Ecology of the Emerald Shiner

Notropis atherinoides Rafinesque

in Dauphin Lake, Manitoba.

A Thesis Presented to

The Faculty of Graduate Studies

of

The University of Manitoba.

By

© PAUL R.H. SCHAAP

In partial fulfillment of requirements

for the degree of

Master of Science.

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ECOLOGY OF THE EMERALD SHINER <u>Notropis atherinoides</u> RAFINESQUE
IN DAUPHIN LAKE, MANITOBA

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ABSTRACT

The emerald shiner, <u>Notropis</u> <u>atherinoides</u> Rafinesque, is an important forage and bait fish in many lakes and rivers of North America, yet there is little information about this species. The emerald shiner dominated the forage fish assemblage of Dauphin Lake, Manitoba in 1984 and 1985 with peak offshore abundance estimates of >50,000 ha^{-1}, 12,000 ha^{-1} and 5,000 ha^{-1} for young-of-the-year, yearling and adults, respectively. Maximum inshore densities for the three same age groups were 17,000 ha^{-1}, 2,000 ha^{-1} and 9,000 ha^{-1}. Average whole-lake abundance of yearling and adult shiners during the summer was only 200-500 ha^{-1} in both years. Comparison of the abundance of 0+ age fish in one year with yearling abundance in the next year suggests significant overwinter mortality. The ages of Dauphin Lake emerald shiners (0+ to 4+ years) were determined using otoliths and scales. Overlapping length-frequency distributions necessitated the use of cumulative probability "Cassie" curves to separate cohorts for growth analysis. Shiner growth in Dauphin Lake was only 40-80% of growth reported for other shiner populations. Spawning in Dauphin Lake began in early July and continued through early to mid-August. Fish ranging from 56 to 81 mm in total length contained 384 to 3365 eggs, respectively. Egg diameters ranged widely within individual females. The prolonged spawning season of this species, together with the wide range in egg diameter observed within individual females suggested

that emerald shiners in Dauphin Lake are multiple spawners.
Feeding habits examined during periods of peak walleye fry
abundance indicate that emerald shiners may compete with
larvae by substantially reducing standing stocks of
zooplankton preferred by walleye fry. Emerald shiners were
opportunistic feeders, ingesting zooplankton, invertebrates,
aquatic insects and fish eggs, depending on their habitat.
Preference was demonstrated for daphnids and copepodids.
Emerald shiner distribution varied according to habitat
substrate, depth and the presence or absence of vegetation.
Water clarity affected the emerald shiners ability to avoid
capture by the sampling nets.

Emerald shiners fill an important ecological niche in
Dauphin Lake as an abundant and prolific source of forage,
inhabiting almost every available habitat. Growth and
age-at-sexual-maturity are retarded in the lake but are
compensated by multiple spawning and increased longevity.

ACKNOWLEDGEMENTS

Finally, I wish to express my sincerest thanks to my families in Manitoba and Ontario. Your encouragement and support is appreciated. I particularily wish to acknowledge the inexhaustible support and patience of my wife, Eugenie. To you I dedicate this thesis.

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INTRODUCTION

The emerald shiner, <u>Notropis atherinoides</u> Rafinesque, is a common minnow of many large lakes and rivers of North America. Its distribution has been examined on a continental scale (McPhail and Lindsey 1970, Scott and Crossman 1973, Lee et al. 1980) and regionally, by provincial and state government agencies (Hinks 1943, Brown 1971, Owen et al. 1981, Becker 1983, Smith 1985). It is widely distributed throughout Manitoba. Throughout its range the emerald shiner is an important forage source for game and panfishes. In many areas it is utilized for bait (eg. Hinks 1943, MacCrimmon 1956, Becker 1983, Lysack 1987) and sold fresh, frozen, salted or preserved.

Although the emerald shiner is an important component of fish assemblages in many inland waters, little is known of its ecology. Completed studies include emerald shiner taxonomy (Snelson 1968), life history (Flittner 1964, Fuchs 1967), food habits (Manny 1928, Siefert 1972, Mendelson 1975, Whittaker 1977), temperature tolerance (McCormick and Kleiner 1976) and biology (Gray 1942, Campbell and MacCrimmon 1970). Despite these examinations, ecological studies synthesizing biological parameters of the emerald shiner with its biological setting are lacking. The purpose of this study was to investigate ecological parameters of the emerald shiner in Dauphin Lake such as population density, growth rates, feeding habits and reproductive biology.

In 1981, a pilot project was initiated by the Canada

Department of Fisheries and Oceans under a cooperative
agreement with the Manitoba Department of Natural Resources
to assess the feasibility of rehabilitating the depleted
walleye[*] population of Dauphin Lake. The emerald shiner is
one of the most abundant species in the lake and an important
dietary component of walleye and other piscivorous species.
This study provides information on the life history of this
important forage species prior to the introduction of large
numbers of walleye planned for the rehabilitation of the
stock. Should the walleye population return to historic
levels through the enhancement program of the project, an
impact on the emerald shiner is expected.

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[*]Scientific names of all fish species referred to in the
text are given in Appendix 1.

METHODS AND MATERIALS

Description of the study area

Dauphin Lake, a shallow prairie lake located in west-central Manitoba (51°17'N, 99°48'W), is a remnant of glacial Lake Agassiz (Butler 1950). It has a surface area of 522 km^2 and a maximum and mean depth of 3.5 m and 2.1 m, respectively (Fig. 1). Maximum length of the lake is 42.4 km and maximum width is 19.5 km. The drainage area of 8,935 km^2 (Anon., Manitoba Dept. Mines, Res. 1971) is bordered on the west by the Duck Mountains, Riding Mountain on the south and on the east by a divide which separates the Lake Manitoba and Dauphin Lake catch basins. Water levels are regulated to approximately 260.5 metres above sea level by a control structure on the Mossy River, the only outflow of the lake, which flows north to Lake Winnipegosis. Six major rivers flow into the south and west sides of Dauphin Lake (Fig. 1).

Lake water chemistry has recently been summarized by Babaluk and Friesen (1988). Summer water temperatures and transparencies range from 15°C to 30°C and 14 to 55 cm, respectively (Schaap 1987). Offshore sediments are dominated by clayey-silt or silty-clay, river mouth sediments by sandy-silt and silty-sand and the north and east shore areas by a variety of substrates ranging from silt to rocks (Heise 1985). Sediment loading to the lake has increased dramatically in recent years due to land clearing, stream

Figure 1. Location and bathymetry of Dauphin Lake, Manitoba.

DAUPHIN LAKE

KILOMETRES

0 5 10

DEPTH CONTOURS IN METRES

N

MOSSY R.
MINK R.
VALLEY R.
WILSON R.
VERMILION R.
EDWARDS CR.
JACKFISH CR.
CROOKED CR.
OCHRE R.
KEROSENE CR.
TURTLE R.

2.5
1.5
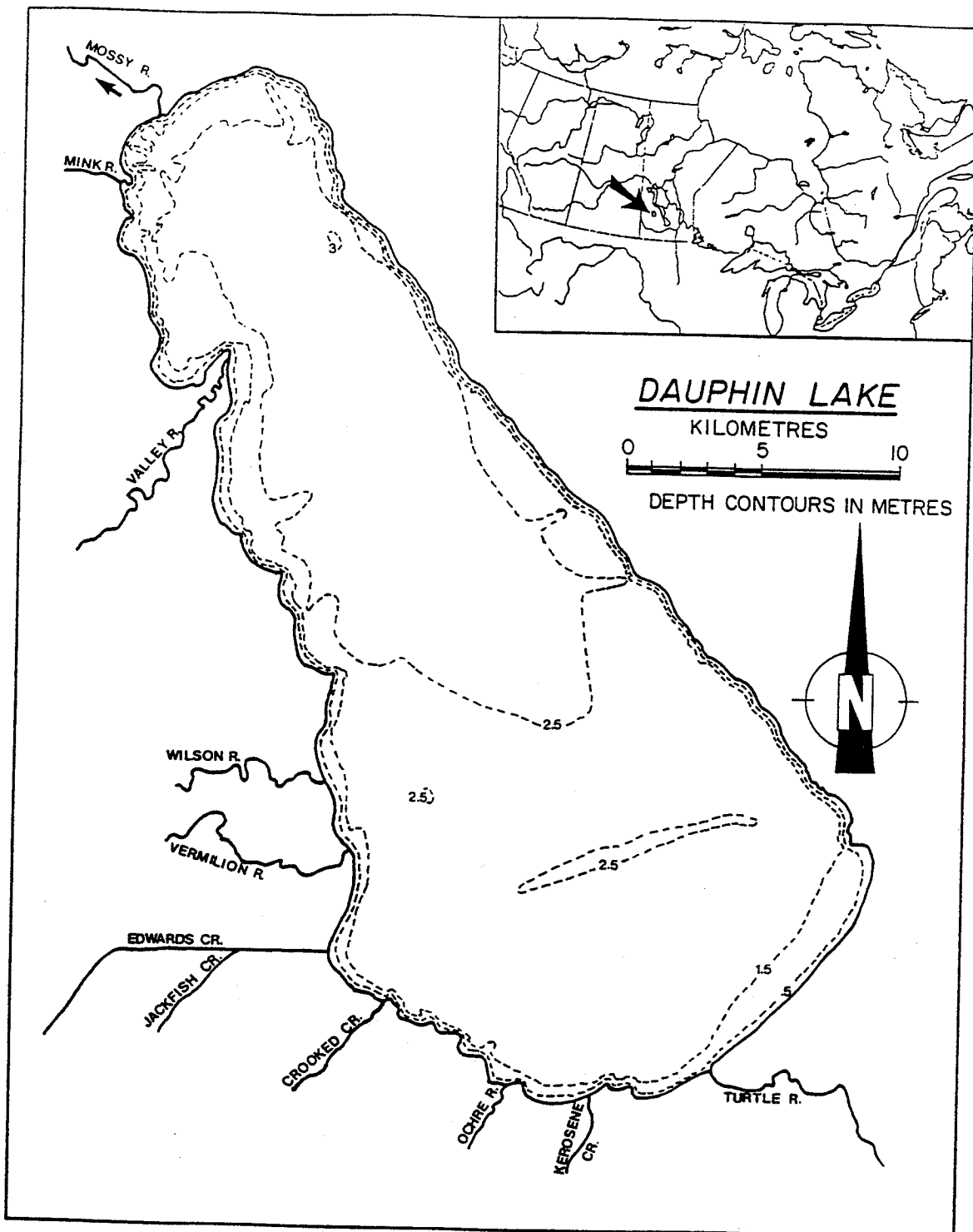
channelization and farming practices in the surrounding catch basin. Average sediment loading over a period of 31 years was estimated at 550,000 tons/year, of which 99% was believed to have been deposited in the south basin (Oshaway 1982).

The north-west orientation of the lake, the absence of sheltered bays or coves, and prevailing summer winds from the west result in continuous surface wave action, restricting the establishment of submergent vegetation. Small areas of Phragmites, Carex and Scirpus occur along the shoreline of the lake. Filamentous algae (Cladophora) is found along the lake margin and pondweed (Potomogeton) is limited to only a few areas in the southeast and northwest corners of the lake.

Collection techniques

Collections of emerald shiners were made at inshore and offshore areas of the lake. Inshore, the shiners were captured using an 18.3 m beach seine with bag. The seine depth was 1.2 m and mesh size was 3 mm, unstretched.

Offshore, emerald shiner collections were made with paired double "bongo" nets. Each bongo net consisted of an aluminum mouth-reducing cone and affixed Nitex™ net with mesh sizes of 300 or 500 u. The mouth area was 0.196 m^2. The conical nets decreased from a diameter of 0.50 m at the cone to a collection jar of 0.12 m diameter, over a 2.7 m length. During sample trawls, the closed collection jar created a "dead water" area which allowed the capture of live,

undamaged specimens. A calibrated General Oceanics®
flowmeter was fastened inside the mouth of one bongo net, and
was used to determine the volume of water filtered over the
standard 5 minute trawling period.

In 1984 the bongo nets were towed from a 5 cm X 25 cm
wooden frame mounted on the bow of a 6.7 m fiberglass yawl
(Fig. 2A). Both bongos were fished just below the water
surface. In 1985 a lighter aluminum pipe apparatus was
utilized (Fig. 2B), and one bongo was fished at the surface
while the other was fished with the net mouth 10 cm above the
lake bottom.

Shiners collected by both methods were preserved in 5%
formalin immediately upon capture, except those to be used
for age determination.

Age determination

Fish were aged using dorsal and pectoral fin-rays,
scales and sagittal otoliths removed from fresh or frozen
samples. Fin-rays were embedded in epoxy, and cross-sections
of varying thicknesses were made with a Buehler® Isomet low
speed saw. Otoliths provided the best results based on
annuli clarity and were chosen as the principal structure for
determining age.

The ages of 200 shiners collected in 1984 and 1985 were
aged by the otolith method. Otoliths were removed by
dissection. When dry, one surface was ground with a

Figure 2. Apparatus used for the collection of emerald shiners in Dauphin Lake in A. 1984 and B. 1985.

A.
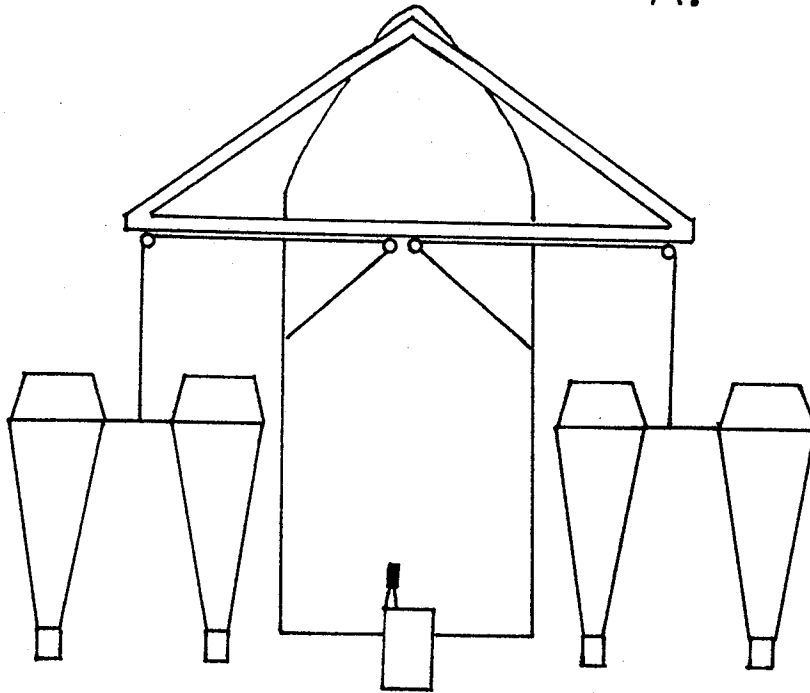
B.
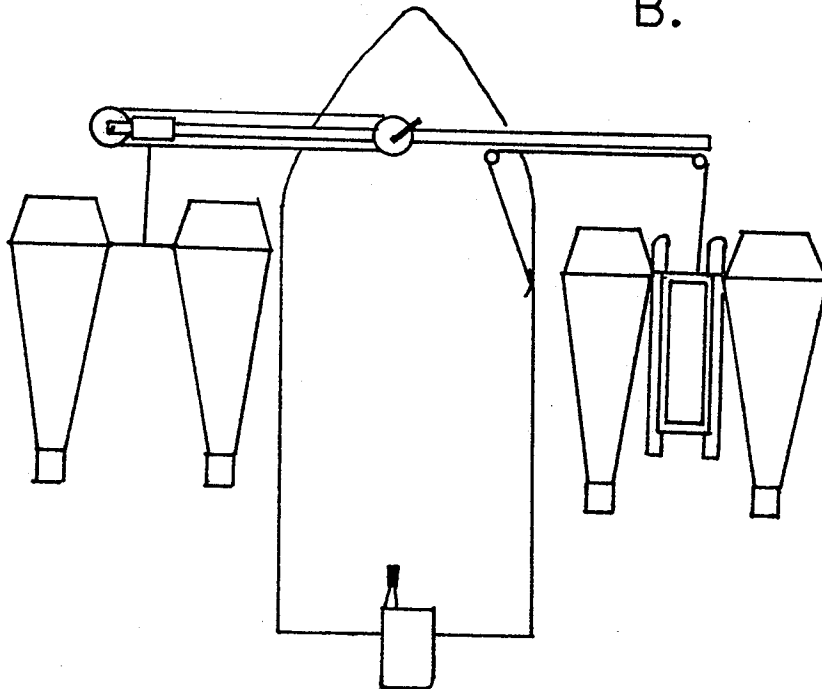
fine-grit sharpening stone to accentuate the appearance of growth rings. Otoliths were cleared with benzyl benzoate and opaque "growth" bands counted using a dissecting microscope, illuminated by reflected light. Otolith ages were determined by myself and J.A. Babaluk (Can. D.F.O., Freshwater Institute) without reference to the fish length or weight, or previously assigned age of any specimen. Some received a third reading from another colleague. Independently assigned ages were compared and discrepancies resolved by re-examination and discussion of ring characteristics. Otoliths were stored in a solution of equal parts glycerine and water.

Otolith length was measured along a longitudinal axis from the rostrum to the posterior base. Otolith width was measured at the narrowest axis (Fig. 3). One otolith of 102 and 99 emerald shiners was measured for length and width, respectively. Length and width measurements were made on paired otoliths from 65 and 61 shiners, respectively. Sample sizes varied because of broken structures. The relationships between otolith measurements with shiner total length were analyzed by linear regression, as was the relationship between otolith length and width. A comparison of paired measurements was also made using a t-test.

