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Temporal and spatial distribution of pelagic larval fishes of Dauphin Lake, Manitoba

by

Kenneth Dale Rowes

A thesis

Submitted to the Faculty of Graduate Studies

in partial fulfilment of the requirements for the degree

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A Thesis submitted to the Faculty of Graduate Studies of the University of Manitoba in partial fulfillment of the requirements for the degree of

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DEDICATED

To my parents

Nillie Ethyl Maud (Keenes) Rowes and Joseph Kelly Rowes

whose gentle prodding and guidance

encouraged me in my studies

and

To my sweet daughter Anna Lee

and

loving son Ryan Joseph

who had to share time from Dad while writing this thesis

for your love and understanding I am forever indebted.

ABSTRACT

The distribution of larval fish was investigated in Dauphin Lake (51° 17′N, 99° 48′W) 283 km northwest of Winnipeg, Manitoba from May - August, 1984 and 1985. Larvae were sampled using dual fine mesh conical nets with non-porous mouth-reducing cones. Twelve species of larval fish were found, of which four species dominated in 1984: *Notropis atherinoides*, *Perca flavescens*, *Etheostoma nigrum*, and *Percopsis omiscomaycus*. *Percina caprodes* replaced *P. omiscomaycus* in 1985. Species composition varied, with *P. omiscomaycus* dominating in late May and early June, *P. flavescens* and *E. nigrum* in late June and early July, and *N. atherinoides* mid July to early August. CPUE was greatest in the clay-silt habitat associated with rivers and lowest in the sandy and cobble habitats. Habitat type and temperature were major environmental factors influencing species distribution. Abundance of fish increased in close proximity to river mouths in early spring, and in mid-water during mid-summer. The hypothesis that the timing of appearance of pelagic larval fish in Dauphin Lake is temperature controlled was supported. I found that (a) the time of appearance of larvae in early spring reflected the cold water (<15.0 °C) spawning preference of benthic spawners using near-shore spawning grounds before and during ice breakup; (b) the timing of occurrence of larvae in early summer was attributed to the cool water (16.0-20.0 °C) spawning preference of other benthic species; (c) the timing of occurrence of larvae in mid-summer reflected pelagic warm water (21.0-23 °C) spawners. The hypothesis that the spatial distribution of the major species of larval fish is attributed to habitat type and in-lake environmental variables such as lake mixing and water currents was also supported by species abundances in each location during each sample period.

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INTRODUCTION

The early life history of freshwater fishes has been studied from a number of different perspectives: embryology (Balon 1985), functional morphology of larval structure, larval features applied to taxonomic and systematic studies, ecology of eggs and larvae (Fish 1932, Norden 1961, Flittner 1964, Mansueti and Hardy 1967, May and Gasaway 1967, Pflieger 1975, Ahlstrom and Moser 1976, Hogue et al. 1976, Snyder et al. 1977, Konrad 1985, Simon 1985, Sifa and Mathias 1987). Larval stages have also been used to address fisheries-related problems such as assessment of spawning stocks and recruitment success (Houde 1969, Houde and Forney 1970, Fuiman 1979, Fuiman and Witman 1979, Kendal et al. 1984, Gaboury 1985, Harbicht and Franzin 1988, Harbicht 1990, Schaap 1989, Mathias et al. 1992). The term 'early life history' is used in this study to include the primary stages of pro-larva, post-larva I and post-larva II as defined by Mathias and Sifa (1982), Kendall et al. (1984), and Konrad (1985).

As part of an enhancement and rehabilitation program on Dauphin Lake, Manitoba, a larval fish survey was initiated by the Canadian Department of Fisheries and Oceans, Central and Arctic Region. The goal of this enhancement program was to stock genetically identifiable 3-4 day old larval walleye and, in alternate years, to stock 60 to 90 day old juveniles in order to increase the walleye population which had declined. Dauphin Lake's commercial fishery was a "Walleye-Cisco" fishery in the 1940's but now is a "Pike-Sucker" fishery (Dauphin Lake walleye rehabilitation pilot project). The walleye production during the past 25 years has averaged 20000 kg, one-tenth that of the 1960's (Gaboury 1985).

Several aspects of the Dauphin Lake basin have been studied previously. Weir (1960) studied the geography of the lake and its basin. The general biology of the lake was surveyed by Stewart-Hay (1951), and fishes utilizing major tributary streams were studied by Harbicht and Franzin (1988). Hydrology, including stream characteristics and improvements was studied by Newbury and Gaboury (1988), and stream channelization by Chapman (1987a,b). Lake chemistry was studied by Babaluk and Friesen (1990) and Schaap (1987). The life histories, distribution, and production of the burrowing mayflies *Hexagenia limbata* (Serville) and *Ephemera simulans* (Walker) in Dauphin L. were studied by Heise (1985). Lake zooplankton was studied by Friesen and Mathias (1990). The ecology of the quillback, *Carproides cyprinus* (Lesueur) (Catostomidae), in Dauphin Lake was studied by Parker (1987), and the ecology of the shorthead redhorse, *Moxostoma macrolepidotum* (Lesueur) (Catostomidae), was studied by Harbicht (1990). The sports fishery of northern pike, sucker, walleye, and yellow perch was described by Babaluk et al. (1984) and stocking walleye fry was evaluated by Mathias et al. (1992).

The species composition of the pelagic larval fish community of Dauphin Lake has not been documented, nor is the role of these larval fishes in Dauphin Lake understood. A useful knowledge of the dynamics of lacustrine environments requires knowledge of life histories and the ecology of organisms at each trophic level (Flittner 1964). In this lake, knowing which species make-up the pelagic larval fish community and by how much including their distribution in time and space would be be useful in understanding their inter-relationships for management purposes.

My objectives in this thesis were: 1) to examine the ecological relationships of the pelagic species of larval fish in Dauphin Lake, Manitoba in terms of their distribution over time and space, habitats used, degree days of lake water above 10°C to first appearance and date of greatest abundance, and diet, and 2) to suggest factors which affect these distributions.

The major larval pelagic fish species observed in Dauphin Lake are the emerald shiner, *Notropis atherinoides* (Rafinesque)(Family Cyprinidae), yellow perch, *Perca flavescens* (Mitchill), logperch, *Percina caprodes* (Rafinesque), Johnny darter, *Etheostoma nigrum* (Rafinesque), (all Family Percidae) and trout-perch, *Percopsis omiscomaycus* (Walbaum) (Family Percopsidae) (Figures 1-5). The following is a review of their spawning and early life history.

These fish larvae are planktophagic, ingesting plankton at first feeding (Clady 1978). Emerald shiners are classified as pelagophilic, trout-perch and johnny darters as lithophilic and yellow perch as phyto-lithophilic in habitat preferences (Clady 1978).

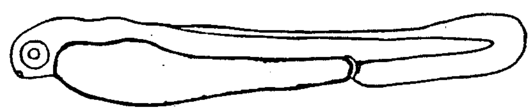
Emerald Shiner

The emerald shiner is the most abundant minnow in L. Erie , L. Simcoe (Scott and Crossman 1973) and in Dauphin Lake (Schaap 1987, Rowes this study). It tolerates a wide range of turbidity and inhabits the epipelagic zone in deep lakes. It can also be found in streams, in low current habitats (Flittner 1964).

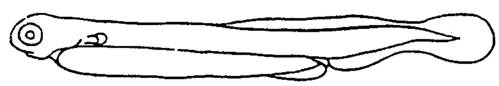
Emerald shiners have a protracted spawning period. In the Great Lakes, spawning occurs from early April to mid-August (Auer 1982, Smith 1985) and in the Missouri River they spawn from late May through to early

Figures 1-5. Drawings of the dominant pelagic larval fish species found in Dauphin Lake, Manitoba during open water trawling 1984-85. *Notropis anthrinoides*, *Perca flavescens*, *Percina caprodes*, *Etheostoma nigrum*, *Percopsis omiscomaycus* are shown in lateral view for each of the pro-larvae, post-I and post-II larval stages. Distinquishing characteristics in pigmentation are included in ventral view where they occur. Mean total length ranges are included for size comparison between species. Drawings are modified from Auer, 1982.

Notropis atherinoides

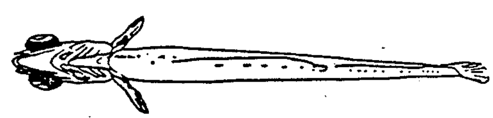


A



B

C

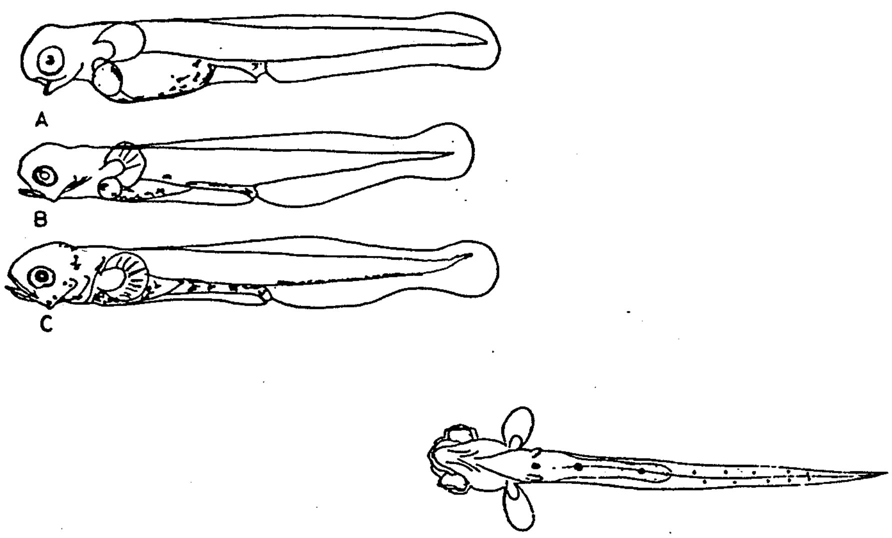


ventral

A	*pro-larva*	*3.40-5.81 mm*
B	*post-larva I*	*6.43-7.63 mm*
C	*post-larva II*	*9.39-13.07 mm*

Figure 1.

Perca flavescens

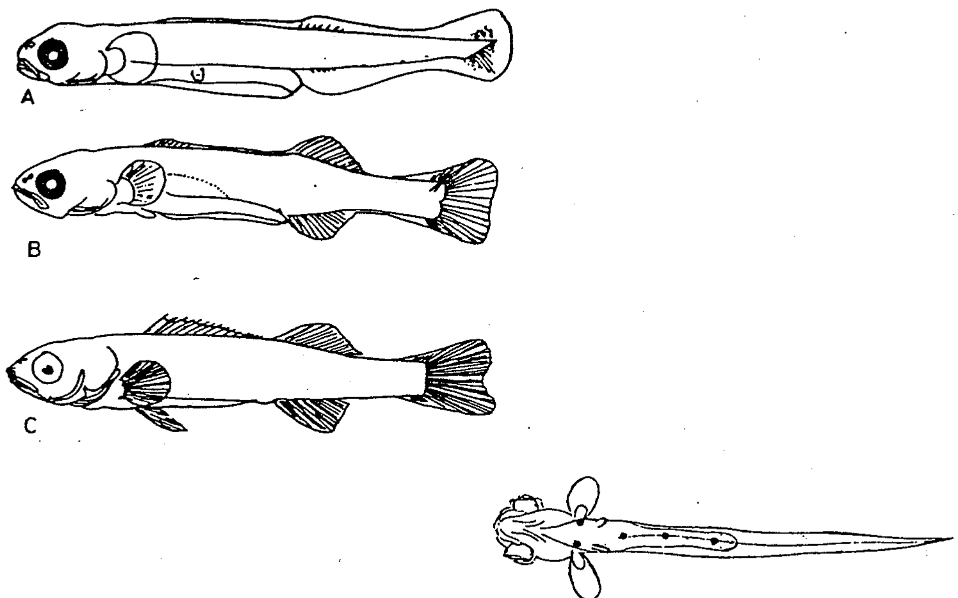


ventral

A	*pro-larvae*	*mm*
B	*post-larvae I*	*6.79-7.65 mm*
C	*post-larvae II*	*7.60-9.52 mm*

Figure 2.

Percina caprodes

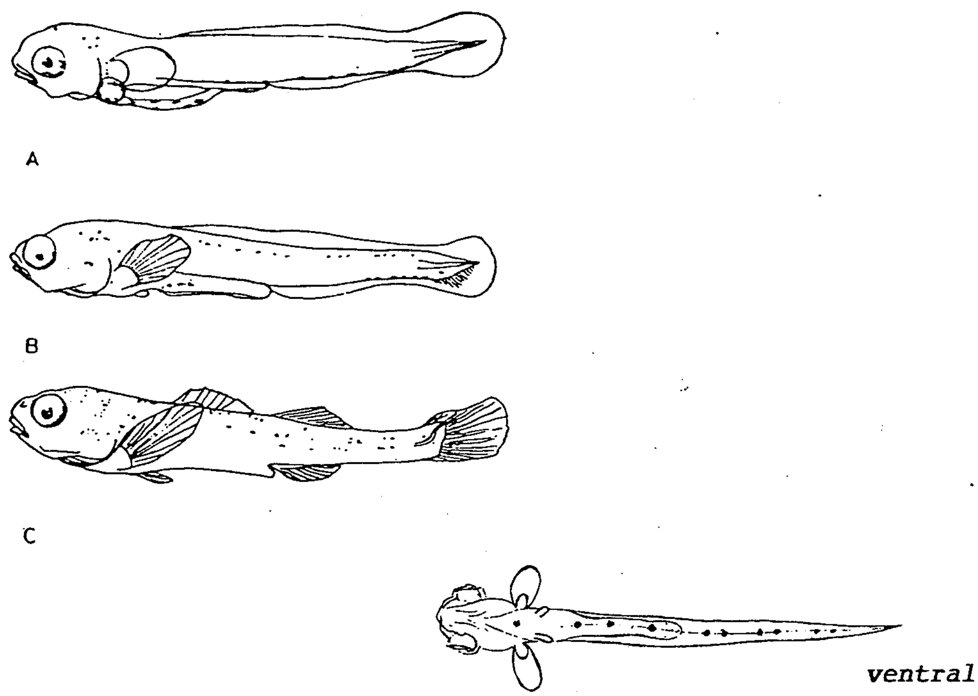


ventral

A	*pro-larvae*	*5.40- 7.69 mm*
B	*post-larvae I*	*7.39- 9.10 mm*
C	*post-larvae II*	*7.98-13.47 mm*

Figure 3.

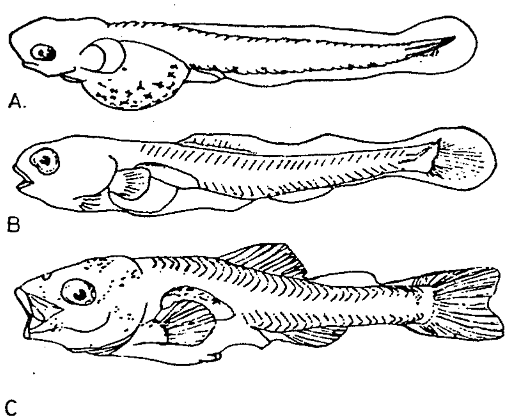
Etheostoma nigrum



A	*pro-larvae*	*4.29-5.69 mm*
B	*post-larvae I*	*5.41-6.47 mm*
C	*post-larvae II*	*6.25-11.50 mm*

Figure 4.

Percopsis omiscomaycus



A	*pro-larvae*	*5.77- 6.72 mm*
B	*post-larvae I*	*7.00- 9.00 mm*
C	*post-larvae II*	*10.00-11.10 mm*

Figure 5.

July. In Lake Erie, spawning is usually at night, just beneath the surface in shallow water, over sandy or firm mud substrate (Pflieger 1975). Temperatures at spawning are 23°C in New York (Smith 1985), or beginning at 22°C (Auer 1982) in the Great Lakes. Spawning has been noted in near-shore areas of lakes over depths of 3 m with hard sand and mud substrates, free of detritus.

Eggs are non-adhesive, lack oil globules and sink to the bottom where they are moved by currents. Hatching occurs in 24-36 hours (Flitter 1964). Fry remain on the bottom 4 or more days then swim up and congregate at the surface in schools (Flitter 1964, Pflieger 1975, Smith 1985).

Pro-larvae have a total length (TL) of 4-5 mm (measured from the tip of the snout to the tip of the caudal fin, Figure 11). Post-I and II larvae are 6-14 mm TL with 23-26 pre-anal and 10-15 post-anal myomeres. The myomere counts of adults are 25 pre- and 14 post-anal (Flitter 1964, Auer 1982).

Distinqishing features used for identifying larvae were: a small body shape with an inferior mouth; pigmentation lacking in pro-larvae, especially in the eyes; single series of chromatophores along underside of stomach to vent that continued with smaller spots from vent to caudal along the ventral ridge (Fig. 1).

Siefert (1972) found that first feeding emerald shiner larvae selected rotifers and copepod nauplii. The items eaten by all feeding larvae were rotifers, copepod nauplii, *Cyclops bicuspidatus*, Cladocera, calanoid copepods, algae, protozoa, and chironomid larvae. Emerald shiners begin feeding at day 6, as post-I larvae swimming near the surface and exhibiting sharp avoidance responses to tactile and visual stimuli such as approaching zooplankton. Feeding larvae are known to drift 10 to 12 miles (Flitter 1964), but it was not clear over what period of time.

Yellow Perch

Yellow perch are phyto-lithophilic, preferring a stony, vegetated habitat and are ranked as a dominant small fish in lake communities. Spawning requires 1.5-3.0 m water depth over sand, gravel and vegetation. Spawning has been reported from April - May at 7-10.5 °C in New York (Smith 1985), into July in Canada (Scott and Crossman 1973) and can last for 6 days at 14-20 °C to 51 days at 5.4 °C (Auer 1982). Spawning of *P. flavescens* has been observed over 14 days to 8 weeks in England (Craig 1987).

Eggs are semi-demersal, with a single oil globule and a thick elastic capsule with radial striations. The eggs are connected in accordion-folded strands 0.6 - 2.0 m in length (Scott & Crossman 1973, Auer 1982, Craig 1987). They are heavier than water and the strands adhere to vegetation or substrate.

Larvae are 5-7 mm TL as pro-larvae, with 17-24 pre- and 13-20 post-anal myomeres, 7-10 mm TL as post-I larvae with 18-20 pre- and 17-21 post-anal myomeres and 11-20 mm TL as post-II larva with 20-24 pre- and 13-14 post-anal myomeres (Norden 1961, Scott and Crossman 1973, Lippson and Moran 1974, Auer 1982).

Distinguishing features used for identifying larvae are: a dorsal fin fold origin at base of head; two or more large, light-coloured stellate chromatophores along the bottom of the yolk sack and an uneven small line along ventral ridge from vent to caudal; PI and PII larvae with 3 ventral spots along ventral stomach and a non-paired series of spots from vent to caudal on opposite sides of ventral ridge (Fig. 2).

First feeding larvae select the rotifer *Polyarthra* and cyclopoid copepods (Siefert 1972). Food organisms eaten by all feeding larvae were copepod nauplii, rotifers, copepods, cladocerans, and some algae.

Logperch

Logperch are lithophilic (Clady 1978), preferring the silt-free, gravel bottom of wave-swept shores (Pflieger 1975). They are bottom dwellers which can be found at depths up to 40 m (Auer 1982).

Spawning occurs during April - May in Missouri (Pflieger 1975), and late June to early July in Michigan (Auer 1982), at temperatures of 10-15°C. Spawning adults bury in the bottom sand and gravel where eggs are laid and fertilized (Pflieger 1975). Incubation varies from 5-6 days at 21-23°C to 8 days at 16°C (Auer 1982).

Newly hatched pro-larvae are 4-6 mm TL and the post-I and II larvae are 7-19 mm TL with myomere counts of 20 pre-anal and 17-18 post-anal as prolarvae and 23 pre-anal and 18 post-anal as post-II larva (Auer 1982).

Distinguishing features used to identify species: 3 black spots along ventral surface of stomach with the last spot located near the anus similar to johnny darters and contrary to yellow perch. One large black spot at the ventral base of each pectoral fin and a faint single series of black specks along ventral ridge from vent to caudal fin (Fig. 3).

Johnny Darter

Johnny darters are also lithophilic, living in stony habitats of streams and lakes that are not excessively turbid and silty but with high or continuous flow. They prefer riffles (Pflieger 1975, Smith 1985). They inhabit a wide variety of aquatic habitats and have been recorded to depths of 40.0 m in Lake Erie (Scott and Crossman 1973).

Spawning dates are generally April to May, and they spawn over sandy-gravel substrate. Spawning is well described by Scott and Crossman (1973).

The eggs are demersal and adhesive with a single large oil globule (Auer 1982). Eggs are very adhesive and usually clustered. They are deposited on the underside of rocks or other objects on the bottom. Incubation varies from 5.5-8.0 days at 22.0 - 24.0 °C to 16 days at 12.8 °C (Auer 1982).

Larvae are 5 mm TL as pro-larvae, 5-7 mm TL as post-I larvae and 8-10 mm TL as post-II larvae (Auer 1982). No myomeric counts are available for larvae, but adults have 37 pre- and 39 post-anal myomeres (Auer 1982).

Distinguishing features used to identify species: very large pectoral fins that extend beyond yolk sack; no marking on ventral surface of yolk sack, but 4 large spots, the first originating between pectoral fin bases, then a series of equally spaced spots along ventral surface of stomach, the last located near anus, in PI and PII larvae; a series of 3 paired spots in single file from vent to caudal fin (Fig. 4).

Trout-perch

Trout-perch are also lithophilic, favouring the stony, sand or gravel bottom of streams or lakes having permanent flow of moderately clear water. They occur from the shallows down to depths of 60 meters, avoiding rooted aquatic vegetation (Smith 1985). According to Pflieger

(1975), trout-perch are nocturnal feeders in shallow water and hide among debris in deeper water during the day.

Spawning of lake populations is preceded by movements of breeding adults into tributary streams or onto beaches in lakes (Pflieger 1975). These fish have a prolonged spawning period from May to August (Pflieger 1975, Smith 1985), even into September in Lake Michigan (Auer 1982). Spawning has been observed on beaches and in streams over sandy-gravel substrates (Auer 1982).

Eggs are demersal, and adhesive, with a single oil globule. Auer (1982) stated that incubation to hatch can be 6.5 days at 20-27 °C. Spawning has occurred at 4.4-10.0 °C and 15.6-20.0 °C (Auer 1982).

