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ABSTRACT

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The general ecology of fish larvae was studied in Penetang Harbour, Severn Sound, from 1988 to 1991 and 1995. The study area is one of Ontario's 17 Areas of Concern in the Great Lakes. Species richness, seasonality, distribution, habitat utilization, and growth were determined of fishes collected in open water and at the shore from early spring to late summer. The fish taxocene (11313 fish larvae collected) consisted of 30 species representing 12 families and 8 reproductive guilds. Centrarchids, led by pumpkinseed *Lepomis gibbosus*, cyprinids (principally bluntnose minnow *Pimephales notatus*), and an atherinid (brook silverside *Labidesthes sicculus*), were numerically dominant fishes. Larvae were mainly associated with submersed rooted plants in the southern sector of the harbour. Fishes most common in open water included yellow perch *Perca flavescens*, rainbow smelt *Osmerus mordax*, and alewife *Alosa pseudoharengus*, all of which emigrated from the harbour before metamorphosis. Virtually all of the east shore has been settled, whereas much of the remainder of the harbour is perturbed by human activity. Conservation of remnant fish habitat is imperative.

RÉSUMÉ

Leslie, J.K., and C.A. Timmins. 1997. Early life of fishes in Penetang Harbour, an Area of Concern in Severn Sound. Can. Tech. Rept. Fish. Aquat. Sci. No. 2188.

Les chercheurs ont étudié l'écologie générale des larves de poissons vivant dans le port de Penetang, Baie de Severn, de 1988 à 1991 et en 1995. La zone d'étude est l'un des 17 secteurs préoccupants de l'Ontario dans la région des Grands Lacs. La richesse spécifique, l'abondance saisonnière, la répartition, l'utilisation de l'habitat et la croissance ont été déterminées chez les poissons capturés en eaux libres et près du rivage du début du printemps jusqu'à la fin de l'été. Les 11 313 larves de poissons capturées appartenaient à 30 espèces réparties en 12 familles et en 8 guildes reproductrices. Les centrarchidés (dominés par le crapet-soleil, *Lepomis gibbosus*), les cyprinidés (principalement le ventre-pourri, *Pimephales notatus*) et un athérinidé (crayon d'argent, *Labidesthes sicculus*) étaient les taxons dominants. La majorité des larves ont été trouvées en association avec des plantes submergées enracinées, dans le secteur sud du port. Les espèces les plus communes en eaux libres étaient la perchaude, *Perca flavescens*, l'éperlan arc-en-ciel, *Osmerus mordax*, et le gaspareau, *Alosa Epseudoharengus*. Toutes ces espèces ont émigré du port avant leur métamorphose. La quasi-totalité des habitats naturels de la rive est ont été détruits, et une bonne part des autres secteurs de la zone portuaire sont perturbés par les activités humaines. Il est impératif de protéger les habitats du poisson qui restent.

INTRODUCTION

The ecosystem of Severn Sound (south-eastern Georgian Bay) is one of Ontario's 17 Areas of Concern in the Great Lakes, owing to cumulative effects of human activity during the past several decades. The most polluted of its embayments, Penetang Harbour, suffers from eutrophication, lost and altered fish habitat, and salient environmental problems. Detailed information is required on the biology of the harbour and catchment to formulate a realistic and effective Remedial Action Plan (RAP) that will ameliorate water quality and improve the recreational fishery (SSRAP 1993). Without these data, attempts at remediation may be only palliative. As the structure of the community of fish larvae is an expression of the quality of an aquatic ecosystem, the present study was designed to provide details on early life history of fishes in Penetang Harbour in support of remediation and conservation plans.

Ecosystem characteristics

The study area is situated in the Great Lakes-St. Lawrence lowland physiographic region. The watershed soils are grey brown luvisolic, which support natural vegetation characteristic of Great Lakes forests. Penetanguishene Harbour (commonly referred to as "Penetang" Harbour, or Bay) (44° 47′N; 79° 56′W) is a semiconfined body of water lying between hills in a north-south attitude. It is thus partly sheltered from effects of prevailing west winds. The harbour consists of two sections that contrast morphologically and hydrologically, i.e., a relatively deep outer harbour forming part of the main body of Severn Sound, and an inner, shallow harbour (Fig. 1), the subject of our investigation. The club-shaped inner section is about 5 km long, 0.5 to 1.3 km wide, has a shoreline length of 14 km, and a shoreline development factor of 2. The surface area of Penetang Harbour is 570 ha, its maximum depth, 14 m, is near its entrance, and it has a mean depth of 4.7 m (Randall et al. 1993). Substrate in the south basin consists of alluvium and detritus, wood chips, bark, water-logged lumber, and human detritus. The bottom of the remainder of the harbour consists of silt, clay, sand, and gravel. The east side of the harbour has been altered in its entirety in keeping with industrial, residential, and recreational interests.

Landscape along the south basin and east side of the harbour is occupied by the town of Penetanguishene (population 7000), whereas the west side is settled sparsely. There are eight commercial marinas, accommodating 1400 "dockings", with at least 350 slips planned (SSRAP 1993). In addition, numerous private docks are situated on the western and northwestern shores.

Minns et al. (1993) noted the prevalence of macrophytes such as *Vallisneria americana, Elodea canadensis, Potamogeton gramineus, Myriophyllum spicatum*, and *Ceratophyllum demersum*. However, at several of our sampling sites, *Eleocharis acicularis* dominated emergent species, and *Heteranthera dubia* was common among submersed plants in the south basin. These species provide complex physical structure for invertebrates. A marsh at the mouth of Copeland Creek (Fig. 1) is the sole remnant wetland in the study area.

The slow flushing rate of water from the harbour is due to a mean daily flow of only 0.1 m^3/s (DOE 1990) from the main influent, Copeland Creek, and minimal affect of prevailing winds on hydrodynamics. Currents along the south shore of Severn Sound are doubtless the major factor in inducing water from the harbour. Therein lies one of the problems in respect of eutrophication: nutrients from the watershed are not readily diluted by water from Severn Sound. Nevertheless, mean Secchi depth (2.4 m) for all dates indicated reasonably good water clarity. In November, 1992, a storm in Georgian Bay caused a temporary drop of approximately 1m in water level in Penetang Harbour. As a result, a large expanse of relic sawmill debris was exposed in the southeast section of the harbour. Subsequently, in 1994, tonnes of debris were removed in order to rehabilitate a small area utilized for recreational purposes.

Site description

Environmental characteristics at four sites, three at the shore, and open water transects sampled at least 2 yr in succession, are outlined in Table 1. Sampling sites not geographically designated were named arbitrarily, e.g., "Control", "West Beach", "Sewage Plant", and "Ontario Hospital". Additional sites sampled only in 1988 are described as follows:

Davidson Point (DP): low shore (0-1 m depth extends offshore at least 50 m). Water-logged by-products of a relic lumbering industry prevail over sand, clay, ooze; vegetated by sparse stands of submersed vascular plants: *Vallesneria americana, Ceratophyllum demersum, Myrophyllum spicatum,* and prominent emergent species, e.g., *Eleocharis acicularis* and *Scirpus heterochaetus.* Site sheltered from wind effects by terrestrial vegetation.

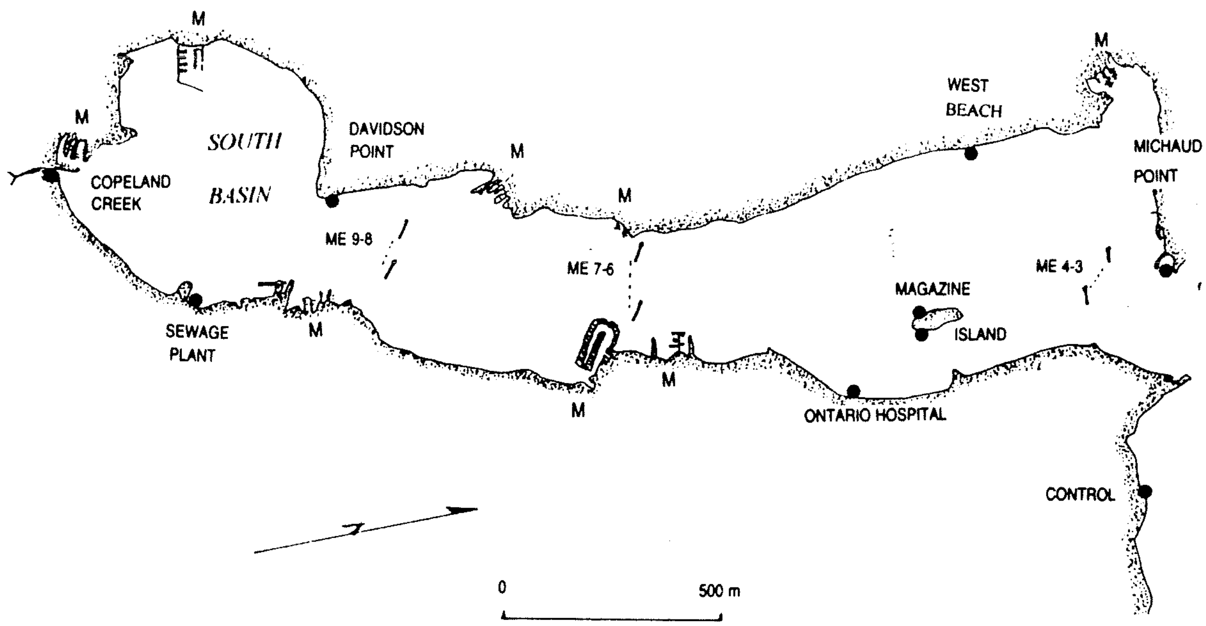

Figure 1. Map of Penetang Harbour, showing sampling sites at the shore and in open water (between buoys 'ME'). M = marina

Michaud Point (MP): at entrance to the inner harbour; (historical note: Samuel de Champlain landed here in 1614); spit consists of gravel and sand. One of few habitats in the harbour possibly utilized for spawning by the top predator, northern pike *Esox lucius*. Dominant macrophytes included *Scirpus americanus, S. heterochaetus, Eleocharis* sp., *Chara* sp., and *Nymphaea* sp. In 1991, this site was dry due to low water levels.