Posterolateral scales were removed from 30 fish and three successive scale readings were made for each fish to assess variability in age estimates. Because all specimens had been frozen together it was necessary to wash each fish, resulting in a loss of scales. Consequently I was unable to

Figure 3. Axes used to measure emerald shiner otolith length and width. L=length, W=width, I and II are first and second winter rings.
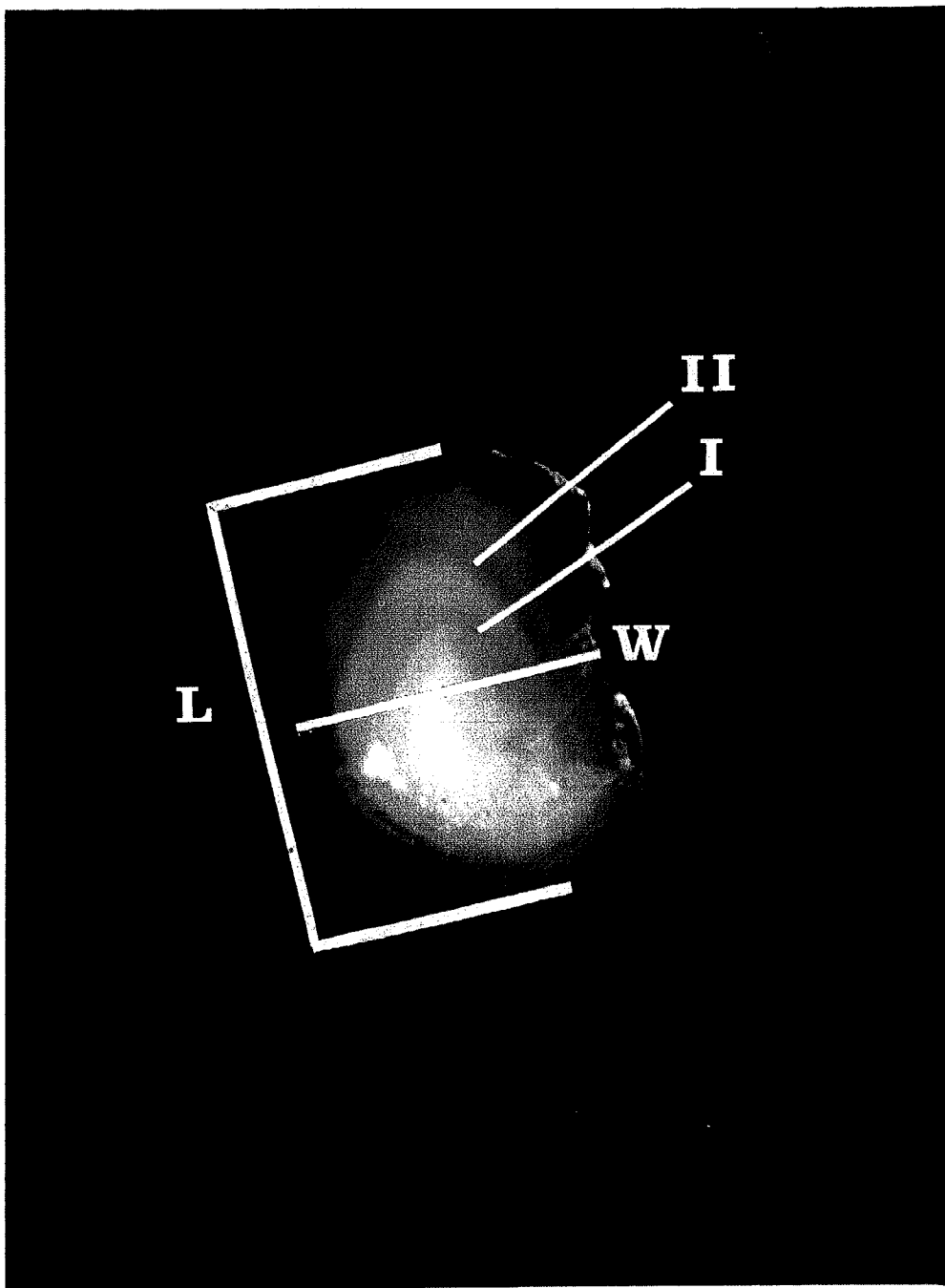
obtain scale samples from young-of-the-year fish. Ages were estimated without reference to fish measurements or previously assigned ages. Dry mounted scales were examined using a microfiche viewer. Discrepancies between any of the three readings resulted in a fourth examination and discussion of scale annuli with S.M. Harbicht (Can. D.F.O., Freshwater Institute). Final scale ages were assigned from the fourth reading and from fish having the same scale age through the first three readings. These ages were then compared to ages determined from otoliths of the same 30 specimens.

Growth

The growth of emerald shiners was estimated from fish captured in beach seines and bongo nets. Young-of-the-year (0+) and yearling (1+) shiners were easily distinguishable as discrete cohorts in both 1984 and 1985 because their length-frequency distributions did not overlap. Wet weights of individual fish were measured, and means and standard deviations calculated for each sampling date, for each cohort. Measurements of age 0+ and 1+ shiners were made on 1,382 and 235 fish in 1984 and 1,390 and 529 shiners in 1985. Growth rates of the 0+ and 1+ age groups were determined by regression analysis.

Adult shiner age groups (age 2+, 3+, and 4+) could not be distinguished from each other because of overlapping

length-frequency distributions. Therefore, the cumulative percentage distributions of length of these age groups was plotted, for each date, on probability paper (Harding 1949, Cassie 1954). Estimates of mean total length and standard deviation were obtained from probability graphs for each adult age group and sampling date. These statistics were translated into weight values using the weight-length relationship described later. Growth rates, determined by regression analysis, were computed using these data.

Weight-length relationship

Emerald shiners collected from beach seines were used to determine the relationship between preserved weight and preserved total length. Young-of-the-year shiners collected in trawls were included for the summer and fall seasons of both years to extend the range of lengths and weights used in the analysis. All measurements were made to the nearest mm (TL) and mg. The regressions of length on weight for 1984 and 1985 were compared by analysis of covariance. As the regressions were not statistically different, a single relationship was calculated from the combined 1984 and 1985 data.

Condition factor

The condition of young-of-the-year, yearling and adult emerald shiners collected in beach seines, was determined throughout the sampling seasons of 1984 and 1985 using the condition factor k:

$$k = 10^5(W/L^b)$$

where W = wet weight in mg

L = total length in mm

b = regression coefficient of the weight-length relationship for each age group (Bagenal 1978b).

Formalin preservative study

The effect of preservation in 5% formalin was measured to assess changes in emerald shiner length and weight over time. Twenty-three shiners were measured and weighed, fresh, to the nearest mm and mg, respectively. They were then transferred to numbered vials filled with 5% unbuffered formalin and measured again 13h, 24h, 48h and 125 weeks after preservation.

Fecundity and progression of reproductive maturity

The absolute fecundity of emerald shiners was measured

from samples collected in beach seines and hoop nets prior to the 1984 and 1985 spawning seasons. Fecundity estimates were made from emerald shiners captured on July 8 (5 fish), July 15 (45) and July 28 (2) in 1984, and June 19 (11), July 2 (5), July 3 (6) and July 4 (39) in 1985. Preserved and frozen emerald shiners were measured to the nearest mm and the ovaries dissected and stored in Gilson's solution (Simpson 1951 in Bagenal 1978a) for a minimum of 24 hours. The preserved ovaries were held in a 315 u Nitex™ seive and gently washed with water to remove connective tissue. Absolute fecundity was determined by direct enumeration of all eggs except very small, clear second generation oocytes. Stages of egg maturity were characterized using the observations of Campbell and MacCrimmon (1970). Regression analysis was used to describe the relationship between fecundity and female body weight. Covariance analysis was used to compare fecundity between years.

Egg diameters were measured using an ocular micrometer, from a random sample of the eggs of 52 shiners. Fish used in the analysis were all collected on July 15 in 1984 (15 fish) and on June 19 (9), July 2 (5), July 3 (6) and July 4 (17) in 1985. Total lengths of shiners used in the analysis ranged from 56-90 mm in 1984 and 56-82 mm in 1985. Average egg diameter was regressed on the length and weight of the female from which eggs were taken. The mean egg diameters of 1984 and 1985 were compared.

The progression of reproductive maturity was assessed in 1985 by examining 954 emerald shiners collected from inshore

waters between July 4 and August 7. Over 90% of the shiners collected were considered spent when this study was terminated. The classification of gonad condition followed that of Kestevan (1960). The sex ratio was determined from the 954 shiners examined.

Feeding

The stomach contents of emerald shiners collected from offshore (open water and river mouths) and inshore locations were examined. Offshore collections were made by bongo net trawls in which larval fish were abundant (June 6 and June 11, 1985). Concurrent horizontal zooplankton tows, using a 73 u Nitex™ mesh plankton net with a mouth diameter of 25 cm, were made to characterize the zooplankton community where fish were collected. Inshore fish collections were made by beach seine on June 19, 1985. All fish were preserved immediately in 5% formalin. Each fish was measured to the nearest mm (TL) and grouped as yearling or adult (>= 2+).

The entire alimentary canal was removed from each fish but only the stomach loop was examined, excluding semi-digested material. The stomach loop was opened, transferred to 70% ethanol and stained with Rose Bengal for at least 24 hours. The contents of each stomach was then collected on a 26 u mesh seive and placed in a 1 ml Sedgwick-Rafter counting cell. The number of each category of food item was determined using a compound microscope.

Copepods were categorized as adult, immature (copepodid) or nauplii; cladocerans as daphnids, bosminids or others; and rotifers to order. Frequencies of occurrence of each item were computed and expressed as percentages.

Prey preference was determined by comparing percent frequency of occurrence of food items in shiner stomachs with percent frequency of occurrence of plankton in the lake and Chesson's (1983) equation of electivity. Prey preference (a_i) was defined as the preference for one food type, relative to the average preference of all other food types and calculated as:

$$(a_i/(a_i + \Sigma_{j \neq i}\ a_j/(m - 1)))\ X\ 2 - 1$$

where i = the number of food types (eg 1, 2, ..., m)
The index ranges from +1 to -1, with 0 indicating no preference, and unlike other electivity indices, is independent of food density.

Estimates of abundance

The abundance of emerald shiners in Dauphin Lake was estimated during the open-water seasons of 1984 and 1985. Inshore and offshore collections were alternated weekly. Prior to the initial sampling of 1984, the offshore area of the lake was partitioned into twenty-one areas including open-water areas, river mouth areas, and shorelines without river mouths (Fig. 4). Eight inshore seining stations were also selected using substrate type, shoreline slope and

Figure 4. Offshore trawl (1-21) and inshore seine (A-H) sampling locations used for the collection of emerald shiners at Dauphin Lake, Manitoba in 1984 and 1985.

DAUPHIN LAKE
KILOMETRES
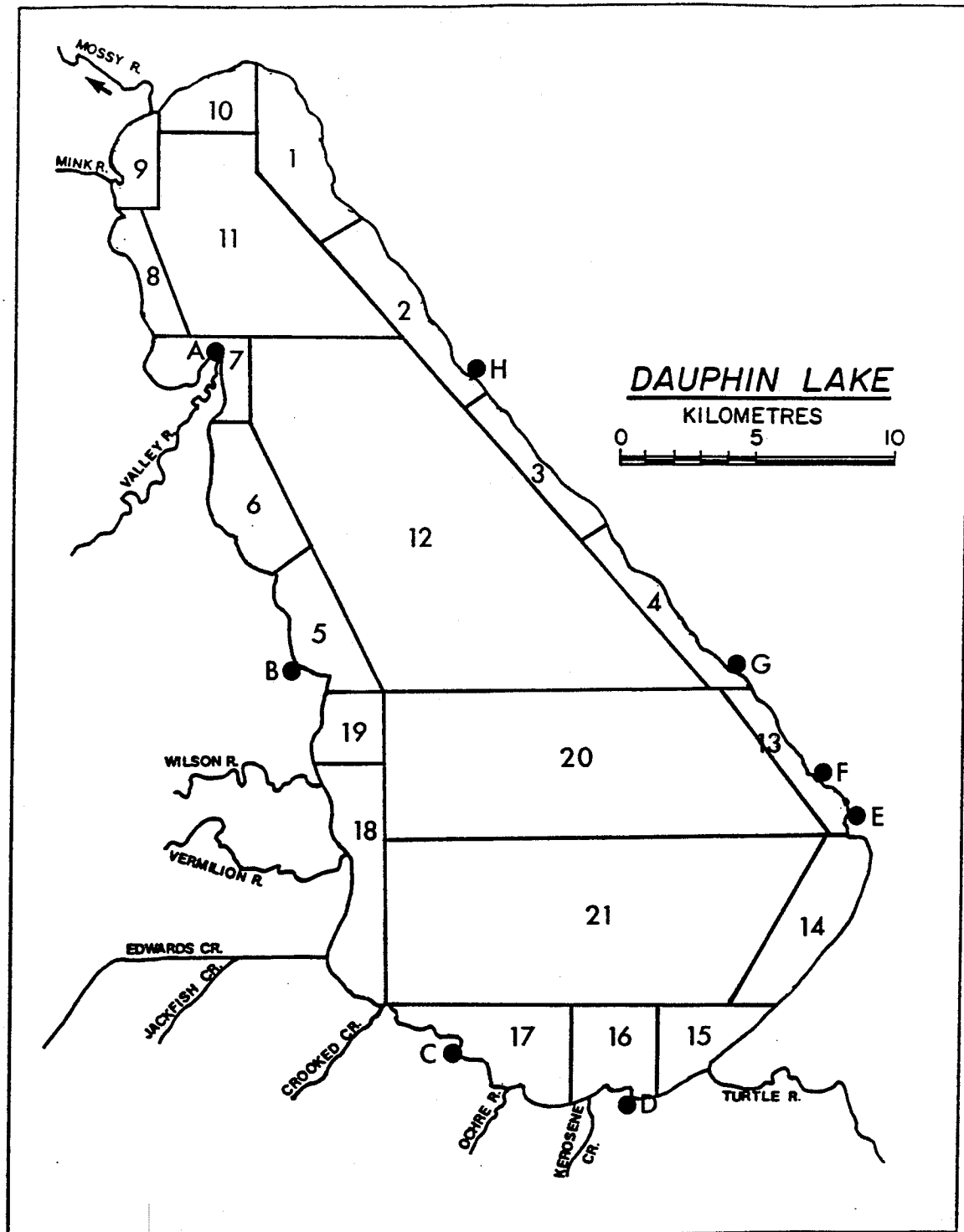
location on the lake as criteria (Table 1).

Offshore sampling

Offshore sampling using double bongo nets, commenced on June 3 in 1984 and every two weeks thereafter, until August 12. Effort was increased in June when larval walleyes were present. In 1985, offshore sampling commenced on June 11 and continued every two weeks until August 22. Autumn samples were collected on September 28 from one location.

Each trawl consisted of one 5 minute tow of four 0.5 m diameter nets per location. On each sampling date, a single trawl was made in each of the 21 sampling locations, requiring two days to complete. Meteorological conditions, secchi depth, air temperature and surface water temperatures were recorded during each tow.

Inshore sampling

Beach seining began in mid-July of 1984 and continued biweekly through to August 29. Autumn samples were collected on September 29 and 30. In 1985, seining commenced on May 27 and was terminated on August 27. Autumn samples were collected on September 27, 1985.

Two collections were made at each location. Standard seine hauls consisted of setting the net perpendicular to the shoreline, then walking the offshore end in an arc to a marker measured 10 m along the shore from the starting point. In this way the surface area sampled was standardized and by

Table 1. Characteristics of seining stations for emerald shiners on Dauphin Lake, Manitoba.

Station	Location	Substrate	Depth at Offshore end of seine	Vegetation
A	Valley River	sandy-silt	0.75 m	absent
B	Stoney Point	gravel, sand	1.25 m	absent
C	Crescent Cove	sand, pebble	0.50 m	absent
D	Welcome Beach	pebble, sand	1.00 m	present
E	Methley Beach	rock, gravel	0.50 m	absent
F	Pelican Cove	sand, gravel	0.50 m	present
G	Christenson Beach	sand	1.25 m	absent
H	Long Point	rock, pebble	1.00 m	absent

assuming a constant slope to the recorded depth at the offshore end of the seine, an estimate of the volume of water filtered was calculated. All fish collected were preserved in 5% formalin except recreationally valuable species which were released after their fresh weight was estimated.

Statistical analysis

Inshore and offshore collections of emerald shiners were treated as separate strata in the calculation of whole-lake population estimates. The inshore stratum was defined as the surface area within the 1.5 m contour, and the offshore stratum constituted the remaining surface area of the lake. Areas were calculated from Figure 1 using a Calcomp™ digitizer. Offshore and inshore areas represented 88.8% and 11.2% of the total lake surface, respectively. Average densities within each stratum were compared by examining the degree of overlap of 95% confidence limits.

Offshore emerald shiner catches were analyzed using the following steps:

a) Mean catch per trawl was calculated from the catch of the four nets towed, and divided by the number of cubic meters of water passing through a single net during the trawl, to yield the average fish density per trawl ($No./m^3$).

b) Fish density per trawl was then scaled by multiplying by 60, the average number of cubic meters of water filtered by a net during a trawl.

c) The average catch per sampling date was then calculated by averaging the mean trawl densities of the 21 sampling stations.

d) The scaled trawl densities were then transformed by log(x+1) as recommended by Elliot (1983) for small samples from contagious distributions because variance and means were correlated.

e) The mean fish density per sampling date, and 95% confidence limits, were calculated on transformed data, and then converted to estimates of the number of fish per hectare for the offshore station.

Analysis of inshore sampling using seines followed a similar procedure.

a) The mean catch per station was derived from catches from paired seine hauls.

b) Mean catch was scaled to the number of fish per 200 m^3.

c) The average inshore catch per sampling date was then calculated by averaging the eight station means.

d) As the variances and means of these data were also correlated, the scaled data were transformed and confidence limits and grand means calculated.

e) The transformed data were then converted to estimates of the number of fish per hectare for the inshore stratum.

Offshore collections of emerald shiners were plotted on maps according to location for each sampling date to assist in the examination of their distribution in the lake.

Isopleths were drawn depicting areas containing greater than 60%, between 30-60%, and less than 30% of the maximum trawl density collected on that date. The degree of contagion of emerald shiners was caluclated from the trawl densities on each sampling date as the ratio of the variance to the mean trawl density. Because the ratio is strongly influenced by sample size (Elliot 1983), it was expressed as the percent of maximum contagion. Maximum contagion was calculated for each date as εx = sample size X mean density. Contagion values were used to assist in the analysis and interpretation of emerald shiner distribution and density.

Whole-lake estimates of abundance were calculated from trawl and seine means scaled to number per 60 m^3 and transformed by log(x+1). Strata means were weighted according to the area of each stratum, summed and converted to estimates of the number of fish per hectare. Sample variance of the stratified means was calculated from the equation in Siniff and Skoog (1964) and used to determine 95% confidence limits of the whole-lake means.

RESULTS

Age, growth and condition

Determination of the age of emerald shiners using dorsal and pectoral fin-rays required long hours of careful preparation, and yielded poor results. Because the fin-rays were soft and small, difficulty occurred during the embedding and thin-sectioning processes. Sections were of poor quality and annuli were not easily distinguished. This method was therefore abandoned.

The annuli of emerald shiner otoliths, on the other hand, were quite easily distinguished and up to 4 winter checks (age 4+) could be counted. The clarity of annuli in otoliths was highest within the first few days following storage in the glycerine-water solution, and declined progressively over 6-8 months. It is recommended that an alternative solution be used for storing emerald shiner otoliths.

Emerald shiner otoliths ranged in length from 0.40-1.23 mm and 0.30-0.78 mm in width. Otolith length was positively correlated with otolith width, and both were correlated with shiner total length. Regression statistics for the three relationships were:

$$lnOW = -0.41 + 0.84\ lnOL\ (r^2 = 0.91)$$

$$lnOL = -4.25 + 1.01 lnTL\ (r^2 = 0.84)$$

$$and\ lnOW = -4.03 + 0.86\ lnTL\ (r^2 = 0.80)$$

where OW=otolith width

OL=otolith length

and TL=shiner total length.

Measurements of length and width did not differ significantly between left and right otoliths when total fish length was used as a co-variate (P=0.319).

Determination of emerald shiner age using scales was not precise. Second scale readings matched only 60% of the first readings. Third scale readings matched 66% of the first readings. Only 40% of the three readings provided the same estimate of age (Table 2). Final scale ages assigned by several re-readings and consultation with a second reader agreed with ages assigned by otoliths only 83% of the time.

Ageing attempted by the length frequency method was only successful for identifying age 0 and age 1 emerald shiners. The length frequency distributions of yearling fish overlapped on several dates in late summer and early fall. When these ages overlapped, the method of Cassie (1954) was employed to determine the maximum length of yearlings. Age determinations could be validated by length-frequency analysis (Ricker 1975) for only these two year classes of emerald shiners.

Young-of-the-year emerald shiners were first collected from Dauphin Lake at a total length of 6.0 mm. Based on the estimates of Flittner (1964) this corresponds to an age of approximately 48 hours old. By late September, young-of-the-year shiners had grown to 27.6 +/- 0.5 mm (mean

Table 2. Variability of three successive scale age
determinations from Dauphin Lake emerald shiners.

