, Showing the Location of the Niagara Escarpment (Cuesta).

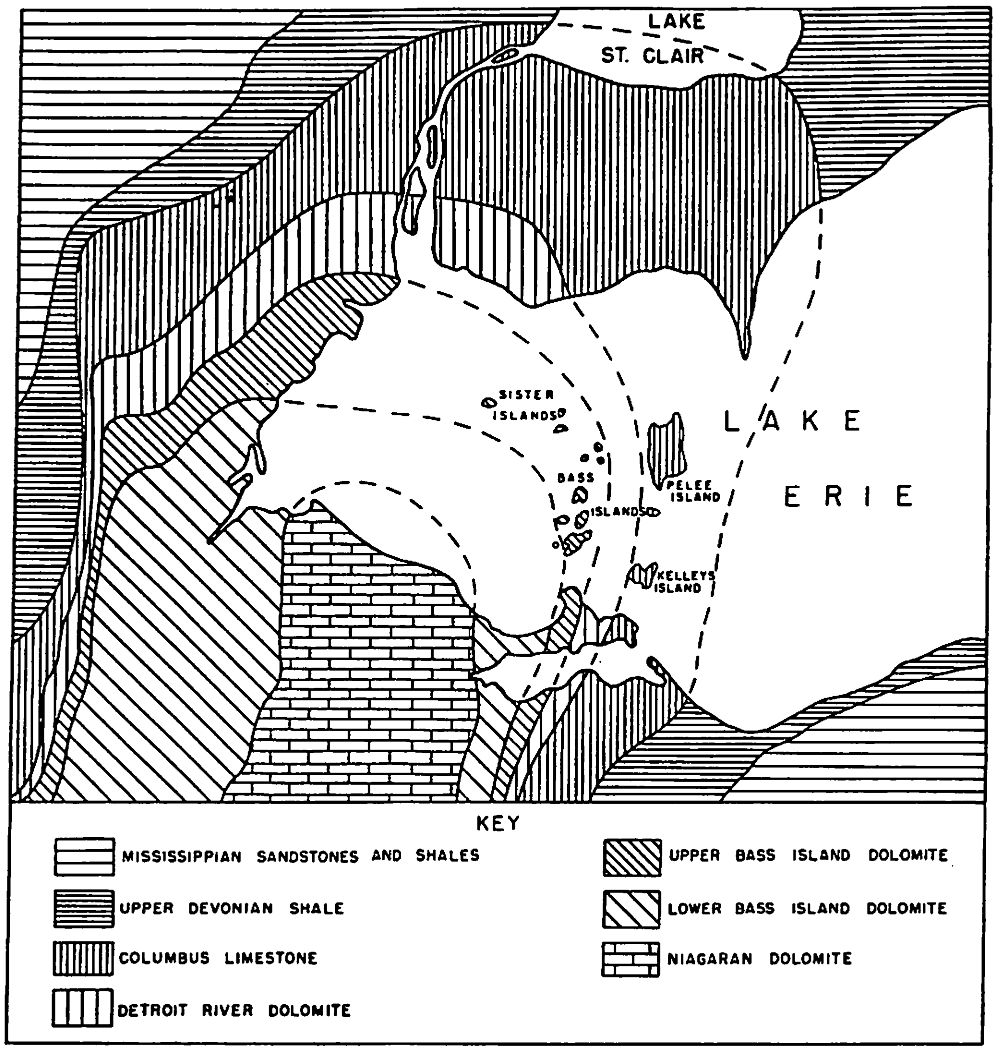


Figure 8. Geologic Map of Western Lake Erie, Showing the Plunging "nose" of the Findlay Arch.

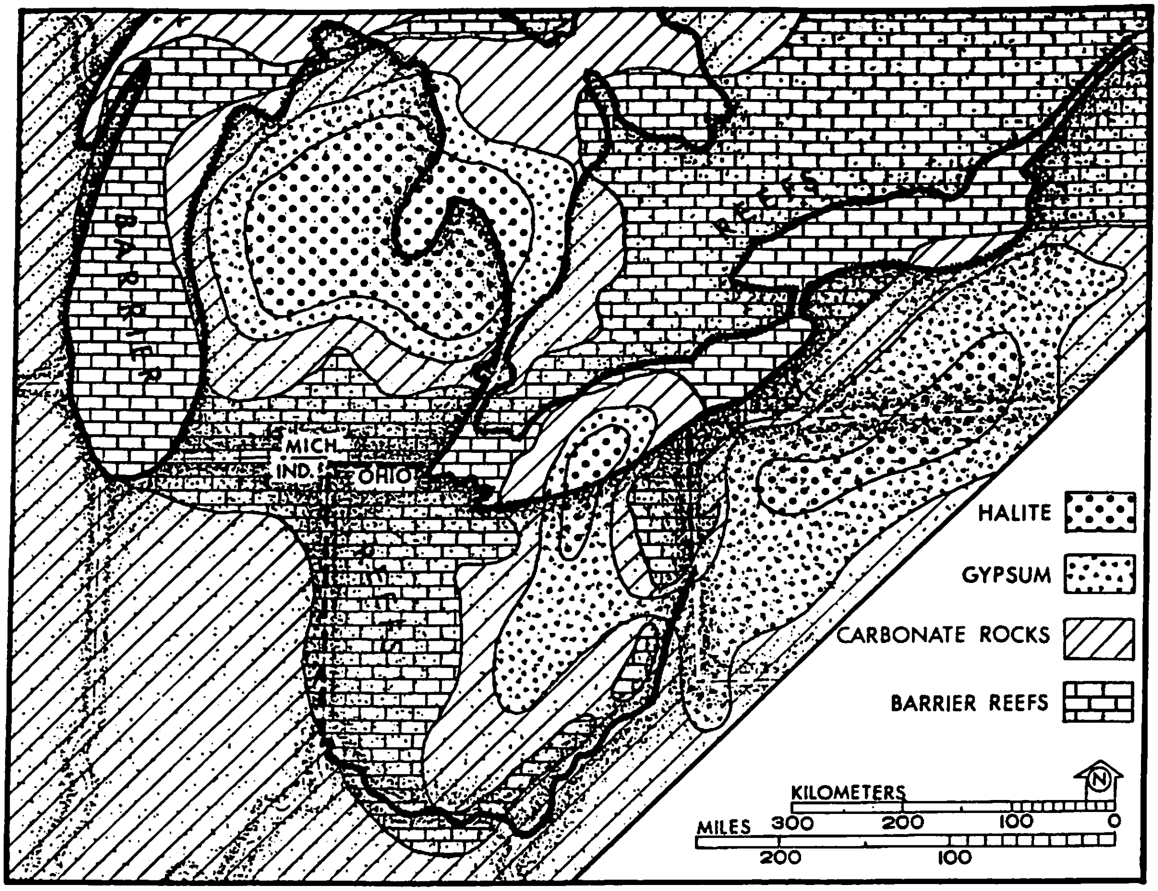


Figure 9. Paleogeographic Map of Silurian Time, Showing the Location Barrier Reef in the Present Islands Region and Evaporite Deposits.

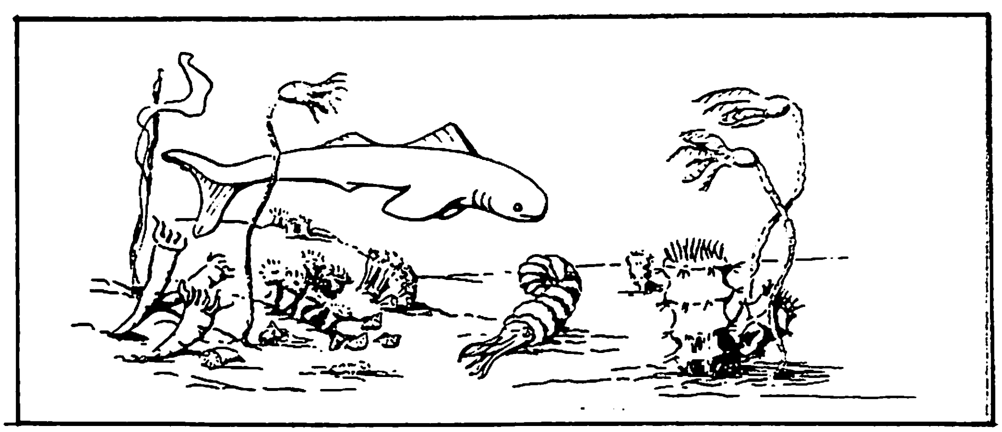


Figure 10. Marine Life in the Devonian Sea.

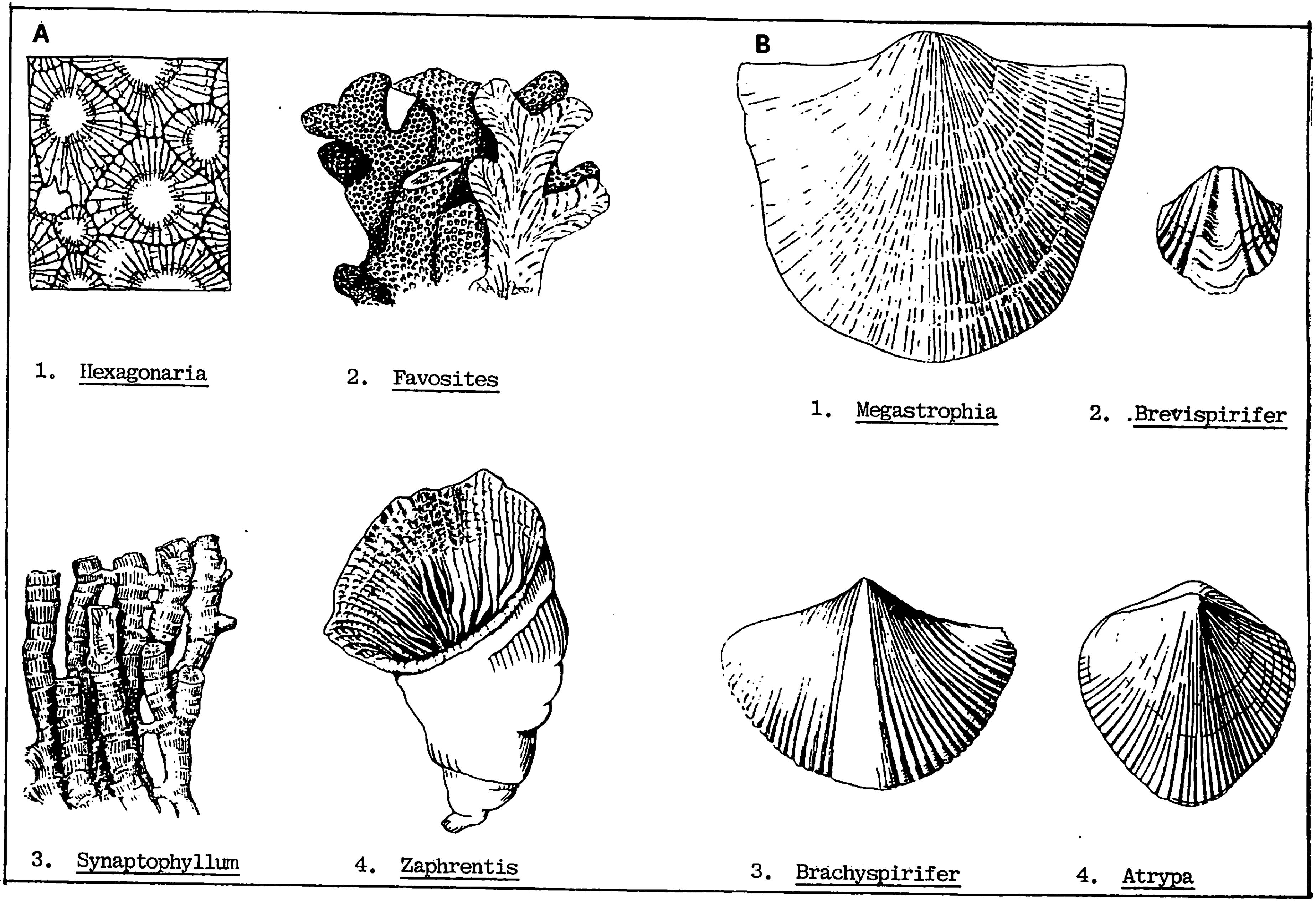


Figure 11. Common Devonian Fossils of the Lake Erie Islands: A) Corals and B) Brachiopods.

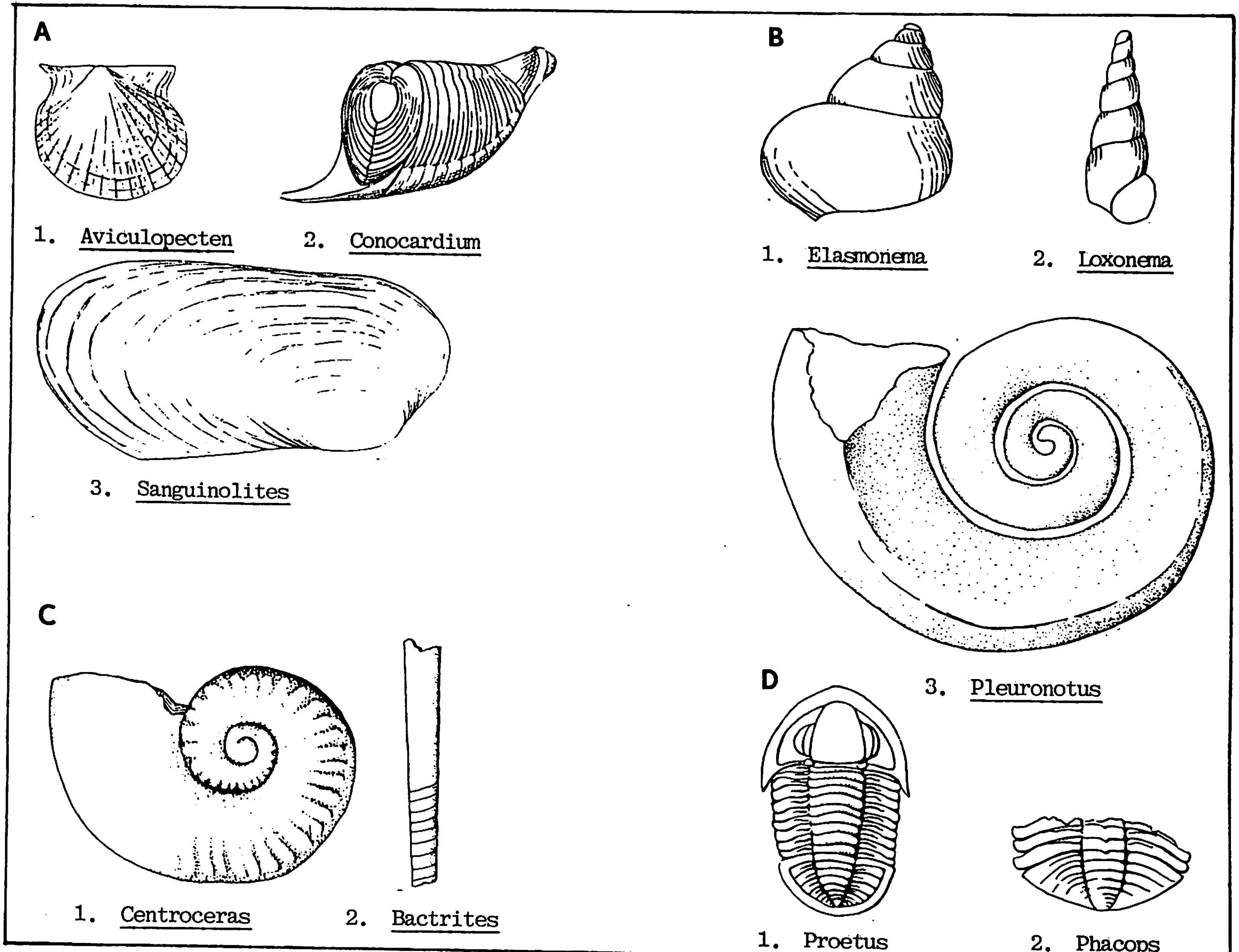


Figure 12. Common Devonian Fossils of the Lake Erie Islands: A) Pelecypods (clams), B) Gastropods (snails), C) Cephalopods, and D) Trilobites.

TABLE 2

GEOLOGIC TIME SCALE

TIME (MILLIONS OF YEARS)	*ERA*	*PERIOD*	*EPOCH*
	CENOZOIC	QUATERNARY *	PLEISTOCENE
		TERTIARY	PLIOCENE
			MIOCENE
			OLIGOCENE
			EOCENE
50			PALEOCENE
100	MESOZOIC	CRETACEOUS	UPPER LOWER
150		JURASSIC	UPPER MIDDLE LOWER
200		TRIASSIC	UPPER MIDDLE LOWER
250	PALAEOZOIC	PERMIAN	UPPER MIDDLE LOWER
300		PENNSYLVANIAN *	
350		MISSISSIPPIAN *	
400		DEVONIAN *	UPPER MIDDLE LOWER
		SILURIAN *	
450 500		ORDOVICIAN	UPPER MIDDLE LOWER
550		CAMBRIAN	UPPER MIDDLE LOWER

*Age of rocks exposed in the Lake Erie Region of the Niagara Escarpment at the east end of the lake (Figure 13).

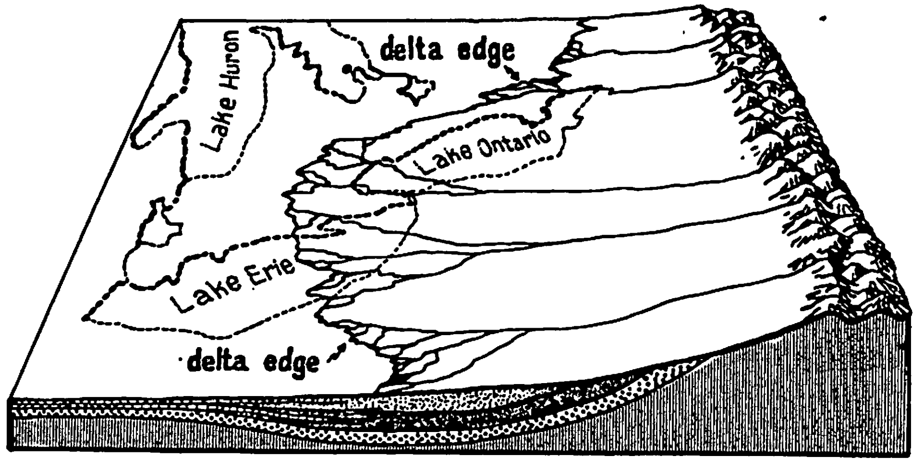


Figure 13. Deltas Deposited during the Building of the Appalachian Mountains in Late Silurian Time.

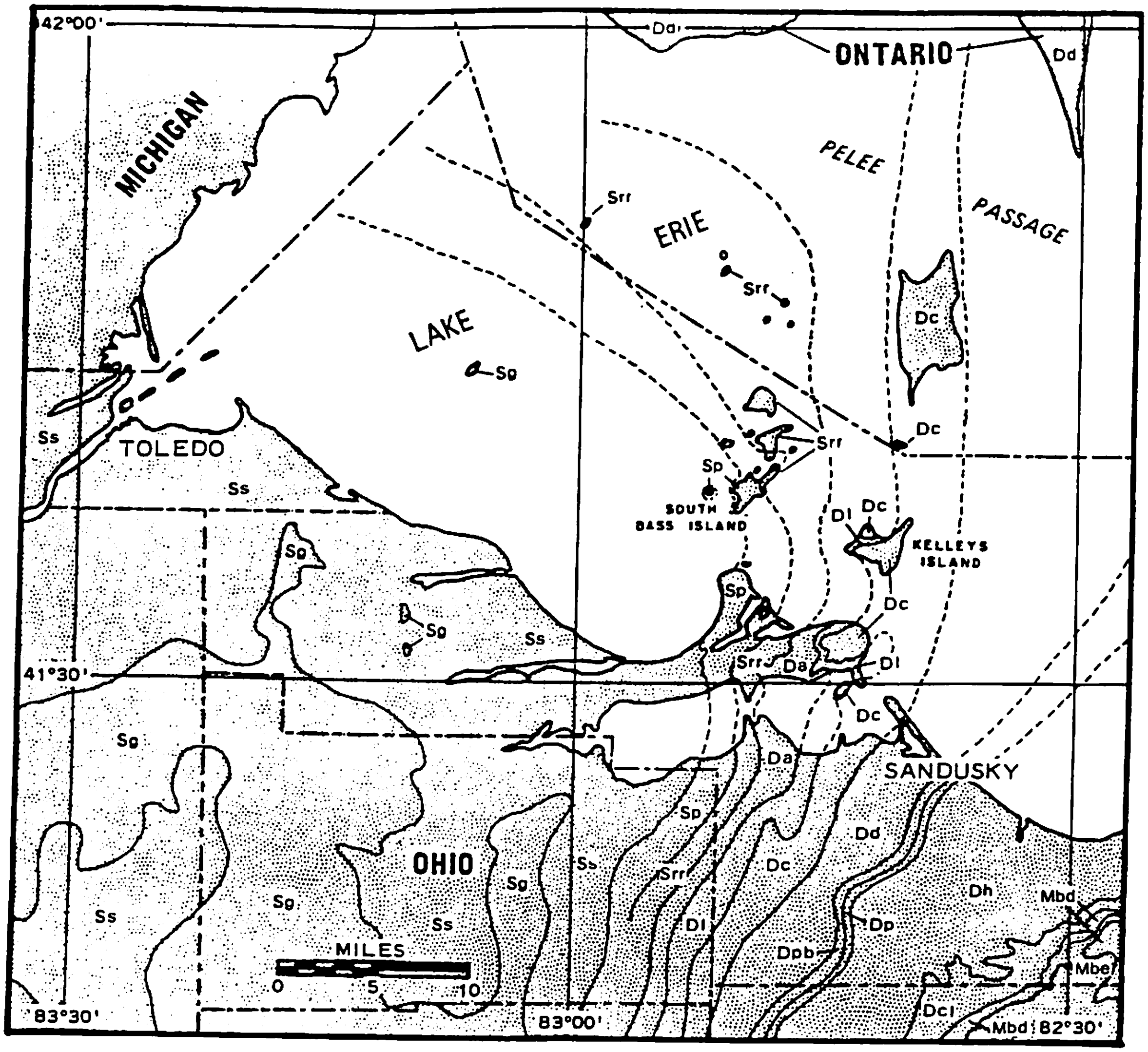
The shores of all of the major islands are rockbound, chiefly rugged in character, with bluffs along the major portions of the island perimeters. The highest elevations are normally adjacent to the west shores, except West Sister Island where the bluffs are highest along the east shore. The upland area adjacent to the west shore of South Bass Island (Victory Woods) reaches a height of 70 feet (21 meters) above lake level, the highest elevation in the islands. Small sand, cobble, or boulder beaches are situated at indentations in the shoreline. The most extensive sand beach lies along the north bay of Kelleys Island.

The dominant structural feature of the bedrock underlying western Lake Erie is the Findlay Arch. The nearly north-south axis of this arch passes through the island region and then plunges gently to the north. A study of the structure of Precambrian or basement rock of Ohio indicates that the crest of the arch lies a few miles east of West Sister Island. As a consequence of the alignment of the arch, the overlying Paleozoic bedrock dips to the east at approximately 20-40 feet (6-12 meters) per mile in the Bass-Kelleys Islands area. For this reason, the oldest rocks are exposed on West Sister Island and successively younger formations crop out to the east along the flank of the arch (Figure 14).

The islands and reefs are arranged in three roughly north-south belts or chains. The most westerly belt lies north of Locust Point and includes approximately 12 reefs and West Sister Island (Figure 15). The middle belt extends from Catawba Island through the Bass and Sister Islands, and includes at least 14 reefs and 10 islands (Figure 16). The easterly belt encompasses Johnson Island, Marblehead Peninsula, Kelleys Island, Middle Island and Pelee Island, and about seven reefs and shoals.(Figure 16). This arrangement and the cuesta shape of the islands are controlled by the structure and relative resistance of the underlying bedrock.

The bedrock exposed on West Sister Island and on reefs in the vicinity of Locust Point as far east as Niagara Reef is the lower portion of the Tymochtee Dolomite (Table 3). This formation is highly variable in its resistance to weathering, a factor that may explain the lack of bedrock reefs between Niagara Reef and the Bass Islands.

The reefs consist of submarine bedrock exposures and associated rock rubble and gravel. The topography of the reef tops varies from rugged surfaces caused by bedrock pinnacles and large boulders to smooth slabs of nearly horizontally bedded rock. In places the exposed bedrock has the appearance of low stairs with the "steps" dipping slightly to the east from the fringe of the reefs to its crest. All of the bedrock formations that form the reefs are carbonate rocks which contain abundant solution cavities. Most of the reefs are conical in shape and elongated, as are many of the islands, in a northeast-southwest direction. Two factors appear to have influenced this elongation: (1) vertical joint systems in the bedrock which are oriented parallel to the elongation and (2) the elongation is in general agreement with the major trends of glacial ice movements as deduced from grooves found on the islands. The



System	Group	Formation	Symbol		Lithology	Thickness (feet)
Mississippian		Berea	Mbe		Sandstone	10-50
		Bedford	Mbd		Shale	0-150
Devonian		Cleveland	Dcl		Shale	30-70
		Huron	Dh		Shale	600
		Prout	Dp		Limestone	15
		Plum Brook	Dpb		Shale	35
		Delaware	Dd		Limestone	35
		Columbus	Dc		Limestone	60
	Detroit River	Lucas	Ddr	Dl	Dolomite	30-75
		Amherstburg		Da	Dolomite	60-80
Silurian		Raisin River	Srr		Dolomite	40-60
		Put-in-Bay	Sp		Dolomite	35-60
	Salina	*Tymochtee*	Ss		Dolomite	670
		Guelph	Sg		Dolomite	200-450

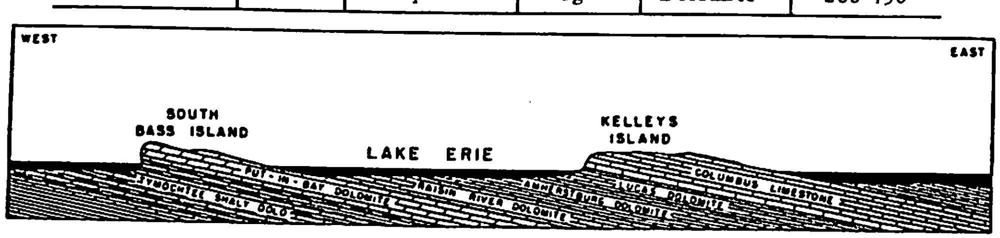


Figure 14. Geologic Map and Cross-section of the Lake Erie Islands Region, Showing Cuesta Shape of the Islands.

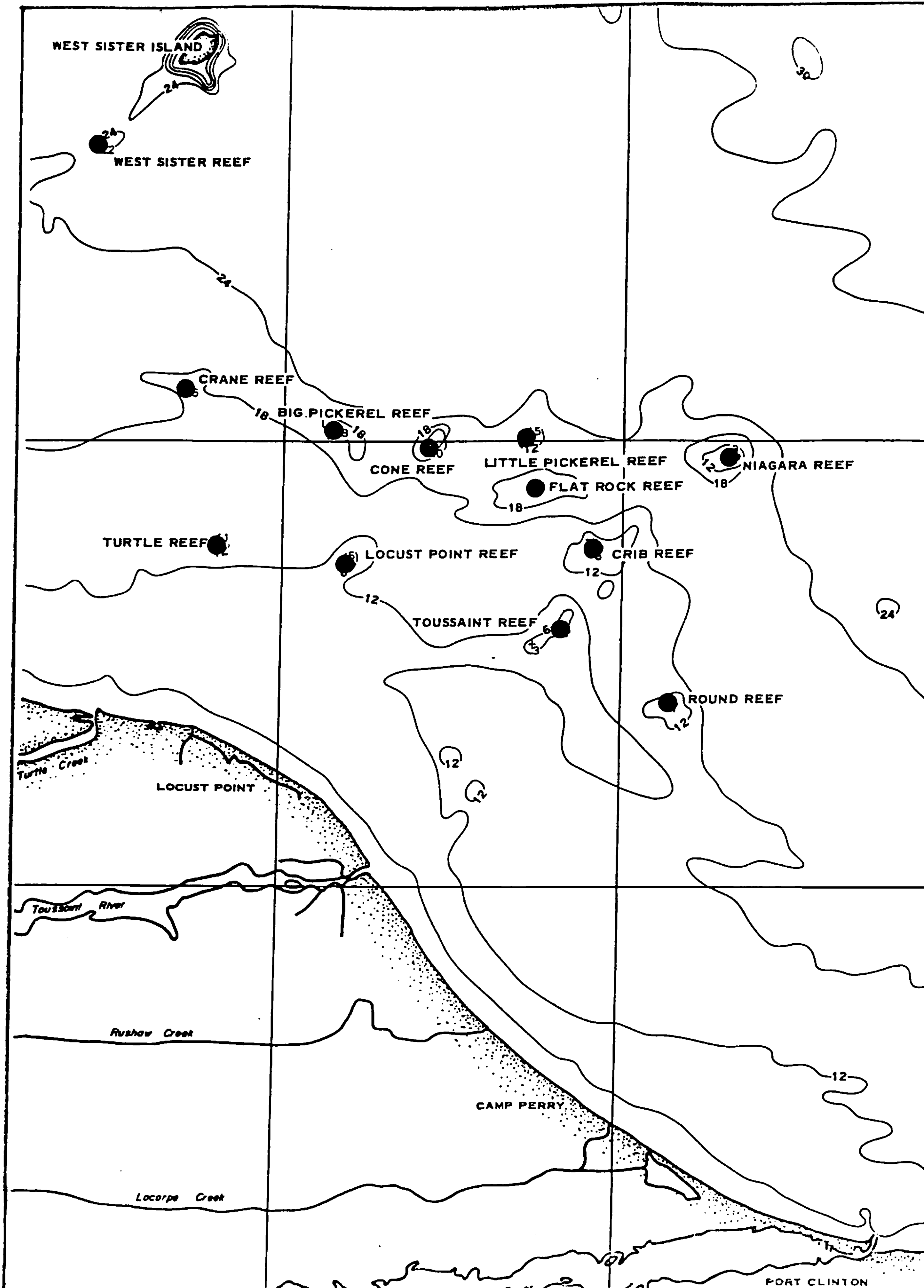


Figure 15. Locust Point - West Sister Island Reef Area.

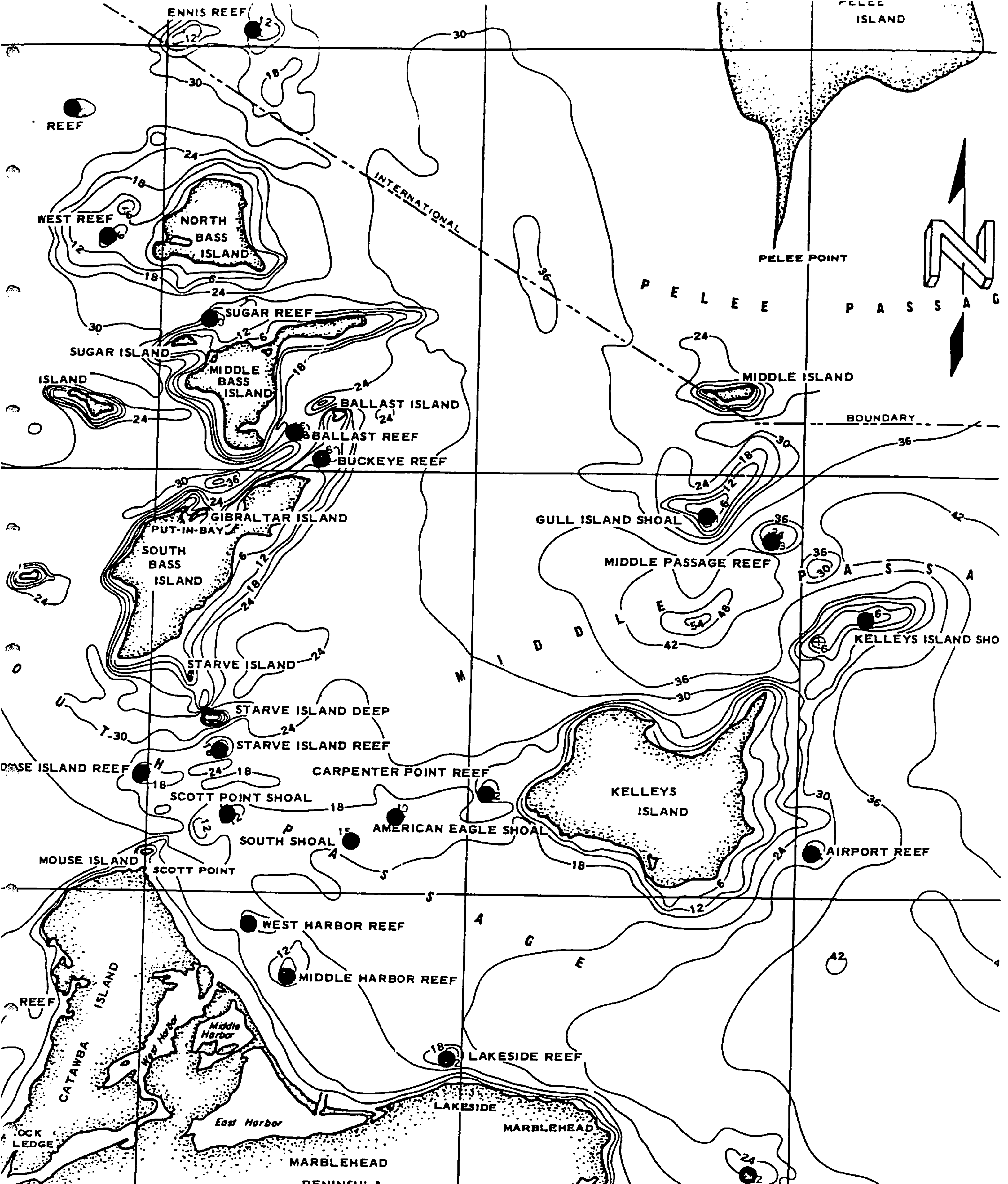


Figure 16. Catawba-Bass-Sister Islands Chain and Marblehead-Kelleys-Middle-Pelee Islands Chain, Showing Reefs and Shoals.

bathymetric map of Gull Island Shoal, north of Kelleys Island, illustrates the rugged topography of the reef area (Figure 17).

TABLE 3

BEDROCK EXPOSED IN THE ISLANDS REGION

System	Group	Formation	Thickness (feet)	Description
Devonian		Delaware	35	Limestone, dark- to bluish-gray, thin-bedded; calcareous shale partings; nodular chert; exposed in vicinity of Sandusky
		Columbus	60	Limestone, light-gray to buff, moderately thin- to massive-bedded, very fossiliferous; locally changing to dolomite; exposed on Kelleys Island, Marblehead, and southwest of Sandusky
	Detroit River	Lucas	30-75	Dolomite, gray to drab, thin- to massive-bedded, relatively nonresistant; carbonaceous parting between layers; exposed in western part of Kelleys Island, on Marblehead, and southwest of Sandusky
		Amherstburg	60-80	Dolomite, drab to brown, massive-bedded, relatively nonresistant; exposed on shore near Lakeside
Silurian	Bass Islands	Raisin River	40-60	Dolomite, blue-gray to drab, thin-bedded to shaly, argillaceous; exposed on Bass Islands and on Marblehead peninsula between Lakeside and Catawba Island
		Put-in-Bay	35-60	Dolomite, gray to drab, medium-bedded, brecciated, rough-textured, crystalline; irregular knobby weathering surface; exposed on South Bass Island, Green Island, and Catawba Island
	Salina	*Tymochtee*	560[1]	Dolomite, dark-bluish-gray to brown, thin-bedded to shaly; calcareous shale partings in upper beds; containing gypsum and anhydrite; uppermost 15 feet exposed on South Bass Island, Catawba Island, and West Sister Island
		Greenfield	110[1]	Dolomite, light-drab to yellowish-brown, thin- to massive-bedded; generally dense and hard but some layers granular or vesicular; equivalent to Greenfield Formation; exposed at Rocky Ridge in Ottawa County
	Lockport	Guelph	200-450	Dolomite, white, light-gray, or bluish-gray, massive-bedded, crystalline; open and porous in texture; exposed in southwest Ottawa County

The middle and eastern belts of bedrock islands (Catawba-Bass and Johnson-Kelleys) are characterized by high elevations and cliffs at their western shorelines; elevations generally decrease eastward resulting in shelving rock along the eastern shorelines. The resulting topographic form is that of a cuesta or asymmetrical ridge, where the gentle slope agrees with the dips of resistant beds and the steeper slope is an eroding cliff maintained partly by undercutting of less resistant rocks. Because West Sister Island lies on the west flank of the Cincinnati Arch the dip of the strata is also to the west. This has resulted

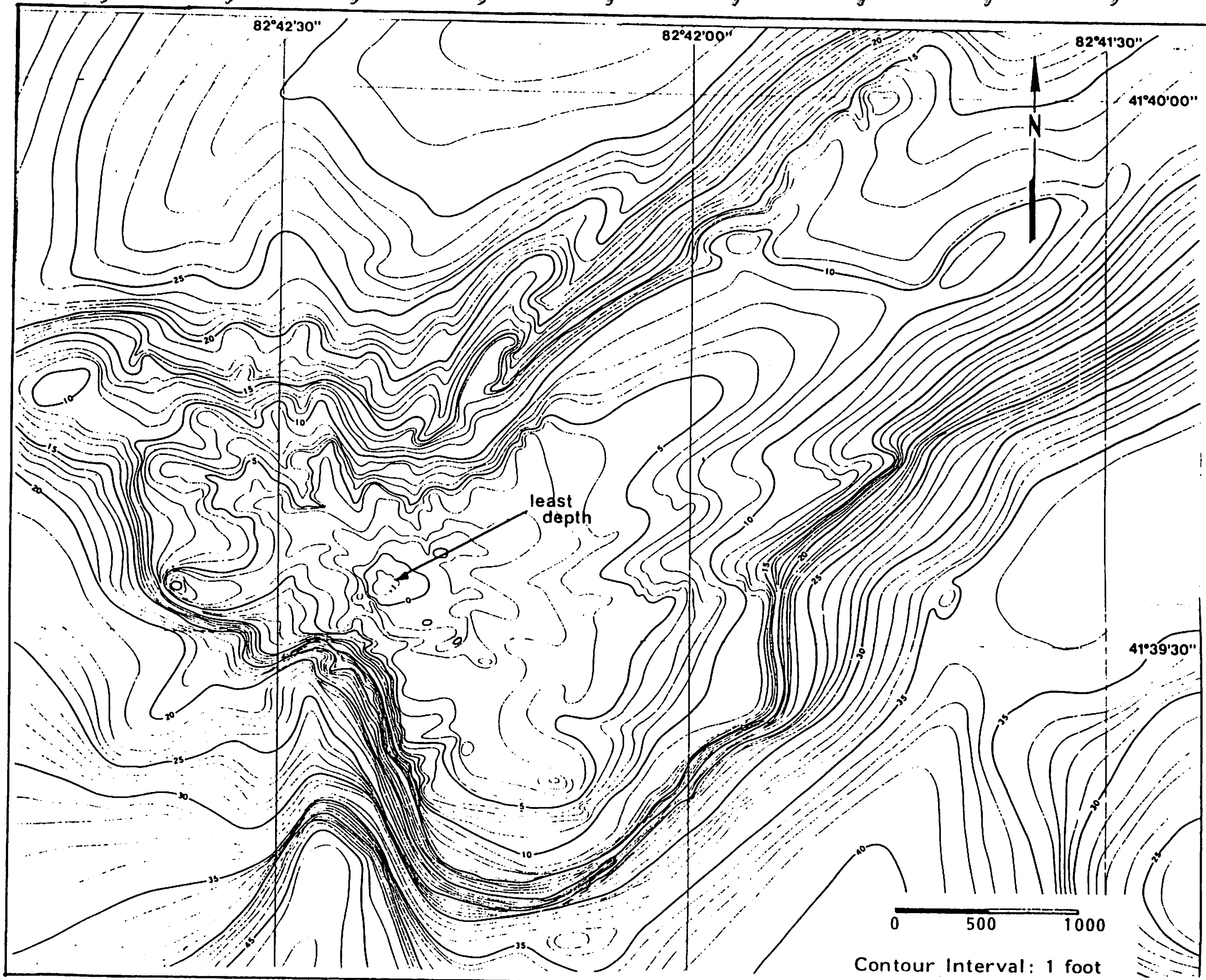


Figure 17. Bathymetric Map of Gull Island Shoal.

the development of a cuesta with its steep cliff on the east side of the island, the opposite of those formed on the more easterly islands.

Catawba and the Bass Islands are underlain by a band of resistant dolomites of the Bass Island Group (Figure 18). The Put-in-Bay Dolomite of this group is responsible for most of the rugged features of the shoreline. The Tymochtee Formation, which underlies the Put-in-Bay Dolomite at the base of the cliffs, is more readily eroded by waves and results in the undermining of the rock above, which fall away in large blocks, forming nearly vertical walls. The shoreline of Catawba Island from Rock Ledge to West Harbor is six miles (10 km) long and consists of an alternation of rocky headlands and glacial bluffs. The dolomite headlands rise to 70 feet (21 meters) above lake level, whereas the glacial till is much less resistant to erosion and has been cut back into coves and indentations along the coast. Pebble and cobble beaches have formed locally in the coves. The four miles (6 km) of shore from West Harbor to Lakeside is low and bordered by sand beaches. The beaches lie on marsh deposits which formed in the shallow bay between Catawba Island and Marblehead Peninsula. The underlying material is glacial till and lacustrine clay. An extensive sand deposit has accumulated in the East Harbor area and low sand dunes have formed behind the beach.

The resistant lower beds of the Columbus Limestone are responsible for the easterly chain of bedrock highs, including Johnson and Kelleys Island. Between South Bass Island and Kelleys Island three formations are less resistant than the Put-in-Bay Dolomite and the Columbus Limestone which explains the depression between the islands.

The Marblehead Peninsula shore arcs for four miles (6 km) from Lakeside to the base of Bay Point and is lines with limestone and dolomite bluffs, generally less than 20 feet (6 meters) above lake level. Sections of the shore are composed of thin-bedded rock which yields to wave attack; elsewhere the rock is

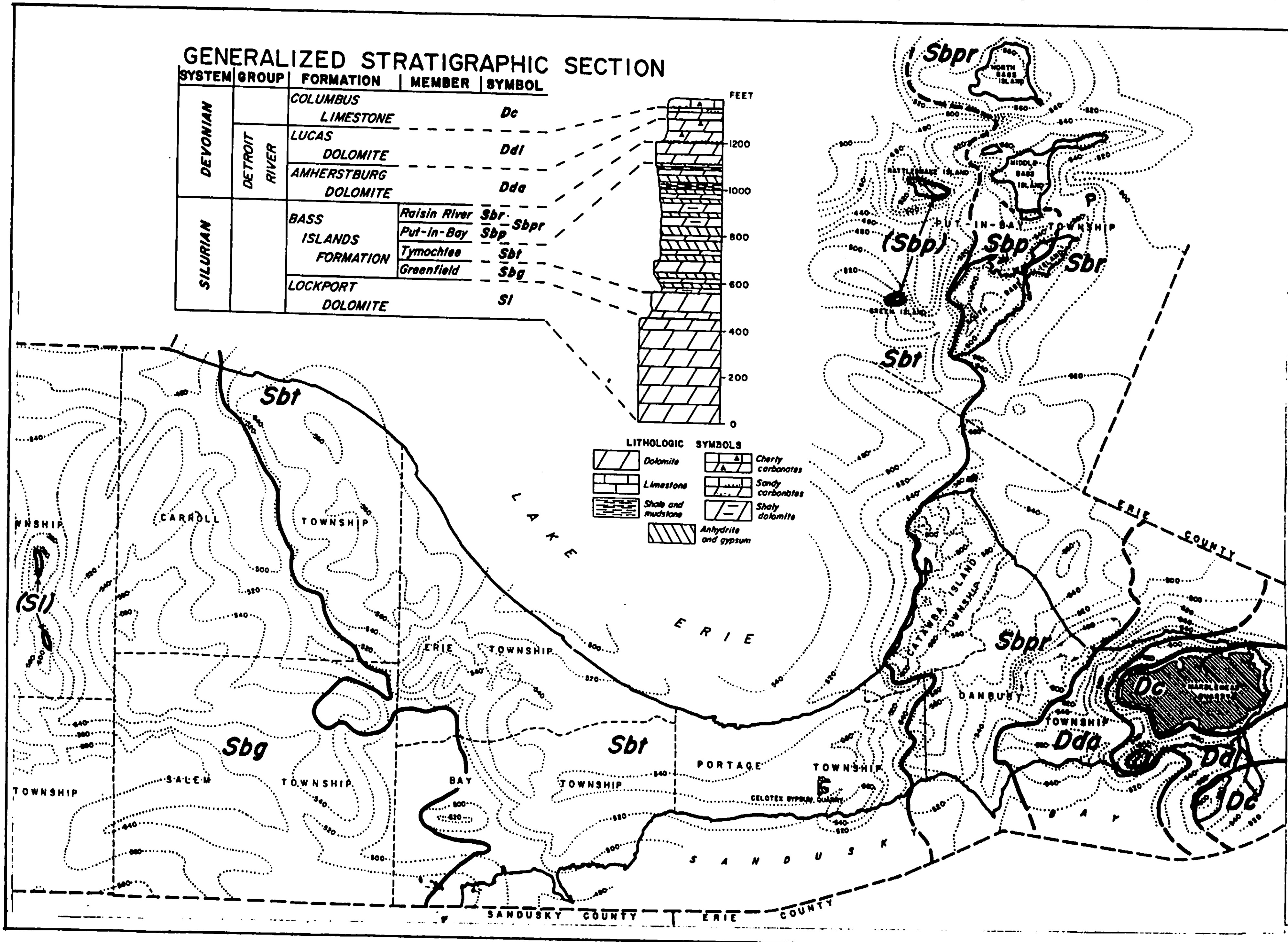


Figure 18. Geologic Map and Stratigraphic Section of Catawba and Bass Islands.

massively bedded and more resistant to erosion. Glacial till commonly caps the bluffs. The narrow pebble beaches which line the shore at the base of the bluffs have been largely derived from the bedrock. Bay Point extends southward from Marblehead Peninsula for two miles (3 km) into Sandusky Bay. This point is a compound spit that is growing from sand contributed by littoral currents moving along Cedar Point and around the end of the Sandusky Harbor jetty. Johnson Island, lying in Sandusky Bay adjacent to Bay Point, is composed of low limestone and glacial till shores. The shore of this island is bordered by discontinuous cobble beaches.

Caves and Sinkholes

The Lake Erie Islands, including Catawba and Marblehead, posses a rather unusual cave and sinkhole topography. The carbonate bedrock of these islands is soluble in weak, naturally-occurring acids, such as carbonic acid and various organic acids. These acids have slowly dissolved portions of the rock producing caves, sinkholes, and other solution features. This process has taken place for millions of years, starting soon after the time when the lime muds which had accumulated in the ancient ocean were drained of sea water. The solution process initially resulted in sinkholes which became filled with dolomite fragments that had broken off the rim, producing a rock called breccia. Exposures of these ancient breccia-filled sinkholes are common on the west shore of South Bass Island.

Solution has also occurred more recently, producing many small caves in the bedrock. Thirty seven such caves have been reported for the islands (Figure 19). Most of the caves are the result of solution and then the collapse of the surrounding and overlying rock into the void. The exact origin of the caves and sinkhole features has been a matter of speculation. The most widely accepted theory states that the structure of the rock materials combined with their mineral composition and contact with water has resulted in cave and

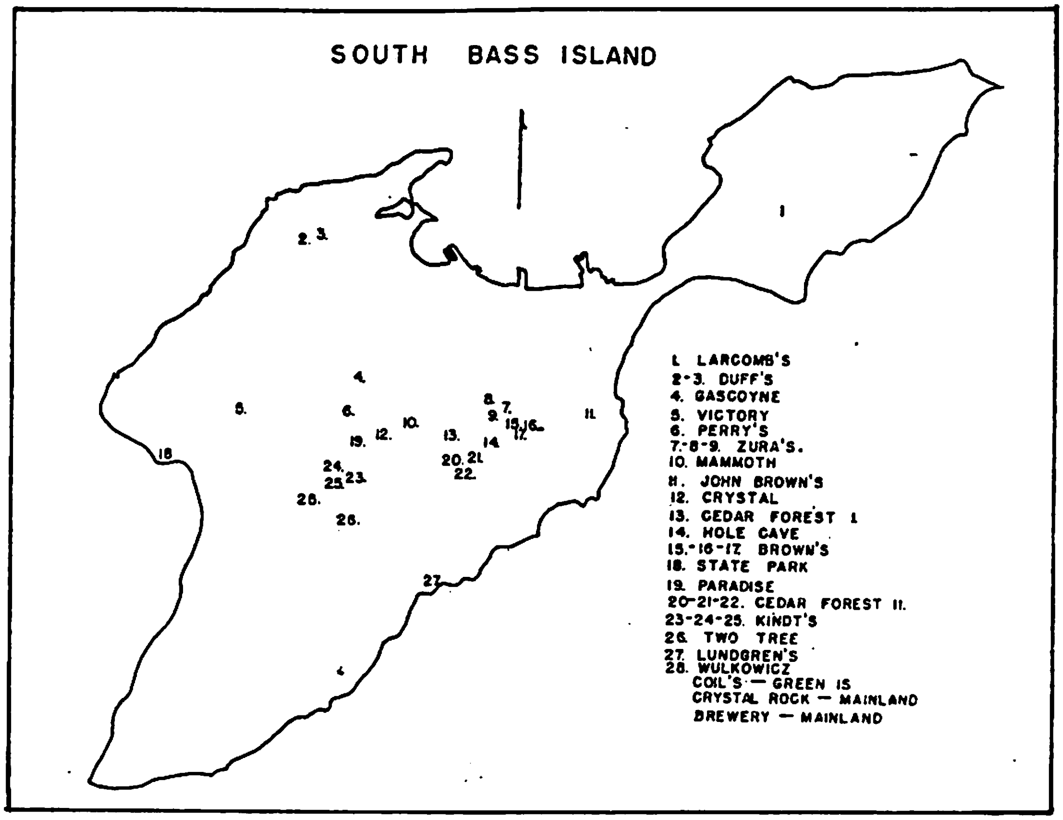
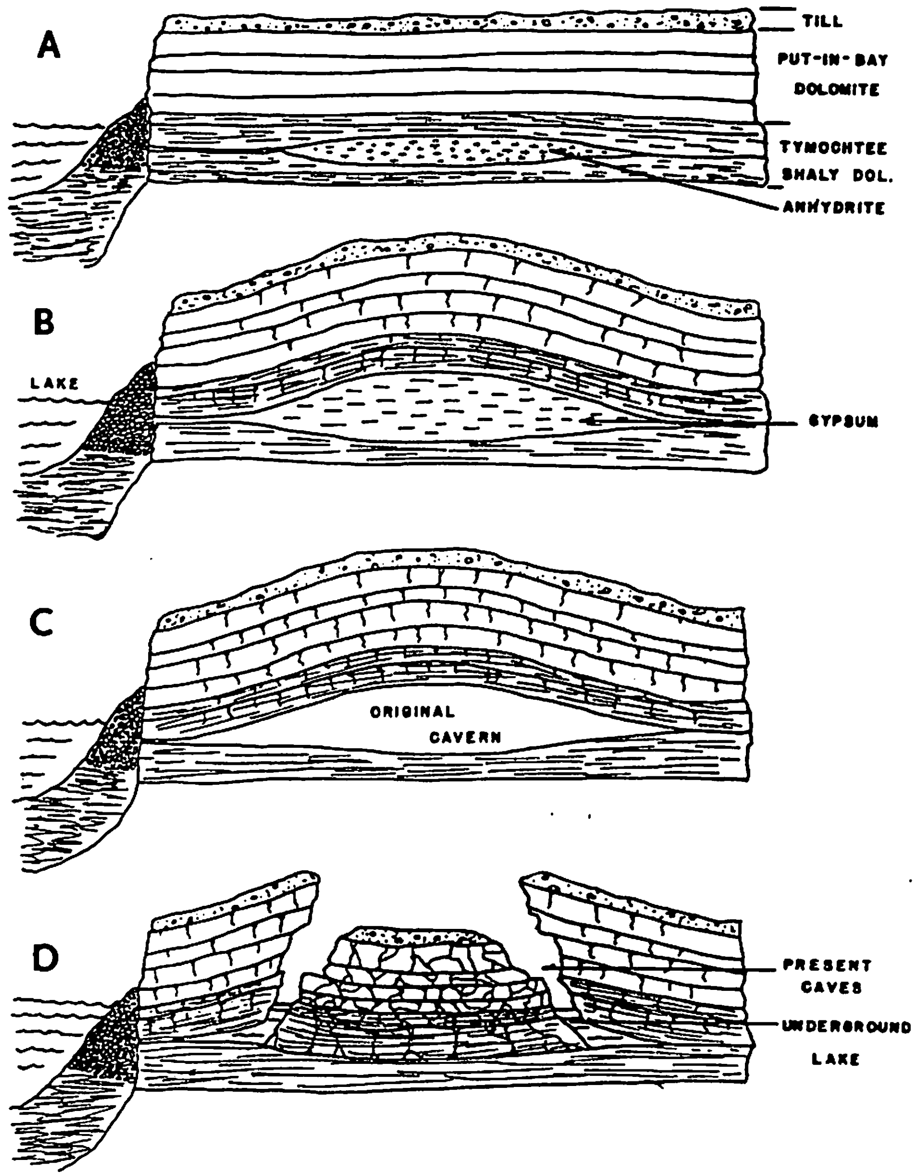


Figure 19. Location of Caves on South Bass Island.

sinkhole formation (Figure 20). Specifically, the Put-in-Bay Dolomite is underlain by the Tymochtee Formation which contains lenses or pockets of anhydrite gypsum. At some time in the past, water filtered down through the surface materials, the Put-in-Bay Dolomite, and eventually into the Tymochtee anhydrite gypsum. Anhydrite gypsum has the property of swelling in contact with moisture. Hydration increases the volume from 33 to 63 percent. The drastic increase of volume exerted approximately one ton (0.16 tons) of pressure per square inch (centimeter) on the surrounding materials. Such pressure caused a doming of the overlying Put-in-Bay rock structure. Later, the gypsum was dissolved away by solution leaving a large, unsupported subterranean cavern. Eventually, the roof of the cavern collapsed, forming crescent-shaped caves and caverns around the perimeter. The collapse generally formed large shallow circular depressions on the land surface and created small caves around the margins of these collapse features. In areas of Catawba and Marblehead, the lenese of anhydrite may have been thinner and less extensive producing only a slight doming, and eventually resulting in the formation of a sinkhole rather than a cave. The lower levels of many of the caves, formed either by solution or collapse, are now flooded by water coming in, along cracks and solution openings, from the lake and thus causing ground water pollution problems. Perry's Cave on South Bass Island and Crystal Rock Cave on the south shore of Sandusky Bay near Castalia are the only caves of this type open to the public.

Crystal Cave is the most unusual cave on South Bass Island because of its mineral deposits. The walls are completely covered to a thickness of two feet (60 cm) by beautiful blue celestite cyrstals ($SrSO_4$). These are very large, usually ranging from eight to fiftenn inches (20 cm to 38 cm) in length and are tabular in form. The appearance of the interior of this cave is that of an immense geode. This cave was discovered by Gustav Heineman in 1891, while digging a water well. The cave is about 30 feet (9 meters) below ground level



EXPLANATION OF FIGURES

A An ideal cross-section showing the anhydrite in place.
B The uplifting of the overlying strata by the anhydrite hydration into gypsum.
C Cavern left by gypsum going into solution.
D Collapse of the overlying strata and the formation of new caves around the edges.

Figure 20. Theory of Cave Formation on South Bass Island.

and consists of two small connected rooms. It had an original height of about three feet (1 meter); crystals removed from the floor when the cave was deepened were sold to fireworks manufacturers for the strontium. Crystal Cave is open to the public during the summer months.

Glacial Geology

Formation of the Lake Erie Basin. Geologically speaking, the last glacier retreated from the Lake Erie basin in very recent times, less than 12,000 years ago. The glacial story starts much earlier. About a million years ago, the first ice sheets invaded the Lake Erie region from the northeast. Geologists refer to this segment of the earth's history as the Pleistocene Epoch or Ice Age. As the ice overrode the resistant limestone which now forms the brink of Niagara Falls, it dug deeply into the softer Devonian shales of western New York. The ice front was obstructed by the steeply rising Portage Escarpment which lies a few miles inland of the present south shore of the lake between Cleveland and Buffalo (Figure 3). Thus, the glacier was deflected to the west along the outcrop of the soft shale. These shale were scoured to form the deep bottom of the narrow eastern basin (Figure 2). Farther west where the width of the shale belt is greater, glacial erosion resulted in the broader, but shallower central basin. The western basin owes its islands, reefs and shallowness to the tough Devonian and Silurian limestones and dolomites which resisted glacial scour.

The preglacial topography of the Lake Erie basin can be inferred from test borings and seismic measurements of the sediments overlying the bedrock surface (Figure 21). During the long period between the deposition of Paleozoic sediments in the region and the first glacier advance, approximately 300 million years, an extensive river drainage system was cut into the rocks. A trellis-shaped stream pattern formed in the islands area while the main-trunk stream entered the present lake basin from the northwest and exited in the vicinity of the Niagara

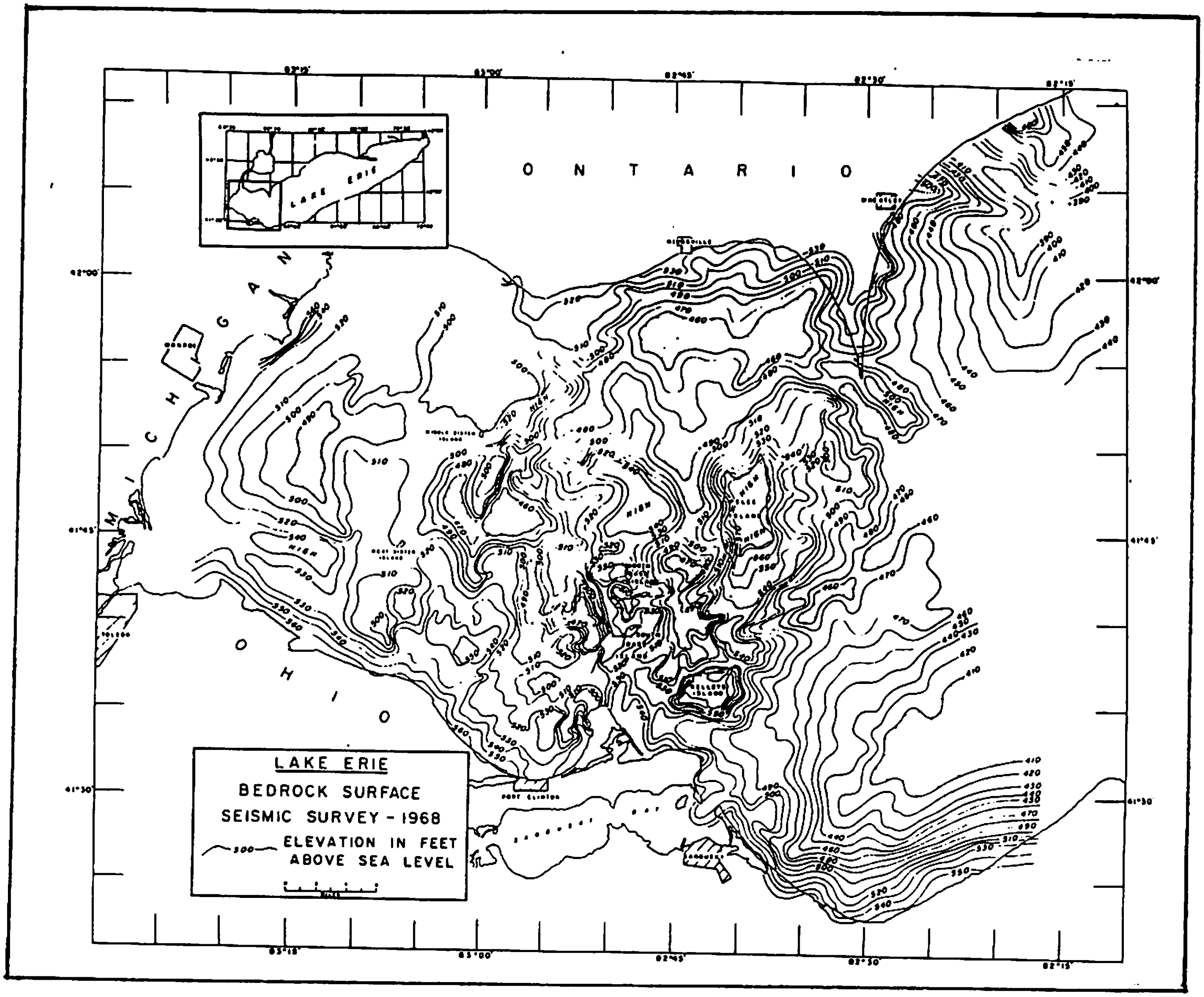


Figure 21. Preglacial Topography of Western Lake Erie Inferred from Bedrock Surface.

River (Figure 22). The Pleistocene glaciers followed these preglacial valleys, scouring them deeper and smoothing their meanders as they move southwest (Figure 23). The islands and reefs are probably high ground or hills between the trellis streams. The end result was greatly broader and deeper stream valleys. Since the retreat of the last glacier over 100 feet of sediment has been deposited in many of the glaciated valleys to give the present Lake Erie a much smoother and flatter bottom than it had when water first filled the basin.

Glacial Lake Stages. As the ice sheets paused in their advance or retreat, ridges known as moraines were built up of rock debris at the ice margins. The debris, often called glacial till is composed of a heterogenous mixture of rock fragments ranging in size from clay to boulders. In places, end moraines were deposited in such a way as to dam the natural drainage and thereby forming large lakes in the scoured depressions (Figure 24). Lake Erie is a remnant of such a lake, which at its highest stage (known as Lake Maumee) was over 800 feet (244 meters) above sea level, which is 230 feet (70 meters) above the present level of Lake Erie. Lake Maumee extended as far southwest as the present city of Fort Wayne, Indiana (Figure 25). At that time, drainage from the lake was toward the southwest via the Wabash and Mississippi Rivers to the Gulf of Mexico. As the ice retreated, other outlets were uncovered and several lake stages (Figure 25) were formed at successively lower levels, except for minor readvances of the ice which blocked outlets and caused temporarily higher lake levels.

The foregoing sequence of events occurred in a 2,000-year span of time from 14,000 to 12,000 years ago (Table 4). When the last glacier retreated from the vicinity of Buffalo, New York, a new drainage outlet became available through the Niagara River. However, the new outlet was as much as 100 feet (30 m) lower than at present because the land surface had been depressed by the weight of glacial ice which was approximately one mile (1.6 km) thick.

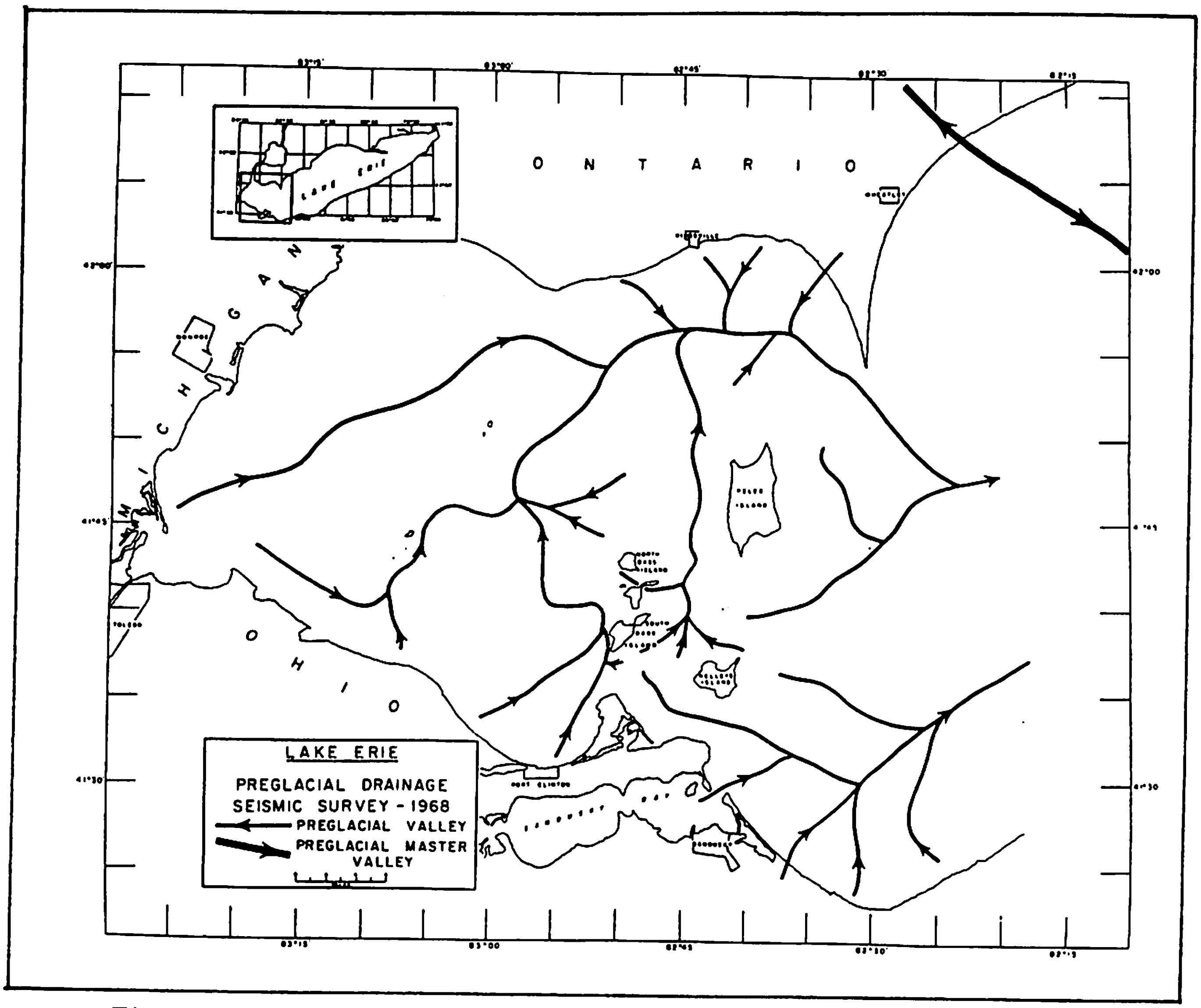


Figure 22. Preglacial Drainage in Western Lake Erie Inferred from Bedrock Surface.

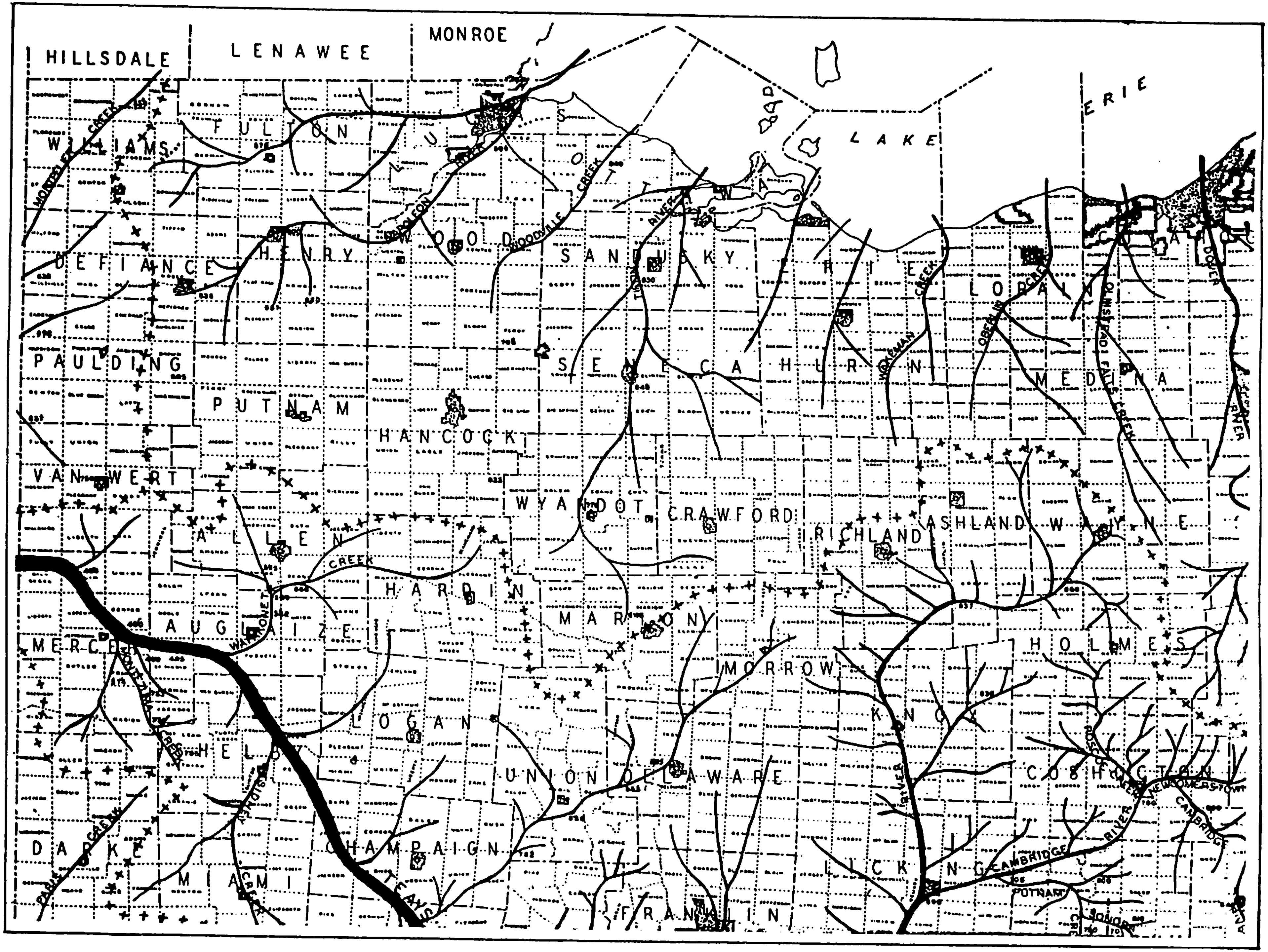


Figure 23. Preglacial Drainage (Teays Stage) in Northwestern Ohio Inferred from Well Logs (Compare with Figure 22).

