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Environmental Study of Fish Spawning and Nursery Areas in the St. Clair-Detroit River System

by

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EXECUTIVE SUMMARY

The U. S. Army Corps of Engineers, Detroit District, is preparing a supplemental Environmental Impact Statement for extension of operations and maintenance of lock facilities at Sault Ste. Marie, Michigan to 31 January ± 2 weeks. This environmental study of fish spawning and nursery areas in the St. Clair-Detroit River System (SCDRS) was conducted to provide baseline data on the abundance and distribution of fish eggs and larvae in this system and to assess potential impacts on fish reproduction that might occur if winter ship passages in SCDRS increase as a result of the extension of lock operations. Fish eggs were collected with an egg pump and larvae with a townet at selected locations throughout SCDRS during 1983 and 1984. Analyses of the distribution and abundance of eggs of 19 species of fish and larvae of 29 species that were collected suggested abundance differed significantly between rivers and between years. The number of eggs collected in the Detroit River was more than 2.5 times greater than the number collected in the St. Clair River during the 2-year period. Eggs of rainbow smelt (*Osmorus mordax*) constituted most of the St. Clair River samples and those of gizzard shad (*Dorosoma cepedianum*) and white bass (*Morone chrysops*) dominated the Detroit River samples. In both rivers, egg abundance was less in 1983 than in 1984. Fish larvae were also less abundant in 1983 than in 1984, but the major difference occurred in the St. Clair River. Alewives (*Alosa pseudoharengus*) were the most abundant larvae in both rivers during both years. Rainbow smelt, various darters, and logperch (*Percina caprodes*) were also abundant in the St. Clair River, and gizzard shad and emerald shiners (*Notropis atherinoides*) in the Detroit River. Because larvae of walleye (*Stizostedion vitreum vitreum*) and yellow perch (*Perca falvescens*) larvae were collected from the St. Clair and Detroit rivers, we concluded that neither species used the two rivers extensively as spawning or nursery areas in 1983-1984.

The distribution of larvae, as indicated by densities of all taxa combined, was significantly different among transects, among locations, and among months for each river and each year of the study. In 1983 in the St. Clair River, the density of larvae was lower at transect I than at other transects; densities were lower at nearshore sampling locations than at mid-channel locations and were lower in May and June than in July and August. In 1984, there were no differences in densities among transects; densities remained lower at nearshore locations than at mid-channel locations; and monthly densities were highest in June and July, and lowest in May and August. In the Detroit River, density differences among transects were significant in 1983, but not in 1984. Densities of larvae were highest in May and June in 1983 and in June and July in 1984.

Water temperatures and ice conditions both affect the abundance of eggs and larvae. Lower water temperatures and a slower rate of warming in 1983 probably contributed to the lower abundance of eggs and larvae in that year. In 1984 an ice jam in the St. Clair River in April probably delayed fish spawning throughout SCDRS, but rapid warming occurred in May and June and larger numbers of eggs and larvae were produced in 1984 than in 1983. Use of SCDRS by a variety of fish species in spring and summer for spawning and as a

nursery area is documented by this study, but the extent of use differed between years. The impacts on fish spawning success that might be caused by an extension of lock operations and the resulting increase in vessel traffic in SCDRS will probably depend on the degree of change such activity might have on ice accumulation and movements, altered water temperatures, and physical modification of spawning habitat.

INTRODUCTION

The St. Clair-Detroit River System (SCDRS), which consists of the St. Clair River, Lake St. Clair, and the Detroit River (Fig. 1), is the interconnecting waterway between the upper Great Lakes (Huron, Michigan, and Superior) and the lower Great Lakes (Erie and Ontario). Millions of tons of commercial shipping transit the SCDRS annually during the navigation season. Shipping access to and from Lake Superior by way of the federal locks operated by the U. S. Army Corps of Engineers (COE) at Sault Ste. Marie, Michigan, is curtailed for the rest of the winter when adverse icing conditions persist in the harbors and the locks are closed. This closure directly affects shipping in SCDRS, although vessel traffic not dependent on the locks continues in SCDRS throughout the winter.

In addition to serving as a major commercial shipping route, SCDRS supports a valuable sport fishery that is very close to the large Detroit-Windsor metropolitan area. The SCDRS is also a spawning and nursery ground for fish populations in Lakes Huron and Erie (Nepszy 1977; Johnson 1977; Goodyear et al. 1982; Hatcher and Nester 1983) and is a migration route between Lakes Huron, St. Clair, and Erie for species such as walleye, white bass, rock bass, yellow perch, and white perch. The importance of SCDRS to fish migration was demonstrated by the capture of walleyes in Lake Huron that had previously been tagged more than 100 miles away along the south shore of western Lake Erie (Wolfert 1963). A study conducted by the Michigan Department of Natural Resources in 1983 and 1984 showed that rock bass, followed by yellow perch and walleyes, were the most abundant fish collected in trap net catches in the St. Clair River and that rock bass, followed by yellow perch, white perch, and walleye were the most abundant species in the Detroit River (Haas et al. 1984). A survey of sport fishing activities throughout the Michigan waters of SCDRS (Haas et al. 1984) indicated that nearly 1.8 million hours of sport fishing occurred from October 1983 to September 1984 and that fish pressure was considerably heavier in the Detroit River (more than 1.2 million hours) than in the St. Clair River (slightly over 0.5 million hours).

Although shipping and sport fishing are not the only uses of SCDRS, they are significantly important socio-economical factors affecting regional interests and the Great Lakes basin as a whole. In recent years, an extension of the winter navigation season has been proposed as a way to provide economic benefits to the shipping industry. However, because such a change in shipping activities might affect the SCDRS fishery, an Environmental Impact Statement (EIS) is required before changes in the navigation season can be approved. The Detroit District COE prepared an EIS in October 1979 entitled, "Supplement to the operation and maintenance Environmental Impact Statement for the Federal facilities at Sault Ste. Marie, Michigan, addressing limited season extension of operation." This statement considered an extension of the lock operation (i.e. winter navigation) to January 8 ± 1 week as being the most feasible plan. The COE then later considered an alternative plan to extend Sault Ste. Marie lock operations to January 31 ± 2 weeks. A supplemental EIS is required to describe potential environmental impacts, including those on

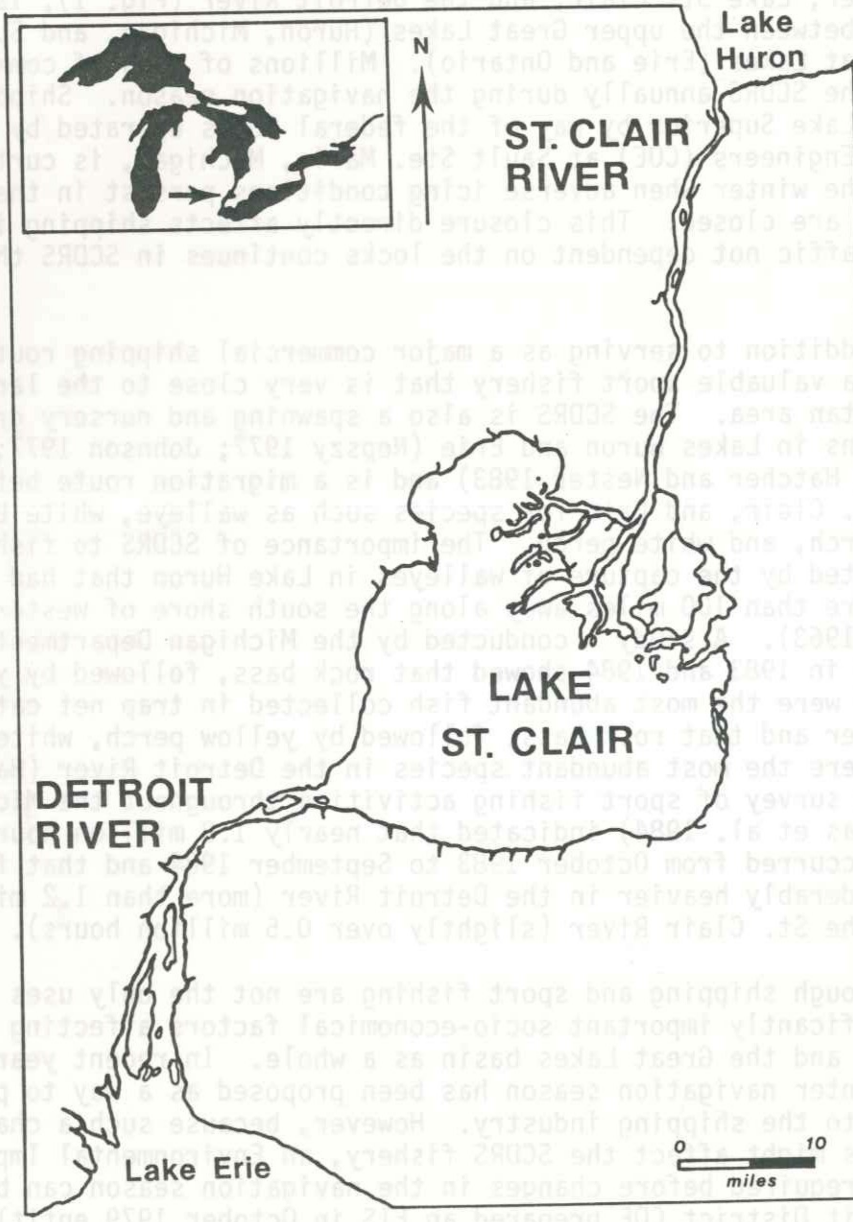


Fig. 1 The St. Clair-Detroit River System.

the fish spawning and nursery areas of SCDRS, that might be associated with the alternative extended winter navigation season. Because available fishery data for SCDRS were limited, COE contracted with the Great Lakes Fishery Laboratory and Michigan Department of Natural Resources to acquire the fishery information needed for the preparation of this Supplemental EIS.

The objectives of the present study were to (1) locate and describe the fish spawning and nursery areas throughout SCDRS during 1983 and 1984, and (2) assess the potential impacts on these areas that might occur as the result of extending the navigation seasons to January 31 ± 2 weeks.

DESCRIPTION OF THE STUDY AREA

The surface bedrock geology in the study area dates back to the Devonian period, is of marine origin, and consists mainly of shales in the St. Clair River and dolomites in the Detroit River. Glaciation has modified the topography by scouring and filling. The SCDRS lies in a morainal trough and is characterized by sediments consisting of glacial till and lake and stream deposits. The rivers are incised into a bed of glacial, lake-deposited clays with thicknesses of 80-200 ft in the St. Clair River (Cole 1903) and 20-140 ft in the Detroit River (Mozola 1969).

The SCDRS is 89 mi (143.2 km) long, drops 8 ft (2.4 m) between Lake Huron and Lake Erie and can be divided into five major segments: the upper St. Clair River, the lower St. Clair River delta, Lake St. Clair, and the upper and lower segments of the Detroit River (Figs. 1 and 2). Most of the following hydrographic information on the system comes from Derecki (1984 a, b, c). The upper St. Clair River is 27.9 mi (45 km) long and receives water from Lake Huron and three major tributaries (the Black, Pine, and Belle rivers). The lower St. Clair River, which begins at the branching of the north and south channels near Algonac, Michigan, is 11.2 mi (18 km) long and divides to form a large delta area consisting of three main channels (north, middle, and south) and a number of secondary channels that empty into Lake St. Clair.

Width of the St. Clair River ranges from 820 to 3,940 ft (250-1200 m) and averages 2,625 ft (800 m) in the upper section. The widths of the three main channels in the delta area range from 700 to 3,000 ft (214-915 m). Mid-channel depths range from 27 to 70 ft (8.2 - 21.5 m) and a minimum statutory depth of 27 ft is maintained by dredging. Littoral depths are typically 6-13 ft (1.8-4.0 m). All but 3.2 mi of the shoreline, excluding the islands, is bulkheaded. The mean annual discharge rate of the St. Clair River into Lake St. Clair was 214,000 ft^3/s (6,060 m^3/s) in 1983 and 209,000 ft^3/s (5,290 m^3/s) in 1984. These flows are about 17% higher than the historical average discharge of 180,000 ft^3/s (5,100 m^3/s). Velocities in the St. Clair River approach 6 ft/s in the navigational channel and near channel velocities range from 0.3 to 2.8 ft/s. Total flushing time from Lake Huron to Lake St. Clair is normally about 21 hours, and about one-third of this time is required to flush the delta area. Stag Island, 8.7 mi (14 km) downstream from Lake Huron and Fawn Island 21.7 mi (35 km) downstream, are the only islands in the upper section of the St. Clair River. The delta area includes Russell, Harsens, Dickinson, and Seaway islands.

Lake St. Clair has a surface area of about 430 mi² (1,114 km²), a mean depth of 11 ft (3.4 m), and a maximum natural depth of 21 ft (6.4 m). A navigation channel 18 mi (29 km) long has a statutory depth of 27 ft (8.2 m) and bisects the lake from the mouth of the South Channel of the St. Clair River to the head of the Detroit River. These data are based on the Great Lakes low water datum of 573.3 ft (174.7 m) above mean sea level, and in 1983-84 water levels were 3.25 ft (1.0 m) above this level. Major tributaries are the Clinton River on the United States side and the Sydenham, Thames, Belle, and Ruscom rivers on the Canadian side. Flushing time of the lake is 5 - 7 days.

The upper Detroit River is 13 mi (21 km) long and receives water from Lake St. Clair. The lower Detroit River, 18.9 mi (30.5 km) long, begins at the head of Fighting Island where the river separates into three channels (Trenton, Livingstone, and Amherstburg). Major tributaries are the Rouge River and the Ecorse River on the U. S. side. Width of the river ranges from 1,970 to 4,920 ft (600 - 1,500 m) in the upper sections, and from 4,920 to 10,400 ft (1,500 - 3,000 m) in the lower section. Mid-channel depths are 20 - 49 ft (6 - 15 m) and littoral depths are 7-20 ft. Excluding the islands, all but 6.9 mi of shoreline is bulkheaded. The mean annual discharge rate of the Detroit River into Lake Erie was 217,000 ft³/s (6,140 m³/s) in 1983 and 215,000 ft³/s (6,090 m³/s) in 1984. These flows are about 17% higher than the historical average discharge of 185,000 ft³/s (5,200 m³/s). Average flow velocities are 2 - 6 ft/s (0.6 - 1.8 m/s) in the mid-channel region and 0.1 - 1.9 ft/s in the nearshore and near channel areas. Total flushing time from Lake St. Clair to Lake Erie is about 19 hours in the main channel. The upper river contains two large islands, Peach Island and Belle Isle, and the lower river contains Fighting Island, Grosse Ile, Bois Blanc, and several smal islands.

