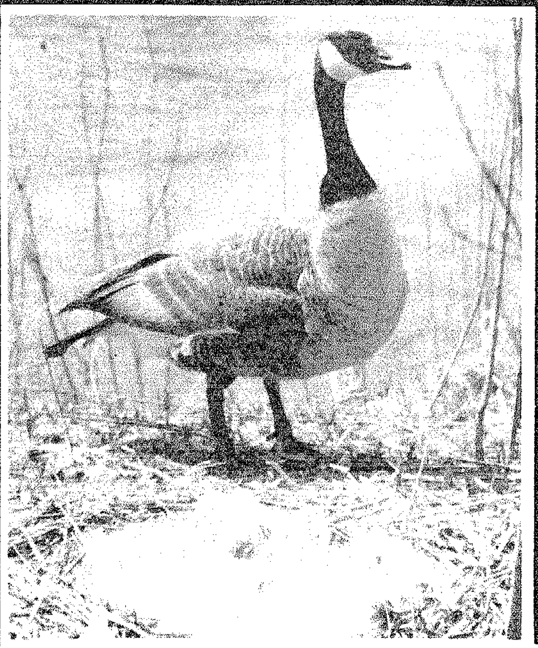
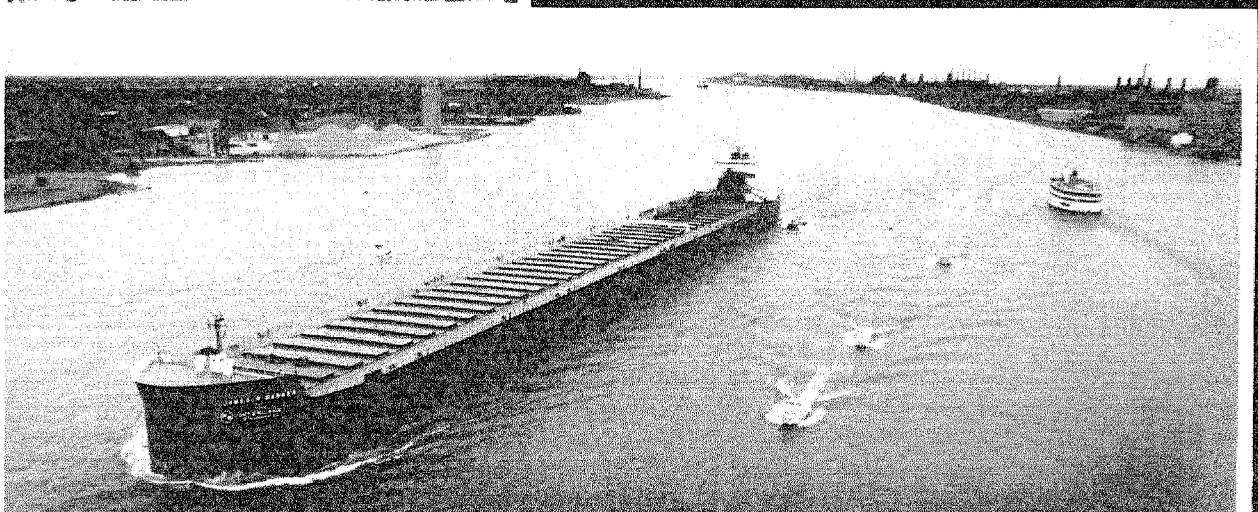
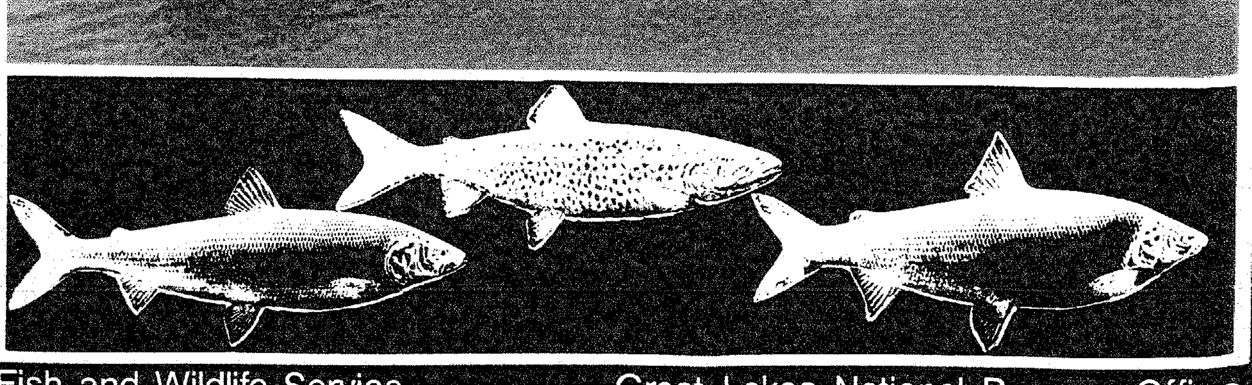
Biological Report 85(7.3)
April 1988



THE ST. CLAIR RIVER AND LAKE ST. CLAIR, MICHIGAN: AN ECOLOGICAL PROFILE





Fish and Wildlife Service
U.S. Department of the Interior

Great Lakes National Program Office
U.S. Environmental Protection Agency

COVER

Top: Canada geese are one of the species of waterfowl which utilize the St. Clair wetlands for nesting.

Middle: A great Lakes iron ore carrier moves one of the major cargoes down the St. Clair system.

Lower: The lake herring, lake trout, and lake whitefish historically were major seasonal species in the St. Clair system.

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THE ST. CLAIR RIVER AND LAKE ST. CLAIR, MICHIGAN: AN ECOLOGICAL PROFILE[a]

by

Thomas A. Edsall and Bruce A. Manny
U.S. Fish and Wildlife Service
National Fisheries Research Center-Great Lakes
Ann Arbor, MI 48105

and

C. Nicholas Raphael
Department of Geography and Geology
Eastern Michigan University
Ypsilanti, MI 48197

Project Officer

Edward C. Pendleton
National Wetlands Research Center
1010 Gause Boulevard
Slidell, LA 70458

Performed for

National Wetlands Research Center
Research and Development
Fish and Wildlife Service
U.S. Department of Interior
Washington, DC 20240

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DISCLAIMER

The findings of this report are not to be construed as an official U.S. Fish and Wildlife Service position unless so designated by other authorized documents. Statements of conclusions, as well as suggested courses of study or action, are exclusively those of the authors.

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PREFACE

This monograph on the St. Clair River and Lake St. Clair is one of an ongoing series of publications concerning current issues facing the Nation's inland and estuarine waters. Its purpose is to synthesize existing information describing the ecological structure and function of the St. Clair River and Lake St. Clair ecosystems, which, together with the Detroit River, compose the channel connecting Lakes Huron and Erie and form the border between the U.S. (Michigan) and Canada (Ontario).

The St. Clair system is an extremely valuable resource that provides quality recreational opportunities to many people in southeast Michigan and the bordering areas of Ontario. Much of the St. Clair Delta remains in its natural state and more than 42,000 acres of wetlands in the delta support a large and diverse flora and fauna.

The St. Clair system is heavily used by recreational boaters, waterfowl hunters, and anglers. Fishing through the ice is a popular winter activity in some parts of the system. The waters of the St. Clair system are also used for navigation and for the disposal of municipal and industrial wastes, while the shorelines support industrial and residential development and agriculture. Recognition of potentially severe use conflicts has focused concern on preparation by Michigan and Ontario of Remedial Action Plans designed to control pollution by toxic substances and restore all beneficial uses to each affected area, consistent with a continued, multiple-use philosophy for the system.

This profile is a synthesis of available information on this waterway, especially information pertinent to managing the biological resources of the river and lake. Information gaps are identified and accommodated by reference to research done elsewhere or to management plans for other similar rivers and lakes. Wherever possible, the river and lake are described from a systems viewpoint as an intact, integrated unit of the Great Lakes ecosystem.

Inquiries about this publication should be directed to:

Information Transfer Specialist
National Wetlands Research Center
U.S. Fish and Wildlife Service
NASA-Slidell Computer Complex
1010 Gause Boulevard
Slidell, LA 70458.

CONVERSION TABLE

Metric to U.S. Customary

Multiply	By	To Obtain
millimeters (mm)	0.03937	inches
centimeters (cm)	0.3937	inches
meters (m)	3.281	feet
meters (m)	0.5468	fathoms
kilometers (km)	0.6214	statute miles
kilometers (km)	0.5396	nautical miles
square meters (m^2)	10.76	square feet
square kilometers (km^2)	0.3861	square miles
hectares (ha)	2.471	acres
liters (l)	0.2642	gallons
cubic meters (m^3)	35.31	cubic feet
cubic meters (m^3)	0.0008110	acre-feet
milligrams (mg)	0.00003527	ounces
grams (g)	0.03527	ounces
kilograms (kg)	2.205	pounds
metric tons (t)	2205.0	pounds
metric tons (t)	1.102	short tons
kilocalories (kcal)	3.968	British thermal units
Celsius degrees (°C)	1.8(°C) + 32	Fahrenheit degrees

U.S. Customary to Metric

Multiply	By	To Obtain
inches	25.40	millimeters
inches	2.54	centimeters
feet (ft)	0.3048	meters
fathoms	1.829	meters
statute miles (mi)	1.609	kilometers
nautical miles (nmi)	1.852	kilometers
square feet (ft^2)	0.0929	square meters
square miles (mi^2)	2.590	square kilometers
acres	0.4047	hectares
gallons (gal)	3.785	liters
cubic feet (ft^3)	0.02831	cubic meters
acre-feet	1233.0	cubic meters
ounces (oz)	28350.0	milligrams
ounces (oz)	28.35	grams
pounds (lb)	0.4536	kilograms
pounds (lb)	0.00045	metric tons
short tons (ton)	0.9072	metric tons
British thermal units (Btu)	0.2520	kilocalories
Fahrenheit degrees (°F)	0.5556 (°F - 32)	Celsius degrees

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ACKNOWLEDGMENTS

We acknowledge photographs taken by Albert Ballert of the Great Lakes Commission, in Ann Arbor, Michigan. Several of the illustrations were drafted by the cartographic laboratory at the Department of Geography and Geology at Eastern Michigan University, Ypsilanti. Technical data for selected portions of this profile were provided by the Great Lakes Environmental Research Laboratory (NOAA) in Ann Arbor, Michigan.

Reviewers of this profile included Paul Bertram, Walter Duffy, John Forwalter, Rich Greenwood, Robert Haas, Peter Kauss, Marge Kolar, Tim Kubiak, Joseph Leach, Edward Pendleton, Keith Rodgers, and Larry Sisk. The document was edited by Robert Brown, laid out by Susan Lauritzen, and typed by Marilyn Murphy.

This report was funded cooperatively under Interagency Agreement No. DW14930945-01-0 between the Great Lakes National Program Office of the Environmental Protection Agency and the National Wetlands Research Center of the Fish and Wildlife Service. This report is also produced as a part of the Upper Great Lakes Connecting Channels Study conducted jointly by State, Provincial, and Federal agencies of the United States and Canada.

CHAPTER 1. INTRODUCTION—THE SETTING

1.1 THE SYSTEM AS A NATURAL UNIT

The St. Clair system, including the St. Clair River and Lake St. Clair, is a significant waterway economically, biologically, and physically. The St. Clair system together with the Detroit River forms, the connecting channel between Lake Huron and Lake Erie (Figure 1). The St. Clair River, forming the outlet of Lake Huron, flows approximately 64 km in a southerly direction to Lake St. Clair where it creates an extensive delta containing numerous distribution channels and wetlands (Figure 2).

Lake St. Clair is heart-shaped, has a maximum natural depth of 6.5 m, a maximum length of 43 km, a width of 40 km, and an area of about 1,115 km². Because of its shallowness, it has no commercial harbors. However, to accommodate heavy commercial marine traffic, a navigation channel dredged to a depth of 8.3 m bisects the lake, running in a northeast-southwest direction between the St. Clair cutoff in the St. Clair River Delta and the head of the Detroit River.

Located on the international boundary between the United States and Canada, the

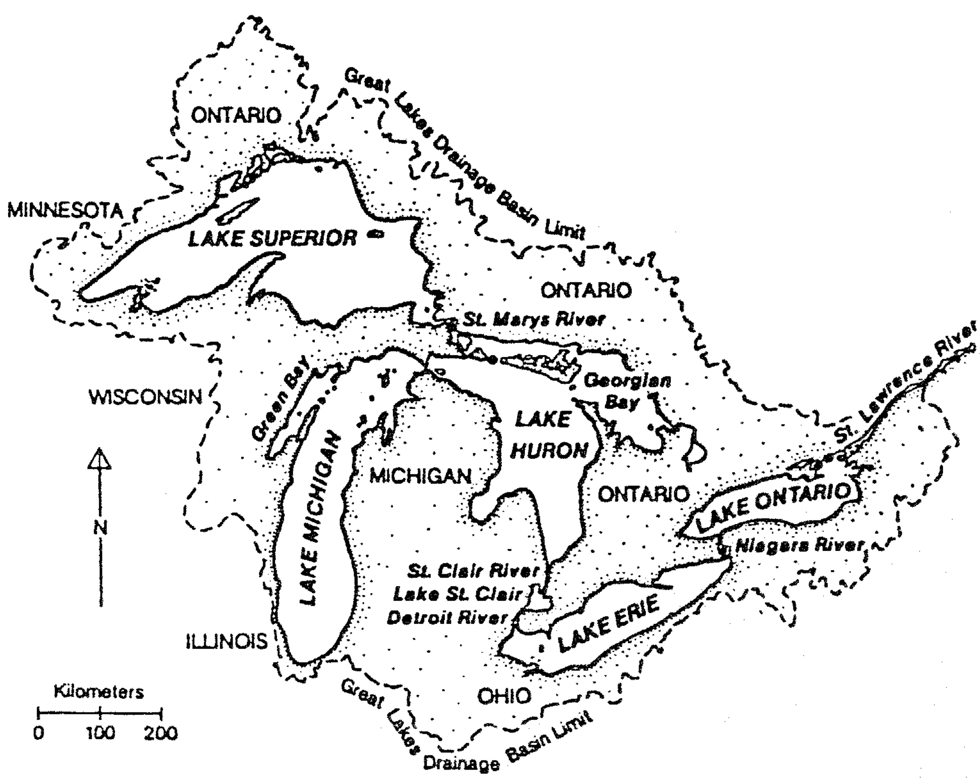


Figure 1. The Great Lakes Basin.

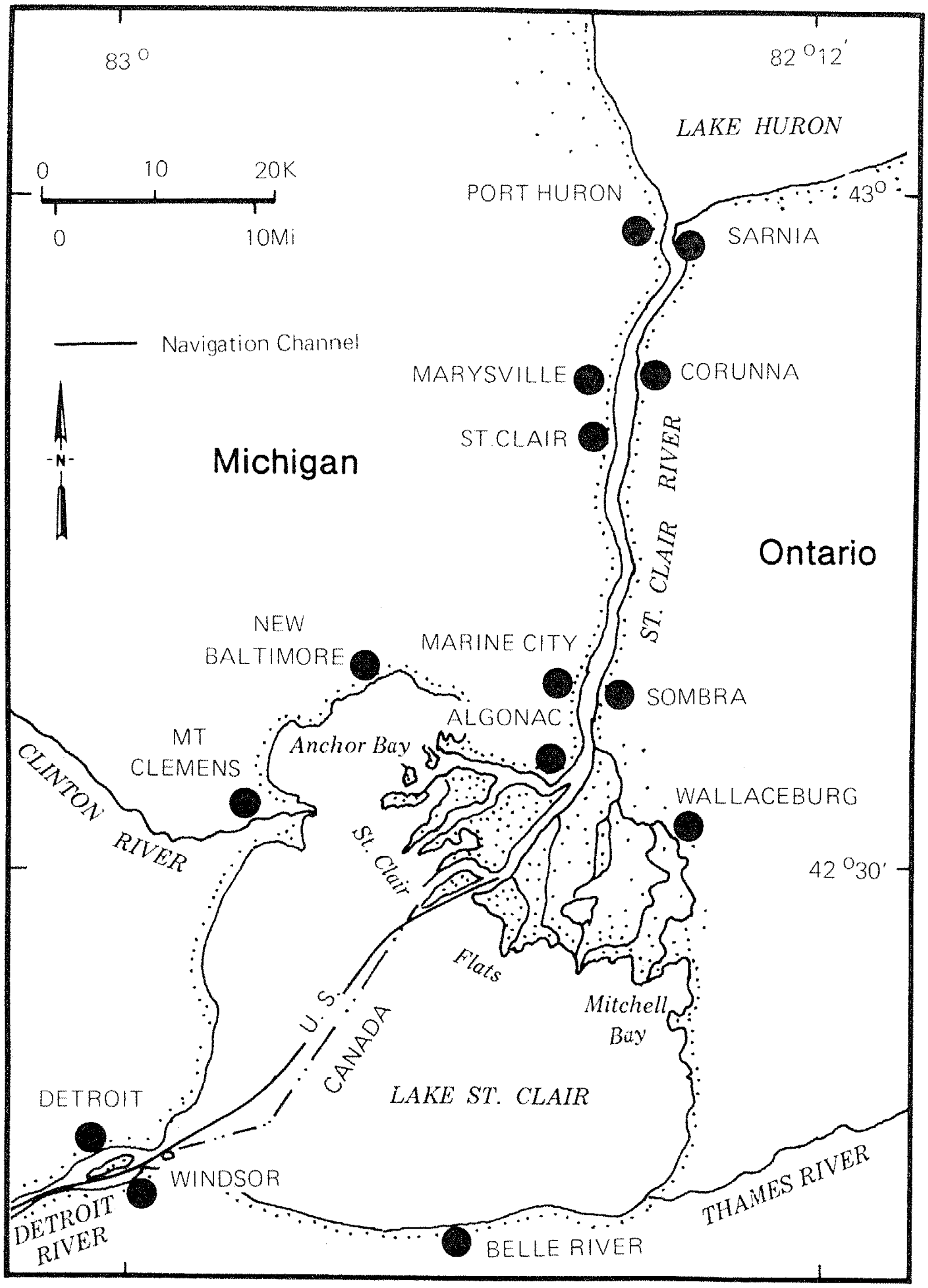


Figure 2. The St. Clair system.

St. Clair system borders Lambton, Kent, and Essex Counties in Ontario and St. Clair, Macomb, and Wayne Counties in Michigan. Lake St. Clair has a shoreline length of approximately 272 km, and the shoreline of the St. Clair River, including main distributary channels in the delta, totals 192 km.

The shoreline of the St. Clair system displays sharply contrasting land uses. Selected reaches of the Upper St. Clair River are heavily industrialized. Ontario's "chemical valley" utilizes much of the upper riverine shoreline. In Michigan, industrialization of the river shoreline is less intensive and is mainly centered at Port Huron. Along the Ontario shoreline of Lake St. Clair, wetlands and agriculture dominate, whereas in Michigan the entire lake shoreline is highly urbanized.

Despite intensive use of the water in the St. Clair River by industry and municipalities, water quality throughout the river is generally high (Greenwood et al. 1985). Some localized degradation of water quality occurs in areas where tributaries join the river, but these effects are not measurable a short distance downstream.

Biologically, the St. Clair system is significant because it supports diverse and productive populations of fish and wildlife that are of use to man. Several waterfowl flyways converge on the system, and habitat necessary for waterfowl resting, feeding, and breeding is provided by the many wetlands on the perimeter of the system, particularly in the St. Clair Delta. These flocks support extensive hunting opportunities in one of the most heavily populated centers in North America. The St. Clair system is also heavily used for recreational fishing, boating, and other water sports. Especially popular sport fish are muskellunge, walleye, yellow perch, northern pike, and smallmouth bass.

Figure 3 illustrates the physically integrated framework of the St. Clair system. Technically, because it does not have typical river characteristics, the St. Clair River is a strait connecting Lakes Huron and St. Clair. In most rivers, the drainage basin typically is the source of water, nutrients, and sediments. In the case of the St. Clair River, contributions of tributaries are modest and the drainage basin is Lake Huron. Therefore, the St. Clair River is not a typical river in an alluvial valley, but rather a conduit which transports water, nutrients, and sediments from Lake Huron to Lake St. Clair.

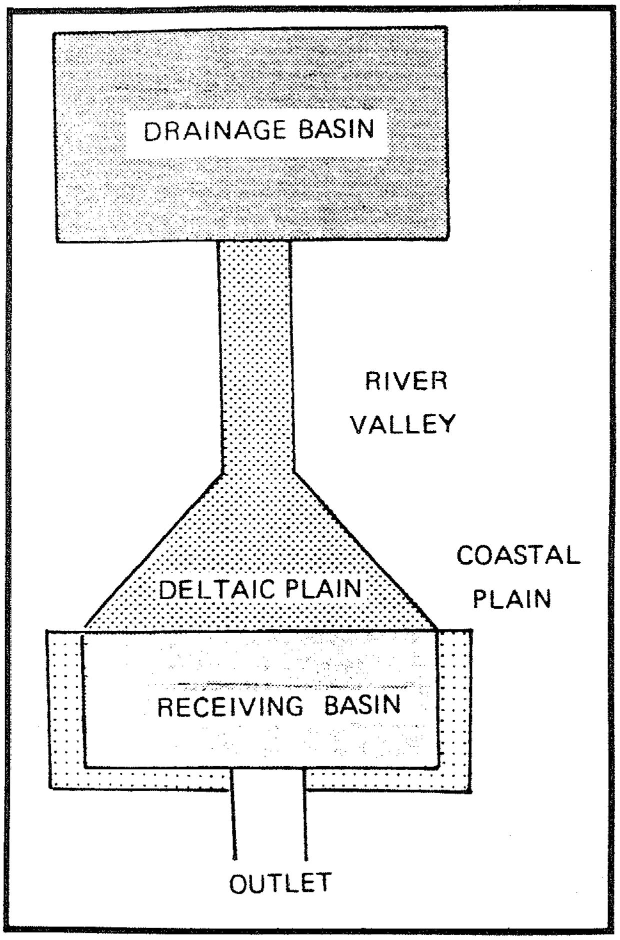


Figure 3. Major components of the St. Clair system.

The deltaic plain is a product of geologic and riverine processes. Its development is linked to riverborne sediments which are to a high degree distributed by waves and currents. The deltaic plain is deposited in the receiving basin of Lake St. Clair. The sediment load of the river is modest, the lake is naturally shallow, and wave action is also modest.

Such characteristics are ideal for delta development. Finally, sediments for the development of the coastal plain are derived from upland sources and the lake's nearshore environment. This depositional feature flanks the shoreline of the lake beyond the delta deposits. It is difficult to define the current extent of the coastal plain on the perimeter of Lake St. Clair because of cultural modifications which have occurred over the past century.

1.2 GEOLOGICAL ORIGIN AND DEVELOPMENT

The rocks beneath the St. Clair system are sedimentary in origin and Paleozoic in age (Figure 4). They are 4,200 m thick and rest upon a floor or "basement" of very ancient Precambrian igneous and metamorphic rocks. During the Paleozoic Era, some 405 million years ago, the Appalachian Mountains to the east began to rise, exposing the area to weathering and

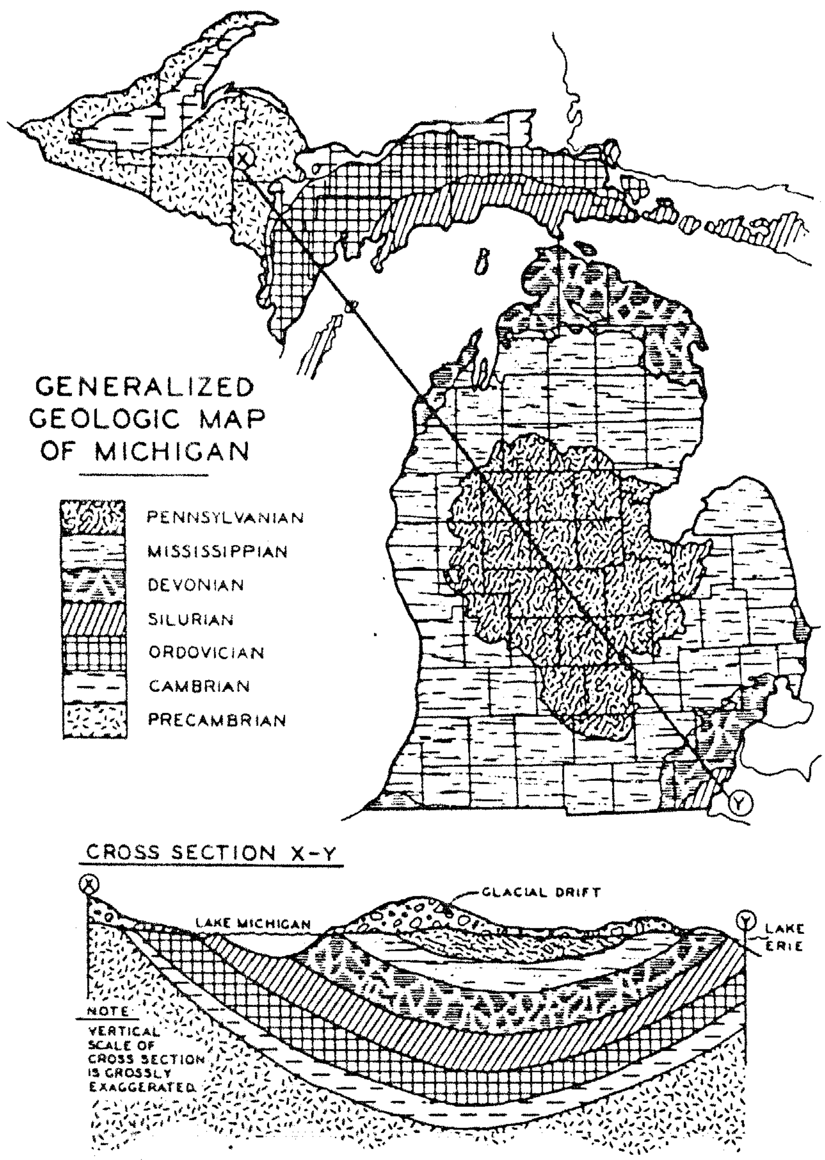


Figure 4. Bedrock geology of Michigan (Santer 1977).

erosion (Dorr and Eschman 1970). Silts and muds were deposited to the west and hardened to form extensive beds of Antrim Shale beneath the St. Clair system.

Sediments from source areas to the east were deposited in Michigan throughout most of the Paleozoic Era. Over time these sediments hardened into the sedimentary rocks which dominate the Lower Peninsula of Michigan. The Paleozoic formations tend to fold upwards and become thinner near the margins of the Great Lakes. Along the shoreline of the St. Clair system, the mantle over the bedrock is thin and increases in depth toward the middle of the Lower Peninsula. In Lake St. Clair, for example, bedrock is encountered at a depth of 93 m (Raphael and Jaworski 1982). Bedrock outcrops also occur in upper reaches of the St. Clair and Detroit Rivers.

The Devonian rocks have been significant to the development of the St. Clair Region. Fossil fuels (gas and oil) are extracted from these formations in the region. In fact, the first oil field in North America was developed at Oil Springs, northeast of Lake St. Clair, in southeastern Ontario in 1858. Evaporite rocks such as salt (i.e., halite) have been extensively mined by the Morton Salt Company for decades in St. Clair, Michigan. To some degree these products continue to contribute to the chemical and petroleum industries of nearby areas.

The next period of geologic time that had a profound impact on the development of the region was the Pleistocene Epoch. Some 2 million years ago, the earth's climate cooled and water budgets on a global scale were upset. Glaciers of continental proportion expanded from centers at the east and west of Hudson Bay and 20,000 years ago covered Michigan and extended as far south as southern Ohio. These enormous ice sheets scoured the land surface, created the Great Lakes, and deposited coarse, glacial sediments throughout the Great Lakes Basin.

Glacial deposits in the form of elongated ridges, or moraines, composed of sand and gravel generally parallel the present shoreline of the Great Lakes (Figure 5). Glacial melt waters were ponded in basins between the moraines and the glacier. Finer sediments accumulated in the ancestral basins to form lake plains. The St. Clair River and Lake St. Clair are today located between the Port Huron moraine to the north and the Detroit moraine to the south. Although the waterway is the link between the upper and lower Great Lakes, in terms of physical geography, it is a distinct basin bordered by moraines left by retreating glaciers.

As a limnological feature, Lake St. Clair is the youngest lake in the Great Lakes Basin. Until about 11,000 years ago, the upper Great Lakes drained southward through the Mississippi River or through the Trent River in Ontario. Some 9,500 years ago, the St. Clair River and Lake St. Clair came into existence along with the Detroit River. However, Lake St. Clair was at first a short-lived lake. As the glacier continued to retreat, the St. Clair connecting waterway was abandoned in favor of an outlet through the Ottawa River valley in Ontario. As the Pleistocene ice sheet retreated and the weight of the ice was removed, glacial "rebound" or uplift occurred. The Ottawa River valley became inoperative and the St. Clair outlet became the dominant outlet of the upper Great Lakes. Some 3,200 years ago, the St. Clair River and Lake St. Clair became permanent features on the landscape.

1.3 SETTLEMENT HISTORY

The association between humans and coastal and riverine environments has been long and intimate. The impact of cultural development in coastal and fluvial settings in recent years has demonstrated the sensitivity of those environments to physical, biological, and chemical alterations. Such changes have historical antecedents which produced the present landscape. Land-use modifications were most often initiated with pioneer settlement and many of our present land-use dilemmas are deeply rooted in the past.

The St. Clair system was initially settled during prehistoric time. The river and lake provided the Indian population with numerous resources, including

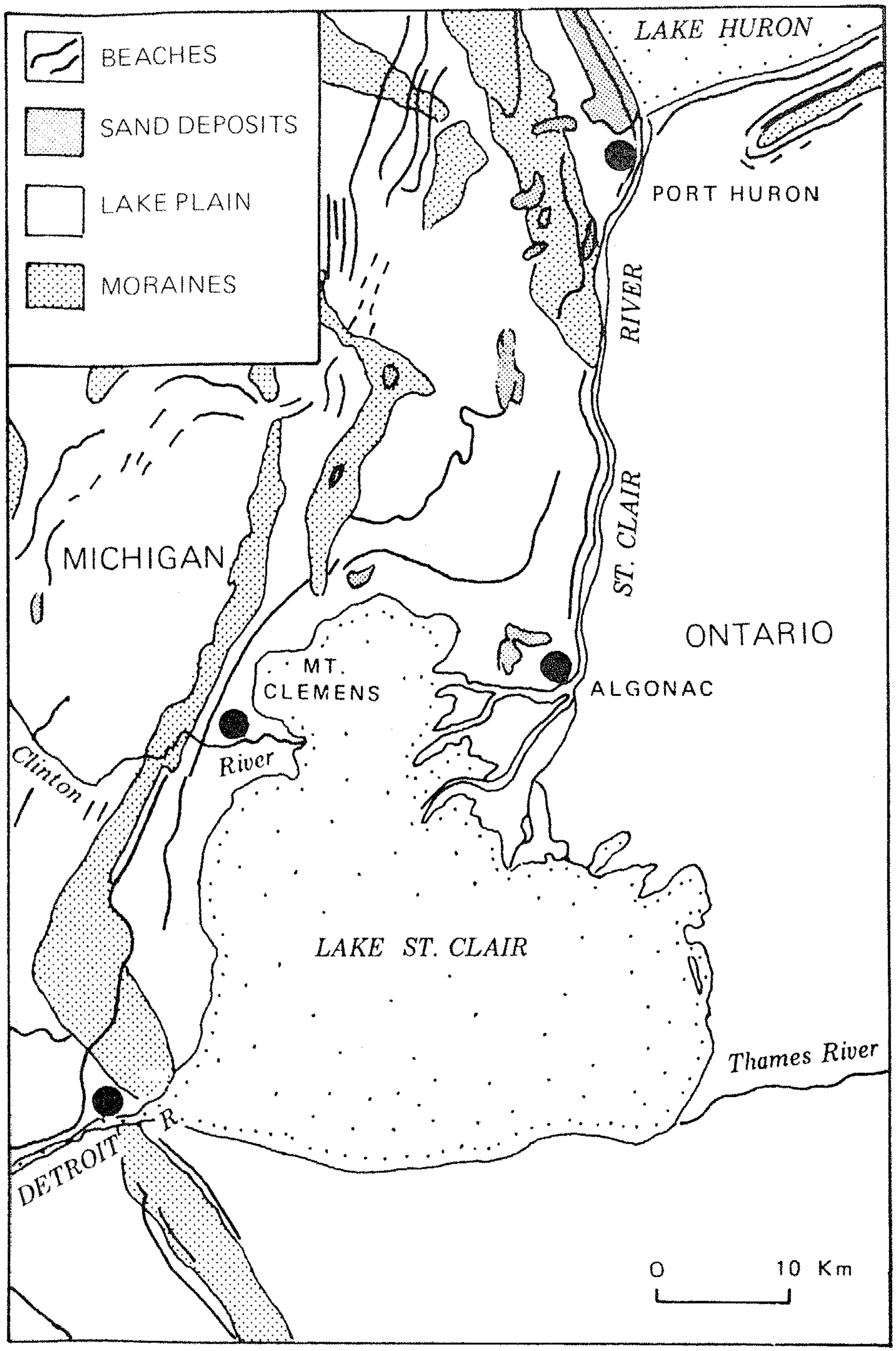


Figure 5. Glacial geomorphology of the St. Clair area (Dorr and Eschman 1970).

a transportation corridor and an abundance of fish and wildlife for consumption and clothing (Raphael 1987). Wetlands produced wild rice (Zizania aquatica) and sweet grass (Hierochloe odorata) (Jones 1935). The latter plant was particularly significant to the Chippewa and Ottawa Indians. Baskets woven from the grass provided a source of income to tribes around Lake St. Clair as late as the 1930's. Much of the Canadian portion of the St. Clair Delta (50 km²) is today a reservation for the Walpole Island Chippewa and Potawatomi tribes.

The archeological record reveals that the Indian population in the region was relatively high compared to other coastal reaches in Michigan (Peebles and Black 1976). Sixty-three prehistoric sites occur in Macomb County, the highest number in any county in the State. St. Clair and Macomb counties have 1.2 and 4.4 prehistoric sites per km of shoreline, respectively. Most of the known sites are concentrated near Port Huron and the shoreline of Anchor Bay. Included are burial and habitation sites of Middle and Late Woodland Indians (ca. 100 B.C. - A.D. 1600). Culturally, these sites represent a time of rapid change and innovation. The cultural and demographic growth of the Late Woodland period set the stage for the cultures first contacted by the French in the early 17th century.

The French are believed to have been the first European settlers in the St. Clair waterway. M. du Lhut, under a directive of the Governor General of New France was ordered to establish a fort on the upper Detroit River in 1686 (Rogers 1955). The settlement, Fort St. Joseph, was abandoned in 1688 and no other fort was established until 1701. The new garrison, Fort Pontchartrain, remained in French hands until 1760. The French settlers practiced trading, trapping, and subsistence type agriculture. The French longlot or arpent field patterns are clearly visible to this day on maps and aerial photographs of the river and lake shoreline (Figure 6). Historically, fur trapping and other exploitation began at this time. However, historical accounts suggest that the shorelines and wetlands were not as excessively exploited as were those of other parts of the Great Lakes, such as western Lake Erie.

From 1800 until nearly the turn of the 20th century, the region was utilized for agriculture. Hamlets such as Mt. Clemens, New Baltimore, and Marine City emerged to service the local farmers. Local industries also developed. From the 1840's and continuing through the Civil War, a modest ship building industry developed in the St. Clair Delta. The schooner "Island City," launched from Harsens Island in 1859, was one of many vessels constructed before a shortage of good ship timbers forced the industry from this island in the delta (Lawler 1938). Salt companies (e.g., Michigan Salt Company) exploited the shallow evaporite bedrock beneath the St. Clair River bank. During this era Great Lake shipping utilized the North Channel of the river because this channel was the deepest. Anchor Bay received its name from the ships that anchored there while waiting for their cargo to be lightened for transit over the river mouth bar of the North Channel. The transferring of cargo furnished employment for a large percentage of the people living on the Lake St. Clair shoreline.

Two significant developments occurred in the mid- and late-1800's which stimulated rapid cultural alterations and development of the region: the Swamp Acts of 1850 and improved transportation. The Surveyor General of the United States reported in 1815 that a large part of the southeastern region of the Michigan Territory was swamp and practically worthless. The purpose of the acts were to allow for the draining and diking of "worthless public lands, lying as marshes or subject to periodic overflow by adjacent water courses" (Donaldson 1970). The Swamp Acts of 1850 stimulated wetland alteration, and by 1873 the land between the Detroit and Clinton Rivers had been converted to agriculture (Herdendorf et al. 1986) and approximately one-half of Harsens Island was diked. On the St. Clair River, less draining and filling were needed because the river banks and surrounding land stood well above the river.

The development and gradual improvement of transportation routes also had a

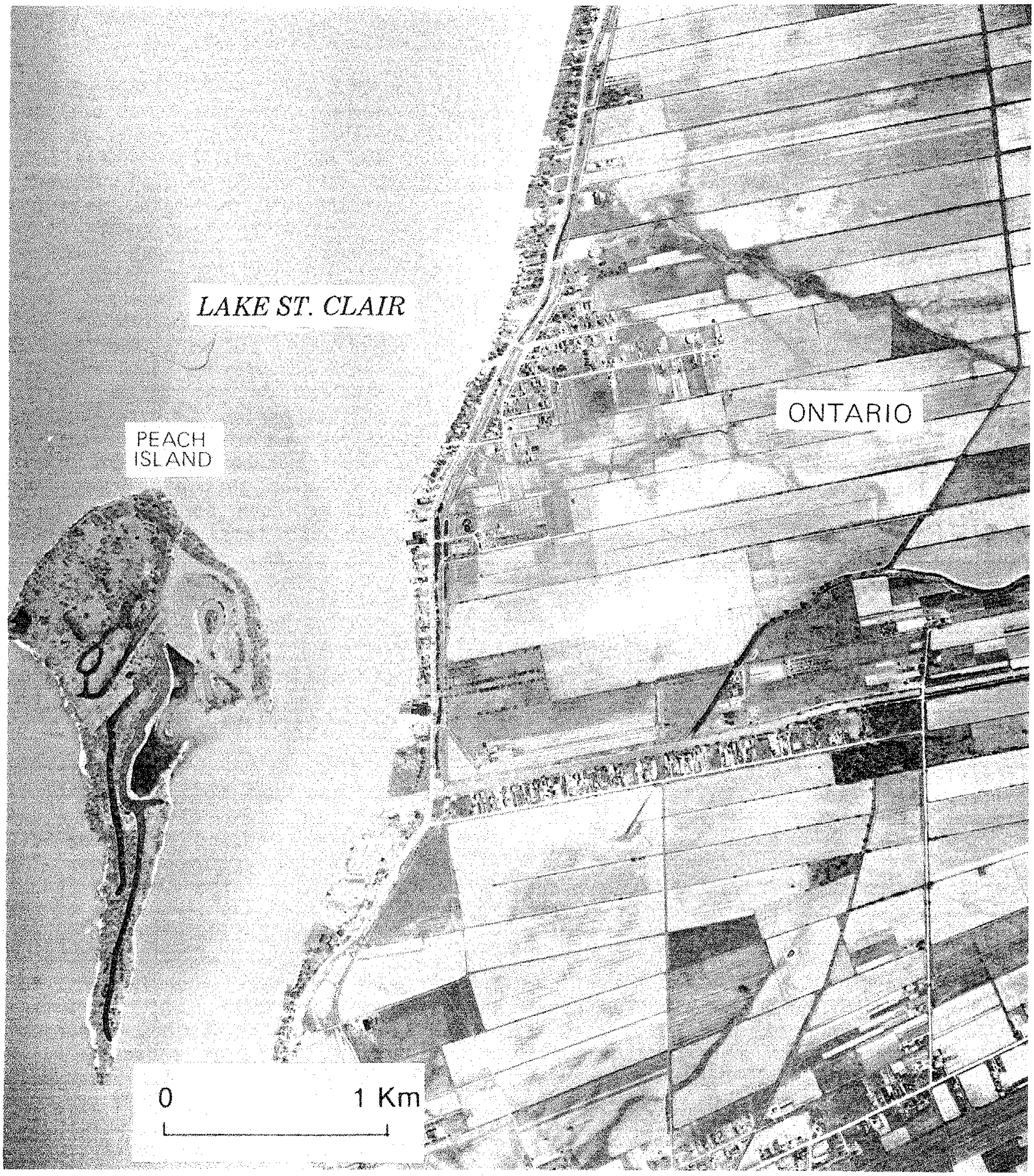


Figure 6. French longlot land system on Lake St. Clair (Photograph by Detroit Edison Company).

significant impact on the cultural development of the landscape. Three modes of transportation, firmly established by the mid-1870's, improved access to the lake and river. An electric railway was constructed along the shoreline of Lake St. Clair from Detroit to Algonac and north along the river to Port Huron. A second mode of transport which particularly impacted the lake shoreline was the development of the U.S. Ship Canal through the South Channel of the delta. A 6-m deep channel was dredged by 1873 to avoid shipping delays caused by the sand bar at the mouth of the North Channel (USACE 1981). Finally, a steam railway, the Lake Erie and Detroit River Line, was constructed along the east bank of the river joining Sarnia and Port Lambton, Ontario, to other agricultural communities in southern Ontario. An additional steam railway skirted the south shore of Lake St. Clair. The Grand Trunk Railway linked the villages of Stony Point and Belle River to Windsor, Ontario.

With the rail and ship lines in place, accessibility to the region was improved. Two significant developments occurred from the late 1800's well into the 20th century. These were private and public recreational activities. An abundance of wildlife and fish attracted farmers from the settlement of Detroit, who quickly recognized the recreational value of the waterway, particularly the lake and its wetlands (Figure 7). Similarly, somewhat later in the 19th century, the esthetics of the islands in the St. Clair River and its delta attracted vacationers from Detroit and Toledo.

The desirable quantity and quality of fish and wildlife, particularly waterfowl, led to the creation of numerous fishing and hunting clubs. One, the "Old Club," is not only the oldest but also probably the most exclusive private club in the region. By the mid-19th century, the organization had expended $80,000 in improvements on property it occupied in the St. Clair Delta (Jenks 1912). Another, the Rushmore Club, was organized by a prominent lumberman, C. W. Cocher, and included among its members many of Detroit's prominent families. In Ontario, the Canada Club and Ste. Anne Club were also well established by the turn of the 19th century. The establishment of these clubs and the investments they represented reflect the popularity of the area a century ago.

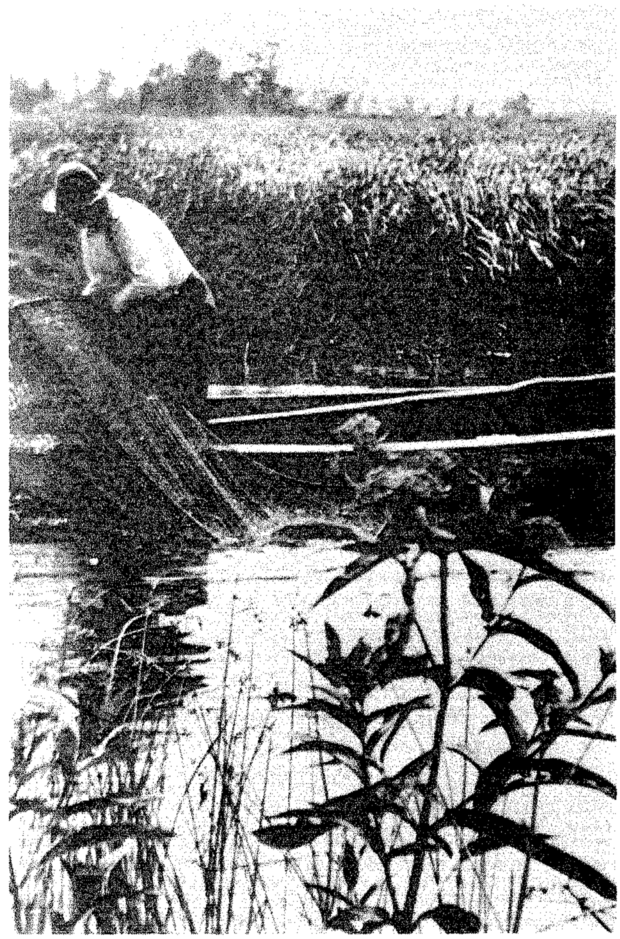


Figure 7. Seining along a Michigan coastal wetland, ca. 1915 (Photograph by Michigan Department of Natural Resources).

Access to the region by boat was not limited to private club members but was open to the public. It was but a short time before a number of resort hotels began to develop along the improved South Channel and the St. Clair River. In 1900, vessel stops on the White Star Line from Lake St. Clair to the apex of the delta included The Old Club, Mervue Hotel, Rushmore Club, Star Island House, Marshland Club, Maple Leaf, Tashmoo Park, Sans Souci, and Grande Pointe Hotel. Three round trips were made each day to thirteen localities for fifty cents. Public recreation facilities were established in Ontario along the St. Clair River and Stag Island (e.g. Griffon Hotel) but were less numerous. Perhaps the most famous of the many steamers plying the waters between Detroit and Lake St. Clair during the late 1800's was the "Tashmoo." She was 105 m long with a beam of 23 m and was licensed to carry 3,000 passengers (O'Brien 1951). The Tashmoo annually transported about 300,000 visitors to resorts in the region until she burned at her dock in 1936, thus ending an historic era in the region.

While public and private recreational development was centered on Lake St. Clair, industry began to emerge upstream on the St. Clair River. Both the Toledo and the Detroit Salt Companies were actively extracting halite by the mid-1860's. Lumber companies in Michigan and Ontario established docks for shipment of products on both sides of the river. By 1897, Imperial Oil Company constructed a refinery in Sarnia, Ontario, which initiated the development of southern Ontario's chemical valley. Within a short time several oil and chemical companies were established from Corunna north to Sarnia (Table 1). In Michigan, most industry was sited from the town of St. Clair north to Port Huron (e.g. Diamond Crystal and Morton Salt, Dunn Paper, Detroit Edison). Industries and electric power generating stations on the river are now the foremost users of water for their operations and contribute substantially to the commerce on the river and lake. They have also been catalysts for navigation improvements in the region.

Despite the industrial development which occurred in the upper reach of the St. Clair River, the lower river and Lake St. Clair generally remained unaltered in the early part of this century. The period from 1900 to 1940 was the beginning of urban development. The development of the automobile was paralleled by a rapid decline in the use of steamboats and inter-urban railways. The bed of the Detroit to Port Huron electric railroad was converted into State Highway M-29. Recreational boating facilities began to appear. The importance of agriculture began to decline at the expense of urban land uses and waterways. Urbanization west of Algonac in the St. Johns Marsh area more than doubled and agricultural land use declined by half (Roller 1976, 1977).

Table 1. Companies in the chemical valley and their major products (Kureth 1971).

Company	Date established	Product manufactured
Imperial Oil	1897	Petroleum and chemical products
Polymer	1942	Synthetic rubber and petrochemicals
Dow Chemical	1942	Industrial and agricultural chemicals
Shell of Canada	1951	Petroleum products
Cabot Carbon	1953	Carbon black
Sun Oil Company	1953	Petroleum products
Ethyl Corporation	1956	Chemical processing
St. Clair Chemicals	1960	Anhydrous aluminum chloride
DuPont of Canada	1960	Plastics
Allied Chemical	1963	Toluene diisocyanate
Canadian Industries Limited	1965	Agricultural chemicals
Chinook Chemicals	1965	Specialized organic chemicals
Dome Petroleum	1969	Butane, propane, condensates, isobutanes

By 1935, summer cottages were prevalent along the west side of the river and lake (Hudgins 1935). As access improved, linear development occured along the Michigan shoreline. In Ontario, by contrast, permanent rural housing remained. The Indians had modest farms on the delta where they cultivated corn, beans, squash, potatoes, hay, and small grains. Ontario farmers of European descent maintained larger farms on the remainder of the Lake St. Clair shoreline and along the lower St. Clair River. These farmers drained the lowlands along the lake to increase their agricultural output.

Throughout the period of settlement, the abundance of fish and wildlife and the esthetic character of the waterway have attracted people, and today Lake St. Clair continues to be a valuable Great Lakes area for non-salmonid recreational fishing in Michigan. For example, in 1975, nearly half of the total Great Lakes non-salmonid fishing effort in Michigan was expended on the lake (Jaworski and Raphael 1978). Muskrat and raccoon fur production also continues to be high in the coastal marshes, and fur trading continues as a local industry (Figure 8). The ready accessibility of the St. Clair system to urban dwellers of metropolitan Detroit and Windsor, as well as to numerous smaller cities such as Port Huron, Flint, and Saginaw in Michigan, and Sarnia, Chatham, and London in Ontario, also contributes to its attractiveness and popularity.

Figure 8. Wholesale fur company on Harsens Island in the St. Clair Delta, 1985 (Photograph by C. N. Raphael).

Urban sprawl, particularly on the Michigan shoreline, intensified in the 1950's. Interstate 94 was constructed along the shoreline of Lake St. Clair, improving access and reducing travel time. Several marinas, both public and private, were constructed, navigation channels were dredged and widened, and bulkheads and seawalls were constructed along the shoreline. Perhaps the most significant navigation improvement was the creation of an 8-m deep navigation channel from the head of the Detroit River through Lake St. Clair and the St. Clair River Delta (USACE 1981).

By the mid-1970's, much of the Michigan shoreline of Lake St. Clair was urban (Figure 9), but the remaining Michigan shoreline of the upper system was in a rural or quasi-natural state. In Ontario, the Upper St. Clair River was industrialized, whereas the lower river and lake shoreline remained in agriculture. Most of the St. Clair Delta in Ontario was included within the Walpole Indian Reservation and was inhabited by Chippewa and Potawatomi Indians. This landscape has changed little since the mid-1970's.

1.4 PRESENT LAND AND WATER USE

The present use of Lake St. Clair and the St. Clair River shorelines in Michigan includes significant and interesting contrasts (Table 2). Permanent residential homes occupy about 30 km of lake and 42 km of river shoreline. Industrial and commercial uses occupy 10 km of the river shoreline but only 2 km of the lake shoreline. Most of the shoreline is in private ownership, but 8.1 km is publicly owned and 5.5 km is dedicated to recreation and wildlife preserves.

