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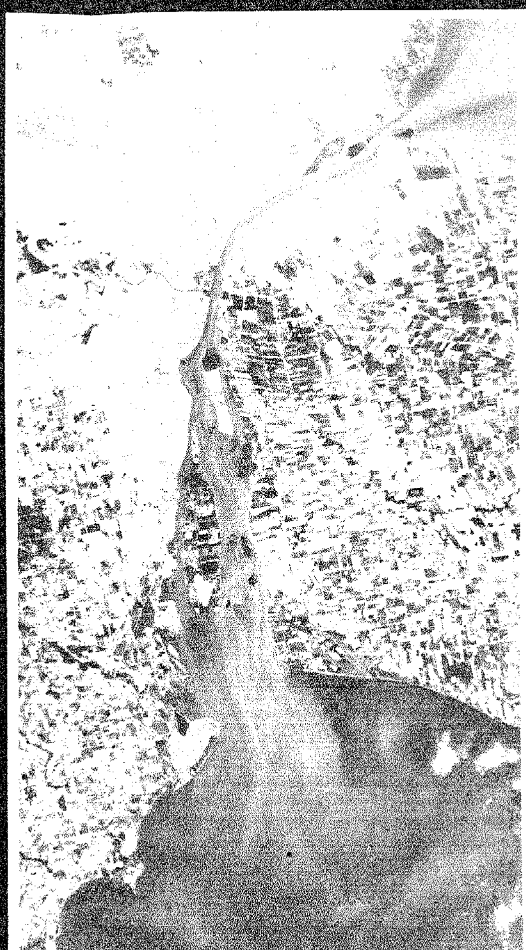
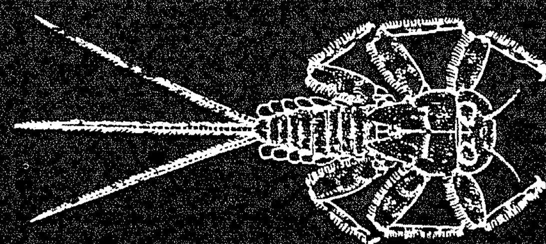
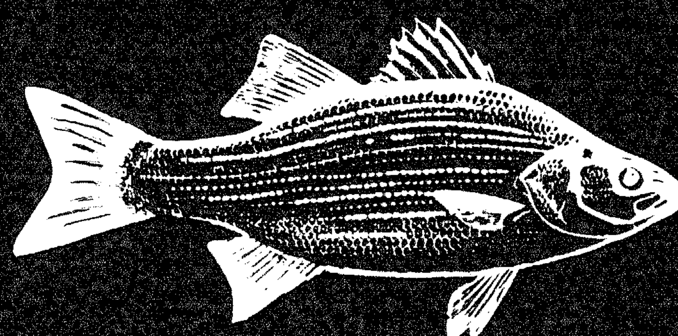
April 1988



THE DETROIT RIVER, 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 left: Aerial photo of the Detroit River (July 19, 1984), including Lake St. Clair at the north, to Lake Erie at the south.

Top right: Mayfly nymph and white bass.

Lower: The _Mesabi Miner_, a large self-unloading carrier of iron ore, limestone, or grain, passes the City of Detroit on the Detroit River.

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THE DETROIT RIVER, MICHIGAN: AN ECOLOGICAL PROFILE[a]

by

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Fish and Wildlife Service
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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, and suggested courses of study or action, are exclusively those of the authors.

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PREFACE

This monograph is part of a series of publications about current issues facing the Nation's coastal environments. It synthesizes existing information describing the ecological structure and function of the Detroit River, which flows between Lakes Huron and Erie and forms the border between the United States (Michigan) and Canada (Ontario). Other reports in this series present information about two similar rivers between these countries, the St. Marys River (Duffy et al. 1987), and the St. Clair River and Lake St. Clair (Edsall et al. 1987).

In gathering the available information on the Detroit River, especially that pertinent to managing its biological resources, we found gaps in the information needed to protect and enhance these resources; they are identified in the report. Wherever possible, the river is treated as a distinct but integrated unit of the Great Lakes ecosystem.

In recent years, the Detroit River has received considerable attention because its fishery resources move freely across the boundary between two nations and represent millions of dollars in revenue each year to each nation. Use of these same waters for navigation as well as for disposal of municipal and industrial wastes, coupled with rapid industrial and residential development of the shoreline, has focused concern on preparation of an action plan to control pollution by toxic substances, identify study needs, and develop management strategies. This report encompasses these needs and should be useful in these important efforts.

Any questions or comments about, and requests for, this publication should be directed to:

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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 thank Pat Hudson for the analysis of primary and secondary production, Donald Schloesser and S. Jerrine Nichols for unpublished data, John Hartig of the International Joint Commission for information on combined sewer overflows, Jerry Martz, Tim Payne, and Frank Horvath of the Michigan Department of Natural Resources for waterfowl statistics and information about the Great Lakes Information System, Bonnie Boynton for editing, Sue Lauritzen for layout, and Marilyn Murphy for typing the manuscript.

The cartographic laboratory of the Department of Geography and Geology at Eastern Michigan University in Ypsilanti drafted several of the illustrations.

Reviewers of the manuscript included Paul Bertram, Walter Duffy, John Forwalter, Richard Greenwood, Robert Haas, Peter Kauss, Marge Kolar, Tim Kubiak, Joseph Leach, Edward Pendleton, Keith Rodgers, and Larry Sisk.

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CHAPTER 1. INTRODUCTION—THE SETTING

1.1 THE DETROIT RIVER AS AN ECOSYSTEM

The Detroit River includes the lower 51 km of the strait or channel connecting Lakes Huron and Erie (Figure 1). An international boundary divides the Detroit River about equally into United States (Michigan) and Canadian (Ontario) waters along the commercial navigation channel, which is part of the Great Lakes-St. Lawrence Seaway System. Because the Detroit River can be delimited both ecologically and hydrologically, it is considered herein as a distinct Great Lakes subsystem.

Limnologically, the Detroit River is a moderately productive ecosystem with water temperatures suitable for cold-water fish from September to June (Muth et al. 1986). Despite intensively developed shorelines and tributary drainage basins, the Detroit River provides important habitat for fish and migratory waterfowl. Moreover, the waterway contains island-nesting colonial birds; rare and endangered species, including mussels; and is used extensively for recreational boating. Within the river system, many use conflicts and adverse environmental impacts occur as shoreline and island development, industrial discharges, municipal effluents, and tributary loadings alter the physical habitat, water quality, and sediments.

1.2 GLACIAL ORIGIN

Atop the limestone bedrock in the Detroit River area is a mantle of glacial drift 6 to 30 m thick (Mozola 1969). Much of this drift was deposited during the end of the Late Wisconsin glacial period about 14,000 years ago (Hough 1958). Based on the topography and soils, these glacial deposits can be separated into till plains and lake plains (Figure 2). The lake plain, a lowland consisting of lacustrine clays and beach sand deposits, extends from the till plains to the Great Lakes shorelines and includes most of the Detroit River area. During the Late Wisconsin glacial period, the Grosse Ile, Detroit, and Mount Clemens moraines were deposited in the waters of ancestral Lake Erie.

During much of its postglacial history, the Detroit River area lay beneath the waters of ancestral Lake Erie (Dorr and Eschman 1970). The present river channel was first established about 13,000 years ago when falling water levels permitted erosion of the lake plain and moraines. Water levels in the Detroit River 12,000-4,000 years ago were lower than the present level of Lake Erie (174 m above sea level): Once during this period, the Great Lakes drained northward through Georgian Bay and the Detroit River was dry. During the last 4,000 years, the average water level of the Detroit River and Lake Erie has changed little (Hough 1958).

1.3 LAND USE HISTORY

North American Indians were the first to use the natural resources of the Detroit River. An archeological survey along the river's west bank revealed 32 sites, most of which were prehistoric (ca. 400 A.D.) late Woodland and Historic Indian habitations (Peebles and Black 1976). Wild rice (Zizania aquatica) grew at the mouths of the Huron and Rouge Rivers (McDonald 1951) and provided a source of trade for the Huron-Wyandot Indians, who had established a settlement near the present city of Wyandotte in 1650 (Santer 1977). Because fish and wildlife were abundant along the river, native

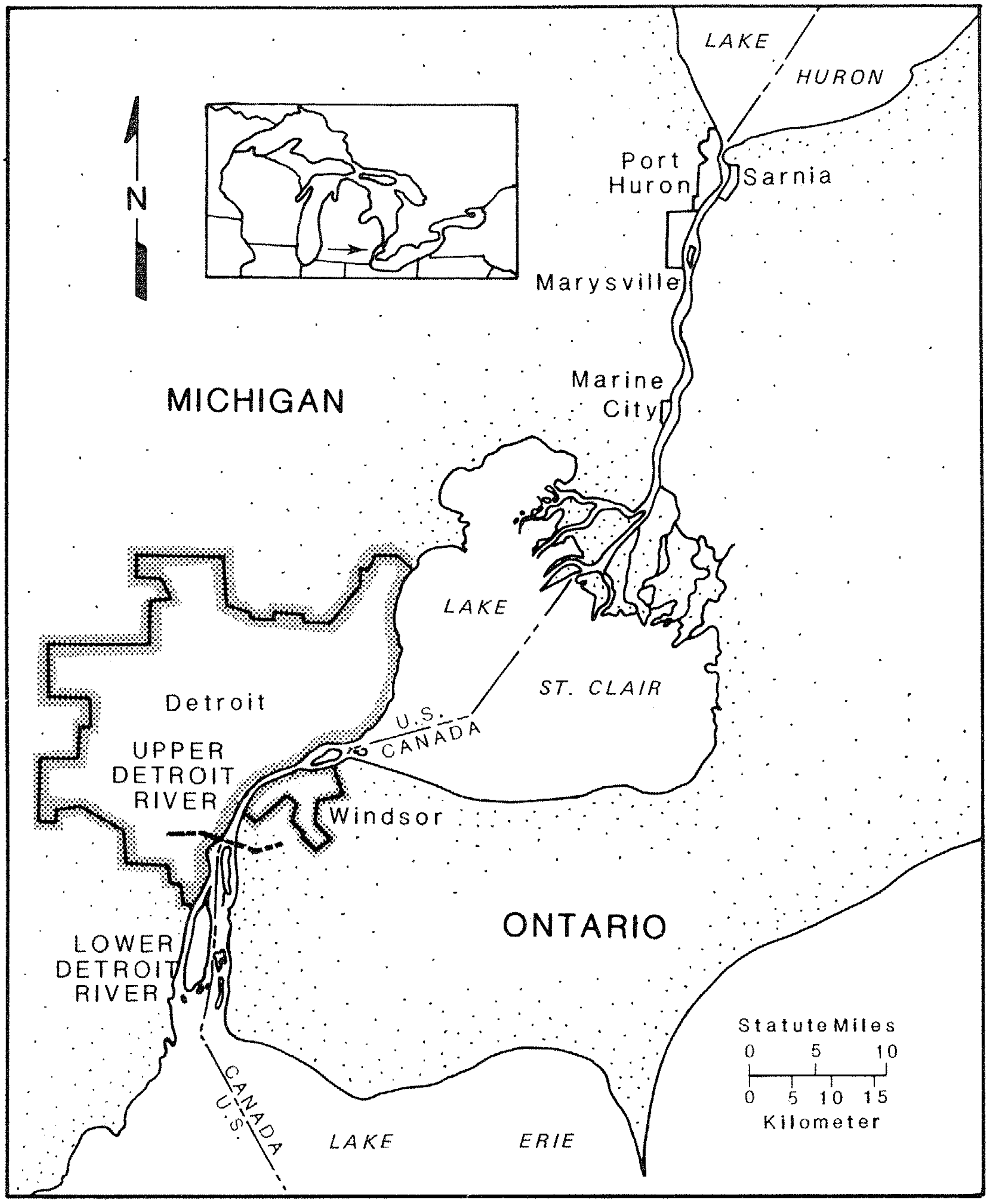


Figure 1. Geographical setting of the Detroit River ecosystem.

Indian economies at the time of European contact were based on fishing, hunting, and gathering (Litting 1973; Raphael 1987). Indians who survived European-induced warfare and diseases refocused their lives on the fur trade and on European goods and settlements (Peebles and Black 1976).

French settlement near the river probably began in about 1686 (Farmer 1890). In 1701, Fort Pontchartrain, the first French trading post along the Detroit River, was erected near the mouth of the Rouge River. American settlement began in 1794 on the west bank shortly after the battle between British and

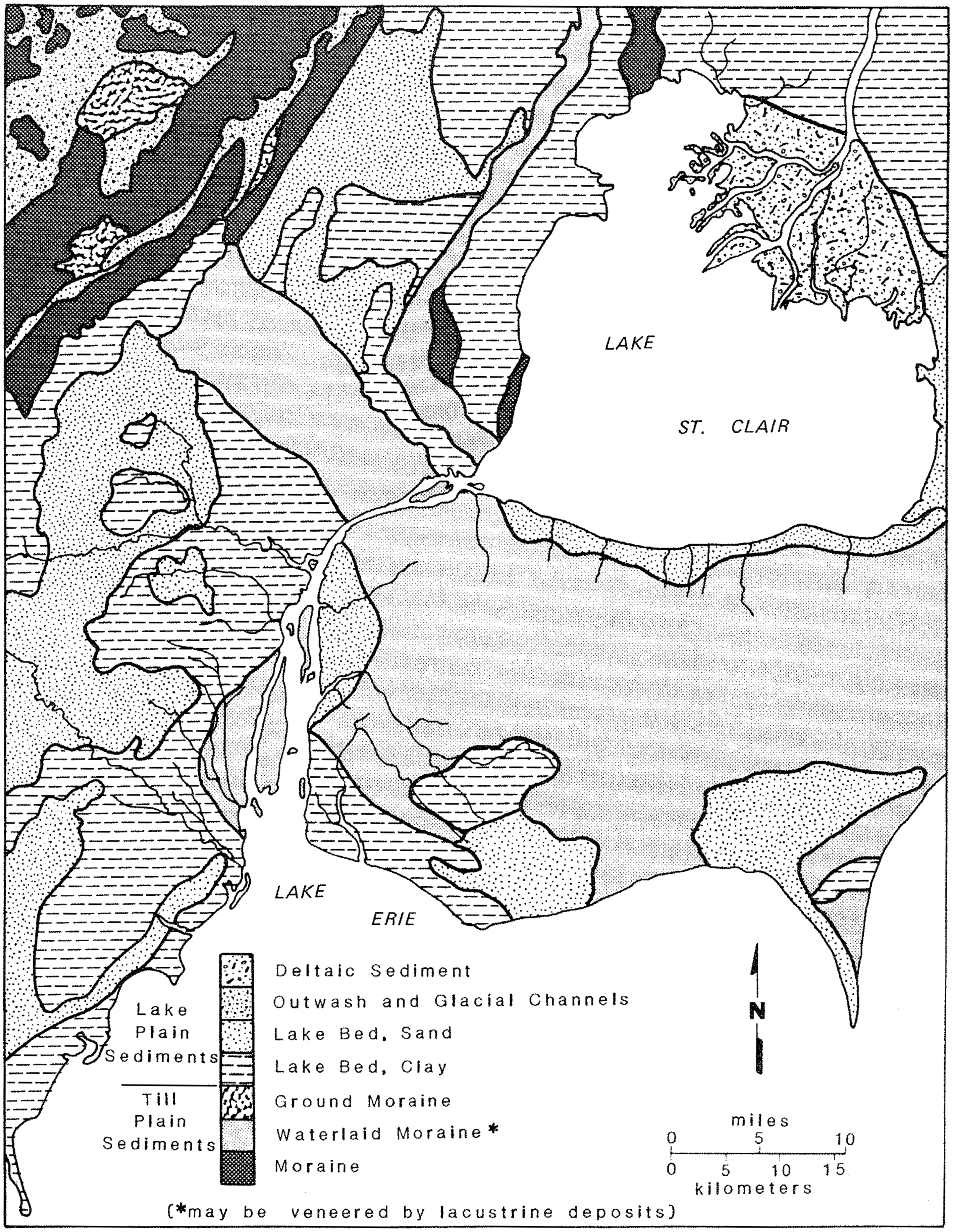


Figure 2. Glacial geology of the Detroit River area (Martin 1955).

American forces at Fallen Timbers. The British settled in the town of Sandwich (now Windsor, Ontario) on the east bank of the river following the war of 1812 between Britain and the United States. During European exploration and settlement, mature oak-hickory forests grew on the lake plains and elm-ash woodlands colonized the "black swamp" soils along the river (Gordon 1969). Land was obtained from the Indians by land sales from 1790 to 1830, and by treaties, particularly the Treaty of Detroit in 1807 (Higgins and Kanouse 1969). The French settled along the Detroit River in a longlot pattern of log cabins and stone windmills (Santer 1977). Each longlot permitted access to the river and upland woods. Both the French and native Indians caught large numbers of lake whitefish, lake trout, and lake sturgeon in the river (Santer 1977).

The Detroit-Chicago Railroad, completed in 1851, spurred agricultural development and initiated commercial activity. By 1870, both shorelines of the Detroit River were colonized by farmers and small merchants. At first, the wetlands along the river were essential for survival of the settlers and were used in many ways (Raphael 1987). Then, wetlands were diked and cleared for pasture and cropland. Lands 2 to 3 km from the waterway were not farmed, but left as "thick woods." By 1900 these woodlands were cleared as agricultural settlement spread inland.

During the 1870's, a depth survey of the Detroit River by Major Comstock of the U.S. Army Corps of Engineers revealed a U-shaped river channel with a sand bottom (see Lamson 1873). Along the river shorelines, a fringe of emergent vegetation grew in waters 0.3 to 2.0 m deep. Landward of this emergent riverine vegetation was a strip of coastal marsh that extended over 1 km inland in places, especially near the mouths of tributaries, such as the Rouge River. According to the Comstock surveys, waters in the Rouge River were 4 to 6 m deep and the bottom was sandy. Thus, we believe that in prehistoric times, the Detroit River and its tributaries were relatively free of fine-grained sediments and supported extensive wetlands.

After 1910, population growth and land-use intensity in the Detroit River area accelerated as industrial development took place in Wayne County (Sinclair 1970). Industrial development of heavy steel, chemical, and refining industries in the towns of River Rouge, Ecorse, Trenton, and Wyandotte dominated the metropolitan area by 1930. Stimulated by the automobile industry and later by World War II, industrial growth spread into the downriver area. With the construction of the Ford Freeway in 1943 and the interstate system during the 1950's, many new automobile plants were established in Detroit. In contrast, except for the City of Windsor, which was initially tied to industrial growth in the City of Detroit, much of the adjacent lake plain in Ontario remained agricultural, producing corn, tobacco, and tomatoes.

1.4 DEVELOPMENT OF THE NAVIGATION SYSTEM

The Detroit River is part of the Great Lakes-St. Lawrence Seaway that extends from Montreal, the present landward limit of year-round navigation by ocean-going vessels, to Duluth, Minnesota, on Lake Superior, a water route of 2,177 km (GLWNB 1976). Completed in 1969, the seaway is maintained to a depth of 8.23 m (27.0 ft). This depth provides a vessel draft of 7.77 m. To maintain the Seaway, the U.S. Army Corps of Engineers, pursuant to the Rivers and Harbors Act of 1899, is authorized to dredge to a depth of 8.23 ± 0.6 m below low water datum. Navigation-related dredging and gravel mining at the head of the St. Clair River lowered the levels of Lakes Michigan and Huron 0.27 m and decreased the storage volume of the two lakes by 32 km³ (Derecki 1985).

In the Detroit River, the commercial navigation system consists of the main, auxiliary, and side channels, commercial harbors and turning basins, and water-level and cross-channel current-control structures (Figure 3). Those waterways, harbors, and berthing areas, all dredged by the U.S. Army Corps of Engineers, are listed in Table 1. In Ontario, the City of Windsor maintains a public harbor at a depth of 8.69 m. Canada allows the U.S. Army Corps of Engineers to maintain the navigation channels in the Detroit River.

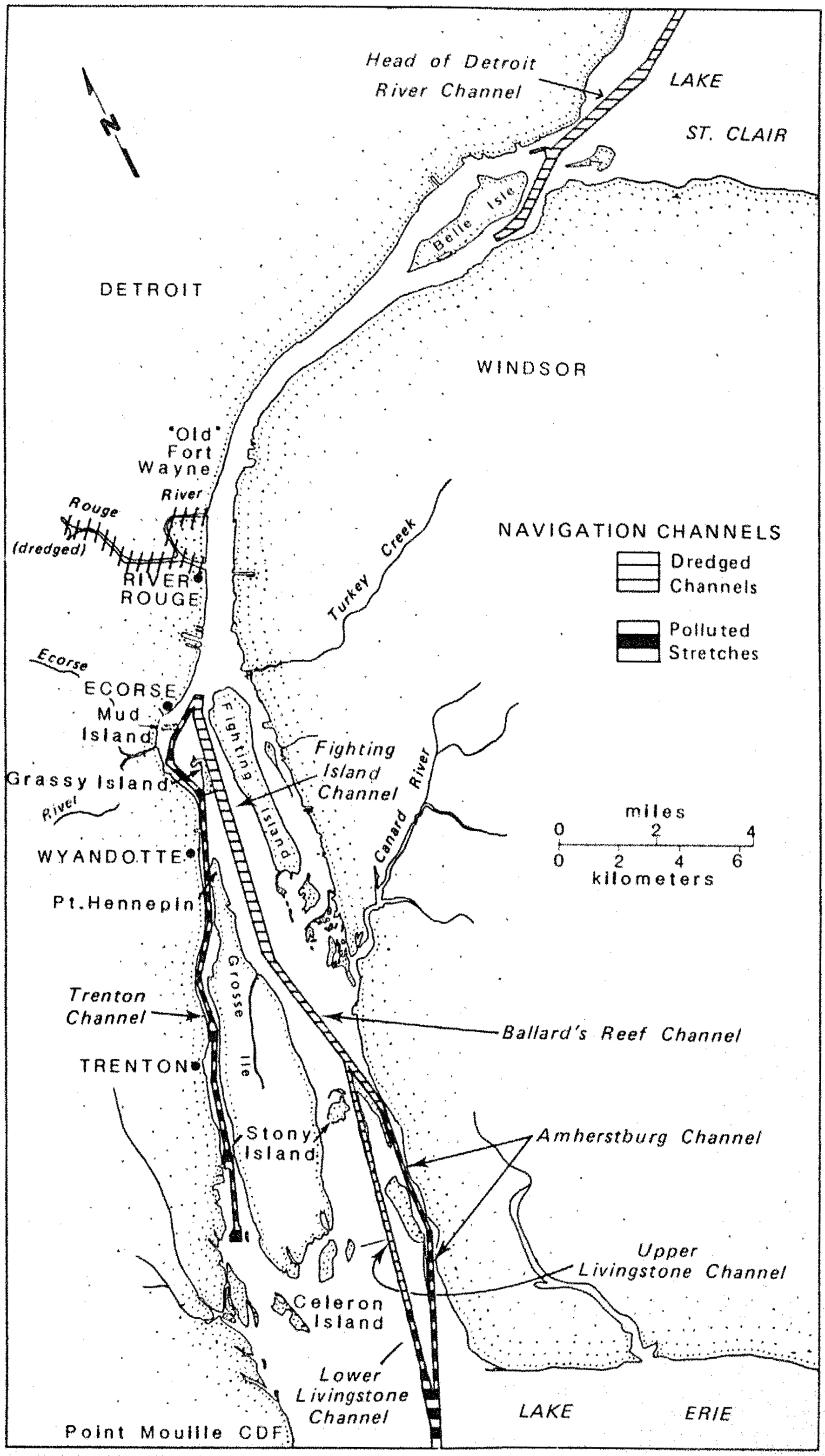


Figure 3. Navigation channels and areas of polluted bottom sediments (U.S. Army Corps of Engineers, Detroit District, Current Files).

Table 1. Waterways, harbors, and other areas of public dredging in the Detroit River (U.S. Army Corps of Engineers, Detroit District, Current Files).

Area	Length (m)	Depth (m)
Main channels		
Head of Detroit River Channel	11,582	8.7
Fighting Island Channel	7,559	8.7
Ballards Reef Channel	3,719	8.7
Livingstone Channel, Upper and Lower	14,996	8.4-8.8
Amherstburg Channel, Hackette Reach, Amherstburg Reach, and Lime Kiln Reach	12,954	6.4-8.7
West Outer Channel	6,401	6.7
East Outer Channel	12,802	8.7
Trenton Channel, Turning Basin, Trenton Reach, and Wyandotte Reach	15,240	6.4-8.5
Side channels and harbors		
Channel north of Belle Isle	No data available	6.4
City of Detroit		8.2
River Rouge		8.2
Ecorse		8.2
Wyandotte		8.2
Trenton		8.2
Windsor, Ontario		8.7

The Detroit River is the busiest port in the Great Lakes. Much of the commercial navigation through the river consists of intralake shipments of iron ore, coal, limestone and gypsum, wheat, and oil (Monson 1980; Figure 4). Commercial navigation in the Seaway has slowed over the past 15 years, owing to declining demand for such commodities. Passenger traffic is minimal and has decreased sharply since 1966. In 1972, 18,268 vessel transits, accounting for about 119 million t of freight passed through the Detroit River (USACE 1973). In 1983, the number of transits decreased to 9,334 and the tonnage to 60.8 million t of freight (USACE 1984). Approximately two-thirds of this freight movement is through traffic as opposed to traffic generated out of Detroit River ports.

Before completion of the Seaway in 1969, water depths in the Detroit River averaged 6.0 to 7.6 m. At present, nearly all main commercial channels and certain public harbors with two or more users are maintained by dredging at 8.2 m below low-water datum. Before the enactment of Public Law (P.L.) 91-611, referred to as the Rivers and Harbors Act of 1970 or the Confined Disposal Program, nearly all dredged material from the river and its tributaries was disposed of at two sites in open Lake Erie or used as construction material (Raphael and Jaworski 1976).

Blasting and grab dredges are used to remove rocky material; hopper dredges are used to remove soft, unconsolidated sediments from the waterways. Limestone and dolomitic rock are encountered in new dredging work and occasionally in maintenance dredging being performed south of Fighting Island. Hopper dredges hydraulically remove fine-grained sediments by suction and are used for much of the maintenance dredging. These dredges are equipped with overflow weirs that allow excess water and fine suspended material

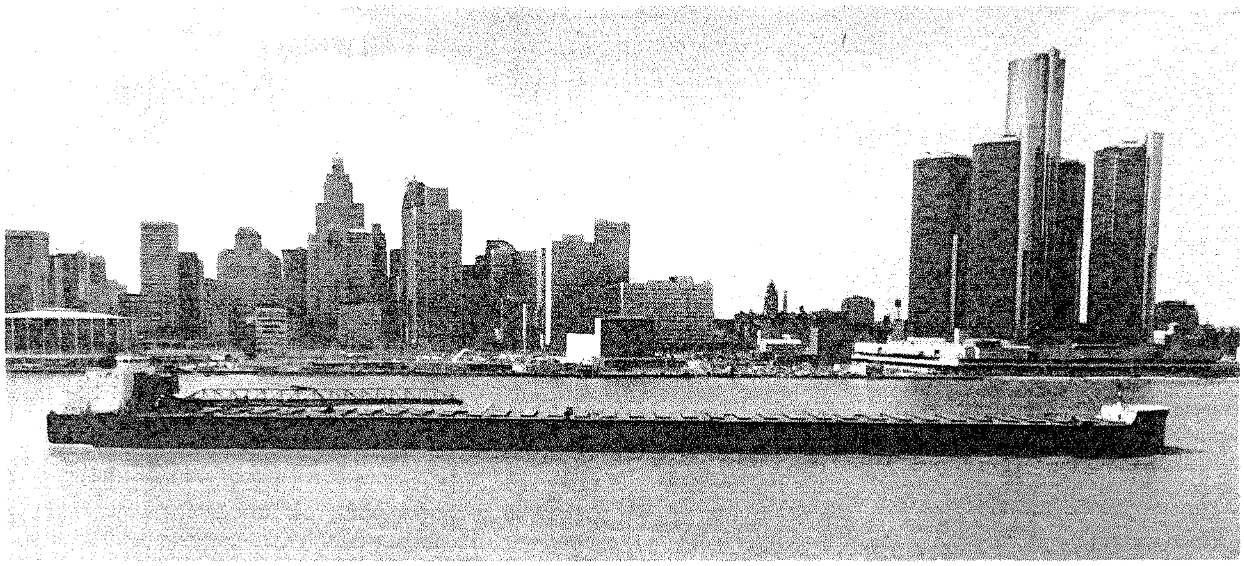


Figure 4. Large self-unloading lake carriers, such as the *Mesabi Miner* shown here passing the City of Detroit, Michigan, carry bulk cargoes of iron ore, coal, limestone, and grain (Photo provided by Albert G. Ballert).

to return to the river until a predetermined dredge load density is attained (USACE 1976a). Since 1985, much of the actual dredging has been performed by private contractors.

From 1963 to 1969, nearly 2.98 million m³ of sediment were dredged from the Detroit River and disposed of in open water. In 1970, with the passage of P.L. 91-611, open-lake dumping of polluted dredged materials was terminated and about 30,100 m³ of polluted dredge spoil was placed on Grassy Island in the Detroit River. From 1979 to 1984, 3.41 million m³ of dredge spoil were removed from the Detroit River and deposited in the Pointe Mouillee confined disposal facility in western Lake Erie near the mouth of the Huron River (U.S. Army Corps of Engineers, Detroit District, Current Files). A total of 814,000 m³ of polluted material were scheduled for removal and disposal at Pointe Mouillee confined disposal facilities in 1985. Most confined disposal facilities in the vicinity of the Detroit River are clay-lined or have limestone core dikes and are equipped with overflow weirs for the discharge of excess water. Retention ponds remove most of the suspended load from this excess water.

The Rouge River sediments were recognized as being grossly polluted many years before the enactment of P.L. 91-611. Material dredged from the Rouge River harbor in 1950-71, was disposed of in the Grassy Island containment site (Raphael and Jaworski 1976). Grassy Island was closed in 1981 and was used only intermittently from 1971 to 1981 to contain small amounts of spoils from maintenance dredging (D. Bilmyer, U.S. Army Corps of Engineers, Detroit; pers. comm.). Before the construction of the Pointe Mouillee confined disposal facilities, some polluted spoils were put in confined sites along the lower Raisin River and on Mud Island, a small containment site near Grassy Island. Fighting Island was used by private interests for the disposal of caustic soda and other chemical wastes from Wyandotte Chemical Corporation. Point Hennepin, the northern tip of Grosse Ile, was also a private disposal site for solid wastes.

1.5 BIOLOGICAL ZONES AND SUBSYSTEMS

The Detroit River ecosystem can be divided into upper and lower subsystems, based on the health of the macrozoobenthic communities (Figure 5).

The macrozoobenthos are a biological group sensitive to both water and sediment quality. Normal, healthy benthic communities are characterized by taxonomically diverse populations and the presence of pollution-intolerant taxa (e.g., caddisflies and mayflies). Abnormal or impaired benthic communities have less diverse populations, almost no intolerant species, and either higher or lower numbers of organisms depending on the nature of the impact. Typically, eutrophication increases and toxic contaminants reduce the numbers of benthos.