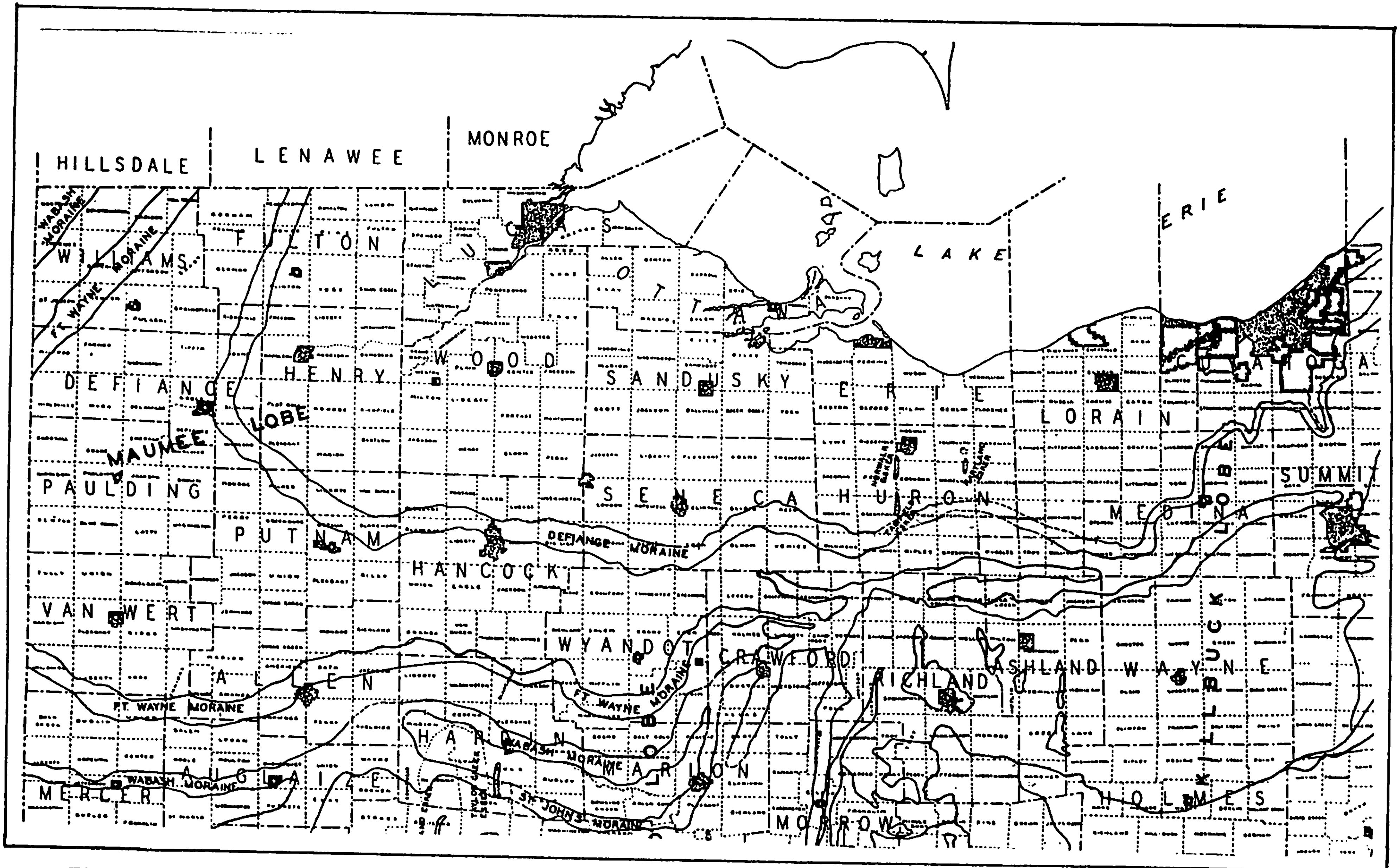


Figure 24. Glacial End Moraines in Northwest Ohio.

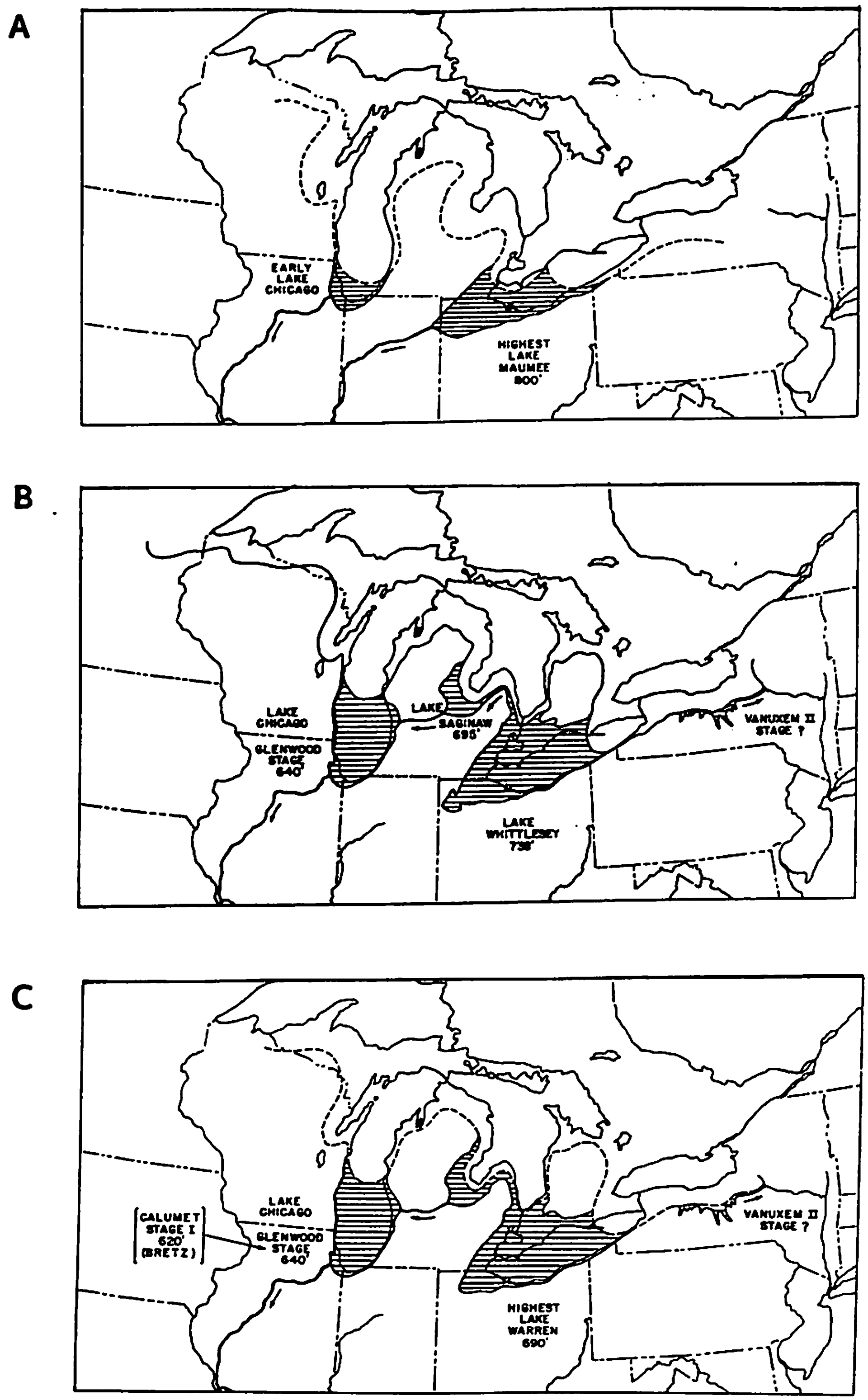


Figure 25. Glacial Lake Stages of the Lake Erie Basin: A) Lake Maumee, B) Lake Whittlesey, and C) Lake Warren.

This new and very low outlet caused a massive flood of water to exit the lake basin toward the east, resulting in draining the western end of the lake and the formation of separate, shallow lakes in the central and eastern portions of the lake basin. During this low lake stage (12,000 to 4,000 years ago) much of the western basin was dry and exposed to erosion, which greatly altered and reshaped the bottom surface. The Niagara outlet gradually rebounded to its present elevation, and Lake Erie correspondingly rose from this low elevation of 470 feet (140 m) to its present level. As the lake rose, waves and currents cut into the lake bottom, locally excavating the glacial deposits and exposing some of the shallowly buried bedrock. The exposed bedrock now forms the islands, reefs, and rocky shorelines of the lake.

TABLE 4

GLACIAL LAKE STAGES OF THE LAKE ERIE BASIN

Lake stage	Age (years B.P.)[2]	Elevation (feet above sea level)	Reason for change in level	Outlet
Erie (modern)	4,300	570	Isostatic uplift to the north	Niagara River
Erie (early)	12,200	490-470	Continued ice retreat	Niagara River
Lundy		640-620	Erosion of outlet and continued ice retreat	Mohawk River or west to Lake Calumet or Lake Glenwood
Warren		680-665	Continued ice advance (Valders Drift)	Grand River, Mich.
Wayne		655	Advance of ice	Mohawk River, N. Y.
Low water stage		?	Extensive retreat of ice	Niagara River(?)
Whittlesey	13,000	735	Readvance of ice (Port Huron Moraine)	Grand River, Mich.
Low water stage		?	Extensive retreat of ice	Niagara River(?)
Arkona		710-695	Retreat of ice and erosion of outlet	Grand River, Mich.
Maumee III		780	Readvance of ice (Lake Border Moraine)	Wabash River, Ind.
Maumee II		760	Continued retreat of ice	Grand River, Mich.
Maumee I	14,000	800	Formation of first major lake stage in depression between ice and Defiance Moraine	Wabash River, Ind.

Ancient Beach Ridges. Low, continuous sandy ridges are common in northern Ohio, often within a few miles of Lake Erie. Numerous east-west roads follow these ridges and many early homes were built on them. Each ridge represents an ancient beach, formed along the shore of former lakes which once occupied the Lake Erie basin at elevation much higher than the present lake. These former lakes are known as Maumee, Arkona, Whittlesey, Warren, Wayne, Grassmere, and Lundy (Figure 26). Because these lakes each had a different outline and each stood at a different elevation, each stage is marked by a separate set of beaches at a characteristic elevation. The three most prominent ridges are illustrated in Figure 27. In some places, such as Amherst, Berlin Heights, and Castalia, where the former lake shore was a rocky, spectacular cliff features resembling sea caves and sea stacks can be seen.

Sediments

The bottom deposits of Lake Erie consits of silt and clay muds, sand and gravel, peat, compact glacio-lacustrine clays, glacial till, shoals of limestone and dolomite bedrock and rubble, shale bedrock shelves, and erratic cobbles and boulders composed chiefly of igneous and metamorphic rocks. The distribution of bottom sediments is closely related to the bottom topography. The broad, flat areas of the western and central basins, and the deep areas of the eastern basin have mud bottoms (Figure 28). Midlake bars and nearshore slopes are comprised mostly of sand and gravel or glacial till. Rock is exposed in the shoals of western Lake Erie and along the south shore of the central basin and both shores of the eastern basin. In general, sand is limited along the shoreline, but extensive dunes have been formed at several places, notably at the base and southwestern side of Long Point, Point Abino, and Sturgeon Point, all in eastern Lake Erie. These dunes were formed presumably under the influence of the prevailing southwest winds. Littoral currents have concentrated sand

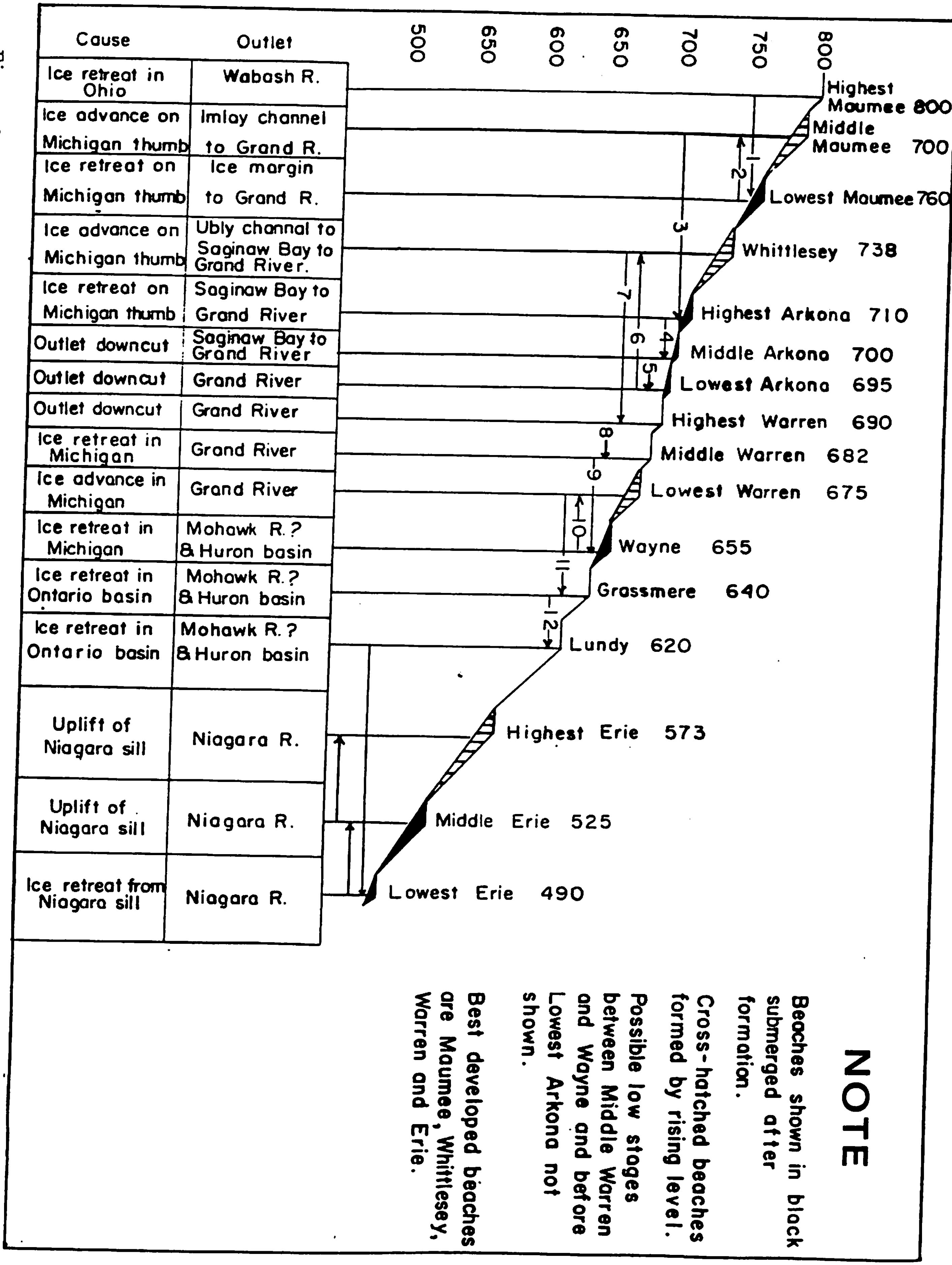


Figure 26. Beach Ridges Formed by Glacial Lakes in the Lake Erie Basin.

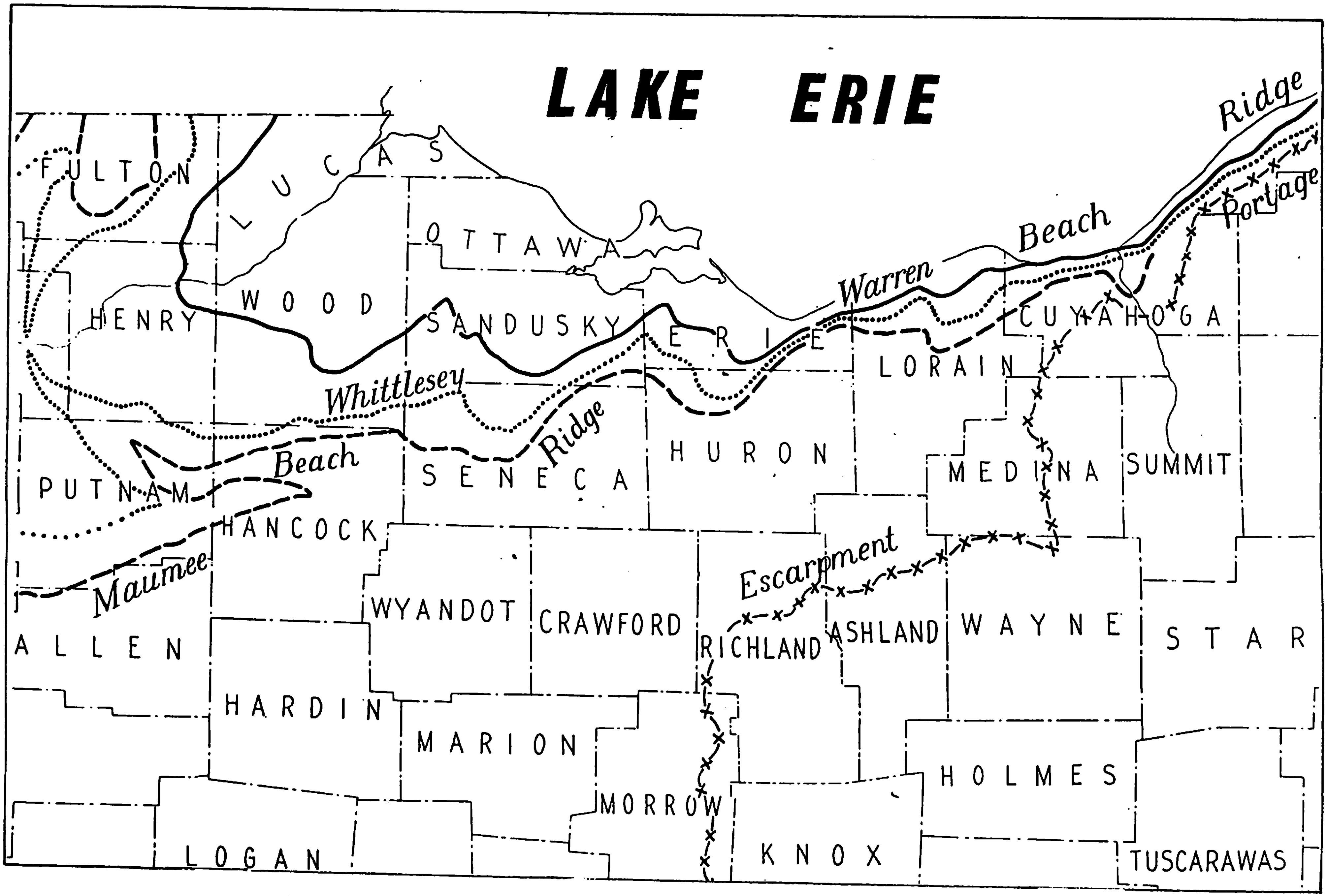


Figure 27. Ancient Beach Ridges in Northcentral Ohio.

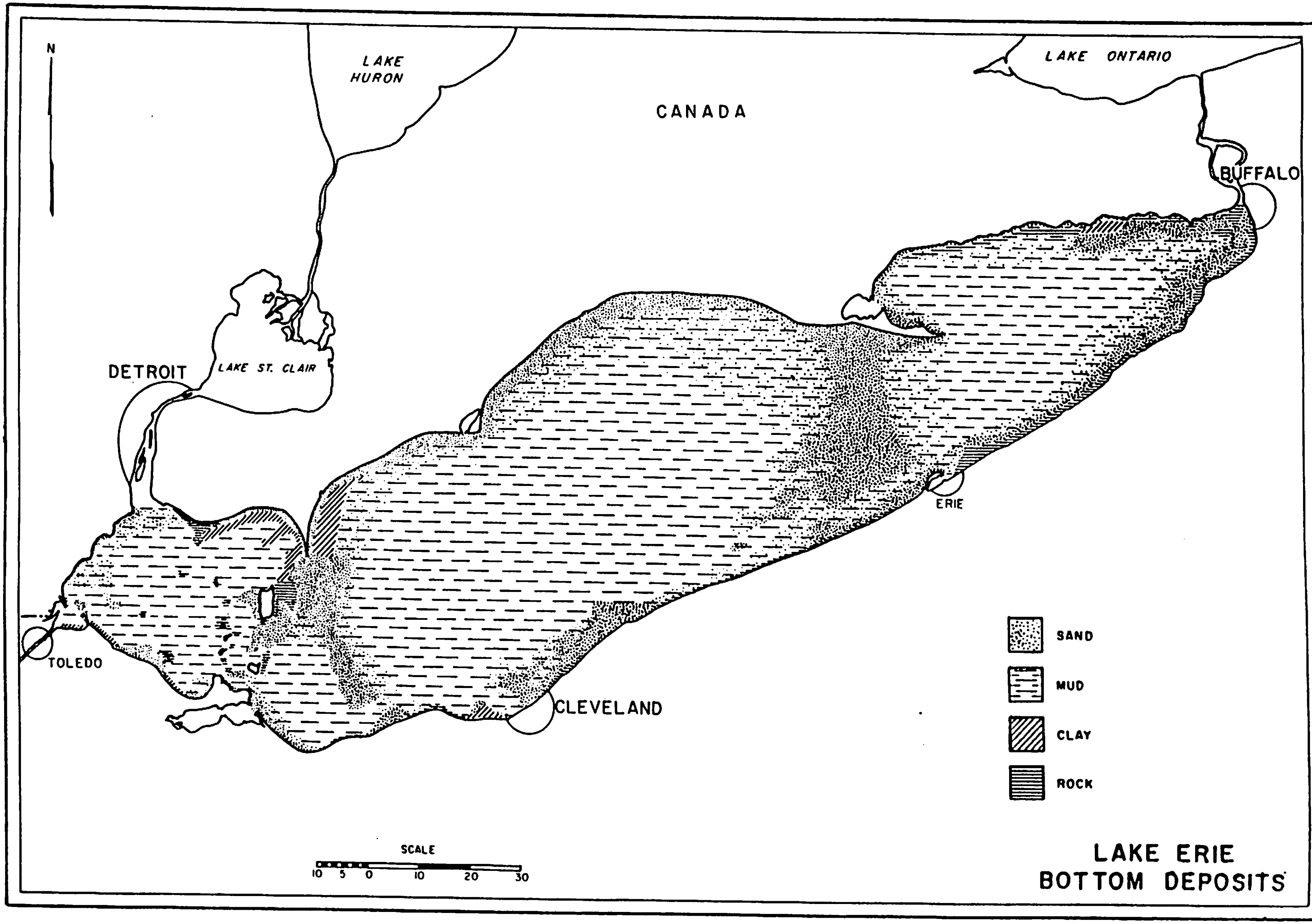


Figure 28. Lake Erie Sediments.

spits, baymouth bars, and harbor breakwalls at such places as Point Pelee, Pointe Aux Pins, and Long Point, Ontario; North Cape, Michigan; East Harbor, Cedar Point, Vermilion Harbor, and Fairport Harbor, Ohio; and Presque Isle, Pennsylvania.

The bottom sediments of the eastern basin of Lake Erie are mostly silt and clay muds bounded by relatively steep slopes of sand and gravel or rock. The massive spits at Presque Isle and Long Point are the largest accumulation of beach sand in Lake Erie. Bedrock is exposed in a narrow strip along most of the shoreline: black shale on the south shore and fossiliferous gray limestone on the north shore.

The bottom surface material of the Ohio portion of central Lake Erie consists of silt and clay (77 percent), sand and gravel (22 percent), and shoal bedrock (1 percent). The unconsolidated material appears to have been derived mainly from glacial deposits, with bedrock supplying a lesser amount of material. Sand and gravel deposits and till occur near the south shore, particularly eastward from Cleveland. Extensive glacial clay deposits are exposed along the north shore of the basin. Large quantities of sand and gravel occur north of Vermilion, nearshore from Cleveland to Fairport, and midlake off Ashtabula and Conneaut. Commercial sand and gravl dredging areas have been designated on both sides of the international boundary on a low morainal ridge between Vermilion and Point Pelee and on the bar between Erie, Pennsylvania and Long Point. Ohio has also assigned another dredging area five miles (8 km) northwest of Fairport in an ancient delta deposit from the Grand River when its mouth was in the vicinity of Mentor Marsh.

The bottom deposits of the Ohio portion of western Lake Erie (Figure 29) are composed mainly of mud, semifluid silt-and clay-sized material (58 percent). Sand (17 percent), mixtures of mud and sand (12 percent), mixtures of sand, gravel, and coarser material (7 percent), glacio-lacustrine clay (3 percent),

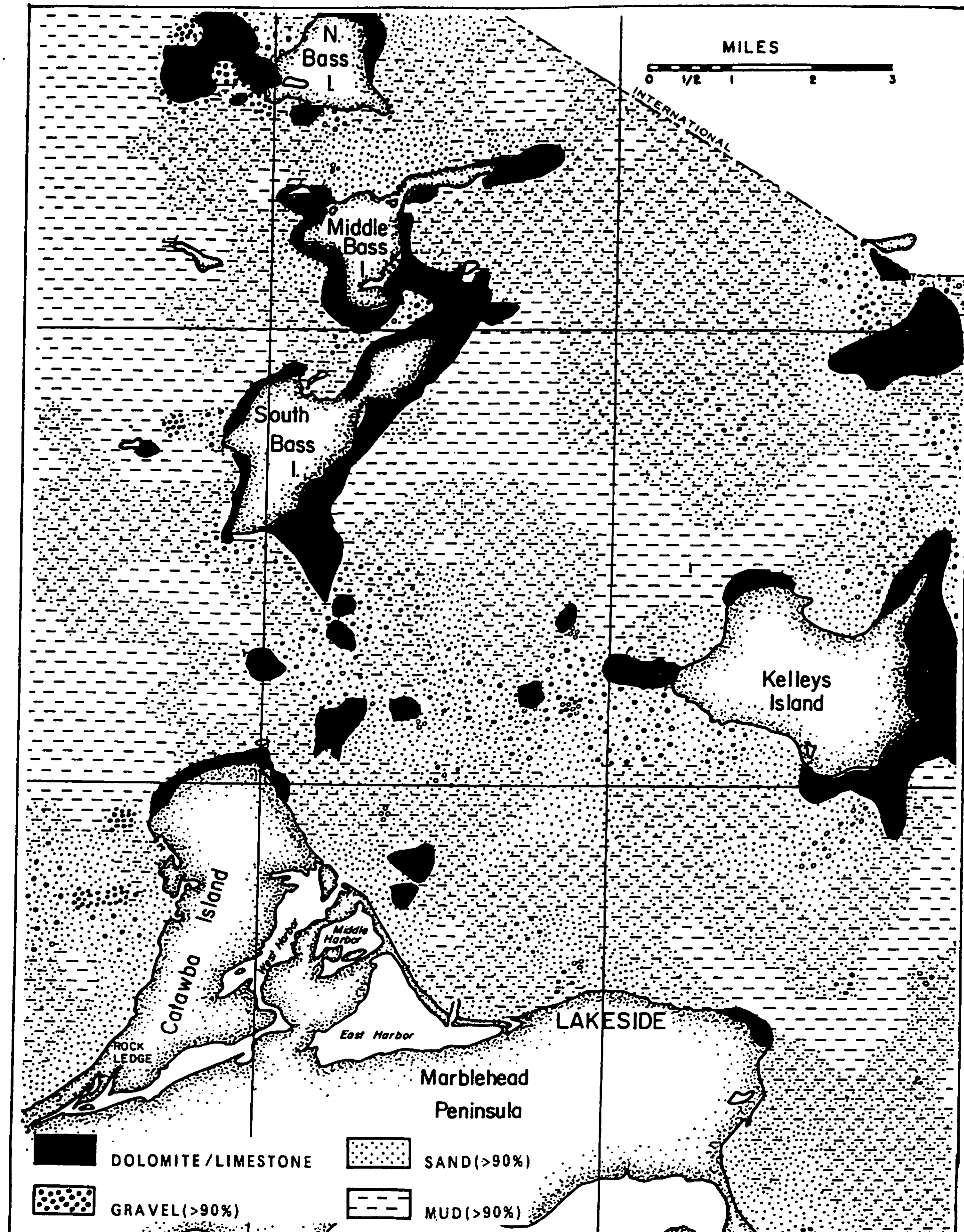


Figure 29. Distribution of Bottom Deposits in Western Lake Erie.

and limestone/dolomite bedrock (3 percent) account for the remaining bottom material. Peat and plant detritus occur in isolated areas along the low, marshy shores. Sand concentration in Maumee Bay and near the entrance to Sandusky Bay are sites of commercial dredging.

Turtle Island, in Maumee Bay, is the only natural island in western Lake Erie not composed of bedrock. Turtle Island is an elevated terminous of sand spit that was formed by littoral currents. Erosion of this sandy material has reduced the size of the island from seven acres (3 hectares) to its present 1.5 acres (0.6 hectares) in the past fifty years. The island is now protected by a seawall and has no beaches.

Test borings into the subsurface bottom deposits in the vicinity of the Lake Erie islands show a predominance of lake-deposited material with only thin glacial till overlying bedrock (Figure 30). Preglacial buried valleys are indicated by bedrock topography, which in places has 200 feet (60 meters) of relief. Some boring also indicates the possibility of interglacial or post-blacial buried valleys and lower lake stages. Beach deposits and peat have been found 35 to 80 feet (11 to 24 meters) below the present lake level, buried under more recent deep-water sediments. A radiocarbon date of 6550 YBP (year before present) was obtained for a sample of oak wood buried 23 feet (7 meters) below the lake bottom. This date permits the calculation of a sedimentation rate of 0.35 feet (10.6 cm)/century. A deep boring in the central basin 30 miles (48 km) north of Cleveland (water depth of 84 feet (26 meters) yielded bottom surface sediment of gray-brown mud. Successively lower sampling at five-foot (1.5-m) intervals yielded soft gray-brown clay that became stiffer downward. At 111 feet (34 meters) of bottom penetration, rock or hard glacial till that could not be penetrated was reached. Seismic reflection surveys have revealed a maximum unconsolidated sediment thickness of 275 feet (84 meters) in the central basin and 130 feet (40 meters) in the western basin.

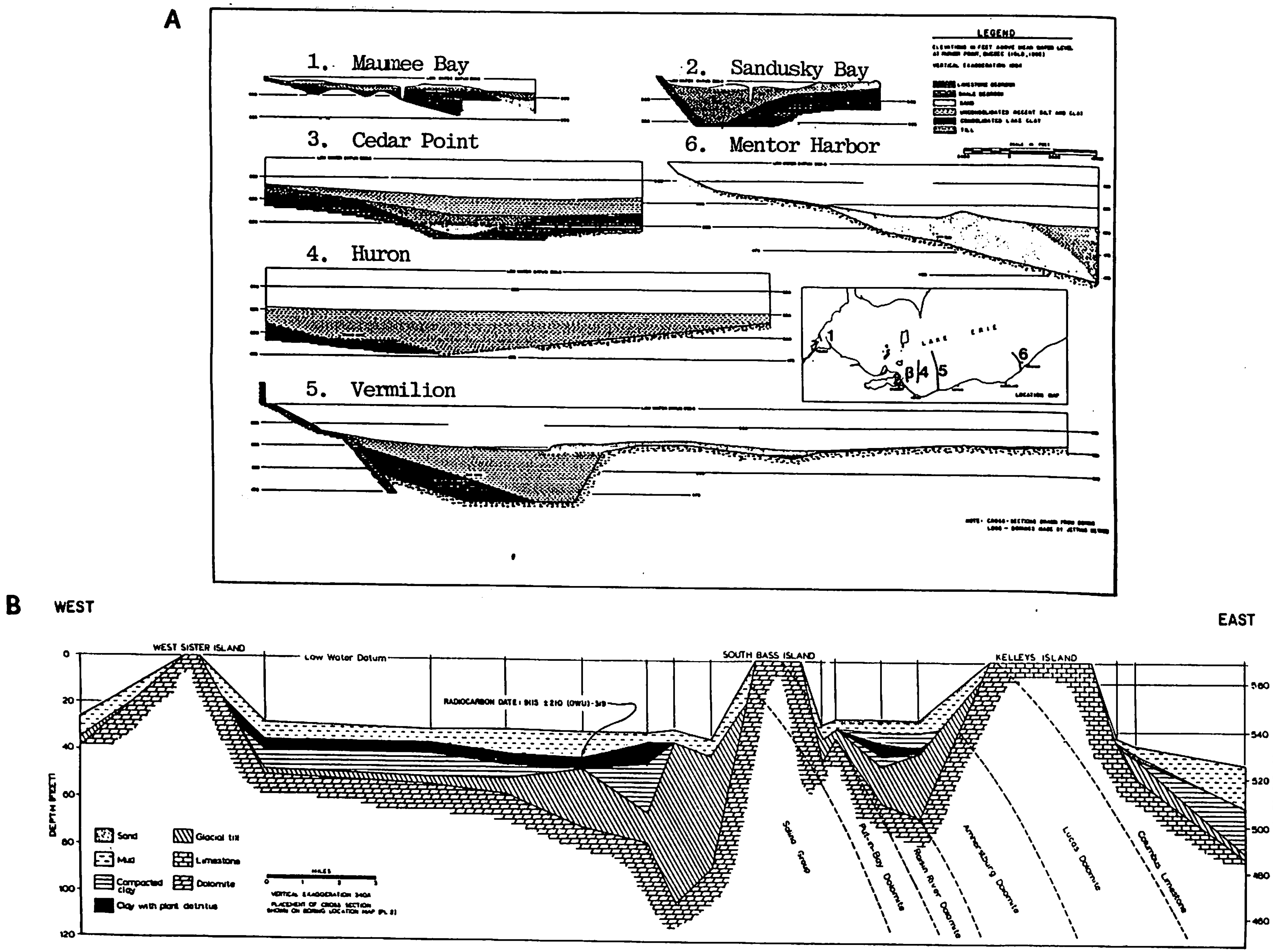


Figure 30. Cross-sections of Bottom Deposits in Lake Erie: A) Central and Western Basins and B) Island Region of Western Basin.

Recent sedimentation in Lake Erie can be attributed to two primary sources: suspended solids from inflowing streams and bluff material contributed by shore erosion. Over six million metric tons of clay, silt and sand are transported annually to Lake Erie from its tributaries. Shore erosion of glacial till and lacustrine clay bluffs is an acute problem at many locations along the shoreline. Maximum shore erosion based on volume of material removed occurs along the north shore of the central basin between Port Stanley and the base of Long Point, although the low-lying south shore of Maumee Bay has experienced the maximum rate of shore recession, which has been as high as 20 feet (6 meters) per year. Estimates of erosion rates for the Ohio shoreline indicate that about 10,000 cubic yards (7,600 cubic meters) of bluff material per mile (2 km) of shore eroded each year. Extended for the entire shore of the lake, 8,500,000 cubic yards (6,500,000 cubic meters) are contributed to the lake each year, which would equate to a thickness of 0.01 inches (0.25 mm) if spread uniformly over the lake bottom.

Mineral Resources

The mineral resources of the Lake Erie Basin are few in number, but are significant to the economy of northern Ohio. Mineral deposits within the basin, but unrelated to the lake include: 1) limestone and dolomite, 2) sandstone, 3) shale and glacial glay, 4) gypsum, 5) salt and brines, and 6) gas and oil. Minerals directly related to Lake Erie are: 1) sand and gravel from beach, dune, and bottom deposits, 2) lake clay, 3) peat, marl, and bog ores, and 4) water itself.

The Ohio Shore Erosion Act of 1955 provides for leases and permits for persons desiring to remove sand, gravel, stone, gas and oil, and other minerals from and under the bed of Lake Erie. The royalties derived from the sale of minerals on and below the lake bottom are used for the support of Lake Erie research activities, the protection of Lake Erie shores from erosion, and for planning and construction of facilities for the recreational use of Lake Erie.

At present, Ohio has established six commercial sand and gravel dredging areas in Lake Erie (Figure 31). Two are located in Maumee Bay on either side of the Toledo navigation channel; one is northwest of the Sandusky channel off Cedar Point; two are at areas 6 and 12 miles (10 and 20 km) offshore between Lorain and Vermilion (Figure 32); and the last is five miles offshore near Fairport Harbor. Several companies presently extract over half a million cubic yards of sand and gravel from the bed of Lake Erie annually.

The International Salt Company on Whiskey Island in Cleveland and Morton Salt Company at the mouth of the Grand River in Fairport Harbor extract over two million tons of salt from beneath Lake Erie per year. The mine at Fairport was opened in June of 1956 and has a capacity of 12,000 tons per day. It is considered to be one of the world's biggest salt mines, and is the deepest salt mine, extending to a depth of 2,025 feet (617 meters). The producing horizon is in the Salina Formation of Silurian age and is about 22 feet (6.7 meters) thick. The mining technique employed is the "room-and-pillar method," providing for the excavation of large "rooms" and the retention of blocks or "pillars" of salt between the rooms, which serve as natural support for the mine. By this technique, approximately 50 percent of the salt will remain untouched in the mine. Eventually, a system of tunnels will provide a five-mile subterranean network extending under Lake Erie. Estimated reserves of salt exceed 200 million tons, or the equivalent of nearly 200 years of production at the present rate. Full production capacity of the mine is between 300 to 500 tons per hour. The Cleveland mine was opened in 1962 after considerable difficulty in grouting an 88-foot-thick (26.8-meter) layer of Oriskany Sandstone at 1300 feet below ground level. Estimates indicate that flows of 20,000 gallons of water per minute (1,260 liters/sec) could have been expected in the shaft if the grouting program

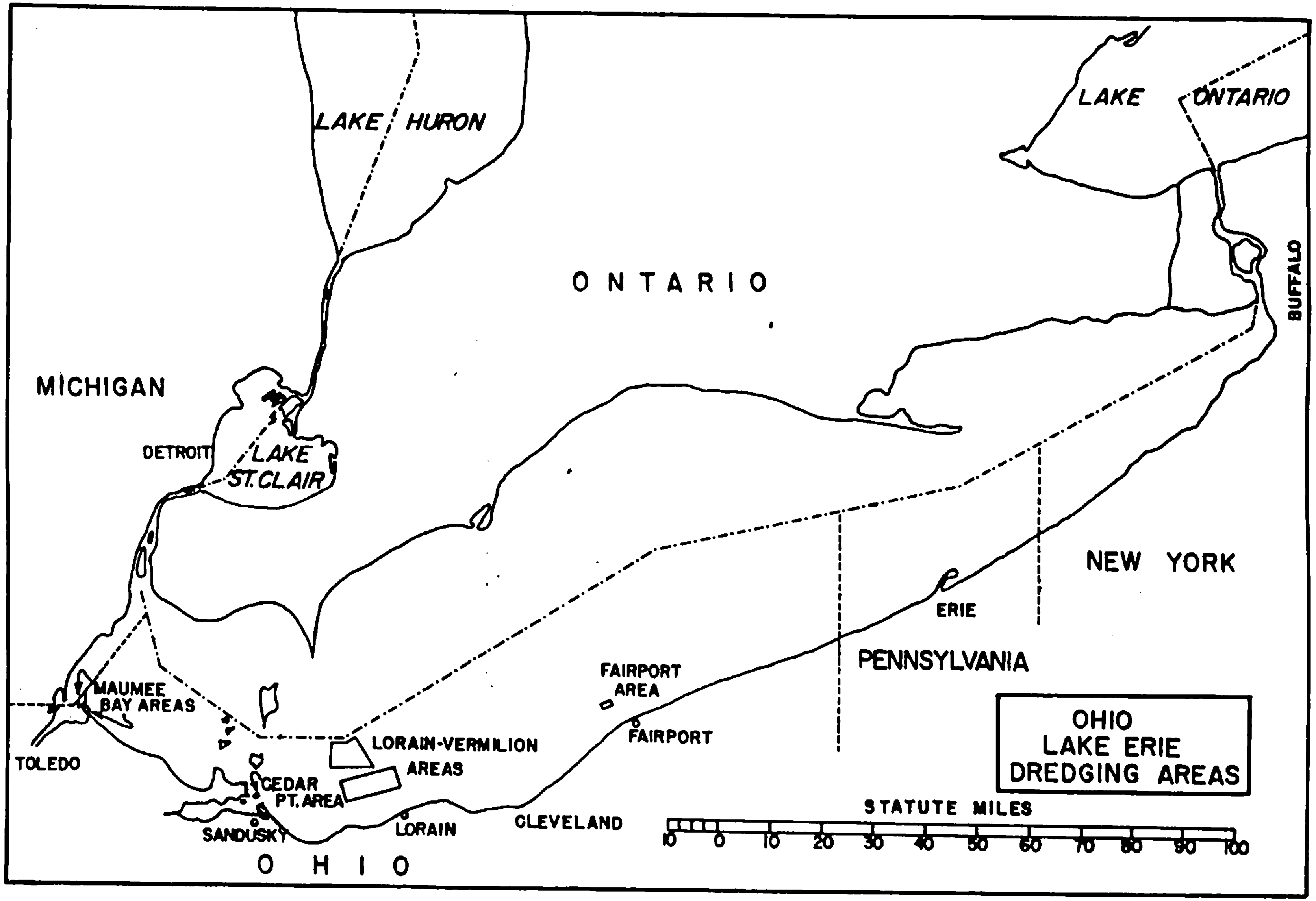


Figure 31. Sand and Gravel Dredging Areas in the Ohio Waters at Lake Erie.

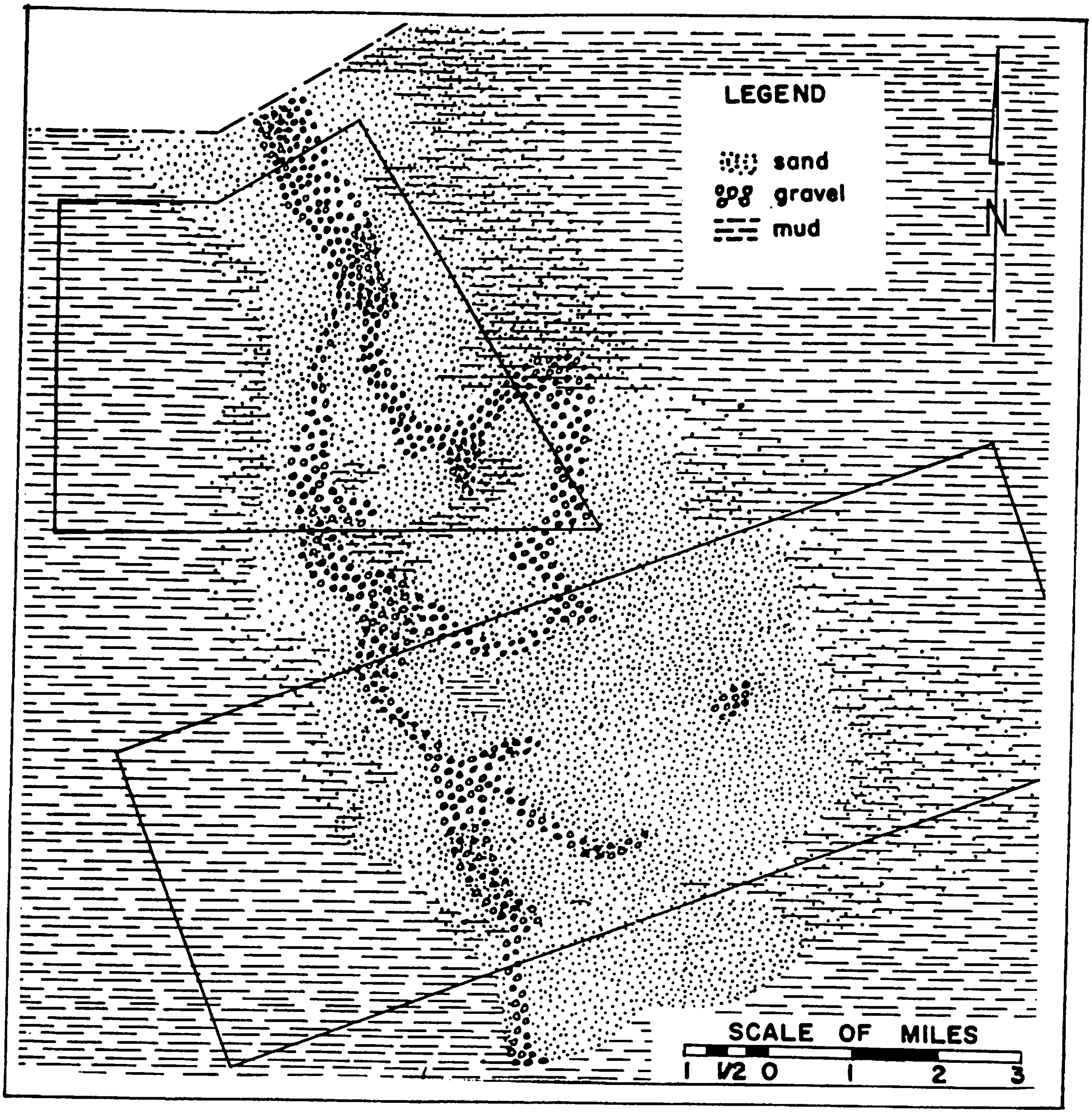


Figure 32. Bottom Surface Material of the Lorain-Vermilion Sand and Gravel Dredging Area (See Figure 31 for Location).

had not been carried out. The producing horizon is also in the Salina Formation but the updip location of the mine requires only a 1816-foot (554-meter) shaft to reach the producing zone. Similar mining techniques to those used at Fairport and employed in the Cleveland mine. The rooms are 17 feet (5.2 meters) high and 45 feet (13.7 meters) wide. The production hoist, with two 20-ton-capacity skips in balance, can deliver salt from the mine to the surface at a rate of 700 tons per hour. Present extraction of salt from under Lake Erie is taking place in the vicinity of the harbor breakwall.

Over 1,500 off-shore gas wells have been drilled during the past 30 years in the Canadian waters of Lake Erie. Approximately 60 percent of the wells were successful. Canadian gas production in the Long Point Bay area is found at a depth of about 1,200 feet (370 meters) in the Clinton Formation (Silurian) and additional gas is believed to be present in deeper formations. Annually, four billion cubic feet (meter) of gas are produced from beneath the Canadian water and prospects for reserves under the Ohio side of Lake Erie are considered excellent.

Peat is found locally along the lake shore and in the vicinity of the abandoned glacial lake ridges where palludal conditions have existed. The broad level topography near the lake and the irregular lake shore favors the development of marshes. The lower courses of the streams are usually sluggish and before the advent of harbor dredging were commonly clogged with vegetation. In general, such accumulations of plant debris are shallow and of little commercial significance. Marsh areas in Lucas, Ottawa, Erie and Lake Counties contain the majority of the peat deposits associated with Lake Erie. Peat has been utilized, to a limited extent, in the past as a low grade fuel. It is now used extensively for humidity control in greenhouses, for adding acidity to soils, and for a moisture and mineral retention agent in fertilizers, and for a packing filler.

Marl is a mixture of clay material and calcium carbonate in varying proportions.

Marl is also found in shallow lakes and marshy areas, and is usually overlain by peat deposits. Marl forms by the incorporation of calcium carbonate, which is precipitated from the water by aquatic life, into the lacustrine bottom sediments. The most notable deposit of marl in the vicinity of Lake Erie is found near Castalia in Erie County. A marshy prairie of over 3,500 acres (1,400 hectares) extends north and west toward Sandusky Bay. Spring water, highly charged with lime, has given rise to this extensive marl deposit which in the past was used on large scale to produce Portland cement. Travertine or calcarious tufa are also associated with the Castalia marl beds.

Bog iron ores are formed by precipitation in springs and in surface waters in swamps and marshes. The iron is derived initially from the country rock (commonly the Bedford and Ohio shales) through the action of organic acids which cause the iron to be carried in a reduced state as a solution of ferrous bicarbonate. Bog ore is later precipitated as ferrous or ferric carbonate or hydroxite, depending upon the local conditions. These ores are found as scattered nodules or thin layers, one to two feet thick, up to several acres in extent. Bog ores have been found along the abandoned beach ridges from west of Vermilion to the Pennsylvania line. Bog iron ore deposits were used extensively during the early 1800s. At least 12 smelting operations were located along the lake shore during this period. These bog ores are not utilized today, but remain as potential resources because of their high manganese and phosphorus contents.

The most basic natural resource of the lake is water. Lake Erie contains more than 100,000 billion gallons (380 billion cubic meters) of water. In Ohio, nearly 2.7 billion gallson (10.2 million cubic meters) of water per day is withdrawn from Lake Erie for municipal and industrial uses. Approximately 70 percent of this amount is used for cooling in manufacturing processes. Nearly 15 percent is used for public water supply and the remaining 5 percent is used as process water in manufacturing. Non-withdrawal water uses include navigation, recreation, commercial and sport fishing, and waste disposal. The Great Lakes have become the fourth coastline of the United States since the advent of the St. Lawrence Seaway. Several of Ohio's ports have facilities for ocean vessels. International and interlake waterborne commerce is essential to the economy of northern Ohio. The navigation season on Lake Erie generally open in March or April and closes in mid-December, depending on ice conditions.

Coastal Processes

The record high water levels in Lake Erie during 1972 and 1973 contributed greatly to increased erosion of the shores. The narrow beaches fronting the shore bluffs of the islands have been submerged exposing the bluffs to direct wave attack and erosion by alonghsore currents. Severe storms have resulted in profound changes in shoreline configuration and disruption of man's use of the coastal zone. Most of Lake Erie's shores are characterized by easily eroded banks of glacial till and lacustrian sediments (Figure 33-A), while lesser reaches are composed of resistant bedrock bluffs. The shore of western Lake Erie consists of low banks of lake clay, while the bluffs of the central basin are more typically till capped by lake clay and sand which rise to 75 feet (23 meters) above lake level on the south shore and over 150 feet (46 meters) on the north shore. Resistant limestone and dolomite crops out only in 30-foot (9-meter) cliffs along the Ohio shore between Port Clinton and Sandusky, on all of the western Lake Erie islands, and in low headlands along much of the Ontario shore of eastern Lake Erie. Shale bedrock forms erosion-resistant, nearly vertical bluffs, 20-50 feet (6-15 meters) high, between Vermilion and Cleveland and from Erie to Buffalo.

Water level changes on Lake Erie are of two principal types: 1) long period and 2) short period oscillations. Long period fluctuations are related to volumetric changes of the lake, caused principally by variations in precipitations, evaporation and runoff. These changes include both seasonal fluctuations

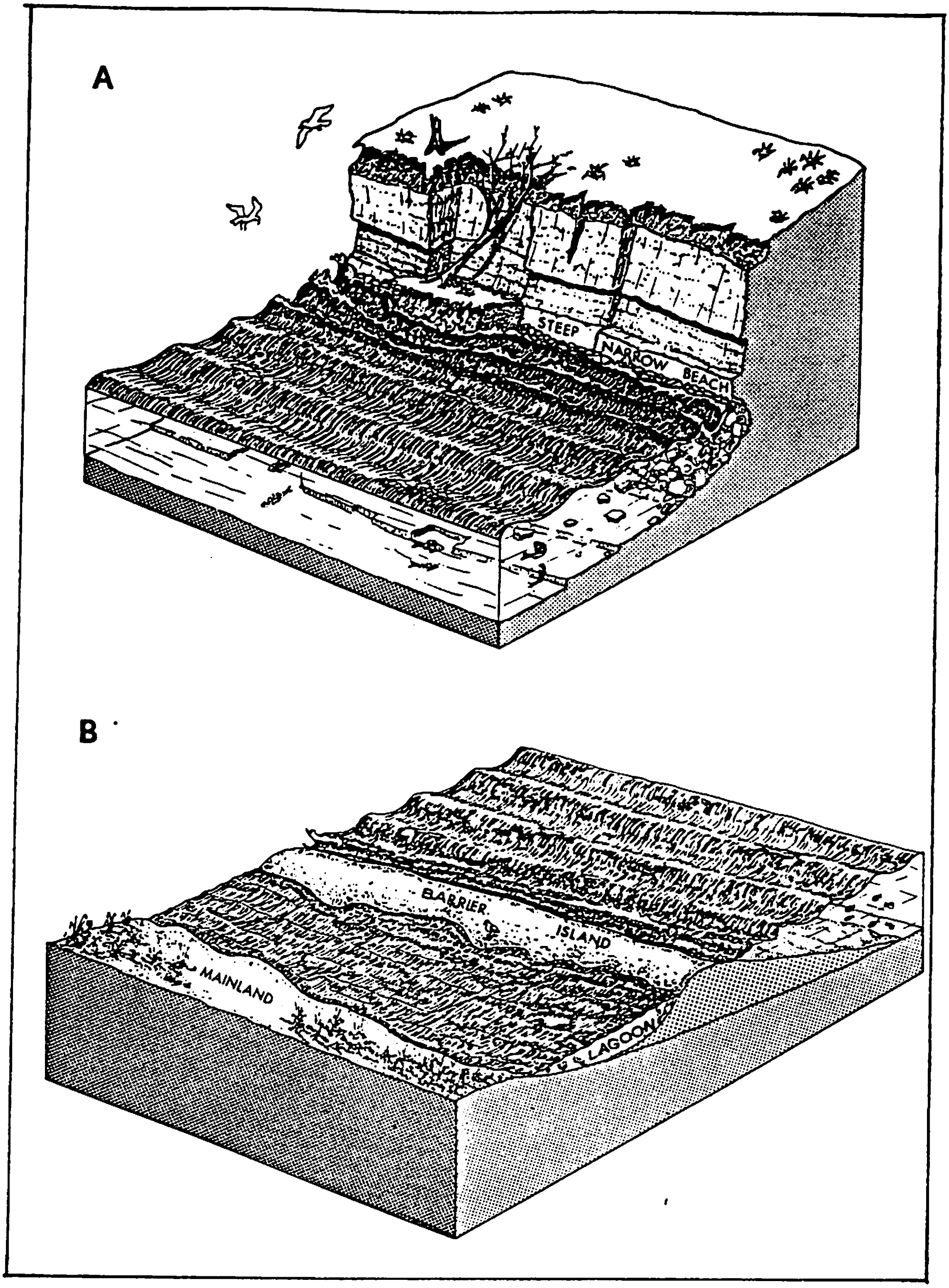


Figure 33. Coastline Morphology: A) Erosional Shoreline and B) Depositional Shoreline.

and those occurring over a period of several years. Short period fluctuations are due to a tilting of the lake surface by wind or atmospheric pressure differentials. Wind tides, seiches and harbor surges, which have periods from a few seconds to several days are examples of short term oscillations. Sun and lunar tides are negligible, resulting in maximum fluctuations of 0.11 feet (3.3 cm).

Water levels at the ends of Lake Erie (Toledo and Buffalo) have a much greater fluctuation than near the center. Tilting of the lake surface is analgous to the up and down movement of the ends of a teeter-totter while the center is stable. High water levels coupled with northeast storms have produced a maximum rise in level of 9 feet (2.7 meters) above Low Water Datum at Toledo. Conversely, low water and southwest winds have lowered the level to 7 feet (2.1 meters) below Datum, a range of 16 feet (4.8 meters). Under the influence of wind, currents tend to bank up water on the windward shore. This forced movement of the lake surface is known as <u>wind tide</u> and the amount of rise produced is the <u>wind setup</u>. The resulting free oscillation of the lake surface caused by the inequality of water level is called a <u>seiche</u>. Such free oscillations are nearly continuous in the islands region and most often have a period of 12 hours and amplitude of less than 2 feet (maximum amplitude: 5-6 feet).

The major seiches on Lake Erie are essentially parallel to the longitudinal axis of the lake. Seiches along this axis have a period of approximately 12-14 hours. Seiche periods as recorded for three years at a water level guage at Put-in-Bay on South Bass Island indicated that longitudinal seiches were in operation about 44 percent of the year (Figure 34). Surface winds from the southwest or northeast are likely to produce such seiches along the long axis of the lake. Wind records from Sandusky, Ohio are in agreement with the frequency of seiche periods; surface winds from these directions occur approximately 150 days (42 percent) of the year.

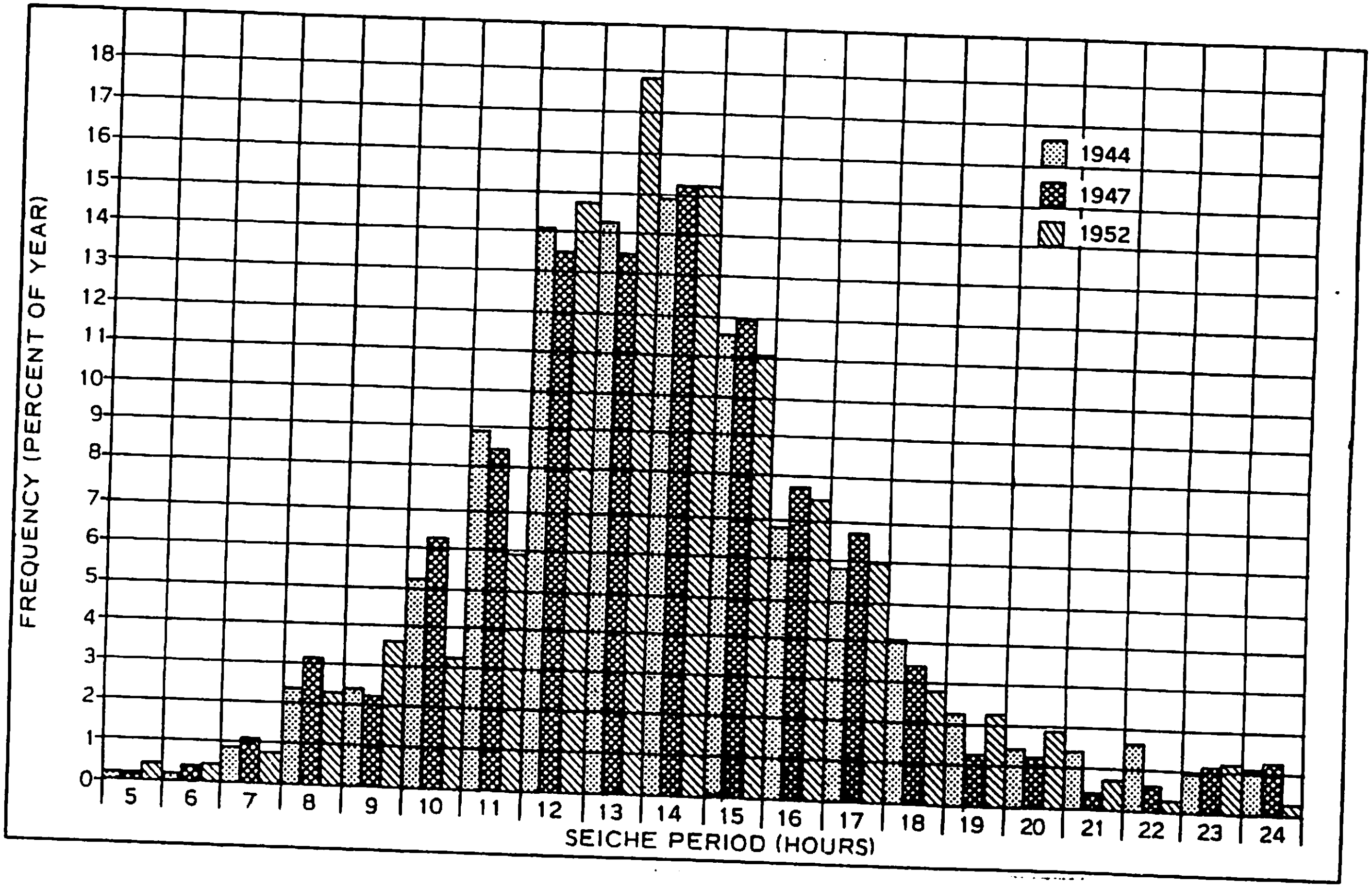


Figure 34. Annual Frequency of Occurrence of Seiche Periods at Put-in-Bay, Ohio.

Wave action follows wind action very closely on Lake Erie because of the shallowness of the lake. Swells, however, often continue into the next day after a storm subsides. The depth of the water and the direction, velocity, duration, and open water fetch of the wind collectively determine the characteristics of waves at a given location. The United States Army Corps of Engineers estimates that off Marblehead Peninsula, with a fetch of 150 miles and a wind velocity of 30 miles (48 km) per hour, the maximum wave for Lake Erie is developed in 20 hours. Given these conditions a wave of 12.5 feet (3.7 meters) high with a 6.5 second period can be developed. Waves of this height break offshore, but reformed waves up to 3.5 feet (1.1 meters) in height can reach the shoreline of the islands.

As waves approach the shoreline the water level rises at the shore and the excess water escapes as alongshore (littoral currents). These currents can be particularly rapid when waves approach the shore at angels other than perpendicular (up to 4 ft/sec or 1.2 m/sec) and can result in the transport of beach materials as large as cobbles and boulders. The currents are important agents of erosion, transportation, and deposition of sediments in the island region.

All of the islands are rockbound (or protected by a seawall as in the case of Turtle Island) and are undergoing very slow erosion by scour from waves and currents. However, during the recent period of high water many large blocks of dolomite have falled from high cliffs of several of the islands. This problem has become particularly acute at the south point of South Bass Island in 1976 and necessitated the relocation of the U. S. Coast Guard navigation light tower which was in danger of falling into the lake. The highest incident of erosion appears to take place in the spring and fall. Ground water seeping into cracks and joints in the rocks freezes, expands, and tends to split the rock from the cliffs, a process known as <u>frost wedging</u>. This process, coupled with frequent and severe storms in the spring and fall, has resulted in many offshore blocks of dolomite which ring the west shores of several of the islands.

The low eastern shores have experienced another problem during the high water period, flooding. Several homes and cottages have been destroyed or severely damaged during northeastern storms which have caused the lake to inundate the eastern shores. This problem has lessened in the past few years as the lake level has fallen to a nearly normal level.

Alongshore currents also produce excellent beaches. The best example in western Lake Erie is on one of the Canadian islands. Fish Point, a spit at the southern tip of Pelee Island, contains the largest depotis of sand in the island region. It is likely that the bulk of the sand has come from glacial moraine deposits of sand and gravel lying east and west of the island. Converging southerly currents along the east and west sides of the island have built the nearly two-mile-long spit.

In the north bay of Kelleys Island at the State Park accretion of sand has formed a bayhead beach, the largest sand deposit in the Ohio islands (Figure 33-B). The sand and gravel is mainly derived from erosion of the low glacial till banks of the bay's shore. Rattlesnake, Green and West Sister islands have pebble bars extending eastward from their eastern shores. The bars were probably formed by strong eastward-moving currents along the north and south shores of the islands. Sand and gravel beaches occur in small pockets on Middle Bass and South Bass Islands. The beaches are thin and are either residual material from the underlying till or are deposits trapped between the bedrock headlands. Wave and current action is vigorous throughout the islands region.

Lake Currents

The surface currents in the western half of the western basin are dominated by the Detroit River inflow (Figure 35). However, in the eastern half of the

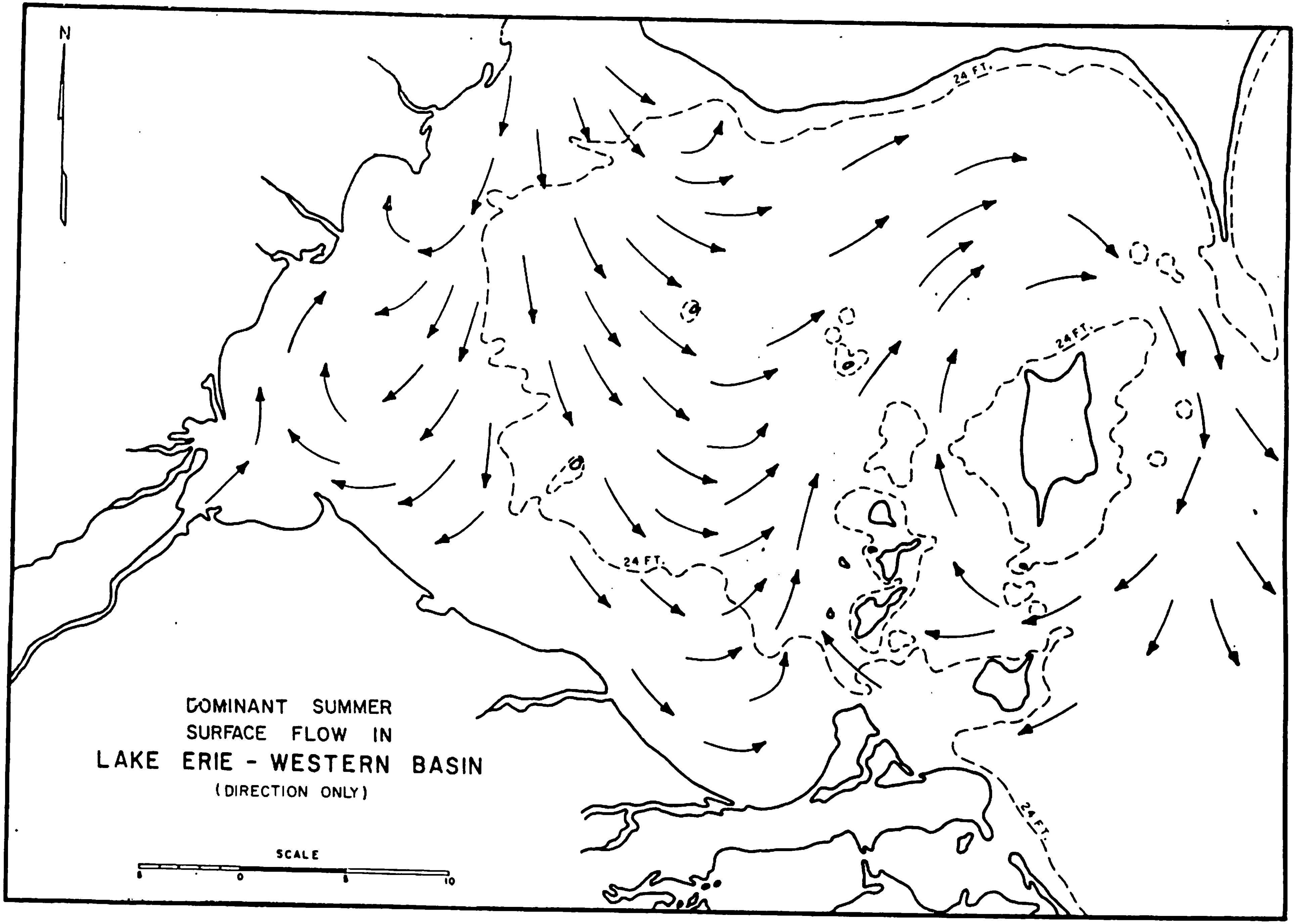


Figure 35. Summer Surface Currents in Western Lake Erie.

basin the surface flow becomes more influenced by the prevailing southwesterly winds, and this effect produces a clockwise flow around the islands. Eddy effects along the sides of the Detroit River inflow lead to sluggish movement of surface water west of Colchester, Ontario and between Stony Point, Michigan and Toledo. These eddies tend to retain waters contained within them, leading to the higher concentrations of pollutants found in these areas.

The surface flow of the western basin water is often changed by changes in wind direction and intensity. The effect of strong winds on surface circulation is to skim the surface water and move it in the direction toward which the wind is blowing. Thus with a sufficiently strong wind most of the surface water, except along the windward shore, may move in the same direction.

In summer, bottom currents in much of the western basin of Lake Erie are similar to surface currents, being dominated by the Detroit River inflow (Figure 36). However, in the island area the bottom currents are often the reverse of the surface currents with a counter-clockwise flow around the islands. Like the surface movement, bottom currents can also be changed by the wind, although it probably takes a stronger wind to create a major change of pattern. With strong winds, which cause major changes in water level, the bottom currents are essentially the reverse of surface currents.

Lake currents were measured at 68 stations in the island region under various wind conditions during a 10-year period. When data from these measurements were plotted to create current maps, one of the most striking features of these plots is that winds from any direction will normally drive surface currents downwind, while subsurface currents are often opposed to the wind. To compensate for the loss of surface water blown downwind, a returning flow of water is created along the bottom. Wind direction, bottom topography and shoreline configuration appear to be the major factors controlling current patterns.