Water of the St. Clair River and Lake St. Clair is utilized in many ways. In Michigan, four heavy industrial plants use river water for paper processing, metal plating, and salt processing. However, the heaviest water users are in Ontario. Eleven plants producing petrochemicals, salt, and agricultural products are sited from Sarnia south along the river to Courtright (Figure 10). A major use of the St. Clair River is to receive industrial and municipal effluents from

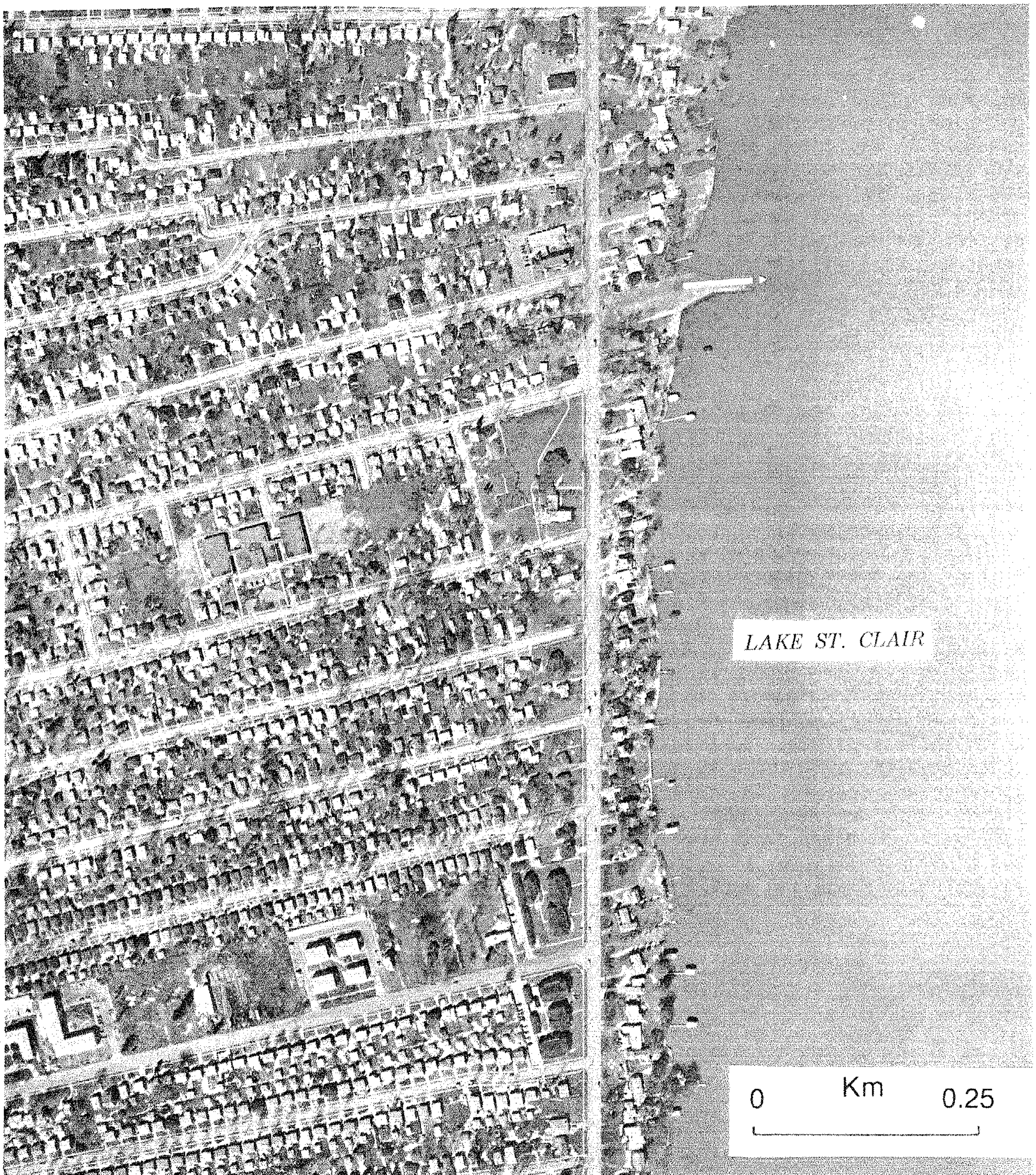


Figure 9. High density residential land use along the Lake St. Clair shoreline in Michigan, April 1973 (Photograph by U.S. Army Corps of Engineers).

Table 2. Use and ownership of the Michigan shoreline of the St. Clair system (GLBC 1975).

Category	Length of shoreline (Km) St. Clair River	Lake St. Clair
Use		
Residential	29.8	41.5
Industrial and commercial	10.2	2.2
Agricultural	1.9	3.0
Forest lands	0.0	0.0
Recreation	0.7	2.4
Wildlife preserves	0.0	2.4
Other public lands	0.0	2.6
Total	42.6	54.1
Ownership		
Federal	0.0	0.0
Non-federal public	0.7	7.4
Private	41.9	46.7
Total	42.6	54.1

the surrounding area. Lake survey charts show a total of 10 municipal and industrial outfalls along the St. Clair River.

Of the 15 water intake cribs existing on the river, many are for potable water supplies. However, others are used for intake of cooling water for condensers in power plants (Figure 11) and other industries. Water intakes, serving several municipalities, power stations, and industries of the area, appear at six locations in Lake St. Clair.

Figure 12 illustrates the importance of the St. Clair system in the flow of goods from Lake Superior through the connecting channels to Lake Erie harbors. An economic profile of the waterborne commerce of the St. Clair system shows commercial cargo traffic since 1979 has been variable and that the total tonnage decreased by nearly half from 1979 to 1983 (Table 3). Nevertheless, in 1983, 72,334,000 tons of commodities were shipped from Lake Superior and about 70% of the total passed "downbound" through the St. Clair system. Iron ore, a major bulk commodity moving through the St. Clair, is carried in large vessels like the one shown in Figure 13.

Traditionally, iron ore, limestone and coal account for 90% of U.S. Great Lakes waterborne commerce (Monson 1980). From a national perspective, about 11% of the total U.S. waterborne commerce occurs on the Great Lakes. It is evident that the future of Great Lakes shipping is linked to the future of the U.S. steel industry. The waterways of the Great Lakes system, including the St. Clair River and Lake St. Clair, have contributed significantly to the economy of the Great Lakes Basin by providing a cheaper alternative to land transportation. Monson (1980) determined that Marquette Range ore can be transported by water from Lake Superior to Lake Erie via the St. Clair system for about $12 less per ton than non-North American ore shipped by rail from East Coast ports to Great Lakes industrial centers.

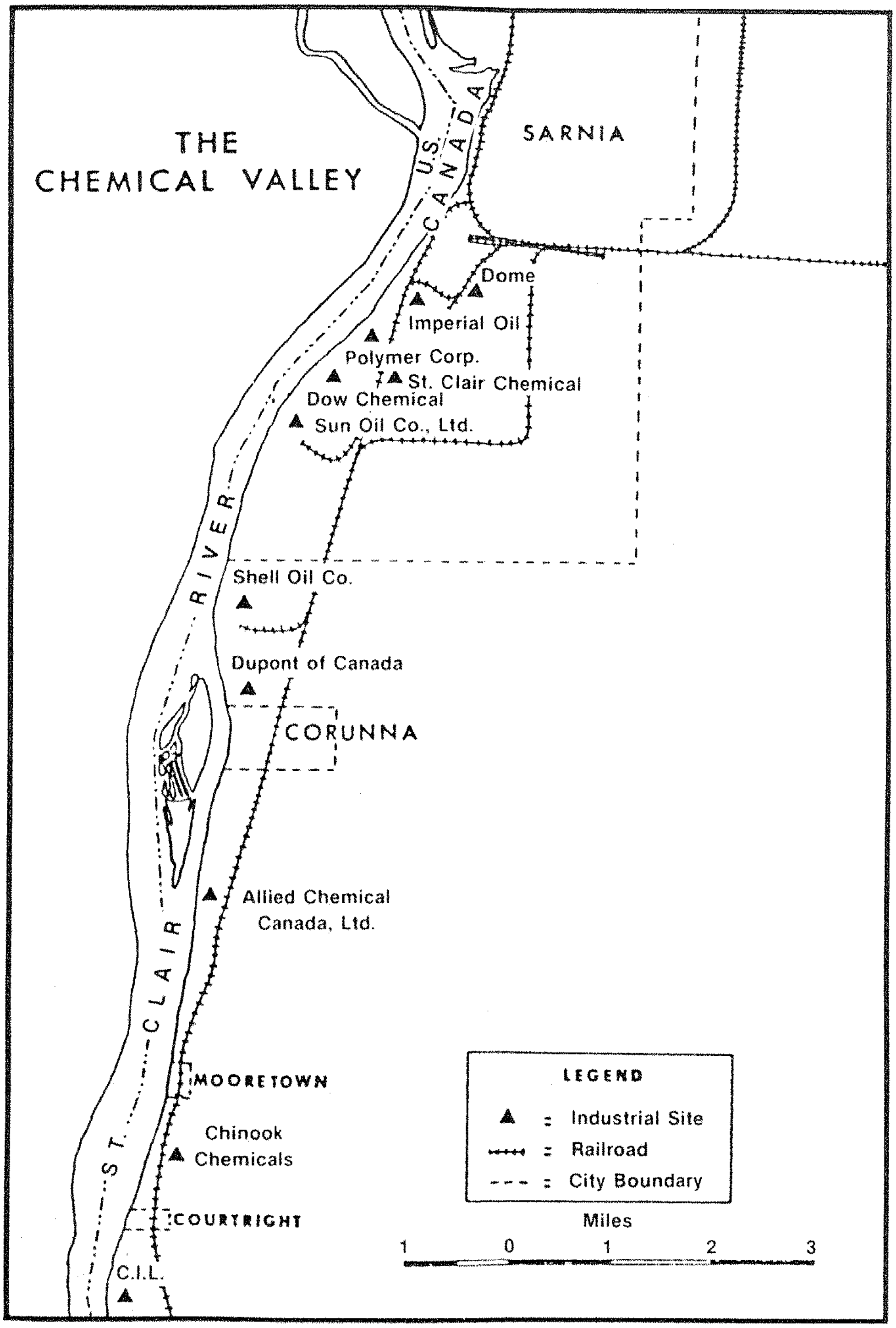


Figure 10. The chemical valley along the St. Clair River in Ontario (Kureth 1971).

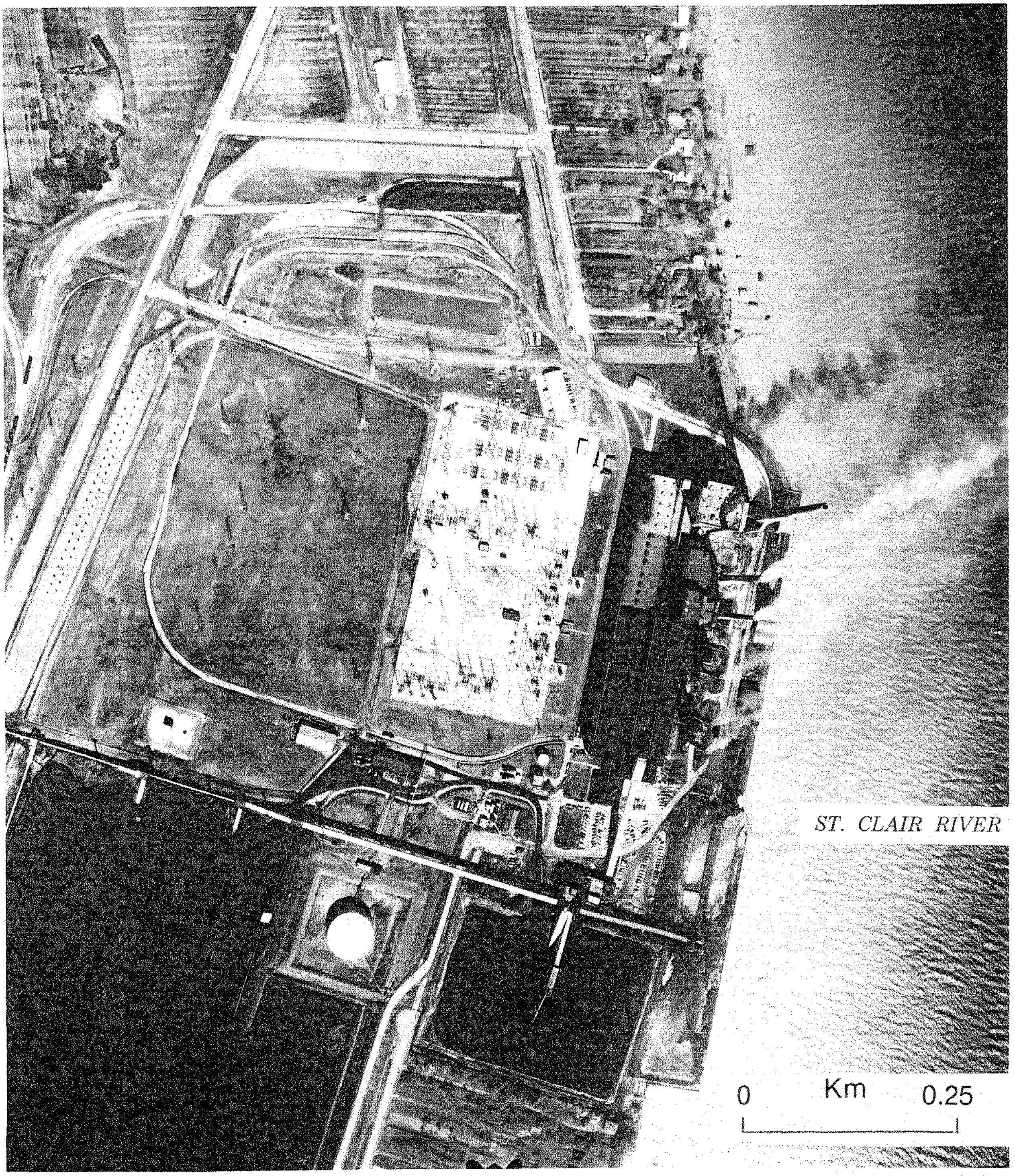


Figure 11. Detroit Edison Company power plant at Marysville, Michigan (Photograph by U.S. Army Corps of Engineers).

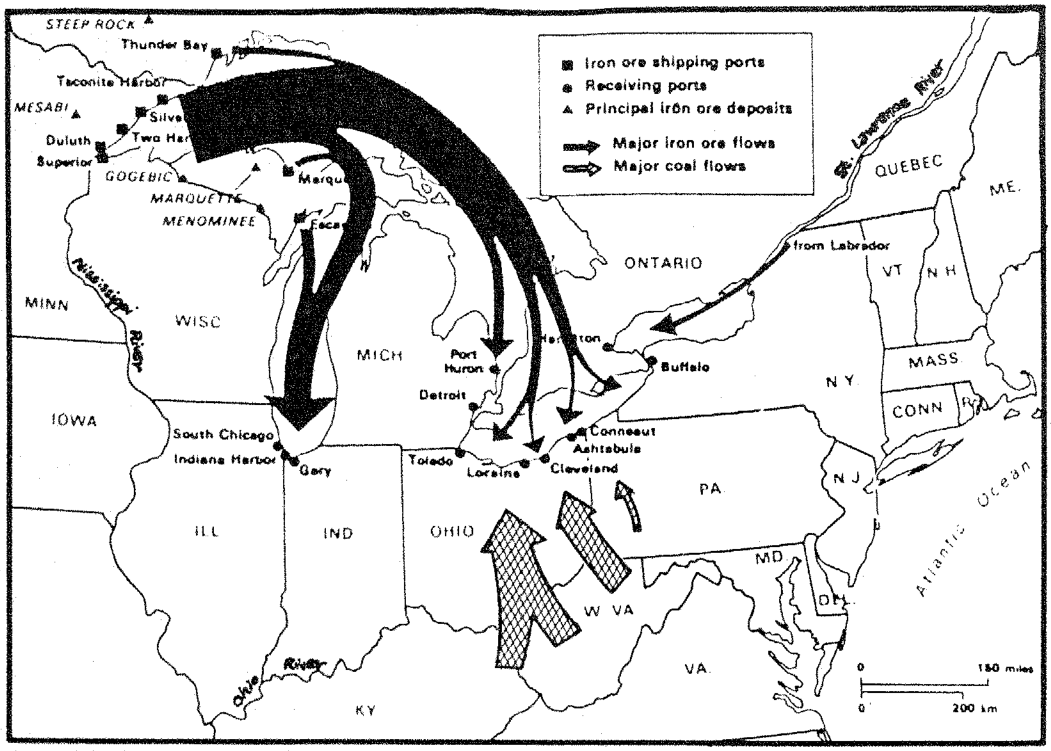


Figure 12. Major iron ore and coal traffic in the Great Lakes (Monson 1980). All of the iron ore shown reaching Lake Erie from Lake Superior ports passes through the St. Clair system.

Despite the various intensive and conflicting land and water uses to which the St. Clair system is subjected, the system continues to provide recreation to many Americans and Canadians (USEPA 1985). Typically, more walleyes, bass, muskellunge, and centrarchid panfish are taken from Lake St. Clair each year than from any of the Great Lakes or other Great Lakes connecting channels. In 1982, anglers licensed in Michigan spent an estimated 500,000 angler-days on the river and 1 million angler-days on the lake; in 1983, over 113,000 water craft were registered in the Michigan counties adjacent to the system. These anglers and boaters are served by more than 140 commercial, municipal, and private marinas in Michigan and Ontario waters of the St. Clair system. Thus, recreational boating and fishing provide a significant economic base on this international waterway.

Table 3. U.S. waterborne commerce of the St. Clair system, 1979-83 (USACE 1984).

Waterbody and direction of movement of various goods	Millions of tons				
	1979	1980	1981	1982	1983
St. Clair River					
Downbound					
Iron ore and concentrates	53.2	-	40.7	18.3	22.3
Limestone	13.8	-	8.8	5.4	6.5
Corn and wheat	5.5	-	6.6	5.4	4.2
Other	15.4	-	11.2	9.1	6.4
Total	87.9	-	67.3	38.2	39.4
Upbound					
Coal and lignite	15.3	-	12.1	9.3	10.9
Iron ore and concentrates	3.8	-	4.0	3.3	1.0
Iron, steel shapes	1.1	-	0.6	0.9	1.0
Other	4.6	-	2.8	2.9	2.4
Total	24.8	-	19.5	16.4	15.3
Lake St. Clair					
Downbound					
Iron ore and concentrates	53.2	41.3	40.7	18.3	22.3
Limestone	12.7	9.8	7.9	4.7	6.5
Corn and wheat	10.6	8.3	6.2	5.4	4.2
Other	7.2	4.8	8.4	6.2	6.4
Total	83.7	64.2	63.2	34.6	39.4
Upbound					
Coal and lignite	15.3	13.1	12.1	9.3	10.9
Iron ore and concentrates	3.8	1.5	4.0	3.3	1.0
Iron, steel shapes	1.1	0.5	0.6	0.9	1.1
Other	3.9	2.7	2.6	2.1	15.3
Total	24.1	17.8	19.3	15.6	28.3
Grand total	220.5	82.0	169.3	104.8	122.4

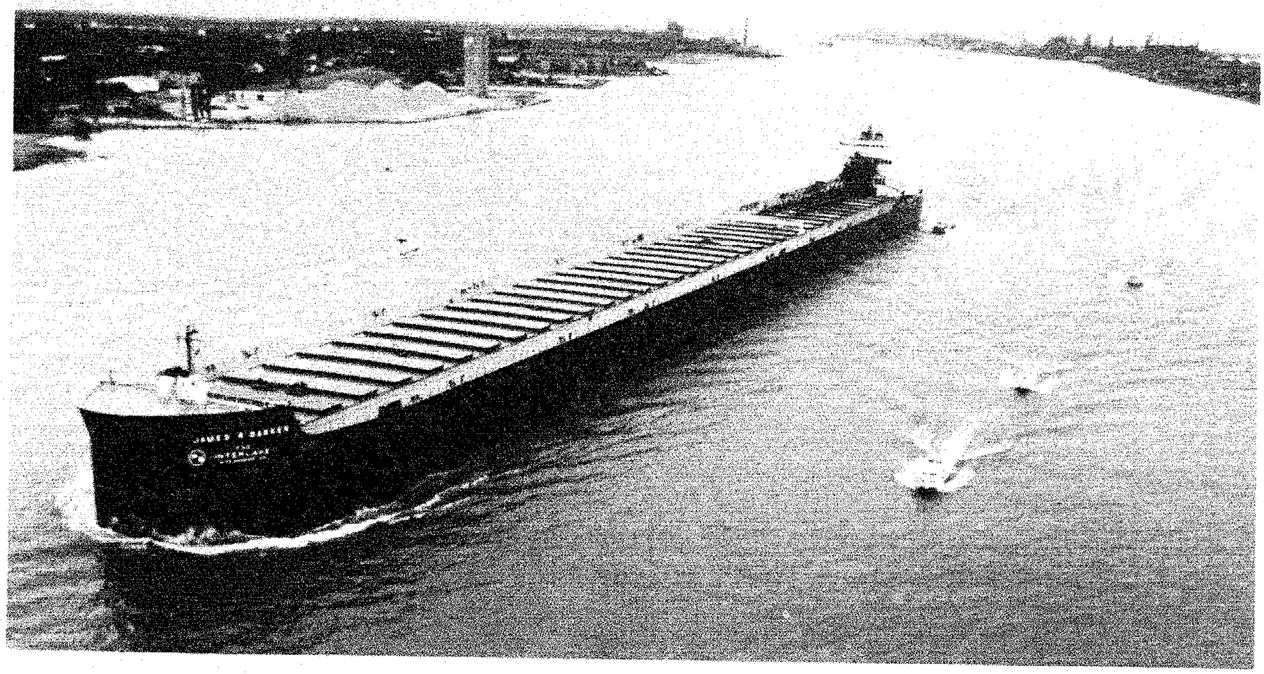


Figure 13. A Great Lakes iron ore carrier (Photograph by A. Ballert, Great Lakes Commission).

CHAPTER 2. DESCRIPTION OF THE ENVIRONMENT

2.1 CLIMATE AND WEATHER

Climatic variables such as temperature, precipitation, and winds dictate or strongly influence lacustrine and riverine processes in the St. Clair system. Climate and weather are primarily responsible for wave and current movements, the extent of the growing season, the distribution and length of ice cover, and water levels on a daily, monthly, and seasonal basis.

The climate of the region is characterized by mild summers and cold winters (Figure 14). Average annual air temperatures range from a high of 23.6°C in July at Detroit to a low of -4.4°C in January at Port Huron. Temperatures recorded at Detroit are slightly higher than those recorded at the other Michigan stations, indicating an urban "heat island" environment (Sanderson 1980). Monthly precipitation ranges from a high of 8.1 cm at Detroit to a low of 3.6 cm at Port Huron. In winter, air temperatures are commonly below 0°C, and during the summer months air temperatures are near 21°C. Water temperatures in the St. Clair system reach the annual minimum of about 0.5°C in January and February and the annual maximum of about 21-22°C in August (Table 4). Ice occurs on many localities of Lake St. Clair and to a lesser degree on the St. Clair River. Precipitation is mainly rain and is well distributed throughout the year. Winter precipitation is most often snow.

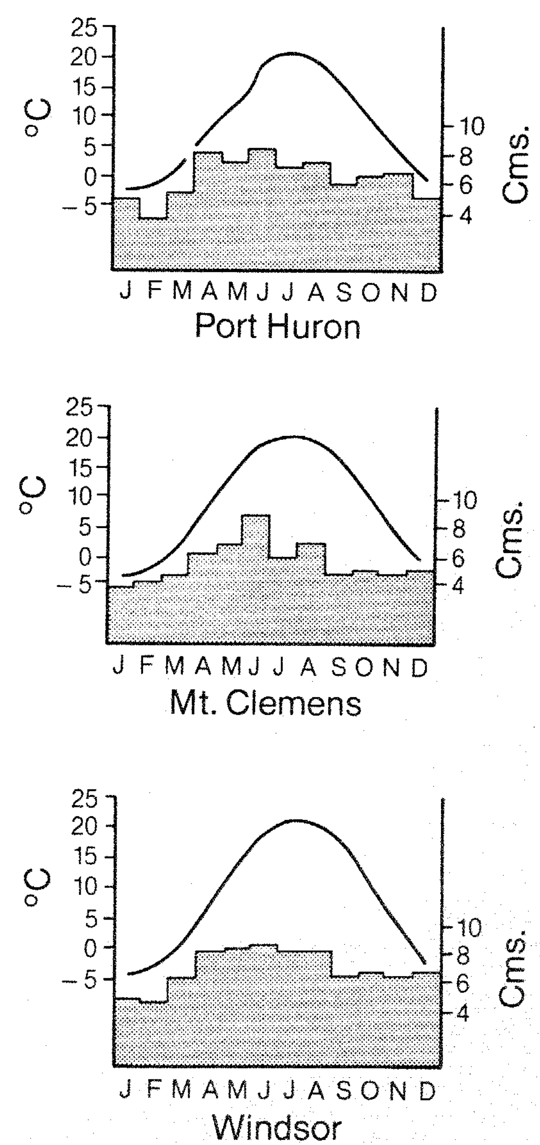


Figure 14. Average monthly air temperatures (line) and precipitation (bars) at Port Huron and Mt. Clemens, Michigan, and Windsor, Ontario.

Precipitation in southeastern Michigan is related to cyclonic storms and to convectional uplift. Cyclonic storms occur throughout the year but increase in frequency during the fall and winter months. They often produce seiches or "wind tides" which raise water levels and cause short-term flooding of low-lying

Table 4. Water temperatures of the St. Clair system (Muth et al. 1986). Temperatures were measured at water intakes of the cities of Port Huron and Detroit. The Port Huron intake is located at the head of the St. Clair River and the Detroit intake is at the outlet of Lake St. Clair.

Year	Average monthly temperature (°C)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
						Head of St. Clair River						
1974	1.1	0.5	1.7	3.9	8.3	11.7	17.8	20.6	18.3	12.2	9.4	- [a]
1975	2.2	-	1.1	2.8	9.4	15.0	19.4	21.7	16.7	13.9	10.6	4.4
1976	0.5	1.1	1.7	5.0	8.9	15.0	18.9	20.6	18.3	12.8	6.1	1.1
1977	0.5	0.5	1.7	4.4	10.6	15.0	19.4	20.6	-	12.8	8.9	3.3
1978	0.5	0.5	0.5	3.3	-	13.3	18.3	-	18.9	12.8	8.9	3.3
1979	0.5	0.5	1.1	3.3	7.8	13.3	17.8	20.6	18.9	13.9	8.9	4.4
1980	1.1	0.5	1.1	4.4	9.4	12.8	18.9	21.7	18.9	12.8	7.2	2.8
1981	0.5	1.1	1.7	5.0	8.9	15.0	21.1	21.7	18.9	12.8	8.9	3.3
1982	1.1	0.5	0.5	3.3	10.0	13.3	18.9	21.1	17.2	14.4	9.4	5.6
1983	0.5	1.1	0.5	3.3	6.7	13.9	18.9	21.7	17.2	12.8	7.8	4.4
1984	0.5	1.1	0.5	3.3	6.7	13.9	18.9	21.7	17.2	12.8	7.8	4.4
Average	0.8	0.7	1.1	3.8	8.7	13.8	18.9	21.2	18.0	13.1	8.5	3.7
						Outlet of Lake St. Clair						
1973	0.5	0.5	1.7	6.1	10.0	17.2	21.1	22.8	20.6	15.6	7.8	2.8
1974	0.5	0.5	1.1	5.0	10.6	16.1	21.1	22.2	18.3	11.7	8.3	2.2
1975	1.1	0.5	1.1	3.9	12.8	17.8	22.2	22.2	17.2	13.3	8.9	2.8
1976	0.5	0.5	2.8	8.3	10.6	20.0	21.1	21.7	18.3	11.1	3.9	0.5
1977	0.5	0.5	1.7	7.2	13.9	18.3	22.8	21.7	20.0	12.2	8.3	1.1
1978	0.5	0.5	0.5	4.4	11.7	17.8	21.1	22.8	20.6	12.2	8.3	2.2
1979	0.5	0.5	1.1	5.0	11.1	16.7	20.6	21.1	19.4	13.3	7.8	3.3
1980	1.1	0.5	1.1	5.5	12.2	16.7	21.7	22.8	20.0	12.2	6.1	1.7
1981	0.5	0.5	1.7	7.8	11.1	18.3	22.8	22.8	18.9	11.7	7.8	3.3
1982	0.5	0.5	1.1	4.4	13.9	17.2	21.7	22.2	18.9	13.9	8.3	4.4
1983	1.7	1.1	3.3	5.5	10.6	17.2	22.8	23.9	21.1	14.4	7.2	2.2
1984	0.5	1.1	1.1	5.5	9.4	17.8	21.1	23.3	18.9	13.9	7.2	3.3
Average	0.7	0.6	1.5	5.7	11.5	17.6	21.7	22.4	19.4	13.0	7.5	2.5

[a] Dash indicates data not available.

shorelines. In summer, thunderstorms nourished by moist subtropical air from the Gulf of Mexico are common and disrupt recreational activities on the river and lake.

The frost-free season, defined as the interval between the last occurrence of frost in spring and the first occurrence in fall, an indicator of the length of the growing season, is 160 days. With the exception of the south shores of Lakes Ontario, Erie, and Michigan, which experience 180 frost-free days annually, the St. Clair system has the longest frost-free period in the Great Lakes Basin. The cold waters of Lake Huron act as a heat sink which retards the rapid rise of air temperatures in the spring, thus preventing premature growth of vegetation and lessening the chances of crop loss due to late spring frosts (Eichenlaub 1979). Conversely, the warm waters of Lake Huron act as a heat source in autumn, retarding frost and extending the growing season into October.

Growing degree-days, an index of the amount of heat available during the growing season, is defined as the number of degrees of mean daily air temperature above a base of 5.6°C. This concept delimits areas suitable for particular vegetation types and predicts the hatching date of various insects (Baker and Strub 1965). The accumulated number of degrees above a base of 5.6°C in a normal year is 2,343°C in the southern portion of Lake St. Clair and 2,056°C at Port Huron.

Wind direction and frequency generate waves, ice jams, and seiches in Lake St. Clair. According to Ayers (1964) and Ibrahim and McCorquodale (1985), water circulation in Lake St. Clair is strongly influenced by prevailing winds, as are alongshore currents. Figure 15 illustrates the average monthly directional frequency of winds for Windsor. Wind direction varies most in March and April. Southwest winds prevail annually. Additional data from the Windsor airport indicate that the highest wind speeds occur in January, February, and March, average 20 km/hr, and are from the west-northwest, while the lowest winds occur in June, July, and August, average 13 km/hr, and are from the southeast.

2.2 HYDROLOGY AND WATER LEVELS

Historically, water level changes have caused erosion and flooding in the St. Clair system. Water levels are also important determinants of the biological distribution and types of wetland resources and, in turn, are related to inflow and outflow of surface water, evaporation, and precipitation (i.e., the water budget). Figure 16 represents the principal parameters which affect volumes, flows, and water levels of Lake St. Clair. The role of groundwater in the overall water budget is not known for the region, but is not considered to be very significant. Inputs include water discharged from Lake Huron into the St. Clair River and ultimately into Lake St. Clair, precipitation over the river and lake, and runoff from adjacent drainage basins. Output of the system includes evaporation and outflow via the Detroit River. The storage of water in Lake St. Clair is the difference between input and output (Quinn 1978).

Lake Huron and five rivers drain into the St. Clair system (Figure 17). In Ontario, the Sydenham and Thames Rivers drain most of the area between Lake Huron and Lake Erie. In Michigan, tributaries to the St. Clair system are the Black, Bell, and Clinton rivers. The only outlet of Lake St. Clair is the Detroit River.

The river drainage basins are a modest source of sediments and non-point pollution sources, particularly where the land is in agriculture. The land use within the Ontario drainage basin is mainly agricultural and the sediments are generally characterized by silts and clays. The Clinton River Basin drains urban landscapes, whereas the Belle and Black Rivers drain gently rolling glacial till plains characterized by agricultural land uses. In the following pages the St. Clair River and Lake St. Clair are discussed individually.

Hydrology of the St. Clair River

The St. Clair River is a 63-km long strait connecting Lake Huron to Lake St. Clair. Its physical and hydraulic characteristics have been investigated in some detail, because of the river's role in navigation, sediment transport, and the movement of pollutants and ice.

Water velocities and flow times of the St. Clair River are illustrated in Figure 18. The river velocity ranges from 6.0 km/hr at the Blue Water Bridge to 1.1 km/hr at Lake St. Clair and averages 3.5 km/hr. Generally, the highest velocity is north of the town of St. Clair and decreases downstream. The lowest velocities occur in the delta and lake where gradients are significantly decreased. The flow time from Lake Huron to Lake St. Clair is 21.1 hours (Figure 18). The total average fall from Lake Huron to Lake St. Clair is 1.5 m (Korkigian 1963).

Derecki (1984) identified three distinct reaches of the St. Clair River on the basis of different hydraulic characteristics and water velocities. In its upper reach, from Lake Huron to the mouth of the Black River, the river falls

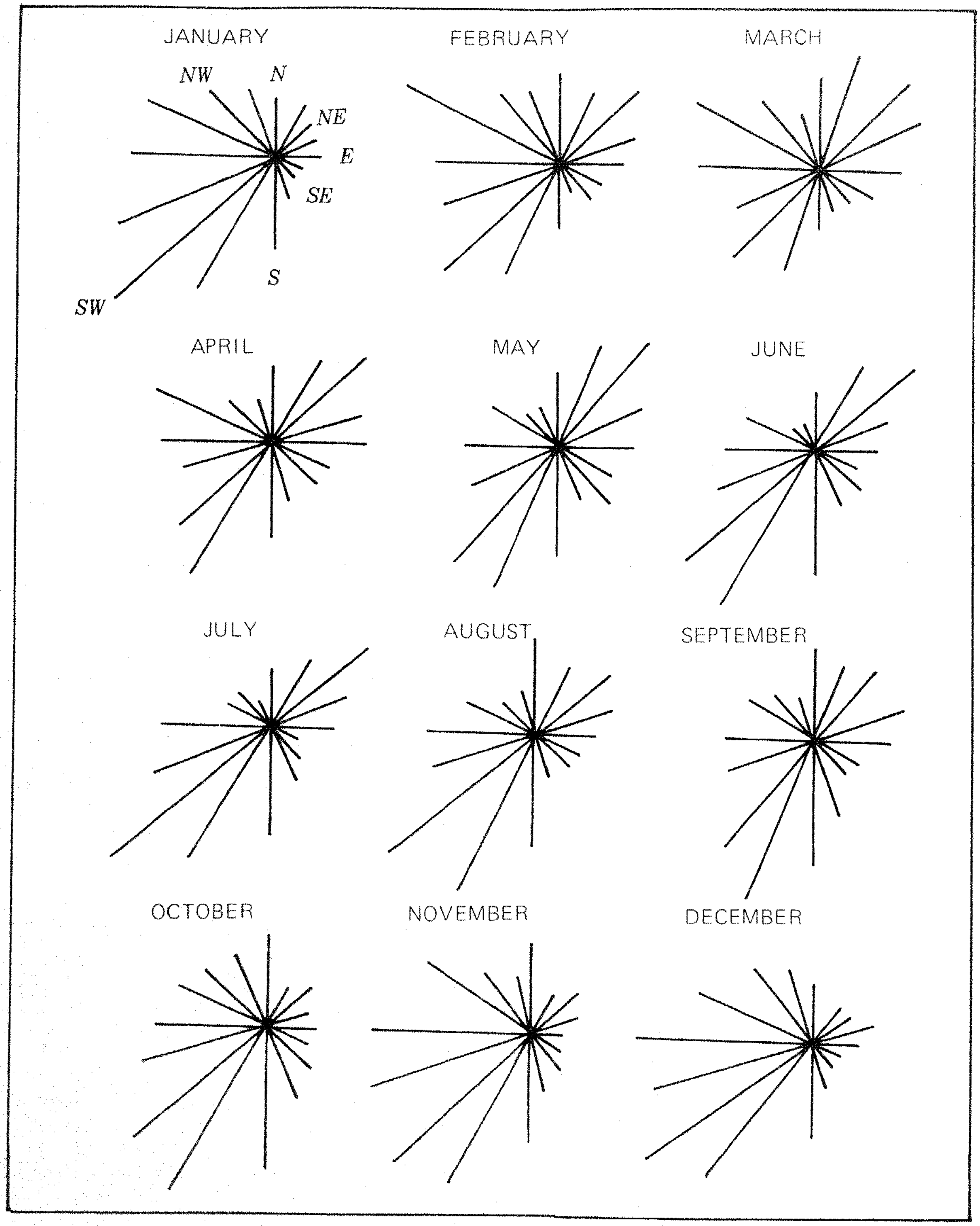


Figure 15. Monthly wind frequency for Windsor, Ontario, 1955–72 (Sanderson 1980).

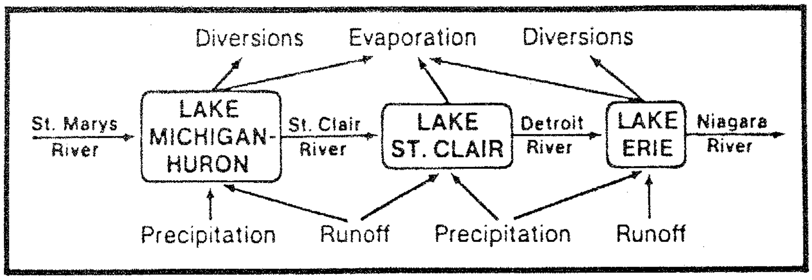


Figure 16. Hydrologic parameters of the St. Clair system (Quinn 1978).

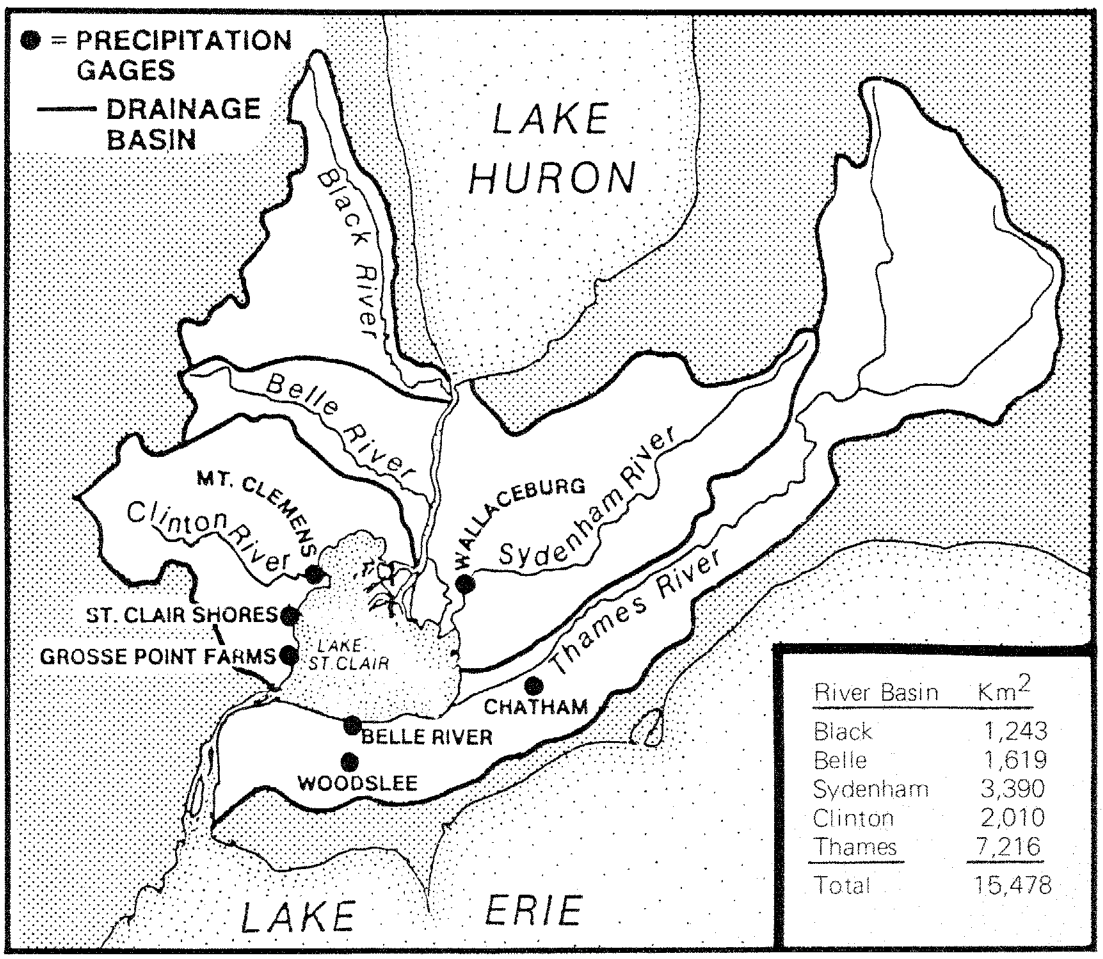


Figure 17. Drainage basins of the St. Clair system (After Quinn 1976).

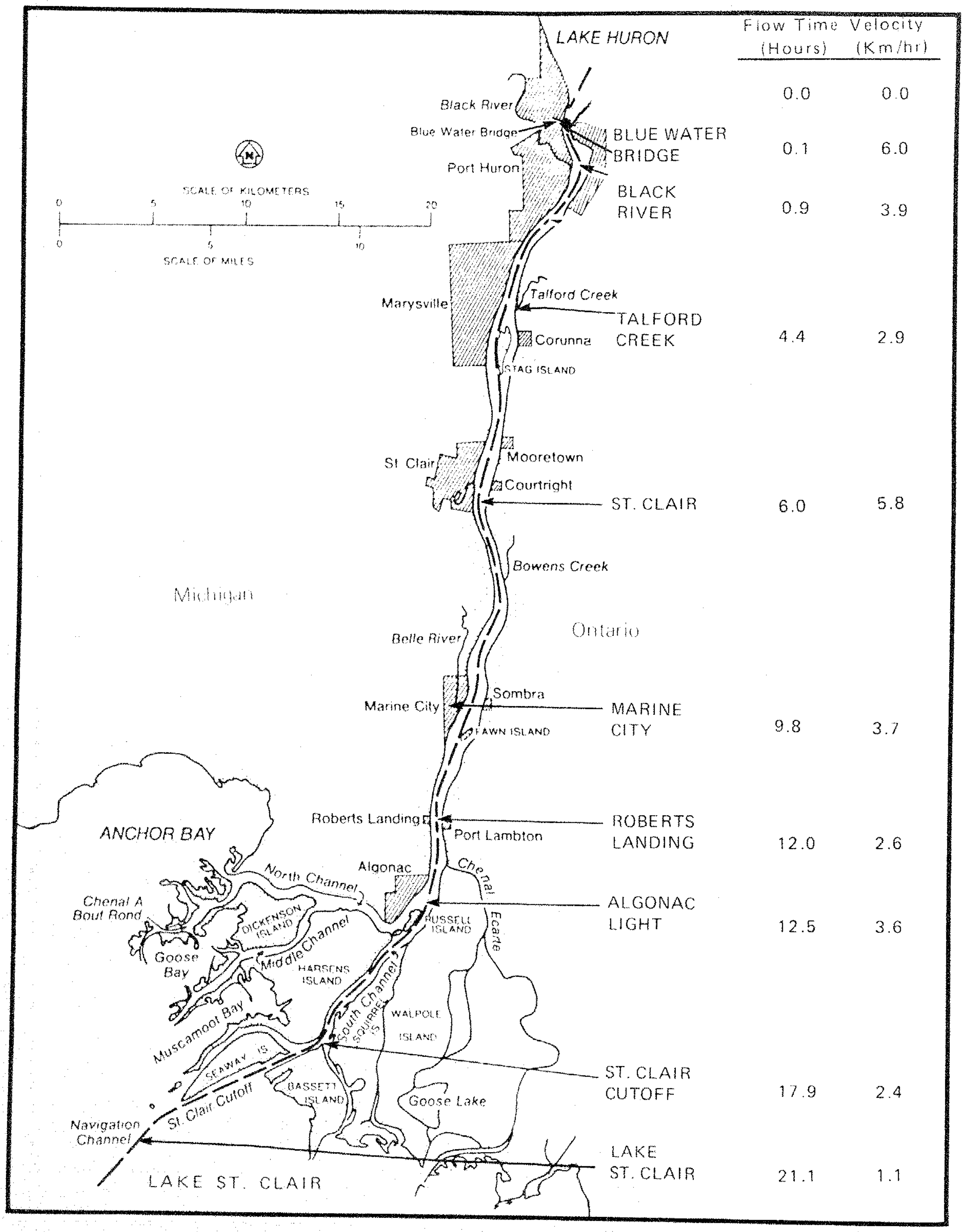


Figure 18. Average flow times and water velocities of the St. Clair River (Modified from Derecki 1983).

approximately 0.3 m in only 5 km. The channel there is generally less than 450 m wide, and the mid-channel depths vary from about 9 to 21 m. The minimum width (250 m) occurs at the Blue Water Bridge.

The middle reach of the river extends 40 km from the Black River to the apex of the St. Clair Delta near Algonac and falls only about 1.1 m. With few exceptions, this middle reach consists of a more or less uniform, rectangular channel approximately 600-900 m wide and 8-15 m deep. The uniformity of the channel is interrupted by Stag and Fawn Island and the St. Clair Middle Ground Shoal located opposite St. Clair, Michigan, where the channel widens to 1,200 m.

The lower reach includes the extensive delta region, which extends downstream for 18 km to Lake St. Clair. In this reach, the river falls less than 0.2 m and is divided into several distributary channels with gentle slopes. Channel depths are extremely variable but average 12 m. The maximum and minimum channel depths occur in the delta. Water depths reach 27 m in the North Channel south of Algonac, and dwindle to less than 3 m over river-mouth bars in distributary channels.

During short-term storm surges, Lake Huron water levels may rise and velocities may exceed the norm by 1.5 times. The lower flow velocities in the Algonac area permit the formation of ice jams, which in turn decrease river flow and create flood problems upriver.

The St. Clair River contributes 98% of the water to the Lake St. Clair basin. The remaining 2% is contributed by other lake tributaries (e.g. Clinton, Thames, and Sydenham Rivers). The average monthly discharge of the river from 1900 through 1981 was 5,121 m^3/s (Figure 19). The variation in discharge is rather modest, ranging from a low in February of 4,250 m^3/s to a high in August of 5,444 m^3/s. As stated earlier, the St. Clair River is not a true fluvial system but rather a strait connecting Lakes Huron and St. Clair. It therefore does not exhibit the seasonal flow variation typical of most river systems and significant natural

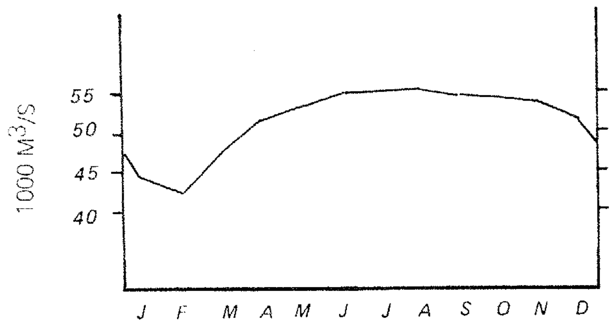


Figure 19. Average monthly discharge of the St. Clair River, 1900-80 (Quinn and Kelly 1983).

channel modification, normally linked to extreme flow regimes, is lacking. Deposition of delta and floodplain landforms are normally associated with spring floods and the influx of high sediment loads. These features do occur in the St. Clair system; however, their development is more closely related to sporadic events, such as major ice jams, rather than spring flooding.

Figure 20 reveals the flow distribution within the distributary channels of the delta. The discharge of the river north of Chenal Ecarte is 5,121 m^3/s. Eight percent of this flow (410 m^3/s) passes through the Ontario distributaries, exclusive of the St. Clair Cutoff Channel. Most of the discharge (92%) passes through the main channels to the west. The skewed distribution suggests that the Michigan sector of the delta is experiencing the more active growth.

Estimates of the hydraulic retention time of Lake St. Clair range from 2 to more than 30 days (average of 9 days) depending on wind conditions (Schwab and Clites 1986).

Channel dredging in the St. Clair River since 1900 has altered river levels and discharge to Lake St. Clair. Dredging activities included commercial gravel removal between 1908 and 1925 and completion of 7.7- and 8.3-m deep navigation channels in 1933 and 1962, respectively (Derecki 1982). These channel changes

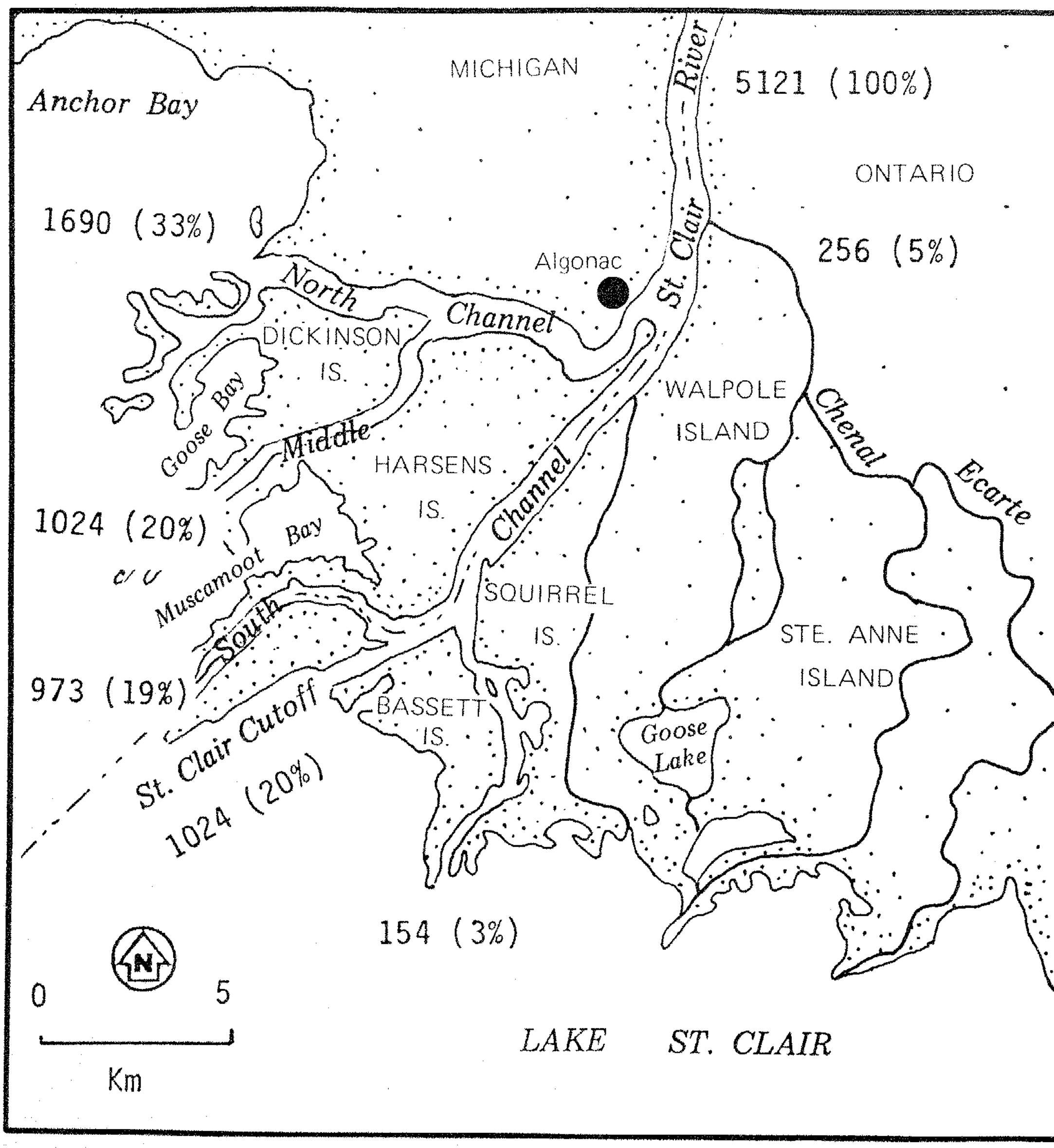


Figure 20. Average flow distribution in the St. Clair Delta (USACE 1968). Flows are shown as m^3/s and (in parentheses) percent of total.

increased the discharge of Lake Michigan and Lake Huron through the St. Clair River and permanently lowered the levels of Lakes Michigan and Huron by 0.27 m (Derecki 1985). With average flow velocities reaching 3.2 km/hr, the travel time of surface water through the St. Clair River is relatively high. The construction of the St. Clair Cutoff Channel in 1962 decreased the flow in the North channel of the river and decreased the proportion of St. Clair River water entering Lake St. Clair through Anchor Bay.