No information is available on the diet of larval trout-perch. Larvae are 5.3-6.0 mm as pro-larvae. There is no information on myomeric counts of pro-larvae. Post I larvae are 6.0-7.0 mm TL, with 14 pre- and 18-20 post-anal myomeres, and post-II larvae are 7.0-12 mm TL, with 14-16 pre-anal and 17-20 post-anal myomeres (Auer 1982).

Distiguishing features used to identify species: a distinct prolonged snout with a small inferior mouth; dosrsal fin fold originates at the 7th or 8th myomere; many black pepper-like stellate melanophores over the yolk sack and along ventral surface from vent to caudal fin (Fig. 5).

MATERIALS AND METHODS

1. Study Area

Dauphin Lake, Manitoba (51° 17'N , 99° 48'W) (Figs. 6 and 7) is situated 283 km northwest of Winnipeg, Manitoba, in a broad level valley bounded by the Duck Mountains, 45 km northwest and the Riding Mountains, 6 km southeast. This valley slopes gently downward to the north and east toward Lakes Winnipegosis and Manitoba.

Dauphin Lake is a shallow water body occupying a depression in glacially compressed limestone, with clay and silt comprising most of the lake bottom. It has a surface area of 532.3 km^2, which is 7.4 % of the total area of its watershed, (App. IV). Heise (1985) divided the lake bottom into three zones following the nomenclature of Shepard (1954), based on the sand-silt-clay particle size ratio. I have divided the lake into four habitats using these zones, but adding tributary influences. These are described in Table 1. No significant thermal stratification of the lake was observed in summer. Dauphin Lake is characteristically mesotrophic (Table 2), although it receives fertile soils from a channelized drainage basin within a vast area subject to intensive agriculture (Penner and Oshoway 1982, Chapman 1987). The dominant inorganic ions controlling Dauphin L. are Ca^{+2} and SO_4^{-2}. During 1982, Dauphin Lake had a specific conductivity of 310-770 $\mu S.cm^{-1}$, a maximum summer chlorophyll-a of 0.1 to 35.3 μg^{-1} and a dissolved oxygen concentration range of 6.4-20.5 $mg.L^{-1}$ (Babaluk and Friesen 1990). In 1984-85 chemical conditions were within the above ranges; specific conductivity 374.0-494.5 $\mu S cm^{-1}$, chlorophyll-a 2.2-35.3 $\mu g l^{-1}$, and dissolved oxygen

Figure 6. Drainage features of the Dauphin Lake watershed.

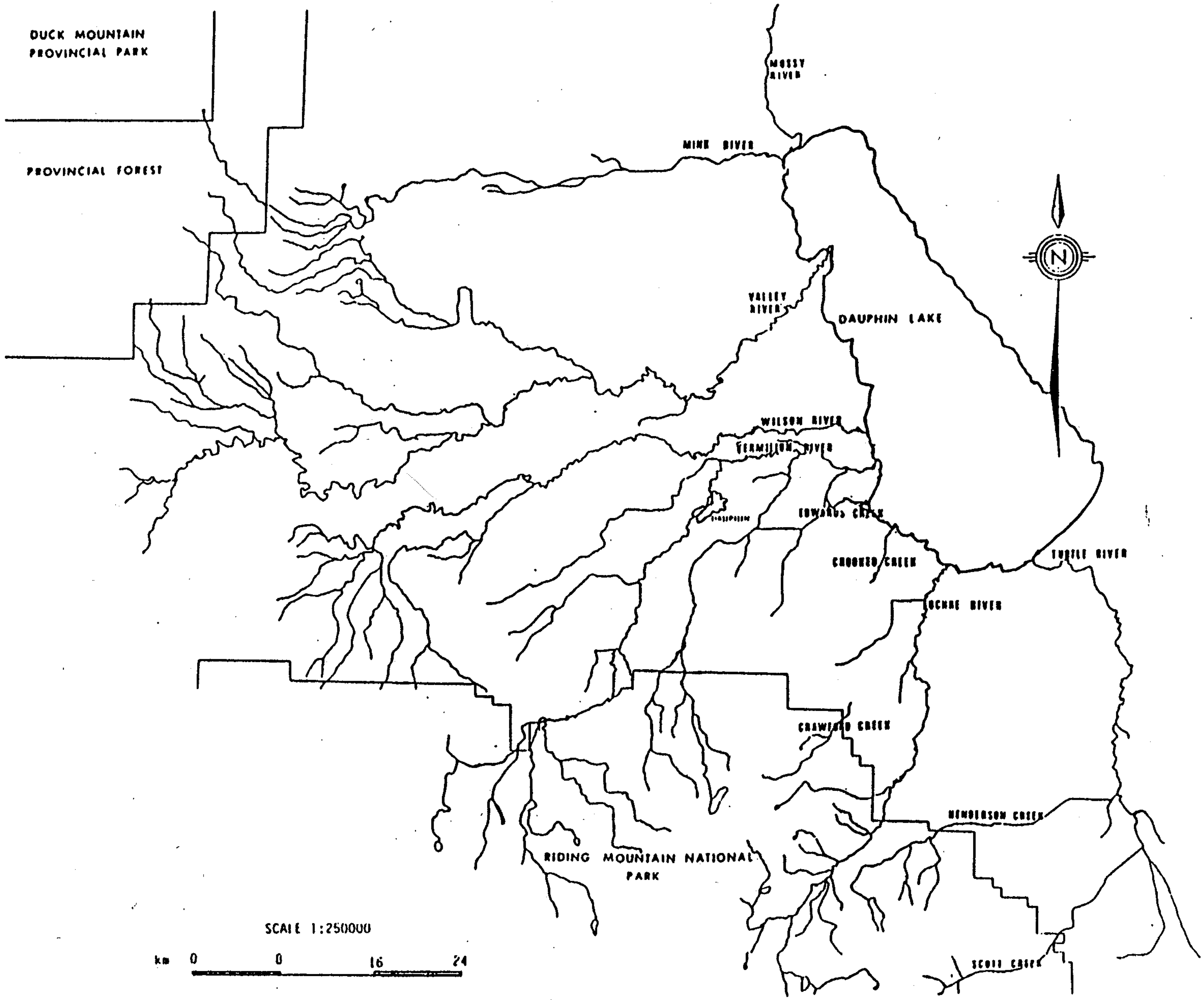

DUCK MOUNTAIN
PROVINCIAL PARK
PROVINCIAL FOREST
MOSSY
RIVER
MINK RIVER
VALLEY
RIVER
DAUPHIN LAKE
N
WILSON RIVER
VERMILLION RIVER
DAUPHIN
EDWARDS CREEK
CROOKED CREEK
TURTLE RIVER
OCHRE RIVER
CRAWFORD CREEK
HENDERSON CREEK
RIDING MOUNTAIN NATIONAL
PARK
SCOTT CREEK
SCALE 1:250000
km 0 0 16 24

Figure 7. Bathymetry of Dauphin Lake in contour form. Sampling locations show the divisions for lake trawling. The double line indicates the arbitrary division of the north basin from the south basin.

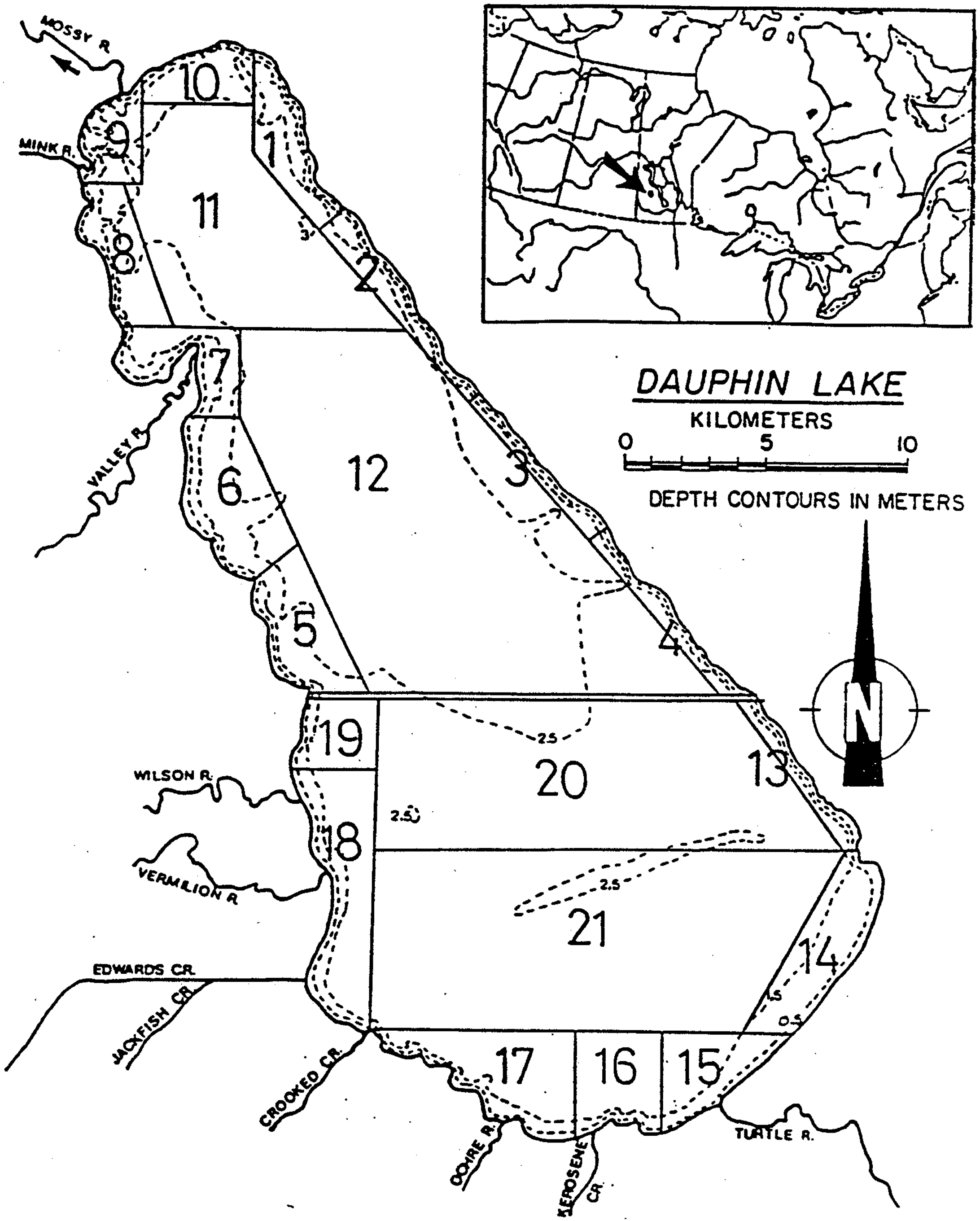

DAUPHIN LAKE
KILOMETERS
0
5
10
DEPTH CONTOURS IN METERS
N
MOSSY R.
MINK R.
VALLEY R.
WILSON R.
VERMILION R.
EDWARDS CR.
JACKFISH CR.
CROOKED CR.
OCHRE R.
KEROSENE CR.
TURTLE R.
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
2.5

Table 1. Sample locations within the four habitat types presented with coordinates for Dauphin Lake, Manitoba, 1984-1985.

HABITAT	A	Bottom = Cobble	NO RIVERS (very little vegetation)
Location			
1	51°27′N	99°54′W	NNE shore
2	51°22′N	99°49′W	NE shore
3	51°19′N	99°44,W	Mid NSE shore
4	51°16′N	99°40′W	Mid E shore
<u>HABITAT</u>	B	Bottom = Sand **NO RIVERS** (some vegetation close to water-line)	
Location			
13	51°12′N	99°35′W	SE shore
14	51°10′N	99°35′W	S shore
<u>HABITAT</u>	C	Bottom = Clay-silt	**RIVERS**
	(vegetation in protected bays 50 to 100m out from the water-line at depths of 0.5 - 1.5m)		
Location			
5	51°16′N	99°51′W	Mid SW shore
6	51°19′N	99°55′W	Mid W shore
7	51°22′N	99°54′W	Valley River
8	51°24′N	99°57′W	NW shore
9	51°26′N	99°58′W	Mink R. and Dauphin L. **OUTLET**
10	51°27′N	99°55′W	North shore
15	51°08′N	99°39′W	Turtle River
16	51°08′N	99°41′W	Kerosene Creek
17	51°08′N	99°45′W	Ochre River
18	51°13′N	99°50′W	Vermilion River - Wilson River
19	51°15′N	99°50′W	SW shore
<u>HABITAT</u>	D	Bottom = Clay-silt	**OPEN MID-LAKE**
Location			
11	51°24′N	99°54′W	Mid North Basin
12	51°19′N	99°50′W	Mid Centre North Basin
20	51°14′N	99°43′W	Mid Centre South Basin
21	51°10′N	99°42′W	Mid South Basin

Table 2. A comparison of the physical and chemical features of Dauphin L. (4) to similar larger mesotrophic lakes in Saskatchewan (2,3), small nearly eutrophic lakes in Manitoba (1), and 109 oligotrophic lakes in western Ontario (5). The (-) indicates no available data.

Lake	Area (ha)	Mean depth (m)	Specific Cond. $\mu S.cm^{-1}$	Chlor-a $\mu g.L^{-1}$	Secchi (m)	pH	$So_4^=$	na^+	Mg^{++}	Ca^{++}	DOC
							mg.L^{-1}				
Dauphin Lake	53230.0	2.1	310-770	0.1-35.3	0.1-100	7.8-8.6	41-133	12-41	13-42	32-82	6.4-20.5
885 (1)	2.4	3.0	1350-2600	1380	0.4-100	8.4-9.4	499	84	131-150	43.0	40-83
882 (1)	6.0	2.1	1980-3000	185	39.2	8.0-9.0	-	83.9	162	44.9	-
Big Peter Pond (2)	55145.0	13.7	-	-	1.2-2.8	7.2-8.4	5.7-4.0	-	10-14	26.7	-
Montreal Lake (3)	45230.0	2.2	-	11.2	0.8-1.3	7.8-8.4	<10	3-5	0.01-0.04	41.4	-
ELA Lakes (5)	1300-13.0	167-8.5	19	2	-	4.8-7.4	4.0	0.9	0.6	2.0	24.16

reference:

(1) Whitaker et al. 1978, Wageman and Barica 1978, Beamish et al. 1976.

(2) Rawson 1957.

(3) Mendis 1956, Merkowsky and Sawchyn 1988.

(4) Babaluk and Friesen 1990.

(5) Beamish et al. 1976, Turner et al. 1986.

Table 3. Whole lake monthly averages of physical and chemical characteristics from May 2 to September 7, 1984. Standard deviations are given in parentheses (calculated from Babaluk & Friesen 1990).

DATE	n	pH	n	Chlor. µg.L^{-1}	n	Secchi M	n	Conductivity µS.cm^{-1}	n	Dissolved O_2 mg.L^{-1}
May 2	3	8.2 (0.04)	51	4.72 (1.12)	18	0.25 (0.02)	19	403.05 (36.82)	22	12.3 (0.79)
June 5	20	6.99 (0.02)	51	8.43 (2.41)	19	0.18 (0.05)	20	406.75 (33.73)	25	9.12 (0.48)
July 30	19	7.84 (0.20)	51	13.89 (9.51)	20	0.40 (0.10)	20	374.00 (16.59)	23	7.57 (0.25)
Sept 7	20	8.41 (0.13)	52	20.23 (4.27)	19	0.19 (0.06)	19	424.00 (22.28)	25	8.98 (1.81)

Table 4. Whole lake monthly averages of physical and chemical characteristics during open water 12 June to 2 October, 1985. Standard deviations are given in parentheses, calculated from Babaluk and Friesen 1990.

Date	n	pH	n	Chlor ug.L^{-1}	n	Secchi m	n	Conductivity $\mu S.cm^{-1}$	n	Dissolved O_2 mg.L^{-1}
12 June	6	8.49 (0.04)	21	4.69 (2.90)	6	0.26 (0.03)	6	489.67 (15.56)	15	10.32 (0.29)
31 July	6	8.18 (0.46)	15	7.01 (1.77)	6	0.37 (0.09)	6	487.83 (13.48)	14	8.64 (0.33)
2 Oct	6	8.49 (0.02)	15	8.49 (0.78)	6	0.35 (0.04)	6	494.50 (3.56)	15	12.16 (0.10)

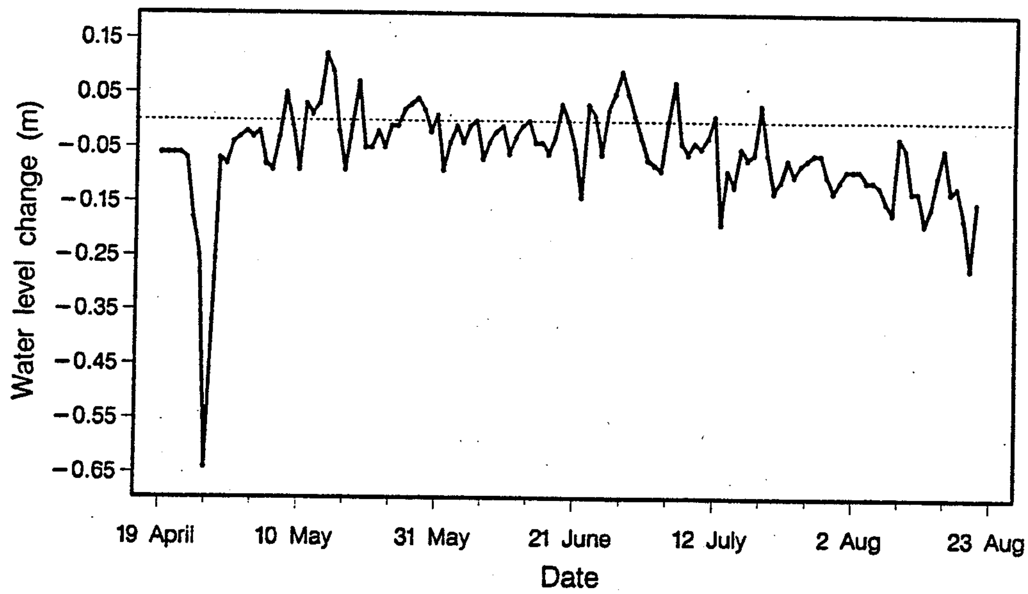
concentration 7.57-12.30 $mg.L^{-1}$ (Tables 3 and 4). The mean and maximum depths are 2.1 m and 3.5 m respectively. Being holomictic, Dauphin Lake mixes top to bottom with any strong wind (Odum 1971). The depth fluctuates by as much as one meter depending on runoff, summer evaporation, and man-made water level controls (Fig. 8).

The northern portion of the lake averages 1 meter deeper than the southern portion, and has a steeper littoral zone (Fig. 7). The relative volumes of the various depth intervals for each sample location on Dauphin L. are shown in Table 5. The percentage of the total lake volume contained in the various depth intervals is presented in Table 6. The North Basin is predominately the 2.6-3.0 m depth interval (78.2%) and the South Basin is predominantly the 1.6-2.5 m depth interval (87.4%). There are six major rivers and three small tributaries entering the lake from the south and west shores draining a 7220 km^2 watershed (Chapman 1987) (Figs 6 and 7). Two major rivers, the Valley R. and the Turtle R., drain 69% of this watershed. The Mossey River is the single out-flowing stream and contains a control structure used to manage water levels in Dauphin L. about 260.4 m above sea level.

Lake vegetation is limited, being restricted by the shallowness and openness of the lake with few sheltered bays. Major water level changes result from the force of winds producing waves that scour and ultimately inundate and drain vast areas of low-lying shorelines. Emergent aquatic plants such as *Phragmites*, *Scirpus*, *Carex*, and *Potamogeton* are sparse along shorelines, but more abundant in sheltered bays along the northwestern and southern shorelines. The filamentous algae, *Cladophora*, is found inshore on the south and west areas, although occasionally,

Figure 8. Changes in the 1984 daily water levels of the Mossy River outlet (location 9) and similar changes at the Ochre River inlet (location 17) in meters. These changes are above and below the summer controlled level at 260.4 m above sea level, dotted line. Seasonal variations are due to snow melt, heavy precipitation, and summer evaporation. Heavy precipitation occurred 25 May and 26 June 1984. The control structure was opened to drop lake level to facilitate spring melt 29 April, 1984. Data taken from Geodetic Survey of Canada (Datum).

SURFACE LEVEL CHANGE AT THE MOUTH OF THE MOSSY RIVER



SURFACE LEVEL CHANGE AT THE MOUTH OF THE OCHRE RIVER

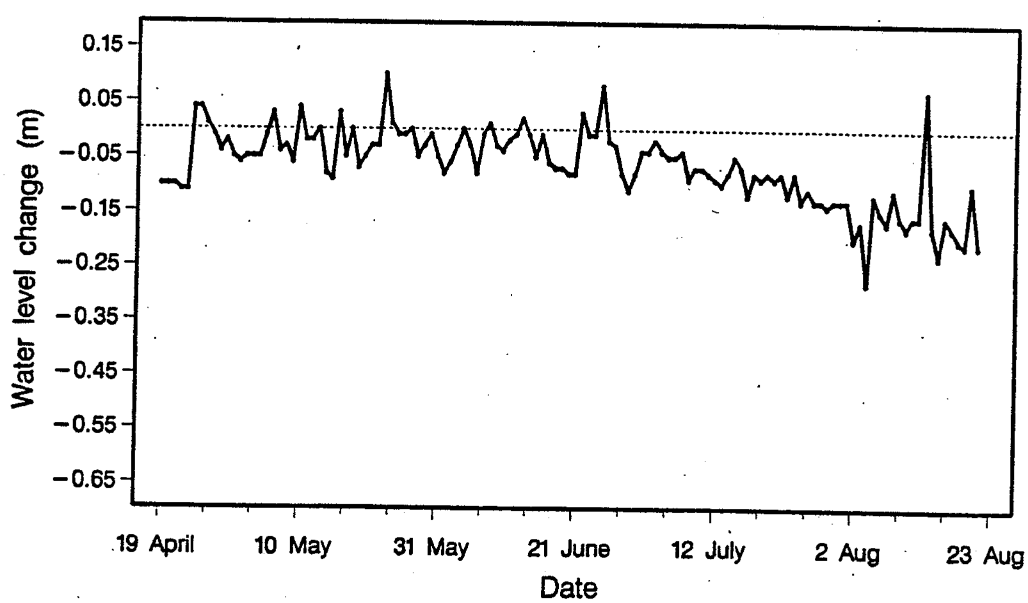


Table 5. Volumes (m^3) of the various depth intervals for each location sampled and each habitat of Dauphin Lake. The volume represented by the contour < 1.5 m represents that portion of the lake unsampled.