The average recorded velocity for surface and bottom currents was 0.28 knots

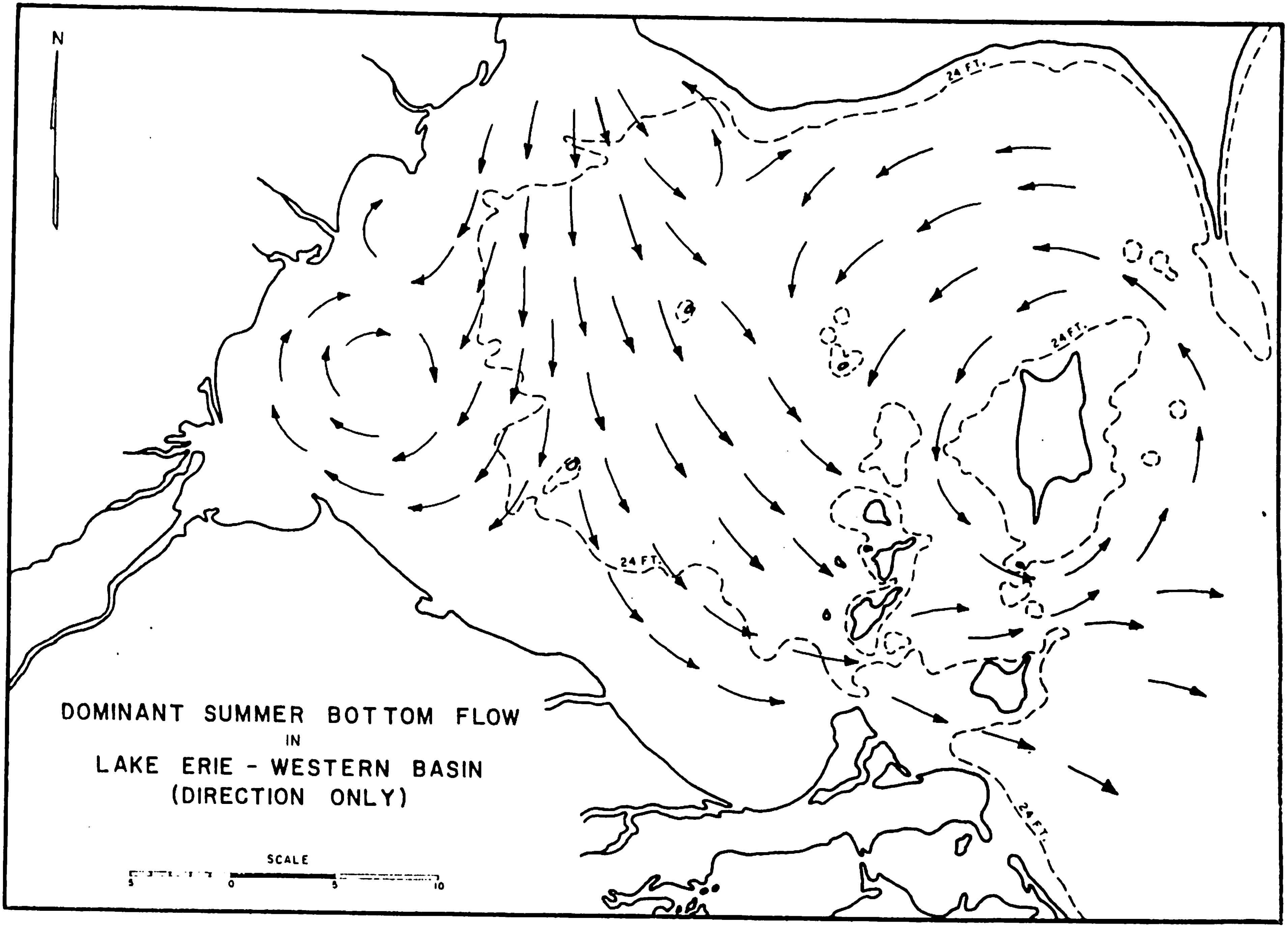


Figure 36. Summer. Bottom Currents in Western Lake Erie.

(14.4 cm/sec) and 0.15 knots (7.7 cm/sec), respectively. The highest velocities were found in restricted areas such as inter-island channels and in the vicinity of reefs. Currents in excess of 0.5 knots were found at 35% of the stations, while currents above 1.0 knots (50 cm/sec) were measured at only one station.

All of the submerged rock exposures within the region project above the surrounding bottom, and are generally swept clean of sediments by the currents. The relatively clean surface indicates that no permanent sedimentation is taking place on the reefs. However, sediment collectors that have been mounted on the reefs indicate that a considerable amount of sediment is being transported over the reefs to be deposited in deeper water. Because the reefs project above the bottom, they are generally areas of higher energy due to the forces of waves and currents. The habitat created closely simulates the environment found in the riffles and streams. Several fish species, particularly the walleye which commonly spawns in streams, appear to have enjoyed success in Lake Erie because of the availability of this type of habitat.

Wind-driven currents are, as the term impoies, the movements of water directly caused by wind stress at the water surface. These currents are the fastest and most variable in direction of large-scale water movements. Large volumes of water can be moved in a very short time, as in wind set-up. The effect of wind is over-riding in the water circulation of the central basin of Lake Erie. The orientation of the basin, with its long axis essentially parallel to the prevailing southwesterly winds makes this effect especially important.

The predominant summer surface water movement in central Lake Erie is as illustrated in Figure 37, based on the results of a drift card, drift bottle, and drogue studies made by several investigators. Surface currents do not exactly parallel the wind direction, but move somewhat to the right of it because of the Coriolis effect. The predominant pattern is essentially that of

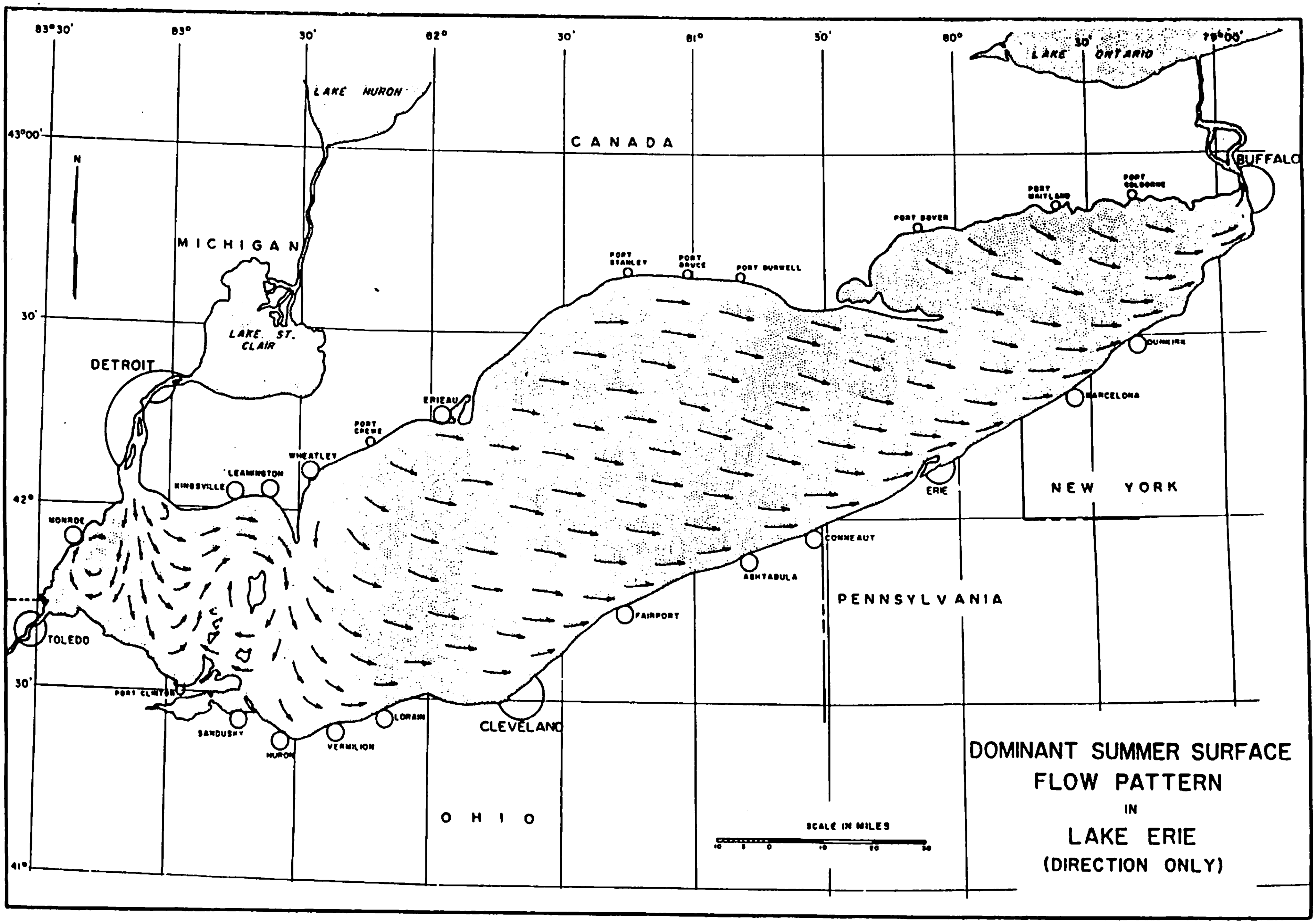


Figure 37. Summer, Surface Currents in Lake Erie.

resultant movement over an extended period, and at any one time, surface movement may be greatly different or even reversed, responding quickly to wind changes.

Bottom currents in central Lake Erie are not similar to surface currents. Because surface currents are generally moving water in mucy greater quantity that can be removed from the basin, the balancing movement must be subsurface and essentially a return flow over most of the basin, responding less quickly to wind changes. The predominant bottom flow pattern for summer is shown in Figure 38.

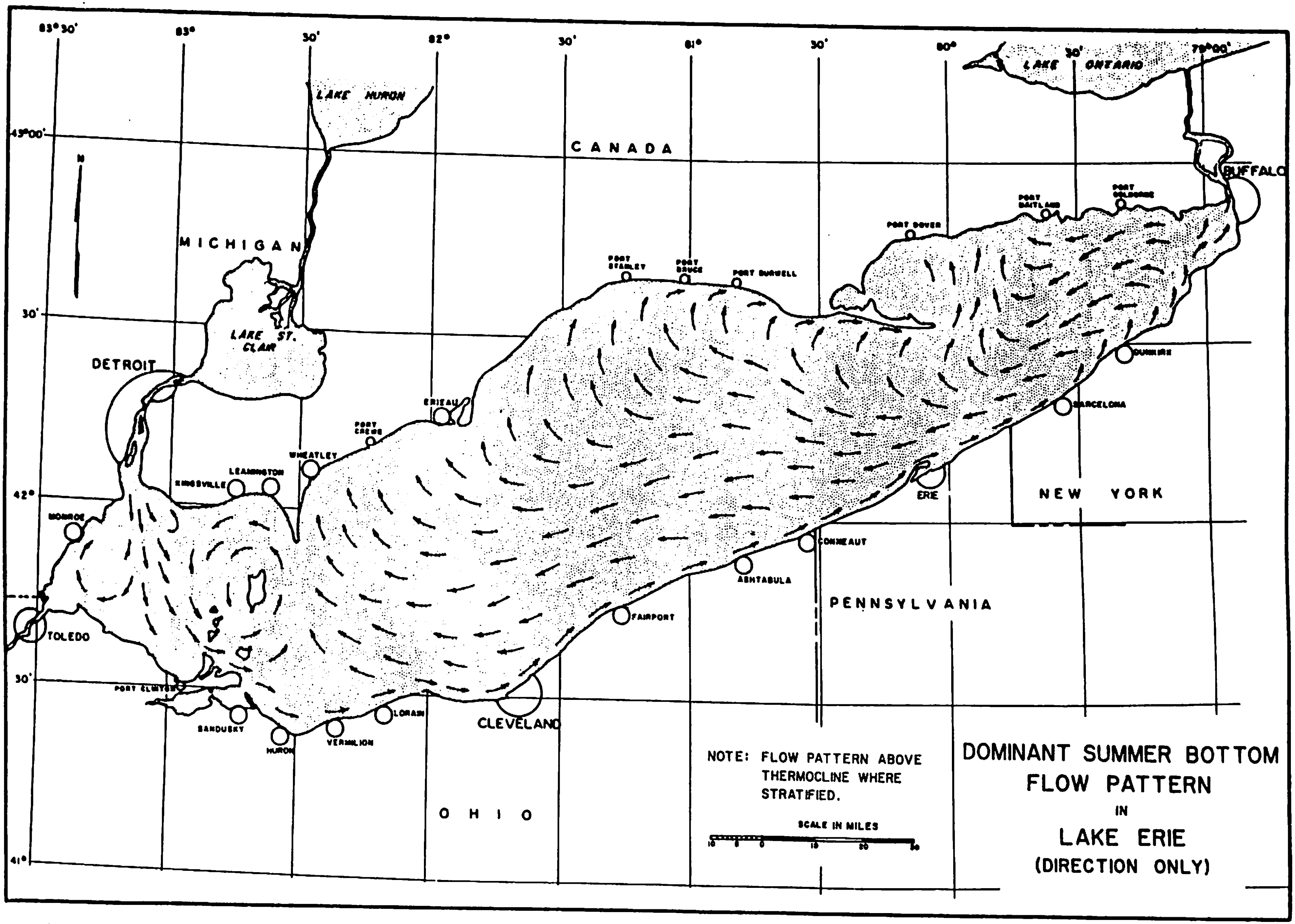


Figure 38. Summer, Bottom Currents in Lake Erie.

CLIMATE

CLIMATE

The climate of the Lake Erie Basin is temperate, humid-continental with the chief characteristic of rapidly changing weather. The location of the Great Lakes between the source regions of contrasting polar and tropical air masses gives the region rapidly changing and complex weather patterns.

Temperature

The annual average temperatures for land stations in the Erie basin range between 47°F and 50°F (8.4°C to 10.0°C). Temperatures generally decrease northeastward from the southwestern end of the basin. The highest average temperature at recording stations is at Put-in-Bay on South Bass Island with an annual average of 51.2°F (51.3°C).

The highest average monthly temperatures occur in July, ranging from 70°F to 74°F (21.1°C to 23.4°C) at land stations. These also generally decrease northeastward across the basin from Toledo to Buffalo (Figure 39). Put-in-Bay again is the highest at 75.1°F (24.0°C). The lowest average monthly temperatures occur in January at the west end of the basin and February at the east end, and range from 24°F to 28°F (-4.4°C to -2.2°C). The extremes of temperature in the Lake Erie basin are about -20°F and 100°F (-28.8°C to 37.8°C).

Precipitation

Average annual precipitation at land stations in the basin is well-distributed

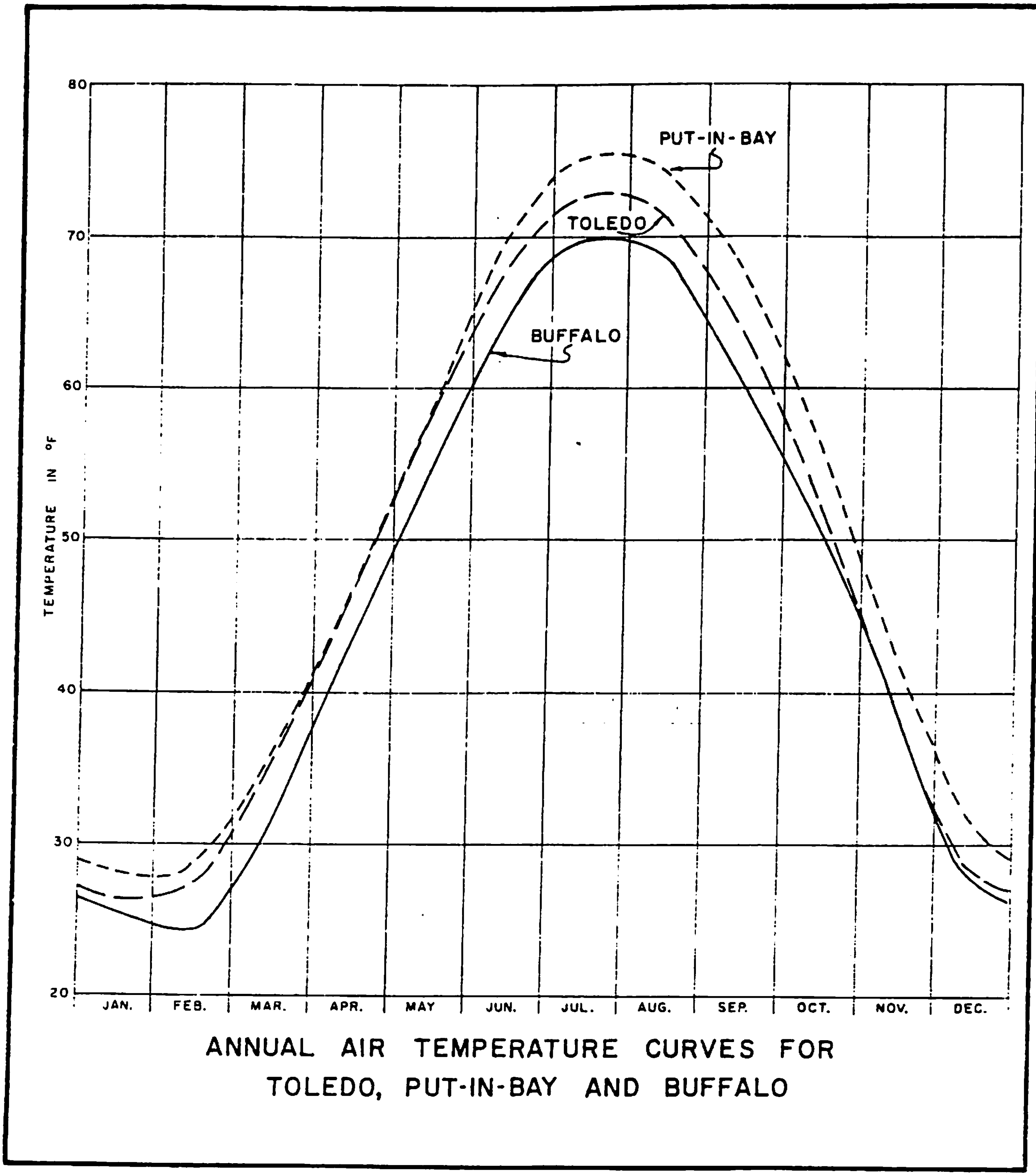


Figure 39. Annual Air Temperature Curves for the Lake Erie Basin.

throughout the year (Figure 40).and ranges from about 30.5 inches (7.75 cm) to more than 40 inches (102 cm) with an overall basin average of about 34 inches (86.4 cm). Yearly precipitation has varied between the extremes of 24 and 43 inches (61.0 and 109.2 cm). Precipitation shows a striking correlation to land elevation and topography (Figure 41). Low-lying flat areas of the basin have the lowest precipitation. Highest precipitation occurs in the southeastern part of the basin.

Most of the precipitation in the Lake Erie basin is derived from the flow northeastward of warm, moisture-laden air of low pressure systems from the Gulf of Mexico. Precipitation results when this clashes with colder, northern air of high pressure systems, moving in from the west and northwest. This kind of weather is characteristic of spring, summer, and early fall, and usually occurs in cycles of a few days. Humidity is high along with high temperatures, and south to southwest winds persist for long periods.

In winter, however, the colder Canadian air masses push southeastward and dominate the weather, resulting in less precipitation and less humidity. Heavier precipitation (usually snow) is experienced in the southeastern part of the basin, explaining the shift in the annual precipitation pattern in that area. This phenomenon is largely local, caused by air moving across Lake Erie, picking up moisture enroute, and precipitating it when the air rises along the front of the hills on the southeastern shore. Snowfall is greater in the eastern part of the basin with Buffalo having an annual average snowfall of 72 inches (182.9 cm), as compared to less than 36 inches (91.4 cm) for Toledo.

Wind

Southwesterly winds prevail over Lake Erie (Figure 42) in all months of the year, a characteristic common to the northern hemisphere temperate region. However, in fall and winter, northwesterly winds occur frequently, reaching high velocities (40-50 mph or 65-80 km/hr) in storms. In spring, the same is

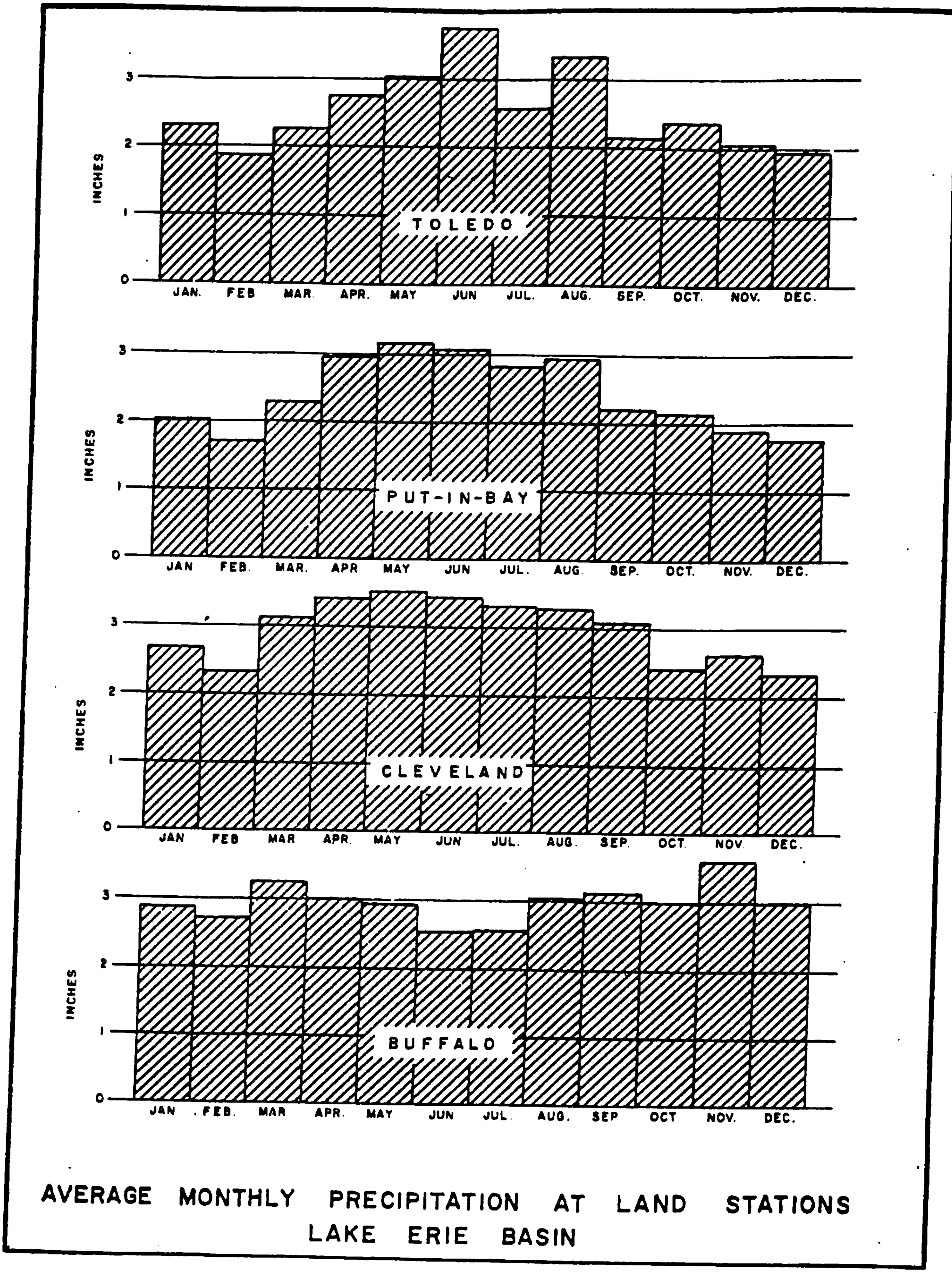


Figure 40. Average Monthly Precipitation in the Lake Erie Basin.

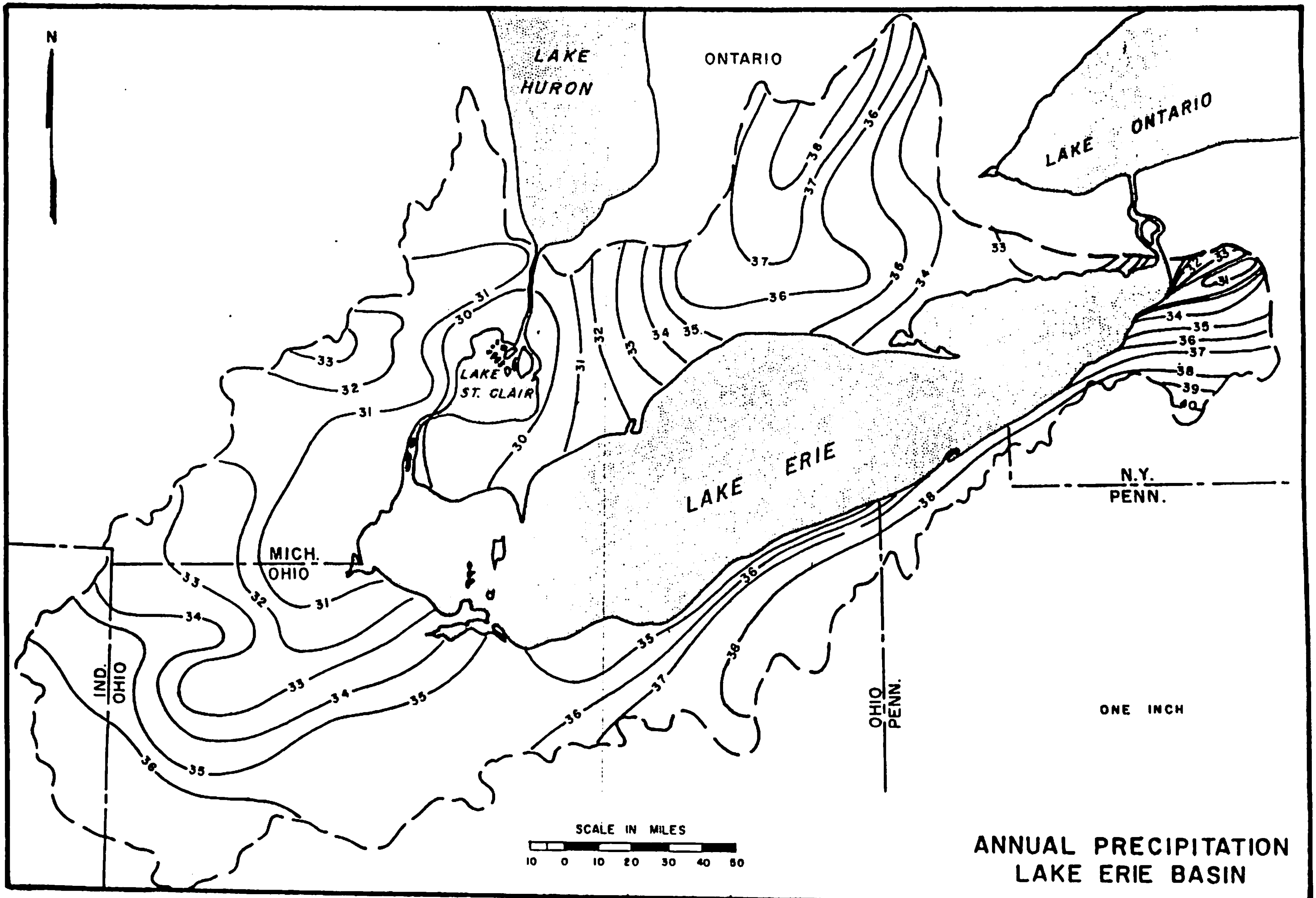


Figure 41. Lake Erie Basin Precipitation.

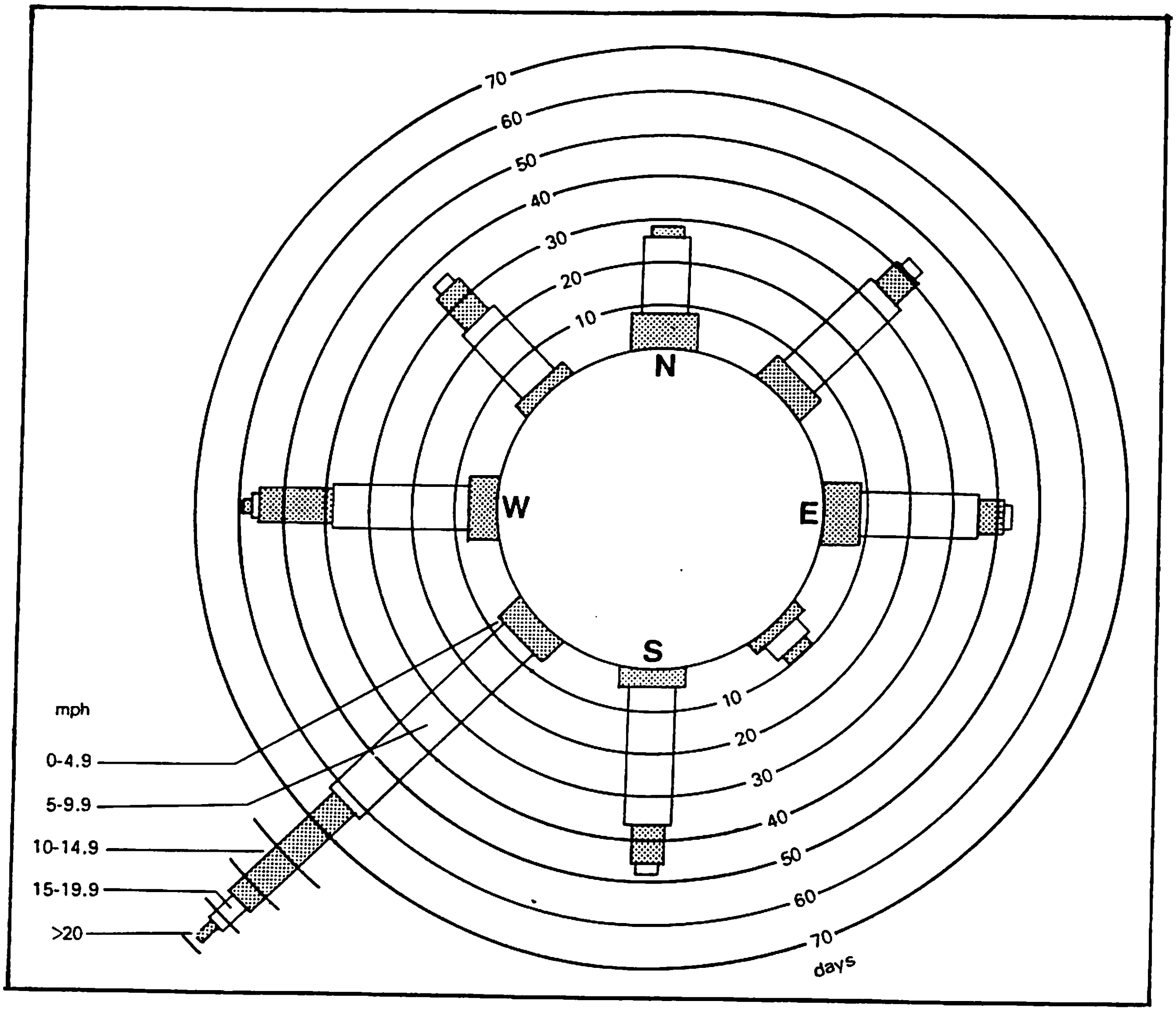


Figure 42. Average Annual Winds at Sandusky, Ohio (1948–1957).

true of northeasterly winds except that velocities (30-40 mph or 50-65 km/hr) are usually lower.

Sunshine

The percent of possible sunshine is greatest in midsummer and least in winter (Figure 43), although precipitation might indicate otherwise. Less sunshine in winter is due to the cloud-producing effects of the lake. December and January ordinarily have less that 40 percent of possible sunshine, while Juen and July average more than 70 percent at most stations. The percentage over the lake in summer is even greater.

Growing Season

Lake Erie has a marked moderating effect on the climate of the basin, especially for a few miles inland from the shore. This is demonstrated by the length of the frost-free season - near shore it is greater than 200 days, while only a few miles inland it is as much as 30 days less. This longer frost-free season is due to a warming effect from the lake water. During the late fall and early winter, the lake is till relatively warm and delays the first killing frost.

Although nearly the most northern portion of the state, South Bass and the other islands have the longest frost-free period of any area in the state of Ohio. South Bass Island has an average frost-free period of 205 days, while Bucyrus, 50 miles (80 km) to the south, has an average of 154 days. North Bass Island has a frost-free period of 206 days. The high heat capacity of the lake prolongs the summer temperature far into fall while the small range of temperature between the maximum and the minimum daily temperature permits a long spring. The long frost-free period, however, does not indicate a long growing season. The spring temperatures are retarded, and the threshold temperature, or temperature denoting the beginning of the blooming period of the flora, in the spring, occurs

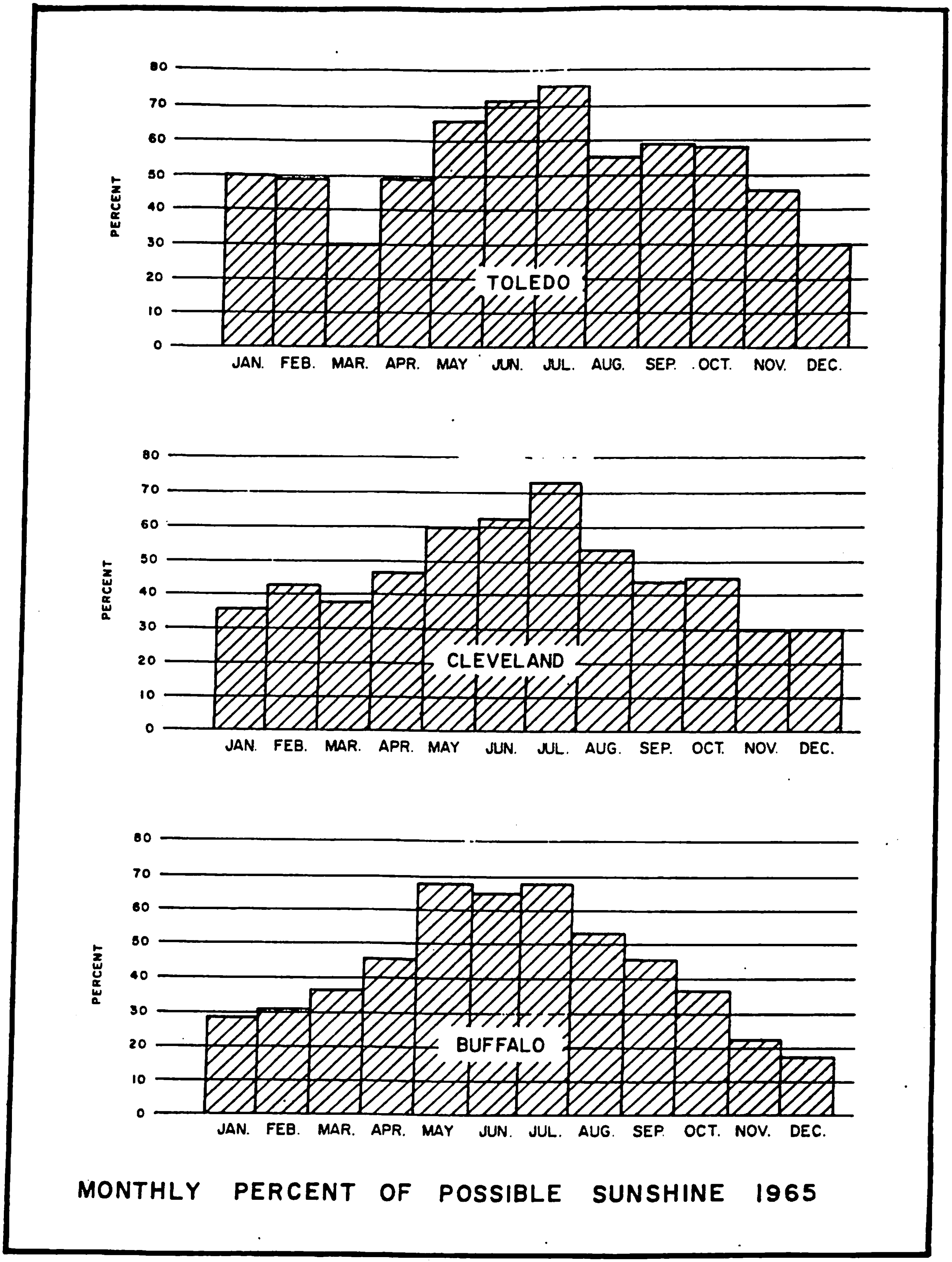


Figure 43. Percent of Possible Sunshine for the Lake Erie Basin.

much later on the islands than on the mainland. This retardation is reflected by the average date of the last killing frost, which is around April 15 for the islands, contrasted with May 20 for the interior of Ashtabula County, nearly in the same latitude, and with April 30 as far south as Columbus. Similarly, the average date for the first killing frost in the fall is around October 30 for the islands, contrasted with September 30 for Ashtabula County, October 15 for Columbus, and October 20 for Cincinnati. Thus, the average length of the growing season for islands is over 192 days.

Microclimates

Microclimatic conditions on South Bass Island were determined by sampling at 37 different temperature stations from July 1944 to August 1948. The following seven microclimates were apparent: (1) high and (2) low leeward shore stations, (3) high and (4) low windward shores, (5) high and (6) low inland stations, and (7) wooded areas. Daily temperatures showed the most significant changes. In winter, the variations between the low frost pockets and the high lee shore stations were as great as 18°F (10°C). During the summer, the lee shore stations, especially the East Point area, were the warmest parts of the island. The frost free season on the island varied in 1945 from 187 to 251 days for the various selected microclimatic habitats. Interestingly, this range on the island is greater than that which normally occurs between South Bass Island and Bucyrus.

LIMNOLOGY

LIMNOLOGY

Limnology is the scientific study of inland waters, including lakes, ponds, and rivers. In this day of widespread concern over the impact of human activity on natural environments, limnology is becoming an increasingly important practical science (Figure 44). Private and public decisions based on the best available limnological information will be necessary if we hope to protect, manage, or restore the quality of lakes and streams.

The term limnology is derived from the Greek work <u>limno</u> meaning pool, marsh or lake. Some limnologists describe it as the study of the fuctional relationships and productivity of biotic communities in lakes as they are effected by the dynamics of physical, chemical, and biotic environmental parameters. Other limnologists stress that the entire sequence of geological, physical, chemical and biological events that operate together in a lake basin are dependent on one another (Figure 45). Limnology is still a developing science; there are areas of disagreement and uncertainty on some fundamental issues. Natural waters are extremely complex systems, and none is ecactly like another; lakes that seem similar in some ways may be quite different in others. The public "common knowledge" about limnology is minimal compared, for example, with society's general knowledge of public health, mathematics, and even some areas of physics. The purpose of this guide is to provide an introduction to limnology, to identify some of the lake problems that are influenced by human activities, and to outline some procedures for studying individual lakes. Professor John B. Lundquist of the University of Minnesota is greatfully acknowledged for providing information and illustrations on lakes in his state which are used to illustrate principles in the following discussion.

Physical Structure of Lake Erie

The first step in understanding a lake is to realize that is has a structure

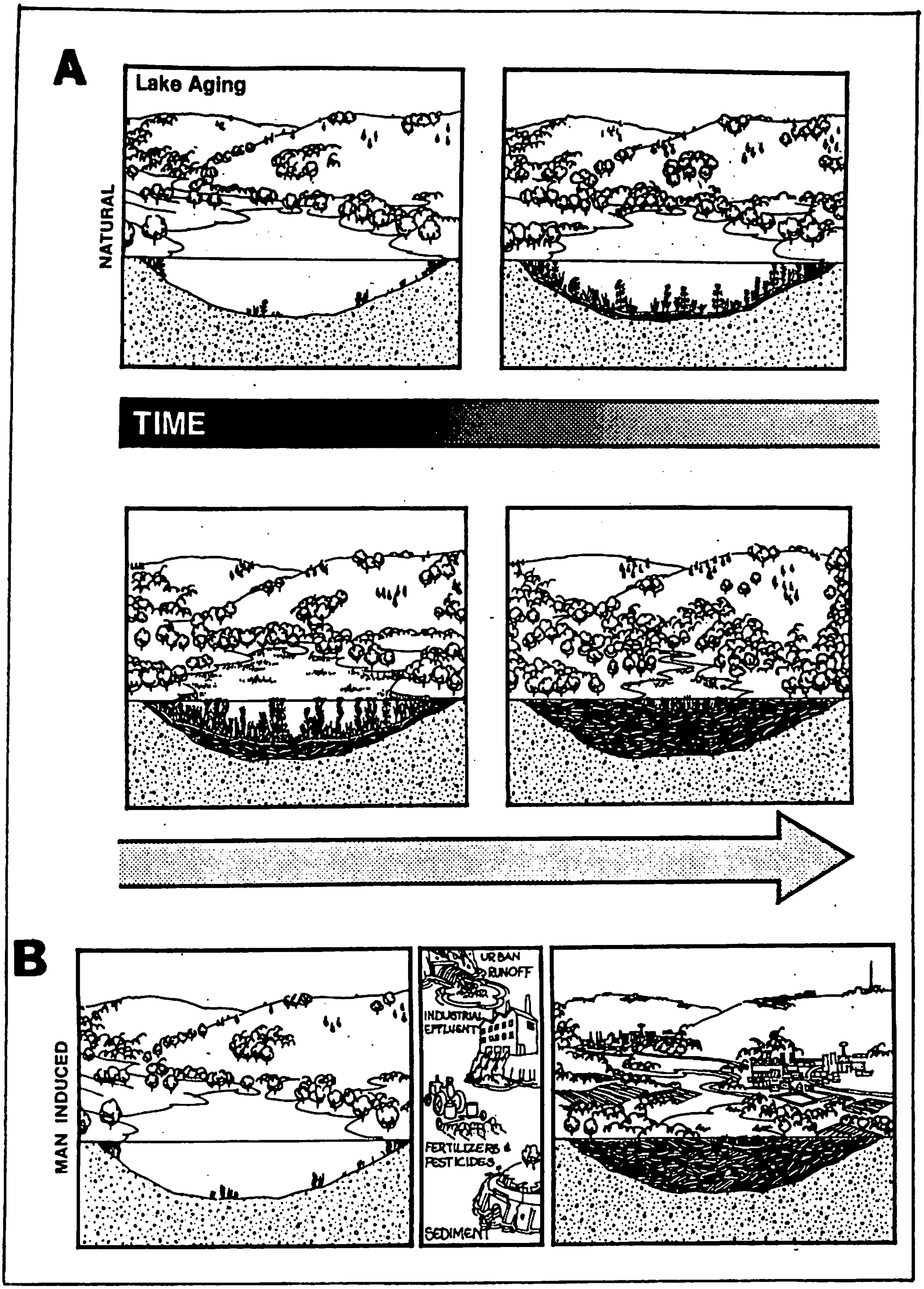


Figure 44. Aging Process in Lakes: A) natural conditions, and B) man induced conditions.

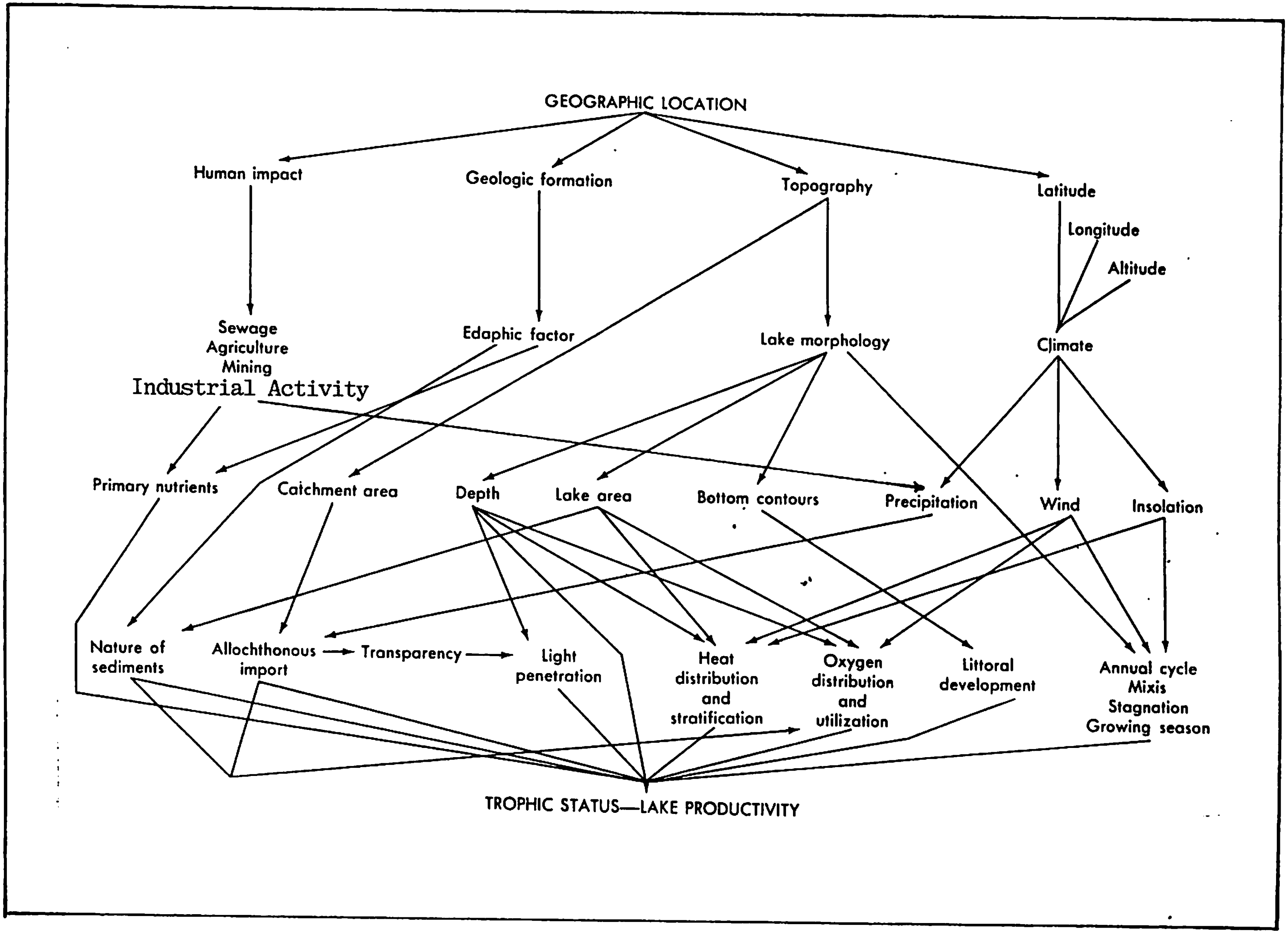


Figure 45. Interaction of Factors that Determine the Composition, Distribution, and Amount of Biota, the Rates at which Nutrients are Recycled, and the General Productivity of the Lake.

and organization that can be identified. The geological, physical, biological, and chemical characteristics of a lake are different in different parts of the lake, and they vary during the year. Certain physical phenomena in lakes occur quite independently of normal biological and chemical influences. Because water varies in density as its temperature changes, lakes in temperate climates tend to stratify, or form layers, especially during the summer.

Water is densest at 4°C and expands, or becomes less dense, at both higher and lower temperatures. This means that in the spring, just before a lake's ice cover melts, the water near the bottom will be at 4°C. Water above that will be cooler, approaching 0°C just under the ice. As the weather warms, the ice melts, and the surface waters begin to heat up. Wind action and the increased density cause this surface water to sink and to mix with deeper water. Soon the temperature of the entire lake will be 4°C. Thereafter, as the spring sun shines more intensely, the surface water absorbs heat and becomes warmer. For a while winds may still mix the lake from bottom to top, but eventually the upper water becomes warm and too light to mix completely with dense, deeper water.

As summer progresses the temperature difference, and thus density difference, between upper and lower water become more distinct and lakes of significant depth, such as the central basin of Lake Erie, generally become physically stratified into three identifiable layers.

Figures 46 and 47 show the terminology used to describe stratification and Figure 48 shows the seasonal circulation in a warm monomictic lake which is the term used to describe Lake Erie.

The warm, surface water layer is termed the epilimnion. Below the epilimnion there is a layer of water in which the temperature declines rapidly, called the metalimnion or thermocline. Below the thermocline lies water much colder than the epilimnion, called the hypolimnion.

The density change across the thermocline provides a real physical barrier.

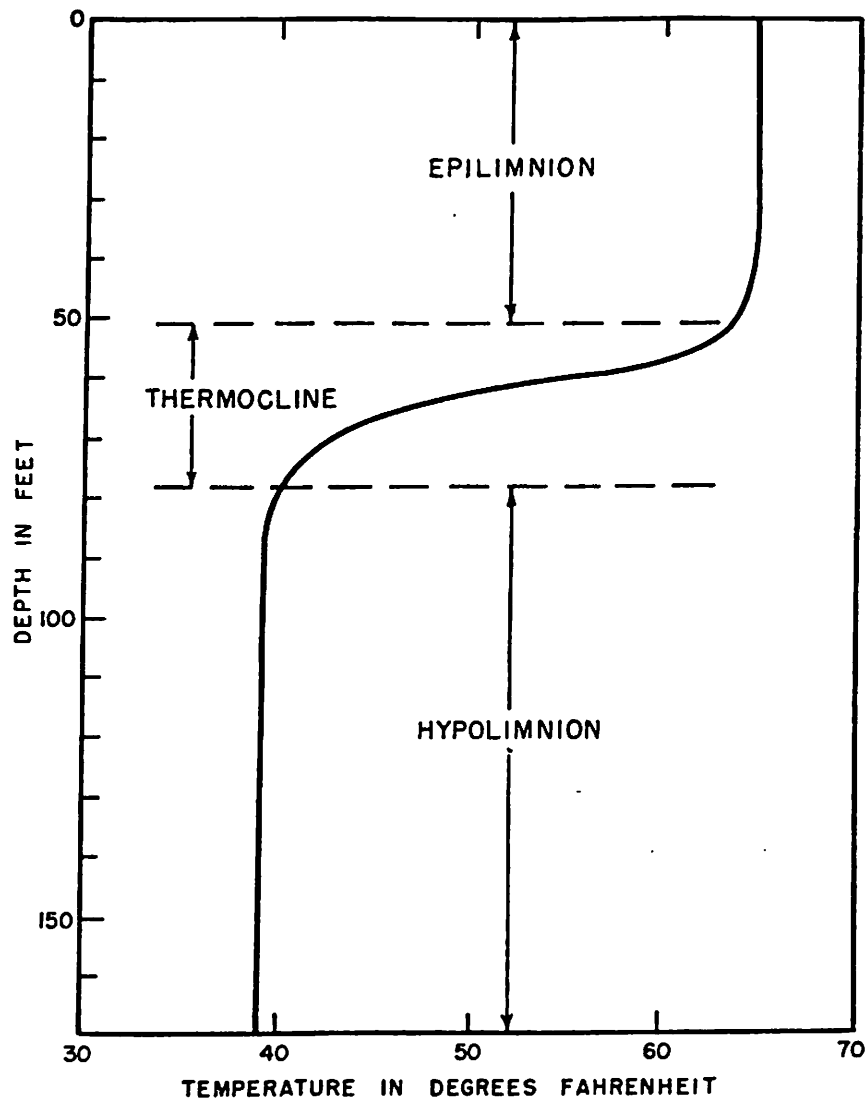


Figure 46. Terminology of a Lake Water Temperature Profile (typical summer disgribution of temperature, with warm isothermal water in the upper zone - the epilimnion, and cold isothermal water in the lower zone - the hypolimnion).

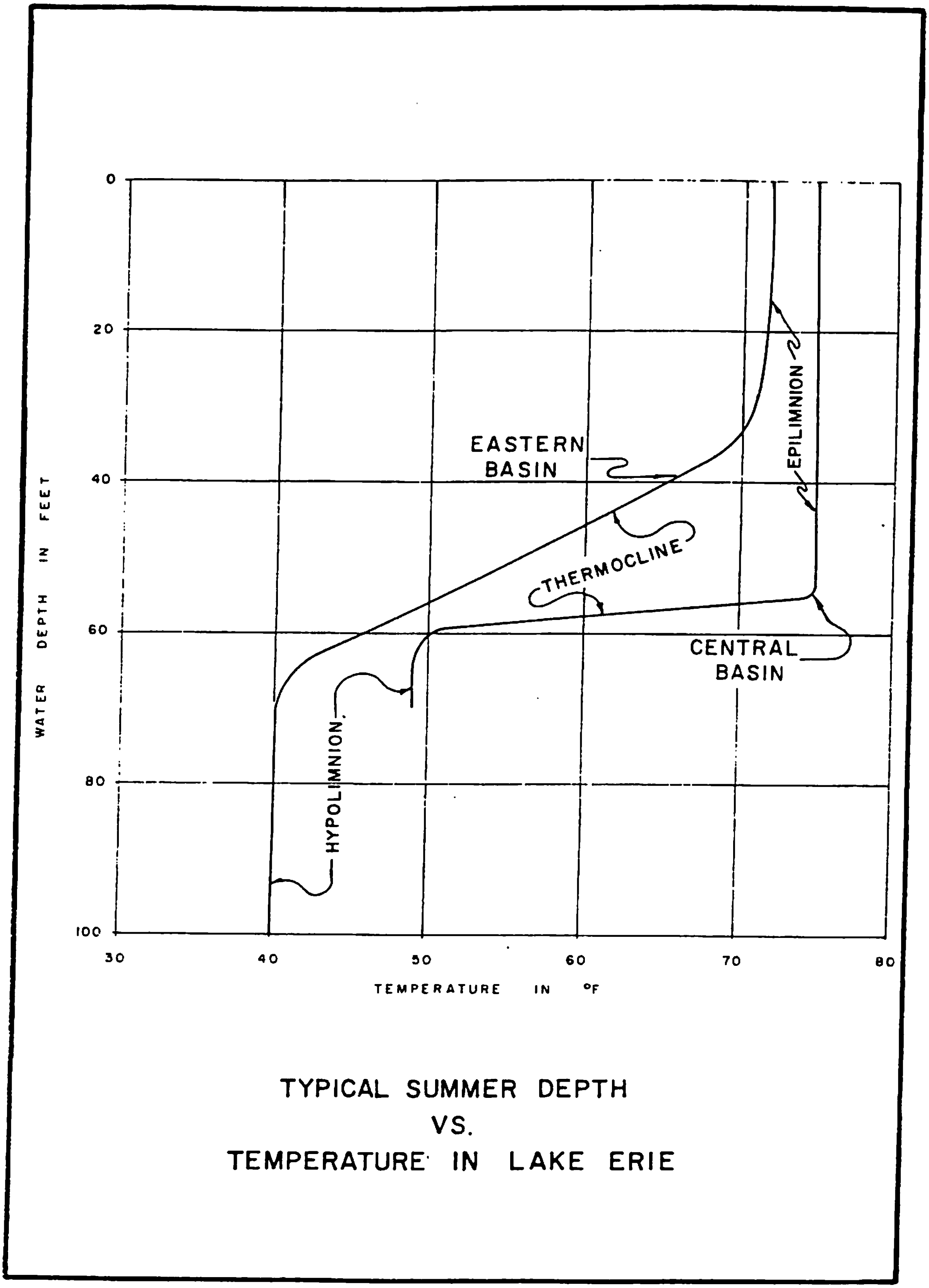


Figure 47. Lake Erie Thermal Profiles.

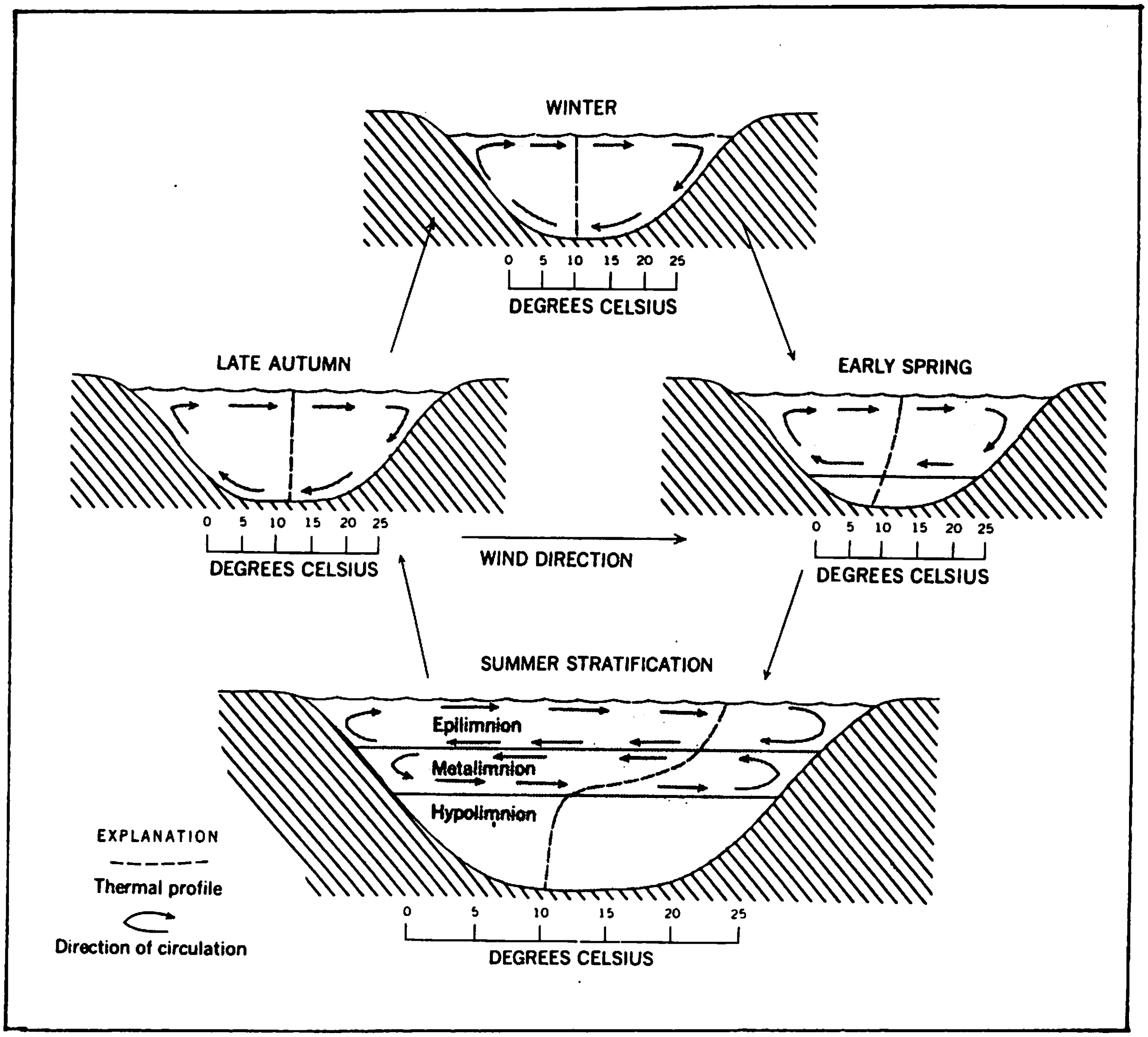


Figure 48. Seasonal Thermal Profiles in a Warm Monomictic Lake.

It effectively eliminates the mixing of upper and lower waters for several months of the summer. This is significant for understanding many other aspects of limnology.

As the weather cools during autumn, the epilimnion cools too, reducing the density difference between it and the hypolimnion. As time passes, winds are able to mix the lake to greater depths, and the thermocline gradually descends. When surface and bottom waters are uniform in density, autumn winds can mix the entire lake; the lake is said to "turn over". The lake becomes isothermal at 4°C; then the surface water cools still more and eventually freezes.

Because the western basin of Lake Erie is so shallow, it is usually uniform in temperature, top to bottom (isothermal), but because of its shallowness it responds more quickly to atmospheric temperature changes than the other basins. Occasionally in summer, the basin stratifies thermally for short periods which deprives the lower layer of water a good supply of oxygen from the atmosphere leading to rapid oxygen depletion near the bottom, drastically affecting the benthic organisms.

Biological Structure of Lake Erie

Besides being dynamic physical systems, lakes are also very complicated biological systems. There are many different kinds of plants, animals, and microorganisms that live, reproduce, and die in lakes (Figures 49 and 50). In the open water of a lake are found plankton -- free-floating microscopic plants and animals. Nekton are the larger animals like fish that are relatively independent of water motion because they can swim much faster than the velocity of normal currents. On the lake bottom grow many kinds of benthic organisms including rooted aquatic plants, clams, snails, worms, insect larvae, crawfish, and bacteria. The rates at which various organisms perform their functions contribute a great deal to the overall character of lakes. Organisms creat differences

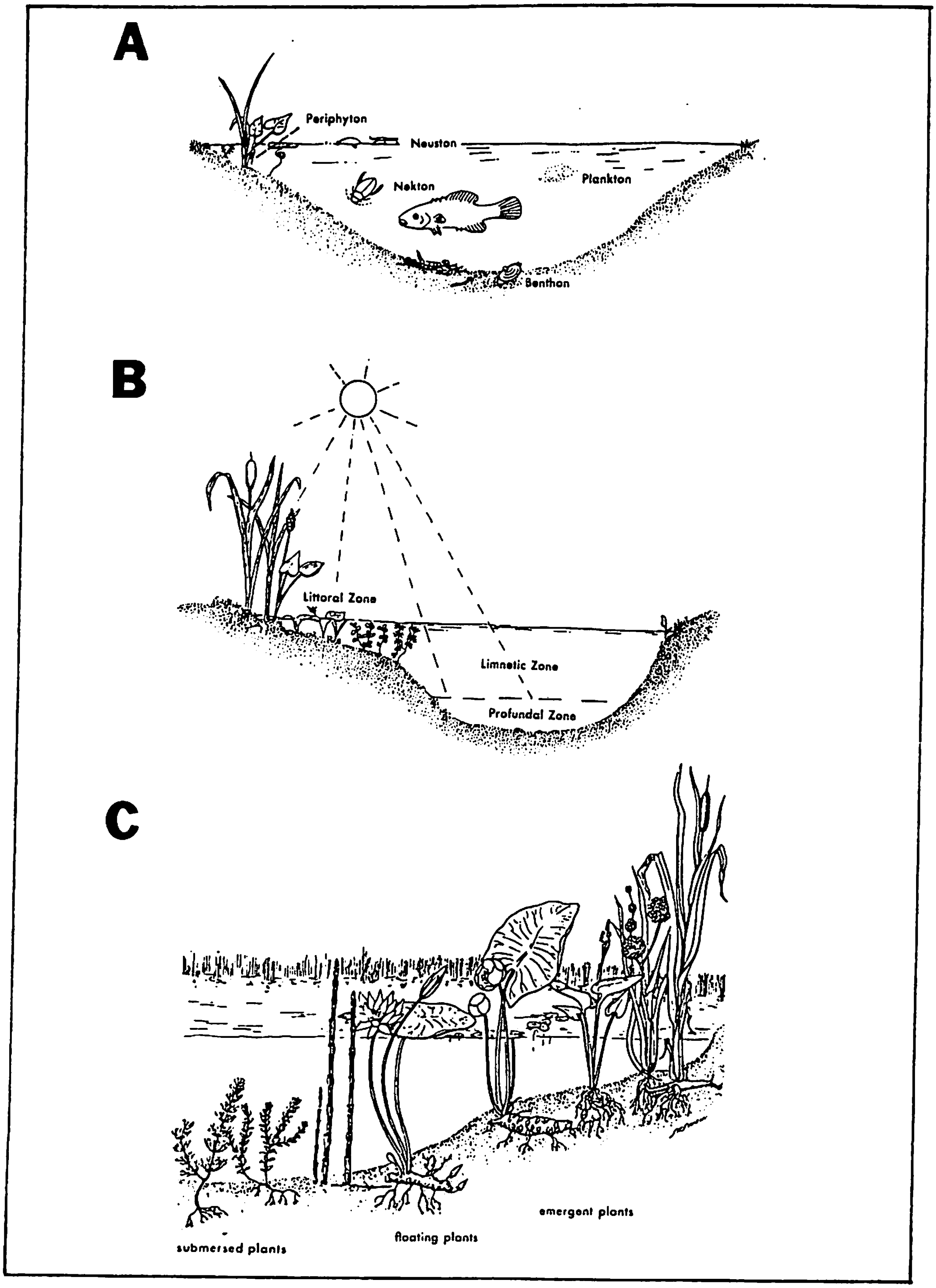
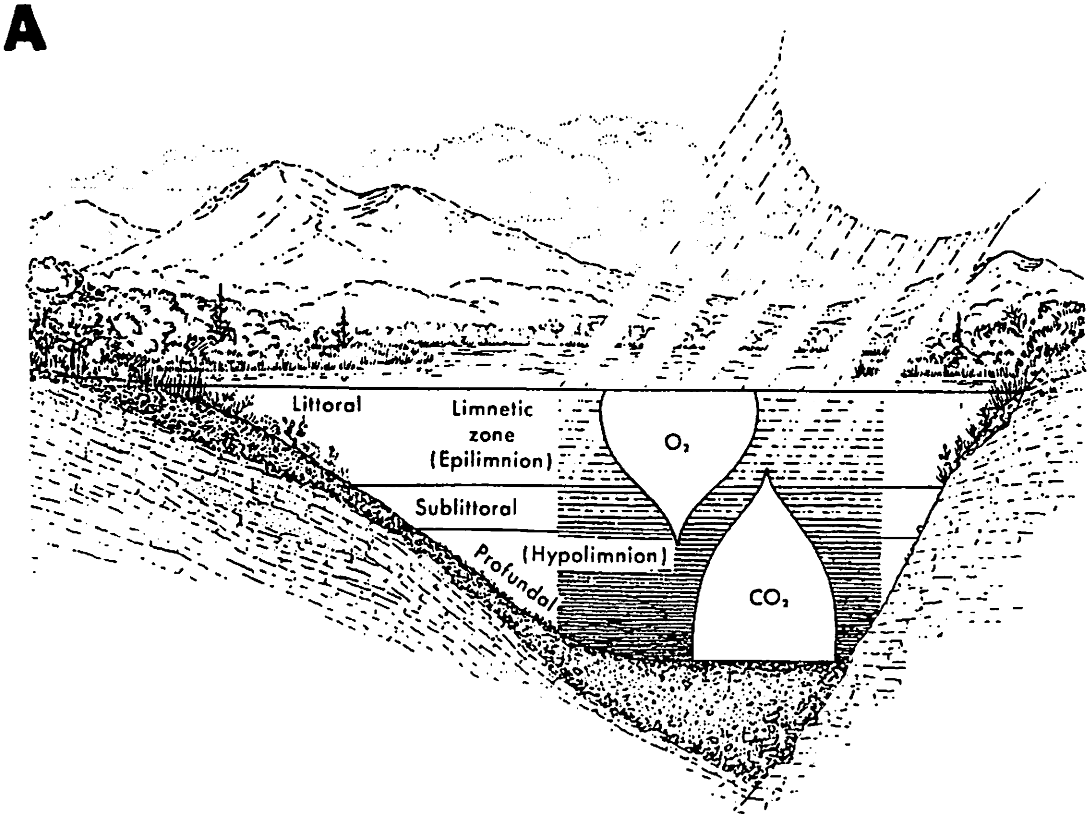


Figure 49. Lake Environments: A) types of littoral organisms, B) areas of population in lentic (lake) water, and C) zonation at the margin of a lake.

A



B

Oligotrophy	**Eutrophy**
Deep and steep-banked	Shallow, broad littoral zone
Epilimnion volume relatively small compared with hypolimnion	Epilimnion/hypolimnion ratio greater
Blue or green water; marked transparency	Green to yellow or brownish green; limited transparency
Water poor in plant nutrients and Ca^{++}	Plant nutrients and Ca^{++} abundant
Sediments low in organic matter	Profundal sediments an organic copropel
Oxygen abundant at all levels at all times	Oxygen depleted in summer hypolimnion
Littoral plants limited, often rosette type	Littoral plants abundant
Phytoplankton quantitatively poor	Abundant phytoplankton, mass great
Water blooms of bluegreens lacking	Water blooms common
Profundal bottom fauna diverse; intolerant of low oxygen tensions	Profundal benthos poor in species; survive low oxygen
Profundal benthos quantitatively poor	Profundal benthic biomass great
Tanytarsus-type midge larvae in profundal benthos, *Chaoborus* usually lacking	*Chironomus*, the profundal midge larva; *Chaoborus* present
Deep-water salmonid and coregonid fishes	No stenothermal fish in hypolimnion

Figure 50. Lake Classification: A) lake zones, and benthic regions and B) trophic classification.

in water chemistry between the top (epilimnion) and bottom (hypolimnion) of lakes and they strongly influence the quality of the water. There are two basic life-sustaining processes in lakes just as there are on land — photosynthesis and respiration. Green plants are able to capture energy from sunlight in order to convert non-living, inorganic chemicals like carbon dioxide, water, and mineral compounds into living, organic plant tissue. In lakes this photosynthesis is carried on by algae and higher green plants closely related to common land plants. These plants are called primary producers because they create the organic material that is required by most other organisms for nutrients and energy. The waste product of photosynthesis, oxygen, is also used by other organisms.