<u>Lake St. Clair Water Levels</u>

Lake level changes and their duration play an important role in the character of Lake St. Clair, its shoreline, and its wetland communities. In general, high and stable water levels favor fish stocks of the lake by providing more spawning and nursery areas, whereas low water conditions rejuvenate stands of many wetland plants (Keddy and Reznicek 1985). Conversely, high water levels, when combined with storm events, encourage higher flood frequencies and coastal erosion. The wetland communities of Lake St. Clair respond to long-term water changes and adjust to such changes over time.

Lake St. Clair has an established elevation of 174.65 m above mean sea level, but that water level is often exceeded (Figure 21). The average lake level of Lake St. Clair in 1900-86 was 174.73 m. The lake has had a record high of 175.78 m (October 1986) and a record low of 173.71 m (January 1936). Low water or chart datum is 174.25 m. This level is a fixed reference plane (i.e., International Great Lakes Datum) selected by the U.S. and Canada. Water levels normally are lowest in February and highest in July. The high levels of Lake St. Clair in 1973 (Figure 21) were attributed to a 16% increase in precipitation and a 24% decrease in evaporation which occurred across the basin in 1972.

The most significant long-term factor affecting the level of Lake St. Clair is probably precipitation. Figure 21 suggests that precipitation in the Great Lakes in 1950-86 was above average in most years. The below average precipitation in the mid-1960's corresponds to the lower water levels in the lakes at that time. During the 1970's and the 1980's, with the exception of 1976, precipitation was above average. Record high precipitation in 1985 and a surplus over the past decade

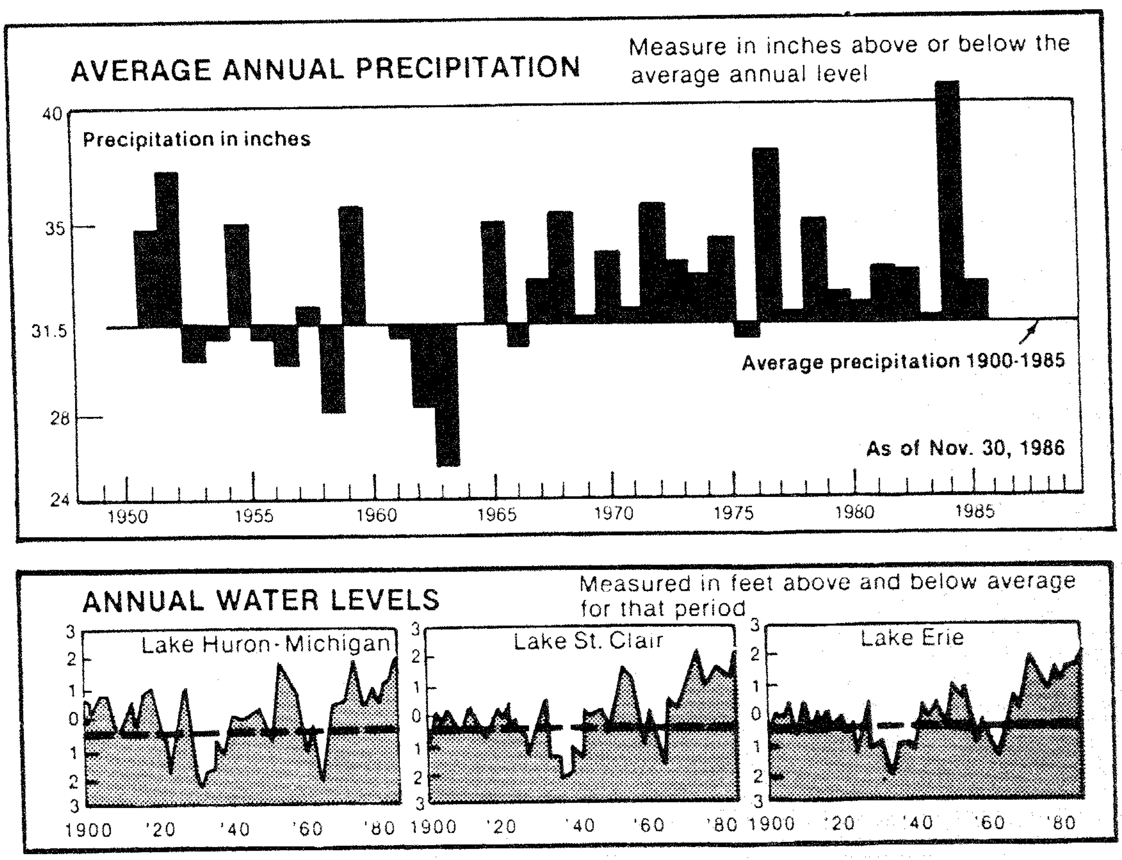


Figure 21. Average annual precipitation and annual water levels for Lakes St. Clair, Erie, and Huron-Michigan (GLPWC 1987).

has resulted in near-record high lake levels for the St. Clair system.

All the Great Lakes, including Lake St. Clair, experience changes in water levels due to short- and long-term weather and climatic changes. Short-term changes include changing barometric gradients which alter water levels for a period of several hours. A storm surge in November 1940 raised the water level 0.5 m for approximately 48 hr on the south shore of Lake St. Clair at Tecumseh, Ontario (Murty and Polavarapu 1975). Short-term depressions of water levels following a storm surge provide some flushing action and sometimes introduce nutrients from marshes into bays and nearshore waters of the lake. However, such depressions are probably too short-lived and too infrequent to have a significant impact.

Ice jams are a common occurrence on the St. Clair River and often impede interlake shipping during February-April in the St. Clair River (Figure 22). Ice jams reduce the outflow from Lake Huron and raise its level, while reducing inflow to Lake St. Clair and lowering its level. During the winters of 1904-05 and 1905-06, for example, average inflow from Lake Huron to Lake Erie decreased 1,369 m^3/s over four months and 904 m^3/s over five months (Bolsenga 1968).

Figure 22. A bulk carrier navigating through an ice jam in the upper St. Clair River (Photograph by A. Ballert, Great Lakes Commission).

Figure 23 shows the impact of a record ice jam in the St. Clair River on the water level of Lake St. Clair in 1984. February was relatively mild and Lake Huron was largely ice-free. However, exceptionally cold weather followed and ice cover formed over the entire lake by about March 10th (GLC 1984). By April, Lake Huron was covered by drifting ice and the head of the St. Clair River was frozen over. Winds from the east and north prevailed for about 3 weeks and caused the massive ice jam. With ice clogging the 62.5 km course of the St. Clair River until the end of April, jams of 3 m or more in depth developed at the apex of the delta. This situation led to a decrease in discharge from the monthly average of 5,096 m^3/s to about 2,520 m^3/s for April. At this time, the water level dropped about 0.4 m in Lake St. Clair, dewatering large areas of wetlands surrounding the lake. Ice jams created flooding on the river in winter 1986-87 that caused the U.S. Coast Guard to send five ice-breaking vessels to the Algonac area in March, 1987.

2.3 CURRENTS AND WATER MASSES IN LAKE ST. CLAIR

Leach (1980) identified two discrete water masses in the lake on the basis of cluster analysis of physical and chemical data: a northwestern mass, consisting primarily of Lake Huron water flowing from the delta region, and a southeastern mass of more stable water enriched by nutrient loadings from Ontario tributaries and shoreline urban development. Ayers (1964) modeled field data before and after the construction of the St. Clair Cutoff Channel and found that wind influenced the lake's current pattern much more significantly than channel construction. Recent numerical modeling of lake circulation (Ibrahim and McCorquodale 1985) confirm

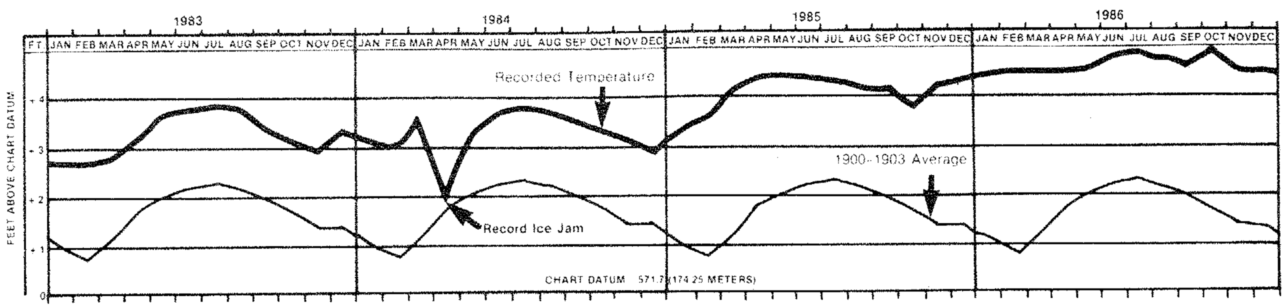


Figure 23. Effects of a record ice jam in the St. Clair River on Lake St. Clair water levels during March – April 1984 (Redrawn from USACE 1986).

the earlier findings of Ayers (1964) and Leach (1980).

In Lake St. Clair the extent and geometry of the circulating water masses are related to wind direction (Figure 24). The prevailing winds in the region are from the southwest, but winds from virtually any quadrant will generate current patterns that result in some degree of isolation of the water mass on the west side of the lake from the water mass on the east side. Perhaps the most distinctive separation is associated with north or northwest winds.

Winds also produce characteristic circulation patterns in Anchor Bay. Water in the bay originates from two distinct sources (Ayers 1964). With southwest winds, there is a net diminution of outflow through North Channel and the creation of a discrete gyre in Anchor Bay composed of Clinton River water. However, with a north wind, Anchor Bay is dominated with water from the North Channel of the St. Clair River as the inflow of Clinton River water is reduced in the bay.

The significance of the two lake water masses lies in their relationship to biological productivity in the lake. The water mass adjacent to Ontario is more influenced by nutrient loadings from the Sydenham and Thames Rivers and the smaller tributaries from Ontario. These waterways drain an intensively cultivated lake plain. Urban development on the south shore of Lake St. Clair also contributes to the loading. Because this water mass is more enriched and more stable than the mass associated with St. Clair River water, it has greater biological productivity (Leach 1972, 1973).

The input of relatively clean water from Lake Huron and the short flushing time of Lake St. Clair (2-30 days) have prevented nutrient concentration and eutrophication and helped stabilize the fish communities over time in most of Lake St. Clair. According to Johnston (1977), fish stocks over the past century have remained reasonably stable, in spite of more intensive agricultural practices in the watershed, increased settlement in the coastal zone, and exploitation of the resource by commercial fisheries.

2.4 REGIONAL GEOMORPHOLOGY OF THE CONNECTING CHANNELS

The St. Clair River

Normally, a river depositing a delta at its mouth is characterized by complex bends or meanders, cut-off channels and oxbow lakes. The St. Clair River is morphologically unusual in that it is a strait with no large network of tributaries. Most rivers depositing deltas are laden with finer sediments. Nine bore holes between the town of St. Clair southward to the apex of the delta reveal that sand and gravel are the principle sediments transported by the river (Wightman 1961). Water clarity in the St. Clair River is exceptionally high and the region is often referred to as "Blue

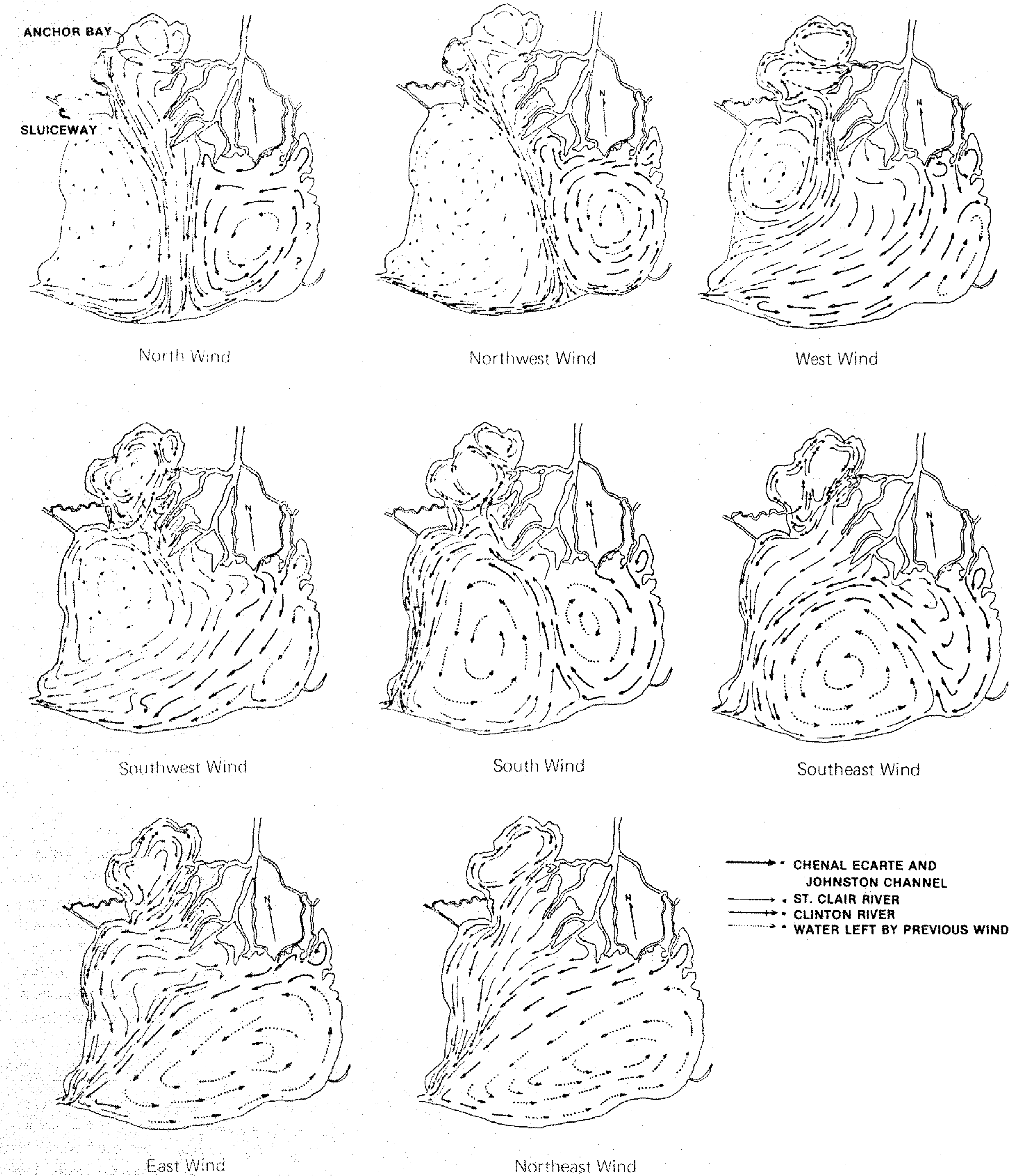


Figure 24. Current patterns in Lake St. Clair under various wind directions (Ayers 1964).

Water Country" by local tourist agencies. Even during stormy conditions the river retains an aqua or blue-green color. The river essentially is flowing through glacial moraine and lake plain topography and has cut its channel in lake clays, which (according to Hjulstrom's curve) are more difficult to erode than sand (Ritter 1986). Although the St. Clair River has created a channel in very fine sediments, the bulk of the sediments being transported are coarser. The entrenchment of the river in fine (clay) sediments may account for the straightness of the river and the lack of floodplain features, such as meanders and oxbow lakes, typical in many alluvial valleys.

Before modern times, the St. Clair River developed a channel west of the present river channel (Figure 25). This channel (Leverett and Taylor 1915) begins at St. Clair, Michigan and parallels the river for 13 km. South of Marine City the channel veers eastward, crosses the modern river, and integrates itself with the interlaced channels on Walpole Island. The mouth of the old channel has been occupied by the Pine River, which has incised its own channel within the old valley.

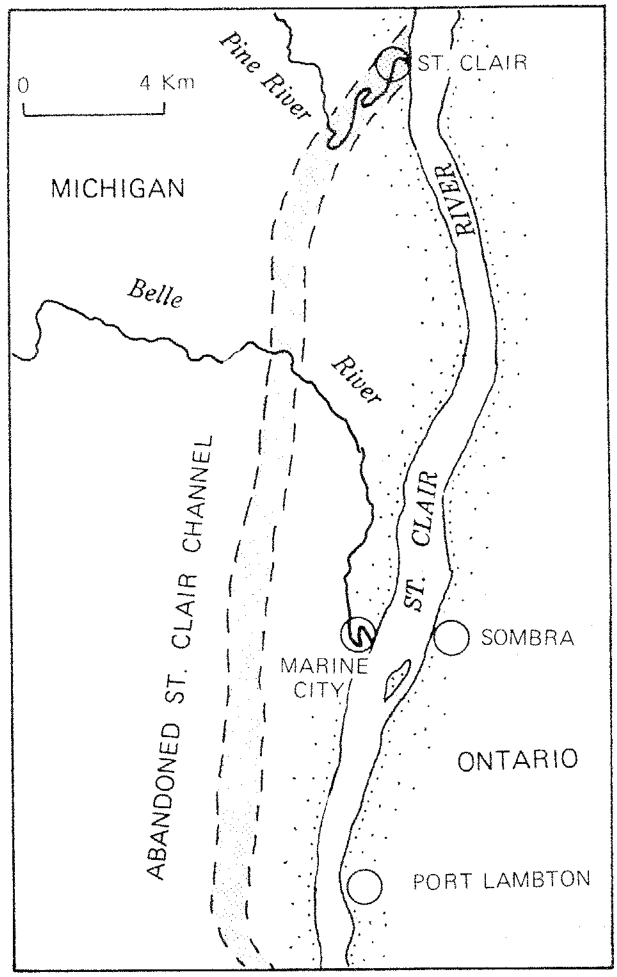


Figure 25. The present and older channel of the St. Clair River (Wightman 1961).

Lake St. Clair Shoreline

The basin of Lake St. Clair is underlain by lake clays deposited some 10,000 to 15,000 years ago. Low, fragmented ancestral shorelines above the present lake suggest that Lake St. Clair was at a slightly higher level in the past. These ancient shorelines roughly parallel the present shoreline from Detroit northward. In Ontario, ancient shorelines are not evident, and the margin of the lake, including the St. Clair Delta area, is classified as a sand plain (Chapman and Putnam 1973).

The eastern shoreline of the lake is low lying and characterized by agricultural and recreational land uses. Low barrier islands parallel the shoreline and are colonized by marsh vegetation. Locally, however, trees occur on the slightly higher ground of the barriers, which are less than 170 m in width and probably not more than 1 m above the level of the lake. Landward shallow lagoons sparsely colonized with emergent wetland plants exist. The wetland zone, which is approximately 1 km wide, extended farther inland (east) in the past. The low plain has been ditched and drained, and wetland tracts in the coastal zone diked. Rutherford (1979) documented a 39% decline in Canadian wetland acreage from 1910 to 1978. McCullough (1982) concluded that the shoreline wetlands have been destroyed by agricultural drainage and not lost to coastal erosion processes. This suggests that the coastal barriers provide a line of defense from wave attack to the lagoon and wetland zone. It has been determined that annual net erosion rates on the south shore of Lake St. Clair are in excess of 2 m/yr (OMNR 1975). However, other coastal reaches on the south shore are actually accreting at rates of up to 0.43 m/yr.

Flow Regime and Sediments of the St. Clair River

Deltaic land forms occur where substantial quantities of clastic sediment are introduced and deposited into a receiving basin. Sediment is normally eroded from a drainage basin and transported down an alluvial valley by a stream and its tributaries. Therefore, the rate of delta development is dependent upon the flow regime and the availability of sediments.

The principal source of sediments to the St. Clair Delta appears to be the shorelines of southern Lake Huron. Although some organic matter is carried in suspension, the clastic fraction is dominant. In terms of composition, quartz sand is the most common, but fragments of feldspar, chert, carbonate minerals, and igneous and metamorphic rock fragments also occur (Sachdev and Furlong 1973). According to Duane (1967), the mean diameter of the suspended river sediment is 0.17 - 3.16 mm, while the mean diameter of the bed load is 1.98 - 2.64 mm. Detailed sedimentological studies suggest that the shallow bays of the delta are composed of sorted deposits of fine (0.115 mm) sand (Mandelbaum 1969), and it may be concluded that the St. Clair Delta is composed of sand-sized sediments. In contrast, most marine deltas consist of sediment fractions finer than sand. Also, the organic deposits which occur in the St. Clair Delta were formed in place, unlike those in marine deltas which are formed elsewhere and transported into the delta complex.

Estimates of the sediment load of the river have been compiled by Pezzetta (1968). Sediment loads are extremely variable and depend upon weather and river current conditions. Sediment loads are highest at the head of the river (54,700-61,600 m^3/yr) and lowest downstream (19,900 m^3/yr). River velocity may decrease downstream, which would account for lower sediment loads downstream and sediment deposition in the delta region.

River velocities are high enough to transport beach sands from southern Lake Huron to Lake St. Clair. Sediment deposits in the nearshore zone of Lake Huron have a mean diameter of 0.125 - 0.25 mm and, according to Duane (1967), the greatest number of clastic sediments suspended in the St. Clair River have mean diameters of slightly finer sizes. This suggests that the delta is derived from reworked nearshore sand sediments in Lake Huron rather than from local streams tributary to the St. Clair River, which have finer sediments.

Delta Features

The most significant landform in the St. Clair system is the Lake St. Clair Delta, which is commonly referred to as the St. Clair "Flats" (Figure 26). Another delta of modest size occurs at the mouth of the Clinton River. The Clinton River Delta is a digitate delta with a single distributary channel and a pair of narrow levees extending lakeward. This delta has been altered by the construction of marinas, a spillway, and numerous housing developments.

Deltas usually have two large morphological units: the prodelta deposits and the subaerial deposits. The prodelta deposits are submarine sediments on the floor of the water body. They are usually composed of finer sediments and represent submarine plateaus upon which the subaerial delta is deposited. In Figure 26 the semicircular prodelta deposit is well defined by the 6-foot depth contour. This deposit is introduced by the river. The composition of the prodelta of the St. Clair Flats has not been investigated in detail, but preliminary sediment sampling suggests it is composed of silt and fine-sand size sediments. The portion of the delta located at or above water level is the subaerial delta characterized by the landform features noted below.

The St. Clair Delta exhibits several of the landform characteristics of marine deltas, such as active and inactive distributaries, interdistributary bays, and crevasses or breaches in the channel banks which lead to interdistributary bays. The St. Clair Delta has a classical

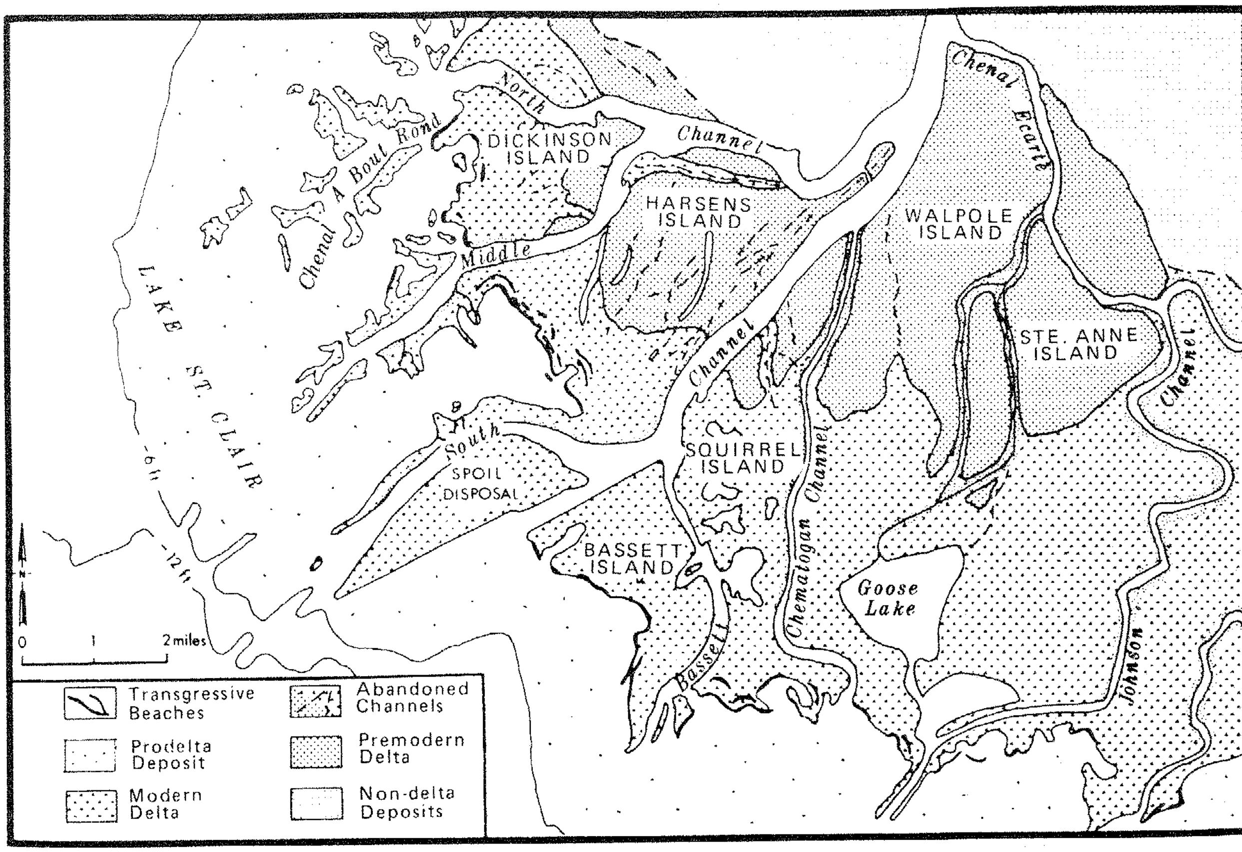


Figure 26. The St. Clair Delta (Raphael and Jaworski 1982).

bird-foot morphology, as does the Mississippi River Delta, but significant landform differences are also apparent. Atypical landforms include a premodern surface located at the apex of the delta and unusually wide distributary channels.

The North, Middle, and South Channels, which are active distributaries, average 500 m wide and 11 m deep (maximum: 675 m wide and 26 m deep). At the mouths of the distributaries, channel depths decrease abruptly, indicating the presence of river mouth bars 2-4 m below mean lake level. As a depositional basin, Lake St. Clair is relatively small, with a maximum depth of 7 m and width of 40 km.

Because the water level fluctuates only 45-60 cm seasonally, spring floods are not a normal occurrence within the delta; hence, natural levees are scarcely discernable adjacent to modern distributaries. Because levees are poorly developed, averaging 10-45 cm in elevation, some flooding does occur. As a levee is breached, crevasse deposits are flushed into the interdistributary bays at right angles to the channel (Figure 27). With continued deposition, the open-water bay will be filled with crevasse deposits and eventually colonized by sedges and emergent aquatics.

Crevasse channels, locally known as "highways," are operative for years because deposition into the bays is not rapid. A comparison of navigation maps reveals that such features may be part of the delta landscape for over a century. Pezzetta (1968) compared the western portion of the delta front between 1903 and 1961 and found crevasse fills over the 56-year period were minor. In fact,

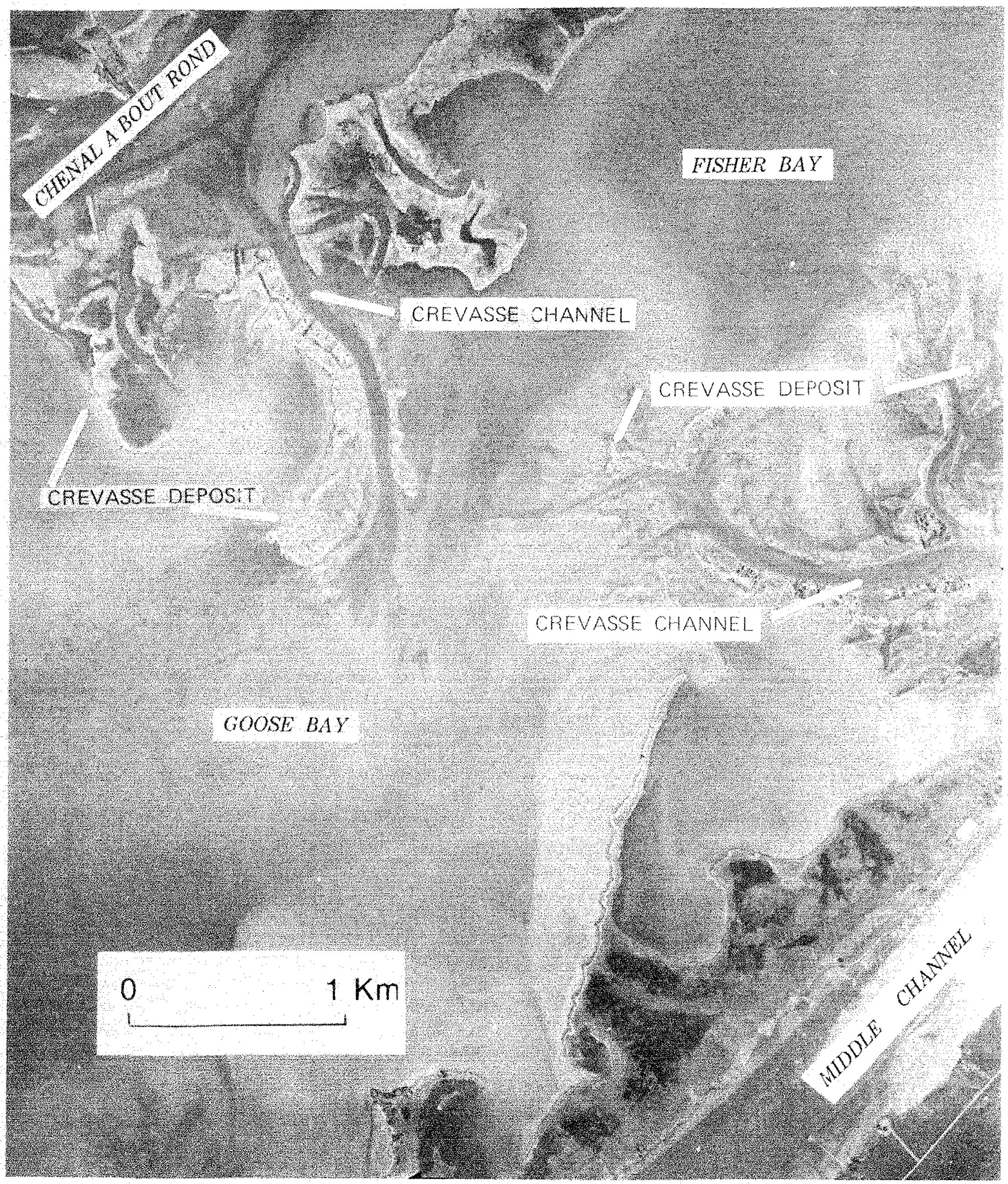


Figure 27. Crevasses and interdistributary bays in the St. Clair Delta, April 1949 (Photograph by Detroit Edison Company).

man-made alterations such as dredging and bulkheading dominated the landscape. This suggests that crevasse channels are active intermittently and transport little sediment into the interdistributary bays.

When Lake St. Clair is frozen, pack ice accumulates at the mouths of distributaries to form ice jams. Channel flow is then diverted into crevasses and some overbank flow may occur. However, because the dominant grain size is sand, little bedload sediment is transported from the deep distributaries into the interdistributary bays. Thus, in the St. Clair Delta, the filling of interdistributary bays and delta growth is a slow process.

Beaches on the present delta shore-line are poorly developed. On the Ontario side, berms may reach 1-1.5 m in height and are colonized with sumac and small trees. Borings reveal that the principal constituents of these beaches are coarse sand or fine gravel (0.3 mm or -1.5 phi units), separated by layers of sand and organic materials, including rafted logs, bulrush stems, and other debris.

Within the interdistributary marshes, especially on lower Dickinson and Harsens Islands, are arcuate-shaped features resembling beach ridges. Borings through one of these ridges revealed up to 3 m of fine sand (Raphael and Jaworski 1982). Washover deposits and organic sediments are not abundant, indicating that these features may be regressive beaches which formed the shoreline as delta accretion took place.

A comparison between the eastern and western portions of the St. Clair Delta illustrates two other differences. On the Canadian side, Chenal Ecarte and Johnson Channel (Figure 26) are narrow, shallow distributaries which do not carry a significant portion of the volume of the St. Clair River. Moreover, open interdistributary bays are few and are colonized by marsh vegetation. Delta extension has ceased and maximum delta accretion is now occurring to the west as evidenced by the active digital distributaries of North, Middle, and South Channels, and Chenal A Bout Rond. In the past, Chematogan and Bassett Channels were approximately 500 m wide, comparable to the modern distributaries, but they have been filled with alluvium and colonized by aquatic plants as abandonment occurred. Delta migration has occurred from east to west at the shoreline of Lake St. Clair. As the Canadian distributaries degenerated, new distributaries were created on the western side of the delta.

Delta Stratigraphy and Geomorphic History

A series of borings, cores, and exposures indicates that in cross section the St. Clair Delta is a thin, sandy deposit (Raphael and Jaworski 1982). An east-west cross section reveals that above the shale bedrock, lacustrine clays have been deposited over a thin deposit of glacial till (Figure 28). The coarse deltaic deposits, having a maximum thickness of 7 m, rest upon blue lake clays.

The north-south cross section from the apex of the delta into Lake St. Clair illustrates the near-surface stratigraphy (Figure 29). Topographically, however, this cross section reveals two distinct levels, a modern and a premodern surface. The premodern surface, standing about 1.5 m above Lake St. Clair, consists of coarse, oxidized sand and is confined to the apex of the delta complex. It has been dissected by long, sinuous channels which have been filled with alluvium. Occasionally, during high lake levels, these channels have been reoccupied, particularly in areas such as Dickinson Island, where human interference has been minimal.

This higher surface is topographically and sedimentologically distinct, which indicates that it was deposited during the higher pre-existing Nipissing lake level (Figure 30). The modern delta, with its fine sand sediment (0.125 - 0.25 mm), is located at present mean lake level and is represented by the active crevasses and interdistributary marsh deposits.

Figure 30 summarizes the relative geomorphological events of the St. Clair Delta, based on the chronology of the ancestral Great Lakes, field data, and available C-14 data. Since the retreat of the Late Wisconsin ice sheet, the outlets of the Great Lakes, and hence lake levels

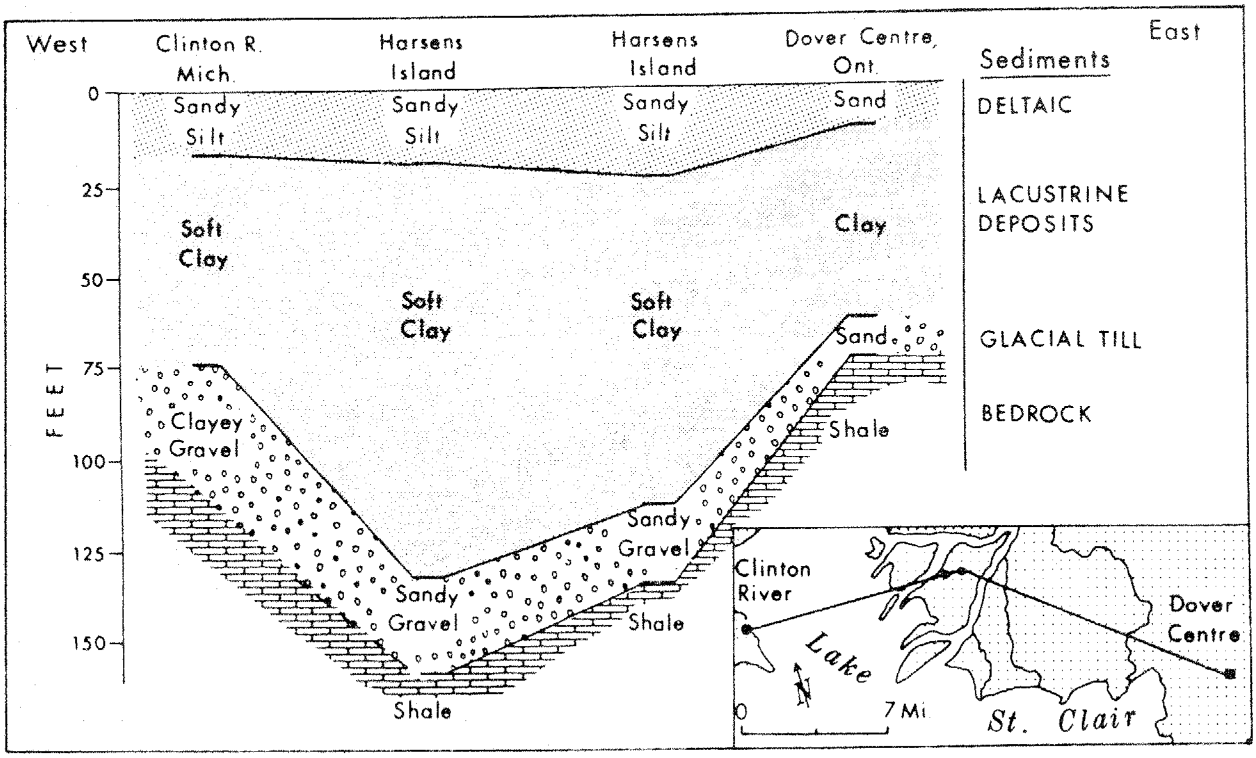


Figure 28. Stratigraphy of Lake St. Clair and the St. Clair Delta (Raphael and Jaworski 1982).

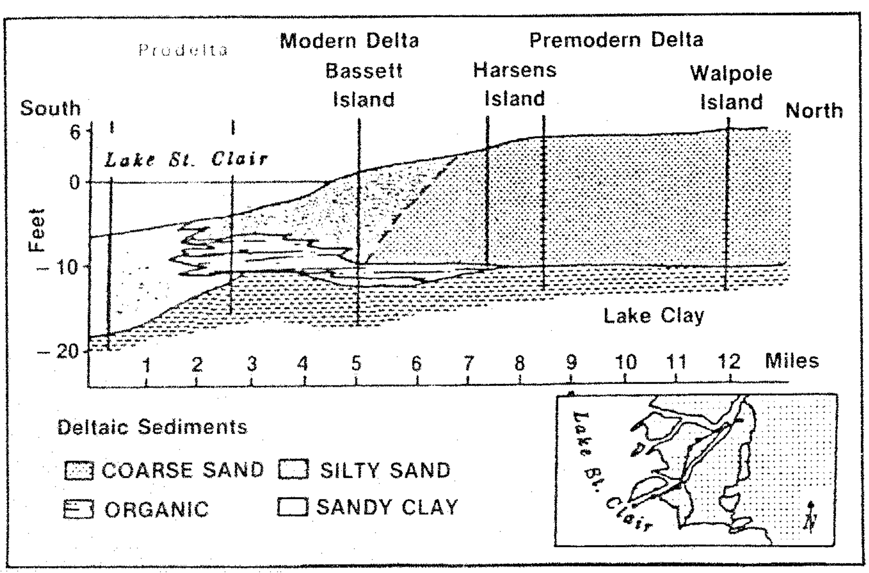


Figure 29. A cross section of the St. Clair Delta (Raphael and Jaworski 1982). The prodelta deposit extends from the shoreline to a depth of 6-8 feet.

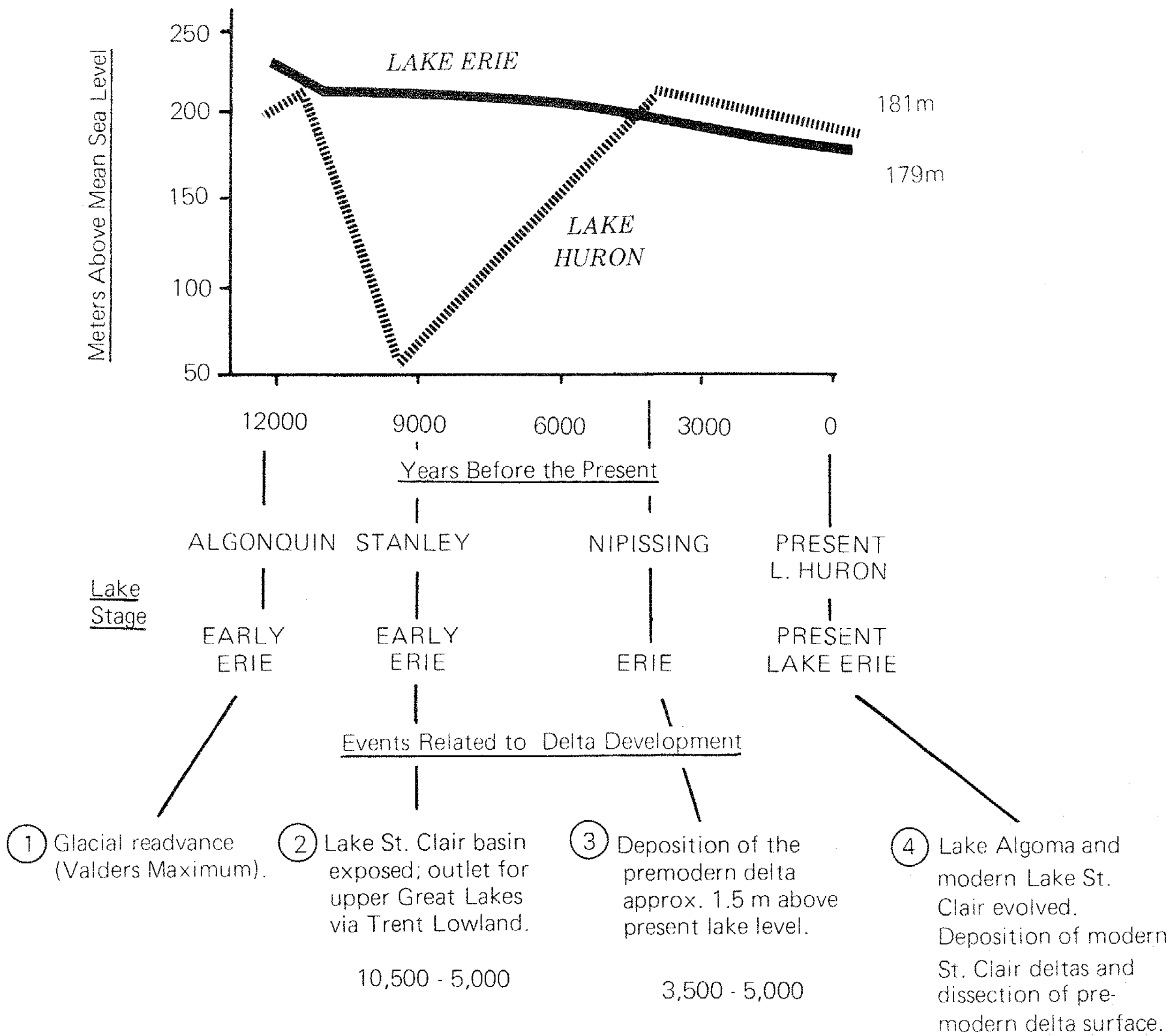


Figure 30. Lake levels and lake stages in the Huron and Erie basins (Dorr and Eschman 1970). Changes in water level in the ancestral lakes affected Lake St. Clair and the St. Clair Delta.

in the St. Clair basin, have oscillated sufficiently to construct two deltas. Compared to other evolving Great Lakes, Lake St. Clair was a less permanent feature as the lake bottom was modified by the fluctuating ice sheet which determined lake level conditions.

2.5 UNIQUENESS OF THE ST. CLAIR DELTA

A morphological comparison of the St. Clair and Mississippi River Deltas (Jaworski and Raphael 1973; Table 5) reveals that factors such as flow regime and structural behavior of the depositional basins are indeed different. The only similarity between the two deltas is the offshore profile which partially controls wave energy. Delta morphology is basically a function of the relative influence of river depositional processes versus coastal processes and submarine topography (Wright and Coleman 1973). Because of the short fetch, the wave energies of Lake St. Clair are low,

Table 5. Physical factors influencing lake and marine delta morphology (Raphael and Jaworski 1982).

Factors	Characteristics	St. Clair Delta	Mississippi Delta
Geomorphic	Base level	Long- and short-term variations	Stable
	Flow regime	Seasonally constant	Seasonally variable
	Channel diversion	Downstream (Spring ice jams)	Within alluvial valley (Spring floods)
	Structural behavior of basin of deposition	Stable	Sediment compaction and significant subsidence
	Dominant sediment size	Fine to coarse sand	Clay to silt
	Relative rate of sedimentation	Slow	Rapid
Marine	Relative wave energy	Low	Low
	Offshore profile	Flat and gently sloping	Flat and gently sloping

resulting in a prograding delta with a digital shape.

In summary, it is apparent that the St. Clair River Delta is not only unique, but complex. Surficially, the delta is composed of three deposits or lobes superimposed on a submarine prodelta feature. Historically, as the St. Clair River emptied into Lake St. Clair, the older premodern delta was deposited. Subsequently, the lake level dropped, exposing the premodern surface to weathering and erosion (Figure 30). The premodern delta sediments were oxidized and the linear channels dissected the surface. Two modern deltas were then formed. Modern Delta I was deposited in Ontario, creating lower Ste. Anne and Walpole Islands. Chematogan, Chenal Ecarte, and Johnson Channels were the principal streams at this time and extended the delta into Lake St. Clair. As the St. Clair River sought a steeper slope, the Ontario distributaries were abandoned in favor of the newly created North, Middle, and South Channels. Deposition continued in Michigan waters and Modern Delta II was deposited. Delta growth is anticipated to continue because the greatest discharge (91%) is through the modern distributary channels.

CHAPTER 3. BIOLOGICAL CHARACTERISTICS

3.1 PHYTOPLANKTON AND PERIPHYTON

Phytoplankton in the St. Clair River more closely resemble those in Lake Huron than those in Lake St. Clair and include the diatoms *Cyclotella*, *Fragilaria*, *Melosira*, *Stephanodiscus*, *Synedra*, and *Tabellaria* (ENCOTEC 1974; Vollenweider et al. 1974). *Tabellaria* and *Fragilaria*, respectively, dominate the spring and fall populations at the head of the river (Williams 1972). In Lake St. Clair, 71 species of phytoplankton have been identified. *Fragilaria* and *Tabellaria* are common except in July-August when the blue-green algae (Cyanophyta) dominate the phytoplankton community (Winner et al. 1970; MWRC 1975). Peak population densities, averaging nearly 4,000,000 cells/L, occur in July and August. During this period, a single blue-green alga, *Oscillatoria*, tends to dominate the phytoplankton. *Microspora*, a filamentous green algae, was also common in Lake St. Clair. This taxon is usually found in embayments and marshes, and may be transported into the lake proper by winds and currents.

No studies of periphyton have been conducted in the St. Clair system, but a recent study in nearby western Lake Erie (Manny et al. 1985) showed that the diatoms *Gomphonema* and *Diatoma*, green algae (primarily *Ulothrix*), the blue-green *Oscillatoria*, and a red alga (*Bangia*) are common overwintering taxa, and that *Cladophora*, a filamentous green alga, dominates during June-August. A similar periphyton community may exist in the St. Clair system.

3.2 MACROPHYTES AND MACROALGAE

At least 21 submersed plant taxa occur in the St. Clair system (Schloesser and Manny 1982; Hudson et al. 1986). The most common native taxa are *Chara* sp. (macroalga), *Vallisneria americana*, *Potamogeton richardsonii*, and *Elodea canadensis* (Table 6). *Chara* sp. includes *Nitella* sp. (Figure 31) and muskgrass, which are often difficult to distinguish from each other. They have short (muskgrass) or medium-length (*Nitella*) branches that arise from the main stem. Muskgrass emits a distinctive musky or skunk-like odor when crushed between the fingers. Both overwinter as green plants. *Nitella* is often found in deeper water (to a depth of 27 m) where few other plants are present. *Vallisneria* (Figure 32) has straight, ribbon-like leaves that all arise from the base of the plant. Leaves are limp, long, and usually have a light green midrib. In summer, plants may have small pods on the ends of long stalks that originate at the base of the plants. *Elodea* (Figure 33) has slender stems up to 3 m long with three leaves in clusters around the stems. Leaves are bunched toward the ends of the stems where new growth occurs; older leaves usually decay nad break off the lower stems. Waterweed may rapidly colonize an area and then decline in abundance within 5 to 7 years. *Potamogeton richardsonii* (Figure 34) derives its common name, clasping-leaf pondweed, from the manner in which its leaves partly surround the stem. Leaves have 3-7 easily visible veins and 10-16 weaker veins that run the length of each leaf; the leaf margins are usually wavy. All three species are among those used extensively by fish and waterfowl (Table 7).

Table 6. Distribution and abundance of submersed plants in the St. Clair system (Schloesser and Manny 1982). Tabular values are the percent frequency of occurrence among stations sampled in each water body segment of the system.

Scientific name	Common name	St. Clair River	Lake St. Clair	
			Anchor Bay	Lake proper
Vallisneria americana	Wild celery	28	42	11
Chara sp.	Muskgrass	68	62	7
Potamogeton richardsonii	Redhead grass	49	13	4
Myriophyllum spicatum	Eurasian watermilfoil	28	30	5
Elodea canadensis	Waterweed	36	20	4
Heteranthera dubia	Water stargrass	<1	2	4
Potamogeton spp.	Narrow-leaf forms	24	12	0
Najas flexilis	Naiad	<1	43	2
Potamogeton gramineus	Variable pondweed	11	3	0
Ceratophyllum demersum	Coontail	0	3	0
Myriophyllum exalbescens	Watermilfoil	<1	2	0
Nymphaea sp.	Water-lily	0	0	0
Potamogeton spp.	Broad-leaf forms	2	0	0
Potamogeton crispus	Curly pondweed	2	0	0
Potamogeton illinoensis	Illinois pondweed	0	0	0
Potamogeton natans	Floating-leaf pondweed	<1	0	0
Potamogeton nodosus	Long-leaf pondweed	2	0	0
Potamogeton zosteriformis	Flatstem pondweed	<1	0	0
Ranunculus sp.	Buttercup	2	2	0

Submersed plant stands are usually composed of 2-3 species, with a recorded maximum of 11 species. Chara is the only taxon consistently occurring in monotypic stands. The greatest water depth colonized by plants has not been adequately documented, but most stands occur at depths of less than 3.7 m. The 0-3.7 m depth interval in the St. Clair River and Lake St. Clair covers approximately 16 and 628 km² respectively, and plant coverage of the bottom within this depth interval is 92% in Anchor Bay, 88% in the St. Clair River, and 35% in Lake St. Clair proper. The lower plant coverage in Lake St. Clair may reflect the more exposed nature of the littoral habitat in the lake proper.