Ontario Hospital (OH): exposed to effects of winds; site located next to a public beach. Upper shore ~ 3 m wide, consists of gravel to edge of water, sand offshore. Forested and settled area (hospital) on upper reaches of hill. Vegetation consists mainly of patches of *Chara* sp.

Magazine Island (MI): windward side of island exposed to effects of wind; gravel and rock substrate, no vegetation; beach area ~2 m wide (1990). Shore on lee of island consists of boulders, gravel, sand and clay; silt predominates offshore. Depth increases to ~3m within 5 m of shore. Trees protect lee side from wind effects .

METHODS

Field work was most extensive in 1988, when six shore sites within the harbour and one near its entrance (see Fig. 1) were sampled regularly. The outlet of Copeland Creek was sampled in early spring only. Magazine Island was sampled both on its windward and lee side. Collections of fishes in 1989 and subsequent years (1990, 1991, and 1995) were made at the same two or three shore stations, i.e., Sewage Plant, West Beach, and Control. In addition to routine collections, sampling took place at various locations at the shore. Three beach seines were used at the shore: one for fish larvae (length 4 m, width 1 m, mesh 0.3 mm); and two for collecting larger fishes (one seine was 10 m long, 1 m wide, mesh 3.0 mm, and another, 61 m long, 3 m wide, mesh 6 mm).

In open water, collections were taken along three transects (navigation buoys ME 3-ME 4, ME 6-ME 7, and ME 8-ME 9; see Fig. 1). In 1989, samples were taken only between ME 7 and ME 6. Ichthyoplankton samples were collected with a rectangular net (mouth opening 1.0 m x 0.5 m), length 2.5 m, and constructed of 0.5-mm mesh, pushed at the bow at a depth of 0.5 m. This net was accompanied by a conical net (mouth diameter 0.4 m, length 2.5 m, and mesh 0.3 mm), weighted and hauled at 2 m. This sampler was not used in the shallow south basin. Hauls were made in both directions, i.e., two separate sets of samples in each transect. A Boston whaler (6 m), with a 75-HP motor, was utilised for plankton hauls, which were made weekly on 9 dates in 1988 and on 8 dates in 1989.

In 1988, the sampling period for open water collections extended from late April to early August. This regime was employed to account for distributional changes in open water of fishes throughout early ontogeny, and to observe movement of species between inner and outer harbours. Tows were made at mean velocities of 0.9 m/s between ME 3 and ME 4, 1.0 m/s between ME 6 and ME 7, and 1.0 m/s between ME 8 and ME 9. In 1989, collections were made from mid-May to early July, employing the same equipment and methods as in 1988.

Plankton nets filtered an average of 77 m^3, 150 m^3, and 92 m^3 between ME 3 and 4, ME 6 and 7, and ME 8 and 9, respectively. The coefficient of variation in volume of water filtered with nets ranged from 8 to 13%. Mean boat speed, measured with a hand-held current meter, ranged from 0.8 to 1.3 m/s. Filtration efficiency of samplers was assumed 100 percent.

Collections took place at intervals of 3-10 d from May to July, then twice monthly or monthly thereafter. Sampling at the shore consisted of three 15-m hauls at each site, parallel to shore at wading depth (1 m). These were always in the same location, and, as the complete seine typically is not submersed when deployed, a total volume of approximately 100 m^3 was estimated to have been filtered at each site on each date.

Static samplers, e.g., wire minnow traps (aperture opening 15-25 mm) and illuminated (chemical 'glow-sticks') rectangular plastic traps (10 L) were occasionally set overnight among submersed macrophytes. These traps were used to collect small adult fishes in wetlands. On two dates, a gang gill net (length 64 m), consisting of 7 equal panels (stretched mesh grading from 1.3 to 10 cm) was set perpendicular to shore at Control (Fig. 1); it was monitored on each occasion and removed after each 2 h set. The purpose of this sampling was to identify adult fishes frequenting shore areas relatively unaffected by human activity. Netted fish were identified and counted, then immediately released.

Fish larvae were placed immediately in ~10% formalin. Specimens were sorted, identified, counted, and stored in a solution of 70% ethanol mixed with 100% glycerol (90:10 v/v) within 6 mo of collection. Mean density of fishes (number/100 m^3) was calculated from total catch and volume of water filtered at each site. Abundant taxa were measured (accuracy ±0.2 mm) for total length (TL) with a Wild M5 stereoscope. These measurements provide an estimate of first year growth, assumed to have ceased by mid-September. On average, 44 fish (range 5-171) were measured for any given date.

Crustaceans co-occurring with limnetic fish larvae represent prey or predator. Hence, single 20-L zooplankton samples were taken with a hand pump just below surface in mid-harbour on 6 dates between mid-May and early July, 1989. Plankton were counted using the procedure of Borgmann et al. (1984). Additionally, weather conditions were taken at time of sampling, and water temperature, conductivity, and electrometric pH were measured routinely at a depth of 0.2 m. Water transparency was measured with a 20-cm Secchi disc.

Table 1. Environmental characteristics at four fish sampling sites (see Fig. 1) in Penetang Harbour, Lake Huron. SP = Sewage Plant, WB = West Beach, C = Control, T = transects. Mean values are given; ranges in parentheses.

Site/Year/Date	Temperature (°C)	Conductivity (μS)	Habitat characteristics
SP 1988 May 26-Aug 10	22.4 ± 4.5 (16.5-29.0)	171 ± 31 (110-210)	Artificial fill throughout site; boulders at shore, gravel and sand; anthropogenic debris in water and on shore; two surface drains and one ditch discharge at shore. Macrophytes: *Myriophyllum spicatum, Elodea canadensis, Chara* sp., *Najas* sp., *Ceratophyllum demersum*
1989 May 4-Aug 15	20.1 ± 5.5 (10.5-28.5)	147 ± 34 (78-180)	
1990 May 17-Aug 14	19.9 ± 3.7 (12.0-26.0)		
1991 May 15-Aug 14	23.4 ± 2.0 (18.5-25.0)		
1995 May 10-Jul 13	17.8 ± 5.2 (9.5-24.0)	120 ± 46 (60-190)	
WB 1988 May 26-Aug 10	20.9 ± 3.9 (16.0-27.0)	175 ± 21 (135-210)	Boulder and gravel at shore form base of road. Road 4.5 m above water. Fully sheltered from wind effects (lee). Shore 1-2 m wide, gravel substrate extends ~3m offshore, thence sand. Gradient steep: 3 m deep about 3 m offshore. No rooted aquatic vegetation. Forest adjacent to road, rise ~50 m to peak. Terrestrial vegetation above shore: white cedar, sumac, red osier. Forest: red oak, beech, white ash
1989 May 4-Aug 15	19.0 ± 6.0 (10.0-26.0)	148 ± 8 (130-155)	
1990 May 17-Aug 14	19.4 ± 3.4 (14.0-23.0)		
1991 May 15-Aug 14	23.4 ± 2.0 (18.5-25.5)		
1995 May 10-Jul 13	17.8 ± 4.7 (11.0-23.0)	144 ± 20 (120-170)	
C 1988 May 26-Aug 10	21.5 ± 5.2 (14.5-28.0)	165 ± 15 (140-185)	Located outside harbour. Upper shore consists of mixed rock, gravel, pebbles, and boulders. Beach area ~8 m wide, backed by mixed forest. Shallow gradient (1 m depth at least 30 m offshore). Substrate gravel, rock, grading to sand at ~6 m offshore. Macrophytes sparse, mainly *Vallisneria americana*
1989 May 4-Aug 15	19.3 ± 6.1 (10.5-29.0)	159 ± 30 (140-240)	
1990 May 17-Aug 14	18.6 ± 4.1 (9.5-24.0)	170	
1991 May 15-Aug 14	22.2 ± 2.0 (18.0-25.0)		
T 1988* May 20-Aug 5	20.0 ± 5.1 (14.5-27.0)	170 ± 16 (140-200)	Depth in mid-transect ME 7-6 = 7.0 m; ME 8-9 = 6.1 m; ME 4-3 = 13.8 m. No natural habitat on east side of harbour (large marina), natural habitat on west side (gravel and sand shore), sparse *Carex* sp. Mean Secchi depth mid-transect (1988): 2.7 m; maximum 5.1 m July 15 at ME 3-4, minimum 1.5 m June 29 at ME 8-9.
`1989 May 17-July 4	18.5 ± 4.4 (14.0-26.0)	155 ± 8.7 (150-170)	

* Mean values for all transects (**T**)

Two measures were used to indicate seasonal co-occurrence ("ichthyosociability") of fish species at pairs of stations. An index of habitat occupancy (HO), and percent coefficient of community (Cc), provided an indication of preference of fishes for specific habitats. The index of habitat occupancy ($N.D/D_t$) denotes the frequency of simultaneous use by all fishes of any two compared habitats throughout the sampling period. The index is the product of the number of species (N) that co-occur and the ratio of dates (D) on which they appear at both stations to total sampling dates (D_t). It places similar importance on numbers of taxa and their co-occurrence (Leslie and Timmins 1994a). For Penetang Harbour, an index arbitrarily > 4.9 was deemed to signify that assemblages had high common affinity for particular habitat types. The percent coefficient of community (Cc) (Whittaker and Fairbanks 1958) emphasises habitat use by minor species. In most ecosystems, these far outnumber dominant fishes. Cc = $c.100/a+b-c$, where a and b are the respective numbers of species at pairs of sites and c is the number of species occurring in both.