Photosynthesis

$$\underset{\text{(light)}}{\text{Energy}} + \underset{\text{(carbon dioxide)}}{6\,CO_2} + \underset{\text{(water)}}{6H_2O} \xrightarrow[\text{chlorophyll}]{} \underset{\text{(sugar)}}{C_6H_{12}O_6} + \underset{\text{(oxygen)}}{6O_2}$$

Respiration

$$\underset{\text{(sugar)}}{C_6H_{12}O_6} + \underset{\text{(oxygen)}}{6O_2} \longrightarrow \underset{\text{(carbon dioxide)}}{6CO_2} + \underset{\text{(water)}}{6H_2O} + \text{Energy}$$

This plant tissue may be eaten by small animals called zooplankters. These primary consumers are then eaten by other animals, like small fish, called secondary consumers. Still larger consumers such as large fish, ospreys, and people eat them and are called tertiary consumers. All of these animals utilize food for building their own tissue by also extracting energy from the food through the process of respiration. Respiration, the oxidation of organic material, releases the energy that was originally captured from sunlight by photosynthesis, and this energy is used by the animals to sustain their lives.

Meanwhile there is excretion of wastes and death of organisms. The remains are attacked by microorganisms, which decompose the material and make some of it re-usable as nutrients for green-plant photosynthesis.

This whole interaction of photosynthesis and respiration by plants, animals, and microorganisms is called a food web by ecologists (Figure 51). Food webs are usually very complex; in any one lake ecosystem hundreds of different species could be involved.

Lakes have somewhat distinct zones where different species perform different functions. Some organisms live on or near the lake bottom, some live in open water; some live shallow, some deep. Furthermore, many species vary in abundance during the year.

Producers. It is understandable that living green plants will be found in those regions of lakes that receive sunlight. In most lakes significant photosynthesis occurs primarily in the epilimnion, with maximum rates found slightly below the water surface.

In shallow water may be found rooted plants, called macrophytes (or weeds). In shallow, clear lakes and ponds, macrophytes may represent most of the green plant material present and may account for most of the photosynthesis. Furthermore, "weed beds" are important habitats for many fish and other aquatic animals. Other lakes may have few macrophytes. The bottom may be too rough, wave action too sever, or the water too deep. Lakes with high populations of algae of high silt concentrations frequently have few macrophytes because little sunlight reaches the lake bottom, even in shallow water.

Algae constitute the other main group of producers. They come in countless forms and live in nearly all kinds of environments. Many are microscopic in size, growing as single cells or small colonies, and are collectively called phytoplankton. Phytoplankton grow suspended in open water by taking up nutrients from solution and photosynthesizing. If their populations are dense, the water will become noticeably green or brown and will have low transparency. There

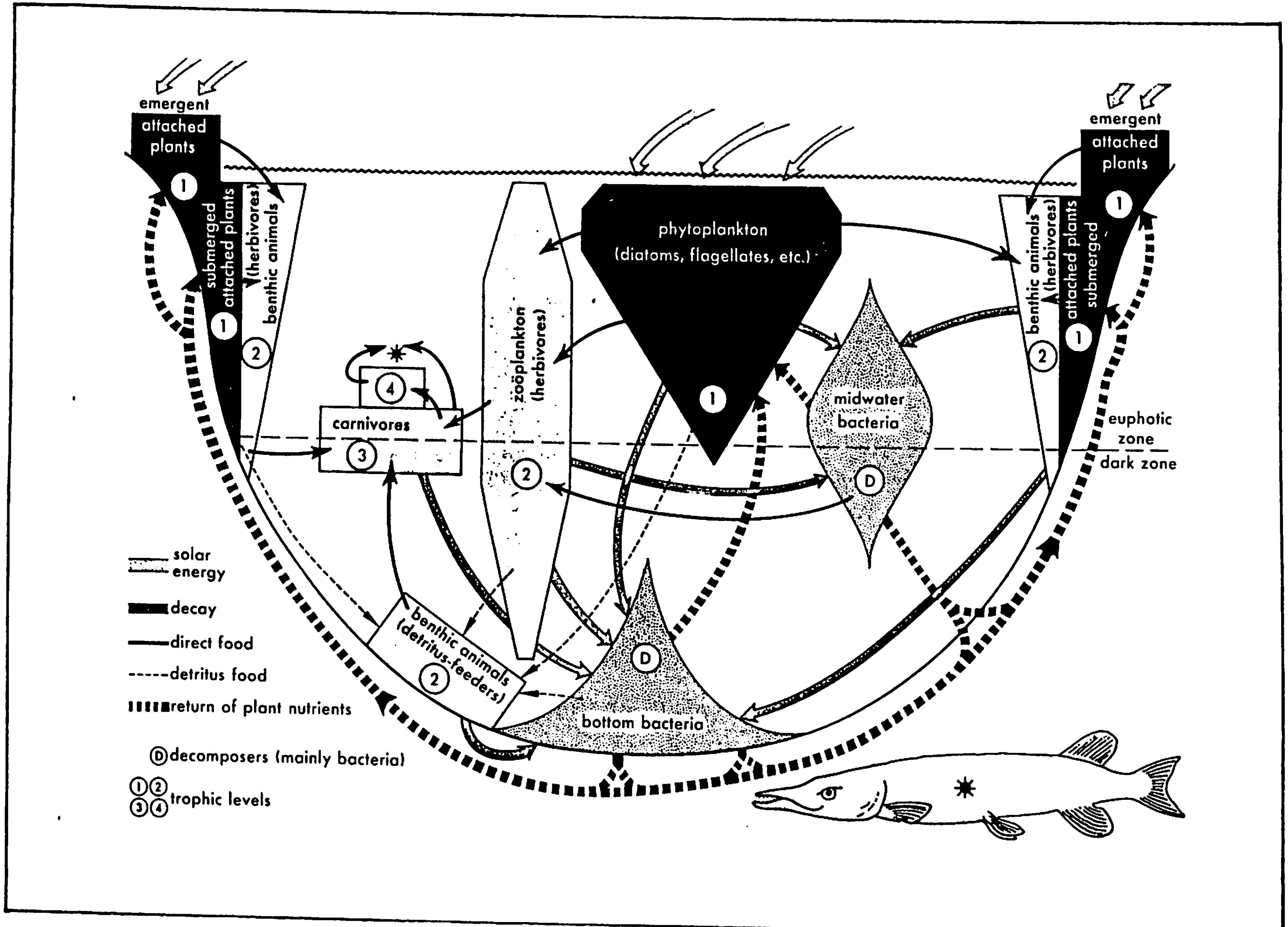


Figure 51. Lake Ecosystem. There are three principal groups of organisms (producers, consumers, and decomposers) organized in two principal food-chains. The first trophic level (primary producers) consists of the microscopic green plants of the phytoplankton for one food-chain and the marginal rooted plants and their epiphytes for the other. The corresponding second-trophic-level animals are filter-feeding zooplankton and browsing benthic herbivores, respectively. The third and fourth trophic levels of carnivorous animals could be lead to an old cannibalistic pike operating at both the fourth and fifth trophic levels.

are several groups of phytoplankton, including diatoms, green algae, and blue-green algae. Diatoms are notable for their cell wells, which are made of silica and have remarkable geometric shapes. Both diatoms and green algae are slightly heavier than water and therefore rely on water turbulence to stay in the sunny epilimnion. They are generally thought to be good food for zooplankton.

Blue-green algae, on the other hand, are a group less suitable as food for primary consumers. A food web that included blue-greens would be different from one dominated by greens or diatoms.

Particularly interesting are two more blue-green characteristics. First, some have the ability to adjust their buoyancy; thus they can float or sink depending on circumstances of light and nutrient supply. Second, a few species are known to be able to fix nitrogen. Most plants, including diatoms and green algae, can use the essential nutrient nitrogen only if it is present in certain forms like nitrate or ammonia. Blue-green algae, however, can also capture atmospheric molecular nitrogen (N_2) and convert it to a useful form through a process called nitrogen fixation. Blue-green algae are frequently responsible to so-called algal blooms, which are dense growths of algae that occur with varying frequency and intensity in many lakes.

In addition to free-floating phytoplankton there are filamentous algae, which grow in long, visible, hair-like strands; and there are "rooted" algae that resemble macrophytes but have no roots, leaves, or flowers. Both of these types are usually found attached to bottom materials, debris, or larger aquatic plants.

Consumers. While photosynthesis by green plants is limited to the sunlit portions of a lake, consumers can live and grow throughout the lakes. Small animals that swim about in open water are called zooplankton. Some species can be seen with the naked eye, although they are more easily observed with a hand lens or low-power microscope. Zooplankton eat algae and are therefore primary consumers.

There are alos many consumer animals that live at the bottom of lakes. Their feeding strategies vary widely. Some, like clams, filter small bits of organic material from water as it flows by. Others eat partially decayed organic material that has sunk to the bottom.

The best known group of aquatic consumers is fish. Fish of one sort or another live in most lakes. Their requirements for food and habitat vary a great deal. Many small fish such as perch eat zooplankton primarily. The larger fish like pike then prey on smaller fish like perch. Bass and pike will be found in lakes that have beds of aquatic macrophytes suitable for spawning. Walleyes, on the other hand, spawn on a gravel bottom.

Lake trout live only in very clear lakes with cold, well-oxygenated deep water. Carp, on the other hand, are adapted to turbid lakes with silt bottoms. There they feed by picking worms and other bottom organisms from the mud.

Decomposers. This group, which includes bacteria and other microorganisms are the other major group in the food web. They feed on the remains of all aquatic organisms and, in so doing, break down or decay organic matter, returning it to an inorganic state. In so doing decomposers use dissolved oxygen for the respiration of organic matter. Furthermore, some of the decayed material is subsequently re-used for nutrition by green plants.

Within each of the food chain groups there are thousands of individual species. Myriad factors affect the species composition and the numbers of individuals that live in a particular lake at any moment and the population fluctuations that occur in time.

Primary factors that determine a lake's biology are such things as climate and total abundance of inorganic nutrients. Subsequent populations will then be influenced as well by the composition and activities of preceding populations. Some species will be effectively eliminated from a lake because they cannot tolerate one or more of the lake characteristics. Other species will be outcompeted by the organisms that are well suited to the environment.

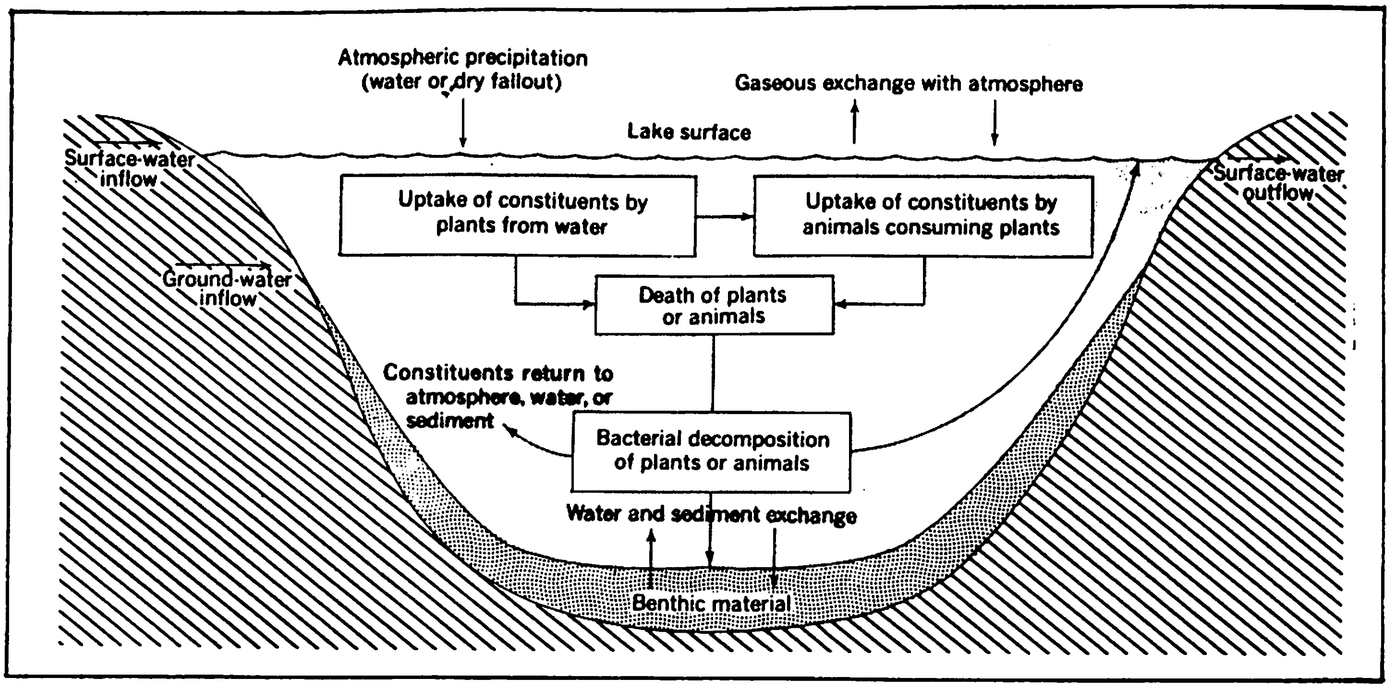
In most natural systems the result is a recognizable, if not exactly repetitive, yearly cycle. Some species flourish for a period of time and then give way to other species, more compatible with changed conditions. Planktonic organisms are particularly significant in this respect. Plankton communities are characterized by seasonal successsions, as species become more and then less dominant during the year. Other organisms — like fish — that must maintain stable populations continuously in order to reproduce have to be tolerant of aquatic conditions year round.

Chemical Structure of Lake Erie

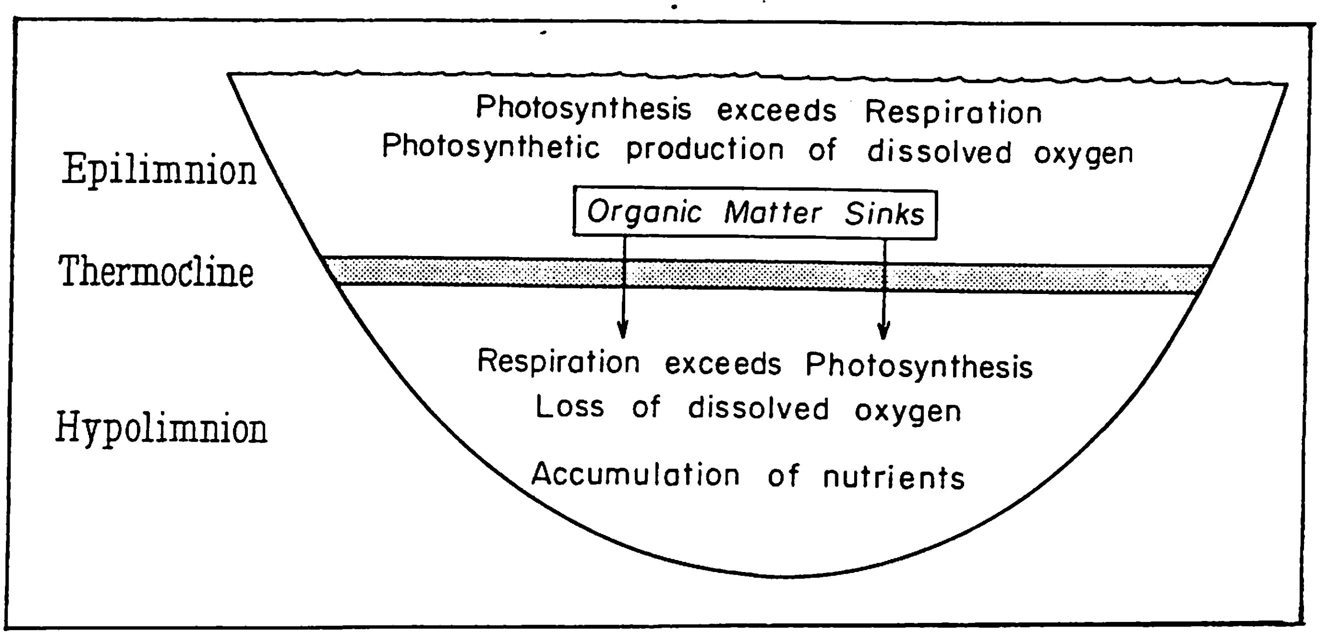
Obviously aquatic organisms are doing more than just being in lakes. They modify their environment through life activites and thereby influence the subsequent chemical and biological characteristics of that environment. For example, phytoplankton extract inorganic minerals from sunlit water to create living organic material. In doing so, they release wastes including oxygen. Therefore, in photosynthetic zones of lakes, nutrients are removed, and oxygen is added to the water. Because algae gradually sink to lower depths and decompose, nutrients are redistributed from the upper water to the lake bottom.

Meanwhile, respiring organisms like zooplankton, fish, and decomposer microooganisms use oxygen and release wastes such as carbon dioxide; these organisms gradually sink to the bottom as well, further concentrating nutrients in lower waters and sediments.

Much of this biological activity occurs during the summer when maximum photosynthetic activity is driven by maximum solar radiation. But also during the summer most lakes in temperate climates are stratified, as explained earlier. Because biological activities are different in the epilimnion and hypolimnion, chemical characteristics can become different too (Figures 52 and 53).

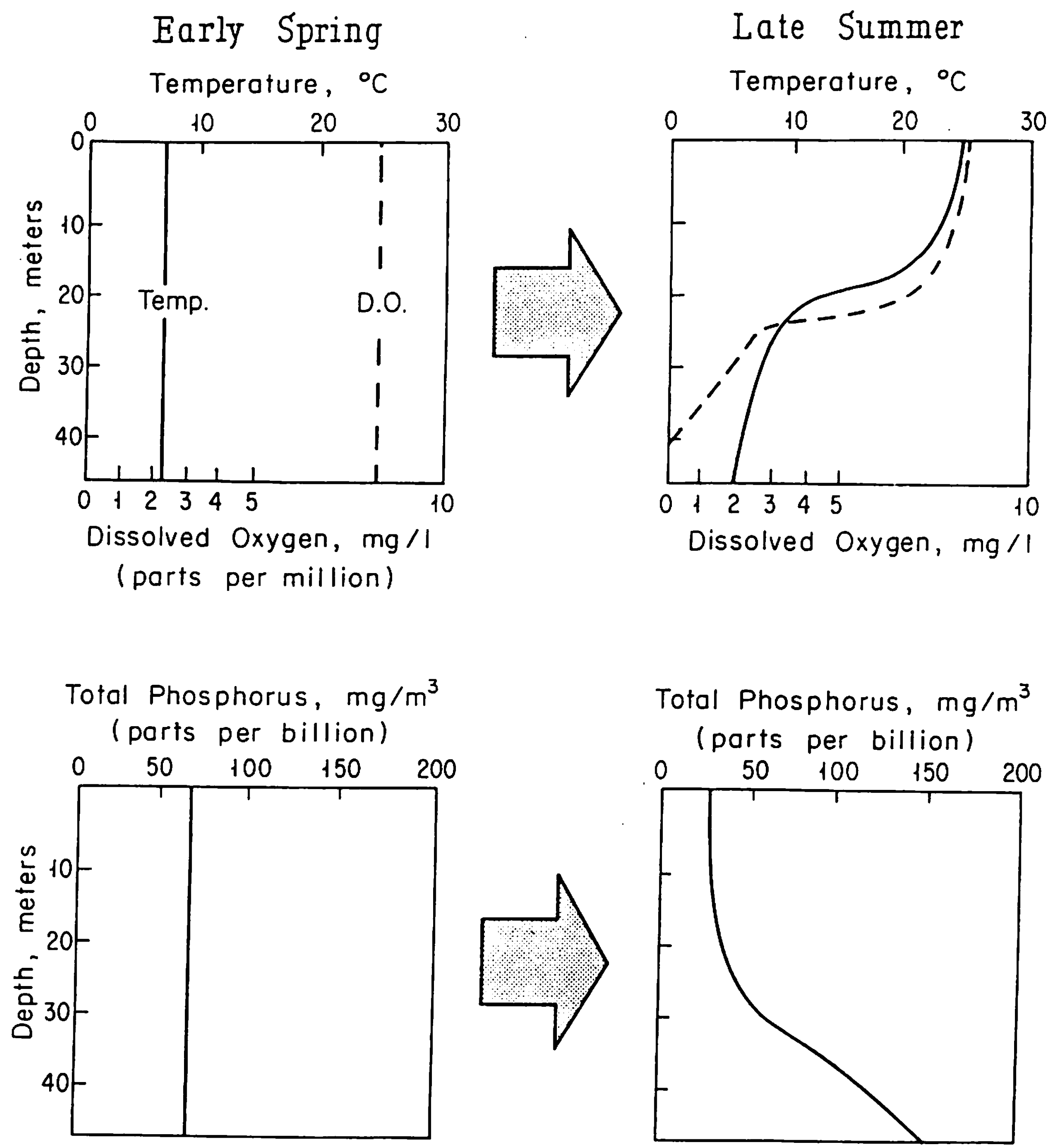


A. Sources of Cycling of Elements in a Lake.



B. Biological Redistribution of Water Chemicals during Stratification.

Figure 52. Sources of Cycling and Biological Redistribution.



Biological activity can cause interesting differences in water chemistry between the epilimnion and hypolimnion of a stratified lake.

The graphs on the left show three water characteristics typical of a Minnesota lake during the spring mixing period. Temperature and concentrations of dissolved oxygen and total phosphorus are uniform at all depths because wind mixes the lake thoroughly during this spring "turn-over."

As the summer weather warms the upper water of the lake, this water expands and becomes less dense than the lower, so mixing ceases. After stratification is established, each layer begins to change. The epilimnion maintains high oxygen content because of photosynthesis and atmospheric contact; meanwhile the hypolimnion loses some or all of its oxygen because respiration occurs there while virtually no new oxygen is added by photosynthesis or atmospheric contact.

On the other hand, phosphorus, an algal nutrient, is taken up by algae in the epilimnion and sinks to the hypolimnion when the algae die. In this manner phosphorus is lost from the epilimnion and is increased in the hypolimnion.

Not until the autumn destratification, or mixing, do these differences disappear.

Figure 53. Seasonal Changes in Water Chemistry Caused by Biological Activity.

Nutritional overenrichment is the single greatest water quality problem in western Lake Erie. Overenrichment has caused undesirable interference with water suuplies, recreation, and fishery. Excess nutrient can result in tremendous overproduction of aquatic plants, especially the planktonic forms. This process is known as cultural eutrophication and western Lake Erie can be classified as eutrophic (Figure 50-B). Also the filamentous algae of the island region, such as Cladophora glomerata, flourish with high nutrient concentrations. Current and wave actions often dislodge and deposit large quanitities of this attached algae onto the shoreline, resulting in nuisance accumulations and obnoxious odors from the decaying biomass. To the public, this is very tangible evidence of excessive algal growth, frequently interpreted as environmental degradation.

Estimates of total phosphorus loading to Lake Erie have been published by several agencies ranging from 13 to 15 metric tons per year. All estimates show a definite decrease in the load of total phosphorus to the lake. In the 10-year period from 1971 to 1980, the contribution of the Detroit River to the total amount of phosphorus loaded to Lake Erie has fallen from 67% to 37%.

Although decrease loadings are evident it has not been possible to translate the decline in phosphorus loading to Lake Erie to decreases in the concentrations or quantities of total phosphorus measured in the lake. In fact, total phosphorus increased in minimum summer quantities for the period 1970 to 1976. This can be partially explained by phosphorus released from sediment through wave resuspension and anoxic regeneration. Several investigations have demonstrated that approximately 80% of the phosphorus loading to Lake Erie becomes incorporated into the bottom sediments. If improvements are to be detected in the lake, they should show up first in the western basin where the greatest decrease in loading has occurred.

The most abundant chemical constituents of Lake Erie water are listed in

Table 5. Lake Erie waters are alkaline, having a total alkalinity of 95 ppm as $CaCO_3$ and an average pH of 8.3. Total dissolved solids in the water average 173 ppm, with the highest concentrations along the south shore. In general, the concentrations of the major cations and anions increase from west to east. Dissolved oxygen in the surface water varies considerably depending on the time of day and the season of the year. Severe oxygen depletion has been observed since 1958 in the bottom waters of central Lake Erie during periods of stratification, with concentrations of less than 2 ppm, common over extended areas.

TABLE 5

CHEMICAL CONSTITUENTS OF LAKE ERIE WATER

	Western basin	Central basin	Eastern basin	Entire lake
Conductivity (umhos/cm)	272	300	301	291
Dissolved solids (ppm)	162	178	179	173
Suspended solids (ppm)	19	7	9	12
Total alkalinity (ppm)	94.2	95.5	96.5	95.4
Calcium (ppm)	33.9	39.5	40.5	38.0
Chlorides (ppm)	21.3	24.5	24.5	23.4
Sulfates (ppm)	17.7	22.4	23.4	21.2
Sodium (ppm)	9.91	11.05	10.86	10.61
Magnesium (ppm)	8.7	10.0	10.0	9.6
Potassium (ppm)	1.47	1.31	1.34	1.37
Silica (ppm)	1.20	0.68	0.47	0.78
Total nitrogen (ppm)	0.71	0.43	0.43	0.52
Ammonia (ppm)	0.159	0.086	0.086	0.110
Organic nitrogen (ppm	0.36	0.25	0.24	0.28
Nitrate (ppm)	0.124	0.090	0.090	0.101
Phosphate (ppm as PO_4)	0.032	0.010	0.010	0.017
Hydrogen-ion concentration (pH)	8.4	8.3	8.3	8.3
Chemical oxygen demand (ppm)	10.37	7.10	7.45	8.31

COASTAL WETLANDS

COASTAL WETLANDS

The Lake Erie lies in the highly industrialized region of the north-central United States and southwestern Canada. However, within this region of intense human activity are located many area of natural beauty. The coastal wetlands are one of the most fascinating natural features available for visitors to enjoy. What are wetlands? Quite simply they are areas of wet soil which promote the growth of aquatic vegetation. Names such as marshes, swamps, flats, bogs, and fens have been applied to wetlands in the Great Lakes region (Figure 54).

Coastal wetlands differ in several ways from inland wetlands. The coast is subject to temporary (short term) water level changes. Seiches and storm surges affect the wetlands adjacent to the shorelines of Lake Erie by raising and lowering the lake level as much as 6 ft. (2 m) in a single day! Long-term cyclic water level changes, related to precipitation and the water budget of the Great Lakes basin, also affects the coastal wetlands. Such fluctuations, occurring over a number of years, may cause wetland plants to die off, erode, or be displaced. Not all coastal wetlands exhibit senescence or the aging process associated with inland wetlands. This process leads from open pond to densely vegetated marshes to, eventually dry fields. Because of the fluctuating water levels, constant rejuvenation of wetland plant communities occurs along the shorelines. Coastal wetlands also show a diversity of land forms not normally encountered in other wetlands environments. Largely the result of major elevation changes of the Great Lakes associated with the retreat of the glacial ice sheets, landforms such as deltas, barrier bars, beaches, spits, lagoons and natural levees have deposited along the shores. Many of these geomorphic features promote the formation of wetlands, each with distinct-

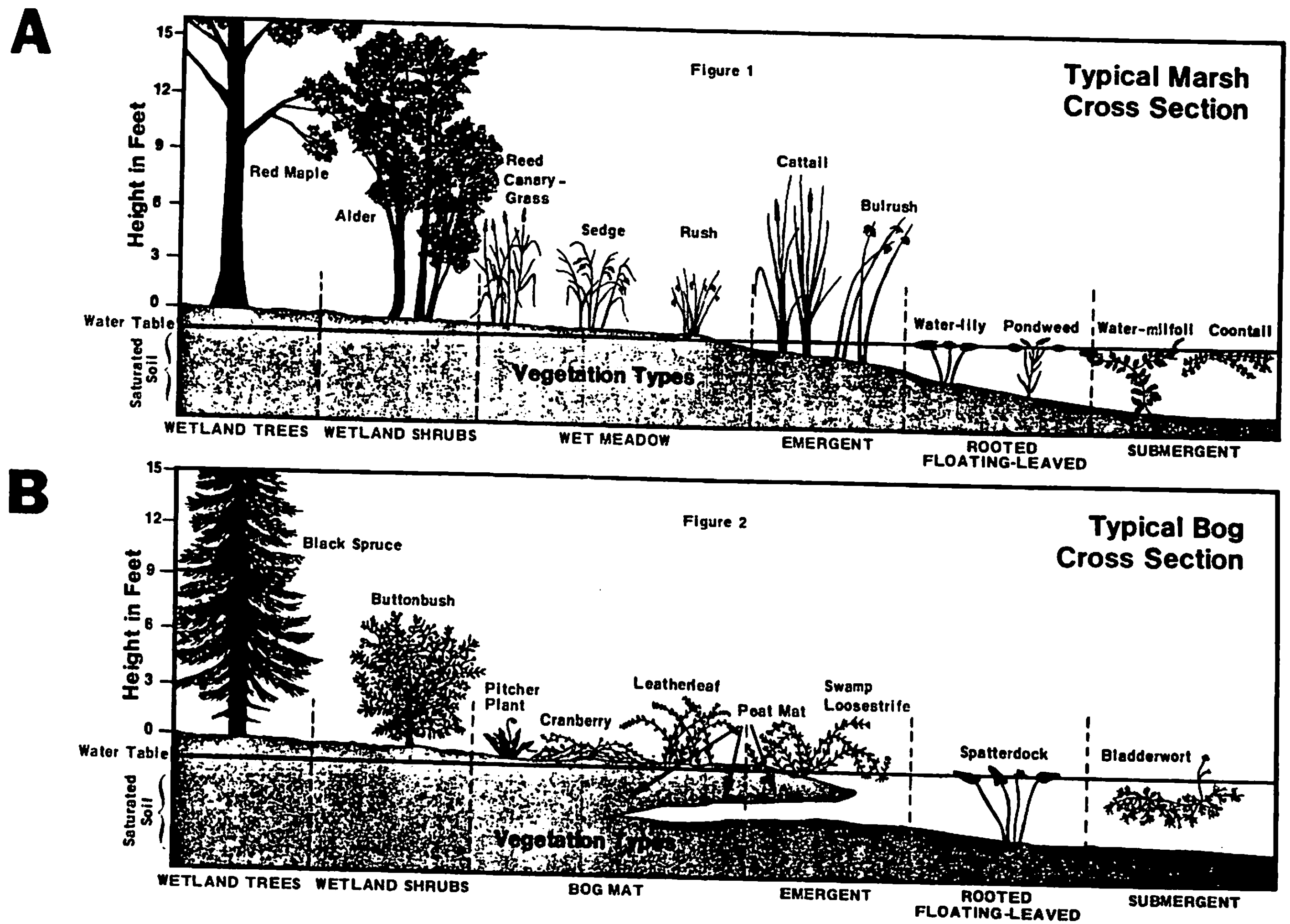


Figure 54. Vegetation Zones of Typical Wetlands: A) Marsh and B) bog.

ive features, which results in the great variety and diversity of coastal wetlands found in the region.

Origin of Coastal Wetlands

The basin occupied by Lake Erie was created by glaciation, and physical features and hydrology differ greatly from regions not exposed to Pleistocene ice sheets. In terms of earth history, the construction of the basins has recently been completed. The lake, with its outlet,and lake level as they are today, probably dates back less than 5,000 years. The processes of stream and coastal erosion/accretion have made only modest changes in the original topography, but these 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 Lake Erie became established, stream and coastal processes provided favorable sites for wetlands. The most significant processes are: 1) delta formation, 2) estuary formation, and 3) sand bard and costal lagoon formation. Although the gross configuration of the Great Lakes have been 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 oberburden 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 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 dirft, 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 (30 m) across, such as Fern Lake in Geauga County, Ohio, while others, such as Trout Lake, Wisconsin, have a diamter of nearly three miles (5 km). In general, the depth of the kettle lakes does not exceed 165 feet (50 m). 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 and ericaceous shrubs, such as leatherleaf and Labrador 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 black 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, four basic outlines are recognized: 1) arcuate, triangular outline, 2) digitate, bird-foot type, 3) cuspate, tooth-shpaed 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 depostional 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 analagous to the alluvial fans found at the base of mountain ranges. The natural levees serve to isolate shallow interdistributary ponds and marshes containing fine muds and organic detritus or peat. 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 somewaht 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 plan 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 particltes 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 (24 km) of the Maumee River, which flows into Lake Erie at Toledo, Ohio and possesses 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 glaical 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 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.

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 istes for wetland development along the Great Lakes.

Professor Edward J. Kormandy 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 (100 to 200 m) long, 33 to 66 feet (10 to 20 m) 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 (Figure 55). 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 protion to about half of its former area. The major vegetation then

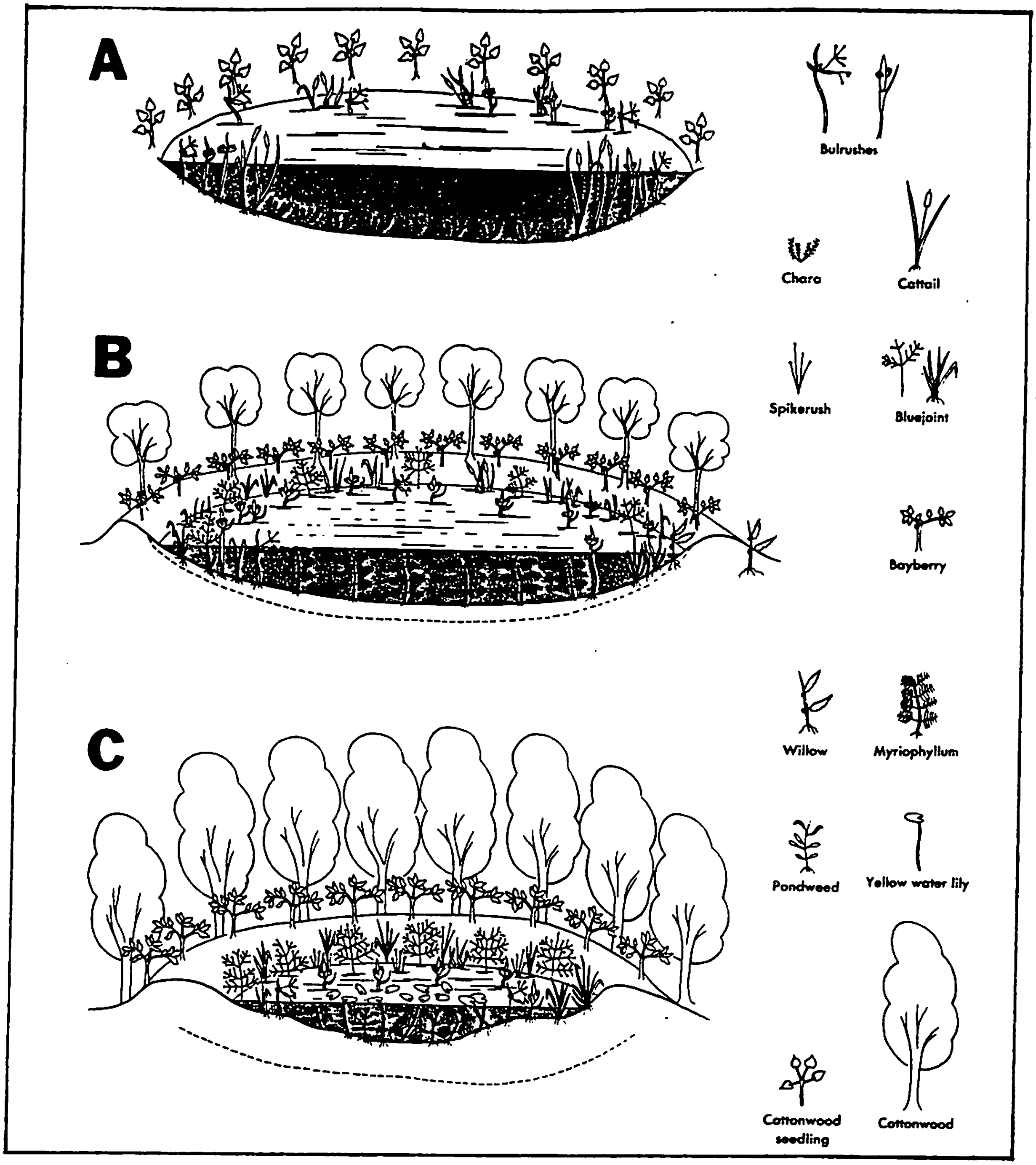


Figure 55. Wetland Succession in a Lake Erie Beach Pond: A) 4 years old, B) 50 years old, and C) 100 years of age.

consists of water milfoil, cattail, bulrushes, blue-joint, 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, blue-joint, spikerush, bayberry, and cottonwood. Sparseness of distribution and limitation of palnt species mark the early ponds; increased density and heterogeneity characterize the older ponds, and the contrast is striking. From this analysis of succession, Professor Kormondy concluded that the ponds or lagoons at the northeast of Presque Isle are the youngest and that the spit has growth from the southwest because the ponds are increasingly older in that direction.

Value of Coastal Wetlands

The value of coastal wetlands is immense but it is not often recognized by the general public. In recent years there has been an increasing awareness of the valuable resources of our Great Lakes coastal wetlands and the urgent need to protect and conserve these ecosystems. Traditionally, wetlands conservation efforts have been aimed at protecting waterfowl breeding sites, or to a lesser degree, fish spawning and nursery habitat. More recent efforts toward preservation are based on the knowledge that wetlands provide additional benefits, including flood control, shore erosion protection, nutrient cycling, accumulation of sediments, and the supply of fundamental material for aquatic food webs. Some of the more important functions and values of coastal wetlands are outlines below:

1. Wetlands as habitats
   a. food chain production and energy flow
   b. fish production, spawning, and nursery
   c. water fowl migration, wintering, and nesting
   d. invertebrate and mammal habitat

2. Economic value of wetlands
   a. agricultural uses (peat, blueberries, wild rice, etc.)
   b. commercial and sport fishing
   c. trapping of furbears
   d. waterfowl hunting
   e. nonconsumptive recreation (birdwatching, canoeing, hiking, etc.)

3. Physical functions of wetlands
   a. groundwater recharge and flood storage
   b. sedimentation basins
   c. pollution control waste by assimilation, toxic substance absorption, and nutrient uptake
   d. coastal protection from wave-attack

Flora and Fauna of Coastal Wetlands

The Lake Erie and Lake St. Clair wetlands are actually composed of a variety of habitats including open ponds, cattail/reed marshes, earthen dikes, barrier beaches, delta flats, and wooded swamps. Collectively these habitats are known as the coastal marsh complex. Each habitat attaches its own species of plants, birds, mammals, reptiles, amphibians, and in some cases, fish. The result is more variety in plant and animal life than in any other area of equal size in the interior of the bordering states and province. The overal conditions of the coastal marshes are still very primitive. The marshes in the region have been visited by no more than a handful of people in the last several decades.

Food Chains. The ultimate source of energy for wetlands ecosystems is the sun. Only a small fraction of the total available energy from the sun eneters the food chain. Even when light falls where vegetation is abundant, such as a coastal marsh, only one or two percent of that light is used for photosynthesis. Yet, this fraction results in the production (from carbon, oxygen, water and minerals) of up to three pounds (6,000 gm) of organic matter per year in a single square yard (m^2) of marshland.

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 types: 1) macrophytes (marsh grasses, macroalgae, and terrestrial plants), 2) benthic microalgae, and 3) phytoplankton. Several studies indicate that the macrophytes are the most important primary producers in the marshes. These photosynthetic organisms use light energy to make carbohydrates and other compounds, which then become sources of chemical energy. Producers far outweigh consumers: 99% 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, the 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 a herbivore becomes incorporated into the body of a 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.

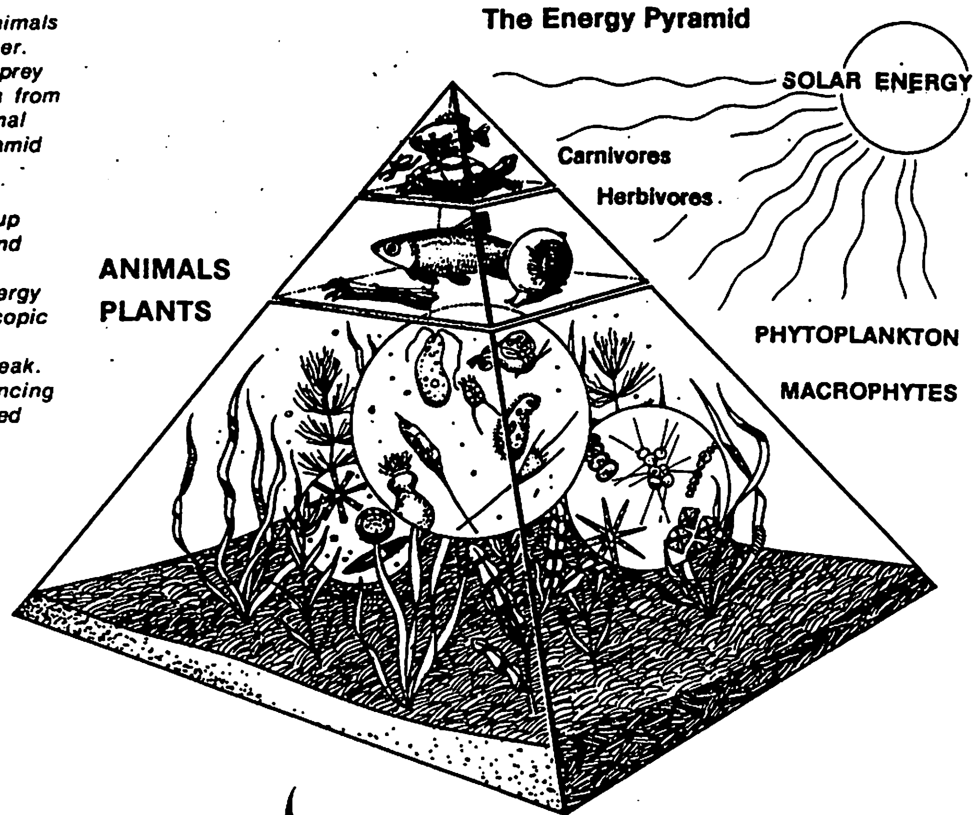
The flow of energy through a food chain is often represented by a graph of quantitative relationships among the various trophic levels.(Figure 56). Because large amounts of energy and biomass are dissipated at every trophic level, these diagrams nearly always take the form of pyramids. Such a pyramid may be: 1) a pyramid of numbers, showing the numbers of individual organisms at each lelve; 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 realtionship 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.

The studies which first introduced the concepts of trophic levels were first worked out in freshwater wetlands. In the early 1940s, Professor Chancey Juday determined the various components of the aquatic population in Weber Lake, Wisconsin, as they existed in midsummer. For this particular lake, he found that the dissolved organic matter composed about 60% of the total pyramid; the fish, only 0.5%; and the other animals, slightly less than 5% of the total pyramid. In freshwater systems there are often three major sources of energy for aquatic consumers: 1) marsh detritus, 2) phytoplankton production, and 3) detritus from terrestrial sources brought in by drainage.

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

In lakes, plants are eaten by animals and animals are eaten by each other. The predator of one species is the prey of another. This process continues from the lowest plant to the highest animal and constitutes the food web or pyramid (also called the food chain).

The fixed amount of energy available to a lake is transferred up through the food web by plants and animals. The "energy pyramid" drawing depicts the transfer of energy in an ecosystem, from the microscopic plants (phytoplankton) to the final consumers, the carnivores, at the peak. These relationships impose a balancing effect even on the most complicated ecosystems.



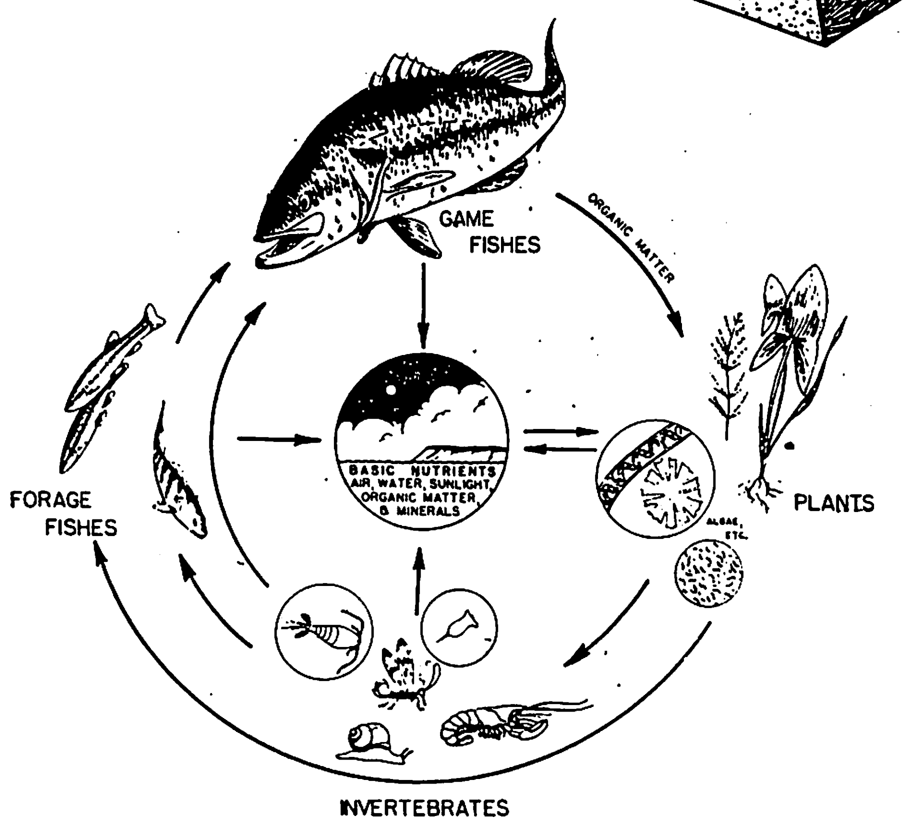


Figure 56. Energy Pyramid and Food Relationships.

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 eutrophy and then decline as the lake undergoes senescence (Figures 44 and 50-B).

Vegetation. An estimated 1000 species of vascular (higher) plants can be found in the marsh communities of the Lake Erie region, of which only 100 are trees and shrubs. The wetlands of western Lake Erie occupy large expanses of low-lying shoreline. Many have been preserved by diking to combat the adverse effects of recent high water episodes. Throughout this area, the dominant wetland species include cattail, burreed, grasses, spatterdock, water lily, and water smartweed. Vegetation composition varies greatly among wetlands, with greates species diversity occurring in the wetlands of the western basin. Upon a reduction in water levels, the acreage and quality of vegetated wetlands on Lake Erie may be expected to increase, particularly in stream mouth and embayment wetlands.

The southwest and west shore of Lake Erie include 40,000 acres (160 km^2) of marsh, most of which is owned by private clubs. Several marshes, such as the State-owned Magee Marsh and the privately owned Winous Point Club are under intensive management for increasing waterfowl breeding population. Most of these marshes are natural lowlands separated from Lake Erie by a stable beach ridge. The sandy beach is strewn with clam shells, small rocks, and pebbles washed ashore during storms. Several species of grasses, sandbar willow, staghorn sumac and several other low plants characterize the beach ridge plant community. Behind the beach ridge is a hardwood swamp zone. Cottonwood and black willow are in abundance and hackberry, sycamore, staghorn sumac and river-bank grape are common. The beach ridge and harwood swamp are probably the most stable communities within the Navarre area.

The freshwater marshes are often surrounded and transected by earthen dikes. Cottonwood, black willow, rough leafed dogwood, staghorn sumac, riverbank grape and several grasses are common on the dikes. Wherever there is standing water throughout most of the year, cattail, softstem bulrush, white water lily, milfoil, sago pondweed, and curly-leafed pondweed are abundant.

Waterfowl management is essentially control of plant succession based on the seasonal needs of waterfowl. Intensive and economical management is best achieved by control of water levels, since fluctuation of water levels has a marked influence on the succession of aquatic plants. Marsh managers in Ohio obtain the best results from drawdowns (by use of dikes and/or pumps) in May to create a nesting habitat for the summer, and reflooding in the fall to attract large numbers of fall migrants. Partial reduction of water levels (rather than complete drying of soil) exposes knolls used for nesting and leads to an interspersion of suitable submerged, emergent and shoreline vegetation. In 1972, an experimental water draw down test was conducted at Locust Point. Where only partial draw down was done, dense growths of smartweed (a good waterfowl food) developed along the dike and other exposed areas. Partially flooded areas developed dense stands of emergents such as bulrush, water milfoil, and spikerush. In areas where the water was not drawn down, less desirable water lillies and arrowhead cover most of the formerly open water areas.

Fish. 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. Approximately 43 species of fishes are or once were associated with the coastal marshes of Lake Erie. Twenty-six of these species are currently of significant recreational, commercial, or prey value. Fishes associated with coastal marshes can be divided into two categories: 1) species directly dependent on coastal marshes as adult habitats or spawning and nursery areas, and 2) species not dependent on marshes for such uses but which are usually common in coastal marshes, apparently making opportunistic use of them as spawning, nursery and feeding areas. The first category includes species such as northern pike, longnose gar, bowfin, bullheads, and crappies, whose dependence on aquatic vegetation has been well established. The second category includes common nearshore and bay species such as gizzard shad, quillback, white sucker, white bass, white perch, channel catfish, and yellow perch, which have been shown by qualitative surveys and observations of marsh managers to be seasonally common or abundant as young or adults in coastal marshes, although the literature indicates that they have no strict dependence on aquatic vegetation.

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 and carp). Often as much as 90% of the standing fish crop of inland wetlands, which commonly ranges from between 250 to 500 lbs. (45-90 kg/hectare), 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 and bullheads, are tolerant of turbidity and siltation.

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. Northern pike usually broadcast their eggs over vegetation and debris in warm, shallow embayments and marshes. 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 has resulted in the elimination or degradation of wetland spawning environments.

Studies related to fish movement into and out of a coastal wetland of Sandusky Bay, Ohio revealed that the exchange of all fish species between the wetland and bay was substantial. Movements in each direction are almost equal, with direction of movement apparently determined by positive rheotaxis. Direction of flow varied with fluctuating water levels in Sandusky Bay. The principal species moving through the culvert were, in order of abundance, gizzard shad, brown bullhead, carp, freshwater drum, white crappie, pumpkinseed, goldfish, and black crappie. Peak adult movement appeared to be related to spawning activity in the spring, with juveniles moving out of the wetland in summer. Studies of the effect of carp on vegetation in the Erie Shooting Club marsh on the Michigan shore of Lake Erie were made by comparing enclosed, carp-free areas with similar areas open to carp. This research demonstrated that carp significantly decreased the abundance of aquatic vegetation in the marsh. Carp had a selective effect on certain submersed plants, particularly in the spring growing season, when plants were young and delicate. Carp retarded growth of plants by feeding on them, uprooting them, and increasing turbidity of the water. Carp can be extremely deleterious in waterfowl marshes because they selectively destroy those submersed plants most attractive at waterfowl food.

Reptiles and Amphibians. Snakes, turtles, frogs and salamanders are common in the Lake Erie wetlands. Representative snakes include the water sanke, fox snake, brown snake and garter snake. Painted, snapping, and Blanding's turtles are the most common. Frogs are represented by the bullfrog, green frog, leopard frog, striped chorus frog, cricket frog, and spring peeper. Marsh salamanders include the mudpuppy, Jefferson, spotted and red-backed. The presence of water, food, and cover, as well as relative isolation from the cultural development which impinges on most dry coastal areas, are among the factors which contribute to the importance of wetlands in maintaining a diverse and abundant herpetofauna. The snapping turtle, eastern spiny softshell, bullfrog, and green frog are edible species which are harvested to an unknown extent in coastal wetlands. Of the turtles, the snapping turtle is the largest. Many reptiles and amphibians also serve as food sources for fish, birds, and mammals utilizing the wetlands.

Birds. In general, wetland habitat along Lake Erie supports a diversity of bird life. Resident and migratory species of waterfowl, waterbirds, wading birds, shore birds, gulls and terns, raptors and perching birds use the region for nesting, feeding, and resting. Noteworthy migratory species which utilize the shoreline environment include the bald eagle, osprey, and Kirtland's warbler. Waterfowl commonly observed in the wetlands of southwestern Lake Erie are mallards, wood ducks, black ducks, pintails, blue-winged teal and American wigeon.

Several species of endangered birds have been recorded in the coastal wetlands of Lake Erie. Bald eagles nested successfully in 1983 within the Locust Point wetland complex, which is located in southwestern Lake Erie. Several nonbreeding resident pairs of bald eagles have also been observed in the region. King rails have been recorded from several wetlands and are known to breed in the vicinity of Catawba Island. The common tern has been observed as an occasional visitor from nearby rookeries. In addition, migrating bald eagles and ospreys use the coastal wetlands of Lake Erie as feeding and resting areas. Other birds endangered or threatened in states bordering Lake Erie and which have been recorded in the coastal zone of the lake include the Caspian tern (Michigan); piping plover (Michigan); Cooper's hawk (Michigan); red-shouldered hawk (Michigan); marsh hawk or northern harrier (Michigan); and sharp-shinned hawk (Ohio). Some other birds such as the common tern, the black-crowned night heron, the barred owl, and the American bittern, are now rare in Michigan.

The Great Lakes lie along the path of two bird migration corridors which comprise the Mississippi and Atlantic Flyways (Figure 57). Each corridor, in turn, is a web of routes as opposed to a single, narrow band rigidly followed by waterfowl. In general, fall movements of dabbling ducks, e.g. common mallard 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.

As waterfowl migrate between breeding grounds and wintering areas, they stop to rest and feed in wetlands with an abundance of food, low wave energy, and little human disturbance. Canvasbacks, redheads, American widgeon, ring-necked ducks and coots feed extensively on submersed plants, whereas shovellers, oldsquaw, goldeneye, and mergansers appear to prefer crayfish, small fish, and other animal foods. 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. Food availability may be more important than food preference, especially during the spring migration when food supplies are less abundant.

Mammals. Cattail marshes provide excellent food and building material for furbearers such as muskrat. Many other species occupy multiple habitats, of which wetlands may function only as one, such as raccoons and white-tailed deer. All told, about 20 kinds of mammals can be found in the marsh complex. The most important furbearer in this region is the muskrat. The muskrat harvest in southwestern Lake Erie wetlands ranks Ohio among the top fur-producing states and accounts for 70% of Ohio furs. The high productivity of muskrat in this region is a direct result of management practices which

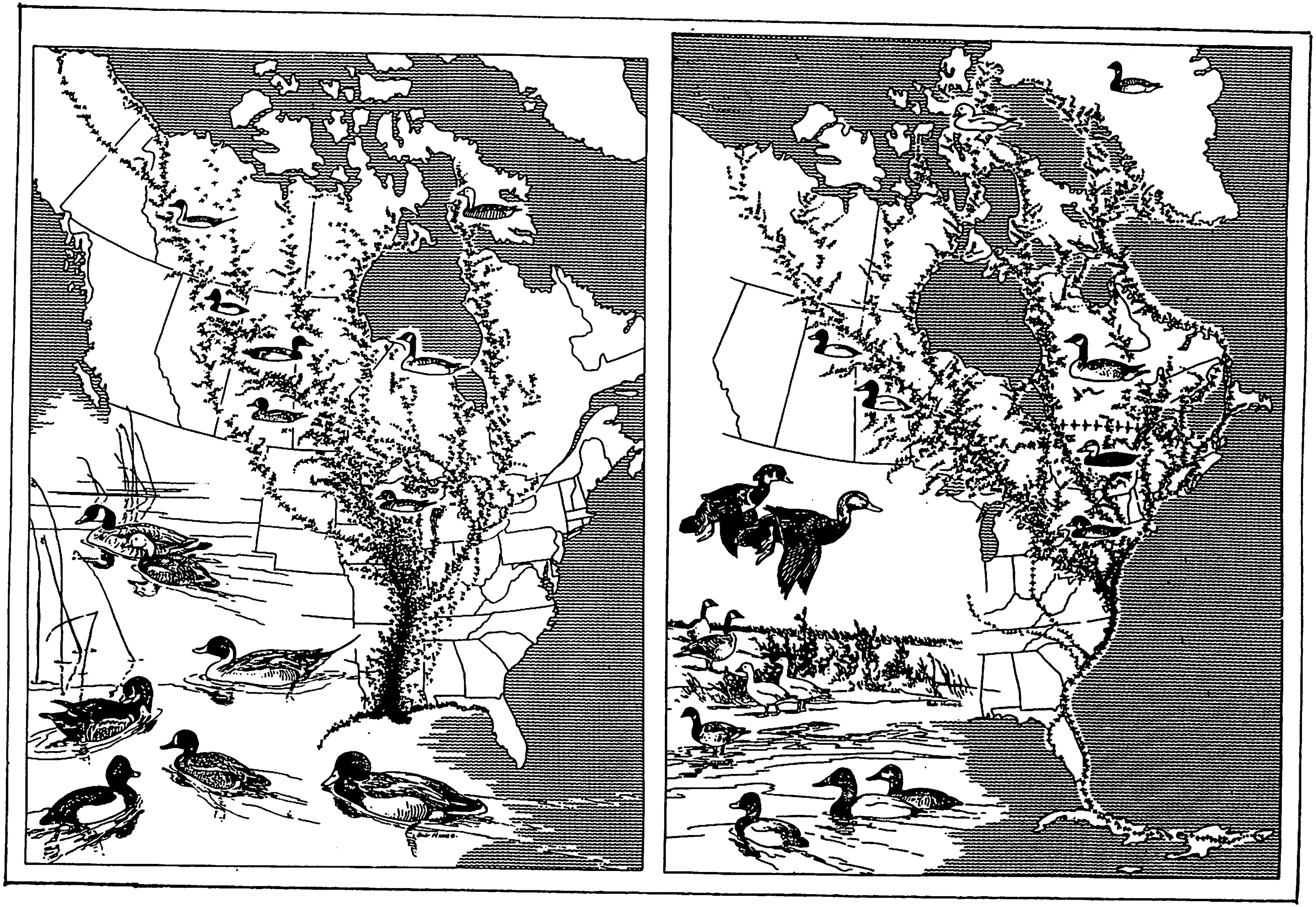


Figure 57. Mississippi (left) and Atlantic (right) Waterfowl Migration Flyways.

maintain stable water levels in the wetlands. Red and gray foxes are also frequent visitors to the wetland margins, feeding on rabbits, rodents and marsh birds.

The coastal wetlands of Lake Erie are important for many mammalian species. The Eastern cottontail, woodchuck, and striped skunk chiefly utilize the dikes of managed wetlands. Fox squirrels are found most commonly in the wooded perimeter of wetlands. White-tailed deer are only transient members of wetland communities. Long-tailed weasels, mink, and red fox are uncommon on most Lake Erie wetlands. Mammalian faunas of the Lake Erie island wetlands generally have a lower diversity than those of the mainland wetlands.

Environmental Changes in Coastal Wetlands

One of the most significant environmental changes in Lake Erie was draining and filling of the extensive coastal marsh system at the western end of the lake. Prior to 1850, an extensive coastal marsh and swamp system, consisting largely of an area known as the Black Swamp, covered an area approximately 4,000 km^2 between Vermilion, Ohio, and the mouth of the Detroit River and extended up the Maumee Valley into Indiana. This area was largely cleared, drained, and filled to provide agricultural land, lumber, and transportation routes, so that at present only about 100 km^2 of coastal marshland remains. Most of this remaining marshland is encompassed by dikes. Between 1850 and 1900, as coastal marshes were drained and filled for conversion to agriculture, dikes were constructed to protect farmlands from seasonal flooding and to separate them from adjacent open water and unfilled marsh. During this time the marshes of western Lake Erie gained considerable fame as waterfowl hunting areas. After 1900, the rate of loss of the remaining marshlands accelerated due to increasing development pressure, changing lake water levels, increasing agricultural siltation, and wave erosion, and groups of wealthy sportsmen interested in preserving quality of waterfowl hunting in the area purchased most of the remaining marshland around western Lake Erie. Marshes were enclosed by a second generation of dikes equipped with gates and pumps to protect the marshes from flooding, siltation, and wave erosion and to permit water level regulation within the marshes for the production of aquatic plants used by waterfowl. Since 1950, many of these privately owned marshes were acquired by the Ohio Department of Natural Resources and the U. S. Fish and Wildlife Service to be used as wildlife refuges, public hunting and recreation areas, natural areas and preserves, and state parks.

Visiting Coastal Wetlands

Over 150 individual wetlands or wetland complexes are found along the coast between the head of the mouth of the St. Clair River and the mouth of the Niagara River. Taken together, the United States and Canadian coastal wetlands of Lake Erie and Lake St. Clair cover an estimated 130,000 acres (530 km^2). Many of the finest marshes and swamps are owned and managed by federal, state and provincial agencies as wildlife preserves. Most of these agencies have established visitor's centers, nature trails or observation towers to accommodate the interested traveler. Six of the best areas to observe coastal wetlands in the vicinity of western Lake Erie are described below:

Maumee Bay. This bay lies at the mouth of the Maumee River and is formed by Cedar Point (locally known as little Cedar Point to avoid confusion with the point of the same name on the east side of Sandusky Bay) on the east and Woodtick Peninsula on the west (Figures 58 and 59). These two sand spits provide the shelter necessary for wetland development on their landward side. The former lies within the Cedar Point National Wildlife Refuge (administered as part of the Ottawa National Wildlife Refuge) and the latter lies partially within the Erie State Game area (administered by the Michigan Department of

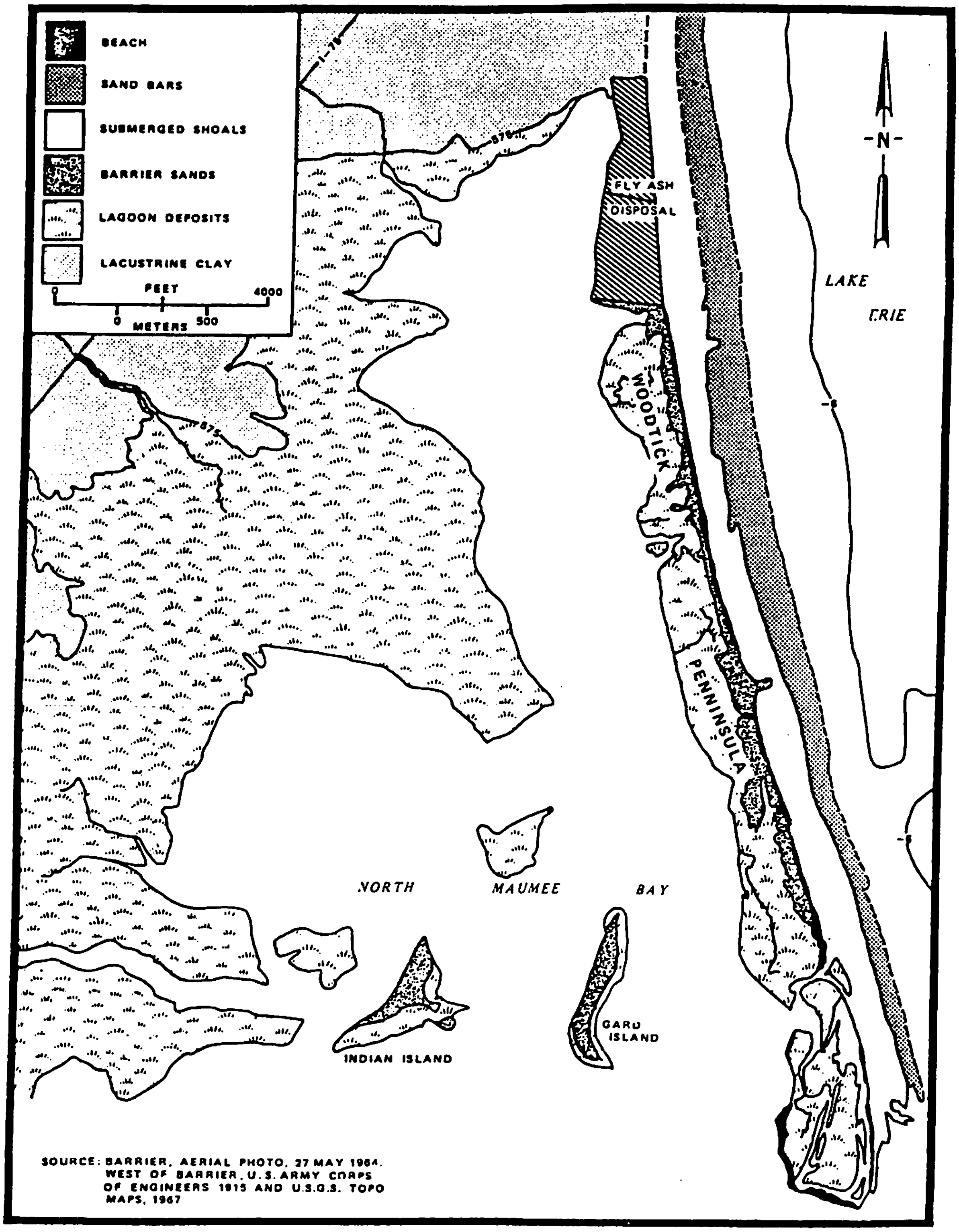


Figure 58. Coastal Wetlands of Woodtick Peninsula and North Maumee Bay.

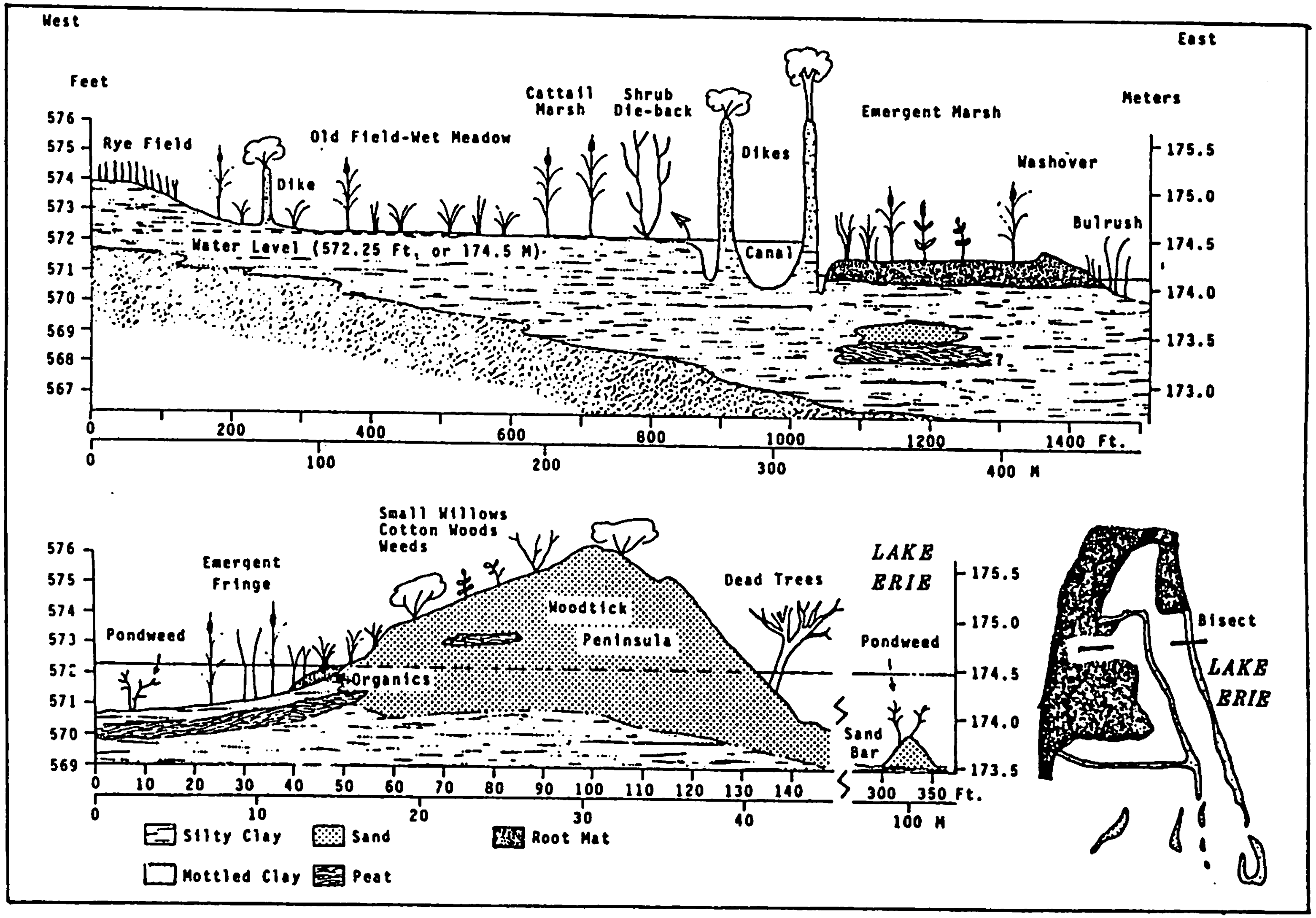


Figure 59. Bisect (Cross-section) of Woodtick Peninsula and North Maumee Bay Coastal Wetlands.

Natural Resources). The Cedar Point marshes extend westward along the south shore of the bay to Maumee Bay State Park. Estuarine wetlands also occur along the Maumee River valley between Rosford and the first bedrock riffles at Perrysburg.

The major plant species thriving in the Maumee Bay marshes include narrow-leaved cattail, broad-leaved cattail, jewelweeds, marsh-mallow, blue-joint grass, and swamp milkweed. In the transition zone between open water and the cattail stands, soft-stem bulrush and American bulrush are the dominant species.

Fish found in the Maumee Bay wetlands include bowfin, carp, yellow perch, largemouth bass, white bass, green sunfish, yellow bullhead, gizzard shad, and walleye.

The historical occurrence (1936) of Forster's tern has been reported for these wetlands. A bald eagle nest is active on Cedar Point. The most common waterfowl are mallard, black duck, green-winged teal, blue-winged teal, northern shoveler, and American coot. Whistling swans and snow geese also utilize the area for resting during spring migration. The area sustains resident populations of 200-300 each for mallards and Canada geese and smaller numbers of blue-winged teal.