The climate in the study area is semi-maritime due to its proximity to lakes Huron and Erie. The mean annual surface air temperature is 9 - 10°C, however, intense cells of cold arctic air can lower temperatures as much as 28°C over a 24-hour period. Air temperatures averaged 4.6°C lower from December to March in 1983-1984 than in 1982-1983. Average air temperatures were 1.0°C higher in April-June and 1.7°C lower in July-September 1984 than in 1983.

High winds and storms are common and significantly affect the thermal budgets of Lake Huron and the SCDRS. Prevailing winds are from the west, although winds come from all directions. High winds generate seiches and surges that strongly affect the lower Detroit River, causing levels to drop or rise 2-3 ft. Wind speed and direction can also affect ice buildup and cause ice jams in the St. Clair River. Typically the river remains clear of ice and only a narrow band of shore ice forms along the banks of the St. Clair River, except in the delta area. However, ice may enter the St. Clair River from Lake Huron under the influence of northerly winds. The current carries this ice downstream until it meets resistance from solid ice cover in the delta or in Lake St. Clair. When large amounts of ice enter the system, the ice accumulation may extend upstream from Lake St. Clair nearly to Port Huron.

During most of the winter, a large natural ice arch forms at the outlet of Lake Huron and prevents ice from entering the river. This condition usually lasts through the winter, but strong southerly winds, particularly in March and April, may disrupt the ice arch and push ice away from the river mouth. If the ice arch does not re-form, a north wind can then push the ice field back into the river in large quantities, as it did in 1901 (Cole 1903), 1920, 1942, and 1984 (COE 1984).

In 1984 the ice jam in the St. Clair River lasted from April 5 to 30 (COE 1984). On April 1, no ice was in the St. Clair River, but a large pack of ice covered the southern portion of Lake Huron. On April 5 a large amount of ice was reported floating downstream in the vicinity of Marine City. By April 7, pack ice extended from Marysville to the lower cutoff channel. The large ice pack in Lake Huron and persistent north winds in April choked the St. Clair River with ice until April 30. Ice thickness of 8 ft was reported. Water temperature during April in the St. Clair River was about 6°F lower than normal and flow was reduced by almost 95,000 ft^3/s, resulting in a 2-ft drop in Lake St. Clair water levels, which persisted for about 3 days. During April at least 140 vessels were assisted through the St. Clair River by four Coast Guard ice breakers. Vessel movement through the river at this time was slow and difficult and, several vessels ran aground.

The upper Detroit River usually does not freeze over, except in the broad, shallow area between Belle Isle and the United States mainland. Minor ice jams occur when large quantities of floe ice come down from Lake St. Clair and encounter the narrow channel and shallow ice covered areas in the lower river, that block downstream passage of the floe ice. Easterly winds also move Lake Erie ice into the lower river, causing ice jams. Ice cover develops in the lower river in the broad, shallow expanses adjacent to the many islands; however, the main navigation channels are generally open. Occasionally the river fills completely with ice, when there is heavy ice movement from Lake St. Clair and the river mouth is blocked by ice from Lake Erie (Derecki 1984 c).

In several areas within the SCDRS the concentrations of toxic materials in sediments are elevated, and it has been demonstrated (Limno-Tech, Inc. 1975) that contaminants affect the health and abundance of fish, macrophytes, and particularly, macrozoobenthos. Concentrations of pollutants in the sediments of SCDRS are relatively high and some exceed criteria set by the U.S. Environmental Protection Agency (EPA). These pollutants include polychlorinated biphenyls (PCB), hexachlorobenzene (HCB), octachlorostyrene (OCS), phenol, polyaromatic hydrocarbons, (PAH), cyanide, oil and grease, cadmium, chromium, and mercury. The contaminated areas tend to be near shore, and near point sources, but also occur in depositional areas far removed from known point sources. The distribution of contaminants in sediments is difficult to assess--as it is typically in riverine environments. The major point source in the St. Clair River is the Sarnia, Ontario, industrial complex. The reported ranges of concentrations of contaminants in the upper St. Clair River follow: PCB, 0-10,000 ppb; OCS, 1-193 ppb; oil and grease, 250-260 ppm; and

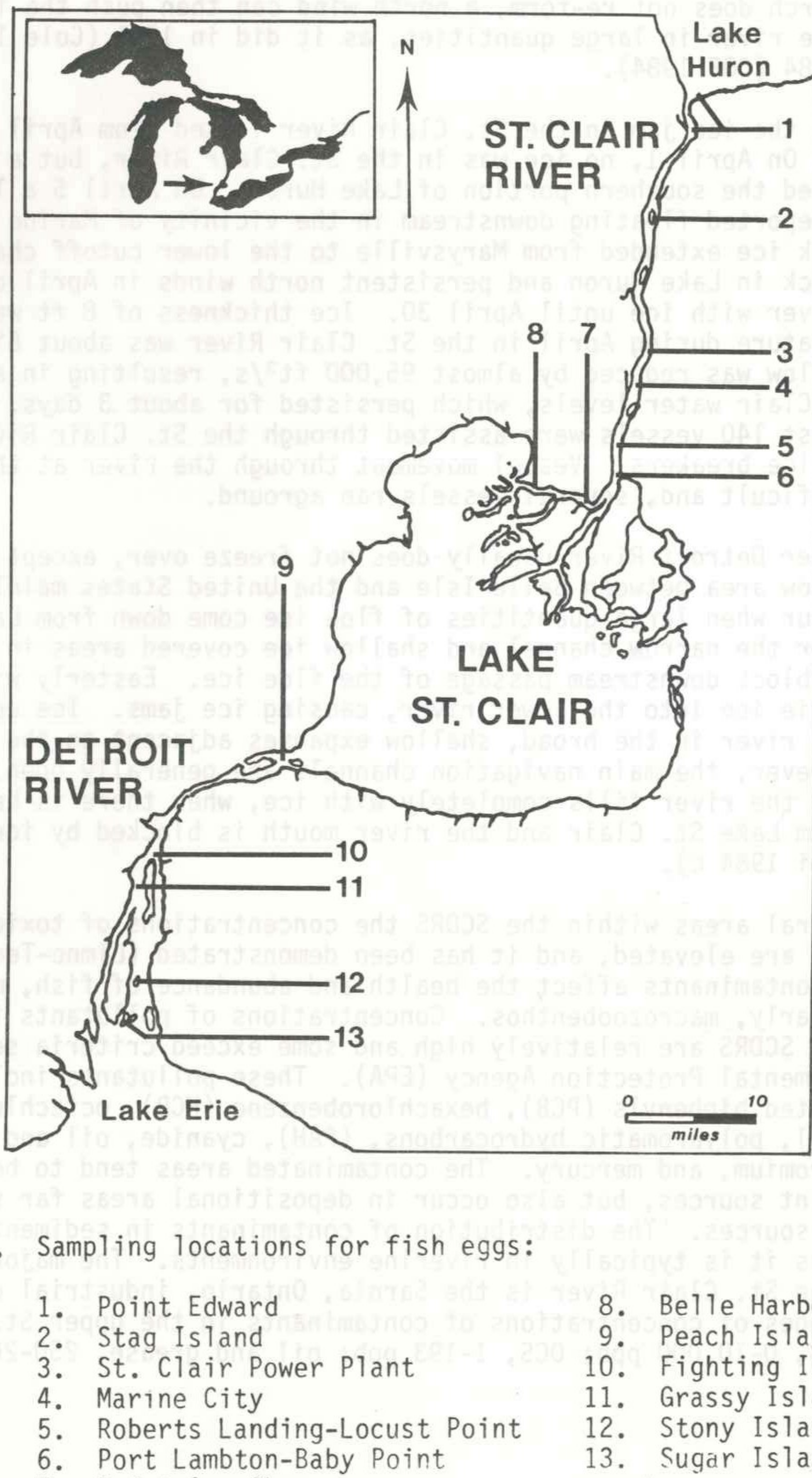


Fig. 2. Sampling locations for fish eggs:

1. Point Edward
2. Stag Island
3. St. Clair Power Plant
4. Marine City
5. Roberts Landing-Locust Point
6. Port Lambton-Baby Point
7. Point Aux Chenes
8. Belle Harbor
9. Peach Island
10. Fighting Island
11. Grassy Island
12. Stony Island-Crystal Bay
13. Sugar Island-Hickory Island

mercury, 0.1-58 ppm. PCB levels exceed the Ontario guidelines (50 ppb) and IJC objectives (100 ppb), and mercury in certain areas (>1 ppm) exceeds the EPA guideline. No standards exist for OCS in sediments. Oil and grease levels are judged acceptable in most areas. Limited sampling has indicated that concentrations of contaminants are lower in the St. Clair delta. Deposition of sediments in Lake St. Clair, in the mid-lake area near the navigational channel, has resulted in the following ranges of concentrations: PCB, 5-50 ppb; HCB, 36-99 ng/g; OCS, 1-30 ppb; cadium, 1-2 ppm; and mercury, 1-3 ppm. Cadmium (>1 ppm) exceeds Ontario's guidelines and mercury levels can be classified as constituting heavy pollution; no guidelines exist for HCB in sediments. The entire Detroit River--particularly the lower section associated with the industrial complex on the U.S. shore--is the most severely polluted area in SDCRS. Pollutants include PCB (20-3800 ppb), HCB (0-36 ppb), OCS (1-10 ppb), oil and grease (100-29,000 ppm), cyanide (0.25-2.94 ppm), phenols (0-1 ppm), chromium (4-330 ppm), mercury (0-8 ppm), and cadmium (0-17 ppm). PCB, oil and grease, cyanide, chromium, cadmium, and mercury levels exceed EPA's guidelines for heavily polluted sediments. (No standards exist for phenol or PAH.) A total of 15 PAH compounds have been found at detectable levels and mean concentrations measured have been as high as 39 ppm for individual compounds. Some of these data were collected in the 1970's and some pollutants have declined since then. More data are needed to provide a comprehensive and current assessment of sediment contaminant levels and to establish standards.

MATERIALS AND METHODS

We attempted to locate stations in the field by triangulation, using fixed visual reference points on the shorelines and by Loran-C navigation. Our previous experience with Loran-C on Lake Erie showed it to be a rapid and reliable technique that enabled us to consistently return to within about 16 m of previously marked locations. We anticipated similar results from Loran-C in SCDRS, but apparently the proximity of shoreline structures, electrical interference, or other conditions distorted the signals received by the Loran-C unit aboard our boat and yielded coordinates for a given location that were grossly unreliable. Although we continued to record Loran-C readings throughout the 2 years of the study, we relied mainly on triangulation and visual reference fixes to locate the stations at which we collected samples. We cannot define the accuracy and precision of the triangulation methods we used, but believe that the approach was adequate to permit us to satisfactorily locate established stations within about 30 m.

Locations for collecting fish eggs (Fig. 2; Appendix 1) were selected because they were described by Goodyear et al. (1982) as spawning areas for walleyes, yellow perch, and lake sturgeon. A total of 159 stations were visited at the 13 locations to collect fish eggs. Sampling was conducted in April-June in 1983 and in May - July in 1984 (Table 1). Sampling was scheduled to begin in April 1984, but was delayed until May due to an unusually severe ice jam in the St. Clair River.

Table 1. Dates and locations (station numbers[a/]) of pumped sampling for fish eggs in the St. Clair and Detroit rivers.

Dates		
April 12-16, 1983 May 15-17, 1984	May 10-12, 1983 June 14-15, 1984	June 7-10, 1983 July 17-18, 1984
9 - 32	1 - 8	41 - 44
45 - 60	33 - 40	51
114 - 137	91	53 - 54
140	100 - 113	56 - 57
142	122	63 - 113
144 - 153	125	138 - 139
155	130 - 135	141
157	138 - 139	143
	141	154
	143	156
	150	158 - 159
	153 - 159	

a/ See Appendix 1 for locations of stations.

Fish eggs were collected with a 3-horsepower gasoline-powered centrifugal pump system capable of delivering about 100 gal/min (371 L/min) through a hose 2 inches (5.1 cm) in diameter. The pump intake head was moved along the river bottom and the pump discharge was strained through a nested series of sieving boxes to separate the larger debris from the finer sediments and the eggs, which accumulated in a plankton net constructed of 355 μm Nitex. The material that accumulated in the plankton net after 5 minutes of pumping was considered to be a sample. One such sample was collected at each visit to a station. Water depth and surface water temperature were recorded, and bottom type was determined from a Ponar dredge sample collected at each station at the time of sampling. Samples were preserved in 10% formalin and taken to the laboratory for analysis.

In the laboratory, eggs were extracted manually from the samples under a dissecting microscope at magnifications of 7 - 30 X, counted, and stored for identification. Attempts to identify fish eggs to species were severely impeded by the lack of suitable keys. However, we were able to use the information published by Auer (1982) to compile a decision table (Table 2) that allowed us to identify the eggs to species on a "most probable" basis. Key characteristics were egg diameter, unique egg structures (such as oil globules), preferred spawning temperatures, and spawning season. Other egg characteristics such as color and adhesiveness were altered by formaldehyde and could not be used to identify preserved eggs.

The procedure used to identify eggs was as follows: first, each egg sample was washed through a nested series of three sieves (mesh sizes of 2.0, 1.0, and 0.5 mm) to sort the eggs into small (0.9 mm), medium (1.0-1.9 mm), and large (2.0 mm) size groups. Most samples contained eggs in only one size group, but occasionally two size groups were represented in a single sample. Subsamples of each size group represented in a sample were then examined under a microscope for definitive characteristics. Egg diameters were measured with an ocular micrometer. Referring this information to the species decision table usually narrowed the choices to one or, at most, a few species. When more than one choice existed, we compared water temperature records at the time of sample collection with preferred spawning temperatures of the species being considered and made the identification on that basis. No statistical analyses were performed on the fish egg data because the number of eggs identified was too small.

Fish were sampled at a total of 51 stations along 15 cross-river transects in SCDRS (Fig. 3, Appendix 2). Transects II, IV, V, and XII were located in the lower reaches of the Black, Pine, and Belle rivers, and the River Rouge, respectively--major U.S. tributaries to the St. Clair and Detroit rivers. A single mid-channel station was located along each of these four transects. The remaining 11 transects were in the main St. Clair and Detroit rivers; three to five stations were located on each of these transects, depending on the depth and width of the river.

Fish were collected with a 0.5 m cylinder-on-cone townet constructed of

Table 2. Key characteristics of eggs and spawning requirements of common fish species in the St. Clair and Detroit rivers (after Auer, 1982).