Location	Volume x 10^6 m^3				Location Total Volume (x $10^6 m^3$)
	<1.5 m	1.6-2.5 m	2.6-3.0 m	> 3.0 m	
1	1.2	4.4	10.4	-	16.0
2	1.4	3.3	7.2	-	11.9
3	1.2	2.5	-	-	3.7
4	1.3	3.8	-	-	5.1
5	1.2	8.3	12.5	-	22.0
6	1.9	7.4	19.9	-	29.2
7	2.5	7.3	0.9	-	10.7
8	1.5	8.4	3.8	-	13.7
9	1.5	5.3	1.1	-	7.9
10	0.8	8.0	2.1	-	10.9
11	-	7.4	110.2	0.6	118.2
12	-	36.7	254.0	-	290.7
13	1.2	3.2	-	-	4.4
14	5.5	4.6	-	-	10.1
15	2.2	9.0	-	-	11.2
16	0.8	14.2	-	-	15.0
17	2.3	20.2	-	-	22.5
18	3.5	18.9	-	-	22.4
19	0.6	9.7	-	-	10.3
20	-	112.4	21.1	-	133.5
21	-	139.5	10.5	-	150.0
					919.4

Habitat	<1.5 m	1.6-2.5 m	2.6-3.0 m	> 3.1 m	Habitat Total (x 10^6 m^3)
A	5.1	14.0	17.6	0	36.7
B	6.7	7.8	0	0	14.5
C	18.8	116.7	40.3	0	175.8
D	0	296.0	395.8	0.6	692.4
Total	30.6	434.5	453.7	0.6	919.4

Table 6. Proportion of total lake volume contained in the various depth intervals and in the North and South Basins of Dauphin Lake.

Volume of each depth interval of the lake

Contour interval	0-1.5 m	30.6 x 10^6 m^3	3.33 % of lake volume
Contour interval	1.6-2.5	434.5	47.26 % of lake volume
Contour interval	2.6-3.0	453.7	49.31 % of lake volume
Contour interval	>3.1	0.6	0.10 % of lake volume

Volume of each basin

North Basin	540.0 x 10^6 m^3	58.73 % of lake volume
South Basin	379.4 x 10^6 m^3	41.27 % of lake volume

Dominant depth interval of each basin

N. Basin	2.6 - 3.0 m depth interval	= 78.2 %
S. Basin	1.5 - 2.5 m depth interval	= 87.4 %

massive blooms were observed in open water during the warmest and calmest weather in July at water temperatures > 23.0 °C.

2. Description of Apparatus

An improved 'Bongo' trawl was used to capture larval fishes. The 'bongo' was composed of two fine mesh conical nets with non-porous mouth-reducing cones and designed from a prototype intended for sampling marine ichthyoplankton, ("SIO BONGO" after McGowan and Brown 1977, Fig. 9 and 10). Sampling effectiveness in terms of water flow without restriction through the nets and increased volume sampled was achieved by using two meshes sizes, increasing conical net length and maximizing the volume filtered (by using 4 nets). The bongo sampler consisted of two nets of circular aperture paired with a common stainless steel hoop assembly consisting of a 505 μm mesh, with 46% open area on the left and a 305 μm mesh, with 49% open area on the right. A bongo was operated on each side of a 22 foot long open boat (Fig. 10). To allow comparison of mesh size, side of boat, and nearness to boat, the two Nitex™ mesh sizes, 305 μm and 505 μm were paired in each bongo. Each net was designed with a 40 cm mouth diameter non-porous reducing cone fitted at the rear to a 50 cm diameter ring where a filtering net 270 cm in length which tapered to a 12 cm diameter fitted for a collection jar that provided a refuge for live specimens. Water volume sampled was measured using a calibrated General Oceanics digital flowmeter model 2030 fitted inside the cone but off-centred to average the flow rate, which varied from the centre to the edge of the net. It was assumed to measure the true volume of water filtered. Thus four conical nets were towed simultaneously, two on each side of the

Figure 9. The Bongo and sled with flag which assisted in determining if sled was in an up-right position when under tow.

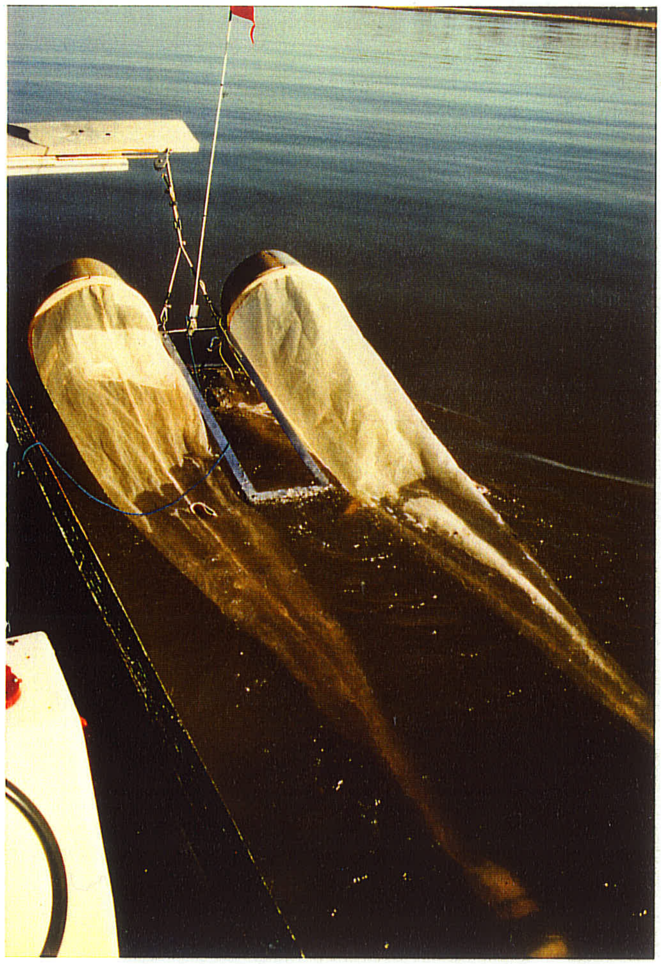
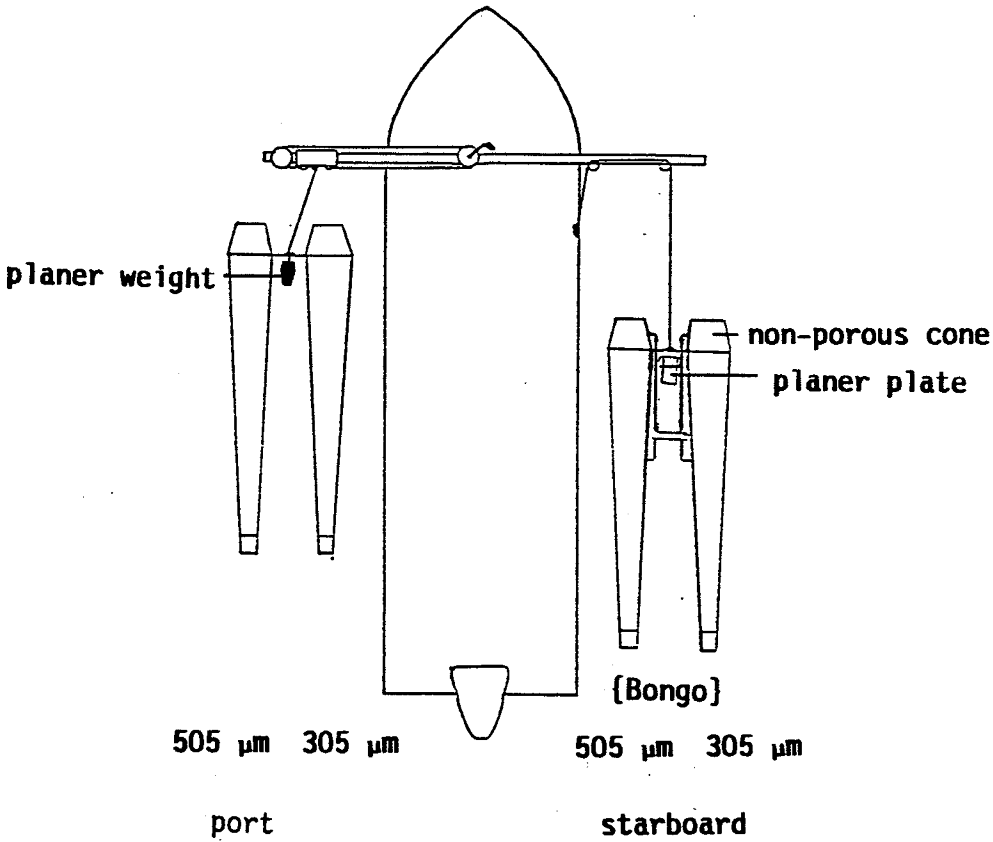


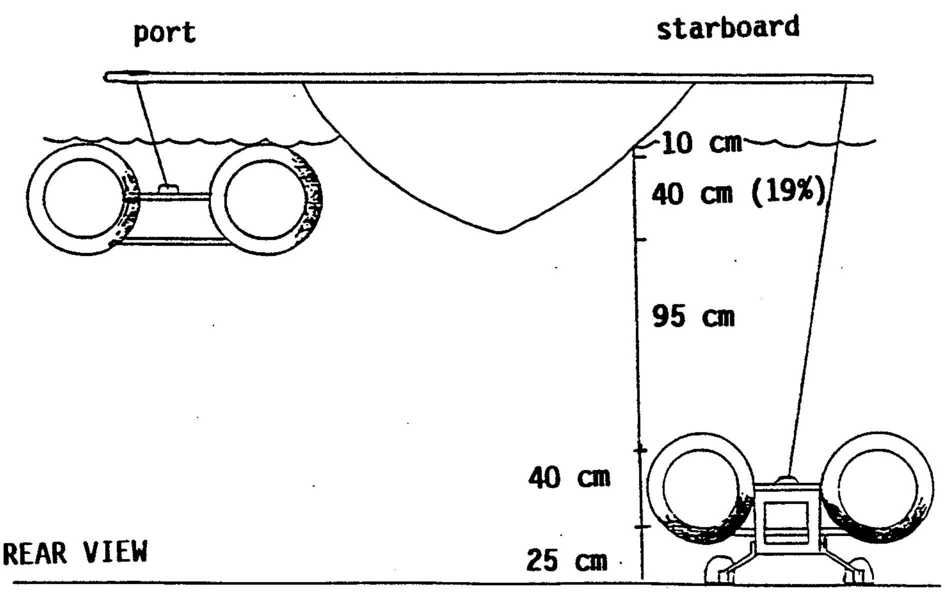
Figure 10.

a. Diagram of Ichthyoplankton trawl depicting the surface bongo and the bottom sled. Each net was operated well forward of the boat motor at an angle controlled by S10 hydrodynamic depressors (Kahl Scientific Instruments Corp.) and with planing plates on the sled.

b. Diagram of the water column showing the surface and bottom profile scaled to the 210 cm mean depth of Dauphin Lake. Per centage of water column sampled by a single net is shown to this scale.



a TOP VIEW



b REAR VIEW

boat for 5 min durations at an average speed of 0.89 m/sec. The average volume filtered in 5 mins. per net was 36 m^3 (SD $\pm$ 6.33 m^3).

Bongos were towed in the top 0.5 meters of water as replicates in 1984. The following year two samples were collected. One sample was collected with a sled that towed one set of nets 20 cm off the lake bottom on the port side, the other sample collected at the surface (Fig. 10), which provided vertical distribution data. Areas sampled were the near-shore and the mid-lake regions. Near-shore refers to that area bordering the 1.5 M contour that is approximately 0.5 Km from shore. Lacking vegetation and harbouring some areas with boulders, it was the shallowest region suitable for trawling with this gear.

3. Sample Collection

Twenty-one sample locations were chosen (Fig. 7) in order to sample the whole lake in one day, weather permitting. These were chosen to represent the pelagic sector of the lake and included all four habitats.

During each sampling period, larval fish were collected, and temperature, secchi depth, wind speed and direction recorded. Wind velocity was estimated according to the Beaufort scale (Environ. Can., Man. Mar. Weather Observation 1982). Turbidity was estimated using a 23 cm diameter black and white secchi disc (Wetzel 1983) and surface water temperatures were recorded using a YSI Instruments Tele-Thermometer, model 43 TD (Schaap 1987).

Daily collections were taken from 30 May to 21 June, 1984. Stormy weather required sample periods to be lengthened to biweekly during July and August. The biweekly sampling schedule was continued throughout 1985 as well. An attempt was made to sample all accessible areas, but sampling in the near-shore regions was limited by the need for a depth of at least 1.5 m, unobstructed by boulders and vegetation.

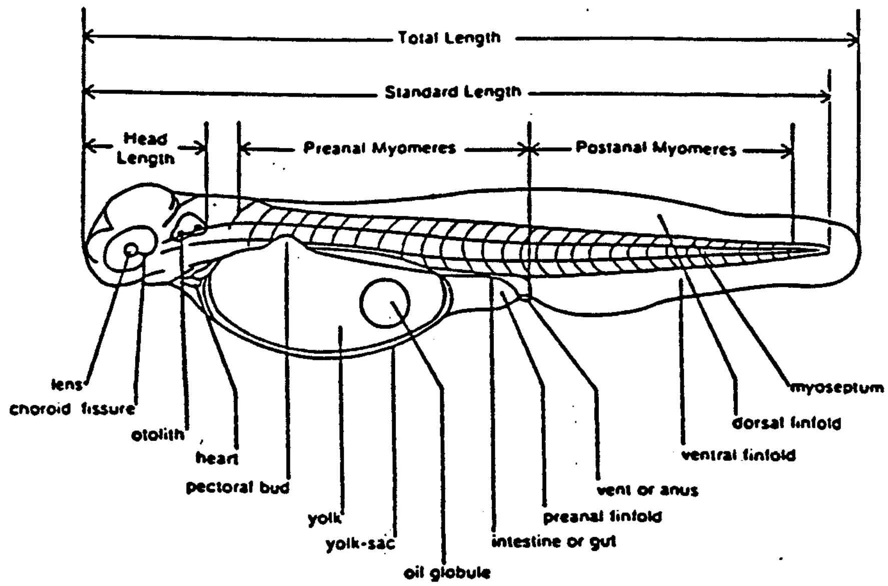
4. Handling Samples

Samples of larval fish were rinsed into a 2 L collection jar attached to each net. These were emptied, rinsed into 4 L pails, and adult fish removed. The remaining sample was filtered through a 200 μm mesh sieve and all retained organisms were rinsed into a 300 mL jar. The rinse water was poured into white enamel pans and scanned again for fish larvae. All fish samples, including adults, were fixed in 5 % formalin solution. Upon returning to shore, the larvae were transferred to 3 % formalin, buffered with sodium borate (after Steedman 1976).

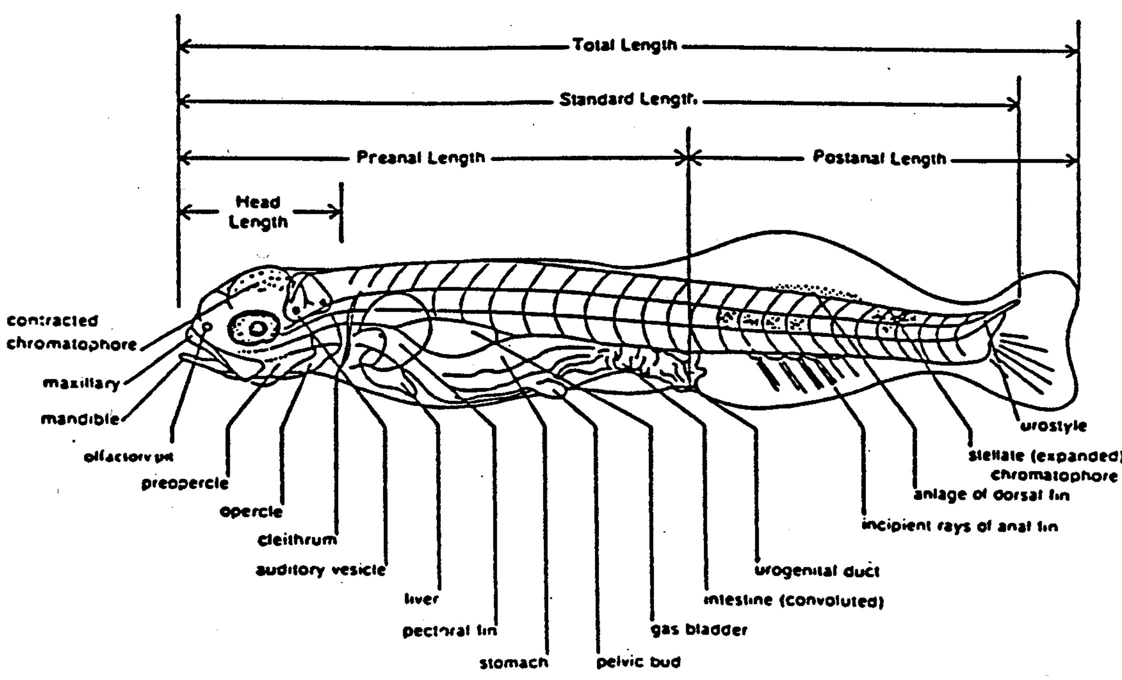
To facilitate the identification of the larval species, I assembled a developmental series for each species from the collected specimens. This series began where possible with identifiable juveniles and continued through progressively smaller larvae on the basis of characteristics described in the literature (Ellis 1917, Jaffa 1917, Norden 1961, Mansueti and Hardy 1967, Nelson 1968, Pflieger 1975, Hardy 1978, Auer 1982, Sifa and Mathias 1982)and comparison with older stages in the series. To confirm my identification of *Etheostoma exile*, *E. nigrum*, *Percina caprodes*, *Perca flavescens*, and *Stizostedion vitreum*, samples were sent to Dr. T.P. Simon (United States Environmental Protection Agency, Region V-Central Regional Laboratory). Complete developmental series could not be obtained for species with total catch numbers <200, which I classified rare.

Figure 11. Diagrammatic representation of typical pro-larva and post-larva (after Mansueti A.J. 1965 and Mansueti and Hardy 1967).

PRO-LARVA



POST-II LARVA



I studied the earliest post-hatching stages of fish development. These stages are: pro-larva, post-I larva, and post-II larva as defined by Sifa and Mathias (1982), Kendall et al. (1984), and Konrad (1985). The pro-larva occurs from hatch until exogenous feeding begins. During this time there is yolk and oil present. The post-I and II larval stages are considered to be the feeding stages. The post-I larvae are characterized by mixed nutrition (oil and prey) and the post-II larvae are characterized by exogenous feeding and no oil globule(s) and considerable structural change in the digestive system beyond a simple tube structure and dorsal inflection of the urostyle. Structures and measurements used for identifying the pro-larva and the post-II larva are shown in Figure 11. Measurements of post-I larvae are similar to the post-II larvae.

5. Lake Volume

The volume of Dauphin Lake was determined through proportionate analysis. The area within each depth contour interval was cut from a bathymetric map (Figure 7) and weighed on a Perkin-Elmer autobalance model AD-6 with a range of 0-200 μg. Distortion caused by photocopying the map was approximately 10% (Franzin and McFarlane 1976). These proportions provided an adequate way to show the relative surface areas and volumes represented by each sample location, basin, and habitat and a means to compare volume sampled to the lake volume.

6. Analysis of Data

Sampling in 1984 was more frequent than in 1985, providing a better resolution of timing so that the 1984 material is used for most of this analysis. Numbers of fish caught (catch number) were standardized into catch per unit effort (CPUE) by dividing the total catch by the volume of water filtered and multiplying by 100 (#/100 m^3).

To show the use of the locations shown in Figure 7, by species, I calculated seasonal mean abundances (CPUE). To do this I calculated a mean CPUE from the 4 nets per location by period. A seasonal mean was then calculated for each location.

Species distribution was examined by treating the data by factorial analysis of variance. I tested for significance between location and habitats on the lake by period using analysis of variance PROC GLM (SAS). Locations were ranked in order of mean CPUE for each species using Duncan's Multiple Range Test (SAS), (De Marsh pers. comm.) on transformed data (Elliot 1977). Transformation was achieved by using (Log_e CPUE+1) because of zero catches. Transformation was used to stabilize variance and eliminate correlations between mean and variance. Date and habitat were treated as treatment effects in 1984. Depth was added as a treatment effect in 1985.

7. Distribution

The most abundant species were evaluated in terms of their temporal and spatial distributions. Because of small numbers for several species, I limited the analysis to the species for which the annual catch exceeded 200 individuals.

Temporal distributions of the species of larval fish were compared by CPUE for Dauphin L. over periods of occurence. The dates of first appearance and greatest abundance including ranges of appearances of each species were compared between the years 1984-1985.

Spatial distribution was evaluated by comparing the relative abundance of larvae among habitats by period for each location. Duncan's Multiple Range Test was used to rank location and habitat assuming equal sampling efficiency in all habitats. A comparison of CPUE between years is not valid because different sampling methods were used. Comparisons are made from the 1985 data on the species occurrence and their vertical distribution. Species diversity was examined by determining the number of species of larval fish occurring during a sample period or within each habitat.

8. Diet and Zooplankton

The purpose of an evaluation of diet was to examine the food consumed by larval fish relative to the abundance in the lake.

To determine which plankton were being eaten by the larvae, I dissected post-I and II larvae, identified and counted the contents of the entire digestive tract. A comparison was made of stomach contents and what was availble in the lake. Average monthly abundnance of each zooplankton taxon in the lake was calculated using data from Friesen and Mathias (1990) for the period May-September 1984.

The temporal appearance of species of larval fish was related to the zooplankton community in the lake by calculating three year averages of plankton for the period 1982-1984 from Friesen and Mathias (1990). Averaging was used to reduce variability between periods and years.

