

# **Age 0+ Fish Occurrence in Modified Habitat in South-western Ontario**

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**1998**

**Canadian Technical Report of  
Fisheries and Aquatic Sciences  
No. 2219**



**Fisheries  
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Cat. No. Fs 97-6/2219E ISSN 0706-6457

**Correct citation for this publication:**

Leslie, J.K., and C.A. Timmins. 1998. Age 0+ fish occurrence in modified habitats in south-western Ontario. Can. Tech. Rept. Fish. Aquat. Sci. No. 2219.

## ABSTRACT

Leslie, J.K., and C.A. Timmins. 1998. Age 0+ fish occurrence in modified habitat in south-western Ontario. Can. Tech. Rept. Fish. Aquat. Sci. 2219.

Fifty-six species of fishes were collected in three artificial habitats: a small wildlife sanctuary at the shore of Lake St. Clair and two drainage ditches in the St. Clair flats of south-western Ontario. The study (1983-1995) focussed on age 0+ fish utilization of environments characterized by high turbidity, few, if any, macrophytes, high temperature, and relatively stagnant water. A larval fish seine and conical net were used to collect age 0+ fishes, and beach seines sampled older fishes from April to November. Most common and abundant fishes included gizzard shad (*Dorosoma cepedianum*), brook silverside (*Labidesthes sicculus*), spottail shiner (*Notropis hudsonius*), and sunfish (*Lepomis* spp.). Gizzard shad peak density exceeded 20,000/100 m<sup>3</sup> in an agricultural ditch, which at least 22 species of age 0+ fishes utilized as a nursery. The assemblage of fishes collected in Lake St. Clair was notably transient. Few piscivores were found at all sites.

## RÉSUMÉ

Leslie, J.K., and C.A. Timmins. 1998. Age 0+ fish occurrence in modified habitat in south-western Ontario. Can. Tech. Rept. Fish. Aquat. Sci. 2219.

On a prélevé cinquante-six espèces de poissons dans trois habitats créés pour l'usage humain: une petite réserve naturelle au bord du lac Sainte-Claire et deux fossés de drainage dans les plaines Sainte-Claire au sud-ouest de l'Ontario. L'étude (1983-1995) s'est concentrée sur l'utilisation que font les poissons d'âge 0+ des environnements caractérisés par une turbidité élevée, la faible présence ou l'inexistence de macrophytes, une température élevée et une eau relativement stagnante. Entre les mois d'avril et de novembre, on a utilisé une senne à larves de poisson et un filet conique pour prélever les poissons d'âge 0+, et des sennes de plage pour les poissons plus âgés. Les poissons les plus communs et les plus abondants étaient l'aloise à gésier (*Dorosoma cepedianum*), le crayon d'argent (*Labidesthes sicculus*), la queue à tache noire (*Notropis hudsonius*) et les crapets (*Lepomis* spp.). Le pic de densité des aloses à gésier a dépassé les 20,000/100 m<sup>3</sup> dans les fossés situés dans des zones agricoles. Au moins 22 espèces de poissons d'âge 0+ utilisent ces fossés comme zone d'alevinage. L'assemblage de poissons capturés dans le lac Sainte-Claire avait un caractère momentané. Dans tous les sites, peu de piscivores étaient présents.

## INTRODUCTION

Fish utilization of Great Lakes littoral habitat is in constant flux owing to human intervention, expressed as ceaseless pollution, fragmentation, shrinkage, and permanent loss of natural systems (Herdendorf 1992). Remnant habitat often hosts a mainly transient fish community high in number of species (Stephenson 1990) and low in richness and diversity. Few studies have attempted to assess the role of such habitats in respect of reproduction and early development of species or their relationship with regional fisheries. Because field studies are required to advance our knowledge of as many fish habitats as are utilized, we investigated seasonality, relative density, and growth of age 0+ fishes in three habitats modified by human activity in south-western Ontario.

## SAMPLING SITES

Three distinct sites were surveyed during this study. One fish sampling site was established at "Paternoster", a religious retreat located 2.5 km south of the mouth of the Thames River on the regular southeastern shore of Lake St. Clair (Fig. 1). A private wildlife sanctuary, which surrounds Paternoster, was developed to improve an ecosystem long ravaged by humans. It is the only coastal area within many kilometers with a concentration of terrestrial vegetation (notably trees). Aspects of life history of larvae frequenting Paternoster are described herein and fish compositions in an agricultural drainage ditch situated 12 km distant, and a wetlands drainage canal located 4 km north are reviewed in this paper.

At Paternoster, two 1m-high breakwaters, one a 25m and the other a 40 m-long extension of rock and rubble perpendicular to shore afford protection from wave effects. These structures form a small 'U'-shaped sanctuary (0.2 ha) open to the lake. In 1990, habitat diversity was extremely low and vegetative cover sparse for fishes. Vegetation consisted mainly of *Cladophora* sp. on breakwater rocks, and scattered clumps of *Najas flexilis* established several metres from the shore. However, by 1994, considerable change had occurred such that beds of *Vallisneria americana*, *Elodea canadensis*, *Chara* sp., and *Myriophyllum spicatum*, as well as several other plants, were established at the sampling site. Development of these macrophytes may be attributed to the effect of increased water clarity, possibly due to particulate filtering by the recently invading mollusc *Dreissena polymorpha* (Dermott and Kerec 1997). In mid-summer, the breakwaters are vegetated with *Phragmites australis* and *Scirpus* spp., which provide a small amount of shade for fishes at the shore. A dense accumulation of decaying organic matter extends about 2 m from shore. Water depth (1m) is constant throughout the sampling area and for a distance of at least 1 km offshore. Stands of cottonwood and aspen (*Populus* spp.) moderate wind effects at the site.

Agricultural drainage ditches and water level regulation systems are a common feature in the landscape of the St. Clair flatlands, and their form and function are reviewed in Leslie and Timmins (1990) and Herdendorf (1992). Briefly, two systems were sampled for fish larvae: Whitebread ditch, which is connected to a St. Clair River delta distributary, and 1.5 km-long Dover canal, which drains a wildlife marsh at Lake St. Clair (Fig. 1). Our sampling site in the Dover canal was located at its outlet to Lake St. Clair. As such, it allows sanctuary for lake and canal fishes during spawning and rearing. Neither Whitebread ditch nor Dover canal is vegetated with aquatic plants. *Typha* sp. and *Phragmites australis* form dense stands along the banks of Dover canal, whereas Whitebread is devoid of such plants. At the margin of ditches, submersed terrestrial grasses provide the only physical structure for fish egg attachment or refuge for small species. Substrate in both canals consists of clay overburdened with alluvium. These drainage ditches are 15-20 m wide and 2-3 m deep (water depth, 0.5-1.5 m).

During the past 150 yr, terrestrial vegetation has given way to intensive agriculture in southern Ontario, causing rapid run-off and high sediment loading of streams, canals, and littoral shallows. The study sites are located in common or adjoining catchments, and their water quality is similar. Water at all sites is turbid and nutrient enriched, and vascular plants are sparse. However, ecotone differences are pronounced.

Whereas Paternoster faces the open lake, Whitebread ditch is essentially closed to larvae, although open to migrating older fishes. Situated at the shore of Lake St. Clair, Dover canal interfaces static and dynamic systems, and thus has physical and limnologic characteristics both of Paternoster and Whitebread ditch.

## MATERIALS AND METHODS

Collections of fish larvae at Paternoster were made in 1990, 1994, and 1995 using a fine-mesh beach seine (4 m long, 1 m wide, 0.4 mm mesh opening) at depths of 1 m or less. In 1990, samples were taken at approximately 3 wk intervals (9 dates) between early May and early November. In 1994, fishes were collected on 18 dates, usually weekly between May and July, then bi-monthly until November. Collections also took place on 15 dates in 1995 at a sampling frequency similar to that in 1994. Coarse mesh seines (3, 6, and 9 m long, 1 m wide, mesh opening 6.0 mm) collected juvenile and adult fishes. These seines were hauled (3-6 samples) at depths of <1 m at a linear distance of 5 to 10 m.