Mean density of fishes collected in upper, middle, and lower transects were compared using Wilcoxon's signed-ranks T test at P = 0.01, whereas Spearman's rank-correlation coefficient (r_s) (Zar 1974) was used to compare mean densities of fishes between pairs of shore stations. In this paper, fish larvae are defined as those in their natal year (period extending from hatch to entry into first winter), whereas age 1+ juveniles and adults are fish that have survived at least one winter. The term "assemblage" refers to the suite or group of fishes found at any given locale on any given date. Reference to "richness" relates to numbers of species at a locale, whilst "fidelity" is the frequency of occurrence of taxa throughout the sampling regime.

RESULTS

Physical characteristics

Temperature

Penetang Harbour usually becomes ice-free in mid to late April, when fish larvae (burbot, lake whitefish) first appear. Until early July, temperature in open water was 2 or 3 degrees lower than at the shore. Generally, minimum spawning temperatures (15-20°C) for most fish species coincide with the appearance of new growth macrophytes, such as *Nuphar* sp. and *Potamogeton* sp., usually in early or mid-May. In 1991, macrophytes appeared about 1 wk earlier than in other years, probably because water temperatures were 2°C higher in spring.

Water levels

Water level affects the quantity of spawning area available for littoral fishes, their food, and vegetative growth. During the study period, levels in May were highest in 1988 (176.50 m) and lowest in 1990 (176.15 m). From 1989 to 1991, water level reach peak in July, about 6-8 wk later than in 1988 (DOE 1988-1991).

Conductivity

Mean conductivity decreased in years following 1988 (Table 1); values were highest in Copeland Creek (x = 260 ± 57 µS, range = 185 to 305 µS), and lowest (165 µS) at Control, and at other sampling sites nearest Severn Sound proper, e.g., Ontario Hospital and Magazine Island (Fig. 1). Mean pH ranged from 7.2 to 8.2 (x = 7.6). Secchi disc transparency extended to bottom (>1 m) at all shore stations except at Sewage Plant, where onshore winds occasionally resuspend sediment.

General features

A total of 11,313 fish larvae, representing 12 families, 30 species, and 8 reproductive guilds was collected in Penetang Harbour. With the possible exception of white sucker and banded killifish, most-abundant species were not represented in similar proportion in successive years (Table 2). The repeated occurrence of pumpkinseed, bluntnose minnow, brook silverside, and white sucker indicated high fidelity (78-100%) for these taxa in the harbour.

Centrarchids contributed the largest number to the collection (4-yr average 48%; range 35%-62%), 90% of which were pumpkinseed. In each year, pumpkinseed larvae occurred every sampling date following their initial appearance, and were found at least once at all shore sites. Their overall fidelity was consistently higher than most taxa, especially at West Beach and Ontario Hospital (Fig. 1). Both sites are unvegetated, although there are patches of submersed plants nearby.

Cyprinids were collected at all sites each year, represented 12 species of fish larvae, and contributed 16% (range 8-18%) to the total catch in 1988-1991 and 1995 (Fig. 2). Bluntnose minnow (53%) and spottail shiner (22% of all cyprinids) were numerically dominant, and with common carp, the only cyprinids found on more than 8 dates in 1988. Bluntnose minnow larvae exhibited high fidelity (60%) for all shore sites in 1988.

Brook silverside is a fish of generally high constancy in Penetang Harbour. It was the second most-numerous fish, and one of 8 taxa collected each year. It contributed 34% of the total catch in 1988, averaged 15% for all years (Fig. 2), and its fidelity was 67%. Larvae were found mostly on the lee side of Magazine Island and at Control and Sewage Plant, and were usually more abundant in open water than at the shore.

Yellow perch, the dominant percid, appeared in moderate numbers, although briefly (May-June) in all years. Yellow perch larvae were found mainly in unvegetated areas, i.e., West Beach and Ontario Hospital. In 1988, "Others" (Fig. 2) were represented by 6 taxa and dominated by rainbow smelt and alewife, which together comprised 34% of the total catch in 1988.

Reproductive habitat

Fishes have been classified in relation to type of habitat utilised for spawning (Balon 1975). For example, lithophils require spawning substrate of rock or gravel. In Penetang Harbour, members of this guild represented 11 taxa, as did phytophils, which usually select substrates consisting of decaying or new vascular plants. Lithophils (e.g., rainbow smelt, lake whitefish) were found mainly in open water near the entrance to the harbour. Phytophils, such as common carp, banded killifish, largemouth bass, and black crappie, were represented by at least one species throughout all sampling periods. Pumpkinseed, the sole polyphil in Canada, utilizes a wide range of spawning substrates, whereas phyto-lithophils (e.g., brook silverside, yellow perch, alewife) spawn in offshore margins of vegetation and in deeper littoral areas. Speleophils, a group of nest-guarding littoral species, were dominated numerically by bluntnose minnow, which spawns on firm substrates.

Table 2. Contribution to total catch (expressed as annual percent) of fishes collected in Penetang Harbour, 1988-1991 and 1995. Asterisk denotes fish collected only as age 1+. "Habitat" specifies areas in which a taxon most often occurred, e.g., OW = open water, SM = submersed plants, EM = emergents, ES = exposed shore, L = languid, S = standing water, F = fluvial. ! = introduced exotic fish.

Species	Common name	Habitat type	Total catch	Contribution 1988	'89	'90	'91	1995
Alosa pseudoharengus	Alewife	OW	450	47	2	46	4	<1
Lepisosteus osseus	Longnose gar	S	*					
Amia calva	Bowfin	SM/S	*					
Salvelinus fontinalis	Brook trout	F	*					
Coregonus clupeaformis	Lake whitefish	OW	8	50	25	25	0	0
Osmerus mordax	Rainbow smelt	OW	403	92	<1	0	7	1
Umbra limi	Central mudminnow	L	*					
Esox lucius	Northern pike	EM	*					
Notropis hudsonius	Spottail shiner	ES	392	45	30	4	21	<1
Luxilus cornutus	Common shiner	F	*					
Notropis heterodon	Blackchin shiner	SM	51	18	0	75	8	0
Notropis heterolepis	Blacknose shiner	EM	3	100	0	0	0	0
Notropis volucellus	Mimic shiner	ES	21	95	5	0	0	0
Notropis stramineus	Sand shiner	ES	89	36	0	1	57	6
Notropis atherinoides	Emerald shiner	ES	19	26	42	0	0	32
Cyprinella spiloptera	Spotfin shiner	EM	1	0	0	100	0	0
Semotilus atromaculatus	Creek chub	F	1	0	100	0	0	0
Cyprinus carpio	Common carp	S	244	91	2	0	6	0
Pimephales promelas	Fathead minnow	F	10	100	0	0	0	0
Pimephales notatus	Bluntnose minnow	SM	958	28	8	25	32	7
Notemigonus crysoleucas	Golden shiner	SM	20	0	5	15	40	40
Phoxinus eos	N. redbelly dace	F	*					
Catostomus commersoni	White sucker	ES	167	65	4	11	12	8
Moxostoma sp.	Redhorse species	U	*					
Serrasalmus sp.	Piranha	!	*					
Ameiurus nebulosus	Brown bullhead	SM	2	0	50	0	0	50
Fundulus diaphanus	Banded killifish	EM/OW	64	0	22	45	31	2
Labidesthes sicculus	Brook silverside	ES	1746	12	8	40	40	<1
Gasterosteus aculeatus	Threespine stickleback	SM	*					
Culaea inconstans	Brook stickleback	SM	*					
Percopsis omiscomaycus	Trout-perch	OW	*					
Morone chrysops	White bass	OW	1	0	0	0	100	0
Morone americana	White perch	OW	20	0	0	0	5	95
Ambloplites rupestris	Rock bass	EM	2	100	0	0	0	0

Table 2 (cont'd.)

Lepomis gibbosus	Pumpkinseed	SM	4914	13	12	38	31	6
Lepomis macrochirus	Bluegill	SM	22	50	0	50	0	0
Pomoxis nigromaculatus	Black crappie	SM/EM	60	73	2	18	7	0
Micropterus salmoides	Largemouth bass	SM	134	10	1	4	83	1
Micropterus dolomieu	Smallmouth bass	ES	331	95	0	0	1	4
Perca flavescens	Yellow perch	ES	1102	16	23	52	6	4
Stizostedion vitreum	Walleye	ES	*					
Etheostoma nigrum	Johnny darter	ES	75	64	0	12	19	5
Cottus bairdi	Mottled sculpin	F	*					
Lota lota	Burbot	OW	3	100	0	0	0	0

Species richness at shore sites in 1988

Throughout the study period, 49% of all fish species (Table 2) were found repeatedly at Sewage Plant, 41% at Davidson Point, and 40% at Ontario Hospital. The assemblage least utilized Michaud Point (24%) and West Beach, where they occurred on 30% of possible sampling dates. Bluntnose minnow, pumpkinseed, and brook silverside were the most common fishes found at all sites on 26 to 31 sampling dates.