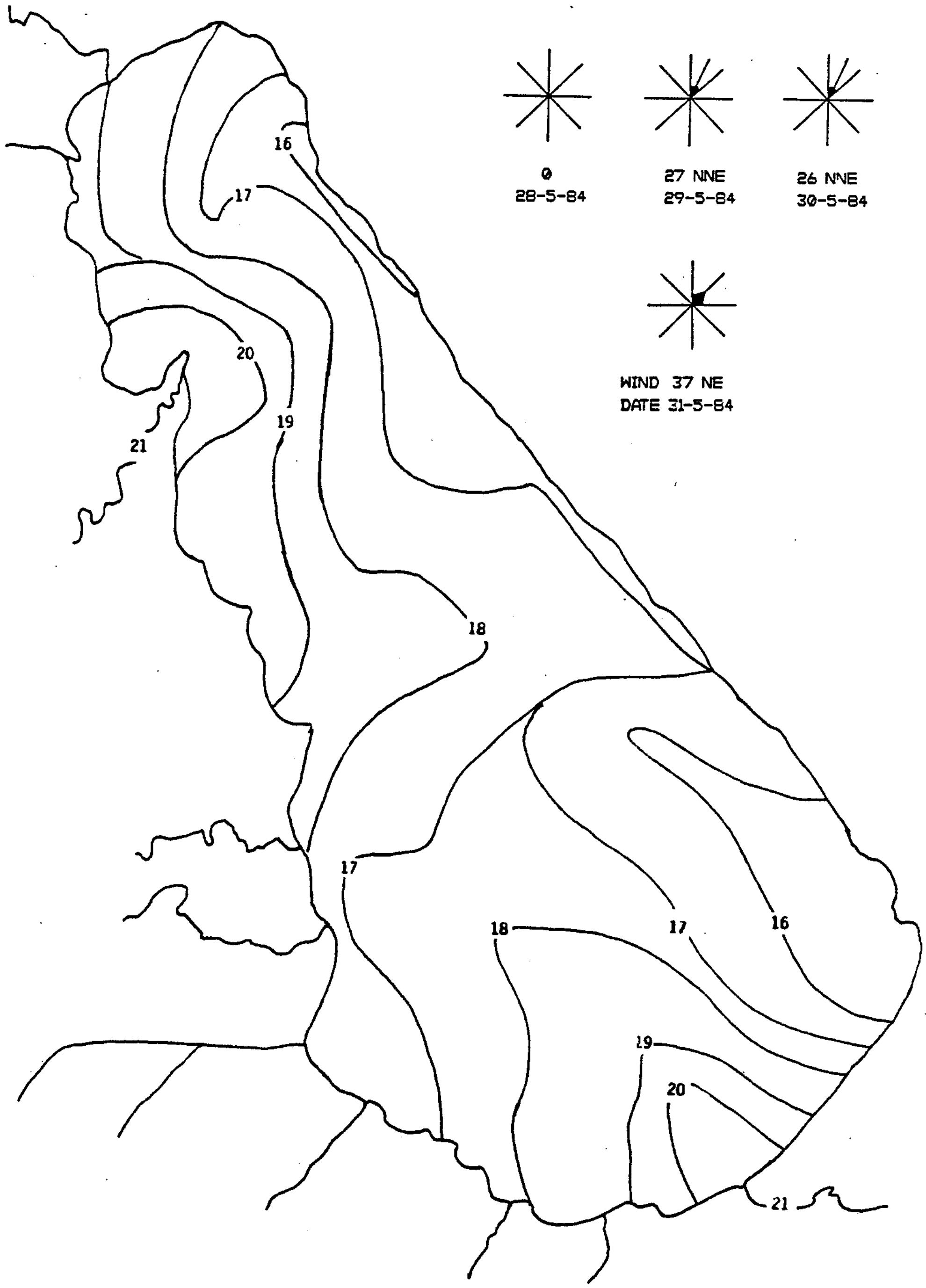
RESULTS

1. Physical Features of Lake

Surface water temperatures and secchi depth readings taken at each trawl location are tabulated in Appendix 3 of Schaap (1987). Ice-off and freeze-up occurred 25 April and 2 November, 1984, and 28 April and 11 November, 1985, respectively. From 30 May to 12 August, 1984 surface temperatures did not vary more than 2 degrees over the entire lake, except during spring mixing, from 30 May and 6 June, when there were 5 degrees difference (Fig. 12) and during mid summer peak warming, 10 July when a difference of 4 degrees also occurred. There was evidence of a major change in lake physical condition (Figs. 12-14), when a shift from a heterogeneous structure to a homogeneous one at 16 °C occurred.

Note that for 30-31 May, 1984, (Fig. 12) the lake surface temperatures were highly heterogeneous, with warm water plumes extending offshore from the mouths of the inlet streams. There were also warm water plumes evident in the northeastern and southeastern corners of the lake that do not correlate with warm water discharge from tributaries. Similarly, a broad warm water plume extended from west to east across the middle of the lake, just north of the Wilson River. During the 1-4 June period (Fig. 13), the surface water temperature mean of 18.06 °C had decreased by 3.25 degrees, and most of the northern portion of the lake surface was isothermal at 14.5 °C. By 5-6 June (Fig. 14), the entire lake had mixed and surface temperatures were isothermal at 16 °C, except for a small area along the northeastern shore where some water at 17 °C remained.

Figure 12. Surface water temperature distribution for Dauphin Lake during initial sampling period, 30-31 May, 1984. Wind roses show the prevailing wind direction and peak velocities in km/h for the Dauphin Lake area. Data obtained from monthly climatological summary records, Environment Canada, Atmospheric Environment Service.



0
28-5-84
27 NNE
29-5-84
26 NNE
30-5-84
WIND 37 NE
DATE 31-5-84
16
17
20
19
21
18
17
18
17
16
19
20
21

Figure 13. Surface water temperature distribution for Dauphin Lake during sampling period 2, 1-4 June, 1984. Wind roses show the prevailing wind direction and peak velocities in km/h for the Dauphin Lake area. Data obtained from monthly climatological summary records, Environment Canada, Atmospheric Environment Service.

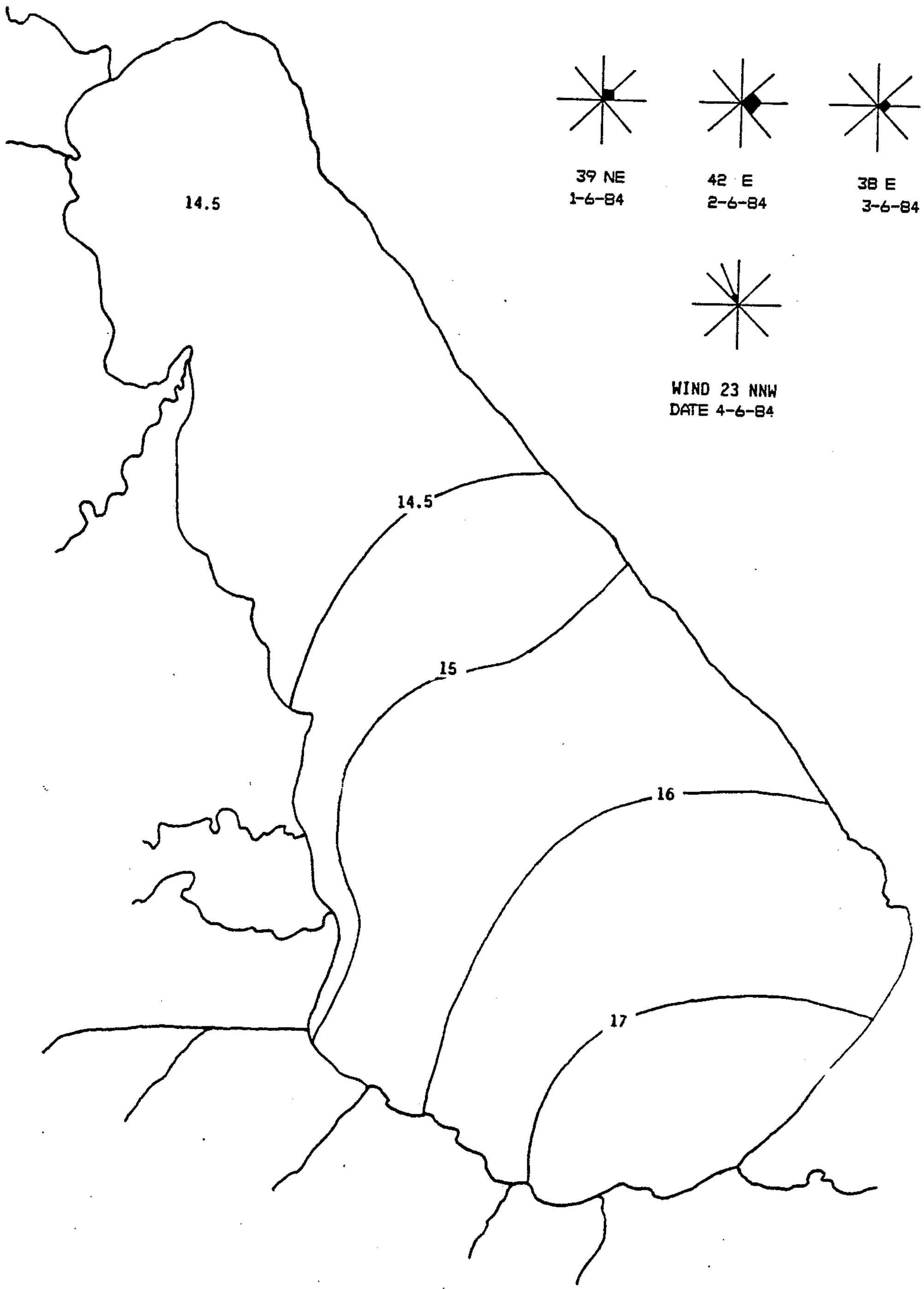
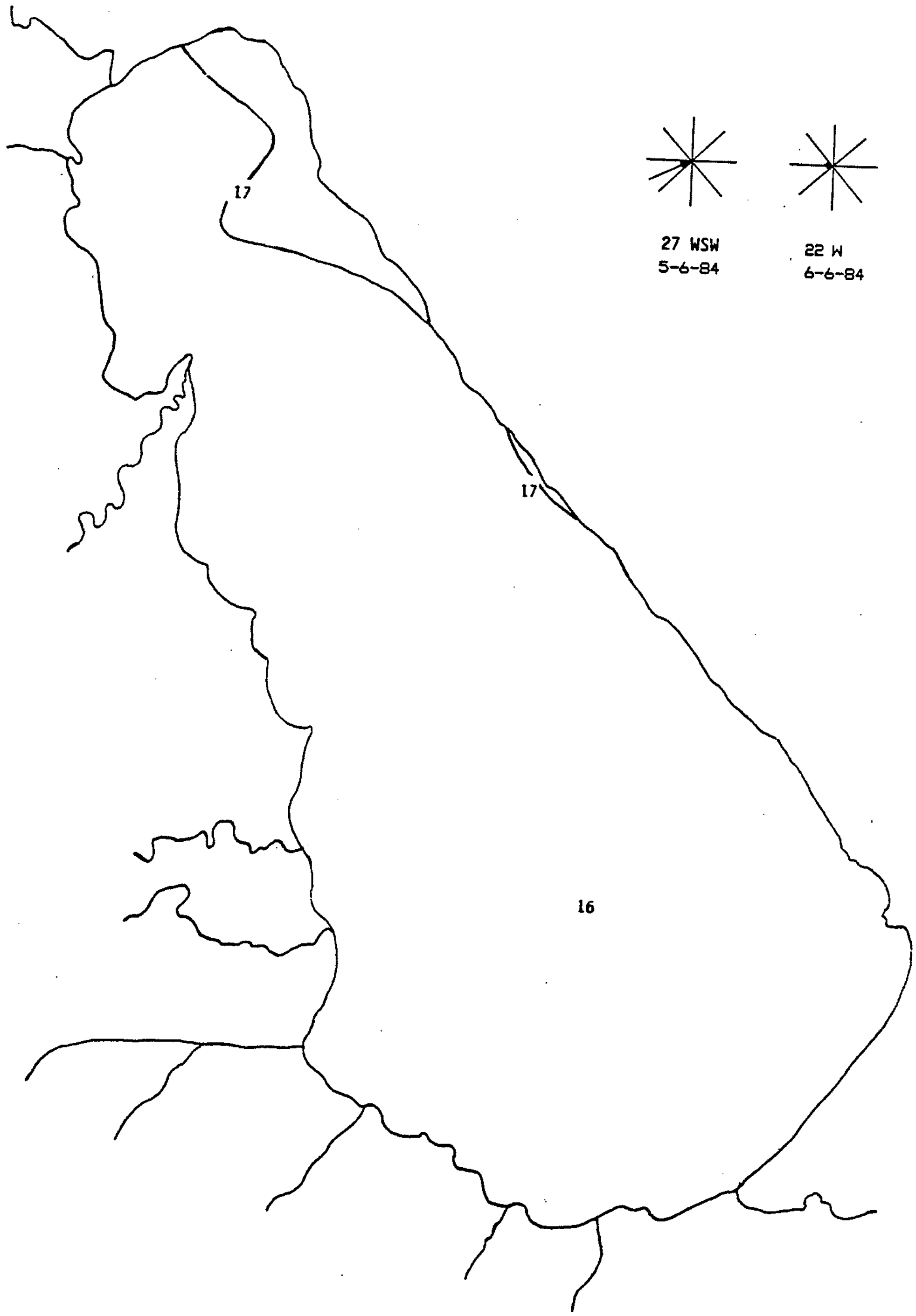

39 NE
1-6-84
42 E
2-6-84
38 E
3-6-84
WIND 23 NNW
DATE 4-6-84
14.5
14.5
15
16
17

Figure 14. Water temperature distribution for Dauphin Lake during sample period 3, 5-6 June, 1984. Wind roses show the prevailng wind direction and peak velocities in km/h for the Dauphin Lake area. Data obtained from monthly climatological summary records, Environment Canada, Atmospheric Environment Service.



17
27 WSW
5-6-84
22 W
6-6-84
17
16

Wind direction and speed for Dauphin Lake are also shown for 27 May to 6 June, 1984 (Figs. 12-14). Note that a northeasterly wind began on 29 May and continued increasing in strength to 2 June, when it became easterly. By 4 June, wind velocity had declined and shifted to north-northwest, and by 6 June, the wind was westerly.

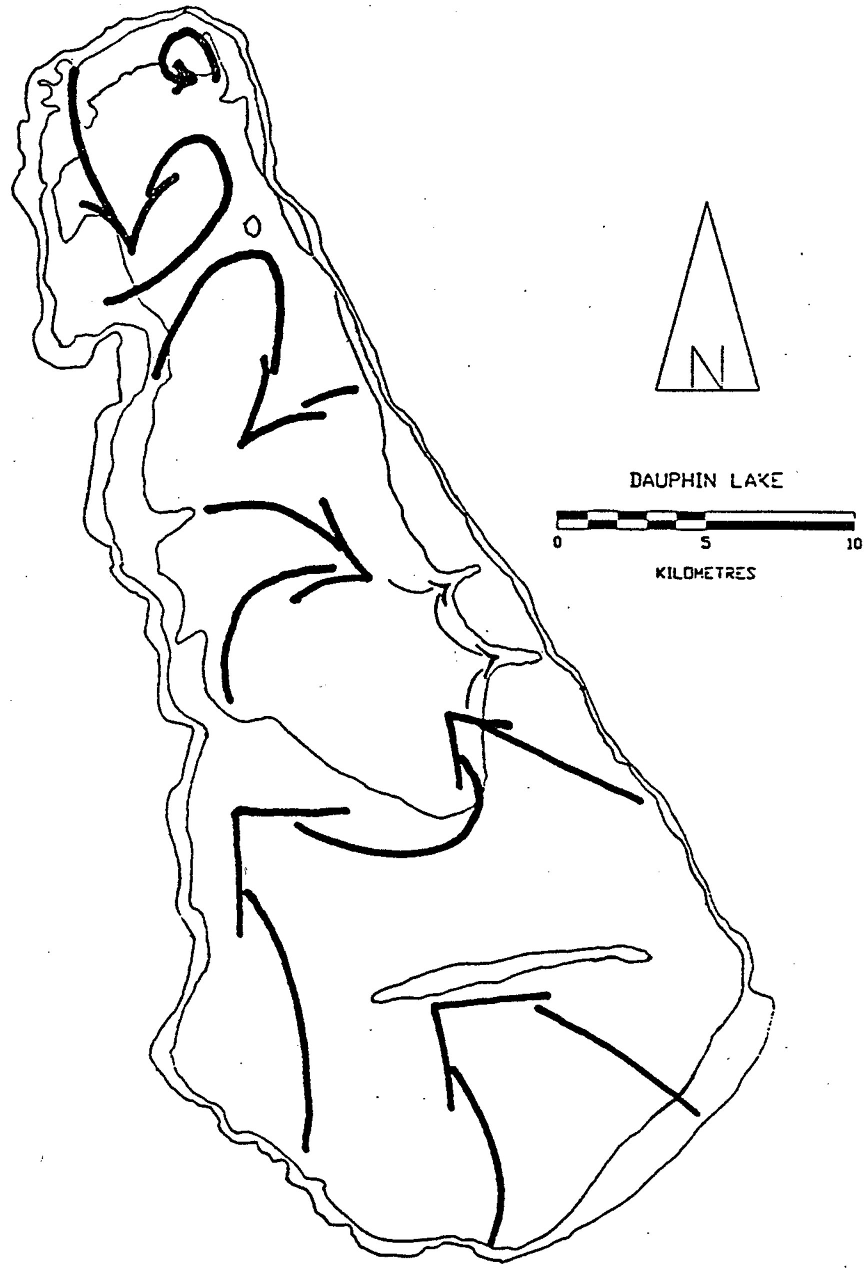
Although the areas of the lake basin are nearly equal in surface area (North Basin = 266.23 km^2; South Basin = 266.06 km^2), the volume of the two basins differs greatly (Table 7) - North Basin at 540 x 10^6 m^3 compared to South Basin at 379 x 10^6 m^3. Volume sampled varied between locations slightly but considerably between habitats such as the low intensity in the mid-lake habitat.

To determine in-lake movement causing larval drift, water current patterns are proposed (Fig. 15). These currents were determined from the daily thermal patterns (Fig. 12-14).

2. Lake Stability

Dauphin Lake is isothermic or nearly so during spring breakup. Temperature differences begin to develop after breakup, with the influx of warm water from tributaries, but the lake quickly becomes mixed and nearly isothermic again due to wind-induced currents. It then remains isothermic for the entire open water season. This is evident from the stable condition which existed at the end of May, 1984. Differential warming occurred throughout the lake (Fig. 12). Warm water entered primarily from the Turtle R. in the south basin and from the Valley R. in the north basin, but did not mix with the lake water immediately (Fig. 13). Continuous NNE winds of 37-42 km/h over a 6 day period from 1-6 June, 1984

Figure 15. Diagrammatical presentation of hypothetical water currents in Dauphin L. are suggested from the daily thermal patterns (Figs. 11-13).


N
DAUPHIN LAKE
0
5
10
KILOMETRES

assisted lake currents and stream inflow to mix the entire lake (Figs. 14, 15). The heterogenous lake temperature, which ranged from 16.0 - 21.0°C, changed to a homogenous whole lake temperature of 16.0 °C. Throughout the summer lake temperatures continued to be uniform during each collection period (Schaap 1987).

3. Water Volume Sampled

The dates and volumes of lake water filtered during each collection period are shown in Table 7. The total volume filtered at each location in each year is presented in Table 8. A summary of the volumes filtered in each habitat during both years is shown in Table 9. A total of 0.004% of the total lake volume was filtered in 1984, and 0.002% in 1985. Each of the four nets sampled 19% of the depth of the average total water column simultaneously (Fig. 10). Of the total lake volume (919.4 x 10^6 m^3), the North Basin comprised 59 % and the South Basin comprised 41 % of the total volume sampled in 1984 and 44.4 % and 55.6 % respectively in 1985.

The North Basin 2.6-3.0 m depth interval contained 45.94% of the total lake volume and the South Basin 1.5-2.5 m depth interval contained 36.09% of the total lake volume. The unsampled portion of the lake represented by the 0-1.5 m contour interval contained 3.32% of the total lake volume. The 1.5-3.0 m contour intervals representing 96.68% of the total lake volume were surveyed in this study.

A total volume of 36062 m^3 in 1984 and 14052 m^3 in 1985 of water were filtered (Tables 7,8). The largest sampling effort was concentrated in areas influenced by rivers (Habitat C) where the volume filterd was 17345 m^3 in 1984 and 6766 m^3 in 1985. In 1985, a sled sampled 7026 m^3, half the

Table 7. Trawling dates and subsequent lake volumes filtered for larval fish assessment of Dauphin Lake 1984-1985.

	1984			1985	
Period	Date		Volume (m^3)	Date	Volume (m^3)
1	30-31	May	3352	16-24 May	426
2	1-4	June	3774	6 June	964
3	5-6	June	3452	11 June	1486
4	11-12	June	3380	25 June	2042
5	13-14	June	3564	8-10 July	2382
6	15-16	June	3622	24-25 July	2400
7	17	June	1956	7-8 July	[2456 calibration]
8	19-20	June	3620	20-22 August	4352
9	21	June	1552		
10	10-12	July	2900		
11	26-27	July	2152		
12	10-12	August	2738		
		Total	36062		14052

Table 8. Water volume filtered at each location on Lake Dauphin, 1984-1985. Totals were derived from pooling the volume of 4 nets for each location and adding the totals from each period. Aborted trawls are not included. Percentages are in parentheses.

Location	1984 Volume (m^3)	1985 Volume (m^3)
1 North	1634	536
2	1824	
3	1680	652
4	1604	602
5	1676	760
6	1540	
7	1692	614
8	1564	512
9	1716	518
10	1586	474
11	1964	686
12	2804	876
13 South	1168	2524
14	1244	600
15	1376	530
16	1292	644
17	1848	628
18	1526	716
19	1540	496
20	2428	970
21	2356	714
Total	36062	14052
Mean	1717	739.6
SD	398.1	450.9

* Locations

North Basin	1-12 (inclusive)
South Basin	13-21 (inclusive)

Habitat

A	1,2,3,4
B	13,14
C	5,6,7,8,9,10,15,16,17,18,19,
D	11,12,20,21

Table 9. Summary of volumes filtered (m^3) in each habitat for 1984 and 1985. Of the volume sampled, per cent comparisons are presented between basins and locations.

1984			
North Basin		21284	(59.0%)
South Basin		14778	(41.0%)
Habitat	A	6742	(18.7%)
	B	2412	(6.7%)
	C	17356	(48.1%)
	D	9552	(26.5%)
1985			
North Basin		6230	(44.4%)
South Basin		7822	(55.6%)
Habitat			
	A	1790	(12.8%)
	B	3124	(22.2%)
	C	5892	(41.9%)
	D	3246	(23.1%)

Habitat Locations:

A	1,2,3,4
B	13,14
C	5,6,7,8,9,10,15,16,17,18,19
D	11,12,20,21

total volume filtered, at an interval 25.5 cm above the lake bottom.

Bongo effectiveness was considered adequate for this study because the filtering capacities exceeded the water flow outside the nets by 1.6% (303μm mesh) and 8.2% (505μm mesh). Since there were no losses of larvae in pre-trials wherein 10-50 walleye larvae were put into the cones under tow, accuracy in catches was assumed unaffected by filtering or by extrusion of the larvae through the mesh.