In Whitebread drainage ditch, seines and an ichthyoplankton net were used for routine collections of fish larvae in 1990, using methods as described in Leslie and Timmins (1990). Results reported herein pertain to collections made in 1990. In Dover canal, a larval fish beach seine was the sole method used to collect fishes. Typically, fine mesh (0.4 mm) seine was hauled at a depth of 1 m for a distance of 10 to 15 m. At least two (usually three) replicates were obtained, and approximately 80-100 m<sup>3</sup> of water were filtered on each sampling date.

Collected fishes were immediately 'fixed' with dilute Formalin (concentration ~10%). In the laboratory, fishes were sorted to species, counted, and at least 30 specimens of most-abundant larvae (or all fish in smaller catches) were measured for total length (TL  $\pm$  0.2 mm). Fishes larger than 30 mm were measured to an accuracy of  $\pm$  1.0 mm. Representative samples were then preserved with a solution of Davidson's B or a mixture of 80% ethanol and glycerin (90:10 v/v). Density of most-abundant fishes was estimated, and expressed as number/100 m<sup>3</sup> of water filtered, on the assumption that catch efficiency was 100%. Fish larvae were identified with reference to Auer (1982) and our own collections from past studies.

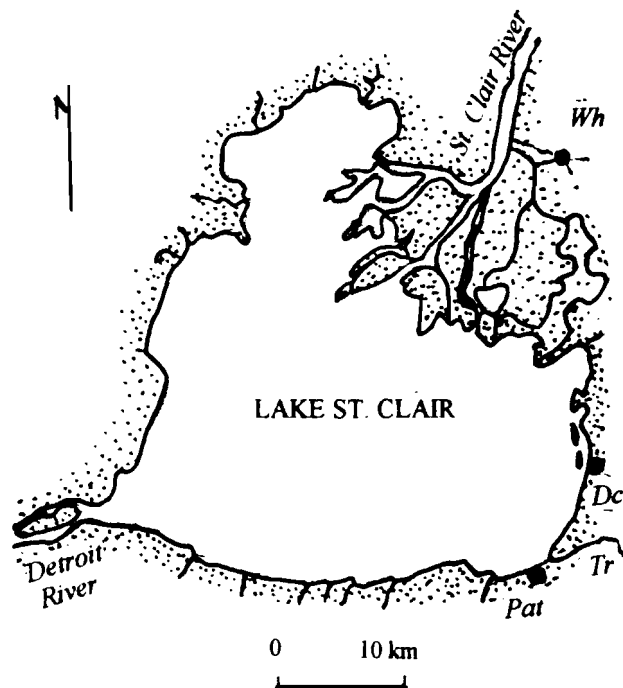


Fig. 1. Map of study area. Sampling sites: *Wh* = Whitebread ditch; *Dc* = Dover canal; *Pat* = Paternoster. *Tr* indicates Thames River.

## RESULTS

### PATERNOSTER

#### Environmental conditions

Minimum water temperature ( $\sim 15^{\circ}\text{C}$ ) required to induce spawning in many taxa occurred in mid to late May. In all years, mean temperature was  $18\text{--}21^{\circ}\text{C}$  (April to November) whereas maximum temperature occurred between mid-July and mid-August. Mean conductivity indicated enriched waters and mean hydrogen ion concentration (7.4–8.3) was well within mandatory criteria for cyprinids (Mann 1996) and many other species. Mean Secchi disc transparency increased from 0.7 m in 1994 to  $\sim 1.3$  m (bottom) in 1995 (Table 1), possibly influenced by proliferation of filter feeding zebra mussels throughout the study area in recent years (Leach 1991).

In 1990, rooted aquatic vegetation was sparse and species diversity low. However, in some areas, *Vallisneria americana* and scattered patches of *Najas flexis* were established by mid-June at depths of  $>0.5$  m. Dense *Cladophora* covered submerged rocks along breakwalls throughout spring and summer. *Cladophora*, *Vallisneria*, and *Ceratophyllum* sp., and several other aquatic plants were much more abundant in mid-July, 1994 than in 1990. These macrophytes were even more numerous in 1995, especially *Chara* sp., *Myriophyllum spicatus*, *Vallisneria*, *Elodea canadensis*, and *Potamogeton crispus*. In November, no rooted plants, except *Myriophyllum spicatum*, remained in the sampling area.

Table 1. Environmental variables for Paternoster (Lake St. Clair), 1990, 1994, 1995.

			Min.	Max.	Mean
Temperature ( $^{\circ}\text{C}$ )	1990	N = 8	9.5 Nov 15	28.5 Jul 18	$21.0 \pm 6.0$
	1994	N = 19	8.5 Nov 2	26.0 Jul 19	$18.3 \pm 5.7$
	1995	N = 15	8.2 Apr 2	30.0 Aug 16	$19.4 \pm 7.1$
Conductivity ( $\mu\text{S}/\text{cm}$ )	1990	N = 2	290	330	295
	1994	N = 18	150	500	$324 \pm 86$
	1995	N = 14	175	425	$277 \pm 79$
Secchi depth (m)	1990	N = 1			
	1994	N = 14	0.15	2.0	0.5
	1995	N = 12	0.40	>water column on 5 dates	$0.65 \pm 0.6$
pH	1990	N = 4	7.5	9.1	$8.3 \pm 0.8$
	1994	N = 5	7.1	8.2	$7.4 \pm 0.5$

Although no common carp were found at Paternoster in 1990, they were prevalent in 1994 and 1995, especially during the main spawning period in early June ( $\sim 24^{\circ}\text{C}$ ). *Cladophora* was abundant, and submersed rooted vegetation was established. Common carp and longnose gar were observed commingling and spawning in the same area. Two or three male common carp ( $\sim 40$  cm) were seen nudging each female in shallow ( $<0.3$  m) water. Similarly, during spawning



activities, 3 or 4 male longnose gar closely followed each large female. Consequently, large numbers of eggs of both species were deposited on mats of *Cladophora*.

#### Species representation and occurrence

In all years, approximately 14400 age 0+ and 900 age 1+ fishes were collected and 37 species (12 families) were represented (Table 2). Total catch and species composition varied each year according to sampling effort and environmental conditions. Thirteen species were common to all years, although only gizzard shad and brook silverside were consistently abundant. In general, the age 0+ fish assemblage (32 species) was dominated by several cyprinids, one clupeid, and one atherinid; other taxa usually appeared sporadically and in small number. Each year, most-common fish larvae appeared more or less chronologically. Percids, gizzard shad, and white sucker were usually the first species collected in May. They were succeeded in early June by common carp and spottail shiner, whereas brook silverside, alewife, emerald shiner, and most centrarchids entered the assemblage in June and July.

Common carp, which contributed 1 to 5% to total catch, was neither dominant nor abundant in any year. Average frequency of occurrence ( $f$ ) for common carp ranged from 0.1 to 0.4 (Table 3). Similarly, yellow perch occurred mainly in May and June ( $f = 0.2$ ), contributing just 1% to the overall catch. Numerical contribution and abundance of all fishes were inconsistent between years, as exemplified by brook silverside, which formed 11% of total catch in 1990 and 1994, and 79% in 1995 (Table 3). Likewise, gizzard shad larvae represented 28%, 57%, and 1% in respective years. Finally, although bluegill furnished 12% to total catch in 1994, it contributed <0.1% in 1990 and 1% in 1995.

Low sampling intensity in 1990 resulted in a small total catch and relatively few taxa (Table 3). Except for spottail shiner, gizzard shad, and brook silverside, no species contributed more than 3% to total catch, and only 6 age 0+ fish taxa were collected on more than two dates. The first age 1+ fishes collected in April and May included longnose gar, spottail shiner, and emerald shiner. Few adult fishes were found in mid-summer at high water temperatures (26-29°C). In late autumn, large numbers of adult emerald shiner and bluntnose minnow as well as small quantities of brook silverside, banded killifish, and freshwater drum frequented the site.

Species diversity was high in 1994; on average, 5.6 age 0+ and 3.7 age 1+ taxa were collected each week. Seasonality of age 0+ fishes according to family is depicted in Fig. 2. Cyprinids were represented on most dates, whereas sporadic early appearances were made by catostomids, and later in the season, by centrarchids. Brook silverside, gizzard shad, and bluegill ( $f = 0.7, 0.6$ , and  $0.5$ , respectively) were the only fishes found on at least 50% of sampling dates in 1994. Highest numbers of taxa and quantity of fishes were collected between late June and mid-August at a water temperature of 21-26°C. As a rule, the number of age 0+ and 1+ fishes was often inversely related on any given sampling date (Fig. 3). As water temperature decreased in late summer and autumn, numerous species of various sizes and ages moved inshore or along the shore. The appearance of one age 0+ tubenose goby in early August, 1994 marked the first occurrence of this exotic species in the area, although not in Lake St. Clair. This fish was collected in a patch of *Vallisneria americana*.