S C A L E		R E A D I N G		Final Scale Age	Otolith Age
First	Second	Third	Fourth		
1	1	2	2	2	2
2	2	2	–	2	2
3	3	3	–	3	3
3	3	3	–	3	3
3	2	3	3	③	2
3	2	3	3	3	3
2	1	3	2	2	2
3	2	3	3	3	3
2	2	3	2	2	2
3	2	3	2	2	2
4	3	4	3	3	3
3	2	2	2	2	2
4	4	4	–	4	4
2	2	3	3	3	3
3	3	3	–	③	2
3	2	2	2	2	2
3	3	3	–	3	3
4	3	3	3	3	3
3	4	3	3	3	3
3	3	2	2	②	3
4	4	4	–	④	3
2	2	2	–	2	2
2	2	2	–	2	2
1	2	1	1	1	1
1	1	1	–	1	1
1	1	1	–	1	1
2	3	2	2	②	3
3	3	2	2	2	2
1	1	1	–	1	1
2	2	3	2	2	2

NOTE: Circled data indicate assigned scale ages which
differ from assigned otolith ages.

+/- 95% CL) and 21.5 +/- 0.3 mm in 1984 and 1985,

respectively. Corresponding mean weights were 142.5 +/- 7.4

mg (mean +/- 95% CL) and 68.8 +/- 3.4 mg. Wide confidence

limits around the mean weight of shiners collected on July 6,

1984 were the result of a very small sample size.

Young-of-the-year emerald shiners grew from 1.4 mg to 119.0

mg and 1.1 mg to 55.9 mg between July 10 and the end of

September in 1984 and 1985, respectively. During this time,

growth could be defined over three distinct growth periods

(Fig. 5). Table 3 summarizes young-of-the-year growth rates

and their comparison by covariance analysis. Instantaneous

growth rates for the first two growth periods were

significantly higher in 1984 ($P<0.05$) than in 1985.

Yearling shiners entered their second summer at a mean

total length of 32.2 +/- 1.0 mm (mean +/- 95% CL, May 15,

1985) and a mean weight of 155.5 +/- 17.0 mg. By late

September yearling shiners averaged 47.5 +/- 1.0 mm in 1984

and 46.5 +/- 0.7 mm in 1985. Corresponding mean weights were

692.1 +/- 54.7 mg and 642.7 +/- 60.6 mg.

Three distinct periods of growth could also be

distinguished for yearling emerald shiners in 1985 (Fig. 6).

Incomplete data of 1984 prevented a comparison with the 1985

growth, although the pattern was similar after mid-July.

Table 4 summarizes growth rates for 1984 and 1985 yearling

shiners and includes a comparison of the growth rate for the

final period.

Emerald shiners aged 2+ and 3+ grew marginally in both

years (Fig. 7A, 7B). In 1984, age 3+ shiners were an

Figure 5. Young-of-the-year emerald shiner growth in Dauphin

Lake, Manitoba, 1984 and 1985. Vertical bars

indicate 95% C.L.. Numbers are sample sizes.
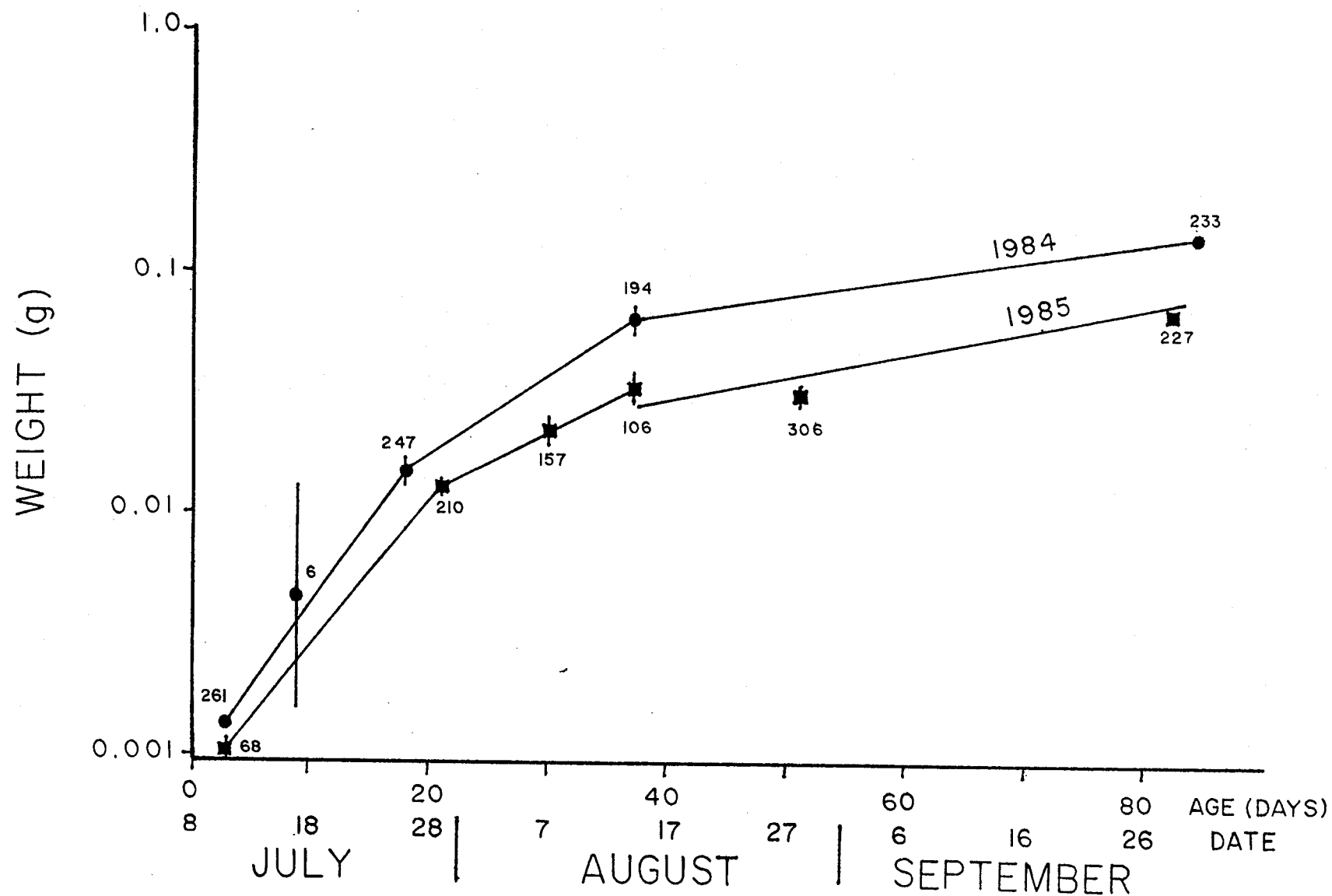
Table 3. Instantaneous growth rates for young-of-the-year emerald shiners in 1984 and 1985 and their statistical comparison using analysis of covariance.

Growth Period		Instantaneous growth rate (%/day)	Statistical probability (p) of similarity	r^2
First	1984	0.164	0.000**	0.76
	1985	0.141		0.80
Second	1984	0.076	0.025*	0.44
	1985	0.060		0.22
Third	1984	0.017	$0.102^{n.s.}$	0.34
	1985	0.020		0.20

Figure 6.   Yearling emerald shiner growth in Dauphin Lake,

Manitoba, 1984 and 1985.   Vertical bars indicate

95% C.L..
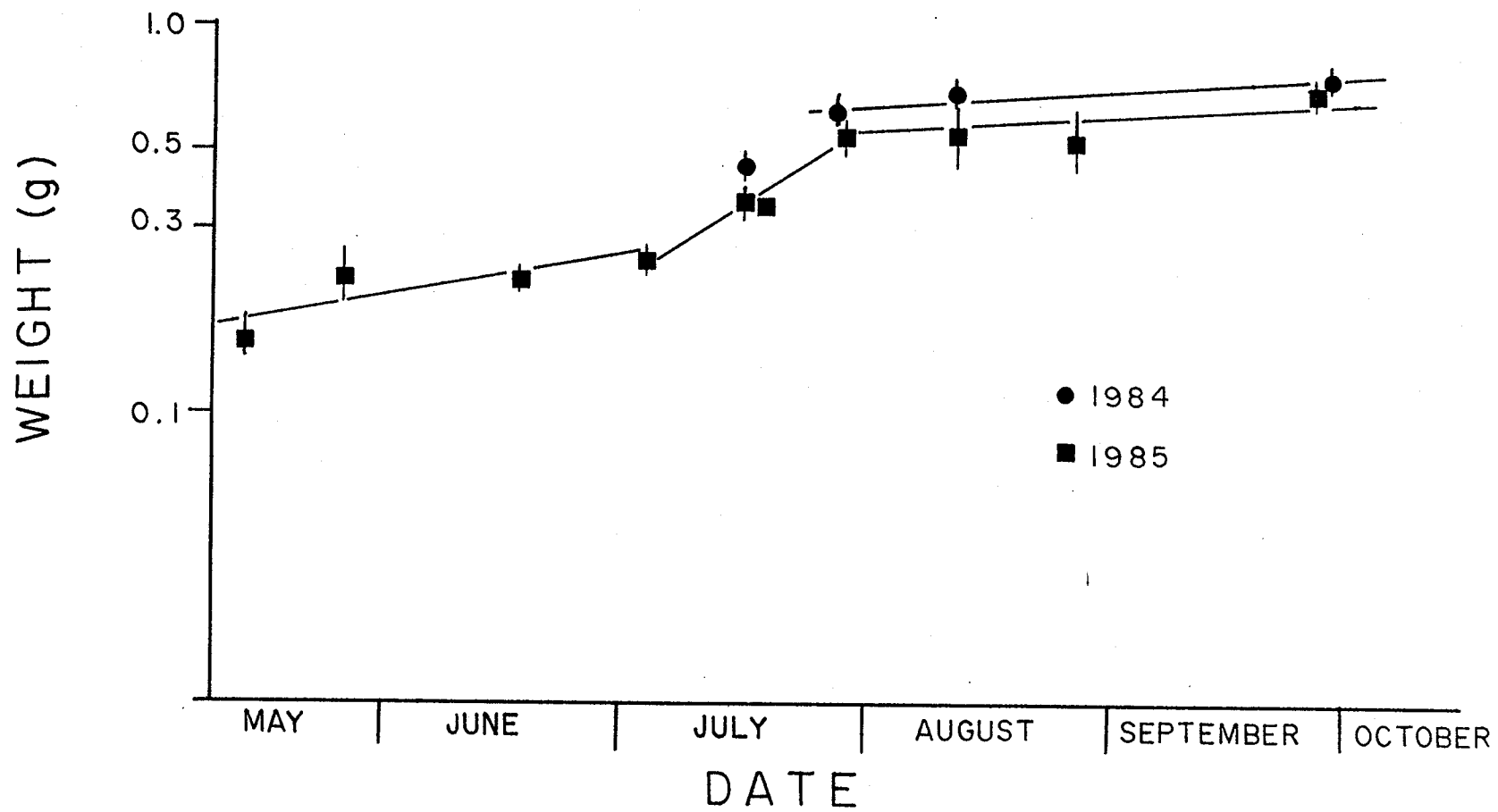
Table 4. Instantaneous growth rates for yearling emerald shiners in 1984 and 1985 and their statistical comparison using analysis of covariance.

Growth Period		Instantaneous growth rate (%/day)	Statistical probability (p) of similarity	r^2
First	1985	0.008		0.15
Second	1985	0.027		0.41
Third	1984	0.003	0.005*	0.86
	1985	0.004		0.67

Figure 7. "Adult" emerald shiner growth in Dauphin Lake,
Manitoba, A. 1984 and B. 1985. Vertical bars
indicate 95% C.L.. NOTE: Circled data not
included in regression.
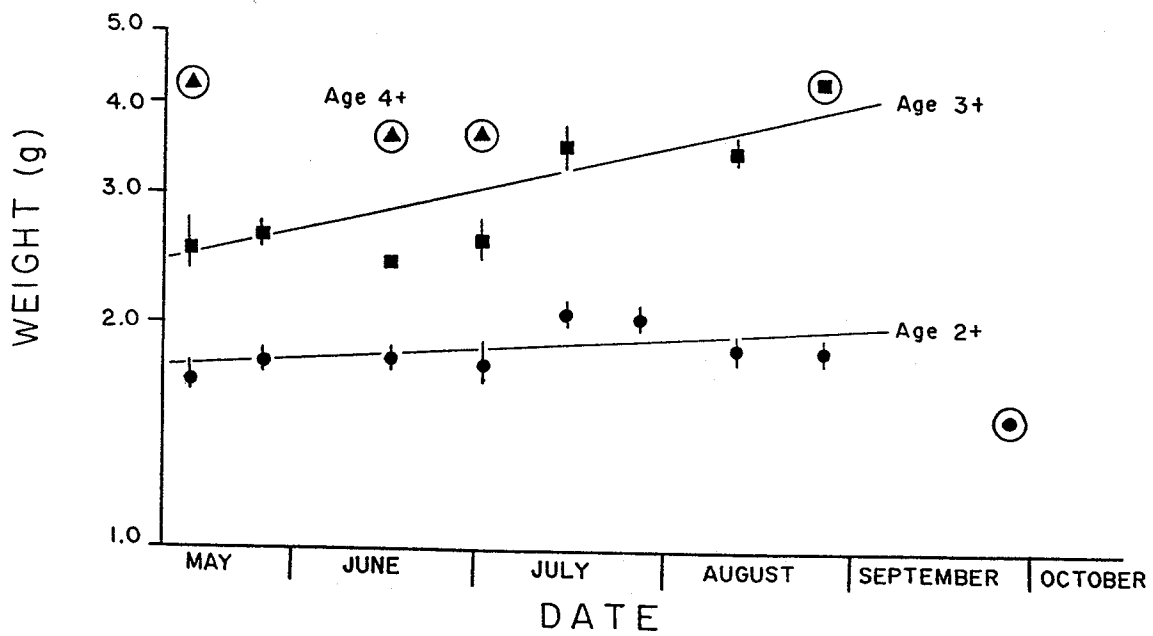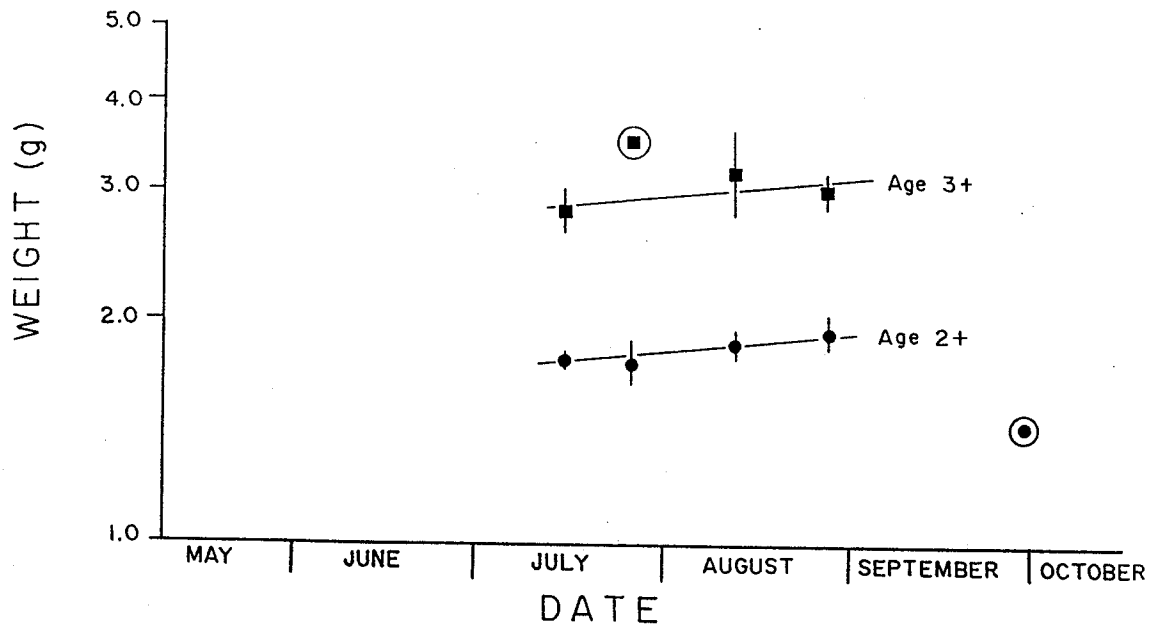
average of 1 g larger than age 2+ fish on the first date of measurement. By the end of August, 3+ shiners remained over 1 g heavier. In early 1985, the average weight of age 3+ shiners was 0.85 g heavier than the mean weight of 2+ shiners but by August 13, had increased to more than 1.5 g heavier than that of the 2+ age group.

Growth differences within shiner age groups in 1984 and 1985 were minimal. Confidence limits of the mean weights overlapped on similar dates of the two years. Only on July 16 did 1985 mean weights of both age groups significantly exceed ($P<0.05$) 1984 mean weights. Instantaneous growth rates of these age groups are summarized in Table 5. Higher growth rates of age 3+ shiners than 2+ shiners are presumably due to the imprecise analysis of the Cassie curves, and are not considered to be biologically important.

Sample sizes of 4+ shiners were very small (maximum of 5) and growth rates were therefore not calculated. Circled points on the growth figures indicate dates of insufficient sample sizes.

A calculation of size-at-age of adult shiners, using otoliths revealed that females were larger than males by age 2 (Fig. 8). Significant growth occurs throughout the lifetime of females while male growth after 2 years appears almost negligible. Female shiners aged 4+ were almost 13 mm larger than 2+ females on average whereas males aged 4+ averaged only 2.3 mm larger than 2+ males.

Table 5. Instantaneous growth rates for "adult" emerald shiners in 1984 and 1985 separated using Cassie curves.

		Instantaneous growth rate (%/day)	r^2
Age 2	1984	0.001	0.89
	1985	0.001	0.23
Age 3	1984	0.002	0.42
	1985	0.003	0.60

Figure 8.   Comparison of emerald shiner length-at-age.

Vertical bars indicate 95% C.L..
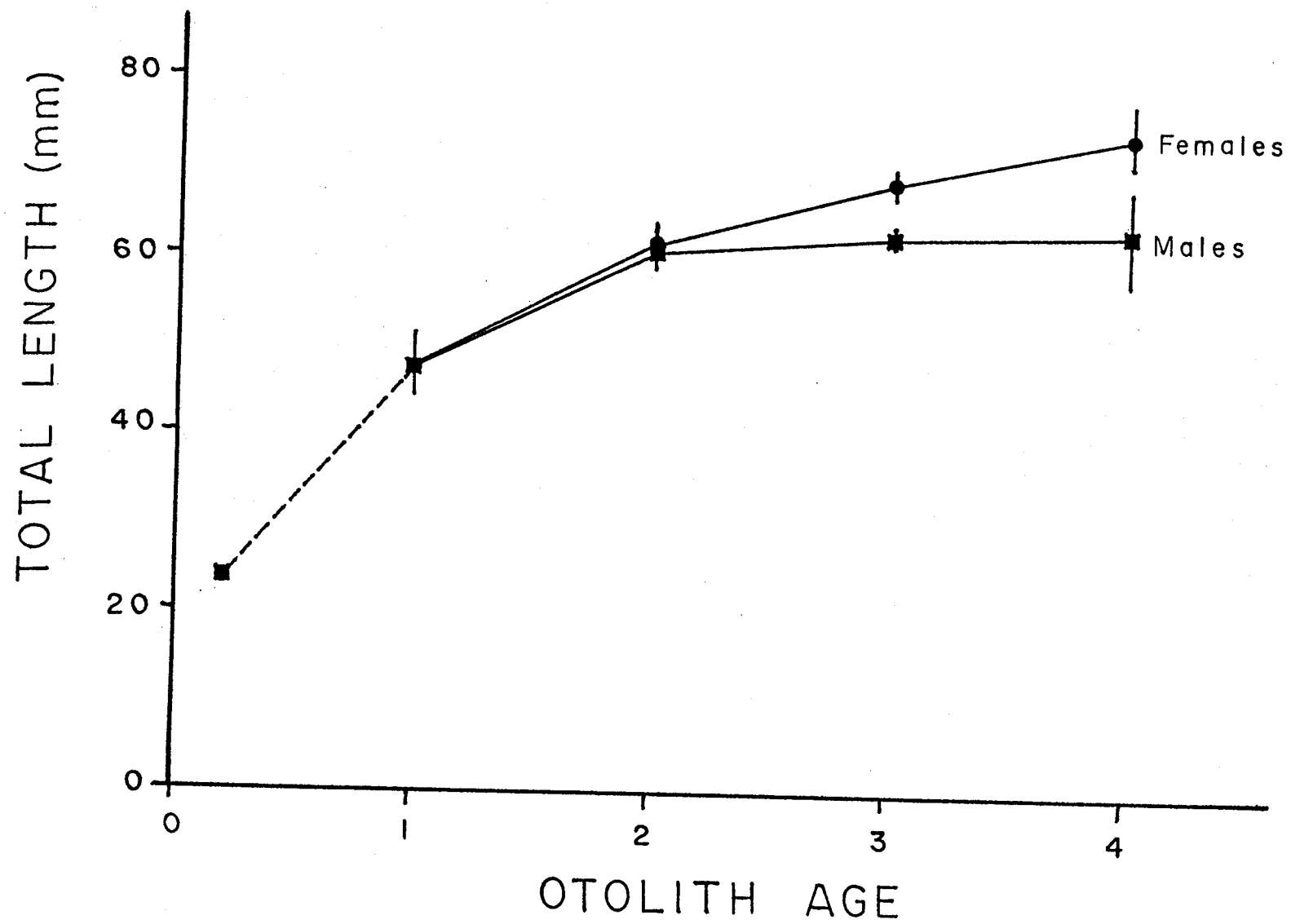
Regression equations of log weight against log total length calculated for fish collected in 1984 and 1985 had slopes and y-intercepts that were not statistically different. Data from the two years was therefore combined to provide the following relationship:

$$LogW = -5.377 + 3.114 LogL \quad (r^2 = 0.99, \ n = 5,293)$$

where W=wet weight (g) and L=total length (mm).