4. Temporal Distribution and Temperature

A total of 14137 larvae was collected in 1984 and 2321 in 1985 (Table 10), representing twelve species of larval fish. In 1984 there were four abundant species; emerald shiner, yellow perch, trout-perch, and johnny darter. In 1985 the dominant species were yellow perch, emerald shiner, logperch, and johnny darter.

The period of greatest abundance of larvae in 1984 occurred at or above the optimal spawning temperature for each species (Table 11, Figs. 16, 17). Abundances of trout-perch and emerald shiner were greatest during their optimal spawning temperatures of 15 °C and 22 °C respectively. Yellow perch abundance peaked above their optimal spawning temperature at 18 °C as did johnny darters at 19 °C.

The time intervals for spawning, hatching and the periods of the larval phases for the species of pelagic larval fish collected from Dauphin Lake in 1984 and 1985 are shown in Figure 18. These times have been inferred from this study based on the appearances of larvae, the water temperature and the incubation time periods needed for each species as stated in the literature. Larval appearances were within 5 days of the

Table 10. Total catch of each species of larval fish collected in Dauphin Lake larval trawls in 1984 and 1985. Included are the % of the total catch contributed by each abundant species.

	Numbers of fish		% of Total Catch	
SPECIES	1984	1985	1984	1985
Notropis atherinoides (Rafinesque)	12,196	796	88.27	34.05
Percopsis omiscomaycus (Walbaum)	550	38	3.88	1.63
Perca flavescens (Mitchill)	691	826	4.88	35.33
Percina caprodes (Rafinesque)	20	344	0.14	14.71
Etheostoma nigrum (Rafinesque)	530	195	3.75	8.34
Coregonus artedii (LeSueur)	31	53	0.22	2.27
Notropis cornutus (Mitchill)	1	0	0.01	0.00
Notropis hudsonius (Clinton)	1	36	0.01	1.54
Catostomus commersoni (Lacépède)	28	7	0.20	0.30
Moxostoma macrolepidtum (Lesueur)	83	0	0.60	0.00
Stizostedion v. vitreum (Mitchill) (juveniles)	2	3	0.01	0.13
Etheostoma exile (Girard)	4	23	0.03	0.98
	14,137	2,321		

Table 11. Average temperature over 3-day periods (three point average) and cumulative degree days above 10°C to first appearance and largest catch per unit effort of each pelagic species of larval fish observed in Dauphin Lake, 1984.The optimal spawning temperatures and ranges for the abundant species are added below. Rare species (*) are those that were < 200 in the total catch.

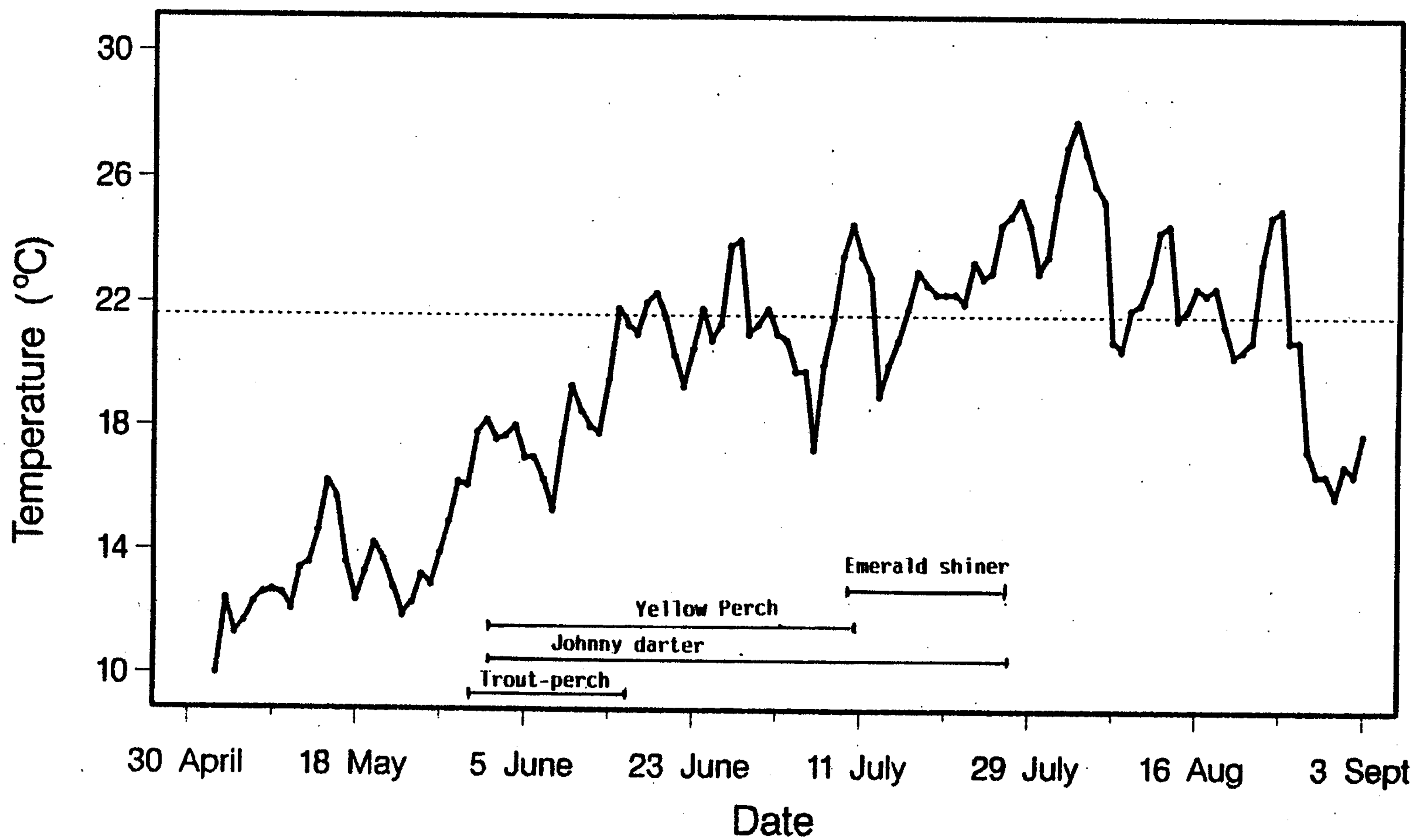
	At First Appearance		At Maximum Density	
Species	Date	3 Point Avg.(°C)	Date	3 Point Avg.(°C)
TP	May 30	15.0	May 30	15.0
* WS	May 30	15.0	Jun 13	18.6
* C	May 30	15.0	May 30	15.0
* SHRH	May 30	15.0	Jun 1	16.7
* ID	Jun 1	16.7	Jul 10	21.9
JD	Jun 1	16.7	Jun 13	18.6
YP	Jun 1	16.7	Jun 11	17.3
LP	Jun 5	17.7	JUL 10	21.6
* GS	Jun 19	21.4	Jun 19	21.4
* SP	Jun 21	21.9	Jun 21	21.9
ES	Jul 10	21.6	Jul 26	23.0

TP = trout-perch
WS = white sucker
C = lake cisco
SHRH = shorthead redhorse
ID = Iowa darter
JD = Johnny darter
YP = yellow perch
LP = logperch
GS = golden shiner
SP = spottail shiner
ES = emerald shiner

Abundant Species	Optimal Spawning	Temperature	Range
Trout-perch	(May - Sept)	15.0	4.4 - 20.0◆
Yellow perch	(April - July)	7.2	5.6 - 18.5◆
Johnny darter	(April - June)	17.0	1.7 - 21.1◆
Emerald shiner	(early April- mid August)	22.0	22.0 - 23.0◆◆

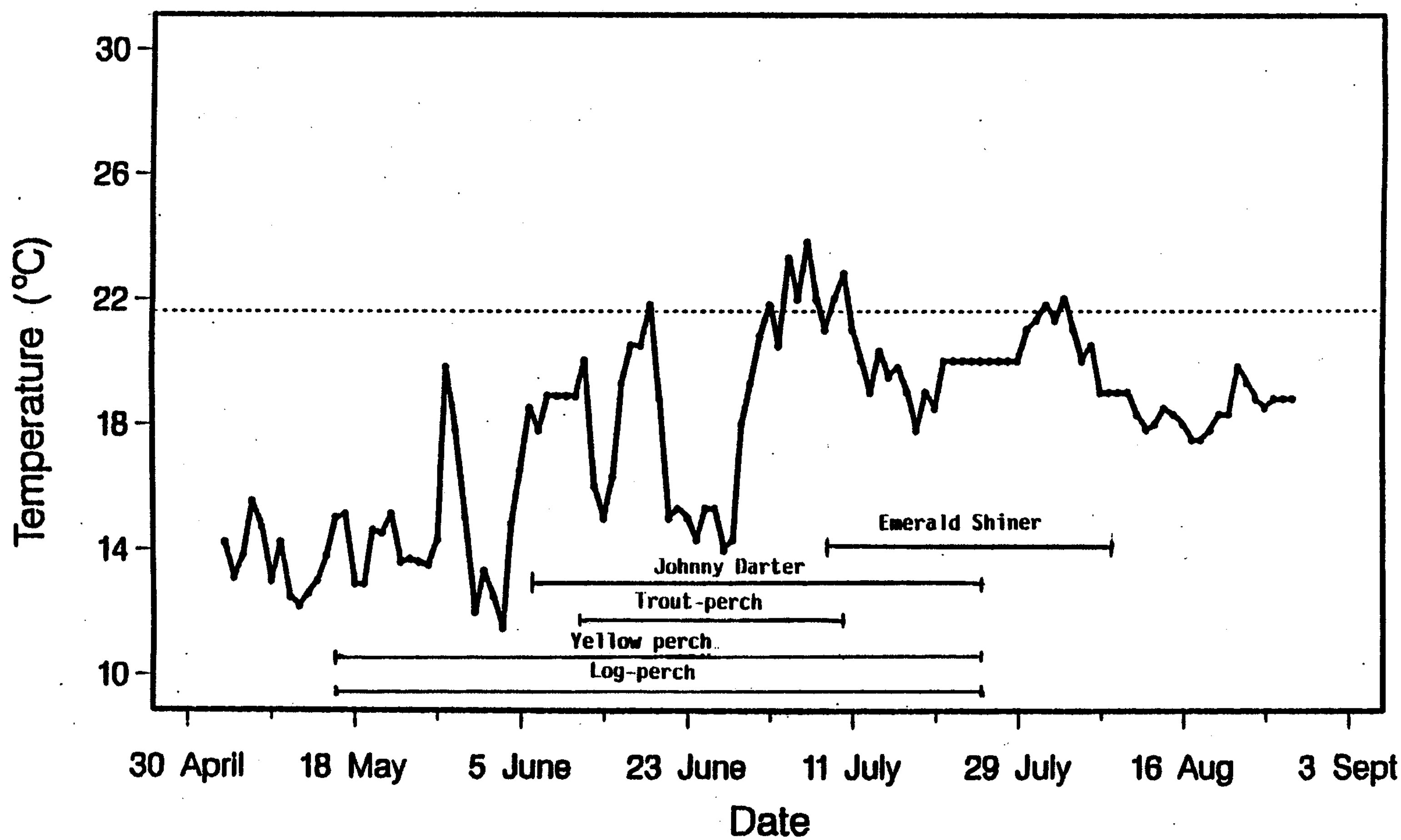
◆ Auer (1982)
◆◆ Smith (1985)

Figure 16. Mean daily lake water temperatures of Dauphin Lake (Environment Canada), 4 May to 3 September 1984. Interval on the x-axis represent 18 day periods. The bars represent the occurence of each species from first to last appearance. The dotted line indicates the temperature (21.6°C) at which the emerald shiner were expected to spawn. Bars indicate time periods and do not relate to temperature.



Temperature (°C)
30
26
22
18
14
10
Emerald shiner
Yellow Perch
Johnny darter
Trout-perch
30 April
18 May
5 June
23 June
11 July
29 July
16 Aug
3 Sept
Date

Figure 17. Mean daily lake water temperatures of Dauphin Lake (Environment Canada), 5 May - 30 August 1985. Interval on the x-axis represent 18 day periods. The bars represent the occurence of each species from first to last appearance. The dotted line indicates the temperature (21.6°C) at which the emerald shiner were expected to spawn. Bars indicate time periods and do not relate to temperature.



30
26
22
18
14
10
Temperature (°C)
Emerald Shiner
Johnny Darter
Trout-perch
Yellow perch
Log-perch
30 April
18 May
5 June
23 June
11 July
29 July
16 Aug
3 Sept
Date

Figure 18. Spawning (——), hatching (***), and larval (■■■) periods of 10 species of larval fish observed in the pelagic off-shore regions of Dauphin Lake, May- August 1984-1985. Larval periods are from this study. The spawning and hatching times are projected from the literature on the basis of tmeperature, incubation times, and back calculation in days from observed day of first appearance to expected day of hatch and spawning.

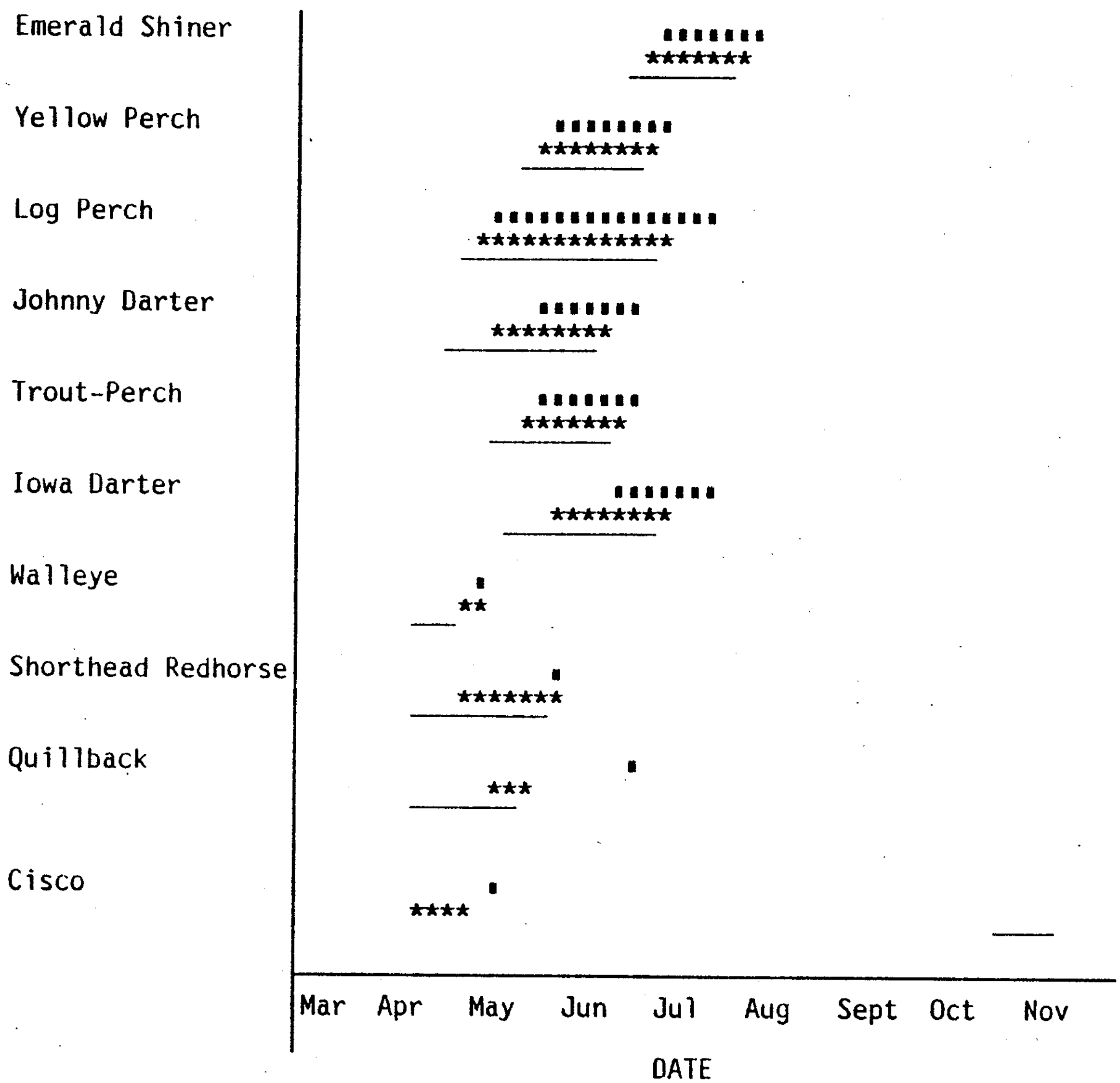
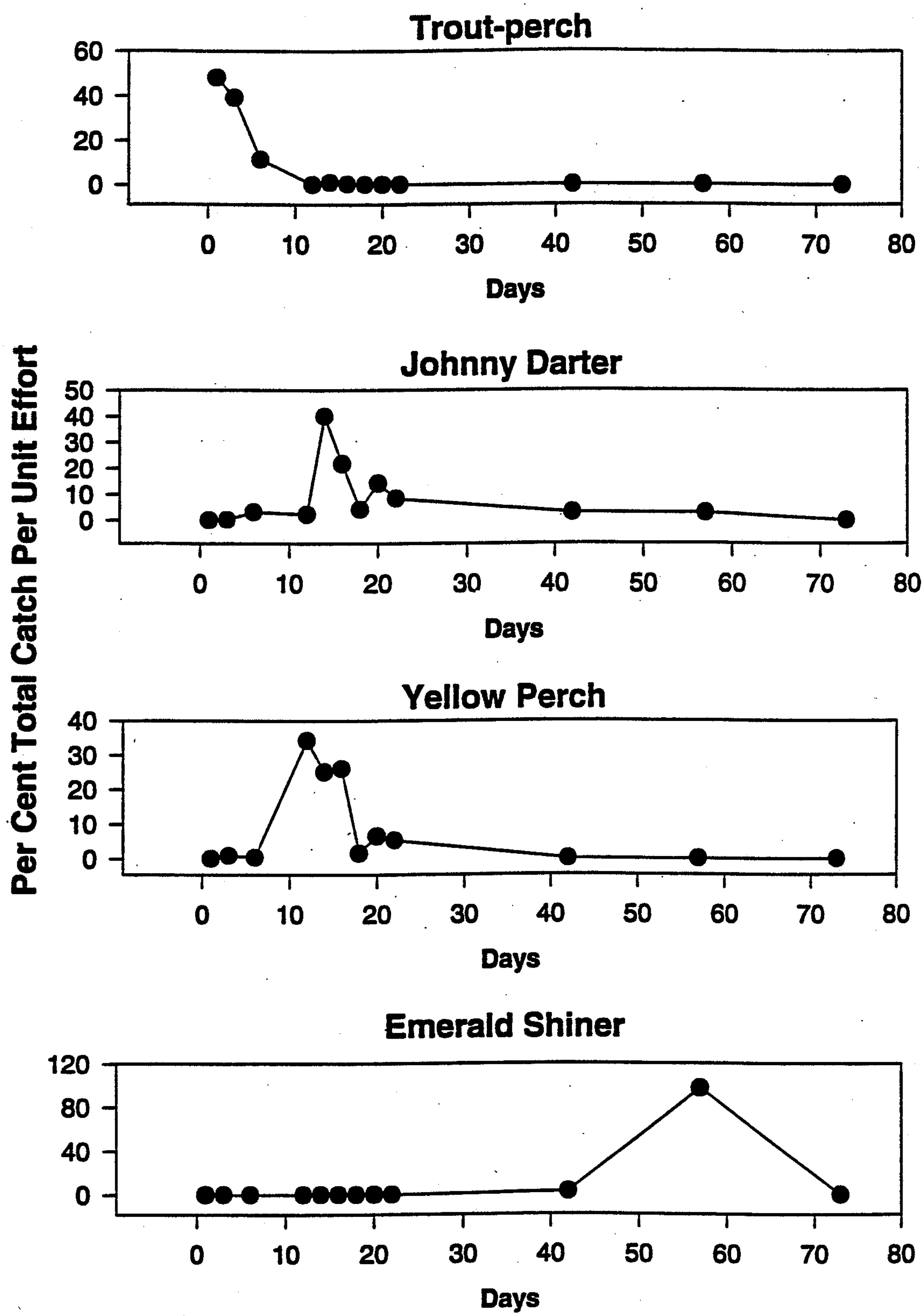

Emerald Shiner
Yellow Perch
Log Perch
Johnny Darter
Trout-Perch
Iowa Darter
Walleye
Shorthead Redhorse
Quillback
Cisco
Mar
Apr
May
Jun
Jul
Aug
Sept
Oct
Nov
DATE

Figure 19. Changes in CPUE of dominant species of fish larvae over time in 1984. Dots indicate the percentage each sample period contributed to the annual CPUE.



Trout-perch
60
40
20
0
0
10
20
30
40
50
60
70
80
Days
Per Cent Total Catch Per Unit Effort
Johnny Darter
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
Days
Yellow Perch
40
30
20
10
0
0
10
20
30
40
50
60
70
80
Days
Emerald Shiner
120
80
40
0
0
10
20
30
40
50
60
70
80
Days

expected dates except for johnny darters which were 15 days beyond the expected date.

Among the abundant species, across all collection periods in 1984, their greatest CPUE occurring on a single collection date were: emerald shiner (97 % 26 July), trout-perch (48 % 30 May), johnny darter (40 % 13 June), and yellow perch (34 % 11 June) (Fig. 19). Trout-perch appeared first in late May, peaking before the other species. The time period of greatest numbers of yellow perch overlapped that of johnny darter occurring in early June, one month earlier than emerald shiner.

Mean daily temperatures for Dauphin Lake, the mid point from lake observations of daily maximum and minimum records, were used to calculate 3 day average temperatures to compare the larval timing of each species (Table 11). A 3 day average temperature was calculated to provide a stabilized temperature over time. The first appearance of trout-perch larvae in the lake is unknown. Their greatest CPUE occurred during the first collections when the 3 day average temperature was 15.0 °C. Yellow perch and johnny darters first appeared when the 3 day average temperature was 16.7 °C. Maximum CPUE of yellow perch occurred at a 3 day average temperature of 17.3 °C and for johnny darters at 18.6 °C. The emerald shiners first appeared when the 3 day average temperature was 21.6 °C their CPUE peaking 26 July at a 3 day average temperature of 23.0 °C.

Differences were observed between 1984 and 1985 in the date of first appearance of each species as well as in the length of time that their larvae were observed. In 1985, yellow perch and logperch were collected first on 16 May compared to the previous year, 1 June and 5 June, repsectively. They persisted until 8 August and 25 July, a period of 92 days and 70 days, a longer period than 1984. Johnny darters first appeared 6 June close to their 1984 appearance 1 June and continued until 25 July (similar to 1984), a period of 49 days. Trout-perch appeared later, 11 June compared to 30 May 1984 and continued until 22 August, a period of 92 days. Emerald shiners appeared 8 July about the same as 10 July in 1984 and continued until 8 August, a period of 31 days.