Table 2. Fishes collected at an exposed shore (Patemoster, 1990, 1994-95), an agricultural drainage "Ditch" (Whitbread, 1986, 1990), and "Canal" (Dover, 1983-84). % Nr. = numerical contribution to total catch (N). A = only age 1+ fishes collected.

Species	Common Name	Shore (N = 14417)		Ditch (N = 28502)		Canal (N = 5745)	
		% Nr.	Occurrence	% Nr.	Occurrence	% Nr.	Occurrence
<i>Lepisostus osseus</i>	Longnose gar		May 31-Jun 22				
<i>Amia calva</i>	Bowfin						Ap-Jul (A)
<i>Alosa pseudoharengus</i>	Alewife	1	Jun 22-Nov 15	Aug 8	2	Jun 17-Aug 24	
<i>Dorosoma cepedianum</i>	Gizzard shad	29	May 15-Nov 15	93	May 23-Sep 23	26	May 24-Aug 17
<i>Coregonus clupeaformis</i>	Lake whitefish					Jun 3	
<i>Umbra limi</i>	Central mudminnow				Sep 26-Nov 16(A)		
<i>Esox a. vermiculatus</i>	Grass pickerel				Sep 26-Oct 23		
<i>Esox lucius</i>	Northern pike				Sep 26-Oct 23		Ap 18(A)
<i>Notropis hudsonius</i>	Spottail shiner	11	May 28-Sep 8	Aug 8-Sep 26	39	May 24-Aug 17	
<i>Notropis atherinoides</i>	Emerald shiner	7	Jun 6-Nov 15	Jul 17-Sep 23	3	Jun 29-Aug 24	
<i>Notropis volucellus</i>	Mimic shiner	2	Jul 7-Sep 25	Ap 25-Aug 8	2	Jul 5-Aug 17	
<i>Cyprinus carpio</i>	Common carp	2	Jun 6-Nov 15	May 29-Oct 23	10	Jun 3-Aug 2	
<i>Cyprinella spiloptera</i>	Spotfin shiner		Jun 1-Nov 15	Sep 23(A)		Aug 12	
<i>Notropis heterolepis</i>	Blacknose shiner		Jul 12-Aug 4				
<i>Pimephales notatus</i>	Bluntnose minnow		Jun 24-Nov 15	Ap 25-Nov 16		Jun 17-Aug 12	
<i>Pimephales promelas</i>	Fathead minnow		Jun 24				
<i>Carassius auratus</i>	Goldfish		Aug 16	May 10(A)			
<i>Notropis stramineus</i>	Sand shiner		Jul 18(A)			Jul 18-Aug 17	
<i>Notemigonus crysoleucas</i>	Golden shiner		Jul 7		1	Jun 29	
<i>Opsopoeodus emiliae</i>	Pugnose minnow			Sep 18-Sep 23			
<i>Notropis heterodon</i>	Blackchin shiner			Sep 23-Oct 23			
<i>Catostomus commersoni</i>	White sucker		Jun 7-Jun 28	Nov 16(A)		Jun 3-Jun 8	
<i>Moxostoma erythrum</i>	Golden redhorse		Jun 7-Jun 28				
<i>Moxostoma macrolepidotum</i>	Northern redhorse		Jun 24-Jul 7				
<i>Moxostoma anisurum</i>	Silver redhorse		Aug 4(A)			Jun 3	
<i>Cariodes cyprinus</i>	Quillback		Jun 1-Jun 24			May 27	
<i>Erimyzon sucetta</i>	Lake chubsucker			Jul 22-Oct 23		May 27	
<i>Moxostoma carinatum</i>	River redhorse						
<i>Ameiurus nebulosus</i>	Brown bullhead			Nov 16(A)		Mar-Apr (A)	
<i>Ameiurus natilis</i>	Yellow bullhead			Sep 26-Oct 23		Jun 27	
<i>Ictalurus punctatus</i>	Channel catfish			Jun 1(A)		Mar 10(A)	
<i>Ameiurus melas</i>	Black bullhead						

Table 2 (continued)

Species	Common name	% N	Shore Occurrence	% N	Ditch Occurrence	% N	Canal Occurrence
<i>Noturus gyrinus</i>	Tadpole madtom				Sep 18 (A)		Mar 10 (A)
<i>Fundulus diaphanus</i>	Banded killifish		Jul 5-Nov 15				Mar 10 (A)
<i>Fundulus notatus</i>	Blackstripe topminnow				May 23-Oct 23		
<i>Labidesthes sicculus</i>	Brook silverside	32	Jun 13-Nov 15		Jun 21-Nov 16	2	Jun 29-Aug 24
<i>Percopsis omiscomaycus</i>	Trout-perch						May 27
<i>Morone americana</i>	White perch		Jun 21-Nov 15		Sep 13-Oct 23		Jul 3
<i>Morone chrysops</i>	White bass		Jun 6-Aug 16				Jul 13-Aug 12
<i>Lepomis cyanellus</i>	Green sunfish		Aug 16 (A)		Jun 10-Oct 23		
<i>Lepomis humilis</i>	Orangespotted sunfish				Sep 26-Nov 16		
<i>Lepomis macrochirus</i>	Bluegill	7	Jun 22-Nov 15	1	Jun 5-Oct 23		Jun 17-Aug 12
<i>Lepomis gibbosus</i>	Pumpkinseed		May 15-Jul 18	3	May 23-Nov 16	8	May 24-Aug 17
<i>Micropterus salmoides</i>	Largemouth bass	1	Jun 22-Sep 8		Sep 13-Oct 23		Jun 29
<i>Pomoxis nigromaculatus</i>	Black crappie		Jun 24-Aug 16		May 23-Oct 23	1	Mar 10-Aug 17
<i>Pomoxis annularis</i>	White crappie			1	Jun 5-Oct 23		
<i>Ambloplites rupestris</i>	Rock bass		Oct 20		Sep 18		Mar 24-Apr 22 (A)
<i>Pomoxis sp.</i>	Hybrid crappie		Sep 18-Oct 14				
<i>Perca flavescens</i>	Yellow perch	1	May 15-Nov 15		Oct 23 (A)	3	May 13-Jul 18
<i>Stizostedion vitreum</i>	Walleye		Jun 15				
<i>Percina caprodes</i>	Logperch	1	May 18-Aug 16		Oct 23		Jun 3-Jun 10
<i>Etheostoma nigrum</i>	Johnny darter						Jun 7-Jun 13
<i>Aplocheilichthys grunniens</i>	Freshwater drum		May 4-Jul 18 (A)		Sep 23		
<i>Cottus cognatus</i>	Slimy sculpin		Jun 1-Jun 22				
<i>Proterorhinus marmoratus</i>	Tubenose goby		Jun 22-Aug 4				
<i>Neogobius melanostomus</i>	Round goby		Sept 7 (A)				