Locust Point. This point is a low, gently curved headlands on the south shore of western Lake Erie between Toledo and Sandusky, Ohio,(Figure 60). Flanking this point, to the east and west, are 8,600 acres (35 km^2) of prime coastal marshes, mostly in federal or state ownership. This wetland complex includes 4 units of the Ottawa National Wildlife Refuge (Cedar Point Marsh, Ottawa Marsh, Navarre Marsh, and Darby Marsh) and 3 areas administered by the Ohio Department of Natural Resources (Metzger Marsh, Magee Marsh, and Crane Creek State Park). All of these wetlands are protected from Lake Erei flooding by extensive earthen and rip-rap dikes. The federal areas, some of

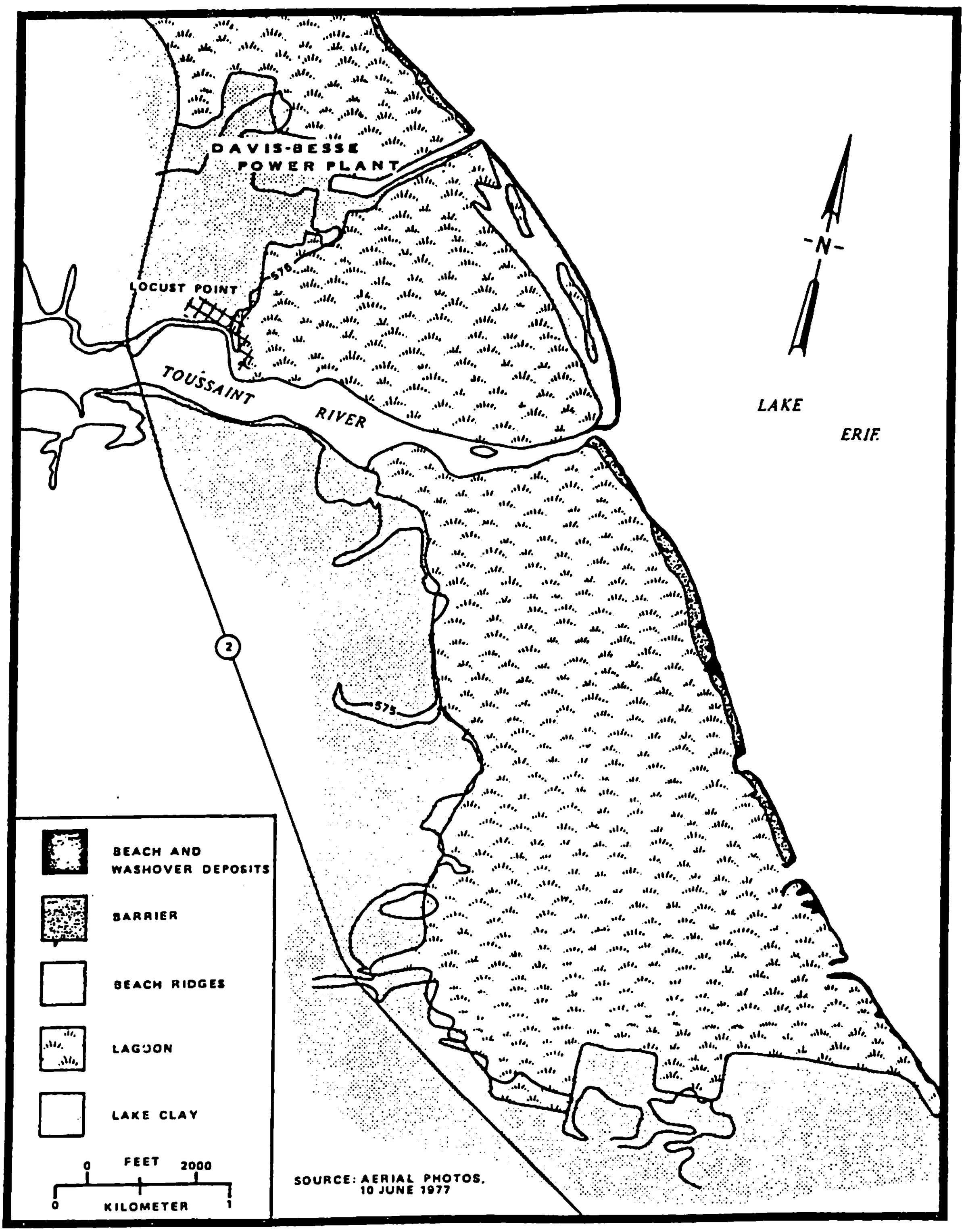


Figure 60. Coastal Wetlands of Locust Point.

which are former hutning club preserves are now managed as waterfowl refuges by the U. S. Fish and Wildlife Service. Controlled waterfowl hunting is permitted in some parts of the state wildlife areas. Several nature trails are open to visitors in both the federal and state refuges and a fine swimming beach is located at Crane Creek State Park.

Because the marshes are managed for waterfowl most of the aquatic plants present are excellent duck food. Walter's millet is the dominant grass. Marsh plants associated with this species include soft-stem bulrush, hardstem bulrush, catchfly grass, mild water-pepper, smartweed and cattails. A recent invader, purple loosestrife produces a beautiful violet flower but offers little food value for wildlife. This plant propagates readily and is a threat to many Lake Erie wetlands.

A fishing survey in connection with an environmental evaluation of the Davis-Besse Nuclear Power Station on Locust Point revealed 48 species of fish in Lake Erie and the coastal wetlands. Of these, only 7 species were found in Navarre Marsh which borders the station: bowfin, gizzard shad, gold fish, carp, largemouth bass, black crappie and white crappie.

Major waterfowl species found in the vicinity of Locust Point are mallard, black duck, American wigeon, wood duck, pintail, blue-winged teal, and Canada goose. The wetlands in this complex also provide important nesting and feeding habitat for bald eagles. Three pairs of bald eagles have been observed nesting here in recent years. Ospreys use this area for feeding and resting during migration.

As with most of the Lake Erie marshes, the muskrat is the most important furbearer. Other mammals common in the marshes and earthen dikes are woodchuck, eastern cottontail, striped skunk, and white-tail deer.

<u>Lake Erie Islands</u>. Small wetlands can be found on most of the larger islands in western Lake Erie. Several of the more prominent ones are listed

below:

Island	Wetland
Pelee Island	Fish Point Swamp
Pelee Island	Lighthouse Point Marsh
Kelleys Island	Carp Pond
South Bass Island	Terwilliger's Pond
North Bass Island	Manila Bay/Smith's Pond
North Bass Island	Fox's Marsh
Middle Bass Island	Haunk's Pond
East Sister Island	East Sister Swamp

Typically, these wetlands occupy depressions between sand spits or barrier bars and the shoreline by alongshore currents. These low, protected areas eventually became the sites of lush growths of vascular aquatic plants. Lagoons with openings to the lake, such as Carp Pond, Terwilliger's Pond and Manila Bay serve as spawning and nursery grounds for several warm-water fish species such as carp, white crappie, bluegill, and yellow perch.

The protected marsh in Haunk's Pond provides an excellent example of aquatic plant zonation in response to water depths. Eight zones have been identified extending from open water to a shrub shoreline:

zone		zone	
1	open water	5	cutgrass
2	waterlily	6	jewelweed
3	dock	7	tall grass
4	cattail	8	shrub shoreline

Each of these zones is transitional in nature, and in no zone does one species dominate to the exclusion of all other species.

Major species occurring in the open water zone are unattached floating plants such as duckweeds, water flaxseed, and water-meal, and submersed aquatic plants such as sago pondweed, water milfoil, elodea, and coontail. July water depth in this zone ranges to 3 feet (1 m).

Major species composing the water lily zone are spatterdock and white water lily. Species associated with this zone include water-plantain, arrowhead, and pickerel weed. The water lily zone is actually several disjunct zones, together occupying a major portion of the wetland. July water depth in this zone ranges up to 3 feet (1 m).

Two species of dock comprise the major cover of the dock zone. Plants thriving under the dock cover include spatterdock, white water lily, sedges, and in some areas rice cutgrass. Occasional hummocks support swamp-loosestrife and buttonbush. July water depth in this zone ranges up to 1.5 feet (0.5 m).

Narro-leaved cattail and broad-leaved cattail are co-dominant species of the cattail zone. Thriving as associates in this zone are sedges, soft rush, burreed, cutgrass, and river bulrush. Early summer water depth in this zone ranges up to 0.5 feet (15 cm). However, this zone was predominantly a mudflat.

In early summer, 2 to 6 inches (5-15 cm) of water covered the cutgrass zone. At this time water-plantain and spatterdock are common associates of cutgrass. As water levels fall, associated species are limited to sedges, spike-rushes, and ditch stonecrop.

The jewelweeds occur in the jewelweed zone nearly to the exclusion of other species. However, in wetter areas cutgrass, spatterdock and dock occur. Additional associates of this zone include cattail, sedges, rushes, monkey-flower, skullcap and iris.

The tallgrass zone is primarily composed of reed-canary grass and blue-joint grass, which in some areas attained a height of 6 feet (2 m). Jewel-weed and cattail are the only herbaceous associates. Small hummocks in this zone support white ash, hackberry, and choke cherry.

The shrub zone is composed primarily of saplings of species found in the nearby swamp forest such as bur-oak, hackberry, slippery elm, white ash, and white mulberry. Low growing plants occurring in this site include choke cherry, prairie rose and common elderberry.

Most of the island wetlands are privately owned, but several can be viewed from nearby roadways, including Haunk's Pond. Carp Pond lies within

Kelleys Island State Park and is open to visitors.

Sandusky Bay. This bay contains several distinctive wetlands extending from the mouths of the Sandusky River and Muddy Creek at the far western end of the bay, along the south shore to the vicinity of the Sandusky Bay bridges, to the sand spits of Cedar Point and Bay Point at the eastern extremity of the bay. The wetlands at the western end of the bay are the most extensive in private ownership on the Ohio shore of Lake Erie (4300 acres; 17.4 km^2). These wetlands are largely non-wooded and protected by earthen and rip-rap dikes. They are mostly managed for waterfowl hunting and propagation and to a lesser extent, trapping and propagation of furbearers. Much of this marshland and the wetlands in the vicinity of the bay bridges are divided by a network of dikes into a number of marsh units, which are managed individually for waterfowl habitat. If it were not for the dikes, it is likely that the erosive action of the waves would eliminate much of the wetland vegetation. In the open water of the marshes the dominant plant species varies from year to year, but the most common ones are coontail, duckweeds, water-milfoil, water-smartweed, American lotus, white water lily, spatterdock, pondweeds, and water-stargrass. The ability to regulate water levels in managed marsh units has proven to be a useful tool in altering species composition and thereby increasing waterfowl food and nesting cover.

The dominant nesting waterfowl of these marshes are mallard (72%), black duck (16%), and blue-winged teal (9%). The adult great blue heron population of these wetlands is estimated at over 3,000 birds; one rookery alone at Winous Point has 1,200 breeding pairs in 1976. Nesting bald eagles have been reported in this area as recently as 1974.

The muskrat is the most important furbearer and receives the greatest trapping pressure in these wetlands. During the November to Marsh trapping season over 5,000 muskrats are taken each year from the Winous Point Marsh (north shore of Sandusky Bay across from the mouth of the Sandusky River). Other marsh mammals trapped for their pelts include raccoon, opossum, mink and red fox.

The marshes at the eastern end of Sandusky Bay are considerably different. They are not protected by dikes, but rather, they benefit from the natural protection provided by the sand spits at the entrance to Sandusky Bay. The mouth of the bay is an area converging alongshore currents. One set of currents has built Bay Point spit in a northwesterly direction. These two spits are now separated by the 40 foot (13 m) deep Moseley Channel. The tip of Bay Point is accreting at a rate of 10 feet (3 m) per year but further growth of Cedar Point has been halted by the construction of a 1.6 mile (2.6 km) long jetty at the tip to keep the channel open for navigation.

Wetlands and open ponds occupy depressions between sand ridges on both of these spits. Bay Point wetlands are relatively undisturbed. Although privately owned, the fine beaches are open to the public for swimming and camping. Cedar Point wetlands were probably similar to those of Presque Isle, but they have since been modified to accommodate a major amusement park. The Cedar Point sand spit also provides natural protection for marshes which have developed between Big Island (near the mouth of Pipe Creek within the city of Sandusky) and Sawmill Creek at the base of the spit. These marshes are typically dominated by cattails and spatterdock.

Similar wetlands can be found at East Harbor State Park. In the shallow depression between Marblehead Peninsula and Catawba Island (also a peninsula), sand spits have formed lagoons known as West Harbor, Middle Harbor, and East Harbor. Marine and residential development has highly altered both West and East harbors, but Middle Harbor (within the State Park) still offers the visitor an excellent opportunity to view lush growths of vascular aquatic plants and the animals of a balanced marsh community.

Old Woman Creek. Old Woman Creek wetland occupies the lower estuarine portion of the stream. It is separated from Lake Erie by a narrow barrier beach at the stream mouth. The wetland is mostly non-wooded, with emergent and floating-leaf plants bordered by a mixed hardwood forest on the steep banks. Located east of Huron, Ohio near the southernmost point of the Great Lakes, this beautiful natural area was designated in 1977 as the first National Estuarine Sanctuary on the Great Lakes. The sanctuary is operated by the Ohio Department of Natural Resources with support from the National Oceanic and Atmospheric Administration. A visitors center and natural trails are open to the public. Portions of the sanctuary are reserved for the use of wetland researchers.

Within Old Woman Creek wetland four aquatic habitats can be found: 1) open water, 2) shoreline, 3) embayment marshes, and 4) mud flats. Common vascular aquatic plants occurring in the open water include American lotus, spatterdock, arrow arum, coontail, pondweeds, and duckweed. The shoreline habitat features buttonbush, rough leaf dogwood, blue flag, and arrowhead. Embayment marshes, which have been reduced in size due to high lake levels since 1972, are characterized by river bulrush, giant burreed, cattail and lizard's tail. In mid-summer the mud flats are marked by marsh-mallow and water-smartweed.

Point Pelee. Point Pelee is a massive sand spit on the north shore of Lake Erie that marks the division of the lake's western and central basins. The 5-mile (8 km) long spit is triangular in shape with an exceptionally sharp, narrow point projecting out into the lake. The spit has been formed by a convergence of alongshore currents, resulting in the deposition of sand eroded from the bluffs far to the east and west of the point. The sand bars deposited by these currents now enclose a cattail marsh of high quality. The entire spit and the 2,500 acre (10 km^2) marsh lie within the boundaries of Point Pelee National Park. The park is surrounded by 13.5 miles (22.5 km) of sand

and pebble beaches.

The terrain of Point Pelee is mostly marsh or woodland. The marsh contains 6 major open-water ponds. The largest (Big Pond) has a broadwater nature trail constructed for the enjoyment of park visitors. Here, aquatic plants and sedges wage a constant battle with the open ponds, encroaching on them, filling the margins with a lush carpet of vegetation, including cattails, spatterdock, pickerel weed and marsh-mallow. Of the 600 species found on Point Pelee, the greatest variety can be seen along the woodland nature trail towards the southern end of the spit. Two major bird migration flyways overlap at Point Pelee. Each spring and autumn thousands of birds and bird-watchers invade the park. It is not uncommon for a single observer to tally more than 100 species during the height of the migration season. Of the 332 species recorded for the area, 90 stay to nest. Waterfowl and shorebirds are abundant in the marshes.

Fishing is permitted within the marsh. The most common species are sunfish, yellow perch, northern pike, largemouth bass, carp and dogfish or bowfin.

Animals found nowhere else in Canada enjoy the mild climate of Point Pelee. The eastern mole burrows in sand dunes adjacent to the marsh ponds and the rust-brown, fox squirrel shares the shelter of the deciduous forest with the grey squirrel. Raccoon and mink can be found near the marshes where they feed on abundant creates that thrive there. Muskrats build their community dwellings near the pond shores. At the edge of the forest other mammals include the eastern cottontail, white-tailed deer, the shy, white-footed mouse, and the insectivous, little brown bat.

VEGETATION

Habitats

The vegetation of the islands in western Lake Erie has been the subject of many studies, the latest and most comprehensive by Dr. Ronald L. Stuckey of The Ohio State University, is a catalog of all the vascular plants on the islands. Much of the material in this section is based on his findings. Several distinctive habitats exist on the islands, each having its own characteristics species composition. These habitats are the woodlots, quarries, open fields, vineyards, and pond-marshes, and the constantly changing shoreline areas of wave-splashed cliffs, low shelf-like rocky shores, sandy beaches,,and gravel beaches.

The islands are unique in possessing a combination of eastern, western, and southern species at the extreme edges of their ranges. Many of these species occur in open, naturally disturbed sites along cliffs, sandy shores, and marsh habitats. These habitats represent the most common environments shortly after the retreat of the Wisconsin glacier. Species from unglaciated lands to the east, west, and south migrated to the recently glaciated soils. Being able to survive only under fluctuating conditions, these species have continued as relic population because of the ever changing conditions on the islands. Only four species in all these habitats are identified as being endemic to the islands: *Rubus corei* (Core's blackberry), *Rubus eriensis* (Lake Erie blackberry), *Rubus gordonii* (Gordon's dewberry), and *Polygonum pennsylvanicum* var. *eglandulosum* (smartweed).

Woodlots. The original forests of the Lake Erie island area developed about 12,500 years ago with the retreat of the late Wisconsin glacier. The lake bottom was drained and became a dry forested region. On the higher ground, the dominant woody species association was spruce, fir, hemlock, jack pine, birch, poplar, creeping juniper, and white cedar. On the lower surfaces, black spruce, alder, and willow were dominant. When the spruce died out, jack pine became the became the dominant member, followed in succession by oaks and the hardwoods common on the islands today (sugar maple, white, red, and chinquapin oaks, white and blue ash, American and slippery elm, hop hornbeam, basswood, and red cedar). On the lower areas succession resulted in a swamp forest association of American elm, white ash, green ash, red maple, and silver maple. These forests existed for 8000 years until the bedrock in the Niagara region began to rise, having been released from the pressure exerted on it by the glaciers. This rise in land formed a catch basin to the west which began filling with water and flooding the postglacial valleys. A stream system developed and a characteristic floodplain vegetation grew on the surrounding hills. As the water level increased, these hills became isolated as islands and the existing vegetation became the virgin forests of the Lake Erie islands 4000 years ago.

Reminiscent of their early development, the woodlots of the islands today still have many characteristic floodplain species even though the area now bears little resemblance to a floodplain, making them unique in Ohio and perhaps in the northeastern United States (Table 6). No virgin forests exist on any of the islands today. Extensive lumbering to provide fuel for steamers affected all the islands, and was particularly devastating to red cedars which once covered Kelleys Island. Much of th land was cleared for agriculture, vineyards, and for settlement.

The major forest association on the islands is sugar maple-hackberry and on the smaller islands this is the only association present with hackberry usually the dominant species. A distinctive feature of this association is lack of leaf litter due to large snail populations and extreme weather conditions. Both these species have an efficient means of seed dispersal which is an important factor in their dominance on the more isolated islands. The larger islands, having been subject to greater influence by man, have several forest associations. Six community types occur on South Bass Island: (1) sugar maple-hackberry-basswood, (2) maple-oak-hickory, (3) hackberry-blue ash, (4) young hackberry,

TABLE 6

PLANT SPECIES OF THE WOODLOT ASSOCIATION

TREES AND SHRUBS

Acer negundo (Box elder)
A. saccharinum (silver maple)
A. saccharum (sugar maple)
Carya ovata (shagbark hickory)
Celtis occidentalis (shagbark hickory)
Fraxinus americana (white ash)
F. pennsylvanica (green ash)
F. quadrangulata (blue ash)
Gleditsia triancanthos (honey locust)
Gymnocladus dioica (Kentucky coffee tree)
Juglans nigra (black walnut)
Juniperus virginiana (red cedar)
Morus alba (white mulberry)
M. rubra (red mulberry)
Ostrya virginiana (hop-hornbeam)
Prunus serotina (black cherry)
P. virginiana (choke cherry)
Ptelea trifoliata (hop-tree)
Quercus alba (white oak)
Q. bicolor (swamp white oak)
Q. coccinea (scarlet oak)
Q. macrocarpa (bur oak)
Q. muehlenbergii (chinquapin oak)
Q. rubra (red oak)
Ribes americanum (black currant)
R. cynosbati (wild gooseberry)
Staphylea trifolia (bladdernut)
Tilia americana (basswood)
Ulmus americana (American elm)
U. rubra (slippery elm)

VINES

Celastrus scandens (bittersweet)
Humulus lupulus (hops)
Menispermum canadense (moonseed)
Parthenocissus quinquefolia (Virginia creeper)
Rhus radicans (poison ivy)
Sicyos angulatus (bur cucumber)
Smilax rotundifolia (greenbriar)
Vitis riparia (riverbank grape)

HERBACEOUS SPECIES

Alliaria officinalis (wild garlic)
Allium cernuum (wild leek)
A. tricoccum (wild nodding onion)
Arabis laevigata (rock cress)
Arisaema atrorubens (Jack-in-the pulpit)
Campanula americana (bellflower)
Camassia scilloides (wild hyacinth)
Carex blanda (sedge)
Circaea quadrisulcata (nightshade)
Geranium robertianum (wild geranium)
Hydrophyllum appendiculatum (water-leaf)
Hystrix patula (bottlebrush grass)
Osmorhiya longistylis (sweet Cicely)
Phlox divaricata (sweet William)
Phryma leptostachya (lopseed)
Smilacina racemosa (false Solomon seal)
S. stellata (starry false Solomon seal)
Trillium grandiflorum (trillium)
Urtica procera (nettle)
Viola pubescens (violet)

(5) box elder-green ash-maple, (6) swamp forest, and (7) cedar. The first four communities represent various stages in the sugar maple-hackberry association, with young hackberry being the youngest and maple-oak-hickory being the most mature. The box elder-green ash-maple association on East Point is unique on the islands. The swamp forest association is found around the edges of ponds, marshes, and in low areas. The species composition is white ash, swamp white oak, American elm, and silver maple.

Cliffs and low shelf-like rocky shores. Perhaps the most dramatic of the shoreline habitats are the high rugged cliffs along the west shore of South Bass, Kelleys, Rattlesnake, and Catawba Islands, the south shore of Middle Bass, the north and west shores of Gibraltar and Ballast Islands, and surrounding Green and Mouse Islands. These cliffs have two distinct vegetation zones, one at the wave splashed base of the cliffs and the other on the drier upper portion (Table 7). The species inhabiting the cliff base are also common to the low shelving rocky shore of the islands. A heavy growth of filamentous algae, mainly Cladophora and Bangia, is attached below the water line. Herbaceous species are the sole survivors here and include grasses, and several species of wild flowers.

The upper portion of the cliffs supports a more diverse flora being less subject to the effects of the lake water. The thin soil along the cliff edge sustains a population of lichens, mosses, algae, and herbaceous species such as chickweed, wild onion, strawberry, grasses and sedges. Farther back are tangled vines of poison ivy, Virginia creeper, and wild grape, which yield to red cedar, dogwood and sumac.

Sandy beaches. Very few sandy beaches occur on the Erie islands. Several of the beaches which do exist are used extensively by the public for recreation and the distinctive beach flora has virtually disappeared. The beach environment is particularly subject to fluctuating water levels, continuous wave action throughout most of the year, and erosive action by ice in the winter. A zonation of species exists in the form of herbaceous species along the shore and vines on the berm and into the forests or fields bordering the beach. Woody species

TABLE 7

PLANT SPECIES OF THE SHORELINE CLIFFS AND LOW BEDROCK ASSOCIATIONS

LICHENS

Biatorella
Teloschistes
Dermatocarpon
Psora

MOSSES

Amblystegium
Brachythecium
Fissidens
Grimmia
Gymnostomum
Tortella
Tortula

AERIAL ALGAE

Trentepohlia

HERBACEOUS SPECIES
TOPS OF HIGH CLIFFS

Achilea millefolium (yarrow)
Allium cernuum (wild leek)
Andropogon gerardii (turkey foot)
Arabis pycnocarpa (rock cress)
A. drummondii (rock cress)
Arenaria stricta (sandwort)
Aquilegia canadensis (columbine)
Asplenium trichomanes (spleenwort)
Aster pilosus (wild aster)
Campanula rotundifolia (harebell)
Carex eburnea (sedge)
Cerastium arvense (chickweed)
Elymus canadensis (wild rye)
Fragaria vesca (wild strawberry)
Geranium robertianum (wild geranium)
Heuchera americana (alum-root)
Houstonia nigricans (houstonia)
Panicum lanuginosum (panic grass)
Pellea glabella (cliff-brake fern)
Penstemon hirsutus (beard tongue)
Prenanthes alba (white lettuce)
Prunella vulgaris (self-heal)
Scutellaria parvula (scullcap)
Sedum sarmentosum (stonecrop)
Solidago memoralis (goldenrod)
Sphenopholis intermedia (wedge-grass)
Viola neprophylla (violet)

BASE CLIFFS AND LOW BEDROCK SHORES

Aster pilosus (wild aster)
Boltonia asteroides (boltonia)
Carex granularis (sedge)
Geranium robertianum (wild geranium)
Juncus dudleyi (rush)
J. tenuis (rush)
Lobelia kalmii (Kalm's lobelia)
Lysimachia quadriflora (loosestrife)
Lythrum alatum (loosestrife)
Panicum lanuginosum (panic grass)
P. virgatum (panic grass)
Penstemon hirsutus (beard tongue)
Poa compressa (Canada bluegrass)
Prunella vulgaris (self-heal)
Pycnanthemum virginianum (mint)
Senecio pauperculus (ragwort)
Solidago gramifolia (goldenrod)
Sphenopholis intermedia (bunchgrass)

WOODY SPECIES

Amelanchier sanguinea (service-berry)
A. spicata (service-berry)
Cornus drummondii (dogwood)
C. olbiqua (dogwood)
Juniperus virginiana (red cedar)
Lonicara dioica (wild honeysuckle)
L. morrowi (wild honeysuckle)
Ostrya virginiana (hop-hornbeam)
Parthenocissus inserta (Virginia creeper)
Physocarpus opulifolius (ninebark)
Prunus virginiana (choke cherry)
Ptelea trifoliata (hop-tree)
Rhus radicans (poison ivy)
R. typhina (staghorn sumac)
Salix bebbiana (willow)
S. discolor (willow)
S. interior (sandbar willow)
Solanum dulcamara (bittersweet)
Taxus canadensis (American yew)
Vitis riparia (riverbank grape)

of an early succesional stage are most common here.

The sandy beaches occur at Honey Point on the southeast corner of North Bass Island, on South Bass Island east of the monument, North Bay on Kelleys Island, and along the east shore of Catawba Island.. The beach at Kelleys is part of the State Park and the one on Catawba is extensively used by the public. Species common to this habitat are listed in Table 8.

Gravel beaches and bars. Gravel beaches composed of pebbles, cobble and boulders, occur on most of the islands and bars located on Middle Bass, South Bass, Gibraltar, and Rattlesnake. No permanent vegetation is found on the parts of the beach in direct contact with continuous wave action. Only a few species exist farther up the beach where waves reach only during storms and periods of high water. The beach is bordered by a row of vines, and on the larger islands by thickets of woody species.

The gravel beach shoreline areas exhibit the greatest amoung of change in species composition of any habitat on the islands due to the considerable disturbance wrought by the unpredictable lake levels and weather. Characteristic species are given in Table 8.

Quarries. Three abandoned quarries exist on Kelleys Island and contain a combination of habitats: deep ponds, shallow pools, mud flats, and dry rock surface. This area represents a disturbance created by man which has provided a habitat for survival of species which would not otherwise be found on the islands. The quarries support an interesting combination of species which do not occur together in other locations. Species characteristic of rocky cliffs, ponds, marshes, gravel beaches, and open fields are all found here. Another habitat has recently been formed in the quarries by debris collected from the Kelleys Island beaches. Quarry species are listed in Table 9.

Open fields. The open field habitat is also one created largely by man and covers vineyards, fallow fields, dumps, and roadside areas. This habitat exhibits a high diversity of both native and non-indigenous species depending

TABLE 8

PLANT SPECIES OF THE SAND AND GRAVEL BEACH ASSOCIATIONS

SANDY SHORES

HERBACEOUS SPECIES

Asclepis syriaca (milkweed)
Bromus tectorum (downy chess)
Cakile edentula (sea rocket)
Cenchurus longispinus (fern)
Cycoloma atriplicifolia (pigweed)
Elymus canadensis (wild rye)
E. virginicus (wild rye)
Euphorbia polygonifolia (spurge)
Mirabilis nyctaginea (four o'clock)
Oenothera biennis (evening primrose)
Panicum virgatum (panic grass)
Physalis heterophylla (ground cherry)
Polanisia dodecandra (clammy weed)
Salsola kali (Russian thistle)
Strophostyles helvola (wild bean)
Teucrium canadense (wood sage)
Tripeasis purpurea (sand grass)
Xanthium strumarium (cocklebur)

WOODY SPECIES

Campsis radicans (trumpet creeper)
Celastrus scandens (bittersweet)
Cornus drummondii (dogwood)
C. obliqua (dogwood)
Fraxinus pennsylvanica (green ash)
Parthenocissus quinquefolia (Virginia creeper)
Ptelea trifoliata (hop-tree)
Rhus radicans (poison ivy)
R. typhina (staghorn sumac)
Salix interior (willow)
Vitis riparia (riverbank grape)

GRAVEL BEACHES AND BARS

HERBACEOUS SPECIES

Asclepias incarnata (milkweed)
Geranium robertianum (wild geranium)
Parietaria pennsylvanica (Pennsylvania pellitery)
Polygonum lapathifolium (nodding smartweed)
Teucrium canadense (wood sage)

WOODY SPECIES

Acer negundo (boxelder)
Celtis occidentalis (hackberry)
Cornus drummondii (dogwood)
C. obliqua (dogwood)
Fraxinus americana (white ash)
F. pennsylvanica (green ash)
Parthenocisus vitacea (Virginia creeper)
Platanus occidentalis (sycamore)
P. tremuloides (quaking aspen)
Rhus radicans (poison ivy)
Salix alba (willow)
S. amygdaloides (willow)
S. fragilis (willow)
Tilia americana (basswood)
Ulmus americana (American elm)
Vitis riparia (riverbank grape)

TABLE 9

PLANT SPECIES OF THE KELLEYS ISLAND QUARRIES

HERBACEOUS SPECIES

POOLS AND PONDS

Ranunculus longirostris (crowfoot)
Potamogeton illinoensis (pond weed)
P. foliosus (pond weed)
Najas marina (spiny naiad)

WET FLATS

Alisma plantago-aquatica (water plantain)
Asclepias incarnate (milkweed)
Bidens cernuus (beggar ticks)
Carex comosa (sedge)
C. garberi (sedge)
C. granularis (sedge)
C. hystericina (sedge)
C. lanuginosa (sedge)
C. stricta (sedge)
C. vulpinoidea (sedge)
Cyperus ferruginescens (rusty cyperus)
C. rivularis (riverbank cyperus)
Dryopteris intermedia (fern)
D. spinulosa (fern)
D. x triploidea (fern)
Eleocharis compressa (spike rush)
E. erythropoda (spike rush)
Eupatorium perfoliatum
Juncus alpinus (rush)
J. x stuckeyi (rush)
J. dudleyi (rush)
J. nodosus (rush)
J. torreyi (rush)
Leucospora multifida
Ludwigia palustris (primrose)
L. polycarpa (primrose)
Lycopus americanus (water horehound)
L. uniflorus (water horehound)
Lythrum alatum (loosestrife)
Mentha arvensis (mint)
Mimulus ringens (monkey flower)
Phyla lanceolata (fog-fruit)
Scirpus acutus (bulrush)
S. pendulus (bulrush)
S. validus (bulrush)
Scleria verticillata (nut rush)
Scutellaria lateriflora (skullcap)
Senecio pauperculus (ragwort)
Strophostyles helvola (wild bean)
Typha angustifolia (cattail)
Verbena hastata (blue vervain)

DRY HABITATS

Achillea millefolium (yarrow)
Allium cernuum (wild leek)
Andropodon gerardii (turkeyfoot)
Anemone virginica (anemone)
Arabis pycnocarpa (rock cress)
Asclepias tuberosa (milkweed)
Carex eburnea (sedge)
Eupatorium altissimum
Festuca pratensis (fescue)
Galium concinnum (bedstraw)
Geranium robertianum (wild geranium)
Helianthus maximilianii (sunflower)
Houstonia nigricans (houstonia)
Hypericum perforatum (St. John's wort)
Isanthus brachiatus (false pennyroyal)
Juncus bufonius (rush)
J. tenuis (rush)
Liparis loeselii (twayblade)
Monardo fistulosa (horse-mint)
Panicum lanuginosum (panic-grass)
P. virgatum (panic-grass)
Parietaria pennsylvanica (Pennsylvania pellitery)
Penstemon hiruutus (beard tongue)
Poa compressa (Canada bluegrass)
Polanisia dodecandra (clammy weed)
Potentilla norvegica (cinquefoil)
Prunella vulgaris (self-heal)
Pycnanthemum virginianum (mountain-mint)
Satureja arkansana (savory)
Scutellaria parvula (skullcap)
Sisyrinchium albidum (blue-eyed grass)
Solidago graminifolia (golden rod)
Spiranthes cernua (ladies' tresses)
Sporobolus vaginiflorus (dropseed)
Thelypteris palustris (marsh fern)
Verbena simplex (vervain)

WOODY SPECIES

Celtis occidentalis (hackberry)
Cornus drummondii (roughleaf dogwood)
C. obliqua (silky dogwood)
Fraxinus pennsylvanica (green ash)
F. quadrangulata (blue ash)
Juniperus virginiana (red cedar)
Lonicera dioica (wild honeysuckle)
L. morrowii (honeysuckle)
Morus alba (white mulberry)
Ostrya virginiana (hop-hornbeam)

TABLE 9 (Continued)

PLANT SPECIES OF THE KELLEYS ISLAND QUARRIES (Continued)

WOODY SPECIES (Continued)

Parthenocissus vitacea (Virginia creeper)
Physocarpus opulifolius (ninebark)
Populus deltoides (cottonwood)
P. tremuloides (quaking aspen)
Prunus virginiana (choke cherry)
Ptelea trifoliata (hop-tree)
Quercus muehlenbergii (chinquapin oak)
Rhus aromatica (fragrant sumac)
R. glabra (smooth sumac)
R. radicans (poison ivy)
R. typhina (staghorn sumac)
Rosa micrantha (sweetbrier)
R. setigera (prairie rose)
Rubus occidentalis (black raspberry)
Salix discolor (pussy willow)
S. interior (sandbar willow)
S. nigra (black willow)
Solanum dulcamara (bittersweet)
Vitis riparia (riverbank grape)

on moisture conditions, disturbances, and proximity of woodlots.

At one time the larger islands were practically covered with vineyards, but many have been abandoned at various times since 1900. Today most of the active vineyards are on North Bass and Middle Bass Islands with several acres still under cultivation on South Bass Island. The active vineyards show a greater species diversity particularly in herbaceous plants, than is seen in the abandoned vineyards, while the abandoned vineyards and fallow fields represent various stages of succession to a sugar maple-hackberry forest association.

Aquatic habitats. There are three aquatic habitats on the islands: open lake, bay, and pond/marsh. Only seven species have been found in the open lake around the islands due to the turbidity of the lake water (Table 10).

The bays of the islands are located on the north shores of South Bass and Kelleys Islands and on the west shore of North Bass. The bay at South Bass Island has been the one most studied due to its close proximity to the Franz Theodore Stone Laboratory and the State Fish Hatchery. It is comprised of three sections: Put-in-Bay Harbor to the east, Squaw Harbor in the middle, and Fishery Bay to the west. Gibraltar Island to the north protects the bay from the open lake and forms a gravel bar separating Fishery Bay from Squaw Harbor. The entire harbor section is lines with boat docks and steel and concrete retaining walls.

A survey in the late 1800's showed 40 species of aquatic vascular plants growing in the bay. By 1977, only 20 of the original species remaining with only two of these being common. All floating vegetation and marsh grasses are either nonexistent or present on a very small scale. Dredging, construction of retaining walls, increased used of motor boats, dumping of wastes and domestic sewage, runoff from vineyards near the bay, and the dramatic rise and fall of water levels during the last several years are all contributing factors to the demise of the once abundant aquatic flora. Species found in the bays today are given in Table 10.

The major pond/marsh habitats include Carp Pond on Kelleys Island,

TABLE 10

PLANT SPECIES OF THE OPEN LAKE AND BAY ASSOCIATIONS

OPEN LAKE

Butomus umbellatus (flowering rush)
Heteranthera dubia (mud-plaintain or water stargrass)
Myriophyllum exalbescens (water milfoil)
Potamogeton nodosus (knotty pondweed)
P. pectinatus (sago pondweed)
P. richardsonii (Richardson's pondweed)
Vallisneria americana (wild celery or eel grass)

BAYS

Asclepias incarnata (swamp milkweed)
Butomus umbellatus (flowering rush)
Carex comosa (bristly sedge)
C. frankii (Frank's sedge)
Ceratophyllum demersum (hornwort or coontail)
Elodea canadensis (water weed)
E. nuttallii (water weed)
Heteranthera dubia (mud plantain or water stargrass)
Juncus torreyi (Torrey's rush)
Justicia americana (water willow)
Myriophyllum exalbescens (water milfoil)
Nelumbo lutea (lotus lily)
Potamogeton crispus (curly pondweed)
P. filiformis (filiform pondweed)
P. pectinatus (sago pondweed)
P. pusillus (small pondweed)
P. richardsonii (Richardson's pondweed)
Rumex verticillatus (swamp dock)
Sagittaria latifolia (arrowhead)
Scirpus acutus (hard-stemmed bulrush)
S. americanus (American bulrush)
S. atrovirens (dark green bulrush)
S. fluviatilis (river bulrush)
S. validus (great bulrush)
Sparganium eurycarpum (giant bur-reed)
Typha angustifolia (narrow-leaved cattail)
T. latifolia (broad-leaved cattail)
Vallisneria americana (wild celery or eel grass)
Zannichellia palustris (horned pondweed)

Terwilliger's Pond on South Bass Island, Haunck's Pond on Middle Bass Island, Smith's Pond, Fox's Marsh, Mound Pond, and Honey Point on North Bass Island. These ponds are subject to fluctuations in the lake level and at times are largely mudflats or even completely dry. Typically, emergent, submerged and floating aquatic plants can be seen at these locations (Figures 61 and 62).

Four ponds on the islands have been filled in or altered. Fischer's Pond on Middle Bass Island was filled in 1967 for the Burgundy Bay Resort Development. It was the site of the only record of Acer rubrum (red maple) for the islands. Wehrle's Pond, also on Middle Bass near Lonz's Winery, was converted to a marina, but with the recent high water, the area is reverting to pond conditions. Kelley's Pond on southeast Kelleys Island was made into the Seaway Marina in 1958, which was soon abandoned. The area began to return to pond conditions until recently when it was again developed as a marina. Perry's Monument is located on the former site of Chapman's Pond, which was filled in 1912 for construction of the monument. Some of the area reverted to marsh between 1973 and 1975 when high water broke the retaining wall, but the area has since been refilled. Common pond species appear in Table 11.

Changing Character of Islands Vegetation

Although man has done much to alter the native vegetation of the Lake Erie Islands, he has also introduced many new species and created the newly distributed habitats necessary for their survival. In a comparison with earlier surveys, Dr. Stuckey estimates an 18% loss of original native species versus a 12% gain of species new to the islands. Seventy-five percent of non-indigenous species are of European origin, due primarily to settlement by German immigrants and climatic and physiographic conditions similar to those of Europe. Even with all the disturbances brought by man, the islands remain a unique area. Efforts are being taken to preserve each habitat type in order to maintain rare and

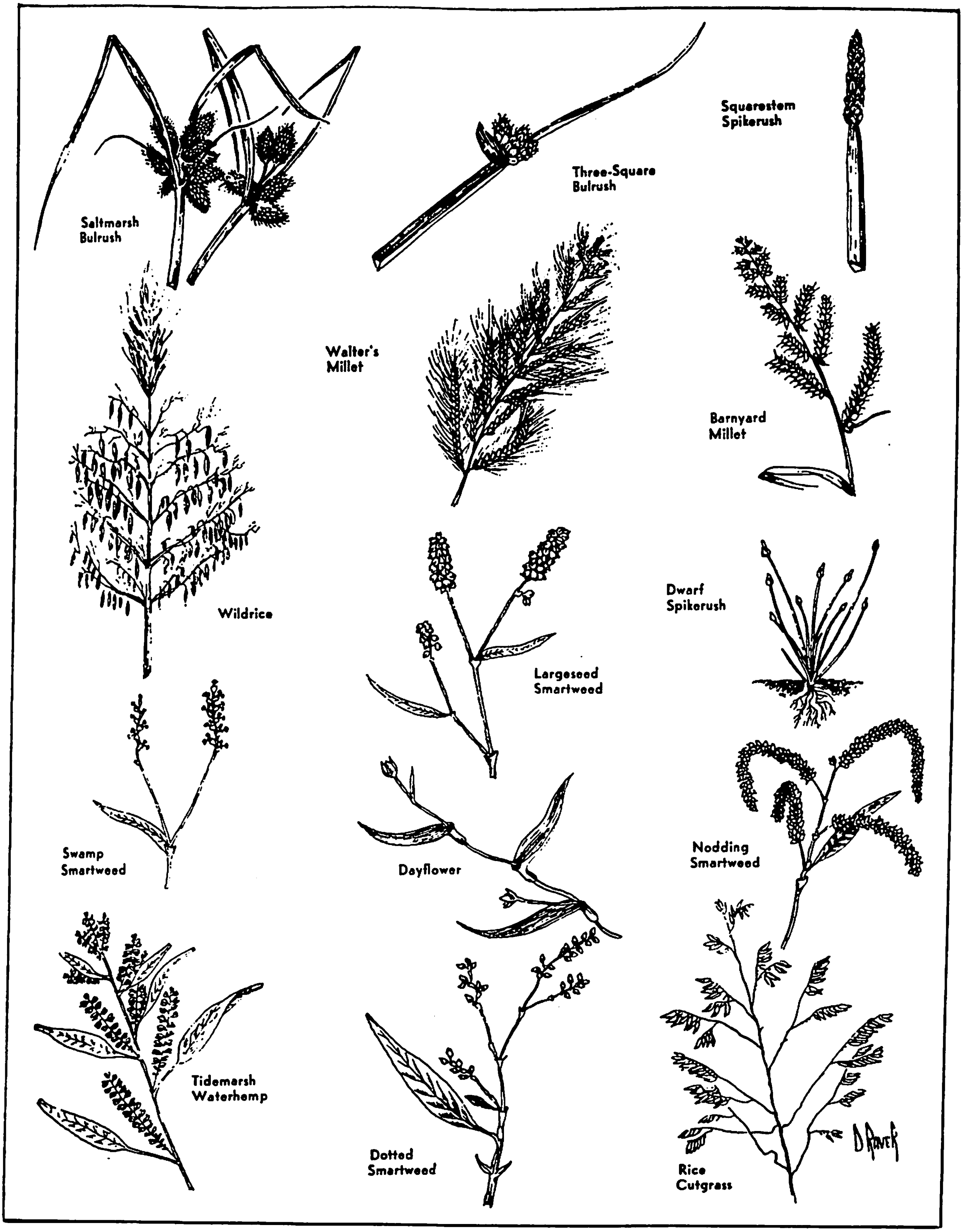


Figure 61. Emergent Aquatic Plants (Macrophytes).

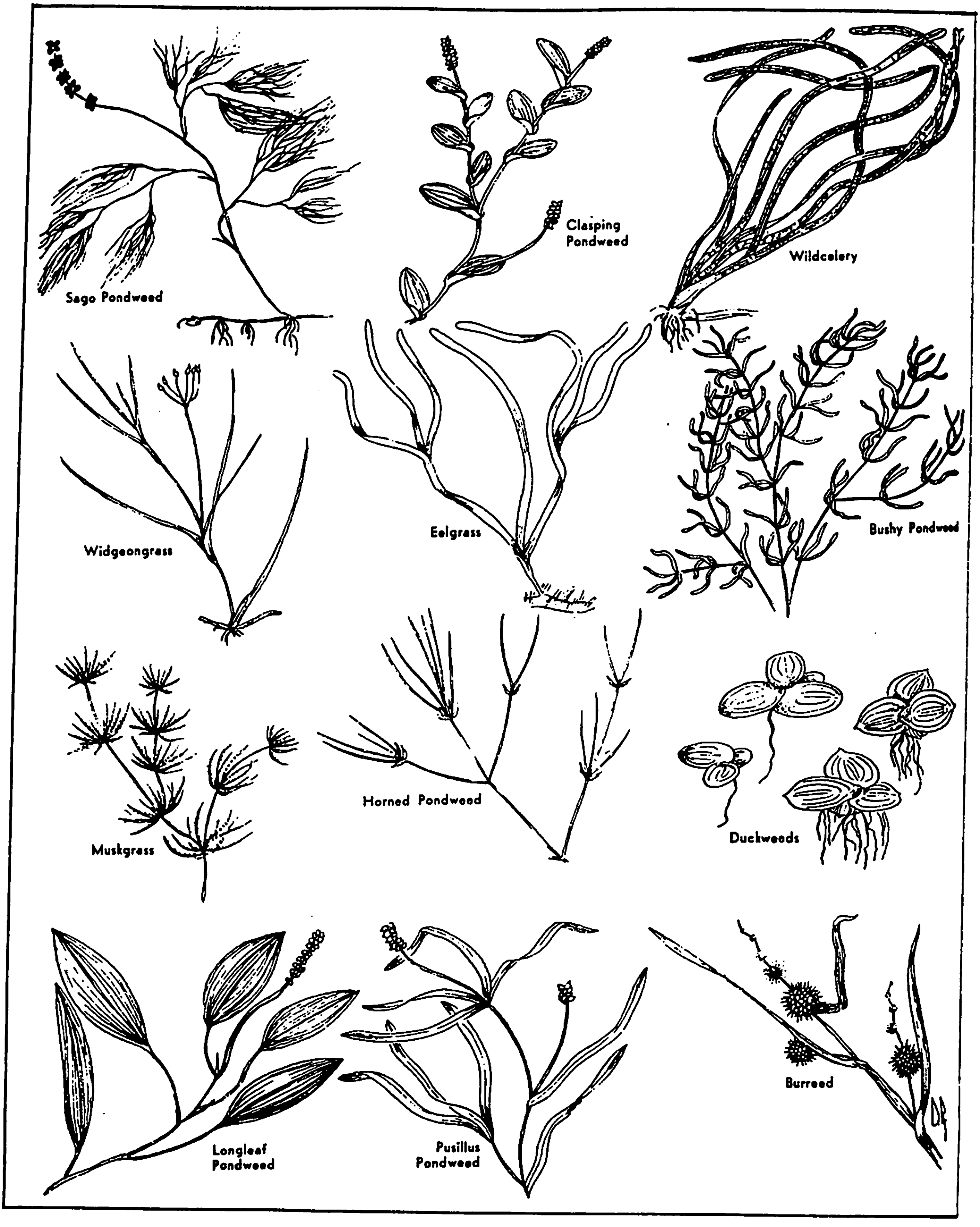


Figure 62. Submerged and Floating Aquatic Plants (Macrophytes).

TABLE 11

PLANT SPECIES OF THE POND ASSOCIATION

SUBMERSED SPECIES

Ceratophyllum demersum (coontail or hornwort)
Elodea canadensis (waterweed)
Myriophyllum exalbescens (water milfoil)
Potamogeton foliosus (leafy pondweed)
P. pectinatus (sago pondweed)
P. pusillus (small pondweed)
Ranunculus longirostris (buttercup)
Utricularia vulgaris (bladderwort)

FLOATING SPECIES

Lemna minor (small duckweed)
Spirodela polyrhiza (large duckweed)
Wolffia columbiana (watermeal)
W. punctata (watermeal)

ATTACHED FLOATING-LEAVED SPECIES

Decodon verticillatus (swamp loosestrife)
Hibiscus moscheutos (swamp rose mallow)
Nuphar advena (yellow water lily or spatterdock)
Nymphaea tuberosa (water lily)
Polygonum amphibium (water smartweed)
Pontederia cordata (pickerelweed)

SPECIES AT EDGE OF POND (EMERGENT SPECIES)

Alisma plantago-aquatica (water-plantain)
Amaranthus tuberculatus (water-hemp)
Asclepias incarnata (swamp milkweed)
Bidens cernus (beggar ticks)
B. connatus (beggar ticks)
B. frondosus (beggar ticks)
Boehmeria cylindrica (false nettle)
Butomus umbellatus (flowering rush)
Calamogrostis candensis (blue joint)
Cardamine pensylvanica (bitter cress)
Carex cristatella (sedge)
C. stipata (sedge)
C. vulpinoidea (sedge)
Cephalanthus occidentalis (buttonbush)
Cornus drummondii (dogwood)
C. obliqua (dogwood)
Cyperus ferruginescens (rusty cyperus)
Eleocharis obtusa (spike rush)
Epilobium glandulosum (willow-herb)
Eupatorium perfoliatum (boneset)
Glyceria striata (manna grass)
Impatiens capensis (jewelweed)
Iris virginica (blue flag)
Juncus dudleyi (rush)
J. effusus (soft rush)
J. torreyi (Torrey's rush)
Leersia oryzoides (rice cut grass)
Lindernia dubia (false pimpernel)
Lobelia siphilitica (blue lobelia)
Lycopus americanus (water horehound)
Mentha arvensis (mint)
Mimulus ringens (monkey flower)
Penthorum sedoides (stonecrop)
Phalaris arundinacea (reed canary grass)
Polygonum lapathifolium (nodding smartweed)
P. persicaria (lady's thumb)
P. punctatum (water smartweed)
Ranunculus sceleratus (buttercup)
Rorippa palustris (cress)
Rosa palustris (swamp rose)
Rumex verticillatus (water dock)
Sagittaria latifolia (arrow-head)
Salix interior (sandbar willow)
Sambucus canadensis (elder)
Scirpus atrovirens (bulrush)
S. fluviatilis (bulrush)
S. pungens (bulrush)
S. validus (bulrush)
Scutellaria epilobiifolia (scullcap)
S. lateriflora (skullcap)
Sparganium eurycarpum (bur-reed)
Stachys palustris (nettle)
Typha angustifolia (cattail)
Verbena hastata (blue vervain)

TREES

Acer saccharinum (silver maple)
Fraxinus pennsylvanica (green ash)
Platanus occidentalis (sycamore)
Populus deltoides (cottonwood)
Quercus macrocarpa (bur oak)
Salix amygdaloides (peach-leaved willow)
Solanum dulcamara (bittersweet)
Ulmus americana (American elm)

endangered species. Private and public areas which are part of this preservation program include Duff's Woods on South Bass Island, a mature woodlot, the unique quarry habitats on Kelleys Island, Carp Pond, also on Kelleys Island, Haunck's Pond on Middle Bass Island, Fox's Marsh on North Bass Island, and the lake cliffs and upland area of Green Island.

AQUATIC ECOLOGY

AQUATIC ECOLOGY

Biology is often simply defined as "the science of life", whereas ecology can be defined as "the science of the interrelationships between living organisms and their environment." The word ecology is derived from the Greek work "oikos", meaning "house" or "place to live." Consequently, it has been defined as "the study of organisms 'at home'" or "the science of the living environment", or "environmental biology." In ecology, the term "population" means a group of individuals of any one kind of organism. The term "community" means all the populations occupying a given area. The community and the non-living environment (abiotic) function together as an ecological system or "ecosystem". The size of the community and the ecosystem to be considered is left to the ecologist. Consequently, one can study the community of microbes inhabiting the ecosystem of a small puddle of water, or one could define the ecosystem to be studied as an intake canal, a stretch of stream, the Western Basin of Lake Erie, Lake Erie, the Great Lakes, etc. As the size of the ecosystem increases, so does the complexity of the interactions between individuals, populations and the environment. With this information as background, let us look at a typical aquatic ecosystem (the water ecosystem) and its components (Figure 63).

In general, the aquatic ecosystem, and all ecosystems, can be subdivided into four major categories.

1. Abiotic substances - the non-living portions of the environment.

2. Producers - Autotrophic (self-nourishing) organisms, largely green plants, capable of manufacturing food from simple inorganic substances and light energy (photosynthesis).

3. Consumers - Those organisms which eat other organisms.

4. Decomposers - Organisms which break down the complex compounds of dead portoplasm absorbing some of the nutrients and releasing simple substances usable by producers.

The preceding classification of organisms is largely upon the role (niche)

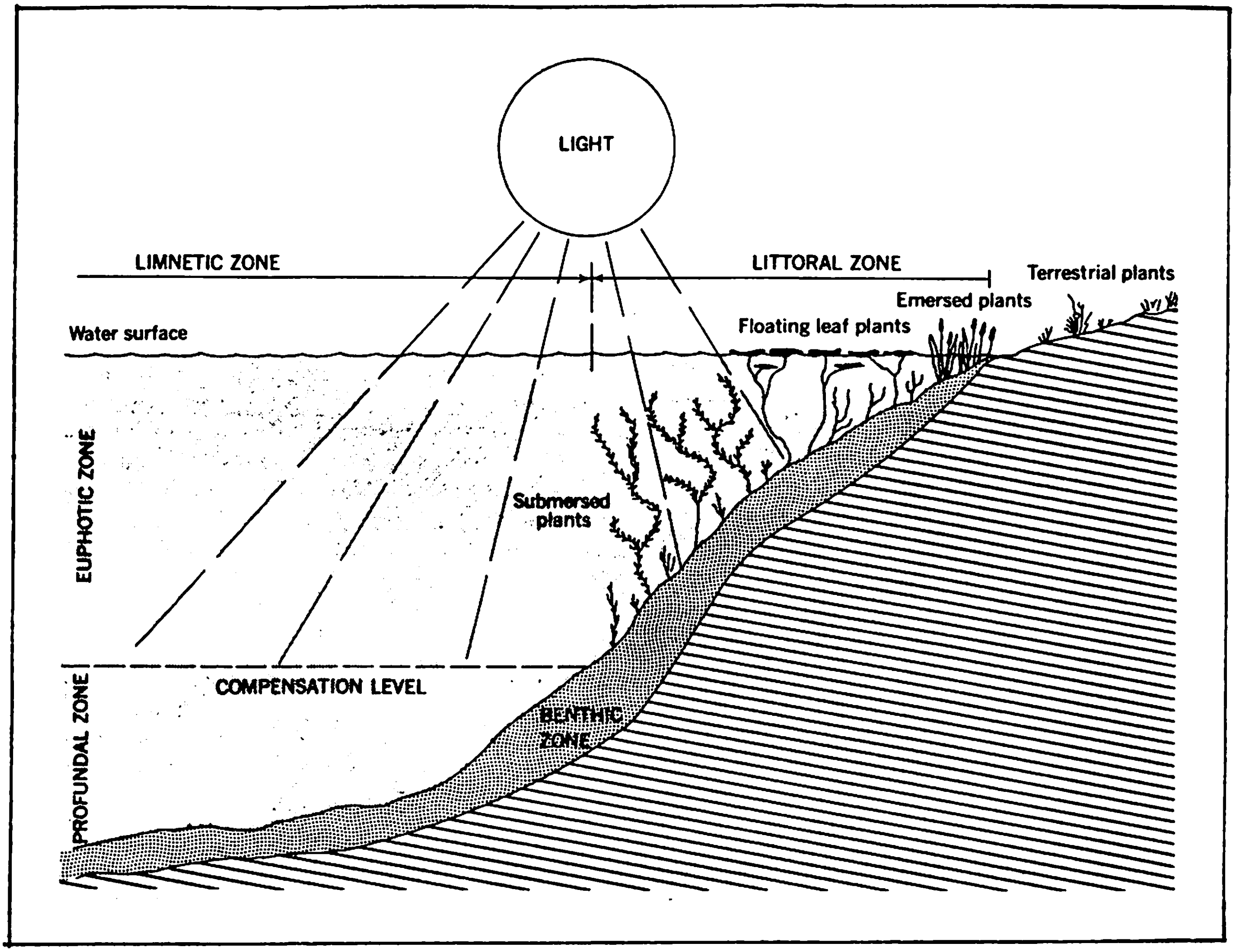


Figure 63. Major Life Zones of a Lake.

of the organism within the community, whereas the most common approach to organism classification in aquatic ecology is by their life form or life habitat. The habitat of an organism is the place where it lives, or the place where one would go to find it. The ecological niche, on the other hand, is the position or status of an organism within its community and ecosystem resulting from the organism's structural adaptations, physiological responses and specific behavior (inherited and/or learned). The ecological niche of an organism depends not only on where it lives but also on what it does. By analogy, it may be said that the habitat is the organism's 'address', and the niche is its 'profession,' biologically speaking.

Based on the life form or life habitat approach, organisms are classified as follows:

1. Benthos: organisms attached or resting on the bottom or living in the bottom sediments.

2. Periphyton: organisms (both plant and animal) attached or clinging to stems and leaves of rooted plants or other surfaces projecting above the bottom (some authors use the German term aufwuchs for this group).

3. Plankton: floating organisms, both plants (phytoplankton) and animal (zooplankton), whose movements are more or less dependent on currents. While some of the zooplankton exhibit active swimming movements that aid in maintaining vertical position, plankton as a whole is unable to move against appreciable currents. In practice, net plankton is that which is caught in a fine-meshed net which is towed slowly through the water; nannoplankton is too small to be caught in a net and must be extracted from water collected in a bottle or be means of a pump.

4. Neuston: organisms resting or swimming on the surface.

5. Nekton: swimming organisms able to navigate at will (and hence capable of avoiding plankton nets, water bottles, ect.).

Benthos

The benthos are organisms that are attached or sessile on the lake bottom or are found living in substrate (Figures 64-68). This definition includes zoo-

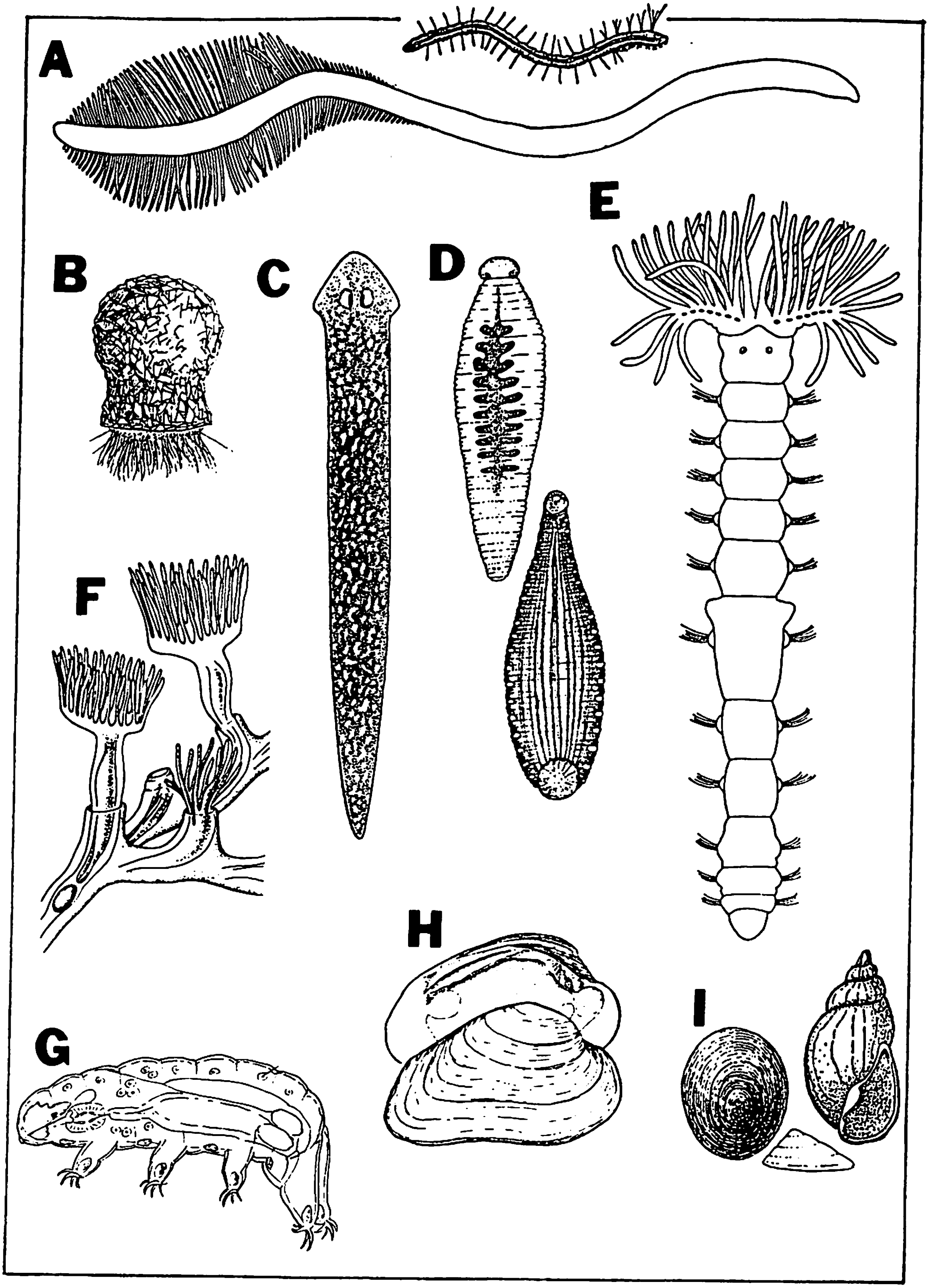


Figure 64. Benthic Invertebrates: A) sludge worm (oligochaete), B) protozoan, C) planarian (flatworm), D) leech, E) polychaete worm, F) bryozoan, G) water bear, H) clam, and I) limpet and snail.

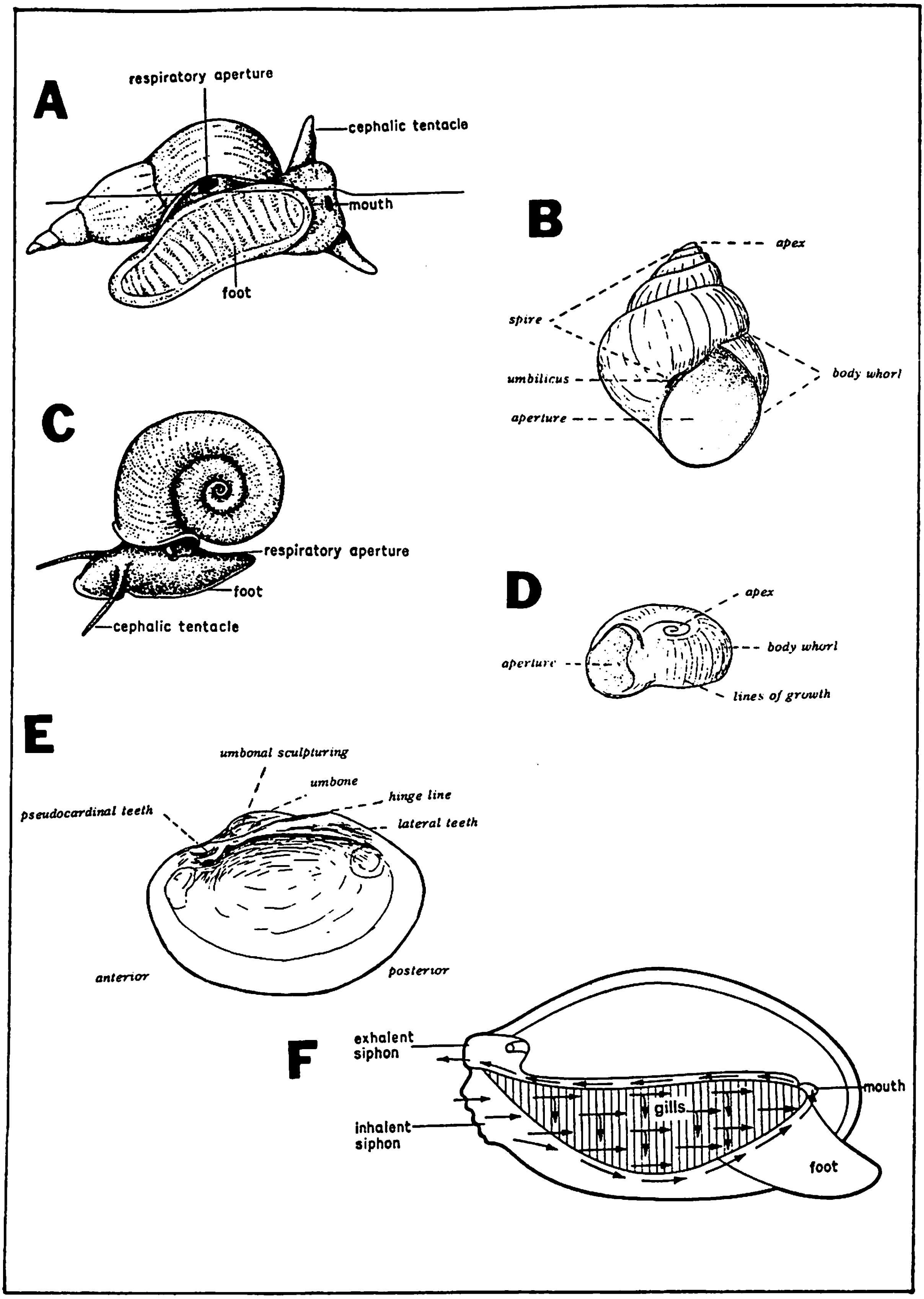


Figure 65. Molluscan Features: A and B) snail, dextral shell (right-hand opening) with elongated spire, C and D) sinsiral shell (left-hand opening) with flattened spire, E) clam shell, and F) water circulation in a clam.

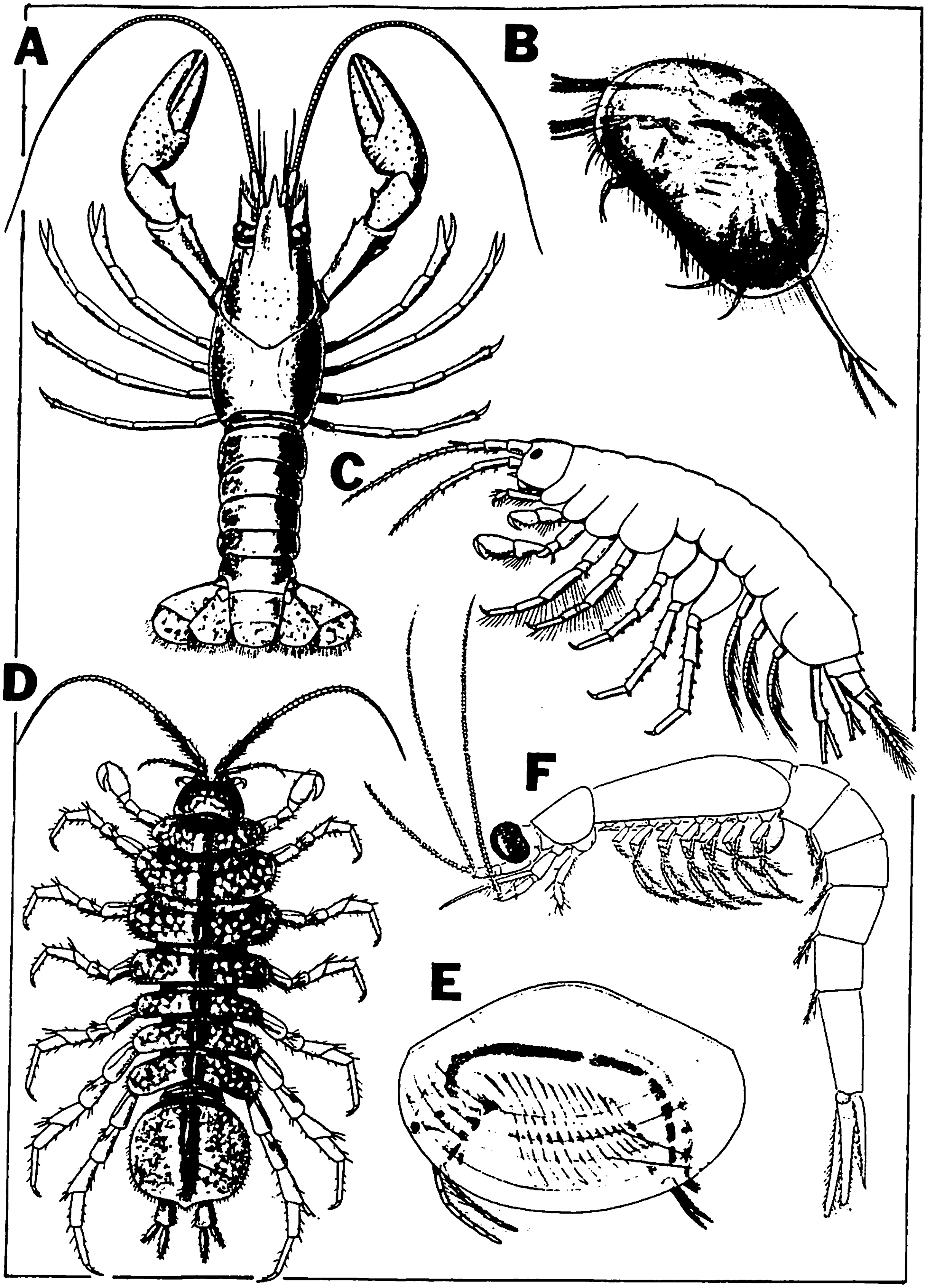


Figure 66. Benthic and Planktonic Crustaceans: A) crayfish (decapod), B) seed shrimp (ostracod), C) scud (amphipod), D) aquatic sowbug (isopod), E) clam shrimp (conchostran), and F) shrimp (mysid shrimp).