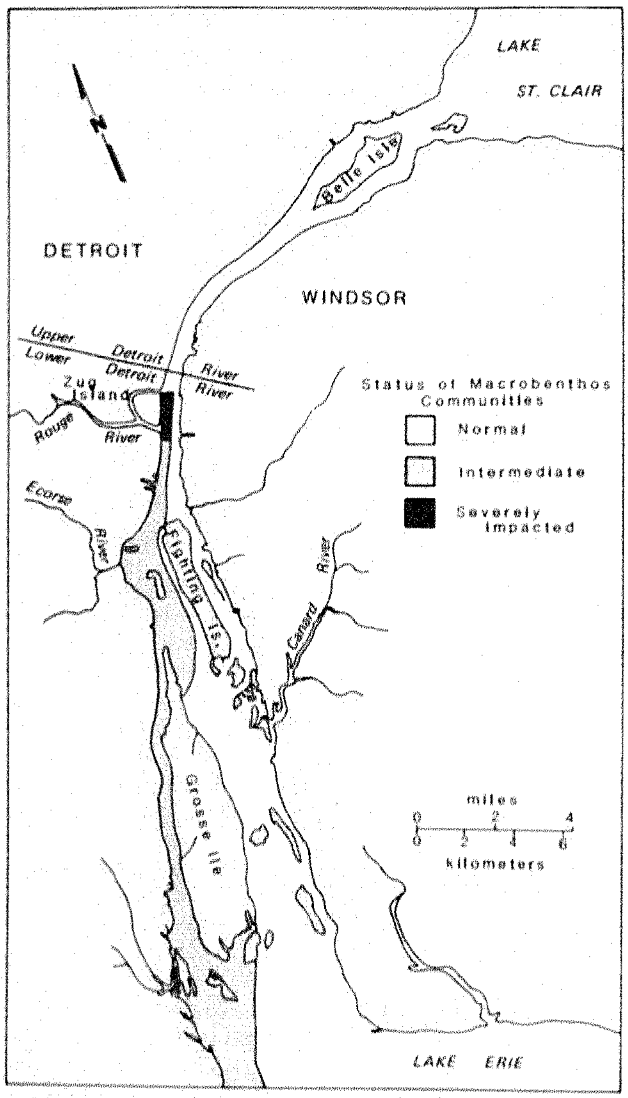


Figure 5. Distribution of normal and abnormal macrozoobenthos communities in the Detroit River (Thornley and Hamdy 1984; Thornley 1985).

The upper river subsystem includes that part of the Detroit River upstream of the Rouge River where the diversity of macrozoobenthos is high and dominated by pollution-intolerant species (Thornley and Hamdy 1984, Thornley 1985). The benthic community of the upper Detroit River, except for that along the shoreline of the City of Windsor, is regarded as normal (Limno-Tech Inc. 1985). In contrast, macrozoobenthos communities of the lower Detroit River, particularly those in the Trenton Channel on the Michigan side, are abnormal. Benthos on the river bottom near the Rouge River harbor and Zug Island is severely impacted, as indicated by low species diversity, very low organism density, and the absence of pollution intolerant taxa, such as nymphs of burrowing mayflies (Hexagenia) and caddisfly (Trichopteran) larvae (Figure 6; MDNR 1973). Field sampling in 1977 and 1980 revealed few burrowing mayflies in Michigan waters of the Detroit River, but many more in Canadian waters (Hiltunen and Manny 1982, Thornley 1985). More recent field sampling in 1982 and 1984 revealed partial recovery of several sections of the lower Detroit River where Hexagenia, Caenis, and Baetisca mayflies have recolonized the bottom in response to water-pollution abatement (Hudson et al. 1986).

The Ontario side of the lower Detroit River exhibits better sediment and water quality as well as more normal benthic communities than the Michigan side (Thornley 1985). Being more agricultural in nature, the Ontario side lacks the heavy industrial, municipal, and urban tributary loadings of the Michigan side. As a result, wetlands east of Fighting Island and at the mouth of the Canard River are diverse biologically. In comparison, on the Michigan side there are more than 100 permitted industrial discharges and combined urban runoff and sewer overflows that cause water pollution (GLWQB 1983). Moreover, the Detroit Wastewater Treatment Plant discharges 2,184,000 m^3/day of secondary sewage effluents. Because downstream impacts are frequently limited to a plume or restricted channel, little lateral transfer of pollutants across the Detroit River to the Ontario side occurs.

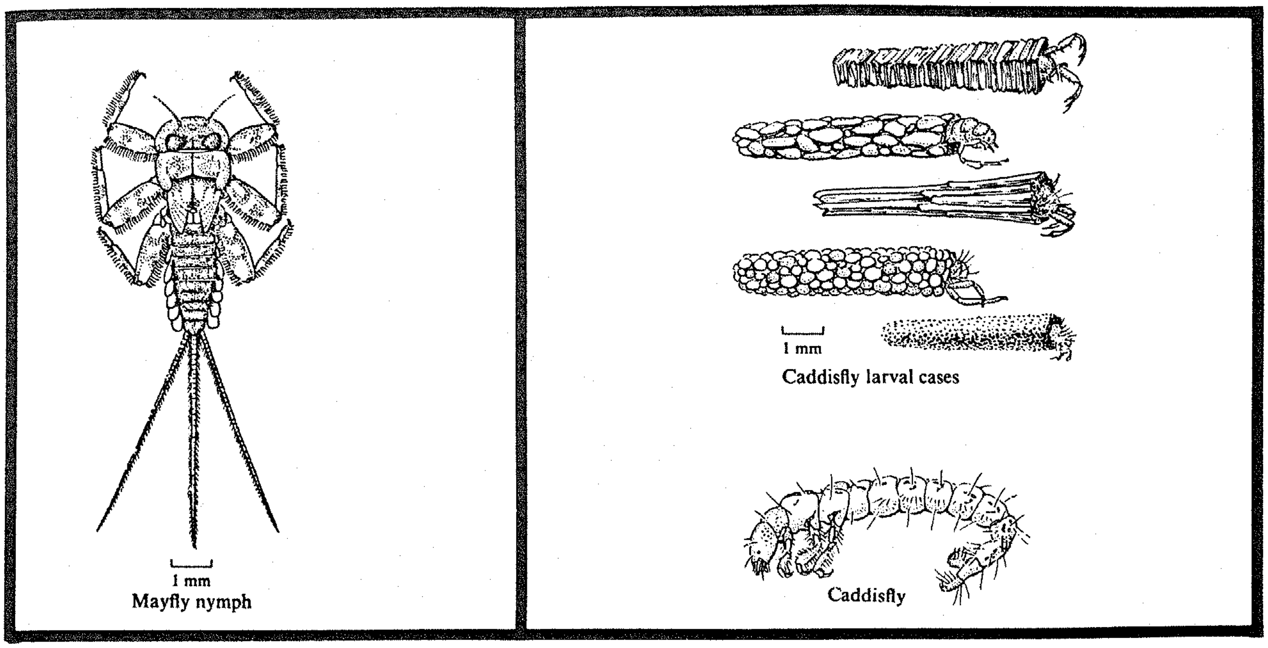


Figure 6. Pollution-intolerant burrowing mayfly (*Hexagenia*) nymph and caddisfly (Trichopteran) larva.

The Detroit River can be separated into three biological zones: deep channel, shallow-water nearshore, and terrestrial. Deep-channel environments generally have water depths exceeding 4 m, relatively high flow velocities, and coarse sediments. Macrophytes and associated periphyton and invertebrates are most abundant in the shallow-water nearshore zone. No submersed macrophytes occur at depths greater than 4 m and most are restricted to depths less than 3 m in sediment depositional areas (Schloesser and Manny 1982; Fallon and Horvath 1985). The terrestrial biological zone includes undeveloped island habitat, areas of coastal wetland, and riparian environments along less developed tributaries, such as the Canard River. Stony, Celeron, Grassy, and Mud Islands provide habitat for shorebirds such as gulls and terns (Scharf 1978).

1.6 ENVIRONMENTAL IMPACTS AND USE CONFLICTS

Compared to other connecting channels in the Upper Great Lakes, sediments in the Detroit River are heavily polluted with hazardous and toxic substances, including high concentrations of polychlorinated biphenyls and heavy metals (Hamdy and Post 1985). The Detroit River has been designated as a Class A area of concern by the International Joint Commission (IJC) because of impairment of beneficial uses by organic and heavy metal pollution (GLWQB 1983). More than 50 large industries are located along the Michigan shore of the Detroit River, whereas only 11 are located on the Ontario shore (Figure 7); more than 100 industries of various sizes hold discharge permits. The principal industrial discharge area lies on the American side of the river and extends from Zug Island southeast to Gibraltar in the Trenton Channel. Major industries include steel mills, petroleum refineries, electrical power generating plants, and manufacturers of chemicals, automotive parts, rubber products, salt, and plastics. Approximately 100,000 gallons of river water are withdrawn to produce one automobile. Industrial wastes of concern include organics, i.e., polychlorinated biphenyls, hexachlorobenzene, octachlorostyrene, and polycyclic aromatic hydrocarbons; cyanide; oil and grease; phenols; and heavy metals, i.e., mercury, cadmium, lead, iron, zinc, chromium, copper, nickel, and cobalt (Limno-Tech Inc. 1985).

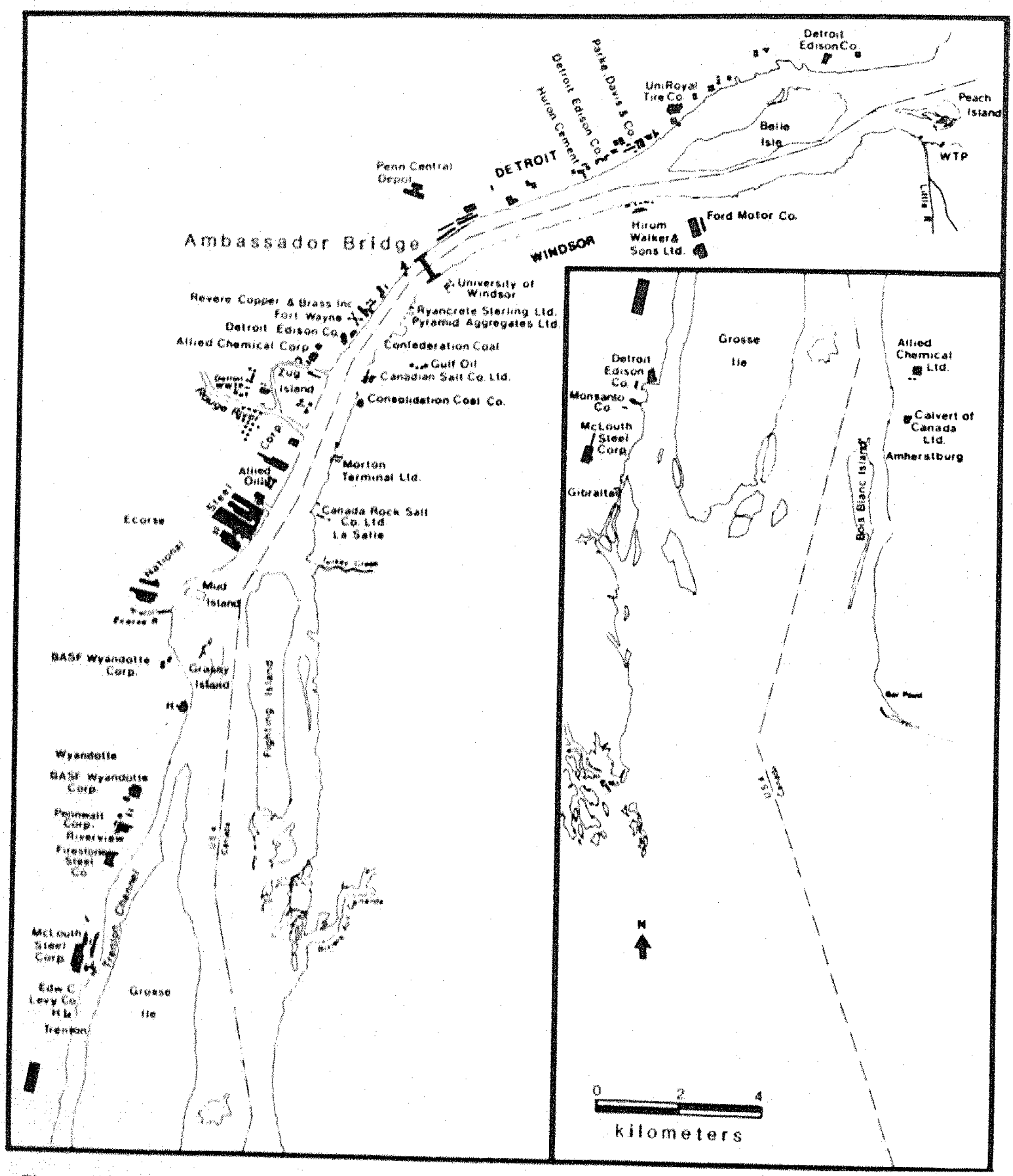


Figure 7. Locations of large industries along the Detroit River (Thornley and Hamdy 1984).

Among the 20-some municipal sewage treatment plants along the river, the largest is the Detroit Wastewater Treatment Plant, serving 1,538,443 people and an area of 39,400 hectares (USEPA 1978). Completed in 1940, the plant was upgraded in 1969 to an activated-sludge process to provide secondary treatment. This plant is located near the confluence of the Detroit and Rouge Rivers. The flow into the plant in 1976 during dry weather was 2,184,000 m^3/day. The capacity of the plant is being increased to 4.216 million m^3/day, but the activated-sludge process will continue to be relied upon for secondary treatment and chemical precipitation will be used for phosphorus removal.

The plant is monitored and controlled by the Detroit Water and Sewer Department, which serves not only the City of Detroit, but also large metropolitan suburban areas in Wayne, Oakland, and Macomb Counties of southeastern Michigan, including wastes from some 150 industries and discharges from a large combined sewer system.

In July 1976, the Michigan Department of Natural Resources revoked the City of Detroit's National Pollution Discharge Elimination System permit to discharge secondary municipal effluents because the Detroit Wastewater Treatment Plant had been performing below design standards for years in regard to primary effluent biological oxygen demand (BOD), suspended solids, secondary effluent phenols, fecal coliforms, and total phosphorus removal (USEPA 1978). Although the discharge permit was reinstated in 1983, the plant continues to have difficulty meeting discharge and operational standards.

Fecal coliforms were widely distributed in the waters of the Detroit River in 1969 (Figure 8). In 1985, the distribution of degraded mussel communities in the river correlated well with this coliform map; mussels survived only in the upper river and in the cleaner waters at mid-channel in the lower Detroit River (Tom Freitag U.S. Army Corps of Engineers, Detroit District, pers. comm.; Hudson et al. 1986; van der Schalie 1986). Heavy metals, particularly copper, also seem to originate from the Detroit municipal sewage outfall and the Rouge River. In 1980, concentrations of cadmium (11-14 ppm), chromium (140-330 ppm), and copper (54-370 ppm) in sediment near the mouth of the Rouge River exceeded Ontario and U.S. Environmental Protection Agency guidelines for open-water disposal of dredged spoils (IJC 1982; Thornley and Hamdy 1984).

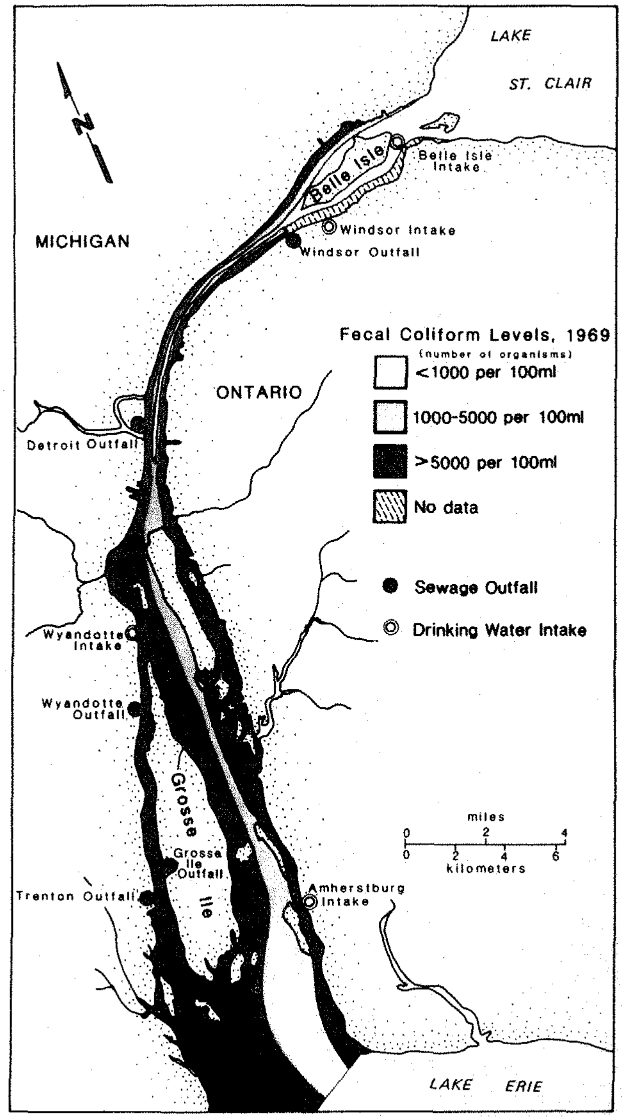


Figure 8. Distribution of fecal coliform bacteria in the Detroit River in 1969 (USEPA 1978).

Another major impact on water quality in the Detroit River is urban runoff and the combined sewage overflows from various streams and public drains that discharge into the Detroit River. Illegal connections can add large amounts of hazardous substances to such drain systems (Schmidt and Spencer 1986) particularly older, poorly maintained drains like those serving the Detroit area (Ecolosciences 1985). When the combined sewers are unable to carry all the flow during periods of storm runoff, excess water overflows into the Detroit and Rouge Rivers at 82 points (USEPA 1978). Because of urban development in the Detroit metropolitan area, combined sewage overflows are much more important on the Michigan side of the river than on the Ontario side. Contaminants in urban areas quickly reach water courses due to extensive drainage networks and impervious surfaces (Sonzogni et al. 1979). Of major concern is contamination from urban areas bordering the Rouge and Ecorse Rivers.

The Rouge River drains an area of about 121,000 ha and consists of three main branches, the Lower, Middle, and Upper Rivers. The stream is very event responsive and frequent flooding occurs along the Middle Rouge. With a mean annual discharge of only 26 m^3/s, over 75 % of the drainage passes through urban areas, collecting considerable stormwater runoff and overflow from combined sewers during wet weather. Because the Lower Rouge is lined with concrete to ensure sufficient flow capacity, runoff rapidly reaches the Detroit River during storms.

The Middle Rouge exhibits low levels of dissolved oxygen and is moderately contaminated by fecal coliforms, dissolved solids, and toxic substances, including heavy metals (MDNR 1973). In contrast, the Lower Rouge is one of the most grossly polluted streams in the Great Lakes region (USACE 1982). In the dredged area, which extends from the Detroit River to the turning basin, guidelines for polluted sediments set by the U.S. Environmental Protection Agency were exceeded by all 10 of the sediment contaminants measured (USACE 1969) including oil and grease, volatile solids, biological oxygen demand, phenols, total orthophosphate, ammonia, organic nitrogen, iron, lead, and zinc. Dredged sediments from the Rouge River harbor have been contained since 1950. Still, bottom sediments downstream of the mouth of the Rouge River near Mud Island are oily and grab samples reek of volatile solids.

The Ecorse River drains an area of 11,556 ha, occupied by 12 communities whose population totaled 198,000 in 1980. The Ecorse River has two open-channel tributaries, the North Branch and the South Branch (or the Sexton-Kilfoil Drain). These branches join approximately 1 km upstream from the point where the Ecorse River enters the Detroit River near Grassy Island (USACE 1982). Frequent flooding, high turbidity, low dissolved oxygen and high dissolved solid loads characterize the upper and middle sections of the Ecorse River, but water and sediment quality are most severely degraded in the lower river system. In 1969, near the confluence of the North and South Branches, the streambed was mantled by a black, oily layer of sludge which averaged 1.2 m thick (Rydquist and Wilson 1969). The sludge layer had a high biological oxygen demand that resulted in stream-bottom dissolved oxygen levels that were too low (0.0 - 0.4 mg/L) to support fish (USACE 1982). From 1969 to 1977, the lower Ecorse River was inhabited only by sludgeworms (Rydquist and Wilson 1969; Youngblood 1980).

The Canard River is the only large Canadian tributary to the Detroit River. It drains agricultural areas, is bordered by extensive natural wetlands, and contributes little pollution to the Detroit River. Agriculture is extensive south of the City of Windsor, in Essex County, Ontario. Although the streams and public drains in Ontario are small, some nutrients and suspended sediments enter the Detroit River from the Canard River.

Other human activities that affect the environment adversely and give rise to land-use conflicts in the Detroit River include 45 marinas that serve the Michigan side of the river and 2 additional marinas that cater to boaters in Ontario (USEPA 1985). Residential and commercial development, as well as recreational facilities, extend from Lake St. Clair down to Grosse Ile along both sides of the river. Drinking water intakes serving over 3.75 million people are located at Belle Isle, Windsor, Amherstburg, and Wyandotte (USEPA 1985).

Navigation and shoreline modifications have adversely impacted fish and wildlife uses of the river, especially wetland environments. Commercial navigation resuspends polluted bottom sediments in the river by wash from props and bow thrusters. Except for 11.1 km of shoreline, the Michigan side is bulkheaded and backfilled with slag and other materials (Muth et al. 1986). As a result, much of the remaining emergent marshes and submersed macrophyte beds are confined to the lee of islands or are distributed in low wave-energy environments. As shown in Section 2.6, these wetlands are important habitat for fish and waterfowl, and several enjoy legal protection from development as "Environmental Areas" under Michigan Act 245 of 1970, as amended, The Shorelands Protection and Management Act.

CHAPTER 2. DESCRIPTION OF THE ENVIRONMENT

2.1 CLIMATIC INFLUENCES

The Detroit River area experiences long, cold winters and short, hot summers (Balwin 1973). Continental polar air masses dominate in winter; tropical air masses prevail in summer. Cyclonic storms, which move from west to east, are common in winter and bring frontal precipitation to the area. In summer, both cold front and convective thunderstorms occur. Precipitation averages about 76 cm, including 40 cm of snow (Eichenlaub 1979). Prevailing winds are from the southwest, and average approximately 16 km/hour. The average date of the first frost in fall is October 21, the last freezing temperature is April 23, and the annual growing season averages 180 days.

During early winter, water from Lake Huron cools rapidly when it flows through Lake St. Clair, and ice enters the Detroit River from Lake St. Clair before it begins to form in the river (USACE 1976b). Before 1930, ice covered most of the Detroit River from mid-December to mid-March; however, since the 1950's the river has rarely, if ever, been completely ice covered, perhaps because of increased volumes of warm industrial effluents added to the river, as postulated by Hunt (1957). During the 1700's and 1800's, horse-drawn sleigh races were held on ice of the river from Grosse Pointe, Michigan, to Petite Cote and from Third Street (Detroit) to the Rouge River mouth (Burton 1922 in Hunt 1957). During the late 1920's, automobiles frequently crossed the river on the ice at several points along the river (Gervais 1980).

For many years, cross-channel icing has been rare and brief in the Detroit River (CIRES 1983). Most winters see the river occupied by slush or drifting ice that rarely freezes solid enough to support even one person (R. Assel, Great Lakes Environmental Research Laboratory, Ann Arbor; pers. comm.). The absence of complete ice cover on the river may be explained in part by a general warming trend in mean Great Lakes water temperatures from 1925 to 1939 (Beeton 1961), generally higher water flows in the river since lowest lake levels in 1926 (Edwards et al. 1987), a general warming trend in Great Lakes air temperatures from 1918 to 1958 (Assel 1980), and maintenance of open channels all winter for river navigation. However, water and air temperatures have declined in the Great Lakes since 1955 and 1958, respectively (Beeton 1961, Assel 1980) and 11 large power generating plants and numerous industries that discharge heated effluents have been built on the Detroit River since 1928 (MDNR 1976). Therefore, the thermal contribution made by heated effluents to the Detroit River since the 1920's may have been significant and the subject deserves further investigation.

Ice cover develops along shorelines in the lower river, especially in the broad, shallow expanses adjacent to the islands (Quinn et al. 1978), but the main navigation channels remain ice-free. Minor ice jams may occur in the river with the breakup of ice in Lakes Huron and St. Clair from late March to early May. Easterly winds can also move Lake Erie ice into the lower Detroit River, causing temporary ice jams (Derecki 1984). Occasionally the river can fill with ice when there is heavy ice movement from Lake St. Clair and the river mouth is blocked with ice from Lake Erie (Derecki 1984).

Highest water temperatures generally occur in August and average 22.4 °C (Table 2). In the shallow nearshore areas, especially in the lower river, water temperatures may rise to 25.5 °C. Lowest temper-

Table 2. Mean monthly water temperatures (°C) in the Detroit River at Belle Isle, 1973-84 (Modified from Muth et al. 1986).

Year	J	F	M	A	M	J	J	A	S	O	N	D
						Month						
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	5.6	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

atures (0.5 °C) occur in January-February. These temperature data, combined with the fact that dissolved oxygen levels in the Detroit River usually average over 6.0 mg/L (GLWQB 1983), indicate that a cold-water fish community of lake trout and other salmonids could survive in selected areas of the river for all but two or three months of the year (Haas et al. 1985).

2.2 HYDROLOGY OF THE DETROIT RIVER

About 95 % of the total flow of the Detroit River enters from Lake Huron via the St. Clair River and Lake St. Clair (Derecki 1984). The discharge of the river averages 5,200 m^3/s and is very constant, ranging from 4,400 m^3/s in winter to 5,700 m^3/s in summer (Derecki 1984). Flow in the Detroit River is relatively constant compared to that in other large rivers, which fluctuate widely from the spring flood to the summer low flows.

In the upper Detroit River, except for channel division by Peach Island and Belle Isle near its head, the river forms a single, well-defined channel about 700 to 1,000 m wide (Derecki 1984). Flow in the lower river follows several channels (see Table 3 and Figure 9).

Very little flow passes through the canal across Grosse Ile or through canals near Elba, Russell, and Swan Islands, but considerable flow passes beneath the bridge that connects lower Grosse Ile with Hickory Island. This water provides circulation in Gibraltar Bay, which is a productive wetland located between Hickory Island and the southeast end of Grosse Ile.

Depending on discharge, flow velocities in the Detroit River range from 0.30 to 0.88 m/s (Figure 9), but can be nearly twice that rate near the surface of the main channels (USACE 1976a). Surface currents in the upper river reach 1.2 m/s near the Ambassador Bridge and have exceeded 1.7 m/s in the Amherstburg Channel (Derecki 1984).

Water levels of Lakes St. Clair and Erie vary seasonally and annually, and directly affect water depths and flow velocities in the Detroit River. The total fall of the river between Lake St. Clair and Lake Erie is 0.9 m (Derecki

Table 3. Flow distribution among various channels in the lower Detroit River (Derecki 1984).

Location and channel	% of total flow
Head of Fighting Island	
Upper Trenton Channel (west of Grassy Island)	26
Fighting Island Channel	51
Channel east of Fighting Island	23
Head of Grosse Ile	
Trenton Channel	21
Fighting Island Channel	56
Channel East of Fighting Island	23
Southern End of Grosse Ile	
Trenton Channel	21
Channel west of Stony Island	6
Upper Livingstone Channel	26
Amherstburg Channel	47
Mouth of the Detroit River	
West of Celeron Island	15
East of Celeron Island	6
West of Sugar Island	12
East of Sugar Island	5
Livingstone Channel	22
East of Livingstone Channel	4
Amherstburg Channel (Hackett Reach)	36

1984). Because the river slope is relatively uniform, this drop in level occurs across the entire length of the river. The average travel time for water to pass through the Detroit River is 20 hours (Derecki 1984).

In response to regional precipitation, the Great Lakes fluctuate in unison over an 8- to 20-year hydroperiod (Jaworski and Raphael 1981). When water levels in the Detroit River are above or below normal, above- and below-average discharges of 6,400 m^3/s and 4,200 m^3/s, respectively, are produced (Derecki 1984). Ice jams in Lake St. Clair and in the Detroit River can temporarily retard flow and raise water levels as much as 1.5 m (Quinn 1976; Derecki 1984).

In the main channels, flow rates decrease near the bottom and along the shoreline. Sediments are transported in the main channels, particularly during high-flow conditions when the flow velocity exceeds 0.42 m/s. In the shoreline and shallow water areas, where flow velocities may drop to 0.25 m/s or less, sediment deposition occurs (Figure 10). In general, the channel sediments are silty and sandy because of the relatively high flow velocities. However, sediments near Mud Island and in the Trenton Channel are sludge-like. Fine-grained materials, particularly clays, are deposited in shallow nearshore environments. Many of these deposition areas support extensive submersed macrophyte communities. Likewise, the macrozoobenthos appear to be more numerous in shallow than in deeper waters (Hudson et al. 1986).