The mean condition factor (k) of young-of-the-year emerald shiners ranged from 0.31-0.36 and 0.23-0.30 in 1984 and 1985, respectively (Fig. 9). Mean condition in 1984 was significantly greater than 1985 ($p < 0.05$) throughout the summer. Young-of-the-year condition was highest at hatch and in late September of both years.

Seasonal progression of the condition factor for yearling and adult emerald shiners was complete only for 1985 as spring, 1984 samples were inadvertently discarded. In 1985, yearling mean condition factor increased from 0.16 in May to a maximum of 0.23 in earling July, then decreased marginally to 0.21 in September (Fig. 10). Mean condition factor of yearling emerald shiners in 1984 was nearly four times greater than condition factor of 1985 yearlings. Mean condition factor of these fish remained constant at 0.88-0.90 throughout the period of study. The condition factor of young-of-the-year emerald shiners decreased from 0.35 in autumn, 1984 to 0.17 by the following spring (yearling, 1985).

Mean condition factor of adult emerald shiners increased

Figure 9.   Mean condition factor (k) of young-of-the-year

emerald shiners in Dauphin Lake, Manitoba, 1984

and 1985.   Vertical bars indicate 95% C.L.
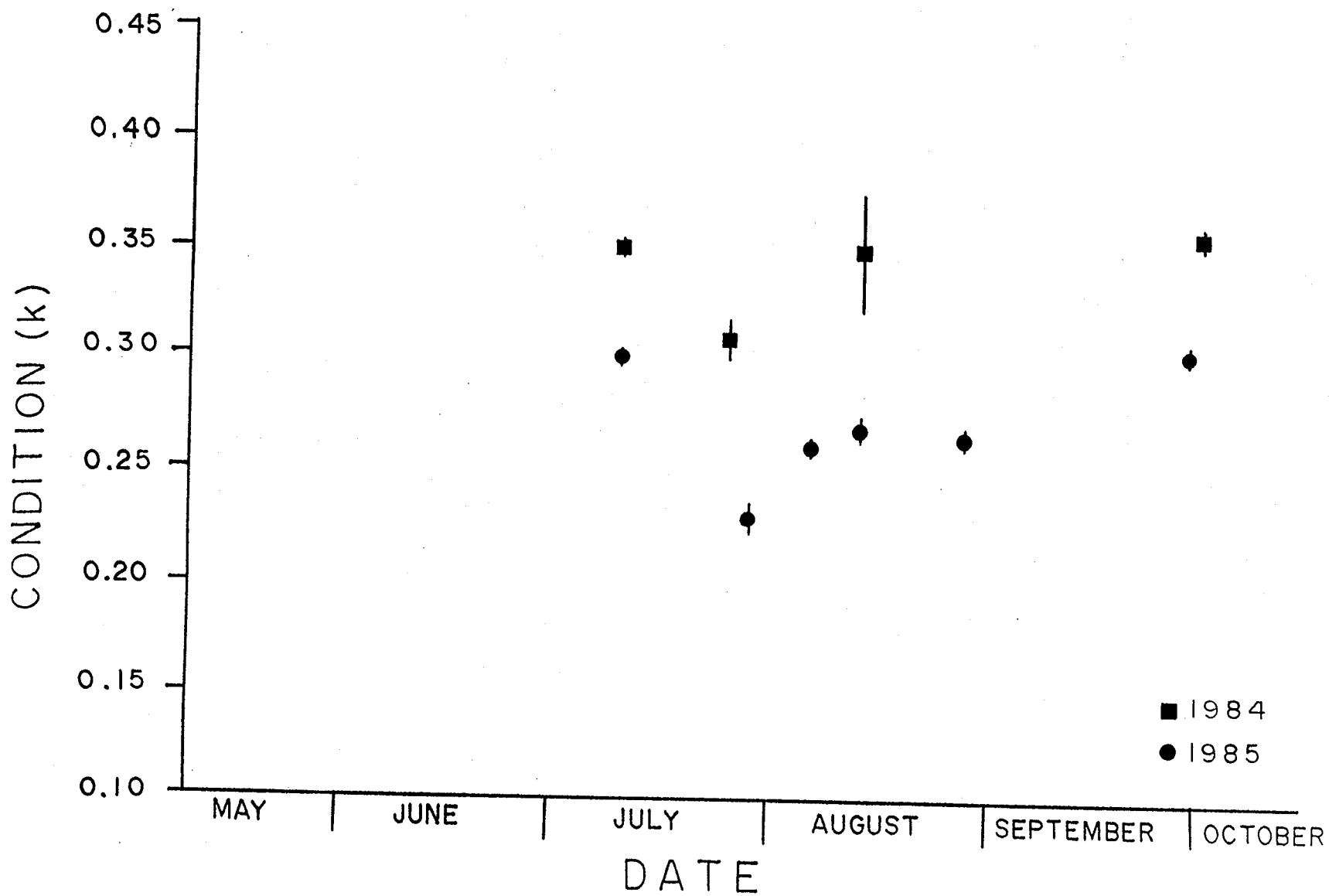
Figure 10. Mean condition factor (k) of yearling emerald
shiners in Dauphin Lake, Manitoba, 1984 and 1985.
Vertical bars indicate 95% C.L..
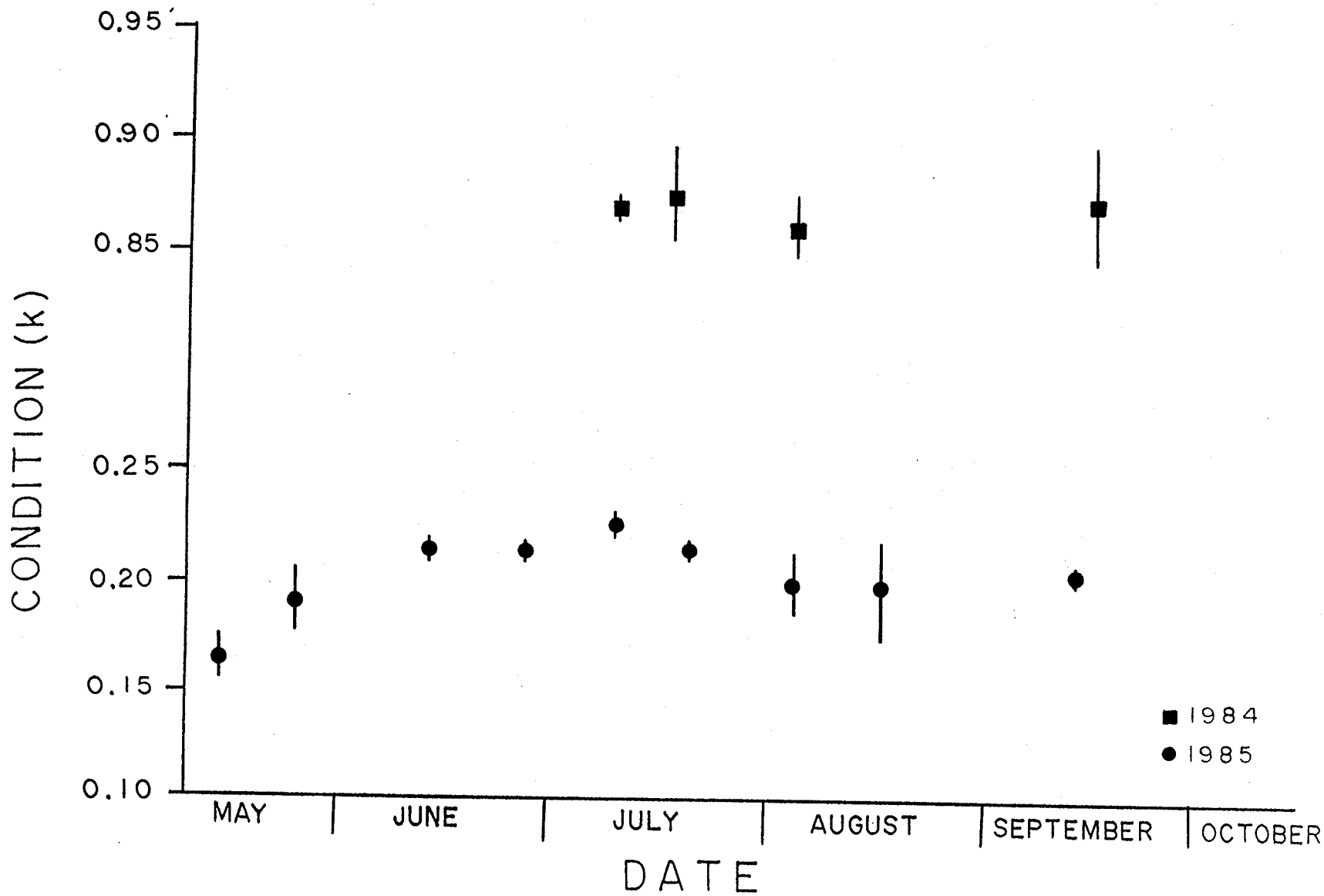
progressively throughout late May and June in 1985 (Fig. 11).
Peak condition factor was measured in early to mid-July of
both years. In 1984, adult shiner condition was
significantly lower (p<0.05) than 1985 condition in early
July and late September. In both years adult condition
declined gradually following July maxima. Mean condition
factor of yearling shiners in the fall of 1984 decreased from
0.87 to 0.65 by the following spring (adult, 1985). Adult
shiner condition factor in late September, 1985 was similar
to the mid-June measurement of the same year.

Preserved emerald shiners increased in weight rapidly
over their first 48 hours in 5% formalin (Fig. 12). The
average measured increase after 125 weeks was 3.47%. Total
length measurements decreased slightly following
preservation. An average decrease of 3.45% was measured
after 125 weeks. The percentage change in weight and total
length were assumed to have stabilized after 125 weeks and
therefore could be considered correction factors for length
and weight of preserved emerald shiners. Correction factors
were not applied to emerald shiners of this study.

Fecundity and reproductive maturity

The number of eggs carried by female emerald shiners
varied from 400 eggs in a 1.0 g fish, to about 3600 eggs in a
5.5 g fish. Emerald shiner fecundity could be described by

Figure 11. Mean condition factor (k) of adult emerald shiners in Dauphin Lake, Manitoba, 1984 and 1985. Vertical bars indicate 95% C.L..
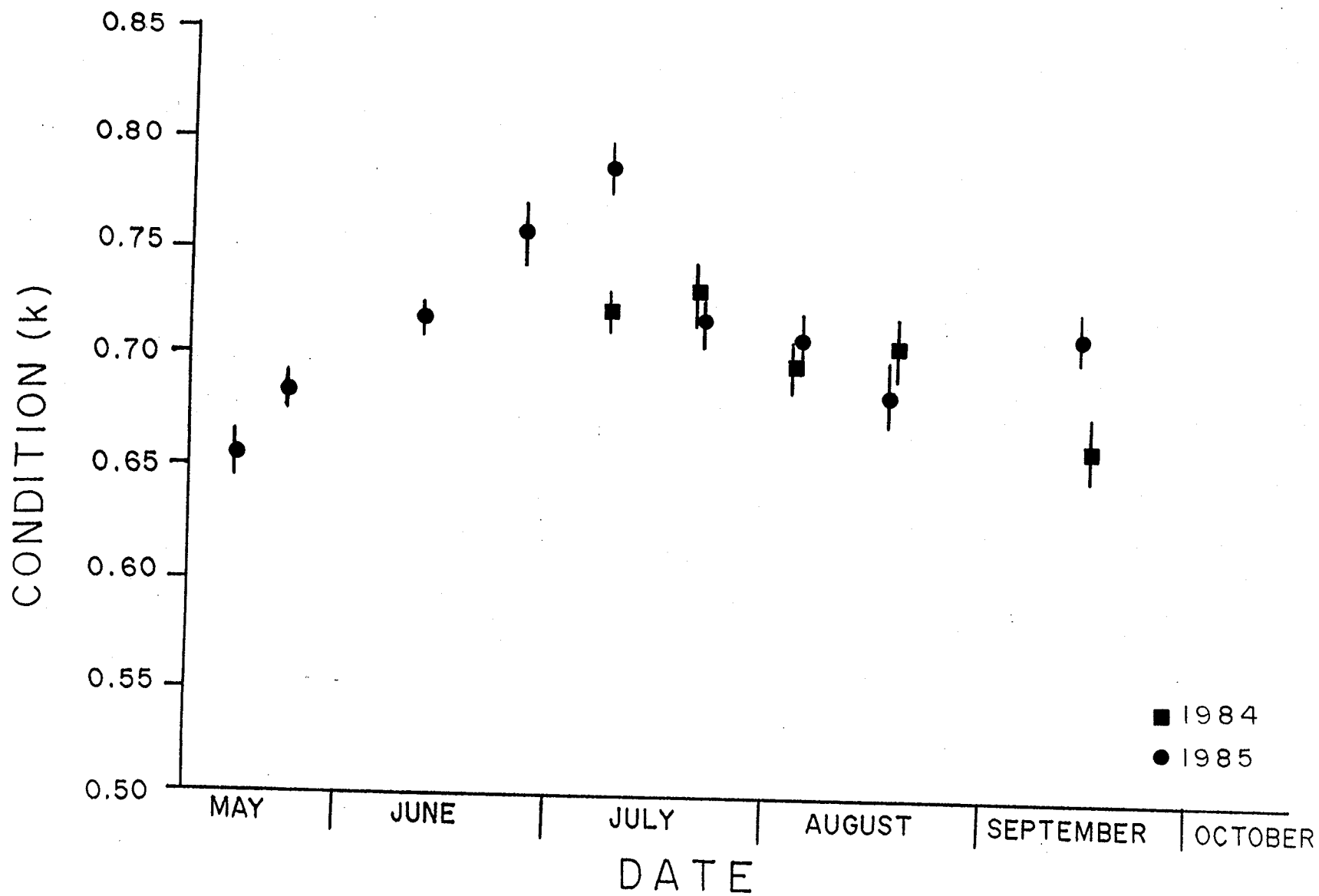
Figure 12. Changes in emerald shiner weight and length

following preservation in 5% formalin. Vertical

bars indicate 95% C.L..
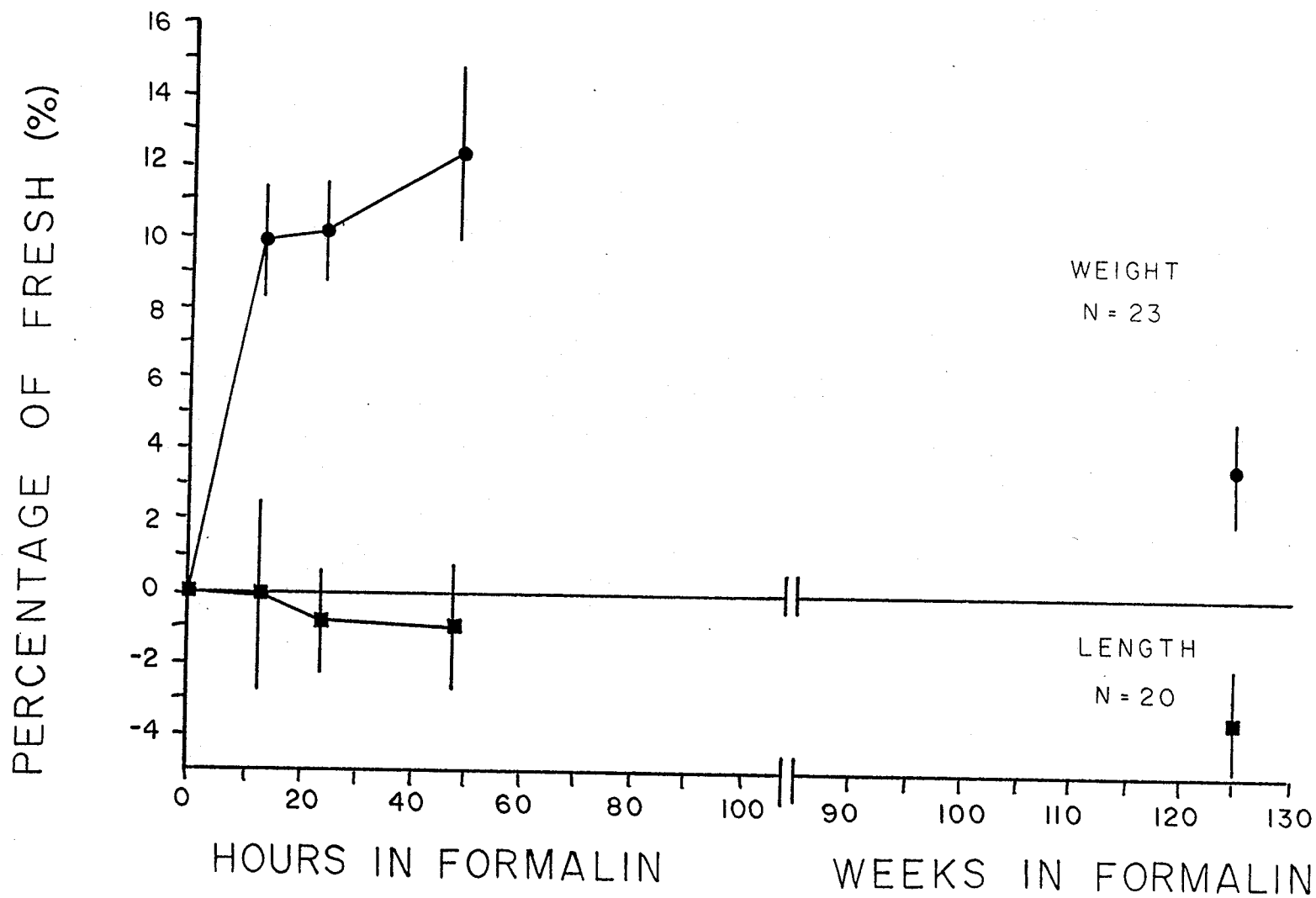
regressing fecundity against wet weight in 1984 (r^2=0.75) and 1985 (r^2=0.61)(Fig. 13). Slopes of the 1984 and 1985 fecundity regression lines were tested for homogeneity by including an interaction term in the covariance model. Slopes were not significantly different (P=0.902, ANOCOVA) and the interaction term was excluded from the model to test the intercepts. Emerald shiners were significantly more fecund per unit of body weight in 1985 (p<0.001, ANOCOVA). The difference in the number of eggs per female, although varying with female body size, was approximately 200 eggs per female higher in 1985.