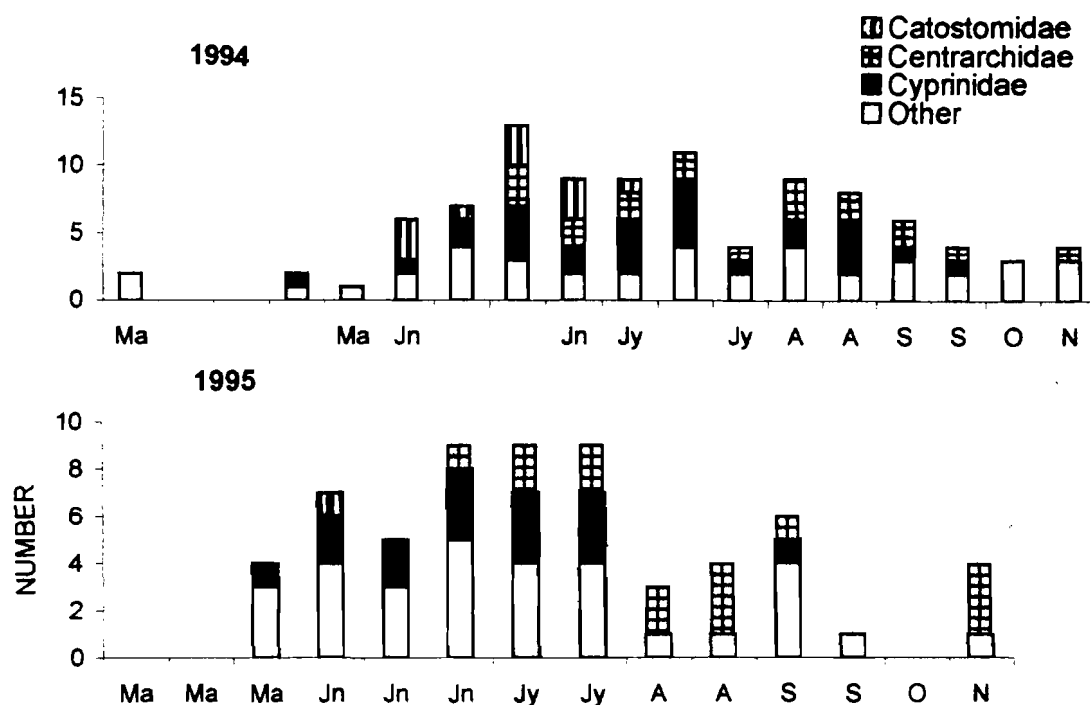


Fig. 2. Seasonal number of age 0+ fishes in dominant families during 1994 and 1995.

Table 3. Dominant age 0+ fishes collected at Paternoster in 1990, 1994 and 1995. % = representation in total catch; f = average occurrence throughout sampling period. Temp. = temperature on date of peak density.

Year	Total catch	Taxa Families	Dominant fishes	Peak density				Temp. (°C)
				(%)	f	(#/100 m <sup>3</sup> )	Date	
1990	2200	13	6	<i>Notropis hudsonius</i>	50	0.3	1320	June 21 23
				<i>Dorosoma cepedianum</i>	28	0.9	575	June 6 24
				<i>Labidesthes sicculus</i>	11	0.6	223	June 21 23
1994	8400	28	9	<i>Dorosoma cepedianum</i>	57	0.6	5403	June 28 20
				<i>Labidesthes sicculus</i>	11	0.7	574	June 24 21
				<i>Notropis atherinoides</i>	10	0.3	864	June 28 20
				<i>Lepomis macrochirus</i>	12	0.5	884	June 24 21
1995	3900	19	11	<i>Labidesthes sicculus</i>	79	0.3	2939	July 5 26
				<i>Notropis hudsonius</i>	9	0.3	284	June 22 25
				<i>Cyprinus carpio</i>	5	0.1	218	June 22 25

Although sampling efforts were similar in 1994 and 1995, total catch in 1994 was twice that in 1995. Lower catch in 1995 was probably a result of low sampling frequency in late June and early July, precisely when larvae of many species abound at the shore. In 1995, brook silverside, the only dominant fish, formed 79% of total catch, and appeared consistently ( $f = 0.9$ ) after mid-June. Otherwise, only spottail shiner (9%) and common carp (5%) contributed more

than 1% to the overall total. Although dominant in 1990 and 1994, gizzard shad was uncommon in 1995, as it declined dramatically to <1% of the total catch.

Age 1+ fishes were more prevalent at lower water temperatures and age 0+ fishes at higher temperatures (Fig. 3). Several age 1+ cyprinids, such as spottail shiner and emerald shiner, were more abundant and occurred more frequently than their larvae counterparts. Small numbers of age 0+ and older round goby and tubenose goby (40-80 mm TL) were also found, mainly in autumn. The occurrence of round goby was the first record of the species in south-eastern Lake St. Clair.

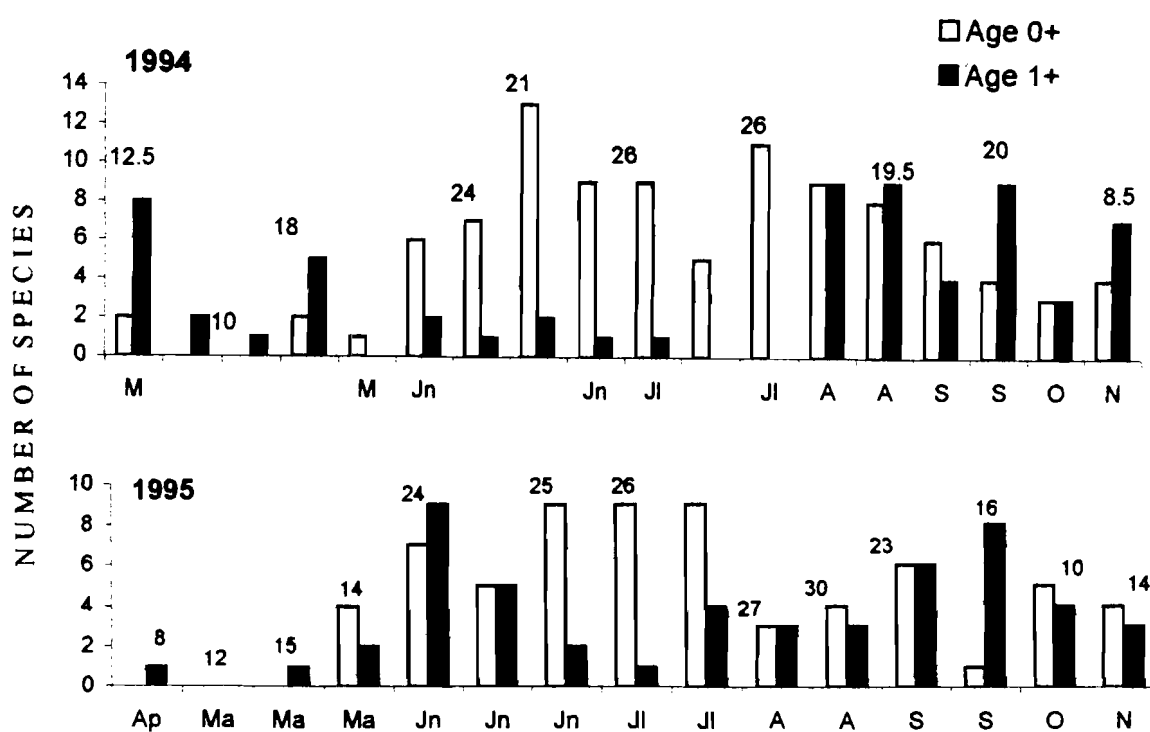


Fig. 3. Comparison of seasonal number of age 0+ and 1+ species collected at Paternoster in 1994-95. Water temperature (°C) shown above histograms.

#### Mean density of abundant fish taxa

In all years, mean density of age 0+ fishes peaked in late June and early July (Fig. 4), coincident with large numbers of recently hatched brook silverside. In 1990, highest fish density

occurred in June, when gizzard shad, brook silverside, and spottail shiner were abundant (575, 223 and 1320 larvae/100 m<sup>3</sup>, respectively). Age 0+ fishes were otherwise collected in 1990 in low peak densities (30-66 larvae/100 m<sup>3</sup>).

In 1994, mean density of all taxa combined was low until late June (Fig. 4), when large numbers of gizzard shad, brook silverside, emerald shiner, and bluegill appeared. Peak densities for these dominant fishes ranged from 574/100 m<sup>3</sup> for brook silverside to 5403/100 m<sup>3</sup> for gizzard shad in late June. Other common fishes, such as emerald shiner and bluegill reached peak density (864 and 884/100 m<sup>3</sup>, respectively) in late June at a water temperature of 20-21°C, whilst peak densities of uncommon fishes, such as common carp and largemouth bass, were low (38-73/100 m<sup>3</sup>). After late June, fish density decreased uniformly until September (Fig. 4).