There is a relationship between heavy metal accumulation and grain size of the bottom sediments the Detroit River. Zinc, nickel, chromium, cobalt, copper, and lead accumulated in the fine clay fraction ($<$ 13 μm) and in the large silt-size

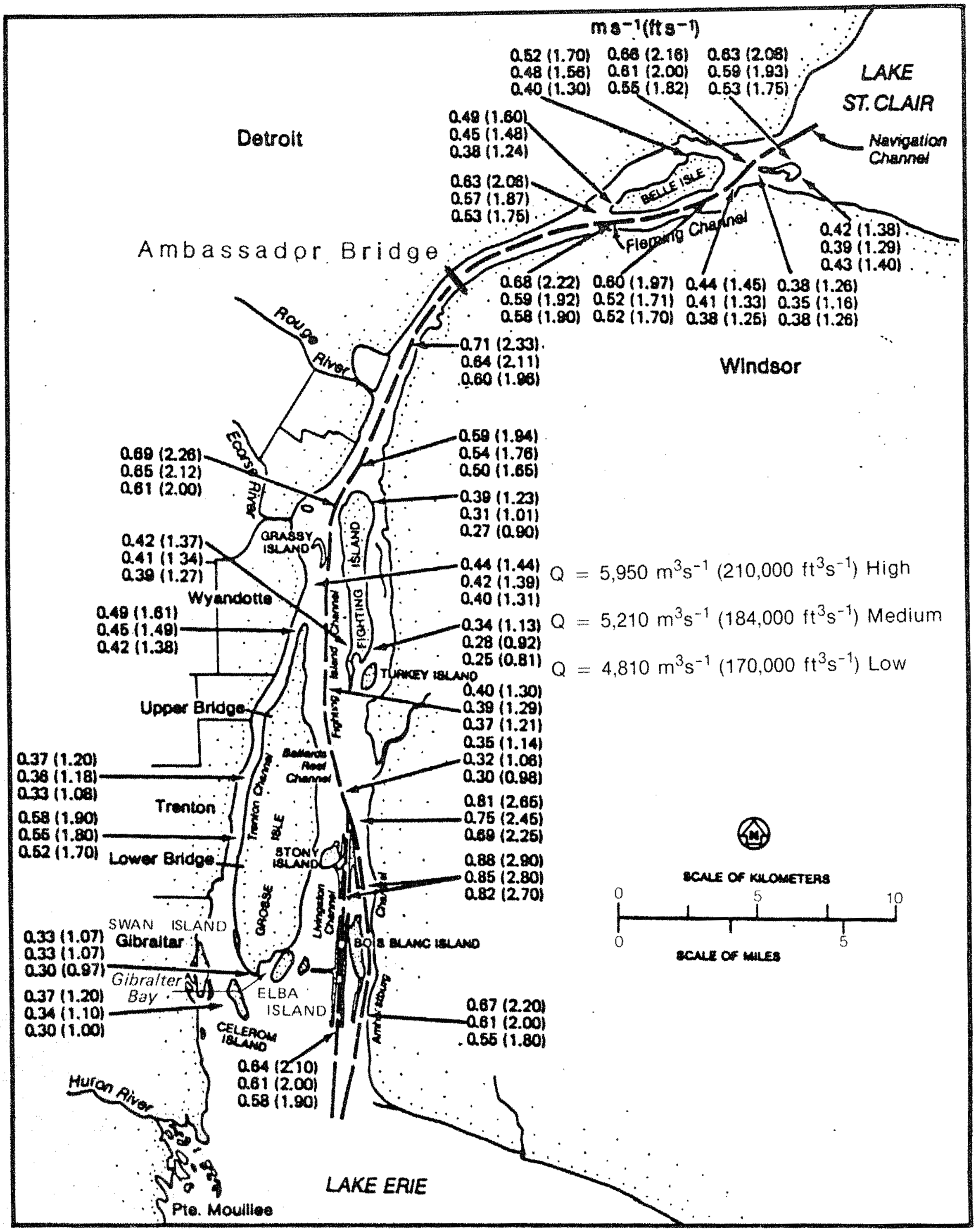


Figure 9. Average flow velocities (m/s and ft/s) in the Detroit River channels at high, medium, and low water discharge levels (Derecki 1984).

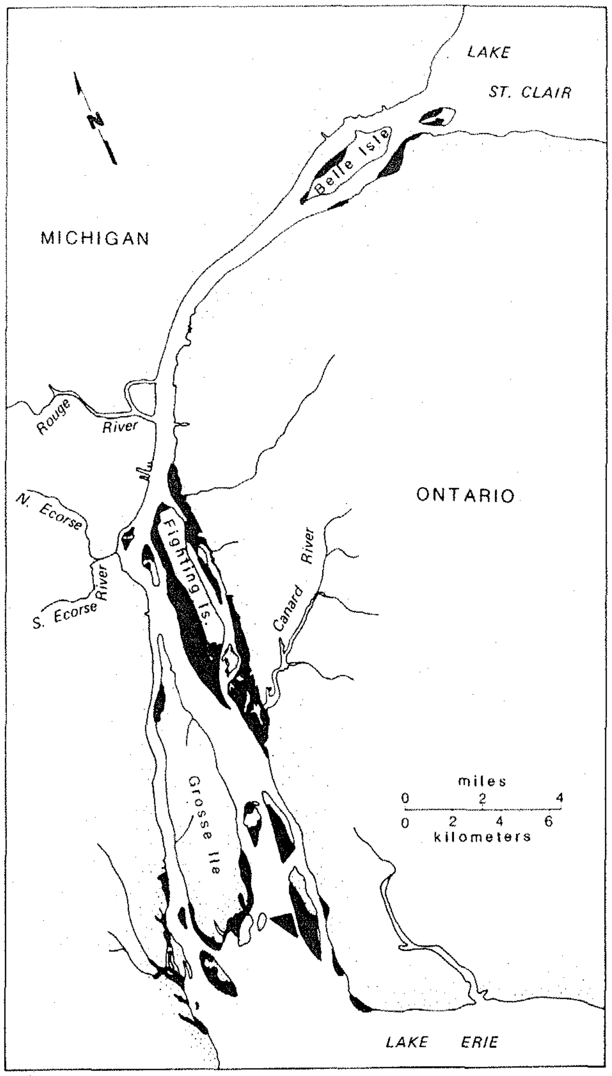


Figure 10. Sediment deposition zones in the Detroit River (Fallon and Horvath 1985).

fractions (48 to 63 μm) (Mudroch 1985). These heavy metals are loosely held to sediments by adsorption or cation-exchange processes.

2.3 RIVER CHANNEL AND SHORELINE CHARACTERISTICS

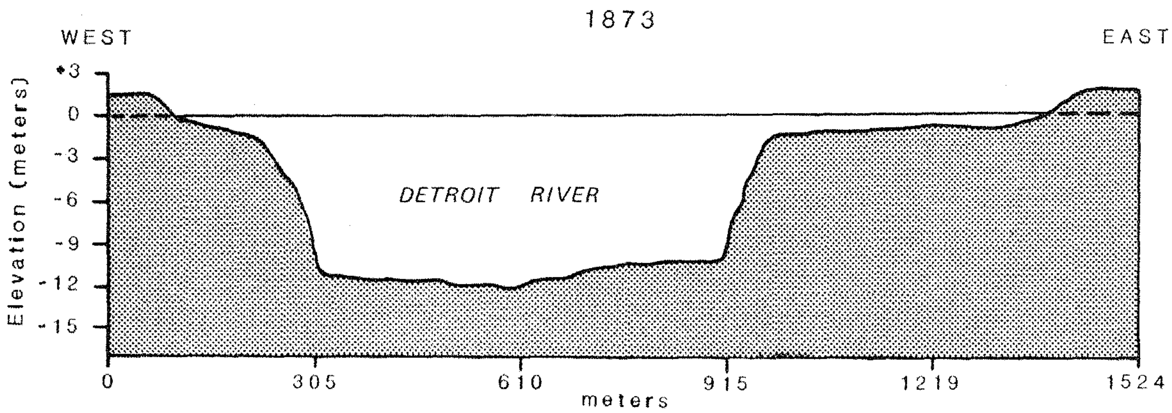
In 1873, the channel just above the mouth of the Rouge River was trough-shaped, with wetland shoulders and a sand bottom (Lamson 1873). The modern channel is more rounded at the margins, and is extensively bulkheaded and backfilled, especially on the American side and on the Canadian side north of Windsor (Figure 11). Loss of the shallow wetland areas, which were important fish and wildlife habitat, is the most significant ecological impact resulting from channel modifications. These losses of functional mainland wetlands make the remaining island wetlands in the river more essential for production of fish and wildlife resources in the Detroit River.

The Ontario shoreline, except for the City of Windsor and berthing areas, lacks shoreline protection structures and is more natural than the Michigan shoreline. However, the Ontario shoreline north of the Canard River is marked with scattered marinas, canals, and private boat slips. In places, Canadian farmers have encroached upon the wetland margins of the Detroit River and its tributaries. Thus, a green buffer zone exists only intermittently between farm fields and the river. Access to the water, whether for commercial navigation and business or for pleasure boating and hunting, is important locally on both sides of the river.

2.4 FLOW MODEL

Using hydrographic data, the Great Lakes Environmental Research Laboratory in Ann Arbor developed a one-dimensional variable-flow model for the Detroit River near Wyandotte (Limno-Tech Inc. 1985). A model for the entire river, assuming ideal channels, is also available. In general, these models predict flow variations and determine short-term and annual loadings of pollutants such as chloride (Quinn 1976). Roginski (1981) developed a two-dimensional finite-element difference model to assess the impact of combined sewer overflows on pollutant concentrations in the river. Wright et al. (1984) generated a theoretical plume model that can define mixing zones for discharges under various flow conditions in the Detroit River.

Because of the relatively high flow velocity and channelized water movements, cross-channel mixing does not readily occur in the river. Rather, contaminants from point sources tend to slowly disperse downstream as a plume. For example, until



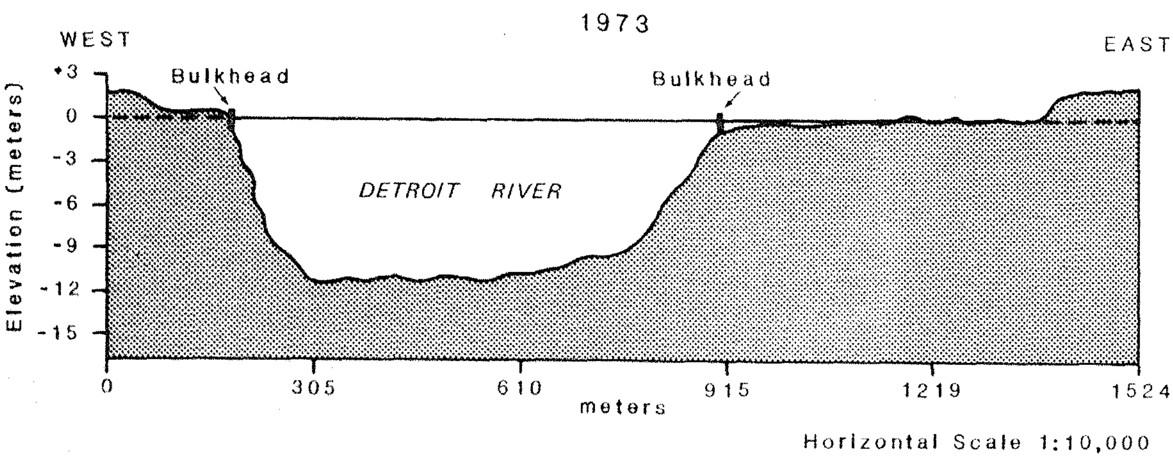


Figure 11. Channel cross-section of the Detroit River just above the mouth of the Rouge River in 1873 and 1973 (Lamson 1873 and U.S. Lake Survey Chart No. 41).

recently, a chlorine plume approximately 400 m long and 25 to 50 m wide could be identified downstream of the Detroit Wastewater Treatment Plant outfall (MDNR 1984). More studies of cross-channel pollutant mixing are needed.

2.5 GEOLOGY OF THE LAKE PLAIN

The Detroit River flows through glacial drift of Pleistocene age, which is underlain by Paleozoic sedimentary rocks (Figure 12). The sedimentary (dolomite) rock strata beneath the Detroit River crops out intermittently in the navigation channels east of Grosse Ile (Mozola 1969). Much of the land surface is a low plain that dips toward the present Detroit River and was deposited in lakes that preceeded the Great Lakes as we know them today. This low lake plain (Section 1.2) consists largely of lacustrine clays and irregular beach ridge deposits.

The topography of the Detroit River area is relatively flat, broken only by the valleys of the Rouge River and a few lesser tributaries. Low glacial morains and beach ridges of ancestral Lake Erie provide slight relief (USACE 1976a). Land elevations above mean sea level range from 214 m near the tributary sources to approximately 174 m along the Detroit River. Generally, the relative relief on

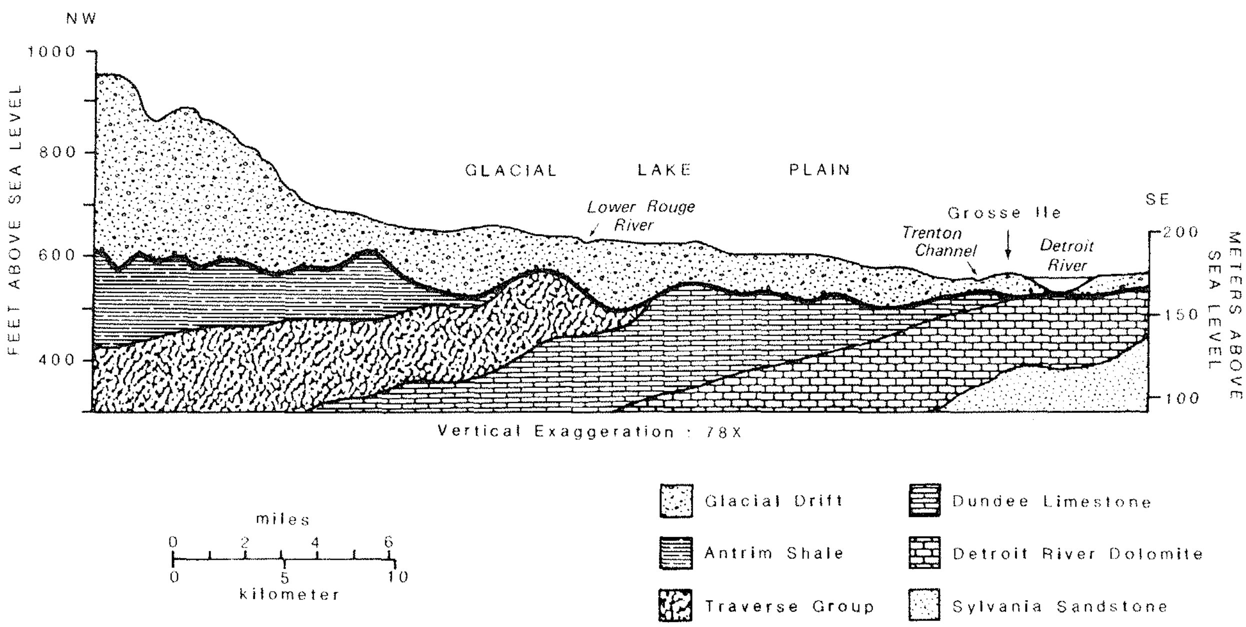


Figure 12. Geological cross-section of the Detroit River (Mozola 1969).

the lake plain is 1-5 m/km and most slopes are less than 3% (SEMCOG 1976).

Soils on the lake plain consist of level, poorly drained loams that developed on former lake bottom or lacustrine clay sediments (USDA 1975). Sandy ridges mark the position of former shorelines, and on the Michigan side an isolated sand sheet marks remnants of the glaciofluvial delta of the Huron River (SEMCOG 1976). When properly drained and tiled, the loamy soils of the lake plain are highly productive agriculturally. However, because the permeability of many surface and subsurface soils is low (0.25 and 1.27 cm/hour; USDA 1975), surface runoff coefficients are high and the local streams are "event responsive" (Sullivan et al. 1981).

Soil type should affect water quality in tributary streams; however, given the number of discharges in the drainage basin and the urban and agricultural runoff, water quality in the local streams and public drains entering the Detroit River reflect land uses, not parent soils. Moreover, natural loadings of available phosphorus from the lake plain soils are small compared to those from sewage treatment plants (Sullivan et al. 1981). Only about 12% of the phosphorus in agricultural land drainage can be traced to fertilizer use (USEPA 1971).

2.6 WETLANDS AND SUBMERSED MACROPHYTE BEDS

Coastal wetlands and large submersed macrophyte beds along the Detroit River were nearly continuous in colonial times, but now exist as 31 small, isolated remnants that cover a total of only 1,382 ha (Figure 13, Table 4). Most of the remaining vegetation along the river consists of submersed macrophytes, because the land formerly occupied by the swamp-shrub-meadow communities along the terrestrial margin of the river has largely been converted to other uses or inundated by high water levels.

Fifty-four per cent (748 ha) of these largely unnamed wetlands are in Ontario. The largest wetland in the Detroit River is immediately north of the mouth of the Canard River in Essex County, Ontario. However, because it is largely diked for waterfowl hunting purposes, it is functional only along its outer undiked margins. Wetlands 3, 13, 25, and 26 have been rendered largely unsuitable for use

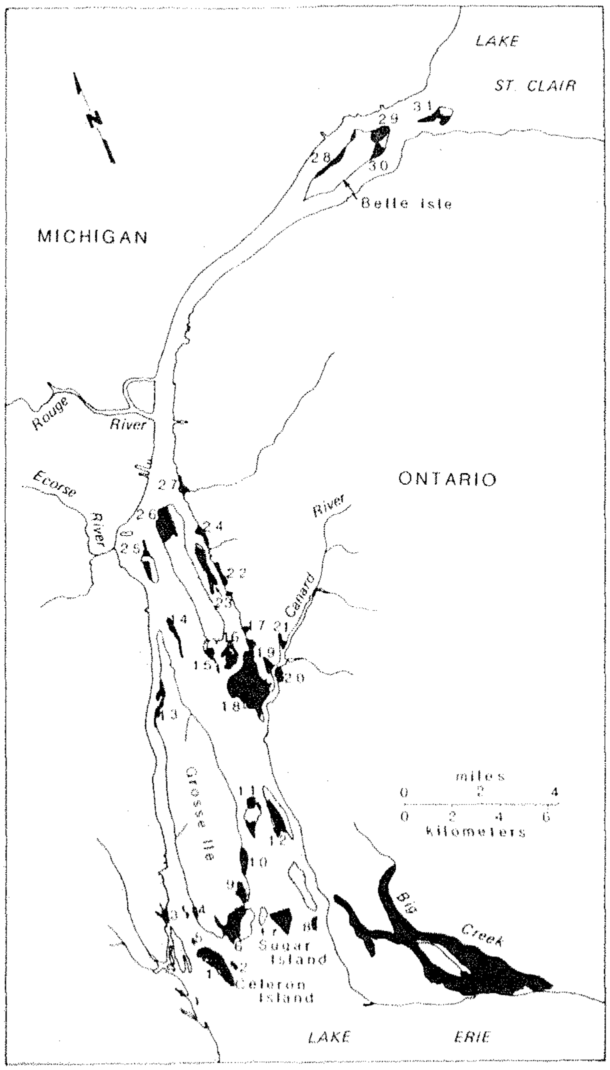


Figure 13. Distribution of wetlands and large submersed macrophyte beds in the Detroit River (From Landsat 4 image dated July 25, 1982; Scale 1:130,000).

by fish and wildlife by chemical pollution, poor substrate quality, or diking. The most functional wetlands appear to be 1, 6, 7, 11, 12, 16, 23, and open-water margin of 18.

Wetland losses over the years have not been systematically assessed because early records describing the extent of wetlands are not available for the whole river. Although it is obvious that the coastal wetlands in the Detroit River are slowly disappearing, the causes are not easily identified. Kreisman et al. (1976) compared the distribution of Detroit River emergent vegetation in wetlands on the Michigan side in 1976 with that recorded in 1967 and found that only 259 ha of the original 1,458 ha remained. Our data indicate that 634 ha of emergent vegetation and large submersed macrophyte beds

Table 4. Areas of wetlands and large submersed macrophyte beds in the Detroit River on July 25, 1982 (Planimetered from Figure 13 by E. Jaworski).

No.	Wetland type	Area (ha)
1	EM/AQ	87.28
2	AQ	7.27
3	EM/AQ	25.46
4	EM/AQ	14.55
5	EM/AQ	7.27
6	EM/AQ	87.28
7	AQ	72.73
8	AQ	25.46
9	AQ	21.82
10	EM/AQ	36.37
11	EM/AQ	43.64
12	AQ	50.91
13	EM/AQ	43.64
14	AQ	29.09
15	AQ	14.55
16	EM/AQ	43.64
17	EM/AQ	14.55
18	EM	247.30
19	EM	18.04
20	SS/EM	25.46
21	SS/EM	14.55
22	EM	29.09
23	EM/AQ	58.19
24	EM	29.09
25	SS/EM/AQ	43.64
26	FO/SS	101.83
27	EM	29.09
28	EM/AQ	43.64
29	AQ	43.64
30	EM/AQ	29.09
31	FO/SS/EM	43.64
	Total	1,381.80

[a] Wetland type: EM = Emergent Marsh, AQ = Submersed Macrophyte, FO = Forested, SS = Shrub-Scrub.

are present today on the Michigan side of the river. We included in our assessment those large beds of submersed macrophytes that were visible on a 1:130,000-scale 1984 Landsat image, but not the many smaller beds of submersed macrophytes that were not detected at this scale. According to the National Wetlands Inventory of Michigan, there were about 500 ha of wetlands and submersed macrophyte beds in Michigan waters of the river in November 1978 (Table 5). Given the lower water level in 1978 than in 1982 and the likelihood that some submersed macrophyte beds were obscured by turbidity, this figure agrees reasonably well with our estimate (Table 4). If turbidity were lower, many more such beds would be visible because much of the Detroit River littoral zone is colonized by submersed macrophytes.

One of the largest and most functional wetlands on the Michigan side is the Gibraltar Bay area, at the southern end of Grosse Ile (Jaworski and Raphael 1984). Other functional wetlands include Belle Isle, Stony Island, the eastern shore of Grosse Ile, and Celeron Island.

Table 5. Area of wetlands in Michigan waters of the Detroit River in 1978 (U.S. Fish and Wildlife Service 1978).

Wetland	Area (ha)
North end of Belle Isle	62.8
Detroit shoreline	58.3
South end of Belle Isle	4.9
South of Rouge River	13.8
Ecorse River Channel	11.7
Grassy Island	23.1
Northern Grosse Ile	55.9
Stony Island	27.9
Canal on Grosse Ile	25.5
Elizabeth Park	11.7
Eastern shoreline of Grosse Ile	6.9
Gibraltar Bay area	69.6
Shoreline north of Gibraltar	27.9
City of Gibraltar	65.2
Celeron Island	37.2
Total	502.4

In addition to the difficulties inherent in mapping submersed macrophyte beds, there are mapping problems stemming from seasonal changes in the kinds and amounts of wetland vegetation. Schloesser et al. (1986b) found that submersed macrophytes are most visible on small-scale (1:5,000) aerial photographs taken during August and September. Much of the National Wetlands Inventory aerial photography of the Detroit River would not have detected submersed macrophyte beds because it was obtained at a scale of 1:80,000.

In 1955, Hunt (1963) mapped the distribution of wild celery (Vallisneria americana) in the lower Detroit River, particularly near Celeron and Sugar Islands. Compared to our map (Figure 13), there has been a loss of submersed macrophytes in the lower Trenton Channel and near Celeron Island since then. Herdendorf et al. (1981) compiled existing data on coastal wetlands on the American side of the Great Lakes from topographic and Lake Survey charts. They identified only 7 wetland areas in Michigan waters of the river, compared to our 16 areas.

Given the rapid (20 hr) flushing time of the Detroit River (Derecki 1984), wetlands and submersed macrophyte beds may constitute critical stable habitat for biological production in the ecosystem. Although the importance of detritus in the Detroit River ecosystem is not adequately quantified, we believe that aquatic macrophytic vegetation exerts primary control over biological production in the Detroit River as it does in other large rivers (Cummins et al. 1984). Therefore, the function of the aquatic macrophytes and their associated periphyton in the wetlands of the Detroit River can be regarded as essential to the fisheries and waterfowl. More research is needed to define how important such wetlands are in the biological production of the river.

Some Detroit River wetlands may have surprisingly large economic values (see Jaworski and Raphael 1984; Seegert 1984). An example is the Gibraltar Bay wetland (Figure 14). Water from the main channel of the Detroit River flows through Gibraltar Bay and out between Russell and

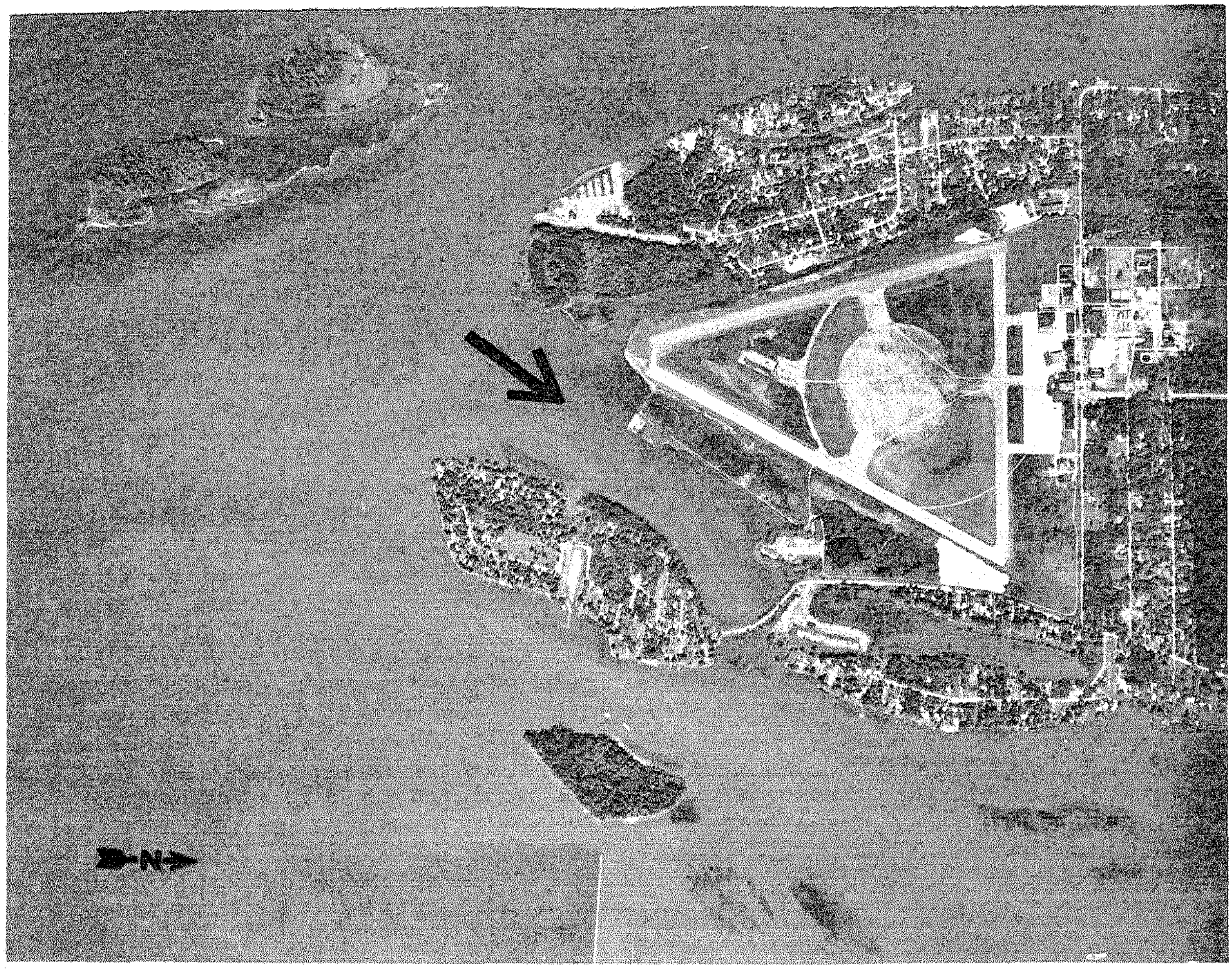


Figure 14. The Gibraltar Bay wetland at the southern tip of Grosse Ile in the lower Detroit River (Photo provided by Southeast Michigan Council of Governments. Aerial photograph No. 80-230-24-42, taken June 11, 1980).

Hickory Islands. High primary productivity in Gibraltar Bay in August is evidenced by the presence of dense beds of wild celery, waterweed, muskgrass, Eurasian watermilfoil, water stargrass, and other submersed macrophytes. The invertebrate populations include clams, snails, midges, amphipods, springtails, and worms (Jaworski and Raphael 1984). Juvenile yellow perch, adult northern pike, and dabbling ducks feed among the submersed macrophytes in the wetland. The area is also heavily used for spawning by numerous species of fish (see section 3.2). The most significant current uses and functions of the Gibraltar Bay wetland are fish production, sport fishing, and waterfowl feeding.

The potential value of the Great Lakes coastal wetlands, as exemplified by Gibraltar Bay, may exceed $5,000 per hectare (Table 6). Although no two wetlands will have precisely the same function and value per unit area (Raphael and Jaworski 1979), the data in Table 6 illustrate the value of such coastal wetlands.

2.7 WATER AND SEDIMENT QUALITY

Pollution from waste discharges has impaired water quality and conflicted with biological productivity in the Detroit River for over 20 years (USDHEW 1965). The chemical characteristics of water in the upper and lower Detroit River are

Table 6. Average economic values of Michigan's coastal wetlands, 1980 (From Jaworski and Raphael 1986).

Function	Dollar value/ ha/yr
Run-off nutrient control	1,680
Sport fishing	1,054
Fish production	1,040
Waterfowl breeding and feeding	720
Nonconsumptive recreation	366
Waterfowl hunting	103
Trapping of fur bearers	74
Water supply	16
Commercial fishing	13
Total	$ 5,066

Table 7. Concentrations of nutrients and major ions (mg/L) in waters of the upper and lower sections of the Detroit River (Vaughan and Harlow 1965, Environmental Control Technology Corp. 1974, Leach 1980, and Kauss and Hamdy 1985).

Variable	Location	
	Upper	Lower
Chloride	7-9	28-58
Calcium	26-28	25-50
Phosphorus	0.05-0.06	0.04-0.14
Ammonia	0.01-0.06	0.33
Suspended solids	7-10	15-23
Phenols	0.003-0.005	0.01-0.04
Alkalinity (as $CaCO_3$)	75-84	80-85
Magnesium	6-7	6-8
Nitrate	0.2-0.3	0.27

substantially different. The concentration of most nutrients and major ions is lower in the upper than in the lower river, owing to additions by the Rouge River and the Detroit Wastewater Treatment Plant (Table 7). However, pollution abatement has reduced concentrations of phenol, iron, chloride, phosphorus, and ammonia in river water since 1970 (Table 8). Moreover, phosphorus and chloride loadings by the river to Lake Erie have decreased steadily since 1967 (Table 9; Figure 15). These changes in concentration and loading were calculated by the Michigan Department of Natural Resources from data they gather monthly at one transect each at the head and mouth of the Detroit River (22 stations total; Table 10). Persistent toxic organic compounds are not measured regularly in Detroit River water by the Michigan Department of Natural Resources.

Because of the relatively high flow velocity and vertical mixing, dissolved oxygen levels in the river have remained

Table 8. Water quality measurements at the mouth of the Detroit River, 1969-81 (GLWQB 1983).

Parameter	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
Phenols (μg/L)	1.7	6.1	1.7	1.8	1.5	2.0	2.1	2.7	2.9	1.7	1.2	0.7	0.8
Total Iron (mg/L)	0.56	0.52	0.37	0.60	0.39	0.35	0.11	0.55	0.42	0.39	0.35	0.30	0.27
Chloride (mg/L)	18	18	16	17	16	16	15	15	15	15	13	13	11
Soluble phosphorus (mg/L)	0.07	0.08	0.04	0.03	0.02	0.02	0.03	0.02	0.01	0.02	0.00	0.01	0.00
Total phosphorus (mg/L)	0.14	0.14	0.08	0.07	0.08	0.05	0.06	0.05	0.04	0.04	0.03	0.02	0.02
Ammonia nitrogen (mg/L)	0.13	0.13	0.16	0.15	0.10	0.12	0.13	0.10	0.10	0.10	0.08	0.07	0.08
Nitrate nitrogen (mg/L)	0.17	0.27	0.28	0.32	0.27	0.27	0.35	0.30	0.25	0.28	0.31	0.32	0.30
pH (lowest and	7.3	7.3	7.6	7.0	7.0	7.0	7.5	7.5	7.7	7.3	7.4	7.6	7.7
highest values)	8.2	8.2	8.3	8.3	8.3	8.1	8.3	8.2	8.6	8.6	8.5	8.6	8.2
Dissolved oxygen (mg/L)	8.6	7.7	7.8	9.1	7.9	8.9	9.8	8.8	8.7	8.8	9.3	9.5	9.6

Table 9. Loadings of solids and dissolved ions expressed as thousands of kg/day (standard deviations are in parentheses) and flow (m^3/s) to Lake Erie from the Detroit River, 1969-81[a].