Emerald shiner egg diameters were highly variable. Mean diameters of individual fish ranged from 0.64-0.88 mm in 1984 and 0.56-1.12 mm in 1985. Figures 14A and B illustrate the broad distributions of egg diameters measured from the two years. In 1984 and 1985, regression analyses of egg diameter upon female total length or weight were not statistically significant. Therefore measurements made on fish eggs within each year were combined for further analysis. Correlation between mean egg diameter and female total length was positive for the combined data (Fig. 15), however not statistically significant. A highly significant difference (p<0.001) was found between the mean egg diameters of 1984 and 1985.

Emerald shiners collected off Methley Beach to assess the progression of reproductive maturity ranged in total

Figure 13. Fecundity of emerald shiners collected from

Dauphin Lake, Manitoba, 1984 and 1985.

1984 F = 562.91 WT − 252.66
r² = 0.75   n = 52

1985 F = 553.83 WT − 41.21
r² = 0.61   n = 61
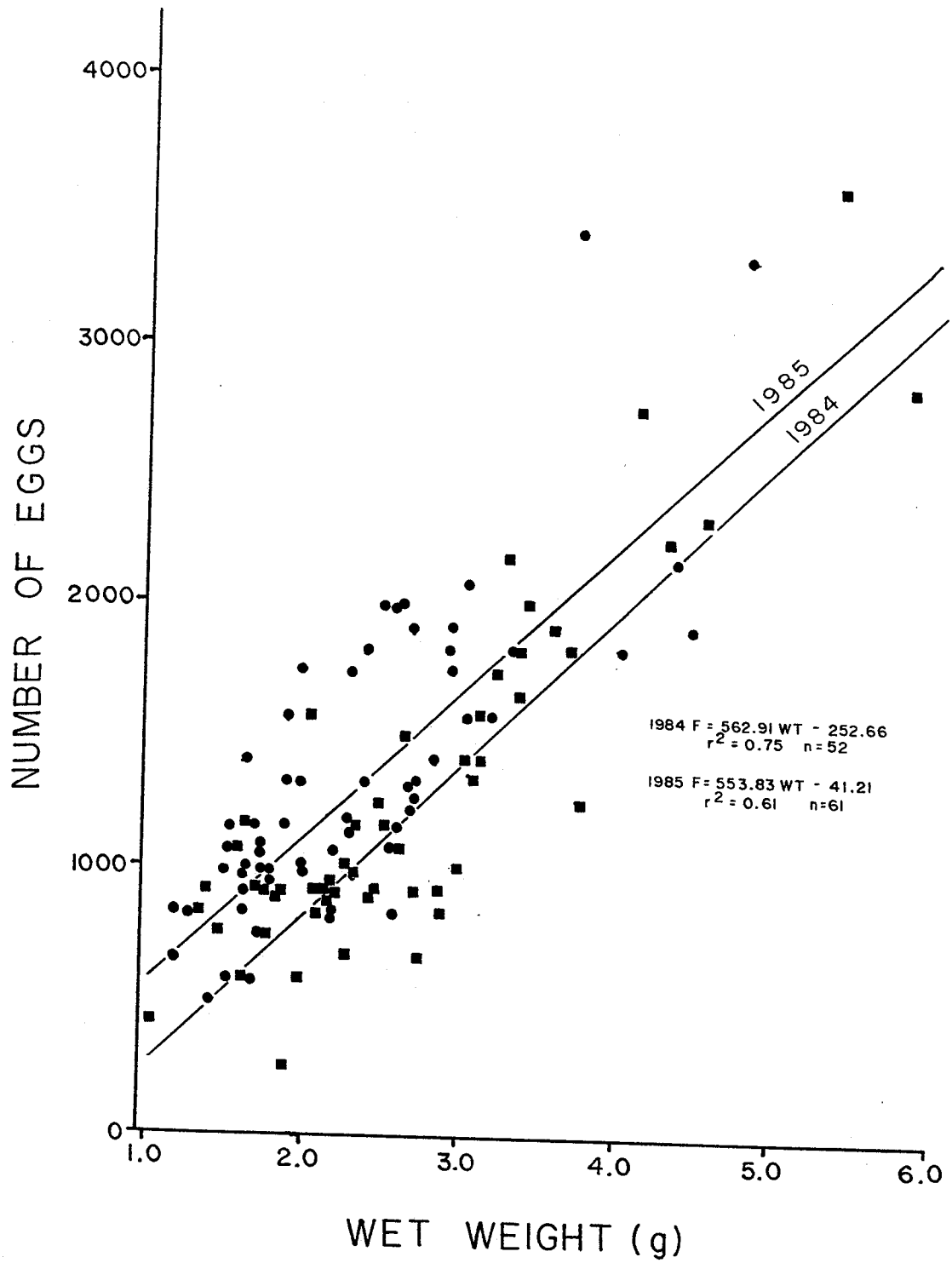
Figure 14. Distribution of emerald shiner egg diameters of

specimens collected from Dauphin Lake in

A. 1984 and B. 1985.

A

1984
$\bar{x}$ diameter = 0.753 mm
Std. dev. = 0.193 mm
n = 975

FREQUENCY

EGG   DIAMETER (mm)

B

1985
$\bar{x}$ diameter = 0.797 mm
Std. dev. = 0.292 mm
n = 2329

FREQUENCY
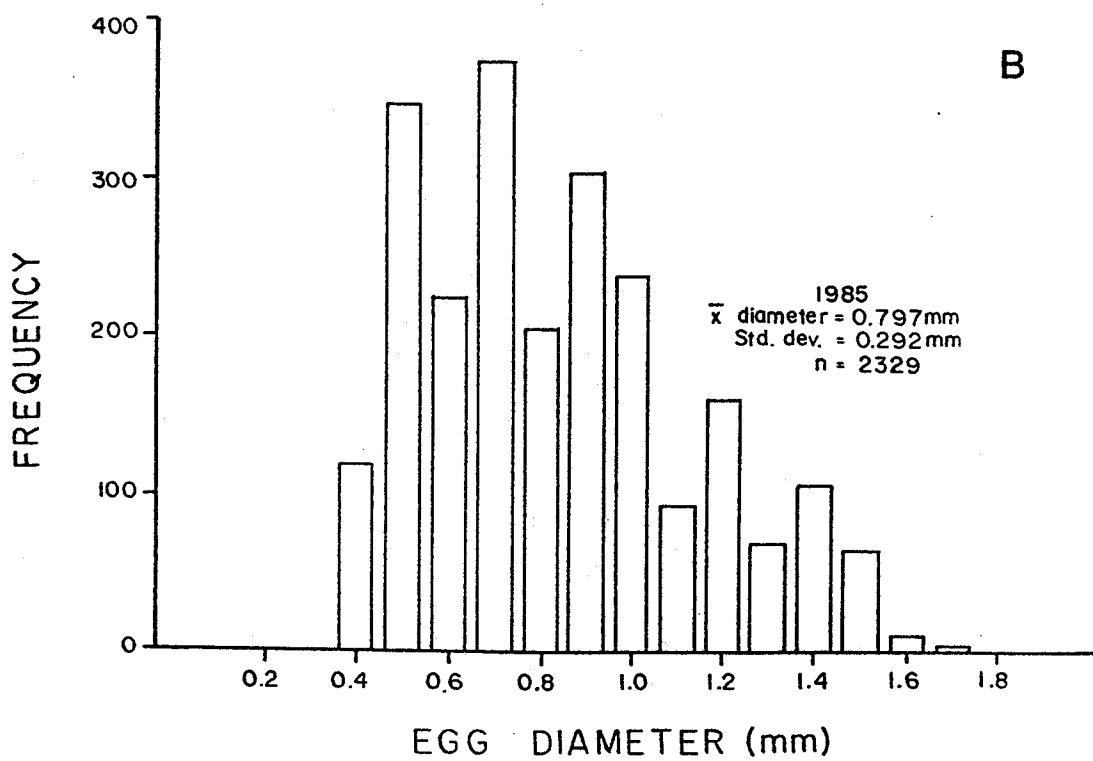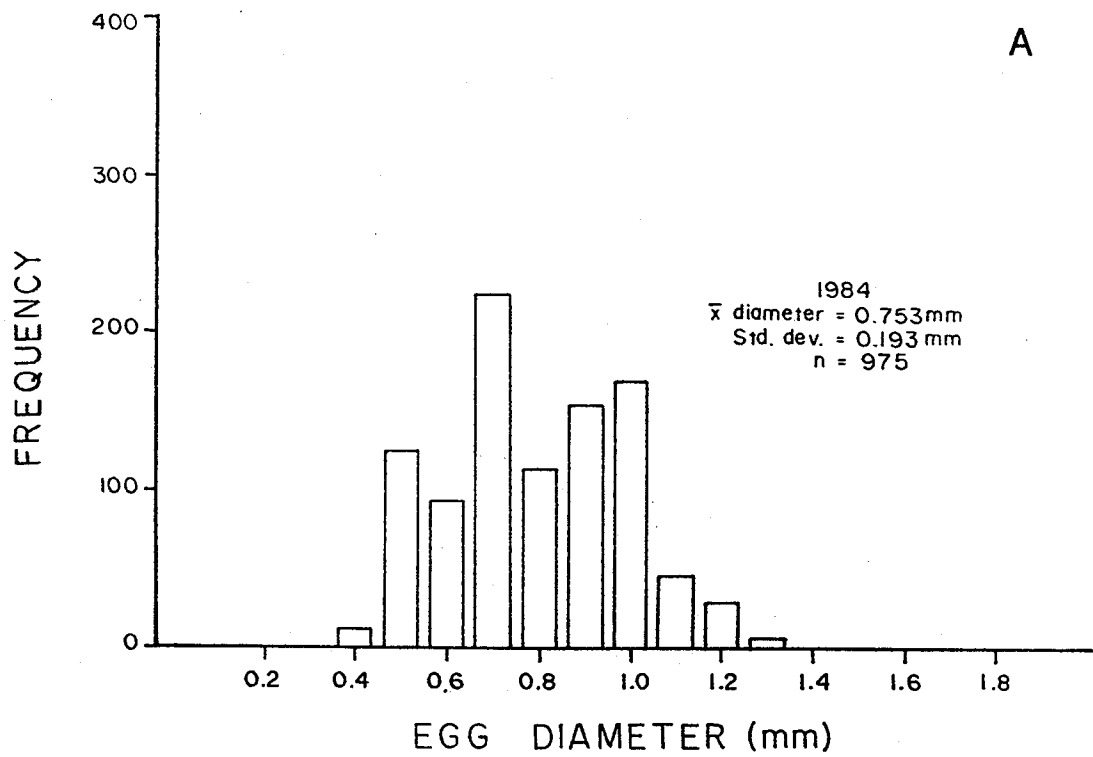
EGG   DIAMETER (mm)

Figure 15. Changes in mean egg diameter with female total
length.
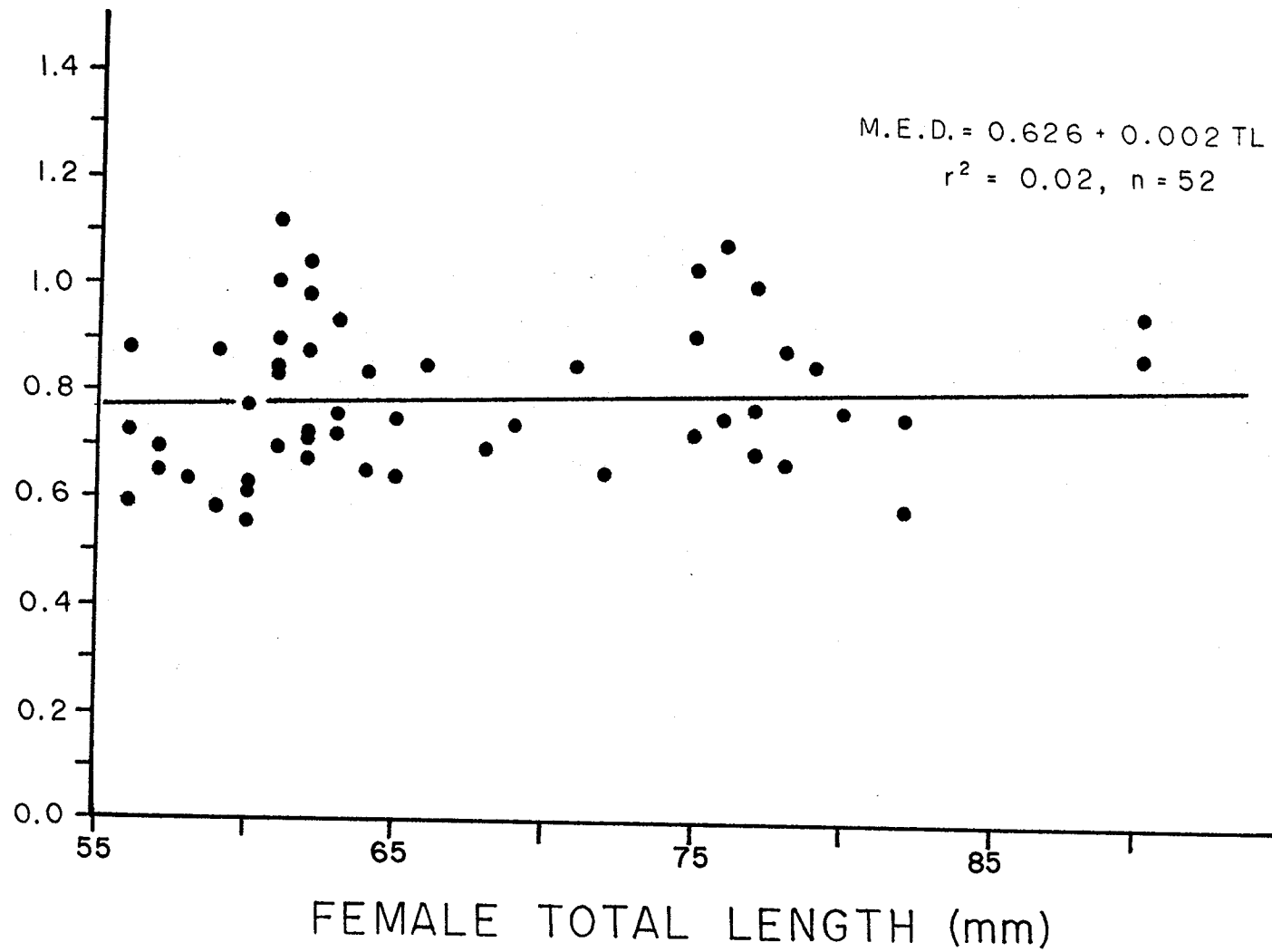
length from 51-89 mm. Emerald shiners of total lengths less than 50 mm at this time of year did not spawn until at least the following summer. Maximum total lengths of males and females collected were 75 and 89 mm, respectively. Female shiners were significantly larger (P<0.05) than males on 11 of 14 dates of collection. Mean total lengths of males and females remained similar throughout the period of spawning. Female to male sex ratios of gravid emerald shiner aggregations varied from 1.0:3.0 to 2.5:1.0. These two extremes occurred on consecutive days with no pattern evident over the collection period. Over the entire period of examination for reproductive maturity the sex ratio was 1.0:1.0.

On July 4, the first date of detailed examinations, 61% of the shiners collected were maturing and less than 7% were spent or partially spent. By August 7, no emerald shiners were maturing, less than 3% were gravid and 90% were spent or partially spent. Figure 16 summarizes the progression of reproductive maturity. Percent "maturing" fish is the cumulative percentage of gravid and maturing shiners. Three-point moving averages were plotted to reduce daily variability.

In Dauphin Lake, emerald shiner spawning extended throughout the month of July and into early August. The reproductive condition of shiners examined on August 14, 1985 indicated that most had completed spawning, although one male was still mature. A female collected on August 29, 1985 was partially spent and contained numerous mature eggs. Larval

Figure 16. Progression of reproductive maturity of emerald shiners collected from Dauphin Lake, Manitoba, 1985.
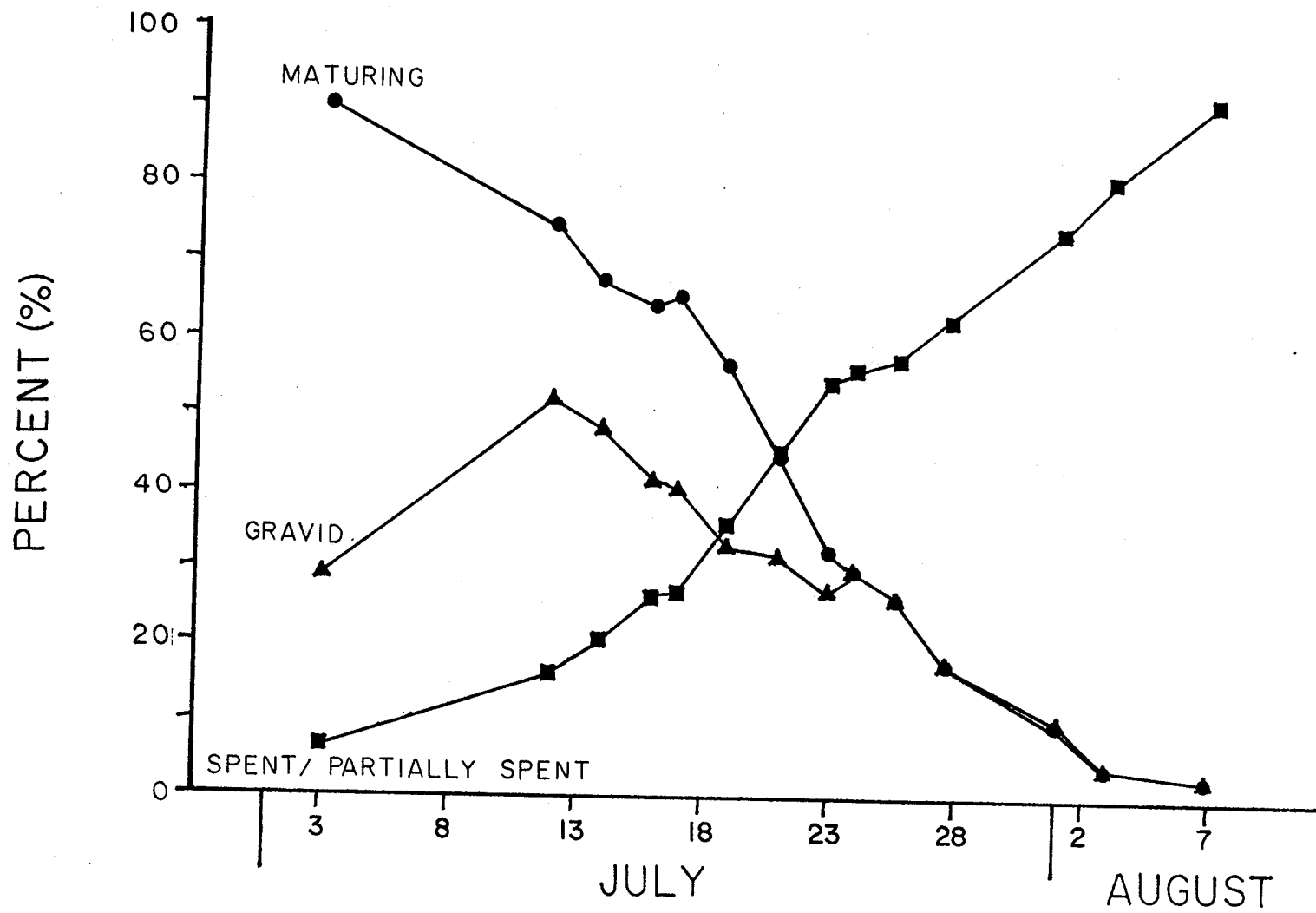
emerald shiners collected from open water trawls had minimum total lengths of 6 mm from July 10 to August 7, 1985 (Fig. 17) verifying the protracted spawning season.