Davidson Point attracted relatively few fishes. Submerged wood and lumber, by-products of a defunct sawmill operation in the south basin, provide extensive spawning habitat for bluntnose minnow. This fish contributed the highest number (49%) in a small total catch of 284. Five reproductive guilds were represented at Davidson Point by one of the smallest number (11) of species at any shore site in the harbour.

Fishes at Ontario Hospital and Magazine Island were also collected in low numbers (totals = 296 and 262, respectively), although their representation was more evenly divided across 6 guilds. Phyto-lithophils including yellow perch, alewife, and brook silverside, together with the polyphil pumpkinseed (38% of total catch), were dominant at Ontario Hospital, whereas pumpkinseed (34%) and the lithophil, smallmouth bass, were dominant at Magazine Island. However, except for incidental catches of smallmouth bass aggregated near nests, none of these species was collected any time in large quantity.

Control was frequented by 14 taxa representing 7 reproductive guilds, only just 263 fish were caught. Pumpkinseed were most numerous (38% of total catch) and occurred on all sampling dates. In contrast, lithophils and psammophils (45% of total catch) occurred sporadically. At Michaud Point (Fig. 1), collections were also dominated by pumpkinseed, which contributed 82% to the total catch of 11 species.

Species richness was highest at West Beach (13 taxa) and Sewage Plant (16). Although larvae representing the same reproductive guilds occurred at both sites, their contribution to total catch differed markedly. For example, at West Beach, smallmouth bass contributed 28%, compared with <1% at Sewage Plant. Common carp and brook silverside each contributed about 22% to the total catch at Sewage Plant but only 1% at West Beach. In 1988, the assemblage at each shore site was dominated by fewer than four species, two of which always included pumpkinseed and at least one cyprinid.

Indices of habitat utilisation

The index of habitat occupancy (Table 3) indicated high fish compatibility (HO = 6.0 to 7.9) at paired sites Control and Michaud Point, Sewage Plant and Davidson Point (in 1988), and West Beach and Control (in 1991). In contrast, the index suggested incompatibility for respective suites of species at Sewage Plant paired with Michaud Point, Control, and West Beach. Lowest HO values (2.2 to 2.4) occurred where fish habitats contrasted, e.g., Sewage Plant, Michaud Point, Control, and West Beach. Assemblages differed each year at three sites selected as "index" stations (Sewage Plant, West Beach, and Control) in years following 1988. These sites were selected because of contrasts in habitat type and fish species composition.

FISH LARVAE REPRESENTATION

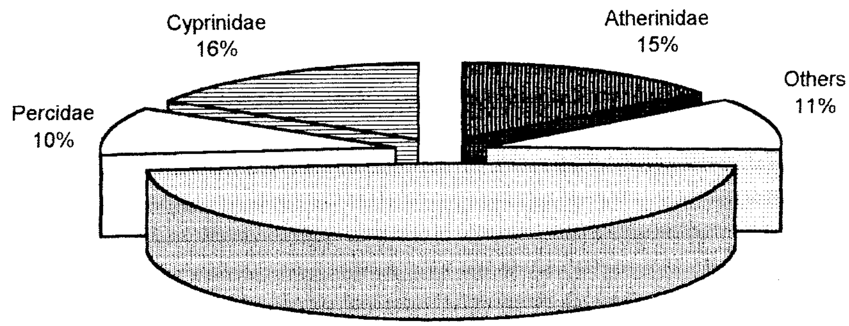

Figure 2. Percent contribution (1988-91 and 1995) of principal families of fish larvae in Penetang Harbour. "Others" are all fishes collected in relatively small number or sporadically in large number.

According to values of coefficient of correlation (Cc) in 1988 (Table 3), composition of fish assemblages were most alike (Cc = 69-71%) at Sewage Plant and West Beach, Sewage Plant and Ontario Hospital, and Ontario Hospital and Magazine Island. Sites paired as SP/C, SP/MP, C/DP, and OH/DP (Fig. 1) were least alike (Cc = 21-26%). Not surprisingly, fish assemblages were alike at Ontario Hospital and Magazine Island, since these sites are proximate and their habitat types are similar. On the other hand, fish habitat at Sewage Plant, a vegetated area, contrasts with those at West Beach and Ontario Hospital, both of which are unvegetated. Relatively high concordance between assemblages at these locations arose from consistent appearance of metamorphosed fishes in mid to late summer.

Although indices of Cc, HO, and species richness were high for several paired sites, correlations of mean density were very low ($r_s = 0.012$ to 0.125). In 1991, for example, highest correlations ($r_s = 0.697$ to 0.864) were accompanied by some of the lowest values of Cc. Generally, trends in values of both indices (Cc and HO) and number of co-occurring species corresponded in successive years. However, because of striking contrast between habitat types at West Beach, Sewage Plant, and Ontario Hospital, concordance between the number of co-occurring species is inexplicable.

Table 3. Matrix of percent coefficient of community (upper), index of habitat occupancy (lower numbers), and maximum number of taxa co-occurring at each pair of shore sites (in parentheses) for fishes in Penetang Harbour, 1988-1991 and 1995. Sampling sites: SP = Sewage Plant; WB = West Beach; C = Control; OH = Ontario Hospital; MI = Magazine Island; MP = Michaud Point; DP = Davidson Point.

Year	Site	WB	C	OH	MI	MP	DP
1988	**SP**	71 4.9 (10)	26 4.4 (5)	69 5.3 (9)	42 5.1 (8)	24 2.4 (5)	47 6.0 (9)
1989		24 3.9 (4)	11 2.2 (2)				
1990		58 4.7 (7)	46 3.3 (6)				
1991		35 4.9 (7)	35 4.5 (7)				
1995		13 2.2 (2)					
1988	**WB**		53 4.9 (8)	33 2.7 (6)	47 5.7 (5)	50 4.0 (7)	40 5.6 (6)
1989			38 3.3 (6)				
1990			42 2.3 (5)				
1991			47 6.3 (8)				
1988	**C**			53 5.2 (8)	43 4.7 (6)	54 7.9 (7)	21 3.1 (3)
1988	**OH**				69 4.6 (9)	47 2.9 (7)	24 5.4 (4)
1988	**MI**					54 4.4 (7)	31 5.1 (5)
1988	**MP**						46 3.4 (6)

Seasonality and density of fishes

Open water (1988)

Twelve taxa were found in open water: 9 in mid-transect ME 6-ME 7, and 7 each in upper (ME 3-ME 4) and lower (ME 8-ME 9) transects (Fig. 1). Burbot, the first fish collected (May 4 at 10°C), was not found after May 20, and only appeared near the entrance to the harbour. Yellow perch larvae were not found after June 2 nor rainbow smelt after June 28, when alewife were first encountered. Thereafter, alewife larvae were collected until sampling ceased in early August. Brook silverside and burbot were found only at the surface, whereas spottail shiner was found only at 2 m.

Densities of fishes were usually higher at the surface than at 2 m and differed significantly (P = 0.01) between all hauls, including those between three transects (Wilcoxon-*T* test). Densities were frequently highest in ME 3-ME 4, and lowest in ME 8-ME 9 (Fig. 3). Alewife, while abundant in the upper part of the harbour, were not found in open water in the south basin. Highest mean densities were attained by rainbow smelt at the surface on May 20 and alewife at 2 m on June 28 (Table 4). However, mean density of few species exceeded 30/100 m^3 on any date.

Transect ME 6-ME 7 (1989)

In 1989, yellow perch, spottail shiner, alewife, and pumpkinseed were the only fishes found in open water. Yellow perch appeared later (May 17) and for a longer duration (until June 20) than in 1988, whilst alewife first appeared on June 27 and last on July 4; thereafter, no fishes were found in open water. Lower water temperatures and water levels in 1989 undoubtedly affected mean densities of fishes, which were much lower than in 1988 (Fig. 3).

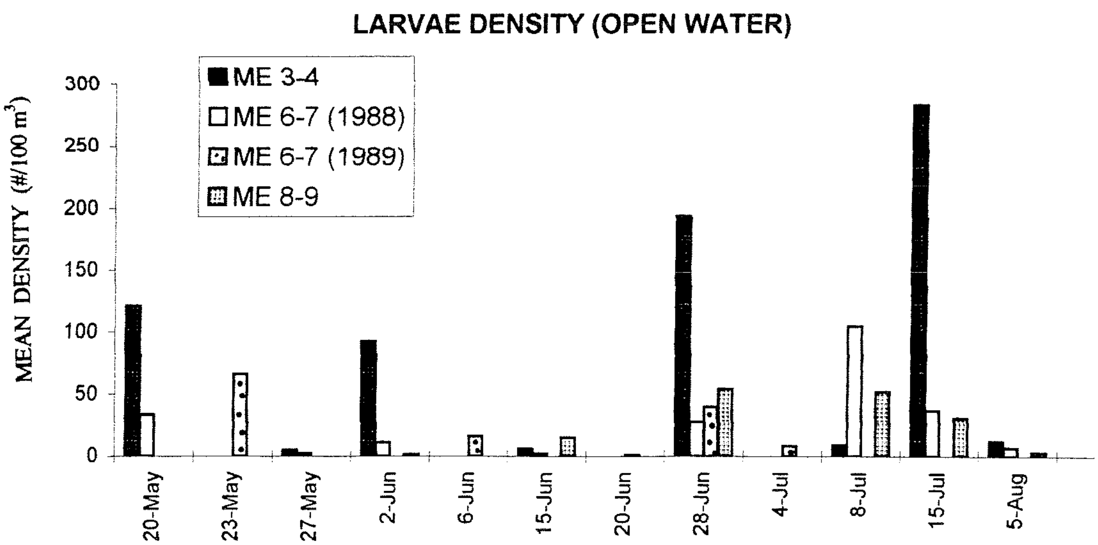

Figure 3. Seasonal density of total fish taxa collected in open water during 1988 (three transects) and 1989 (ME 6-ME 7 only).