Species	Egg diameter (mm)	Oil globule	Spawning season	Spawning temperature (°C)	Miscellaneous
Lake sturgeon	3.2-3.5		Spring	11-16	Very tough
Longnose gar	3.3-3.5		Late spring - early summer	18.9-21.2	Similar to sturgeon eggs
Shortnose gar	1.5		May - June		Surrounded by gelatinous substance
Alewife	0.95-1.27	Tiny droplets	May - August	10-27	Pelagic
Gizzard shad	0.9-1.1	One large (0.2 mm); 1-5 droplets	April - June	10-24	
Lake whitefish	2.0-3.0	Between 100 and 200; largest 0.2 mm	October - December	4-12; peak 8	Chorion colorless, yolk amber
Rainbow smelt	0.9-1.3	Numerous	April - May	4-15; peak 10	
Mud minnow	1.6	Small and highly refractive		12.8-15.6	In algal nests
Northern pike	2.2-3.0	Numerous and small; in clusters	March - May	4-11	Surface of chorion obscurely reticulate
Goldfish	1.0-1.7	Many sparsely scattered droplets (0.01-0.05 mm) in yolk	May or June	16	Perivitelline space narrow (0.1 mm)
Common carp	1.5-2.1		Mid-May - early June	15-25	Perivitelline space 0.2-0.3 mm
Silver chub	0.8-1.3		Mid-June - mid-August	Begins at 18; most above 21	
Golden shiner	1.0-1.4	None	May - August	20-21; ceases above 27	
Emerald shiner	3.0-3.3		April - mid-August	Begins at 22	Over hard sand and mud
Spottail shiner	1.0-1.4	None	June - July	15-20	Not attached to substrate
Quillback	2.0-2.2	None	Late April - Mid-June	10-28	
White sucker	2.0-3.6	None	April - mid-May	7.2-10	
Shorthead redhorse	2.0-3.3	None	May	11-16	

Table 2 (Cont'd)

Species	Egg diameter (mm)	Oil globule	Spawning season	Spawning temperature (°C)	Miscellaneous
Brown bullhead	3.0		April - June	18.5-25.8	
Channel catfish	3.5		Spring and summer	21.1-29.5	
Tadpole madtom	2.8-3.5		May - July		
Trout-perch	1.3-1.9	Single (0.7 mm)	May - August	4.4-10; 15 and 15.6-20	Spawns on beaches and over gravel
Burbot	1.0-1.7	Single; large and clear	December - March	0.4-4.0	Spawning period incompletely known
Brook silverside	1.1-1.4	Numerous (0.1-0.5 mm)	May - August	20-23	
White perch	0.7-0.8	Single; sometimes many small globules (0.2-0.4 mm); amber	Mid-May - late June	11-15	Single attached disk on chorion
White bass	0.7-1.0	Single (0.25-0.3 mm)	April - June	12-16; up to 24	Perivitelline space 0.04-0.8 mm
Pumpkinseed	0.8-1.2	Largest 0.3-0.4 mm; sometimes 1-2 minute droplets	May - August	17.5-29	Eggs in nests or attached
Bluegill	1.2-1.4	Single (0.38 mm)	May - August	17.2-30.5	Nests on gravel, sand, clay, or mud bottom
Smallmouth bass	1.8-2.8	One large (0.9-1.7 mm); numerous smaller droplets	April - June	12.8-23.9	Spawns on rock, gravel, and coarse sand
Largemouth bass	1.4-2.0	Usually single (0.65-0.7 mm); a few small ones may be present	April - July	16-23.9	Eggs are attached to stones, roots, detritus, etc.
White crappie	0.8-0.9	Large and single	April - July	14-23	Spawns on rocks, gravel, sand, clay, mud, roots, or tree leaves
Black crappie	0.9	Single	April - July	17.4-20	Nests constructed on clay or mud, but sand and gravel preferred
Johnny darter	1.4-1.5	Single and large	April - June	11.7-21.1	Deposits eggs on underside of rocks, logs, and other debris

Table 2 (Cont'd)

Species	Egg diameter (mm)	Oil globule	Spawning season	Spawning temperature (°C)	Miscellaneous
Yellow perch	1.9-2.8; sometimes - 3.5	Single; amber or clear yellow (0.4 mm)	April - June	7.2 and 11.1 but also at 5.6-18.5	Yolk light amber
Logperch	1.09-1.15	Single and large or numerous and small (0.43 mm)	April - July	10-15	Attachment disk present; granular yolk (0.77 mm); spawns on sand
Walleye	1.5-2.1	Single	April - May	3.3-14; mostly 4.4-10	Eggs broadcast over large unguarded areas of coarse gravel, rocks and boulders
Freshwater drum	1.0-1.7	Single; sometimes with smaller globules (0.6-0.7 mm)	April - August	18-25	Yolk diameter 0.9-1.1 mm
Mottled sculpin	1.3	Single	March - May	5.6-16.7	Short spawning period (2 to 5 days)
Slimy sculpin	2-3		April - June	3.0-11.5	

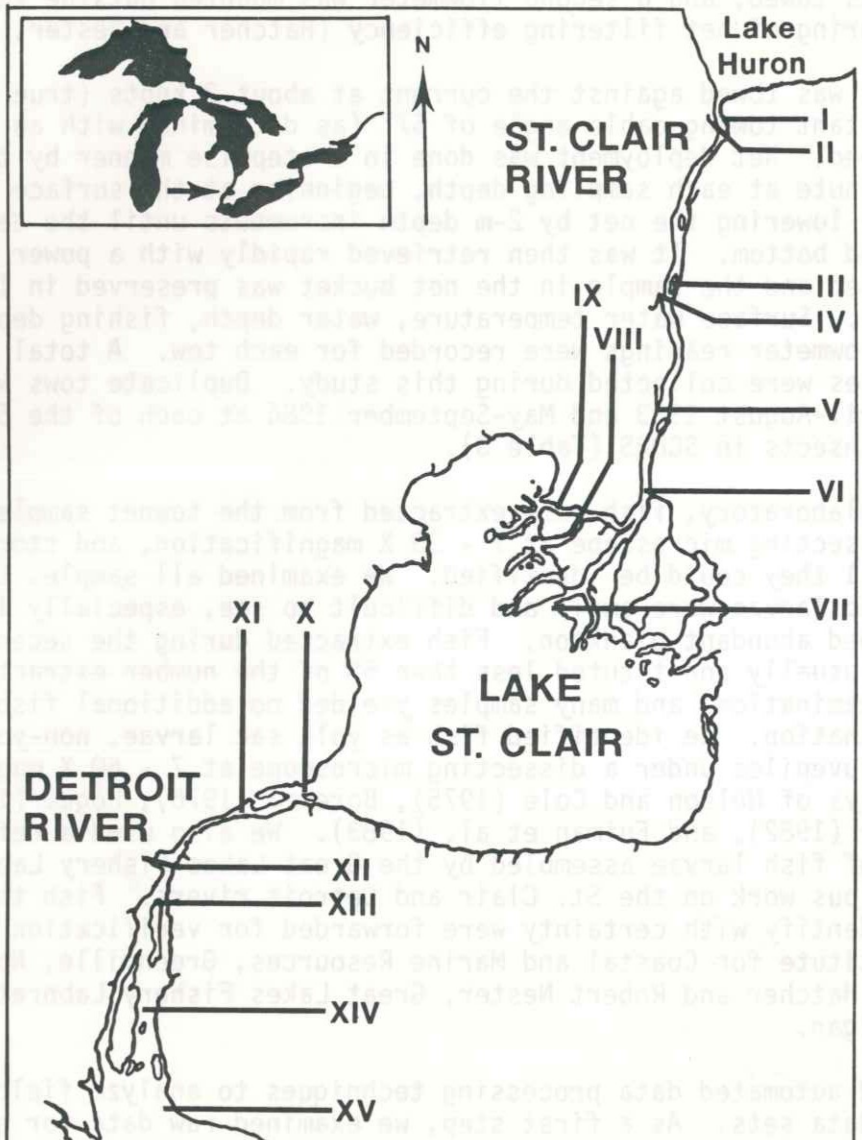


Fig. 3. Sampling transects for fish larvae:

I. Port Huron
II. Black River Mouth
III. St. Clair
IV. Pine River Mouth
V. Belle River Mouth
VI. Willow Point
VII. Cutoff Channel
VIII. Middle Channel
IX. North Channel
X. Upper Belle Isle
XI. Lower Belle Isle
XII. River Rouge Mouth
XIII. Fighting Island
XIV. Stony Island
XV. Bois Blanc Island

355 μm Nitex (Fig. 4). The net was lashed to a 0.5-m net ring suspended in a square frame, with the towing bridle attached to the four corners so that the bridle wires were not directly in front of the net opening when the net was in tow. A General Oceanics Model 2030 digital flowmeter was mounted inside the net as it was towed, and a second flowmeter was mounted outside the net to allow monitoring of net filtering efficiency (Hatcher and Nester, 1983).

The net was towed against the current at about 3 knots (true water speed) while a constant towing cable angle of 67° (as determined with an inclinometer) was maintained. Net deployment was done in a stepwise manner by towing the net for 1 minute at each sampling depth, beginning at the surface and successively lowering the net by 2-m depth increments until the depressor plate touched bottom. It was then retrieved rapidly with a power winch. The net was rinsed and the sample in the net bucket was preserved in 10% formalin for analysis. Surface water temperature, water depth, fishing depth, towing time, and flowmeter readings were recorded for each tow. A total of 1,020 townet samples were collected during this study. Duplicate tows were made monthly, April-August 1983 and May-September 1984 at each of the 51 stations along 15 transects in SCDRS (Table 3).

In the laboratory, fish were extracted from the townet samples with the aid of a dissecting microscope at 7 - 30 X magnification, and stored in 30% ethanol until they could be identified. We examined all samples twice because newly hatched larvae were small and difficult to see, especially in samples that contained abundant plankton. Fish extracted during the second examination of a sample usually constituted less than 5% of the number extracted during the first examination, and many samples yielded no additional fish during the second examination. We identified fish as yolk sac larvae, non-yolk sac larvae, or juveniles under a dissecting microscope at 7 - 60 X magnification, using the keys of Nelson and Cole (1975), Boreman (1976), Hogue (1976), Cooper (1978), Auer (1982), and Fuiman et al. (1983). We also used a reference collection of fish larvae assembled by the Great Lakes Fishery Laboratory staff during previous work on the St. Clair and Detroit rivers. Fish that we were unable to identify with certainty were forwarded for verification to John Cooper, Institute for Coastal and Marine Resources, Greenville, North Carolina; and Charles Hatcher and Robert Nester, Great Lakes Fishery Laboratory, Ann Arbor, Michigan.

We used automated data processing techniques to analyze field and laboratory data sets. As a first step, we examined raw data for errors, using the computer to generate data verification plots. Data points outside the range of expected values were immediately apparent and easily checked to determine if they were faulty. These suspect data points were usually traceable to recording errors or faulty equipment. Each error was corrected, or the suspect data point was discarded. Estimated substitute values were not used. The occasional malfunctioning of flowmeters resulted in the loss of a few data points needed to calculate the density of fish larvae, but these missing data points did not significantly affect our analyses.

Estimates of the density of fish larvae, expressed as the number of larvae per 1000 m^3 of water strained, were obtained by dividing the total

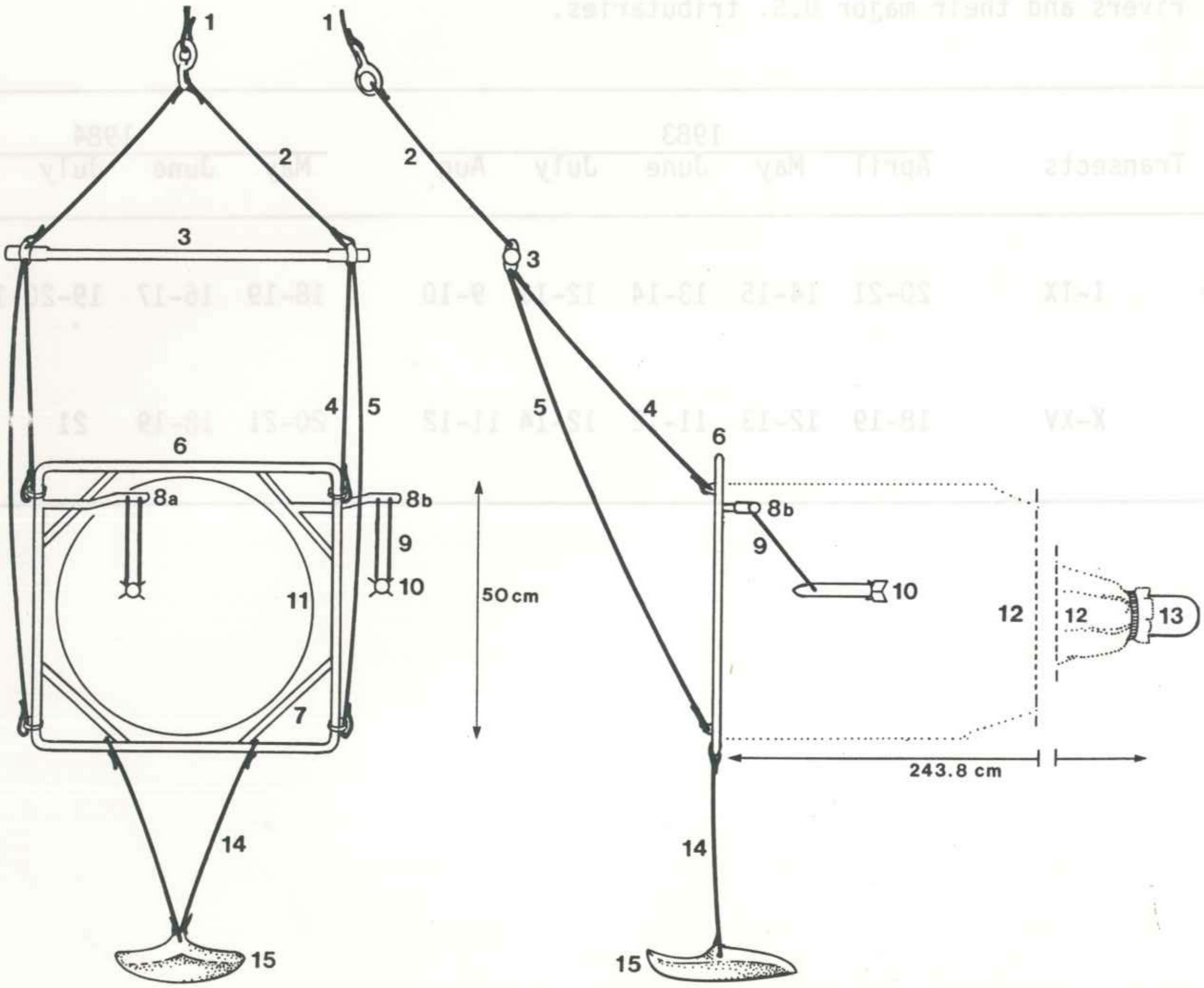


Fig. 4. Front and side views of cylinder-on-cone townet (after Hatcher and Nester, 1983).

1. Towing cable
2. Fore-bridle
3. Spreader bar
4. Side cable
5. Side cable
6. Net frame
7. Net grame corner supports
8. Flowmeter support brackets
9. Flowmeter support cable
10. Flowmeter
11. Net ring
12. Net
13. Net bucket
14. Depressor cable
15. Depressor plate

Table 3. Dates and locations of townet sampling for fish larvae in the St. Clair and Detroit rivers and their major U.S. tributaries.