Water year	Total[a] solids	Dissolved solids	Suspended solids	Chloride	Total phos-phorus	Soluble phos-phorus	Nitrate[b] nitrogen	Ammonia nitrogen	Total iron	Phenols	Flow[c]
1969	NA[d]	NA	8,400 (540)	9,400 (660)	72 (8)	37 (7.2)	90 (7)	68 (9.9)	290 (16)	0.9 (0.1)	6,030
1970	NA	NA	8,000 (490)	9,500 (630)	71 (6)	42 (6.6)	140 (12)	68 (10)	270 (18)	3.1 (1.4)	6,060
1971	87,000	81,000 (2,300)	6,400 (300)	8,900 (630)	42 (4)	19 (2.3)	150 (17)	84 (12)	200 (11)	0.91 (0.12)	6,260
1972	98,000	90,000 (2,200)	7,700 (610)	9,100 (560)	40 (4)	18 (2.5)	170 (14)	84 (9.3)	330 (29)	0.99 (0.15)	6,350
1973	100,000	98,000 (2,000)	4,700 (270)	9,500 (530)	45 (2.6)	12 (1.1)	160 (9.5)	60 (8)	230 (13)	0.88 (0.12)	6,790
1974	100,000	96,000 (1,900)	5,100 (310)	9,500 (500)	31 (3)	12 (1.5)	160 (6.8)	73 (8.9)	308 (11)	1.2 (0.17)	6,820
1975	100,000	93,000 (1,600)	8,800 (510)	8,600 (390)	33 (3.6)	14 (1.8)	200 (12)	76 (9)	240 (18)	1.3 (0.60)	6,640
1976	100,000	89,000 (1,800)	9,000 (610)	8,400 (430)	28 (2.4)	8.9 (0.820)	170 (11)	59 (6.7)	320 (17)	1.6 (0.84)	6,640
1977	82,000	77,000 (1,500)	5,400 (280)	7,100 (390)	17 (1.8)	6.1 (0.79)	120 (6.4)	50 (6.5)	200 (11)	1.4 (0.08)	5,640
1978	85,000	79,000 (1,600)	6,500 (270)	7,000 (400)	17 (1.4)	8.3 (3.9)	136 (4.6)	49 (6.2)	188 (10)	0.8 (0.07)	5,740
1979	86,000	80,000 (1,600)	6,300 (290)	6,700 (400)	14 (1)	2.6 (0.260)	160 (6.8)	43 (5.9)	186 (8.9)	0.63 (0.06)	6,100
1980	85,000	80,000 (1,900)	4,700 (320)	6,400 (440)	13 (0.8)	3.8 (0.29)	164 (6)	38 (5)	152 (9.5)	0.34 (0.03)	5,940
1981	80,000	75,000 (1,400)	4,600 (200)	5,400 (330)	9 (0.5)	2.1 (0.16)	154 (4.4)	40 (5.3)	140 (15)	0.39 (0.03)	5,904

a Summation of dissolved solids and suspended solids.
b Nitrate nitrogen for water year 1969 through 1972. Nitrate plus nitrite nitrogen to present.
c Represents Detroit River flow on days samples were obtained.
d Not available.

Table 10. Water quality parameters monitored monthly by the Michigan Department of Natural Resources at the head and mouth of the Detroit River (IJC 1984).

Temperature
pH
Alkalinity
Conductivity
Turbidity
Suspended solids
Dissolved solids, total
Residue, total
Nitrate + Nitrate
Ammonia
Nitrogen, organic
Phosphorus, ortho and total
Chlorophyll *a*
Chloride
Silica
Phenols, total
Cyanide
Total organic carbon
Biological oxygen demand, 5-day
Chemical oxygen demand
Sulfate
Manganese

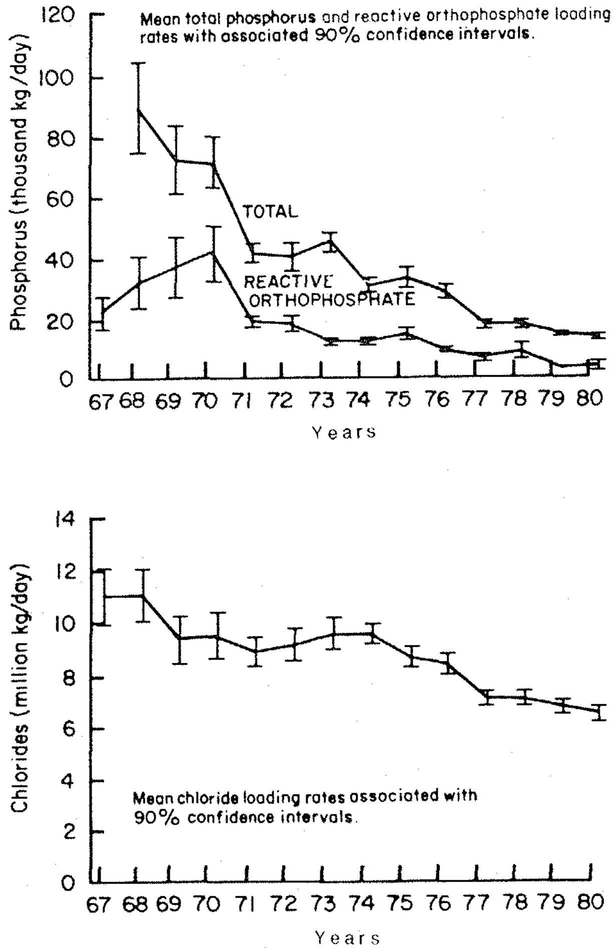


Figure 15. Long-term water quality trends at the Detroit River mouth, water years 1967-80 (Michigan Department of Natural Resources, Open Files).

high (7.7-9.8 mg/L) from 1969 to 1981 (GLWQB 1983).

Because of the tremendous dilution capacity and the very short residence time of water in the Detroit River, water quality may be acceptable even though the sediments are degraded. Sediments in the river are seriously polluted with a variety of toxic organic substances and heavy metals (Table 11). For example, PCB's, which are only slightly soluble in water, are present in the Detroit River sediment in concentrations between 0 and 3,800 parts per billion (ppb), greatly in excess of the Canadian guideline (50 ppb) for disposal of dredged spoils in open waters of the Great Lakes. The highest PCB concentrations in sediments are found

Table 11. Contaminant levels (mg/kg dry weight) in Detroit River sediments and Ontario pollution guideline for each (Compiled from IJC 1982, Limno-Tech Inc. 1985, Lum and Gammon 1985, and Bertram et al. 1987).

Contaminant	Level (range)	Guideline
Volatile solids	11,000 - 379,000	60,000
Oil and grease	100 - 29,000	1,500
Polychlorinated biphenyls	0.02 - 3.8	0.05
Cyanide	0.5 - 0.8	0.1
Mercury	0.04 - 55.8	0.3
Lead	4.8 - 960.	50
Zinc	21 - 5,300	100
Iron	15,800 - 3,710,000	10,000
Chromium	4 - 330	25
Copper	0.5 - 380	25
Cadmium	0.30 - 17.0	1
Nickel	5 - 293	25
Hexachlorobenzene	0.0031 - 0.36	none
Octachlorostyrene	0.001 - 0.01	none

along the Michigan shoreline near Peach Island, Zug Island, the Rouge River, and in the Trenton Channel (Thornley and Hamdy 1984; Kauss and Hamdy 1985). Levels of PCB's 10 times as high as those along the Canadian shore were prevalent on the U.S. side in 1980. The highest levels of organochlorine pesticides and PCB's were observed on the U.S. side of the river near Fort Wayne, Zug Island, Rouge River, and the City of Trenton. Mercury levels in sediment declined in the Detroit River between 1968 and 1980, but cadmium, chromium, copper, lead, nickel and zinc concentrations increased significantly during the same time period, especially around the mouth of the Rouge River (Thornley and Hamdy 1984).

Pollutants in the sediments are either adsorbed onto the clay or organic fractions, or concentrate in the interstitial waters and may be released upon dredging (Munawar et al. 1985). Dredging itself disturbs sediment, but more important is spoil disposal by open-water dumping where the material disperses over large areas. Even the material that settles at the typical disposal site depths will be subject to agitation and transport by waves and currents over time. The dispersion problem is magnified by the fact that most trace contaminants are associated with the fine fraction of the sediment (e.g., clays), which is very light, takes a long time to settle, and is easily carried by water currents. Through open water spoil disposal, contaminants become more readily available to the aquatic food chain, eventually becoming concentrated in fish and endangering human health. Thus, sound environmental practice requires that contaminated dredge spoils be confined to safeguard against contamination of the food chain.

There is evidence that contaminants in the sediments are toxic to phytoplankton (Munawar et al. 1985) and are cycling into the biota. Herring gull eggs from Fighting Island (Struger et al. 1985) and carcasses of wintering ducks (Smith et al. 1985) from the Detroit River contain high PCB concentrations, suggesting transfer into the food chain. However, the ecosystem effects of the polluted bottom sediments in the Detroit River are poorly understood at this time.

CHAPTER 3. BIOLOGICAL CHARACTERISTICS

3.1 PRIMARY AND SECONDARY PRODUCERS

Eighty-two species of phytoplankton are present in the river at low densities (about 500 cells/ml). The phytoplankton assemblage is dominated most of the year by diatoms (Fragilaria crotonensis and Tabellaria fenestrata), which are common in Lake Huron (Williams 1962; Wujek, 1967). In July and August, the bluegreen alga Oscillatoria sp., common in Lake St. Clair at that time (Winner et al. 1970), contributes substantially to the Detroit River phytoplankton. Relative to other waters, the mean number of diatom species in the Detroit River (29.8) is third highest in the Great Lakes, about equal to that in major tributaries of the Ohio River Basin (range: 23.4-29.3), lower than that in major rivers of the Pacific Northwest (27.2-37.0), and higher than that in the Mississippi and Arkansas Rivers (13.4-19.0) (Williams 1972).

No studies of periphyton have been conducted in the Detroit River. However, a recent study by Manny et al. (1985) at a wave-exposed breakwater area in western Lake Erie suggests that the diatoms Gomphonema and Diatoma, green algae (primarily Ulothrix), the blue-green Oscillatoria, and the red alga Bangia might be common during winter in the Detroit River. Cladophora, a filamentous green alga, could be expected to be dominant during the summer months. Of these species, the diatoms would likely occur on submersed aquatic vegetation in the Detroit River.

At least 20 submersed macrophyte taxa occur in the river (Schloesser and Manny 1982; Hudson et al. 1986). In decreasing order of relative abundance, the more common forms are Vallisneria americana, Chara spp., Potamogeton spp. narrow-leaf forms (those with leaves less than 3 mm wide), P. richardsonii, Elodea canadensis, Myriophyllum spicatum, P. gramineus, and Heteranthera dubia (Table 12). Macrophyte stands are typically composed of 2 or 3 species, but up to 11 have been recorded in a single stand. Chara is the only taxon that occurs in monotypic stands. Additional research is needed to determine why Heteranthera and Chara are found in the Detroit River in relatively higher and lower abundance, respectively, than in the St. Clair River and Lake St. Clair. In the Detroit River, the lower depth limit for plant colonization has not been adequately documented, but most beds occur in water less than 7 m deep (Schloesser and Manny 1982). The area of the riverbed between the shoreline and the 3.7-m depth contour is about 99 km². About 72% of this area is occupied by submersed plants (Hudson et al. 1986). The total area covered by emergent macrophytes in the Detroit River is estimated to be 860 ha. Over 95% of the emergent vegetation is found in the lower section of the river.

Schloesser et al. (1985) studied submersed aquatic macrophytes at three stations in the Detroit River; Belle Isle, the west side of Grosse Ile, and north of Sugar Island. Growth of submersed macrophytes in the river follows one of three seasonal patterns (Figure 16): dominant taxon may grow alone (Pattern A); codominant taxa may grow sympatrically without species succession (Pattern B); and codominant taxa grow sympatrically with species succession (Pattern C). Differences in growth and seasonal succession of some taxa were likely caused by presence or absence of overwintering buds, competition, and life-cycle differences. Peak biomass productivity was attained in either July, August, or October, depending on the taxonomic composition of plants at each sampling station. At Belle Isle, Vallisneria americana was the dominant

Table 12. Distribution and relative abundance of submersed macrophytes by water body segment (expressed as the percentage frequency of occurrence) at 595 stations scattered through the St. Clair-Detroit River system in 1978 (Schloesser and Manny 1982).

	Distribution			
			Lake St. Clair	
Taxon	Detroit River	St. Clair River	Anchor Bay	Lake Proper
Vallisneria americana Michx. (Wild celery)	49	28	42	11
Characeae (Muskgrass)	9	68	62	7
Potamogeton richardsonii (Benn.) Rydb. (Redhead grass)	4	49	13	4
Myriophyllum spicatum L. (Eurasian watermilfoil)	13	28	30	5
Elodea candensis Michx. (Waterweed)	7	36	20	4
Heteranthera dubia (Jacq.) Mac M. (Water stargrass)	31	< 1	2	4
Potamogeton spp. (Narrow-leaf forms)	3	24	12	0
Najas flexilis (Willd.) Rostk. & Schmidt (Bushy pondweed)	5	< 1	43	2
Potamogeton gramineus L. (Variable pondweed)	3	11	3	0
Ceratophyllum demersum L. (Coontail)	< 1	0	3	0
Myriophyllum exalbescens Fern. (Watermilfoil)	0	< 1	2	0
Nymphaea sp. (Water-lily)	< 1	0	0	0
Potamogeton spp. (Broad-leaf forms)	0	2	0	0
Potamogeton crispus L. (Curly pondweed)	0	2	0	0
Potamogeton illinoensis Morong. (Illinois pondweed)	< 1	0	0	0
Potamogeton natans L. (Floating-leaf pondweed)	0	< 1	0	0
Potamogeton nodosus Poiret (Long-leaf pondweed)	1	2	0	0
Potamogeton zosteriformis Fern. (Flatstem pondweed)	0	< 1	0	0
Ranunculus sp. (Buttercup)	0	2	2	0
Total number of macrophyte taxa	13	16	12	7

Nitellopsis obtusa, Nitella hyalina, Potamogeton crispus, Potamogeton zosteriformis, Ranunculus longirostris, Butomus umbellatus and Sagittaria sp. (in the submersed stage) were also found in the Detroit River by Schloesser et al. (1986a) and Hudson et al. (1986).

plant in September and October (14 g/m^2). At Grosse Ile, Elodea canadensis was prevalent in August and September (280 g/m^2). At Sugar Island, Potamogeton crispus was dominant in June (100 g/m^2), Myriophyllum spicatum in August (100 g/m^2), and Heteranthera dubia in October (80 g/m^2). Biomass values at all these sites were within the range reported for aquatic macrophyte stands in rivers at temperate latitudes (Edwards and Owens 1960; Westlake 1963).

No detailed studies of emergent macrophyte species composition, distribution, and relative abundance in the river have been completed, although wetland communities have been mapped using aerial photographs and satellite images (Jaworski and Raphael 1976; Lyon 1979; Herdendorf et al. 1981; Raphael and Jaworski 1982; McCullough 1985). In 1983-84, the emergent plants at Stony Island in the Detroit River consisted of 11 taxa (Table 13). Typha angustifolia, Sparganium eurycarpum, Scirpus fluviatilis, and S. americanus produced the highest biomass. In Anchor Bay of Lake St. Clair, Typha latifolia, T. angustifolia, Scirpus validus, Phragmites communis, and Eleocharis quadrangulata are the predominant taxa (Manny and Kennedy 1986).

Three exotic submersed macrophyte taxa have been found in the Detroit River: Potamogeton crispus L., Nitellopsis obtusa, and Myriophyllum spicatum (Schloesser 1986). Potamogeton crispus (Figure 17), generally assumed to have been introduced from Europe, was first recorded in the Great Lakes in 1946 (Voss 1972), and was first recorded in the Detroit River in 1951 (Hunt 1963). Because P. crispus grows in early spring, it has not been extensively surveyed. Curly pondweed gets its name from the wavy

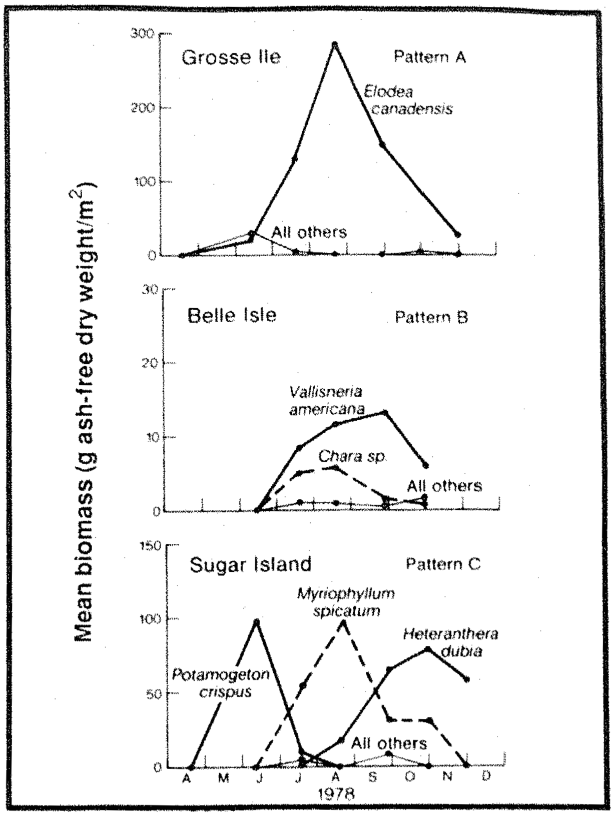


Figure 16. Three patterns of seasonal growth of submersed macrophytes (g/m²) in the Detroit River, April-November 1978 (Schloesser et al. 1985).

margins on the sides of its leaves. Leaves are dark green with a reddish hue and have small teeth along the margins. Plants may grow up to 2 m long. This pondweed is a European invader of water bodies in North America that may spread by rerooting of small plant fragments. In spring, curly pondweed provides shelter for small aquatic animals used as food by migrating waterfowl, and spawning substrate for fish. It is one of the most abundant submersed macrophytes from April to June.

No Myriophyllum spicatum (Figure 18) was found in the Detroit River in 1954 (Hunt 1957); the species was first found in Lake St. Clair in 1974 (Dawson 1975). By 1978, it was the third most common submersed macrophyte in the Detroit River (Figure 19; Schloesser and Manny 1984). Eurasian watermilfoil is brownish-green, usually with some red on the stems. Stems may be up to 3 m long and have clusters of 4 to 5 feather-like leaves that are more abundant near stem tips than on lower stems. Each leaf has 5 to 24 pairs of small leaflets. Eurasian watermilfoil is a European invader of water bodies in North America; it may spread from lake to lake by small fragments transported by boats and trailers. This milfoil can crowd out other underwater plants used by

Table 13. Percent frequency of occurrence and mean dry weight, above-ground biomass (g/m²) of emergent macrophytes at Stony Island in the Detroit River, 1983-84 (Hudson et al. 1986).

Taxon	Occurrence		Biomass	
	1983	1984	1983	1984
Eleocharis spp.[a]	6	15	37.2	18.4
Phalaris arundinacea	3	5	29.6	42.7
Sagittaria latifolia	12	15	13.4	35.5
Sagittaria rigida	0	26	0	198.0
Scirpus acutus	3	5	2.8	9.6
Scirpus americanus	18	23	178.7	299.4
Scirpus fluviatilis	9	3	965.8	8.2
Scirpus validus	9	23	28.0	44.9
Sparganium eurycarpum	36	33	196.2	357.5
Typha angustifolia	36	26	903.5	865.3

[a] Two closely related species, E. smallii and E. erythropoda.

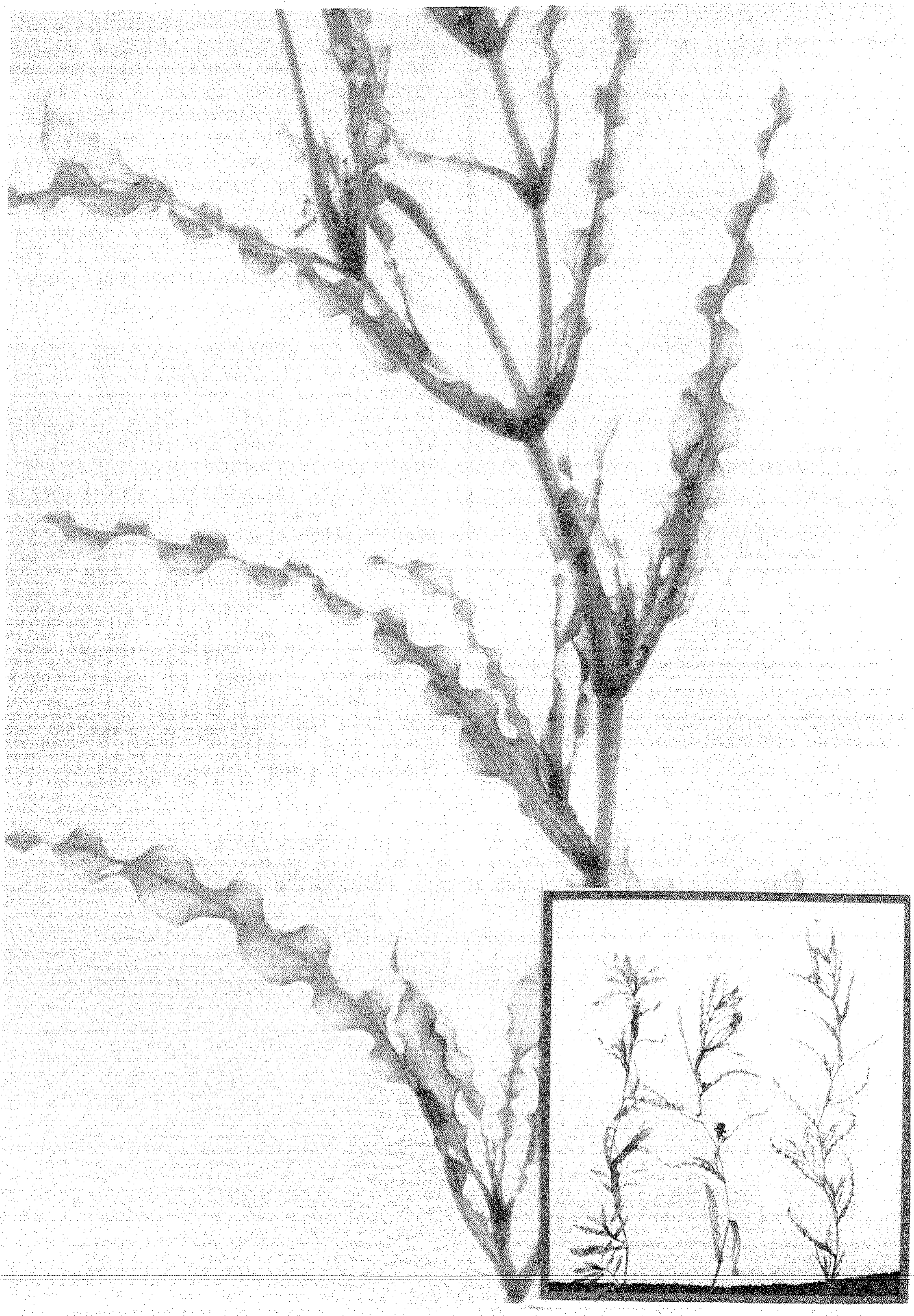


Figure 17. Curly pondweed (*Potamogeton crispus*; Schloesser 1986).

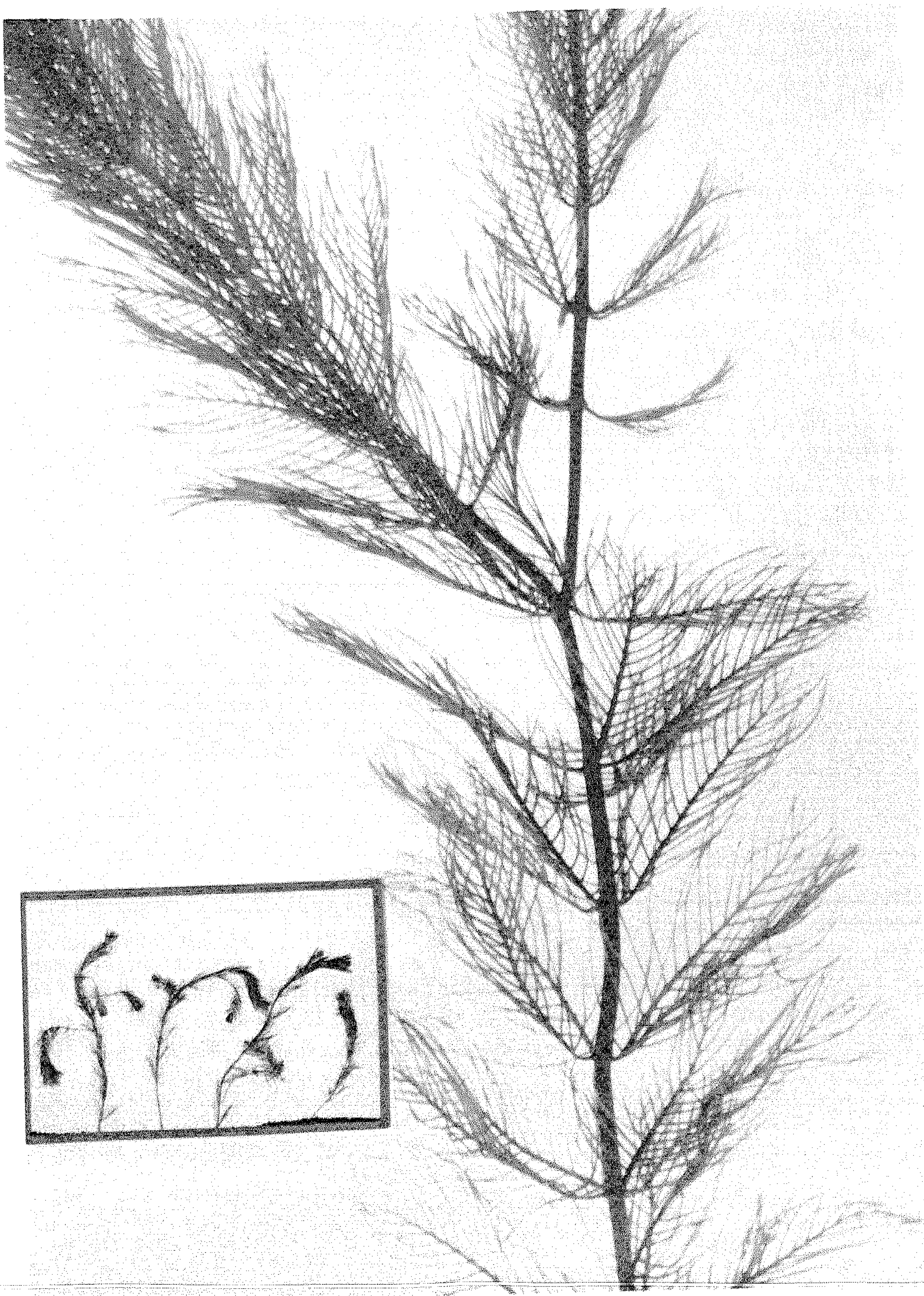


Figure 18. Eurasian watermilfoil (*Myriophyllum spicatum*; Schloesser 1986).

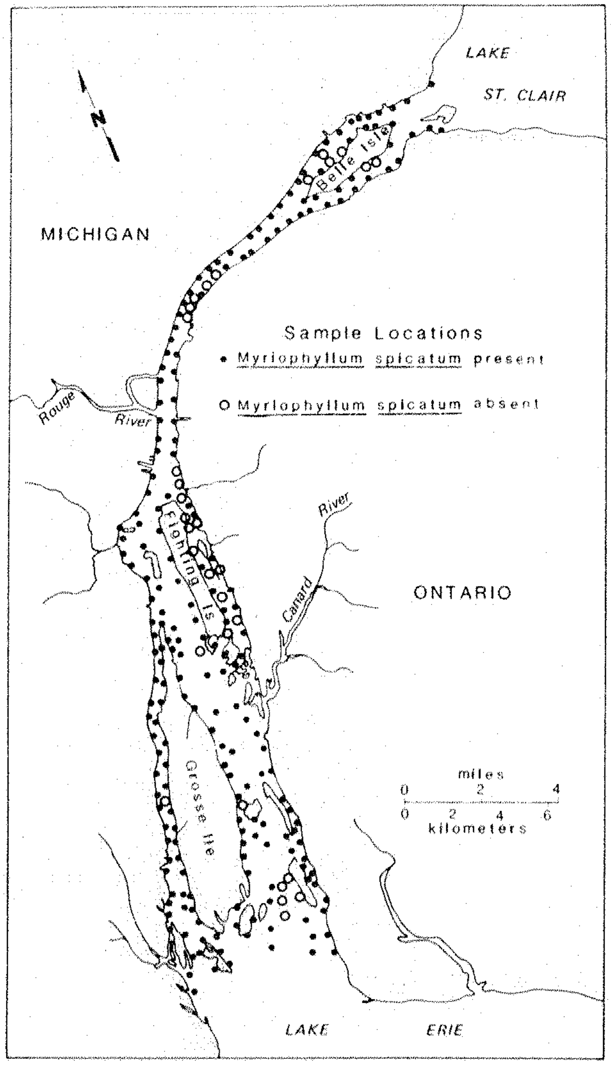


Figure 19. Distribution of *Myriophyllum spicatum* in the Detroit River in 1978 (Schloesser and Manny 1984).

fish and waterfowl. However, Eurasian watermilfoil provides habitat to many aquatic animals because it has many fine leaves and overwinters as a decaying mat upon which they feed. In general, watermilfoils were little noticed 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, the Chesapeake Bay, and TVA reservoirs. In the Great Lakes, massive growths of M. spicatum have been reported, but these represent only minor impediments to human water uses such as recreation and navigation (Schloesser and Manny 1984).

The most recently found exotic macrophyte in the river system is a macroalga (Characeae), Nitellopsis obtusa (Figure 20), native to Europe and Asia. This plant was first discovered on this continent in the St. Lawrence River in 1978. Although not extremely abundant, this taxon has been found at two widely separated locations in the Detroit River (Belle Isle and Point Hennepin; Schloesser et al. 1986a) and in the St. Clair River. The occurrence of N. obtusa in the United States only in waters frequented by merchant vessels suggests that it is distributed by this mechanism. N. obtusa has long, uneven-length branches that look angular at the joints and may have one cream-colored bulb at the base of each cluster of branches. Like the Nitellas, N. obtusa is sometimes found in deep, slow-moving water where other plants are scarce.