Table 4. Mean density (number/100 m^3) of fish larvae (all taxa) at 4 shore sites, Penetang Harbour, sampled only in 1988. Dominant fishes: *Pon* = *Pomoxis nigromaculatus, Pin* = *Pimephales notatus, Ls* = *Labidesthes sicculus, Lg* = *Lepomis gibbosus, Md* = *Micropterus dolomieu.* * denotes dense aggregations of zooplanton species. Number of fish species occurring each date in parentheses.

	Site (see Fig. 1)			
Date	DP	MP	MI	OH
May 2		0	0	0
May 19		4 (1)	1	26 (2)
May 26	7 (1)	8 (2)	4 (1)	20 (2)
June 2	0	5 (3)**Bp*	3 (1)	11 (3)
June 14	51 (2) *Pin*	35 (4)**Lk*	13 (4)	26 (4) *Pon*
June 24	21 (2)	4 (2)	0	33 (6) *Ls*
June 28	10 (3)	1	5 (3)	13 (5)
July 7	8 (3)	2 (2)	114 (4) *Lg, Md*	11 (6)
July 14	78 (4) *Lg*	292 (3) *Lg*	62 (4)	0
Aug. 4	34 (3)	76 (2)	24 (2)	96 (4) *Lg*
Aug. 10	20 (5)	0	10 (3)	27 (4)

**Bp* = *Bythotrephes cederstroemi, Lk* = *Leptodora kindtii*

Shore

Numbers of fishes caught in consecutive beach seine hauls on each date were significantly different at each station (Wilcoxon test; $P < 0.01$). As well, in 1988-1991, mean densities of fishes collected at Sewage Plant, West Beach, and Control usually differed significantly on any given date. Mean densities of all species combined at Davidson Point and West Beach were significantly correlated in 1988, as were those at Davidson Point and Ontario Hospital ($r_s = 0.786$ and 0.768, respectively; Spearman's rank, $P<0.01$). These correlations were coincidental, since on most occasions, different species were caught at each site. Furthermore, mean densities of individual species at all paired sites were not correlated in any year. At four sparsely-vegetated or unvegetated sites (Table 4), mean densities of fishes usually remained low until early to mid-July.

Seasonal (1988-1991) mean densities of fish larvae at Sewage Plant, West Beach, and Control are depicted in Fig. 4. Total catch and mean density of fishes at Sewage Plant increased with water temperature and vegetative growth until July, when common carp, brook silverside, and pumpkinseed dominated the taxocene. At West Beach and Control, fish densities were consistently low and temporally variable (Fig. 4A).

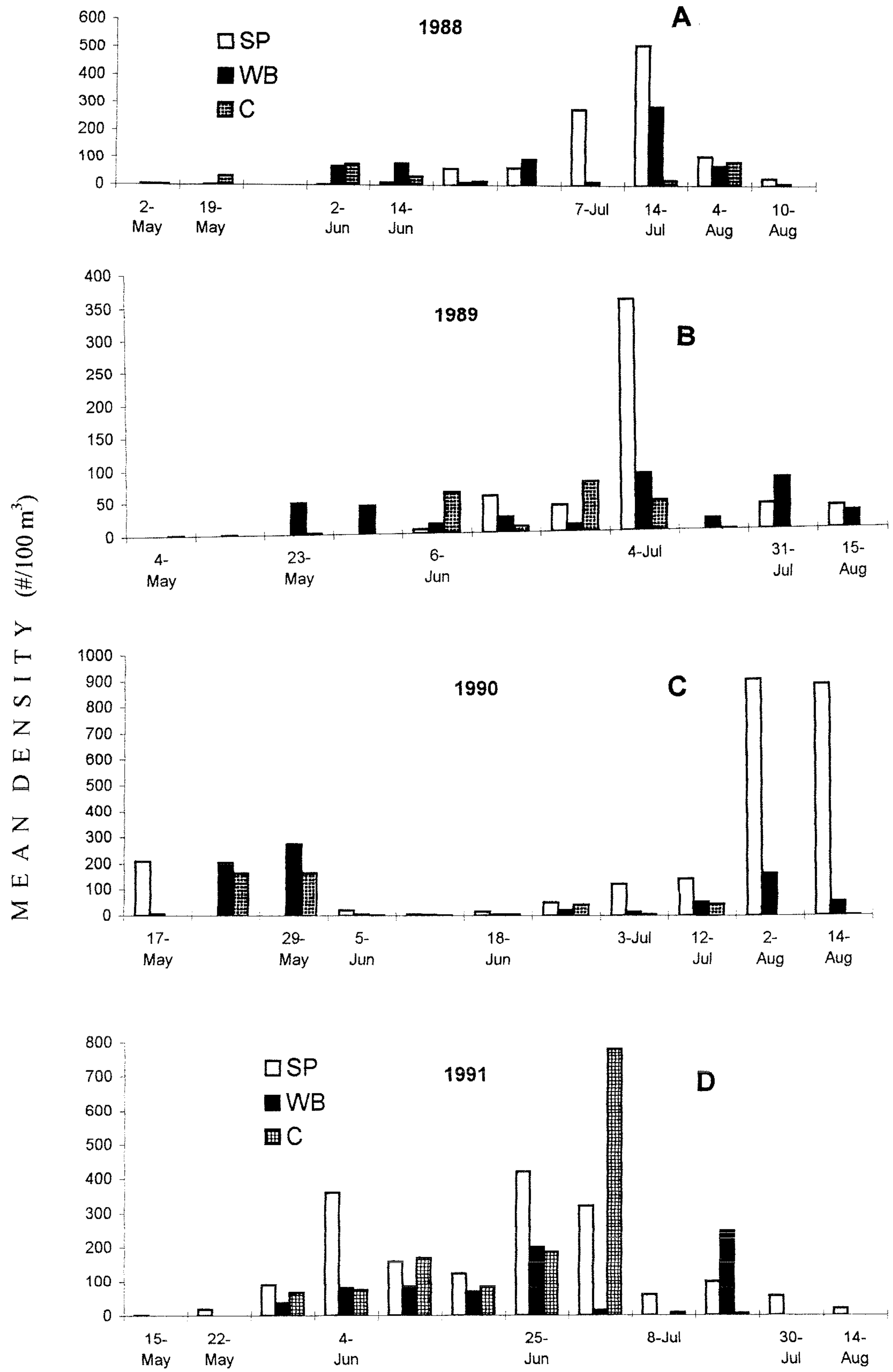

Figure 4. Seasonal density of fishes at SP, WB, and C (shore) in (A) 1988, (B) 1989, (C) 1990, and (D) 1991.

In 1989 (as in 1988), early occurring larvae, such as yellow perch and rainbow smelt, were found at West Beach and Control before they appeared at Sewage Plant. Lack of spawning habitat in the upper sector of the harbour and the close proximity of these sites to the main body of Severn Sound suggests migration or drift of small larvae into the harbour. Generally, mean densities at these sites, and in open water, were about half those in 1988 (Fig. 4B). Yellow perch larvae were collected almost exclusively at West Beach, where their density peaked in late May, whereas pumpkinseed and brook silverside attained highest densities in early to mid-summer (Table 5).

Occurrence and peak density of fishes contrasted in 1990 and 1991 (Fig. 4C,D). Yellow perch first appeared at Sewage Plant and was the only fish found in the inner harbour in early May, 1990. Its temporal distribution shifted from Sewage Plant in mid-May to West Beach and Control in late May, an indication of spawning in the south basin, and subsequent migration from the harbour. As in previous years, appearances of yellow perch were rare after mid-June, which suggests limited use of the harbour as a nursery area. Peak density of alewife coincided with maximum water temperature (23.5-26.0°C) at Sewage Plant in early August (Table 5). In late spring and early summer, fishes were scarce at all stations (Fig. 4C).

Table 5. Mean peak densities (#/100 m^3) of 7 dominant species, and temperature at time of collection, in Penetang Harbour, May-August, 1988-91 and 1995. Sampled sites: SP = Sewage Plant, WB = West Beach, C = Control, MP = Michaud Point, MI = Magazine Island, ME = open water transect (Fig. 1). Freq. = number of sampling dates fish occurred at site specified.