Yellow perch and emerald shiners were the most abundance species in 1985 (CPUE of 2517 and 2415, respectively). Logperch were the most abundant species in the 1985 spring collections. Occurrence of logperch, yellow perch, johnny darters, and trout-perch larvae overlapped during mid June through to early July. All species were present between 8-25 July.

5. Spatial Distribution

Location was significant ($p \leq 0.05$) in affecting the distribution of species of larval fish during most sampling periods. An order of importance was derived for each location from mean abundances for each species using Duncan's Multiple Range Test. The highest ranking locations for each species for the periods of their greatest abundance in 1984 are presented in Table 12. Species dispersion in terms of number of locations larvae were found in during these maximum densities varied from 4 to 21 locations among species.

The mean number of larvae for each of the most abundant species per 100 m^3 for all locations in 1984 is shown in Figures 20 and 21. The greatest number of fish larvae were caught at river mouth locations 7 and 16. Johnny darters occurred in greatest numbers in the south basin near locations 16 and 17. Yellow perch also occurred in greatest numbers in the

Table 12. Significant locations contributing most larvae for each of the four pelagic species during their period of maximum abundance. Significance is derived from ranking following Duncan's Multiple Range Test on transformed CPUE data, 1984. There was no significant difference in CPUE among locations * (p=0.05). Species distribution during these times is indicated by the number of locations in which larvae were found.

Species	* Locations of Maximum CPUE	Date Range of Occurrence	Distribution
Trout-perch	16,7,21	30-31 May	12
Yellow perch	17,15	11-12 June	4
Johnny darter	17,16	13-14 June	12
Emerald shiner	17,18	26-27 July	21

south basin at locations 15, 16, and 17. Emerald shiners were the most abundant and widely distributed species (Fig. 21 and Table 12). They appeared in greatest numbers during a collection period at location 6 in the north basin although their greatest numbers for the lake were caught in the south basin at locations 17 and 18. During peak abundance, trout-perch were caught at 12 locations (the volumes of these locations representing 61.6 % of the total pelagic volume estimated in this study for the lake); johnny darters 12 locations (that represented 34.1 % of the pelagic lake volume); yellow perch 4 locations (that represented 6.4 % of the pelagic lake volume); emerald shiners at all 21 locations (100% of the pelagic lake volume) (Table 12).

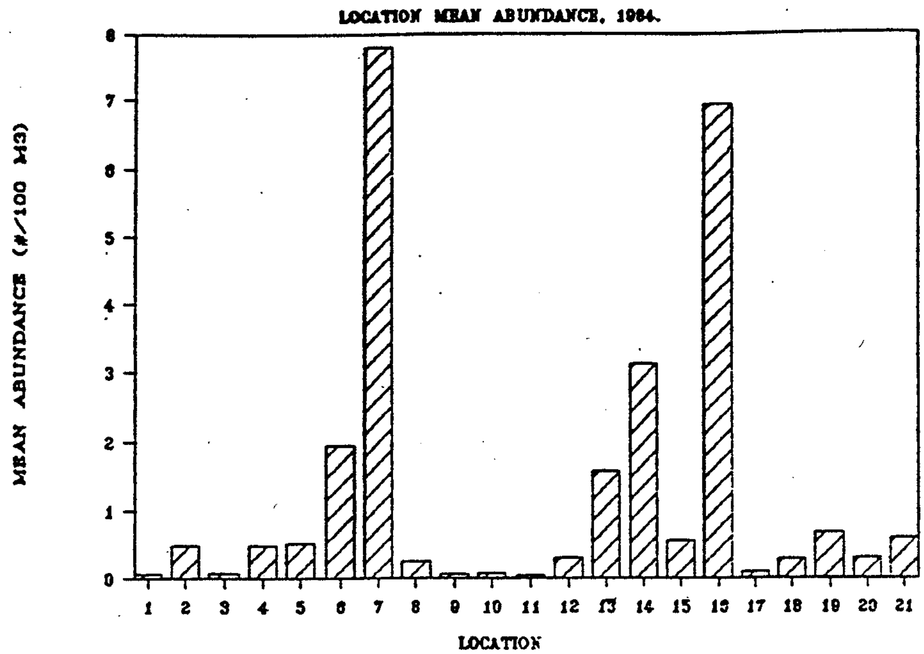
6. Habitat Use

The area and volume of each habitat varied considerably (Table 5, App. IV Table 2), as did the samples filtered in each habitat. An effort to sample all areas of the lake resulted in an unbalanced sampling effort. Habitat C received the greatest sampling intensity in both years: 48.1% of the total volume filtered in 1984 and 41.9% in 1985.

Twelve species of larval fish were collected during this study. In 1984, 10 species were observed in the north basin compared to 9 in the south basin (Table 13). However, in 1985, all 12 species were collected in the north basin compared to 6 in south basin. Habitat C in this study contributed 12 species in 1984 and 10 species in 1985. 5-7 species were caught in habitats B and D, the least number of species. Habitat A along the northeastern basin, was intermediate and 9 species were caught there in 1984 and 7 in 1985.

Figure 20. Mean abundance of *Percopsis omiscomaycus* and *Etheostoma nigrum* at each sampling location on Dauphin Lake, 1984. Abundances are generated by adding numbers from the four nets during each trawl period and calculating a mean during the time of first to last appearance for each species. The total catch has been normalized (#/100 m^3).

a Percopsis omiscomaycus



b Etheostoma nigrum

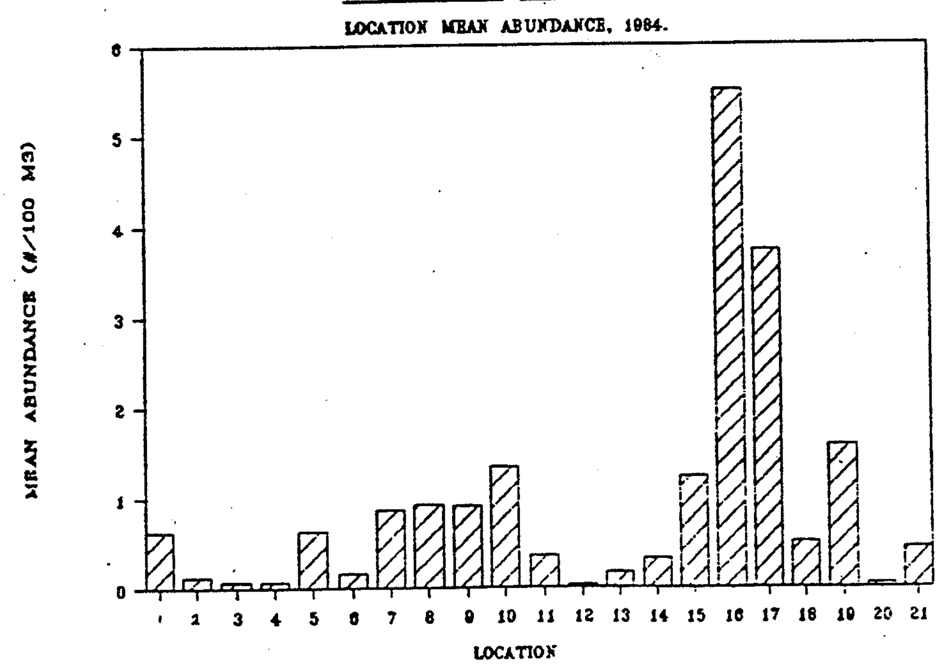
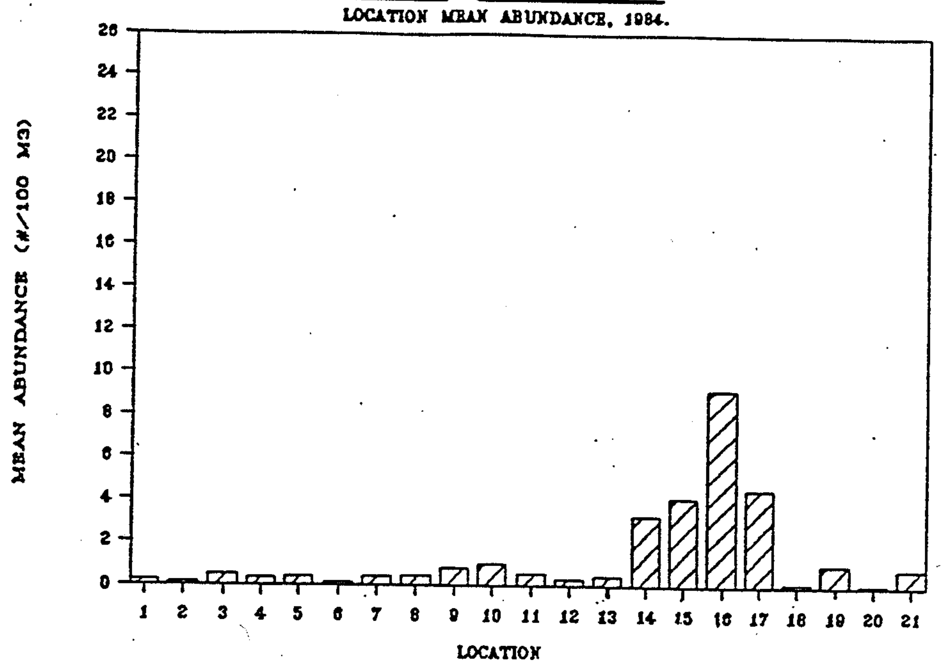


Figure 21. Mean abundances of *Perca flavescens* and *Notropis atherinoides* at each sampling location on Dauphin Lake, 1984. Abundances are generated by adding numbers from the four nets during each trawl period and calculating a mean during the time of first to last appearance for each species. The total catch has been normalized (#/100 m^3).

a Perca flavescens



b Notropis atherinoides

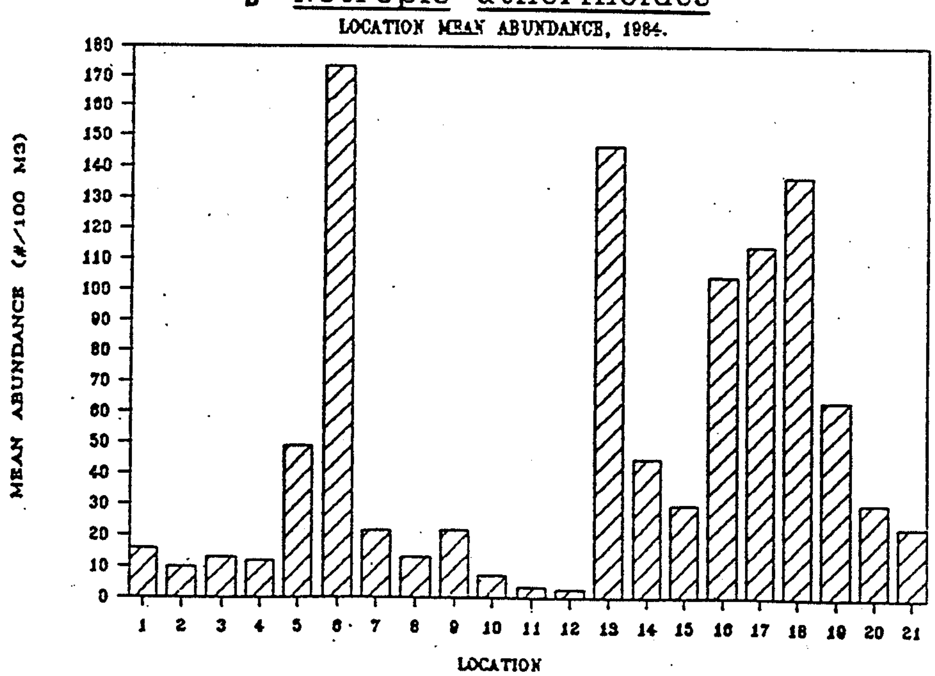


Table 13. Number of species of pelagic larval fish caught at each location and in each habitat from May to August in Dauphin Lake, 1984 and 1985.

Location	Numbers of Species 1984	Numbers of Species 1985
1	6	7
2	6	-
3	7	4
4	6	3
5	10	5
6	7	-
7	8	5
8	8	6
9	9	8
10	7	4
11	6	4
12	6	3
13	4	6
14	3	2
15	4	4
16	4	4
17	4	4
18	4	5
19	2	6
20	3	2
21	4	3
North Basin	10	12
South Basin	9	6

Numbers of species found in each habitat.

		1984	1985
Habitat A	Cobble no rivers	9	7
Habitat B	Sand no rivers	7	6
Habitat C	Clay-silt with rivers	12	10
Habitat D	Open mid-lake	6	5

Table 14. ANOVA table for the effects of sample date and habitat on the abundances of larval fish, 1984.

Source	DF	F value	P value
Emerald shiner			
Model	6	5.16	0.0671
Date	3	10.18	0.0241
Habitat	3	0.13	0.9344
Yellow perch			
Model	10	3.06	0.0279
Date	7	2.36	0.0817
Habitat	3	4.70	0.0180
Johnny darter			
Model	13	5.62	0.0069
Date	10	3.97	0.0250
Habitat	3	11.13	0.0022
Trout-perch			
Model	8	4.04	0.0410
Date	5	4.77	0.0323
Habitat	3	2.82	0.1171

Table 15. Ranking of the four habitat types by species using Duncan's Multple Range Test (p=0.05) on the 1984 CPUE data. Habitats having the symbol S are significantly different and those with NS are not.

Emerald shiner

HABITAT	A	B	C	D
A		NS	NS	NS
B			NS	NS
C				NS
D				

Yellow perch

HABITAT	A	B	C	D
A		NS	S	S
B			S	NS
C				NS
D				

Johnny darter

HABITAT	A	B	C	D
A		S	NS	NS
B			S	S
C				NS
D				

Trout-perch

HABITAT	A	B	C	D
A		NS	NS	NS
B			NS	NS
C				NS
D				

Table 16. ANOVA table for the effects of sample date, habitat and the interaction of habitat and depth on larval fish abundances in 1985.

Source	DF	F values	P-value
Emerald shiner			
Model	13	7.14	0.0001
Date	6	13.04	0.0001
Habitat	3	4.55	0.0084
Depth	1	0.79	0.3797
Habitat*Depth	3	0.04	0.9874
Yellow perch			
Model	13	7.23	0.0001
Date	6	12.88	0.0001
Habitat	3	4.77	0.0070
Depth	1	1.77	0.1916
Habitat*Depth	3	0.23	0.8776
Johnny darter			
Model	13	6.33	0.0001
Date	6	11.48	0.0001
Habitat	3	3.98	0.0162
Depth	1	0.42	0.5197
Habitat*Depth	3	0.37	0.7779
Trout-perch			
Model	13	8.25	0.0001
Date	6	13.21	0.0001
Habitat	3	9.24	0.0002
Depth	1	0.19	0.6653
Habitat*Depth	3	0.02	0.9960
Logperch			
Model	13	3.15	0.0043
Date	6	4.98	0.0011
Habitat	3	2.10	0.1208
Depth	1	1.95	0.1721
Habitat*Depth	3	0.95	0.4304

Table 17. Ranking of the four habitat types by species using Duncan's Multple Range (p=0.05) on the 1985 CPUE data. Habitats having the symbol S are significantly different and those with NS are not.

Emerald shiner

HABITAT	A	B	C	D
A		S	S	S
B			NS	NS
C				NS
D				

Logperch

HABITAT	A	B	C	D
A		NS	NS	NS
B			NS	NS
C				NS
D				

Yellow perch

HABITAT	A	B	C	D
A		S	NS	S
B			S	NS
C				S
D				

Trout-perch

	A	B	C	D
A		S	NS	NS
B			S	S
C				NS
D				

Johnny darter

HBITAT	A	B	C	D
A		S	S	NS
B			NS	S
C				S
D				

Habitat and period (sampling date) were evaluated using ANOVA to test for their effects on larval abundance in 1984 (Table 14). Depth and the interaction of habitat vs depth were also evaluated using ANOVA in 1985 (Table 16). Tables 15 and 17 present the Duncan's ranking of the habitats in both years. The effect of habitat was significant in explaining the distribution of johnny darters (p=0.0022), yellow perch (p=0.0180), and to a lesser degree trout-perch (p=0.1171) but had little significance in explaining emerald shiner distribution (p=0.9344) (Table 14). Sampling date was important in explaining the distribution of johnny darters (p=0.025), emerald shiners (p=0.025), trout-perch (p=0.0323) and yellow perch (p=0.0817). In 1985, the habitat affect was significant in explaining the distribution for trout-perch (p=0.0002), yellow perch (p=0.0070), emerald shiner (p=0.0084, johnny darters (p=0.0162) but not logperch (p=0.1208).

The effects of sampling date and habitat are also supported by total CPUE (Table 18, 1984) wherein, trout-perch and emerald shiner CPUE were greatest during distinct sampling dates compared with abundance of yellow perch and johnny darters which were less abundant over more sampling dates. The bi-modality seen in habitat C for these species (Tables 18 and 19) is an artifact of sampling because some locations could not be sampled during period 7.

Habitat C contributed the greatest number of larvae for all species of fish (Tables 18 and 19). Habitat A contributed very few larval fish. Although 100% of the CPUE for trout-perch were from habitat A (period 6, Table 19), only 3 larvae were caught. Habitat B also produced low numbers of larval fish during the 1984 sampling periods. Numbers of larval fish

Table 18. The total CPUE for four abundant species within each habitat showing their temporal distribution and percentage contribution to the total CPUE of each habitat in Dauphin Lake, 1984.

	HABITAT A				HABITAT B			
Period	ES	YP	JD	TP	ES	YP	JD	TP
1	0	0	0	17	0	0	0	0
2	0	0	0	29	0	0	0	158
3	0	4	0	13	0	0	0	0
4	0	0	0	0	0	41	0	0
5	0	3	0	0	0	0	0	4
6	0	6	0	3	0	183	28	0
7	0	11	17	0	0	0	0	0
8	0	13	13	0	0	12	4	0
9	0	30	18	0	0	0	0	0
10	602	0	0	0	69	0	0	0
11	1762	0	0	0	7770	0	0	0
12	0	0	0	0	0	0	0	0
%	93.0	2.6	2.0	2.4	94.7	2.9	0.4	2.0

	HABITAT C				HABITAT D			
Period								
1	0	0	0	606	0	0	0	144
2	0	18	3	361	0	3	0	75
3	0	6	34	86	0	0	0	83
4	0	778	32	0	0	0	0	0
5	0	474	823	7	0	119	12	5
6	0	266	229	0	0	164	49	0
7	0	21	27	0	0	6	15	0
8	0	120	169	0	0	9	14	0
9	0	40	100	0	0	56	0	0
10	229	0	32	0	382	0	9	0
11	31418	0	39	0	2241	0	0	0
12	3	0	0	0	5	0	0	0
%	88.1	4.8	4.1	3.0	77.5	10.5	2.9	9.1

ES = emerald shiner
YP = yellow perch
JD = johnny darter
TP = trout-perch

Table 19. The total CPUE for each species of larval fish distributed across habitats and through time (collection period) in 1984. CPUE on the left and percentages on the right.

Emerald shiner

Period	Habitat A	Habitat B	Habitat C	Habitat D	Habitat A	Habitat B	Habitat C	Habitat D
1	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0
7	0	NS	0	0	0	NS	0	0
8	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0
10	602	69	229	382	47.0	5.1	17.9	30.0
11	1762	7770	31418	2241	4.1	18.0	72.7	5.2
12	0	0	3	5	0	0	37.5	62.5

Yellow perch

Period	A	B	C	D	A	B	C	D
1	0	0	0	0	0	0	0	0
2	0	0	18	3	0	0	85.7	14.3
3	4	0	6	0	40.0	0	60.0	0
4	0	41	773	0	0	5.0	95.0	0
5	3	0	474	119	0.1	0	79.9	20.1
6	6	183	266	164	1.0	9.5	43.0	26.5
7	11	NS	21	6	28.9	NS	55.3	15.8
8	13	12	120	9	8.5	7.8	77.9	5.8
9	30	0	40	56	23.3	0	31.7	44.5
10	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0

Trout-perch

Period	A	B	C	D	A	B	C	D
1	17	0	606	144	2.2	0	79.0	18.8
2	29	158	361	75	4.7	25.4	57.9	20.0
3	13	0	86	83	7.1	0	47.3	45.6
4	0	0	0	0	0	0	0	0
5	0	4	7	5	0	25.0	43.8	31.2
6	3	0	0	0	100.0	0	0	0
7	0	NS	0	0	0	NS	0	0
8	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0

Johnny darter

Period	A	B	C	D	A	B	C	D
1	0	0	0	0	0	0	0	0
2	0	0	3	0	0	0	100.0	0
3	0	0	34	9	0	0	79.1	0
4	0	0	32	0	0	0	100.0	0
5	0	0	548	12	0	0	97.8	2.2
6	0	28	229	49	0	9.2	74.8	16.0
7	17	NS	27	15	28.8	NS	45.8	25.4
8	13	4	169	14	6.5	2.0	84.5	7.0
9	18	0	100	0	15.3	0	84.7	0
10	0	0	32	9	0	0	78.0	22.0
11	0	0	39	0	0	0	100.0	0
12	0	0	0	0	0	0	0	0

NS = no samples

varied among sampling dates and habitats. The greatest CPUE for emerald shiner changed over time from habitat A, period 10, to habitat C, period 11, then to habitat D during period 12. When the emerald shiner larvae first appeared, they occurred in all habitats and were the only species to do so.

Overlap was observed in all habitats during 1984. Habitat A was shared between yellow perch and trout-perch during period 3 and again during sampling periods 7-9 between yellow perch and johnny darters. Habitat B was shared between yellow perch and johnny darters during sample periods 6-8. Overlap in habitat C occurred in early summer among trout-perch, yellow perch, and johnny darters, then again between emerald shiners and johnny darters in late summer. Habitat D was shared by trout-perch, yellow perch, and johnny darters during periods 3-5 in early summer; yellow perch and johnny darters during periods 6-9 in mid-summer; johnny darters and emerald shiners during period 10 in late summer.

7. Vertical Distribution

Vertical distribution of fish larvae was determined by surface and bottom catches in 1985 (Table 20). Depth was not a significant factor (ANOVA) influencing the numbers of larval fish caught - emerald shiner p= 0.3797, yellow perch p= 0.1916, johnny darter p= 0.5197, trout-perch p= 0.6653, and logperch p= 0.1721 (Table 16).