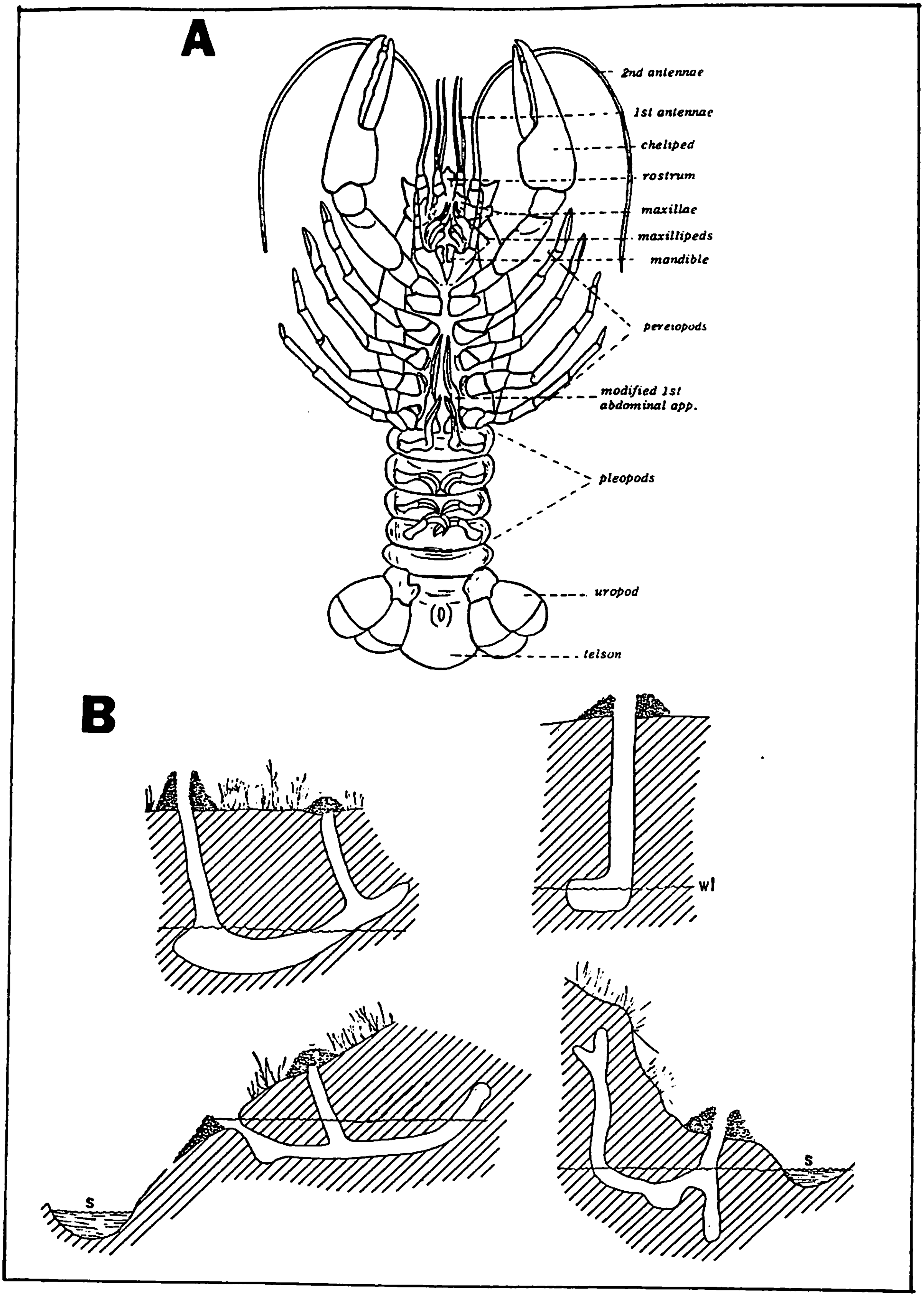


Figure 67. Crayfish Features: A) body appendages and B) chimney and burrow configuration.

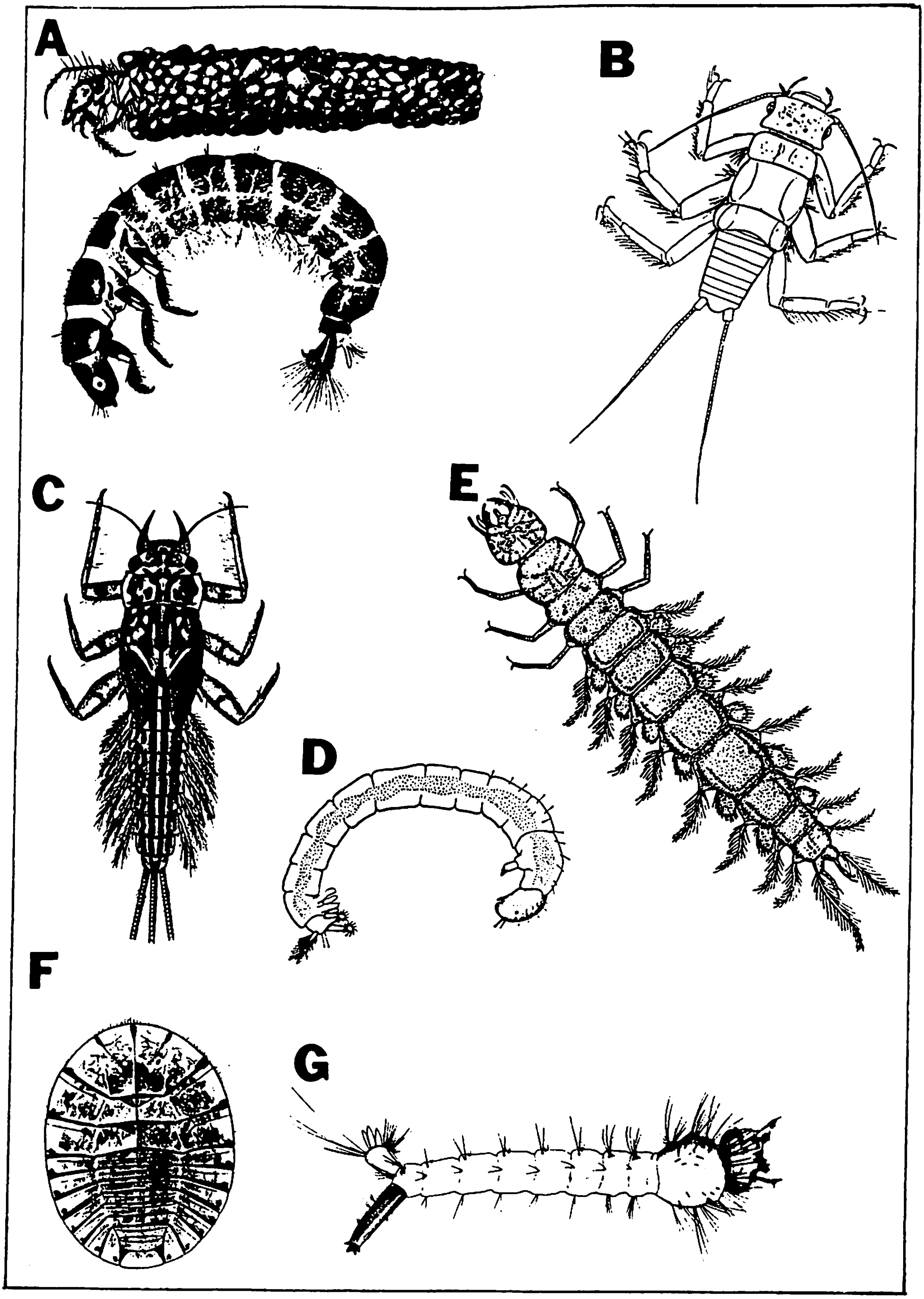


Figure 68. Benthic Insects: A) caddisfly larvae and case, B) stonefly nymph, C) mayfly nymph, D) midge larva, E) hellgrammite (dobsenfly nymph), F) penny beetle larva, and G) mosquito larva.

and phyto-benthos, attached algae and higher aquatic plants found growing in the substrate. A typical benthic habitat within an aquatic ecosystem consists of many different kinds of organisms and many species of each type. This component of the aquatic community may include the molluscs (snails, clams), the immature and mature stages of aquatic insects (mosquitoes), midges (Chironomids), mayflies (Hexagenia), Stonefly nymphs, Caddisfly larvae and many others. Benthic plants include the attached algaes Cladophora, Ulothrix, and Bangia with Vallisneria and the Potamogeton representatives of aquatic vascular plants.

The distribution and density of benthic organisms is quite dependent upon the type of substrate. Burrowing forms like chironomids and oligochates are most common in soft mud bottoms, whereas dragonflies would be most common in shallow water with emergent vegetation and some of the mayflies and caddisflies would be most abundant in a pebble-cobble substrate.

The benthos are an important link in the food chain and provide an indicator of the current state of health of the lake. Sampling the sediments and the benthos is done with dredges such as an Eckman, Ponar, or Petersen (Figure 69). These are quantitative sampling devices, as is the Surber Sampler used for streams (Figure 70-C).

The bottom fauna of the western basin is composed principally of the aquatic earthworms, midge larvae, fingernail clams, and snails (Table 12). Most of these forms are pollution tolerant and occur in greatest concentrations near the mouths of the Detroit, Maumee, and Raisin Rivers. Pollution sensitive organisms such as amphipods, mayfly nymphs, larger clams and caddisfly larvae are scarce near the river mouths and more abundant in the islands area. The benthic community of bottom animals in the lake and nearby ponds is an accumulation of diverse and abundant organisms occurring in several different substrates; mud, sand, clay, gravel and rock. The oligochaetes comprise over 60% of the total bottom fauna, particularly in the soft mud which is the most common sediment.

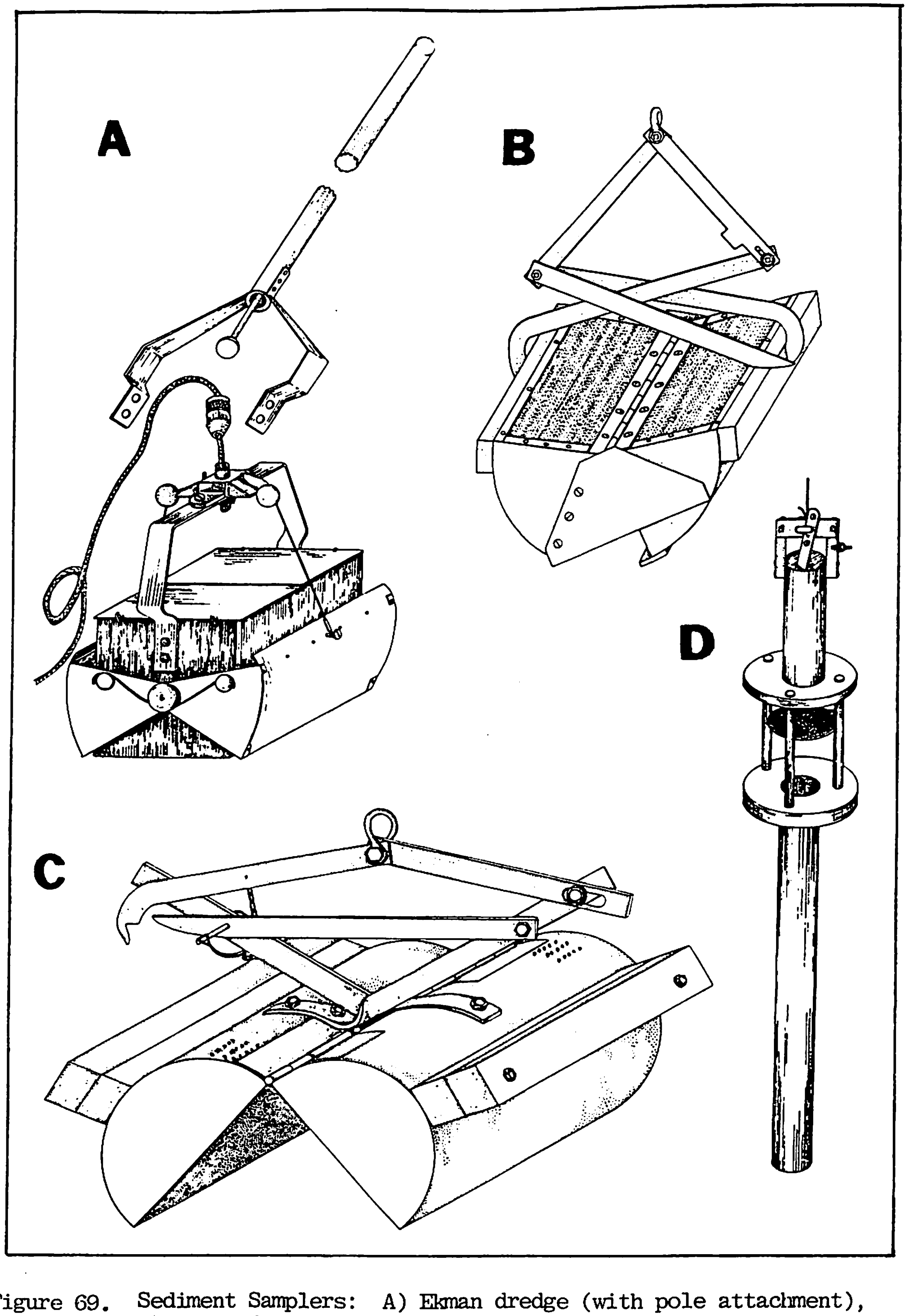


Figure 69. Sediment Samplers: A) Ekman dredge (with pole attachment), B) Ponar dredge, C) Peterson dredge, and D) core sampler (with check valve).

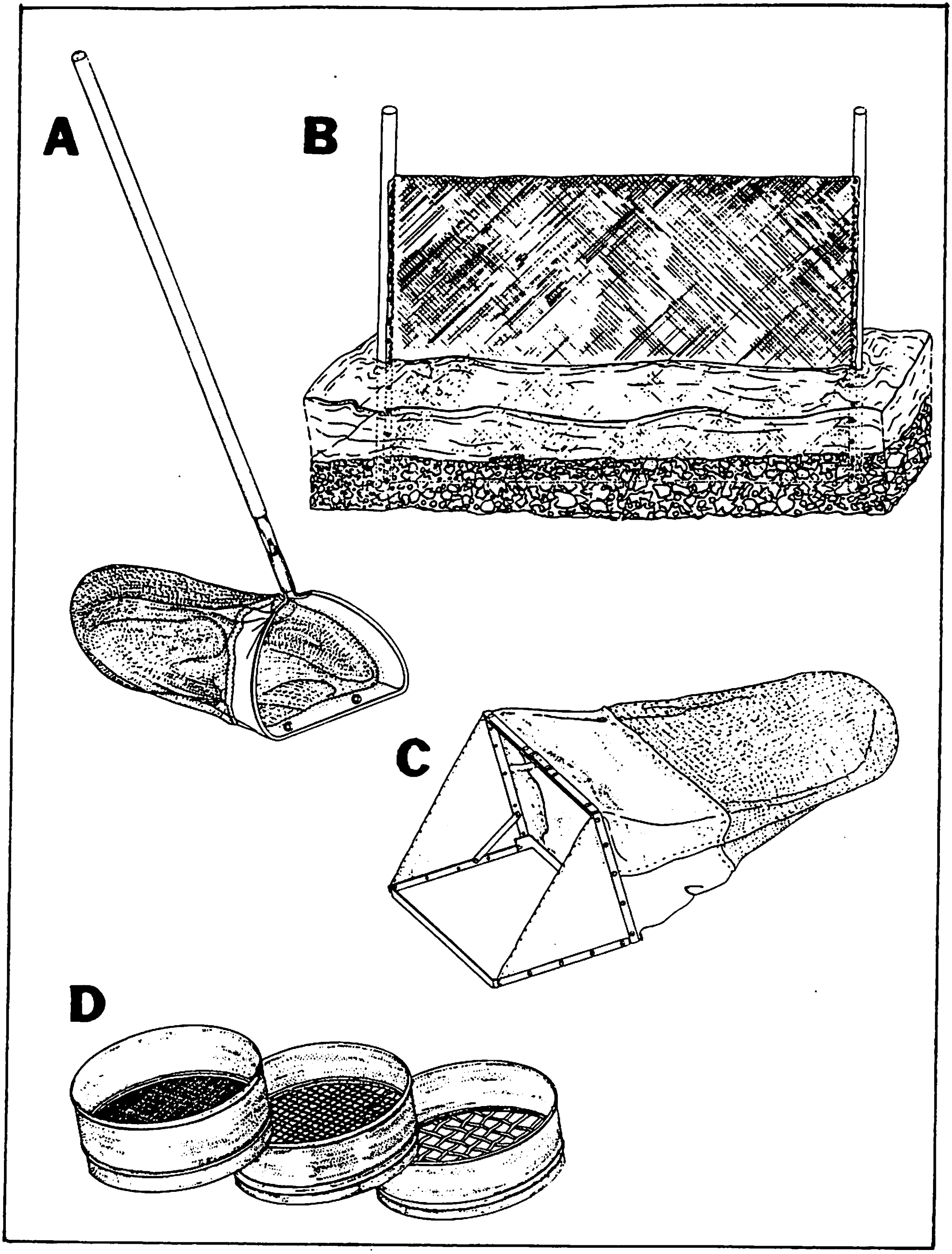


Figure 70. Benthos Samplers: A) D-frame dip net, B) hand-held screen collector, C) Surber sampler and D) size-grading seives.

TABLE 12

COMMON BENTHIC MACROINVERTEBRATE ORGANISMS OF WESTERN LAKE ERIE

ANNELIDA
- Hirudinea
  - *Helobdella elongata*
  - *H. stagnalis*
  - *H. fusca*
  - *Glossiphonia complanta*
  - *G. heteroclita*
- Polychaeta
- Oligochaeta
  - *Aulobdrilus limnobius*
  - *A. pluriseta*
  - *Branchiura sowerbyi*
  - *Ilyodrilus templetoni*
  - *Limnodrilus cervix*
  - *L. cervix variant*
  - *L. claperedeianus*
  - *L. hoffmeisteri*
  - *L. maumeesis*
  - *L. spiralis*
  - *L. udekemianus*
  - *Peloscolex ferox*
  - *P. multisetosus*
  - *Potamothrix moldaviensis*
  - *P. vejdovskyi*
  - *Tubifex tubifex*
  - *Dero digitata*

ARTHROPODA
- Crustacea
  - *Asellus r. racovitzai*
  - *Gammarus fasciatus*
- Insecta
  - *Oecetis* sp.
  - *Oecetis eddlistoni*
  - *Chironomus plumosus*
  - *C. riparius*
  - *C. (Cryptochironomus)* sp.
  - *Coelotanypus* sp.
  - *Procladius* sp.
  - *Tanypus* sp.

MOLLUSCA
- Gastropoda
  - *Physa* sp.
  - *Heliosoma* sp.
  - *Amnicola* sp.
  - *Bulimus tentaculata*
  - *Valvata sincera*
  - *V. tricarinata*
  - *Campeloma* sp.
  - *Goniobasis* sp.
  - *Somatogyra* sp.
- Pelecypoda
  - *Ligumia recta*
  - *Lampsilis radiata luteola*
  - *Leptodea* sp.
  - *Pisidium* sp.
  - *Pisidium compressum*
  - *Sphaerium* sp.

COELENTERATA
- *Hydra* sp.

PLATYHELMINTHES
- *Planaridae*
- *Rhabodocoela*

ECTOPROCTA
- *Pectinatella magnifica*

Chironomid larvae make up less than 20% and sphaerid clams 10% of the benthos. The remaining percentage of the benthic fauna includes isopods, leeches, and crustaceans. The benthic population of western Lake Erie is representative of eutrophic (Figure 50-B) but not grossly polluted waters.

Periphyton

Periphyton, although variously used, usually refers to microfloral growth upon substrata (Figure 71). Among the algal communities, the following subdivisions are used: 1) epipelic algae as the flora growing on sediments (fine, organic); 2) epilithic algae growing on rock or stone surfaces; 3) epiphytic algae growing on macrophytic surfaces; 4) epizooic algae growing on surfaces of animals; and 5) epipsammic algae as the rather specific organisms growing on or moving through sand. The general word psammon refers to all organisms growing or moving through sand.

A group of algae found aggregated in the littoral zone is the metaphyton, which is neither strictly attached to substrata nor truly planktonic. The metaphyton commonly originates from true phytoplankton populations that aggregate among macrophytes and debris of the littoral zone as a result of wind-induced water movements. In other situations, the mataphytonic algae derive from fragmentation of dense epipelic and epiphytic algal populations.

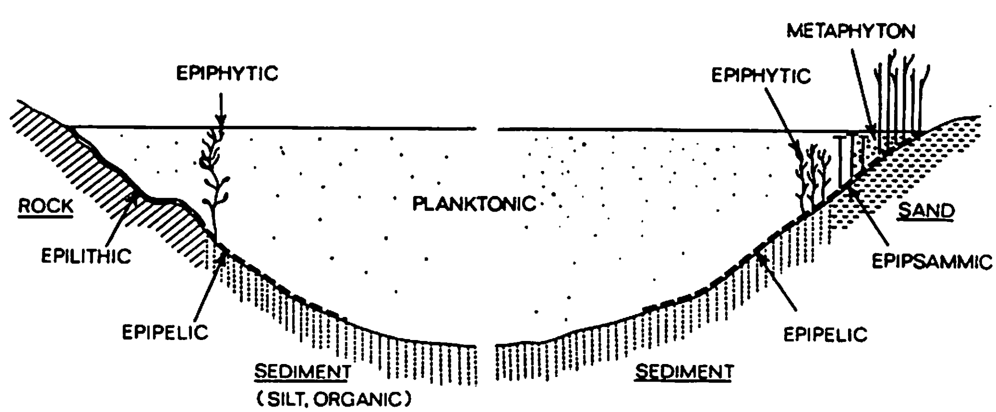


Figure 71. Terms used for Freshwater Algal Communities with Different Substrate.

Phytoplankton

Phytoplankton are the algae of open lakes and streams whose movements are dependent on currents for the most part, and they consist of a diverse assemblage of nearly all major taxonomic groups. Phytoplankters can be single floating cells or floating colonies in the forms of spheres, globes, or filamentous (Figure 72). The cell walls can be composed of cellulose (blue-green and green algae) or silica (diatoms).

The western basin of Lake Erie with its high nutrient concentrations is an excellent media for phytoplankton. The most common algae found in the lake are the Bacillarophyceal (diatoms), Chlorophyceae (green algae), Cyanophyceae (blue-green algae) and Erytophyceae (cryptomonad algae).

There are several environmental factors which interact to regulate spatial and temporal growth of phytoplankton populations. These include basic physiological requirements of temperature and light and the means of remaining within the photic zone sufficiently long to complete growth and reproduction. Densities of phytoplankton populations are largely affected by the availability of inorganic and organic nutrients and by herbivorous predation and parasitism.

The following size classification and terminology is in current use:

NAME	SIZE RANGE
Macroplankton	>500 um
Microplankton (net plankton)	50-500 um
Nanoplankton	10-50 um
Ultraplankton	0.5-10 um

Plankton is collected in the field with a tow net, either vertically, obliquely, or horizontally (Figure 73-C). The plankton net is both a qualitative and quantitative sampling device. The sample may be quantified by calculating flow rates or by determining the volume of water filtered through the net.

The algae population of Lake Erie is composed mainly of diatoms (~75%). Two periods of peak plankton abundance occur yearly. A spring pulse consists

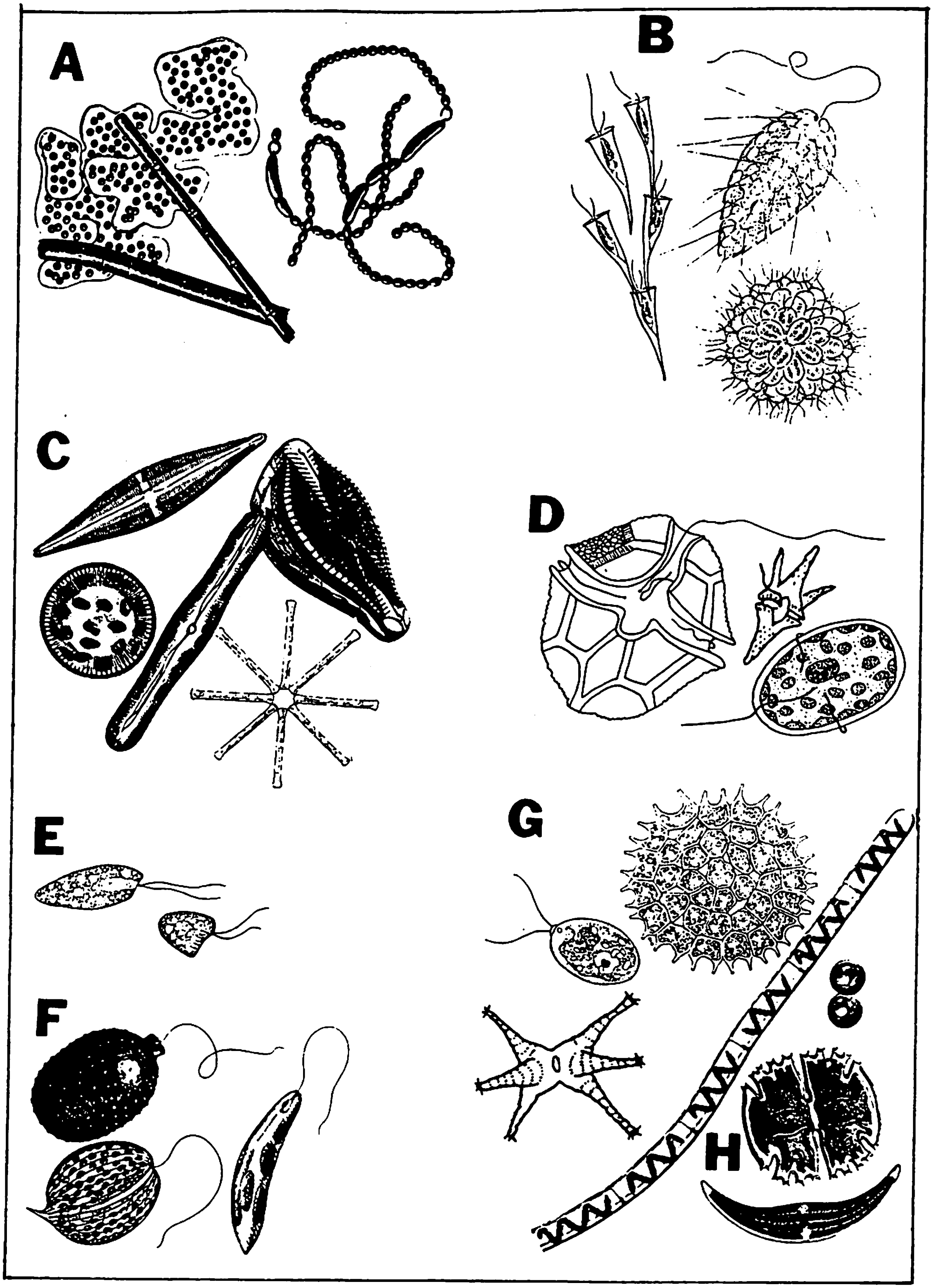


Figure 72. Phytoplankton: A) blue-green algae, B) golden-brown algae, C) diatoms (golden-brown algae), D) dinoflagelates, E) cryptomonads, F) euglenoids, G) green algae, and H) desmids (green algae).

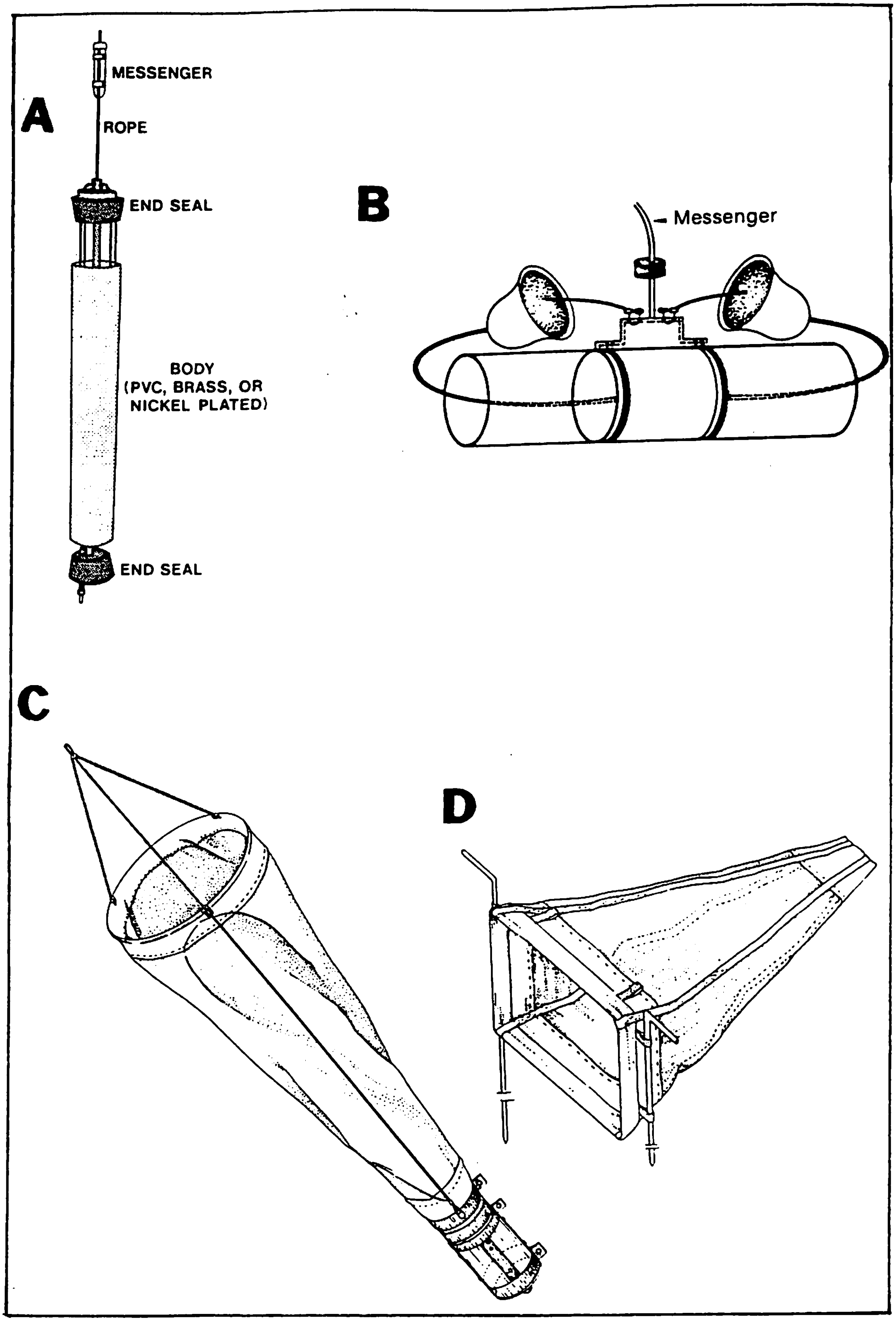


Figure 73. Water and Plankton Samplers: A) Kemmerer sampler, B) Van Dorn bottle, C) plankton tow net (with collection bucket), and D) plankton drift net.

almost entirely of diatoms and the most predominant genera are Asterionella, Fragilaria, Melosira, and Synedra. These genera are indicators of eutrophic conditions. Early summer is characterized by green algae such as Pediastrum and Spirogyra. In August and September, blooms of blue-green algae are common with Anabaena, Nostoc, and Anocystis the most dominant. A bloom of Oscillatoria and Aphanizomenon often occurs during the hot days of August, too. This annual cycle of algal forms is illustrated in Figures 74 and 75.

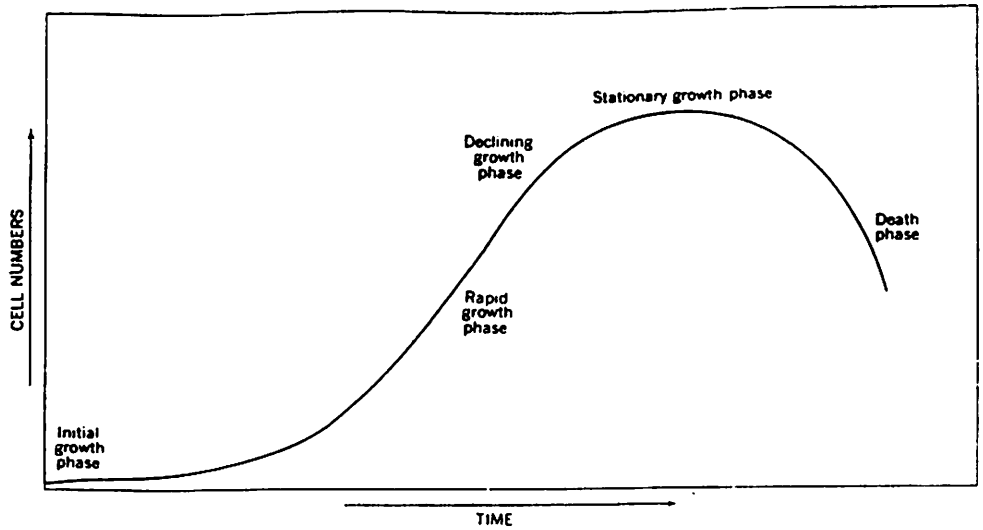
Zooplankton

Zooplankton are the animals of the plankton community. They are herbivores (eating phytoplankton), carnivores (eating zooplankton) and omnivores (eating phytoplankton and zooplankton). These animals are capable of some degree of locomotion and are divided into 3 major groups: the rotifers, and two small crustacean forms, the cladocera and copepoda (Figure 76). Protozoans, depending upon the author, may be grouped with phytoplankton or zooplankton.

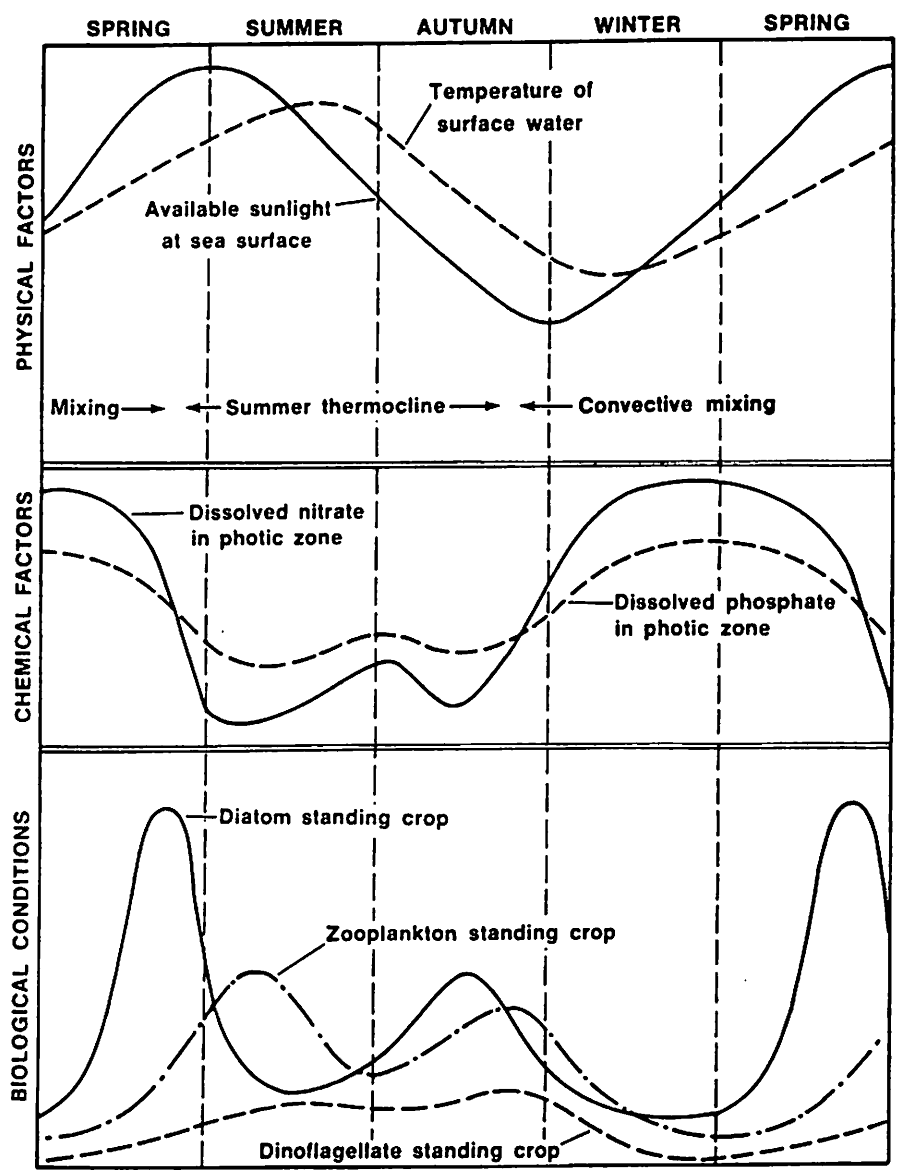
Rotifers

The Rotifera is a large class of the pseudocoelomate Phylum Aschelminthes, clearly arisen from fresh water since only two significant genera and a few species are marin (Wetzel 1975). They are essentially microscopic, the length range for the phylum being approximately 40 microns to 2.5 mm, but the great majority are between 100 and 500 microns long. Most rotifers, both sessile and planktonic, are nonpredatory. Omnivorous feeding occurs by means of ciliary direction of living and detrital particulate organic matter into the mouth cavity.

Rotifers occur in a variety of aquatic habitats, but most are largely sessile and associated with substrate in the littoral region of lakes. The vast majority of rotifers encountered under natural conditions are females (Reutter 1980). Males are known for relatively few species and are much smaller than females, degenerate and seldom live for more than a few days. Common examples in Lake

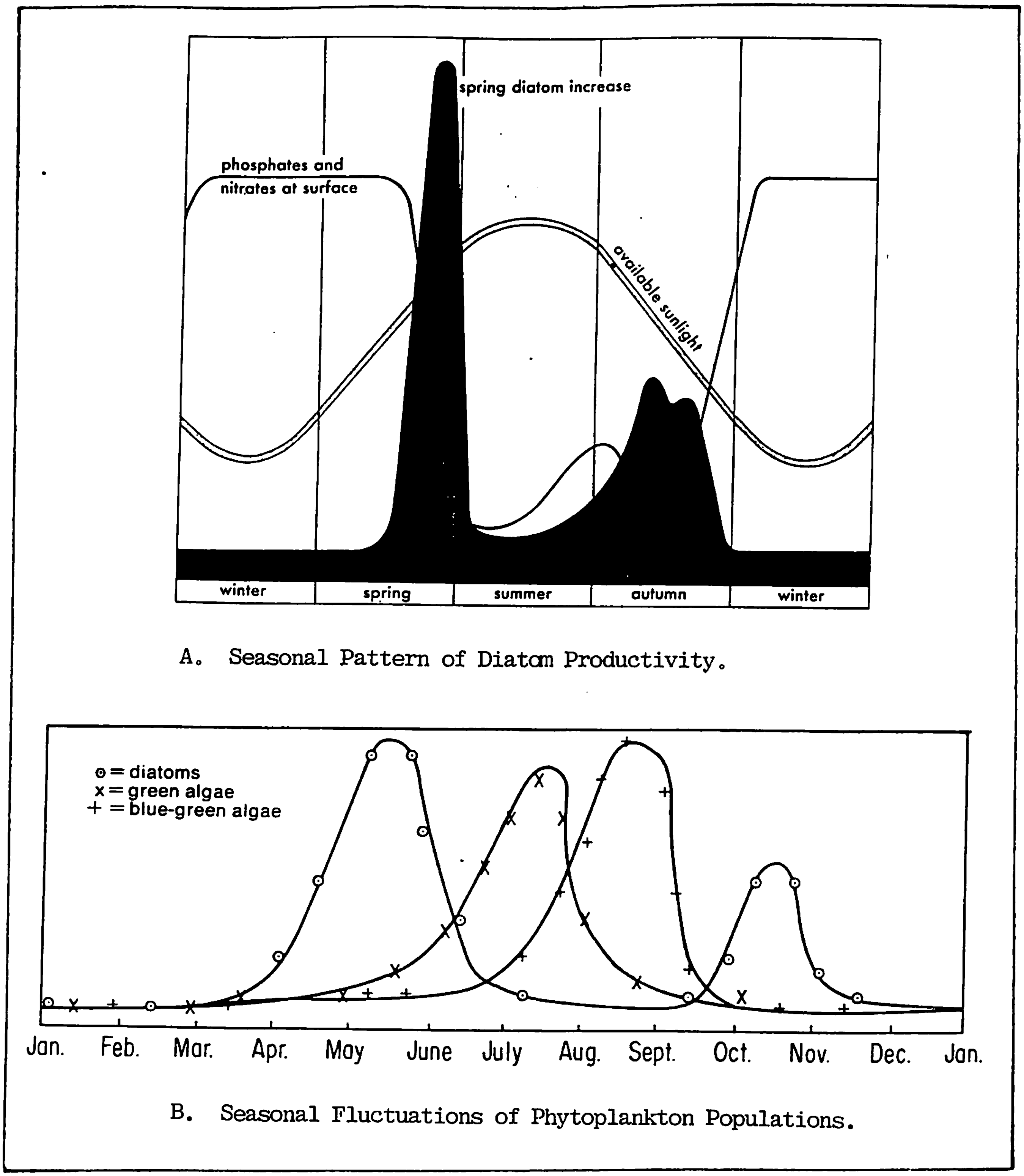


A. Typical Growth Pattern of Blooming Unicellular Algae.



B. Seasonal Fluctuations of Some Physical and Chemical Factors of Lake Erie, Which in Turn Influence Phytoplankton and Zooplankton Population Sizes.

Figure 74. Growth Pattern and Seasonal Influences of Plankton Populations.



A. Seasonal Pattern of Diatom Productivity.

B. Seasonal Fluctuations of Phytoplankton Populations.

Figure 75. Seasonal Pattern and Fluctuations of Diatom and Phytoplankton Populations.

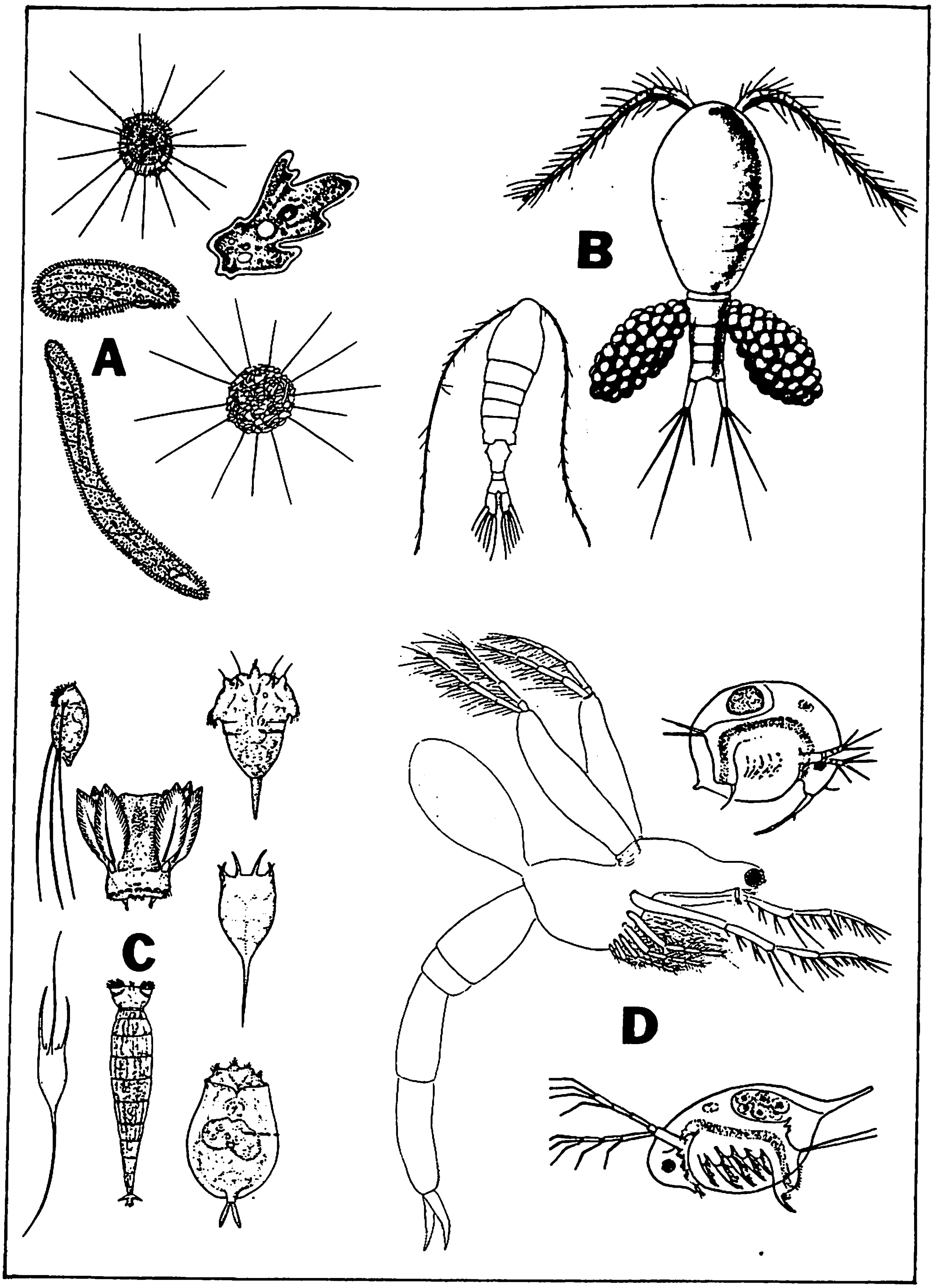


Figure 76. Zooplankton: A) protozoans, B) copepods, C) rotifers, and D) cladocerans (water fleas).

Erie include Synchaeta, Keratella, and Brachionus.

The maximum density of rotifer populations appears to be correlated with the relative amount of available substrate and exposed surface. Using 5,800 per liter as a maximum for plankton, the corresponding maximum for sessile species inhabiting finely divided littoral plants is approximately 25,000 per liter. Thus, the greater the surface area, the greater the rotifer population,,and more food and protection for these organisms.

Copepods

The copepods of the class Crustacea are categorized into 3 distinct groups: the suborder Cyclopoida, Calanoida, and Harpacticoida (Figure 77). The body length ranges from 0.3 to 3.2 mm, but the great majority are less than 2.0 mm long. Identification of the suborders is based mainly on morphological details of appendages and feeding habits:

	Cyclopoida	Harpacticoida
Anterior part of body much broader than posterior	Anterior part of body much broader than posterior	Anterior part of body little broader than posterior
1 egg sac, carried medially	2 egg sacs, carried later-ally	1 egg sac, carried medially
First antennae long	First antennae short	First antennae very short

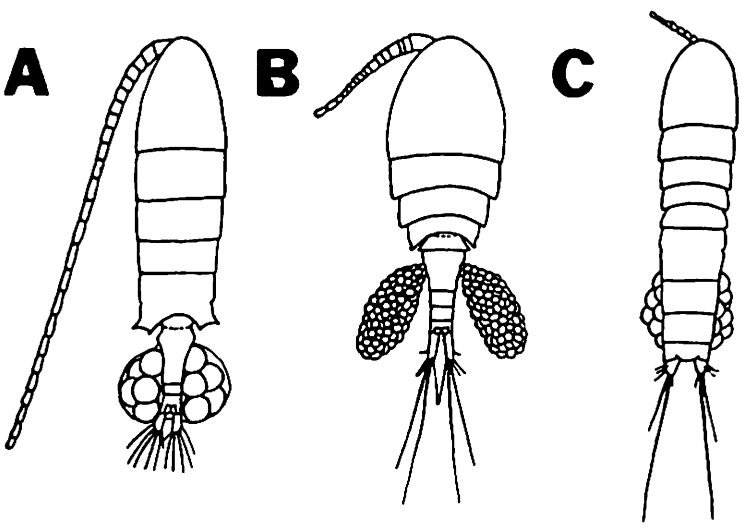


Figure 77. Three Major Types of Free-Living Freshwater Copepods: A) Calanoid, B) Cyclopoid, and C) Harpacticoid.

Calanoids feed largely by filtration of plankton, the antennae used as screws to produce a current, from which particles are filtered by the mouth parts modified for seizing and biting. The food consists mainly of unicellular plant and animal organisms and organic debris.

The harpacticoid copepods are almost exclusively littoral, habitating macro-vegetation, mosses, littoral sediments and particulate organic matter. The cyclopoid copepods are primarily littoral benthic species and the calanoid copepods are exclusively planktonic in the pelagic zone.

Reproductive habits in free-living copepods is similar, but the various species differ widely in their detailed behavior and breeding periods. Refer to Wetzel 1975 and Pennak 1953 for complete details.

Littoral and plankton copepods are easily collected with a plankton net or dipnet. Many species may be obtained by drawing nets through rooted aquatic vegetation and by skimming the bottom. To collect harpacticoids the top centimeter or two of mud and debris should be scooped up, brought into the laboratory and allowed to settle. The harpacticoids can be found moving about at the mud-water interface and can be removed with a pipette.

Cladocerans

Cladocerans, the water fleas, vary in size with individuals ranging from 0.2 to 3.0 mm (Figure 78). They are very common, good swimmers, and are a preferred fish food. The common Daphnia have been favorite objects of observation by students and professional biologists. All have a distinct head, and the body is covered by a bivalve cuticular carapace. Light sensitive organs usually consist of a large compound eye and a smaller ocellus. The second antennae are large swimming appendages and constitute the primary organs of locomotion. The mouth-parts consist of chitinized mandibles that grind food, maxillules to push food between the mandibles, and others.

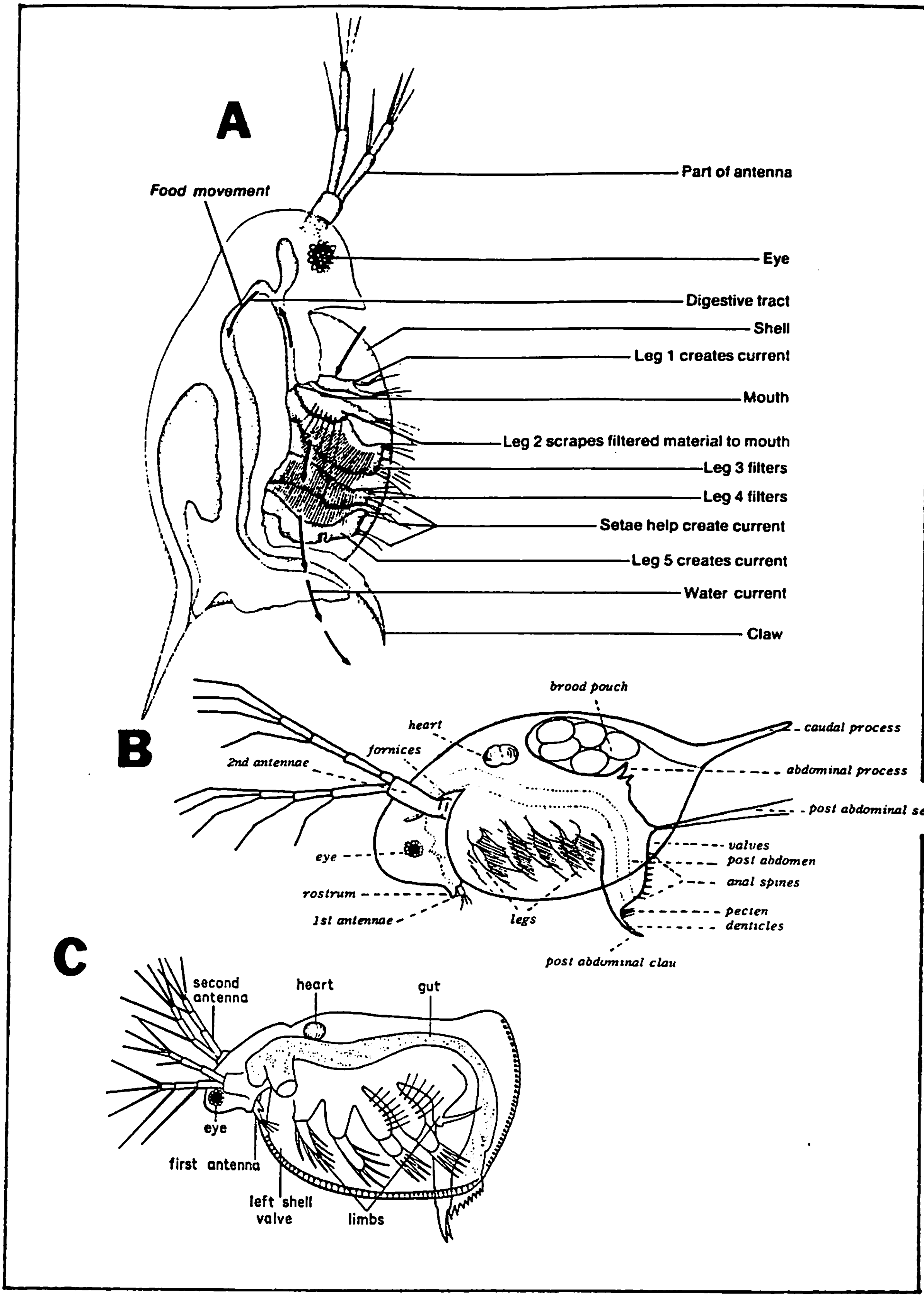


Figure 78. Cladoceran (Water Flea) Features: A) feeding mechanisms, B) external features, and C) internal features.

Complex movement of the highly setose thoracic legs produce a constant current of water between the valves. These movements further serve to filter food particles from the water and collect them in a median ventral groove at the base of the legs. This stream of food is fed forward to the mouth parts where the particles may be ground between the surfaces of the mandibles, then transported into the mouth (Pennak 1953).

Algae, Protozoa, organic detritus, and bacteria are the chief foods for Cladocera. It has been demonstrated that the feeding movements of the legs of planktonic species are efficient enough to separate coloidal organic particles from the water. A few genera, such as Polyphemus and Leptodora, are predaceous and have legs modified for seizing.

Reproduction in the cladocerans is parthenogentic most of the year until interrupted by sexual reproduction. Females produce eggs which develop into more parthenogentic females without fertilization. For detailed discussions, refer to Wetzel 1975 or Pennak 1953.

Seasonal succession of the Cladocera is variable among species and within species among different lake conditions. Some are perennial species that over-winter in low population densities as adults rather than as resting eggs. Some perennial species exhibit maxima in surface layers during colder periods in the spring and in the cooler hypolimnetic and metalimnetic layers during summer stratification. Common open water and limnetic forms include Daphnia longispira, D. pulex, Bosmina, and Eubosmina. The greatest abundance of species may be collected in the vegetation at margins of lakes and rivers. A plankton net is adequate for collecting limnetic species, but is of little use for collecting littoral vegetation. For these habitats, a dip net does a good job.

The zooplankton in Lake Erie has doubled in the past 50 years. The dominant genera include: Cyclops and Diaptomus (Copepoda); Daphnia, Bosmina, and Leptodora

(Cladocera); Keratella, Asplanchna, and Synchaeta. Zooplankton populations are low during the winter months. Adult crustaceans are rare in the spring and fall, but nauplic (immature copepods) are most abundant in late spring and form an important part of the diet of larval fish. The adult crustaceans achieve the greatest abundance during the summer and also serve as a significant link in the food chain of Lake Erie fishes.

Neuston

The neuston is the community of flora and fauna associated with surface tension. The difference in density between the water and the air above is on the order of 1,000 times. This great density difference produces a film with which small organisms are associated.

Another thin organic film on the upper surface of the water is said to contain lipoproteins. This layer and the material collecting in it support the animals of the epineuston. Two abundant taxa in this assemblage are small arachnids, called water mites, and the insects known as springtails. These insects have a markedly hydrophobic cuticle fitting them for such a habitat. The water striders, consisting of two hemipteran (bug) families, are among the most conspicuous of the epineuston (Figure 79).

The conspicuous green covering on some ponds is made up of the duckweeds. These tiny angiosperms float with rootlets hanging in the water below the surface. The dusty or oily appearance of some pond surfaces is due to an epineustic microflora. Floating chrysophyceans, euglenophytes, and chlorophyceans contribute to this appearance.

The hyponeuston is the community living at and under the surface film. A host of algae and protozoans can be found here. They provide food for other organisms, such as mosquitoes, which in turn are preyed upon by cyprinodont topminnows, such as Gambusia.

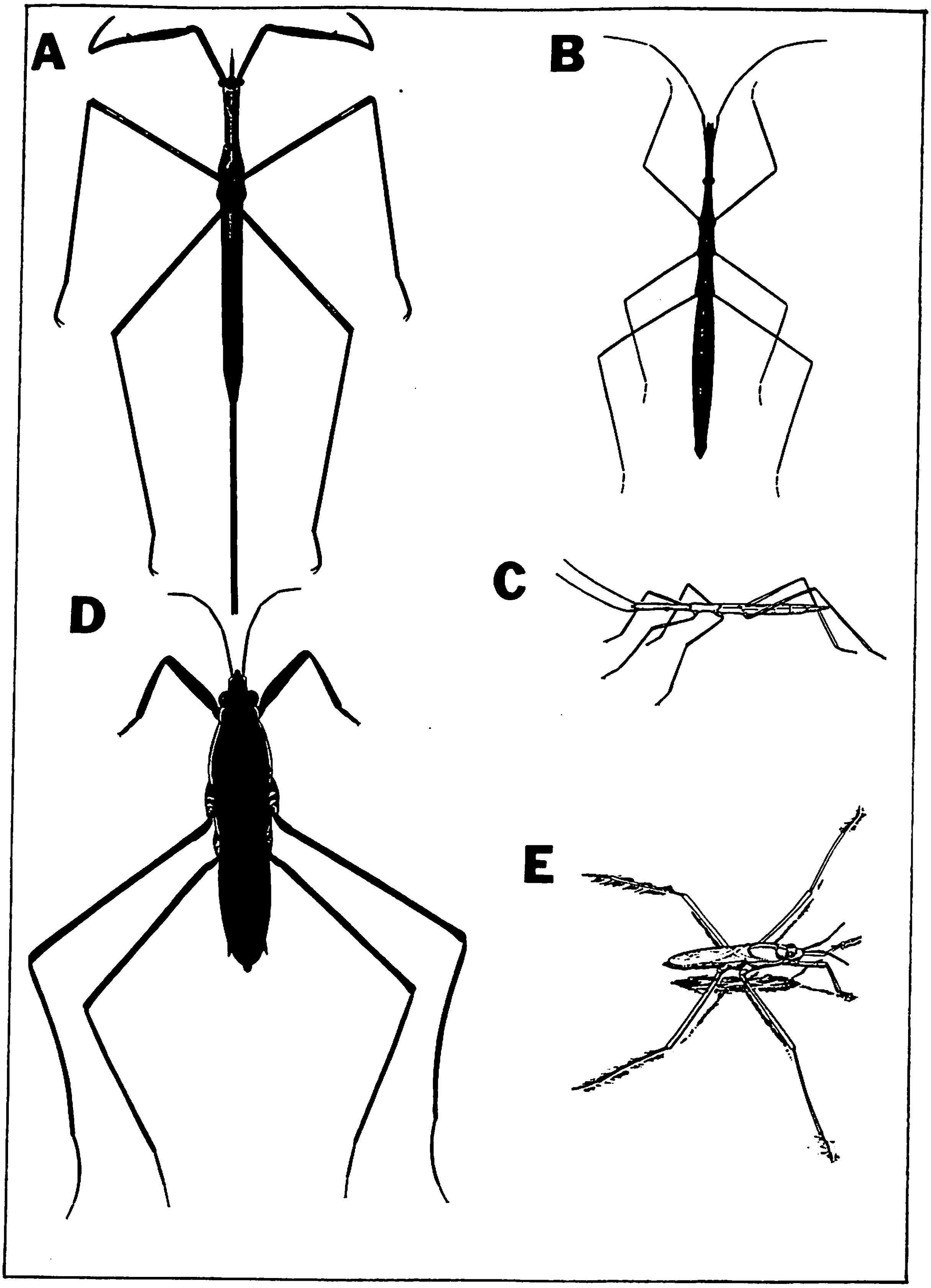


Figure 79. Neustonic Insects: A) water scorpion, B and C) marsh treader, and D and E) water strider.

Nekton (Fish)

Although fish are the largest and most visible nektonic organisms in our aquatic ecosystems, some insects (Figure 80) and water snakes (Figure 81) are good swimmers. Figures 82 and 83 identify some of the important external and internal parts of the fish. Fish are cold-blooded animals, with backbones, gills, anf fins, and are primarily dependent on water as a medium in which to live. Fishes are the most numerous of the vertebrates estimates from 15,000 to as high as 40,000. It is really no wonder that there are so many different kinds of fishes when their antiquity and the extent and variety of their habitat are considered. At present, more than 70% of the earth's surface is covered with water. When the fish group was in its evolutionary youth, there was even more because much that is now land was under water. Development of diversity of living conditions in water might be expected to accelerate the rate of speciation.

Lake Erie, in its nearly 200-year history of commercial fishery, has produced greater numbers and varieties of commercial species of fish than any other Great Lake, accouting for at least a third of the total fish production from the Great Lakes. Annual production in the past 50 years has averaged approximately 50 million pounds and at least 17 species have been significant in the landings at one time or another.

The western basin has long been considered to have the most valuable fish spawning and nursery grounds in the lake, and is the location of intense sport fishing. Ninety-five species of fish have been reported from the water surrounding the islands. These species have differed in abundance and dominance throughout recorded time. No other large lake has experienced such extensive changes in the drainage basin, the lake environment, and the fish populations over the last 150 years (Hartman 1973). Deforestation and prairie burning led to the watershed and siltation of spawning grounds. Many marsh areas were drained and Lake-to-river spawning migration of sturgeon, walleye, and other fishes were blocked by

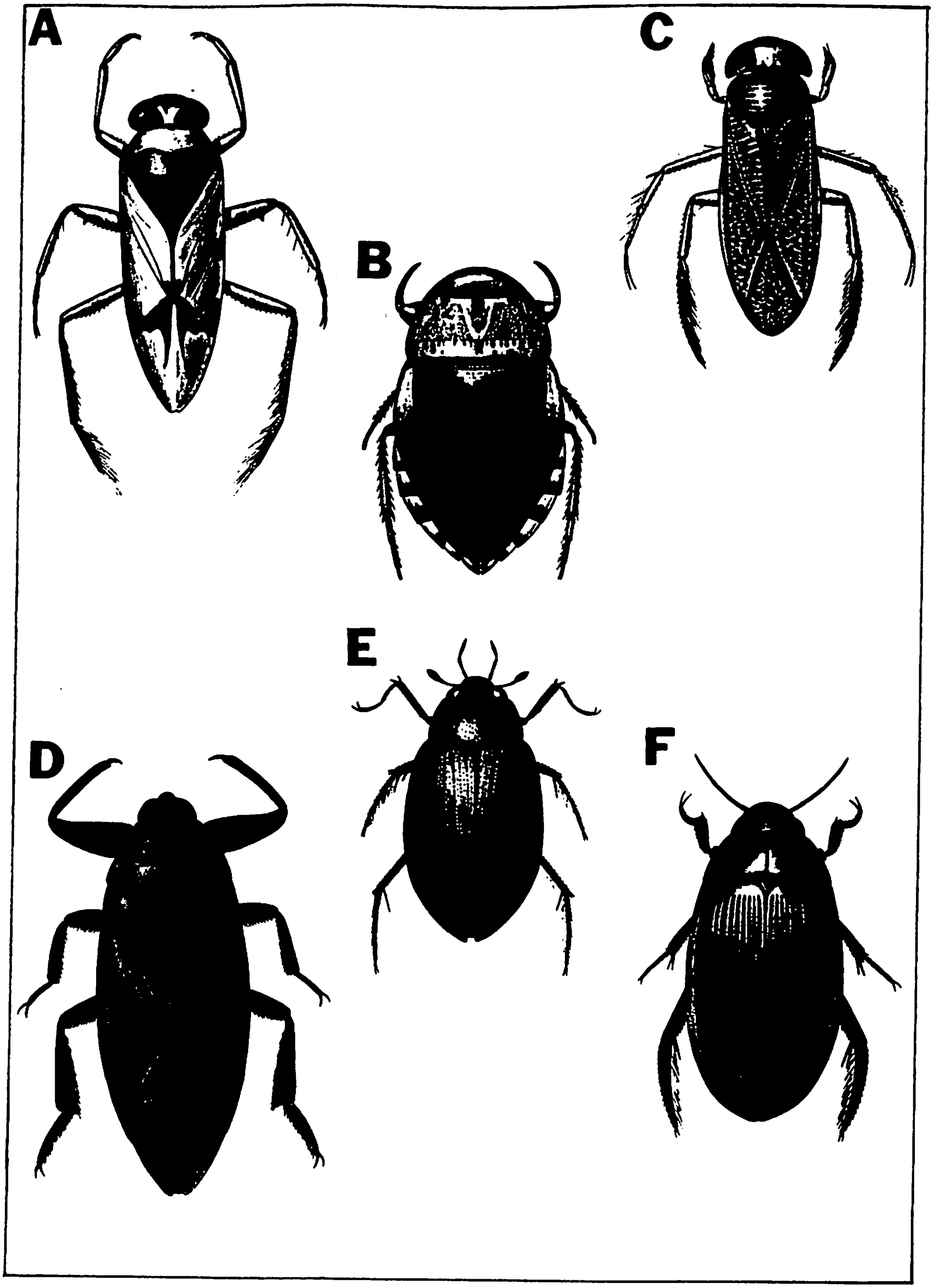


Figure 80. Nektonic Insects: A) backswimmer, B) creeping water bug, C) water boatman, D) giant water bug, E) water scavenger beetle, and F) predaceous diving beetle.

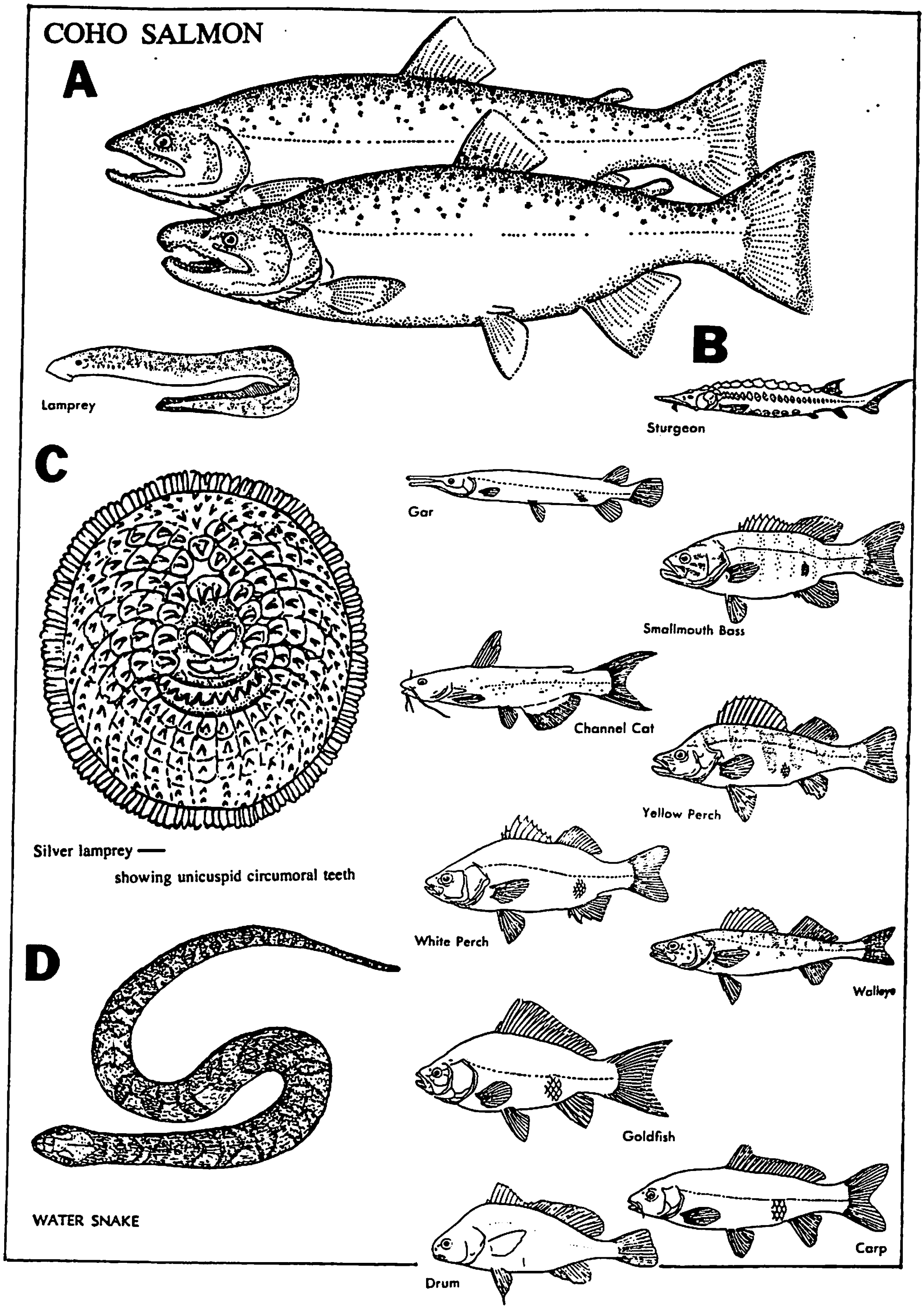


Figure 81. Vertebrate Nekton: A) bony fish (coldwater species), B) bony fish (warm water species), C) jawless fish and D) reptile.