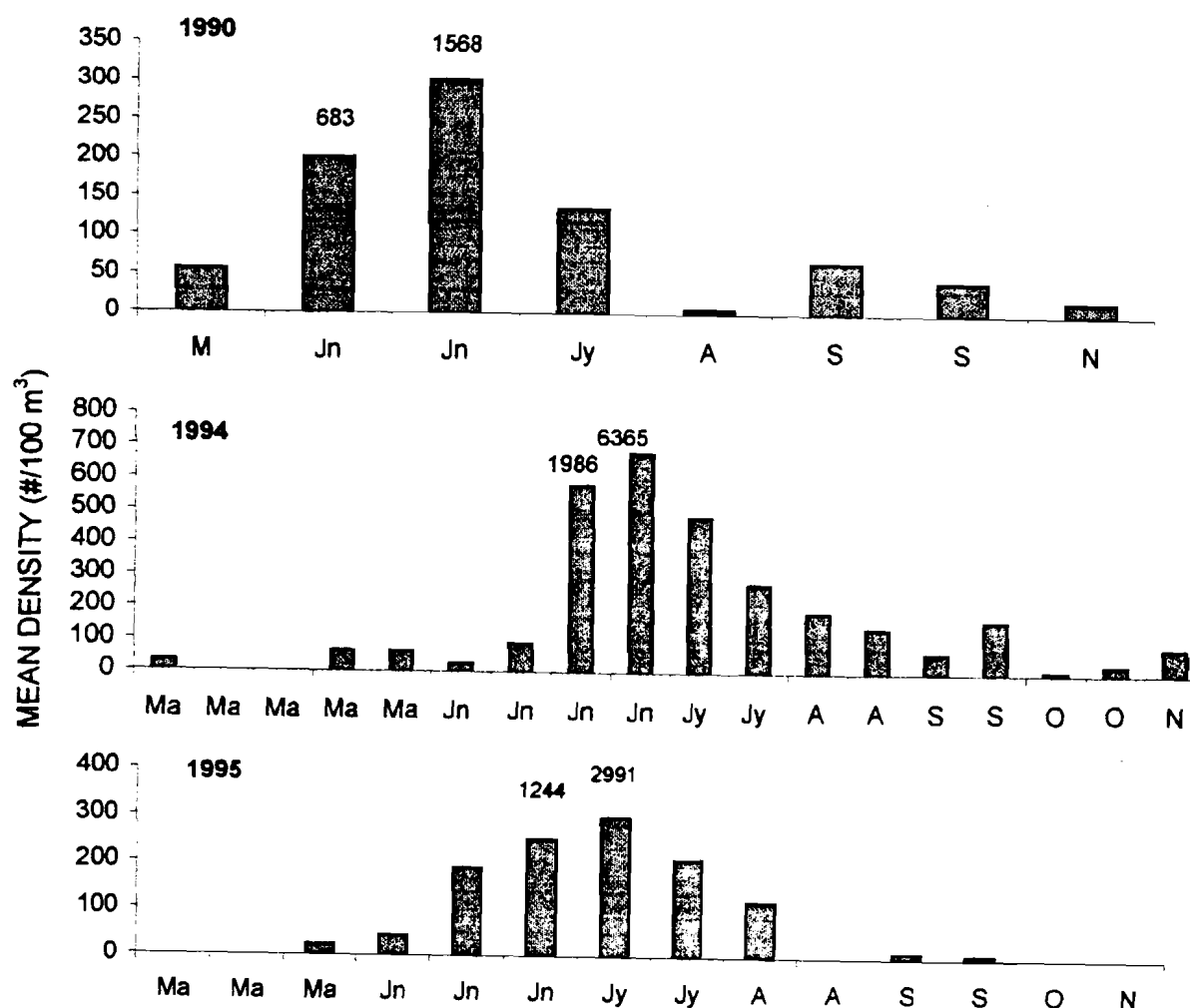


Fig. 4. Mean density of combined age 0+ fishes in 1990, 1994-95. Numbers above bars refer to high values of peak density.

In 1995, mean density of fishes peaked at approximately the same time as in 1994, but was in general lower for most species (Fig. 4; Table 3). However, peak densities of dominant taxa were higher in 1995, e.g., spottail shiner (284/100 m<sup>3</sup>) compared with 14/100 m<sup>3</sup> in 1994; brook silverside (293/100 m<sup>3</sup> and 574/100 m<sup>3</sup>), and common carp (218/100 m<sup>3</sup> in 1995 and 73/100 m<sup>3</sup> in 1994).

### First year growth

Total length achieved by late summer and early autumn indicates growth of fish larvae during the first year. Clupeids, brook silverside, and largemouth bass attained approximately the same total length (50–60 mm) compared with 30–40 mm in pumpkinseed, bluegill, spotfin shiner, and blacknose shiner (Table 5). Variability in total length of small larvae was often higher than in older larvae. Mean length in gizzard shad and bluegill and emerald shiner was most variable for fishes <20 mm, whilst mean length in common carp was least variable (Fig. 5). Typically, total length of brook silverside varied least near the end of first year growth.

Rate of growth in dominant fishes ranged from an average of 0.2 to 0.4 mm/d in largemouth bass and bluegill to 0.6 to 1.0 mm/d in brook silverside and alewife, depending on year. Based on our collections in 1994, alewife and gizzard shad were similar in total length near the end of the first year, but grew at different rates. For example, alewife grew 0.7 mm/d between late June and early September, whereas gizzard shad grew 0.4 mm/d between early June and early November. Smallest increase in length occurred in cover-oriented species given in Table 4, e.g., bluegill, largemouth bass, and cyprinids, whilst the largest increase occurred in brook silverside and alewife.

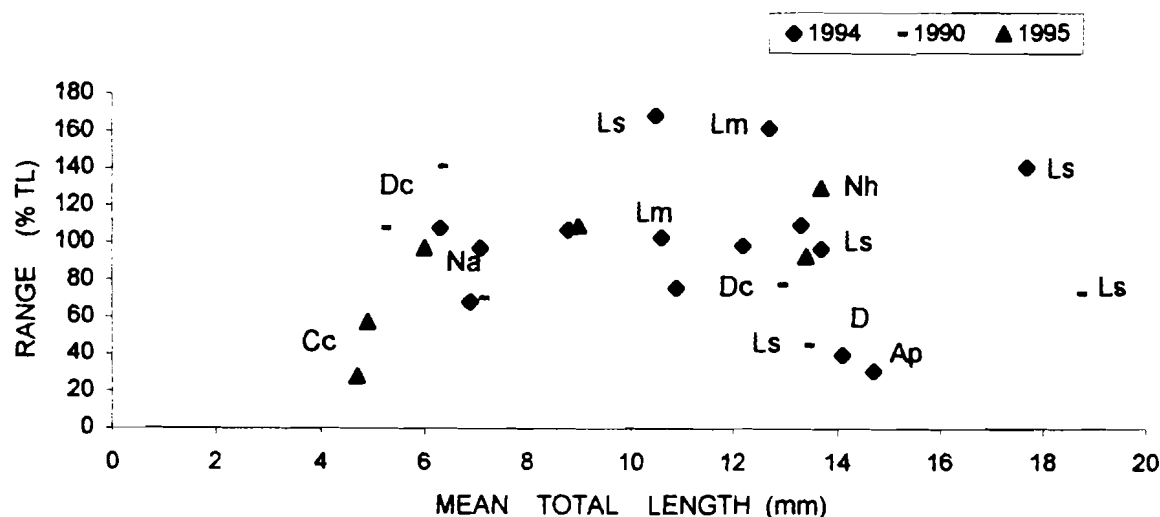


Fig. 5. Range in total length for most-common fishes at <20 mm mean TL. Cc = *Cyprinus carpio*; Dc = *Dorosoma cepedianum*; Na = *Notropis atherinoides*; Lm = *Lepomis macrochirus*; Ls = *Labidesthes sicculus*; Nh = *Notropis hudsonius*; Ap = *Alosa pseudoharengus*.

Table 4. Total length near end of first year growth in age 0+ fishes collected at Paternoster. N = number of fish measured.