To date, three exotic submersed macrophyte taxa have been found in the St. Clair system: Potamogeton crispus, Nitellopsis obtusa, and Myriophyllum spicatum. Potamogeton crispus (Figure 35) is generally assumed to have been introduced from Europe, and was first recorded in the Great Lakes in 1946 (Voss 1972) and in Lake St. Clair in 1974 (Dawson 1975). The plant derives its common name, curly pondweed, from the wavy margins on the sides of its leaves. The leaves are dark green with a reddish hue and small serrations along the margins. Plants may grow up to 2 m long and can spread by re-rooting small fragments. P. crispus is one of the first aquatic plants to appear in the spring, and it is important because it is colonized by invertebrates that are eaten by waterfowl on their northward migration. As one of the most abundant macrophytes in the St. Clair system from April-June, it is also important as a spawning substrate for fish (Schloesser 1986).

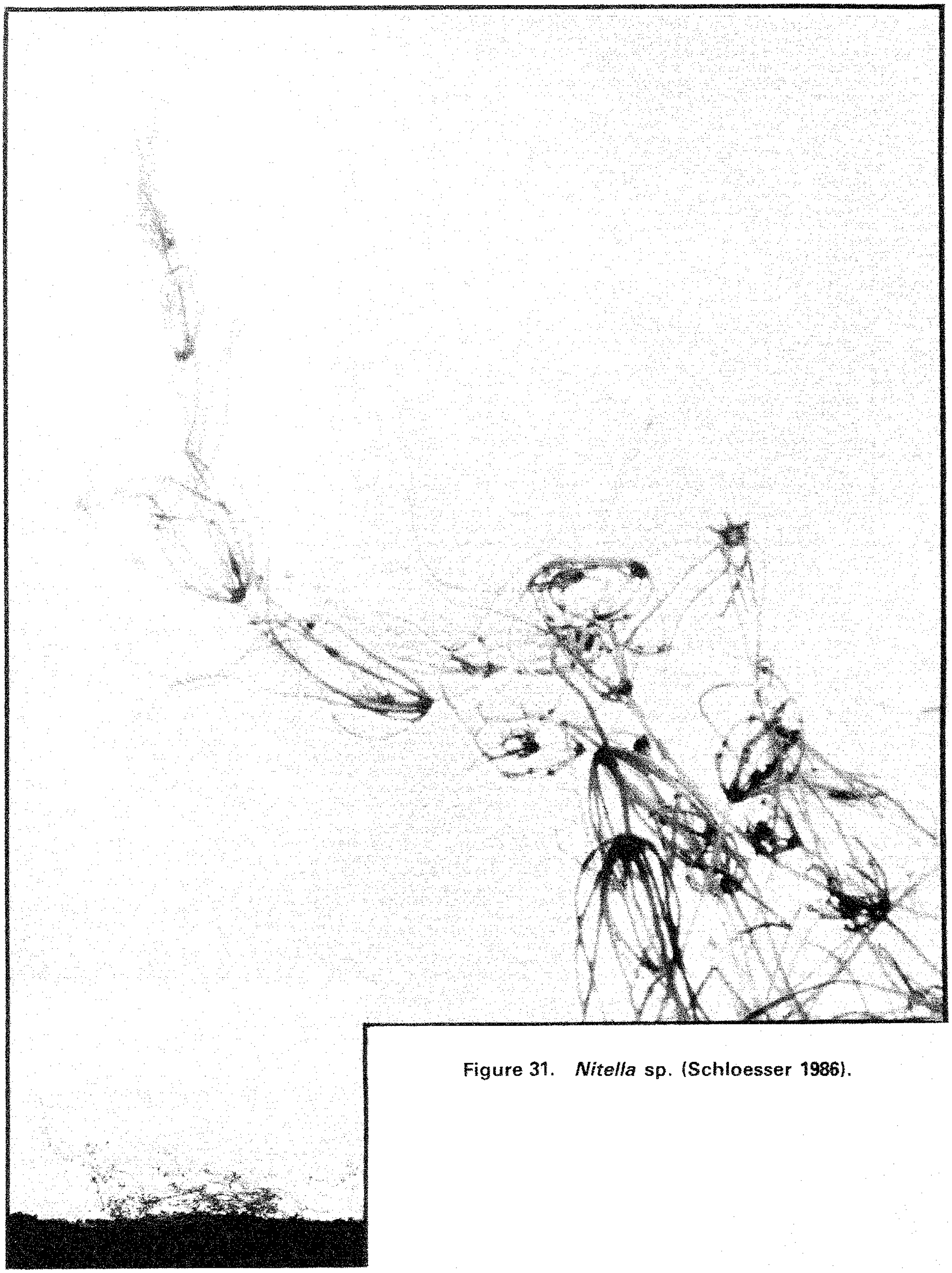


Figure 31. *Nitella* sp. (Schloesser 1986).

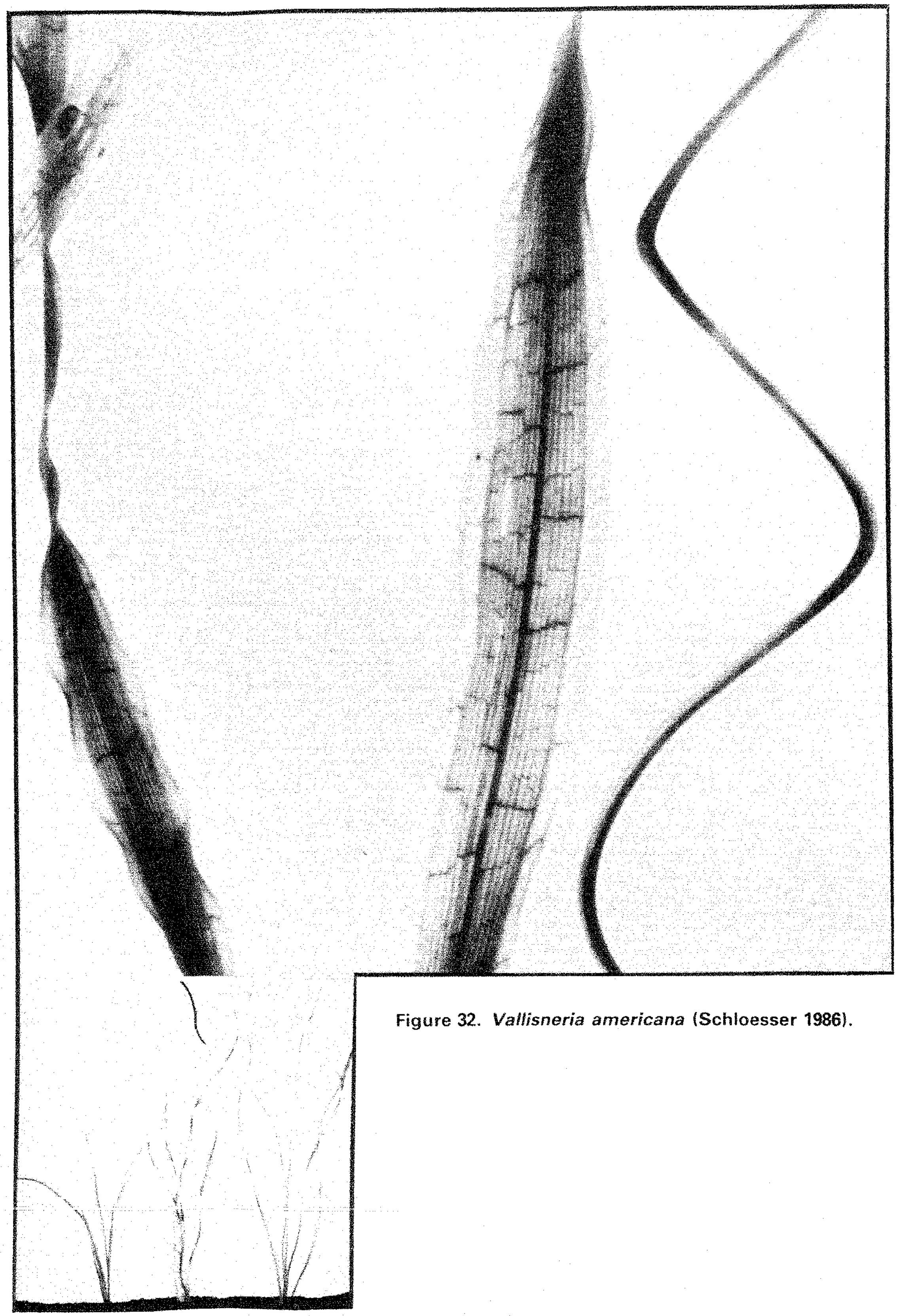


Figure 32. *Vallisneria americana* (Schloesser 1986).

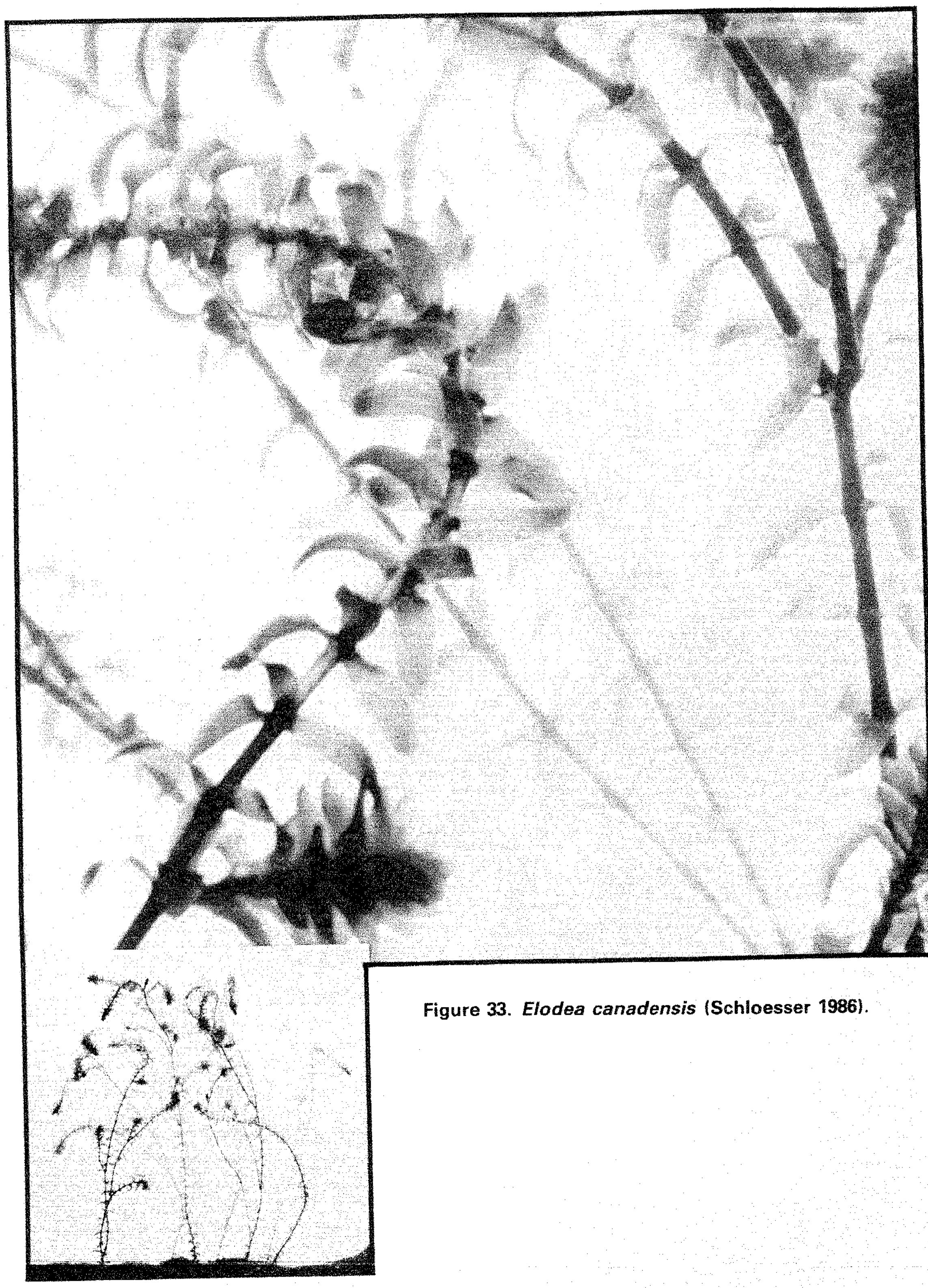


Figure 33. *Elodea canadensis* (Schloesser 1986).

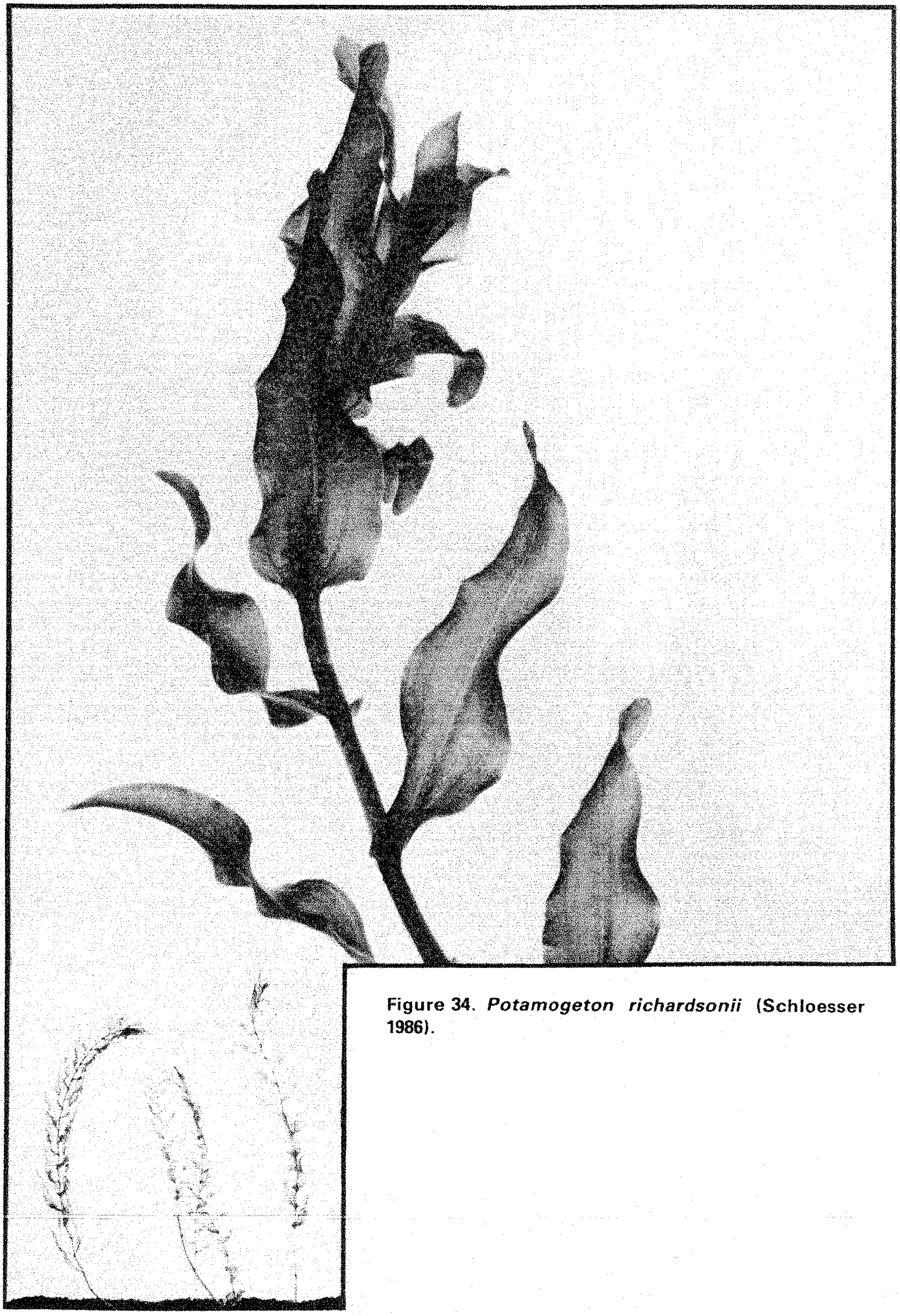


Figure 34. *Potamogeton richardsonii* (Schloesser 1986).

Table 7. Submersed plants that provide cover and food for fish and waterfowl in Great Lakes connecting channels (Schloesser 1986)[a].

	Musk-grass	Coon-tail	Eurasian water-milfoil	Naiad	Water star-grass	Water-weed	Wild celery	Clasping leaf pond-weed	Narrow leaf pond-weed
Fish									
Alewife	x		x	x	x	x	x	x	x
Black crappie	x		x		x	x	x	x	x
Bluegill			x	x	x	x	x		
Bluntnose minnow	x		x	x	x	x	x	x	x
Brown bullhead	x		x	x		x	x	x	x
Largemouth bass	x	x	x	x	x	x	x	x	x
Muskellunge	x		x	x	x	x	x	x	x
Northern pike		x	x	x		x	x		
Rockbass	x	x	x	x	x	x	x	x	x
Yellow perch	x		x	x	x	x	x		x
Waterfowl									
American coot	x		x	x		x		x	
Black duck	x			x	x				x
Bufflehead	x			x			x		
Canvasback			x		x	x	x		
Common scooter	x			x			x	x	
Goldeneye	x		x	x			x		
Greater scaup	x		x	x			x	x	x
Lesser scaup	x	x	x	x	x	x	x	x	x
Mallard			x			x	x		x
Redhead	x	x	x	x		x	x	x	x
Ringneck	x		x	x			x		x

[a] Fish feed primarily on the invertebrates that colonize the plants, whereas waterfowl ingest both the plants and the invertebrates. Scientific names of fish and waterfowl are presented in Sections 3.5 and 3.6.

Nitellopsis obtusa, (Figure 36), a macroalga (Characeae) native to Europe and Asia, was first discovered in the Great Lakes in the St. Lawrence River in 1978. Since then, it has also been found in the St. Clair and Detroit Rivers (Figure 37), and will probably spread to other parts of the Great Lakes (Schloesser et al. 1986). N. obtusa is sometimes found in deep, slow-moving water where other plants are scarce. In the United States, N. obtusa is found only in water frequented by commercial shipping vessels, suggesting that this taxon is distributed by these vessels. N. obtusa has long branches of uneven length that make angular attachments to the main stem at each joint. There may be one cream-colored bulb at the base of each cluster of branches.

Myriophyllum spicatum (Figure 38) was first recorded from Lake St. Clair in 1974 (Dawson 1975), and was the fourth most common submersed macrophyte in the St. Clair system in 1978 (Figure 39, Table 6). In general, watermilfoils were relatively unnoticed in the United States until the late 1950's when they became a nuisance in large water bodies such as the Potomac River, Currituck Sound, Chesapeake Bay, and TVA reservoirs. In the Great Lakes, massive growths of M. spicatum (Figure 40) have been reported to cause only minor hindrances to recreation and navigation (Schloesser and Manny 1984). M. spicatum is brownish-green to brown, usually with some red on the stems. Stems may be up to 3 m long and have clusters of 4 or 5 feather-like leaves that are more abundant

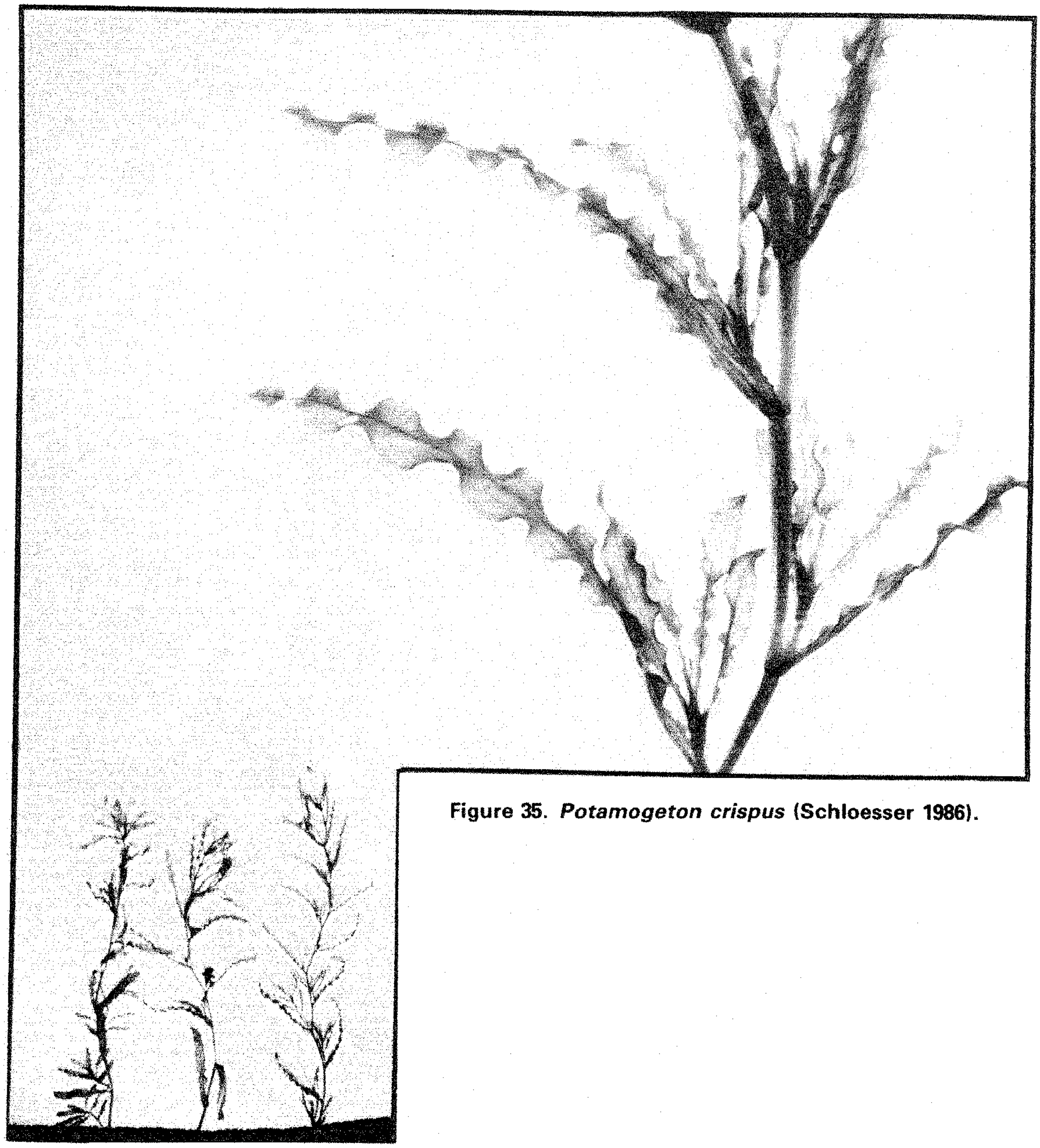


Figure 35. *Potamogeton crispus* (Schloesser 1986).

near stem tips. Each leaf has between 5 and 24 pairs of small leaflets. M. spicatum may spread from lake to lake when small fragments of the plant are accidentally transported by recreational boaters. Although this milfoil can crowd out other underwater plants used by fish and waterfowl, it provides an overwintering mat of decaying vegetation on which many aquatic invertebrates can feed (Schloesser 1986).

The seasonal growth and development of the submersed plant community at four widely spaced locations throughout the St. Clair system are described in Figure 41). In one case (Pattern A), the dominant

Figure 36. *Nitellopsis obtusa* (Schloesser 1986).

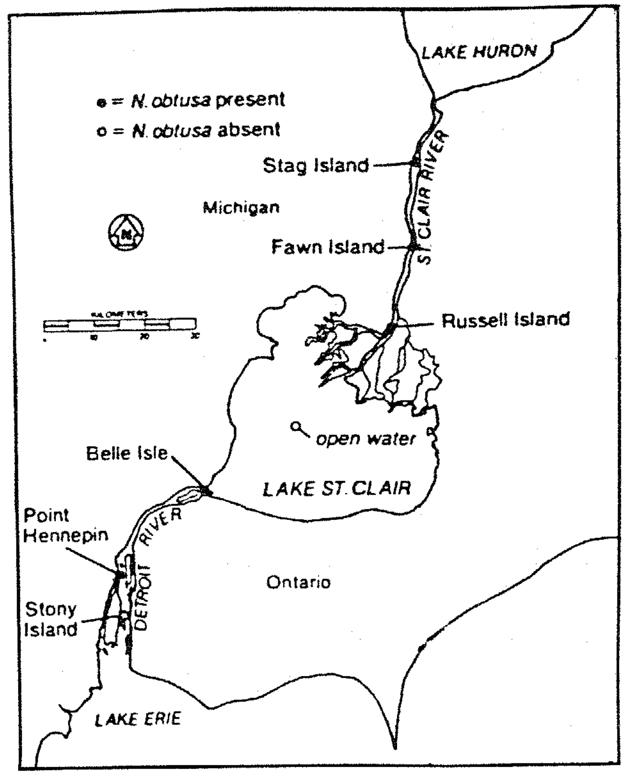


Figure 37. Distribution of *Nitellopsis obtusa* in the St. Clair and Detroit River systems in 1983 (Schloesser et al. 1986).

taxon grew alone; in another (Pattern B), the codominant taxa grew sympatrically without species succession; and in yet another (Pattern C), codominant taxa grew sympatrically with species succession (Schloesser et al. 1985). Differences in growth and seasonal succession of some taxa are caused by competition, life-cycle differences, and the presence of overwintering plant material, which can root or sprout quickly and results in new growth beginning early in the spring. Maximum dry weight biomass values are within ranges (100-520 g/m^2) reported for aquatic macrophyte stands in rivers at temperate latitudes (Edwards and Owens 1960; Westlake 1963), suggesting that in each pattern of community development, resources were maximized on a species basis whether one or many species were present.

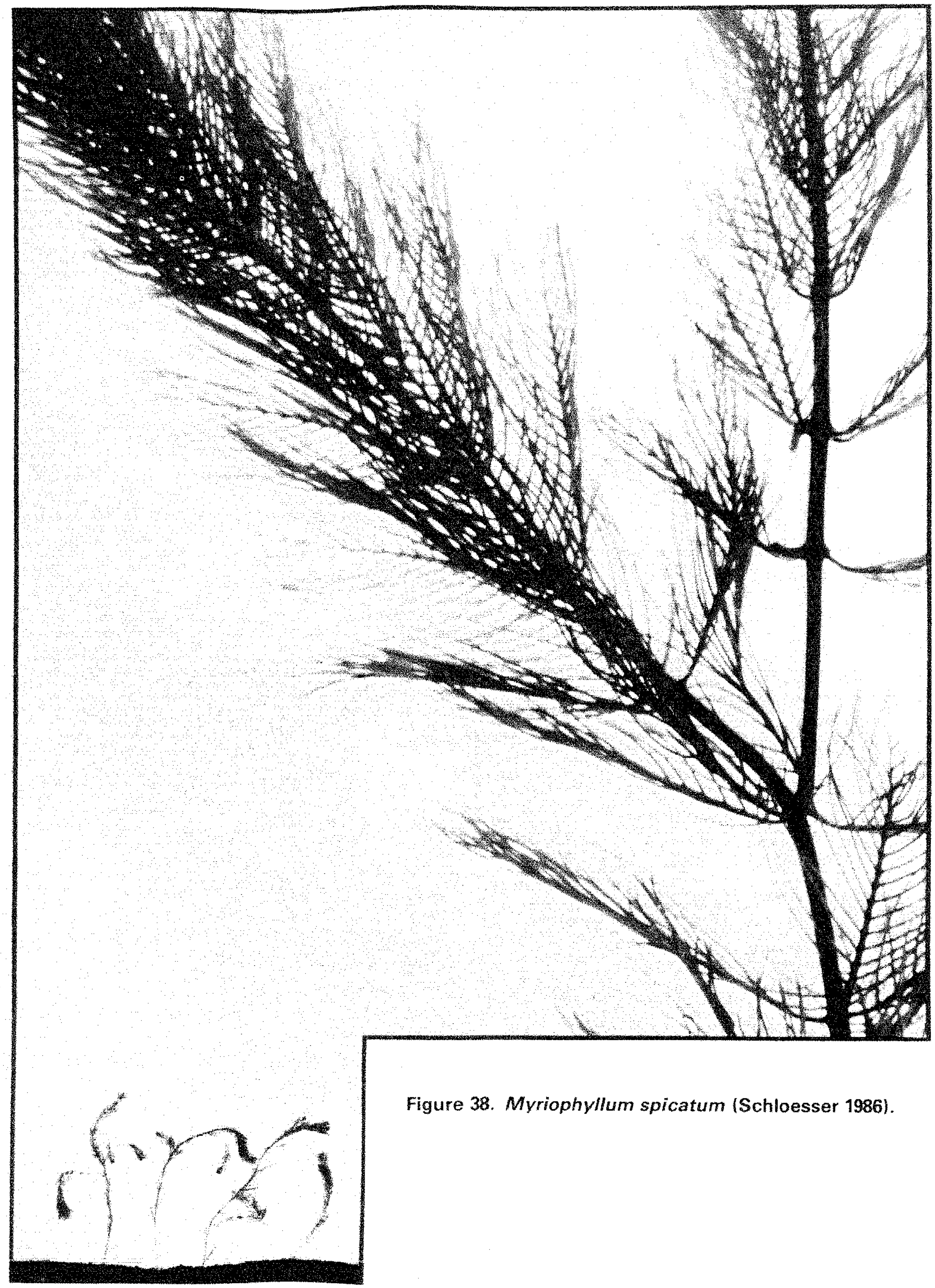


Figure 38. *Myriophyllum spicatum* (Schloesser 1986).

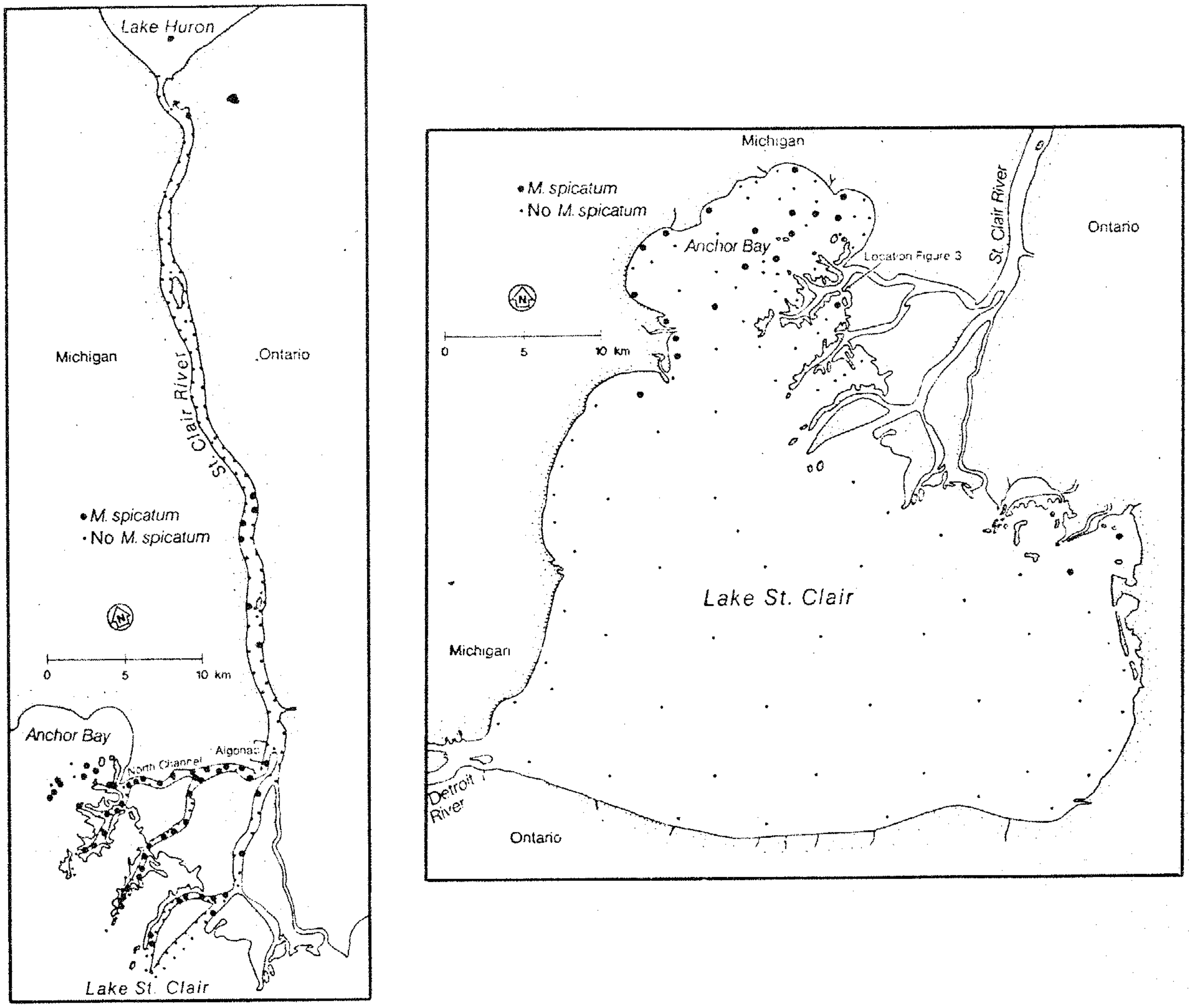


Figure 39. Distribution of *Myriophyllum spicatum* in the St. Clair system in 1978 (Schloesser and Manny 1984).

No detailed studies of species composition, distribution, and relative abundance of emergent macrophytes in the St. Clair system have been completed. Over 84% (7,500 ha) of the wetland communities bordering the west side of Lake St. Clair were destroyed by shoreline development between 1873 and 1973 (Jaworski and Raphael 1976), and wetlands bordering these waters continue to be lost at an alarming rate (Lyon 1979a; Herdendorf et al. 1981; Raphael and Jaworski 1982; McCullough 1985). Manny (National Fisheries Research Center-Great Lakes, unpubl. data) sampled selected stands of *Typha*, *Scirpus*, and *Eleocharis* in Anchor Bay, to estimate plant stem and rootstock biomass. *Typha latifolia*, *T. angustifolia*, *Scirpus validus*, *Phragmites communis*, and *Eleocharis quadrangulata* were the dominant taxa. Other species of emergent plants, including *Pontedaria cordata*, *Scirpus acutus*, and *S. americanus*, have also been identified in the St. Clair system (Section 3.7). Estimated total areal extents of emergents in the St. Clair River and Lake St. Clair are 3,380 and 9,170 ha, respectively (Lyon 1979a). Over 95% of the emergent beds in the river occur in its lower sections.

Collectively, submersed and emergent aquatic plants are the dominant primary producers supporting animal populations

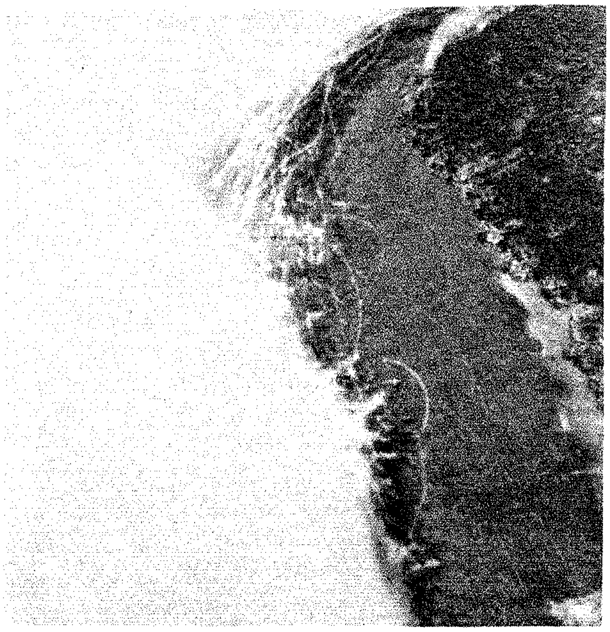
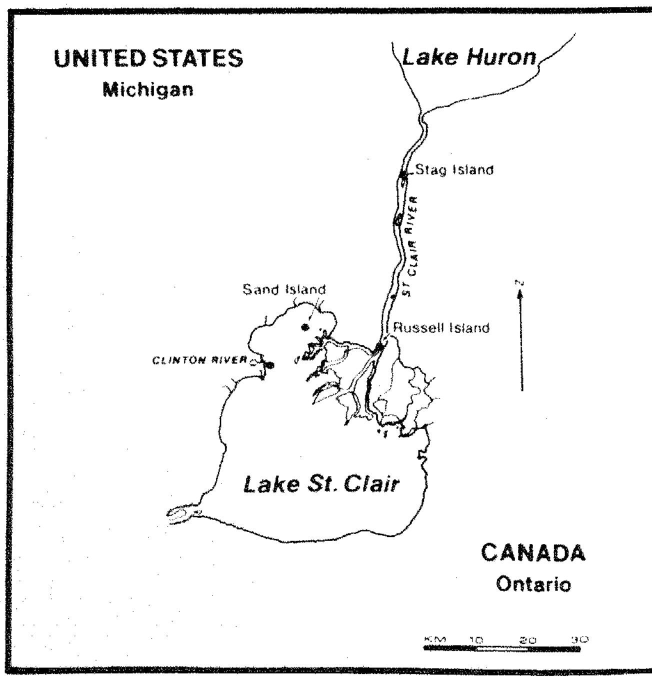


Figure 40. Dense bed of *Myriophyllum spicatum* in the St. Clair River in 1978 (Schloesser and Manny 1984). The curved lines are small-boat tracks.

in some areas of the St. Clair system (Chapter 4). They provide substrate for periphyton and for invertebrates that are fed upon by fish and waterfowl (Table 7) and also provide cover for young fish. As detritus, they serve as food for macrozoobenthos. The patterns of seasonal growth and community development of submersed plants shown in Figure 41 may also influence fauna that depend upon these plants for food and shelter. For example, Poe et al. (1986) showed that a percid-cyprinid-cyprinodontid fish community was



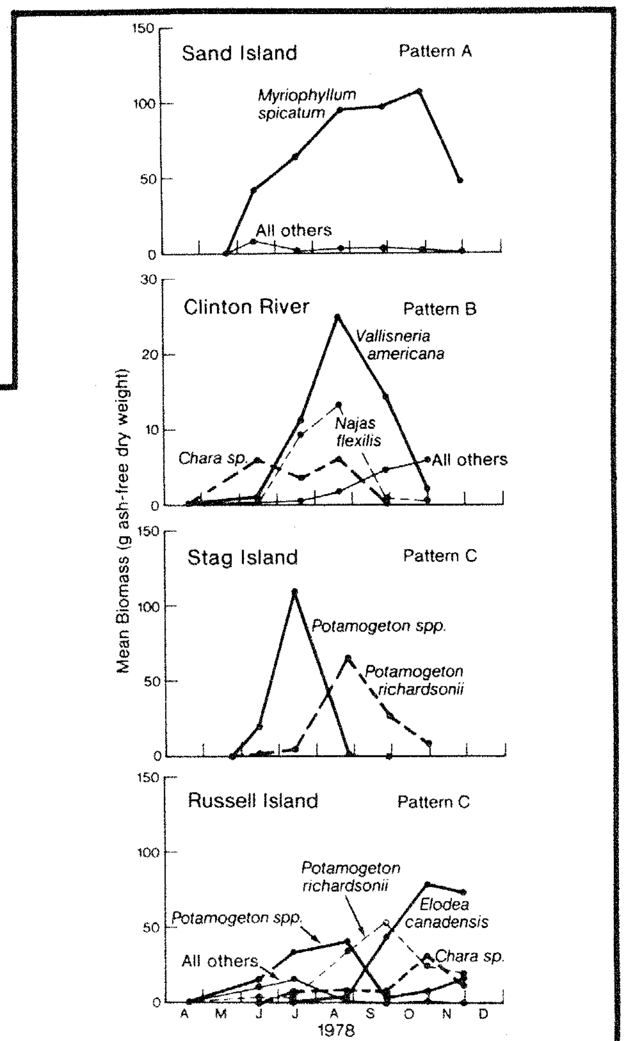


Figure 41. Three patterns of seasonal growth of submersed macrophytes in the St. Clair system (Schloesser et al. 1985). Pattern A is growth of one dominant taxon, pattern B is growth of codominant taxa without species succession, and pattern C is growth of codominant taxa with species succession.

dominant in Lake St. Clair in vegetatively complex areas occupied by many plant species and that a less diverse, centrarchid community dominated in the areas with fewer plant species. More recently, foraging studies of young rock bass (Ambloplites rupestris) and pumpkinseeds (Lepomis gibbosus) in Lake St. Clair (J. R. P. French III, National Fisheries Research Center-Great Lakes; pers. comm.) have shown that seasonal increases in the canopy of bushy, submersed aquatic plants and Heteranthera dubia hindered the rock bass more than the pumpkinseeds and caused resource partitioning between the two species.

3.3 ZOOPLANKTON

The St. Clair River and Lake St. Clair have relatively low densities of limnetic zooplankton, one of the main primary consumer groups (Bricker et al. 1976). The zooplankton community in the St. Clair River is dominated by the adjacent Lake Huron zooplankton communities, which constantly are being flushed downriver. In this area, 18 rotifers, 9 calanoid copepods, 4 cyclopoid copepods, and 6 cladocera have been identified (Watson and Carpenter 1974). The dominant zooplankton are the cladoceran Bosmina longirostris and the copepods Cyclops thomasi and Diaptomus minutus.

The zooplankton population of Lake St. Clair differs slightly from that of the St. Clair River. In general, cladocera (28 species) are present in higher densities than cyclopoid copepods (5 species), which are more abundant than calanoid (7 species) or harpacticoid copepods (4 species) (Bricker et al. 1976). The dominant species are Bosmina longirostris, Cyclops vernalis, and Diaptomus ashlandi. Zooplankton populations are unevenly distributed in the lake, and densities are highest along the southeast shoreline and near the Clinton River, probably in response to the higher nutrient levels in those portions of the lake (Winner et al. 1970).

The overall low abundance of limnetic zooplankton (average of less than 10/L) in Lake St. Clair has been attributed to two factors. First, much of the lake has well-developed macrophyte beds, in which the density of limnetic zooplankton is low (Bricker et al. 1976). Second, the rapid flushing time of Lake St. Clair inhibits the development of permanent or abundant limnetic zooplankton populations (Bricker et al. 1976).

Cyclops thomasi and Diaptomus minutus are dominant in the St. Clair River, but are replaced by C. vernalis and D. ashlandi in Lake St. Clair. This change in the composition of the zooplankton community from oligotrophic to mesotrophic species, plus the higher abundance of zooplankton in southeastern Lake St. Clair, reflect the increase in nutrient levels from the river to the southeastern portion of the lake. Fourteen taxa of planktonic copepods and 18 cladocerans are present in these waters. Among other groups, Difflugia is the most common protozoan, and Conochilus, Keratella, Polyarthra, Synchaeta, and Branchionus are the most common rotifers. Maximum numbers of zooplankton occur between June and September.

3.4 MACROZOOBENTHOS

The macrozoobenthos of the St. Clair system has been studied extensively by OMOE (1979), Hiltunen (1980), Hiltunen and Manny (1982), Thornley and Hamdy (1984), Thornley (1985), and Hudson et al. (1986), mainly in response to concerns about water quality and navigation-related development. Nematoda, Oligochaeta, Amphipoda, Diptera (Chironomidae), Ephemeroptera, Trichoptera, Gastropoda, and Pelecypoda are abundant in the St. Clair River and Lake St. Clair, and Polychaeta and Isopoda are also abundant in the lake (Table 8). Cricotopus, Parachironomus, Parakiefferiella, Rheotanytarsus, and Stictochironomus are the most common Chironomids. Amnicola and Elimia are the most common snail taxa (Table 9). Hexagenia (Figure 42) is the most common mayfly (Table 10) and reaches densities of 3000 nymphs/m² in Lake St. Clair and the lower St. Clair River (Hudson et al. 1986). Cheumatopsyche, Hydropsyche, and Oecetis are dominant trichopterans (Table 11) and Hyalella is the most common amphipod. Species diversity within these taxa is greatest in the Chironomidae (127), Trichoptera (38), and

Table 8. Density (mean no./m²) of 10 major taxa of macrozoobenthos in the St. Clair system in 1977 (After Hiltunen 1980 and Hiltunen and Manny 1982).

Taxon[a]	St. Clair River	Lake St. Clair
Nematoda	424	596
Oligochaeta	7,680	1,983
Polychaeta	0	801
Amphipoda	513	418
Isopoda	33	175
Diptera[b]	3,039	583
Ephemeroptera	99	128
Trichoptera	42	0
Gastropoda	843	333
Pelecypoda	495	331

[a] *Hydra* were abundant but not enumerated.
[b] About 95% were Chironomidae.

Table 9. Density (mean no./m²) of Gastropoda in the St. Clair system in 1983-84 (After Hudson et al. 1986)[a].

Taxon	St. Clair River	Lake St. Clair
Amnicola	563	33
Bithynia	0	T
Campeloma	T	T
Elimia livescens	198	7
Ferrisia	19	0
Gyraulus	88	28
Lymnaea	4	0
Physa	116	T
Pleurocera acuta	2	2
Somatogyrus subglobosus	T	T
Valvata sincera	2	2
Valvata tricarinata	96	9

[a] T = trace (< 0.5/m²).

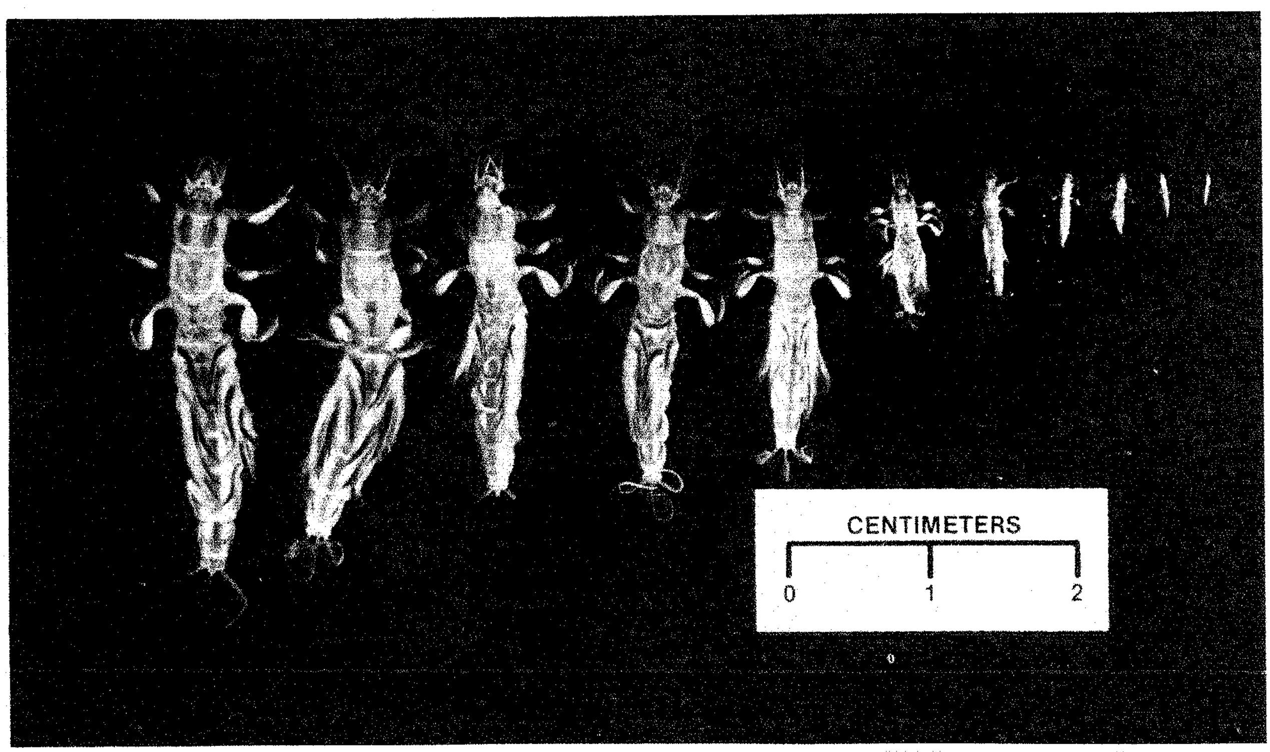


Figure 42. Nymphs of the burrowing mayfly *Hexagenia* (Schloesser and Hiltunen 1984). Smallest nymphs are newly hatched and the largest are nearly 2 years old and are preparing to emerge as winged-adults.

Table 10. Density (mean no./m²) of Ephemeroptera in the St. Clair system in 1983-84 (After Hudson et al. 1986)[a].

Genus	St. Clair River	Lake St. Clair
Baetis	T	0
Baetisca	6	T
Caenis	223	1
Ephemerella	22	T
Hexagenia	447	1,210
Stenacron	A	0
Stenonema	15	T
Tricorythodes	T	0

[a] A = adult; T = trace (< 0.5/m²).

Table 11. Density (mean no./m²) of Trichoptera in the St. Clair system in 1983-84 (After Hudson et al. 1986)[a].

Genus	St. Clair River	Lake St. Clair
Branchycentrus	15	0
Ceraclea	9	0
Cheumatopsyche	68	3
Helicopsyche	S	0
Hydropsyche	65	0
Hydroptila	T	0
Limnephilus	A	0
Micrasema	T	0
Mystacides	7	T
Nectopsyche	1	0
Neureclipsis	18	0
Nyctiophylax	A	0
Oecetis	26	41
Orthotrichia	T	0
Oxyethira	A	0
Phylocentropus	T	0
Phryganea	T	0
Polycentropus	8	0
Protoptila	9	0
Pycnopsyche	T	0
Setodes	2	0
Triaenodes	3	0

[a] A = adult; T = trace (< 0.5/m²); S = shell only.

Oligochaeta (25). Freshwater mussels are present and the fingernail clams, Pisidium and Sphaerium may be the most abundant mussels in the St. Clair system (Table 12). Crayfish are present but have not been adequately sampled. The St. Clair River has a higher taxonomic diversity of macrozoobenthos than Lake St. Clair. The number of macrozoobenthic taxa in the St. Clair system is in excess of 300 species.

Comparison of zoobenthos diversity among large riverine systems is difficult because taxonomic detail is usually inadequate. The following studies are exceptions. Barton (1980) collected 114 taxa of benthic macroinvertebrates from the Athabasca River in northern Alberta, Canada. Hudson and Nichols (1987) recorded 206 taxa from the Savannah River, South Carolina-Georgia. The list of 334 taxa from the wave-zone habitat (0- to 2-m depth zone) of the exposed shores of the Canadian portion of the Great Lakes (Barton and Hynes 1978) surpassed that for the St. Clair system (Hudson et al. 1986).