Zooplankton in the Detroit River have not been studied, but because of the short flushing time, their composition and abundance in the Detroit River should resemble that in Lake St. Clair. In Lake St. Clair, 14 taxa of planktonic copepods and 18 of cladocerans are reportedly present (Winner et al. 1970; Leach 1973; Bricker et al. 1976). Cyclops vernalis and Diaptomus ashlandi are dominant in Lake St. Clair. Difflugia is the most common protozoan, and Conochilus, Keratella, Polyarthra, Synchaeta, and Brachionus are the most common rotifers. Zooplankton numbers should peak between June and September. A study of foods eaten by larval yellow perch during passage through the Detroit River identified zooplankton, including copepod nauplii, older cyclopoid and calanoid copepods, cladocera, and rotifers (Poe 1983). Hence, zooplankton likely are a critical food resource to larval fish in the Detroit River. Additional research is needed to determine the biological significance of zooplankton in the river.

Macrozoobenthos has been well documented throughout the river (Hiltunen and Manny 1982; Thornley and Hamdy 1984; Thornley 1985; and Hudson et al. 1986) but micro- and meiozoobenthos have not been studied. The number of macrozoobenthic species in the Detroit River system exceeds 300. Oligochaeta, Chironomidae,

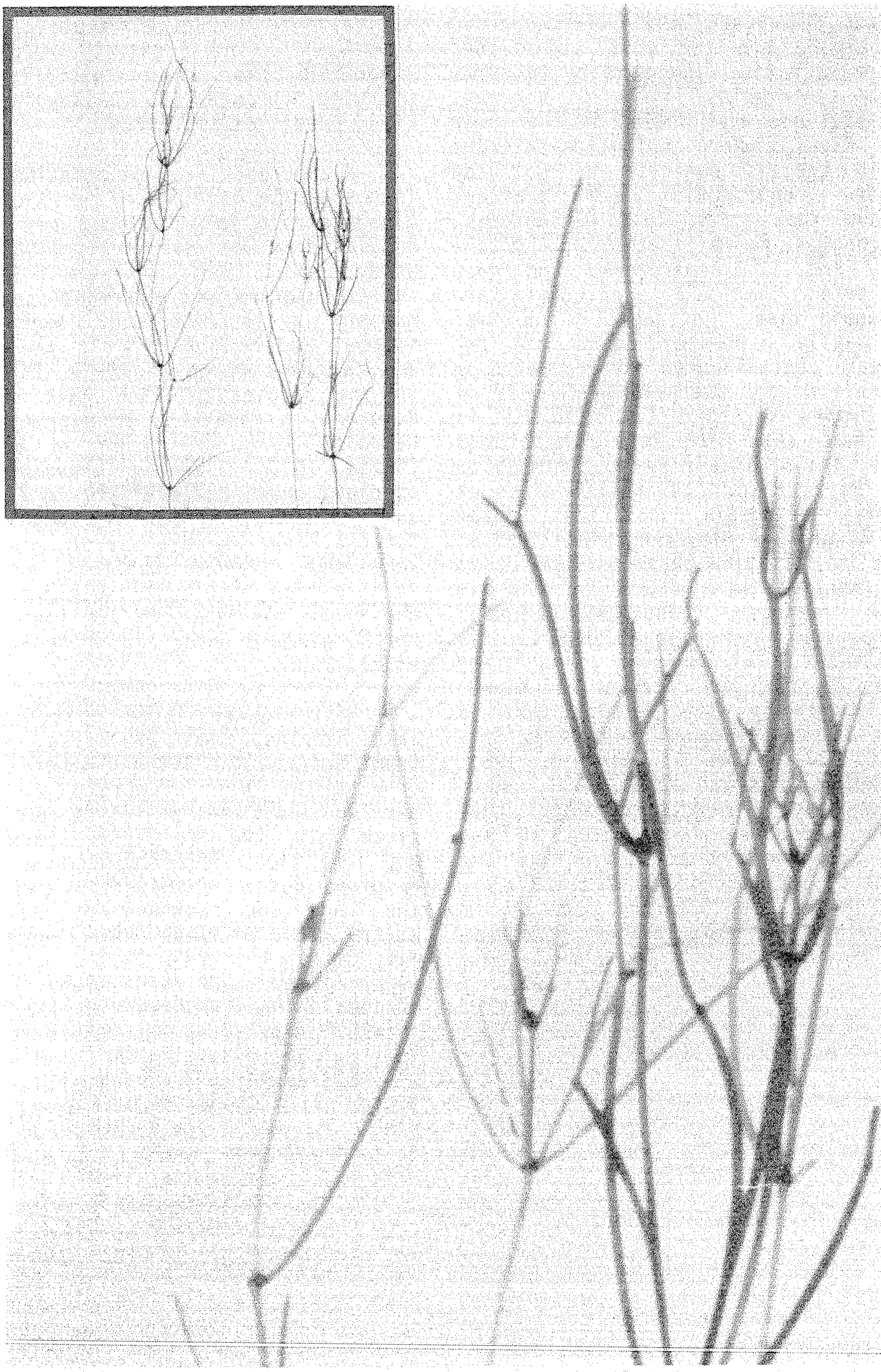


Figure 20. Nitellopsis (*Nitellopsis obtusa*; Schloesser 1986).

Gastropoda, Ephemeroptera, Trichoptera, and Amphipoda are the most significant on a biomass basis. Hydra is quite abundant but contributes little to biomass. Oligochaetes are most common in the lower Detroit River, where pollution-tolerant tubificid species dominate on polluted sediments. Chironomids are abundant throughout the system, with Cricotopus, Parachironomus, Parakiefferiella, Rheotanytarsus, and Stictochironomus the most common taxa. Amnicola and Elimia are common snail taxa. Hexagenia is the most common mayfly. However, owing to the widespread contamination of sediments in the Detroit River, the average density of mayfly nymphs in the river ($88/m^2$) is lower than that in Lake St. Clair ($271/m^2$), the St. Clair River ($95/m^2$), or the St. Marys River ($199/m^2$) (Edwards et al. 1987). Hexagenia populations in the Detroit River have recovered since 1967 in response to pollution abatement and up to 1,925 nymphs/m^2 were found in 1980 in Canadian waters (Thornley 1985). Cheumatopsyche, Hydropsyche, and Oecetis are dominant trichopteran taxa, and Hyalella is the most common amphipod. Species diversity within these taxa is greatest in the Chironomidae (127), Trichoptera (38), and Oligochaeta (25). Freshwater mussels and crayfish are taxonomically diverse and abundant but have not been adequately documented in the river. In general, the diversity and abundance of most macrozoobenthic taxa are lower in deeper, fast-flowing areas of the river and higher in shallow sediment-deposition zones (Hiltunen and Manny 1982).

3.2 NATIVE AND EXOTIC FISHES

Fish exhibit several basically different life-history strategies in their use of the Detroit River habitats. Some 32 species are permanent residents; another 28 species are migrants that use the river as a feeding, spawning, or nursery ground or as a migratory pathway between Lakes Erie and Huron. Recent studies of the movements of marked fish (Haas et al. 1985) have revealed diverse life-history strategies among the different stocks of some species using the river. The present-day fish populations of the Detroit River are a mix of about 65 native and introduced (exotic) species (Table 14). At least 40 more species inhabited the river historically or migrated through it (Bailey and Smith 1981; Edsall et al. 1988).

A comprehensive description of the fish spawning and nursery areas of the St. Clair-Detroit River system was recently completed by Goodyear et al. (1982). This study showed that the Detroit River and its tributaries are important spawning and nursery areas for many species that support major fisheries in the waterway and in Lakes Huron and Erie (Figure 21). Of the species of fish that have been recorded as residents or migrants in the Detroit River, 39 spawn in the river (Table 15). Spawning areas of these species, shown collectively in Figure 22, are concentrated near the mouth of the Detroit River where a variety of suitable lake and riverine habitats are found. At this time, the most important users of the river for spawning are smelt, yellow perch, gizzard shad, and white bass (Muth et al. 1986).

Historically, large spawning runs of lake herring, lake whitefish, and lake trout entered the Detroit River from Lake Erie in the fall. A portion of the lake herring and lake whitefish ran up the river into Lake St. Clair. Lake herring and lake trout spawning grounds were not recorded but some whitefish spawned near the mouth and the head of the Detroit River. All of these runs ceased in the late 1800's or early 1900's because rock outcroppings used for spawning were destroyed by construction of the shipping channel or rendered unsuitable for spawning by water pollution (Smith 1917). Limited spawning by whitefish may be taking place in the Detroit River, because a few whitefish larvae were caught there in 1977 and 1983 (Hatcher and Nester 1983; Muth et al. 1986).

The Detroit River was also an important spawning ground for lake sturgeon that entered the river in the spring from Lake Erie. The lower river was believed to be the major spawning area but spawning grounds have also been identified near Fighting Island in the midreaches of the river and near Belle Isle at the head of the river (Goodyear et al. 1982). Lake

Table 14. List of 65 fishes commonly found in the Detroit River (Lee et al. 1980; Goodyear et al. 1982; and Haas et al. 1985).

Common name	Scientific name
Sea lamprey	Petromyzon marinus
Lake sturgeon	Acipenser fulvescens
Spotted gar	Lepisosteus oculatus
Longnose gar	Lepisosteus osseus
Bowfin	Amia calva
American eel	Anguilla rostrata
Mooneye	Hiodon tergisus
Alewife	Alosa pseudoharengus
Gizzard shad	Dorosoma cepedianum
Chinook salmon	Oncorhynchus tshawytscha
Coho salmon	Oncorhynchus kisutch
Pink salmon	Oncorhynchus gorbuscha
Rainbow trout	Salmo gairdneri
Brown trout	Salmo trutta
Lake trout	Salvelinus namaycush
Lake whitefish	Coregonus clupeaformis
Rainbow smelt	Osmerus mordax
Northern pike	Esox lucius
Muskellunge	Esox masquinongy
Goldfish	Carassius auratus
Common carp	Cyprinus carpio
Silver chub	Hybopsis storeriana
Golden shiner	Notemigonus crysoleucas
Emerald shiner	Notropis atherinoides
Pugnose minnow	Notropis emiliae
Blacknose shiner	Notropis heterodon
Spottail shiner	Notropis hudsonius
Sand shiner	Notropis stramineus
Mimic shiner	Notropis volucellus
Quillback	Carpiodes cyprinus
Longnose sucker	Catostomus catostomus
White sucker	Catostomus commersoni
Northern hogsucker	Hypentelium nigricans
Bigmouth buffalo	Ictiobus cyprinellus
Smallmouth buffalo	Ictiobus bubalus
Spotted sucker	Minytrema melanops
Redhorse, unidentified	Moxostoma spp.
Silver redhorse	Moxostoma anisurum
Golden redhorse	Moxostoma erythrurum
Shorthead redhorse	Moxostoma macrolepidotum
River redhorse	Moxostoma carinatum
Black bullhead	Ictalurus melas
Yellow bullhead	Ictalurus natalis
Brown bullhead	Ictalurus nebulosus
Channel catfish	Ictalurus punctatus
Stonecat	Noturus flavus
Trout-perch	Percopsis omiscomaycus
Burbot	Lota lota
Brook silversides	Labidesthes sicculus

(Continued)

Table 14. (Concluded).

Common name	Scientific name
White perch	*Morone americana*
White bass	*Morone chrysops*
Rock bass	*Ambloplites rupestris*
Green sunfish	*Lepomis cyanellus*
Pumpkinseed	*Lepomis gibbosus*
Bluegill	*Lepomis macrochirus*
Smallmouth bass	*Micropterus dolomieui*
Largemouth bass	*Micropterus salmoides*
White crappie	*Pomoxis annularis*
Black crappie	*Pomoxis nigromaculatus*
Logperch	*Percina ceprodes*
Yellow perch	*Perca flavescens*
Sauger	*Stizostedion canadense*
Walleye	*Stizostedion vitreum vitreum*
Freshwater drum	*Aplodinotus grunniens*
Four horn sculpin	*Myoxocephalus quadricornis*

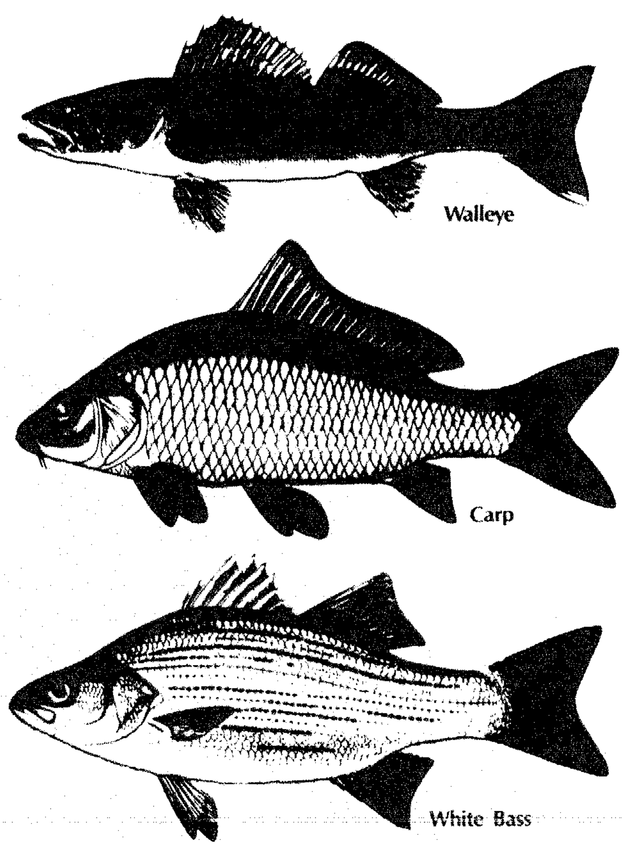


Figure 21. Several fishes that support major fisheries in the Detroit River (Illustrations by E. B. S. Logier and C. M. Godkin).

Table 15. Fishes that spawn in the Detroit River (Goodyear et al. 1982 and R. Hass, Mich. Dep. Nat. Resour.; pers. comm.).

Common name	
Lake sturgeon	Trout-perch
Spotted gar	Burbot
Longnose gar	Brook silverside
Bowfin	White bass
Alewife	Rock bass
Gizzard shad	Green sunfish
Lake herring	Pumpkinseed
Lake whitefish	Bluegill
Lake trout	Smallmouth bass
Rainbow smelt	Largemouth bass
Northern pike	Black crappie
Muskellunge	White crappie
Goldfish	Johnny darter
Carp	Yellow perch
Emerald shiner	Logperch
Spottail shiner	Sauger
White sucker	Walleye
Northern hog sucker	Freshwater drum
Channel catfish	Fourhorn sculpin
Stonecat	

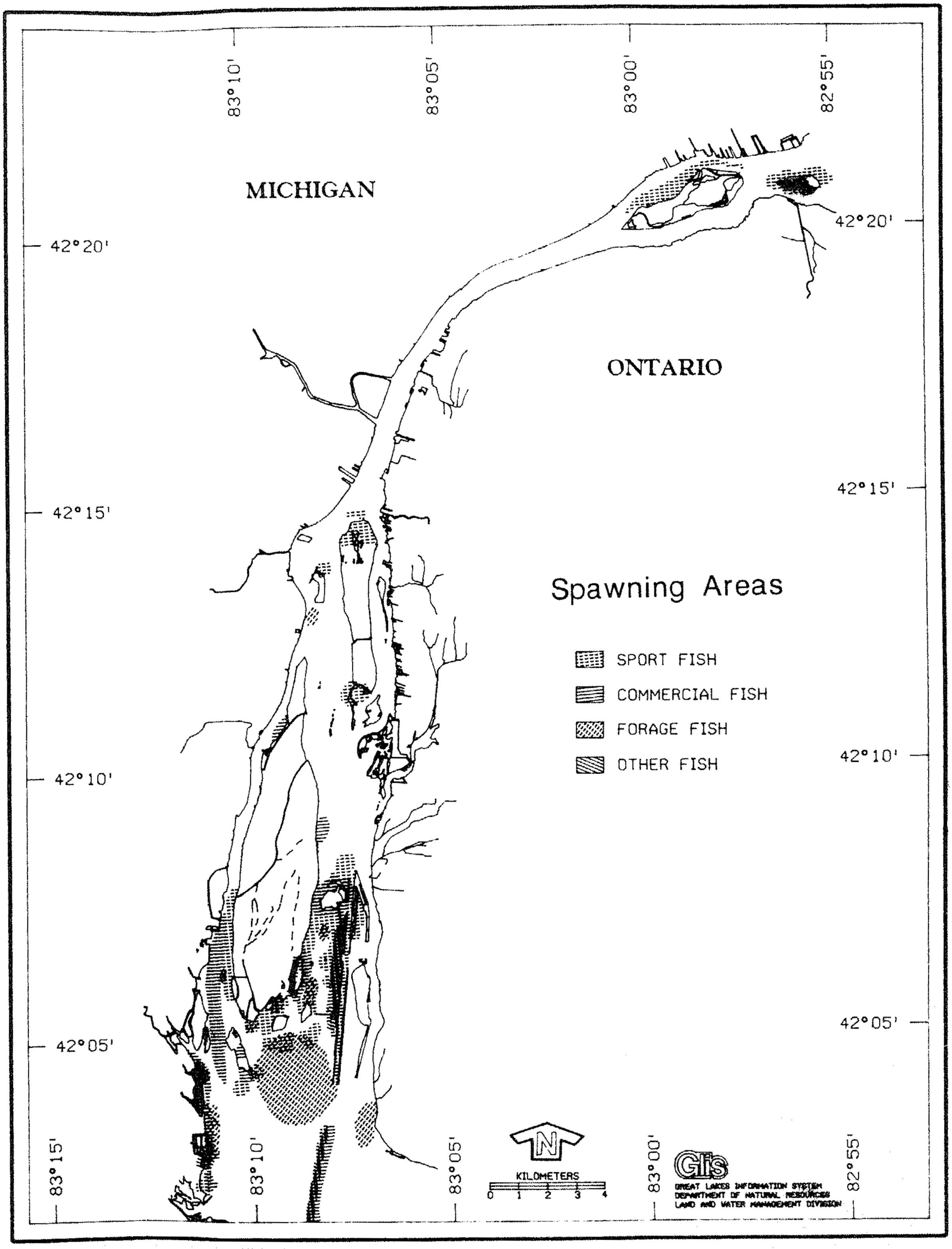


Figure 22. Fish spawning areas in the Detroit River (Goodyear et al. 1982).

sturgeon populations have been sharply reduced from historical levels by overfishing and pollution, but spawning was reported in the midreaches of the Detroit River in the 1950's and in the lower river around Stony and Sugar Islands in the 1970's (Goodyear et al. 1982).

Walleye, yellow perch, and white bass are important recreational species that spawn in the Detroit River. The river is part of a complex migration route these species follow between Lake St. Clair and Lake Erie. Large post-spawning runs of walleyes enter the river from Lake Erie. Reduction in historical spawning runs of these species was attributed to pollution. In the 1970's, walleye spawning was again documented and walleye larvae were collected at several locations in the lower 16 km of the Trenton and Main Channels. Historical records of yellow perch spawning in the Detroit River are lacking, but in the 1970's spawning occurred in the mouth of the Detroit River (Goodyear et al. 1982).

The river is also an important nursery area for fish because the densities of larvae of all fishes combined in the Detroit River and its tributaries in 1983-84 were higher than at the outflow of Lake St. Clair, (Table 16). Tow-net catches of fish larvae in the Detroit River in 1977-78 and 1983-84 (Hatcher and Nester 1983; Muth et al. 1986) showed that the river is a nursery ground for 25 species of fish (Table 17). Most abundant among the larvae were three forage fish, alewives, rainbow smelt, and gizzard shad (Table 18). Yellow perch, logperch, emerald shiner and unidentified minnows were also relatively abundant. The other species represented in the catch tended to be much less abundant (less than one larva per 1,000 m^3 of water). Because sampling in these studies was restricted to deeper open-water areas, the relative importance of submersed vegetation as nursery areas was not assessed. In the St. Marys River, the abundance of fish larvae increased with distance away from the channel areas into the submersed and emergent vegetation (Duffy et al. 1987). Further research is needed to assess the role of littoral aquatic vegetation as nursery habitat for fish larvae in the Detroit River.

Table 16. Average density of fish larvae in the Detroit River, 1983-84 (Muth et al. 1986).

Location	Average number of larvae/1,000 m^3 of water: 1983	1984
Outflow of Lake St. Clair into Detroit River	91	223
Detroit River proper	214	335
Detroit River tributary	319	485

Table 17. Fishes that use the Detroit River as a nursery area (Hatcher and Nester 1983; Muth et al. 1986).

Alewife	Trout-perch
Gizzard shad	Walleye
Emerald shiner	Burbot
White perch	Lake herring
Rainbow smelt	Lake whitefish
Logperch	Johnny darter
Spottail shiner	White sucker
White bass	Spotted sucker
Yellow perch	River carpsucker
Deepwater sculpin	Slimy sculpin
Common carp	Freshwater drum
Brook silverside	Lake whitefish
	White crappie

Submersed vegetation, also provides nursery habitat for juvenile fish in the Detroit River (Hamilton 1987). Electrofishing at 16 sites in the Detroit River, including Gibralter Bay, in October 1986 in beds of submersed macrophytes produced numerous young-of-the-year of 16 fish species as well as a variety of older fish (Table 19). In general, the electrofishing survey showed that fish could tolerate poor water conditions and that the distribution of fish in the Detroit River was limited chiefly by the lack of heterogeneous physical habitat, (i.e., concrete breakwalls and piers create a hostile environment for fish).

Records of the early fisheries showed runs of native cold-water species, including lake trout, lake whitefish, and lake

Table 18. Average density (no. larvae per 1000 m^3 of water) and relative abundance of fish larvae in the Detroit River, 1977-78 (Hatcher and Nester 1983).

Species	1977		1978	
	Average density	Relative abundance	Average density	Relative abundance
Rainbow smelt	132.01	33.6	204.07	29.9
Gizzard shad	71.74	18.2	90.40	13.3
Yellow perch	51.72	13.2	26.24	3.9
Alewife	40.13	10.2	240.11	35.2
Unidentified minnows	29.11	7.4	11.36	1.7
Logperch	26.35	6.7	35.09	5.1
Emerald shiner	18.16	4.6	57.87	8.5
White bass	9.24	2.4	3.49	0.5
Common carp	7.70	2.0	4.15	0.6
Unidentified darters	1.57	0.4	1.01	0.1
Unidentified sunfishes	0.93	0.2	0.20	<0.1
Johnny darter	0.82	0.2	0.20	<0.1
Trout-perch	0.81	0.2	1.01	<0.1
Walleye	0.77	0.2	0.20	<0.1
Spottail shiner	0.71	0.2	3.15	0.4
Burbot	0.48	0.1	0.31	<0.1
Deepwater sculpin	0.46	0.1	0.63	<0.1
White sucker	0.39	<0.1	0.68	<0.1
Freshwater drum	0.21	<0.1	0.32	<0.1
Lake whitefish	0.02	<0.1	0.07	<0.1
Brook silverside	--	--	0.27	<0.1
Average total density	393.3		680.8	

herring entered the Detroit River from Lake Erie in the fall to use the spawning habitat in the system. However, there is no evidence to indicate these native cold-water species were year-round residents. Indeed, the thermal regime of the river suggests they probably were not. In most years, water temperatures in the river might permit year-round residence of cold-water species. However, temperatures in July and September approach or exceed the limits at which most indigenous cold-water species can use food effectively for growth, and temperatures in August approach the lethal range for lake trout. Nevertheless, by virture of their propensity for short migrations, which allowed them to use the Detroit River during the cooler months, cold-water fish species were apparently able to successfully exploit critical spawning and nursery habitat in the river that would otherwise have been unavailable to them.

Among the numerous exotic fish that have been introduced into the Great Lakes (Emery 1985), the common carp is linked historically to the Detroit River, having been first introduced to the Great Lakes in 1883 near the mouth of the Sandusky River in western Lake Erie. From there it spread through the Detroit River to the upper Great Lakes, destroying beds of wild celery and wild rice preferred as food by native canvasback and redhead ducks as it spread (Cole 1905, McCrimmon 1968). Because of their large impact on native vegetation and their ability to tolerate higher levels of pollution and higher water temperatures than native fishes, carp have displaced many native fishes in the river and are ecologically one of the

Table 19. Fishes caught in 19 minutes of electrofishing among submersed aquatic vegetation in Gibraltar Bay, October 15, 1986 (Hamilton 1987).

Species	Age class	Total no.	Length range (cm)
Yellow perch	0	47	5 - 10
Brook silverside	0	10	5
Alewife	0	7	5 - 7
Pugnose minnow	0	7	2 - 7
Trout perch	0	5	7 - 10
Spottail shiner	0	5	2 - 7
Gizzard shad	0	4	5 - 15
Black crappie	0	3	2 - 7
White perch	0	3	7
Pumpkinseed sunfish	0	2	2
Unidentified cyprinids	0	2	5 - 10
Bluntnose minnow	0	2	10
Smallmouth bass	0	1	15
Bluegill	0	1	7
Rainbow smelt	0	1	5
White sucker	0	1	15
Yellow perch	1	22	10 - 15
Walleye	1	2	30 - 46
Rockbass	1	2	13
Pumpkinseed sunfish	2+	6	15 - 18
Yellow perch	2+	5	15 - 20
Common carp	2+	4	48 - 58
Golden shiner	2+	3	13 - 18
Rockbass	2+	3	18 - 20
Yellow bullhead	2+	3	25 - 28
Walleye	2+	2	58 - 64
Mirror carp	2+	1	51
Northern pike	2+	1	56
Bluegill	2+	1	18

most important exotic fish that has been introduced into the river. Large populations of common carp now inhabit the Detroit River and adjacent water bodies, where they recently made up much of the commercial fish catch (see Section 5.2).

Other exotic fishes that frequent the Detroit River include the parasitic sea lamprey, which spread through the Detroit River to the upper Great Lakes in the 1940's, bringing desirable fishes like the lake trout to the brink of extinction during the 1950's and 60's (Lawrie 1970; Christie 1974). The sea lamprey has a long, complicated life cycle, including a 6-year nonparasitic juvenile period in spawning tributaries that makes it vulnerable to chemical control and integrated pest management techniques (Smith 1971). Control of the sea lamprey continues presently and will be required in the future throughout the Great Lakes.

Rainbow smelt and alewife, which were accidently introduced into the lower lakes in 1932, also spread through the Detroit River to the upper lakes, and now make up the bulk of the forage fish base in all the Great Lakes (Emery 1976; Goodyear et al. 1982).

The latest exotic fish to spread from the lower Great Lakes to the upper Great Lakes through the Detroit River is the white perch. This species was first introduced into Lake Erie in 1953 and now is abundant in western Lake Erie and Lake St. Clair, where it has begun to hybridize with native white bass (Todd 1986). The invasion of the Detroit River and adjacent waters by white perch poses a dilemma. In small cold-water lakes in Maine, white perch are a serious competitor with and usually dominate yellow perch, trout, and salmon, because they live much longer (12-13 years commonly) and reach good size (15-30 cm and 1-2 kg). Though they may be displacing native fishes, they are considered more palatable than other fishes by many anglers (AuClair 1960). Therefore, public attitudes towards the white perch are ambivalent. The proportion of exotic species in the Detroit River may increase as the Michigan Department of Natural Resources seeks to upgrade cold-water fisheries by stocking Pacific salmon along the urban waterfront (Fogel 1978, 1984).

3.3 WATERFOWL

Important waterfowl in Michigan include ducks, geese, swans, and coots (Table 20). At least 3 million waterfowl migrate annually through the Great Lakes region, which is situated at the intersection of the Atlantic and Mississippi Flyways (Bellrose 1968; Herdendorf et al. 1986). An estimated 700,000 diving ducks, 500,000 dabbling ducks, and 250,000 Canada geese migrate across Michigan each fall.

Table 20. Waterfowl that frequent Michigan's coastal wetlands (Johnsgaard 1975).

Scientific name	Common name
Ducks and mergansers	
Aix sponsa	Wood duck
Anas acuta	Pintail
Anas clypeata	Northern shoveler
Anas crecca	Green-winged teal
Anas discors	Blue-winged teal
Anas penelope	American widgeon (Baldpate)
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 (American) goldeneye
Clangula hyemalis	Oldsquaw
Mergus cucullatus	Hooded merganser
Mergus serrator	Red-breasted merganser
Oxyura jamaicensis	Ruddy duck
Geese and brant	
Anser caerulescens	Snow goose
Branta bernicla	Brant goose
Branta canadensis	Canada goose
Swans	
Cygnus columbianus	Whistling swan
Cygnus cygnus	Trumpeter swan
Cygnus olor	Mute swan
Coots	
Fulica americana	American coot

Detailed documentation of migratory waterfowl use of the Detroit River is generally lacking and portions of the following discussion (derived from Jaworski and Raphael 1978) includes waterfowl use of the western shore of Lake Erie, the lower Detroit River, Point Mouillee, and Lake Erie marshes, wetland areas which collectively total 38,225 ha.

Accurate counts of summer-resident ducks are lacking, but at least six species, including mallards, blue-winged teal, wood ducks, black ducks, pintails, and redheads, nested in wetlands along the lower river area in 1957-68 (Jaworski and Raphael 1978). Duck nesting densities in the Pointe Mouillee wetland area near the lower Detroit River averaged 145 nesting pairs/km^2 of wetland during that period.

A small (123 ha) federal refuge, the Wyandotte National Wildlife Refuge, was established in 1961 off the northern end of Grosse Ile in the Detroit River as a breeding ground for migratory waterfowl; it is an important nesting and staging area (Jaworski and Raphael 1978). In September, local nesting waterfowl gather in this area and are soon joined by other waterfowl from more northerly breeding grounds. In October, they begin migrating southward.

Beginning in the 1930's, warm industrial effluents from the Detroit metropolitan area prevented ice from forming along the entire river south to Gibraltar (Hunt 1957). Attracted by the open water, thousands of ducks wintered along the lower Detroit River and foraged on the bottom in littoral areas (Hunt 1957). Canvasback (Figure 23), redhead, mallard, scaup (Figure 24), and Canada geese account for a majority of the waterfowl wintering on the Detroit River in recent years. Canvasback, redhead and greater scaup tend to eat plants, whereas lesser scaup, common goldeneye, bufflehead, and ruddy duck rely principally on animal foods (Bellrose 1976). In 1980 and 1981, about 11,700 and 4,500 ducks, respectively, wintered on the Detroit River (Jones 1982). Peak abundance of ducks using the open waters of the lower Detroit River in winter months has exceeded 26,000 (Jones 1982).

The spring migration of waterfowl begins in March following ice breakup on water bodies used for resting. Spring flights through the Michigan area may last only about 45 days, but can be impressive. For example, on March 27, 1941, an estimated 400,000 canvasback, scaup, redhead, bufflehead, goldeneye, and other ducks congregated on the east side of Grosse Ile in the Detroit River (Miller 1943).