River	Transects	1983 April	1983 May	1983 June	1983 July	1983 Aug.	1984 May	1984 June	1984 July	1984 Aug	1984 Sept
St. Clair	I-IX	20-21	14-15	13-14	12-13	9-10	18-19	16-17	19-20	14-15	19-20
Detroit	X-XV	18-19	12-13	11-12	12-14	11-12	20-21	18-19	21	16	18

number of yolk-sac and non-yolk-sac larvae captured in each set of duplicate tows at a station by the total volume (cubic meters) of water strained during those tows, and multiplying the result by 1000.

Analysis of Variance (ANOVA) and, when appropriate, Tukey's studentized range test were used to test for significant temporal and spatial differences in the density of all species combined and of alewife larvae (too few larvae of other species were taken to permit statistical analysis by species). We also tested the significance of correlations between the abundance of larvae, and the physical variables of water temperature, and fishing depth. The 5% level of significance ($\underline{P}$ = 0.05) was adopted for all statistical tests. We performed these analyses with the main frame computer of the Michigan Terminal System on the University of Michigan campus, using the Statistical Analysis System (SAS) program.

All field data collected each time sampling was conducted in 1983 and 1984 are given in Appendices 3 and 4.

RESULTS AND DISCUSSION

Water Temperatures and Warming Rates

Inasmuch as water temperatures and warming rates are considered to be important factors affecting the time of fish spawning, the time of egg hatching, and the survival of eggs and larvae (Busch et al. 1975), we recorded surface water temperatures at all stations (Table 4; Appendices 3 and 4) to determine if the abundance of eggs and larvae in 1983 and 1984 was influenced by temperature. We also obtained water temperature data collected in 1977 and 1978 (Hatcher and Nester 1983) at several of the same transects that were sampled during the present study. Finally, we acquired mean monthly temperature data for 1983-1984 from the Port Huron and Detroit municipal water intakes (Table 5) to permit us to describe water temperature trends for each river.

Differences in water temperatures between years and between rivers in 1983-1984 were evident (Table 4). Temperatures in the St. Clair River (transects I-IX) were similar in May during both years, but in June were nearly always 3-5°F lower in 1983 than in 1984. In July and August, temperatures were about 1-2°F lower in 1983 than in 1984. Although these year-to-year differences are small they nevertheless indicate that the rate of water warming was slower in 1983 than in 1984. The portion of the Detroit River represented by transects X-XV did not demonstrate this consistent difference in warming rate between years, but since the temperatures in June and August were about 3-6°F lower in 1983 than in 1984, the net effect was generally one of lower summer water temperatures in 1983. Water temperature differences between rivers during May-August in 1983-1984 (Tables 4 and 5) were also evident. Lake St. Clair acts as a warming basin raising water temperatures in the Detroit River about 5°F above those in the St. Clair River during May, June, and July, when many species spawn. Temperatures in the St. Clair River were consistently

Table 4. Mean surface water temperatures (°F) at townet stations in the St. Clair and Detroit rivers and their major U.S. tributaries.

Transect	Station	April 1983	May 1983	May 1984	June 1983	June 1984	July 1983	July 1984	August 1983	August 1984	Sept 1984
St. Clair River											
I	1	38	45	44	54	57	64	65	71	72	62
	2	38	45	43	50	56	63	65	71	72	61
	3	38	43	44	49	56	63	65	71	71	60
II	1	41	59	55	66	64	70	69	77	77	62
III	1	38	45	44	54	57	64	65	72	72	61
	2	38	44	44	53	56	64	65	72	72	61
	3	38	44	44	51	56	64	65	72	72	61
IV	1	40	51	46	72	63	69	68	74	75	64
V	1	41	61	52	71	68	75	70	76	78	64
VI	1	40	47	46	54	58	65	66	73	73	62
	2	40	47	46	54	58	65	66	73	73	62
	3	40	44	44	52	57	64	66	72	72	61
	4	40	45	45	51	57	64	66	72	72	61
	5	40	47	48	54	59	68	67	75	75	62
VII	1	41	45	45	52	57	64	66	71	72	62
	2	41	45	45	52	57	64	66	71	72	62
	3	41	45	45	52	57	64	66	71	73	62
	4	41	45	45	52	57	64	66	71	73	62
	5	41	45	45	53	57	64	66	71	73	62
VIII	1	40	45	44	53	58	65	66	72	73	63
	2	40	45	44	53	58	65	66	71	73	63
	3	40	45	44	53	58	65	66	71	73	63
	4	40	45	45	53	58	65	66	71	73	63
	5	40	45	46	53	58	65	66	71	73	63
IX	1	40	46	45	54	58	65	66	72	73	63
	2	40	46	45	53	58	65	66	71	73	63
	3	40	45	45	53	58	64	66	71	73	63
	4	40	45	45	53	58	65	67	71	73	63
	5	40	45	59	53	58	65	67	72	73	63
Detroit River											
X	1	41	54	51	59	65	71	70	71	76	64
	2	41	53	49	58	65	71	69	71	75	63
	3	41	50	49	60	66	70	69	70	75	65
	4	41	52	50	60	67	70	71	70	76	64
XI	1	42	54	51	59	66	72	70	71	76	64
	2	42	51	48	57	65	72	69	71	74	63
	3	42	51	49	59	67	72	71	70	76	64
XII	1	42	58	55	64	70	76	76	76	80	66
XIII	1	41	56	52	60	66	72	71	73	76	64
	2	41	52	51	59	67	72	69	72	76	63
	3	41	51	49	59	67	70	70	72	75	64
	4	41	51	50	60	67	70	70	72	76	64
XIV	1	41	51	49	60	66	72	70	73	76	64
	2	39	51	49	60	66	72	70	73	76	64
	3	39	51	48	60	67	72	70	73	76	64
	4	39	52	49	60	67	72	70	73	76	64
	5	39	54	49	60	70	72	71	72	76	65
XV	1	41	51	51	62	66	71	70	73	75	64
	2	41	51	50	61	66	71	70	72	75	63
	3	41	51	51	61	67	71	71	72	75	64
	4	41	51	49	60	67	71	71	72	75	64
	5	41	52	51	61	68	71	71	72	76	64

Table 5. Mean monthly water temperatures (°F) in the St. Clair and Detroit rivers at the water intake of the cities of Port Huron Detroit.

Year	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
						St. Clair River[a]						
1974	34	33	35	39	47	53	64	69	65	54	49	30
1975	36	--	34	37	49	57	67	71	62	57	51	40
1976	33	34	35	41	48	59	66	69	65	55	43	34
1977	33	33	35	40	51	59	67	69	--	55	48	38
1978	33	33	33	38	--	56	65	--	66	55	48	38
1979	33	33	34	38	46	56	64	69	66	57	48	40
1980	34	33	34	40	49	55	66	71	66	55	45	37
1981	33	34	35	41	48	59	70	71	66	55	48	38
1982	34	33	33	38	50	56	66	70	63	58	49	42
1983	33	34	33	33	44	57	66	71	63	55	46	40
1984	33	34	33	33	44	57	66	71	63	55	46	40
Average	34	33	34	39	48	57	66	70	65	56	47	39
						Detroit River						
1973	33	33	35	43	50	63	70	73	69	60	46	37
1974	33	33	34	41	51	61	70	72	65	53	47	36
1975	34	33	34	39	55	64	72	72	63	56	48	37
1976	33	33	37	47	51	68	70	71	65	52	39	33
1977	33	33	35	45	57	65	73	71	68	54	47	34
1978	33	33	33	40	53	64	70	73	69	54	47	36
1979	33	33	34	41	52	62	69	70	67	56	46	38
1980	34	33	34	42	54	62	71	73	68	54	43	35
1981	33	33	35	46	52	65	73	73	66	53	46	38
1982	33	33	34	40	57	63	71	72	66	57	47	40
1983	35	34	38	42	51	63	73	75	70	58	45	36
1984	33	34	34	42	49	64	70	74	66	57	45	38
Average	33	33	35	42	53	64	71	72	67	55	46	37

[a] Dashes indicated data not available.

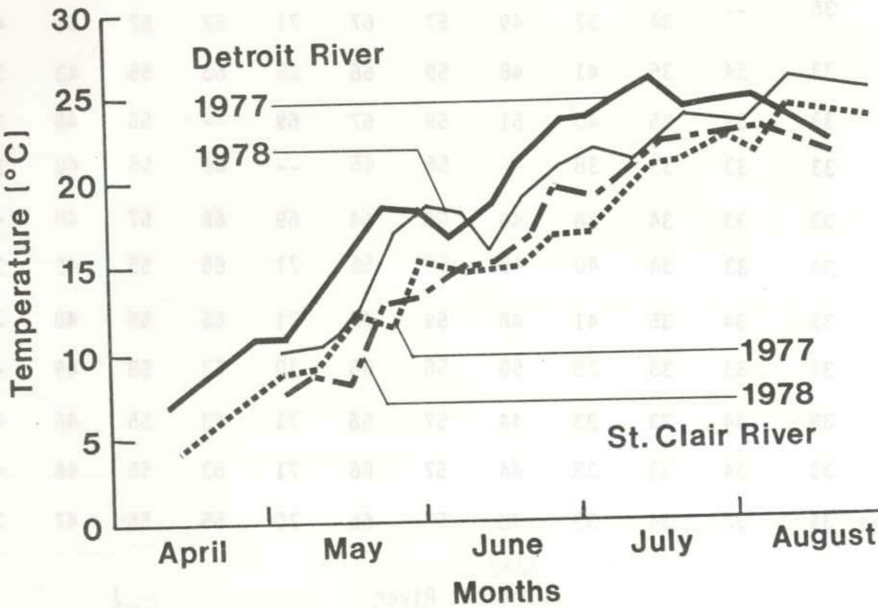


Fig. 5. Mean surface water temperature (°C) in the Detroit River at transects V and VI in 1977 and at transects V-VIII in 1978, and in the St. Clair River at transects I-IV in 1977 and at transects II and IV in 1978 (Hatcher and Nester, 1983).

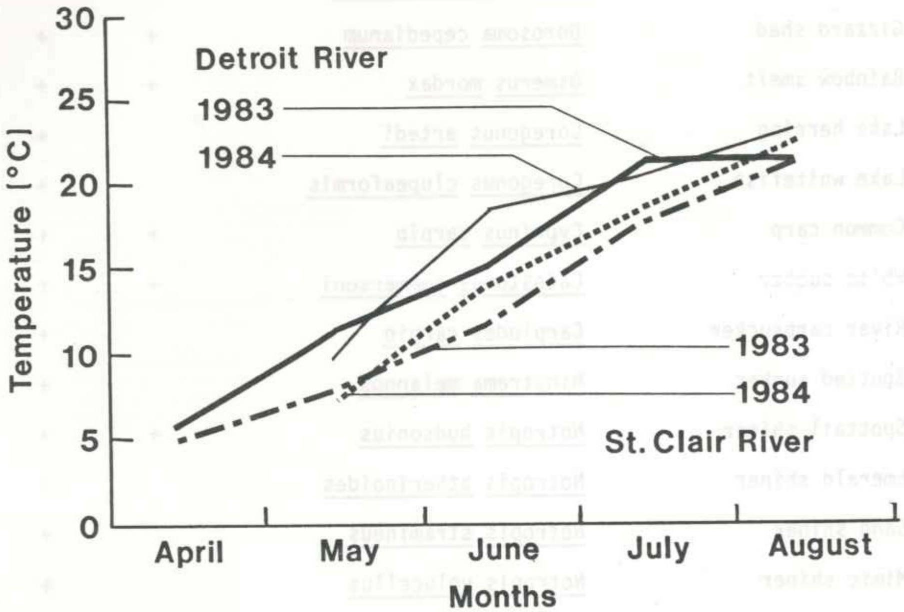


Fig. 6. Mean surface water temperature (°C) in the St. Clair River at transects I, III, VI, VII, VIII, IX, and in the Detroit River at transects X, XI, XIII, XIV, and XV in 1983 and 1984.

Table 6. Species of fish represented in catches of eggs and larvae made in the St. Clair and Detroit rivers and their major U.S. tributaries in 1983-1984.

Common name	Scientific name	Life stage collected Egg	Life stage collected Larva
Sea lamprey	*Petromyzon marinus*		+
Alewife	*Alosa pseudoharengus*	+	+
Gizzard shad	*Dorosoma cepedianum*	+	+
Rainbow smelt	*Osmerus mordax*	+	+
Lake herring	*Coregonus artedi*		+
Lake whitefish	*Coregonus clupeaformis*		+
Common carp	*Cyprinus carpio*	+	+
White sucker	*Catostomus commersoni*	+	+
River carpsucker	*Carpiodes carpio*		+
Spotted sucker	*Minytrema melanops*		+
Spottail shiner	*Notropis hudsonius*	+	+
Emerald shiner	*Notropis atherinoides*		+
Sand shiner	*Notropis stramineus*		+
Mimic shiner	*Notropis volucellus*		+
White bass	*Morone chysops*	+	+
Rock bass	*Ambloplites rupestris*		+
White crappie	*Pomoxis annularis*	+	+
Burbot	*Lota lota*	+	+
Trout-perch	*Percopsis omiscomaycus*	+	+
White perch	*Morone americanus*	+	+
Freshwater drum	*Aplodinotus grunniens*	+	+
Brook silverside	*Labidesthes sicculus*		+
Johnny darter	*Etheostoma nigrum*	+	+
Logperch	*Percina caprodes*	+	+
Yellow perch	*Perca flavescens*	+	+
Walleye	*Stizostedion vitreum vitreum*	+	+
Central mudminnow	*Umbra limi*	+	
Northern pike	*Esox lucius*	+	
Mottled sculpin	*Cottus bairdi*	+	+
Slimy sculpin	*Cottus cognatus*		+
Deepwater sculpin	*Myoxocephalus thompsoni*		+

Table 7. Number of fish eggs collected in the St. Clair and Detroit rivers in 1983-1984.

River and species	Number of eggs	Percent of total for river
St. Clair		
Rainbow smelt	7,357	82
Gizzard shad	728	8
Alewife	458	5
Trout-perch	187	2
Johnny darter	127	1
Yellow perch	44	< 1
Walleye	1	< 1
Others	72	< 1
Total	8,974	
Detroit		
Gizzard shad	14,188	65
White bass	3,397	16
Rainbow smelt	1,414	7
White perch	827	4
Central mudminnow	483	2
Alewife	480	2
Yellow perch	282	1
Walleye	411	2
Others	341	1
Total	21,823	

Table 8. Number of fish eggs of different species collected in the St. Clair River in April-June 1983.