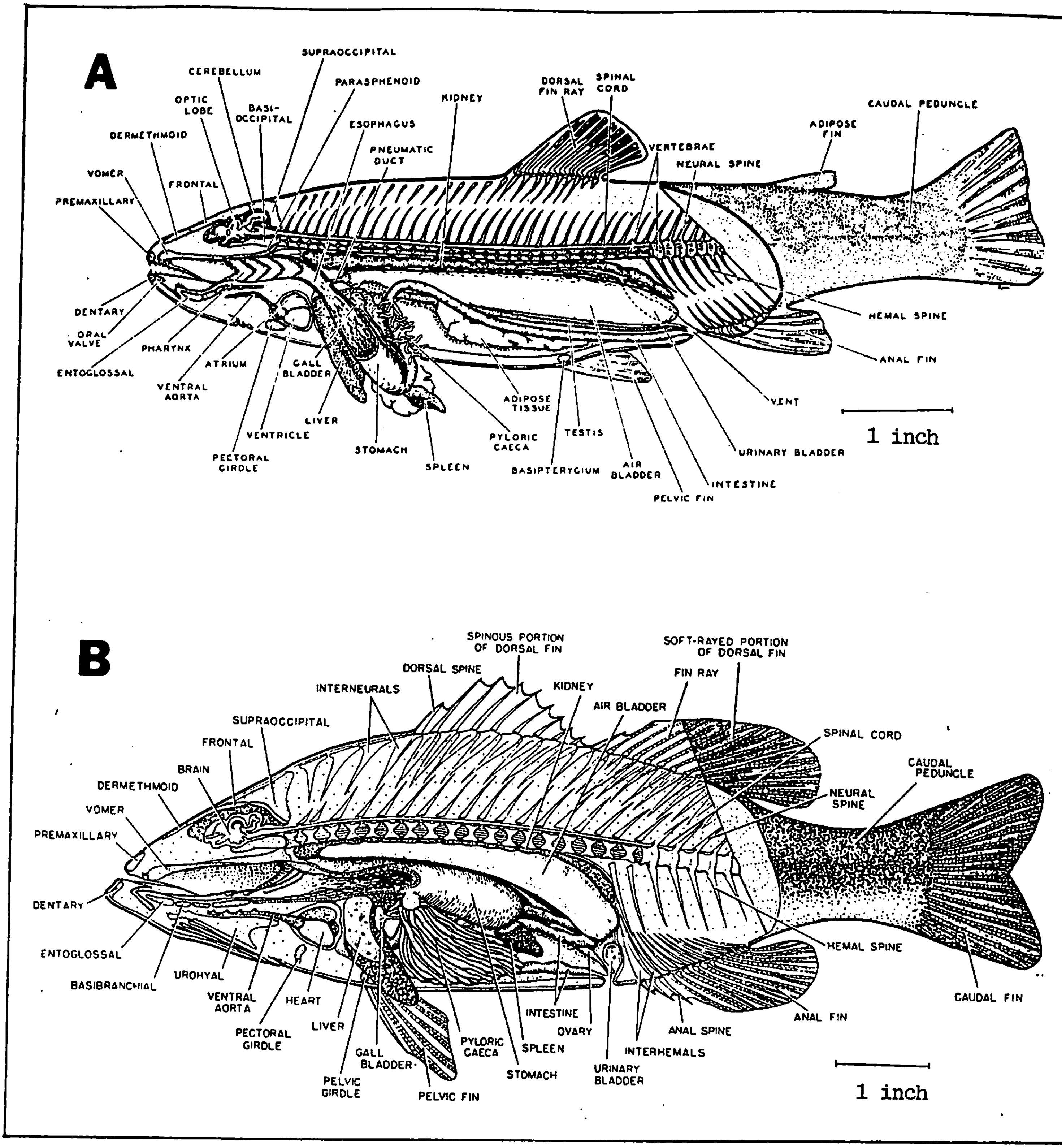


Figure 82. Fish Anatomy: A) soft-rayed fish (trout) and B) spiny-rayed fish (bass).

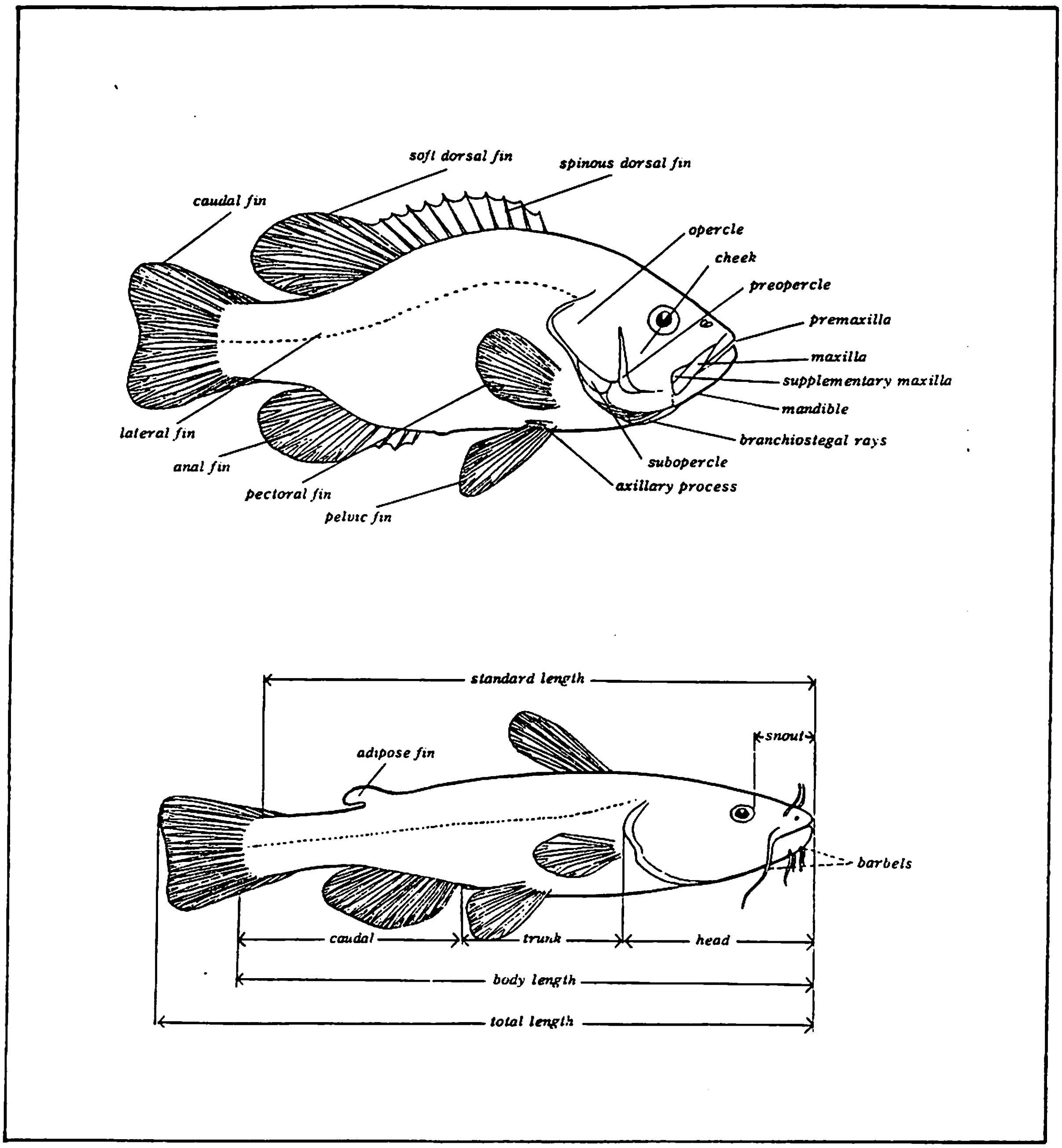


Figure 83. External Features, Body Region and Standard Measurements of Fish.

mill dams. Accelerated cultural nutrient loadings have increased these algal fertilizers in the lake. Today the present phosphate loading to Lake Erie is estimated between 12-15 metric tons each year. From this increase in nutrients phytoplankton biomass increased 20-fold between 1919 and 1963, thus the oxygen demand from decomposition of these algae degraded the oxygen regimes in the western and central basins by the 1950's. The once extremely abundant mayfly nymphs (Figure 68-C) were destroyed and the central basin hypolimnion became anoxic. The sequence of disappearance or severe depletion of fish species was as follows: lake trout, sturgeon, lake herring, lake whitefish, sauger, blue pike and walleye.

The argument to what really caused the decline of Lake Erie fishes has been ongoing for many years. The following reasons are the most commonly accepted reasons for the decline of our fishes: (1) changes in the watershed, such as erosion and siltation of stream beds and inshore lake areas, and construction of dams in tributaries; (2) an extensive, ineffectively controlled commercial fishery; (3) nutrient loadings, destruction of flora and fauna, and reduction of dissolved oxygen; and (4) the competitive and predatory activities of invading species.

Dominant species today are perch, bass, channel catfish, alewife, gizzard shad, carp, goldfish, drum and emerald shiner. The gizzard shad is the most abundant rough fish species collected. Important commercial and sport fish in the island area include walleye, yellow perch, smallmouth bass, white bass, and channel catfish.

The abundance of walleye in western Lake Erie increased throughout the 1970's. During the 1960's, the "fishable" population of walleye (age two and older) was below two million fish. The Ohio Division of Wildlife estimates that the fishable population present in 1982 was 25 million walleye. This represents a more than 10-fold recovery of walleye within one decade. The increased walleye population has been attributed to good young-of-the-year recruitment into the fish stock, favorable climate conditions, and the international management programs to control sport and commercial harvests which are coordinated by the Great Lakes Fishery Commission.

Several methods of collecting fish are shown in Figures 84 and 85. The trap net is the most common commercial fishing gear used in western Lake Erie and gill nets are most often used in central Lake Erie.

Aquatic Ecology Cruise

By reviewing the following aquatic ecology discussion, visiting classes and workshops will be well-prepared for their education visit to Stone Laboratory. The most important concept to remember is that all components of the ecosystem are interrelated in such a way that any effect causing a modification of one component will also cause a modification of the other components. The aquatic ecologist's role and responsibility is to be able to quantitatively define the extent of these modifications.

These relationships are the theme of the standard Science Cruise on Lake Erie. The research cruise is performed near Rattlesnake or Middle Bass Islands depending on weather conditions. The following routine activities are included on the Science Cruise, but other experiments and gear may be added to the cruise agenda depending on the group's interests and needs:

1) Boat trip to sampling site
2) Introduction to the Great Lakes and Lake Erie Geology
3) Measurement of light penetration with a Secchi disc (Figure 86) and discussion of primary productivity
4) Collection and preservation of plankton with a vertical net tow
5) Collection of water samples with various types of water bottles (Kemmerer, Van Doren, etc.)
6) Dissolved oxygen and temperature profiles generated with a DO meter

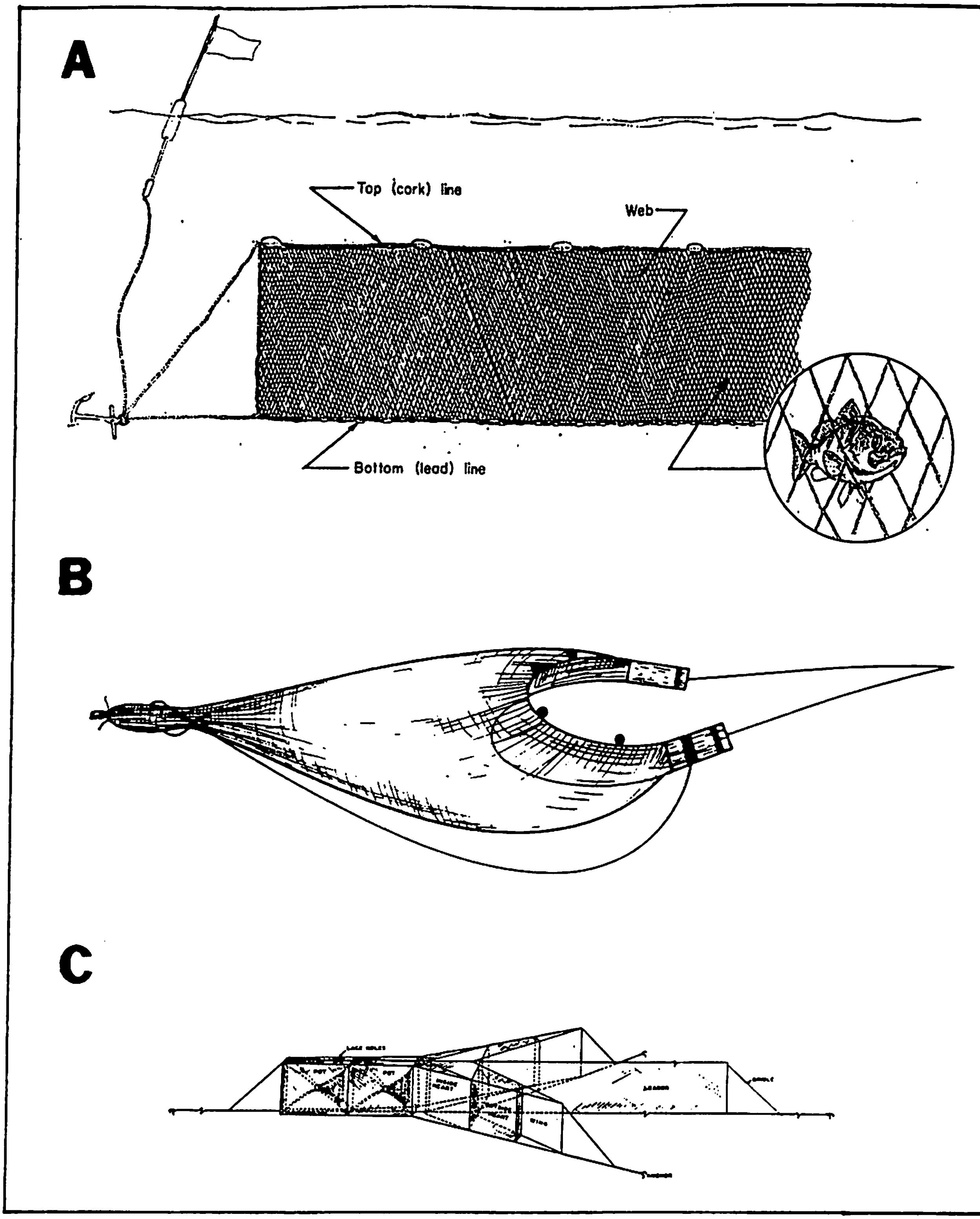


Figure 84. Fish Collection Equipment: A) gill net, B) otter trawl, and C) trap net.

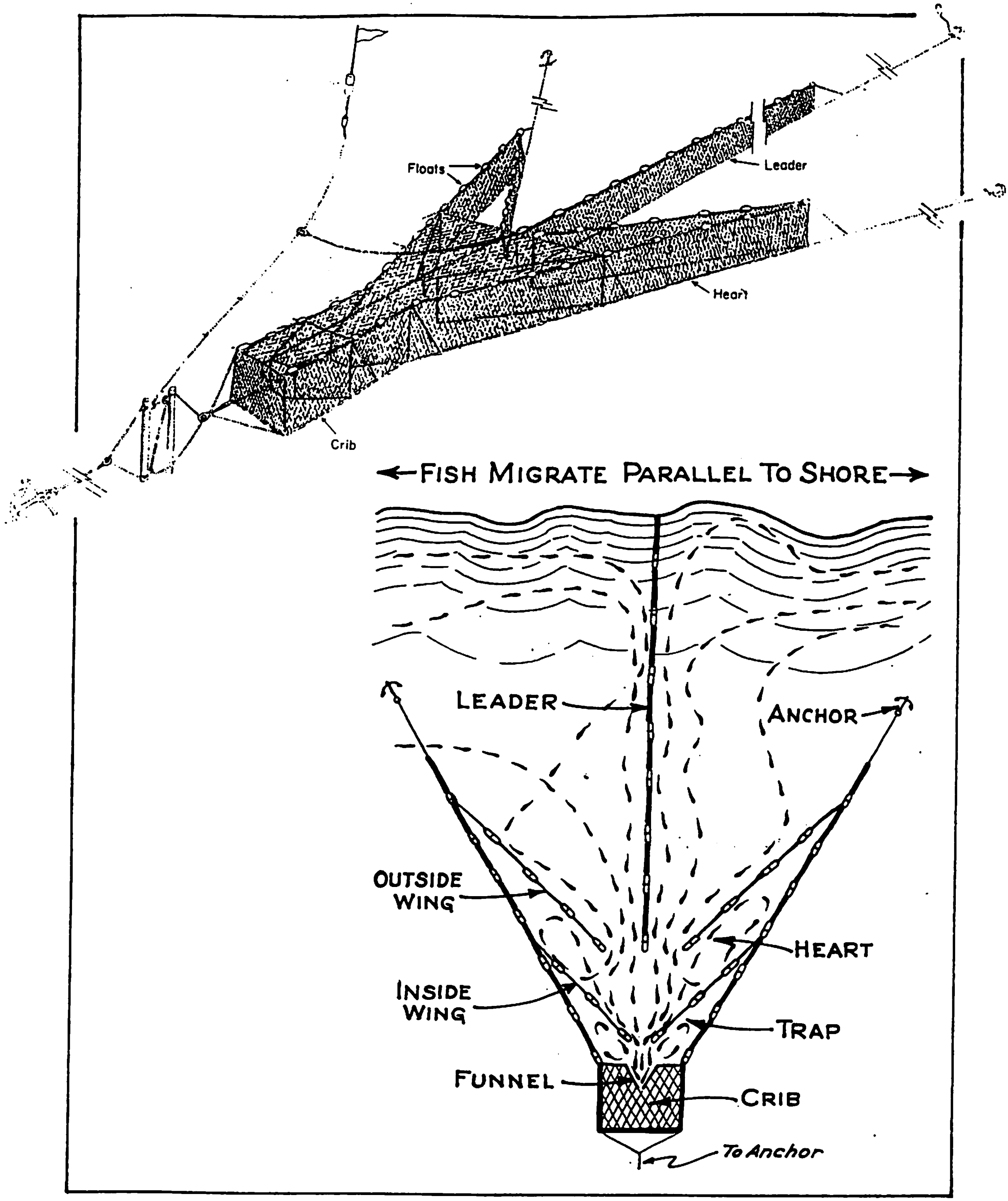


Figure 85. Trap Net Design and Function.

7) Collection of sediment and benthic organisms with an Eckman dredge

8) Collection of fish with Otter Trawl

9) Review of concepts and methods utilized on cruise

10) Return to laboratory to identify organisms and to discuss and analyze the collected data.

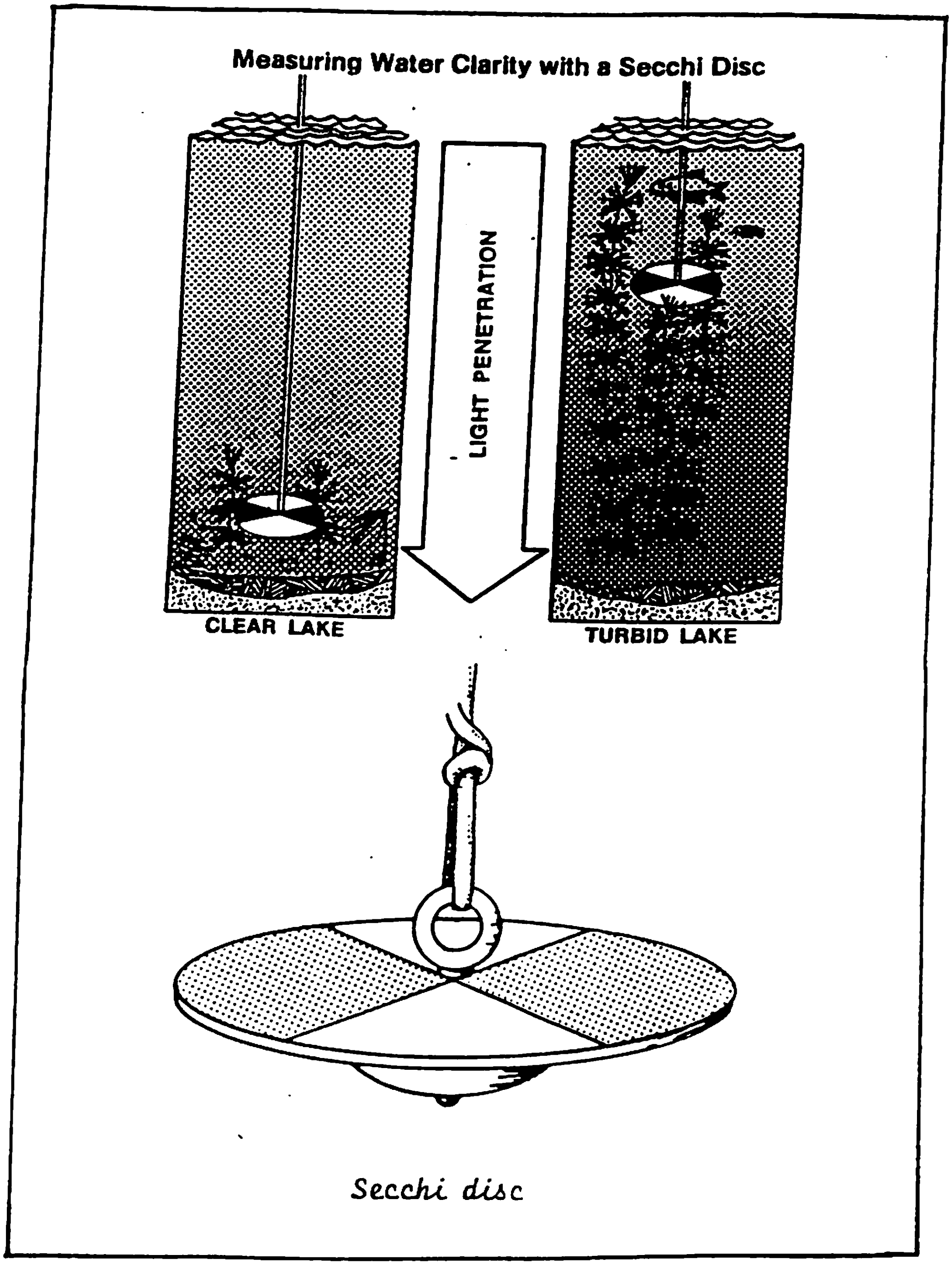


Figure 86. Water Transparency Measurement Device (Secchi disc).

Fish Parasites

Parasites are customarily divided into two types: 1) external and 2) internal. External parasites live on the outer surface of their host, usually feeding on the hair, feathers, scales, or skin of the host or sucking its blood. The copepod Lernea cyprinacaea (anchor worm) which attaches itself to the scales of carp and goldfish is an example of an external parasite. The fish in Carp Pond on Kelleys Island have high incidence of Lernea infection. Internal parasites live in the open spaces of various passages in the body or live embedded in tissues or cells of the host. The trematode Clinostomum marginatum (yellow grub fluke) which infests yellow perch and great blue heron and the cestode Proteocephalus ambloplitis (bass tapeworm) which inflicts smallmouth bass are examples of internal parasites.

The life cycles of the yellow grub (Figure 87) and the bass tapeworm (Figure 88) illustrate the complicated nature of parasite existence in Lake Erie. The following statements refer to the life stages of these two flatworms as shown in Figures 87 and 88, The research on these cycles was originally done by Drs. R. V. Bangham and G. W. Hunter in the 1920s and 1930s:

Yellow Grub

(1) The adult stage of this parasite may be found in the oral cavity of of the great blue heron, where it is attached by means of its muscular suckers.

(2) The eggs are shed from the adult worms and find their way into the water when the bird (the determinate host) is feeding. These eggs are equipped with a lid, or operculum (open in the outline sketch between numbers 2 and 3).

(3) The miracidium, a minute larval stage, emerges from the egg and is

equipped with numerous cilia, by means of which it swims about in the water, and a spinous projection, or stylet, which aids it in penetrating its next host, a snail.

(4) Within the snail, which is the first intermediate host, the miracidium undergoes several successive stages of development. It grows first into a large sac-like structure called the mother sporcyst; from this sporocyst another stage, the redia, is developed, and finally the cercaria (5).

(5) The cercaria, a free-swimming little animal with a bluntly shaped fore-body and a forked tail, swims about upside down in the water, and may make contact with a suitable kind of fish for its second intermediate host.

(6) The cercaria penetrates the skin of a yellow perch, its second intermediate host. Within the muscles of the host, the cercaria loses its tail, and becomes encysted, where it is known as the yellow grub or the metacercarial stage in the life history of the parasite. When grub - by fish, that is, fish infected with this stage of the parasite, are eaten by the heron, the metacercaria develops into the adult worm. The worm fastens onto the tissues of the mouth, throat, or esophagus of the bird (the final or determinate host), after which time the cycle may be repeated.

(7) Final host, great blue heron.

Bass Tapeworm

(1) The adult tapeworm commonly infests the intestine of smallmouth bass. Here it maintains its position by means of the muscular suckers on the head of the worm which attach to the intestinal wall of the host. The body of the worm is comprised of a number of segments, proglottids, the largest of which are at the caudal end of the worm, and the smallest near the head, where growth takes place. Each one of these segments is an independent unit, containing its own reproductive system. These worms maintain no digestive system; they absorb food from the host through the walls of each

segment. As the segments mature and become filled with eggs, they break off from the rest of the adult worm and are shed through the anus of the fish into the water.

(2) In the water, the wall of the proglottid disintegrates and the eggs are released. For the life cycle of this parasite to continue, the eggs must be eaten by certain copepod crustaceans.

(3) Within the body of the crustacean (the first intermediate host), the egg hatches and develops into a bluntly shaped larva, called the procercoid. The crustacean with this stage may be eaten by the second intermediate host of the parasite.

(4) The second intermediate host may be almost any forage fish in which the parasite, as a procercoid larva, bores through the wall of the digestive tract and invades the tissues of the visera (liver, spleen, or reproductive organs). Development of the parasite continues in these organs until the larva has grown from its procercoid to the plerocercoid stage.

(5) The final host, usually a piscivorous centrarchid (although yellow perch, walleyes, and others will also serve) easts the infected, secondary fish host. As the secondary host is digested, the larvae are released into the intestine of the final host where they grow into adult tapeworms anchoring themsleves in the intestine of the fish by means of an apical sucker. From this point, the cycle may be repeated.

The yellow grub apparently cause little damage to fish other than occasional emaciation. However, the bass tapeworm larvae can damage ovaries beyond repair; in hatcheries this parasite can inflict serious damage on brood stock causing sterility.

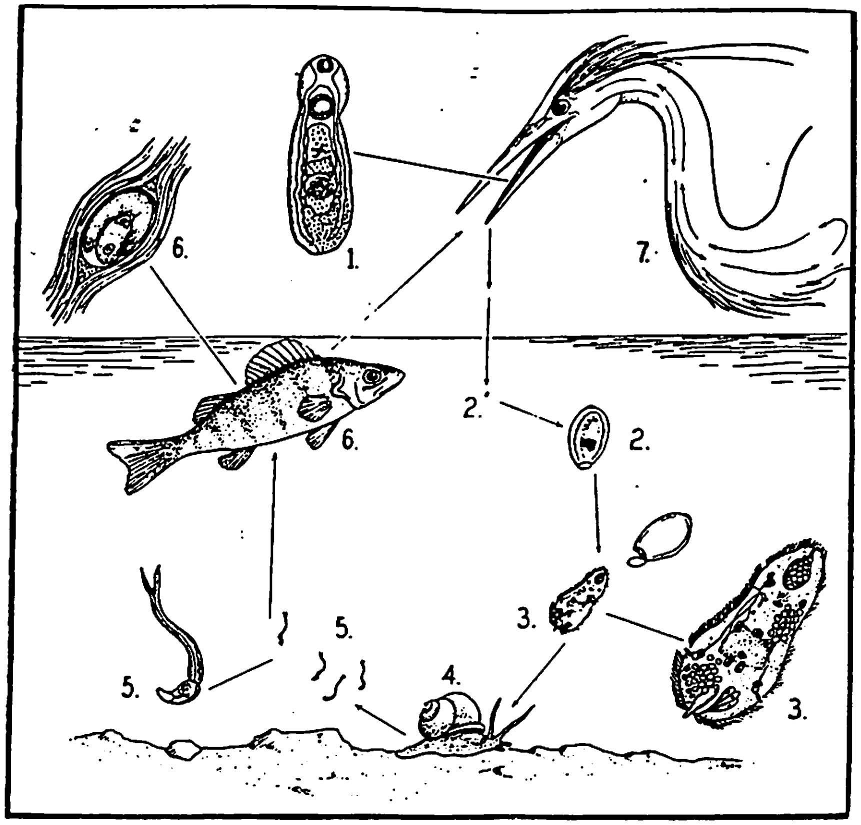


Figure 87. Life Cycle of the Yellow Grub (Clinostomum marginatum).

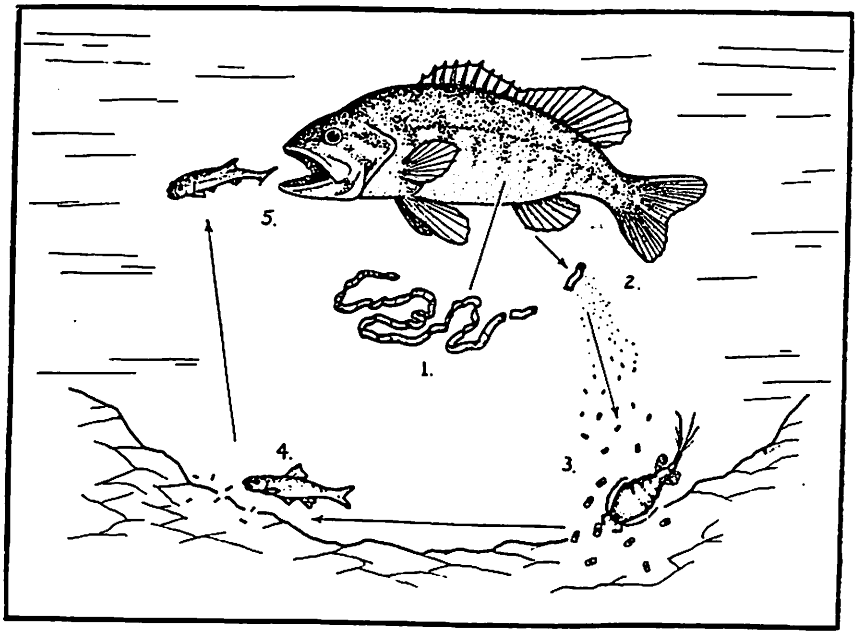


Figure 88. Life Cycle of the Bass Tapeworm (Proteocephalus amblopitis).

AMPHIBIANS AND REPTILES

AMPHIBIANS AND REPTILES

Amphibians and reptiles form two natural and distinct classes of vertebrate animals. Both groups are cold-blooded, deriving heat from outside sources and controlling their body temperatures by moving to cooler or warmer environments as necessary. Amphibians have moist, glandular skins and their toes are devoid of claws. Their young pass through a larval stage, usually aquatic, before they metamorphose into the adult form. Belonging to the Class Amphibia are the salamanders (including newts) and the toads and frogs. By comparison, reptiles are clad in scales or plates, and their toes bear claws. Young reptiles are miniature replicas of their parents, although some differ in color patterns from adults. To the Class Reptilia belong the turtles, snakes and lizards.

The amphibians and reptiles of the islands region are found in a variety of habitats including the open lake, ponds, marshes, along the shore, upland, and in caves. The common fauna includes the mudpuppy, six other salamanders, a newt, a toad, six frogs, seven turtles, twelve snakes, and a skink (Figure 89).

Amphibians

Mudpuppies are fairly common in embayments with soft bottoms and aquatic plants. They get their name from the doglike head with wavy red gills which look somewhat like ears. The body of this large salamander is mottled brown with black spots, slimy, and about 12 inches (30 cm) long. They burrow into mud during the day and crawl along the bottom at night, looking for water insects, snails, fish eggs, small fish and other creatures to eat. They are active throughout most of the year. Mudpuppies mate in autumn, but the female does not lay her eggs until late spring. She glues the jelly-coated eggs to the underpart of logs or stones and guards them until they hatch, nearly two months later. The newly hatched larvae are about 3/4 inch (2 cm) long. It takes seven years for them to become mature at a length of about eight inches (20 cm). Their lifespan

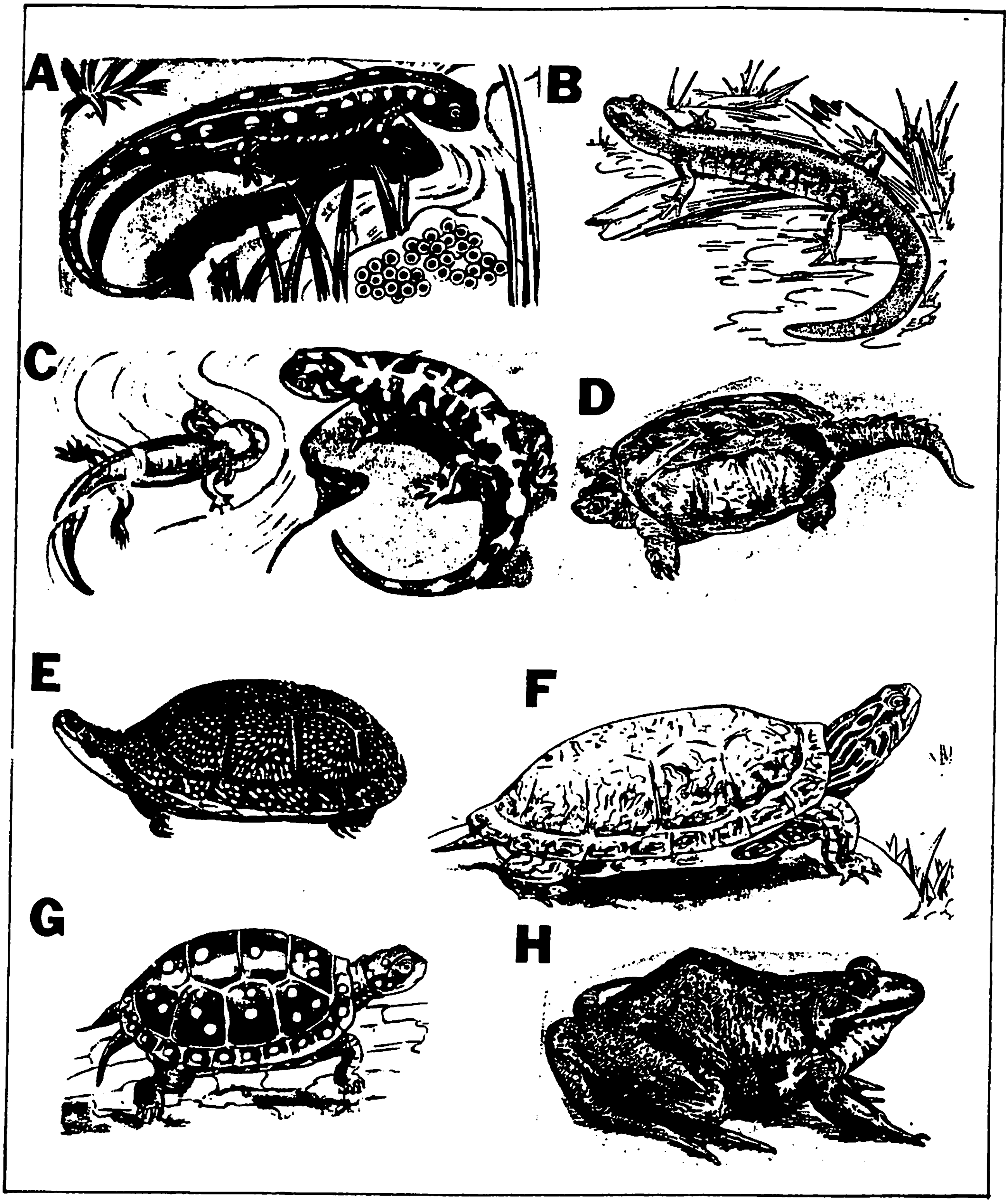


Figure 89. Benthic Vertebrates: A) spotted salamander, B) Jefferson salamander, C) tiger salamander, D) snapping turtle, E) Blanding's turtle, F) map turtle, G) spotted turtle and H) bullfrog.

is estimated at over 20 years.

The smaller spotted, tiger, Jefferson, and smallmouth salamanders belong to a family known as mole salamanders because they spend most of their lives underground. At the early spring breeding time, they take to the icy water. Looking for these salamanders usually requires donning hip boots, dressing warmly, and wading in the cold water with seine or dip net. The eggs are usually laid in large clusters and attached to submerged sticks or debris. After several weeks they hatch into greenish-brown larvae about 1/2 inch (1.3 cm) long. The newly hatched larvae resemble tadpoles with external gills. By the end of summer, the larvae are nearly 3 inches (8 cm) long, they begin to develop lungs and are ready to leave the water for moist woods. Adult spotted salamanders are black with yellow spots and reach a length of 7 inches (18 cm). They become slimy when annoyed. Tiger salamanders are black with yellow blotches and grow to a length of 8 inches (20 cm). Jefferson salamanders grow to 7 inches (18 cm) long and are dark brown with small blue spots on their sides. The live in the woods, where it hides under rocks and feeds at night on insects, snails, and worms. Smallmouth salamanders are similar in lenght but they are plain black in northern Ohio. The marshes of Middle Bass and North Bass islands are especially good locations to study mole salamanders.

The northern dusky salamander and the red-backed salamander belong to another family of salamanders which is lungless. They breathe through the throat membrane and the skin, which must be kept continually moist. These slender salamanders often live among the rocks of a sheltered shoreline or in moist caves. In summer, the female dusky salamander lays 10 to 25 jelly-coated eggs in bunches like grapes in moist places under moss, leaves or rock. The larvae hatch in about two months; they live on land for three weeks, until their gills and tail fin develop. Then, at a length of 3/4 inch (2 cm), they enter the water and stay there until the following spring, when they lose their gills and return to the land. The red-backed salamander has been observed in caves on South Bass Island. Complete development takes place within the egg; there is not aquatic larval stage as is the case among most other salamanders.

Newts are not as slippery as most salamanders; their skin is rougher, not as slimy, and they do not slide easily through your fingers when you try to catch them. The red-spotted newt lives in water during the beginning and end ot its life, while the time between is spend on land. The are olive-green with red and black spots on the back and yellow underneath. Breeding adults are 4 inches (10 cm) long and live in water. In spring, the females lay eggs on water plants. In less than a month, the larvae hatch, each with external gills, buds for front feet, and a tail fin. By autumn, they are able to leave the water when the gills are replaced by lungs. Legs and a slender tail form and the greenish coloring changes to brigh red with darker red spots on the back. The young newts are called red efts. They live in the woods for a year or longer, then mature into newts which return to the water to live and breed.

Toads live on land most of the time. But in spring, after leaving their water shelter under rock and logs, they seek ponds and sheltered embayments. There they mate and the females lay their eggs. The American toad has a warty light or dark brown skin. The female's throat is light; the male's is marked with dark specks and swells out when he sings. In April, the males arrive at the shore and start the humming chorus which is the mating song. Soon after the females come and lay their eggs in long strings of jelly in the water. In a little over a week, the eggs hatch into black tadpoles which grow fast. When they are two months old, they metamorphose into tiny toads 1/2 inch (1.3 cm) long. They hop out onto the ground and begin a terrestrial life feeding on insects and worms.

Most of the year, frogs in the treefrog family live on land, but in spring they find their way to ponds to mate and lay their eggs. The tiny spring peepers are among the first to come out of hibernation. In March, crowds of peeper start the shrill piping which is one of the first signs of spring. In the evening, with a flashlight, males can be seen singing with their dark throats puffed out like a small balloon. Female peepers lay their eggs separately on leaves and stems in shallow water. In about ten days, tiny tadpoles hatch which metamorphose into 1/2 inch (1.3 cm) peepers. In three months, with the sticky pads on their feet, they can climb shrubs and feed on insects. The western chorus frog, sometimes called the swamp treefrog, has a vibrant voice with regularly repeated crreek or prreep speeding up and rising in pitch toward the end. A similar sound can be produced by running a finger over the small teeth of a pocket comb, rubbing the shortest teeth last. The cricket frog's call is a clicking sound, resembling a cricket's chirp. Like the spring peeper, it is no more than an inch (2.5 cm) long and may be heard in ponds from April until June. Although the cricket frog belongs to the treefrog family, pads on their toes are too small for them to climb trees. Most of the time, they live along the cattail and rush borders of ponds and marshes. Because of their ability to leap so high, they are sometimes called grasshopper frogs.

Members of the true frog family in the Lake Erie islands region include the pickeral frog, leopard frog, and bullfrog. They are the typical frogs of ponds and marshes; all have long legs, smooth skin, separated fingers, and toes joined by webs. Pickeral frogs live in or near water except in summer when they may wander inland in search of insects and other creatures in the fields. They have dark brown rectangular spots on light brown backs and a light stripe along each side. In April, the males make a croaking sound in shallow water; females lay masses of jelly-coated eggs in the water. A full-grown 3-inch (8 cm) tadpole has a dark back, purplish tail crest, and an irridescent underside. The slightly larger leopard frog is green or brownish and the rounded dark spots on its back are outlined in white. The tadpoles are brown with black specks on the back, light underneath, and have translucent edges on their tails. As the tadpoles change into frogs, the back legs develop and the front ones break through; although the small leopard frogs still have tails, they can now jump out of the water. Bullfrogs always live in or near water. These large frogs, 8 inches (20 cm) long, are the last to mate and lay their eggs. In June and July the males produce a garrump corak in ponds and embayments of the lake. The females lay thousands of small black jelly-coated eggs which float on the surface of the water in large masses over 3 feet (1 meter) across. After a few days, the eggs hatch into tadpoles which take two years to grow to the frog stage. Full-grown bullfrog tadpoles are 5 inches (13 cm) long, splotchy brownish in color, and change into 2-inch (5 cm) frogs which have the same coloring on the back and are white underneath. As bullfrogs grow, they become green on the back and the males have yellow throats in the summer.

Reptiles

The snapping turtle grows to over 2 feet (0.7 meters) long and may weigh more than 40 pounds (18 kg). It is the largest reptile in the island region and makes its home in ponds, marshes and embayments of the lake. The dark brown upper shell does not cover its heavy neck, legs and saw-toothed tail, giving the head and legs room to move freely. When catching food, the snapping turtle darts its head forward and snaps with powerful jaws. It eats fish, frogs, insects, crayfish, ducklings, and other creatures, as well as some water plants. In spring, the female digs a hole in the soft, moist bank and deposits 20 or more round, white, hard-shelled eggs that are about an inch (2.5 cm) in diameter. They hatch in about three months into tiny turtles with long tails. Snapping turtles hibernate in the mud bottoms of the ponds and marshes.

The map, spotted, midland painted, box and Blanding's turtles all belong to the water and box turtle family. The map turtle prefers water and places where aquatic plants are thick. Its name comes from its olive-brown upper shell with light yellowish markings, which resemble a chart. This turtle grows to 10 inches (25 cm) long. Spotted turtles are scarce in the islands region and this reptile has been placed on the Ohio Endangered Species List. They often feed under water where they eat small fish and shellfish, but they also forage on land. Their 5-inch (13 cm), smooth, black, highly arched shells have bright yellow spots. The midland painted turtle always lives near the water since it does all its eating under water. It will eat almost anything it finds, either dead or alive. The shell of the painted turtle grows to 7 inches (18 cm) in length and is shiny olive-brown or black with yellow lines on the back and red marks along the edges. On the head, it has yellow marks and on the neck and legs, red stripes. The box turtle is mostly terrestrial, but sometimes enters the water to cool off or escape from an enemy. The under shell of this turtle is hinged and can be closed tightly against the upper shell to form a box with the turtle inside. The upper shell is 5 inches (13 cm) long, high, rounded, and is dark brown with yellow marks. Box turtles eat plants, insects, worms, slugs, and snails; at times they grow so fat they cannot close their shells. The Blanding's or semi-box turtle also has a high hinged shell, but closure is less complete than the box turtle. It is essentially aquatic, but at times wanders about on land, although seldom far from the lake or marshes. The upper shell is plain brownish gray with light spots that tend to run together forming bars or streaks. They also have bright yellow patches on the chin and throat. This turtle often hisses sharply when picked up in the field.

Soft-shelled turtles are odd-looking aquatic creatures which prefer rivers. They are scarce in the islands region having only been reported from Catawba Island. The spring soft-shelled turtle has a light brown, flexible shell up to 10 inches (25 cm) in length. They commonly float over shallow muddy bottoms with only their snouts sticking up for air. These turtles eat fish and some aquatic plants.

The Lake Erie water snake is the snake most often seen in or near the lake throughout the islands region. It is a uniform green-brown color without the distinct light and dark brown of its close relative, the northern water snake which inhabits the mainland shore and some of the islands. The rarer Kirtland's water snake has only been observed on South Bass Island. When alarmed, this snake can flatten its body making itself almost ribbon-like and rigidly immobile. It is a good swimmer but the least aquatic of the water snakes. Water snakes grow to a length of about 4 feet (1.3 meters). They catch and eat small creatures which live in or near water, such as fish, frogs, insects, and mice. Water snakes are not poisonous, but they will hiss, coil and strike if annoyed. They also secrete a fowl smelling substance from musk glands as a defense mechanism. Late in summer, the female has from 15 to 40 young which she bears live. The Lake Erie water snake is fairly common around the islands, particularly the uninhabited ones, and can be seen swimming along the shore with its head above water or sunning on flat rocks near the water's edge. Along the walkway near the shrubs in front of the Stone Laboratory classroom building on Gibraltar Island is a particularly good place to observe this fascinating species.

In addition to the water snakes, there are eight other common species of snakes on the islands which belong to the colubrid family. The garter snake is sometimes found near water where it eats frogs, toads, salamanders, crayfish, and minnows. It grows to 3 feet (1 meter) long and its back is brown with three yellow stripes; underneath it is light yellow. The fox snake is a resident of the marshes which border Lake Erie and the adjacent upland areas. This attractive snake is boldy patterned with background colors varying from yellowish to light brown, to reddish and the dark spots and blotches from chocolate to black. Unfortunately, the reddish head frequently causes it to be killed as a "copperhead," and its black and yellowish coloration plus its habit of vibrating the tail cause it be slain as a "rattler". The black rat snake is a plain, shiny black reptile. Its habitats range from rocky, wooded cliffs to flat shorelines; an excellent climber, it sometimes takes up residence in cavities high up in hollow trees. It constricts rats, mice and birds in its strong coils as does its close relative the fox snake. The northern brown or Dekay's snake is small, generally not over 12 inches (0.3 meters), gentle, and very common throughout the island region. It can be found near the marshes, in the moist woods, and near the rocky shoreline. The hog-nosed snake is a serpent of extraordinary behavior which includes hissing, head-spreading, body inflation and playin "possum." It has an upturned snout, hence the name, and reddish brown coloration. Frogs, toads and tadpoles are the mainstay of its diet. The ring-necked snake is a plain, dark, slender serpent with a golder collar. It is a secretive woodland snake, preferring rocky, wooded cliffs and hillsides. The blue and the black racers are fast-moving, slender snakes. They kill their prey by holding them with strong jaws while a loop of the body is thrown over the struggling victim pressing it down, not by constriction as their scientific name suggests. Food items consist of rats, mice, rabbits, birds, and frogs. Habitats include woodlands, marshes and environs of lakes and ponds. The black racer is plain black both above and below while the blue racer is plain blue above and pale blue below.

Journals of early islands explorers and settlers tell of great numbers of rattlesnakes. After over 100 years of being slaughtered on sight and hunted by domesticated hogs, the timber rattlesnake has probably been extirpated from the islands. The last sightings of this species, the islands only poisonous snake, were on Kelleys Island in the 1950s.

Skinks form a family of lizards which are smooth, shiny, alert, and active. Most species are terrestrial, foraging in the daylight but taking shelter at night, in bad weather, or from high temperatures. The five-lined skink is the only species found in the islands region and it is not abundant. Hatchlings have five white or yellowish stripes on a black back and their tails are bright blue. Adult females retain some indications of this striped pattern but males usually become a nearly uniform brown or olive color. The preferred habitats are cutover woodlots with rotting stumps and logs, moist rock ledges, and decaying debris accumulations in woods. Skinks are difficult to catch and hold. Their tails break off very easily. They will try to bite, and one can pinch painfully hard.

AVIFAUNA

AVIFAUNA

The island region of western Lake Erie supports a wide variety of birds which can be divided into several groups; water birds, wading birds of the marsh and shore, upland game birds, birds of prey (raptors) and songbirds which consists of passerines and non-passerines (perching and non-perching birds).

Water Birds

The water birds division embraces all members of the waterfowl family (swans, geese, and ducks) plus several other bird groups that obtain their food mainly from the water. Gulls and terns are included despite the fact that they do spend a great deal of time on the shore resting. Also added are the coot and moorhen (formerly gallinule), because of their duck-like behavior and habitat.

Wading Birds

The wading bird category includes the long-legged, shallow-water waders (egrets and herons) and the shorebirds (sandpipers, plovers and a few other birds that run along the beaches in search of food).

The water-margin habitat produces much invertebrate life that is attractive to birds. The abundance of insects, mollusks and crustaceans explains why so many birds of different families concentrate on this limited environment.

Birds of the marsh and shoreline have little direct economic importances, nor are they prized as gamebirds. They are an interesting segment of life in wet marginal areas. Most of these birds feed mainly on animals and some of the long-legged species eat fish extensively.

Upland Game Birds

Our principal upland game birds are the ring-necked pheasant, woodcock, and mourning dove. Although the woodcock is closely allied to the shorebirds, its habitat includes lowland woods and upland fields. Furthermore, it is a well-known game species. Most of the game birds are primarily plant eaters. Wildlife scientists have devoted special attantion to the feeding habits of these birds. In some cases, a knowledge of a bird's food - especially when dealing with plants - has been helpful in restoring and maintaining a particular species.

Raptors

The term "birds of prey" (raptor) has been applied only to species which feed on vertebrates and is used in its broad sense to include hawks, vultures, eagles and owls. These predators help control the population growth of many species that would, if left unchecked, be disasterous to the environment. Game managers note in some instances, that raptors aid a species by weeding out sick and weak individuals. By helping to keep populations in balance, birds of prey - along with other predators - benefit all of us.

The size and build of a bird has a great deal to do with what it eats. The larger species are able to handle large prey, while the smaller species usually choose prey in proportion to their size. Thus, while eagles feed on medium-sized fish, ground squirrels, rabbits, ducks and lambs, many hawks hunt rats, mice and small birds. Members of the raptor group have strong talons and bills for holding and tearing meat.

Songbirds

The songbird group of passerines and non-passerines includes almost all birds not covered in the previous categories and includes many unmelodious species such as the crow, starling, and grackle.

Most of the songbirds are migratory. Many that winter in the south, nest in this area while many Arctic songbirds make the Lake Erie island area their winter home. Still other songbirds are permanent residents, remaining here throughout the year.

Besides making life more enjoyable for us, songbirds are economically important in two ways; many species help control insects that are harmful to crops, orchards, forests and gardens, and in a negative sense, they can damage fruit orchards, vineyards or grain crops severely.

Viewing Locations

Specific areas of interest around the island region for seeing birds vary from season to season.

Spring and fall migrations are the best times to see a wide variety of waterfowl which use branches of the Atlantic and Mississippi flyways (migratory routes) that pass over the western end of Lake Erie. Over one million ducks use these routes during the peak of migrations. The marshes here are also used by 60,000 migratory whistling swans.

Land bird migrations also attract a great deal of interest where concentrations of these birds appear at such places as Lighthouse Point on South Bass Island, Point Pelee National Park, and Rondeau Provincial Park, the latter two being in Canada.

In the late spring and early summer months, rookeries of herons can be found on West Sister Island - a National Wildlife Refuge and Wilderness Area. One must obtain permission from the Ottawa National Wildlife Refuge Office before visiting here. Two other islands for viewing rookeries of herons are in Canadian waters and are nature reserves, East Sister and Middle Sister islands. Permission from the Ontario Ministry of Natural Resources is needed in order to visit these islands.

With such large concentrations of these birds on small islands, the herons are forced to fly great distances to feed and can be seen in the wetlands, and shores of the mainland and the islands.

Herring gulls are the most common gull seen in the summer and can be found nesting on rocky shores of several unpopulated islands and on many outcroppings of rock around the islands. One must take care not to pay a lengthy visit to these areas during the nesting season as the young gulls are not waterproff and will drown if in the water too long or may be pecked to death by unneighborly adults when they search for their nest.

Double-crested cormorants nest alongside herring gulls on Big Chicken Island in Canada - nests take up the entire cobble covered mount. They can be found nesting on East Sister and Pelee islands as well, but in trees rather than on the ground.

Winter is the time of year when birds are smallest in number. Some of the more common species to be seen include, the Canada goose, mallard, red-tailed hawk, ring-necked pheasant, great horned owl, flicker, downy woodpecker, crow, blue jay, black-capped chickadee, cardinal and goldfinch.

Included in the Appendix section of this manual is a list of 100 of the most commonly found birds in the island region. Information includes phylogenetic order, the season during which each bird is likely to be seen, their ecological niche and habitat. Also for further reference are illustrations depicing each bird on the list. In most cases, only the adult male of a species is shown and care should be taken when trying to identify a bird in the field using these drawings as the female often differs in appearance from the male.

Useful books for bird identification and information are Peterson's 1980 edition of A Field Guide to the Birds East of the Rockies, and National Geographic's 1983 edition of The Birds of North America.

TERRESTRIAL FAUNA

TERRESTRIAL FAUNA

Invertebrates

Published studies of terrestrial invertebrates from the Lake Erie islands are limited in number. Stone Laboratory researchers have compiled a list of insects found on Gibraltar Island. This study related species encountered to habitat. The dominant groups present were Trichoptera, Diptera, Hymenoptera, and Coleoptera. These species also occur in similar habitats on the other islands and that many additional species occur on the larger as well as less developed islands. Professor Kennedy studied the distribution of dragonfly species encountered in the vicinity of the island wetlands. A distinct species preference was noted for wetlands in different successional stages, with Put-in-Bay harbor being the most open area and Fox's Pond (marsh) being the most advanced successional area studied (Table 13).

The distribution of spiders on the Lake Erie islands has been studied intensively by Professor Beatty. This effort has resulted in a "Checklist of Spiders of the Lake Erie Islands" which records species, frequency of occurrence, and collection site. Dr. Beatty has collected spiders in the island region annually since 1959. The long term goal of the study is a contribution to the field of island biogeography.

Most publications dealing with the terrestrial mollusks of the islands were prepared forty to fifty years ago. All of these reports describe a large number of snails covering the ground throughout their respective study areas. Researchers attribute the lack of leaf litter in the island woodlots to the large local snail populations and to extreme weather conditions. Professor Goodrich indicates that the islands support a number of unique subspecies:

"We hope at some future date to pay a more leisurely visit to these islands and make a more thorough study of the geology and botany

TABLE 13

SUCCESSION OF DRAGONFLY SPECIES AS ISLANDS PONDS DEVELOP AND AGE

TAXA	Open Water → Closed Pond								
	Put-in-Bay Harbor	Hatchery Bay	Squaw Harbor	Terwilliger's Pond	Monument Pond	Haunck's Pond	Fischer's Pond	Smith's Pond	Fox's Pond
Gomphus plagiatus	X	X							
Gomphus vastus	X	X	X						
Neurocordulia yamaskensis	X	X	X						
Macroma illinoiensis	X	X	X						
Argia moesta	X	X	X	X					
Enallagna carunculatum		X	X	X	X	X	X	X	
Enallagna exsulans		X	X	X	X	X	X	X	
Ischnura verticallis		X	X	X	X	X	X	X	X
Enallagna ebrium		X	X	X	X	X	X	X	
Tramea lacerata			X	X	X	X	X	X	
Anax junius			X	X	X	X	X	X	X
Enallagna signatum				X	X	X	X	X	
Libellula pulchella				X	X	X	X	X	X
Libellula luctuosa				X	X	X	X	X	
Lestes rectangularis				X	X	X	X	X	X
Leucorrhinia intacta					X	X	X	X	
Erythemis simplicicollis					X	X	X	X	
Nehalennia irene					X	X	X	X	
Pachydiplex longipennis					X	X	X	X	X
Lestes forcipatus					X	X	X	X	X
Sympetrum obtrusum					X	X	X	X	X
Sympetrum vicinum					X	X	X	X	X
Sympetrum rubicundulum					X	X	X	X	X
Lestes uncatus								X	X
Lestes unquiculatus								X	X

with the idea of getting additional light on their age, as this may indicate how long it takes a species, such as Pyramidula solitaria (Anguispira kochi)-which goes back to inter if not pre-glacial time unchanged from its present typical form-to change to distinct, and strongly marked races, as on the islands."

Nine species of snail occur only in the island area. One species, Triodopsis albolabris goodrichi, was found only on South Bass Island and Kelleys Island. Anguispira kochi strontiana is currently confined to Green Island.

Mammals

The species diversity of mammals inhabiting the islands is understandably low considering their isolation from the mainland and the small area involved. Only thirteen species have been recorded as being permanent residents and these are all small animals (Figure 90). Raccoon, red fox, and muskrat occur in small numbers due to lack of suitable habitat.

Several species of mice exist, usually in areas of human population. The Norway rat is particularly dependent upon human habitation as its main center of repopulation is the dump. An exotic population of the eastern woodrat is found on Gibraltar Island. It is known in Ohio only in the southern portion of the state. It is suggested that a pregnant female arrived with a shipment of equipment delivered to the F. T. Stone Laboratory on the island, and the population became established in 1973 when the lab was relatively unoccupied. Its continued existence on Gibraltar Island is unconfirmed.

A campaign to eliminate the high number of rats on South Bass Island by poisoning in 1952 severely depleted the population of eastern gray squirrels. Concerned islanders imported several black squirrels from Belle Isle Park in Detroit to help reverse this situation. The two species interbred to the extent that the only squirrels present today are melanistic eastern gray squirrels. The cottontail rabbit accounts for a large percentage of the mammal population of the islands.

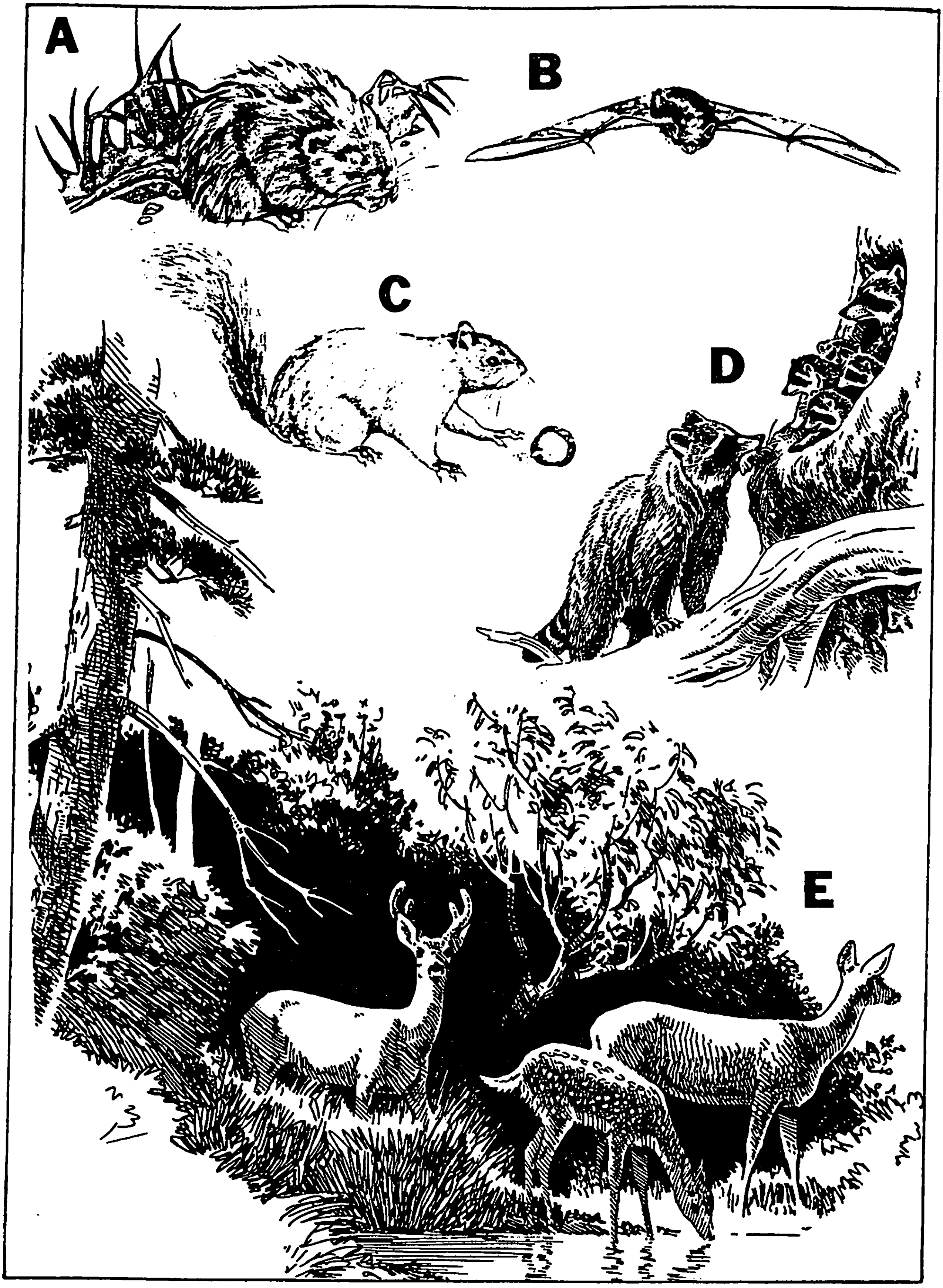


Figure 90. Aquatic, Aerial and Terrestrial Mammals: A) muskrat, B) little brown bat, C) gray squirrel, D) raccoon and E) white-tailed deer.

The little brown bat is a permanent resident of the islands, but its secretive nature prevents it from being obvious. It remains dormant throughout the winter and is able to withstand extreme cold temperatures. Empty cottages, boathouses, sheds, barns and caves provide an abundance of sites suitable for habitation.

A herd of African Mountain sheep roamed wild on Rattlesnake Island where they were introduced a number of years ago. During the severe winter of 1976-1977 the herd was reduced from nine to three and during the severe blizzard in the winter of 1978, the last of the herd was extinguished.

A small number of deer live in the remaining wild areas of Catawba Island and the adjacent Marblehead Peninsula. During cold winters when the lake freezes over they occasionally cross the ice to some of the islands. Several were sighted on Kelleys Island in December, 1976 soon after the ice had formed.

HISTORY

HISTORY OF THE LAKE ERIE ISLAND REGION

Historical Background

Due largely to use of the Ottawa River system across Canada as a route between the St. Lawrence River and the upper lakes and the ferocity of the Iroquois Indians occupying the territory to the south, Lake Erie was the last of the Great Lakes to be discovered by European man. The Frenchman Louis Jolliet is the first to have recorded seeing Lake Erie in 1669. In 1679, on a trip across the lake aboard the Griffin, the famous explorer Sieur de la Salle may have stopped at Middle Bass Island where Father Louis Hennepin is claimed to have celebrated the first Catholic mass in the midwest.

Rene Robert Cavalier, the Sieur de la Salle, his Jesuit companion, and Father Louis Hennepin built a 60-ton wooden sailing ship "Griffin" on the banks of the Niagara River in winter 1678-79 and launched her in the spring. The ship was built with the intention of sailing the upper lakes above the falls at Niagara for the purpose of obtaining furs, by bartering with the indians along the shores, eventually to be marketed in the European export trade. On 7 August 1679, the "Griffin" started her voyage with 34 men aboard, sailing up the Niagara River as the first ship to sail onto the broad waters of Lake Erie. La Salle's party crossed Lake Erie in three days; enroute they discovered the Lake Erie Islands. Grace Goulder Izant (1953) gives the following account of that discovery:

> "Out of the lake's mist a patch of green appeared. Land at last! The good ship Griffin, with the mythical monster - half lion, half eagle - on its prow, nosed into a cove. La Salle and Father Hennepin leaped from her deck and soon discovered that they had stopped at an island, one of twenty dropped across Lake Erie like stepping stones to Canada."

The Griffin then sailed on through, up the Detroit River, through Lakes St. Clair and Huron, and anchored in Green Bay on Lake Michigan on 3 September. Here, La Salle found an abundance of valuable furs, loaded the Griffin for the return trip and ordered the ship's pilot and five sailors to spread her sails for Lake Erie. La Salle, Father Hennepin and the other members of the party, remained on the shores of Lake Michigan to explore the wilderness and await the return of the Griffin in the spring. On 18 September 1679, the Griffin weighed anchor. The following week, the lakes were swept by gales. The Griffin was never seen again and it is believed that she perished with all hands in this storm, possibly on Lake Erie.

The succession of ownership and habitation of the islands is rather confusing due to conflicting reports and lack of accurate records. Reports show that land to be simultaneously claimed by the French, British, Americans (including several states), and the Indians. After the War of 1812, there was still some confusion as to which islands were Canadian and which were American. A commission established by the Treaty of Ghent determined ownership of the islands as follows: Middle, Pelee, Hen and Chickens, East and Middle Sister, and North Harbor - Canadian; South Bass, Middle Bass, North Bass, West Sister, Kelleys, Sugar, Green, Ballast, Rattlesnake, and Gibraltar - American. A definitive boundary was not set until 1913 when the International Waterways Commission established the boundary as a series of straight lines determined in reference to fixed objects on the islands.

Archeological excavations on Kelleys Island indicate occupation as early as 3000 B.C. Inscription Rock tells the story of the Erie Indians, after whom the lake was named, and pictures the final annihilation of the tribe by the Iroquois. It is thought that none of the other islands served as permanent residences for any Indian tribe, rather they were used for hunting grounds and resting points for travel across the lake. The Ottawa Indians frequented the area until 1831 and are the subject and source of many legends about Catawba Island.

A large part of northern Ohio and Pennsylvania was granted to Connecticut in 1662 by Charles II of England. All but 3,000,000 acres along the lakeshore, the Western Reserve, were relinquished in 1786 when Congress designated the Northwest Territory. In 1763, Connecticut deeded 500,000 acres of the Western Reserve to the people who had been burned out during the Revolutionary War and it became known as the Firelands. Another tract of the Western Reserve, including most of the islands, was sold to the Connecticut Land Company. South Bass, Middle Bass, Gibraltar, Sugar, Ballast, Green and Starve Islands fell to the lot of stockholder Pierpont Edwards. The heirs of the Edwards began lumbering on the islands and clearing land for agriculture. In 1854, Jose Rivera St. Jurgo bought the islands, surveyed and sold parcels of land, and actually began the establishment of a community on South Bass Island.

After Ohio gained statehood in 1803 and the Fort Industry Treaty of 1805 rescinded all Indian claims to the south shore of Lake Erie, settlement of the northern part of the state accelerated and Ottawa County was organixed in 1840. Permanent settlement on the islands did not occur until the mid 19th century.

South Bass Island

South Bass is the most widely known of the islands due to the military exploits of Commodore Oliver H. Perry in the War of 1812. A monument commemorating his famous victory was dedicated in 1913 and declared and declared a national peace memorial in 1935.

The earliest known use of the island was as a hunting ground and stopover for journeys across the lake by the Indians. Records as early as 1776 show the island frequented by French traders to collect furs, hides, beeswax and honey, and French squatters were living here when Pierpont Edwards became the owner in 1807. Agents for the Edwards family attempted to raise wheat and flocks of sheep, but the most profitable venture was lumbering. Firewood was in great demand by the steamships on the lake, and the abundance of the supply coupled with the protection offered by Put-in-Bay Harbor made it an ideal fueling station. Much of the high quality lumber was also sent to the mainland cities for shipbuilding.

In 1854, the island was purchased by Jose Rivera St. Jurgo whose main priority was development of the islands. Rivera encouraged settlement on South Bass by having the land surveyed and divided into parcels which he sold to the early inhabitants. Rivera's first venture was raising sheep for which the rocky, cutover land seemed well suited. Seeing the success of viniculture on North Bass, Middle Bass and Kelleys Islands, Rivera was instrumental in influencing German immigrants to come to South Bass and plant vineyards. By 1858, the vineyards were well established and several wineries were in operation. Viniculture flourished in the late 1800s but gradually declined under the influence of Prohibition, mainland competition, erosion and depletion of the soil. Only one winery remains in operation on the island today and only a fraction of the former acreage is cultivated as vineyards.

The late 1800s were also peak years for the resort industry. People would flock to the island on the large excursion steamships of the period and the island saw a succession of grand hotels catering to affluent society. The most famous of the island hotels was the elegantly furnished Victory Hotel boasting a capacity of 600 guest rooms and dining space for 2000. It was surrounded by spacious wooded gardens landscaped with native limestone, elaborate statues and fountains, pavilions and a large swimming pool. An electric railway line ran from the hotel to the Bay (business district). The original intention of the owner was to establish the hotel as a convention center, but this dream was never realized and the hotel was only open erratically for the 27 years it existed. Although opened in 1892, it was not completely finished until 1896. The hotel closed in 1909 due to financial difficulties, but was remodeled and reopened for the summer season in 1919. In August of that year a disastrous fire completely destroyed the ill-fated hotel. Ruins of the famous hotel can still be seen in the state park on the island's west shore. Most of the other large hotels also fell victim to devastating fires or were demolished after years of disuse.