<u>Species</u>	<u>Date</u>	<u>Mean TL (mm)</u>	<u>Range (% TL)</u>	<u>N</u>
<i>Dorosoma cepedianum</i>	Sep 14/90	52	56	37
	Sep 25/90	59	66	27
	Nov 2/94	61	26	8
<i>Labidesthes sicculus</i>	Aug 16/94	46	52	23
	Sep 14/90	54	19	13
	Sep 21/94	66	27	10
	Oct 20/94	64	22	14
	Nov 2/94	62	22	25
	Aug 2/95	47	45	37
<i>Alosa pseudoharengus</i>	Sep 8/94	58	57	46
<i>Lepomis macrochirus</i>	Aug 4/94	25	44	39
	Aug 16/94	26	65	13
	Nov 2/94	40	50	75
<i>Lepomis gibbosus</i>	Aug 4/94	24	63	11
<i>Cyprinella spiloptera</i>	Aug 16/94	34	62	9
	Oct 20/94	38	66	9
<i>Notropis heterolepis</i>	Aug 4/94	30	37	11
<i>Micropterus salmoides</i>	Aug 2/95	52	27	12
	Nov 2/94	68	26	18

## WHITEBREAD DITCH

### Environmental conditions

Water temperature was at least 16°C between mid-May and mid-September in 1990 and reached maximum (28°C) in mid-July. Conductivity ( $\geq 400 \leq 700 \mu\text{S/cm}$ ) indicated a system rich in electrolytes at pH 7.9-8.7. Water colour was somewhat affected by wax and wane of dominant algae species. For example, in early June and August, blooms of green algae transformed the colour of the water to brownish-green. Colour of the water varied from "milky" in spring and brownish-green in summer, to light green in autumn. Secchi disc transparency was lowest (8-10 cm) during high surface run-off in May, and highest (15-20 cm) in late autumn. Water level stabilized at 0.5 m between mid-May and late September, after peaking in late April (depth 0.9 m in the centre).



### Species composition and occurrence

Thirty-four taxa were represented in the 1986 and 1990 collection of approximately 29,000 fishes, of which 26 species possibly hatched and developed in the ditch, and 8 collected only as age 1+ fishes (Table 2). Eleven families and 22 species were represented in 1990, when 90% of the total number of fishes were caught. Gizzard shad dominated all species in 1990 (97% of total catch). Although not collected, longnose gar adults were occasionally observed swimming at the surface of the ditch. Fishes normally inhabiting relatively clear waters were not found at any life stage in the turbid waters of the ditch. These taxa include bowfin, most cyprinids, percids, catostomids, banded killifish, trout-perch, sculpins and gobies. The occurrence in August of three adult and one larval alewife was unusual in the prevailing darkly turbid water as this species does not normally tolerate turbid conditions.

Gizzard shad and green sunfish were two of only a few taxa collected in sufficient quantity and frequency to be considered continuous residents of the ditch during their first year of life. They, and common carp, were the first fishes to appear in samples, but not until early June, when water temperature was 22°C. Otherwise, brook silverside and white crappie were the only fishes collected before September. The majority of species (15) appeared when water clarity improved in late summer and autumn, but occurred on just one or two sampling dates. At least 11 species remained in the ditch in mid-November, when water temperature was 8.5°C and water clarity was highest. At this time, the most abundant fishes were ictalurids and centrachids.

Blackstripe topminnow, a vulnerable species in Canada (COWESIC 1994), was collected mainly as age 1+ fish, although not routinely. Indeed, we pursued them at the margin of the ditch, from which they characteristically dispersed in an eclamptic manner upon our intrusion. Efforts to collect larvae with a plankton net in open water, and fine-mesh seine at the margin of the ditch, were futile.

### Seasonal density of larvae

Mean density of gizzard shad increased rapidly from 3139/100 m<sup>3</sup> in early June to 20,000/100 m<sup>3</sup> in mid to late June. Thereafter, abundance declined sharply and remained low until late September, after which no gizzard shad was found. Mean density of green sunfish and white crappie reached peak values of 99 to 223/100 m<sup>3</sup> in June and July, whereas densities of all other fishes were <50/100 m<sup>3</sup>.

### Growth in dominant fishes

Mean total length of a small collection (N = 18) of gizzard shad was 74.0 mm (range = 66-92 mm) in mid-September and 71.8 mm (50-86 mm; N = 44) in late September. Respective concurrent mean total lengths of white crappie, brook silverside, bluegill, and orange-spotted sunfish were 52.9 mm (range = 42-70 mm), 45.7 mm (35-58 mm), 36.7 mm (27-52 mm), and 36.6 mm (31-45 mm). Other species were collected in quantities too low to allow accurate estimates of their growth.

## DOVER CANAL

### Environmental conditions

Typically, water in the canal was turbid and rooted vegetation absent. Terrestrial vegetation at waters' edge consisted of bank grasses and roots of willow (*Salix* sp.) and other trees and shrubs. These provided structural support for eggs and shelter for small fishes. During most of April 1984, an ice-jam at the mouth of the St. Clair River (Fig. 1) resulted in the lowest water level downstream in Lake St. Clair since 1955. Consequently, water depth in the canal was <0.5 m, and a vast expanse of the bottom of Lake St. Clair was exposed. This greatly reduced the volume of water available for early spawners. Concurrently, patches of shallow water attained abnormally high early spring temperatures. These phenomena were followed by the inevitable surge of water in early May when the ice-jam broke and flooding occurred along the shore of Lake St. Clair.

In 1983, water temperature ranged from 11.8°C to 24.5°C between late April and early June, when most fishes reproduce. During the same period in 1984, temperatures ranged from 6.5°C to 26.0°C. The highest temperature in 1983 occurred in mid-July (27.0°C) or 5-6 wk later than in 1984. Conductivity averaged 376  $\mu\text{S}/\text{cm}$  for both years (range = 320-460  $\mu\text{S}/\text{cm}$ ) and highest values were observed during spring run-off.

### Species composition and occurrence

Sampling occurred between March/April and November in 1983 and between April and November in 1984. Eighteen of 34 species were collected only once or twice; transients were thus major constituents of the assemblage in Dover canal. Cyprinids had the highest representation (8 species), followed by catostomids and centrarchids (4 species each), and percids (3 species). Total catch ( $N = 5745$ ) was highest in 1984, when 82% of all age 0+ fishes were collected. With few exceptions, species occurrences were the same in both years, although proportionate representation differed considerably in several dominant taxa. For example, common carp contributed 1% in 1983 and 12% in 1984. Pumpkinseed appeared exclusively in 1984, whereas bluegill appeared mainly in 1983. Neither species contributed >10% to the total catch, which in both years was dominated by spottail shiner and gizzard shad.

Seven transient age 1+ taxa (banded killifish, brown bullhead, black bullhead, tadpole madtom, northern pike, bowfin, and rock bass) were collected only as adults. They were found shortly after ice left the canal in March and April, when spottail shiner, emerald shiner, yellow perch, bluegill, pumpkinseed, and brook silverside also frequented the area.

In 1983 and 1984, yellow perch, spottail shiner, and logperch were the first species collected in May. In 1983, common carp and gizzard shad occurred in late May, about 2 wk earlier than in 1984. Generally, common species appeared in the following chronological order: black crappie, pumpkinseed, golden shiner in early to mid-June, and brook silverside, alewife, emerald shiner and bluegill in late June to early July. Spawning was protracted in pumpkinseed, brook silverside, and alewife, as their recently hatched larvae were found in mid-August. Common carp, spottail shiner, and gizzard shad are tolerant of varying degrees of turbidity and may have been spawned in or near the canal. Similarly, the repeated occurrence of bluegill suggested reproduction occurred near our sampling site.

Alewife, emerald shiner, yellow perch, white perch, and brook silverside frequent the shallow littoral zone but normally reproduce in open water. Therefore, the occurrence of these fishes suggests small larvae may have drifted into the canal. In both years, catostomids made a single appearance in late May or early June. They were considered "incidental" species, as were white bass, white perch, logperch, sand shiner and spotfin shiner. Indeed, most species were collected sporadically in small number in Dover canal.

#### Mean density of common fishes

In 1983, spottail shiner and gizzard shad were the sole abundant taxa and reached peak density (543 and 213/100 m<sup>3</sup>, respectively) as small larvae, or 1-2 wk after they were first collected. Spottail shiner, pumpkinseed, common carp, emerald shiner, gizzard shad and yellow perch were collected in larger quantity and higher peak density in 1984 than in 1983 (Table 5), whereas brook silverside and bluegill were more abundant in 1983.

Table 5. Dominant age 0+ fishes collected in Dover canal, 1983 and 1984. Density value at peak occurrence. Maximum TL indicates largest age 0+ specimen of each taxon collected.