Species	April	May	June	Total	Percent of total for all species
Alewife	--	--	456	456	6.6
Gizzard shad	--	1	714	715	10.3
Rainbow smelt	3,679	1,507	372	5,558	79.8
Trout-perch	--	--	168	168	2.4
Logperch	--	--	7	7	0.1
Yellow perch	--	--	25	25	0.4
Mottled sculpin	--	3	--	3	< 0.1
Unidentified	--	18	11	29	0.4
Total	3,679	1,529	1,753	6,961	

Table 9. Number of fish eggs of different species collected in the St. Clair River in May-July 1984.

Species	April	May	June	Total	Percent of total for all species
Alewife	--	2	--	2	0.1
Gizzard shad	--	13	--	13	0.6
Rainbow smelt	1,792	27	--	1,799	89.4
Trout-perch	9	10	--	19	0.9
White perch	--	6	--	6	0.3
Common carp	--	--	2	2	0.1
White sucker	2	1	--	3	0.1
Johnny darter	--	127	--	127	6.3
Yellow perch	14	5	--	19	0.9
Walleye	--	1	--	1	< 0.1
Unidentified	--	22	--	22	1.1
Total	1,797	214	2	2,013	

lower in 1983 than in 1977 and 1978, but temperatures in 1984 were similar to those in 1978 (Figs. 5 and 6). In the Detroit River, temperatures were generally similar in 1978, 1983, and 1984, and were lower than in 1977.

Species Composition and Abundance of Fish Eggs

Of the more than 31 species collected during this study (Table 6; Appendices 5 and 6), at least 13 were represented by fish eggs collected in the St. Clair River in 1983-1984 (Tables 7-9). Eggs of rainbow smelt were the most abundant (82% of the total) followed by those of gizzard shad (8%), alewife (5%), trout-perch (2%), and johnny darter (1%). Yellow perch, walleyes, and lake sturgeon were selected as species of special interest. In the St. Clair River, yellow perch and walleye eggs made up less than 1% of the total egg catch, and no lake sturgeon eggs were taken (Table 7). Nearly 7,000 of the 8,974 fish eggs collected in the St. Clair River were taken in 1983 (Tables 8 and 9). Most of the eggs collected in April and May 1983 were identified as rainbow smelt, and those collected in June were mostly gizzard shad, alewife, smelt, trout-perch, and johnny darter. Eggs collected in 1984 in the St. Clair River were mostly smelt, nearly all of which were taken in May. Eggs of johnny darters, trout-perch, yellow perch, and gizzard shad eggs were among those most frequently collected in 1984.

Low water temperatures in the St. Clair River persisted through April and May during both years and probably extended the spawning season for smelt and increased the chances of collecting smelt eggs. The relatively large numbers of smelt eggs collected in June and the nearly total absence of eggs of other species in May probably reflects the delayed warming in 1983. Rapid warming in May and June 1984 probably enhanced spawning of many species and caused smelt spawning to be nearly completed in May or early June.

During 1983 and 1984, nearly 22,000 eggs of at least 19 species of fish were collected in the Detroit River (Table 6; Appendix 5), nearly 2.5 times the number of eggs collected in the St. Clair River during the same period. This difference suggested that the Detroit River was the more heavily used as a spawning area. Gizzard shad eggs were the most abundant (65% of the total), followed by white bass (16%), smelt (7%), white perch (4%), and alewife (2%). Walleye and yellow perch eggs composed 2% and 1% of the total, respectively, and were more abundant in the Detroit River than in the St. Clair River. No lake sturgeon eggs were taken in the Detroit River.

Year-to-year variations in egg abundance in the Detroit River differed from those observed in the St. Clair River in several ways. About 7,700 (35%) of the 21,823 eggs collected in the Detroit River were taken in 1983 (Tables 10 and 11). Eggs of smelt and yellow perch were most abundant in April and May and those of gizzard shad and white bass predominated in June. In 1984 (when no sampling was done in April), eggs of walleye and yellow perch were most abundant in May and those of gizzard shad and white bass in June.

Lower water temperatures in 1983 apparently decreased spawning success in the Detroit River, where most indigenous fish species are warm-water spawners.

Table 10. Number of fish eggs of different species collected in the Detroit River in April-June, 1983.

Species	April	May	June	Total	Percent of total for all species
Alewife	--	1	466	467	6.1
Gizzard shad	--	--	2,575	2,575	33.4
Rainbow smelt	666	727	--	1,393	18.1
Central mudminnow	--	--	483	483	6.3
Northern pike	7	--	--	7	0.1
Burbot	6	--	--	6	0.1
Trout-perch	--	3	21	24	0.3
White perch	--	--	182	182	2.4
White bass	--	--	2,016	2,016	26.2
Logperch	--	59	--	59	0.8
Yellow perch	82	70	35	187	2.4
Walleye	--	16	255	271	3.5
Mottled sculpin	--	9	--	9	0.1
Unidentified	19	1	--	20	0.3
Total	780	886	6,033	7,699	

Table 11. Number of fish eggs of different species collected in the Detroit River in May-July, 1984.

Species	May	June	July	Total	Percent of total for all species
Alewife	--	12	1	13	0.1
Gizzard shad	--	11,615	--	11,613	82.2
Rainbow smelt	21	--	--	21	0.1
White perch	--	645	--	645	4.6
White bass	--	1,381	--	1,381	9.8
Freshwater drum	--	15	--	15	0.1
Common carp	--	8	--	8	0.1
White sucker	18	--	--	18	0.1
Spottail shiner	--	14	15	29	0.2
White crappie	--	--	1	1	< 0.1
Yellow perch	94	1	--	95	0.7
Walleye	140	--	--	140	1.0
Unidentified	1	140	4	145	1.0
Total	274	13,829	21	14,124	

Rapid warming in May 1984 promoted spawning of most species and gizzard shad and white bass demonstrated the largest increase in number of eggs produced.

Distribution of Fish Eggs

Egg distribution in the St. Clair River varied markedly with month and year (Appendix 5). In April 1983, a few eggs were collected at nearly all stations sampled in the St. Clair River, but 100-400 eggs were collected at each of stations 13, 18, 24, 27, 30, and 31, in the vicinity of Stag Island. Station 51 near Port Lambton and stations 58, 60, and 61 near Chenal Ecarte' each yielded 250-500 eggs. In May, samples at most stations contained few or no eggs, but stations 1, 5, 7, and 8 near Point Edward each contained several hundred eggs. In the June samples most stations contained few or no eggs, but a few hundred eggs were collected at each of the Port Lambton and Chenal Ecarte' stations, and at stations 72 and 74 in the North Channel. Egg abundance in the St. Clair River in May 1984 varied from 10 to about 150 at nearly all stations. In June, 120 eggs were collected at station 1, but fewer than 10 were collected at each of the other stations. In 1984, egg sampling was continued into July because we had been unable to sample in April; however, only 11 eggs were collected in July in the St. Clair River--indicating that most fish had finished spawning.

In the Detroit River in April and May 1983, eggs were abundant at a few stations and scarce or absent at others. Samples from station 137 near Crystal Bay and station 149 near Hickory Island each contained more than 200 eggs in April, and station 150, southeast of Hickory Island, provided nearly 700 eggs in May. Eggs were distributed more uniformly in June; few eggs were collected from stations 83 to 95, but most other stations produced 100-400 eggs and station 101 (at the head of Fighting Island) yielded more than 1,200. In sampling in the Detroit River in May 1984, we collected eggs at only three stations: 131 at station 148 near Hickory Island, 37 at station 151, and 21 at station 146. In June, eggs were more uniformly distributed throughout the river except for a few locations where large egg concentrations occurred. From 20 to 100 eggs were taken at most stations, but stations 143, 153, and 154 each yielded over 1,000; station 135 yielded 2,219 and station 150 yielded 5,006. Only 21 eggs were collected in July in the Detroit River.

The relative abundance of fish eggs on various substrate types is shown in Table 12. Almost 70% of the eggs were collected from substrates composed of either sand or some combination of sand with mud, gravel, or clay. About 60% of the 159 stations sampled had such substrate.

Species Composition and Abundance of Fish Larvae

Fish larvae of at least 29 species were collected in SCDRS during the study (Table 6; Appendix 6). Although some larvae could not be identified to species, most could usually be identified to family level. Species distribution and abundance differed greatly between years and rivers and therefore is best described separately for each river.

Table 12. Percent of total number of fish eggs taken over differemt types of substrate and percent of total number of stations with each type of substrate.

Substrate type	Percent of total number of eggs	Percent of total number of stations
Sand and mud	30.0	11.9
Sand and gravel	23.2	28.3
Mud and clay	18.7	0.6
Sand	14.3	10.7
Mud	5.8	14.5
Sand and clay	3.1	10.1
Gravel and clay	2.5	9.4
Fine gravel	1.0	2.5
Coarse gravel	0.9	6.3
Organic debris	0.3	0.6
Mud and gravel	0.1	1.3
Clay	0.1	1.9
Rubble	< 0.1	1.9

In the St. Clair River a total of 2,056 fish larvae were collected from in 1983 (Table 13). Alewife larvae constituted more than 62% of the total and were nearly 4 times more abundant than smelt, which ranked second. Unidentified darter larvae were collected in large numbers in June and in smaller numbers during other months, and were the third most abundant larvae in the catch. Only small numbers of other species were collected, and many species were represented in the catch by only one or two fish. The catch of larvae in the St. Clair River in 1984, (Table 14) was about twice that in 1983. Of the 4,195 larvae taken in 1984, alewives were the most abundant (63% of the total), followed by logperch (13%) and emerald shiners (7%). Other species were relatively scarce. Neither lake sturgeon nor walleye larvae were collected from the St. Clair River in 1983-1984, but some yellow perch larvae were taken mainly in 1984.

The lower water temperatures and slower rate of warming in the St. Clair River in 1983 (Fig. 5) may have reduced reproductive success of most species in that year. Smelt, a cold-water spawner, is perhaps less adversely affected by delayed water warming; perhaps as a result, the abundance of larvae of this species was higher in 1983 than in 1984 (Tables 13 and 14). Conversely, the alewife is a late-spawning species, and the large numbers of larvae present in August suggested that the slower water warming rate probably delayed spawning, but did not severely reduce it. In 1984, persistent ice conditions during April resulted in low water temperatures through May, but rapid warming in June was apparently conducive to successful spawning for most species. Alewife spawning probably peaked earlier in 1984 than in 1983, and larvae were most abundant in July.

Hatcher and Nester (1983) also offered evidence that water temperature affected the production of fish larvae in the St. Clair River. Abundance of smelt was higher--and water temperature was lower--in 1978 than in 1977. Alewife and logperch larvae were more abundant and yellow perch larvae were also slightly more abundant during the warmer water conditions in 1977.

In the Detroit River a total of 2,076 fish larvae were collected in 1983 (Table 15). Alewife larvae dominated the catch (33% of the total); other abundant species were gizzard shad (20%), emerald shiner (15%), and white perch (10%). Only a few larval yellow perch and walleyes were taken, indicating that spawning by these species in the Detroit River was limited. In 1984, the 2,800 fish larvae collected in the Detroit River (Table 16) were mostly alewife (28%), gizzard shad (23%), emerald shiner (20%), and white perch (8%). The abundance of yellow perch increased slightly in 1984 from that in 1983, but walleye abundance remained low and unchanged. Improved spawning success in 1984 for some species was suggested by the small increases in the abundance of larvae shown in Tables 15 and 16.

Between year differences in water temperatures and in the abundance of larvae in the Detroit River were not as large as those observed in the St. Clair River during the same general period. Abundance of larvae was highest in June and July in both 1983 and 1984 in the Detroit River (and in 1983 in

Table 13. Number of fish larvae of different species collected in the St. Clair River and its major U.S. tributaries in 1983.

Species	April	May	June	July	August	Total	Percent of total for all species
Alewife	--	--	6	567	703	1,276	62.1
Rainbow smelt	--	310	25	--	--	335	16.3
Unid. darter	--	1	192	20	26	239	11.6
Logperch	--	--	34	17	--	51	2.5
Gizzard shad	--	--	26	6	11	43	2.1
Emerald shiner	--	--	1	8	17	26	1.3
Deepwater sculpin	10	5	--	--	--	15	0.73
Unid. species	--	5	5	5	--	15	0.73
Burbot	--	13	--	1	--	14	0.68
Spottail shiner	--	--	--	--	13	13	0.63
White sucker	--	--	--	8	--	8	0.39
Unid. Morone sp.	--	--	3	--	--	3	0.15
Freshwater drum	--	--	1	--	2	3	0.15
White perch	--	--	2	--	--	2	0.1
Unid. Clupeidae	--	--	--	2	--	2	0.1
Unid. Percidae	--	--	--	1	1	2	0.1
Lake herring	--	1	--	--	--	1	0.05
Yellow perch	--	1	--	--	--	1	0.05
Unid. Cyprinidae	--	--	--	1	--	1	0.05
Mottled sculpin	--	--	--	1	--	1	0.05
Brook silverside	--	--	--	--	1	1	0.05
Sea lamprey	--	--	--	--	1	1	0.05
Lepomis sp.	--	--	--	--	1	1	0.05
Etheostoma sp.	--	--	--	--	1	1	0.05
White crappie	--	--	--	--	1	1	0.05
Total	10	336	295	637	778	2,056	

Table 14. Number of fish larvae of different species collected in the St. Clair River and its major U.S. tributaries in 1984.

Species	May	June	July	August	Total	Percent of total for all species
Alewife	--	4	2,605	33	2,642	63.0
Logperch	--	473	85	--	558	13.3
Emerald shiner	--	206	17	83	306	7.3
Rainbow smelt	--	191	10	--	201	4.8
Gizzard shad	--	136	20	22	178	4.3
Unid. darter	--	58	2	7	67	1.6
Freshwater drum	--	52	3	--	55	1.3
Common carp	--	15	25	--	40	1.0
Yellow perch	12	20	3	--	35	0.8
Burbot	31	--	--	--	31	0.7
Spottail shiner	--	2	16	--	18	0.4
White sucker	--	4	14	--	18	0.4
White crappie	--	3	6	--	9	0.2
Deepwater sculpin	8	--	--	--	8	0.2
Johnny darter	--	2	5	--	7	0.2
Unid. species	--	5	1	--	6	0.1
Trout-perch	--	--	6	--	6	0.1
White perch	--	2	1	--	3	0.1
Unid. Clupeidae	--	2	1	--	3	0.1
Unid. Cyprinidae	--	--	1	--	1	< 0.1
Sand shiner	--	--	--	1	1	< 0.1
Mimic shiner	--	--	--	1	1	< 0.1
Rock bass	--	--	--	1	1	< 0.1
Total	51	1,175	2,821	148	4,195	

Table 15. Number of fish larvae of each species collected in the Detroit River and its major U.S. tributary in 1983.