Species	Date	Site	Mean density	Temp (°C)	Freq. (Wk)	Seasonal occurrence
Lepomis gibbosus	July 14/88	MP	292	24	3	July 7-Aug 4
	July 14/88	SP	408	23	5	June 24-Aug 10
	July 4/89	SP	233	27	6	June 6-Aug 15
	Aug 14/90	SP	781	24	6	June 18-Aug 14
	July 16/91	WB	240	24	7	May 28-Jul 16
	July 3/91	C	206	22	7	June 13-Jul 16
	June 25/95	WB	235	23	4	June 16-Jul 13
Pimephales notatus	July 3/91	C	223	22	3	June 13-July 3
Cyprinus carpio	July 7/88	SP	116	26	3	June 24-Jul 14
Labidesthes sicculus	July 4/89	SP	117	26	3	June 27-Jul 31
	June 25/91	SP	258	25	7	June 4-Jul 16
Perca flavescens	June 2/88	ME 3-4	60	18	3	May 20-June 3
	May 23/89	ME 6-7	66	14	5	May 17-June 20
	May 23/89	WB	45	15	4	May 23-June 20
	May 17/90	SP	210	12	3	May 17-July 3
	May 29/90	WB	275	17	5	May 17-June 18
Osmerus mordax	May 20/88	ME 3-4	114	15	5	May 20-June 29
Alosa pseudoharengus	June 28/88	ME 3-4	143	13	4	June 28-Aug 5
	Aug 2/90	SP	218	26	2	July 3-Aug 2

In 1995 and for the first time in the study period, pumpkinseed larvae were much less abundant at Sewage Plant than at West Beach (Table 5). This may reflect habitat disturbance effects adjacent to our sampling site at Sewage Plant in 1994, when tonnes of wood debris were removed from the south basin. The first larvae (yellow perch) appeared at both sites in small number at 14°C. Pumpkinseed was the sole abundant fish found regularly, and represented 59% of the total catch at both sites (58% at West Beach). Peak density of pumpkinseed occurred on June 25 at 23°C. As in previous years, smallmouth bass larvae were collected, and adults observed, mostly at West Beach. No fishes were found at West Beach in July.

Seasonal growth in length in most-common species

Seasonal growth in several dominant fish species was difficult to determine due to co-occurrence of cohorts at sampling sites. This phenomenon was especially evident in pumpkinseed and brook silverside (Fig. 5 and Fig. 6). The coefficient of variation of mean TL for pumpkinseed ranged from 7% for 6.0 mm larvae on July 4, 1989 to 43% for 7.3 mm fish on June 4, 1991. In all years, the overall CV for pumpkinseed averaged 23%. Total length of pumpkinseed increased approximately incrementally only in 1990 (Fig. 5).

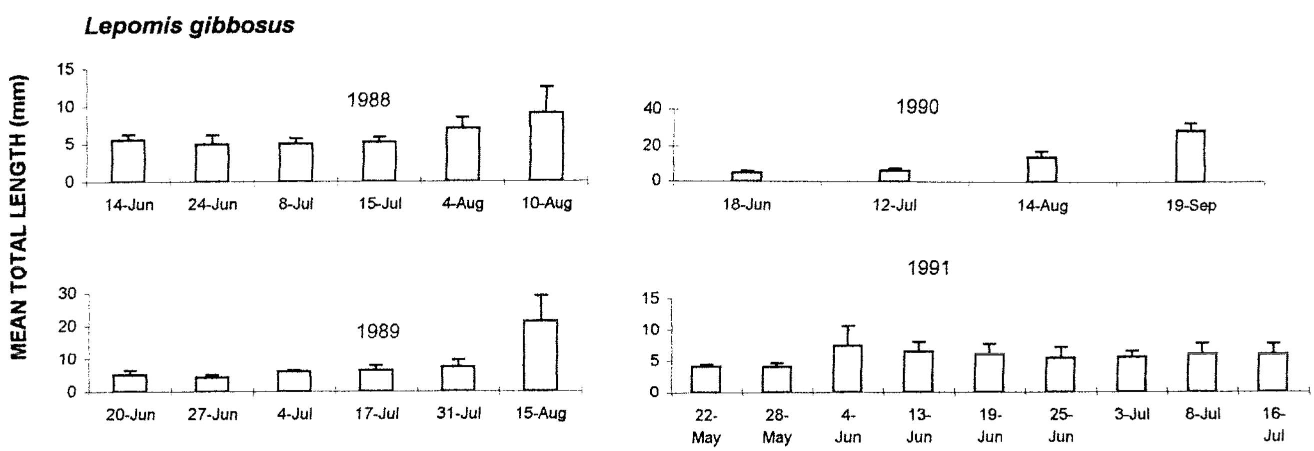

Figure 5. Seasonal total length (+SD) of *Lepomis gibbosus* in Penetang Harbour, 1988-1991.

Brook silverside larvae grow very rapidly (Scott and Crossman 1973), yet, in 1988, growth appeared to be insignificant (1.4 mm) between June 24 and August 4 (Fig. 6). Similarly, in 1989 and 1990 small (5 mm) fish grew at a rate of 0.2 mm/d. However, larvae attained adult size by early September, 1991, in spite of apparent static growth in June and July, when the largest brook silverside collected was 11.5 mm.

Whereas alewife probably spawn once, bluntnose minnow spawn at least twice and newly-hatched fish may be collected with older cohorts (Fig. 7). Growth in alewife was comparatively linear (Fig. 8) although CV of mean TL varied widely between years (3% for 6.8-mm fish in mid-June, 1988 to 43% for 13.6-mm fish in early July, 1991). Bluntnose minnow were 29-34 mm (mean TL) in late July and mid-September, thus, they may have approached maximum growth for the year in August. Length of alewife, on the other hand, increased 0.12 mm/d from late June to early August, 1988 (Fig. 8). As alewife sometimes spawn as late as August, overlap in several size classes was probable. Consequently, the overall CV in mean TL (36%) of alewife was higher than for other fishes.

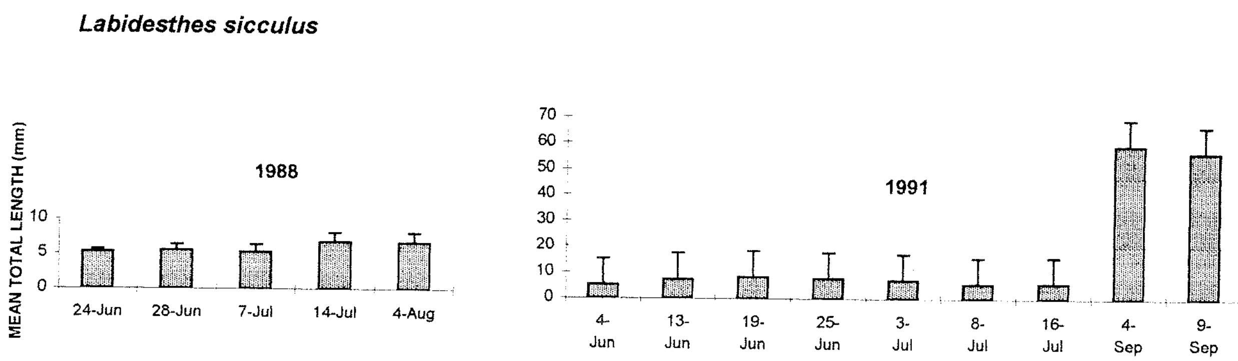

Figure 6. Seasonal total length (+SD) of *Labidesthes sicculus* in Penetang Harbour, 1988-1991.

Just prior to metamorphosis, yellow perch typically move from shore to open water. Aggregates of larger cohorts in open water (Fig. 9) may be in the process of forming schools just prior to emigration from the harbour. During early development, banded killifish are usually found in small number, if at all. Smallest fish disperse soon after hatch, but in late summer form schools along the shallow open shore or at the margin of *Scirpus* sp. or *Eleocharis* sp. Such was their temporal and spatial distribution in Penetang Harbour.

Table 6. Mean total length (mm) of selected fish collected in Penetang Harbour, 1988-91 and 1995.
N = number of fish measured, CV = s.100/x.

Species	Date/site	Mean length	Range	N	CV (%)
Labidesthes sicculus	June 27/89 SP	5.1	4.8-8.3	20	18
	July 4/89 SP	6.8	5.0-10.3	117	15
	July 12/90 SP	4.9	4.3-5.8	36	7
	Aug 14/90 SP	12.9	4.8-21.2	59	33
Pimephales notatus	June 20/89 SP	7.0	5.8-8.0	33	26
	Sept 5/90 SP	32.6	25.2-45.1	17	23
	Sept 12/90 SP	28.9	20.4-37.4	38	23
					19
Catostomus commersoni	June 2/88 WB	13.2	11.6-14.4	40	6
	June 14/88 MP	15.5	12.0-19.1	23	14
Cyprinus carpio	June 24/88 SP	5.2	4.8-5.6	11	5
	July 7/88 SP	5.3	4.5-6.3	42	8
	July 14/88 SP	5.8	4.2-11.6	49	21
	May 28/91 SP	5.8	5.1-6.1	9	5
Notropis hudsonius	June 2/88 SP	5.3	4.6-5.8	29	6
	June 14/88 SP	7.2	4.5-9.6	23	19
Micropterus dolomieu	June 28/88 WB	14.5	12.0-17.9	48	13
	July 7/88 MI	24.1	18.6-24.1	97	5
	July 7/88 WB	19.9	16.9-24.1	9	11
	June 13/91 WB	15.9	14.4-20.4	42	7
Fundulus diaphanus	Aug 4/88 SP	13.7	10.0-19.3	7	26
	Aug 8/88 SP	18.4	10.5-26.6	22	23
	Sept 7/88 SP	30.7	20.6-38.2	5	23
	Sept. 12/90 SP	32.9	17.2-44.3	20	19

Rainbow smelt first appeared as recently hatched (3-5 mm) transients in May. They were rarely found in the harbour after temperature reached approximately 18°C, but returned in mid-October at lengths ranging from 34 to 52 mm (mean = 39.7 mm). Length of smallmouth bass larvae differed according to site of collection, however, overall low CV (Table 6) suggested that siblings were collected in the vicinity of nests.