The village of Put-in-Bay was incorporated on the island in 1877, and the name Put-in-Bay is commonly used to refer to the whole island. The Inter Lake Yachting Association has held an annual regatta here since 1884 and prompted the organization of the Put-in-Bay Yacht Club in 1886.

In 1889, the federal government built a fish hatchery on Peach Point on 0.60 acres of land purchased from Rivera. The State of Ohio built a hatchery adjacent to the federal building in 1907. The state building burned to the ground in 1914 and was replaced with the brick building housing the present hatchery. The federal hatchery discontinued operations in the mid 1930s and the facilities were transferred to the state. With the development of Gibraltar Island as a biological field station by Ohio State University, the old federal hatchery was converted to laboratory space for researchers and is so used today.

Peach Point was also the site of the Forest City Ice Company which had several large warehouses at the end of the point in the late 1800s and early 1900s. During winters of thick, clear ice, fields were laid out and blocks cut and hauled into the warehouse for storage.

Still a popular summer retreat, the visitors are no longer primarily from high society. Many summer cottages are located on the island, particularly along the west shore. The island is serviced by two ferry lines and an airline, and has accommodations for private boats and airplanes. Histories of South Bass Island have been written by Langlois and Langlois (1948), Frohman (1971), and Dodge (1975) which describe in great detail life on the island, cultural background, and historic events.

Middle Bass Island

Middle Bass has the distinction of being the site of white man's first recorded visit to the islands. Rene Robert Cavalier, the Sieur de la Salle, stopped at the island on a trip across the lake aboard the Griffin in 1679, and the first Catholic service in the midwest was celebrated by Father Louis Hennepin. The Frenchmen were so enchanged by the abundance and beauty of the natural flora that they named the island, Isle des Fleur, Island of Flowers.

Middle Bass Island feel to the lot of Pierpont Edwards in a draft of the Connecticut Land Company, and agents for the Edwards family lumbered the island. In 1854, it was sold to Rivera who sold it to three Germans: Count William Rehburg, Andrew Wehrle, and a Mr. Caldwell. Finding the island soils and climate ideal for vineyards, they planted grape vines and induced other German immigrants to do the same. The island was soon covered with vineyards and in 1884 the imposing Lonz's Winery was built on the south shore.

In the 1870s, a group of Toledoans organized the "Lake Erie Boating and Fishing Association" and built a club at Ten Mile Creek near Maumee Bay. The group fished regularly off Middle Bass and soon decided the island would make a better location for their organization. In 1880, the group leased land from Count Rehburg and built a clubhouse, private cottages, dance hall, boat houses, a central dining area and a small chapel and became known as the Middle Bass Club. Membership was limited to 200 and included Toledo socialites and prominent citizens of the period. President Hayes, Garfield, Arthur, Cleveland, Benjamin Harrison and Taft all spent time here and Taft later built a summer home on the island.

North Bass Island

Reminiscent of the French influence when North Bass Island was crossed by the International boundary between Canada and the United States, the island was called Isle St. George for many years and is still so listed by the post office. An official concrete international boundary was not fixed until 1913, placing

North Bass entirely in the United States.

The first court records showing island ownership were filed in 1840 with the sale of the island to Horace Kelley (of the Kelleys Island family) by Mrs. Abigail Dunming. In 1853, Simon and Peter Fox bought 500 acres and, inspired by the number of wild grape vines covering the island, planted grapes. Within two years the island was covered with vineyards. Roswell Nichols, the first permanent settler, moved to the island in 1844.

The vineyard industry peaked in 1890 and steamers stopped there regularly to carry grapes and wine to mainland cities. Today over half the island is owned by Meiers Wine Cellars, Inc. of Silverton, Ohio and cultivated as vineyards. North Bass Island is serviced by Island Airlines, but no ferries stop at the island as there is no resort development.

Kelleys Island

Kelleys Island has more evidence of early occupation by the Indians than any of the other islands. Artifacts have been unearthed indicating settlement as early as 3000 B.C. Indian village sites dating back to the 1600s have been discovered and one of the best examples of American Indian petroglyphic art is located on the south shore. Known as Inscription Rock, the petroglyph was found by Charles Olmstead in 1833. The strange carvings on the rock have been translated as the history of the Erie Indians and their final slaughter in 1655 by the Iroquois.

In the early 1800s the island was known as Cunningham's Island after a French Canadian fur trader living there. After the War of 1812, several families moved to the island, selling the red cedar which covered the island to passing steamers for firewood. Kelleys was so extensively lumbered that by the 1820s it had practically been stripped of woody vegetation.

Datus and Irad Kelley bought the island in 1833 and it has since been known as Kelleys Island. They formed the Kelleys Island Lime and Transport Company in 1886, quarrying limestone for building materials, lime, and crushed stone. Besides the many local buildings the limestone was used in construction of churches in Detroit, office buildings in Cleveland, and the Poe Lock at the Soo. Graudally, the industry began to decline and finally shut down in 1941 being unable to compete with more conveniently located quarries on the mainland. Only the abandoned lime kilns, loading docks, and quarries remain as evidence of the once profitable industry.

In the process of quarrying, impressive glacial grooves were uncovered along the north shore. Some of the deepest grooves were removed before their historical significance was realized, but a number of them have been preserved and are now under state protection. They are located on the north shore near the state park public beach.

As on the other inhabited islands, viniculture also flourished on Kelleys, but it was never as economically important as the quarries. Seven hundred acres of grapes were cultivated from 1850 to the early 1900s, but under pressures from Prohibition, over-utilization of the soil, and competition from mainland growers most of the vineyards were abandoned. No vineyards remain under cultivation today.

The resort business was never developed on Kelleys to the extent that it was on South Bass. The island economy depended upon the quarries, vineyards, and fisheries which supported a peak populations of 1200 in 1916. Today a permanent population of approximately 150 people depends upon the tourist trade during the summer season as the mainstay of its economy.

Mouse Island

The first recorded visit to Mouse Island was during the War of 1812 when a Captain Bonner and his men spent the night there, describing it as the best accommodations the wilderness could offer. In 1860, Mr. and Mrs. Clark Neal bought the island from Waldo Converse and E. B. Sadler. They operated a small commercial fishery on the island for several years.

When Rutherford B. Hayes returned to his estate in Fremont, Ohio after serving as president of the United States, he bought the island as a retreat for his family and friends. The island remained in the hands of the Hayes estate until Marianna H. Mercer of Rocky River, Ohio bought it in 1956. The only evidence of habitation remaining is an old stone hearth and chimney standing alone amid the dense forest covering the island.

Rattlesnake Island

There is some controversy as to whether the name Rattlesnake Island was derived from the number of rattlesnakes once inahbiting the island or because its shape, with the two small islands at the northwest end resembling rattles, is similar to that of a rattlesnake. The island was once the private summer home of Hubert Beenett, a prominent Toledoan, who stocked the island with wild turkey and golden and ring-necked pheasants. Later the island was operated as a fishing and hunting lodge for private parties. Closed in 1970, the resort reopened in 1976, and the restaurant and one lodge are open year-round on a membership basis only. The island is also noted among stamp collectors for its unique stamps. In 1966, the island initiated its own local post and puts out a new issue stamp annually, with a mailing list of 2200 customers.

Gibraltar Island

Gibraltar, so named because of its resemblance to the rock at the mouth of the Mediterranean Sea, was part of the original tract owned by Pierpont Edwards. It went to Rivera in 1854, who in turn sold it to Jay Cooke, Civil War financier. Cooke built a large, impressive, Victorian summer home on the island which he called the castle. Many famous men of that time including Presidents Hays, Cleveland, and Benjamin Harrison, senators, generals, and financial magnates were lavishly entertained at the castle. Being of strict religous bearing, Cooke invited many clergymen too poor to afford their own vacations for weeks of fishing, sailing and relaxing throughout the summer.

While Rivera still owned Gibraltar he offered to donate half of the island for erection of a monument to Perry's victory in the War of 1812. A base was laid in 1858 but the monument was never built. Being an ardent admirer of Commodore Perry, Cooke had a monument built on the existing base when he bought the island. The monument is at the northeast end of the island near Lookout Point where Perry reportedly stationed lookouts to observe the British fleet in the distance.

Between 1873 and 1879, Jay Cooke's company experienced financial difficulties and Gibraltar went into receivership. By 1879, Cooke had rebuilt his fortune, repurchased Gibraltar from the trustee in bankruptcy and reopened his beloved castle.

In 1925, Cooke's heirs sold the island to Julius Stone who donated it to Ohio State University in memory of his father. Ohio State erected the Franz Theodore Stone Laboratory building and several other buildings and utilized the castle as dormitory space for summer residents.

Green Island

Green Island is known on earlier maps as Moss Island and Strontium Island. Large deposits of strontium were found there, but the bulk of the high quality mineral was removed before 1900. As on all the other islands, Green was lumbered in the 1800s.

In 1853, Green Island was purchased by the United State government from the heirs of Pierpont Edwards for the purpose of erecting a lighthouse. Keepers and their families occupied the island from 1860 to 1915, but after a tragic fire during the winter of 1863, the island was only inhabited during the navigation season. In 1915, the government transferred the light to the Put-in-Bay lighthouse and installed a light with an electrically controlled beacon. With the exception of several summer residents prior to World War II, the island has been uninhabited since 1919. Green Island is presently managed as a wildlife refuge by The Ohio Department of Natural Resources.

Ballast Island

Ballast Island was so named because Commodore Perry is said to have removed boulders from its shore for use as ballast in the ships of his fleet. While owned by Rivera, the island was quarried for gravel. In 1869, he sold the island to a private interest.

A large ice house, for storing blocks cut from the frozen lake, was built in 1874 together with a dock for the landing of small steamers. Plans were made to develop a resort community with 25 cottages, a dining hall, kitchen and recreational facilities, but only ten of the cottages were ever built.

A home was built at the edge of the dock for use as a residence for a year-round caretaker. James Fullerton, known more often as Uncle Jimmie, was caretaker for a number of years and lived a hermit-like existence coming to the mainland only once or twice a year for supplies. Year after year Uncle Jimmie would watch the great steamers pass on their way to South Bass Island and finally, in the spring of 1882, he decided to book passage on one for an excursion to Sandusky. On the return trip, aboard the American Eagle, a boiler exploded killing six passengers, the 79 year old Uncle Jimmie among them. He was buried on South Bass Island.

Today the island is privately owned and inhabited only during the summer season. The old caretaker's house lies dangerously close to the rising waters of the lake and may soon be undermined by the force of the waves.

Starve Island

Starve Island is little more than a gravel covered slab of Put-in-Bay dolomite rising just high enough above the lake level to support a few woody species, lichens, and algae. A legend that a human skeleton was found on its shore many years ago, apparently having starved to death, accounts for the name.

Formerly a favored nesting area for terns, the island has been taken over by thousands of herring gulls for the rearing of their young. The island has never been inhabited by man.

Sugar Island

This island was among the original group owned by Pierpont Edwards. Rivera bought it in 1854 and sold it soon thereafter in 1859. It derived its name from the abundance of sugar maple trees on the island. Today the entire island is owned by Gebhard Kenny of Columbus, Ohio and is maintained as a summer residence.

Catawba Island

Now a peninsula, Catawba Island was once separated from the mainland by the Portage River which then emptied into the lake northeast of the island. Rising lake levels decreased the gradient of the old river forcing it to find another outlet farther west. Since the relocation of the river mouth in the late 1800s much of the marshland occupying the old river bed has been drained or filled joining the island with the mainland. A causeway across the eastern end of West Harbor connects Catawba with Marblehead Peninsula. The island is called Catawba after the grape developed in the Catawba, North Carolina region and found to thrive on the islands.

The Ottawa Indians roamed the area for many years and evidence of villages and burial grounds have been unearthed. The Indians left behind many legends, many of them centered on sites along the shore of Catawba Cliffs. One such legend explains the face of an Indian chief carved into a cliff facing the lake shore. Nabagon, a mighty chieftain of the Ottawa Indians and much beloved by his people, was attacked by a fierce panther and lay dying for many days. The Great Spirit was in need of Nabagon's valorous soul to protect him from enemy gods, and the Indians believed the panther was the Great Spirit himself coming to personally claim the soul of their chief. To appease the grief of the tribe, the Great Spirit promised to carve the head of Nabagon in rock to guard the destiny of the island throughout eternity. The next morning, an Indian profile appeared carved on the cliff face with a cedar tree at the crest forming the resplendent headress of a great warrior. Although worn by years of weather and loss of the cedar headress, the face of Nabagon is still visible behind a squaw, Mo John, and her children. Betsey Mo John, one of the squaw's children, married a man who built a hand-hewn log cabin which stands on the island today.

With the departure of the Ottawas many settlers began moving into the area in the mid-1800s, most of them coming from southern Ohio and Hanover, Germany. The island soils were found to be ideal for raising fruit, and Catawba became a major producer of peaches, grapes, and apples. The island became famous for the quality of its peaches. Three wine companies prospered on the island - Catawba Wine Company, Gideon S. Owen Wine Cellar, and the Mon Ami. After more than 100 years, the Mon Ami is the only winery still in existence.

During the peak years of the fruit industry a small village known as Ottawa City was formed at the north end of Catawba. A large dock at the site of the present Miller Ferry Dock was operated by the Catawba Island Fruit Company and lake steamers transported tons of peaches and grapes every summer across the lake to Detroit. Just west of the fruit dock was another large dock and warehouse owned by the Booth Fish Company. Ottawa City has its own post office, general store, school, chapel and a number of hotels and boarding houses to serve summer visitors.

Planning to draw more settlers to Ottawa City, J. R. James built a lime kiln and a cooper factory along the northwest shore in 1850 for the express purpose of amnufacturing cement. Limestone was quarried along the lake shore just north of the kiln for five years, but the industry did not prosper. The old quarry and lime kiln are still visible today just inside the north entrance to Catawba Cliffs. With improved land transportation and new markets for the island produce, the steamers no longer found business at the fruit dock and Ottawa City was abandoned. Another small village, Peachton, also existed at one time near the center of the island.

In the early 1900's the area along the west shore, Catawba Cliffs, was developed as a private housing complex popular with the wealthy or that period for summer homes. All of the original homes still exist and present unique architecture blending beautifully with the natural setting. The J. H. Bellows Company, the firm instigating the development, was instrumental in a proposal to declare the area along the west shore from the Cliffs to Sugar Rock as a perpetual state bird sanctuary, but the proposal was never accepted.

The present state park is located on the site of the former G. W. Snyder and Son Fish Company. A monument commemorating the site of a corner stake marking the boundaries of the Western Reserve is found in the park. Today the island is mostly residential and surrounded by marinas heavily used by boaters during the summer.

West Sister Island

There are few historical records available for West Sister Island. Of all the Lake Erie islands, West Sister has perhaps had the least use as a site for private dwelling.

Indians and early explorers and travelers are presumed to have used the island during storms and as an occasional resting spot. However, the first mention of the island in history is also its most famous. This took place on September 13, 1813 following the Battle of Lake Erie, when Commodore Oliver

Hazard Perry defeated the British fleet in a decisive battle of the War of 1812. In a letter datelines "Off Western Sister Island", Perry sent his famous message of victory: "We have met the enemy and they are ours." Both the British and American common seaman killed in the battle were buried just off West Sister by being sewed up in their hammocks with a cannonball at their feet.

West Sister remained undeveloped until 1848 when a lighthouse was constructed on the southwest corner of the island.

The light keeper's journal from West Sister for the years 1880-1895 is in the Local History Department of the Lucas County Public Library. The journal offers a rare glimpse into the day-to-day life of the lighthouse keeper and his family. Entries were made each day concerning weather and wind conditions. There are also notations of shipwrecks in the area and of the assistance given by the keeper.

The lighthouse was made automatic in 1937 making it unnecessary to have a keeper on the island. The Coast Guard still maintains a navigation light atop the old lighthouse tower.

The island was made a National Wildlife Refuge by an executive order of President Roosevelt on August 9, 1938. The island is a nesting ground for large numbers of black-crowned nigh herons, great blue herons, and common egrets.

During World War II the island was used for bombing practice by naval pilots from Grosse Ile (Michigan) Naval Air Station. In 1967, West Sister was removed from the bombing list.

<u>Johnson Island</u>

Indians of the Sandusky Bay region once used Johnson Island as a torturing ground for their captured prisoners. The first historical record of the island occurred during the War of 1812 when a group of settlers were attacked by Indians.

The first owner of Johnson Island was Epiphras W. Bull of Danbury, Connecticut and until 1852, the island was known as Bull's Island. Mr. Bull received the island as a part of the Firelands settlement. Three men built log cabins on Bull Island in 1811 and a village was plotted out. However, the plan to erect a town on the island was abandoned. In 1852, Bull sold the island to L. B. Johnson and the island's name was changed to Johnson Island.

During the Civil War Johnson Island was leased by the government for use as a confederate prisoner-of-war camp. In 1861, Colonel William Hoffman visited all of the Lake Erie islands to select a suitable location for such a prison. He thought that the wine industry on the Bass Islands and Kelleys Island would be too great a temptation to the prison guards. He chose Johnson Island because it was uninhabited and near to Sandusky which would make supplies easier to obtain.

The prison was completed on February 1, 1862 and prisoners arrive a month later. The prisoners held on Johnson Island were special in that all were officers in the Confederate Army. Thus, the island became infamous in the South as the prison where many of the leading men of the day were incarcerated.

The island never held more than 2500 men at a time but during the period of the war, some 10,000 men passed through the prison's gates. The 206 men who died on the island are buried in a small cemetary, which is still maintained by the government. For a detailed account of the prison and the cemetary see Frohman (1965b).

Following the Civil War, the prison was abandoned and the buildings and prison items were sold at public auction. On June 8, 1866, the island was completely evacuated by the government and an orchard was planted on a 150 acre tract. The rest of the island was in oak, hickory and black walnut.

A resort was opened on the east end of the island in 1894, but it was soon abandoned after a fatal shooting incident for which the resotr company was sued. A second resort was begun in 1904, however, it was soon acquired by a competing resort and its buildings were moved to Cedar Point.

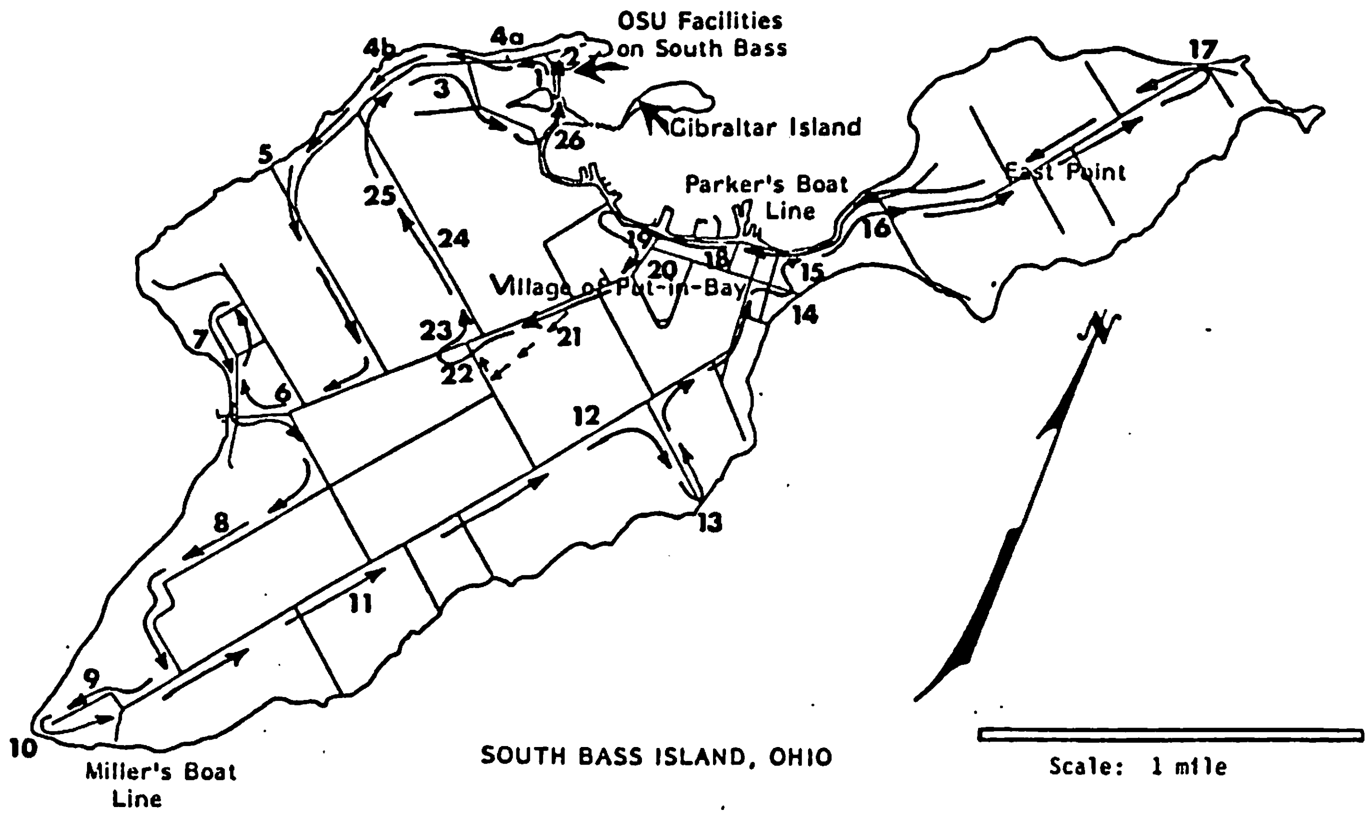
For a time, the island was quarried on a small scale and planted in orchards by its new owner Phillipine Dick of Sandusky. Only one family lived on Johnson Island until the 1940s.

In 1956, the Dick estate sold Johnson Island to a group of Cleveland developers for $100,000 dollars. The purchase group was headed by Cleveland Heights realtor Shirley Auslander with three builders as partners: Clifford Reichwein, Walter Zaremba and Herbert Luxemburg. The developers divided the island into 1/4-acre plots all with water frontage. They agreed to preserve the cemetary and to build nothing near it.

In 1974, the Johnson Island developers completed a private causeway to the island from Marblehead Peninsula. Today, little remains of the old prison except the earthworks for the centrally located Fort Hill. The cemetary is maintained by a government caretaker, and is the only area accessible to the public. The remainder of the island is ringed by privately-owned cottages.

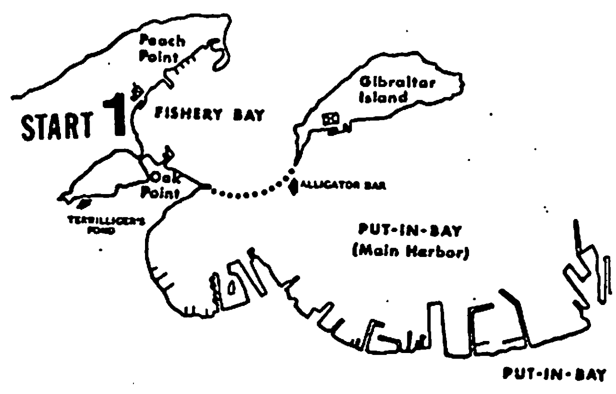
HIKE/BIKE TOUR

SELF-GUIDED HIKE/BIKE TOUR OF SOUTH BASS ISLAND

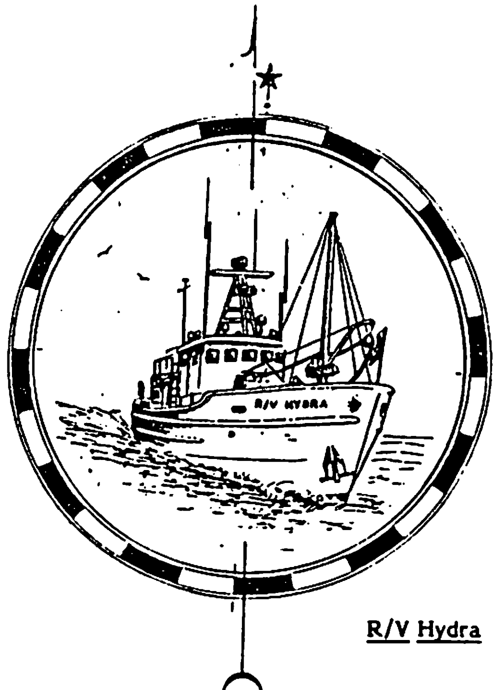


Welcome to South Bass Island and the Village of Put-in-Bay. The island is a treasury of historic sites and natural beauty. One way to enjoy your visit is to tour the island on foot or bicycle. The following guide takes you on a 20-kilometer (12.5-mile) journey around the island to see 26 points of interest. The tour starts at The Ohio State University research center on Peach Point. See how many of the plants, animals, and other natural and historical features you can find along the way.

Peach Pt. Research Lab

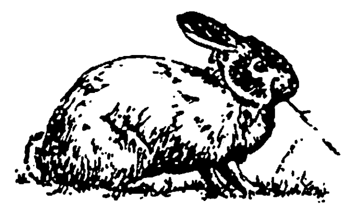


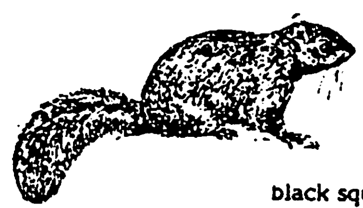
1. Ohio State University, Center for Lake Erie Area Research (CLEAR) - Offices for CLEAR and Franz Theodore Stone Laboratory, including a Science Library (open to the public 8:00 a.m. to 4:00 p.m., weekdays); Peach Point Research Laboratory (former Federal Fish Hatchery, built in 1893) and dock for OSU's 68-foot research vessel, R/V Hydra (tours by appointment only, 285-4754) are located nearby on the shore of Fishery Bay. A bird sanctuary is located in a 2-acre woodlot (dominated by sugar maple, Acer saccharum) adjacent to the office building (Bayview); several nature trails wind through the woods and along the banks of Terwilliger's Pond. Black squirrels (Scinus carolinensis) and cottontail rabbits (Sylvilagus floridanus) are commonly seen on the edge of the woodlot.



R/V Hydra

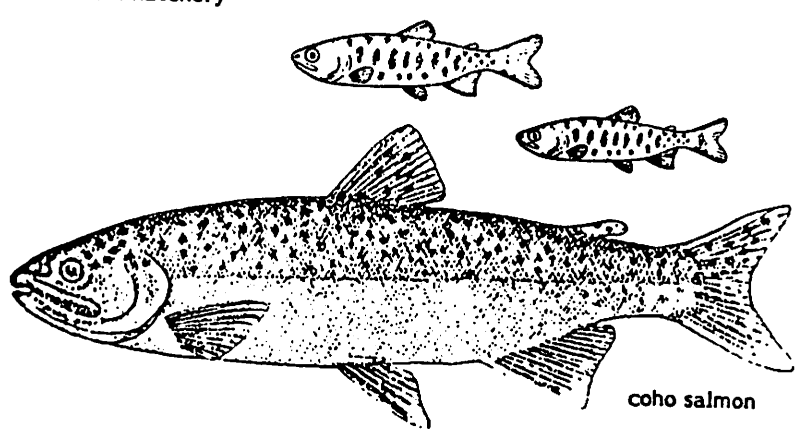

sugar maple


cottontail rabbit


black squirrel

2. State Fish Hatchery - Operated by the Ohio Department of Natural Resources, Division of Wildlife, this hatchery rears Coho salmon (Oncorhynchus kisutch) for stocking in Lake Erie tributary streams; recording devices for lake level, water temperature and air temperature as well as life history information on Lake Erie fish are on display here (open to the public 8:00 a.m. to 12:00


fish hatchery


coho salmon

noon, weekdays; other times by appointment, 285-3071).

3. Duff's Woods - Former home of the Ohio State Music Camp, this natural area contains several foot-paths which lead through a woods dominated by sugar maple (Acer saccharum) and hackberry (Celtis occidentalis). Jewelweed (Impatiens pallida) and showy trillium (Trillium grandiflorum), wild leek (Allium tricoccum), and Dutchman's britches (Dicentra cucdullaria) are common understory plants. Several large trees were uprooted by hurricane-force winds during the blizzard of January 1878; these trees now form interesting habitats for terrestrial animals and herbaceous plants (such as pokeweed, Phytolacca americana).

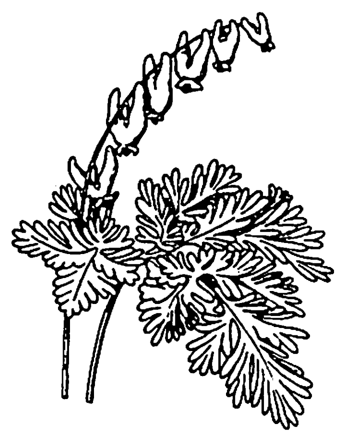
4. Peach Point (4a) and Reidling Beach (4b) Runways - Located along the picturesque west shore, these runways are used as access ramps for ice-fishing shanties and vehicles (December-February). In summer, they serve as excellent lookout points for observing Rattlesnake Island and the boat traffic along the west shore. The runways are maintained by the Put-in-Bay Township and open to the public from 6:00 a.m. to 10:00 p.m. daily. Swimming is not recommended due to the steep drop-off. Dense

hackberry

jewelweed (touch-me-not)

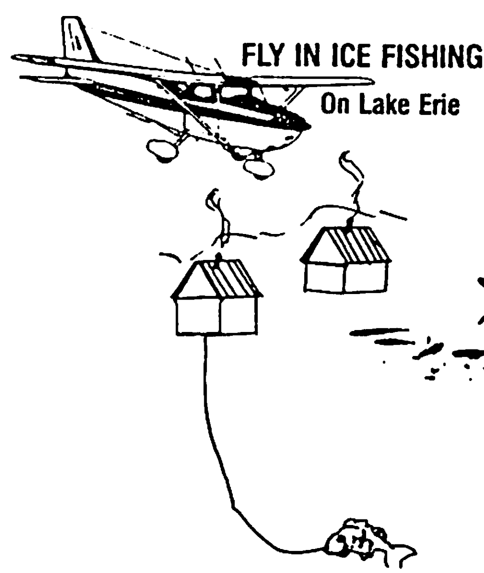
Trillium

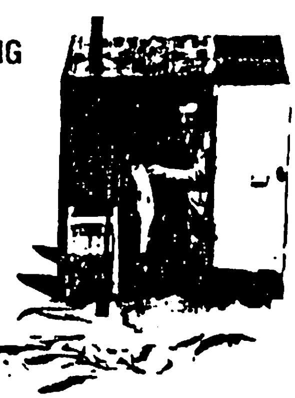
wild leek



Dutchman's britches

pokeweed





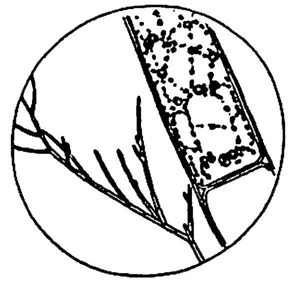
fishing shanty

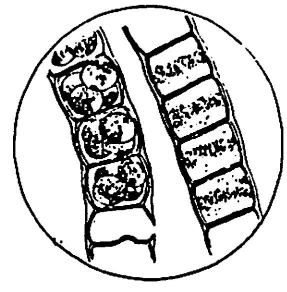
growth of filamentous algae can be seen in the "splash zone" on the runway and on the rocks along the shore; the long green algae is Cladophora glomerata, the short green form is Ulothrix zonata, and the reddish-brown algae, a recent marine invader, is Bangia atropurpurea.

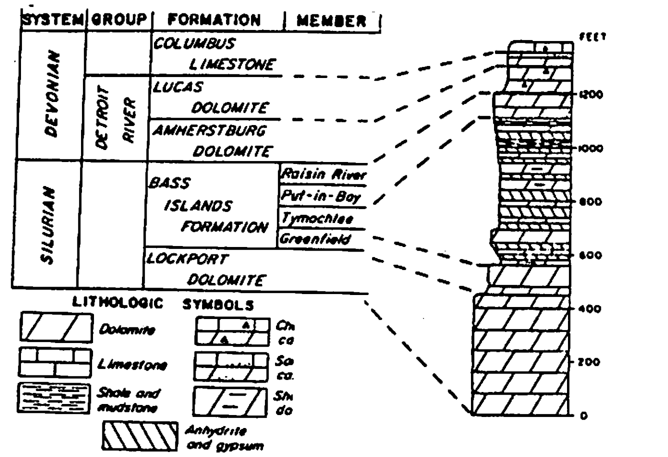
5. West Shore Cove - Township Park at the foot of the roadway which offers a scenic vista of the west shore dolomite cliffs (Put-in-Bay dolomite of Silurian Age, deposited about 400 million years ago in tropical, marine sea); excellent lookout point to enjoy South Bass sunsets. Open to the public from 6:00 a.m. to 10:00 p.m.; swimming not recommended due to submerged rocks.

6. Crown Hill Cemetary - Burial site for historic island figures, including DeRivera (island founder), John Brown, Jr. (son of noted abolitionist), and Valentine Doller (early merchant).

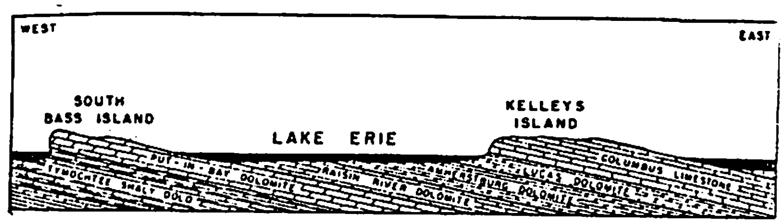
7. South Bass Island State Park and Victory Woods - Former grounds of the famed Victory Hotel, built in 1889 and burned in 1919. All that remains of the structure is the grand natatorium (America's first public swimming pool where men and women were permitted to bathe together). Bedrock exposures along the shoreline exhibit structural


Cladophora


Ulothrix

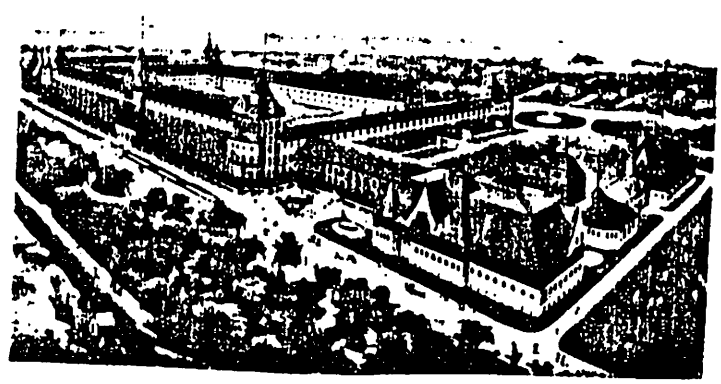


STRATIGRAPHIC SECTION




Tomb of Jose de Rivera


John Brown, Jr.


Victory Hotel

features including an excellent example of an anticlinal arch. The park roadway leads through a wooded hillside (predominantly sugar maple, Acer saccharum) which is studded with camp sites. The crest of the hill is the highest point on the islands (638 feet above sea level), about 70 feet above Lake Erie (22 meters). Glacial grooves can be observed at the crest near the park fence. A cobble beach swimming area, temporary dockage, and a boat ramp are available for park visitors. A Park Naturalist is on duty several days each week for nature hikes and lectures (285-2112).

8. Viking Longhouse and Museum - Replica (80% scale) of a longhouse used as a meeting place in the Viking era (700-1100 A.D.). Scottish Highland cattle, which were an important part of the Viking age because of their ability to survive cold climate, can be seen roaming the grounds. Open daily 10:00 a.m. to 7:00 p.m.; admission charge.


cobble beach

9. Lighthouse Woods - Hackberry--blue ash (Celtis occidentalis--Fraxinus quadrangulata) community; this woods abounds with wildflowers such as Dutchman's britches (Dicentra cucdullaria), in the spring and waterleaf (Hydrophyllum appendiculatum) in the early summer.


blue ash


waterleaf

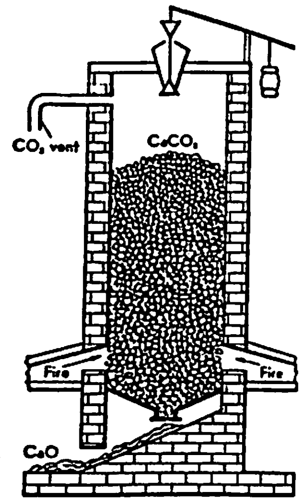
Bedrock outcrops abound in the woods and along the lake shore.

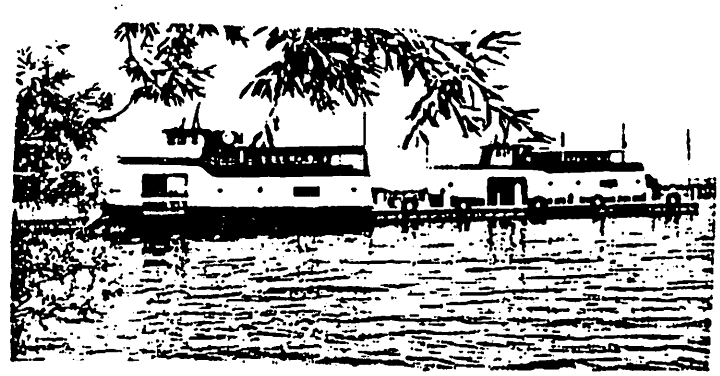

South Bass Lighthouse

10. South Bass Lighthouse - Constructed in 1895, this former U.S. Coast Guard lighthouse now serves as part of The Ohio State University's Lake Erie research facilities. The bedrock cliffs show signs of erosion with large blocks having recently fallen into the lake. Cobble beaches have formed in small coves along the shore; here, waves have arranged the pebbles in a particular kind of stacking called "imbricate structure."

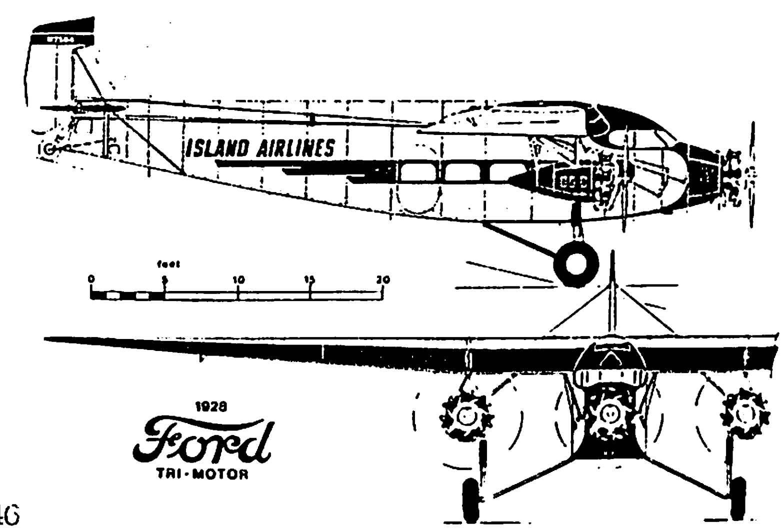
After leaving the lighthouse grounds, a historic lime kiln (used to convert the local dolomite bedrock, $Ca{+}MgCO_3$ to lime CaO), which was used to make mortar for the construction of early buildings, can be seen on the shore near the Miller Ferry Dock. A quarry in the dolomite bedrock is located between the ferry dock and the airport on the west side of the highway.


lime kiln




Miller Ferry Dock

11. Put-in-Bay Airport - Excursion flights on the historic Ford Tri-Motor, "Tin Goose," can be arranged at the airport office. The airport serves as the only year-round transportation link between the mainland and the other Lake Erie Islands. Two other historic aircraft, a DeHavilland Beaver and Otter, make daily trips to these locations.

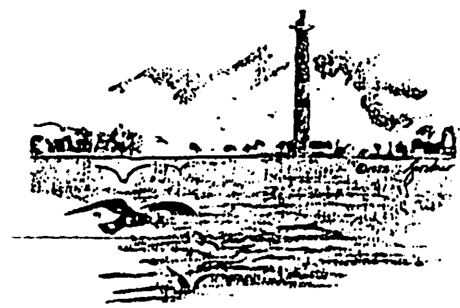


12. Stonehenge - Historic stone house, barn and wine press cottage built circa 1855. The buildings are constructed of local dolomite bedrock held together by grout, and are currently being renovated. Other historic structures on Langram Road include carved entrance posts (Pioneer and Indian) to a house south of the airport and an early inn (Reibel House) built in 1884.

carved entrance posts

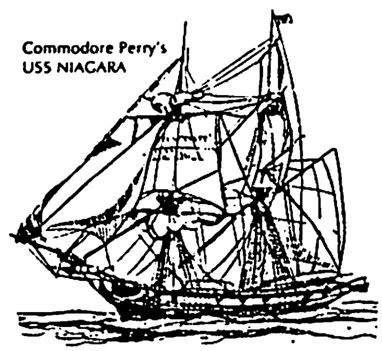
13. Glacial Grooves - Along the shore at the foot of Ibis Road, grooves and striations have been cut into the bedrock by massive ice sheets of Pleistocene glaciers. Grooves to the south of the roadway are on private property; permission to view them must be obtained from the owners.

sand beach



Perry's Monument

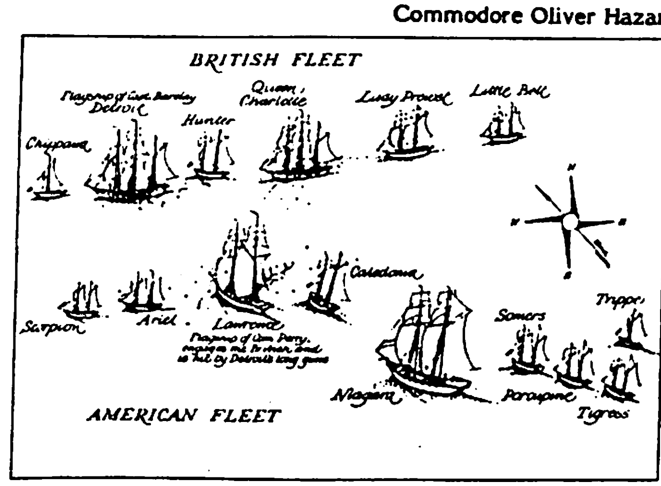
14. Put-in-Bay Beach - One of the few sand beaches on the island, this beach lies adjacent to the grounds of Perry's Monument and is open to the public.



Commodore Perry's USS NIAGARA

Commodore Oliver Hazard Perry

15. Perry's Victory and International Peace Memorial - Located on a narrow isthmus and former wetland which connects East Point with the main part of South Bass Island, this monument was constructed between 1912 and 1915 to commemorate Oliver Hazard Perry's victory over a British naval squadron in Lake Erie on September 10, 1813. It also memorializes the principle of peace



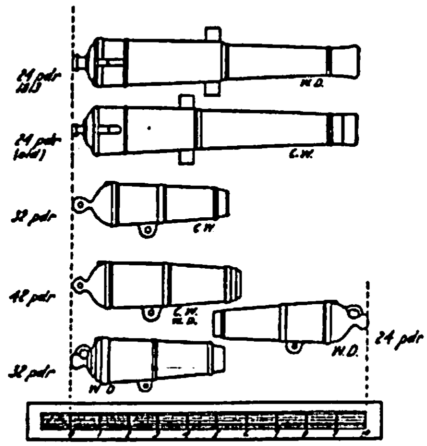
The Battle of Lake Erie

among nations by arbitration and disarmament. The 352-foot doric column is constructed of pink granite. Its cap serves as an observation deck from which one can see all of the Lake Erie islands. Above the cap is a bronze urn 23 feet high (7.1 m) and 18 feet wide (5.6 m), weighing 11 tons, upon which navigation lights are mounted to guide ships within a 25-mile (40 km) radius. Beneath the rotunda floor are the remains of 3 British and 3 American officers killed in the action. The surrounding grounds cover more than 25 acres (10 hectares) of manicured lawn. An interesting shore protection device which turns back approaching waves, known as a "Galveston Wall," has recently been constructed along the shore of Put-in-Bay harbor. A Visitor Center (9:00 a.m. to 8:00 p.m., 285-2184) provides tours and lectures on many historical and natural science topics as well as a small museum containing excellent photographs of the early history of Put-in-Bay. The monument is administered by the National Park Service, U.S. Department of Interior.

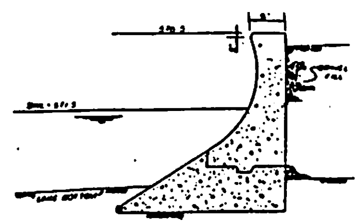
16. Monroe House - This "Steamboat-Gothic" house was built in 1875 by George Gascoyne for J.B. Monroe, a Toledo railroad agent and merchant. This building is registered as a National Historic Landmark.

Capt. Barclay
British Commander

Battle of Lake Erie by Powell



Cannon from Battle of Lake Erie



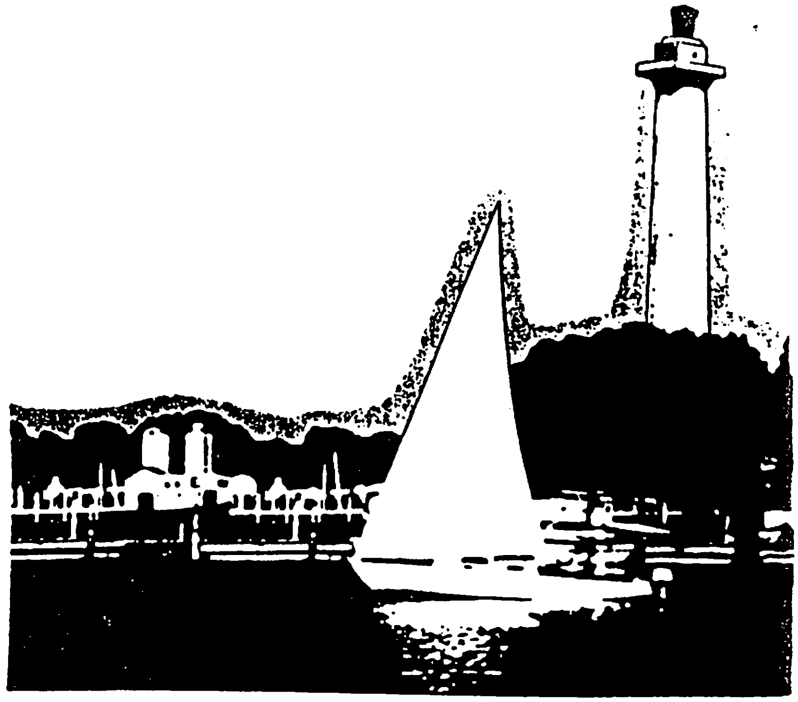
TYPICAL SECTION
GALVESTON WALL

Galveston Wall

Monroe House

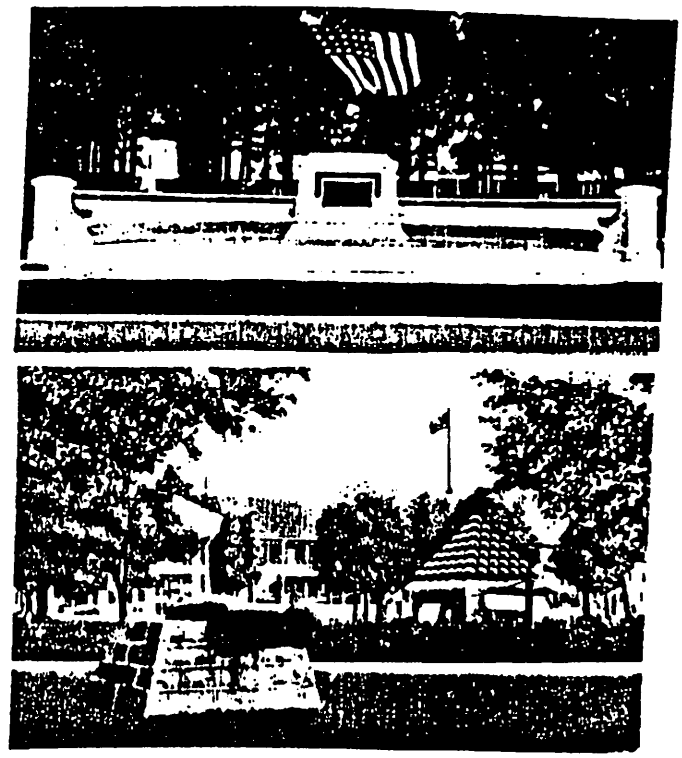
Lonz Winery

17. East Point - Located at the terminus of State Route 357, East Point provides an excellent view of Middle Bass Island (including the exquisite Baroque architecture of Lonz Winery) and Ballast Island. The shore is low beach composed of cobbles, gravel and sand. Northeast storm waves are particularly spectacular when viewed from this point.



Put-in-Bay waterfront

18. DeRivera Park - Formerly known as Perry Park, this wooded block in the heart of Put-in-Bay Village contains a lighted fountain, children's recreational area, war and yachting memorials, gothic gazebo (bandstand) which contains a time capsule with 1977 memorabilia to be opened in 2077, tourists' information center (285-2832), drinking water, picnic tables and pay restrooms/showers. Across Bayview Avenue (State Route 357) from the park, the village operates a public marina with dockage facilities for over one hundred boats.



DeRivera Park

19. Doller House - A majestic Italiante villa built for Valentine Doller, island merchant, circa 1868. This villa, with its perennial flower gardens, stands on Bayview Avenue near the "Doller Store" building which graces the corner of Bayview and Catawba Avenues.

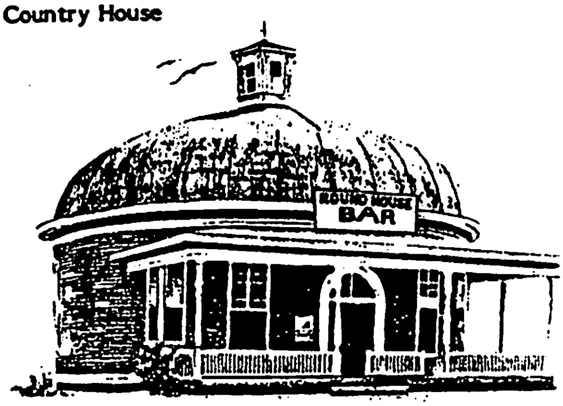
Doller House

20. Village of Put-in-Bay - This quaint little lakefront village preserves some of the traditions of the 1870s. Buildings from that period to the turn of the century, which are still in use include the Park Hotel, Round House Bar, Country House, The Colonial, Put-in-Bay Town Hall, Crew's Nest (formerly the Friendly Inn), Blacksmith Shop, and several other hotels and stores which presently serve as gift shops and taverns. The village also has a U.S. Post Office (43456), a public school (K-12) which houses the Put-in-Bay Library (285-3614), churches, several restored Victorian homes, and essential mercantile establishments and public services.

21. Shady Path - Leading from the edge of the village, just beyond the Catholic Church, this interesting path wanders through a sugar maple and Norway maple (Acer platanoides) woods. At the south end of the path, near Thompson Road, a grove of red cedar (Juniperus virginiana) can be seen. Cooper's Restaurant, a former winery, is nestled in the woods along the path. The path is rugged and may be difficult for bicycles.

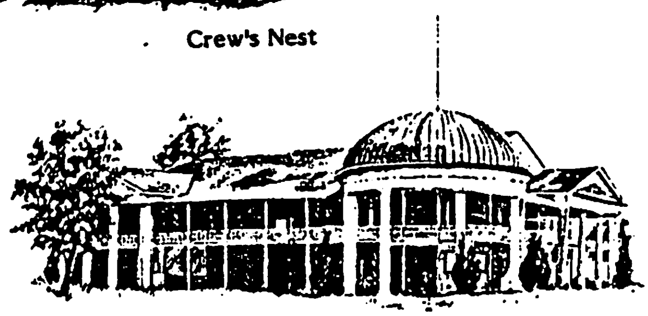
22. Heineman Winery and Crystal Cave - Wines and grape juice are produced from island-grown grapes at this

Country House



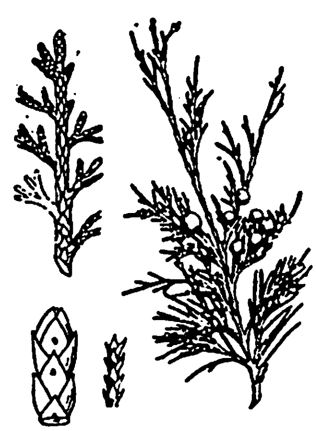
Round House Bar

Crew's Nest



The Colonial

Norway Maple



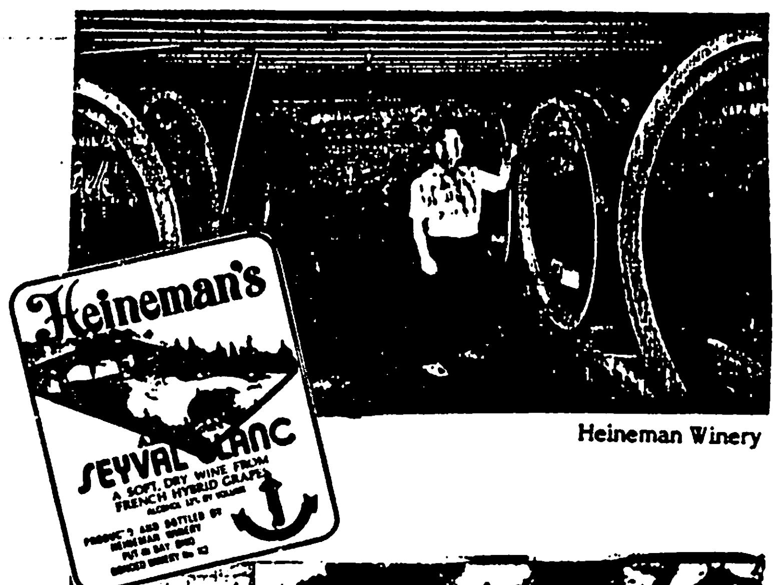
red cedar

traditional winery which dates back to the late 1800's. Tours of the winery are available which demonstrate all phases of the wine-making process. In 1897, when a well was being dug under the present winery at the 40-foot level (12 m), a cavern lined with brilliant crystals was broken into. Crystal Cave, as it is now known, is a huge geode encrusted with bluish-white celestite crystal composed of strontium sulfate ($SrSO_4$). The geode is roughly 30 feet (9 m) in diameter and the crystal weighs in excess of 50 tons. Some of the original crystal had to be removed to construct passageways. The largest crystal is about 24 inches (61 cm) long and weighs over 300 pounds (135 kg). Combined winery and cave tours are available to the public from Memorial Day to Labor Day. An admission fee is charged.

23. Perry's Cave - This cave lies 52 feet (16 m) below the surface of the island, extends 280 feet (87 m) along a fracture in the dolomite bedrock, and its greatest width is 165 feet (51 m). The walls, ceiling and floor are heavily encrusted with calcite deposits (calcium carbonate). The cave was probably formed when a lens of gypsum was dissolved by groundwater solutioning. This left an elliptical cave which has since partially


Episcopal Church


Catholic Church

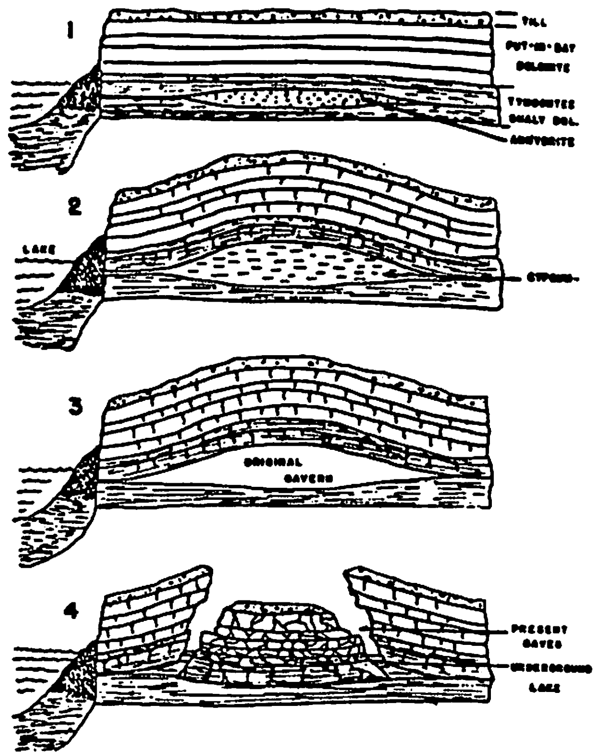


Heineman Winery

Crystal Cave

collapsed. The cave contains a pool which rises and falls with the level of Lake Erie, indicating a subterranean connection. The temperature of Perry's Cave remains constant at 42°F (6°C) throughout the year. Approximately 25 other caves on the island have been formed by a similar process; Perry's Cave is the one of this type which is open to the public.

24. Heineman Vineyard - Located on Mitchell Road, as well as the corner of Catawba Avenue and West Shore Boulevard, these vineyards provide the grapes used to make the island wines and grape juices. The lime soil of the island is conducive to the growing of fine grapes (Vitis labruscana). The most prominent varieties grown on the island are Catawba (pink), Niagara (white), and Concord (red). The lake-influenced climate of the island permits a longer growing season than interior locations in Ohio. Grape harvesting usually takes place in September and October. Adult ring-necked pheasants (Phasianus colchicus) and their broods are often seen between the rows of grape vines. Abandoned vineyards, which are numerous on the islands, are excellent places to observe plant succession, birds, and terrestrial animals.



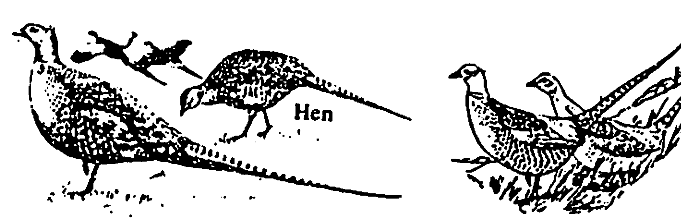
1. An ideal cross-section showing the anhydrite in place.
2. The uplifting of the overlying strata by the anhydrite hydration into gypsum.
3. Cavern left by gypsum going into solution.
4. Collapse of the overlying strata and the formation of new caves around the edges.

Formation of caves

Heineman Vineyard

Concord grapes

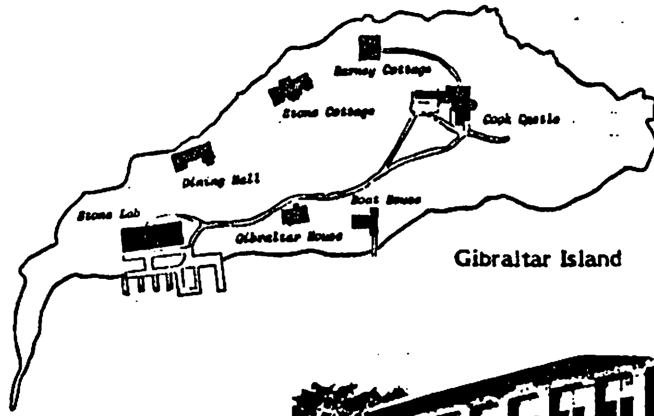
Niagara grapes



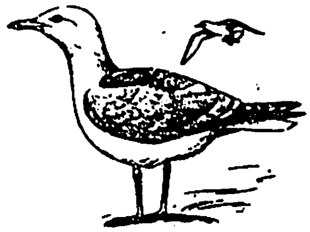
ring-necked pheasants

25. DeRivera House - A Greek Revival-style house, built circa 1854 for Joseph deRivera St. Jurgo, a Puerto Rican merchant and first resident proprietor of the island. This house is probably the oldest existing structure on South Bass Island.

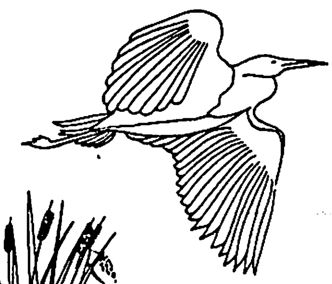
26. Oak Point State Park and Terwilliger's Pond - The Park is located at the base of Alligator Bar which connects South Bass Island to Gibraltar Island. During prolonged southwest storms, "seiches" can expose this shallow bar and much of the bottom of Fishery Bay and Put-in-Bay harbor. Park facilities include overnight boat docks, cooking grills and picnic tables, restrooms, drinking water and bank fishing sites. From Oak Point, one can see Ohio State University's biological field station on Gibraltar Island, the Franz Theodore Stone Laboratory and the historic Jay Cooke Castle (National Historic Landmark) which now serves as a men's dormitory. Terwilliger's Pond, adjacent to Oak Point, is an excellent natural area which harbors over 25 species of fish, contains many varieties of submergent and emergent aquatic plants, and boasts a rookery of black-crowned night herons (Nycticorax nycticorax). Mallards (Anas platyrhynchos) and their ducklings, great blue herons (Andea herodias), great egrets (Casmerodius

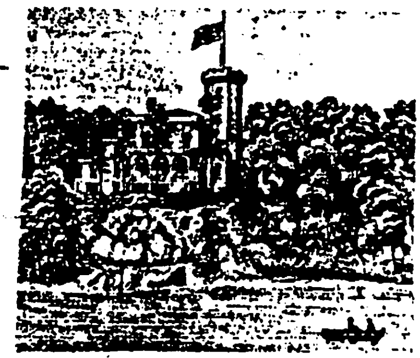


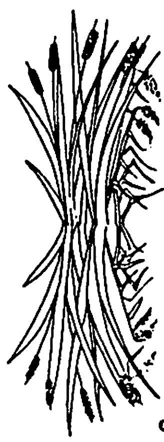
Gibraltar Island

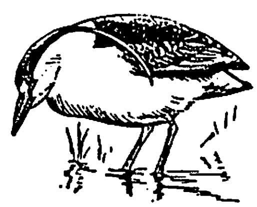

herrring gull

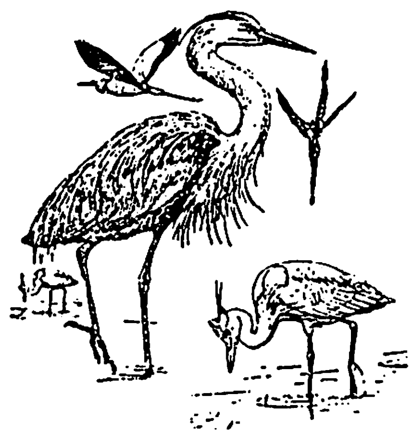
Franz Theodore Stone Laboratory

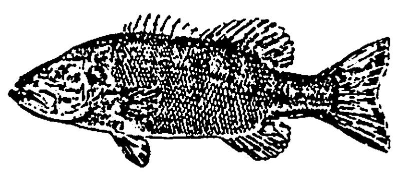

egret

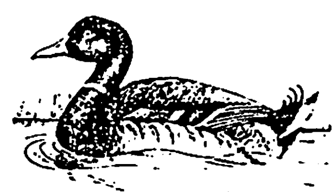

Jay Cooke Castle


cattail


Black-crowned Night Heron


great blue heron

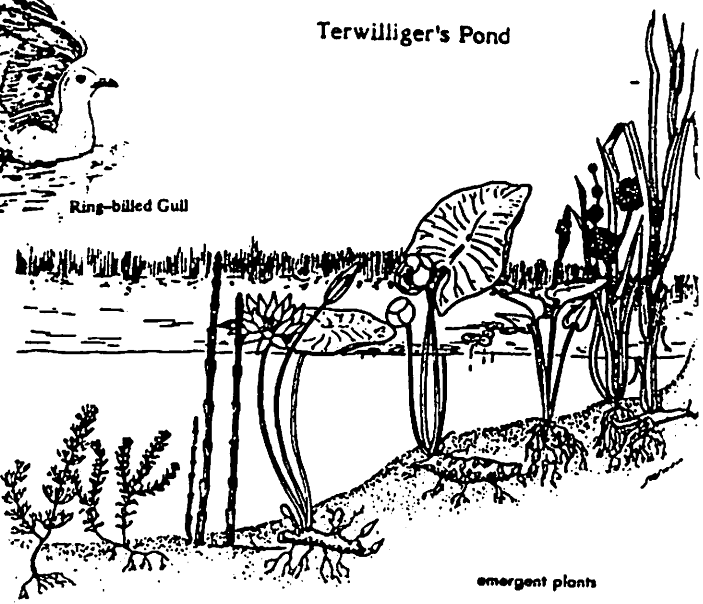

smallmouth bass


mallard

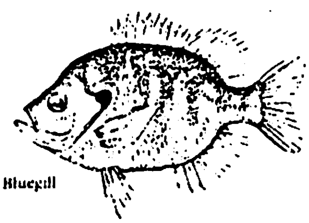
abbus) and herring gulls (Larus glaucoides) are commonly seen in the pond or in the vicinity of Alligator Bar.

Ring-billed Gull

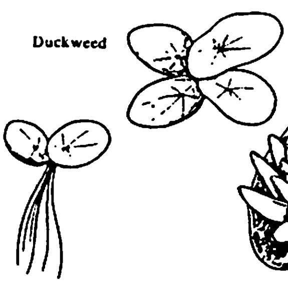
Terwilliger's Pond



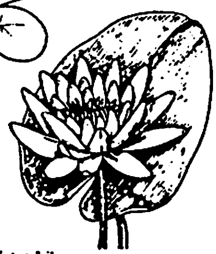
Marsh Mallow



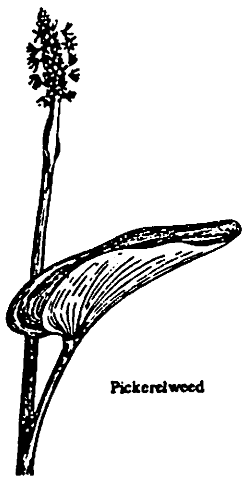
Bluegill



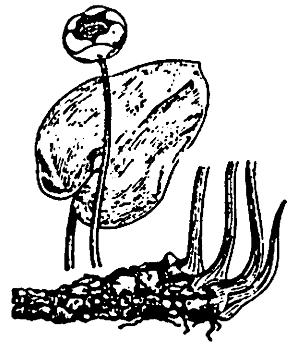
Duckweed



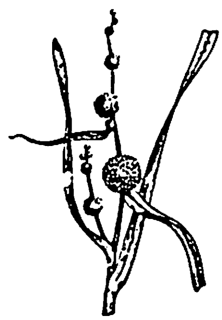
White Water Lily



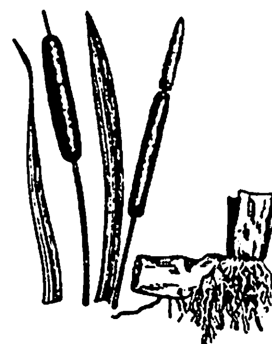
Pickerelweed



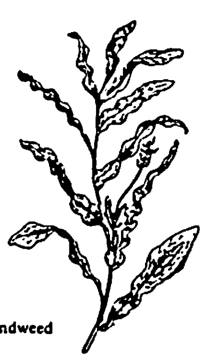
Spatterdock



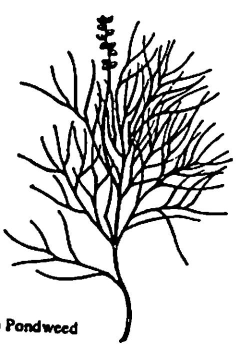
Burreed



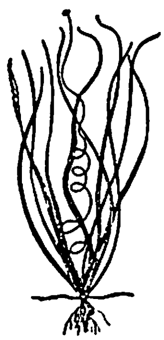
Common Cattail



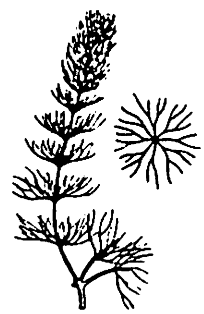
Curly Pondweed



Sago Pondweed



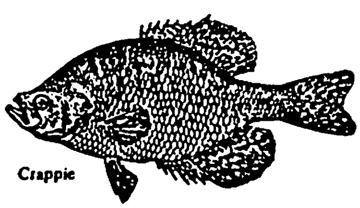
Wild Celery, Tape Grass, Eel Grass



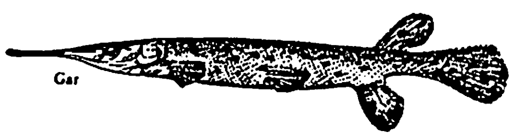
Hornwort

Water Milfoil

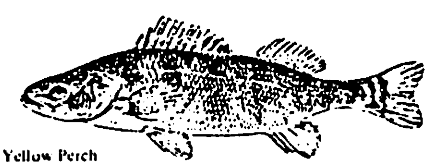
Water Smartweed



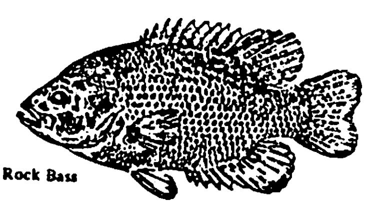
Crappie



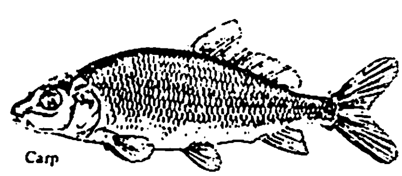
Gar



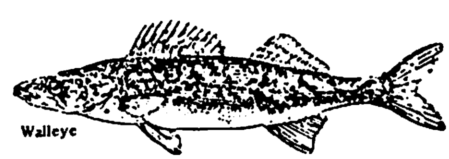
Yellow Perch



Rock Bass



Carp



Walleye