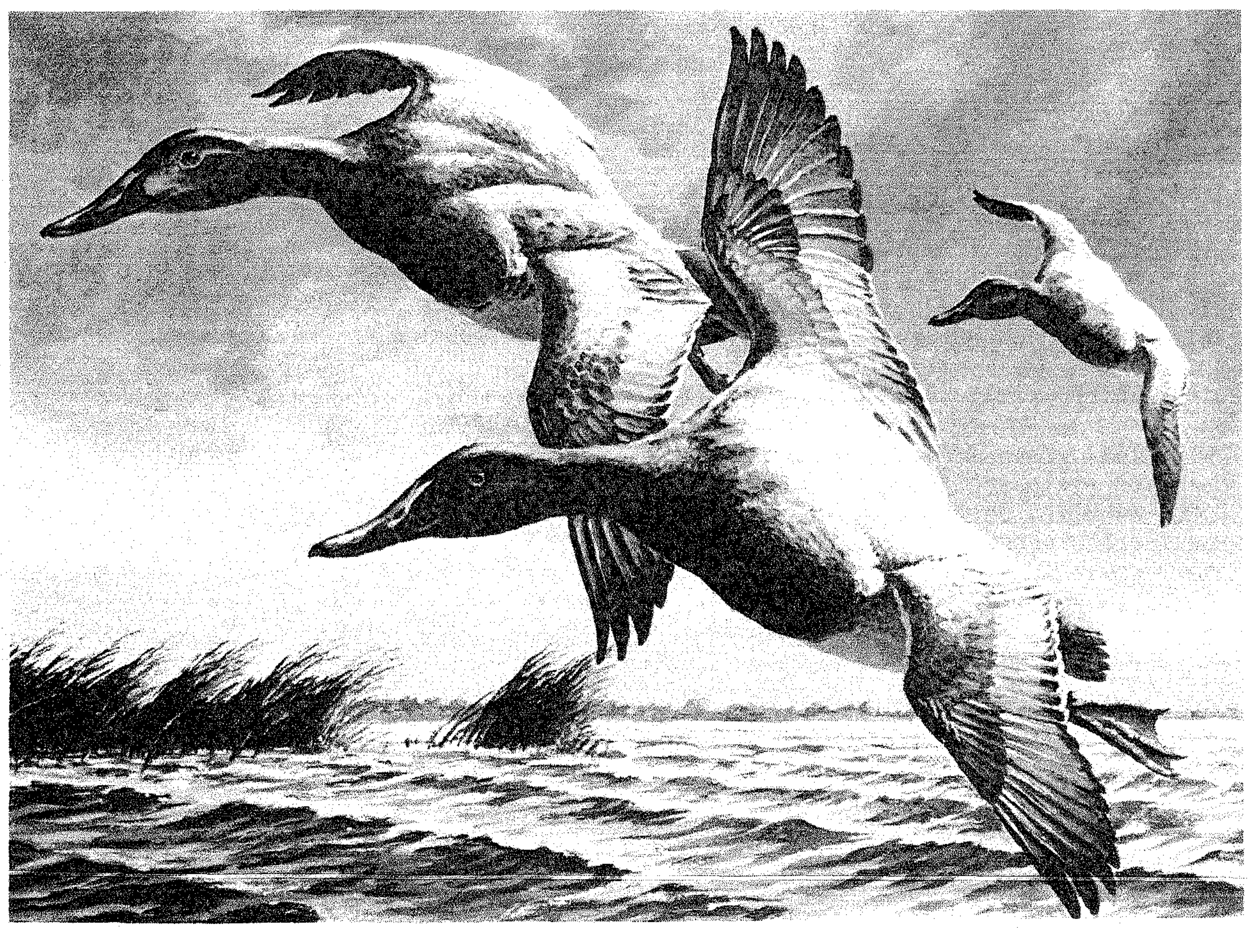


Figure 23. Canvasback ducks are protected from hunting on the Detroit River (Printed with the permission of David Maass, the artist; 1982-83 Federal Duck Stamp).

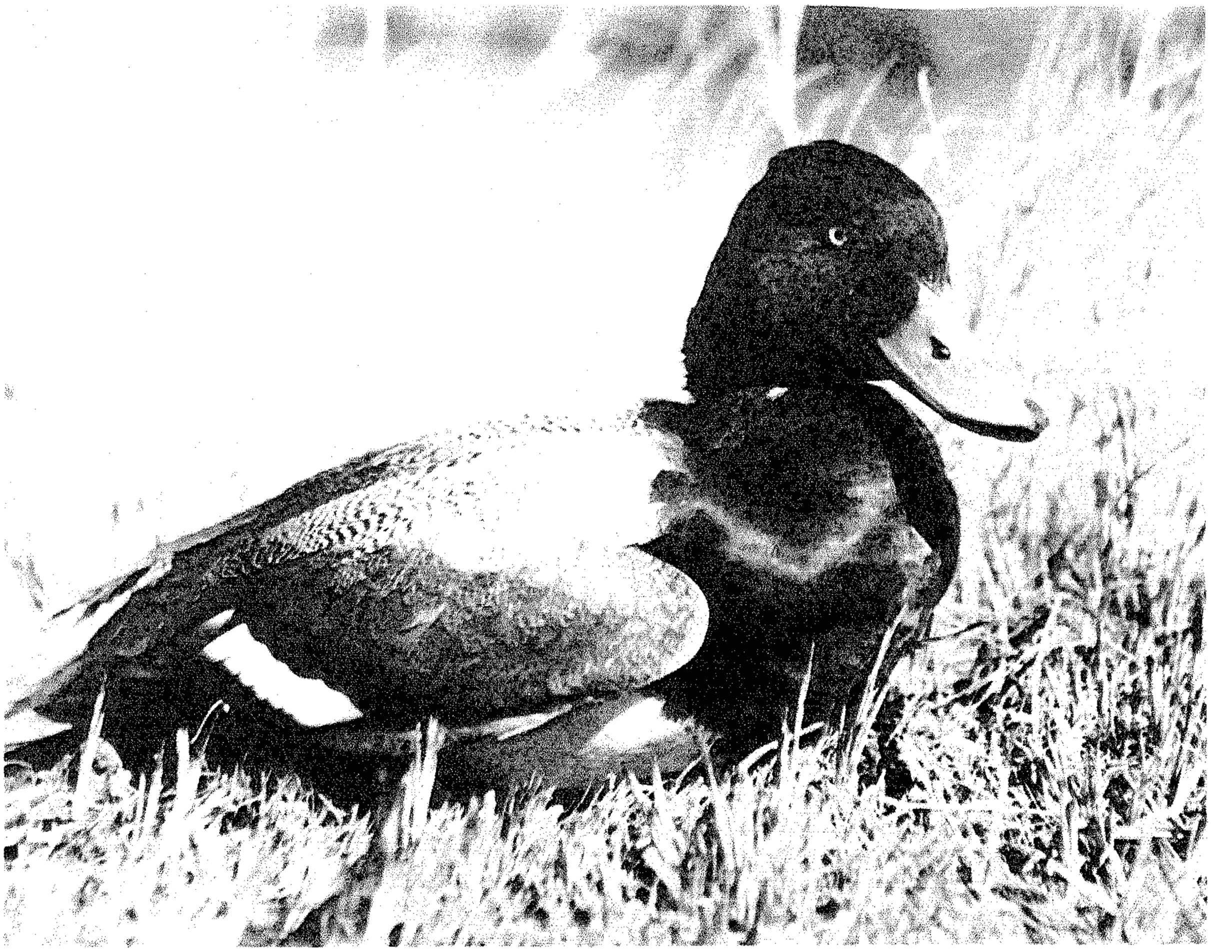


Figure 24. Lesser scaup are harvested frequently by Detroit River hunters (Photo provided by E. R. Quortrup).

In the past, 24 species of ducks regularly fed in the Detroit River (Hunt 1957). Major concentrations of feeding ducks are usually observed in littoral waters around Belle Isle and Mud, Fighting, Sugar, and Celeron Islands, and Grosse Ile (Jones 1982). Mergansers feed primarily on fish, whereas American goldeneye prefer crayfish, clams, and other invertebrates. Many diving ducks, such as canvasbacks, redheads, and scaup, feed on submersed aquatic plants, including _Vallisneria americana_, _Potamogeton_ spp., and _Elodea canadensis_. In general, submersed plants and their associated invertebrate animal communities provide most of the foods required by waterfowl (Schloesser 1986).

CHAPTER 4. ECOLOGICAL RELATIONSHIPS

4.1 PRIMARY AND SECONDARY PRODUCTION

As noted earlier (Section 3.1), the phytoplankton and periphyton in the Detroit River are not well studied. Fortunately, production by plants and animals in connecting channels of the Great Lakes was recently reviewed (Edwards et al. 1987). This review concluded that submersed aquatic macrophytes are the major primary producers of organic matter in the Detroit River (Table 21). Production of emergent macrophytes in Table 21 represent above ground biomass only. The amount of allochthonous input of organic matter (leaves and insects) into the Detroit River is unknown so estimates in Table 21 were based on data in the scientific

Table 21. Annual mean standing crop, and net production of primary and secondary producers, and terrestrial inputs in the Detroit River (Edwards et al. 1987).

Producers	Standing crop (g AFDW/m^2)[a]	Net production (t AFDW/yr)	Total Production (%)
Primary producers			
Phytoplankton	0.67	7,430	26
Periphyton	3.0	4,370	15
Submersed macrophytes	113	12,380	44
Emergent macrophytes	374	4,030	14
Total		28,210	
Secondary producers			
Zooplankton	0.46	1,140	64
Macrozoobenthos	0.75	640	36
Total		1,780	
Tertiary producers			
Fish	3.4	280	
Terrestrial inputs			
Leaves and insects		260	
Sewage		25,665	

[a] Ash-free dry weight.

literature (VPI 1985; Gasith and Hasler 1976). Direct sewage inputs to the Detroit River in Table 21 were estimated by Edwards et al. (1987) from STORET retrieval of 1984 water year data. The estimate of fish production in Table 21 is extremely tenuous because it was derived from estimated primary production using the 10% trophic transfer rule of Lindemann (1942). A more adequate estimate would include production by resident and migratory fish stocks, neither of which has been measured yet. More research is needed to determine fish production in the Detroit River.

The next most important primary producer is the phytoplankton. Sewage effluents now add about as much organic matter to the river as all natural primary production combined. Presumably, the production of fishery resources in the Detroit River is more dependent on naturally produced organic matter than on organic matter in sewage. Fish and waterfowl, for example, feed directly on macrophytes and the invertebrate animals that colonize macrophytes (Table 22). However, filter feeding benthic animals, such as caddisflies and small clams, would remove particulate organic matter from the water indiscriminantly before they were consumed by fish. Additional research is needed to determine how much organic matter in sewage effluents forms the basis for the food web in the river.

Production data (Table 21) are an important first step in understanding food chain dynamics of the Detroit River, but one must know how each level is used or transferred to subsequent trophic levels. This understanding would integrate the simultaneous effects of all components according to their interrelationships in the ecosystem. The Detroit River produces net biomass and does not simply transport phytoplankton and zooplankton from Lake

Table 22. Underwater plants that provide cover and food for fish and waterfowl in connecting channels of the Great Lakes (Schloesser 1986)[a].

	Muskgrass	Coontail	Eurasian water-milfoil	Naiad	Water stargrass	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 upon the invertebrates that colonize the plants; waterfowl feed on both the plants and the invertebrates.

Huron to Lake Erie. However, available information is inadequate to determine how much of the phytoplankton, macrophytes, and zooplankton produced in the river is used by river biota. If only a small amount of phytoplankton and zooplankton biomass passing through the Detroit River is retained, then the littoral plant complex of emergent and submersed macrophytes and the associated periphyton are the dominant primary producers and macrozoobenthos are the main secondary producers in the river.

Not included in Table 21 are pools of dissolved organic matter (DOM) and particulate organic matter (POM), which often exceed by many times the amount of organic carbon of the living plankton, macrophytes, and fauna produced in streams (Wetzel 1975). The only DOM measurements available are from Lake Huron and average 2.7 g/m^3 (Robertson and Powers 1967). The amount of POM coming into the St. Clair-Detroit River system from Lake Huron may be about 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 in Lake St. Clair (Leach 1972). A single POM sample from the mouth of the Detroit River measured 3.8 g/m^3 (Robertson and Powers 1967), but bedload movements of POM have not been studied so this value of 3.8 g/m^3 may underestimate POM in the Detroit River. In 1982, suspended solids increased more than two-fold from an average of 8.8 g/m^3 in headwaters to 19.6 g/m^3 at the mouth of the Detroit River (Kauss and Hamdy 1985). Estimated loadings of suspended solids by the river to Lake Erie are very large (4,600 t/day; Table 9). Therefore, much POM is either produced in or added to the Detroit River continuously. Additional research is needed to determine the loadings of organic matter in all forms by the Detroit River to Lake Erie.

For at least 30 years, the largest contributors of organic matter to the Detroit River have been sewage treatment plants (see Sections 1.6 and 6.4). Macrophytes produce large quantities of organic matter and also provide much of the physical structure available in the river. Large plant debris (trees) that serve as centers of fish production in other rivers (Karr and Schloesser 1978; Benke et al. 1985) are removed during periodic channel dredging of the Detroit River.

The amount of organic matter produced in littoral waters, its storage, and its transport deserve more attention. Without this information, a full understanding of fish and other secondary production in the Detroit River will not be possible.

4.2 DETRITAL FLOW

Of the nearly 210,000 t of plant biomass produced in the St. Clair-Detroit River System each year, only 13% originates in the Detroit River (Table 23). In contrast to the dominance of emergent aquatic macrophytes in the St. Clair River and Lake St. Clair, most primary production (44%) in the Detroit River was produced by submersed macrophytes. Some of this plant biomass is consumed directly by waterfowl (Dawson 1975; Jones 1982) but we assume most of this plant biomass becomes detritus each year. We do not know how much of it is used for animal production in the river or in Lake Erie.

Owing to the short flushing time of the connecting channel, almost all the phytoplankton biomass (71,490 t), representing 34% the total plant biomass produced in the connecting channel system, likely passes through to and is used in Lake Erie. The fate of the remaining plant biomass is incompletely known. In 1985-86, aquatic macrophytes drifting down the Detroit River were studied by the U.S. Fish and Wildlife Service (National Fisheries Research Center-Great Lakes, unpubl.). Preliminary analysis of these drift data suggest that most plant biomass is produced from June to September in the Detroit River and drifts down to Lake Erie from July to September. Large movements of dead and decaying plant matter were also observed near the bottom in the St. Clair River in spring (Edsall et al. 1988). Apparently, much of the periphyton and submersed macrophytic biomass produced in the Detroit River dies back in fall, remains on the bottom during winter, and moves downstream to Lake Erie in spring. If true, this analysis partly explains the high productivity of benthic macroinvertebrates in the western basin of Lake Erie. For at least half the year, the production

Table 23. Annual net production by primary producers in the St. Clair-Detroit River System (Edwards et al. 1987).

Producers	Annual net production (t ash-free dry wt/yr) Detroit River	St. Clair River	Lake St. Clair	Total	% of Total
Primary producers					
Phytoplankton	7,430	3,900	60,160	71,490	34
Periphyton	4,370	1,160	16,720	22,250	11
Submersed macrophytes	12,380	2,290	13,780	28,450	14
Emergent macrophytes	4,030	22,620	60,990	87,640	42
Total	28,210	29,970	151,650	209,830	
% of total	13	14	72		

of macrozoobenthos probably benefits from an abundant food supply, owing to the large accumulation of decaying macrophytes from the Detroit River.

The rate with which detritus is produced, processed, and moved downstream, in large measure determines the productivity of and energy flow through biotic communities in rivers (Cummins et al. 1984; Minshall et al. 1985). In fact, the most inclusive theory available (Cummins et al. 1984) suggests that riverside vegetation exerts primary control over biotic associations in the river by providing organic matter that can be utilized directly by animals. The organic matter added to the Detroit River by sewage treatment plants may be too contaminated with toxic substances to directly support higher forms of animal life. Therefore, biomass produced by emergent and submersed aquatic macrophytes is probably the basis for most animal production in the river and some animal production in western Lake Erie. Any human activity that reduces the production of aquatic macrophytes in the river may also reduce the production of fish and wildlife resources in both the Detroit River and western Lake Erie.

4.3 TROPHIC RELATIONS

The trophic structure of the Detroit River has not been adequately described. A number of biological surveys have documented biotic communities in the river, particularly diatoms, emergent wetlands, macrozoobenthos and fish (Wujek 1967; Jaworski and Raphael 1978; Thornley 1985; Haas et al. 1985). These studies indicate that the river is becoming more biologically productive in response to controls implemented to reduce pollution and improve water quality. However, we do not understand in detail how the various trophic levels in the river relate to one another. From calculations of detrital biomass (Section 4.2) and studies of fish larvae (Section 3.2) it is apparent that the Detroit River is a large source of detrital organic matter and larval fish that support productivity in western Lake Erie. The river does not simply transport organic matter from Lake St. Clair to Lake Erie, but rather is a net producer of organic matter. No information exists on how much pollutant loading, past or present, depressed biological production in the river. Research on this topic would be useful in restoring beneficial uses of the river, in conformance with the 1978 Water Quality Agreement between Canada and the United States.

If only a small amount of drifting organic matter (primarily plankton and particulate detritus) entering the Detroit River from Lakes Huron and St. Clair is deposited or utilized in the river, then the littoral emergent and submersed macrophyte beds in the river are the dominant primary producers. Conversely, if large amounts of the drifting organic matter from upstream waterbodies are deposited and used as an energy source by the resident biota of the river, then secondary production in the Detroit River is based mainly on drifting phytoplankton and detritus. Measurements to resolve this trophic question are needed and should include organic matter added by municipal sewers and urban runoff.

CHAPTER 5. COMMERCIAL AND RECREATIONAL ACTIVITIES

5.1 INDUSTRIAL SIGNIFICANCE OF THE WATERWAY

The Detroit River is the most heavily industrialized connecting channel in the Great Lakes (USACE 1976b). Like the Indiana Harbor-Calumet Waterway of southern Lake Michigan and the Toronto-Hamilton Harbor area of Lake Ontario, the principal industries include steel mills, electrical power generating plants, and automobile manufacturing facilities. Such primary industries develop on the shoreline, rely on Great Lakes shipping, stockpile raw materials, and use relatively large quantities of freshwater for cooling or industrial processes (Table 24). These industries, though vital to the Great Lakes economy, have intensively developed the shoreline and reduced the amount and diversity of habitats available to fish and wildlife.

Industrial use of the waterway derives, in large part, from the Great Lakes-St. Lawrence Seaway and the Detroit and Windsor harbors, as well as the ports of Rouge River, Ecorse, Wyandotte, Riverview, Trenton, and the City of Detroit (USACE 1979). As discussed in Section 1.4, navigation on the Detroit River consists largely of intralake shipments of bulk commodities such as coal, limestone, iron ore, grain, and liquid fuels. Since the early 1970's, the traffic volume and number of vessel transits has declined by half because of an overall decline in Great Lakes commercial shipping.

The most significant adverse environmental impacts of commercial navigation are associated with dredging, disposal of dredged materials, and the operation of large or deep-draft vessels (USDI 1985). Dredging of the Detroit River navigational channels resuspends and disperses contaminated sediments. The plumes of turbidity from dredging upriver tend to remain close to the shore, but diffuse across the

Table 24. Resource use of the Detroit River (USEPA 1985)[a].

Use category	Extent of use
Commercial shipping	
Through traffic	Approx. 75 million t (1981)
Freight handled at ports	33.4 million at 16 ports (1981)
Drinking water supply	19 water intakes, serving 3.95 million people
Major population center	Population over 5.0 million in 5 major cities
Point source discharger	28 municipal facilities, 111 industrial
Recreational fishing	Approximately 1.5 million angler days/year
Shoreline land use	Industrial, commercial, and residential developments occupy about 78% of the Michigan shoreline

[a] Michigan waters only.

entire river below Fighting Island (USDI 1985). Vessel-induced currents resuspend contaminated sediments and also fragment or uproot submersed vegetation in the littoral areas. Strong currents are produced by vessel passage and the action of the bow thrusters of lake carriers that occupy over 50% of the cross-sectional area of the ship channel in the narrow parts of the river. Ship channels are largely devoid of submersed vegetation and lined with coarse sediments.

Deepening of the Great Lakes-St. Lawrence Seaway does not appear to be economically feasible at this time; however, there has been much research regarding the potential environmental impacts of winter navigation (USACE 1976b, Niimi 1982). The potential impact of winter navigation on fish spawning is uncertain, but ice scour could disrupt spawning substrate. An ice jam in the St. Clair River in 1984 reduced water temperatures and delayed fish spawning activity for about 2 months (Muth et al. 1986). Winter navigation apparently does not affect feeding by wintering waterfowl because they tend to cluster in shallow, ice-free areas adjacent to islands or the mainland, few of which are near the ship channels (Davis and Erwin 1982, Jones 1982). However, ice scour and ice jams associated with winter navigation reduced the taxonomic diversity of benthos (from 24 to 15 abundant species) in littoral areas of the Detroit River for one year (Hudson et al. 1986). In the St. Marys River, winter navigation resuspended detritus and accelerated the downstream losses of organic matter (Poe and Edsall 1982). Such impacts of winter navigation have not yet been documented in the Detroit River.

The industrial use of the Detroit River is not expected to change much in the near future. However, there will be more attention to discharges of industrial and municipal wastes into the river, because the Detroit River was designated a Class A Area of Concern by the International Joint Commission. There are 42 such areas in the Great Lakes. In the Detroit River, criteria were exceeded for acceptable concentrations of fecal coliform bacteria in water, PCB's in fish and waterfowl, mercury in sediments and for damage to benthic invertebrate communities. These criteria were defined in the 1978 Water Quality Agreement between Canada and the United States or jurisdictional standards to protect beneficial uses of the river. In 1986, the International Joint Commission recognized that remedial actions were needed to restore municipal and industrial water supplies, recreation, and healthy aquatic life. A remedial action plan for the Detroit River is being developed in 1987 by Michigan and Ontario.

Because of inadequate monitoring and surveillance data, there is no agreement that water quality in the Detroit River is good or that it has been improving since 1970 (MDNR 1984). Reductions in point-source loading, coupled with the rapid flushing rate of the river, tend to improve water quality, but high levels of heavy metals and chlorinated organic compounds in river sediments, especially on the Michigan side south of the Rouge River mouth, continue to exceed safe guidelines (Limno-Tech 1985). These polluted sediments, plus combined sewer overflows and discharges from the Detroit Wastewater Treatment Plant (Section 6.1) are the main reasons for the area-of-concern designation and fish-consumption advisories.

5.2 COMMERCIAL FISHERIES

There is presently no commercial fishery in the Detroit River. A commercial fishery primarily for lake whitefish, lake herring, walleye and yellow perch first developed in the river in the early 1800's (Haas and Bryant 1978). By the 1870's, catches of 10 major native species in the St. Clair-Detroit River system were recorded annually and in 1900 catches of carp, a nonnative species introduced into the Great Lakes in the 1880's, were added to the record (Table 25). These records show that the catches of lake sturgeon, lake herring, lake whitefish, smallmouth bass, 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

Table 25. 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.

through the 1960's. Catches of northern pike (exclusively a Canadian fishery), common 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 the more desirable species were probably due to overfishing (Haas and Bryant 1978).

The catch records reflect the closure of the commercial fishery in 1909 in Michigan waters to promote sport fishing. 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, an Ontario commercial fishery for selected species was reopened in Lake St. Clair but not in the Detroit River.

5.3 RECREATIONAL FISHERIES

A significant recreational fishery has existed in the Michigan waters of the St. Clair-Detroit River system since the turn of the century, but there are few records of the early fishery. The first creel census conducted by 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 that the average annual fishing effort had increased to 1,331,000 angler days, and the annual catch to more than 500,000 fish in 1966-67, and to 1,429,000 angler-days and 8,381,000 fish annually 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

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 (all species)
1942-1943[a]	319,000	698,000
1966-1967[a,b]	1,331,000	5,074,000
1971-1977[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 1966.
[c] Includes winter fishery and fishing activity on the St. Clair and Detroit Rivers.

interpreted with caution because the earlier records did not include the winter fishery, fishing activity on the St. Clair and Detroit rivers, or both. In 1983-85, an extensive survey of the recreational fishery in Michigan waters of the St. Clair system (the St. Clair River, and Lake St. Clair), and the Detroit River (Haas et al. 1985) revealed an average annual fishing effort of 4,172,000 angler-hours and an average combined catch of 2,813,000 fish by boat, shore, and ice anglers. The average annual fishing effort in 1983-85 was higher in the St. Clair system, but the catch was higher in the Detroit River (Table 27). Boat anglers expended about 66% of the effort, followed by shore (22%), and ice (16%) anglers and the total catch by these groups was roughly proportional to effort; boat anglers caught 64% of the total catch, shore anglers 19%, and ice anglers 16%. 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. In 1983-85, white bass was the single most abundant species caught in the Detroit River, followed by walleye and yellow perch (Table 28).

Records show the recreational fishery in Ontario waters of the Detroit River (Sztramko 1980) to be substantially smaller than that in U.S. waters (Haas et al. 1985). Each year from 1976 to 1979, in Ontario waters of the Detroit River, anglers expended an average of 149,787 hours of fishing effort and caught an average of 142,363 walleyes, white bass, freshwater drum, yellow perch, smallmouth bass, and rock bass. In 1983, in Michigan waters of the Detroit River, anglers expended 1,523,485 hours of fishing effort and caught 1,782,802 white bass, walleyes, yellow perch, rock bass, and drum.

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

Section	Angler hours	Catch of all species combined
Detroit River	1,409,000	1,421,000
St. Clair system	2,763,000	1,392,000
Total	4,172,000	2,813,000

Table 28. Major fish species composing the recreational catch in the St. Clair-Detroit River system, 1983-85 (Haas et al. 1985)[a].

Species	Detroit River	St. Clair system
Walleye	12	48
Drum	7	8
Yellow perch	10	35
White bass	63	0

[a] Percentage of total catch by species.

The value of the recreational fishery in just Michigan waters of the St. Clair-Detroit River system in 1975-77 was in excess of $10 million annually (Haas and Bryant 1978).

Major recreational fishing areas, as identified by charter boat operators, are illustrated in Figure 25. Study of these fishing areas reveals a positive correlation with nearshore environments, wetlands, and relatively higher water quality. In the upper Detroit River, walleye fishing takes place in nearshore and island environments. In the lower Detroit River, fishing tends to focus on white bass, northern pike, and other species, in the main channels near Stony and Bois Blanc Islands. Large catches of white bass are taken east of Grosse Ile, west of Stony Island, and adjacent to Sugar Island. The major fishing area in the southern part of the Trenton Channel is not of high environmental quality, but is an area where walleyes are caught as they migrate upstream in late spring and early summer.

5.4 WATERFOWL HUNTING

Michigan has long enjoyed a tradition of quality duck hunting, as evidenced by the popularity of duck shooting clubs that

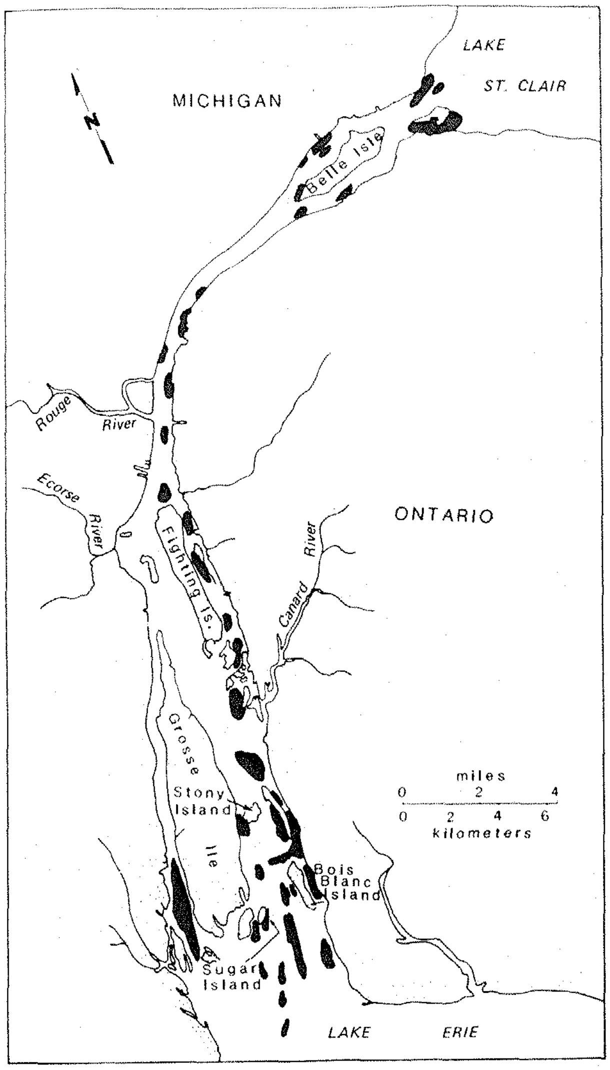


Figure 25. Major recreational fishing areas in the Detroit River (Lake St. Clair Advisory Committee 1975).

trace back to the mid-1800's. Dawson (1975) and Jaworski and Raphael (1978) provide useful descriptions of this activity, upon which we have drawn freely in the following discussion.

The lower Detroit River from the northern end of Grosse Ile to open waters of Lake Erie serves as an important resting and feeding ground for migrant diving ducks (Miller 1943). Before 1960, great rafts of canvasback, redhead, scaup (locally called bluebills), and other divers fed intensively on wild celery and other aquatic resources in a zone stretching from Gibraltar and the southern tip of Grosse Ile to the Detroit River Light Point, which is located at the southern end of Livingstone Channel (Hunt 1963; USDI 1967).

During the 1941 waterfowl hunting season, an estimated 4,800 hunters harvested a total of 44,500 ducks in the lower Detroit River and adjacent Lake Erie (Miller 1943). A daily kill of several canvasbacks, redheads, or both was common at that time. Because most of the shooting was done in open water, hunters used floating blinds, drift boats, and layout boats to distribute their decoys, and pick up the kill (Figures 26 and 27).

A high proportion of the waterfowl taken annually in Michigan comes from the St. Clair-Detroit River system because waterfowl congregate there. 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%

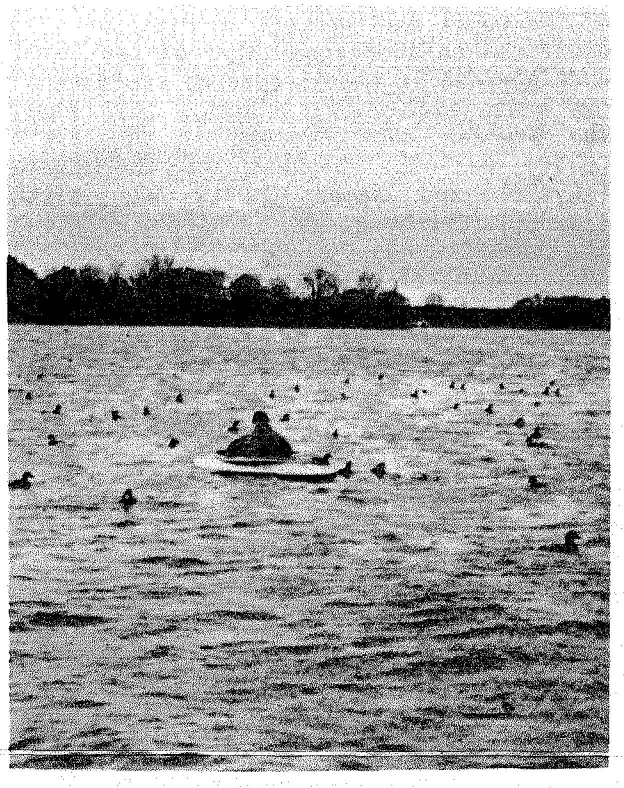


Figure 26. Waterfowl hunter in a layout boat hunting diving ducks, circa 1940 (Miller 1943).