Stomach content analysis

The diet of the emerald shiners varied according to the location of capture and age group examined. On average, 90-95% of the diet, by volume, was zooplankton. The remaining volume included terrestrial and aquatic insects, plant material and fish eggs and scales. Dominant zooplankters in shiner stomachs were immature copepods (copepodids), Bosmina longirostris and Daphnia retrocurva. Keratella spp. was the most numerous rotifer found. Adult copepods contributed a small proportion to the diet of emerald shiners at the time of diet examination. Phytoplankton was observed in numerous stomachs, however it was assumed to be a negligible component of the diet. Larval fish were not found in shiner stomachs. The fewest number of food organisms found in any stomach was nine. Although some stomach contents were partially digested almost all organisms could be identified.

Stomachs of both yearling and adult shiners collected from open water locations were full of copepodids, comprising 62% and 75% of the total number of organisms consumed, respectively (Fig. 18). Bosmina longirostris were the second most abundant organism consumed for both age groups.

Figure 17. Mean total lengths of young-of-the-year emerald

shiners (dots) collected from Dauphin Lake,

Manitoba, 1984. Vertical bars indicate range.
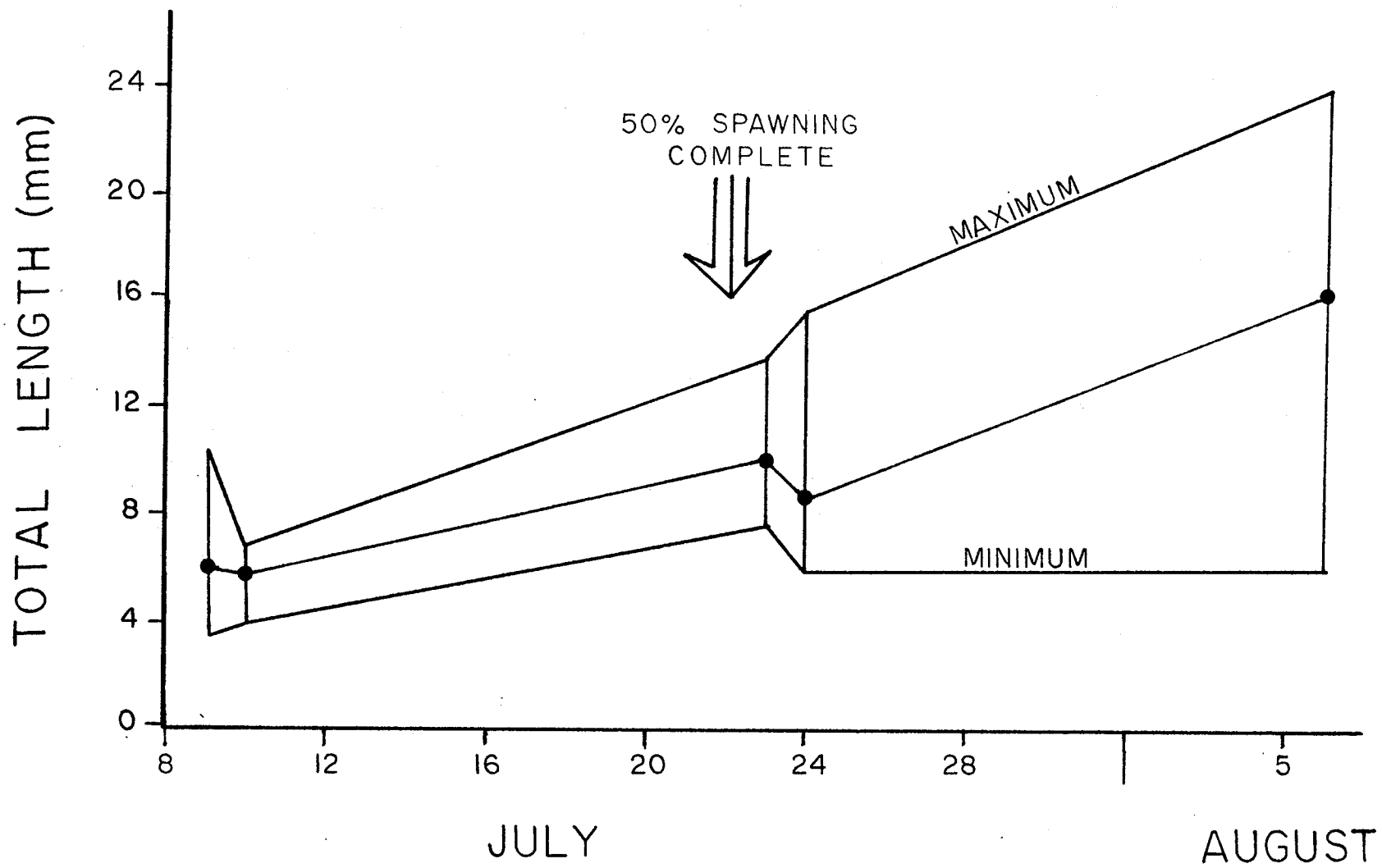
Figure 18. The percentage composition of the stomach
contents of emerald shiners, by number, in
Dauphin lake, Manitoba. NOTE: Numbers indicate
the number of fish stomachs examined.

Legend

Keratella   Nauplii and other copepods

"Other"

Copepodids   Daphnia

Other Rotifers   Bosmina

35

	INSHORE	OPEN WATER	RIVER MOUTH	TOTAL
YEARLING	15	23	20	58
ADULT	15	14	15	44
ALL AGES	30	37	35	102

99
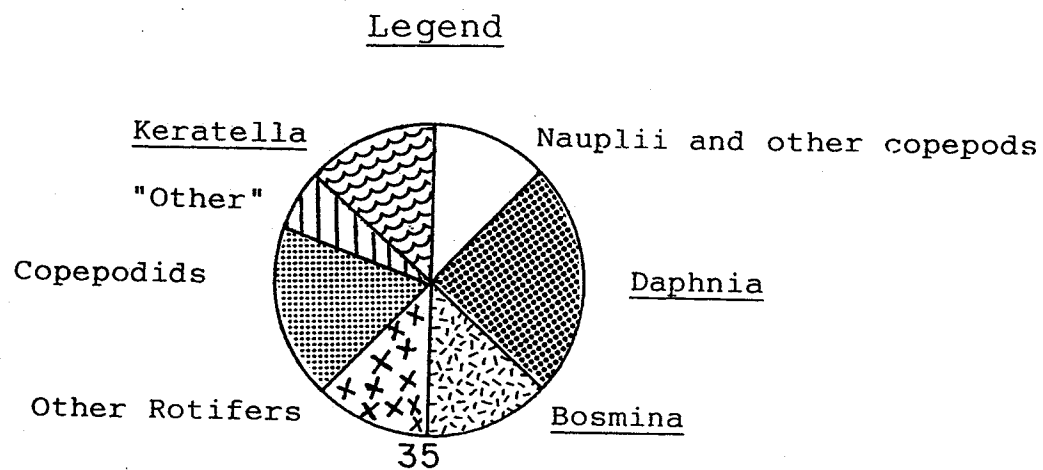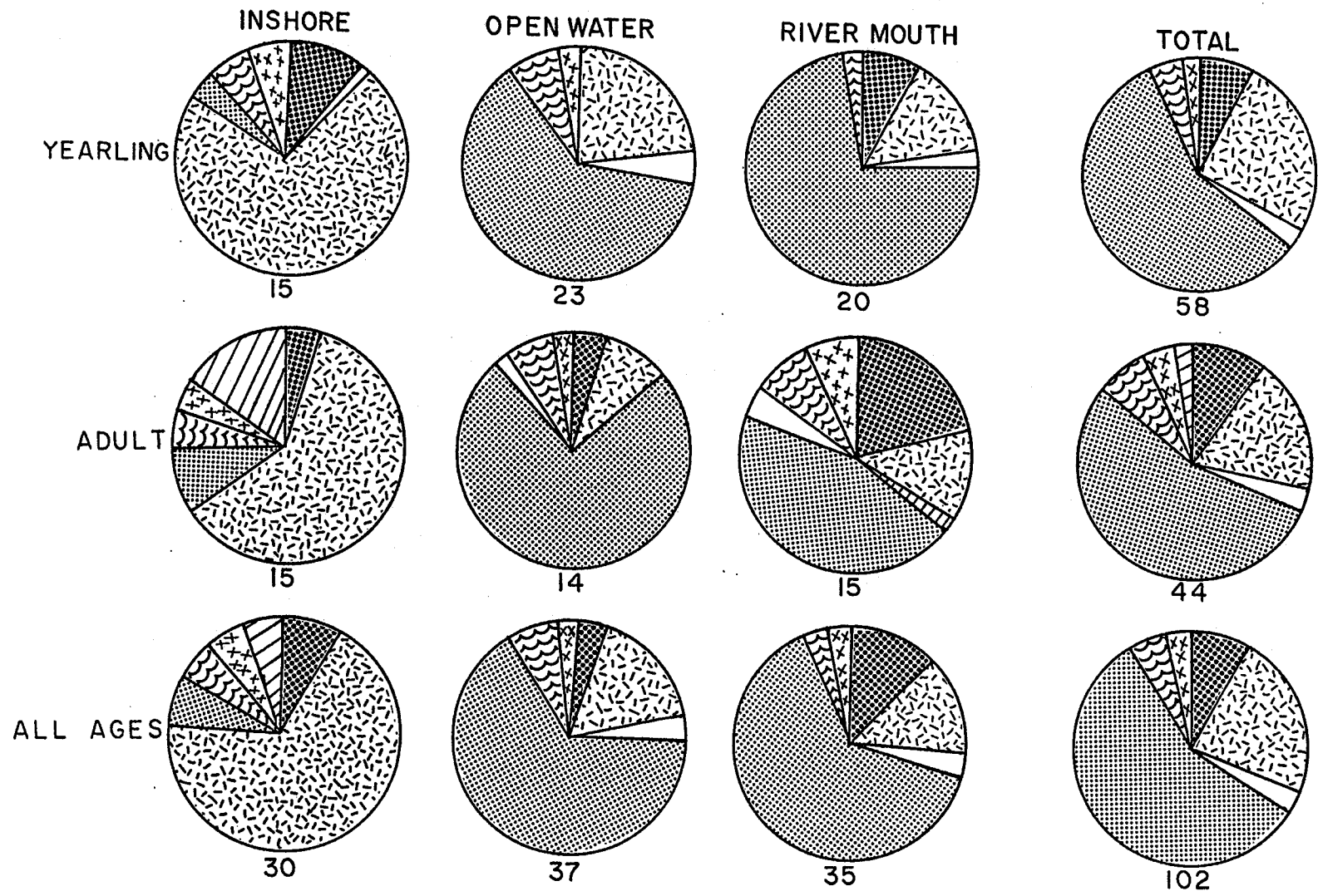
Adult shiners also consumed small numbers of daphnids and rotifers. Yearling shiners ingested rotifers and nauplii.

At river mouth locations copepodids dominated the contents of both yearling and adult stomachs. Bosminids and daphnids were abundant in the stomachs of both age groups. Adult shiners consumed a large number of rotifers as well.

Inshore, B. longirostris contributed over 72% and 60% to the diets of yearling and adult shiners, respectively. Rotifers and daphnids were of secondary importance to yearlings. Copepodids contributed only 8% to the stomach contents of adults. "Other items" were important for adults. Fish eggs, for example, were present in the stomachs of over 50% of adult shiners collected inshore. One individual, with a total length of 75 mm, had consumed 65 eggs. Mean diameter of ingested eggs measured 1.2 mm. Based on the descriptions of egg diameters in Scott and Crossman (1973), these could be the eggs of darters, logperch or one of the other small fishes of the lake.

Copepodids were the main food item consumed for the combined age groups of emerald shiners collected from open water (67%). Bosminids contributed over 16% to the overall diet and rotifers contributed nearly 10%. At river mouth locations, bosminids (14%) and daphnids (12%) were important supplements to copepodids. Collectively, emerald shiners captured inshore displayed a different diet composition. Bosmina longirostris was the most abundant organism consumed (68%) and was supplemented equally by rotifers, daphnids and copepodids (5-10%). Whereas "other items" were infrequent in

the stomachs of offshore-caught shiners, they contributed

over 5% to the shiner diet of inshore specimens. These items

included chironomid larvae, fish eggs and fish scales.

Insects were also a more important dietary component of

inshore shiners, contributing up to 70% of the volume of a

few stomachs. The insects found in fourteen adult and

yearling shiner stomachs were all adult members of the orders

Coleoptera, Diptera and Hymenoptera, listed in decreasing

order of observed frequency. Fragmented insect parts were

chiefly from dipteran adults.

The percent occurrence of zooplankton in the diet was

compared with percent occurrence in the lake at the same time

and locations (Fig. 19). Immature copepods dominated the

stomach contents of adult and yearling shiners collected

offshore on June 6. Relatively, copepodids were the second

most abundant plankter available to the shiners with an

estimated density of 32,716 per m^3 (M. Friesen, Can.

D.F.O., Freshwater Institute). The most abundant plankters,

copepod nauplii, were virtually ignored by emerald shiners.

On June 11, adult shiners collected at a river mouth consumed

daphnids, bosminids and copepodids (in decreasing order of

frequency) while yearling shiners ingested copepodids,

daphnids and bosminids. Nauplii were, again, the most

abundant plankton available, followed by copepodids, rotifers

other than Keratella spp., and B. longirostris.

Results of the electivity index revealed, for shiners of

Figure 19. Comparison of zooplankton availability and
zooplankton consumption by yearling and adult
emerald shiners in Dauphin Lake, Manitoba.
NOTE: Numbers indicate total density of lake
zooplankton (No./m^3).

PERCENT OCCURRENCE (%)   PERCENT OCCURRENCE (%)
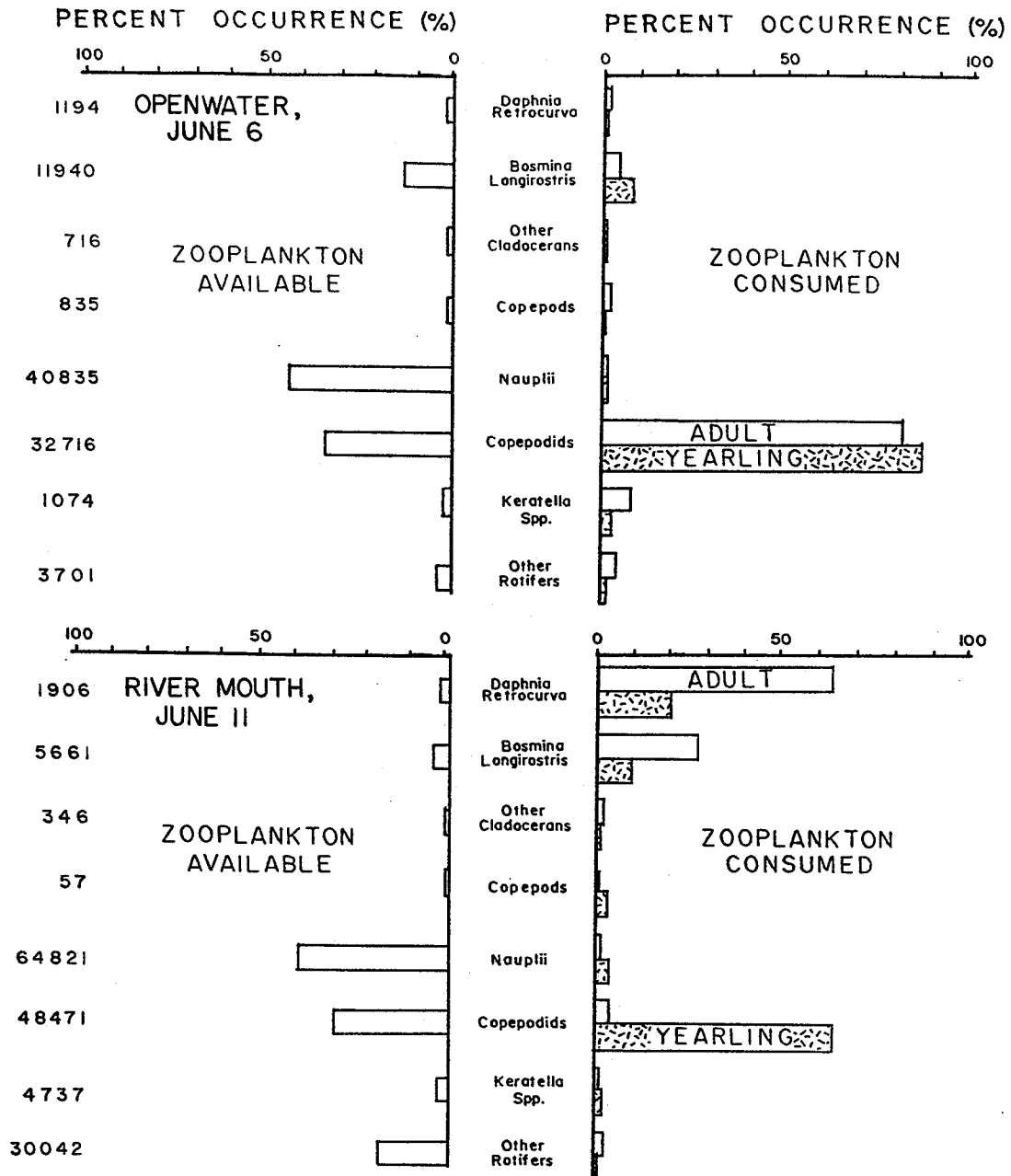
both locations, that nauplii were strongly selected against
(Table 6). In open water, yearling shiners showed a strong
preference for copepodids and a moderate preference for D.
retrocurva. Adults had a weaker, but still positive
preference for copepodids and selected against all other
zooplankters except Keratella spp.. At the river mouth,
copepodids were selected against by yearlings (-0.28) and
adults (-0.90). Both adult and yearling shiners showed their
strongest preference for D. retrocurva (0.79 and 0.87,
respectively), and in fact preferred no other zooplankter.
Although bosminids occurred frequently in the shiner
stomachs, all electivity values for bosminids were negative
relative to the average preference for other available
zooplankton.

Evaluation of offshore sampling methodology

Meter ring nets have been used extensively for the
collection of pelagic marine and freshwater larval fish.
Avoidance of these nets by larval fishes and other organisms
(Clutter and Anruku 1968) limits their effectiveness,
particularily for quantitative measurement. When this
sampling program was initiated in early June 1984, the double
bongo nets captured numerous emerald shiners of all ages. It
was supposed that the turbidity of the lake (Schaap 1987)
reduced the fishes' visibility, and hence prevented avoidance
of the nets by the fish. By late spring, however, few

Table 6. Prey preference of yearling and adult emerald shiners from Dauphin Lake, determined using Chesson's (1983) electivity index.