9. Species Diversity

Numbers of species of larval fish were compared among sample

Table 20. Surface (S) and bottom (B) totals of mean CPUE (#/100m^3) for the four dominant species in Dauphin Lake in 1985. Pooled for all locations by period (P). N = number of samples.

		Yellow perch		Emerald shiner		Trout-perch		Johnny darter		Logperch	
P	N	S	B	S	B	S	B	S	B	S	B
1	20	412	179	0	0	0	0	0	0	56	409
2	28	403	425	0	0	0	0	5	0	0	0
3	52	231	308	0	0	3	0	125	72	56	3
4	68	289	229	0	0	0	0	69	74	66	21
5	16	0	16	146	1723	21	28	89	50	6	13
6	75	25	0	225	301	0	0	99	41	7	8
7	52	0	0	6	14	0	0	0	0	0	0
8	48	0	0	0	0	0	0	0	0	0	0

S Surface
B Bottom
P Period
N Number of samples.

Table 21. Numbers of species present during each collection period in Dauphin Lake in 1984. Dominant species were those with > 200 individuals in total catch. Rare species were those < 200 in the total catch. See Table 5 for period dates.

Period	1	2	3	4	5	6	7	8	9	10	11	12
Dominant Species	1	3	4	2	1	1	2	2	4	4	2	1
Rare Species	3	4	2	4	2	1	0	2	2	1	0	0
Total	4	7	6	6	3	2	2	4	6	5	2	1

periods, location, and by habitat (Table 13 and 21). The greatest numbers of species at one time was 7, during period 2, 1-4 June. Numbers exceeded 5 species on five occasions out of 12 during 1-12 June, then during 21 June and 10 July. The number of rare species in these collections was greatest (3-4), during 30 May and 12 June.

Numbers of species of larval fish within habitats were greater in 1984. Habitat A supported 9 species in 1984 and 7 in 1985, while, habitat B supported 7 in 1984 and 6 in 1985. Habitat C supported the greatest number of species in both years, 11 in 1984 and 10 in 1985. Habitat D produced the least species in the catches, 6 in 1984 and 5 in 1985.

10. Diet and Lake Zooplankton

Numbers of food items and the per cent composition of the stomach contents of the dominant species of larval fish are shown in Table 22. Mean sizes of zooplankton eaten by these larvae are presented in Table 23.

The relative bi-monthly abundance of lake zooplankton in 1984 has been calculated from Friesen and Mathias, 1990 (Table 24). The three year monthly average numbers of zooplankton per litre in Dauphin Lake for the years 1982, 1983 and 1984 are presented in Table 25 to show the trend in monthly zooplankton abundance (calculated from Friesen and Mathias 1990). The 1984 bi-monthly zooplankton abundnace follows the 3 year average with few exceptions. Rotifers were the most abundant planktor every month, but in 1984, their greatest numbers appeared in June instead of May. All zooplankton showed a decline in abundance between May and September, although rotifers increased in September 1984.

Stomach contents of feeding larvae reveal that their natural diet

Table 22. Mean number and per cent composition of food items in the digestive tracts of first feeding post-I (PI) and post-II larvae from Dauphin Lake, Manitoba, 1984. The % composition for each species of each food item is in brackets.

	ROTIFERA		Nauplii		COPEPODA		CLADOCERA					
							Bosmina		Diaphanosoma		Daphnia	
	Mean #	%	Mean #	%	Mean #	%	Mean #	%	Mean #	%	Mean #	%
N. atherinoides												
PI	3.0	(27.0)	6.6	(59.5)	1.5	(13.5)	0	0	0	0	0	0
PII	23.0	(5.4)	9.7	(33.0)	3.9	(13.3)	6.7	(22.8)	7.5	(25.5)	0	0
Total	26.0	(40.1)	19.3	(29.7)	5.4	(8.3)	6.7	(10.3)	7.5	(11.6)	0	0
P. flavescens												
PI	0	0	0	0	7.0	(100.0)	0	0	0	0	0	0
PII	0.3	(1.4)	7.0	(33.2)	13.7	(64.9)	0.1	(0.5)	0	0	0	0
Total	0.3	(1.1)	7.0	(24.9)	20.7	(73.7)	0.1	(0.4)	0	0	0	0
E. nigrum												
PI	0.6	(2.8)	8.9	(41.4)	7	(32.5)	0	0	0	0	5	(23.3)
PII	0.3	(3.0)	4.7	(46.5)	4.4	(43.6)	0.7	(6.9)	0	0	0	0
Total	0.9	(2.9)	13.6	(43.0)	11.4	(36.1)	0.7	(2.2)	0	0	5	(15.8)
P. omiscomaycus												
PI	0.1	1.1	4.1	46.6	4.6	52.3	0	0	0	0	0	0
PII no specimens												

Food item breakdown:

Copepoda = *Cyclops bicuspidatus, Diaptomus siciloides*
Cladocera = *Bosmina longirostris, Diaphanosoma leuchtenbergianum, Daphnia retrocurva*
Rotifera = *Trichocera sp., Keratella sp., Filinia sp., Polyarthra sp.*
Nauplii = young copepods, not copepodid stages which are included in the Copepoda.

Table 23. Mean lengths and widths (mm) of zooplankton obtained from the stomachs of larval trout-perch, yellow perch, johnny darter, and emerald shiner collected in Dauphin Lake. N represents the number of specimens measured. One standard deviation is presented in brackets.

	N	LENGTH	WIDTH
Trichocera sp.	6	0.054 (0)	0.027 (0)
Keratella sp.	2	0.180 (0.076)	0.104 (0.019)
Filinia sp.	1	0.324 (0)	0.108 (0)
Polyarthra sp.	5	0.104 (0.053)	0.056 (0.025)
Nauplii	11	0.061 (0.021)	0.029 (0.007)
Copepoda	23	0.130 (0.040)	0.040 (0.010)
Bosmina longirostris	5	0.097 (0.016)	0.076 (0.012)
Diaphanosoma leuchtenbergianum	5	0.061 (0.012)	0.034 (0.008)
Daphnia retrocurva	2	0.878 (0.286)	0.432 (0.077)

Table 24. Monthly mean number of zooplankton per litre in Dauphin Lake from May to September 1984, calculated from Friesen and Mathias (1990), and monthly relative abundance of the Copepoda developmental stages.

DATE	ROTIFERA		COPEPODA		CLADOCERA	
	Mean #/L	%	Mean #/L	%	Mean #/L	%
MAY	357	67.9	168	31.9	1	0.2
JUNE	589	74.4	202	25.5	1	0.1
JULY	144	49.3	112	39.0	34	11.7
AUGUST	123	50.0	115	47.0	7	3.0
SEPTEMBER	273	69.0	104	27.0	16	4.0

Relative abundance of the copepod developmental stages.

	COPEPODA					
	nauplii	%	copepodids	%	adults	%
MAY	119	71.0	48	28.0	32	1.0
JUNE	123	60.0	78	39.0	1	1.0
JULY	36	32.0	64	57.0	13	11.0
AUGUST	72	63.0	29	25.0	13	12.0
SEPTEMBER	73	70.0	27	26.0	4	4.0

Table 25. Three year average number of zooplankton per litre in Dauphin Lake during the open water season May to September for 1982, 1983, 1984, calculated from Friesen and Mathias (1990).

DATE	Number of Samples	ROTIFERA Mean #/L	ROTIFERA %	COPEPODA Mean #/L	COPEPODA %	CLADOCERA Mean #/L	CLADOCERA %
MAY	35	533	77.0	159	22.0	1	1.0
JUNE	33	264	62.0	154	36.0	6	2.0
JULY	32	134	59.0	80	36.0	12	5.0
AUGUST	40	92	46.0	101	50.0	9	4.0
SEPTEMBER	28	79	56.0	54	38.0	8	6.0

consisted of at least 4 genera of Rotifera: *Trichocera sp.*, *Keratella sp.*, *Filinia sp.*, and *Polyarthra sp.*; at least 2 species of Copepoda: *Cyclops bicuspidatus* (suborder Cyclopoida) and *Diaptomus sicilodes* (suborder Calanoida) and their nauplii; at least 3 species of Cladocerans: *Bosmina longirostris*, *Diaphanosoma leuchtenbergianum*, and *Daphnia retrocurva*.

First feeding larvae eat rotifers, naupii, cyclopoids and *Daphnia*. Nauplii, the early developmental stages of Copepoda, made up the largest component of stomach contents of both post-I and II feeding larval stages. Post-II larvae eat more kinds of items. Dimensions measured on zooplankton are shown in Appendix III. The mean size of zooplankton found in the diets ranged from 0.054mm to 0.878 mm total length and 0.027 to 0.432 mm in width (Table 23).

Trout-perch, yellow perch and johnny darters ate 1-2 genera of rotifers. *Trichocera sp.* was the most common rotifer eaten, being absent only in yellow perch PI-larvae. The largest food item, *Daphnia retrocurva* (0.878mm x 0.432mm), was eaten only by post-I johnny darters.PI and PII johnny darter larvae fed on both some of the smallest and some of the largest plankton. *Daphnia retrocurva*, found exclusively in the PI-larvae of johnny darters, was the largest food item (0.878 mm length, 0.432 mm width).

Differences in feeding were observed with time and temperature among species. Trout-perch, the cold water species, ate nauplii (46.6%), copepods (52.3%), rotifers (1.1%) (Table 22), while the dominant plankter in the lake was rotifers (67.9 %) (Table 25). During the cool water period, yellow perch ate copepods (73.7%) and nauplii (24.9%), and to a lesser amount rotifers (1.1%) and cladocerans (0.4%). During the same time johnny darters ate nauplii (43%), copepods (36.1%), cladocerans (18.4%), and least of all rotifers (2.9%). The lake zooplankton at this time (June) was predominantly rotifers (74.4 %). Copepoda made up 25.5% of the lake zooplankton, of which the nauplii made up 60 %, adults 1.0 %, and copepodids made up 39 % (Tab.25).

Emerald shiner larvae ate rotifers (40.1%), copepod nauplii (29.7%), cladocerans (21.9%), and copepods (8.3%) during the warm water period. Zooplankton during this time was made up of rotifers (49.7%), copepods (16.0%), and cladocerns (11.7%).

Discussion

1. The Role of Water Temperature in the Temporal Distribution of the Dauphin Lake Larval Fish Community

Not all temperate species breed at the beginning of the growing season (Conover 1992), as was seen in Dauphin Lake. Walleye, white sucker, quillback, shorthead redhorse, trout-perch, and yellow perch larvae first appeared in May. Johnny darter larvae appeared in June and emerald shiner larvae appeared later in July.

Given the importance that temperature plays in reproduction and in growth and development, the timing of pelagic larval fish in Dauphin Lake to first appearance and greatest abundance can be explained by water temperature required for hatching and development by each species.

From the dates when the pelagic larval fish first occur, there appears to be three major spawning periods in the Dauphin Lake. These periods may be defined by water temperature and serve to isolate fish species temporally into specific breeding periods by temperature requirements necessary for spawning, incubation, and hatching.

The first spawning period beginning in the cold water period appears to be associated with temperatures between 11.5-23.8°C. Species that began spawning during this period were trout-perch, yellow perch, logperch, walleye, white sucker, shorthead redhorse, quillback, and lake cisco. The second spawning period commencing in the cool water period occurred within water temperatures of 17.8-24.5°C. Larval johnny darters, spottail shiners, common shiners, and Iowa darters were the species that occurred during this period. The third spawning period occurred when the lake reached temperatures between 22.3-27.8°C. Emerald shiner larvae occurred during these conditions.

There are at least two biological responses that can be inferred from the mean daily lake temperatures (Fig. 16, 17). Before hatching there appears to be a drop in lake temperature seen just prior to first appearance of larvae. Secondly there appears to be a rise in lake temperature necessary before the time of greatest abundance. In 1984 there was a 4.3° drop in lake temperature over 7 days (16 May-24 May) prior to the appearance of trout-perch, johnny darters and yellow perch (Tab. 11). A 7-8° rise occurred before these species peaked in abundance between 11-13 June 1984. In 1985 a similar drop in lake temperature of 3.3° occurred prior to the appearance of larval yellow perch and logperch between 8-13 May, and a 8.3° drop with johnny darter and trout-perch between 29 May-11 June. A rise of 1.5-1.6° preceeded the johnny darter, yellow perch and logperch greatest abundances in 1984. The spawning adult emerald shiners were subjected to a 6.7° drop over 9 days and a 7.8° drop over 8 days in 1984 and 1985, respectively. They reached greatest numbers after a rise of 7.1°in 1984 and 8.3° in 1985.

Extended spawning occurred among the fish species contributing to the larval fish stocks found in this study. I have interpreted the appearance of larvae in excess of 21 days for a species to represent extended spawning for species known to be extended spawners. This prolonged spawning phenomenon was observed in logperch (92 days), johnny darters (57 days), emerald shiners (31 days), and trout-perch (72 days) (Figs. 16-18). Extended spawning may be a result of sequential or more rapid complete gonadal development that would result in different eggs in the gonads being ready to spawn at different times. There may be a good reason for this. This would permit small fish that have a small body size to produce a large number of eggs. However, prolonged occurrence of larvae of a species may also be the result of older females spawning early and younger females spawning later found in single spawning species like yellow perch (Sheri and Power 1979) that occurred over 70 days and was not from extended spawning.

Water temperatures in May were warmer during 1985 than 1984, but June and July water temperatures were cooler in 1985 than 1984 (Figs. 16-17). This fact may have caused the earlier appearances of logperch and yellow perch larvae in 1985, and prolonged the spawning of emerald shiners into August in that year.

2. Spatial Distribution of Dauphin Lake larval fish

From this study, spatial distribution of the most abundant larval fish appear to be, in addition to habitat selection of spawning adults, a function of lake currents, lake mixing, and possibly larval feeding strategies.

Lake mixing and water currents are a function of inflowing water and wave mechanics. Frictional action of wind on the water surface sets the surface into oscillation, producing surface waves. When the wavelength is much greater than the water depth, shallow water long waves result. The cycloid motions are transformed into a to-and-fro sloshing which extends the surge zone to the bottom of the water column. Since, in a shallow lake such as Dauphin Lake, the wave action extends to the bottom over most of the lake, sedimentation is limited and surge is too severe for most aquatic plants to grow. This limits fine sediments and aquatic plants to areas protected from wave action. This effect on the distribution of spawning habitat, in turn, affects the spatial distribtution of the pelagic larval fish and their placement in the water column.

In addition to wave mechanics affecting the spawning habitats, wind action and inflowing rivers also cause larger scale water movement. From daily changes in surface water temperature distribution, wind force and direction (Figs. 12-14), water currents consisting of offshore movements of warm water plumes from the Turtle and Valley Rivers were inferred (Fig. 15). In addition to the internal drainage flow toward the Mossy River outlet, the southward deflection of the Valley River plume was apparently caused by the northeasterly wind, which also caused a westward deflection of the Turtle River plume.

Along with these currents, temperature differences between stream and lake water may produce some turbulent entrainment and mixing of warmer and cooler water as streams enter Dauphin Lake. The result of these currents was that the lake became isothermal over a span of 8 days in 1984. Variations in densities, discharge, and amounts of dissolved and suspended material (Chapman 1987), as well as in geostrophic deflection (Wetzel 1983) of incoming water may also contribute to the strength and direction of the currents shown in Figure 15.

Currents are known to displace larvae (Houde and Forney 1970). Organisms that live in the water column and are displaced by currents whether they can actively swim or not are considered drift. Larval yellow perch, which were abundant in habitat C during periods 4 and 5, decreased there while increasing in habitat D (mid-lake) during periods 5 and 6 (Table 19). Habitat D did not have suitable vegetation or substrate for yellow perch spawning, so that their presence is probably due to passive distribution. Thus, areas with increases in abundances of larvae over time could be a reflection of locations down wind or down current of probable hatch locations or spawning grounds. Passive distribution can be considered a factor in the distribution of trout-perch, yellow perch, and johnny darter. In each case, the habitat type in which a species is first seen corresponds with or is in close proximity to the known preferred spawning habitat. This habitat remains the one in which a species is most abundant, but all 4 species increased in % CPUE in other habitats over time. This probably resulted from passive distribution of larvae.

Larvae of the cold and cool water species occurred in greatest numbers in near-shore habitats associated with vegetated bays and river mouths. The warm water species occurred in greatest numbers in the off-shore sites.

Pro-larvae may use the lake bottom as a refuge from predators and water movement (Hutchinson 1957). Pelagic near-surface spawners such as emerald shiners appear to have strongly demersal pro-larvae, but it is not known whether this results from active movement or negative bouyancy.

The Dauphin Lake pelagic larval fish are planktivores and require an abundant supply of edible zooplankton at the time of first feeding, as Mathias and Sifa (1982) found for larval walleye in the lake. In-shore regions that have shallow vegetated bays and tributaries have a rapid resource renewal through drift and shifting of the sand-gravel substrate (Baker and Ross 1981). The sand-cobble substrate with vegetation is ideal for spawning yellow perch, johnny darters, trout-perch and logperch. Although adult trout-perch prefer deep water by day, they use cobble and streams for feeding and breeding by night, as do johnny darters and logperch (Scott and Crossman 1973, Pflieger 1975, Smith 1985). Thus their larvae would occur in or near shore. Their presence as feeding larvae in the off-shore locations would be an indication of drift.

This off-shore occurrence of larvae in a habitat lacking perferred spawning substrate or vegetation implies that there are spawning and pro-larval nursery areas in-shore that were not sampled. These areas probably contributed the larvae to the near-shore areas I sampled. Numbers of species in the near-shore areas of habitat C reflect this assumption. The greatest number of species found in a habitat was 10 and that was found in habitat C (Table 13). Locations 5 through 9 (all in habitat C) had the most larval fish species with location 5 supporting 10 species in 1984. The greatest CPUE over all habitats of johnny darters (89.5%), yellow perch (72.3%), emerald shiners (71.2%), and trout-perch (66.6%) were from habitat C. Locations 5 and 6 might be considered the most productive locations in Dauphin Lake because the highest numbers of species and greatest number of larvae were collected there. However, locations 5 and 6 are areas of possible larval drift accumulation. This could occur because of the counter-clockwise current from the Valley River and the clockwise current from the Turtle River converge in this area (Fig.15). However, locations 7 and 16 are nearest the main spawning areas for trout-perch, as are locations 16 and 17 for johnny darters, locations 15-17 for yellow perch, and locations 6, 13, 16-19 for emerald shiners, (Figs. 20 and 21) .

Locations like 5, 6 and 8 have shallows associated with extensive shoreline development, and are not much affected by prevailing winds, making them ideal nursery habitat. Keast et al. (1978) found fish biomass to be concentrated in similar physically diverse habitats. Kelso (1988) observed both production and biomass decreased with increasing depth. Because the depth in these areas is fairly uniform at 1.5 to 2.5 m, one might expect less of a decrease in production. Furthermore, Baker and Ross (1981) determined that cyprinid larvae were more abundant in areas with aquatic vegetation. In Dauphin Lake, habitat C locations that are adjacent to vegetated shorelines with clay-silt substrate produced the greatest abundance of larval fish of all species (Table 13).

Concentrations of larval fish are known to occur in or at river mouths. Shevchenko et al. (1986) observed such distributions in the mouth of the Desna River where the abundance of fry increased with daily movements of food organisms and temperature fluctuations of 4-5 degrees C. Larvae of trout-perch, johnny darters, and yellow perch occurred in greatest numbers in the mouths of the Valley and Turtle Rivers during 1984 (Figs. 20 and 21). There is some evidence that part of the lake catch of troutOperch, yellow perch and johnny darters could be from rivers because monitoring of larval drift in the Valley River by the Manitoba Department of Mines and Natural Resources revealed these species were drifting in the river in low numbers at the same time as they we found in the lake. Furthermore, Shevchenko et al. (1986) and Wurtsbaugh and Neverman (1989) found that larvae move or are carried along thermal gradients and zooplankton concentrations. Zooplankton abundances and temperature changes are down-current with respect to river outfalls and lake currents. This would carry both larvae and zooplankton into habitat C areas.

Spatial distribution of fish larvae can also be related to the standing crop of zooplankton. The cropping of zooplankton is detected by changes in lake plankton abundance. Over three years lake zooplankton always decreased during July (Table 26). This was in spite of conditions supporting maximum zooplankton production, i.e. mid-summer high temperatures and primary productivity peaks determined by high chlorophyll-a production and high TDN values (Babaluk and Friesen 1990). This correlates with the period of highest emerald shiner abundance. This is strong evidence of emerald shiner larval predation on the lake zooplankton. To achieve such effects, emerald shiner larvae must be in all locations and in great numbers, facts supported by their distribution and abundance.

Surface and bottom catch comparisons in 1985 did not reveal any significant differences in vertical distribution by any species of larval fish during the day ($p < 0.05$).

Nutrient loading in terms of total dissolved nitrogen (TDN) increased over the summer and was higher in the North Basin (Babaluk and Friesen 1990). This high TDN in the North Basin was likely a result of the Valley River outfall and the northward flow toward the outlet of the whole lake. This may account for species diversity of larval fish being greatest in the north basin at locations 5-9 (Table 13).

Diet and Lake Zooplankton

Numbers of zooplankton species eaten by larvae fish were greatest in emerald shiner and johnny darter. There were 6 zooplankton taxa in the post-I and 7 in the post-II larval emerald shiner stomachs suggesting a full utilization of the plankton community (Tables 22-23) a feature of an efficient and/or an opportunistic predator. Johnny darter had 6 taxa in the post-I and 4 taxa in the post-II larval stomachs. The rotifer, *Trichocerca sp.*, the smallest food item (0.054 mm L and 0.027 mm w) occurred in all but trout-perch larvae.

Johnny darter larvae fed on both the smallest and largest plankton species, taking the smallest rotifer, *Trichocerca sp.*, as well as *Daphnia retrocurva*, the largest food item (0.878 mm L and 0.432 mm W). The bimodal size distribution of prey in johnny darter stomachs (Table 20), combined with the fact that the frequency of taxa in darter stomachs did not correspond to the relative abundance of the taxa in the lake (Table 25) is evident that johnny darters are feeding at both ends of the prey size scale. The reasons for this are unclear. The johnny darter was the smallest feeding larva, it was expected that its diet would be weighted toward the smaller taxa, the rotifers and smallest crustaceans.

Trout-perch appear to have a narrow selection of food items (nauplii and cyclopoids), at a time when the abundant food item in the lake was rotifers. However, mouth gape may be more important than body length.

Diets could not be directly associated with hatching periods. During the early cold period, trout-perch selectively fed on nauplii and copepods. Conversely, later hatching species such as yellow perch and emerald shiners usually ate the most abundant taxa.

These larval diet analyses can not be considered definitive because of the low number of stomachs analyzed, but they are an indication of prey type and size.