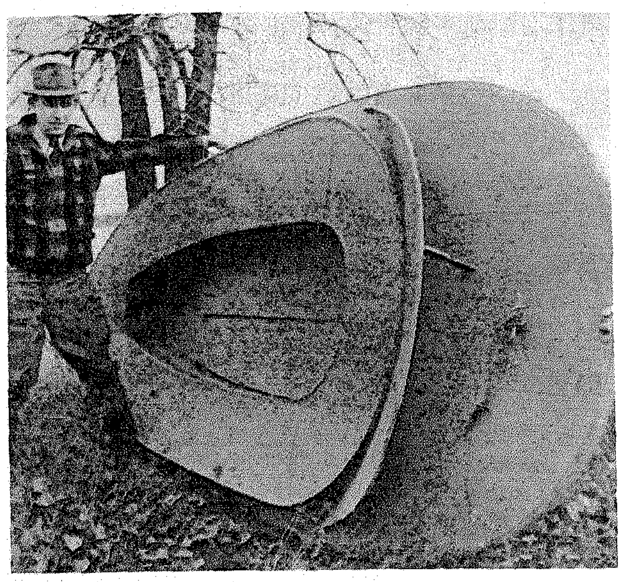


Figure 27. Closeup of layout boat used to hunt waterfowl on the Detroit River, circa 1940 (Miller 1943). Note the canvas coaming that may be raised to keep out the waves that often roll over the decking.

of the total duck harvest in Michigan's 83 counties and about one-third of the total duck harvest in the 41 coastal counties of the state (Table 29). During this time, the average duck harvest in St. Clair County was the highest in the State (16,426) and Wayne County was sixth (10,080) (Carney et al. 1975).

Hunting of waterfowl (primarily scaup and mallard ducks) in Michigan during the October-November hunting season continues to be an important recreational activity. During 1971-75, 116,744 waterfowl hunters expended 1,232,526 "recreation" days of hunting effort and bagged about 685,000 ducks, geese, and coots annually in Michigan (Table 30).

At present, waterfowl hunting in the Detroit River is characterized by fewer hunters and a declining duck harvest. Using Wayne County data as the best available measure of waterfowl hunting in the Detroit River (Table 31), it is evident that diving ducks dominated the annual kill, from 1971 to 1980, and that lesser and greater scaup composed 56% of the ducks taken. According to Martz and Ostyn (1977), over half of the scaup arrive in southeastern Michigan, including the Detroit River, in November, which is near the end of the 55-day waterfowl season. Whereas diving ducks are taken with floating blinds, sneak (or drift) boats, and the few remaining layout boats (cf. Figures 26 and 27), the mallard and other dabblers are hunted from the shore or from blinds.

Michigan's waterfowl hunting regulations provide for a daily limit of birds worth a total of 100 points, based on the Mississippi Flyway Point System. According to that system a female mallard or a black duck is 100 points; a redhead is 70 points; a drake mallard, bufflehead, common goldeneye, or ruddy duck is worth 35 points, and a scaup is 20 points. According to the Michigan Department of Natural Resources Small Game File computer print-out for Wayne County, in 1985 a total of 589 waterfowl hunters expended 3,259 recreational days and bagged a total

Table 29. Annual average harvest of ducks in Michigan, 1961-70 (Carney et al. 1975).

County	Dabblers	Divers	Total	%
St. Clair	8,475	7,951	16,426	7
Wayne	2,210	7,870	10,080	4
All 41 other coastal counties	40,050	27,632	67,682	28
All 40 inland counties	102,581	44,196	146,777	61
Total	153,316	87,649	240,965	

Table 30. Annual waterfowl hunting effort and harvest in Michigan, 1971-75 (Michigan Department of Natural Resources, Biennial Reports).

Year	Effort		Harvest		
	Number of hunters[a]	Number of recreation days	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 31. Annual average duck harvest, Wayne County, Michigan, 1971-80 (Carney et al. 1983).

Diving ducks		Dabbling ducks	
Lesser scaup	4,773	Mallard	1,643
Greater scaup	1,480	Black duck	292
Ruddy duck	858	American wigeon	163
Common goldeneye	443	All others	385
Bufflehead	375		
All others	838		
Total	8,767		2,483

of 3,176 ducks, 468 geese, and a few coots. These figures compare most unfavorably to the number of hunters and the duck harvest cited above for the 1941 hunting season. The population in the Detroit area has increased markedly since 1941, yet the number of waterfowlers dropped by approximately 32%, and the duck kill declined 93%.

Examination of the current waterfowl census data reveals a long-term population decline of many waterfowl species, especially of canvasback and redhead (J. Martz, Michigan Department of Natural Resources; pers. comm.). However, the decline in the annual harvest of waterfowl in the Detroit River may reflect not only population declines and changing hunting regulations, but also the quality and quantity of feeding and resting habitat in the lower Detroit River (cf. Section 6.6).

Since 1979, the season on canvasback has been closed in Michigan but Ontario hunters are still allowed to shoot canvasback ducks. Today most hunters would be pleased indeed to bag one relatively large duck, such as a canvasback or mallard, per daily outing.

Although Michigan licensed approximately 116,750 waterfowl hunters annually in the 1970's (Table 30), 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 estimate 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. In 1976, at three public game areas located within coastal wetlands, there were 10,700 applicants, but only 3,460 possible reservations (Michigan Department of Natural Resources, Permanent Files). Hence, only 32 % of the applicants could be served, and there is a large unsatisfied demand for quality waterfowl hunting.

A study by the Great Lakes Basin Commission (1975b) showed a projected increase in hunters throughout Michigan, but a projected decrease in acres of wildlife habitat and a decrease in potentially huntable land. Another study of Monroe County, just south of the Detroit River mouth, revealed that wildlife in North Maumee Bay was suffering from a degraded and decreasing habitat base and that future waterfowl hunting opportunities in the North Maumee Bay area were limited due to restricted access, poor water quality, lack of supportive facilities, and vandalism (Jaworski and Raphael 1978). A recent study of wild celery tubers available as food for ducks in the lower Detroit River showed a net decrease of 73% in the densities of tubers in traditional feeding areas (see Section 6.6).

Waterfowl hunting does contribute to the economy of Michigan. The 1980 National Survey of Hunting and Fishing indicates that each American waterfowl hunter spent an average of $120 on equipment, licenses, transportation, and miscellaneous related items. Although most waterfowl hunters are residents of rural areas and hunt in nearby counties, hunters from Detroit, Lansing, Grand Rapids, and Flint often travel considerable distances to hunt waterfowl and probably spend much more than $5, the transportation component of the estimated annual waterfowl hunter expenditure. Therefore, an economic evaluation based on estimated annual expenditures may underestimate real expenses.

Using the 1977 estimated average waterfowl-hunter expenditure of $130.25, Michigan's waterfowl hunters contributed over $15 million dollars to the state economy, and in terms of harvest, waterfowl hunting is worth $37.79 per bird. If data on number of hunters and distance traveled were available for each coastal wetland, the economic importance of waterfowl hunting and protection of wetlands could be determined. Further, if expenditures by potential hunters were included, the value of waterfowl hunting in Michigan could exceed $30 million.

Other economic techniques, for example, methods based on opportunity costs or on the willingness of participants to pay, may yield values higher than the above analysis. Other values, including the harvest of Michigan-reared birds in other states, in addition to those estimated above, may also increase the value of waterfowl hunting.

Lastly, the meat from harvested waterfowl is important because many families, particularly in rural areas, supplement their diet with wild game.

5.5 RECREATIONAL USES

Recreational boating in the Detroit River is well established due to relatively good water quality and marinas and public boat launch areas. In the Detroit River area, nearly 60% of the boating activity was related to fishing (Stynes and Safronoff 1982). May, June, and July are the most important months for recreational fishing in the Detroit River (Haas et al. 1985). Boating activity during waterfowl hunting season in October and November has not been adequately quantified.

In general, there is a relatively large unfulfilled demand for recreational opportunities and facilities in the City of Detroit and the Wayne County area. In 1976, an interagency task force found that development of marinas and other recreational facilities in the Detroit River was hampered by lack of aid to develop property, inaccessibility of available land on the riverfront, and incompatibility of other existing land variances (WCPC 1976). Local recreational plans have not been prepared, due to inadequate funding, lack of land for public acquisition, incompatibility with industrial use, and localized areas of degraded water quality (WCPC 1977).

Much of the available land for recreational development lies in the township of Grosse Ile. Although most of the island and wetlands along the shores of Grosse Ile are currently zoned as "natural areas" with only approved research allowed, the township's development plan is under revision. From a legal standpoint, the shoreline of Grosse Ile is a resource of State and National importance (Dean 1986). Pressure for additional marina facilities nearly resulted in the loss of Gibraltar Bay on southern Grosse Ile to commercial development (Seegert 1984).

CHAPTER 6. MANAGEMENT ISSUES AND RECOMMENDATIONS

6.1 COMBINED SEWER OVERFLOWS

Until recently, water from storm drains was combined with that in sanitary sewers and allowed to overflow into surface channels at designated points when volume exceeded capacity. Numerous combined sewer overflows (CSO's) enter the Detroit River, including 64 on the Michigan shoreline, 24 on the Ontario shoreline, and 185 on the Rouge River, which empties into the Detroit River. The extensive system of rural, suburban, and urban storm drains are a direct man-made extension of the river system. In addition to providing efficient drainage of precipitation runoff and high groundwater, the stormwater drainage system also transports to the river pollutants generated by modern society, including effluents from landfills containing sanitary and hazardous wastes. This immense sewer system, into which millions of gallons of domestic and industrial wastes are discharged daily is, in effect, a parallel river system designed to carry wastewater used by society. As with the river, this wastewater flows downstream in interceptors that parallel the river. At Detroit's Waste Water Treatment Plant they are treated and returned to the natural environment as discharge to the Detroit River. Combined sewer interceptors that serve the Rouge River Basin, including all the separate sanitary sewer systems, represent an interconnection between the sewer system and the Detroit and Rouge Rivers. This interconnection provides the avenue for wastewater pollutants to enter the Rouge River through combined sewer overflows during virtually all periods of wet weather.

Combined sewer overflows are not only a source of raw sewage during wet weather, but also a source of toxic substances (Table 32). Concentrations of many of these pollutants in CSO's exceed safe levels. During an average year, the total CSO volume from sewers to the Rouge River and from the City of Detroit to the Detroit River is very large (22.7 and 47.1 million m^3, respectively, Giffels/Black and Veatch 1981; Ecolsciences 1985). Sediments in many of the sewer pipes probably contain very high concentrations

Table 32. Average concentrations of various pollutants (mg/L) and fecal bacteria (no. of organisms/100 ml) entering the Detroit and Rouge Rivers from combined sewer overflows (Giffels/Black and Veatch 1981).

Pollutant	Rouge River	Detroit River
Biological Oxygen Demand	73	85
Total Suspended Solids	149	205
Total Dissolved Solids	357	360
Total Volatile Solids	210	131
Total Phosphorus	6	4
Inorganic Phosphorus	1	2
Fecal Coliform	5,170	161
Fecal Streptococci	505	49
Arsenic	91	69
Cadmium	28	41
Chromium	79	129
Copper	129	218
Iron	2,550	2,270
Lead	166	447
Mercury	34	45
Nickel	455	139
Silver	33	38
Zinc	222	555
Chlorides	74	44
Oil and grease	154	94
Polychlorinated biphenyls	17	2
Phenols	14	17
Total Kjeldahl Nitrogen	6	18

of persistent toxic substances originating from past spills, landfills, and illegal discharges. For example, recent studies showed that sediments in sewer pipes entering the Detroit River possessed very high PCB concentrations (up to 4,900 mg/kg dry weight; Kenaga 1986) and that such sewer pipes are active sources of PCB contamination in sediments of the Detroit River (Kenaga and Crum 1987). These findings indicate that not only the overflows from such pipes, but also the sediments they carry, should be carefully monitored to identify sources of contaminants. Clearly, CSO's are a major active source of toxic substances to the Detroit River and a more vigorous enforcement of pretreatment programs is needed to control these substances at the source.

A recent study of improper waste discharges to a stormwater system in Ann Arbor, Michigan, concluded that urban non-point pollution is not limited to road runoff, but also contains wastes from permitted and illegal discharges, many that were previously unsuspected (Schmidt and Spencer 1986). The Ann Arbor study evaluated the magnitude of the problem, isolated individual pollutant dichargers, and demonstrated that control of illegal discharges rapidly reduced pollutant concentrations in the stormwater drains. Of the 160 businesses investigated, 50% had at least one storm drain connection that discharged potentially hazardous substances. Improvements in water quality were noted as these discharges were eliminated. It is recommended that a similar approach (i.e., control at the source) is warranted to eliminate illegal discharges to stormwater systems that enter the Rouge and Detroit Rivers.

Operation of the sewer interceptor systems and planning for pollution control have not been coordinated in a basinwide effort to control the discharge of pollutants. In disregard for the manner in which hydrologic systems function, interact, and transport pollutants, sewer planning in the Rouge and Detroit River Basins has been established along political boundaries rather than along subdrainage basin boundaries. Until recently, plans were formulated by local political entities to secure multimillion dollar Federal construction grants and enhance sewage transport facilities within their own jurisdictions, with little regard for the benefits or impacts such measures might have on river water quality in adjacent jurisdictions.

In 1985, it was recognized that water quality in the Rouge and Detroit Rivers could be greatly improved by creating a basinwide authority that would formulate and implement a coherent plan for reducing contaminant inputs by CSO's (Ecolsciences 1985). Moreover, monitoring and surveillance to estimate pollution entering the rivers from CSO's was recognized as necessary but almost nonexistent.

In 1986, the Rouge River Basin Committee was organized with support from the State of Michigan and the Southeast Council of Governments to address these issues. The Committee includes drain commissioners and wastewater engineers from each jurisdiction, political leaders, and representatives from citizens action groups. Through cooperation and mutual respect, with support at State and Federal levels, this Committee will strive to reduce pollutant loadings by CSO's to the Detroit and Rouge Rivers. They recognize that everyone benefits from improved water quality.

The Michigan Department of Natural Resources has monitored ambient water quality in the Detroit River for the last 20 years (MWRC 1967). The sampling method was designed to document water-quality trends and calculate annual pollutant loads to Lake Erie, particularly phosphorus. These measurements showed that water quality has steadily improved in the Detroit River over the past 20 years (see Table 8 and 9 in Section 2.7). In 1985, this sampling design was reviewed for relevance of the data to modern water quality concerns. Recent methods for calculating pollutant loads have shown that monthly surface grab samples on the Detroit River may neither be adequate for load determinations, nor of sufficient accuracy for modern resource management needs. While a new sampling design is being developed, the existing monitoring program, with some modification, will be continued so that there is no break in the record.

6.2 DREDGING

Enormous quantities of sediment have been dredged from the Detroit River and its tributaries (Table 33). Dredging will continue to be authorized to maintain the seaway navigation channels, approach channels, and berthing areas in the Detroit River (Section 1.4). However, due to recent high water levels and a decline in vessel traffic on the Great Lakes, there is little current economic justification for other than maintenance dredging. In both Michigan and Ontario, much of the actual dredging work is contracted out to private industry. In Ontario, the Ontario Ministry of the Environment and Department of Public Works regulate dredging of the public harbors near Windsor and private sites along the east bank. In Michigan, the U.S. Army Corps of Engineers regulates all public dredging activities in the river, including the issuance of Section 10 permits authorized under the Rivers and Harbors Act of 1899. Private dredging activities are regulated by the Corps and by the Michigan Department of Natural Resources (Raphael et al. 1974).

Sediment contaminant regulations will continue to require the confinement of polluted dredged materials removed from the Detroit River. In Ontario, pursuant to the Environmental Protection Act of 1971 and the Ontario Water Resources Act of 1972, the discharge of any polluted dredgings above levels prescribed by these regulations is prohibited. Similar regulations are in effect in the United States as a result of Public Law 91-611, Amendment to the Rivers and Harbors Act of 1970, and Public Law 92-500, Clean Water Act of 1972, as amended (Raphael et al. 1974). Chemical testing of bottom sediments to be dredged is performed by the Ontario Ministry of the Environment for Ontario waters, and by the Corps for Michigan waters. The most direct and informative approach to estimating the biological effect of in-place pollutants, for the purpose of deciding where the dredge spoils should be disposed of, is measurement of contaminant uptake by aquatic organisms exposed to the sediments

Table 33. Dredging and spoil disposal in the Detroit River, 1970-86 (U.S. Army Corps of Engineers, Detroit District, Open Files).

Dredging Project	Year	Volume (m^3)	Disposal site
Detroit River	1970	30,100	Confined[a]
	1971	30,146	Open lake (Erie)
	1975	417,922	Open lake (Erie)
	1976	605,715	Open lake (Erie)
	1980	1,287,966	Confined[a]
	1981	1,181,469	Confined[a]
	1982	150,706	Confined (Pt. Mouillee)
	1983	27,421	Confined (Pt. Mouillee)
	1984	576,016	Confined (Pt. Mouillee)
	1985	904,522	Confined (Pt. Mouillee)
	1986	499,284	Confined (Pt. Mouillee)
Rouge River			
	1976	45,876	Confined[a]
	1985	73,402	Confined (Pt. Mouillee)
Total		5,830,545	

[a] Principally on Grassy and Mud Islands in the Detroit River.

of concern (Willford et al. 1987). However, such bioassays are recommended only when chemical characterization of bulk sediments does not exceed contaminant guidelines or it is suspected that a special contaminant problem may exist at a particular site (IJC 1982). The containment site for most polluted dredged material derived from the Detroit and Rouge Rivers, including private dredgings, is located at Pointe Mouillee. The Pointe Mouillee confined disposal facility was first utilized in 1983, and dredged material input has not yet exceeded its designed capacity of 23 million m^3 (USACE 1974). Creation of islands and management of them for waterfowl production, as is planned for Pointe Mouillee, illustrates one way to mitigate environmental impacts of dredging and enhance waterfowl production, a long term goal of the U.S. Fish and Wildlife Service in the Nation's large rivers (Schnick et al. 1982). However, using contaminated materials for island creation may result in an attractive nuisance. Waterfowl may be attracted to a site which may ultimately provide undesirable nesting space. Contaminant studies of waterbirds at Great Lakes confined disposal facilities are ongoing.

U.S. Army Corps of Engineers' civil works projects are not regulated under individual or general permits. However, an environmental impact statement on Detroit River maintenance dredging was prepared in 1976. Supplements to this statement are issued when needed. The adverse environmental effects of maintenance dredging, e.g. increased turbidity, removal of benthic macroinvertebrates, and increased bioavailability of contaminants--particularly with overflow dredging--are usually regarded as short term. Moreover, removal of polluted bottom sediment may be characterized as remedial, if done properly without overflow dredging. A harmful environmental condition is eliminated and contained within confined disposal facilities. In some cases, leaving contaminated sediments in place may be a better option. To date, the overall productivity of benthic animals in the Detroit River has probably been reduced by dredging, but this lost productivity has not been accurately estimated.

6.3 WATER LEVELS

Water levels in the Detroit River have recently been at record high levels (Quinn 1981; Edsall et al. 1988). Erosion and flooding along the Detroit River are not as severe as, for example, in Lake St. Clair, because 78% of the Michigan shoreline of the Detroit River is already bulkheaded (Muth et al. 1986). However, some localized erosion is occurring on the north end of Belle Isle and along the east side of Grosse Ile. Both public agencies and private landowners have installed additional bulkheads and riprap to combat erosion.

Fluctuating water levels are vital to maintaining wetlands in the Great Lakes (Jaworski and Raphael 1981; Keddy and Reznicek 1986), but can produce both positive and negative impacts on various water uses (Table 34). In general, high water levels tend to favor fisheries, boating, and navigation. In contrast, low water levels tend to increase habitat for shorebirds and reduce shoreline erosion. In the Detroit River, the positive effect of high water levels on fish spawning and nursery areas results largely from inundation of islands. Because the banks of the

Table 34. Effects of water level on uses of the Detroit River[a].

Use	Water level: Low	Water level: High
Fish spawning	-	+
Nursery of juvenile fish	-	+
Recreational fishing	0	0
Feeding of wading and shorebirds	+	-
Nesting of colonial birds	+	-
Feeding of diving ducks	0	0
Recreational boating	-	+
Commercial navigation	-	+

[a] + = Favored
0 = Not significant
- = Negative effect

river are almost entirely bulkheaded or covered with riprap, remaining wetlands and submersed vegetation cannot move shoreward in response to high water levels. Negative effects of high water levels include inundation of nesting islands and beach habitat required by colonial shore birds--one reason for the recent decline in common tern and piping plover populations in the Great Lakes.

Hunt (1963) showed more widespread distribution of the submersed macrophytes around Grosse Ile, Sugar Island, and Celeron Island during a low-water period than was visible on aerial photos taken during a high-water period in 1982. However, more field work is needed to determine the effect of high water levels on submersed macrophyte beds in the Detroit River. Wild celery is still the most abundant submersed macrophyte around Grosse Ile (Schloesser et al. 1985), but present high water levels and other factors may further reduce the distribution and abundance of this plant and the migratory waterfowl that depend on it for food (Section 6.6).

The high water is causing retrogression of what little emergent vegetation remains along the Detroit River. For example, the diked cattail marshes at the mouth of the Canard River are dying back, as more open water and submersed macrophytes prevail. Also, in Gibraltar Bay at the south end of Grosse Ile and along the west shore of Stony Island, cattails have died back and much of the wetland is now submersed macrophytes. Even the mature swamp oak (*Quercus bicolor*) hardwoods on Russell Island just west of Gibraltar Bay, are threatened by high water (Jaworski and Raphael 1984). The long-term fluctuation of water levels in the Great Lakes is a natural phenomenon. It appears that current water levels are causing no significant problems in the Detroit River, and no management strategies are called for to mitigate erosion and flooding along the river.

6.4 WASTE DISCHARGES AND SPILLS OF HAZARDOUS SUBSTANCES

Use of the Detroit River for municipal and industrial waste discharges conflicts with most other uses of the river. Large quantities of sewage organic matter are added to the Detroit River from the municipal sewage treatment plants of Detroit, Wyandotte, Trenton, and Grosse Ile, which serve over 3 million people. From data presented by Vaughan and Harlow (1965), we calculated that in 1965, these sewage discharges added over 235,000 t of solids and biological oxygen demand to the Detroit River. This amount is 8.3 times more organic matter than the present-day total annual primary production of all plants in the Detroit River (28,210 t; Table 21). Solids in the effluent from the largest of these plants serving the City of Detroit (226,665 t) were reduced in 1969, when the plant was upgraded to include secondary treatment. In 1984, additions of suspended solids by the Detroit Wastewater Treatment Plant to the river totaled only 25,665 t (U.S. Environmental Protection Agency STORET Data Files for 1984). Although reduced, the loadings of organic matter from sewage treatment plants still nearly equal primary production of organic matter by aquatic plants in the Detroit River.

A preliminary activity-effect matrix we constructed following the procedures of Leopold et al. (1971) indicates that industrial discharges, municipal sewage effluent, urban runoff, and combined sewer overflows are the primary causes of adverse environmental impacts in the Detroit River (Table 35). These three activities are interrelated because they all influence water quality. Water and sediment quality is most degraded in nearshore habitats along the City of Detroit's shoreline and at the Rouge and Ecorse River mouths. Water quality concerns caused the City of Detroit to install a second, supplemental water intake in southern Lake Huron near Port Huron in 1980. However, it costs less to pump water from the original intake at Belle Isle, so most of the supply has originated from the river in recent years.

Polluted bottom sediments, particularly in the Trenton Channel, and associated water quality problems (Sections 1.6 and 2.7) persist in the Detroit River (MDNR 1985a). Except for nitrates, pollutant levels in water have declined since 1967, but relatively clean water is

Table 35. Activity- and use-effect matrix for the Detroit River.

Activity	Effect[a] Water quality: Fish use	Water quality: Human use	Sediment quality	Nearshore habitat for benthos and plants	Island habitat for wildlife	Migratory waterfowl use	Total
Industrial discharges	2	2	2	2	0	1	9
Municipal sewage effluents	2	2	2	2	0	1	9
Urban runoff and sewer overflows	2	2	1	2	0	1	8
Recreational boating	0	1	0	2	2	2	7
Agricultural development	0	1	0	1	0	1	3
Commercial navigation	1	2	0	1	1	0	5
Bulkheading and backfilling	0	0	0	2	1	2	5
Total	7	10	5	12	4	8	46

[a] 2 = Major adverse impact.
1 = Minor adverse impact.
0 = No adverse impact.

found only in the upper river and the middle channel area of the lower river. Polluted bottom sediments occur throughout the river, but sediments on the Michigan side below the mouth of the Rouge River and in the Trenton Channel are most heavily polluted (Bertram et al. 1987). Because fish accumulate contaminates from water and sediment, consumption warnings have been issued by Michigan and Ontario for fish caught in the river (MDNR 1985).

The probability of hazardous substance spills into the Detroit River is high (Schulze and Horne 1982). To evaluate the potential hazard posed to fish and wildlife resources in the Detroit River by spills of oil and other hazardous substances, the records of hazardous substances shipped through and spilled in the river, and also contingency plans that have been formulated to minimize the environmental impact of such spills were recently reviewed by Manny and Inman (1986). The following summarizes their findings.

Spills of hazardous substances, especially oil, pose a threat to fish and wildlife resources in the Great Lakes (Emery 1972; Kiellor 1980) and have caused large losses of waterfowl throughout the Great Lakes in past years (Hunt 1965), particularly in the Detroit River (Hunt 1961). Fuel oil is particularly dangerous because it floats on water and contains toxic water-soluble compounds such as benzene, toluene, and naphthalene, which even in low concentrations (about 1 mg/L) reduce growth, reproduction, and survival of many aquatic plants and animals (Anderson 1977; Burk 1977).

The number of shipments of petroleum products on the Great Lakes has reportedly decreased during the past 15 years, but the average size of oil tankers and the number of tank barges in use on the Great Lakes has increased during the same period (Scher 1979). During recent years, petroleum shipments have also continued throughout the winter on the Great Lakes as part of the Navigation Season Extension Program proposed by U.S. Army Corps of Engineers. Most petroleum shipments through the Detroit River originate within the St. Clair River or Lake Erie. In 1977, over 3 million short tons of petroleum products and 300,000 short tons of other hazardous substances were shipped on vessels through the Detroit River (Table 36). Values given in Table 36

Table 36. Petroleum products and other hazardous substances transported on the Detroit River in 1977 (USACE 1977; Statistics Canada 1977)[a].

Products transported	Amount (short tons)
Petroleum	
Crude petroleum	14,421
Crude tar, oil and gas	268,138
Gasoline	352,223
Distillate fuel oil	507,233
Residual fuel oil	2,003,064
Lubricating oils and grease	176,077
Asphalt, tar, pitch	280,984
Other products	695
Total	3,602,835
Other Hazardous Substances	
Animal fats and oils	130,664
Vegetable oils	14,690
Sodium hydroxide	2,641
Dyes, tanning materials	1,611
Benzene, toluene	50,654
Drugs	2,092
Soaps and detergents	9,874
Paints and varnishes	1,374
Fertilizer	36,881
Insecticides, disinfectants	4,179
Copper, lead and zinc	57,398
Total	312,058

[a] Includes through traffic and shipments into, out of, and within the Ports of Detroit and Windsor.

differ from those in Table V-3 of Schulze and Horne (1982) because we included not only total upbound and downbound traffic on the Detroit River, but also shipments into, out of and within the Ports of Detroit and Windsor. In 1977, these latter shipments composed the majority of hazardous substances transported aboard vessels on the Detroit River. During January and February 1979, when the river was ice-covered, up to 6,600 short tons of fuel oil were shipped about every 2 days on the St. Clair River from Sarnia, Ontario, to power-generating plants in Detroit, Michigan (A.G. Ballert, Great Lakes Commission, Ann Arbor, Mich.; pers. comm.).

From 1973 to 1979, there were 581 spills of petroleum products totaling over 704,000 L and 45 spills of other hazardous substances totaling over 334,000 L into Michigan waters of the Detroit River (Table 37), primarily from land-based facilities located along the upper river reaches. Spills into Michigan waters of the Detroit River greatly exceed those into Michigan waters of the St. Clair River (Edsall et al. 1988). A comparison of spills into American and Canadian

Table 37. Number and volume (L) of spills of petroleum products and other hazardous substances into the Detroit River, 1973-79 (U.S. Coast Guard 1980).

Spill	Number	Volume
Petroleum product		
Waste oils	124	309,159
Lube oils	289	168,622
Other oils	44	82,990
Fuel oils	44	41,298
Bunker oils	56	64,133
Gasoline	10	17,721
Hydraulic oil	4	405
Animal oil	6	19,459
Vegetable oil	1	757
Grease	3	95
Total	581	704,639
Other hazardous substances		
Ammonia	4	146,593
Ammonium compounds	2	11,487
Sodium bisulfite	1	7,570
Sodium hypochlorite	1	7,570
Copper and zinc compounds	3	4,625
Toluene	2	3,785
Phenol	1	1,892
Glycol	1	1,892
Sulfuric & hydrochloric acid	5	2,101
Sodium hydroxide	1	38
Miscellaneous	24	146,517
Total	45	334,070

waters of the Detroit River could not be made because records of spills into Ontario waters were not available. Only a small proportion of the petroleum product spills (2% by volume), but a much larger proportion of spills of the other hazardous substances (69% by volume) occurred in winter (Table 38), when much of the river is covered with ice. Winter spills are of particular concern because current technology is largely inadequate to detect, contain, or recover spills of hazardous substances under ice, particularly in fast-flowing waters like the Detroit River (SLEOC 1979).

Under criteria established by the U.S. Fish and Wildlife Service (Adams et al. 1984), there are extensive fish spawning grounds, productive wetlands, and other environmentally sensitive areas in the Detroit River (Sections 1.5, 2.6, and 6.7) that would be ranked as high-priority areas for protection from spills of hazardous substances. Manny and Inman (1986) therefore concluded that spills of petroleum products and other hazardous substances represent a threat to biological resources in the Detroit River. They also concluded that the huge volumes of hazardous substances transported through the river on vessels (Table 36) represent a potential threat to those same resources because even through vessel accidents have caused no large spills of hazardous substances yet (Schulze and Horne 1982) just one serious vessel grounding or collision, particularly in winter, could produce a catastrophic spill and long-lasting reduction in the biological productivity of the Detroit River.