Zoobenthos biomass estimates for eight large rivers (Barton and Smith 1984) ranged from 0.1 to 8.6 g/m². The mean value (1.33 g/m²) for the St. Clair system given by Hudson et al. (1986) equals or exceeds the mean values for six of the eight rivers listed by Barton and Smith

Table 12. Density (mean no./m²) of Pelecypoda in the St. Clair system in 1983-84 (After Hudson et al. 1986)[a].

Taxon	St. Clair River	Lake St. Clair
Anodonta grandis	0	T
Lampsilis sp.	T	T
Lampsilis radiata siliquoidea	0	1
Leptodea fragilis	0	T
Pisidium sp.	280	671
Proptera alata	0	T
Sphaerium sp.	19	30
Unionidae (juveniles)	T	1

[a] T = trace (< 0.5/m²).

(1984), is higher than most values listed for rivers below impoundments (Walburg et al. 1983), and is nearly identical to that reported for the St. Lawrence River (1.4 g/m^2) by Mills et al. (1981).

3.5 FISHES

The fish fauna of the Great Lakes has been described recently by Bailey and Smith (1981) and Hocutt and Wiley (1986). This fauna is of relatively recent origin on a geologic timescale, having colonized the Great Lakes basin in the last 9,000-14,000 years following the retreat of the ice mantle at the end of the Wisconsin glacial stage. The origins of this native fauna are diverse. Most of it apparently arrived from the Mississippi River drainage, which contains one of the largest temperate fish faunas in the world, and the remainder colonized the Great Lakes from populations in the Atlantic coast drainage. The fish fauna of the Great Lakes is relatively large and diversified numbering 174 species in 71 genera and 28 families, of which 117 species, 58 genera, and 24 families occur in the St. Clair and Detroit River system and their tributaries (Table 13). Scott and Crossman (1973) summarize the life history information for these fishes, many of which are or were important in the commercial and recreational fisheries (Section 5).

Major Native Species

Historically, the lake trout, lake herring, and lake whitefish (Figure 43) were major seasonal components of the native coldwater fish fauna of the St. Clair system. All three are northern species with ranges that extend into the Arctic drainage east and west of Hudson Bay. Populations in the Great Lakes are at or very near the southern limits of their natural ranges. All three species typically occupy the colder, deeper waters of the Great Lakes during the summer. The lake herring is pelagic, the lake whitefish tends to be more strongly associated with the bottom, and the lake trout occupies both habitats. The lake trout and lake whitefish are among the largest native species in the Great Lakes. A lake trout weighing slightly more than 63 lb was taken by angling in Lake Superior in 1952 and a 42-lb lake whitefish was caught in Lake Superior in 1918.

The lake sturgeon, northern pike, muskellunge, walleye, and yellow perch are the most important members of the coolwater fish community of the St. Clair system. These coolwater species, unlike the representatives of the coldwater fish community, are present in the St. Clair system throughout the entire year. Although the abundance of lake sturgeon (Figure 44) is presently much reduced from historical levels, it remains a prominent species in the St. Clair system, because it is the largest and longest-lived of the native fishes in the Great Lakes basin. A specimen of unknown age with a length of nearly 8 ft and a weight of 310 lb was recorded in Lake Superior; a 208-lb fish taken in Minnesota was 154 years old.

In North America, the northern pike occupies a range which extends from the Arctic drainage south through the Mississippi River drainage to Missouri. A 55-lb specimen was reported from an Alberta, Canada, lake. Trap net catches (Haas et al 1985) suggest Northern pike are more abundant at the head of the St. Clair Delta in the St. Clair River than elsewhere in the St. Clair system. Northern pike are opportunistic feeders, and the optimum food size is estimated to be between one-third and one-half the size of the pike.

The muskellunge, unlike the pike, is restricted to eastern North America, and its range is geographically centered at about the southern end of the Great Lakes basin. The species reaches a weight of nearly 70 lb in the Great Lakes system, and it is the second largest fish in the system. Lake St. Clair is one of the two major centers of muskellunge abundance in the Great Lakes. Trap net catches (Haas et al. 1985) show the muskellunge is distributed throughout Lake St. Clair and the St. Clair River. A wide variety of fishes form the major part of the diet of the muskellunge, but almost any living animal of the appropriate size, including adult waterfowl, may be eaten. The muskellunge may hybridize naturally with northern pike in some areas.

Table 13. Fishes of the St. Clair and Detroit River systems and their tributaries (After Bailey and Smith 1981).

Petromyzontidae (Lamprey)	
Ichthyomyzon fossor	Northern brook lamprey
I. unicuspis	Silver lamprey
Lampetra appendix	American brook lamprey
Petromyzon marinus	Sea lamprey[a]
Acipenseridae (Sturgeon)	
Acipenser fulvescens	Lake sturgeon
Lepisosteidae (Gar)	
Lepisosteus oculatus	Spotted gar
L. osseus	Longnose gar
Amiidae (Bowfin)	
Amia calva	Bowfin
Anguillidae (Eel)	
Anguilla rostrata	American eel[a b]
Hiodontidae (Mooneye)	
Hiodon tergisus	Mooneye
Clupeidae (Herring)	
Alosa pseudoharengus	Alewife[a]
Dorosoma cepedianum	Gizzard shad
Salmonidae (Trout)	
Salmoninae	
Oncorhynchus gorbuscha	Pink salmon[a]
O. kisutch	Coho salmon[c]
O. nerka	Sockeye salmon[c]
O. tshawytscha	Chinook salmon[c]
Salmo gairdneri	Rainbow trout[c]
S. salar	Atlantic salmon[c]
S. trutta	Brown trout[c]
Salvelinus fontinalis	Brook trout[c]
S. namaycush	Lake trout
Coregoninae	
Coregonus artedii	Lake herring
C. clupeaformis	Lake whitefish
Osmeridae (Smelt)	
Osmerus mordax	Rainbow smelt[a]
Umbridae (Mudminnow)	
Umbra limi	Central mudminnow
Esocidae (Pike)	
Esox americanus vermiculatus	Grass pickerel
E. lucius	Northern pike
E. masquinongy	Muskellunge
Cyprinidae (Minnow)	
Campostoma anomalum	Stoneroller
Carassius auratus	Goldfish[c]
Cyprinus carpio	Common carp[c]
Hybognathus hankinsoni	Brassy minnow
Hybopsis amblops	Northern bigeye chub
H. storeriana	Silver chub
H. x-punctata	Gravel chub
Nocomis biguttatus	Horneyhead chub
N. micropogon	River chub
Notemigonus crysoleucas	Golden shiner
Notropis anogenus	Pugnose shiner
N. atherinoides	Emerald shiner
N. buchanani	Ghost shiner
N. chrysocephalus	Central common shiner
N. cornutus	Common shiner
N. emiliae	Pugnose minnow
N. heterodon	Blackchin shiner
N. heterolepis	Blacknose shiner
N. hudsonius	Spottail shiner
N. rubellus	Rosyface shiner
N. spilopterus	Spotfin shiner
N. stramineus	Sand shiner
N. umbratilis	Redfin shiner
N. volucellus	Mimic shiner
Phoxinus eos	Northern redbelly dace
Pimephales notatus	Bluntnose minnow
P. promelas	Flathead minnow
Rhinichthys atratulus meleagris	Blacknose dace
R. cataractae	Longnose dace
Richardsonius elongatus	Redside dace
Semotilus atromaculatus	Creek chub
S. margarita nachtriebi	Northern pearl dace
Catostomidae (Sucker)	
Carpiodes cyprinus	Quillback
Catostomus catostomus	Longnose sucker[b]
C. commersoni	White sucker
Erimyzon sucetta	Lake chub sucker
Hypentelium nigricans	Northern hog sucker
Ictiobus bubalus	Smallmouth buffalo[b]
I. cyprinellus	Bigmouth buffalo
Minytrema melanops	Spotted sucker
Moxostoma anisurum	Silver redhorse
M. carinatum	River redhorse
M. duquesnei	Black redhorse
M. erythrurum	Golden redhorse
M. macrolepidotum	Shorthead redhorse
M. valenciennesi	Greater redhorse
Ictaluridae (Catfish)	
Ictalurus melas	Black bullhead
I. natalis	Yellow bullhead
I. nebulosus	Brown bullhead
I. punctatus	Channel catfish
Noturus flavus	Stonecat
N. gyrinus	Tadpole madtom
N. miurus	Brindled madtom
N. stigmosus	Northern madtom
Percopsidae (Trout-perch)	
Percopsis omiscomaycus	Trout-perch
Gadidae (Cod)	
Lota lota	Burbot
Cyprinodontidae (Killifish)	
Fundulus d. menona	Banded killifish
Atherinidae (Silverside)	
Labidesthes sicculus	Brook silversides
Gasterosteidae (Stickleback)	
Culaea inconstans	Brook stickleback
Gasterosteus aculeatus	Threespine stickleback
Pungitius puntitius	Ninespine stickleback
Percichthyidae (Bass)	
Morone americana	White perch[a b]
M. chrysops	White bass
Centrarchidae (Sunfish)	
Ambloplites rupestris	Rock bass
Lepomis cyanellus	Green sunfish
L. gibbosus	Pumpkinseed
L. macrochirus	Bluegill
L. megalotis peltastes	Longear sunfish
Micropterus dolomieui	Smallmouth bass
M. salmoides	Largemouth bass
Pomoxis annularis	White crappie
P. nigromaculatus	Black crappie
Percidae (Perch)	
Ammocrypta pellucida	Eastern sand darter
Etheostoma blennioides	Greenside darter
E. caeruleum	Rainbow darter
E. exile	Iowa darter
E. f. flabellare	Fantail darter
E. microperca	Least darter
E. nigrum	Johnny darter
Perca flavescens	Yellow perch
Percina caprodes	Logperch
P. copelandi	Channel darter
P. maculata	Blackside darter
P. shumardi	River darter
Stizostedion canadense	Sauger
S. v. vitreum	Walleye
Sciaenidae (Drum)	
Aplodinotus grunniens	Freshwater drum
Cottidae (Sculpin)	
Cottus bairdi	Mottled sculpin
C. cognatus	Slimy sculpin

[a] Colonized recently via canal or by natural dispersal following introduction. [b] Presence confirmed by Haas et al. (1985).

[c] Introduced.

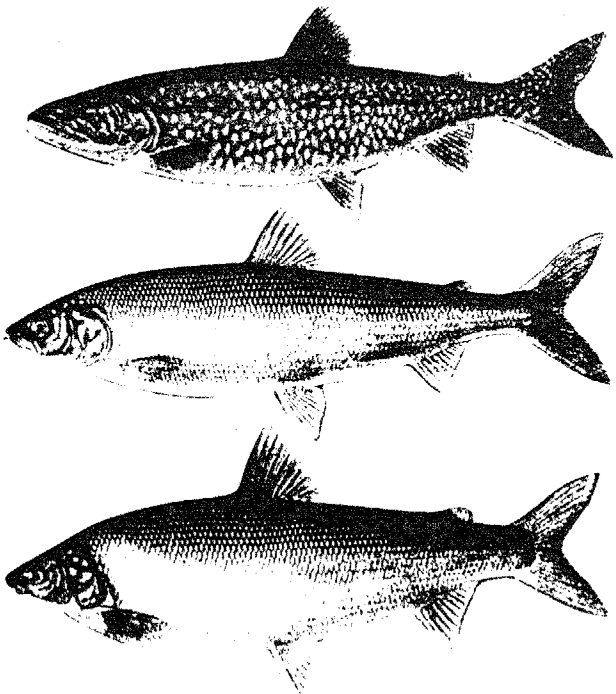


Figure 43. Lake trout, lake herring, and lake whitefish (Jordan and Evermann 1923).

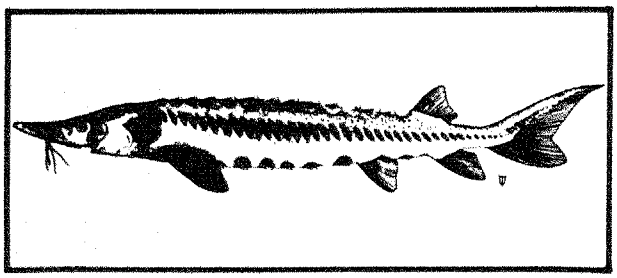


Figure 44. Lake sturgeon

Yellow perch and walleyes are important species in the Great Lakes, particularly in the St. Clair system, where they are abundant and much sought after by anglers. Both species are well adapted to large rivers and lakes with habitats similar to rivers (Kitchell et al. 1977), and the St. Clair system is, therefore, probably well-suited to their production. Yellow perch typically utilize a wide variety of habitats, feed mainly on fish and invertebrates, and are preyed upon extensively by walleyes and members of the pike, bass, and sunfish families. The Great Lakes are in the east-central portion of the natural range of the yellow perch in North America. The maximum size reached by the species may be about 4 lb. In the St. Clair system, walleyes apparently frequent the deeper channel water, in contrast to yellow perch, which occupy the shallower waters near shore. The walleye feed primarily on fish, but emerging aquatic insects may be seasonally important. The maximum size attained by the walleye may be about 22 lb.

Major components of the warmwater fish community of the St. Clair system include the sucker, catfish, bass, sunfish, and drum families. Like the coolwater fishes, the warmwater species are year-round residents. The sucker family in the St. Clair system may include all 5 species of suckers and 6 species of redhorse. These fish appear to occupy a common ecological niche. All typically inhabit shallow, warm water and are bottom feeders, ingesting small invertebrates, immature insects, worms, molluscs, and algae. Throughout their ranges, the maximum size attained by these species is about 3-11 lb. The young are forage for other species and the adults may be eaten by northern pike and muskellunge.

The important members of the catfish family in the St. Clair system are the black, yellow, and brown bullhead, and the channel catfish. All four have similar distributions and occupy most of the central drainages of North America, from the Great Lakes south to the Gulf of Mexico. The range of the brown bullhead also includes the eastern drainages of the U.S. All four species are nocturnal. Their barbels have tastebuds and are used in locating food. The bullheads typically occupy warm, quiet, shallow water in areas with soft bottoms, while the channel catfish typically inhabit deeper, cooler flowing water on hard bottoms. All four species feed on a broad spectrum of invertebrates, fishes, and plant material. The bullheads may reach weights of 3-8 lb. The largest channel catfish on record weighed nearly 60 lb and was taken from the southern portion of the range.

The white bass is the only species of the bass family native to the St. Clair system. The white bass is carnivorous and a pelagic feeder, usually occupying warmer waters within 20 ft of the surface. The Great Lakes and the St. Lawrence River are the northern limits of the species' range. The maximum size recorded for the species in the southern portion of its range is about 5 lb.

Among the sunfishes, the rockbass, bluegill, and smallmouth bass are important in the recreational fishery. All three species are native to the east-central portion of North America, and the Great Lakes are near the northern boundary of the range. Rock bass and bluegill are small species reaching maximum weights of slightly more than 3 and 2 lb, respectively. The maximum size attainable by smallmouth bass in the Great Lakes is probably less than 10 lb, but in the southern portion of its range it may be considerably larger. The bluegill is a generalized feeder, consuming insects, crustaceans, and plant material, whereas the rock bass and smallmouth bass feed mainly on aquatic insects, crayfish, and fishes. These three fishes typically inhabit warm, shallow water, but in some areas the bluegill and smallmouth bass may move to depths of 20 ft or more during the hottest part of the summer.

The freshwater drum is distributed throughout the Mississippi River drainage southward into Central America and is generally credited with having the greatest latitudinal range of any North American freshwater species. The Great Lakes form a portion of the northern boundary of its range. The eggs of this species are unique among North American fishes because they are buoyant and float at the surface, a characteristic which may partly account for the wide distribution of the species. In the Great Lakes, the species is most abundant in Lake Erie. The freshwater drum is adapted to bottom feeding, and molluscs, crayfish, other invertebrates, and fish typically compose its diet. The drum is not preyed upon extensively by other fish because it rapidly reaches a size that prevents all but the largest fish from ingesting it.

Other native species not represented in the commercial and recreational fisheries are also important in the St. Clair system as forage. Little published information is available to describe the feeding habits of fish in the St. Clair system, but a study of the food habits of Lake Erie fishes (Price 1963) suggests important forage fishes in the St. Clair system probably include gizzard shad, minnows, trout-perch, killifish, silversides, sticklebacks, and sculpins. The gizzard shad may attain a maximum size of about 3 lb and is important as forage only during its first year or two of life. The other members of the forage fish community are small species that can be preyed upon even as adults. Collectively, this forage component of the fish community occupies the entire St. Clair system, including the deeper channel water, the shallow water wetlands, and the open water pelagic habitat.

Introduced Species

Non-native fishes are also important components of the fish fauna of the St. Clair system. Recent additions to the fish fauna of the Great Lakes are described by Emery (1985), and the 15 introduced species that occur in the St. Clair and Detroit River systems are listed in Table 13. These additions include species whose presence reflects deliberate or accidental introductions, natural dispersal following introduction elsewhere, or dispersal through man-made canals. Among the introduced species listed in Table 13, only the alewife, rainbow smelt, coho and chinook salmon, rainbow and brown trout, common carp, and white perch are abundant or important in the St. Clair system. The alewife, rainbow smelt, and white perch are native to the marine or brackish waters of the east coast of North America. In their native habitats all three are anadromous species, ascending streams to spawn in freshwater, and rainbow smelt and white perch have established land-locked (freshwater) populations outside the Great Lakes basin in northeastern North America.

The alewife was probably introduced into the Great Lakes when it was accidentally included with juvenile Atlantic shad (*Alosa sapidissima*) that were deliberately stocked in Lake Ontario in 1870. The movement of the alewife into the upper Great Lakes is assumed to have occurred through the Welland Canal, which was constructed between Lakes Ontario and Erie in 1824. Alewives were recorded in Lake Erie in 1931 and had moved into Lake Huron by 1933. The alewife is one of the most abundant fish in Lakes Ontario, Huron, and Michigan, and it is an important forage fish in these waters. Alewives are present in the St. Clair system in May-September but are abundant only in May-June at the head of the St. Clair River (Haas et al. 1985). They may be seasonally important in the St. Clair system as forage. Alewife larvae are one of the most abundant fish larvae observed in the St. Clair system (Hatcher and Nester 1983; Muth et al. 1986).

The rainbow smelt was introduced in an inland lake in the Lake Michigan drainage in the early 1900's and escaped to Lake Michigan. It is now one of the most abundant forage fish in the Great Lakes. Rainbow smelt are present in the St. Clair River in March-September, but are abundant only in March-June in the upper portions of the river (Haas et al. 1985). Like the alewife, they may be seasonally important in the St. Clair system as forage and their larvae are among the most abundant fish larvae in the St. Clair system (Hatcher and Nester 1983; Muth et al. 1986).

The white perch is the newest exotic fish to spread from Lake Ontario to the upper four Great Lakes. White perch are believed to have invaded the Great Lakes Basin in about 1950, when they apparently gained access to Lake Ontario from the Hudson River drainage by way of the Erie Barge Canal and the Oswego River. White perch were first reported in Lake Ontario in 1952, and by 1960 had become the dominant species in the Bay of Quinte region. White perch were first collected in Lake Erie in 1953, but were not reported again until 1973. By 1975, however, they had become firmly established in the shallow, warmer western end of the lake. White perch were captured in 1977 in Canadian waters of Lake St. Clair and in 1983, adults were captured in trap nets set by commercial fishermen in Saginaw Bay, Lake Huron. Continued expansion into the upper Great Lakes is probable, primarily into the shallower, warmer areas of the lakes such as Green Bay and other smaller bays.

The invasion of the St. Clair system and adjacent waters by white perch poses a dilemma. White perch are now abundant in the Detroit River and the St. Clair system, and have begun to hybridize with native white bass (Todd 1986). The white bass presently supports an important recreational fishery in the St. Clair system, and the impact of white perch on this fishery is unknown. There is also potential for the expanding white perch population to adversely impact other important recreational species. In some portions of their native range the white perch is a serious competitor for food with yellow perch, trout, and salmon (AuClair 1960). However, negative impacts of white perch competition with native species have not been observed in the Great Lakes, and the species presently provides an important recreational fishery in the Detroit River (Haas et al. 1985) that may soon spread to the St. Clair system.

Coho and chinook salmon and the rainbow trout are native to the Pacific coast of North America, and the brown trout is native to Europe. All four species are anadromous and the rainbow trout and brown trout also have non-migratory populations that are naturally resident in freshwater. Chinook and coho salmon were stocked in the Great Lakes in the 1800's, but the first successful introductions occurred in Lake Michigan in 1966-67. Both species are now present in all five Great Lakes and successful natural reproduction occurs in some areas.

Rainbow trout were first stocked in the Great Lakes in a tributary to Lake Huron in 1876. Early releases consisted primarily of progeny of nonmigratory rainbow trout, but in the late 1890's some hatcheries replaced their brood stock with anadromous (steelhead) trout from the west coast. Rainbow trout were first reported in the lakes in 1895 and 1896, when individual fish were captured on two occasions by commercial fishermen in Lake Superior. Significant, self-sustaining rainbow trout populations are established in Lakes Michigan, Huron, and Superior.

Brown trout from Germany and Scotland were first stocked in the Great Lakes Basin in 1883. The State of Michigan released brown trout fry in the Pere Marquette River, a tributary to Lake Michigan, in 1883. During the same year, some of the fry raised at a hatchery in New York accidentally escaped into the Genesee River, a tributary to Lake Ontario. Eventually, brown trout were stocked by all States bordering the Great Lakes and by Canada, and self-sustaining populations are now widely distributed throughout the Great Lakes Basin. The brown trout, like the coho and chinook salmon and rainbow trout, appear to have had little adverse impact on the native fishes of the St. Clair system, and collectively they provide an important recreational fishery in the spring (Section 5.3).

The common carp (Figure 45) was first introduced from Europe to North America in 1883. The first fish were released near the mouth of the Sandusky River in western Lake Erie. The species spread through the St. Clair River to the upper Great Lakes, where it destroyed beds of native aquatic vegetation (wild celery and wild rice) preferred as food by canvasback and redhead ducks (Cole 1905; McCrimmon 1968). By the late 1890's the common carp was considered such a serious problem that the importation of fish from foreign countries was severely curtailed (Radonski et al. 1981). Large populations of common carp presently inhabit Lake St. Clair, where in recent years they have made up much of the commercial fish catch (Section 5.2).

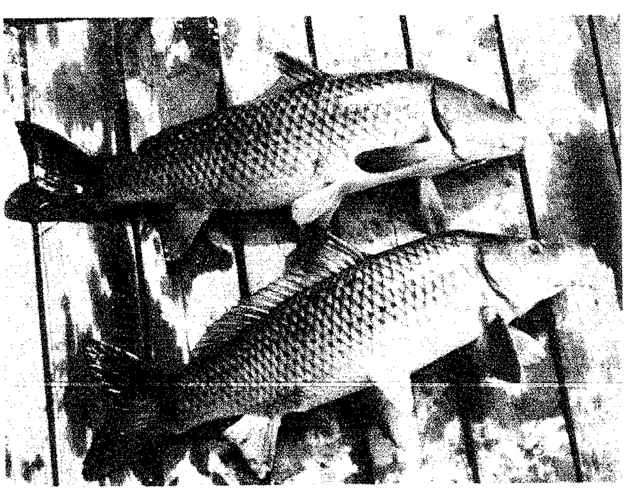


Figure 45. Common carp (Photograph by T. Edsall).

Spawning and Nursery Areas

A comprehensive description of the fish spawning and nursery areas of the St. Clair system and the reproductive characteristics of the fishes frequenting the system was completed by Goodyear et al. (1982). Muth et al. (1986) have recently described the distribution and abundance of fish larvae in the system, and OMNR (1986) has described the abundance of juvenile fishes which use Lake St. Clair as a nursery area. Collectively, this information demonstrates that the St. Clair system provides valuable spawning and nursery habitat for at least 46 species of fishes that are permanent residents of the system or which enter the system from Lake Huron and Lake Erie to spawn (Tables 14 and 15).

The spawning and nursery habitat in the St. Clair River (Figure 46) includes shoals, shallow littoral areas around islands, and river shoulders (Section 3.8). The water velocity in these areas is lower than in the deeper areas of the main channel, and the substrate ranges from rock, gravel, and sand to mixtures of sand, silt, and organic matter. Some of the areas are colonized by submersed and emergent aquatic plants. Spawning also occurs in the deeper areas of the main channel, where the substrate is hard, the channel edge is a bulkhead, water velocities are high, and rooted aquatic plants are absent. In Lake St. Clair (Figure 47), spawning is concentrated in the nearshore waters and embayments. The lake bottom along the open shoreline of the lake is typically firm sand, or a mixture of sand, silt, and organic material, while in the embayments the surficial sediments tend to be softer. Submersed and emergent aquatic plants are common in the nearshore areas and the embayments. Wave-induced turbulence may be high at times on the exposed shorelines of the lake but is much lower in the more sheltered embayments, especially in areas colonized by rooted aquatic plants. Collectively, these waters of the St. Clair system offer the wide variety of

Table 14. Fishes which spawn in the St. Clair system (Goodyear et al. 1982).

Species	St. Clair River	Lake St. Clair
Sea lamprey	+	+
Lake sturgeon	+	+
Longnose gar		+
Bowfin		+
Alewife	+	+
Gizzard shad	+	+
Mooneye		+
Lake herring	+	+
Lake whitefish	+	+
Rainbow trout	+	+
Lake trout	+	
Rainbow smelt	+	
Northern pike		+
Muskellunge	+	+
Goldfish		+
Carp	+	+
Silver chub	+	
Golden shiner		+
Emerald shiner	+	+
Common shiner		+
Spottail shiner		+
Spotfin shiner		+
Bluntnose minnow		+
Fathead minnow		+
White sucker	+	
Northern hog sucker	+	
Brown bullhead	+	+
Channel catfish		+
Trout-perch	+	
Burbot	+	
White bass	+	+
Rock bass	+	+
Pumpkinseed		+
Bluegill		+
Smallmouth bass	+	+
Largemouth bass		+
White crappie		+
Black crappie		+
Greenside darter		+
Yellow perch	+	+
Logperch	+	
Walleye	+	+
Freshwater drum	+	
Mottled sculpin	+	
Slimy sculpin	+	
Fourhorn sculpin	+	

habitats needed to satisfy the spawning and early life history requirements described in the literature (Goodyear et al. 1982; Scott and Crossman 1973) for the diverse fish fauna of the system.

Historically, large numbers of lake herring and lake whitefish migrated from Lake Erie into Lake St. Clair. The lake herring were believed to spawn over the large _Chara_ beds along the western side of the lake, while some of the whitefish in this run may have proceeded farther upstream to spawn in the St. Clair River. Large spawning runs of lake herring, perhaps from Lake Huron, also entered the St. Clair River, and spawning runs of lake trout, presumably from Lake Huron, were also common in the river. All of these runs of native coldwater fish disappeared in the late 1800's to early 1900's apparently as a result of overfishing. Intensive sampling in the last decade (Hatcher and Nester 1983; Muth et al. 1986; Haas et al. 1985) indicates virtually no spawning presently occurs by these species in the St. Clair River.

Historically, the St. Clair system and its tributaries were also an important spawning ground for native coolwater species, including the lake sturgeon and members of the pike, sunfish, and perch families. Spawning areas of lake sturgeon have been identified in the lower St. Clair River near Marine City and Port Lambton, and in the North Channel of the river at depths to 80 feet. The capture of a lake sturgeon larva at the head of the St. Clair River (Hatcher and Nester 1983) suggests that there may also be spawning there or in lower Lake Huron. The shallow marshes of the St. Clair Flats are the only known nursery areas for the species in the St. Clair system.

Historically, walleyes spawned in Anchor Bay of Lake St. Clair, along the south shore of the lake, in the Clinton, Sydenham, and Thames Rivers, in the St. Clair Delta, in several areas in the St. Clair River, and in tributaries to the river. Stocks depressed in the early-to-mid-1900's from historical levels of abundance have rebounded in the past two decades and major spawning runs now occur in the St. Clair system. The results of a recent tagging study (Haas et al. 1985)

Table 15. Relative abundance of young-of-the-year fish in mid-water trawl catches in Lake St. Clair, 1968-85 (After OMNR 1986).

	Average number per trawl hour				
	1968-69	1970-74	1975-79	1980-84	1985
Alewife	0	583	2,019	706	1,024
Gizzard shad	0	0	309	175	472
Rainbow smelt	20[a]	4	557	1,059	515
Spottail shiner	0	0	2	42	2
Channel catfish	0	0	0	2	0
White perch	0	0	0	364	1,232
White bass	0	22	24	108	7
Trout-perch	0	0	23	474	1,180
Yellow perch	172	695	73	1,008	203
Walleye	3	11	18	46	31
Freshwater drum	51	< 1	2	106	56

[a] No data for 1968.

suggest most of the spawning in the St. Clair system may now occur in the Thames River. Yellow perch spawn along the western shoreline of Lake St. Clair, in Anchor Bay, in the St. Clair Delta, at several locations in the littoral zone of the St. Clair River, and in the Black River. The St. Clair system also serves as a nursery area for this species.

Northern pike spawn along the shoreline of Lake St. Clair from the mouth of the Clinton River, around the north side of the lake into the delta, and along the east side of the lake to about the mouth of the Thames River. The embayments of the delta are important nursery areas. Historically, muskellunge spawning areas extended along the shoreline of the lake across the St. Clair Delta into Anchor Bay, and intermittently along the west shoreline to the head of the Detroit River. Spawning may also have occurred in Canadian waters in the northeast and southeast portions of the lake. Presently, there may be only one major spawning area in Lake St. Clair. This area is located in Anchor Bay about 1-2 mi east of the Selfridge Air Force Base (Haas 1978). Spawning areas in L'Anse Creuse Bay appear to have been destroyed by pollutants discharged into the lake from the Clinton River cutoff canal, which was completed in 1947. Marshes of the St. Clair Delta are the only recorded muskellunge nursery areas.

Native warmwater species also spawn extensively in the St. Clair system. Longnose gar, bowfin, and several species of minnows and sunfishes spawn in the embayments, marshes, and canals in the delta; these are also nursery areas. Smallmouth bass spawn in the tributaries of the St. Clair River, in the river proper near Stag Island, along the shoreline of Lake St. Clair from the head of the Detroit River north into the St. Clair Delta, and along the east shoreline of the lake to the Thames River. Virtually all of the delta and the shoreline of Anchor Bay are also nursery areas for smallmouth bass. Largemouth bass spawn along the shoreline of Lake St. Clair from about Mt. Clemens north around Anchor Bay through the delta, and along the east shore of the lake to the Thames River. The embayments and marshes are nursery areas. Channel catfish in Lake St. Clair spawn in the nearshore waters of Anchor Bay in the St. Clair Delta and in the Thames River. St. Johns Marsh on Anchor Bay is an important

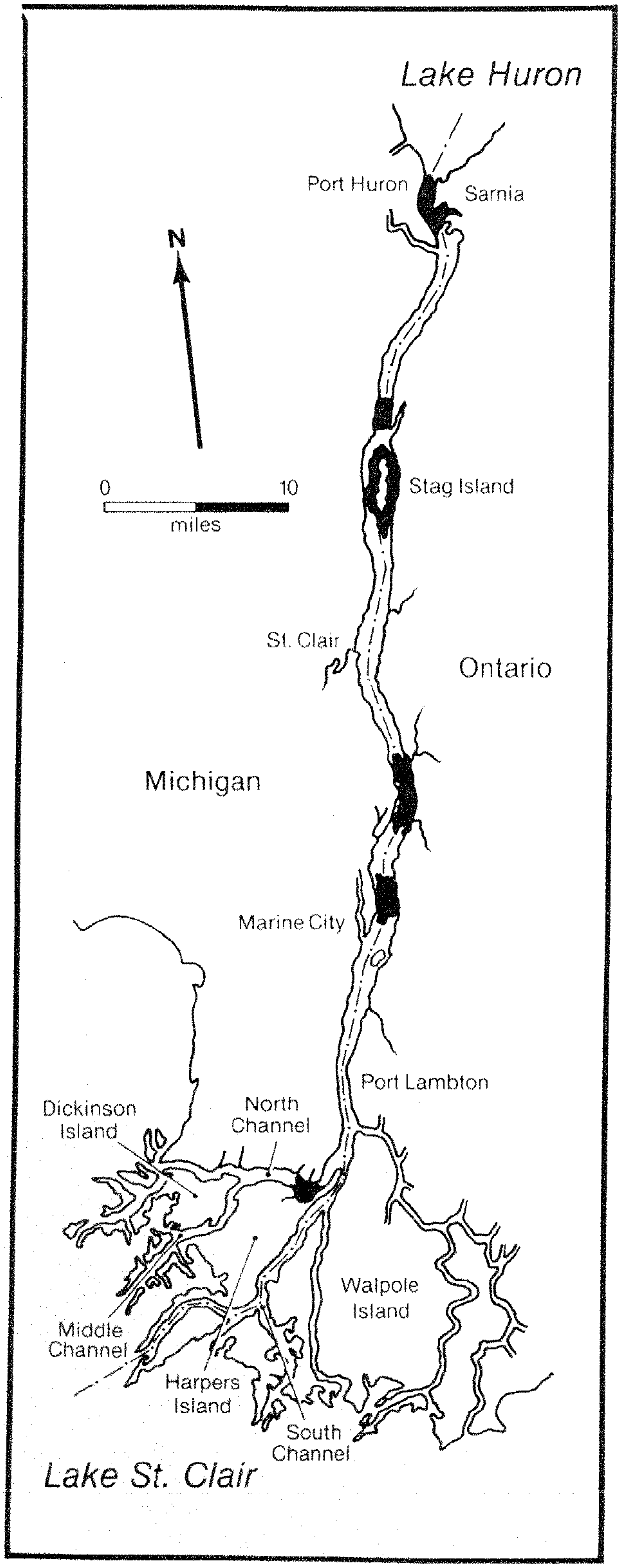


Figure 46. Major fish spawning areas in the St. Clair River (Goodyear et al. 1982).

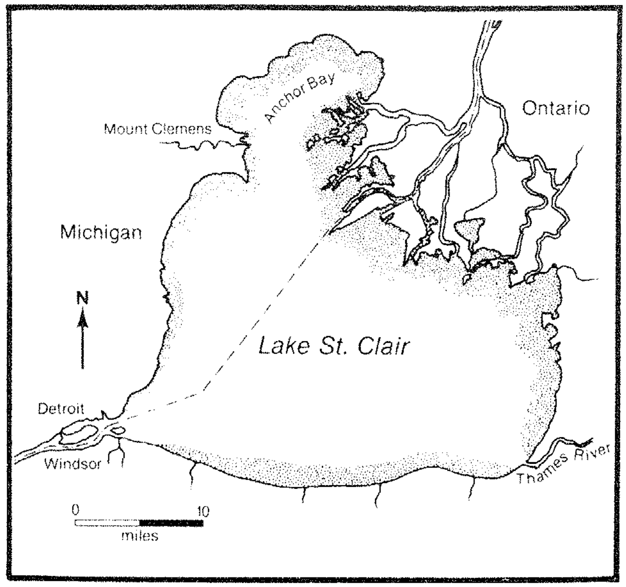


Figure 47. Major fish spawning areas in Lake St. Clair (Goodyear et al. 1982).

nursery area. Channel catfish may also spawn in the Belle River, a tributary to the St. Clair River. Suckers and redhorse in Lake St. Clair spawn in the Clinton and Sydenham Rivers, and a spawning run also enters the Belle River from the St. Clair River. White bass from Lake St. Clair spawn in the Clinton and Thames Rivers and their larvae are present in the St. Clair River, indicating spawning may occur in the St. Clair River or its tributaries.

Alewives, rainbow smelt, and common carp are among the most abundant introduced species in the St. Clair system. All three species spawn in the St. Clair River and its tributaries. Spawning by alewives and rainbow smelt also occurs in the St. Clair Delta and in Lake St. Clair near Sand Island at the mouth of the North Channel of the St. Clair River. Common carp spawn widely along the western, northern, and eastern shorelines of Lake St. Clair and throughout the delta. Alewife and rainbow smelt larvae are among the most abundant fish larvae encountered in the St. Clair system, suggesting the entire system may be a nursery for these species. White perch apparently also spawn in the St. Clair system. In 1983-84, a few white perch larvae were captured in the St. Clair River, and young-of-the-year white perch were among the most abundant fish captured by mid-water trawling in Lake St. Clair in 1980-85 (Table 15).

Movements

Fish utilizing the St. Clair system exhibit several basically different life history strategies that are reflected in the degree and kind of movements they display within the St. Clair system and between it and adjacent systems. Some species or stocks are permanent residents of the St. Clair system, while others are migrants which use the system as a feeding, spawning, or nursery area, or as a migratory pathway between Lakes Erie and Huron. These differences among species and stocks probably reflect the tendency for natural populations to develop life history strategies that allow them to competitively exploit the available habitat as needed to successfully complete critical life stages or functions.

Coldwater fishes exhibit the most obvious migrations in the St. Clair system. Native coldwater species, including lake trout, lake whitefish, and lake herring, historically migrated into the St. Clair system from Lakes Huron and Erie in the fall to utilize the spawning habitat in the system. There is no evidence to indicate these native coldwater species were year-round residents and indeed, the present thermal regime of the system (Table 4) suggests they probably were not. In most years, water temperatures in the St. Clair system might permit continuous residence of these species, although temperatures in July and September may approach or exceed the limits at which they can utilize food effectively for growth, and temperatures in August approach the lethal range (NAS 1973; McCauley and Casselman 1980). Lake, brown, and rainbow trout and coho and chinook salmon now frequent the St. Clair River and Lake St. Clair during the cooler months of the year (Haas et al. 1985; MDNR unpubl. data) in sufficient numbers to support a significant recreational fishery (see Section 5.3). These fish are apparently using the system as a migratory pathway between Lakes Erie and Huron, or are taking advantage of the feeding opportunities provided by concentrations of forage fish which occur seasonally in the system.

As indicated by recent studies of the movements of marked fish (Haas et al. 1985), most of the warmwater and coolwater species which frequent the St. Clair system are not strongly migratory. Species which appear to be permanent residents and exhibit little movement within the system include the smallmouth bass, brown bullhead, and black crappie. Northern pike, white suckers, and redhorse are permanent residents and exhibit a slightly greater tendency to move within the system. Muskellunge exhibit a clockwise movement around Lake St. Clair after spawning, and white bass and channel catfish tend to move from Lake St. Clair into the St. Clair River and tributaries in the spring and summer to spawn. Rock bass, after spawning in Lake St. Clair in the spring and early summer, make substantial movements into the St. Clair River and then return to the lake in the fall to overwinter.

3.6 WATERFOWL

Important waterfowl in Michigan include ducks, geese, and swans (Table 16). An estimated 1.5 million waterfowl visit some portion of lower Michigan each year, and Lake St. Clair, with its extensive wetlands, is nationally recognized as valuable habitat for these waterfowl (Jaworski and Raphael 1978). The St. Clair system lies on major migration corridors of both dabbling and diving ducks (Figures 48 and 49), and the extensive wetlands of Lake St. Clair are a nesting area for waterfowl. Important species of waterfowl that nest in the St. Clair system include Canada geese (Figure 50), mallards (Figure 51), blue- winged teal, and black ducks. If nesting boxes are available, wood ducks also will produce broods. Redhead ducks nest in St. Johns Marsh and on Harsens Island. Duck nesting densities of 72 pairs per square mile have been documented on Harsens Island (Jaworski and Raphael 1978).

In September, local nesting waterfowl gather in large wetlands in the Lake St. Clair area, where they are joined by waterfowl from more northerly breeding

Table 16. Waterfowl which frequent coastal wetlands in Michigan (After Johnsgaard 1975).

Scientific name	Common name
Aix sponsa	Wood duck
Anas acuta	Pintail
Anas americana	American wigeon
Anas clypeata	Northern shoveler
Anas crecca	Green-winged teal
Anas discors	Blue-winged teal
Anas platyrhynchos	Common mallard
Anas rubripes	Black duck
Anas strepera	Gadwall
Aythya affinis	Lesser scaup
Aythya americana	Redhead
Aythya collaris	Ring-necked duck
Aythya marila	Greater scaup
Aythya vallisneria	Canvasback
Bucephala albeola	Bufflehead
Bucephala clangula	Common goldeneye (American goldeneye)
Clangula hyemalis	Oldsquaw
Mergus cucullatus	Hooded merganser
Mergus serrator	Red-breasted merganser
Oxyura jamaicensis	Ruddy duck
Anser caerulescens	Snow goose
Branta bernicla	Brant
Branta canadensis	Canada goose
Cygnus columbianus	Tundra swan
Cygnus olor	Mute swan

grounds. Major concentration areas extend from the lower St. Clair River to the middle of Lake St. Clair. In October, or with the beginning of cold weather, resident and migrating waterfowl begin to funnel southward. The coastal wetlands and shallow waters of Lake St. Clair are critical resting and feeding habitat for these fall migrants.

Waterfowl whose primary fall migration corridors traverse Michigan with a resting stopover in the vicinity of Lake St. Clair include tundra swan, canvasback, bufflehead, and ruddy duck. The Canada goose, black duck, redhead, and greater and lesser scaup also make significant use of the St. Clair system (Bellrose 1976). Dabbling ducks are found more frequently in the waters surrounding Harsens and Dickinson Islands and in St. Johns Marsh on Anchor Bay than on the open waters of Anchor Bay in Lake St. Clair; diving ducks are typically more abundant in Anchor Bay (Table 17).

Spring migration from southern overwintering grounds begins in mid-March with the onset on ice breakup and generally follows in the opposite direction the route of the fall migration. Spring migrations appear more hurried than the fall migrations, and by late April or early May the main flights have passed through Michigan.

Historically, Lake St. Clair and the Detroit River were very important resting and feeding areas for the eastern population of the canvasback duck (Figure 52). In the fall the migrants moved from breeding grounds in the western United States and Canada to staging areas in the upper Mississippi River, where a portion of the population moved south to the lower Mississippi Valley and the Gulf of Mexico. The remaining portion of the population moved eastward to feeding and resting areas in the Great Lakes, where, in 1955, as many as 64,000 birds overwintered, while the rest proceeded on to the Atlantic coast. The entire overwintering eastern population, which was estimated to be more than 400,000 birds in the early 1950's, declined to less than 148,000 by 1960 and thereafter varied between 131,000 and 284,000 birds (Table 18). Surveys conducted by the Michigan Department of Natural Resources during 1950-76 (Martz et al. 1976) yielded results which paralleled the national trends. The number of canvasback ducks in Michigan was highest in 1951-55, lowest in 1966-70, and slightly higher in 1971-75. Annual waterfowl surveys conducted by the Michigan Department of Natural Resources (MDNR, Open Files) in January 1976-87 in the St. Clair-Detroit River system revealed midwinter populations of canvasback ducks varied widely from year to year and declined irregularly from 1981 to 1987. The highest population 1976-87 (21,500 birds) was recorded in 1981 and the lowest (2,000 birds) was recorded in 1982.

Causes for the nationwide decline in abundance of the canvasback duck are

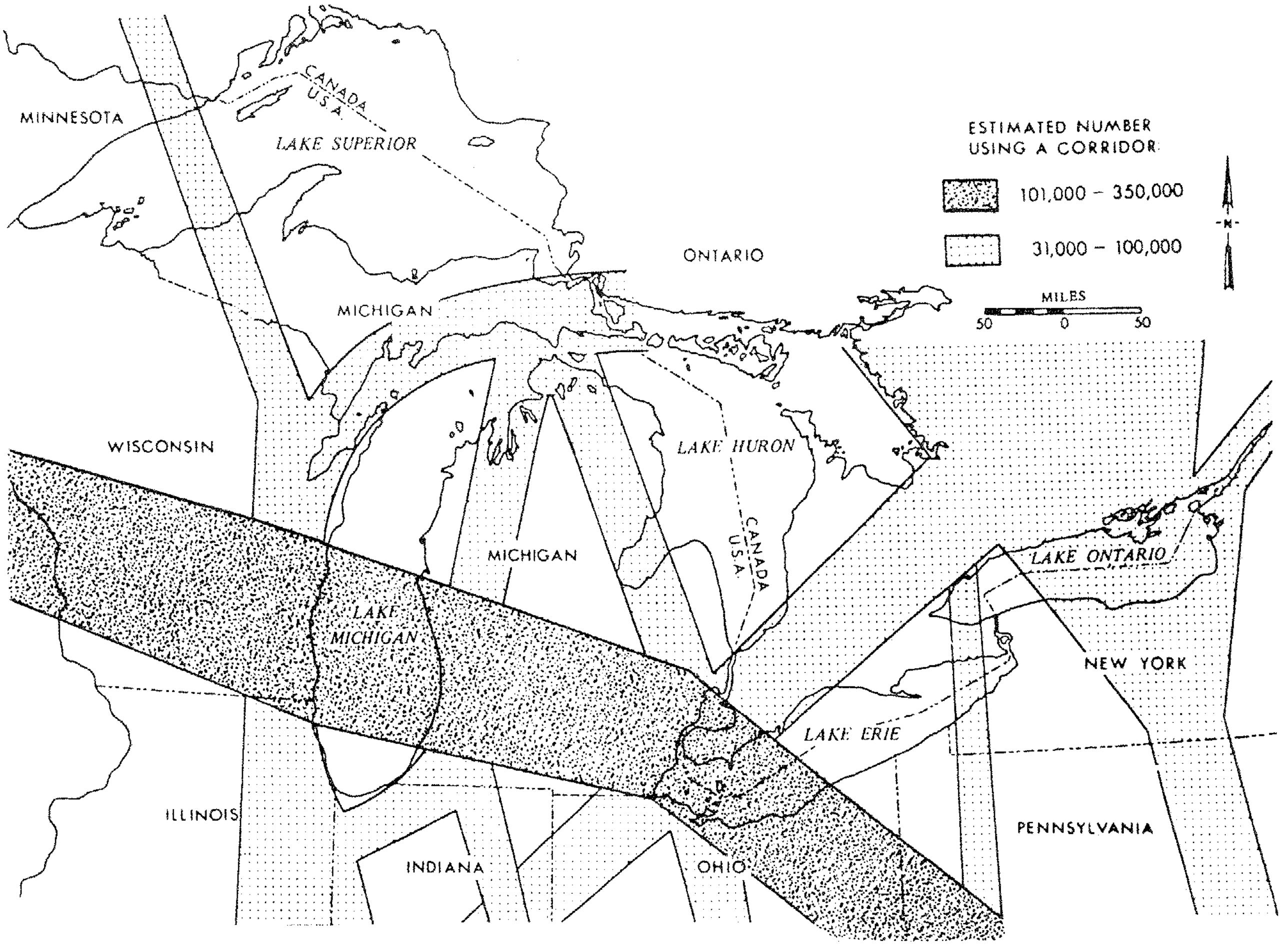


Figure 48. Fall migration corridors of dabbling ducks (Bellrose 1968).

incompletely known. However, the species possesses rigid habitat requirements and behavioral traits, including a strong dependence on wild celery (Vallisneria americana) as food, which limit their adjustment to environmental change. In Michigan, and particularly in the Detroit River, canvasback duck habitat has been adversely affected by many forms of human activity. Impacts include gross pollution by oil, chemicals, and heavy metals from industry and municipalities; excessive nutrient and sediment inputs from agriculture; sediment stirring and pollution with greases and oils from commercial and recreational navigation; and finally, disturbances from recreational boating. Fortunately, the canvasback duck habitat in Lake St. Clair has not been seriously affected by pollution because the St. Clair system receives large volumes of clean water from Lake Huron, and the addition of oil and other pollutants to Michigan waters of the St. Clair system is not extensive. As a result, Anchor Bay and the open waters of Lake St. Clair still produce a large variety of desirable submersed aquatics, including wild celery, in amounts that could support substantially larger canvasback populations than currently use the lake. Current use of this food by canvasback ducks may be restricted by the intense recreational boating activities on Lake St. Clair during the fall, which cause the ducks to seek less disturbed waters elsewhere.

3.7 OTHER BIOTA

Other prominent biota of the St. Clair system include amphibians, reptiles,

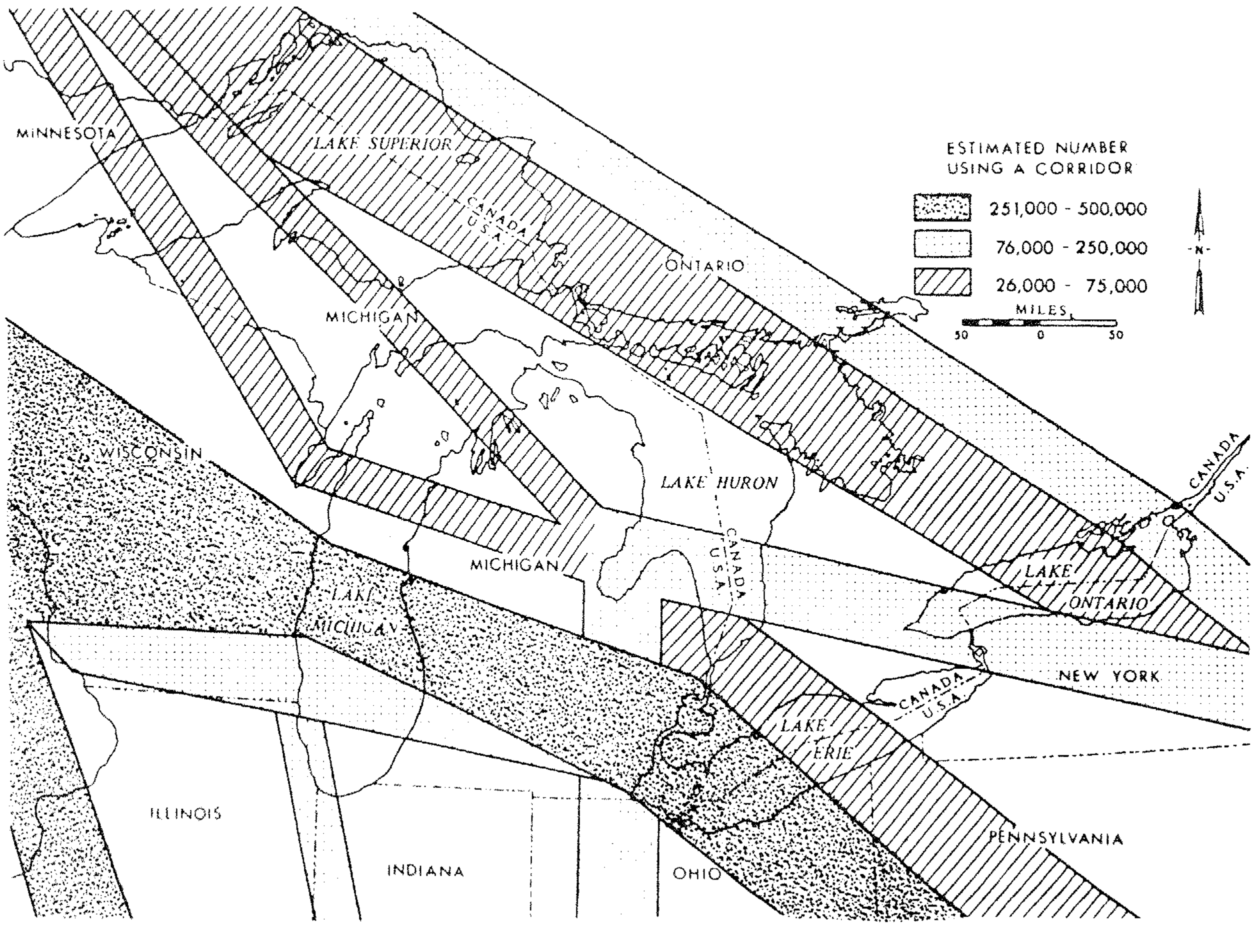


Figure 49. Fall migration corridors of diving ducks (Bellrose 1968).

birds other than waterfowl, and mammals. Species lists are available in Herdendorf et al. (1981 and 1986), but few studies have been conducted on the populations of these biota inhabiting the St. Clair system and their ecological importance and value to man is generally not well established.