Species	April	May	June	July	August	Total	Percent of total for all species
Alewife	--	--	10	636	28	674	32.5
Gizzard shad	--	--	48	360	5	413	19.9
Emerald shiner	--	--	--	307	10	317	15.3
White perch	--	--	208	4	--	212	10.2
Rainbow smelt	--	77	62	--	--	139	6.7
Unid. <u>Morone</u> sp.	--	--	120	1	--	121	5.8
Unid. darter	--	5	17	18	9	49	2.4
Logperch	--	--	13	16	3	32	1.5
Spottail shiner	--	--	13	1	2	16	0.8
White bass	--	--	12	2	--	14	0.7
Unid. species	--	1	8	3	--	13	0.6
Yellow perch	--	9	3	--	--	12	0.6
Unid. Clupeidae	--	--	--	10	--	10	0.9
Deepwater sculpin	5	4	--	--	--	9	0.4
Common carp	--	--	--	9	--	9	0.4
Unid. Cyprinidae	--	--	5	3	--	8	0.4
Trout-perch	--	--	7	1	--	8	0.4
Walleye	--	3	1	--	--	4	0.2
Burbot	--	1	--	3	--	4	0.2
Lake herring	1	1	--	--	--	2	0.1
Johnny darter	--	--	--	2	--	2	0.1
White sucker	--	--	2	--	--	2	0.1
Spotted sucker	--	--	1	--	--	1	< 0.1
River carpsucker	--	--	1	--	--	1	< 0.1
Slimy sculpin	--	--	1	--	--	1	< 0.1
Freshwater drum	--	--	--	1	--	1	< 0.1
Lake whitefish	1	--	--	--	--	1	< 0.1
Unid. Percidae	--	--	--	--	1	1	< 0.1
Total	7	101	532	1,378	58	2,076	

Table 16. Number of fish larvae of each species collected in the Detroit River and its major U.S. tributary in 1984.

Species	May	June	July	August	Total	Percent of total for all species
Alewife	--	191	591	6	788	28.1
Gizzard shad	--	613	25	--	638	22.8
Emerald shiner	--	103	454	6	563	20.1
White perch	1	197	14	--	212	7.6
White bass	--	110	14	--	124	4.4
Logperch	--	17	97	--	114	4.1
Common carp	--	89	12	--	101	3.6
Yellow perch	78	6	--	--	84	3.0
Rainbow smelt	6	45	9	--	60	2.1
Burbot	19	1	--	--	20	0.7
White crappie	--	20	3	--	20	0.8
Freshwater drum	--	12	5	--	17	0.6
Unid. darter	--	5	2	8	15	0.5
Spottail shiner	--	8	1	--	9	0.3
Unid. Percichthyidae	--	7	--	--	7	0.3
Trout-perch	--	6	--	--	6	0.2
Walleye	6	--	--	--	6	0.2
Unid. species	1	3	1	--	5	0.2
Unid Clupeidae	--	1	3	--	4	0.1
White sucker	--	1	1	--	2	0.1
Unid. Morone sp.	--	--	1	--	1	< 0.1
Deepwater sculpin	1	--	--	--	1	< 0.1
Total	112	1,435	1,233	20	2,800	

the St. Clair River), but peaked in July and August in 1984 in the St. Clair River. The relation between Detroit River water temperatures and relative abundance of fish larvae in 1977 and 1978 (Hatcher and Nester 1983) were similar to those seen in 1983 and 1984. The relatively high abundance of smelt larvae in 1977-1978 was an exception that remains unexplained.

Statistical Analysis of the Distribution of Fish Larvae

Statistical analysis of differences in the density of fish larvae (all taxa combined) in the St. Clair River (Table 17; Appendix 8) was limited to transects I, III, VI, VII, VIII, and IX. Since the mid-channel (M), U.S. shoreline (S1), and Canadian (S) shoreline sampling locations were representative of similar habitats common to all main river transects, we tested densities of larvae at those locations. The number of yolk-sac and non-yolk-sac larvae at each location were summed and the logarithm of this number (N) plus one [log(N+1)] was used in the analyses. When preliminary analyses suggested that densities of fish larvae in the upper St. Clair River (transects I, III, VI) differed from densities in the lower St. Clair River (transects VII, VIII, IX), we performed separate analyses for these two sections of the river.

Densities of larvae differed significantly between years, between months, and among locations in both sections of the St. Clair River (Table 18; Appendix 8). No significant differences in density occurred between transects in the upper section, but one barely significant difference ($P = 0.047$) was noted between transects VII and VIII in the lower St. Clair River.

The interactions of year x month and location x month, which were significant in both sections of the St. Clair River, are of greater importance for understanding the distribution of fish larvae than are the differences between years, months, transects, or locations. Interaction diagrams (Fig. 7) for the upper St. Clair River suggested that densities of larvae increased more rapidly and were higher in June and July in 1984 than in 1983, but were higher in May and August in 1983 then in 1984. One possible reason for these differences could be the differences in water temperature and rate of warming in 1983 and 1984. In 1984, the ice jam and low water temperatures (which persisted through April) probably delayed spawning and caused the density of larvae in May to be low. Rapid warming after May induced high levels of spawning over a relatively short period, resulting in high densities of larvae in June and July, but not in August. In 1983, lower water temperatures and slower warming rates may have produced lower densities of larvae and extended the spawning season, thereby increasing the number of larvae present in August. The location x month interaction (Fig. 7) in the upper St. Clair River indicated that the density of larvae at mid-channel sampling locations was always higher than at the U.S. or Canadian shoreline locations in May and June, and was higher than densities at the U.S. shoreline locations through July and August; however, densities at Canadian shoreline locations exceeded those at mid-channel and along the U.S. shoreline during July and August. Reasons for this shift are unknown.

ble 17. Mean density (number per 1000 m³ of water) of fish larvae (all species combined) in the St. Clair and Detroit rivers and their major U.S. tributaries. (No larvae were taken in September.)

Transect	Station	April 1983	May 1983	May 1984	June 1983	June 1984	July 1983	July 1984	August 1983	August 1984
I	1	7.2	0.0	12.0	49.7	98.1	41.3	676.0	188.6	28.8
	2	6.5	6.8	0.0	21.4	105.2	83.0	919.9	157.3	5.6
	3	0.0	0.0	0.0	8.7	44.7	23.2	678.9	199.4	104.2
II	1	0.0	20.9	0.0	67.4	2926.3	393.9	752.3	69.1	179.4
III	1	7.6	15.8	5.8	17.0	42.1	133.7	323.4	118.7	13.1
	2	6.8	23.8	14.5	145.0	306.8	125.0	798.6	191.7	28.3
	3	0.0	18.9	0.0	7.4	182.4	79.4	1320.0	217.1	7.7
IV	1	0.0	15.6	67.5	125.5	54.1	31.4	572.8	18.7	67.9
V	1	0.0	18.3	148.5	393.9	1655.9	123.4	550.1	117.2	257.2
VI	1	27.0	13.3	18.7	0.0	220.0	67.3	1119.5	42.1	37.3
	2	5.7	4.5	13.6	7.4	200.8	239.2	664.0	139.6	22.6
	3	0.0	97.7	19.1	78.8	169.0	142.7	548.4	135.7	35.4
	4	0.0	32.0	0.0	202.4	270.9	82.9	1178.4	228.1	21.6
	5	0.0	0.0	0.0	0.0	106.1	413.9	7716.4	169.9	33.2
VII	1	0.0	72.5	0.0	0.0	54.7	89.5	492.2	181.3	0.0
	2	15.0	68.8	0.0	95.0	549.4	145.0	570.4	150.0	5.5
	3	0.0	113.7	12.3	286.6	319.9	398.0	522.0	83.4	39.4
	4	0.0	26.7	0.0	42.6	262.9	188.7	778.0	134.0	11.5
	5	0.0	70.2	0.0	0.0	18.6	61.8	880.0	170.9	17.0
VIII	1	0.0	107.8	35.0	17.4	48.1	173.9	236.6	721.1	16.0
	2	6.3	174.6	24.8	56.5	226.5	114.7	475.5	488.7	0.0
	3	0.0	162.3	22.8	39.6	213.5	42.6	561.8	375.1	8.6
	4	0.0	530.5	8.6	59.4	437.6	121.3	507.0	28.7	0.0
	5	0.0	251.6	0.0	0.0	96.6	866.9	1002.1	60.2	49.5
IX	1	0.0	436.9	17.9	0.0	319.7	584.5	89.8	33.7	0.0
	2	0.0	171.1	0.0	233.1	174.6	398.8	430.4	31.7	6.3
	3	5.2	97.8	15.9	77.8	215.7	183.7	445.1	92.9	22.2
	4	0.0	143.7	15.8	42.6	328.8	142.3	461.2	380.4	5.3
	5	0.0	0.0	40.5	37.8	64.2	176.8	642.9	33.4	0.0

Table 17 (Cont'd).

Transect	Station	April 1983	May 1983	May 1984	June 1983	June 1984	July 1983	July 1984	August 1983	August 1984
X	1	0.0	17.4	36.4	24.8	510.0	664.7	639.5	26.6	0.0
	2	8.2	19.0	13.9	24.6	320.7	208.3	483.2	34.7	33.9
	3	6.9	0.0	20.8	115.0	193.3	259.2	153.4	14.3	0.0
	4	15.4	0.0	61.6	33.9	654.4	344.7	438.3	0.0	0.0
XI	1	0.0	14.6	49.5	44.7	657.9	2292.3	593.5	43.8	0.0
	2	12.8	0.0	26.0	14.7	221.3	183.8	452.8	11.5	11.7
	3	0.0	10.7	82.5	101.3	361.2	135.1	248.4	12.8	0.0
XII	1	7.1	62.9	7.1	133.1	501.6	1393.8	1425.5	0.0	5.6
XIII	1	0.0	0.0	28.3	50.4	144.4	263.6	213.6	4.8	0.0
	2	0.0	15.0	26.0	5.3	593.0	427.6	814.3	10.6	0.0
	3	0.0	9.8	38.5	52.9	220.7	143.3	56.8	0.0	10.4
	4	0.0	0.0	66.9	499.7	480.4	147.8	301.3	5.8	18.3
XIV	1	0.0	157.3	35.5	355.5	353.9	813.3	668.9	67.8	33.3
	2	0.0	64.3	28.7	294.2	501.4	818.2	491.9	52.9	0.0
	3	0.0	41.0	65.2	274.9	278.4	413.4	71.4	55.1	6.2
	4	0.0	0.0	44.2	189.4	308.1	305.5	126.7	7.0	0.0
	5	0.0	17.2	144.6	495.0	225.7	808.6	549.8	47.4	0.0
XV	1	0.0	11.9	38.5	2095.0	1209.0	1286.5	783.8	0.0	0.0
	2	0.0	291.8	0.0	485.7	948.1	700.7	475.6	11.0	12.0
	3	0.0	261.8	0.0	166.0	3162.1	911.9	462.1	61.0	0.0
	4	0.0	212.2	23.0	0.0	3018.6	536.9	227.2	34.0	45.1
	5	30.2	146.9	211.4	188.8	1497.8	868.9	1486.2	130.5	34.0

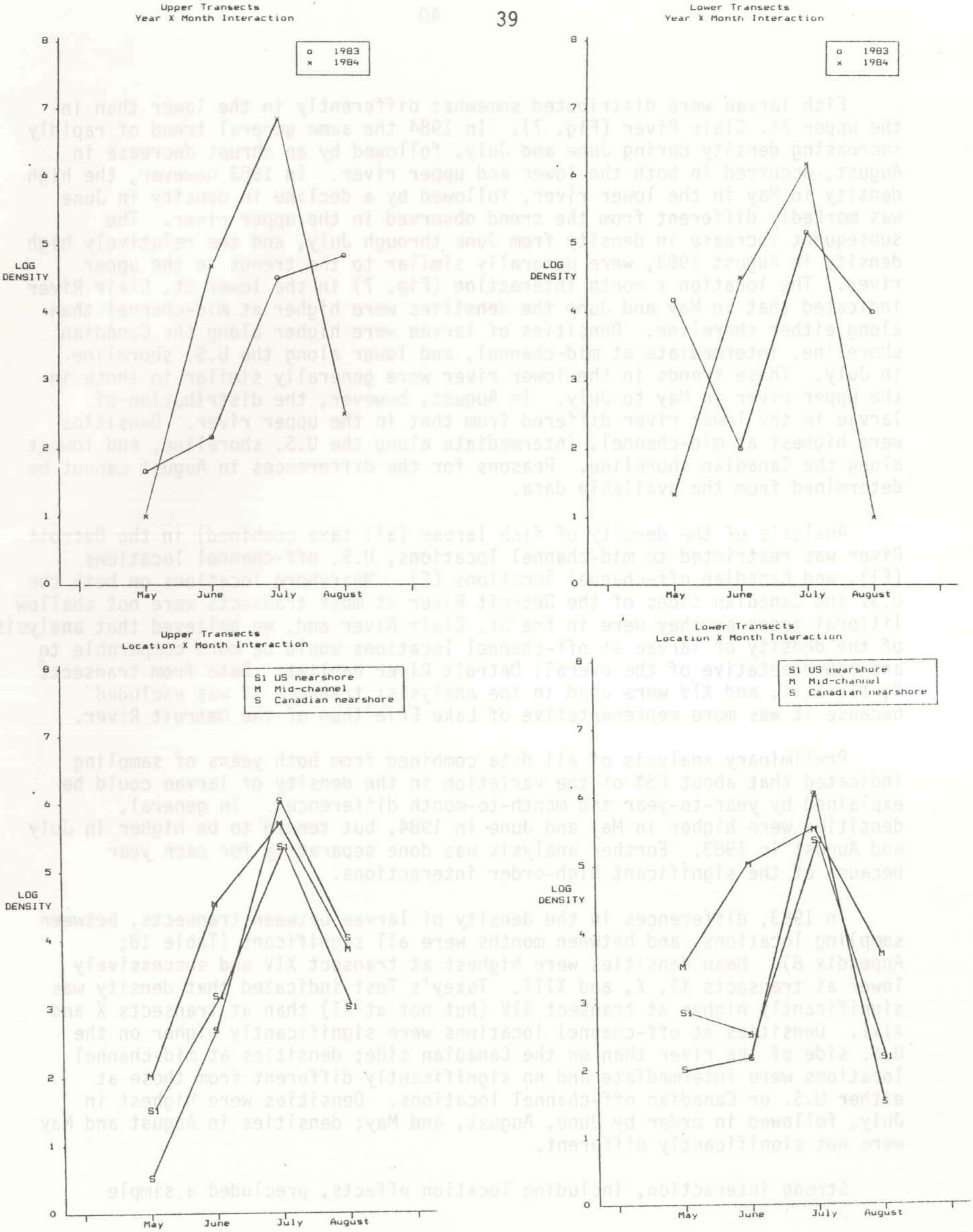


Fig. 7. Interaction diagrams showing trends in ANOVA means for densities of fish larvae (all species combined) in the St. Clair River. Transects I, III, and VI are in the upper river and VI-IX in the lower river.