Species	Year	Total catch	Occurrence		Density (#/100 m <sup>3</sup> )	Max. TL (mm)
			initial	peak		
<i>Dorosoma cepedianum</i>	1983	169	June 3	June 17	213	17.9
	1984	1310	May 24	June 12	1608	34.0
<i>Alosa pseudoharengus</i>	1983	44	June 17	June 29	20	26.2
	1984	61	July 18	Aug 17	32	22.4
<i>Notropis hudsonius</i>	1983	452	May 27	June 3	543	22.9
	1984	1715	May 24	June 8	1924	16.8
<i>Notropis volucellus</i>	1983	44	May 27	July 3	24	22.4
	1984	94	July 5	July 18	111	30.2
<i>Cyprinus carpio</i>	1983	57	June 3	June 16	61	11.6
	1984	545	June 8	June 8	249	17.3
<i>Labidesthes sicculus</i>	1983	37	June 29	June 29	59	55.0
	1984	79	July 18	Aug 2	32	20.6
<i>Lepomis macrochirus</i>	1983	86	June 17	June 29	100	51.0
<i>Lepomis gibbosus</i>	1984	476	May 24	June 13	616	34.9
<i>Perca flavescens</i>	1983	51	May 13	May 13	40	14.9
	1984	130	May 15	May 24	157	20.6

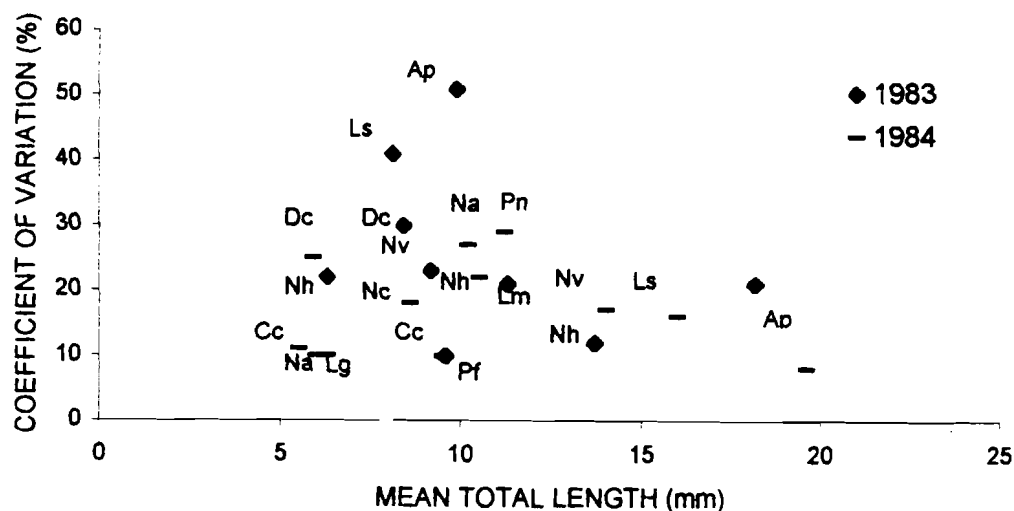


Fig. 6. Variation in mean TL of dominant fishes collected at various sizes <20 mm in 1983-84. Ap = *Alosa pseudoharengus*; Cc = *Cyprinus carpio*; Na = *Notropis atherinoides*; Dc = *Dorosoma cepedianum*; Nc = *Notemigonus crysoleucas*; Nv = *Notropis volucellus*; Lg = *Lepomis gibbosus*; Pf = *Perca flavescens*; Nh = *Notropis hudsonius*; Pn = *Pimephales notatus*; Lm = *Lepomis macrochirus*; Ls = *Labidesthes sicculus*.

#### First year growth

In 1983, few specimens of dominant fishes were found in late summer (Table 5). Consequently, first year growth in any fish was not possible to estimate. Total length in early developmental stages was typically variable (Fig. 6). For example, for 8 mm larvae, CV of mean total length in brook silverside and gizzard shad were 41% and 30%, respectively, from 1983 data. For 8-10 mm bluegill and mimic shiner, variation in length was moderate (21-23%). Smallest variation (10%) was observed in common carp and yellow perch at 10 mm and alewife at 19-20 mm. Similarly, in 1984, size range was small in recently hatched common carp, whereas at 6 mm, gizzard shad and spottail shiner were moderately variable in length (CV = 25-27%). This variability did not differ significantly (paired t-test;  $P = 0.05$ ) between three replicate collections on each date. In 1984, age 0+ fishes were collected sporadically and in small number during August and September. Protracted spawning was evident in brook silverside according to presence of small (6-10 mm) larvae, which were more abundant than large larvae in mid-August. Mid-summer growth in gizzard shad was estimated at 0.5 mm/d.

## DISCUSSION

In keeping with their capacity to elaborate partial or completely new systems (Dansereau 1957), humans created a wildlife sanctuary and developed two drainage ditches in south-western Ontario. Ironically, although neither sanctuary nor ditch was designed for fish usage, diverse assemblages frequented these paranthropophytic habitats. Indeed, our collection of fishes represents a wide spectrum of reproductive strategies, many of which seem inappropriate to the various biotopes. Fish production in Lake St. Clair nevertheless owes significantly to these, and a multitude of fragmented coastal habitats.

All three environments share many of the same fish species, with assemblages dominated by a common taxon, namely gizzard shad, tolerant of turbid conditions. Thirty-three species of age 0+ fishes were recorded at Paternoster, six more than in Whitebread ditch and eight more than in Dover canal. In spite of the occurrence of a large number of fish larvae, reproduction at all study sites was probably limited to taxa tolerant of high loads of suspended sediment. Species compositions dominated by fishes such as brook silverside, spottail shiner, and gizzard shad portray simple structural habitat diversity.

### *Considerations on fishes at Paternoster*

Fishes at Paternoster undoubtedly experience high temporal variation in environmental variables effected by onshore winds and changing water levels. During most of the summer, winds are from the south-west (Fig. 1), causing natural detritus and garbage to accumulate in an area embraced by two breakwalls extending perpendicular to shore. This highly nutrient-enriched area may attract certain fishes. Although fish fauna diversity is perhaps higher than may be assumed for exposed sandy shore of a large lake, it is consistent with high biological productivity in the area (Leach 1991). Occurrence of many species arose from transient migration and, during early developmental stages, drift of small larvae vectored by currents. Fish diversity was marked by fluxing assemblages, a phenomenon seemingly prevalent on exposed shores of Lakes Huron and Erie (Leslie and Timmins 1991; 1998).

Early spawners, such as percids, esocids, and possibly several catostomids, are among few species listed in Table 2 that reproduce at approximately 5 to 12°C. Age 1+ fishes migrated from the area when larvae first appeared, then returned in late summer and autumn (Fig. 3). As few percids and catostomids were collected, they may have originated in nearby Thames River or in the St. Clair River system. Ictalurids, central mudminnow, and esocid larvae were absent in all years, as neither spawning nor refuge habitat exists for these taxa. Low frequency of occurrence in all cyprinids, except spottail shiner, suggests they did not utilize Paternoster extensively for reproduction or as a nursery.

Short-term exploitation by age 0+ fishes of the shore habitat is one of the features of the assemblage. On any given sampling date, a maximum of two fishes co-dominated, but they were usually temporally separate according to size. The unique, semi-enclosed area at Paternoster may have effected distributional changes, because occurrences in several common species were at variance with those reported by several researchers. For example, according to Scott and Crossman (1973), brook silverside spawn near or in rooted vegetation or over gravel. They avoid turbid waters and the young move offshore. At Paternoster, rooted vegetation is sparse, the substrate sandy, and water turbid. Nevertheless, larval and age 1+ brook silverside co-occurred throughout summer, often in high densities. Further, the apparent avoidance of the shallows by small age 1+ fishes during high temperatures does not agree with the findings of Tonn and

Paszkowski (1987), who suggested that “warm” shallows were used by several species to avoid predators. Similarly, Garner et al. (1998) found *Phoxinus phoxinus* occupied shallows in which water temperature was higher than ambient river temperature, presumably to avoid predators. Because we rarely collected predators, our results are inconclusive in this regard. However, our observations concur with those on exposed shore in western Lake Erie (Leslie and Timmins 1998).