	Daphnids	Bosminids	Other Cladocerans	Adult Copepods	Nauplii	Copepodids
Open water trawl						
Yearlings	0.25	-0.04	-1.00	-0.78	-0.96	0.66
Adults	-0.27	-0.72	-0.74	-0.07	-0.98	0.11
River mouth trawl						
Yearlings	0.87	-0.62	-0.77	-0.40	-0.96	-0.28
Adults	0.79	-0.58	-0.77	-0.73	-1.00	-0.90

shiners were being captured despite constant fishing effort. Beach seine sampling indicated that densities were not increasing inshore during this time, therefore it was hypothesized that shiners were migrating deeper to avoid warm surface waters. An aluminum sled was therefore constructed and attached to the starboard bongo to sample the lake bottom in 1985. As in 1984, shiners were abundant in all nets for trawls made during the spring of 1985 but became scarce as the sampling season progressed. When the bongos efficiently captured shiners in trawls made during the fall of 1985 it became evident that shiners were avoiding the nets in mid-summer.

Analysis of physical and chemical parameters of the lake and trawl characteristics indicated important correlations of shiner catch with secchi depth (Fig. 20) and water temperature and trawl speed (Fig. 21). Strongest trends occurred for adult shiners only, suggesting that the shiner swimming speed relative to trawl velocity may be important. Based on this information, an equation was formulated which could identify trawls where, because of low trawl speed and/or high water clarity, shiners could avoid capture. The equation used to differentiate between effective and ineffective trawls was:

$$A = \frac{a / B}{(R + b) / V}$$

where A = avoidance ratio

Figure 20. Relationship between secchi depth and emerald
shiner density estimated from bongo trawls,
Dauphin Lake, Manitoba, 1984.
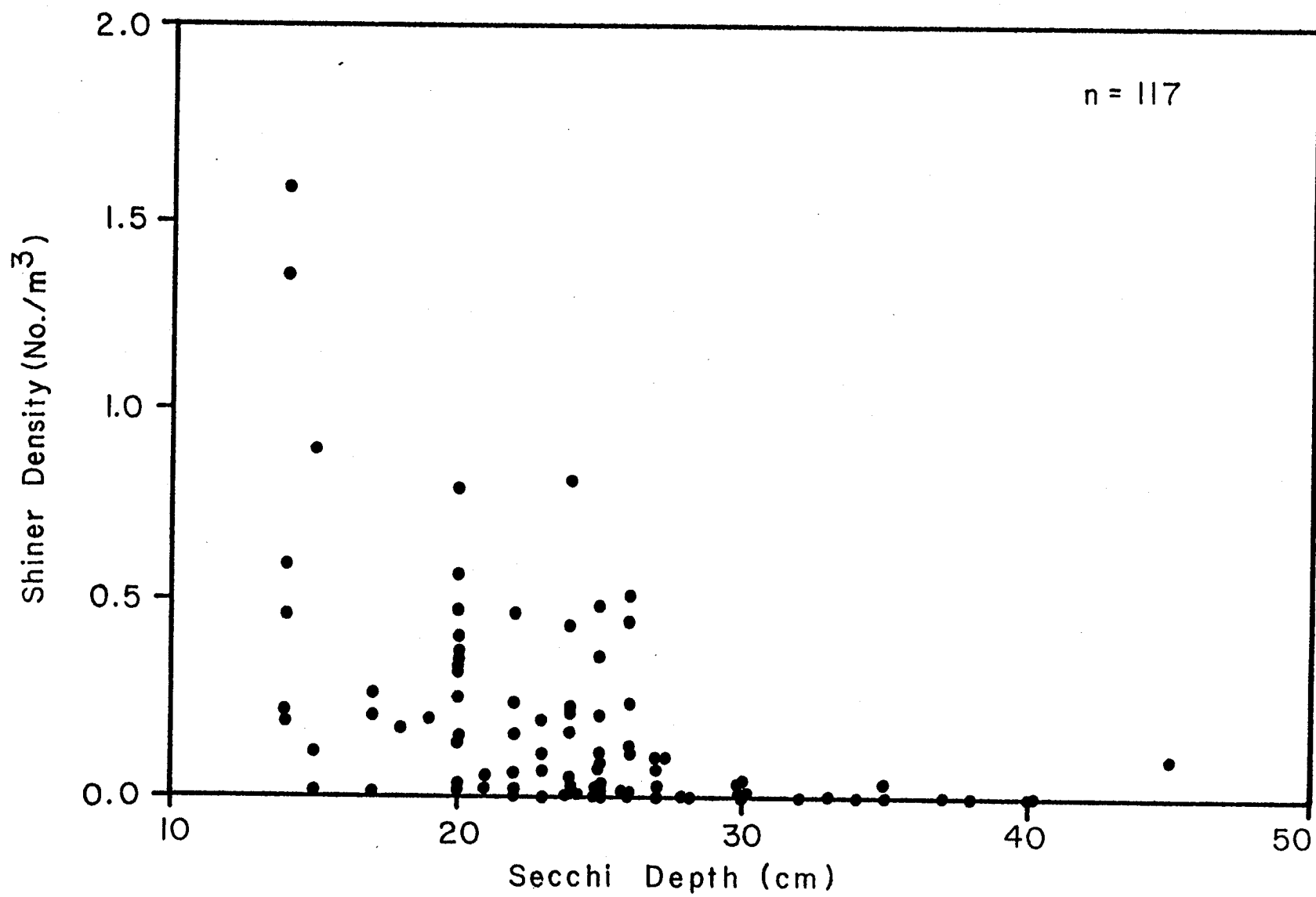
Figure 21. Relationship of trawl speed and water temperature with adult emerald shiner density estimated from bongo trawls, Dauphin Lake, Manitoba, 1984.
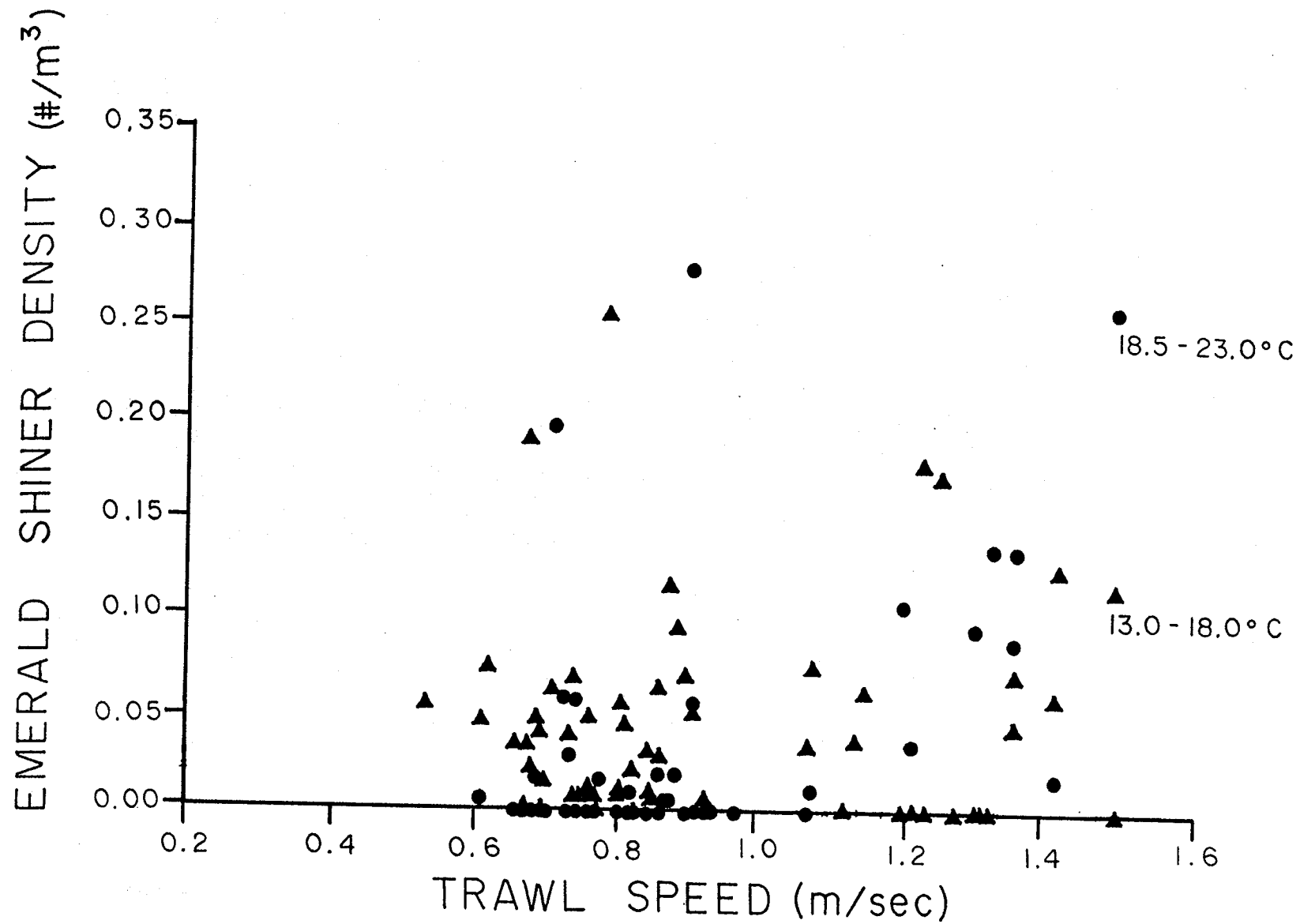
a = swimming distance required for fish
    to escape capture (cm)

B = shiner burst swimming speed = 75 cm/sec

R = distance at which fish can see approaching
    net = secchi depth (cm)

b = distance to capture following reaction
    of the fish (cm)

and V = velocity = trawl speed (cm/sec).

A pictorial description is given in Figure 22.

The equation may be considered as a ratio of "the number of seconds available to the fish for escape" (a/B) and "the time required for the net to capture the fish" ((R+b)/V). When the "time required for escape" is greater than the "time required for the net to capture" (A >= 1), conditions favour the fish being caught. The "time required for the net to capture" is sensitive to water clarity and trawl speed. The "time required for the fish to escape" for a shiner is defined as the speed (B) at which the fish can cover the distance necessary to pass beyond the path to be sampled (a). This distance (a), and the extra distance that the net must move to capture the fish following its reaction (b), are dependent on the angle taken by the fish in avoiding capture. Various angles of avoidance were inserted into the equation and fitted to the data. An avoidance route of 85° from the direction of the approaching net resulted in high shiner catch above the A = 1 line and low catches below this line (Fig. 23). Therefore, for assessment of all trawls, an escape angle of 85° was assumed, and when A was less than 1.0, the trawl was considered invalid and data from that

Figure 22.   Pictorial description of the avoidance

equation.

$$A = \frac{a/B}{(R+b)/V}$$
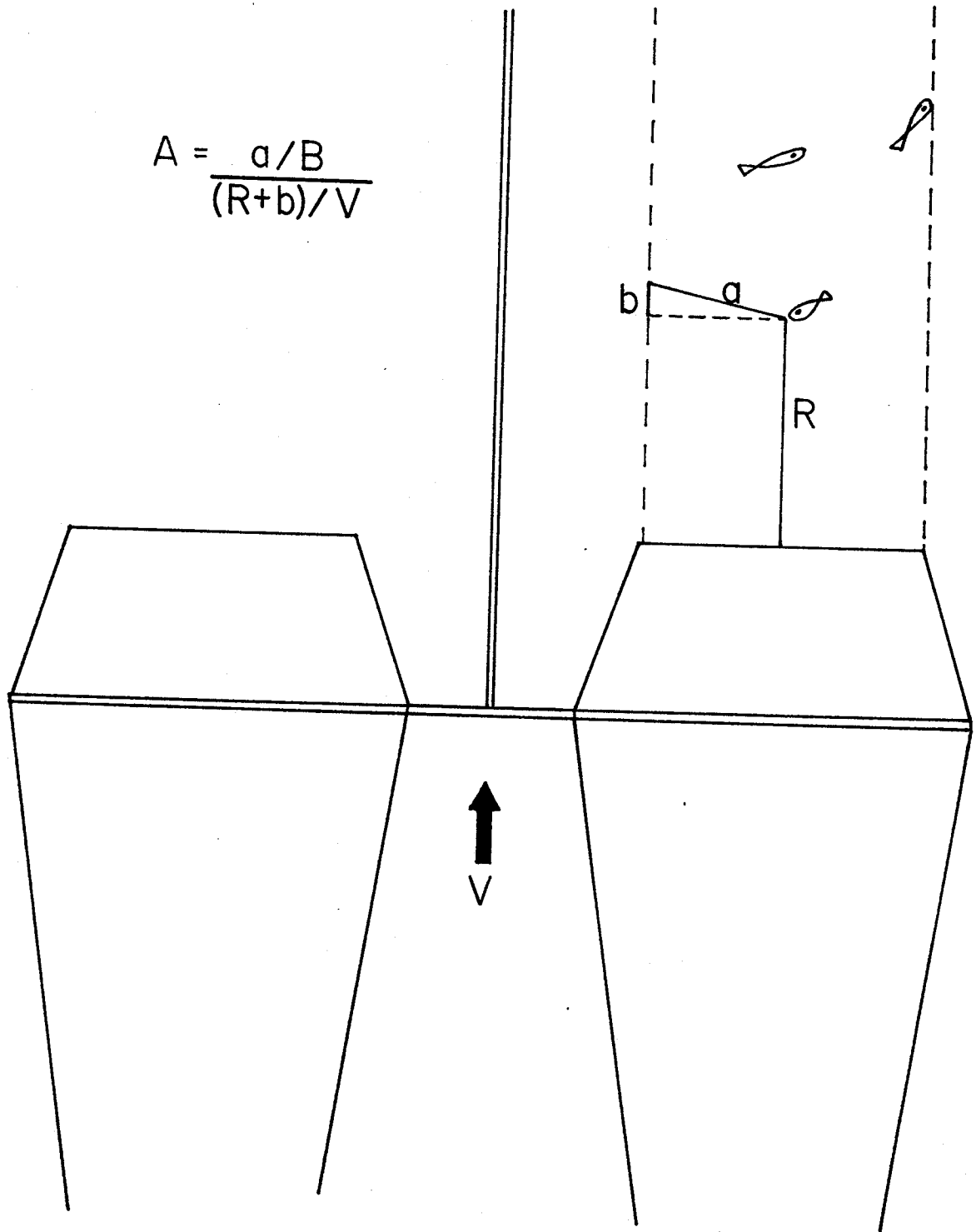
Figure 23.   Avoidance calculation fitted to shiner density

estimates using an escape route angle of 85°.
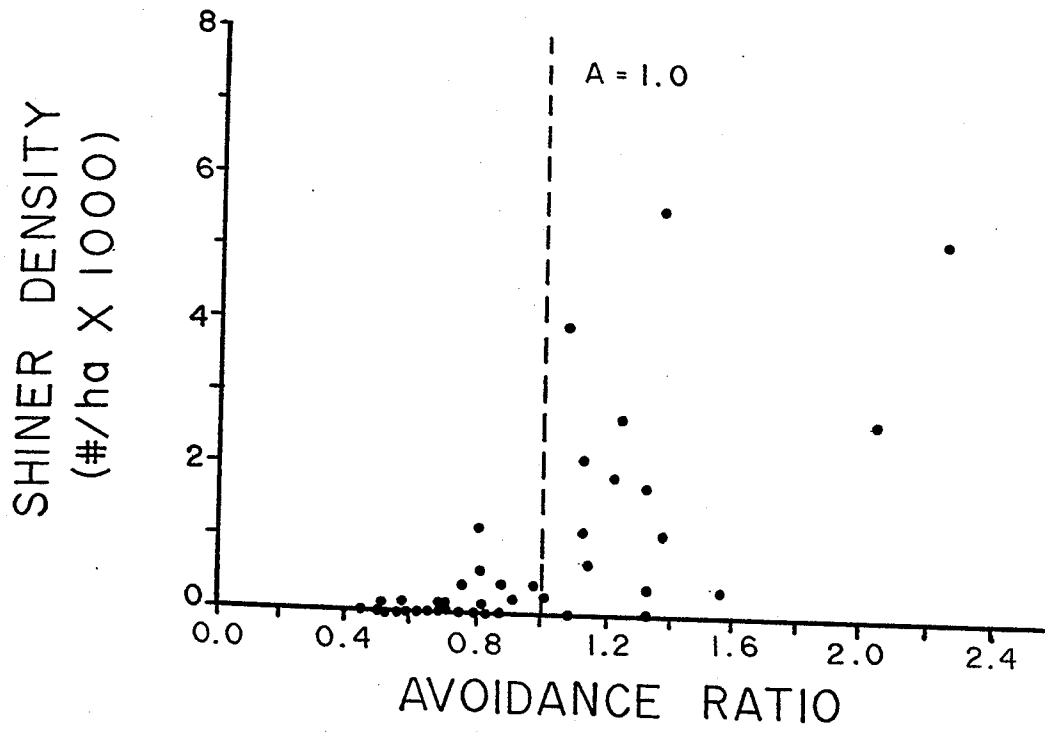
trawl were not used in the density estimation.

Density Estimates

a) Offshore density

Yearling and adult shiners declined markedly in abundance in the spring of 1984. Apart from high spring densities of shiners which had overwintered from 1983, the average emerald shiner densities observed during the summers of 1984 and 1985 were near 400 ha^{-1} and 900 ha^{-1} for adults and yearlings, respectively (Fig. 24).

In mid-summer of 1984 the density of young-of-the-year shiners exceeded 50,000 ha^{-1}, but by spring 1985 the density had fallen to levels similar to those of spring 1984 (2,000-2,500 ha^{-1}). The rapid decline of yearling shiner abundance was evident in both years. Changes in offshore densities were not explained by changes of inshore abundance estimates.

b) Inshore density

Inshore abundance estimates in both 1984 and 1985 were much more variable than offshore estimates (Fig. 25). Summer average densities inshore over both years of study were 1,000 ha^{-1} and 1,500 ha^{-1} for yearling and adult emerald shiners, respectively. Average shiner densities in 1985 were slightly higher than in 1984. Inshore, adult shiners were always more abundant than yearlings. Autumn collections of

Figure 24. Offshore emerald shiner abundance in Dauphin

Lake, Manitoba estimated from bongo trawls,

1984 and 1985. Vertical bars indicate 95% C.L..