Fish larvae were distributed somewhat differently in the lower than in the upper St. Clair River (Fig. 7). In 1984 the same general trend of rapidly increasing density during June and July, followed by an abrupt decrease in August, occurred in both the lower and upper river. In 1983 however, the high density in May in the lower river, followed by a decline in density in June was markedly different from the trend observed in the upper river. The subsequent increase in density from June through July, and the relatively high density in August 1983, were generally similar to the trends in the upper river. The location x month interaction (Fig. 7) in the lower St. Clair River indicated that in May and June the densities were higher at mid-channel than along either shoreline. Densities of larvae were higher along the Canadian shoreline, intermediate at mid-channel, and lower along the U.S. shoreline in July. These trends in the lower river were generally similar to those in the upper river in May to July. In August, however, the distribution of larvae in the lower river differed from that in the upper river. Densities were highest at mid-channel, intermediate along the U.S. shoreline, and lowest along the Canadian shoreline. Reasons for the differences in August cannot be determined from the available data.

Analysis of the density of fish larvae (all taxa combined) in the Detroit River was restricted to mid-channel locations, U.S. off-channel locations (E1), and Canadian off-channel locations (E). Nearshore locations on both the U.S. and Canadian sides of the Detroit River at most transects were not shallow littoral zones as they were in the St. Clair River and, we believed that analysis of the density of larvae at off-channel locations would be more comparable to and representative of the overall Detroit River habitat. Data from transects X, XI, XIII, and XIV were used in the analysis; transect XV was excluded because it was more representative of Lake Erie than of the Detroit River.

Preliminary analysis of all data combined from both years of sampling indicated that about 65% of the variation in the density of larvae could be explained by year-to-year and month-to-month differences. In general, densities were higher in May and June in 1984, but tended to be higher in July and August in 1983. Further analysis was done separately for each year because of the significant high-order interactions.

In 1983, differences in the density of larvae between transects, between sampling locations, and between months were all significant (Table 18; Appendix 8). Mean densities were highest at transect XIV and successively lower at transects XI, X, and XIII. Tukey's Test indicated that density was significantly higher at transect XIV (but not at XI) than at transects X and XIII. Densities at off-channel locations were significantly higher on the U.S. side of the river than on the Canadian side; densities at mid-channel locations were intermediate and no significantly different from those at either U.S. or Canadian off-channel locations. Densities were highest in July, followed in order by June, August, and May; densities in August and May were not significantly different.

Strong interaction, including location effects, precluded a simple

Table 18. Mean density of alewife larvae (number per 1000 m^3 of water) in the St. Clair and Detroit rivers and their major U.S. tributaries.

Transect	Station	June 1983	June 1984	July 1983	July 1984	August 1983	August 1984
I	1	0.0	0.0	35.6	592.3	177.8	57.5
	2	0.0	0.0	47.8	749.1	138.6	0.0
	3	0.0	0.0	23.3	633.5	199.4	60.7
II	1	0.0	18.6	306.4	421.7	51.6	0.0
III	1	11.4	0.0	128.0	317.4	83.4	26.1
	2	0.0	0.0	101.2	693.3	168.4	17.1
	3	0.0	0.0	79.4	973.2	174.8	15.3
IV	1	69.3	0.0	31.4	434.0	37.3	0.0
V	1	33.4	0.0	215.9	427.9	66.0	47.4
VI	1	0.0	0.0	71.7	842.0	0.0	74.6
	2	0.0	0.0	193.4	464.1	118.0	0.0
	3	0.0	0.0	126.3	523.8	113.0	8.7
	4	0.0	0.0	82.9	893.0	228.1	28.9
	5	0.0	0.0	378.9	5016.9	110.2	0.0
VII	1	0.0	0.0	89.5	451.6	362.5	0.0
	2	0.0	0.0	111.6	523.9	133.3	11.1
	3	0.0	0.0	326.2	446.8	59.1	20.1
	4	0.0	25.6	171.2	722.0	111.7	11.5
	5	0.0	0.0	61.8	836.5	273.5	0.0
VIII	1	0.0	0.0	167.3	236.6	701.0	32.0
	2	0.0	0.0	104.8	464.0	470.6	0.0
	3	0.0	0.0	31.5	530.9	367.5	8.3
	4	0.0	0.0	111.4	462.6	28.7	0.0
	5	0.0	0.0	866.9	914.2	38.0	0.0
IX	1	0.0	0.0	584.5	89.8	0.0	0.0
	2	0.0	0.0	365.7	320.5	15.7	0.0
	3	0.0	0.0	173.3	429.4	77.3	8.9
	4	0.0	0.0	117.3	404.3	354.8	0.0
	5	75.7	0.0	135.1	624.2	66.8	0.0

Table 18 (Cont'd).

Transect	Station	June 1983	June 1984	July 1983	July 1984	August 1983	August 1984
X	1	0.0	150.9	310.3	211.1	17.8	0.0
	2	0.0	147.5	57.9	265.1	23.0	22.2
	3	0.0	56.1	115.1	72.8	28.7	0.0
	4	0.0	92.7	124.1	65.9	0.0	0.0
XI	1	19.5	194.0	1146.1	173.8	35.3	0.0
	2	0.0	48.7	41.0	345.9	11.5	0.0
	3	0.0	36.5	88.3	70.8	12.8	0.0
XII	1	14.3	87.6	651.1	395.1	0.0	0.0
XIII	1	9.7	32.6	106.4	65.2	0.0	0.0
	2	0.0	128.3	207.7	449.3	10.6	0.0
	3	0.0	46.2	66.1	21.3	0.0	0.0
	4	0.0	22.8	55.0	51.5	0.0	18.3
XIV	1	0.0	33.8	358.2	429.4	0.0	0.0
	2	0.0	84.7	354.5	290.9	34.8	0.0
	3	13.4	37.4	285.7	13.3	22.6	0.0
	4	19.3	112.9	209.2	48.4	0.0	0.0
	5	34.3	288.6	665.2	346.7	0.0	0.0
XV	1	22.4	172.6	419.4	436.2	0.0	0.0
	2	0.0	51.8	212.1	293.1	22.0	24.0
	3	0.0	243.1	376.1	265.7	45.3	0.0
	4	0.0	58.2	132.4	120.8	22.3	0.0
	5	125.0	130.1	452.0	1254.6	130.5	67.9

description of trends in the density of larvae in the Detroit River in 1984 (Appendix 8). In general, density peaked in June or July and declined sharply in August. Different locations had high densities in different months, depending on transect, and no explanation for the variability was readily apparent. Overall, transect-to-transect differences may not be important. Interaction diagrams (Fig. 8) help to illustrate some of the complex relations. For example, density in May at mid-channel locations was intermediate, lower, lower, and higher than at off-channel locations at transects X, XI, XIII, and XIV, respectively, on both U.S. and Canadian sides of the river; however in June the density at mid-channel, with respect to that of other locations, was lower, lower, higher, and intermediate. The density relation between off-channel locations also changed between transects. Similar differences occurred at other locations and collectively prevented us from identifying consistent temporal or spatial trends that were representative of the entire Detroit River.

Only alewife larvae were collected in adequate numbers in each river to allow us to statistically analyze the distribution of an individual species (Table 18; Appendix 9). In the St. Clair River, enough alewife larvae were present along transects I, III, VI, VII, VIII, and IX in July and August to permit statistical treatment. Because preliminary analysis indicated that alewife densities at transect I were distinctly different from those at the other five transects, we considered data for transect I separately from the combined data for the other five transects. The effects of year and month on alewife density in the St. Clair River were dominant. The three two-way interactions involving month effects at all transects (excluding transect I) were also significant (Fig. 9). In general, densities were higher in July than in August, and more alewife larvae were present in 1983 (when higher densities were sustained through August) than in 1984 (when density declined sharply from July to August). Although alewife densities in July were highest at Canadian shoreline locations, there was little variation from location to location except in August, when densities at shoreline locations were significantly lower than those at mid-channel. Densities at transect I increased from July to August in 1983 and densities were highest at the Canadian shoreline location and lowest at mid-channel (Fig. 10). Trends in alewife density by month in 1984 were the opposite of those observed at the other transects, suggesting that alewife density at transect I may have more accurately reflected conditions in Lake Huron than in the St. Clair River proper.

Sufficient alewife larvae were captured in the Detroit River on transects X, XI, XIII, and XIV in June, July, and August each year to allow us to analyze their density for these months. Year and month effects accounted for most of the variability. Location was also a significant factor but densities did not vary significantly among transects. Tukey's Test showed that densities at off-channel locations tended to be higher on the U.S. side than on the Canadian side, whereas densities at mid-channel locations were intermediate and not significantly different from those of off-channel locations. The year x month interaction effects on alewife densities (Fig. 11) showed that densities

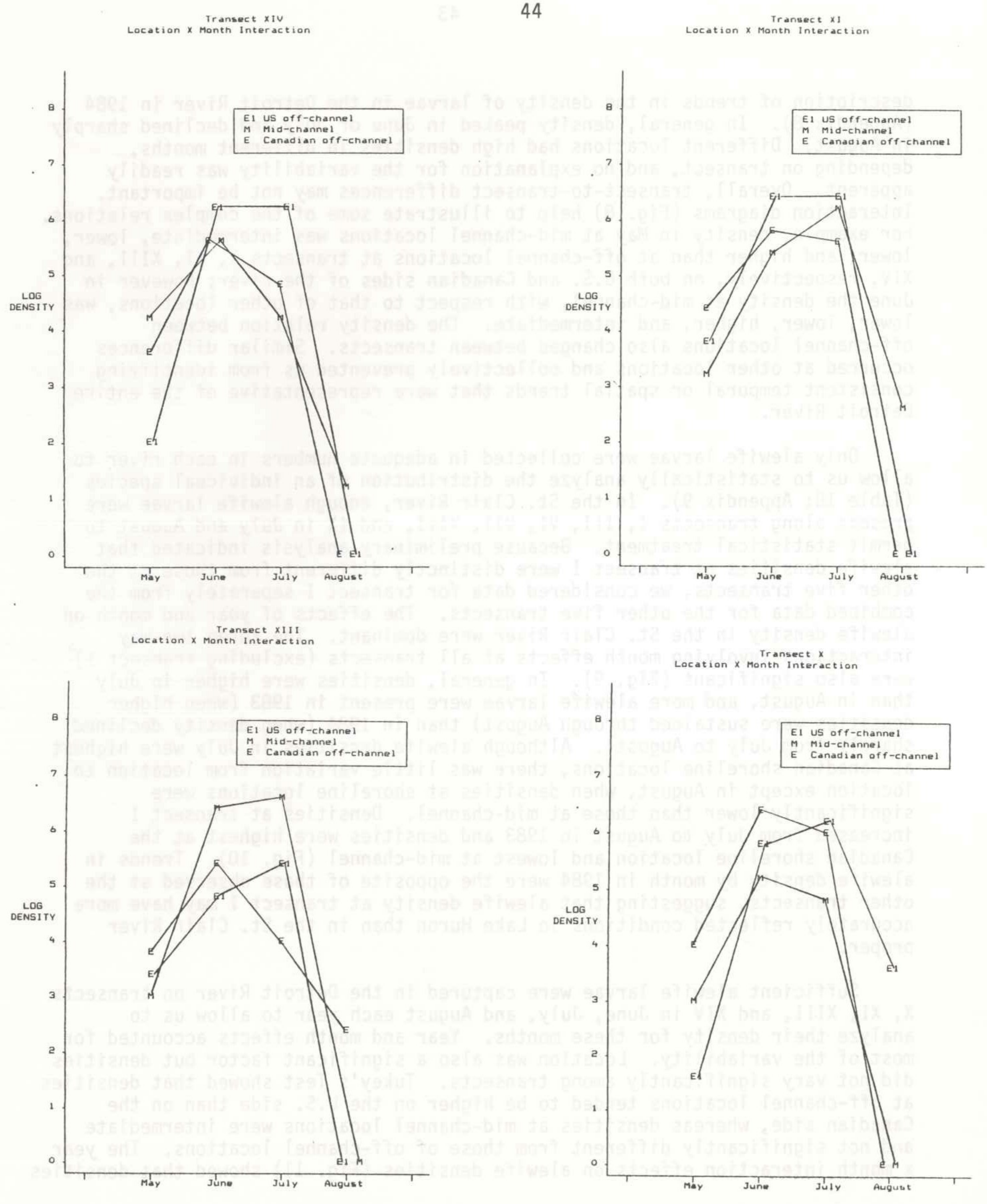


Fig. 8. Interaction diagrams showing trends in ANOVA means for densities of fish larvae (all species combined) on transects X, XI, XIII, and XIV in the Detroit River.