Thirty-nine species of amphibians and reptiles, including salamanders, frogs, toads, snakes, lizards, and turtles, occur in aquatic, wetland, and adjacent terrestrial habitats in the St. Clair system. The mudpuppy (Necturus maculosus) is a large aquatic salamander which inhabits the open waters and river channels of the St. Clair system. A recent fishery and limnological survey, conducted during winter in Anchor Bay and the channels of the St. Clair River in the delta adjacent to the bay (Werner and Manny 1979) suggests that the mudpuppy is abundant in the nearshore waters of the lake and delta. The catch in 16 small hardware cloth traps set through the ice or in open, flowing water during February and early March was 0.6 mudpuppy per trap-day.

Birds other than waterfowl that may be found in and around the St. Clair system include grebes (2 species), rails (5), herons (7), plovers (3), sandpipers (12), gulls and terns (11), hawks and eagles (8), osprey, falcon, owl, kingfisher (1 each), and an extended list of perching birds. Only the Virginia rail (Rallus limicola), sora (Porzana carolina), American coot (Fulica americana), American woodcock (Scolopax minor), and

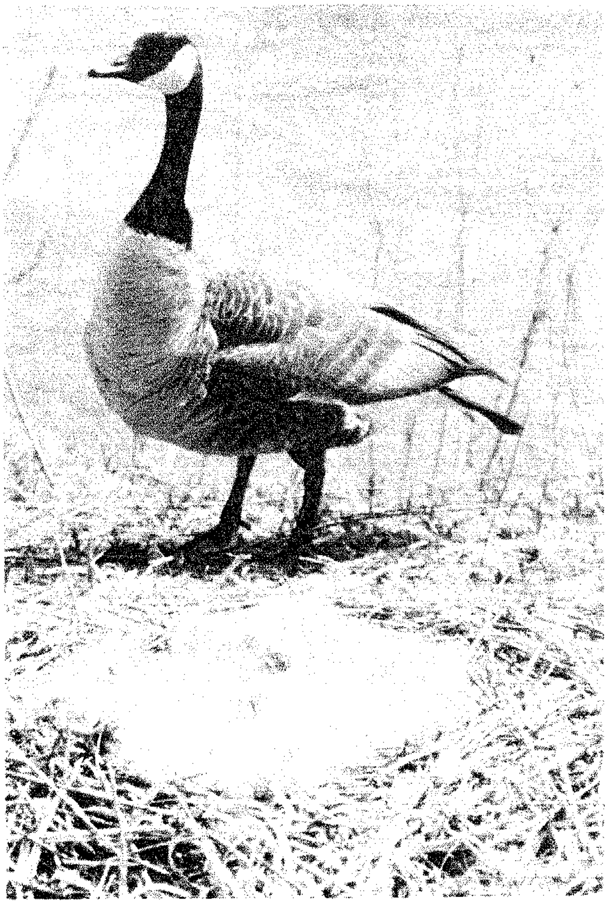


Figure 50. Canada goose with nest (Photograph by T. Edsall).

common snipe (*Gallinago gallinago*) are game birds in the Great Lakes area, and probably none of these species supports a significant hunting industry in the St. Clair system area.

More than a dozen species of medium-to-large mammals occur in the St. Clair system wetlands. The Virginia opossum (*Didelphis virginiana*), eastern cottontail rabbit (*Sylvilagus floridanus*), muskrat (*Ondatra zibethicus*), striped skunk (*Mephitis mephitis*), and whitetailed deer (*Odocoileus virginianus*) are abundant or common. All are game species or are harvested as furbearers. Muskrats are also valuable because manipulation of their populations can be an effective wetland management technique. Muskrats use large amounts of cattail and bulrush as food and to create winter shelters. If the muskrat population is allowed to increase, more open-water areas favored by wading birds and nesting waterfowl are created in the wetland. Once the optimum ratio of open water to cover is achieved, the excess muskrats can be harvested (MDNR 1982). More than 20,000 muskrats were harvested annually in 1965-75 in St. Clair and Macomb counties, which border the St. Clair system in Michigan (Jaworski and Raphael 1978).

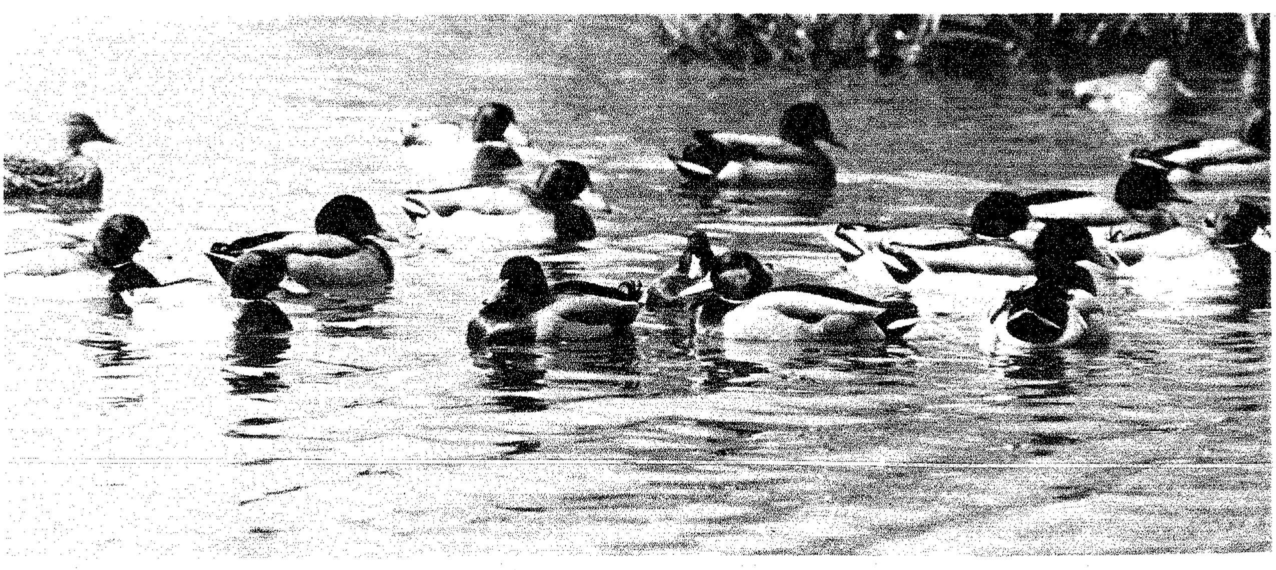


Figure 51. Mallard ducks (Photograph by Luther C. Goldman).

Table 17. Waterfowl observed on Lake St. Clair during the fall migration, October-December 1974 (Michigan Department of Natural Resources, Permanent Files).

Composition	Michigan Harsens Island	Michigan Dickinson Island	Michigan St. Johns Marsh	Michigan Anchor Bay	Ontario	Totals
Dabblers						
Mallard	19,550	137	1,354	647	4,598	26,286
Black duck	4,900	20	35	460	2,937	8,352
Baldpate	0	0	0	17	1,830	1,847
Pintail	650	0	31	45	0	726
Blue-winged teal	0	0	247	0	0	247
Green-winged teal	95	0	27	0	0	122
Total	25,195	157	1,694	1,169	9,365	37,580
Divers						
Canvasback	0	950	0	8,064	56,305	65,319
Redhead	0	10	0	6,509	3,896	10,415
Scaup	0	0	0	6,098	7,956	14,054
Goldeneye	0	865	0	3,496	382	4,743
Bufflehead	0	205	1	10	24	240
Total	0	2,030	1	24,177	68,563	94,771
Coots	90	12	360	258	612	1,332
Swans	0	0	0	0	402	402
Grand Total	25,285	2,199	2,055	25,604	78,942	134,085

3.8 WETLANDS

The St. Clair system contains one of the largest coastal wetlands in the Great Lakes. Topographic maps and navigation charts indicate there are 550 ha of wetlands in the St. Clair River and 13,230 ha in Lake St. Clair and the St. Clair Delta. These figures are conservative because wetlands composed of submersed macrophyte stands are common in the St. Clair system, but are incompletely documented on maps and charts.

One of the first regional studies of wetland vegetation was conducted by Pieters (1894) who mapped reasonably well-defined wetland zones in western Lake St. Clair relative to water depth. Several systematic studies of wetlands in the region have been completed recently (Schloesser and Manny 1982, 1985; Mudroch 1981), and an annotated bibliography of the aquatic plants of the St. Clair system (McCauley 1984) is available. Other recent studies have examined local plant distributions using remote sensing techniques (Roller 1976; Lyon 1979a, b; Schloesser et al. 1985). The most recent surveys (Figure 53) indicate there are 32 coastal wetlands in the St. Clair River and Lake St. Clair (Jaworski and Raphael 1979; Herdendorf et al. 1981; McCullough 1985; Herdendorf et al. 1986).

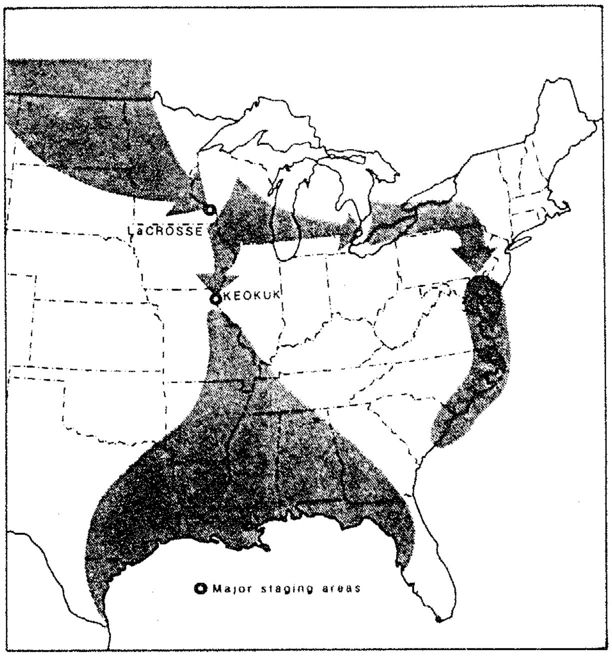


Figure 52. Major migration routes of eastern population canvasback ducks (USDI 1983).

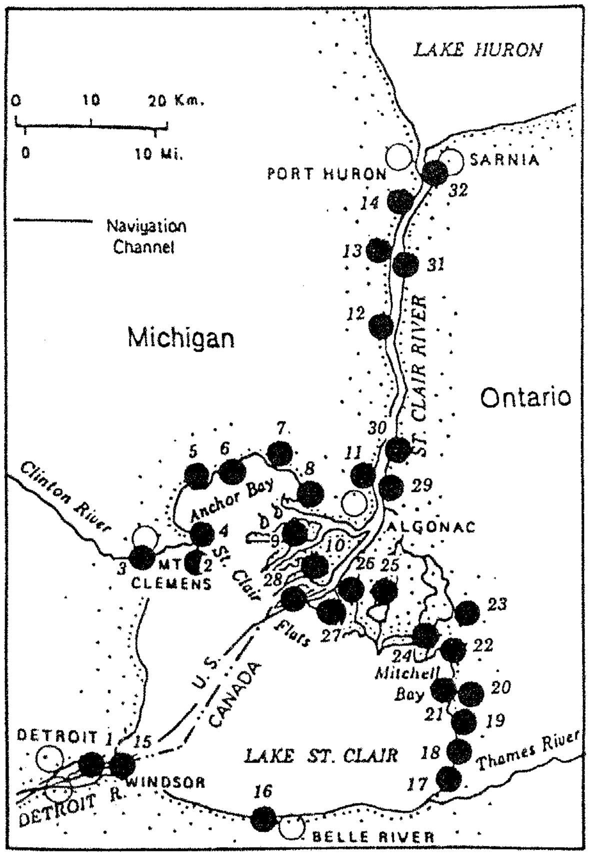
The wetlands of the St. Clair system can be divided into at least eight major types, (Table 19) based on various, well-defined physical settings which influence soil drainage and type, exposure to currents, and waves, and the composition of the plant community.

Open-water wetlands (Figure 54) support both submersed and emergent aquatic plants. These wetlands occur in the shallower waters along the perimeter of Lake St. Clair and in interdistributary bays (Figure 27) which are basins between distributary or main river channels. On the landward side, these interdistributary bays have been silted in by crevasse deposits and form most of the modern delta. On the lakeward boundary, water depth in open-water wetlands does not exceed 2 m. Anchor Bay, Fishery Bay, Goose Bay, and Muskamoot Bay contain open-water wetland habitat.

River-channel wetlands are colonized largely by submersed species but emergent macrophytes occur occasionally on point bars. River-channel wetlands occur on river shoulders (Figure 55) and the lake shelf. River shoulders are shallow, submerged shoals along the St. Clair River and the distributary channels. The lake shelf borders most of the Lake St. Clair shoreline. The shoulders and shelf are approximately 35 m wide and water depth does not exceed 2 m. The St. Clair River and its main channels in the St. Clair Delta are sites with river-channel wetlands.

Table 18. Eastern canvasback duck wintering populations by flyway, 1955-82 (USDI 1983).

Year	Numbers (thousands) by flyway			
	Central	Mississippi	Atlantic	Total
1955	8	94	306	408
1956	11	67	230	308
1957	7	104	179	290
1958	8	94	97	199
1959	6	68	92	166
1960	9	31	107	147
1961	9	37	158	204
1962	4	40	136	180
1963	12	41	163	216
1964	12	41	189	242
1965	11	42	161	214
1966	10	68	151	229
1967	11	44	226	281
1968	7	37	94	138
1969	6	31	133	170
1970	10	50	88	148
1971	10	50	88	148
1972	19	21	91	131
1973	12	39	104	155
1974	3	27	113	143
1975	27	65	118	210
1976	10	76	149	235
1977	13	54	142	209
1978	37	39	117	193
1979	50	91	143	284
1980	17	86	144	247
1981	43	79	132	254
1982	30	96	125	251
Average	15	58	142	214



MICHIGAN	ONTARIO
Wayne County	*Essex County*
1. Belle Isle	15. Peach Island 16. Ruscom River 17. Thames River Estuary
Macomb County	
2. Black Creek 3. Clinton River Estuary 4. Belvidere Bay 5. Salt River Estuary	*Kent County* 18. Bradley Marsh 19. Big Point Marsh 20. Tacky Marsh 21. Mitchell Point Marsh 22. Mitchell Bay 23. Wallaceburg
St. Clair County	
6. Marsac Point 7. Swan Creek Estuary 8. St. John's Marsh 9. Dickinson Island 10. Harsens Island 11. Belle River Estuary 12. Pine River Estuary 13. Marysville 14. Port Huron	*Lambton County* 24. St. Anne Island 25. Walpole Island 26. Squirrel Island 27. Bassett Island 28. Seaway Island 29. Port Lambton 30. Fawn Island 31. Stag Island 32. Sarnia

Figure 53. Coastal wetlands of the St. Clair system (After Herdendorf et al. 1986).

Beach and shoreline wetlands are represented by a mix of species including trees and shrubs, other terrestrial, non-woody plants, and emergent species. These plants grow on beach deposits (Figure 56), which are often erosional in origin and generally stand 30 cm above the lake surface. They are discontinuous, sinuous features and are most common on the delta. Lower Harsens Island and Dickinson Island contain beach and shoreline wetlands.

Cattail wetlands (Figure 57) occur in broad zones in the lower St. Clair Delta and Clinton River. Cattails are the dominant plants in this habitat. Stands of hybrid cattails are associated with the more clayey and organic sediments. Shallow openings are colonized by floating and submersed species. Cattail wetlands are typically found in the shallowest waters of interdistributary bays and behind dikes (Figure 56) constructed in premodern-modern delta transitional areas, the modern delta, and along the shorelines adjacent to the lake shelf on the perimeter of Lake St. Clair. The Clinton River and Harsens Island are sites occupied by cattail wetlands.

Sedge wetlands (Figure 58) occur in the shallowest waters of interdistributary bays in premodern-modern delta transition areas. These transition areas are often bounded by cattail wetlands at their lower elevations and gradually increase landward to the higher elevations of the premodern delta. Areas which support sedge wetlands include Dickinson and Harsens Islands.

Abandoned river channel wetlands support emergent and submersed aquatics. Occasionally buttonbush is also present. The abandoned channels (Figure 59), which provide the physical setting for these wetlands, include the premodern channels

Table 19. Wetland types in the St. Clair system (After Jaworski and Raphael 1979; Raphael and Jaworski 1982; Herdendorf et al. 1981).

Wetland type	Representative species			
Open water	Wild celery	*Vallisneria americana*	Hybrid cattail	*Typha x glauca*
	Pickerel weed	*Pontederia cordata*	Hard-stem bulrush	*Scirpus acutus*
	Yellow water lily	*Nuphar advena*	Three-square bulrush	*Scirpus americanus*
	Water smartweed	*Polygonum amphibium*	Sago pondweed	*Potamogeton pectinatus*
	Eurasian watermilfoil	*Myriophyllum spicatum*	Muskgrass or stonewort	*Chara* sp.
River channel	Cattails	*Typha*	Muskgrass or stonewort	
	Reed grass	*Phragmites australis*	Wild celery	
	Pond weeds	*Potamogeton* sp.	Milfoils	*Myriophyllum* sp.
Beach and shoreline	Eastern cottonwood	*Populus deltoides*	Touch-me-not, jewelweed	*Impatiens capensis*
	Staghorn sumac	*Rhus typhina*	Reed grass	
	Willow	*Salix*	Swamp thistle	*Cirsium muticum*
	Reed canary grass	*Phalaris arundinacea*	Stinging nettle	*Urtica dioica*
	Bluejoint grass	*Calamagrostis canadensis*	Morning glory	*Convolvulus sepium*
	Tussock sedge	*Carex stricta*	Black bindweed	*Polygonum convolvulus*
Cattail	Cattails		Little watermilfoil	*Myriophyllum alterniflora*
	Hybrid cattail		Bladderwort	*Utricularia vulgaris*
	Duckweeds	*Lemna minor* and *Spirodela polyrhiza*		
Sedge	Bluejoint grass		Common comfrey	*Symphytum officinales*
	Tussock sedges	*Carex lacustris*, *C. stricta*, *C. lasiocarpus*, *C. lanuginosa*, and *C. sartwellii*	Nightshade	*Solanum dulcamara*
Abandoned river channel	Buttonbush	*Cephalanthus occidentalis*	Common arrowhead	*Sagittaria latifolia*
	Yellow water lily		Hard-stem bulrush	
	White water lily	*Nymphaea tuberosa*	Three-square bulrush	
	Little watermilfoil			
Wet meadow	Quaking aspen	*Populus tremuloides*	Rattlesnake grass	*Glyceria canadensis*
	Red ash	*Fraxinus pennsylvanica*	Panic grass	*Panicum* sp.
	Red osier dogwood	*Cornus stolonifera*	Tussock sedge	
	Swamp rose	*Rosa palustris*	Swamp milkweed	*Asclepias incarnata*
	Goldenrods	*Solidago* sp.	Soft rush	*Juncus effusus*
	Bluejoint grass		Marsh fern	*Pryopteris thelypteris*
	Fowl meadow grass	*Poa palustris*	Silverweed	*Potentilla anserina*
	Rice cutgrass	*Leersia oryzoides*		
Shrub	Eastern cottonwood		Gray dogwood	*Cornus racemosa*
	Quaking aspen		Wild grape	*Vitis palmata*
	Red ash		Hawthorn	*Crataegus* sp.
	Red osier dogwood			

which dissect the premodern delta, and those displaying more recent deterioration on the modern delta surface. Examples of abandoned river-channel wetlands may be found on the upper portions of Harsens and Dickinson Islands.

Wet meadow wetlands contain low, woody plants interspersed with grasses. These wetlands, like the beach and shoreline wetlands, are distinctly above lake level and are characteristic of drier settings found along the lower margins of the premodern delta. Wet meadow wetlands usually occur landward of cattail and sedge wetlands and typical examples can be found on Dickinson and Harsens Islands.

Shrub wetlands are dominated by mixed shrubs, water-tolerant trees, and understory plants. These wetlands are usually found landward of the wet meadow wetlands

Figure 54. Open-water wetland in Muscamoot Bay. The emergent vegetation is bulrush (*Scirpus* sp.). In the background a beach colonized with cottonwood (*Populus deltoides*) and willows (*Salix* sp.) can be seen (Photograph by C. N. Raphael).

on the drier, lower pre-modern delta. Dickinson and Harsens Islands contain shrub wetlands.

More of the eight wetland types described here occur within the St. Clair Delta than along the St. Clair River or the lake shorelines. Although the wetland diversity is lower in the St. Clair River and along the perimeter of the lake, the submersed vegetation characteristic of these habitats is nevertheless important to a number of animal species (Section 3.2).

Figure 60 illustrates the vegetation and land use in the St. Clair Delta. The vegetation is distributed in broad arcuate zones. Oak and ash woodlands occur on the higher ground near the delta apex. On the west side of the delta, where there has been extensive clearing for agriculture, only fragments of natural vegetation remain. Wet meadow wetland is located lakeward of the woodlands, between the slightly higher and older delta to the north and the lower and modern delta to the south. Physically, it is a transition zone between the premodern and modern deltas. The sedge wetlands are dominated by the sedge Carex stricta var. strictior. Where water depths exceed 0.3 m, the sedges are replaced by cattail marsh, which is extensive, especially in Ontario. In deeper water, the cattail marsh gives way to open-water wetlands dominated by hard-stem bulrush. This zone of emergents is less dense lakeward where submersed macrophytes, primarily V. americana, Characeae, Najas flexilis, and Potamogeton sp., occur in bays at low density (Schloesser and Manny 1982).

Figure 55. River channel wetlands on the river shoulders in the North Channel of the St. Clair River (Photograph by Detroit Edison Company).

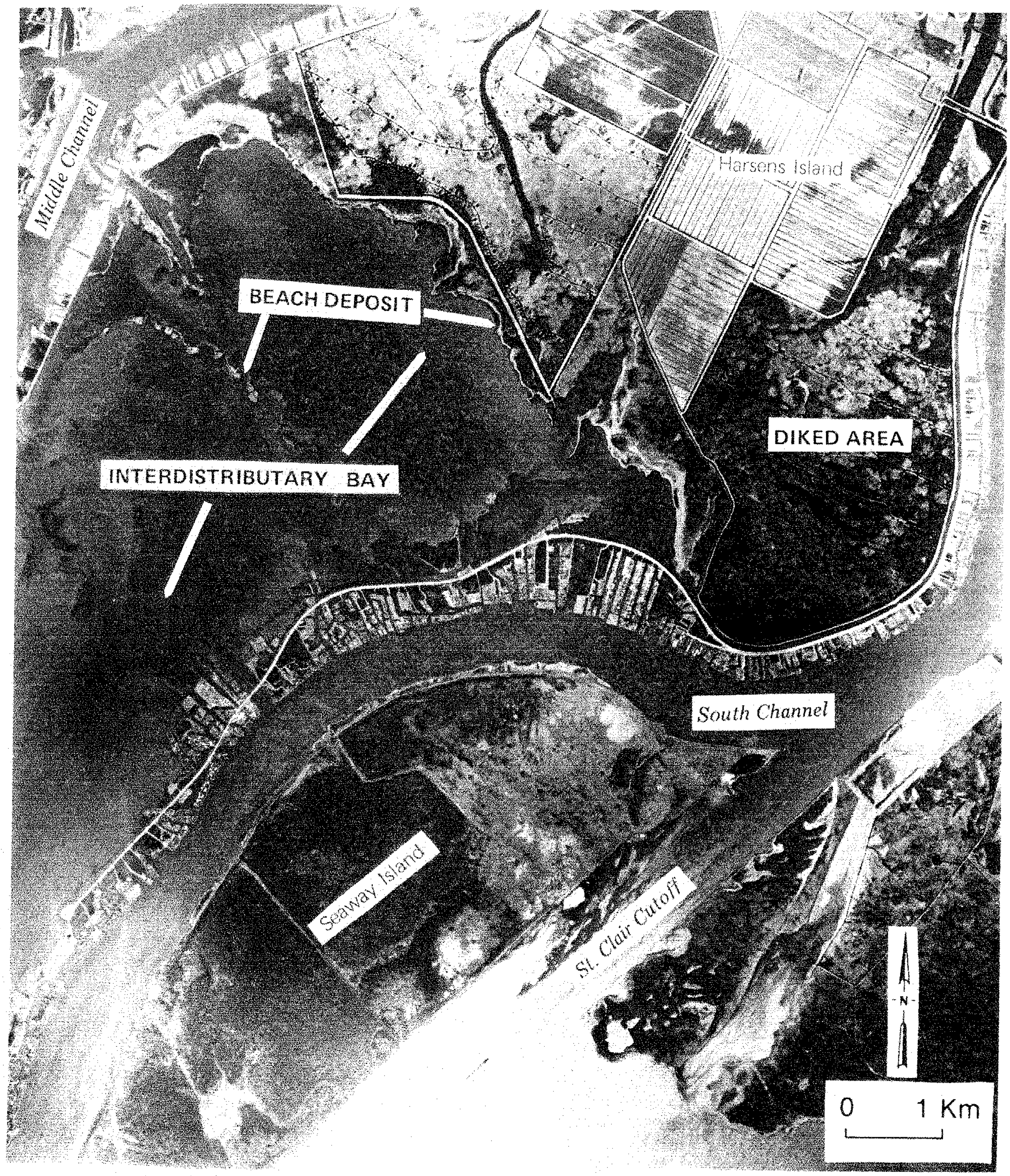


Figure 56. Beach and shoreline wetlands on beach deposits in the St. Clair Delta (Photograph by U.S. Army Corps of Engineers).

Figure 57. Cattail wetland on Harsens Island in the St. Clair Delta. Note the wooded premodern surface on the right (Photograph by C. N. Raphael).

Figure 58. Sedge wetland adjacent to an abandoned premodern channel on Harsens Island (Photograph by C. N. Raphael).

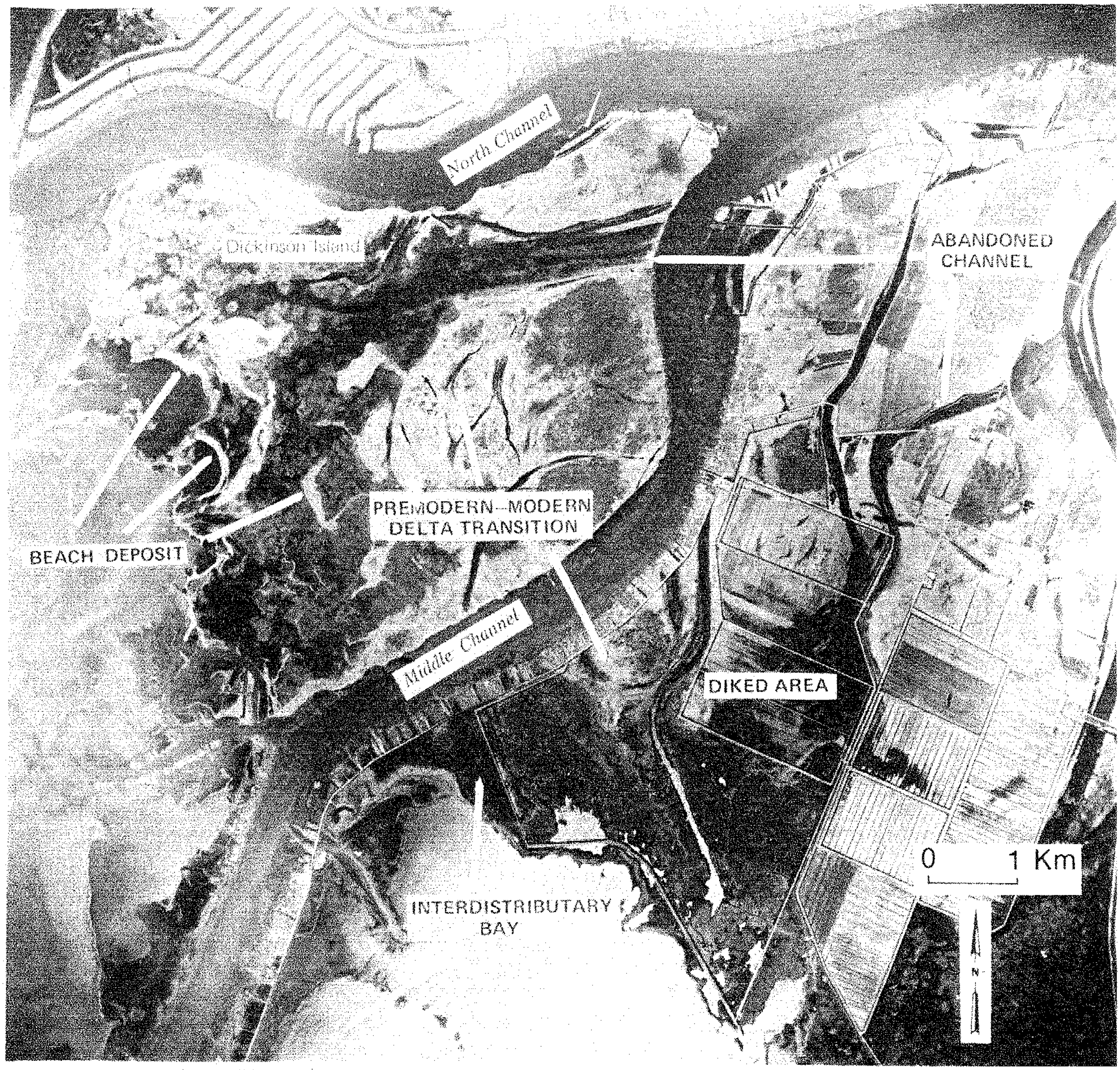


Figure 59. Abandoned river channel wetlands on Dickinson Island (Photograph by U.S. Army Corps of Engineers).

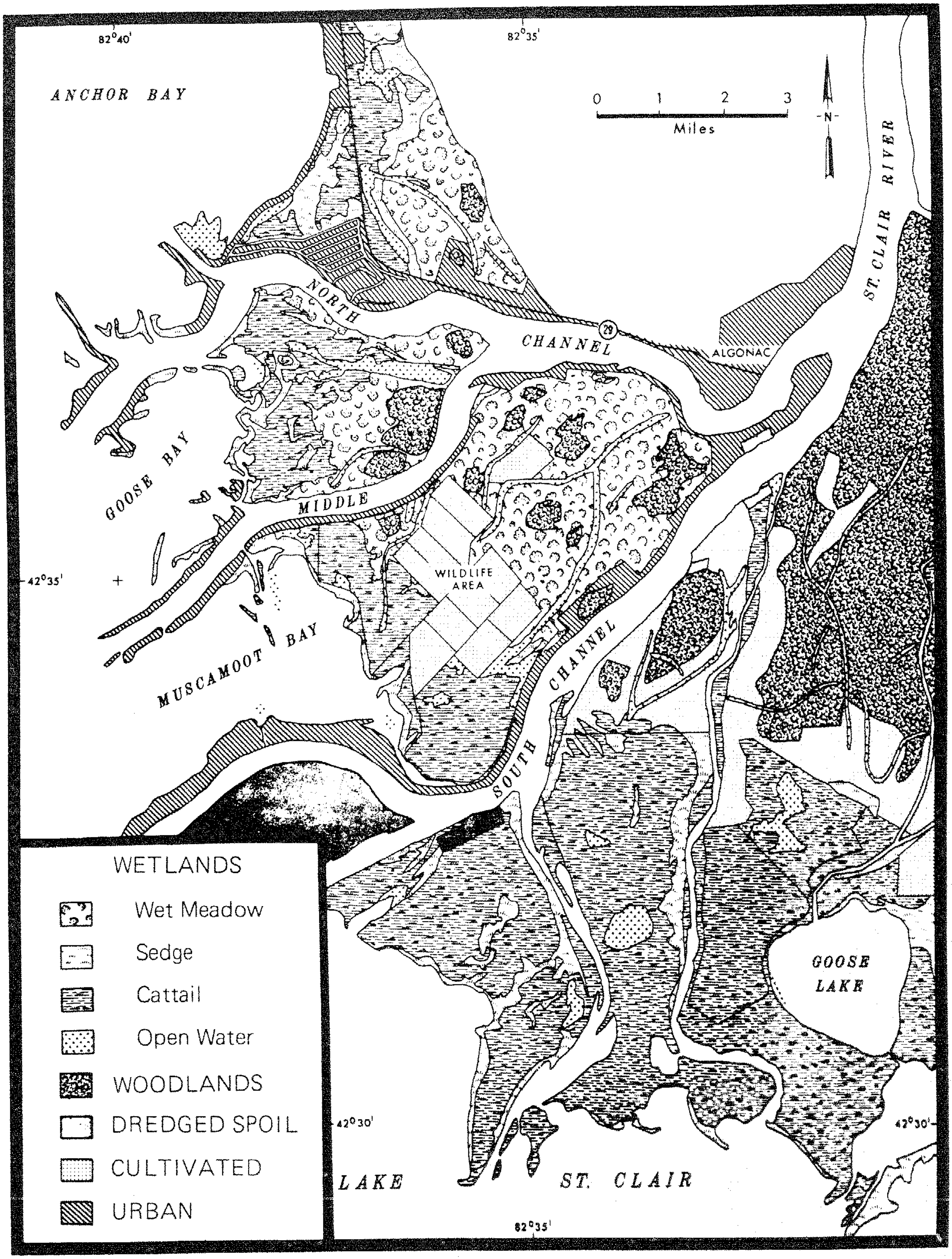


Figure 60. Wetlands, woodlands, and developed lands in the St. Clair Delta (Raphael and Jaworski 1982).

CHAPTER 4. ECOLOGICAL RELATIONSHIPS

4.1 NUTRIENT DYNAMICS

Water entering the St. Clair River from Lake Huron is of consistently high quality (OMOE 1977). Earlier records show turbidity was low (3-19 NTU) at all times (IJC 1951). Nutrient additions are of an anthropogenic origin. Five sewage treatment plants along the U.S. shoreline discharged a total effluent of about 76,000 m^3 per day in 1964 (MWRC 1967), while in the early 1980s, at least 11 Michigan and Ontario municipal and industrial waste water discharges with flows of about 1,000-49,000 m^3/day and total phosphorus loadings of 0.1-48 kg/day entered the river (Limno-Tech 1985). However, concentrations of total phosphorus (0.006 mg/L) and nitrate (0.310 mg/L) measured in the St. Clair River in 1980 (Edwards et al. 1987) were low and typical of unpolluted, oligotrophic waters (Wetzel 1975).

Additional research on the nutrient dynamics of the St. Clair River is needed. The fate of the nutrients entering the St. Clair River has not been described, but sediment phosphorus measured in the river (USEPA 1975, 1977) showed dry weight values ranging from 10 mg/kg of wet sediment near Port Huron-Sarnia at the head of the river to 600 mg/kg in the St. Clair Delta. The highest concentrations in the delta were found in clay sediments in deposition zones and may not have been typical of phosphorus levels in other sediment types. This suggests a portion of the river input of phosphorus is trapped in the delta and does not enter Lake St. Clair.

Lake St. Clair is a highly productive north-temperate lake that has been largely overlooked by limnologists since the early biological investigation of Reighard (1894). The distribution of chlorophyll and nutrients in Lake St. Clair is influenced primarily by lake currents (Section 2.3) and the flow of Lake Huron water through the delta system (Section 2.5). In Ontario waters, concentrations of chlorophyll, nutrients, and other chemical constituents increase across the lake from northwest to southeast (Figure 61). Average values in Ontario waters of the lake are similar to values measured in the South Channel of the St. Clair River delta and are substantially lower than those measured in the Thames River in the southeast corner of the lake (Table 20). Because of nutrient inputs from agricultural drainage and sewage discharge, and the greater stability of the water mass, the southeastern area is more nutrient rich than the remainder of the Ontario section of the lake (Leach 1972). More recently, cluster analyses of physical and chemical data from Lake St. Clair further confirmed the existence of two distinct water masses, a northwestern mass consisting primarily of Lake Huron water flowing from the main channels of the St. Clair River, and a southeastern mass of more stable water enriched by nutrient loadings from Ontario tributaries and shoreline urban development. The margins of the masses shifted according to wind direction and speed, but the overall discreteness of the distribution was maintained (Leach 1980).

The Michigan portion of Lake St. Clair was sampled in July, August, and September of 1973 (MWRC 1975). The lake waters are well mixed and essentially the entire lake basin is within the photic zone. Thermal and chemical stratification did not occur and oxygen concentrations were always near 100% saturation throughout the lake. Moderate alkalinity, low

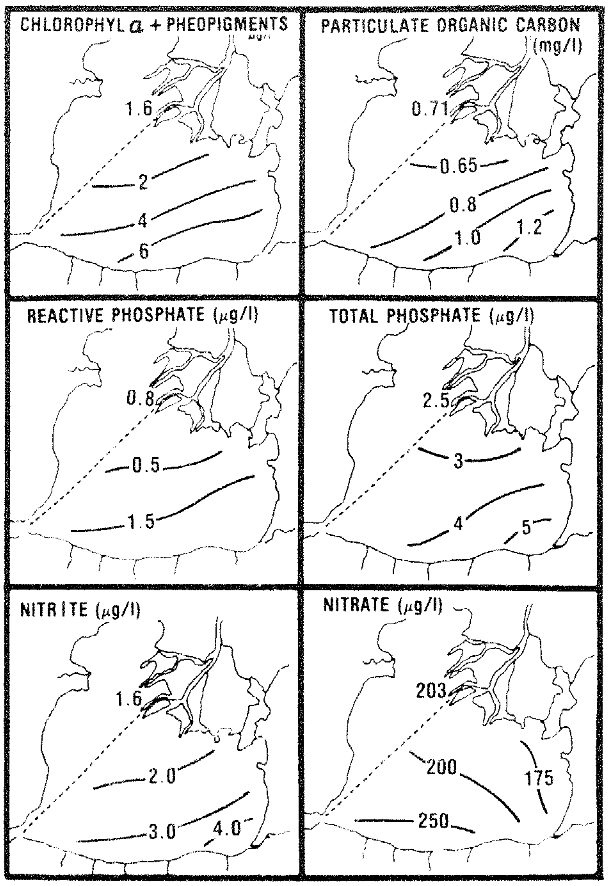


Figure 61. Distribution of nutrients, plant pigments, and related variables in Ontario waters of Lake St. Clair, April–November 1971 (Leach 1972).

specific conductance, and low pH variability indicate Lake St. Clair is a well-buffered, hard water lake. The input of large volumes of high quality water via the St. Clair River maintains water quality and biota in the open waters of Lake St. Clair, comparable to lower Lake Huron. The open waters of Lake St. Clair are classified mesotrophic based on low specific conductance, total dissolved solids, total phosphorus and chlorophyll (chl *a*), non-depletion of nitrate and silica, high oxygen content, and the predominance of pollution-intolerant planktonic organisms. Plankters common to oligotrophic conditions but capable of tolerating moderate enrichment were dominant in open waters of the lake (Williams 1972). Limitation of winter phytoplankton by phosphorus and silica was demonstrated for the Canadian waters of Lake St. Clair by Wallen (1979). Trace metal and vitamin limitations were also demonstrated.

In 1973, water quality in the Clinton Spillway area of the lake was severely degraded. Water quality and biota in this area reflected sewage inputs from the Clinton River and were comparable to Saginaw Bay (Lake Huron) and the western basin of Lake Erie. The Clinton Spillway area of Lake St. Clair was eutrophic as indicated by high total phosphorus and chl *a* concentrations, low diversity of benthic

Table 20. Distribution of chlorophyll, nutrients, and related variables in Ontario waters of Lake St. Clair, the South Channel, and the Thames River (Leach 1972).

	Lake St. Clair	South Channel	Thames River
Chlorophyll *a* + pheopigments (µg/L)	4.5	1.6	19.6
Chlorophyll *a* (µg/L)	3.4	1.2	13.0
Particulate organic carbon (mg/L)	0.89	0.71	1.68
Reactive phosphate (µg/L)	1.1	0.8	72.0
Total phosphate (µg/L)	4.0	2.5	80.0
Nitrate (µg/L)	202.0	203.0	835.0
Nitrite (µg/L)	2.7	1.6	52.0
Reactive silicate (mg/L)	0.33	0.42	0.36
Total alkalinity (mg/L)	89.2	88.1	168.0
Sulphate (mg/L)	16.8	15.3	47.5
Chloride (mg/L)	10.0	8.1	36.7

macroinvertebrates with pollution-tolerant oligochaetes and chironomids dominant, and high algal densities with the phytoplankton assemblage dominated by Stephanodiscus, which is common in enriched situations.

The upper St. Clair River is designated a Class A area of concern by the IJC because water concentrations of phenol (4-7 mg/L) exceed recommended water quality criteria, and bottom sediments in the upper river are badly contaminated with chlorinated organic compounds, such as polychlorinated biphenyls (PCB's), hexachlorobenzene and octachlorostyrene, and volatile hydrocarbons, such as perchloroethylene, carbon tetrachloride, dibenzodioxins, and dibenzo-furans (OMOE 1979, 1986a). Concentrations of these toxic substances in St. Clair River waters entering Lake St. Clair are typically 10-100 fold lower than at the headwaters of the river due to dilution and volatilization (OMOE 1986a), but significant amounts of these toxics may still be entering Lake St. Clair, which appears to act as a sink for some of them. Concentrations of heavy metals, including lead, mercury, and zinc, in Lake St. Clair sediments were generally low except at the Clinton River Spillway area and at the dumping grounds adjacent to the international shipping lane. Toxic substances in these areas frequently exceeded background levels and U.S. Environmental Protection Agency dredged materials criteria. Organic contaminants were generally low in the sediments except for PCB's which were found at high concentrations in the Clinton Spillway area. The persistent, long-standing problem of mercury-polluted sediments in excess of the U.S. Environmental Protection Agency criterion of 10 mg/kg in Lake St. Clair is gradually disappearing as polluted sediments are transported by currents into Lake Erie (Thomas et al. 1975; Thomas and Jaquet 1976; Hamdy and Post 1985).

The effects of these toxic substances on the nutrient dynamics of the St. Clair system have not been adequately addressed. However, a recent study by Munawar et al. (1985) in the Detroit River suggests there is considerable potential for an adverse impact of various sediment-bound contaminants on the ultraplankton (organisms smaller than 5 µm) which contribute to the base of the aquatic food chain and may also exercise influence over the nutrient dynamics of the St. Clair system.

4.2 BIOLOGICAL PRODUCTION

Estimates of production by primary producers and consumers in the St. Clair River and Lake St. Clair were developed by Edwards et al. (1987) from information in the literature (Table 21) and represent the best synthesis presently available.

Phytoplankton standing crop and production values for the St. Clair River in Table 21 are based on studies in Lake Huron by Glooschenko et al. (1973) and Vollenweider et al. (1974). The average standing crop from May to November in Lake Huron was 1.7 mg chl a/m^3, and the mean production rate was 3 mg carbon (C)/m^3/hr; these values were converted to ash-free dry weights (AFDW) of 17.05 mg C/mg chl a (Paerl et al. 1976) and 1.98 mg AFDW/mg C, respectively, after Lind (1979). An average daylight period of 10 h and a 50% reduction in C values to account for night respiration (Vollenweider 1969) were used to estimate annual production. Since productivity data were representative of only 7 months, an annual estimate was obtained by using 50% of these values for the remaining months (Vollenweider et al. 1974). The standing crop estimate was assumed to be representative of a yearly average based on Glooschenko et al. (1973). A mean depth of 7.8 m for the St. Clair River was used to convert volumetric units to areal estimates, and it was assumed that the entire water mass was photosynthetically productive. Daily production rates per m^2 were summed over the two periods and multiplied by the area of the St. Clair River (5,815 ha) to provide an estimate of total annual production in the river. Average annual phytoplankton biomass in Lake St. Clair of 4.3 mg chl a/m^3 was derived from data collected by Leach (1972), the Michigan Water Resource Commission (MWRC 1975), and Bricker et al. (1976). The only production data (Winner et al. 1970) were from the littoral area, which may not be representative of the whole lake, so an annual turnover rate of 150, based on the Lake Huron data, was used instead. A mean depth of 4.4 m, a photic zone of 2.5 m, and a surface area of 111,400 ha were used

Table 21. Mean standing crop, net production, and system production of primary producers and consumers in St. Clair River and Lake St. Clair (After Edwards et al. 1987)[a].

	St. Clair River			Lake St. Clair		
	Standing crop	Net production	System production	Standing crop	Net production	System production
Primary producers						
Phytoplankton	0.45	67	3,900	0.64	54	60,160
Periphyton	2.0	26	1,160	2.5	32	16,720
Submersed macrophytes	131 [b]	164	2,290	46 [b]	58	13,780
Emergent macrophytes	532 [b]	665	22,620	532 [b]	665	60,990
Total			29,970			151,650
Primary consumers						
Zooplankton	.56	10	590	0.44	7.9	8,800
Macrozoobenthos	1.0	7	440	1.1	6.8	7,600

[a] Tabular values are reported as follows: standing crop and net production as grams ash-free dry weight/m²; system production as metric tons ash-free dry weight/yr. Surface areas of the river and lake were estimated to be 5,813 and 111,400 ha, respectively.

[b] Seasonal maximum standing crop.

to calculate standing crop and annual production.

No periphyton standing crop or production data exist for the St. Clair system so estimates were obtained from the literature. Periphyton standing crops in Wetzel (1983) ranged from 1 to 7 g/m² for a variety of substrates. A conservative mean annual estimate of 2 and 2.5 g/m² for the St. Clair River and Lake St. Clair, respectively, was established. Submersed and emergent plant surface areas (m² of plant surface/m² of bottom) available for epiphyte colonization were, respectively, 1.22 (Brown et al. 1986) and 0.75 (B. Manny, National Fisheries Research Center-Great Lakes; pers. comm.). Epipelic and epilithic algae were assumed to develop in areas where plants were absent and at a depth range of 0-3.6 m in the St. Clair River, but only 0-1.8 m in Lake St. Clair because of reduced light penetration (Hudson et al. 1986). An annual turnover ratio of 13 was taken from Wetzel (1975). The mathematical product of bottom surface area available, adjustments for macrophyte surface area, standing crop, and turnover ratio equals the annual production values for periphyton.

Areal coverage and biomass estimates for submersed macrophytes in the St. Clair system are from Schloesser and Manny (1982), Schloesser et al. (1985), and Hudson et al. (1986), and estimates for emergents are from McCullough (1985), Raphael and Jaworski (1982), Herdendorf et al. (1981), Hudson et al. (1986), and B. Manny, pers. comm. Annual mean net production is usually assumed to be equal to maximum seasonal standing crop; however, the production peak is rarely sampled, and grazing, physical damage, and other mortality imply a turnover rate greater than one. A turnover ratio of 1.25 was arbitrarily chosen and assumed to be conservative (Rich et al. 1971). The product of the surface area within the 0-3.7 m contour, percent coverage, turnover ratio of 1.25, and standing crop as ash-free dry weight equals total production of submersed macrophytes in the St. Clair system. The product of the areal coverage of emergents, the turnover ratio, and the standing crop as ash-free dry weight equals total production of emergents. Estimates for submersed and emergent plants represent only aboveground biomass.

An annual zooplankton standing crop of 0.056 g AFDW/m^3 for the St. Clair River was estimated from Watson and Carpenter (1974) from data for Lake Huron. Standing crop estimates for Lake St. Clair are unknown so a value of 0.100 g AFDW/m^3 was arbitrarily chosen based on standing crops for mesotrophic lakes (Wetzel 1975). An annual turnover ratio of 18 was used to estimate production and represents an average of several turnover times given for oligotrophic and mesotrophic bodies of water (Wetzel 1975). Water volumes for the St. Clair system were the same as those used for phytoplankton except no adjustments were made for the photic zone.

Macrozoobenthos standing crops in the St. Clair system are from Hudson et al. (1986), with total biomass weighted by areas associated with 0-1.8-, 1.8-3.6-, and >3.6- m depth contours in the river. Lake St. Clair biomass estimates are from mid-lake and were expanded to total lake surface regardless of depth. Production was obtained by using turnover ratios given by Waters (1977) for the 10 dominant taxa in each section of the St. Clair system. A weighted turnover ratio for each section was derived using relative biomass of each taxon as the weighting factor. The relative biomass of each taxon in a section was obtained by multiplying numerical abundance by an average individual biomass. Community turnover ratios ranged from 6 to 8 depending on the abundance of faster growing chironomids, oligochaetes, nematodes, and polychaetes versus slower growing amphipods, molluscs, and mayflies.

Edwards et al. (1987) provide no detailed interpretation of the values in Table 21, but state that the differences in standing crop and production in the St. Clair River and Lake St. Clair probably reflect differences in nutrient levels and in the quantity of suitable habitat between the river and the lake. According to Table 21, most net primary production occurs in the macrophyte component of the system. Net primary production by the phytoplankton, periphyton, and emergent macrophyte components in the river is similar to production in the lake by those same components, but the net production by submersed macrophytes is almost three times higher in the river than in the lake. Total production in the lake by all plant components is about five times higher in the lake than in the river. The higher standing crop values for phytoplankton in the lake seem reasonable because of the higher nutrient levels and the longer retention time of water in the lake. The lower net production values for the lake could be attributed to the higher turbidity and consequent reduction in photosynthetic activity, particularly in the lower end of the water column. The higher system production of primary producers in the lake appears to reflect not only the variables already described that influence standing crop and net production, but also the greater surface area of the lake. The higher standing crop of submersed macrophytes in the river is consistent with the lower turbidity, and thus the greater light penetration in the river. The river setting also provides a habitat in which the submersed macrophytes are more protected from wave-generated turbulence that uproots or fragment plants and reduces the standing crop. Emergent macrophytes are much less common in the river than the lake, and the greater total production in the lake probably reflects the greater amount of suitable habitat along the lake border. The higher standing crop and net production of periphyton in the lake are consistent with the higher nutrient levels in the lake, and the greater total production seems reasonable in terms of the greater quantity of substrate (about threefold higher system production) provided in the lake by submersed and emergent macrophytes.

The net production of zooplankton and macrozoobenthos differs little from each other and is similar in the river and lake, but system production values for the two components combined are about 16 times higher in the lake than in the river. The greater system production in the lake is consistent with the longer residence time and the greater amount of habitat available in the lake.

Net production values for the St. Clair system (Table 21) are generally higher than those for the St. Marys River (Table 22), the outflow from oligotrophic Lake Superior. An exception occurs in the macrozoobenthos which has a considerably higher net production value in the St. Marys River than in the St. Clair system. Net production values for the St. Clair system are similar to those in the Detroit River, which receives the direct outflow of the St. Clair system, and lower than those for the St. Lawrence River, which is more nutrient rich.