Avoidance of Sampling Gear

Escape movements of fish to avoid the sampling gear were not tested in this study. Startled escape responses were reported (Baxter and Fuiman 1989). The question of active avoidance to the sampling gear by larvae is discussed here to support the low expectation of avoidance occurring. Dabrowski et al. (1986) suggested that swimming efficiency would be much lower in fish larvae than adults because of body drag. Batty (1984) suggested low larval swimming ability because anguilliform swimming movement is 4 orders of magnitude less efficient mechanically than the sub-caragiform swimming of adults. If there was significant avoidance of the gear, it would likely have occurred later during late larval development, when increasing size of larvae and warmer water temperatures would both have forced increase swimming speeds.

Fish behaviour may also result in avoidance. Pro-larvae which are primarily bottom dwellers remain on the bottom after hatching if spawned at the bottom or drift and sink if spawned at the surface (i.e. emerald shiners) (Pflieger 1975). Suspension of the pro-larvae would result from pelagic hatching or lake mixing. Although Dauphin Lake is well mixed, few pro-larvae were collected. Related to the relatively calm conditions when the wave surge did not mix the water column to the lake bottom, the demersal nature of this larval stage, or inshore nursery sites rather than avoidance of nets could account for the low cathes.

Catchability of post-I and II larvae in Dauphin Lake can be linked to their feeding behaviour because these larvae were feeding when captured. This activity brings these larvae higher in the water column where they are more susceptible to capture. Feeding larval fish will adopt a sustained swimming speed of 0.4-1.0 cm sec^{-1} for 10 mm larvae (Dabrowski et al. 1986). He believed swimming to be the lowest metabolic cost during feeding. The swimming speeds of Dauphin Lake larvae would likely be within the 0.4-1.0 cm sec^{-1} range because their total body lengths were between 4.36 mm and 11.4 mm. The mean net towing speed of 89 cm sec^{-1} maintained in this study exceeds the burst speeds of 0.6-0.9 cm sec^{-1} for Dauphin Lake larvae that have 10-15 mm total length (Dabrowski et al. 1986).

Net avoidance is considered minimal due to improvements in the nets and their placement near the bow of the boat. Nets with non-porous cones, extended lengths > 270 cm and enlarged filtering areas of 0.126 m^2 provided filtering capacities of 108.2% (505 μ mesh) and 101.6% (305 μ mesh). This means that fish within the rim boundaries should be entrained into the nets by the increased flows produced around the cone opening and by the Venturi action of the cone. Nets were also placed as far forward of the motor as possible to minimize acoustic and mechanical signals.

The effectiveness of the Bongo Sampler for this study was considered adequate. The filtering capacities exceeded the water flow outside the nets by 1.6% in the 303 μm mesh and 8.2 % in the 505 μm mesh and there was no loss of larvae due to filtering or extrusion through either mesh in pre-trials when 10-50 walleye larvae were put into the cones under tow.

Abiotic Factors Affecting Catch

There are several factors associated with ichthyoplankton trawling that affect catches and which are not addressed by this data analysis.

Although design of the apparatus has been improved, there are still inherent problems. According to Zijlstra and Schnack (1974), towing direction and lake currents can redistribute larvae or affect net operation during turbulence. Irregularities in net towing speed might change filtration efficiency, either positively or negatively. Irregularities arise from cavitation and/or irregular motor operation, wave surge, etc.

Dauphin Lake pelagic larval fish community and the young-of-the-year walleye

No walleye larvae were collected in this survey, even though approximately 4 million larval walleye were introduced into Dauphin Lake 23 May, 1984 (Rowes, unpub. data), and another 7.1 million between 19 May and 22 May, 1985 (Mathias et al. 1992). The introduced larvae may have been too dispersed to be captured or may have been eaten by adult emerald shiner and other piscivores. Larvae from spawning of resident walleye were not collected because they appeared and had passed through the larval stage well before my sampling period began. Larval drift from resident walleye spawning was recorded in the Valley River between 17-24 May, 1984 (Harbicht, unpub. data) and in very low numbers, during 8-10 May 1985 from drift assessments by Caun (1991).

Summary

Larval distributions in this study have been explained temporally and spatially in terms of thermal units, lake currents, and feeding behaviour. Because these factors are environmentally controlled, they are in constant change. Lake communities are altered during catastrophic events such as high winds and spring run-off. In addition, anthropogenic changes in the watershed cause changes that are permanent and require long periods to stabilize to their present productive states (Karr et al.1987). Vannote et al. (1980) suggested that biological systems move toward a balance between a tendency for efficient use of energy inputs through resource partitioning (food, substrate) and an opposing tendency for a uniform rate of energy processing. It is through early life history studies such as this one, concerning the ecological relationships of pelagic larval fish in terms of their distribution over time and space, habitat type, thermal requirements, and their diet, that an explanation of such balances will be understood. I believe this study constitutes, as Lewis Thomas (1990) has stated, another piece in a larger jigsaw puzzle.

CONCLUSIONS

1. Within Dauphin Lake, between late May and mid August during the years 1984 and 1985, 97% of the fish larvae collected in tow nets belonged to five taxa: emerald shiner, *Notropis atherinoides* (Family Cyprinidae); logperch, *Percina caprodes*; yellow perch *Perca flavescens*, johnny darter, *Etheostoma nigrum* (Family Percidae); trout-perch, *Percopsis omiscomaycus* (Family Percopsidae).
2. The most abundant species changed between years: 1984 trout-perch - 3.3%, johnny darter - 3.2%, yellow perch - 4.2%, emerald shiner - 88.3%; 1985 trout-perch - 14.7%, johnny darter - 8.34%, yellow perch -35.3%, emerald shiner - 34.1%, logperch - 13.7%.
3. The CPUE for pelagic larvae was highly variable among seasons,

locations and between years.

4. Location, habitat, and time period were important factors in determining species distributions. To draw comparative year to year conclusions about spatial distribution would not be appropriate because of the irregularity of sampling between years.

5. Three thermal ranges were indicated when spawning commences in Dauphin Lake; a cold water period with temperatures <15°C, a cool water period with temperatures 16°C-20°C; and a warm water period with temperatures >20°C.

6. The greatest abundance of fish larvae in Dauphin Lake occurred during the warmest temperatures (>20°C), of July. This coincides with the abundance of small forage fish required by young-of-the-year of piscivorous species aged 60 to 90 days old.

7. The 21.6 °C spawning temperature found in this study for emerald shiners concurs with that observed by Flittner (1964), Auer (1982), and Campbell and MacCrimmon (1970).

8. Spatial distribution of larval fish was attributed to habitat type and in-lake environmental variables such as lake mixing and lake currents.

9. In Dauphin Lake Emerald shiners are lake spawners that are distributed by spawning adults, lake water currents and foraging. Johnny darters and trout-perch are benthic lake spawners. There is some evidence that part of the lake catch of trout-perch, johnny darters, and yellow perch were from river spawning (Caun 1991).

10. Initial spawning times were mid-May for trout-perch, logperch, and yellow perch, early-June for johnny darters, and early-July for

emerald shiners.

11. Numbers of species were highest (7 species) during 1-4 June. The deeper North Basin had a greater number of species than the South Basin (Table 13).

12. Larval abundance off-shore was substantial. These larvae were probably available as food to Dauphin Lake young-of-the-year walleye, as believed by Harbicht (1990). Their period of occurrence, between late May and July, coincides with the onset of piscivory of young-of-the-year walleye.

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Appendix I

SPECIES OF THE DAUPHIN LAKE FISH COMMUNITY

App I Table 1. Twenty-eight fish species observed in Dauphin Lake and its tributaries (Craig J. person. comm., C. Day person. comm.).

Scientific Name	Common Name
Hiodonidae	
Hiodon alosoides	goldeye
Salmonidae	
Coregonus artedii	lake cisco
Esocidae	
Esox lucius	northern pike
Cyprinidae	
Cyprinus carpio	common carp
Notropis atherinoides	emerald shiner
Notropis cornutus	common shiner
Notropis heterodon	blackchin shiner
Notropis heterolepis	blacknose shiner
Notropis hudsonius	spottail shiner
Pimephales promelas	fathead minnow
Rhinichthys atratulus	blacknose dace
Rhinicthys cataractae	longnose dace
Catostomidae	
Catostomus commersoni	white sucker
Carpriodes cyprinus	quillback
Moxostoma anisurum	silver redhorse
Moxostoma macrolepidotum	shorthead redhorse
Percopsidae	
Percopsis omiscomaycus	trout-perch
Gadidae	
Lota lota	burbot
Gasterosteidae	
Cluaea inconstans	brook stickleback
Centrarchidae	
Micropterus dolomieui	smallmouth bass
Percidae	
Etheostoma exile	Iowa darter
Etheostoma nigrum	Johnny darter
Percina caprodes	logperch
Percina flavescens	yellow perch
Percina shumardi	river darter
Stizostedion canadense	sauger
Stizostedion vitreum v.	walleye
Sciaenidae	
Aplodinotus grunniens	freshwater drum

AppI Table 2. Preferred spawning habitat of Dauphin Lake fish species.

Common Name	Description	Location				
					River Shore	Lake
Goldeye	turbid backwaters		x		f	
Lake cisco	near-shore, open water (shallow gravel-stoney areas)		x	x	e,c	
Northern pike	vegetated area	x	x		e,c	
Common carp	shallow marshy areas	x	x		e,c	
Emerald shiner	near-shore	x			e,c,j	
Common shiner	streams, inshore gravel area, lake shoals	x	x	x	e,c,f	
Blackchin shiner	clear weedy areas, quiet pools in creeks, rivers & weedy inshore	x	x		c,f	
Blacknose shiner	sand or gravel quite streams or bays	x	x		e,f	
Spottail shiner	in-shore, river mouths	x			c,i	
Fathead minnow	shallow, vegetated, quiet areas	x			e,c	
Blacknose dace	shallows	x			e,c	
Longnose dace	shorelines & with white sucker	x			e,c	
White sucker	shallows	x	x		e,c	
Quillback	vegetated areas	x	x		e,c	
Silver redhorse e	rivers					x
Shorthead redhorse e	rivers					x
Trout-perch	beaches	x	x		d,e,h	
Burbot	sand or gravel shallow bays, shoals	x	x		e	
Brook stickleback	rivers	x			e	
Smallmouth bass	shoreline (no waves)		x		e	
Iowa darter	shoreline,rivers	x	x		k	
Johnny darter	quiet water, bottom	x	x	x	i,e,k	
Logperch	shorelines (eggs are buried)		x		e,c	
Yellow perch	littoral area, shallow bays		x		a,e,c	
River darter	rivers and lakes	x	x		e,i	
Sauger	turbid shorelines		x		e,c	
Walleye	rivers and shorelines	x	x		a,b,c,e,i	
Freshwater drum	open water			x	e	

a	Craig	1987	h	Stewart (person. comm.)	
b	Corbett and Powels	1983	i	Pflieger	1975
c	Auer	1982	j	Flittner	1964
d	Ratynski	1978	k	Simon	1985
e	Scott and Crossman	1973			
f	Mansueti and Hardy	1964			
g	Lawler	1954			

App I Table 3. Optima and range of spawning temperatures for the species of rarely collected pelagic larval fish in Dauphin Lake, 1984 and 1985.

SPECIES	Date	Optima °C	Range °C	*
Coregonus artedii	(Nov.-Dec.)	3.3	3.0- 5.0	e
Notropis cornutus	(May-June)	18.3	15.6-25.0	i
Notropis hudsonius	(June-July)	18.0	15.0-20.0	h
Catostomus commersoni	(April-mid May)	10.0	7.2-10.0	d
Carpriodes cyprinus	(April-June)	16.0	10.0-22.0	g
Moxostoma macrolepidotum	(May)	14.0	11.0-18.0	f
Etheostoma exil	(April-Mid-June)	15.0	13.0-16.0	c
Percina caprodes	(April-July)	13.0	10.0-15.0	a
Stizostedion vitreum v.	(April-May)	7.0	4.4-10.0	b

References *

a,b,d,f,h	Auer	1982
c	Jaffa 1917, Simon and Faber	1987
e	Auer 1982, Scott and Crossman	1975
f	Harbicht	1990
g	Parker	1987
i	Auer 1982, Scott and Crossman	1975

Appendix II

EARLY LIFE HISTORY CHARACTERISTICS

The following are generalized observations and comparative features of larval fish from Dauphin Lake that do not contribute directly to the thesis.

Body measurements were made on a small sample of specimens from each species, (App. II. Tables 1,2). No test for shrinkage was performed and no corrective factors applied to measurements. Shrinkage was assumed to be 2 % (Johnston and Mathias 1993, Glenn C.L. and Mathias 1987, Leslie 1983). Leslie (1983), found that larvae of freshwater fish in the length range 4.0 -14.0 mm shrank approximately 2% in buffered formalin during the first two days after preservation and any further shrinkage was not substantial in older fish. Shrinkage also occurred during the capture process, before preservation which would add further error to measurements (Leaslie person. comm.).

The smallest larvae collected in Dauphin Lake were emerald shiner pro-larvae, 4.27 mm TL. The smallest PI and PII-larvae were the johnny darter 5.94 mm TL, and 7.00 mm TL respectively. The largest larvae were the yellow perch PII-larvae at 8.56 mm TL. There were no trout-perch fitting my criterion of a P II larvae, without an oil globule or stomach that is more than a simple tube structure.

Body development appears to be greater in the length to vent dimension between the feeding larval of emerald shiners, whereas, this development appears to be in the body depth dimension of yellow perch and johnny darter. Trout-perch could not be compared because of no PII larvae.

Growth comparison among species. Differences given in brackets:

species	Total Length		Length to Vent		Greatest Body Depth	
	PI	PII	PI	PII	PI	PII
Emerald shiner	6.49	8.40 (1.9)	4.16	5.16 (1.0)	0.80	0.86 (0.06)
Yellow perch	6.15	8.56 (2.4)	3.77	4.57 (0.8)	0.86	1.14 (0.28)
Johnny darter	5.94	7.00 (1.1)	3.02	3.75 (0.73)	0.68	0.82 (0.14)
Trpout-perch	6.48		3.39		0.70	

App. II Table 1. Morphometry of Dauphin Lake *Perca flavescens*, *Etheostoma nigrum*, and *Percopsis omiscomaycus* in the Pro, Post-I and II larval forms, (N=number, lengths in mm).

Species		Phase	Mean TL	Mean SDL	Mean LV	Mean GBD	Mean MxL	Mean IL	Mean GAPE
P. flavescens									
	N=1	Pro	6.15	0	3.50	0	0	0	0
	N=10	PI	7.22	7.03	3.77	0.86	0.74	2.56	0.61
		SD	(0.43)	(0.4)	(0.25)	(0.1)	(0.1)	(0.54)	(0.15)
	N=11	PII	8.56	8.34	4.57	1.14	1.04	2.58	0.54
			(0.96)	(0.94)	(0.52)	(0.23)	(0.02)	(0.29)	0
E. nigrum									
	N=5	Pro	5.1	0	0	0	0	0	0
			(0.42)						
	N=13	PI	5.94	5.73	3.02	0.68	0	0	0
			(0.53)	(0.53)	(0.33)	(0.08)			
	N=7	PII	7.00	6.78	3.75	0.82	0	0	0
			(0.49)	(0.49)	(0.43)	(0.12)			
P. omiscomaycus									
	N=17	Pro	6.10	0	0	0	0	0	0
			(0.77)						
	N=10	PI	6.48	6.35	3.39	0.70	0.63	2.41	0.54
			(0.34)	(0.38)	(0.22)	(0.06)	(0.09)	(0.73)	(0.08)
	N=0	PII							
	N=1	J	10.86	9.36	2.21	1.14	2.8	0	0

TL = total length
SDL = standard length
LV = length to vent
GBD = greatest body depth
MxL = maxilla length
IL = length of intestine

App II Table 2. Morphometry of Notropis atherinoides, in the Pro, Post-I and II larvae forms, (N = number of samples, lengths in mm).

Species	Phase	Mean TL	Mean SDL	Mean LV	Mean GBD	Mean MxL	Mean IL	Mean GAPE
N. atherinoides								
N=88	Pro	4.27 (0.51)	0	3.12 (0.34)	0.80 (0.13)	0	0	0
N=12	PI	6.49 (1.08)	6.21 (1.10)	4.16 (0.70)	0.72 (0.15)	0.22 (0.03)	3.60 (0.6)	0.56 (0.13)
N=19	PII	8.4 (0.95)	7.98 (0.67)	5.16 (0.55)	0.86 (0.13)	0.65 (0.15)	4.21 (0.37)	0.7 (0.07)

N=94	yolk	length width	= 2.77 (SD = 0.42) = 0.63 (SD = 0.15)
N=4	Oil globule	diameter	= 1.13 (SD = 0.65)

TL = total length
SDL = standard length
lv = length to vent
GBD = greatest body length
MxL = maxilla length
IL = length of intestine

AppII. Table 3. Summary of surface and bottom catch totals for each species in 1985. Appearance dates showing the dates of first and greatest abundance are indicated for each species.

	Numbers Caught			
	Surface	Bottom	First Appearance	Greatest Abundance
LP	95	225	May 16 *	May 16-24
LC	37	32	May 16	May 24
YP	418	412	May 24	June 6
WS	7	0	June 6	June 25
JD	126	63	June 6	June 11
TP	19	19	June 11	July 8
SHRH	0	1	June 11	June 11
SP	15	21	July 8	July 8
ES	169	645	July 8	July 11
ID	11	12	July 8	July 11

* 16-24 May, only 2 locations out of 21 were sampled.

SPECIES:

LP	logperch	LC	lake cisco	YP	yellow perch
WS	white sucker	JD	johnny darter	TP	trout-perch
SHRH	shorthead redhorse	SP	spottail shiner	ES	emerald shiner
ID	Iowa darter				

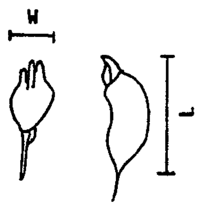
Appendix III

ZOOPLANKTON MORPHOLOGY

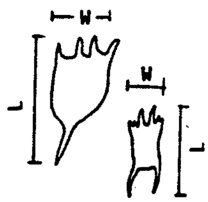
Diagrammatical presentation of the length (L) and width (W) measurements performed on zooplankton found in the digestive tracts of post-I and post-II larvae. Bars show from which view body measurements were taken. Copepoda and Cladocera drawn after Ward and Whipple (1959).

ROTIFERA

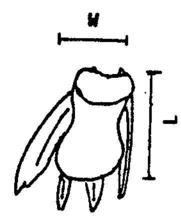
Ticohocerca sp. (Lamarck)



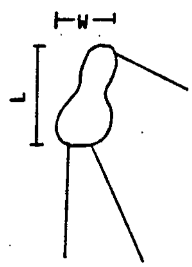
Keratella sp. (Bory de St. Vincent)



Polyarthra sp. (Ehrenberg)



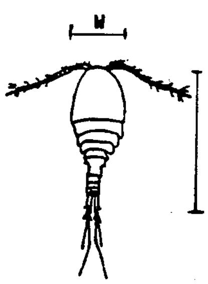
Filinia sp. (Bory de St. Vincent)



COPEPODA

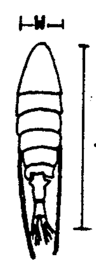
Cyclopidae

Cyclops bicuspidatus (Claus)

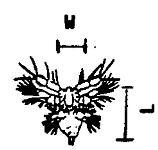


Diaptomidae

Diaptomus siciloides (Lilljebrg)

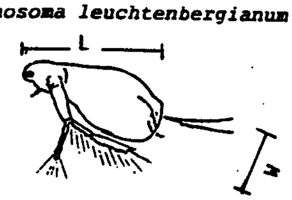


Nauplii

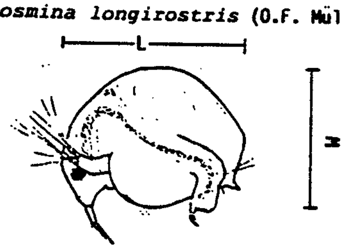


CLADOCERA

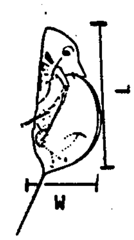
Diaphanosoma leuchtenbergianum (Fisher)



Bosmina longirostris (O.F. Müller)



Daphnia retrocurva (Forbes)



APPENDIX IV

DAUPHIN LAKE WATERSHED AND MORPHOLOGY

App IV. Table 1. Watershed area (Km^2) of each river within the Dauphin L. watershed originating primarily in the Riding Mountain escarpment to the southwest. The Valley R. is the one single river having the largest (40%) drainage area (Chapman 1987).

River	Watershed Area km^2	% of Drainage area
Turtle R.	2064	29
Ochre R.	344	5
Edwards Creek	311	4
Vermilion R.	432	6
Wilson R.	925	13
Valley R.	2870	40
Mink R.	274	4

The total watershed area = 7220 km^2

The Valley River in the north basin and the Turtle River in the south basin comprise 69% of the drainage area.

App IV. Table 2. The areas in Km^2 of each contour are presented for each sample location of Dauphin Lake. Areas were cut from the bathymeteric map (figure 7) and weighed to obtain their relative percentage contribution. A 10% distortion is possible, however, the weight relationship was assumed adequate to compare the relative area of each location and how well the lake was surveyed.

Location	% of Lake	Area Lake km^2	% Area of each depth contour < 1.5-01	1.5	2.5	>3.0
1	1.77	9.42	25.04	30.81	44.15	
2	1.42	7.82	35.04	28.30	36.66	
3	0.75	3.99	58.05	41.95		
4	0.96	5.11	50.43	49.57		
5	2.42	12.88	18.23	42.91	38.86	
6	3.13	16.66	22.40	29.72	47.88	
7	1.90	10.11	48.68	47.90	3.42	
8	1.91	10.11	29.66	55.44	14.90	
9	1.30	6.92	42.76	51.06	6.18	
10	1.47	7.82	21.30	67.89	10.80	
11	9.25	49.24		10.08	89.50	0.42
12	23.69	126.10		19.42	80.58	
13	0.85	4.52	52.37	47.63		
14	2.65	14.11	78.24	21.76		
15	1.95	10.38	42.28	57.72		
16	2.09	11.12	15.19	84.81		
17	3.40	18.10	25.73	74.27		
18	3.67	19.54	35.54	64.46		
19	1.45	7.72	16.38	83.62		
20	15.66	83.36		89.86	10.14	
21	18.26	97.20		95.66	4.34	

Dominant Features:

North Basin	266.24 km^2	Habitat A	26.34 km^2
South Basin	266.05 km^2	Habitat B	18.63 km^2
		Habitat C	131.42 km^2
Total	532.29 km^2	Habitat D	355.90 km^2