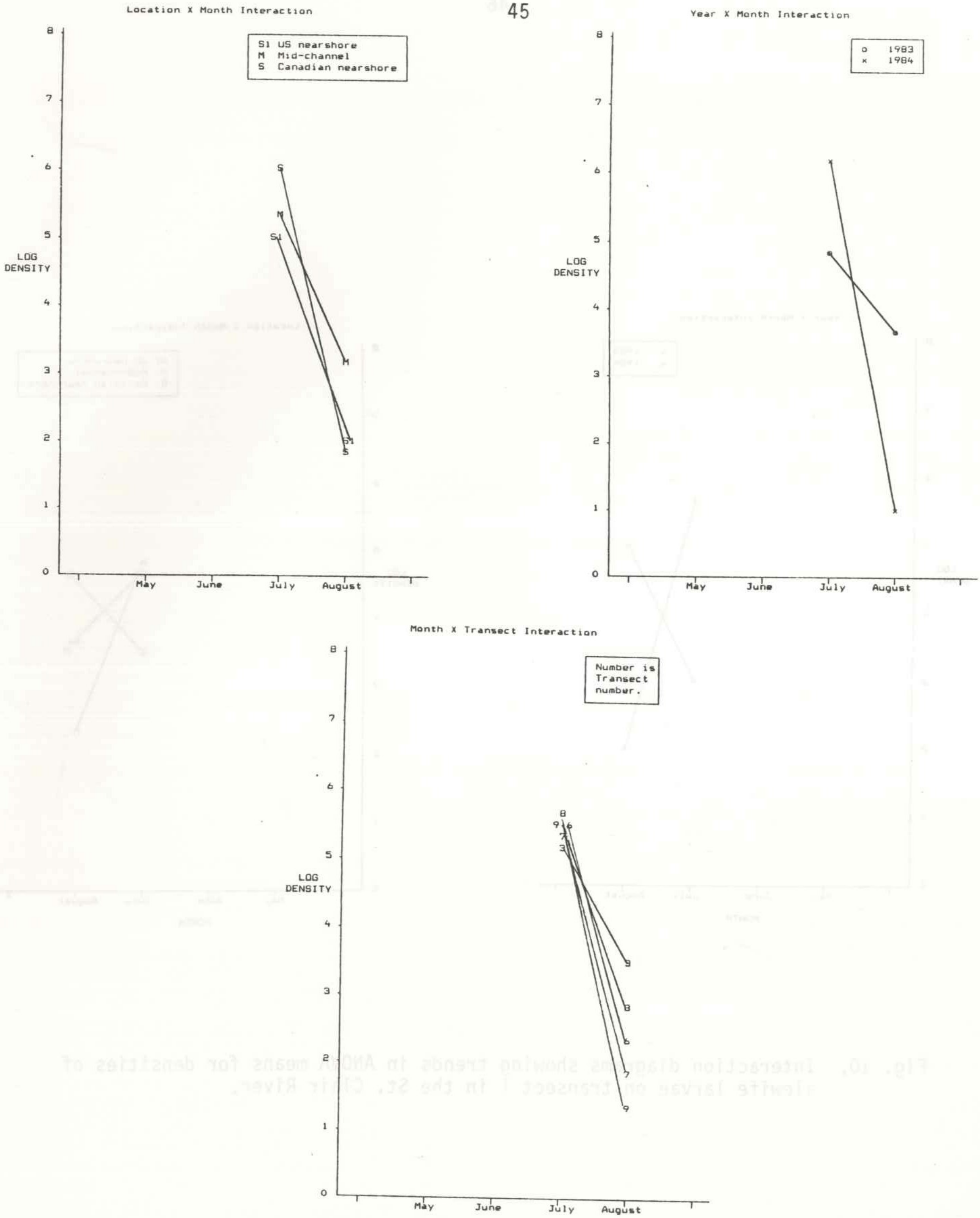
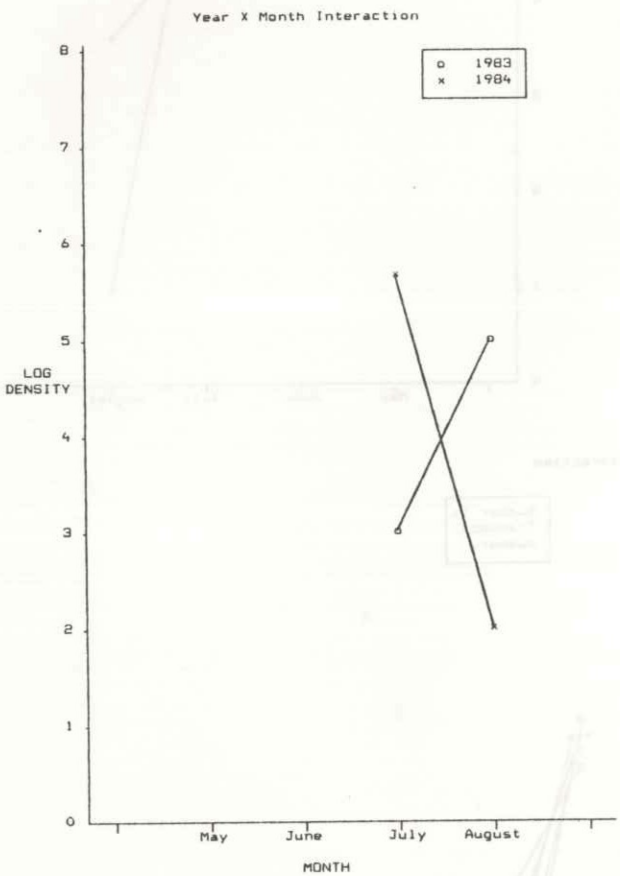


Fig. 9. Interaction diagrams showing trends in ANOVA means for densities of alewife larvae on transects III, and VI-IX in the St. Clair River.



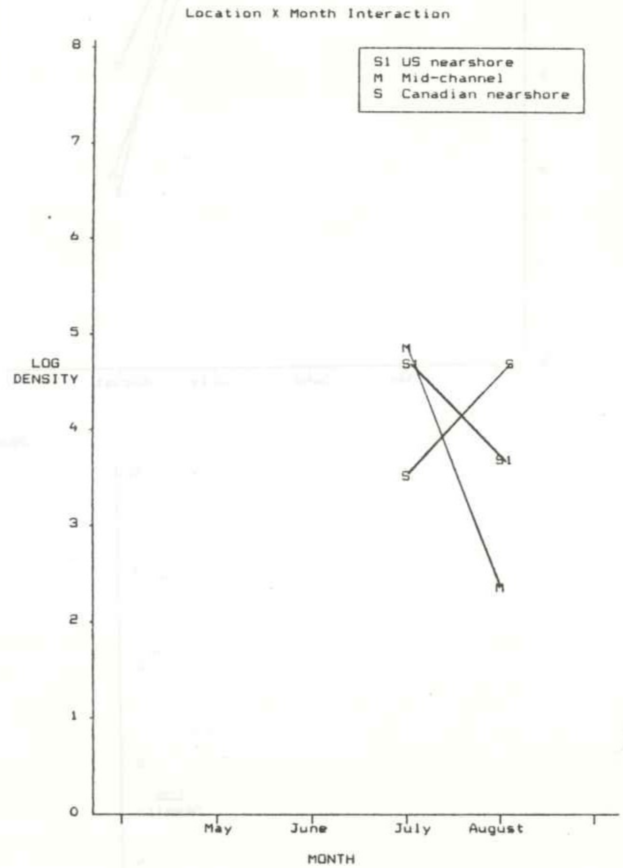


Fig. 10. Interaction diagrams showing trends in ANOVA means for densities of alewife larvae on transect I in the St. Clair River.

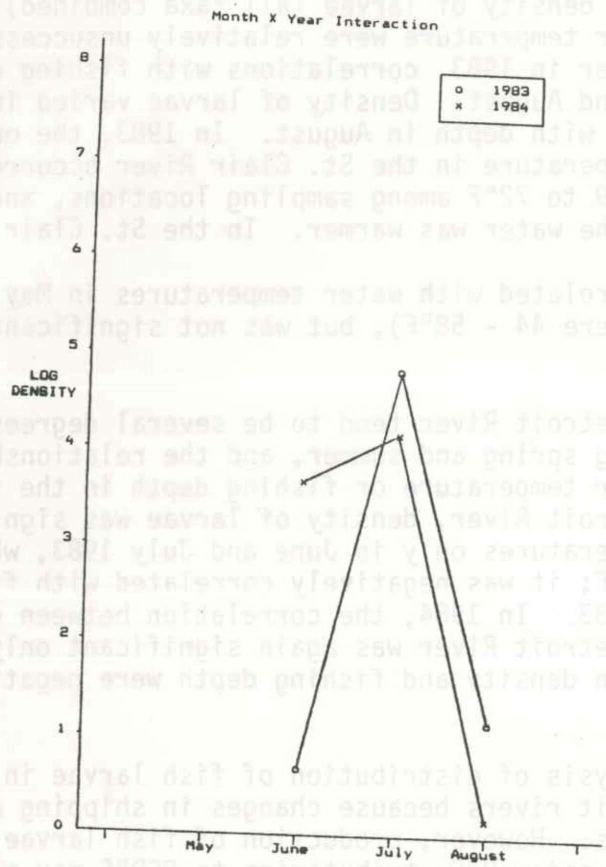


Fig. 11. Interaction diagrams showing trends in ANOVA means for densities of alewife larvae on transects X, XI, XIII, and XIV in the Detroit River.

in 1983 were low in June, increased rapidly to peak levels in July, and then declined sharply in August. Density was high in June 1984, probably because spawning was earlier than in 1983. It increased only slightly in July and then declined sharply in August to lower levels than had occurred during the previous year, when spawning may have been delayed by lower water temperatures.

Attempts to correlate density of larvae (all taxa combined) with fishing depth or with surface water temperature were relatively unsuccessful (Table 19). In the St. Clair River in 1983, correlations with fishing depth (0-46 ft) were significant in July and August. Density of larvae varied inversely with depth in July and directly with depth in August. In 1983, the only significant correlation with water temperature in the St. Clair River occurred in June. Temperatures varied from 49 to 72°F among sampling locations, and density was higher at stations where the water was warmer. In the St. Clair River in 1984,
density was positively correlated with water temperatures in May and June (when water temperatures were 44 - 58°F), but was not significantly correlated with fishing depth.

Temperatures in the Detroit River tend to be several degrees higher than the St. Clair River during spring and summer, and the relationship between density of larvae and water temperature or fishing depth in the two rivers also differs. In the Detroit River, density of larvae was significantly correlated with water temperatures only in June and July 1983, when water temperatures were 57 - 72°F; it was negatively correlated with fishing depth during July and August 1983. In 1984, the correlation between density and water temperature in the Detroit River was again significant only in June and July. Correlations between density and fishing depth were negative in June and July in 1984.

This statistical analysis of distribution of fish larvae in SCDRS focused on the St. Clair and Detroit rivers because changes in shipping activities directly affect these areas. However, production of fish larvae in Lake St. Clair, Lake Huron, and the major U.S. tributaries to SCDRS may also be important, because these larvae move into the St. Clair and Detroit rivers, where they become vulnerable to any potentially adverse effects associated with shipping. Although the mean density of larvae varied widely among the segments of SCDRS and between years, densities were lower at the head of the St. Clair and Detroit rivers and higher in the tributaries than in the rivers proper (Table 20). Thus it appears that Lakes Huron and St. Clair may contribute large numbers of larvae to SCDRS, and that considerable production may also occur in the St. Clair and Detroit rivers and their tributaries. A more rigorous evaluation of the relative contributions of larvae by each segment of SCDRS is needed to adequately assess the potential effects of extended navigation on the SCDRS, but such an evaluation will require the development and use of a hydrodynamic model--a task that was beyond the scope of the present study.

CONCLUSIONS

The data on fish egg and larvae collected in SCDRS during 1983 and 1984

Table 19. Coefficients of correlation between the density of fish larvae (all taxa combined) and fishing depth or water temperature.[a/]

Factor	1983					1984			
	April	May	June	July	Aug	May	June	July	Aug
St. Clair River									
Fishing depth	NS	NS	NS	-0.266	0.311	NS	NS	NS	NS
Water temperature	NS	NS	0.394	NS	NS	0.375	0.680	NS	NS
Detroit River									
Fishing depth	NS	-0.516	NS	-0.340	-0.430	NS	-0.497	-0.324	NS
Water temperature	NS	NS	0.419	0.423	NS	NS	0.334	0.469	NS

[a/] NS = Not significant. _P_ = > 0.05.

Table 20. Mean density of fish larvae (number of fish larvae all species combined per 1000 m^3 of water) in the SCDRS. Values are based on data in Table 17.

Location	1983	1984	1983-1984
Head of St. Clair River (transect I)	53	223	128
St. Clair River proper (transects III, and VI - IX)	116	296	243
St. Clair River tributaries (transects II, IV, and V)	178	603	360
Head of Detroit River (transect X)	91	223	149
Detroit River proper (transects XI, and XIII - XV)	214	335	272
Detroit River tributary (transect XII)	319	485	393

are useful for assessing the importance of this area as a spawning and nursery area. Differences in water temperatures and ice conditions in spring in 1983 and 1984, probably affected spawning success of many species. The distribution and abundance of fish eggs and larvae differed markedly between the two years, and appeared to be greater in the St. Clair River, where water temperatures were inversely correlated with the abundance of fish eggs and larvae in 1983, and where monthly water temperatures in spring and summer are normally lower than in the Detroit River. Although severe ice conditions in the St. Clair River persisted during April 1984, rapid warming in May and June was associated with higher densities of eggs and larvae in both rivers, the larger increase occurring in the St. Clair River.

Analyzing the importance of SCDRS as a spawning and nursery area is particularly difficult because of the multi-species fish community that occurs there. Changing environmental factors may favor the spawning of some species and adversely affect that of others. Comparisons of spawning and nursery areas between locations within or between rivers during any month or between years are necessarily descriptive because the 2-year data base from this study is generally inadequate for quantitative analyses of most comparisons that would be of interest.

Our fish egg collections show that at least 19 species spawned in SCDRS. These collections also suggested that in years when adverse spawning conditions prevailed, only the more suitable sites tended to be used, whereas in years with more favorable spawning conditions all available spawning habitat seemed to be used.

The density of fish larvae differed markedly between years and especially between months. The usually higher densities in the Detroit River after May could be attributed to three possible causes: First, species that prefer lower water temperatures for spawning, such as smelt, spawn earlier in the St. Clair River, and are the prevalent species in this river. Second, more species spawn in the Detroit River, as evidenced by the higher diversity of larvae there and third, larvae drifting downstream from Lake St. Clair and the St. Clair River may contribute to the higher diversity and density of larvae observed in the Detroit River. Whatever the cause, the densities of fish larvae that we measured suggested that the Detroit River was probably more important than the St. Clair River as a nursery area in June and July.

Low densities of yellow perch and walleye eggs and larvae in the St. Clair River probably indicated that these species did not spawn heavily in the river in 1983-1984, and that eggs and larvae produced in Lake Huron did not enter the St. Clair River in large numbers. Although densities of eggs and larvae of these species were slightly higher in the Detroit River, it also probably did not serve as a major spawning or nursery area in 1983-1984. Walleye and yellow perch larvae found in the St. Clair and Detroit rivers may have been spawned in tributaries or in Lake St. Clair. Thus the St. Clair and Detroit rivers are probably more important as migration routes for adults and immature fish than as spawning areas for these species.

Potential impacts on fish spawning in SCDRS associated with the proposed extension of winter navigation could result from two possible alterations of the habitat. First, the spawning sites could be eroded by ice accumulation, movement, and scouring that resulted from increased vessel movement through the waterway: such alterations could reduce available spawning habitat and decrease spawning success of some species. Second, extended navigation could alter the water temperatures of SCDRS by facilitating or delaying ice breakup or jams. Either positive or negative impacts on fish spawning could result, depending on the species of fish and whether water temperatures were increased or decreased, and warming rates were advanced or delayed.

Because only three species found during this study typically spawn during fall or winter, it seems highly unlikely that shipping and ice movement associated with extended navigation would destroy significant numbers of fish eggs or recently hatched larvae in SCDRS. Larvae of lake whitefish and lake herring, which spawn in November, and burbot, which spawn in November-March, were present in our samples in April and May 1983, but none were abundant, suggesting that SCDRS may not be an important spawning or nursery area for these species.

In summary, the use of SCDRS by a variety of fish species as a spawning and nursery area differed in 1983 and 1984. Changing water temperatures and ice conditions probably contributed to this difference. The effect of extended lock operations to January 31 ± 2 weeks on fish reproduction is uncertain. Only three species spawn immediately before or during the period covered by the proposed extension, the others spawn in spring or summer. Spawning activities and the deposited eggs of fall and winter spawners could be affected directly by season extension, whereas the impact on spring and summer spawners would be indirect, through physical modification of spawning grounds or modification of the thermal regime. Results from this study cannot be used to demonstrate impact, but will serve as baseline data to identify existing fish spawning and nursery conditions under current vessel traffic levels in SCDRS. If extended lock operations result in increased vessel traffic in the future, the study data can be used to help determine if fish reproductive success in SCDRS is being altered by this change in shipping practice.

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