4.3 TROPHIC STRUCTURE

A number of surveys have described the phytoplankton, wetlands, submersed macrophytes, macrozoobenthos, and fish of the St. Clair River and Lake St. Clair (Winner et al. 1970; Jaworski and Raphael 1979; Schloesser and Manny 1982; Thornley 1985; Haas et al. 1985), but no studies have been conducted which adequately describe the trophic structure of the St. Clair system. As a result, we do not understand in detail how the various trophic levels in the system relate to one another. The values in Table 21 are an important first step in understanding the trophic structure and food web dynamics of the St. Clair system, but knowledge of the energy and materials utilized at each trophic level and transferred to other trophic levels is essential for even the most basic analysis of ecosystem structure and function.

As Table 21 indicates, about 181,620 metric tons of plant biomass are produced in the St. Clair system each year, of which about 17% and 83% originates in the St. Clair River and Lake St. Clair, respectively. Because of the short flushing time of the St. Clair system, most of the phytoplankton biomass (64,060 metric tons), representing about 35% of the total plant biomass produced in the system, probably passes into Lake Erie before it is utilized. If that is the case, emergent aquatic macrophytes account for 75%

Table 22. Mean net production in the St. Marys, Detroit, and St. Lawrence Rivers (After Edwards et al. 1987)[a].

	River		
	St. Marys	Detroit	St. Lawrence
Primary producers			
Phytoplankton	5	54	295
Periphyton	12[b]	39	65
Submersed macrophytes	35	174	110
Emergent macrophytes	650	468	715
Primary consumers			
Zooplankton	1.0	8.3	27.2
Macrozoobenthos	15.5	5.4	13.4

[a] Tabular values are grams ash-free dry weight/m²/yr.
[b] In emergent wetlands only.

of the primary production in the St. Clair River and 40% of that in Lake St. Clair. It seems reasonable to assume virtually all of the submersed and emergent plant biomass and the associated periphyton becomes detritus each year, but it is difficult to estimate how much of that detritus is utilized in the St. Clair system. A study of the aquatic macrophytes drifting into the Detroit River from Lake St. Clair in 1985 (National Fisheries Research Center-Great Lakes, unpubl.) revealed that only about 8% of the biomass produced in the St. Clair River and Lake St. Clair by periphyton and submersed and emergent macrophytes entered the head of the Detroit River in May-October, despite the fact that most macrophytes die back in the fall (Schloesser et al. 1985). Other earlier observations (Werner and Manny 1979; D. W. Schloesser, pers. comm.) revealed that much of this senescent plant material remains on the lake bottom through the winter and moves downstream in spring just after ice break-up. This explains, in part, the high productivity of benthic macroinvertebrates in Anchor Bay and around the delta of the St. Clair River in Lake St. Clair--where, for a major portion of the year, the production of macrozoobenthos is probably not limited by food, owing to the large accumulations of decaying macrophytes that are washed into the lake from the river.

Large amounts of allochthonous organic matter are also added to the St. Clair River and Lake St. Clair as sewage. From data presented by Vaughan and Harlow (1965), we estimate that municipal sewage treatment plants at Port Edward, Port Huron, Sarnia, Mt. Clemens, and St. Clair Shores, which collectively serve a population of over 220,000 people, added over 53,500 metric tons of suspended and settleable solids to the St. Clair system in 1965. This amount is equivalent to 29% of the total annual primary production of all plants in the St. Clair River and Lake St. Clair combined. Direct sewage inputs to the St. Clair system estimated by Edwards et al. (1987) from STORET retrieval of 1984 water year data were 556 metric tons (ash-free dry weight).

In most natural waters, dissolved organic carbon (DOC) and particulate organic carbon (POC) greatly exceed the amount of organic carbon contained in living plankton, macrophytes, and fauna (Wetzel 1975). No DOC measurements are available for the St. Clair system, but measurements for Lake Huron average 2.7 g/m^3 (Robertson and Powers 1967). The amount of POC coming into the St. Clair River from Lake Huron is approximately 0.7 g/m^3 (Robertson and Powers 1967); an average of 1.4 g/m^3 was measured at the mouth of the St. Clair River and up to 2.0 g/m^3 was measured in Lake St. Clair (Leach 1972). Suspended solids increase by a factor of six between Lake Huron and Lake Erie (Kauss and Hamdy 1985). The largest contributors to the organic portion of the suspended solid load are probably aquatic macrophytes. Littoral macrophytes not only produce large quantities of organic matter, but, because woody debris is generally lacking in the St. Clair system, their stems provide most of the above-bottom structure available for colonization by periphyton and invertebrates. Aquatic macrophytes help retain POC in the system by trapping it within the plant bed and storing it among their root systems. However, the virtual lack of peat in the St. Clair River and Lake St. Clair wetland substrates is unusual and suggests that there is either rapid decomposition or, more probably, rapid flushing of organic materials from the system.

The rate at which detritus is produced, processed, and moved downstream determines, in large measure, the productivity of and energy flow through biotic communities in rivers (Cummins et al. 1984; Minshall et al. 1985). In fact, the major tenet of the most inclusive stream ecosystem theory available (Cummins et al. 1984) is that terrestrial riverside vegetation exerts primary control over biotic associations in the river. In the St. Clair River, terrestrial riverside vegetation may contribute a significantly smaller proportion of the plant matter that becomes detritus because the river banks are largely urbanized or industrialized and because the source of the river is Lake Huron, which serves as a settling basin for upstream allochthonous inputs of terrestrial plant matter. Edwards et al. (1987) estimate the input of terrestrial organic matter (leaves and insects) to the St. Clair River to be a minimum of 140 metric tons (ash-free dry weight) per year, which even if doubled is still less than 1% of the system production of periphyton and macrophytes in the river (Table 21). The preceding analysis of detrital flow indicates that the St. Clair River may differ from many other rivers in that the biomass produced by emergent and submersed aquatic macrophytes and added by the sewage treatment plants is the basis for most of the subsequent biological production in the river and for some of the production in Lake St. Clair.

Also important to a consideration of detrital flow is the impact of commercial navigation on the production of aquatic macrophytic plants and the movement of detritus. Several studies suggest that wave forces generated by the passage of large commercial vessels through the St. Clair River reduce the areal extent and abundance of aquatic macrophytes by uprooting or fragmenting them (Schloesser and Manny 1986). Other studies on Great Lakes connecting channels (Poe et al. 1980; Poe and Edsall 1982; Liston and McNabb 1986a, b; Jude et al. 1986) indicate vessel traffic may also wash detritus from littoral areas into the river channel where it is transported rapidly downstream. Such rapid transport would reduce the spiraling rate (simultaneous recycling and downstream progression) of the nutrients (Elwood et al. 1983) represented by these resources and therefore also reduce overall production in the river.

As shown in Table 21, the St. Clair system is a major source of detrital organic matter that can support macrozoobenthos in the river and lake and also in downstream areas, including the Detroit River and western Lake Erie. Thus, the St. Clair system is not only a conduit that transports organic matter from Lake Huron to the Detroit River and Lake Erie, but it is also a net producer of organic matter, some of which is recycled within the system. The magnitude of this autochthonous production, its use, and qualitative change in composition during storage and transport will require additional study if we are to develop an adequate understanding of production in the St. Clair system based on both physical and trophic level dynamics.

4.4 WATER LEVELS AND WETLANDS

The effects of water level fluctuations on Great Lakes coastal wetlands have been discussed by Jaworski and Raphael (1979, 1981), IJC (1981a), Geis (1985), Prince and D'Itri (1985), and Keddy and Reznicek (1985), but our knowledge of the subject is meager (Burton 1985). Consequently, our ideas about the structure and function of Great Lakes coastal marshes are based on generalities and extrapolations from other systems. The data gaps exist in part because research efforts in the Great Lakes Basin have been directed to inland rather than coastal wetlands.

Jaworski and Raphael (1979) have advanced the hypothesis that the Lake St. Clair wetlands are in a state of dynamic equilibrium or "pulse stability," in which the size, location, and structure of the wetland plant communities shift dramatically in response to the periodic changes in water levels that occur frequently in the system. In Great Lakes coastal wetlands, seiches or short-term oscillations of water levels occur. The effect of these water level changes on wetlands is unmeasured, but they may profoundly influence the import and export of wetland materials (Burton 1985). Simpson et al. (1983) suggest that frequency and duration of inundation determine the properties of the wetland substrates, which in turn determine species diversity, primary production, rate of decomposition, and uptake and release of nutrients. The effects of long-term water level oscillations over a period of 8-20 yrs are more evident (Figure 21). In Lake St. Clair, near record low water levels (about 174 m) in 1964-65 followed by record high water levels (about 175.5 m) in 1972-74. These fluctuations caused dramatic lateral shifts of the wetland types on Dickinson Island in the St. Clair Delta (Figure 62). The island, which covers 11.3 km², exhibits many of the wetland types discussed, because it has not been as severely modified by man as have other portions of the shoreline. During low water conditions in July 1964, cattail, sedge, shrub, and wet meadow wetlands dominated the island. However, during the record high water period of the mid-1970's, widespread dieback of wetland vegetation occurred to

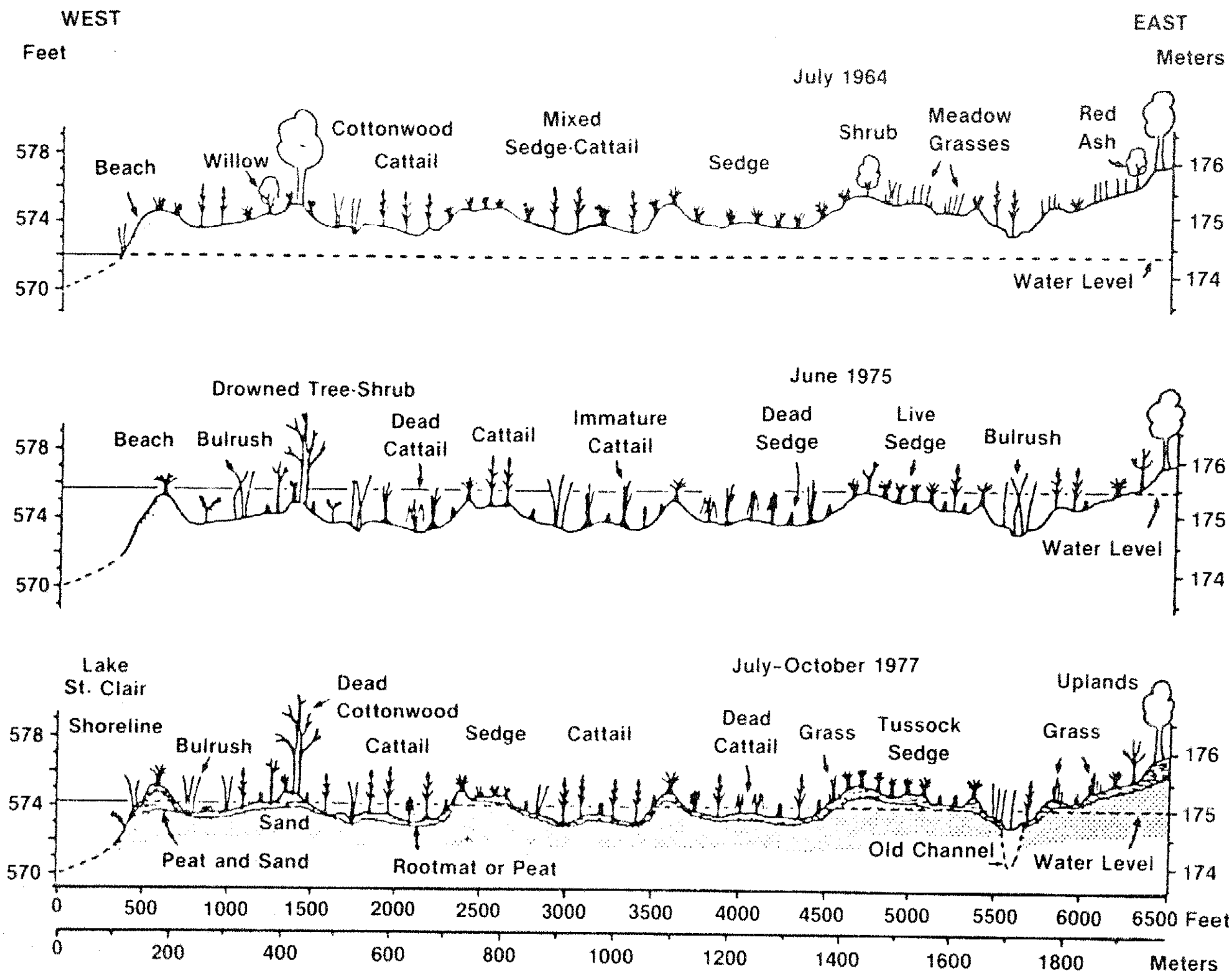


Figure 62. Vegetation transects on Dickinson Island (Modified from Jaworski and Raphael 1979). Wetland designations follow Table 19.

the lakeward border of the uplands, which were colonized by oak-ash woodlands. During high water periods, most of the former cattail wetlands became open water wetlands that were colonized by bulrushes and submersed macrophytes. By the summer of 1977, after water levels dropped somewhat, more extensive cattail, sedge, wet meadow, and shrub wetlands were re-established.

The wetlands not only change location but alter their areal extent in response to long-term water level oscillations (Figure 63). The dominance of cattail and sedge wetlands during periods of low water is clear. In contrast, during periods of high water, more extensive open-water wetlands with floating leaved and submersed macrophytes occurred along with the cattail wetlands. The area occupied by shrub wetlands changed little as the water levels changed because that wetland type was located slightly above the high water mark.

Quantitative areal changes in wetland vegetation corresponding to each of the time periods illustrated on the maps of Dickinson Island (Figure 63) are shown in Table 23. In 1949, under average water levels, 63% of the island was cattail and sedge wetland, and 13.5% was open-water wetland. Wet meadow wetlands and woodlands-shrub wetlands each covered some 10% of the region, and developed lands

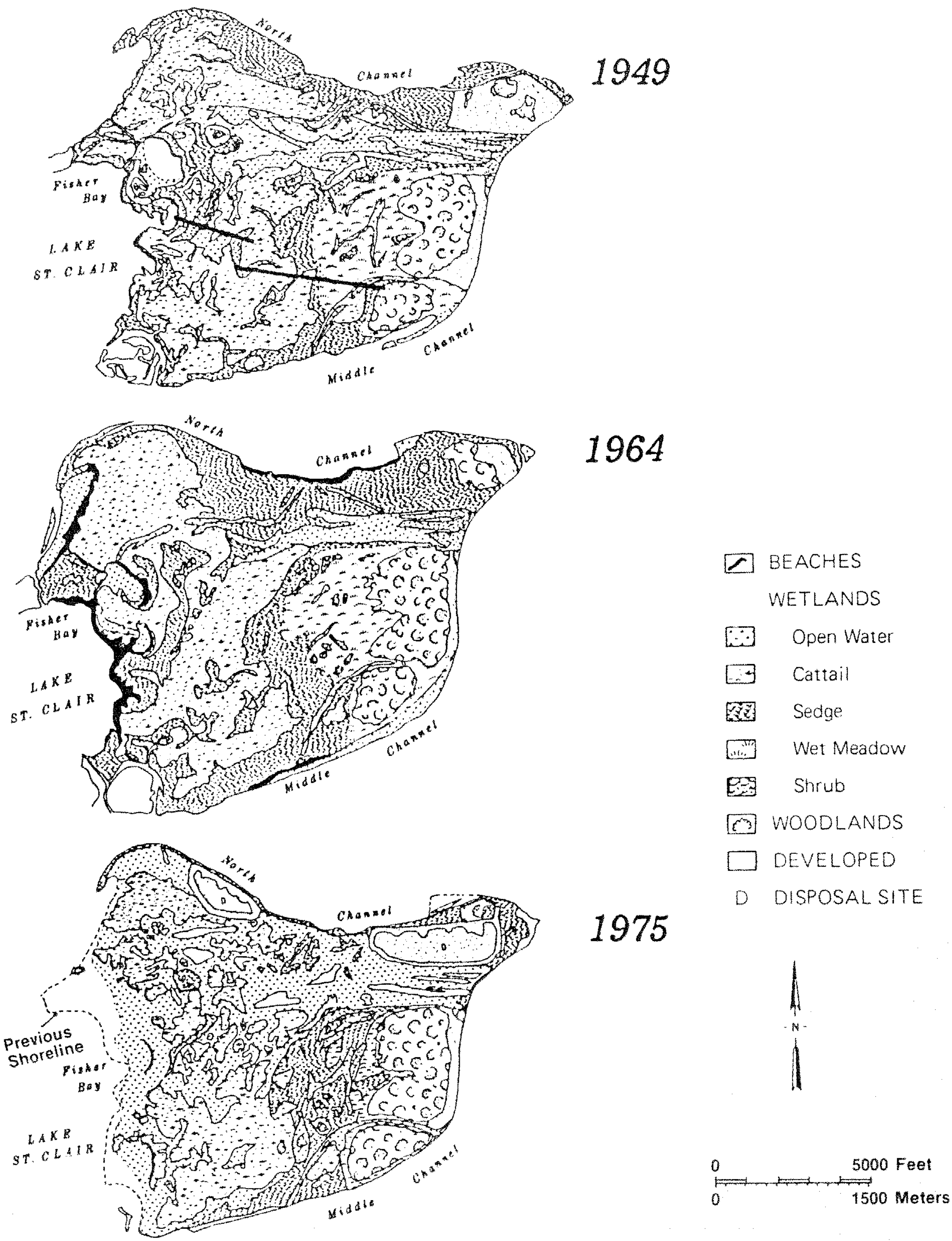


Figure 63. Changes in vegetation and land use on Dickinson Island during periods of average (1949), low (1964), and high (1975) water levels (Modified from Jaworski and Raphael 1981). Wetland designations follow Table 19.

Table 23. Changes in the areal extent of woodlands, wetlands, and developed lands on Dickinson Island associated with changes in water level (Modified from Jaworski and Raphael 1981).

Land and type	Low to average water level (1949)		Low water level (1964)		High water level (1975)	
	ha	% of total	ha	% of total	ha	% of total
Woodlands and shrub wetlands	102	9	113.5	10	113.5	10
Wet meadow	102	9	102	9	45.5	4
Sedge	260.5	23	414	36.5	147.5	13
Cattail	453.5	40	419.5	37	317.5	28
Open water	153.5	13.5	62.5	5.5	425	37.5
Developed lands	62.5	5.5	22.5	2	85	7.5
Total	1,134.0	100.0	1,134.0	100.0	1,134.0	100.0

accounted for only 5.5% of the total area. At lower-than-average water levels in 1964, the sedge and cattail wetlands together expanded to occupy 73.5% of the total area, open-water wetlands decreased to 5.5%, developed land to 2%, and woodlands-shrub wetlands and wet meadow wetlands exhibited no change.

The record high water of the 1970's had little effect on the woodlands-shrub wetlands, but caused extensive changes in the areal extent of all other wetlands. The wet meadow wetlands decreased sharply to 4% of the total and sedge and cattail wetlands almost as sharply to 41% of the total. Perhaps the most dramatic impact of the high water was to increase the extent of the open-water wetlands to 37.5% of the total. At these high water levels, the wet meadow communities were largely displaced by the sedge communities, while the sedge and cattail communities were displaced by the open-water plant communities.

A plant community displacement model (Figure 64) illustrates wetland succession on Dickinson Island associated with different Lake St. Clair water levels. This model shows the percent of the total wetland area (horizontal axis) in each vegetative zone which would result at various water levels above and below the long-term annual mean (vertical axis). Each symbol represents a field measurement taken from Jaworski and Raphael (1979). The high and low water levels are an average of the 4 consecutive years of highest or lowest water levels in 1973-76 and 1963-66, respectively. A 4-yr time period was selected because it takes 3-5 yr of sustained water levels for the vegetative structure to develop.

The effect on wetland vegetation of the record high water level (about 175.8 m) measured in Lake St. Clair in October 1986 (Figure 23) has not been evaluated, but could be even more pronounced than that observed in 1975 (Figure 62).

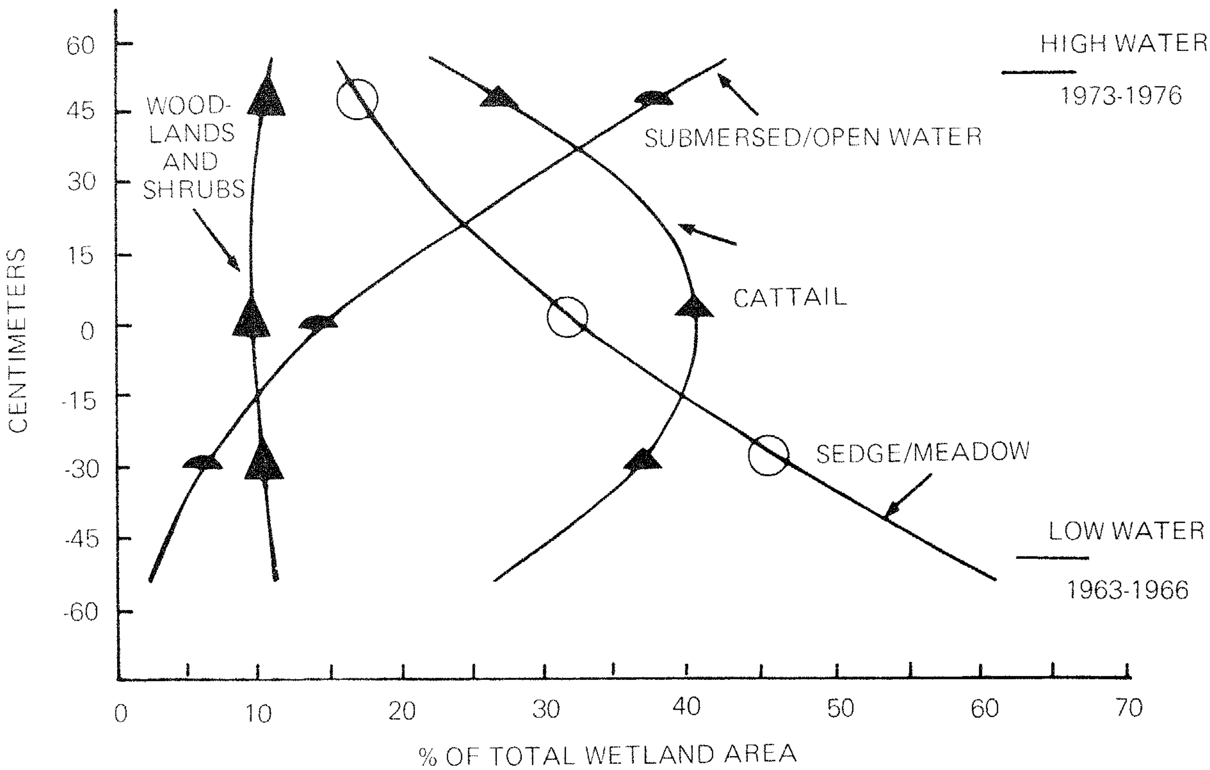


Figure 64. Effect of lake level on wetlands on lower Dickinson Island (Modified from Williamson 1979).

CHAPTER 5. COMMERCE AND RECREATION

5.1 INDUSTRIAL SIGNIFICANCE OF THE WATERWAY

Historically, the availability of natural resources adjacent to the St. Clair River and Lake St. Clair played a major role in determining the industrial development of the waterway and nearby areas. Oil discovered over a century ago in southern Ontario was the basis for the chemical and petroleum industries which now flourish along the St. Clair River. In Michigan, subterranean salt (halite) deposits led to mining and the siting of plants in Michigan by the Diamond Crystal and Morton Salt companies. The proximity to an abundant water resource attracted steam-electric power generating companies and also other industries requiring large volumes of processing water. The steel and automobile industries, and others that benefited from water transport of products and raw materials, also found the area adjacent to the waterway to be an attractive site for development.

The St. Clair River and Lake St. Clair are part of an important transportation route linking the upper and lower Great Lakes. The main commodities carried upbound in the system are coal, lignite, and iron ore from the lower lakes and ocean ports, while those moving downbound from the upper lakes are iron ore, limestone, and grain. In 1983, about 72% of the cargo originating in Lake Superior passed through the St. Clair River and Lake St. Clair (Figure 65). By far the major portion of freight traffic generated in ports along the St. Clair River are incoming shipments of limestone at Port Huron and coal and lignite at Marysville and St. Clair for the two fossil-fueled electric generating plants. The steel and automobile industries depend on the system for iron ore and limestone, although in recent years the decline in both industries has economically impacted the system. Grain shipped through the Great Lakes declined from 26 million short tons in 1984 to 17 million short tons in 1985 due to drought in western Canada (Risen 1987). However, the economy appears to be recovering and the newer, larger bulk freighters (Figure 66) have provided economies of scale that have significantly improved the transport of grain from the western Great Lakes to St. Lawrence River elevators. There is also a new westerly movement of iron ore from eastern Quebec and Labrador into the Great Lakes (Schenkler et al. 1976), and low-sulfur coals in the western States are being commercially developed and are now moving through the St. Clair system into the lower lakes.

The cost of petroleum and the uncertainty concerning the future of nuclear power generation continue to favor coal as an industrial energy source, and the National Energy Plan assumes a doubling of coal use from 1978-79 to the year 2000. Michigan utilities and industries already use coal for a major portion of their energy, and coal use and transport may rise significantly if the economy continues to improve (GLBC 1980). However, these predictions should be viewed with caution because of the diverse and problematic circumstances affecting the use of coal, including the delivered price, the reliability of supply, and the cost of meeting pollution control requirements relative to those of other sources of energy. Recent changes in the availability of foreign oil, together with the discovery of potentially very large deposits of natural gas in deep geological formations in the U.S., may, for example,

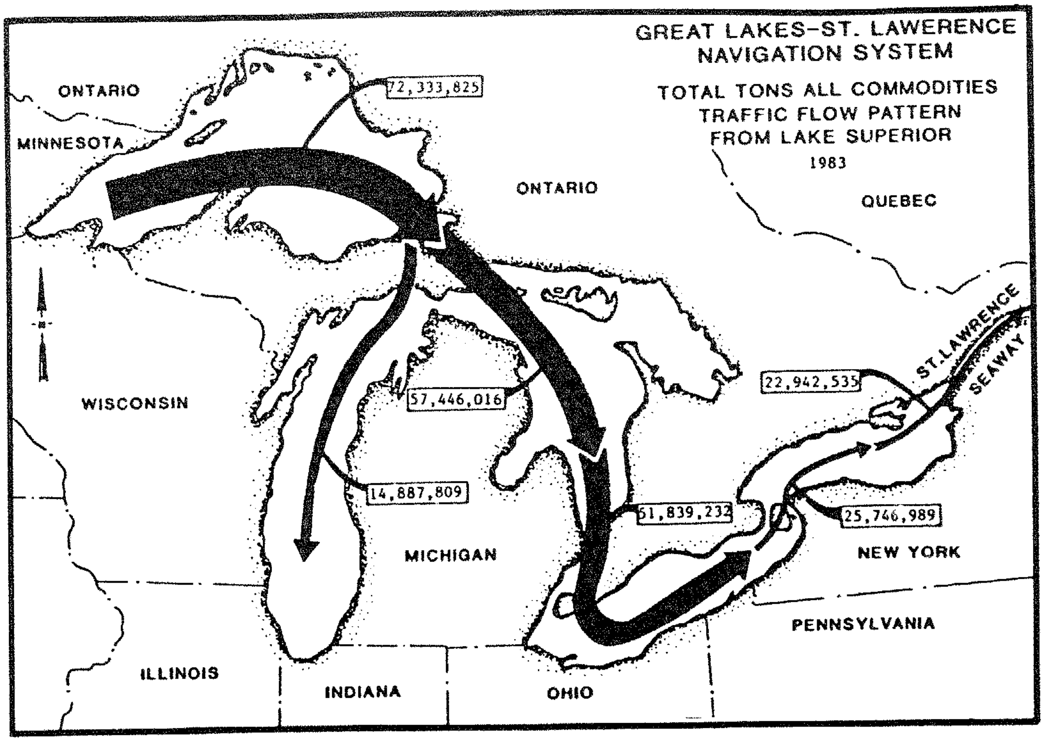


Figure 65. Tonnage and traffic flow in the Great Lakes in 1983 (USACE 1985).

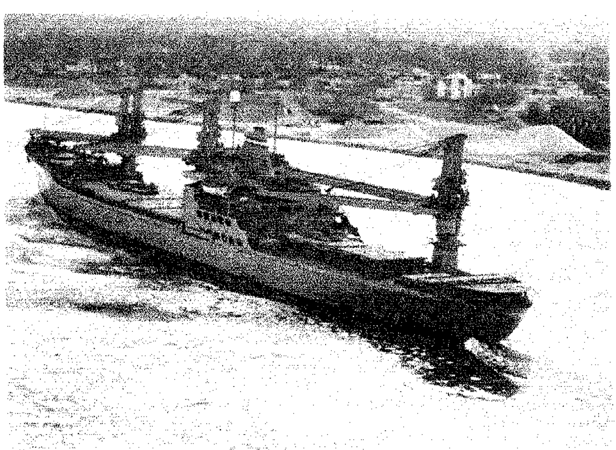


Figure 66. A cargo vessel in the St. Clair River (Photograph by A. Ballert, Great Lakes Commission).

reduce the future attractiveness of coal as an energy source. However, in Michigan a steady increase in coal use is predicted, and similar increases could perhaps be expected in other Great Lakes States. If the more modest predictions for increased use of coal in the Great Lakes States are realized, movement of coal through the St. Clair system can be expected to increase and growth in the coal unloadings at existing facilities and the construction of a modest number of new facilities probably can be anticipated. If these new facilities are constructed in existing industrial areas, they probably will have little adverse impact on water quality, wetlands, or submerged bottomland habitat.

5.2 COMMERCIAL FISHERIES

A commercial fishery primarily for lake whitefish, lake herring, walleye, and yellow perch developed in the St. Clair-Detroit River system in the early 1800's (Haas and Bryant 1978). Records of the commercial catch are not available for this early fishery, but beginning in the 1870's and 1880's catches of major native species in the fishery were recorded annually, and at the turn of the century catches of carp were also added to the record (Table 24). These records show that the catches of lake sturgeon, lake herring, lake whitefish, smallmouth bass,

Table 24. Commercial fish production in Michigan and Ontario waters of the St. Clair-Detroit River system, 1870-1969 (Baldwin et al. 1979)[a].

Year	Average annual landings (thousands of kg) by decade										Total all species
	Lake sturgeon	Lake herring	Lake whitefish	Northern pike	Carp	Suckers	Channel catfish and bullhead	Smallmouth bass	Yellow perch	Walleye	
1870-79	50[b]	57[c]	168[d]	6[g]				19[e]		67[h]	417[d]
1880-89	37	191[d]	60	10		139[b]	17[b]	19	98[b]	74	584[d]
1890-99	46	106	38	12		53[c]	10	16	146[b]	239	821
1900-09	22	3	26	16	142[g]	9	21	1[f]	31	135	597
1910-19	15	2[e]	28	21	186		26		54	25	592
1920-29	6		1	15	119		24		44	23	379
1930-39	5		< 1[d]	10	147		20		21	18	349
1940-49	3		< 1[f]	8	127		41		15	24	328
1950-59	5			6	243	50[c]	29		13	29	430
1960-69	6			10	115	44	35		16	117	427

[a] Production values for each decade were obtained by dividing the total recorded production for the decade by the number of years in the decade for which production records were available; values based on less than 10 years of recorded production are footnoted as follows: [b] 1 year, [c] 8 years, [d] 9 years, [e] 5 years, [f] 2 years, [g] 4 years, and [h] 6 years.

yellow perch, and walleye were highest in the late 1800's and thereafter decreased substantially. Smallmouth bass, lake herring, and lake whitefish disappeared from the catch by 1910, 1930, and 1950, respectively, while lake sturgeon, yellow perch, and walleye continued to contribute significantly to the fishery through the 1960's. Catches of other species, including northern pike (exclusively an Ontario fishery), carp, channel catfish-bullheads, and possibly also suckers (although the records for suckers are fragmentary), appear to have varied without trend during the period of record. The observed early declines in the catch of some of the more desirable species were probably due to overfishing (Haas and Bryant 1978), but the catch records may also reflect the permanent closure of the commercial fishery for smallmouth bass in Ontario in 1902 and for species other than carp in Michigan waters in 1909, in response to pressure from recreational fishing interests.

The Ontario commercial fishery continued through 1969, but was closed in 1970 when high levels of mercury were discovered in Lake St. Clair fish. In 1980, when mercury in fish in Lake St. Clair had declined to levels that no longer prevented human consumption, the Ontario commercial fishery was reopened under a quota management system. Quotas for lake sturgeon, northern pike, carp, suckers, channel catfish-bullheads, and yellow perch in 1980-85 were similar to the average annual catches for these species during the last decade before the closure of the commercial fishery, except that there was no allocation for walleyes in the new fishery (Tables 24 and 25). However, none of the allotted annual quotas were filled in 1980-85 and catches for most species that contributed to the earlier fishery were substantially lower in 1980-85 than in the 1960's. Although the reduced catches of economically valuable species such as lake sturgeon and yellow perch in 1980-85 may reflect their lowered abundance in the St. Clair system, the reduced catch of carp and other low-value species, which make up the majority of the present fishery, probably reflect market conditions. Thus the overall decline in catch since 1981 appears to reflect the marginal economics of the fishery (OMNR 1986), and there is speculation that a complete closure of the Ontario commercial fishery is imminent. Seven of the ten commercial fishing licenses issued by the Province of Ontario for Lake St. Clair in the 1980's were bought back by the Province and retired in December 1985 (OMNR 1986).

5.3 RECREATIONAL FISHERIES

A significant recreational fishery has existed in the Michigan waters of the St. Clair-Detroit River system since the

Table 25. Commercial fishery quotas and landings for Ontario waters of Lake St. Clair, 1980-85 (OMNR 1986)[a].

Species	Quota	1980	1981	1982	1983	1984	1985
Bowfin	--	2	3	2	7	6	3
Bullheads	5	1	2	1	1	< 1	0
Carp	150 [b]	15	58	66	19	28	8.7
Catfish	33	6	42	32	30	27	20
Freshwater drum	--	5	14	23	15	2	0
Northern pike	4	1	2	1	2	1	1
Rock bass and crappie	3	< 1	1	2	3	1	1
Lake sturgeon	5	0	0	0	0	0	< 1
Suckers	45	5	19	19	23	6	2
White bass	11	2	9	9	5	3	1
White perch	--	0	0	< 1	1	< 1	0
Yellow perch	14	< 1	1	2	4	2	< 1
Mixed[c]	--	< 1	7	< 1	1	1	< 1

[a] Quotas and landings are in thousands of kg.
[b] An additional quota was allocated for 1981-85.
[c] Includes bowfin, freshwater drum, garpike, gizzard shad, suckers, white perch. (When this value is large, it is predominantly freshwater drum and suckers.)

turn of the century, but there are few records of the early fishery. The first creel census conducted by the Michigan Department of Natural Resources revealed that an average of 319,000 angler days of effort were expended and about 698,000 fish were caught annually during the ice-free season in 1942-43 (Table 26). Subsequent surveys indicate the average annual fishing effort and catch, respectively, had increased to 1,331,000 angler days, and more than 500,000 fish in 1966-67 and to 1,429,000 angler days and 8,381,000 fish in 1971-77. Although these statistics suggest a significant improvement in the fishery over the period of record, differences between the three periods must be interpreted with caution. The earlier records did not include the winter fishery, fishing activity on the St. Clair and Detroit Rivers, or both. Furthermore, the estimates obtained from these creel censuses which were conducted by mail are suspected of being somewhat inflated (R. Haas, Michigan Department of Natural Resources; pers. comm.). In 1983-85, an extensive survey of the recreational fishery in Michigan waters of the St. Clair system (Table 27) revealed an average annual fishing effort of 2,763,000 angler hours and an average combined catch by boat, shore, and ice anglers (Figure 67) of 1,392,000 fish. The average annual fishing effort and catch in 1983-85 varied widely among the various sections of the St. Clair system but were highest in Lake St. Clair. Boat anglers expended about 66% of the effort, followed by shore (22%) and ice (12%) anglers. The total catch by these groups was roughly proportional to effort, with boat anglers making 64% of the total catch, shore anglers 19%, and ice anglers 16%.

Yellow perch and walleye, respectively, were the most abundant fish in the catch in 1942-43 and 1971-77. Yellow perch and walleyes contributed an average of about 70% of the total number of fish caught by anglers in 1966-77 in the St. Clair-Detroit River system, and the catch of walleyes in Lake St. Clair alone in 1975-77 was approximately equal to the angler catch for the species in all other Michigan waters (Table 28). Lake St.

Table 26. Creel census estimates of average annual effort and catch for the recreational fishery in Michigan waters of the St. Clair-Detroit River system, 1942-77 (Haas and Bryant 1978).

Period	Number of angler days	Total number of fish caught of all species
1942-43[a]	319,000	698,000
1966-67[a,b]	1,331,000	5,074,000
1971-77[c]	1,499,000	8,381,000

[a] Does not include winter fishery.
[b] Does not include fishing activity on St. Clair and Detroit Rivers in 1967.
[c] Includes winter fishery and fishing activity on the St. Clair and Detroit Rivers.

Table 27. Average annual fishing effort and catch in the St. Clair system, 1983-85 (Haas et al. 1985).

Section	Angler hours	Number of fish caught
St. Clair River	552,000	139,000
St. Clair delta	258,000	55,000
Lake St. Clair	1,953,000	1,198,000
Total	2,763,000	1,392,000

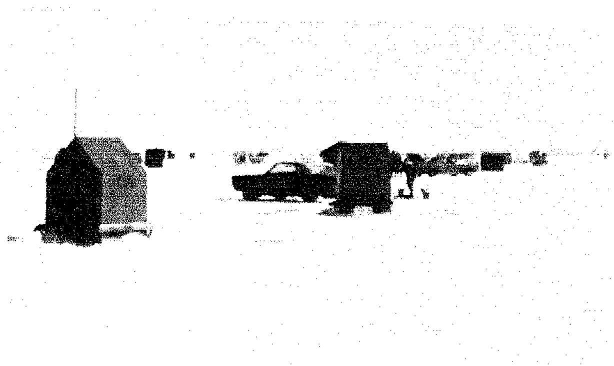


Figure 67. Ice fishing on Anchor Bay, Lake St. Clair (Photograph by A. Ballert, Great Lakes Commission).

Clair was the largest producer of smallmouth bass in Michigan in 1967 with 135,000 landed. The lake was also the site of one of the most productive muskellunge fisheries in North America in 1972 when 1,017 angler days of effort produced 1,273 fish (Haas and Bryant 1978).

In 1983-85, the yellow perch was the single most abundant species in the catch in the St. Clair system (37% of the total catch), followed by white bass (34%), walleye (15%), and drum (5%). Walleyes made up the greatest portion of the catch in the St. Clair River and the St. Clair Delta (75% and 58%, respectively, of the total catch), while yellow perch dominated the catch in Lake St. Clair (73%).

Coldwater species, including lake, brown, and rainbow trout, and chinook and coho salmon, also supported limited but important recreational fisheries in the St. Clair system in 1975-79, when an average of about 9,700 fish of these species were taken annually (Michigan Department of Natural Resources, unpub. data).

Records for the recreational fishery in Ontario waters (Sztramko 1980; OMNR 1986) show the fishery is substantial but considerably smaller than in Michigan waters. Ice anglers on Lake St. Clair

Table 28. Walleye catch in Michigan waters of Lake St. Clair and other waters of the State, 1975-77 (Haas and Bryant 1978).

Year	Total number of walleyes caught: Lake St. Clair	Other Great Lakes waters	Inland lakes and streams	Lake St. Clair catch as % of statewide total
1975	809,000	97,000	739,000	49
1976	831,000	179,000	681,000	49
1977	1,044,000	220,000	753,000	52

fished an average of 132,559 h and harvested an average of 128,838 walleyes, yellow perch, and bluegills annually in 1977-85. No records are available for the catch of other species in 1977-84, but in 1985 the ice-angler harvest in Lake St. Clair included 13 species and totaled 20,353 fish, of which 19,193 fish (94% of the total) were walleyes, yellow perch, and bluegills. Summer anglers expended an average of 372,898 h and harvested an average of 193,382 walleyes, yellow perch, smallmouth bass, and muskellunge annually in Lake St. Clair in 1977-85. The total catch by summer anglers in 1985 in Lake St. Clair included 21 species and totaled 168,846 fish, of which 145,235 (86% of the total) were walleyes, yellow perch, smallmouth bass, and muskellunge.

The value to the State and local economy in Michigan in 1975-77 of the multispecies recreational fishery in the St. Clair-Detroit River system was reported by Haas and Bryant (1978) to be in excess of 10 million dollars annually.

5.4 WATERFOWL HUNTING

Michigan has long enjoyed a tradition of quality duck hunting, as evidenced by the popularity of duck shooting clubs which trace back to the mid-1800's. The harvest of waterfowl, particularly ducks, in Michigan during the October-November hunting season is an important recreational activity. During 1971-75, 116,744 waterfowl hunters expended 1,232,526 days of hunting effort and harvested about 685,000 ducks, geese, and coots annually in Michigan (Table 29).

The proportion of the annual waterfowl harvest in Michigan which occurs in the St. Clair-Detroit River system is relatively high because several of the fall concentration areas are located within coastal wetlands of that system. In 1961-70, St. Clair County, which borders the St. Clair River and Lake St. Clair, and Wayne County, which borders the Detroit River, collectively contributed an average of 11% of the total duck harvest in Michigan's 83 counties and more than one-third of the total duck harvest in the 12 coastal counties of the State (Table 30). The harvest in St. Clair County was the highest in the State and Wayne County was sixth, close behind the third-, fourth-, and fifth-ranked counties which had harvests of 10,800 to 11,000 ducks (Carney et al. 1975).

Although Michigan licenses approximately 116,750 waterfowl hunters annually (Table 29), there are many potential hunters who do not participate because of a lack of accessible, quality hunting. Today, the prospective hunter, particularly from metropolitan southeastern Michigan, usually applies for a reservation at a public game area, because permission from private shooting clubs or owners of the few remaining wetlands is difficult to obtain. An example of the unsatisfied waterfowl hunting demand may be obtained by comparing the number of applicants for reservations at the public game area to the number of available blinds or hunting areas. For the three public game areas located within coastal wetlands near human population centers in southeastern Michigan, there were 13,450

Table 29. Annual waterfowl hunting effort and harvest in Michigan, 1971-75 (Michigan Department of Natural Resources, Biennial Reports).

Year	Number of hunters[a]	Number of hunter days	Number of waterfowl harvested		
			Ducks	Geese	Coots
1971	123,000	1,311,050	593,280	38,000	87,750
1972	109,130	1,120,040	530,960	25,550	34,560
1973	116,310	1,324,930	598,290	38,610	54,260
1974	116,780	1,200,980	615,440	43,090	48,280
1975	118,500	1,205,630	651,860	32,430	32,450
Average	116,744	1,232,526	597,966	35,536	51,460

[a] Includes waterfowl hunters under the age of 16 not requiring a Federal duck stamp.

Table 30. Average annual duck harvest in Michigan, 1961-1970 (Jaworski and Raphael 1978).

County	Dabblers	Divers	Total	Percent of statewide harvest made in county
St. Clair	8,475	7,951	16,246	7
Wayne	2,210	7,870	10,080	4
All other coastal counties	49,667	27,632	67,682	28
All inland counties	102,581	44,196	146,777	61
Total	162,933	87,649	240,785	

applicants in 1976, but only 3,475 possible reservations (Michigan Department of Natural Resources Permanent Files); only 26% of the applicants could be served, which indicates that a large unsatisfied demand for quality waterfowl hunting exists.

Waterfowl hunting and the game harvested in coastal wetlands contribute materially to the economy of Michigan. Preliminary estimates for 1977, based on the 1970 National Survey of Hunting and Fishing, indicates that each waterfowl hunter spent on the average $130.25 on equipment, licenses, transportation, and so forth. This figure was obtained by multiplying the 1970 annual hunter expenditure of $84.47 by 1.542, which is the 1970-77 cost-of-living increase factor for Detroit, Michigan (Bob Craig, Michigan Department of Natural Resources; pers. comm.). Thus, if the 116,750 waterfowl hunters in Michigan each spent $130.25 annually, waterfowl hunting in Michigan contributed at least $15.2 million annually to the economy in 1977 dollars. If data on number of hunters and distance travelled were available for each coastal wetland, then the economic importance of waterfowl hunting could be determined and protection priorities established. Further, if the value of the unfulfilled demand for quality waterfowl hunting were included, the total annual value of waterfowl hunting in Michigan could be $30 million or more.

The meat from the waterfowl is also important because many families, particularly in rural areas, supplement their diet with wild game. Further, in most instances, except at game areas with cropping programs, the waterfowl utilize food resources which man is not effectively exploiting. The carcass value for Michigan's waterfowl harvest in 1975 slightly exceeded $474,000 (Table 31). A cost-of-living factor of 1.129 was employed (Bob Craig, Michigan Department of Natural Resources; pers. comm.) to project the total 1975 carcass value of $474,263 to an estimated total 1977 value of $535,443. Thus, the sum of the total average annual hunter's expenditures and the value of the carcasses for 1977 indicates the total economic value of Michigan's waterfowl hunting is $15.74 million, or $37.79 per bird harvested. Other economic techniques based, for example, on opportunity costs or on the willingness of participants to pay, may yield values which exceed that of the above analysis.

Table 31. Carcass values of waterfowl harvested in Michigan in 1975 (Michigan Department of Natural Resources, Current Files).

	Number of waterfowl harvested annually[a]	Average carcass weight (lb)	Total value[b]
Ducks	358,284	1	$358,284
Coots	29,575	1	29,575
Geese	21,601	4	86,404
Total	409,460		$474,263

[a]U.S. Fish and Wildlife Service figures of 1975 were used because they are conservative.
[b]Based on carcass value of $1/lb.

5.5 SWIMMING AND RECREATIONAL BOATING

The St. Clair system is readily accessible to the four million people of southeastern Michigan and southwestern Ontario, and it is one of the water bodies most intensively utilized for recreation in North America. Because of the nature of the shoreline, the amount of natural beach is limited. Metropolitan Beach (Figure 68) is partly natural. It is about 785 m long, covers 2.8 ha, and is the largest beach on the lake south of the Clinton River. No significant beach use occurs on the river or the delta shoreline. Because the beaches are readily accessible to nearby densely populated areas, visitor travel costs are minimal and the value per visit ($3.29 in 1979 dollars) was the lowest in the lower Great Lakes, with the exception of the Detroit River area beaches (IJC 1981a). Nevertheless, the Lake St. Clair beaches are extensively used and their potential value from late May to early September, 1979, exceeded $261,000.

Recreational boating on the St. Clair system is a $1.2 million dollar industry annually (IJC 1981a). Boating facilities on the Michigan side of the river and lake are extensive (Table 32). All types of boats utilize the system, including approximately 230 cruisers 12- to 20- m long and 2,560 sailboats (Figure 69) or boats with auxiliary sails (IJC 1981a). Numerous smaller inboard and outboard craft also utilize the waterway. A survey in 1980 indicated that recreational boaters spent an average of 700,000 days annually on the St. Clair River and Lake St. Clair (Stynes and Safronoff 1982). This was an increase of over 23% from the preceding survey in 1977. Boating days involved fishing (53%), cruising (35%), waterskiing (5%), and miscellaneous pursuits, including hunting (3%). The typical registered boat owner included in the 1980 survey was 50 years of age, a high school graduate, and had an income of $23,000.

A water-oriented, urban lifestyle has developed particularly along the Michigan side of Lake St. Clair from Detroit to the St. Clair Delta (Figure 70). Extensive canal networks for permanent residents have been constructed, and in some instances these developments have occurred at the expense of the coastal wetlands.

Figure 68. Metropolitan Beach, Lake St. Clair (Photograph by A. Ballert, Great Lakes Commission).

Table 32. Boating facilities in Michigan serving the St. Clair system (IJC 1981a).

Facility	Number
Wet berths and slips	11,215
Dry storage	11,400
Launch ramps	35
Launch capacity (boats/h)	329
Ramp parking spaces	1,671
Hoists	133

Figure 69. Sailing on Lake St. Clair (Photograph by A. Ballert, Great Lakes Commission).

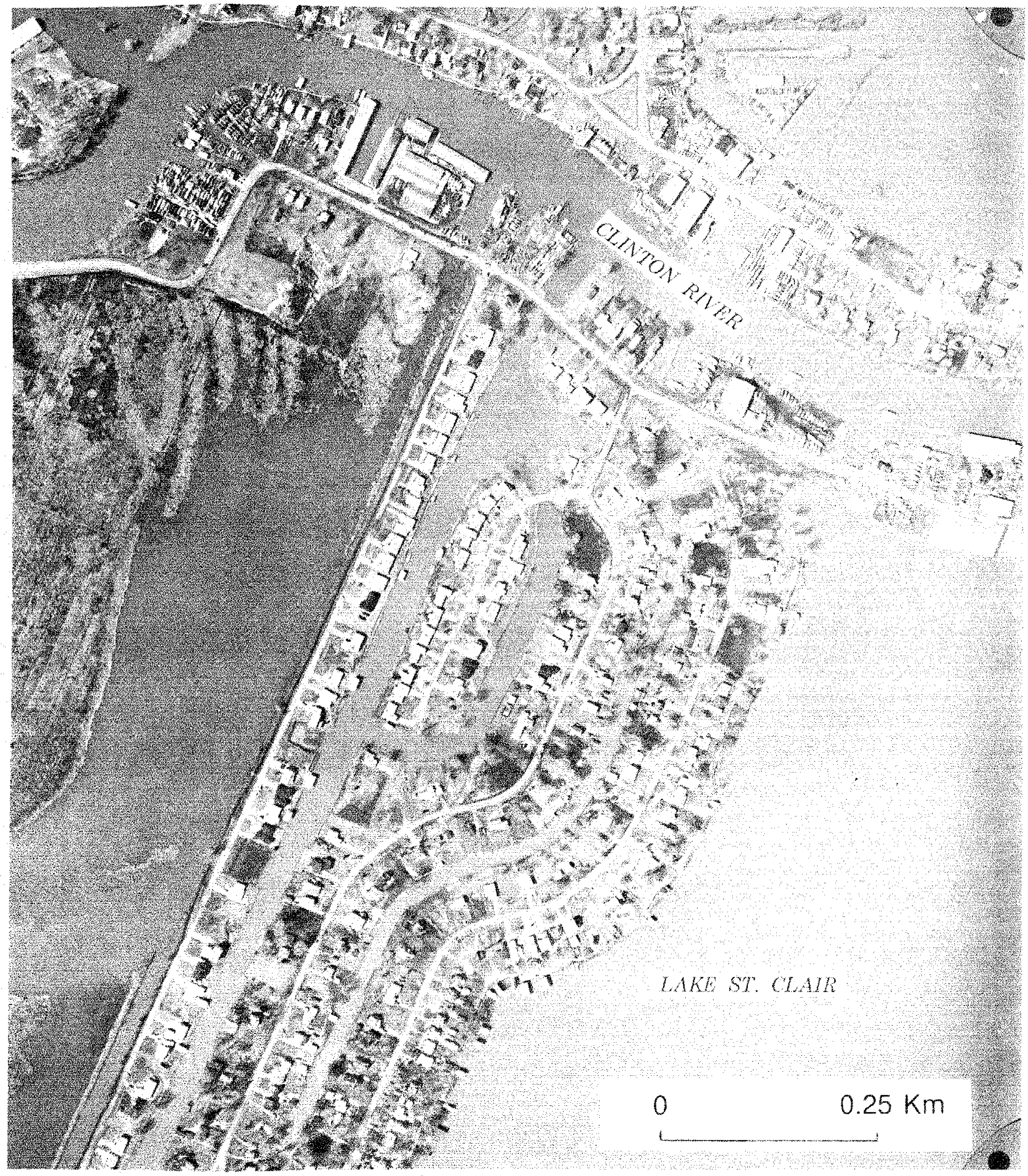


Figure 70. Water oriented urban development along the Lake St. Clair shoreline in Michigan.