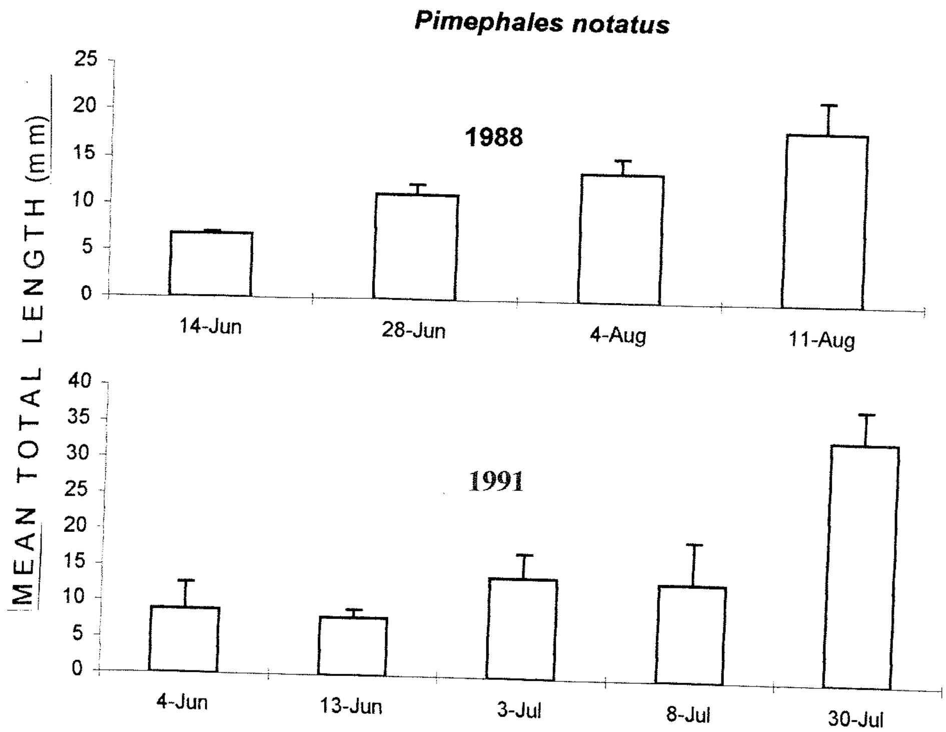

Figure 7. Total length (+SD) of *Pimephales notatus* in Penetang Harbour, June 14-August 11, 1988 and June 4-July 30, 1991.

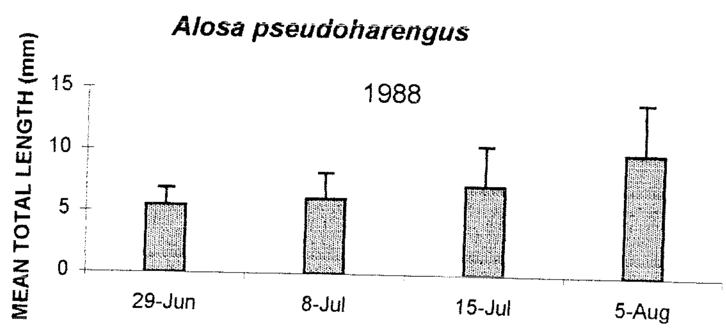

Figure 8. Total length (+SD) of *Alosa pseudoharengus* in Penetang Harbour, June 29-August 5, 1988.

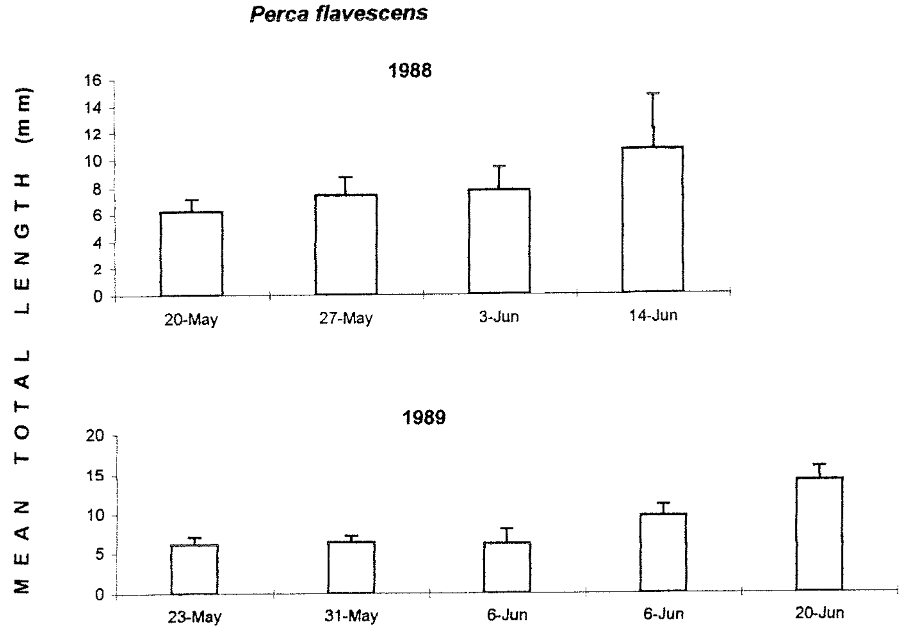

Figure 9. Total length (+SD) of *Perca flavescens* in Penetang Harbour, 1988 and 1989.

Age 1+ fishes collected in Penetang Harbour

Routine surveys collected 2422 age 1+ fishes, and an additional 834 were caught during unscheduled sampling. In the total collection, 37 species (18 families) and 9 reproductive guilds were represented. Bluntnose minnow, pumpkinseed, and brook silverside dominated the age 1+ fish assemblage. Each year prior to ice-free conditions in the harbour, small numbers (1-10) of fishes were caught at Sewage Plant and West Beach in mid-April. Most fish were 25-60 mm TL, and catches consisted of bluntnose minnow, pumpkinseed, brook silverside, sand shiner, emerald shiner, johnny darter, threespine stickleback, and bluegill. These species were both the earliest and the latest fishes collected at the shore, and thus represented the "resident" population. Highest diversity and largest numbers of species occurred in May (26 species, 13 families) and early June (21 and 9), when most fish spawn. Fewest species were found in mid-summer to late autumn (9 species, 4 families) and November (6 species, 4 families).

Yellow perch, white sucker, and northern pike were caught almost exclusively with gill nets at Control in April and May, whereas brook trout, central mudminnow, mottled sculpin, northern redbelly dace, and stickleback were found only at the mouth of Copeland Creek (Fig. 1). Adult alewife were caught in September and October only on the lee side of Magazine Island. Collections of several species could be assured at specific locations on every sampling date. For example, bluntnose minnow and pumpkinseed were resident fish at Sewage Plant and Magazine Island, whereas brook silverside was most often caught at Ontario Hospital, and smallmouth bass at West Beach. No adult fishes were found consistently at Davidson Point. An emerald shiner (111 mm), collected at West Beach on October 1, 1988, was possibly a record (total length) for Ontario. At Sewage Plant, a large (43 cm TL) recently-expired piranha (*Serrasalmus* sp.), was collected on September 20, 1992 at 20°C. At time of capture, this fish retained body mucous and had not reached the state of *rigor mortis*. Although the origin of this fish is unknown, it was undoubtedly a wantonly discarded 'pet'.

Zooplankton assemblage

Eighteen zooplankton taxa were collected in the centre of the harbour (ME 6-ME 7) on six dates in 1989 (Table 7). Cyclopoid copepodid and nauplii were more abundant than most plankton and occurred on all sampling dates and accounted for 35% and 10%, respectively, of the total number of zooplankton. In contrast, calanoids of these life stages occurred in very small quantity. *Bosmina longirostris* was the most abundant and numerically dominant species (52% of total number) in the harbour. Large numbers of *Bythotrephes cederstroemi* coincided with the appearance of yellow perch in open water (ME 3-ME 4) in late May and early June, 1988. They were abundant at Sewage Plant and West Beach in mid to late June, 1989. Extremely dense concentrations of this species were observed at the town docks on September 29, 1988. *Leptodora kindtii* and *Holopedium gibberum* were not collected with our plankton sampler in 1989, yet were caught in June in quantities that clogged our larval fish nets. *Bosmina longirostris* (May 27, 1988) and *Polyphemus pediculus* (mid-July, 1989) were caught in fish nets on unscheduled zooplankton sampling dates.

Table 7. Species and relative abundance of zooplankton collected during fish larvae survey in Penetang Harbour, 1989. Density = number x $10^3/m^3$.

Species	Sampling date					
	May 17	May 23	May 31	June 6	June 20	July 4
Cladocera						
Holopedium gibberum	0.5			0.4	4	
Bosmina longirostris	63	19	184	114	262	177
Ceriodaphnia lacustris			0.8	2.4	15	14
Chydorus spaericus	1	0.3		0.4	0.2	
Diaphanosoma birgei	0.3				0.4	
Daphnia retrocurva					0.2	2
Daphnia ambigua					0.2	
Polyphemus pediculus					0.2	
Copepoda						
Eucyclops speratus	0.1					
Mesocyclops edax	0.2					0.2
Eurytemora affinis					0.4	
Diaptomus sicilis	0.1					
Diaptomus minutus	0.7					
Acanthocyclops vernalis						0.6
Diacyclops bicuspidatus	4	1			0.6	
Tropocyclops prasinus	0.1					
Calanoid copepodid	0.2	0.5		0.4	0.8	0.2
Calanoid nauplii	0.6			0.2	0.2	
Cyclopoid copepodid	82	164	90	104	42	31
Cyclopoid nauplii	54	76	0.1	9	3	3
**Bythotrephes cederstroemi*						
**Leptodora kindtii*						

*collected with fish larvae only

DISCUSSION

The fish community in Penetang Harbour is species-rich (42 taxa, 19 families, including age 1+ fishes collected in this study) and represents all 9 reproductive (12 ecoethological) guilds in freshwaters of Canada. Environmental conditions sustain a large number of fishes, at least during part of their life cycle, as did Hamilton Harbour, one of the most polluted of Areas of Concern in the Great Lakes (Leslie and Timmins 1992a). There, as in Penetang Harbour, spawning and nursery habitat lacked connectivity between biotopes. This assures their vulnerability to human activities. During the past 50 years, approximately 70% of wetlands in the harbour have succumbed to development (SSRAP 1993) and along with it, changes in fish species composition. Indeed, recent studies (Randall et al. 1993; Minns et al. 1993) suggest an imbalance whereby small, short-lived fishes are both abundant and diverse, whilst large piscivores are relatively few.