Table 38. Number and volume (L) of spills of petroleum products and other hazardous substances into the Detroit River during the period of ice cover, 1973-79 (U.S. Coast Guard 1980).

Spill	Number	Volume
Petroleum product		
Fuel oils	5	8,346
Bunker oil	3	6,370
Other oils	2	197
Waste oil	2	79
Tar or pitch	1	19
Lube oil	1	11
Total	14	15,022
Other hazardous substances		
Toluene	2	3,785
Phenol	1	1,892
Miscellaneous	11	226,475
Total	14	232,152

6.5 FISH LOSSES AT WATER INTAKES

Water withdrawal from the Detroit River by industries and municipalities poses a threat to fishes using these waters. In 1982, more than 30 water intakes were operational in the Detroit River (IJRT 1982). No complete assessment of fish losses at these intakes has been made, but annual losses at nine Michigan thermal electric generating stations on the Detroit River in the mid-1970's were about 1,176,000 juvenile and adult gizzard shad and other clupeid fishes and 39,536,542 clupeid larvae (MDNR 1976). A more extensive review estimated the annual fish losses at 17 thermal electric generating stations in the St. Clair-Detroit River system were about 7,422,000 juveniles and adults, and 94,159,000 larvae in the mid-1970's (Kelso and Milburn 1979). The significance of the fish losses at water intakes in the Detroit River has not been established, but the water-use rate at electric generating stations provided by Kelso and Milburn (1979) was equivalent to about 8% of the total flow in the river per day. A use rate much lower than that (Spigarelli et al. 1981) from Lake Michigan in 1980 caused ecologically significant losses of recreational and forage fish (Manny 1984). The cumulative impacts of power-plant water withdrawal on fish larvae and fish production in the Detroit River need to be more adequately assessed.

6.6 HABITAT FOR CANVASBACK DUCKS

For many years, the Detroit River has been an important resting and feeding area for the eastern (Atlantic) population of canvasback ducks (<u>Aythya vallisneria</u>) during their fall migration (Figure 28). Historically, migrants first moved to staging areas in the upper Mississippi River from breeding grounds in the prairie-pothole and parkland country in the western United States and Canada. From there about half of the population moved south to the lower Mississippi Valley and the gulf coast, and half moved eastward to feeding and resting areas in the Great Lakes. A high of 64,000 canvasbacks wintered on the Detroit River in 1955 (Martz et al. 1976), but generally,

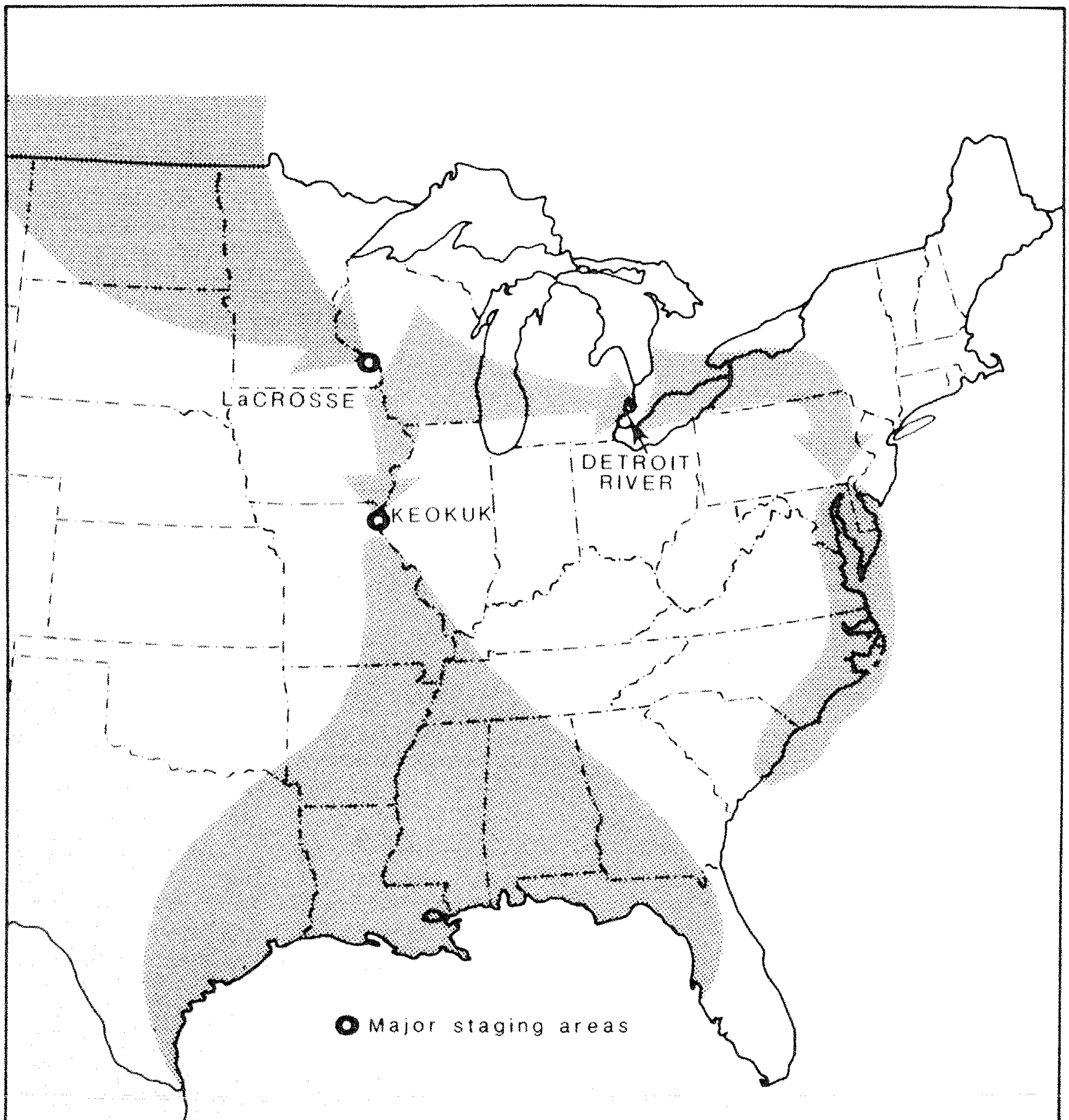


Figure 28. Major migration corridors of the eastern population of the canvasback duck (USDI 1983).

most birds historically proceeded to the Atlantic coast.

Migration routes evolve in response to available foods, as birds interrupt their flight to replenish energy reserves (Bellrose and Crompton 1970). Former staging areas in the midwest, including the Detroit River, are not used now as much as they were before 1970. Instead, most canvasbacks wintering in the Atlantic now stage on three pools of the upper Mississippi River, then migrate to the Detroit River and western Lake Erie. Here the birds feed and rest before continuing their migration eastward to the Atlantic coast (Serie et al. 1983).

The entire overwintering eastern population of canvasbacks, which was estimated at more than 400,000 birds in the early 1950's, declined to less than 147,000 by 1960 and thereafter varied between 131,000 and 284,000 birds (Table 39). Surveys conducted by the Michigan Department of Natural Resources from 1950 to 1976 (Martz et al. 1976) yielded results that paralleled the national trends. Peak concentrations of canvasbacks during 1954-58 along Lake St. Clair, the lower Detroit River, and adjacent Lake Erie numbered 260,000. Numbers of canvasbacks on the Detroit River were highest in November-December of 1951-55 (61,500-104,600), and lowest in 1966-70 (1,075). By the mid-1970's, canvasback numbers on the Detroit River rarely exceeded 50,000 (Jaworski and Raphael 1978). Over the past 12 years, the number of canvasbacks wintering on the Detroit River has varied from a high of 21,500 in 1981 to none in 1977 (Michigan Department of Natural Resources, Open Files).

Causes for the nationwide decline in canvasback duck numbers are incompletely known, but migration routes by waterfowl are partly dependent on foods available along the flyways (Bellrose and Crompton 1970). The canvasback has rigid habitat requirements and behavioral traits that limit their adjustment to environmental change, including a strong dependence on wild celery (Vallisneria americana) as food and an intolerance of disturbance by boat traffic. A recent survey of the tubers of Vallisneria americana (Figure 29), a preferred food of many waterfowl in

Table 39. Wintering canvasback duck populations by flyway, 1955-82 (USDI 1983).

Year	Number of ducks (thousands) by flyway in January: 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	14	44	98	156
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	57	142	214

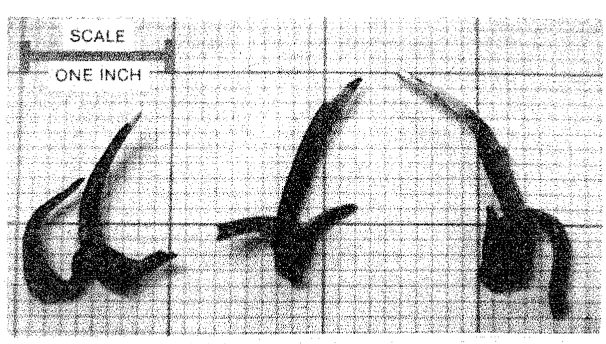


Figure 29. Wild celery (*Vallisneria americana*) tubers, a preferred food of canvasback ducks in the Detroit River.

the sediments of the lower Detroit River, indicates that, over the past 35 years, the densities of tubers have decreased substantially at three locations and increased moderately at two locations where ducks once fed, resulting in a net decrease of 73% in tuber densities (Table 40). The declines of such preferred foods as wild celery, fennel-leaf pondweed, and fingernail clams have been cited as possible causes for the disappearance of canvasbacks from formerly used areas (Mills et al. 1966; Trauger and Serie 1974). The loss of these important waterfowl foods explains in part why fewer waterfowl now use the Michigan migration corridor.

In Michigan, canvasback habitats also have been adversely affected by many forms of human activity. These include oil, chemical, and heavy metal contamination from industry and municipalities; nutrients and sediments from agriculture; sediment resuspension, addition of greases and oils by commercial and recreational navigation; and finally, disturbances from recreational boating activities including fishing, sailing, pleasure motoring, and hunting (Hunt 1957; Martz et al. 1976). These problems continue to affect canvasback habitat in the Detroit River, although oil pollution in the river has been significantly reduced since the 1950's (Hunt 1961, Schloesser and Manny 1986b).

Federal and State plans have been formulated for rehabilitating the eastern population of canvasback ducks and their habitat. The Federal plans identify pollution and limited food resources as primary causes of dwindling migration habitat and reduced numbers of birds (USDI 1983), particularly industrial pollution and the loss of wild celery beds in the Detroit River (Oetting 1985). The State plan predicts slow improvement of canvasback habitat in the Detroit River, if pollution controls are continued (Martz et al. 1976). The overall strategy of these plans is to provide adequate migration habitat across the Great Lakes states, rather than crowding fall-migrating canvasbacks into the two or three pools on the upper Mississippi River where suitable habitat is still available for them.

6.7 PROTECTION OF REMAINING WETLAND AND ISLAND HABITAT

Special protection of remaining wetlands and islands in the Detroit River is warranted because most of the naturally-produced organic matter for animals living in the Detroit River probably derives from these environments. Second, prior loss or pollution of the Michigan shoreline ascribes greater biological function and value to the remaining wetland and island habitats. Finally, wetlands around

Table 40. Average number of wild celery tubers at five waterfowl feeding areas in the lower Detroit River in May 1950-51 and 1984-85 (Schloesser and Manny 1986b).

Location	1950-51			1984-85		Net change	
	Area (km^2)	No./m^2	No./area	No./m^2	No./area	No./m^2	No./area
Ballards Bar	1.717	19	$3.3x10^7$	5	$8.6x10^6$	-14	$-2.4x10^7$
Sugar Island Bar	0.745	23	$1.7x10^7$	5	$3.7x10^6$	-18	$-1.3x10^7$
Humbug Bar	0.228	2	$4.6x10^5$	0	0	-2	$-4.6x10^5$
North Bar	0.237	2	$4.7x10^5$	4	$9.5x10^5$	+2	$4.8x10^5$
Swan Island Bar	0.234	2	$4.7x10^5$	5	$1.2x10^6$	+3	$7.3x10^5$
Total	3.161		$5.2x10^7$		$1.4x10^7$		$-3.6x10^7$

islands provide protective habitat for planktonic life and higher life forms.

The differences in land use between the Michigan and the Ontario shorelines are striking. As discussed in sections 1.3 and 1.6, the Michigan shoreline is heavily industrialized, especially between Zug Island and Trenton. In contrast, the Ontario side is largely agricultural south of Windsor, though the shoreline is dotted with marinas, recreational facilities, and private boating areas. Most of the non-industrial land uses, such as nesting by colonial birds (Figure 30), occur on the islands in the river. In terms of open space, recreational land, and natural areas, it is the islands and their associated shoreline that offer the best fish and wildlife habitat available today.

Several studies have demonstrated that wave forces generated by commercial vessels moving up and down the Detroit River reduce the distribution and abundance of aquatic macrophytes and macrozoobenthos by uprooting or fragmenting plants and resuspending littoral sediments (Schloesser and Manny 1986a), especially under ice where the channel is constricted (Poe et al. 1980; Poe and Edsall 1982; Liston et al. 1986). Because of their detrimental impact on the biological productivity of the Detroit River, vessel speed limits should be reexamined to determine if they could be reduced in the river near remaining wetlands.

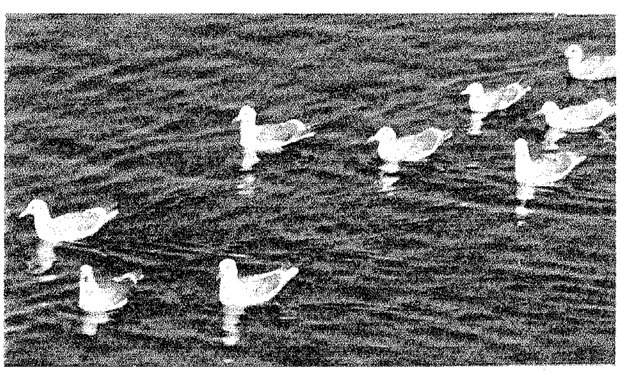


Figure 30. Herring gulls, a shorebird that nests in colonies on Fighting Island in the Detroit River (Photo provided by Victor B. Scheffer).

The adverse impact of isolating and fragmenting wetlands on the mainland and islands by means of roadbeds, canals, earthen dikes, and other developments appears not to be fully recognized. Although most people would not consider isolated or fragmented wetlands to be adversely impacted or lost, the importance of maintaining hydrologic connections between wetlands on islands and the Detroit River through underground water flows, was recognized in recent planning considerations recommended to the Grosse Ile Planning Commission (Dean 1986).

There were 1,382 ha of wetlands in the Detroit River in 1982 (Table 4, section 2.6). The wetlands are more widespread in the southern section of the river; their contribution, in an ecological sense, is also greater on the eastern than on the western side of the river (Figure 13).

The existing wetlands on the Michigan side of the river are protected largely as a result of the permitting process outlined in Federal Section 404 of the Clean Water Act (P.L. 92-500) and Section 10 of the Rivers and Harbors Act of 1899. The Regulatory Branch of the U.S. Army Corps of Engineers is empowered to protect Great Lakes wetlands from destruction and alteration. In Michigan, Section 404 permits are issued by USACE for wetlands in the Detroit River. The Land Resources Division of Michigan Department of Natural Resources has assumed the Federal 404 permit program for lands inland of the Great Lakes and connecting channels. The State uses the Goemaere-Anderson Wetlands Protection Act of 1979 (P.A. 203) to protect isolated wetlands over 1.5 ha in area, in certain counties, and all wetlands contiguous to a river or lake, regardless of size. The State of Michigan also employs the Great Lakes Submerged Lands Act of 1955 (P.A. 247) and other statutes to lease bottom lands and protect Great Lakes coastal environments. Some protection of islands along the Great Lakes shoreline is afforded by the Michigan Shorelands Protection Act of 1970. To develop any Michigan shoreline of the Detroit River, a permit is required under the Inland Lakes and Streams Act of Michigan (P.A. 346).

As review agencies, both the U.S. Fish and Wildlife Service and the U.S. Environmental Protection Agency carefully study proposed development projects to avoid or mitigate wetland losses. In general, permits from the State or Federal agencies are not issued to develop wetlands unless the proposed project is water dependent; high quality wetlands are not involved; and there is no feasible and prudent alternative on upland areas.

There is greater need for wetlands protection at the local level than at the State or Federal level. The largest undeveloped wetland area under control of local government in the Detroit River is in the township of Grosse Ile. Through its 1969 Master Plan and the Zoning District Maps, some development has been allowed in wetlands. At present, the need for additional private marinas and pressure for coastal residential development is influencing the township board to review the coastal lands zoned for recreation (Seegert 1984). Currently the wetlands in Gibraltar Bay and near Celeron and Sugar Islands cannot be developed unless the zoning is changed to active recreation or some more intensive use. Proposals to rezone these wetlands for more intensive use (a marina) were submitted to the township in 1986, but no wetland development has been authorized to date. To adequately protect remaining wetlands in the Detroit River, some funds or incentives from local, State, or Federal governments may be needed (Dean 1986). In particular, the islands in the Detroit River, should be the subject of comprehensive planning and protection from development. As shown in Table 41, there are 12 large islands, 7 in Michigan and 5 in Ontario. Grosse Ile, by far the largest island in the river, is privately owned and the shoreline is largely developed. Mud, Grassy, and Fighting Islands, along with Point Hennepin on the northern tip of Grosse Ile, are spoil islands. Vegetation on these islands appears to be

Table 41. Characterization of major islands in the Detroit River.

Name	Area (ha)[a]	Shoreline length (km)	Land use	Ownership	Jurisdiction
Peach Island[b]	37.2	3.1	Undeveloped	Public	Ontario
Belle Isle	385.8	11.1	Urban park	Public	Michigan
Mud Island	9.3	1.0	Spoil island	Public	Michigan
Grassy Island[c]	23.1	2.9	Spoil island	Public	Michigan
Fighting Island	492.2	13.2	Spoil island	Private	Ontario
Grass Island[b]	74.3	5.7	Undeveloped	Public	Ontario
Turkey Island[b]	46.5	2.9	Undeveloped	Public	Ontario
Grosse Ile	2,348.9	37.2	Mixed	Mostly private	Michigan
Stony Island[b]	37.2	3.3	Mostly undeveloped	Private	Michigan
Sugar Island[b]	18.6	1.2	Undeveloped	Public	Michigan
Celeron Island[b]	53.5	4.1	Undeveloped	Public	Michigan
Bois Blanc Island	90.8	7.3	Partially developed	Mostly private	Ontario
Total	3,617.4	93.0			

[a] Planimetered from U.S. Geological Survey Topographic quadrangle maps.
[b] Includes adjacent wetlands.
[c] This island is a National Wildlife Refuge administered by the U.S. Fish and Wildlife Service.

succeeding to dense upland habitat, consisting largely of grasses, willow trees, and cottonwood trees.

Peach, Grassy, Turkey, Stony, Bois Blanc, Sugar, and Celeron Islands are undeveloped, publicly owned, and have the greatest management potential. As noted in Section 3.3, Grassy Island is part of the Wyandotte National Wildlife Refuge, managed by the U.S. Fish and Wildlife Service. Of the others, only Sugar and Celeron Islands are located in Michigan waters. Because wetlands occupy over half of the land area on these islands, they are especially important fish and wildlife habitat that could be managed effectively to enhance fish and wildlife resources using established procedures (Schnick et al. 1982). However, given the proximity to the cities of Detroit and Windsor, disturbance by boaters, picnickers, and sight-seers is a major problem. Gulls, wading birds, shore birds, and waterfowl nesting on these islands are especially vulnerable to human disturbance (Davis and Erwin 1982).

Any wetland protection policy for the Detroit River ecosystem should include the more extensive Ontario wetlands, particularly those south of the Canard River. A joint U.S.-Canadian study to determine the value of the islands in the Detroit River as fish and wildlife habitat is clearly in order. It is timely to perform such a study, because dredged spoils are no longer disposed of on Mud and Grassy Islands, and enhancement of fish and wildlife resources on the islands would greatly increase the recreational potential of the Detroit River urban riverfront. Because fish and wildlife produced in Detroit River wetlands freely cross the international border, management of the wetland habitat in the river should be coordinated by a joint international authority, such as the Habitat Advisory Board of the Great Lakes Fishery Commission.

6.8 MANAGEMENT FRAMEWORK

Numerous organizations, each of which has its own mission and expertise with regard to the management of the Detroit River ecosystem, have jurisdiction in the Detroit River (GLBC 1975c). Because of the international nature of the Detroit River waterway, programs of the International Joint Commission (IJC), and the Great Lakes Fishery Commission (GLFC) are most relevant.

The IJC was created in 1909 by the Boundary Waters Treaty between Canada and the United States. The GLFC was created in 1955 by the Convention on Great Lakes Fisheries between Canada and the United States. The principal advisor to the IJC on water quality issues is the Great Lakes Water Quality Board, which is composed of agency and scientific leaders. The Canadian-U.S. Water Quality Agreement of 1978, administered by the IJC, contains both general and specific objectives designed to reduce pollution discharges to the Great Lakes. As a result of the 1985 Report of the Water Quality Board to the IJC documenting the loss of beneficial uses in the Detroit River, the Province of Ontario and the State of Michigan are developing a remedial action plan to restore all beneficial uses of the resources in the Detroit River, including municipal and industrial water supplies, recreation, and aquatic life.

The GLFC is composed of four Canadian and four United States Commissioners, and a Secretariat to assist them. Its purpose is to coordinate efforts between the two countries to maintain high, sustained productivity by Great Lakes fish stocks. The GLFC recognizes that authority for management and regulation of fish in the Detroit River is vested in the State of Michigan and Province of Ontario and relies on a number of people from those agencies to conduct its business. The principal advisor to the GLFC on habitat issues is the Habitat Advisory Board, composed of agency and scientific leaders.

New cooperative agreements between institutions in the United States and Canada are needed to address the following data gaps:

(a) The trophic structure of the Detroit River ecosystem, including a mass balance for organic detritus from coastal wetlands and contaminants from Lake St. Clair, the Detroit Wastewater Treatment Plant, and all industrial waste discharges combined;

(b) Detailed mapping of remaining wetlands and littoral island habitat in the Detroit River and research to define their function and value in producing fish and wildlife; and
(c) The effect of the polluted bottom sediments on the fish and wildlife resources of the river, particularly in the areas around Fort Wayne, Zug Island, the Rouge River mouth, and in the Trenton Channel.

In June 1977, the GLFC published a feasibility study for rehabilitation of aquatic ecosystems in the Great Lakes (Francis et al. 1979). The Strategic Great Lakes Fisheries Management Plan, (GLFC 1980) concluded that comprehensive plans to rehabilitate the Great Lakes ecosystem can be developed. In 1986, through its Habitat Advisory Board and Lake Committee structure, the Great Lakes Fishery Commission developed guidelines for including fishery information, goals, and objectives in the remedial action plan for the Detroit River. If objectives are incorporated, the plan will ensure that fish from the Detroit River are palatable and acceptable for human consumption; that fish habitat is restored to full productive capacity within a specified time by reducing pollutant loadings and removing in-place polluted sediments, if necessary; and that impacts of water quality affecting fish and wildlife habitat in the river are mitigated so self-sustaining populations of edible fish are maintained and socioeconomic benefits from the fishery accrue to society.

As a common property resource and open hydrologic system between two countries, the Detroit River is used by many who are not subject to comprehensive and accountable management. Current institutional programs and authorities result in either narrow, closely defined responsibilities or poorly defined multi-jurisdictional arrangements. Arrangements between Canada and the United States need to be strengthened to facilitate the exchange of monitoring data on water and sediment quality in the Detroit River; in particular, persistent water and sediment quality problems in the river deserve prompt remedial action by Ontario Ministry of the Environment and Michigan Department of Natural Resources. Also, greater efforts must be made to provide results of scientific research on fish, wildlife, and their habitat in the Detroit River to regional and local governments with zoning and planning authority. In the United States, the Southeast Michigan Council of Governments, via the (Michigan) Council on Environmental Strategies and the Rouge River Basin Committee, could reduce combined sewer overflows to the Rouge and Detroit Rivers.

Public Act 247 concerns leasing of State-owned bottomlands in the Great Lakes and Lake St. Clair. It does not include the Detroit River from the northern tip of Peach Island to the southern tip of Celeron Island. However, P.A. 346 and P.A. 203 require permits for construction activities on both public and private bottomlands and wetlands in Michigan waters, including the Detroit River.

In Ontario, diking of wetlands alters their tax status. The Provincial Ministry of Revenue considers marshland to be recreational land and taxes it at twice the rate of farmland (McCullough 1985). Therefore, the pressure to drain marshes and convert them to farmland is now greater because generous tax subsidies for farmland are available from the Provincial government.

The loss of wetland productivity due to fragmentation, degradation, and conversion of marshes to competing land uses must be addressed because they are essential habitat for production of fish and wildlife in the river. In Ontario, the property taxes on marshland need review, and in both countries the private sector should be educated regarding the value of wetlands. Because many of the islands in the river are in public ownership or undeveloped, a joint Michigan-Ontario management policy would be timely.

6.9 RECOMMENDATIONS

Use of the Detroit River for the dilution and disposal of liquid and solid wastes is in clear conflict with basic biological processes in the river, including the production of valuable fish and wildlife resources. However, many conflicts between uses could be resolved, by implementing the following recommendations.

1. Sewage treatment plants discharging into the river and its tributaries could be upgraded to tertiary effluent level for organic matter and heavy metals, and operated at design standards.

2. Wetland habitat on islands in the river could be protected and managed for production of fish and wildlife.

3. Combined sewer overflows and industrial discharges to the river and its tributaries could be reduced and their toxic substances content more adequately monitored.

4. Contaminated sediments could be removed from catch basins and pipes that discharge into the river and its tributaries and be properly disposed of.

5. New connections to sewers that have insufficient storm water capacity could be delayed until combined sewer overflows are eliminated.

6. Heavily polluted bottom sediments in the river and its tributaries could be dredged (with no overflow), decontaminated, and disposed of in acceptably designed and monitored confined disposal sites, preferably on land.

7. Confined disposal facilities could be protected and managed for production of fish and wildlife, if studies show such sites are not toxic to plants and animals.

8. Boating activity could be restricted to main channels during spring and fall near areas where large numbers of migratory waterfowl feed and rest in the river.

9. Protection of remaining wetlands could be encouraged by restricting shoreline development along and in the river.

10. The development of new wetlands or recreation of once-existent wetlands could be encouraged in and along the river.

11. Adequate containment safeguards around hazardous substance storage and handling facilities on shore could be installed and maintained to prevent oil and contaminant spills into the river, especially during winter.

12. A joint Canadian-U.S. repository for records of hazardous substances spilled into the river and stored in landfills that drain into the river could be established.

13. A public education campaign could be launched to promote the river and its tributaries as valuable natural resources, discourage pollution of them, and generate support for planned pollution control efforts.

Lastly, to better visualize and manage competing uses of the river, a geographic information system, similar to that of the U.S. Army Corps of Engineers for the Tennessee-Tombigbee Waterway (USACE 1985), could be employed. The data base of such a system consists of digitized maps, such as of water depths and fish spawning areas, which are projected in a common, sufficient scale. Software routines, such as suitability analyses, interrelate the digitized map data to show potential adverse environmental impacts, existing ecosystem capability, and land use conflicts. Microcomputers with large format digitizers are commonly used for data capture and editing, whereas data management systems on either small or large computers are employed for merging the digitized maps into a single spatial data base and performing complex data analyses. Considerable pertinent data already exists in map form for minimizing the impact of various uses on natural resources in the Detroit River. The following data can be obtained in map form from a computerized Great Lakes Geographic Information System organized by the Michigan Department of Natural Resources:

(a) Distribution of wetlands,
(b) Location of degraded benthic communities,
(c) Location of polluted sediments,
(d) Water quality,
(e) Location and composition of waste discharges,
(f) Fish spawning areas,
(g) Location of drinking water intakes, and
(h) Recreational fishing areas.

Such information systems are capable of integrating chemical, physical, biological, and land-use information and creating maps displaying this information. We recommend that a geographic information system be used to illustrate use conflicts in the Detroit River and formulate management alternatives for remedial actions needed to resolve the conflicts.

It should be recognized that effective, balanced management of the Detroit River to minimize conflicting uses necessitates an ecosystem approach (Ryder and Edwards 1985). Briefly, an ecosystem approach for the Detroit River would require (1) knowledge of how badly the river is polluted, (2) selection of objectives for remedial actions, (3) selection of plant and animal species that are expected to respond to remedial action by increasing in number and distribution, and (4) documentation of the critical habitat and niche requirements of those selected species.

An evaluation of the state-of-the-health of the ecosystem could then be made in terms of the degree to which the critical habitat and niche requirements of the selected species are met or can be met under extant environmental conditions or under conditions which may prevail, if cultural stresses were increased or decreased. Such an ecosystem approach has been developed for managing fish populations in large rivers (Petts et al. In press), and it shows promise as a means for generating quantitative empirical criteria that could be used to regulate the impact of cultural stresses on natural resources in the Detroit River.

Because the Detroit River is connected hydrologically with Lake St. Clair, the urban sewer systems in Michigan and Ontario, and western Lake Erie, it will be necessary to include information about pollution loadings, land uses, and shipping activities to minimize use conflicts within the river itself. The discharges from the Rouge and Ecorse Rivers, for example, are relatively small, but the impact of wastes discharged into these tributary waters on the water quality and bottom sediments in the Detroit River is substantial.

In applying an ecosystem approach, it should be understood that the Detroit River is common (public) property, shared by all, and, therefore, vulnerable to the tragedy of the commons (Hardin 1968). Briefly stated, each individual or industry that empties wastes into the Detroit River gains by having cheaply disposed of them, but all those downstream are robbed of clean water for their use. This attitude is linked to long-standing traditions in western society (White 1967) and will not change significantly until all who use the River come to regard it as they would their own private property. In some areas around the Great Lakes, urban dwellers have developed new protective attitudes towards natural resources along their waterfront (Fetterolf 1984). Should everyone come to regard the Detroit River in that manner, future generations will enjoy a quality of life from the River at least equal to that their parents enjoyed.

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16. Abstract (Limit: 200 words)

A part of the connecting channel system between Lake Huron and Lake Erie, the Detroit River forms an integral link between the two lakes for both humans and biological resources such as fish, nutrients, and plant detritus. This profile summarizes existing scientific information on the ecological structure and functioning of this ecosystem. Topics include the geological history of the region, climatic influences, river hydrology, lower trophic-level biotic components, native and introduced fishes, waterfowl use, ecological interrelationships, commercial and recreational uses of the river, and current management issues. Despite urbanization, the river still supports diverse fish, waterfowl, and benthic populations. Management issues include sewer overflows; maintenance dredging for navigation and port activities; industrial discharges of potentially hazardous materials; and wetland, fishery, and waterfowl protection and enhancement.

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