CHAPTER 6. MANAGEMENT ISSUES AND RECOMMENDATIONS

6.1 DREDGING

Navigation-related dredging in the St. Clair system began in 1873 (Section 1.3), intensified with increased commerce in the 1900's, and culminated with the construction of the Great Lakes-St. Lawrence Seaway in the late 1950's, which increased the minimum channel depth in the St. Clair River, South Channel, and Lake St. Clair to 8.3 m. Originally, most dredged materials were dumped at disposal sites in the open waters of Lakes Huron and St. Clair. However, the construction of the Seaway or St. Clair Cutoff Channel created a large volume of dredged materials, which were deposited beside the new channel at the edge of Lake St. Clair, thereby creating Seaway Island (USACE 1981).

The demand for recreational boating and fishing resulted in additional dredging to create several marinas along the river and lakeshore. Residential property owners on the Michigan shoreline also dredged and filled areas and installed bulkheads. The total volume of sediments dredged by landowners was estimated to be more than 3,800 m^3 annually in 1961-70 (Raphael et al. 1974).

Table 33 reveals the dredging and disposal activity in the St. Clair system waterway from 1971 through 1986. During that period, more than 1.2 million m^3 of material were dredged from the system. Dredged materials were disposed of in the open lake until 1976 and thereafter were confined in diked disposal facilities. The change from open lake dumping to the use of confined or diked disposal of dredged materials marked a significant change in the management of dredged materials. This change resulted from the enactment by Congress in 1970 of Public Law 91-611 (Rivers and Harbors Flood Control Act), which authorized the U.S. Army Corps of Engineers to construct facilities for containment of polluted dredge spoil from the Great Lakes harbors and waterways. The act was the first such specific legislation promulgated in the United States to ensure containment of polluted dredged materials (Jaworski and Raphael 1976). As a result of Public Law 91-611, two diked facilities were constructed on Dickinson Island adjacent to North Channel in the St. Clair Delta. Both sites were located on the high pre-modern delta deposit and did not infringe on the wetlands. As required by Public Law 91-611, these disposal sites were designed to accommodate dredgings produced during a 10-year period, and they presently receive the materials dredged from the St. Clair system.

Navigation-related dredging has unquestionably altered the character of the St. Clair River and Lake St. Clair by altering flow regimes and replacing what was undoubtedly productive shoal-water habitat with less productive channel habitat. Navigation-related dredging, coupled with sand and gravel mining in the St. Clair River, which have removed more than 23 million m^3 of material since 1920 (Raphael et al. 1974), may also have retarded the growth of the St. Clair Delta Bulkheading, dredging, and backfilling (Figure 71) have also resulted in the loss of significant amounts of littoral habitat in the system. Collectively, the historical loss of shoal and littoral waters, the removal of gravel, and the lack of delta growth represent loss of habitat that was utilized by many Great Lakes fishes to satisfy spawning and other early life history requirements (Goodyear et al. 1982). Important shorebird habitat was probably also lost.

Table 33. Dredging and disposal activity in the St. Clair system, 1971-86 (U.S. Army Corps of Engineers, Open Files).

Dredging project	Dredged depth (m)	Dredged volume (m^3)	Disposal site
Black River	6.1	100,927	Confined
Clinton River	2.4	133,588	Confined
Lake St. Clair	8.2	407,834	Confined
St. Clair River	8.2	613,903[a]	Open lake (37%) and confined (63%)
Total		1,256,252	

[a] Includes 68,814 m^3 estimated to be dredged in 1986.

Figure 71. Bulkheaded, dredged, and backfilled shoreline on Lake St. Clair. Most urban expansion occurs in the shallow water of the lake's margin which is important spawning habitat for fish and a wave energy dissipation zone.

Dredging of contaminated sediments poses other problems. Concentrations of pollutants in the sediments of the St. Clair system are relatively high and some exceed U.S. Environmental Protection Agency criteria. Potential contaminants treated by Ontario guidelines and International Joint Commission objectives are polychlorinated biphenyls (PCB's), hexachlorobenzene (HCB), octachlorostyrene (OCS), phenol, polyaromatic hydrocarbons, cyanide, oil and grease, cadmium, chromium, and mercury (Limno-Tech, Inc. 1985). The contaminated areas tend to be near shore and near point sources, but also include depositional zones far removed from known point sources. The reported ranges of concentrations of contaminants in the upper St. Clair River follow: PCB's, 0-10,000 ppb; OCS, 0-193 ppb; oil and grease, 250-600 ppm; and mercury, 0.1-58 ppm. PCB levels exceed the Ontario guidelines (50 ppb) and IJC objectives (100 ppb), and mercury in certain areas (> 1 ppm) exceeds the EPA guideline (no standards exist for OCS in sediments). Oil and grease levels are low in most areas. Concentrations of contaminants are lower in the St. Clair Delta, but sampling there has been limited.

Deposition of sediments in Lake St. Clair in the mid-lake area near the navigational channel has resulted in the following ranges of concentrations: PCB's, 0-50 ppb; HCB, 36-99 ppb, OCS, 0-30 ppb; cadmium, 1-2 ppm; and mercury, 1-3 ppm. Cadmium concentrations (> 1 ppm) exceed Ontario's guidelines and mercury levels indicate heavy pollution; no guidelines exist for HCB in sediments. Navigation-related maintenance dredging, which removes these polluted sediments from the system and deposits them in confined disposal facilities, can of course be considered beneficial in terms of reducing the total contaminant load in the system. However, this potential benefit can be offset by resuspension of contaminated sediments and a concomitant increase in bioavailability of contaminants in those suspended sediments.

6.2 WATER LEVELS

The present, near-record-high water levels of the Lake St. Clair system impact shipping, power generation, and shoreline residents (Section 2.2), as well as the plant and animal communities of the system. An analysis of present and historical precipitation data for the Great Lakes from 1854 to 1979 (Quinn 1981) revealed that distinctly different precipitation regimes are linked with water levels in the system. Prior to the mid-1880's, precipitation levels were high and lake levels were also high. This relatively wet period was then followed by a relatively dry period which persisted from the mid-1880's until the late 1930's and resulted in record low lake levels in Lake St. Clair between 1925 and 1936 (Figure 72). This was followed by another relatively wet period which continues at present and which has produced record high lake levels from 1974 to the present. The two wet periods were due primarily to higher precipitation during spring and summer. The period of lower water from about 1890 to 1940 may represent an anomaly, and the present wetter conditions may constitute the normal climate for the Great Lakes Basin. The dry period and corresponding low water levels between 1931 and 1960 appear to represent "climate accidents" because such a regime has not occurred at any other time in the last 1,000 years (Bryson 1974).

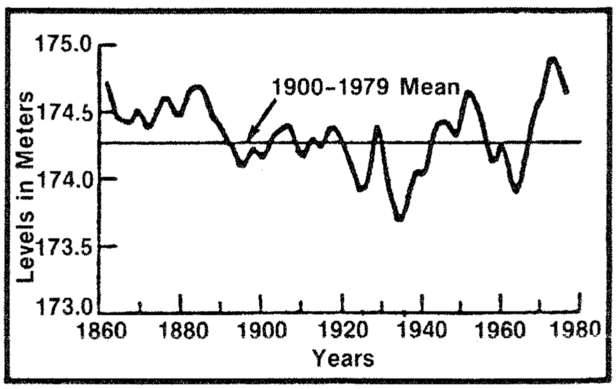


Figure 72. Five-year weighted average levels of Lakes Michigan, Huron, and Erie (Quinn 1981).

On marine shorelines there is increasing concern about rising sea levels (Titus et al. 1985). At Ocean City, Maryland, for example, a 25 mm rise in global sea level would transgress landward between 55 m and 75 m. The question of whether a similar event can be anticipated in the Great Lakes is worthy of consideration. Two significant parameters which may override the factors that controlled lake levels in the past and determine future lake levels are climatic change and consumptive water use. A significant factor associated with rising sea levels is the increased carbon dioxide in the atmosphere caused by combustion of fossil fuels. Carbon dioxide and other trace gases allow short-wave solar radiation to penetrate the lower atmosphere and prevent the emission to space of long-wave radiation from the earth. This so-called "greenhouse effect" would warm the earth's climate causing glacial melting and rising sea levels. It has been suggested that by the middle of the next century a doubling of the carbon dioxide and other "greenhouse gases" may occur causing an overall temperature increase of 3°C (Bruce 1984). Undoubtedly evaporation losses of Great Lakes water would increase with higher air temperatures, higher lake water temperatures, and a larger net radiation balance. The evaporation increase resulting from a 3°C increase in annual air temperature could amount to 13% for Lake Erie (Bruce 1984). It is difficult to predict whether the increased evaporation rates would also increase precipitation rates. However, if summer is extended, a reduced base streamflow is plausible because increased precipitation would probably not offset the increased evaporation.

A second factor which also suggests lake levels will be lower in the future is increased water consumption. Figure 73 reveals probable increases and reallocation of water between 1975 and 2035. Water use in steam-electric power generation may rise most rapidly, from 10% of the uses in 1975 to 47% in 2035; steam-electric power generation also raises water temperatures and increases evaporative water loss. Lake water could also be

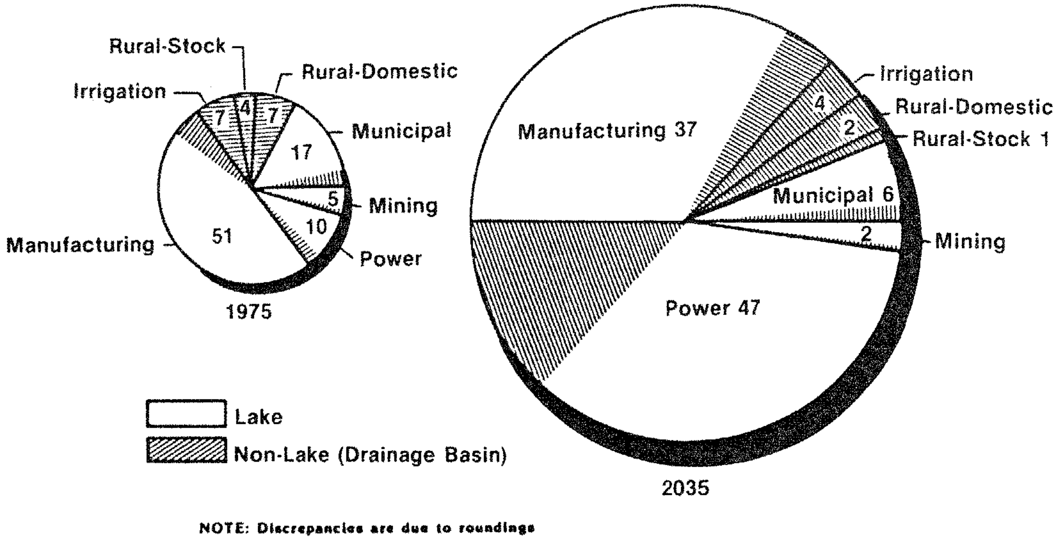


Figure 73. Water consumption by use sector (as a % of total use) in the Great Lakes Basin in 1975 and 2035 (IJC 1981b). Total use in 1975 and 2035 respectively is estimated to be 4,900 and 25,400 ft³/s.

diverted out of the Great Lakes Basin (Manny 1984). Thus, it seems likely that future Great Lakes water levels will be lower than they were in 1940-86.

Anticipated changes resulting from the scenario of lower water levels and warmer temperature may include

a) An extended navigation season, because the period of heavy ice cover would be shortened to less than 3 months;
b) Less frequent flooding along the shoreline from the Clinton River north to the Anchor Bay shoreline;
c) Less erosion of the shorelines;
d) Extension of the St. Clair and Clinton River Deltas;
e) Fewer ice jams and related short-term water level changes in Lake St. Clair;
f) Increased emergent wetlands on shorelines and shoulders of the St. Clair River and distributary channels;
g) Increased dredging and disposal of sediments from navigation channels to accommodate shipping;
h) A lakeward shift of plant communities on the St. Clair Delta;
i) Loss of submersed plant wetland habitat with concomitant decreases in fish spawning, feeding, and nursery habitat, especially in interdistributary bays and near-shore zones;
j) Loss of emergent wetland habitat used by waterfowl and shorebirds;
k) Fewer recreational boating opportunities in areas that are now submersed wetlands;
l) More exposure of river shoulders and the lake shelf; and
m) Greater adverse impact of commercial navigation on the production and decomposition of aquatic macrophytic plants (Sections 3.2 and 4.3).

6.3 WETLAND LOSS

Wetland losses on the Michigan side of Lake St. Clair were determined by Jaworski and Raphael (1976). In 1873, the U.S. portion of Lake St. Clair supported 7,274 ha of wetland vegetation (Table 34). By 1973, this habitat had dwindled to 2,020 ha, a 72% loss. Significant losses not only occurred on the St. Clair Delta

Table 34. Lake St. Clair wetland losses in Michigan, 1873-1973 (Jaworski and Raphael 1976).

Location	Wetland area (ha) 1873	1973	Loss (ha)
St. Clair Flats	5,473	1,779	3,694
Swan Creek	75	2	73
Marsac Point	61	2	59
New Baltimore	21	0	21
Salt River	162	18	144
Clinton River	1,295	221	1,074
Gauklers Point	187	0	187
Total	7,274	2,022	5,252

and St. John's Marsh, but on the entire margin of the lake as well (Figure 74). Gauklers Point at the head of the Detroit River contained 187 ha of wetlands and the Clinton River had over 1,295 ha at its mouth and in its flood basin; by 1973, the wetlands at Gauklers Point had completely disappeared and the Clinton River wetlands had been reduced to 221 ha. Some coastal areas, particularly north of the Clinton River, appear to have been drained for agriculture in the 1860's, so the 1873 data do not include the entire wetland acreage that existed prior to European settlement.

In Ontario, wetlands are currently being lost to agriculture. The wetlands from the Thames River north to Chenal Ecarte dwindled from 3,574 ha in 1965 to 2,510 ha in 1984 (McCullough 1985). Figure 75 and Table 34 detail the specific areas of wetland loss in the coastal Ontario wetlands, excluding the Walpole Island Indian Reserve. Draining for agriculture accounted for 89% of the wetland loss and marina and cottage development consumed the remaining 11%. During the record high lake level in the early 1970's, about 1,000 ha of emergent shoreline marsh from Mitchell Bay southward to the Thames River were also temporarily lost (McCullough 1982). This loss was tempered in part by the flooding of transition vegetation on the upland (east) margin of the wetlands. The St. Clair Delta and Anchor Bay in Michigan are also subject to flooding, but most of the recent wetland losses there are due to diking and filling for urban development.

In Ontario, the coastal zone north of the Thames River was once an open marsh, but over the decades many dikes have been constructed, and the enclosed marshes have been colonized with cattails. Although the shoreline in these areas remains as wetland, the diking has separated it from the inland portions of the wetland and altered the hydrology. These diked Ontario wetlands (like those on Harsens Island in Michigan) are effectively managed for waterfowl hunting, and the result is a loss of other diverse wetland functions, particularly those related to fish production. The adverse impact of isolating and fragmenting wetlands by means of roadbeds, canals, earthen dikes, and other developments appears not to be fully recognized. For example, many conservationists in Michigan are advocating the preservation of St. Johns Marsh, but few call for an increase in its hydrologic connectivity to Lake St. Clair. Moreover, unless a wetland is physically destroyed, not merely fragmented or disconnected from a lake, most people would not refer to an isolated wetland as being "lost".

Wetland losses exceed those shown in Table 35 and Figure 74, if the definition

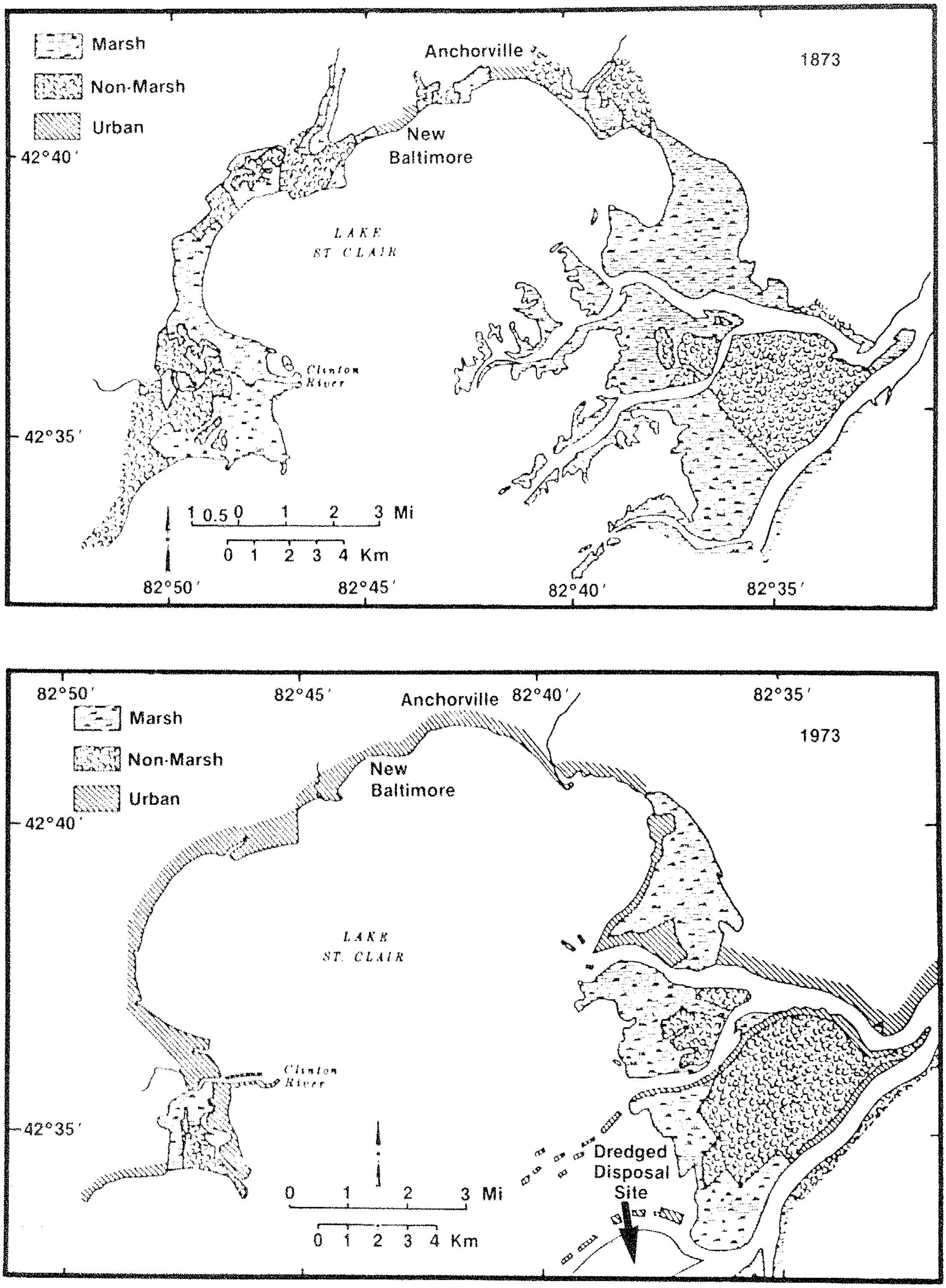


Figure 74. Land use in Michigan on the Lake St. Clair shoreline and the St. Clair Delta in 1873 and 1973 (Jaworski and Raphael 1976).

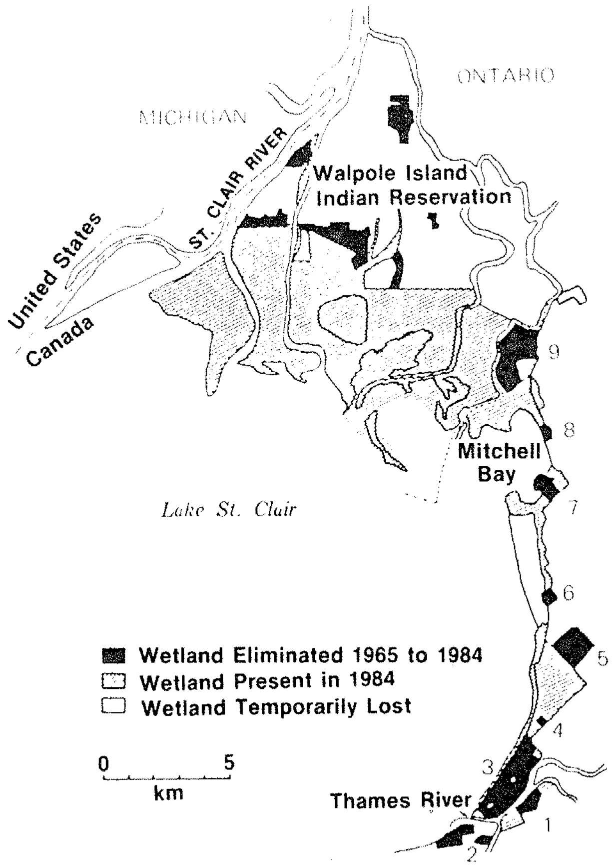


Figure 75. Lake St. Clair wetland losses in Ontario, 1965-84 (McCullough 1985). Wetland loss to high lake levels is considered temporary. Location numbers are identified in Table 35.

of wetlands is expanded to include areas colonized by submersed vegetation. The addition of submersed macrophyte habitat to the total wetland habitat (Jaworski and Raphael, 1976) shows that more than 9,000 ha of wetlands were actually lost to shoreline development in Lake St. Clair (Table 36) between 1873 and 1968. Losses are most evident in the Clinton River, the St. Clair Delta, and the eastern shore of the lake; wetlands in all three areas have been modified along their margins. The wetlands on the eastern shoreline were approximately 2.5 km wide. Since 1873, they have been impacted from the landward side and are now about 0.8 km in width. The progressive losses in both areas were initially stimulated by agriculture. In the Clinton River area, wetland losses occurred from both landward and lakeward boundaries, and the remaining wetlands are now isolated from Lake St. Clair. Wetland quality and diversity have also undoubtedly been adversely impacted over the past century, but these changes have not been adequately described.

Wetland losses in the St. Clair system represent significant revenue losses to both Michigan and Ontario. Michigan's coastal wetlands were worth $1,210/ha/yr in 1977 (Table 37). The gross annual return from Michigan's 42,840 ha of coastal wetlands from fish and wildlife related uses and non-consumptive uses was estimated to be $51.8 million (Table 38), of which about $7.7 million can be attributed to the St. Clair system wetlands. If the 3,192 ha of Lake St. Clair wetlands in Ontario were similarly valued in U.S. dollars, the total for Michigan and Ontario wetlands in the St. Clair system in 1977 would have been $11.6 million.

The value of an acre of coastal marsh in Michigan appears to be intermediate to values established elsewhere in the United States. For example, Benson and Perry (1965) reported that inland freshwater marshes in New York State had a gross annual value of $1,926/ha, whereas in the Corpus Christi, Texas, area, Anderson (1960) determined tourism, sporting activities, and fisheries generated an annual return of $412/ha of wetland. However, the potential value of the St. Clair system wetlands may exceed $1,210/ha/yr, because these wetlands are in close proximity to the Detroit-Windsor metropolitan areas where there is a large, demand for waterfowl hunting (Section 5.4), fishing, and other outdoor recreation.

6.4 FISH LOSSES AT WATER INTAKES

The withdrawal of water from the St. Clair system for use by industry and municipalities poses a direct threat to the fish communities of these waters. In 1982, there were 25 operational water intakes in the St. Clair River and 9 in Lake St. Clair (IJRT 1982). No complete assessment of fish losses at these intakes has been attempted, but annual losses at steam-electric generating stations in the mid-1970's in Michigan waters of the system included about 6,257,000 fish

Table 35. Lake St. Clair wetland losses in Ontario, 1965-73 (McCullough 1985).

Location[a]	Wetland loss (ha)	Wetland type	Cause
1. Thames River	59	diked	agriculture
2. Thames River mouth	115	open	marina and cottage construction
3. Bradley Marsh	327	diked	agriculture
4. Balmoral Marsh	11	diked	agriculture
5. Snake Island Marsh	156	diked	agriculture
6. St. Lukes Bay	22	diked	agriculture
7. Patricks Cove	60	diked	agriculture
8. Mitchell Bay	7	diked	agriculture
9. Mud Creek Marsh	307	diked	agriculture
Total	1,064		

[a] Location numbers are shown on Figure 75.

Table 36. Lake St. Clair wetland losses, 1873-1968 (Jaworski and Raphael, unpubl. data).

Location	Wetland area (ha) Michigan 1873	Michigan 1968	Ontario 1873	Ontario 1968	Loss (ha)
St. Clair Delta	5,414	3,077	9,641	7,234	4,744
Clinton River	1,192	248	-	-	944
Remaining shoreline	1,900	806	4,219	1,862	3,451
Total	8,506	4,131	13,860	9,096	9,139

larvae (mostly clupeids) and 452,000 older fish (mostly gizzard shad) at two intakes on the St. Clair River and about 39,459,000 larvae and 1,173,000 older fish at six plants on the Detroit River (Michigan Department of Natural Resources 1976). A more extensive review (Kelso and Milburn 1979) estimated the fish losses in the mid-1970's at 17 steam-electric generating stations in Michigan and Ontario to be about 94,159,000 larvae and 7,422,000 older fish annually. The significance of these fish losses at water intakes in the St. Clair-Detroit River system has not been established, but the water-use rate at steam-electric generating stations was equivalent to about 8% per day of the total flow in the system (Kelso and Milburn 1979). This use rate was much higher than the 0.7% per day rate estimated for Lake Michigan in 1980 (Spigarelli et al. 1981), which was judged

Table 37. Value of coastal wetlands in Michigan in 1977 (Raphael and Jaworski 1979).

Activity	Average value/ha/yr
Recreational fishing	$ 707
Non-consumptive recreation	342
Waterfowl hunting	77
Trapping of furbearers	75
Commercial fishing	9
Total	$1,210

Table 38. Average annual monetary return from coastal wetlands in Michigan (Jaworski and Raphael 1979).

Coastal region	Wetland (ha)	Average annual return
Saginaw Bay	13,509	$ 16,345,850
Lake Michigan	12,078	14,615,290
Lake St. Clair-St. Clair River	6,325	7,653,855
St. Marys River	4,847	5,865,510
Lake Erie	2,718	3,288,270
Lake Huron (excluding Saginaw Bay)	2,301	2,784,380
Detroit River	575	695,360
Lake Superior	486	587,630
Total	42,839	$ 51,836,145

to result in significant losses of sport and forage fish in that lake (Manny 1984).

6.5 WASTE DISCHARGES AND SPILLS

The use of the St. Clair River and Lake St. Clair as a receiving water for municipal and industrial discharges conflicts with most other potential uses of the system. In Ontario waters, 12 industrial waste dischargers and 6 municipal sewage treatment plants are concentrated along the shoreline of the upper river, where about 1.7 million m^3 of effluent are discharged daily from the large petrochemical complex near Sarnia (Figure 10). In June 1985, there were 19 permitted industrial waste discharges and 7 discharges of treated sewage to Michigan waters of the St. Clair system. The impact of these municipal and industrial effluents on biological resources of the St. Clair system is incompletely known, but a recent spill of perchloroethylene in Ontario waters of the river prompted a major investigation of the biological effects of the spill and related discharges. Results of this study (DOE/MOE 1986) indicated water, sediment, and biota were adversely affected by discharges of organics and other pollutants from chemical industries located in the Sarnia area, and that the spill of perchloroethylene further compounded the problem. High concentrations of chlorinated organics were found in the water, sediment, and biota along the Ontario shoreline of the river, and sediments near the spill site were acutely toxic to some species of benthic invertebrates.

The recent spill of perchloroethylene was not an isolated event. The record (Table 39) shows that during 1974-85 there were 11 major oil spills (of 10 tons or more), totaling 1,182 tons, and 21 major spills of other hazardous substances, totaling 10,336 tons, into Ontario waters of the St. Clair River and its tributaries, primarily from land-based facilities located along the upper river. Although the Michigan side of the river is less industrialized than the Ontario shoreline, in 1973-79 there were 120 spills of petroleum products from land-based facilities and vessels there, totaling nearly 22,000 L, and 2 spills of other hazardous substances, totaling over 1,700 L, into Michigan waters of the St. Clair system (Table 40). Spills of oil pose serious hazards to fish and wildlife resources in the Great Lakes (Emery 1972; Kiellor 1980) and have caused large losses of waterfowl throughout the Great Lakes (Hunt 1965). Fuel oil is of particular concern because it floats on the surface of the water, where it poses a threat to waterfowl. Fuel oil also contains toxic, water-soluble compounds, such as benzene, toluene, and naphthalene, that in low concentrations reduce growth, reproduction, and survival of many aquatic plants and animals (Burk 1977; Anderson 1977).

Although improvements in water and sediment quality in the St. Clair system have occurred in the last decade (DOE/MOE

Table 39. Major spills (10 tons or more) of oil and other hazardous substances into Ontario waters of the St. Clair River and its tributaries, 1974-85 (DOE/MOE 1986).

Substance spilled	Year	Source	Amount (tons) Spilled	Unrecovered[a]
Bunker C oil	1976	Suncor	150	30
Bunker C oil	1976	Suncor	300	0
Bunker C oil	1977	CNR	86	17
Gas oil	1978	Esso Petroleum	29	0
Bunker C oil	1980	Hall Corp. (vessel)	21	13
Bunker C oil	1981	CNR	21	4
Gasoline	1981	Esso Petroleum	348	0
No. 2 fuel oil	1984	Esso Petroleum	116	23
No. 2 fuel oil	1984	Esso Petroleum	16	3
Catalytic cracker feed	1985	Imperial Bedford (at Shell)	75	1
Slop oil	1985	Esso Chemical	120	0
Total			1,282	91
Latex	1975	Polysar	17	17
Latex	1976	Polysar	18	18
Latex	1980	Polysar	87	87
Latex	1980	Polysar	20	20
Total			142	142
Styrene	1974	Dow	4,504	2,700
Styrene	1978	Polysar	411	80
Total			4,915	2,780
Hydrochloric acid	1974	Dow	21	21
Sodium hydroxide	1975	Dow	28	28
Sodium chlorate	1979	Dow	4,080	4,000
Sulphuric acid	1981	Polysar	13	13
Sodium chloride	1981	Dow	379	76
Hydrochloric acid	1982	Suncor	16	0
Sodium hydroxide	1983	Esso Chemical	19	4
Brine	1984	Esso Petroleum	164	33
Total			4,720	4,175
Lignin liquor	1975	Polysar	159	33
Phenolic waste water	1975	Esso Petroleum	239	239
Process water	1975	Suncor	91	73
Xylene	1975	Eagle Transport	11	2
Ethylene glycol	1976	Dow	13	0
Wash water	1982	Esso Petroleum	46	46
Perchloroethylene	1985	Dow	54	0
Total			613	393

[a] Estimate based on reports of % recovered.

Table 40. Number and volume (L) of spills of hazardous substances into Michigan waters of the St. Clair system, 1973-79 (USCG 1980).

Substance spilled	St. Clair River		Lake St. Clair		Total	
	Number	Volume	Number	Volume	Number	Volume
Waste oils	15	1,253	3	416	18	1,669
Lube oils	3	458	9	1,219	12	1,677
Fuel oils	8	8,758	4	454	12	9,213
Bunker oils	16	3,066	1	76	17	3,141
Other oils	45	4,663	3	174	48	4,837
Gasoline	1	378	12	1,132	13	1,510
Methyl alcohol	-	-	1	1,514	1	1,514
Other substances	1	208	-	-	1	208
Total	89	18,784	33	4,985	122	23,769

1986), waste discharges and spills from vessels and land-based facilities continue to threaten the suitability of the system as habitat for fish and wildlife, as a municipal and industrial water supply, and for swimming and other recreational uses. Polluted sediments, which reflect accumulated wastes added to the system, and present runoff from urban and agricultural areas are issues that must be considered in the management of the system.

6.6 MANAGEMENT FRAMEWORK

Management of the St. Clair system resources proceeds within a regulatory framework that is based on legislation and policy development implemented primarily at the Federal and State or Provincial level of government, but often with significant fishery input from other international or regional institutions and the public. The following discussion, although not intended to be exhaustive or overly detailed, illustrates that there is extensive legislation in both the U.S. and Canada that can be implemented to protect the fish and wildlife resources and their critical habitats in the St. Clair system. This same legislation also provides for the maintenance of safe drinking water supplies and indirectly enhances opportunities for tourism and water-oriented recreation, while allowing for the orderly use and development of other system resources of interest to commerce and industry that contribute to the general economic base of the region.

Legislation designed to protect the public's interest in the submerged lands of the Great Lakes, including Lake St. Clair in the State of Michigan, has its roots in Article VI of the Northwest Ordinance of 1787, which holds Great Lakes waters to be common and free highways. Act 171 of Michigan Public Acts of 1899 sets aside all submerged lands as public shooting and hunting grounds, and Act 362 of the Michigan Legislature, passed in 1913, provides for leasing and control of State-owned submerged lands. Illegal filling and conversion of these public trust bottomlands continued after 1913 and resulted in the passage in 1955 of (Michigan) Act 247, entitled the Submerged Lands Act, which provided a means for citizens to obtain clear title to certain filled Great Lakes bottomlands and for government to halt additional indiscriminate filling of such bottomlands (Nielsen 1986).

In 1970, Act 245, the Michigan Shorelands Protection Act, was passed. The Act covers critical shoreline habitat, including environmentally sensitive coastal areas up to 1,000 feet landward of the Great Lakes and connecting channels shorelines. Such areas include wetlands, uplands, and islands that are essential for nesting, reproduction, feeding, rearing of young, or some other critical life process of coastal fish and wildlife species. The Act takes a non-structural approach to minimizing property loss, requiring the Michigan Department of Natural Resources to designate Environmental Areas and to regulate dredging, filling, alteration in drainage or vegetation, and the placement of buildings within such areas (MDNR 1982). Although Environmental Areas have been designated in the St. Clair system, the protection of environmentally sensitive coastal habitat in much of the system is already offered by the St. Clair Flats Management Recommendations (MDNR 1981).

In 1979, recognizing that wetland losses were still occurring throughout the State, the Michigan Legislature passed the Goemaere-Anderson Wetland Protection Act (PA 203), which requires a permit for the modification of wetlands, including those contiguous with the Great Lakes or Lake St. Clair and their tributaries (MDNR 1982). PA 203 complements other wetland protection legislation and has the potential to significantly retard encroachment into the coastal wetland areas. Michigan and New York are the only States in the Great Lakes Basin that have comprehensive wetland protection programs.

In Ontario, the Federal Fisheries Act of 1867 is the primary legislation for managing fish habitat. Amendments to the Act in 1977 significantly strengthened its habitat protection provisions. The Act defines habitat broadly in biological as well as physical-chemical terms and states that there shall be no net loss in productive fish habitat (DFO 1983). Constitutional authority for Canada's fisheries lies with the Federal government. The Ontario Ministry of Natural Resources has been delegated administrative responsibility for fisheries management within the Province, but the provisions of the Fisheries Act dealing with fish habitat are retained by the Department of Fisheries and Oceans (Holder 1985); provisions of the Act controlling the release of deleterious substances into fish habitat are administered by Environment Canada on behalf of Fisheries and Oceans.

The fate of the non-public wetland habitat in Ontario's portion of the St. Clair system is also strongly influenced by cultural and economic considerations as these are expressed in a legal context involving property ownership and taxation. For example, Ontario's tax law provides economic benefit for diking of wetlands and their conversion to agricultural use, considering wetlands to be recreational land and taxing it at twice the rate of farmland. From a property tax standpoint alone, the pressure to convert St. Clair system wetlands to farmland is even greater because generous tax subsidies for farmland are also available from the Provincial Government (McCullough 1985). On the other hand, the establishment under Canadian law of the Walpole Island Indian Reserve on Walpole, Seaway, Squirrel, and Ste. Anne Islands has retarded conversion of a significant portion of the wetlands in the Ontario portion of the St. Clair Delta to agriculture and may help ensure these lands continue to contribute to fish and wildlife production in the St. Clair system.

In Michigan, specific proposed actions involving dredging or filling in Great Lakes navigable waters and coastal wetlands are regulated under permit by the U.S. Army Corps of Engineers under Section 10 of the Rivers and Harbors Act of 1899, Section 404 of the Clean Water Act, and State statutes. The U.S. Fish and Wildlife Coordination Act and Executive Orders 11988 and 11990 of 1977 may also apply. Michigan's submerged lands of the St. Clair system are also protected from the dumping of polluted materials dredged from the system or adjacent waters by Section 123 of PL 91-611 of the Rivers and Harbors Act. Polluted materials dredged from the U.S. waters of the St. Clair system since the late 1970's have been deposited in large (1.5 million m^3 capacity), confined disposal facilities constructed on upland areas of Dickinson Island. These confined disposal facilities are less than 50% filled at present (IJC 1986) and may continue to meet disposal needs in the St. Clair system beyond 1990, the date at which they were originally scheduled to be filled. Lower than anticipated volumes of dredged materials in recent years, due in part to the recent record high water levels, have contributed to the extended longevity of the Dickinson Island facilities.

In Ontario, navigation-related dredging in the St. Clair system is limited to the St. Clair Cutoff Channel. Dredged material disposal is regulated by the Federal Navigable Water Protection Act, which controls siting of confined disposal facilities; the Fisheries Act, which enjoins that all effluents from confined disposal sites meet water quality criteria; and the Migratory Birds Convention Act, which prohibits deposition of material deleterious to aquatic environments in areas frequented by migratory birds (IJC 1986). Contaminated materials dredged from Ontario waters of the St. Clair system have been deposited in a confined disposal facility constructed on Seaway Island. This facility is presently filled to 125% of its 350,000 m^3 design capacity, but a pressing need for a new confined disposal facility in the St. Clair system may not now exist because sediment contamination levels (of mercury) have declined markedly and future dredgings may qualify under existing law for open lake disposal (Seawright 1986).

Water resources development and dredging can be expected to continue in the St. Clair system and further wetland losses may occur. In Michigan, compensation for such losses in terms of the rehabilitation of damaged wetlands or the creation of new wetlands is addressed by Section 150 of the Water Resources Development Act of 1986, which allows the U.S. Army Corps of Engineers to provide up to $400,000 for each wetland required as mitigation for losses resulting from permitted wetland developments or in connection with adverse impacts occurring from other Federal dredging projects. This Act has been implemented in connection with the creation of the confined disposal facility at Pt. Mouillee in western Lake Erie, but no wetland creation or rehabilitation projects as provided for by the Act have been undertaken in the St. Clair system (J. Galloway, U.S. Army Corps of Engineers, pers. comm.). The leaking of contaminants from confined disposal facilities and the creation within these facilities of contaminated aquatic habitats that are attractive to fish and wildlife have been identified as potentially significant concerns (IJC 1986). These concerns may impede the full implementation of Section 150 of the Water Resources Development Act in connection with the confined disposal facilities which receive contaminated sediments.

Pressure for residential development in the St. Clair Delta has been strong since the 1950's, and sewage treatment, which relies heavily on septic tanks, has created a health hazard in some areas, particularly during periods of high water. The Michigan Department of Natural Resources has recommended that Public Act 368 be applied to mitigate and correct water pollution and public health problems associated with sewage treatment (MDNR 1981).

The extraction of sand, gravel, and other aggregates has occurred historically from the lands beneath the Great Lakes and their connecting channels. These activities are regulated by Act 326 in Michigan and by the Federal Fisheries Act in Ontario. Interest in these submerged deposits is not presently high but can be expected to increase as on-land supplies dwindle. Careful application of existing legislation is necessary to regulate the mining of such submerged deposits in the St. Clair system to prevent environmentally unsound extractions like those that occurred at the head of the St. Clair River in the early 1900's. These extractions, together with navigation channel dredging, lowered water levels in Lakes Huron and Michigan by 0.27 m (Derecki 1982).

In the United States, overall water policy is embodied in the Federal Clean Water Act, and the Federal Government traditionally establishes water quality goals that are consistent with the Act. In the Great Lakes, the Water Quality Agreement of 1978 between the United States and Canada sets the water quality goals for the boundary waters shared by the two countries, and each country implements the agreement as permitted by its own policies and laws. The U.S. Environmental Protection Agency administers and implements the Clean Water Act and delegates a portion of its responsibility and authority to the State of Michigan, which is extensively engaged in regulating water quality in the Great Lakes, including the St. Clair system (Hacker and Martin 1986).

In Canada, the main Federal role in Great Lakes water quality matters is defined in an agreement between the Canadian Government and the Province of Ontario. This agreement, the Ontario Water Resources Act, has been the workhorse statute dealing with water pollution in Ontario since 1957 (IJC 1986). The Act contains provisions for dealing with the protection of water quality and provides the basis for construction, financing, and operation of municipal sewage treatment plants. The (Ontario) Environment Protection Act of 1971 supplements the Water Resources Act in several important ways, including provision of a legal framework for waste management, the establishment and operation of waste-disposal sites, and the cleanup of discharges that have already occurred. The Environmental Contaminants Act and the Fisheries Act are the two major pieces of Canadian Federal legislation controlling the release of toxic substances to the environment. The Environmental Assessment Act of 1975, administered by the Ontario Ministry of the Environment, controls the development of new projects that are likely to impact on water quality or other aspects of the natural environment (USEPA/EC 1984).

International commissions also exert significant influence on the management of Great Lakes resources. The International Joint Commission, which was created in 1909 by the U.S. and Canadian Governments, plays a major role in water quality issues affecting the two countries along their common border in the Great Lakes and connecting channels. The Commission reports to both countries and although their recommendations do not carry the force of law, they usually influence and guide water policy and the development of the water quality management framework. The Commission has recently identified 42 Areas of Concern in the Great Lakes and connecting channels where the worst pollution threats to the aquatic environment occur, and the Commission is working with Michigan and Ontario to develop Remedial Action Plans, which, when fully implemented, will clean up and restore all beneficial uses to each area. The St. Clair River and the Clinton River, a tributary to Lake St. Clair, are Areas of Concern.

The Great Lakes Fishery Commission, established in 1955 under the Convention for Great Lakes Fisheries between the U.S. and Canada, has the major international role in Great Lakes fisheries issues. The Commission works through the various Federal, State, and Provincial agencies to coordinate fisheries research and management in the Great Lakes. A recent thrust of the Commission has been to develop a Fish Habitat Advisory Board which will help the Commission determine policy direction on habitat matters, increase interaction among fishery agencies and other agencies whose actions influence fish habitat quality, and influence decisions on management of habitat for the benefit of fish (Fetterolf 1984).

Various other regional institutions and organizations also have significant roles in the management of Great Lakes resources including either directly or indirectly those of the St. Clair system. The Council of Great Lakes Governors, which is attempting to develop consensus on Great Lakes water-use issues, including out-of-basin water diversion, has the power to make legal and financial commitments to support regional action. Members of Congress from the eight Great Lakes states also represent a potentially significant force with common regional goals that can shape legislation and policy affecting Great Lakes resources. The numerous agencies and institutions that compose the Great Lakes research community also often perform key roles in developing resource policy and providing information required for the development of sound management strategies. And finally, citizen involvement with advocacy groups operating in various forums can also often significantly influence policy, legislation, and the management framework within which resources are allocated, used, and protected.

6.7 RECOMMENDATIONS

The St. Clair system is a natural resource of national and international significance. Managing it effectively will require that it be viewed realistically and holistically as an ecosystem which includes natural functional relationships between physical and biological processes and forms upon which are superimposed cultural modifications. Application of an ecosystem approach in the management of Great Lakes resources has been given explicit endorsement by the Governor of Michigan (Blanchard 1986), and a conceptual framework for applying an ecosystem approach to support fisheries and water quality management objectives has been developed jointly by the International Joint Commission and the Great Lakes Fishery Commission (IJC 1985a).

Because the St. Clair system is a binational resource shared by the U.S. and Canada, a logical first step in managing that resource is the development of a joint strategic plan which would incorporate an ecosystem approach. Such a plan should ensure that the most sensitive and desirable natural components of the system are protected, while allowing the system to continue to serve the common interests of both nations as a multi-purpose resource of considerable and sustaining economic value. Such a joint strategic plan would provide an umbrella under which tactical or operational plans to guide the management of specific components of the resource could be developed and coordinated among the various jurisdictions.

A joint strategic plan for the management of Great Lakes fisheries (GLFC 1980) is in place. This plan is serving as the focus for tactical fisheries management plans that are being developed by the States and the Province of Ontario for each of the Great Lakes. A complementary fish habitat management planning initiative is also under consideration by the Great Lakes Fishery Commission and its cooperators, the U.S. and Canadian fishery agencies (Fetterolf 1984). These planning initiatives could contribute significantly to the management of the St. Clair system both in terms of providing a general or conceptual framework for developing strategic and tactical plans and also by helping resolve issues of substance that relate to fisheries and fish habitat. In the latter regard, concerted efforts should continue to ensure that explicit consideration is given to the St. Clair system fishery resources and fish habitat, either in one of the lake management plans or in a separate management plan which deals with the Great Lakes connecting channels.

Other issues that need to be explicitly addressed in a management plan for the St. Clair system include those described in the preceding sections of this chapter. Among these, the issues of perhaps greatest concern to resource users and resource managers are spills and discharges of toxic contaminants and the effects of these materials on drinking water quality and on the natural components of the St. Clair system, which directly or indirectly provide recreation and food for humans. A binational state-provincial strategy for managing toxic substances is being developed through the Council of Great Lakes Governors (Milliken 1986), and a commitment has been made by Ontario for the virtual elimination of inputs of persistent toxic substances to the St. Clair system (OMOE 1986b). Both initiatives are to be strongly endorsed, and this issue should be addressed definitively in future management plans.

The fate of sediment-associated contaminants and the effectiveness of dredging and disposal in confined disposal facilities as a means of removing and isolating persistent environmental contaminants also need to be examined (IJC 1986) and addressed in an overall strategy for the elimination of these materials from the St. Clair system. Remedial Action Plans being developed for the St. Clair system and adjacent waters (IJC 1985b) can also be an important component of a tactical management plan, and completion and effective implementation of these action plans is strongly recommended.

Development of a joint strategy to minimize or prevent further degradation or piecemeal loss of wetland habitat that supports important transboundary fish and wildlife resources in the St. Clair system is also recommended. Consideration also should be given to addressing fish losses occurring at water intakes, should these losses be shown to significantly impact the multimillion dollar fishery resource.

Water levels need to be addressed primarily in the context of a non-structural, long-term strategy for ameliorating the impact on existing and future shoreline developments within the system, and also in terms of tactical plans which cope with the record high water levels presently occurring. The St. Clair Flats Management Recommendations (MDNR 1981) provide the current official policy for administering Public Acts 326 and 247, which regulate shoreline development in Michigan's portion of the St. Clair system.

The successful implementation of a management plan for the St. Clair system will depend to a significant degree on the database available for decisionmaking and the ease with which that database can be effectively accessed, manipulated, and displayed. A substantial database already exists, but it is located in various scattered repositories and is not readily accessible to decisionmakers and managers. We recommend, therefore, that database consolidation and the development of a geographic information system designed to aid resource decisionmaking be given high priority by management agencies. This information transfer capability is currently under consideration or development by several resource agencies and institutions in the Great Lakes area and the Michigan Department of Natural Resources presently has an operational system (Frank Horvath, Michigan Department of Natural Resources; pers. comm.) that appears capable of providing much of the information transfer support needed for resource management and protection.

Several major research and development needs that we perceive to be critical to the effective management of the St. Clair ecosystem emerged while this document was in preparation. These include development and application of mass balance models for consideration of toxic substances and phosphorus problems and for cumulative impact assessment. There is also a need for basic research that will provide a satisfactory understanding of biological production processes and materials and energy transfer in the aquatic food web of the system.

The mass balance approach, which has also been endorsed by the Upper Great Lakes Connecting Channels Study Management Committee (UGLCC 1985), should be used in estimating loadings of toxic substances and phosphorus from industry, wastewater treatment plants, tributaries, surface runoff, and contaminated ground water. These mass balance models should also permit consideration of other contaminant sources, such as sediments and the atmosphere.

The development of cumulative impact assessment models is essential because the use of the St. Clair system for recreation, navigation, a municipal and industrial water supply, and the final dispersion of the waterborne wastes of the bordering communities poses a poorly quantified but increasingly significant impact on the productivity of the system. In similar situations elsewhere, impact evaluation typically has been made on a site-specific or use-specific basis rather than in the broader, cumulative context needed to adequately assess additive and synergistic effects and address the combined effects of past, present, and foreseeable future actions on a system-wide basis. Cumulative impact assessment strategy development for the Great Lakes and connecting channels is currently underway by several elements of the U.S. Fish and Wildlife Service.

Research needed to fill critical gaps in our knowledge of production processes and material and energy transfer in the St. Clair system is described in Chapters 3 and 4 of this document. The results of this research would contribute significantly to the development of functional cumulative impact assessment models and to the successful application of the ecosystem approach in the management of the St. Clair system.

Our final recommendation involves the legal and institutional framework within which resource management proceeds. The Federal, State, and Provincial resource protection and management roles outlined in Section 6.6 generally reflect the mandates of the various agencies and outline the legal basis for interaction among the agencies. The existing legislative tools are powerful and the system has worked, but actions to eliminate overlapping mandates and jurisdictions and confusing multi-agency involvement (Hacker and Martin 1986; Holder 1985) would promote more effective implementation of the legislation, facilitate policy development, and simplify management and protection of the natural resources of the Great Lakes and connecting channels, including those of the St. Clair system. Continued effort by the regional research community to develop information is needed to evaluate the impact of human activities on the St. Clair system, as is the continued involvement of the regional research community and the public in policy formulation if the natural resources of the system are to be properly managed and the public trust preserved.

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15. Supplementary Notes

16. Abstract (Limit: 200 words)

The St. Clair River and Lake St. Clair form a part of the connecting channel system between Lake Huron and Lake Erie. This report synthesizes existing information on the ecological structure and function of this ecosystem. Chapters include descriptions of climatology, hydrology, and geology of the region; biological characteristics; ecological relationships; and commercial and recreational uses, as well as discussions of management considerations and issues. The St. Clair system provides valuable habitat for migratory waterfowl and fish spawning and nurseries, and contains some of the most extensive emergent wetlands in the region. The system is used for navigation, municipal and industrial waste disposal, recreational boating, fishing and waterfowl hunting. Allowing for multiple human uses while maintaining important waterfowl and fish populations is the greatest challenge facing managers of this system.

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