Carpenter and Lodge (1986) concluded that changes in macrophytes effect dramatic impacts on associated biota and nutrient cycling. Concurrent changes in fish assemblages at Paternoster were not dramatic but nevertheless may have been related to increase in biomass of *Myriophyllum spicatum* and other rooted plants. Keast (1984) found that numbers of age 1+ bluegill decreased whereas co-occurring species were unaffected by the presence of *M. spicatum*. At Paternoster, the total number of bluegill larvae collected in 1995 was half the number caught in 1994, in spite of increased presence of *M. spicatum*. Also, numbers of most-common fishes either increased or decreased substantially with increasing presence of vascular plants. In 1995, for example, common carp numbers increased as macrophytes become more common, whilst numbers of gizzard shad decreased radically. In keeping with habitat preference, frequency of occurrence of both species decreased between 1990 and 1995 as water clarity improved. Zebra mussels colonized the small available rocky habitat at Paternoster. Their contribution to improved water clarity in the lake cannot be overlooked in influencing distribution, abundance, and growth in many fish species. The relationship between fish reproduction and zebra mussel distribution and abundance warrants study in the Great Lakes.

Notwithstanding our limited knowledge of the Gobiidae, the appearance of tubenose goby in 1994, and of round goby in 1995, was surprising in that they are adapted in their native Caspian Sea and Black Sea environments to benthic existence in lotic systems. These exotic species have a pelvic fin modification (a single median suctorial ‘disc’) that allows attachment to solid substrate. The fish we collected (40 to 80 mm TL) were probably at least one year old, and their occurrence suggests adults were present in south-eastern Ontario in 1993, if not earlier. Round goby was first observed in the Great Lakes in 1990 by anglers in the St. Clair River, south of Sarnia, Ontario (Crossman et al. 1992). Tubenose goby was first collected in 1990 at the Belle River power plant, St. Clair River, Michigan, associated with vegetation (Jude et al. 1992). In establishing themselves at Paternoster, gobies’ search for an ecological niche was apparently rewarded, in spite of the paucity of solid substrate in areas south of their local “origin” (Jude et al. 1992; Ghedotti et al. 1995).

Peak densities of dominant fishes (gizzard shad, brook silverside, and spottail shiner) varied widely between years. Densities of spottail shiner were similar to those observed on the exposed shores of Lakes Huron and Erie (Leslie and Timmins 1991a; 1998). They were also considerably higher than recorded in the Bay of Quinte, Lake Ontario (Leslie and Moore 1985), Severn Sound, Lake Huron (Leslie and Timmins 1995) and Long Point inner bay, Lake Erie (Leslie and Timmins 1997). Brook silverside densities matched those in nearby Mitchell Bay (Leslie and Timmins 1993) and were much higher than Chubb and Liston (1986) recorded (20/100 m<sup>3</sup> in 3 yr) in Pentwater Marsh, Lake Michigan. Finally, the 1-yr decline in gizzard shad from 5400/100 m<sup>3</sup> in 1994 to just 18/100 m<sup>3</sup> in 1995 is not uncommon in fish larvae abundance and thus may not necessarily relate directly to effects of zebra mussel filtration of particulates.

Because mixed cohorts of small and medium-bodied taxa are often encountered in large open systems, an increase in divergence in size of age 0+ fishes is sometimes apparent at the end of the first year. Although all species are represented by a wide size range throughout early

ontogeny, divergence late in the year was not evident in dominant fishes, e.g., largemouth bass, bluegill, emerald shiner, gizzard shad, alewife, spottail shiner, and brook silverside (Fig. 5). Keast and Eadie (1984) considered divergence an effect of protracted spawning in small-bodied fishes in relatively small Lake Opinicon, Ontario. Disparities between fish size divergence in Paternoster and Lake Opinicon may result from differences in trophy in large and small systems, as well as differences in species compositions, habitat complexity, water level changes, food resource, sampling methods, and a host of other factors.

First year growth in gizzard shad, alewife, brook silverside and largemouth bass was slightly higher than observed in many ecosystems in the Great Lakes. These systems include, for example, eutrophic embayments in south-eastern Lake Huron (Leslie and Timmins 1995; 1997), Lake Ontario (Leslie and Moore 1985; Leslie and Timmins 1992), open shore habitat in western Lake Erie (Leslie and Timmins 1998) and north-eastern Lake St. Clair (Leslie and Timmins 1993). Relatively large fish size 'at the end of the year' (September/October) probably reflects the general trophic status of eastern Lake St. Clair rather than environmental conditions enhancing growth at Paternoster.

#### *Ditch and canal environments*

Aspects of ecology of fish larvae in Whitebread ditch and Dover canal during the 1980s have been described in Leslie and Timmins (1990). In 1986, a total of 27 species was represented in Whitebread ditch, or 8 less than accounted for both in 1986 and 1990. The assemblage in 1990 was strongly dominated by gizzard shad, whose peak density ( $>20,000$  larvae/100 m<sup>3</sup>) surpassed virtually all species we have collected in the Great Lakes in at least two decades. Other common larvae were generally found in lower densities than those in low gradient systems in the region, e.g., Big Creek, western Lake Erie (Leslie and Timmins 1998), Cedar Creek and Canard River (Timmins unpubl. data 1998) in south-western Ontario.

As a turbid, low gradient system, Whitebread ditch provides habitat more suited to ictalurids than to cyprinids and centrarchids. Of course, not all centrarchids are alike; species such as green sunfish and white crappie tolerate high concentrations of suspended clay in the ditch, just as vegetation-dependent sunfish do not. Cyprinids were represented by many species, but few occurred repeatedly. Ictalurids were rarely collected, probably because turbid conditions favour these elusive fishes during our sampling attempts. Two taxa Campbell (1996) considered rare (pugnose minnow) and vulnerable (blackstripe topminnow) in Canada were found in small numbers in Whitebread ditch. Scott and Crossman (1973) and Trautman (1981) state that pugnose minnow is found in slow-moving, clear waters with abundant vegetation. Such conditions do not exist in agricultural ditches in south-western Ontario, although pugnose minnow was located in nearby densely vegetated Mitchell Bay (Leslie and Timmins 1993). Judging by our complete lack of success during repeated attempts to find them, blackstripe topminnow larvae probably did not hatch or develop in the main body of the ditch. Studies of reproduction and early life have ignored pugnose minnow and blackstripe topminnow, not to mention a vast array of lesser-known fishes. This situation stems in part from environmental research that is mainly policy-driven concurrent with a universal decline in the number of taxonomists (Haffner 1992; Penczak et al. 1997).

The environment in Dover canal may be considered at once a refuge and an opportunity for fishes to utilize an open system. As such, species not usually found in low gradient waters occurred on each sampling date. Percids, white bass, white perch, and esocids were notable

components of the transient group, but probably owe their presence to adjacent fringe vegetation and onshore drift. The assemblage has been deemed a cyprinid-clupeid complex (Leslie and Timmins 1990), mainly on the basis of co-dominants spottail shiner and gizzard shad. Both taxa may have spawned on sand bars, which prevail along the eastern shore of Lake St. Clair. Mean densities of most-common species were generally higher in 1984, possibly because during the spawning period, temperatures were more stable and slightly higher, and water levels higher than in 1983.

According to survey data (Fig. 6), variation in total length in small (5-10 mm) limnetic species, such as alewife, brook silverside, and emerald shiner, was approximately half as much as fish twice their size. In cover and turbid-oriented taxa, e.g., pumpkinseed and gizzard shad, respectively, the opposite seems to be the case. Much more data are required on individual species over a period of at least several years. Large variation in size is a fact of life in studies of ichthyoplankton. Freshwater fishes do not consistently hatch at the same size, nor develop at the same rate, even in small ponds. Collections taken in large open systems may encounter intermingled cohorts whose origins differ spatially and temporally. Further, differences in growth rate can result in large differences in size distribution of the same age class from various locations (Rounsefell 1975). These realities are banes to researchers endeavouring to develop models of fish recruitment, biomass, and productivity.

## ACKNOWLEDGEMENTS

The authors appreciate field assistance in the early 1980s provided by Shelly Bray, Lester Son Hing, James E. Moore, and Chris Blanche. Thanks are due D. M. Whittle and an anonymous reviewer for helpful comments on the manuscript.

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