No shibboleth describes the present fish community. However, fishes that commonly co-occur in a specific sector of the harbour may be considered a representative "group". For example, a group of thigmotropic fishes (e.g. mottled sculpin, stickleback, dace) frequent a remnant marsh at the mouth of Copeland Creek, another (e.g., blackchin shiner, bluntnose shiner, pumpkinseed, largemouth bass), in the south basin, is associated principally with dense submersed vegetation. An "open water" group (rainbow smelt, lake whitefish, white perch) consists of ephemeral and transient species, while a so-called "peripheral" group (bluegill, banded killifish, spottail shiner), inhabit the offshore margin of macrophytes or along the exposed shore. Assemblages formed temporally, the first (percid-osmerid-centrarchid) in early spring as new vegetation appeared. In early summer, centrarchids and cyprinids predominated, and in late summer, brook silverside joined the assemblage.

The composition of the fish community is strongly influenced by the occurrence, distribution, and structural complexity of rooted aquatic plants (Keast et al. 1978; Conrow et al. 1990; Garner 1997). Accordingly, the highest biological productivity, including the fish component, takes place in the south basin (Gilmore and Craig OMNR unpubl. data 1980; Barton OME unpubl. data 1983; Minns et al. 1993). Many species of fish larvae are associated with multispecies plant communities. Such communities are scarce in Penetang Harbour, and are confined to the south basin, the area most vulnerable to human activities. Planktonic food is relatively sparse within the plant complex, thus fish larvae mainly inhabit the margin, or patches of canopy-type plants, such as *Nymphaea* sp., and *Potamogeton* sp. Fewest taxa inhabited scattered pillar-type species (especially *Scirpus* and *Eleocharis*) that provide scant lateral cover. In contrast, pillar-type macrophytes with relatively large surface area, e.g., *Myriophyllum spicatum*, *Elodea canadensis*, and *Ceratophyllum demersum*, provide multistructured substrates for fish eggs, refugia for larvae, and food items for juvenile and adult fishes.

Reproductive habitat in Penetang Harbour is abundant for prey species, limited for predators, such as ictalurids and esocids, and absent for salmonines and walleye. Low ictalurid representation in the present study (Table 2) corresponds with results from Gilmour and Craig (OMNR unpubl. data 1980) and King and Portt (OMNR unpubl. data 1989), as indicated by a combined catch of 3 age 0+ brown bullhead. Similarly, Minns et al. (1993) reported an average of one age 1+ brown bullhead in each of 29 electrofishing transects. Adult northern pike were also scarce, although absence does not preclude the possibility of spawning or the presence of larvae in the study area. In general surveys, however, the young both of brown bullhead and northern pike are infrequently encountered, let alone quantifiable. Likewise, although two adult walleye were caught at Control, larvae were neither found nor expected, since the nearest productive spawning habitat for this species is located at least 40 km north of Severn Sound (Leslie and Timmins 1995a). Although black crappie was implicated as an agent in changing fish populations in Severn Sound (SSRAP 1993), it was not abundant either as adult (beyond a moderate spawning pulse in early spring) or larva (Table 2, Table 4), nor its residence prolonged in the harbour.

Fishes that indicated high fidelity for the culturally developed eastern shore will probably persist whether or not remedial action plans are implemented. Ephemeral and transient species such as lake whitefish, rainbow smelt, burbot, white sucker, yellow perch and several cyprinids immigrated to the harbour from nearby areas in the main body of Severn Sound. Apparently, their affinity for the harbour is not high. Banded killifish, brook silverside, centrarchids, and especially bluntnose minnow, an historically abundant species throughout Severn Sound (Bensley 1915), will probably prevail should environmental conditions continue to degrade (Trautman 1981). Indeed, the repeated occurrence of bluntnose minnow, pumpkinseed, and brook silverside suggests they may be classified as "indicator" species. In view of diminishing habitat in the harbour, wetland-dependent species, such as northern pike, bowfin, longnose gar, and brown bullhead are in jeopardy of extirpation.

Similar assemblages of fishes occurred at adjacent sites, whether or not their habitat characteristics differed. As expected, species differences were more distinct between contrasting habitat types and sites farthest removed, e.g., Control and Davidson Point. In most cases, low values of coefficient of community and habitat occupancy derive from comparisons of assemblages where habitats contrast, e.g., vegetated and non-vegetated, submersed and emergent, exposed unvegetated and sparsely-vegetated emergent. However, numbers of co-occurring taxa at three reference sites were inconsistent between years, especially at Sewage Plant and West Beach in 1988 and 1989 (Table 3). The indices verify the unpredictability in distribution of fish in early ontogeny.

Large weekly, seasonal, and annual fluctuations occurred in species composition, numerical representation, and density (Tables 2-5). Mean density of most common species at the shore were typically lower than in eutrophic Bay of Quinte (Leslie and Moore 1985) and Mitchell Bay (Leslie and Timmins 1993), but higher than in eutrophic Long Point inner bay (Leslie and Timmins 1997), where pillar-type emergent macrophytes prevail. Densities of pelagic fishes were much higher than in Lake Mendota, Wisconsin (Post et al. 1995), polluted Hamilton Harbour (Leslie and Timmins 1992a), or a marsh in Lake Erie (Petering and Johnson 1991). Such comparisons are extreme generalizations of complex phenomena. In order to account for gross annual change in abundance incurred naturally, let alone from human causes, sampling must be both intensive and extensive (Cyr et al. 1992). Yet, practicality and cost to a large extent dictate sampling regimes, since biologically significant changes of 20-50% in density of any given fish usually require a prohibitive number (hundreds) of samples (Leslie 1986).

High variability in total catch of individual species is generally unavoidable in ichthyoplankton surveys, as has been stressed repeatedly (e.g., Nellen and Schnack 1975; Treasurer 1978; Marcy and Dahlberg 1980; Hamley et al. 1983; Houde and Lovdal 1985; Viljanen 1987; Kubecka 1991; Leslie and Timmins 1992b,c; 1994b). This does not, by any means, imply floccinaucinhilipilification. Since quantitative biological data are so fallible (Fryer 1987), additional qualitative information is needed in support of the RAP process. For example, primary research has not examined ichthyoplankton sociology in rapidly changing environments, addressed the distributional effects on fish larvae of lost plant species, or studied larvae utilisation of unnaturally developed shoreline structures. These topics are pertinent to remediation of perturbed environments in the Great Lakes and elsewhere.

Length of most taxa at hatch was similar to that of fish found in bays, harbours, and various ecotones elsewhere in the lower Great Lakes hereas growth to the end of the "first" year (August or September) was typically less. In particular, brook silverside and largemouth bass, whose respective early growth bears on quantity and quality of food in the surface layer and small invertebrates associated with rooted plants (Scott and Crossman 1973), were generally smaller. Smaller sizes of larvae at the end of first year growth may be indicative of effects at this latitude of slightly lower water temperatures: late spawning, extended egg incubation, and lower density of food items.

Species occurrence, composition, and dominance of early planktonic crustaceans in Penetang Harbour resembled plankton dynamics in Mitchell Bay, Lake St. Clair (Leslie and Timmins 1993) and the Bay of Quinte (Leslie and Moore 1985). In the limnetic zone, zooplankton were dominated by *Bosmina longirostris* and cyclopoid copepodids. With the exception of *B. longirostris*, no cladoceran plankton appeared in large quantity in our samples. Yellow perch larvae utilise nauplii and small cyclopoids (Keast 1980; Leslie and Moore 1985), thus, the population of *B. longirostris* and cyclopoid nauplii may have been depressed by larvae prior to their emigration from the harbour in early June. Although Gemza (1995) did not find *Bythotrephes cederstroemi* in nearshore areas, we collected large quantities of this species at the shore in Penetang Harbour and Hog Bay (Leslie and Timmins 1995b), and in the Moon River, just north of Severn Sound (Leslie and Timmins 1996). Their distribution is therefore not confined to limnetic areas. Although we cannot provide empirical evidence, we suggest they may prey on small fish larvae or compete with them for food and space.

In conclusion, pressure on the aquatic ecosystem will increase with growth of Penetanguishene and environs, and from densely populated southern Ontario. Whilst poor water quality is remediable (Sherman and Brown 1995), habitat destruction or modification is usually irreversible. As virtually all of the east shore of the harbour is artificial, fish reproduction on natural substrate is essentially limited to enclaves in the south basin and segments of the western shore. Undoubtedly, fish with poor powers of dispersal find spawning substrate and vegetative cover increasingly wanting. Conservation, if not rehabilitation, of remnant littoral habitat in the inner harbour is therefore imperative, because the outer harbour and south shore of Severn Sound are almost bereft of wetland and offer minimal alternate fish spawning or nursery habitat.

Spero meliora!

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