Legend

● Adults

■ Yearlings
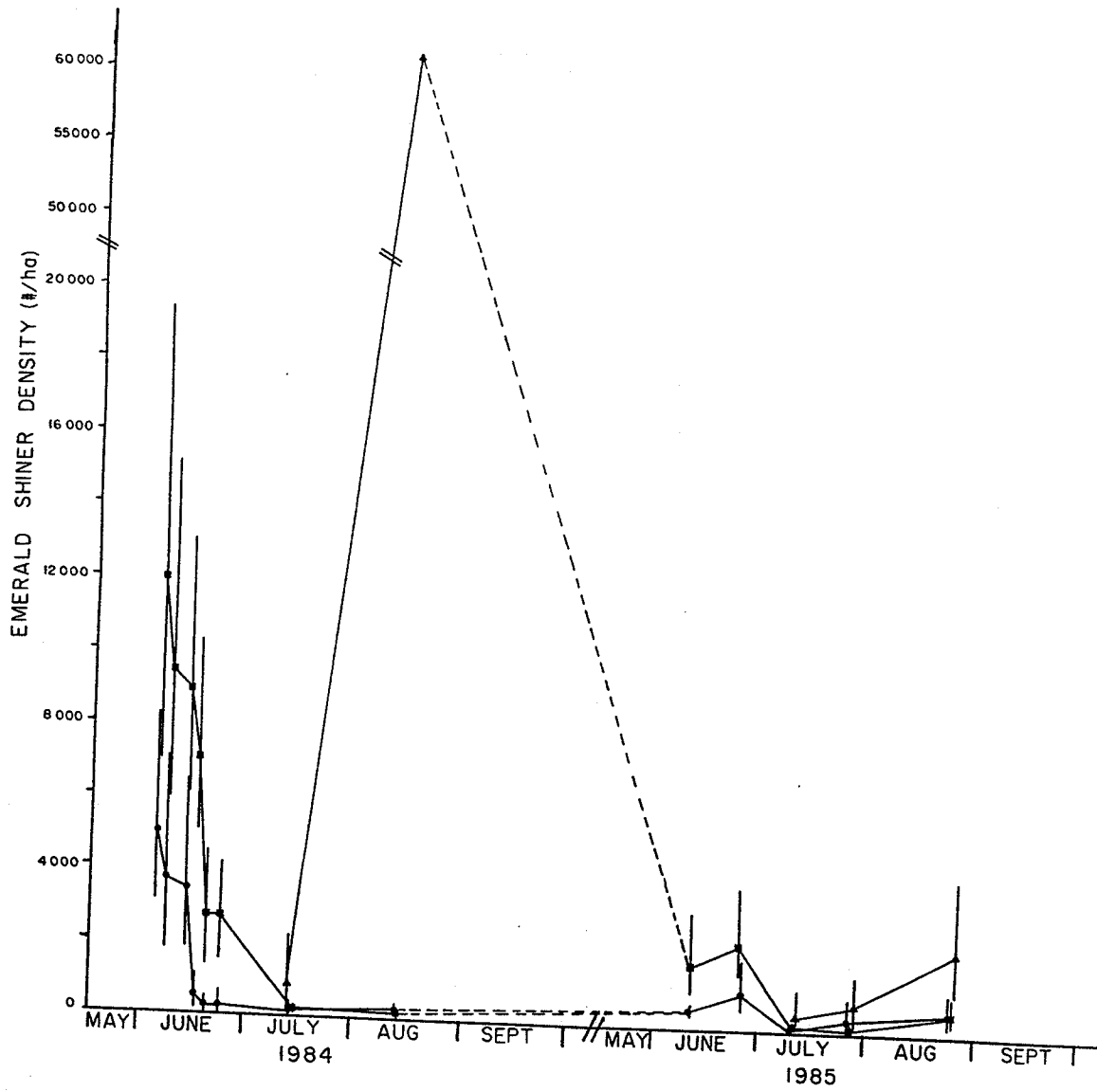
▲ Young-of-the-year

Figure 25. Inshore emerald shiner abundance in Dauphin Lake,

Manitoba estimated from beach seines,

1984 and 1985. Vertical bars indicate 95% C.L..

Legend

● Adults
■ Yearlings
▲ Young-of-the-year
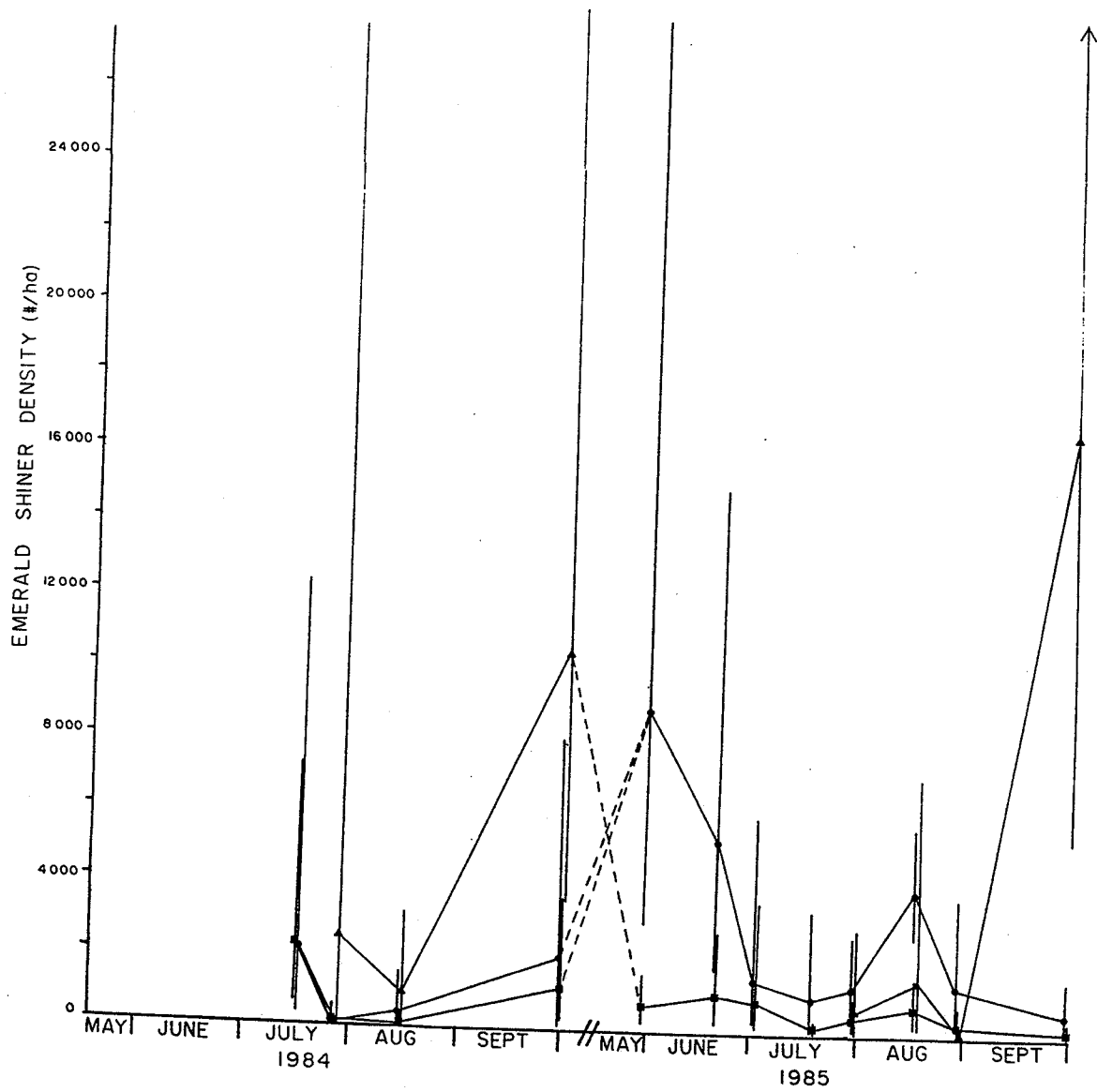
young-of-the-year shiners increased dramatically from summer density estimates. Changes in measured densities for all age groups could not be explained by changes in offshore abundance.

c) Whole-lake density

Whole-lake estimates of abundance were made for 2 dates of 1984 and 5 dates of 1985 (Fig. 26). Offshore density estimates are included in this figure for the period prior to inshore sampling to aid in interpretation. The density of both adult and yearling shiners was high in the spring of 1984 (5,000 ha^{-1} and 12,000 ha^{-1}, respectively), falling to about 200-500 ha^{-1} during the summer months. In August of 1984 high densities of young shiners were measured (60,000 ha^{-1}). The density of these young-of-the-year shiners was reduced to less than 2,000 ha^{-1} by the spring of 1985. The production of young-of-the-year shiners in 1985 was very low, and densities were only about 4% of those in 1984, about 2,300 ha^{-1} at the end of August.

Distribution of shiners in offshore trawls

Changes in the offshore distribution of emerald shiners over the sampling season are given in Appendix 2 for each age group. Adult emerald shiners were loosely aggregated during the first collection dates of both years. As the spring progressed, adult shiners became concentrated in smaller

Figure 26. Whole-lake emerald shiner abundance in Dauphin

Lake, Manitoba, 1984 and 1985. Vertical bars

indicate 95% C.L..

Legend

● Adults

■ Yearlings

◉ Adult offshore density

◉ Yearling offshore density

▲ YOY offshore density
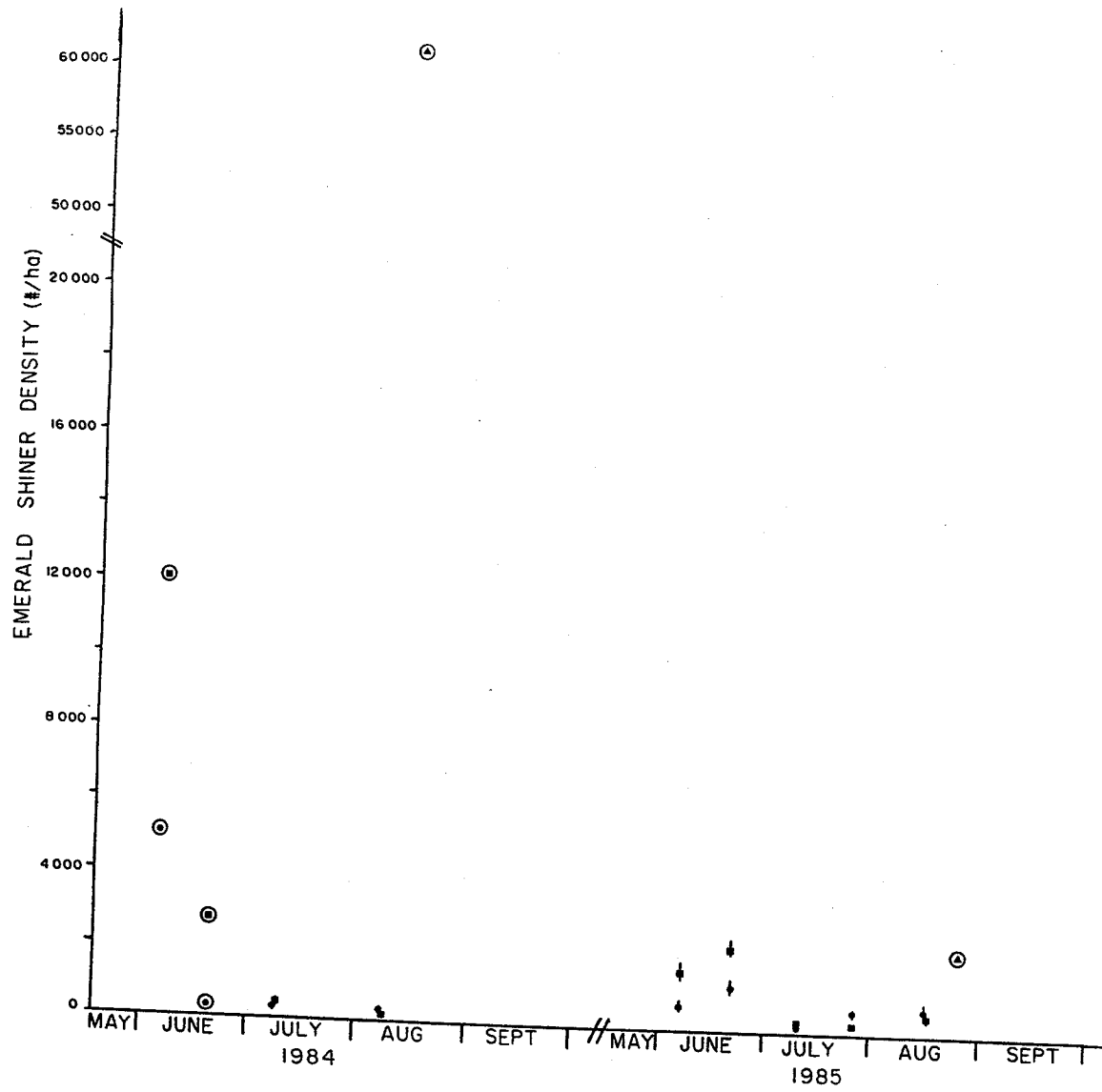
areas of the lake. Yearling emerald shiners also were more evenly distributed initially. They were usually collected at each trawling location in spring, but during summer they aggregated in particular areas of the lake. Adults and yearling shiners did not appear to aggregate in the same areas at the same times. Young-of-the-year emerald shiners, in contrast, were notably clumped when first collected, but as the summer progressed, they became more evenly distributed throughout the lake. The effect of environmental conditions on shiner distribution, including wind direction, degree of cloud cover and water temperature, was examined but failed to assist in the interpretation of emerald shiner distribution in the lake.

Variance:mean ratios, expressed as a percentage of maximum contagion, supported the analysis of distribution from the maps in Appendix 2. The degree of contagion was similar in both years of study (Fig. 27). The degree of contagion of adult shiners was low through June, increased during mid-summer, and returned to levels slightly above those of spring by late July or early August. The degree of contagion of yearling emerald shiners decreased marginally in June and increased in July of both years. Maximum contagion occurred in mid-August, 1984 and late July, 1985. Young-of-the-year shiners were more aggregated in July of 1985 but had similar distributions by August.

Figure 27. Contagion of A. adult, B. yearling, and C.

young-of-the-year emerald shiner distribution

in Dauphin Lake, Manitoba, 1984 and 1985.
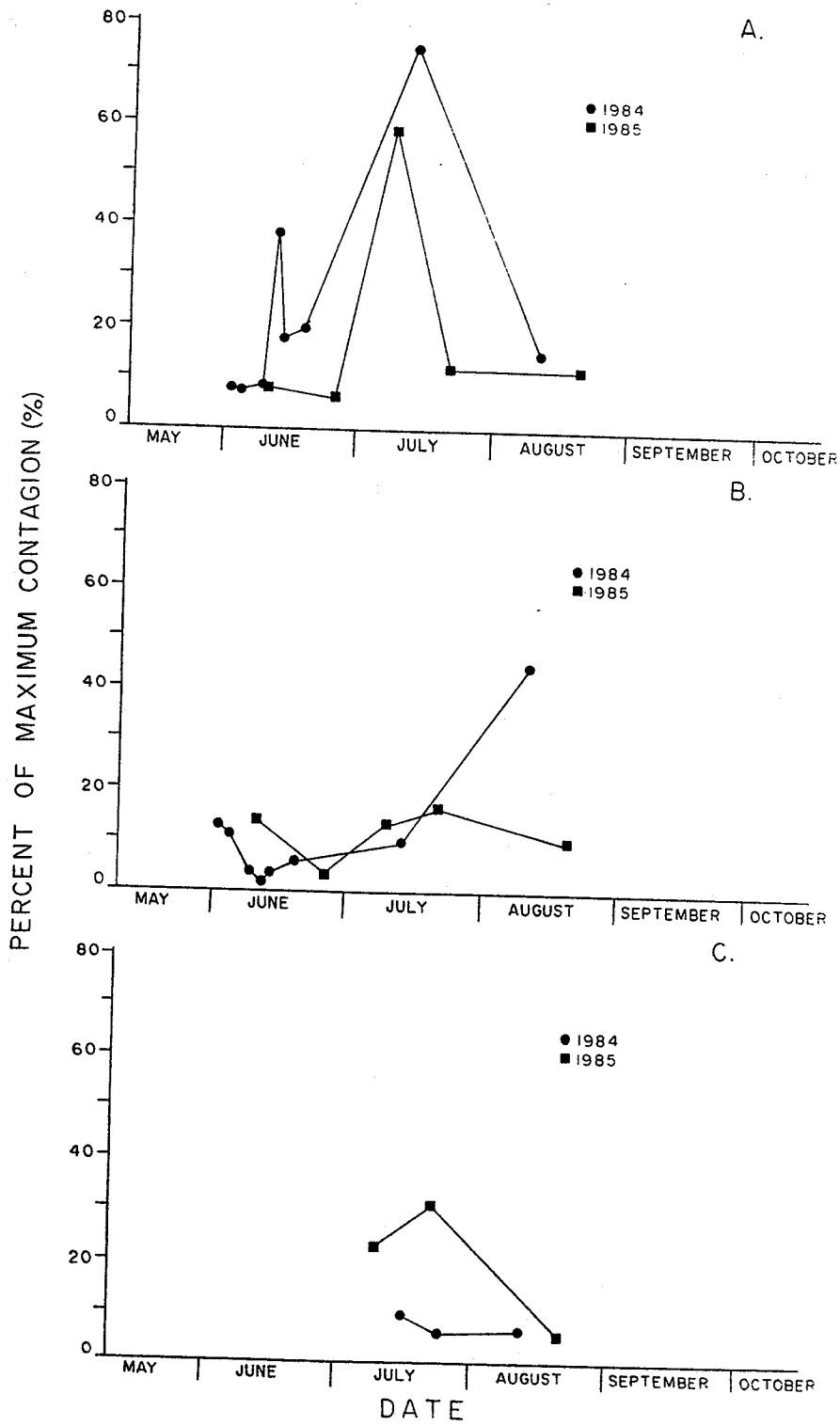
Emerald shiner biomass at inshore stations

The biomass of emerald shiners dropped sharply at inshore stations during summer, 1984 following an initial estimate of 10.86 kg ha^{-1} on July 16 (Table 7). This drop of over one order of magnitude was not reflected by increased abundance offshore. In 1985 emerald shiner biomass declined gradually by nearly one order of magnitude over the sampling season. In contrast to 1984, collections made in 1985 were less variable as measured by the lower coefficients of variation in 1985. These values were near 50% in 1985 and well over 100% in 1984. All stations sampled in 1985 produced higher estimates of mean biomass than 1984, resulting from large collections in spring. Variation within stations was reduced in 1985 compared to 1984 but may be explained by the number of sample dates.

Figure 28 illustrates changes in age composition which took place inshore during the two years of study. In both years the decreasing proportion of adult abundance over the sampling season was offset by the increasing presence of young-of-the-year shiners inshore. Yearling shiner composition varied from 1-60% in 1984 and 2-40% in 1985. Young-of-the-year shiners were first collected in beach seines on July 27 and July 26 of 1984 and 1985, respectively.

Table 7. Total biomass of emerald shiners collected from inshore seines (kg/ha). Station letters refer to Fig. 1. C.V.=coefficient of variation (SD/x X 100).

DATE	A	B	C	D	E	F	G	H	x̄	std. dev.
1984										
15 July	-	11.88	0.63	-	14.32	1.81	19.18	17.33	10.86	7.88
27 July	0.78	2.63	0.01	0.00	0.06	0.02	3.24	1.05	0.97	1.28
13 August	0.08	0.33	-	3.49	5.85	1.34	0.29	0.33	1.67	2.19
28 September	0.78	3.07	1.22	6.45	3.71	-	36.22	6.95	8.66	13.68
x̄	0.55	4.48	0.62	3.31	5.98	1.06	14.73	6.41		
std. dev.	0.40	5.08	0.60	3.23	6.05	0.93	16.55	7.86		
C.V.	72.7	113.4	96.8	97.6	101.2	87.7	112.3	122.6		
1985										
27 May	2.30	47.60	32.99	32.44	37.10	13.78	42.37	15.25	27.98	15.78
17 June	0.75	12.85	24.70	21.59	25.48	9.97	16.97	16.88	16.15	8.26
2 July	3.01	5.90	6.79	66.34	12.06	20.95	4.58	1.54	15.15	21.59
18 July	4.52	3.78	6.03	13.53	23.80	12.98	11.31	4.37	10.04	6.86
28 July	2.57	7.33	22.40	17.68	28.84	16.33	12.11	9.96	14.65	8.46
13 August	-	13.38	9.14	-	4.20	9.55	5.68	-	8.39	3.59
28 August	4.69	9.17	7.44	3.30	8.65	4.47	24.28	8.84	8.86	6.63
27 September	-	-	5.08	-	4.48	2.38	1.48	-	3.36	1.70
x̄	2.97	14.29	14.32	25.81	18.08	11.30	14.85	9.47		
std. dev.	1.48	15.10	10.73	22.04	12.35	6.08	13.30	5.96		
C.V.	49.8	105.7	74.9	85.4	68.3	53.8	89.6	62.9		

Figure 28. Temporal changes in age composition of emerald

shiners collected inshore (seines) from Dauphin

Lake, Manitoba, 1984 and 1985. Numbers are

sample sizes.
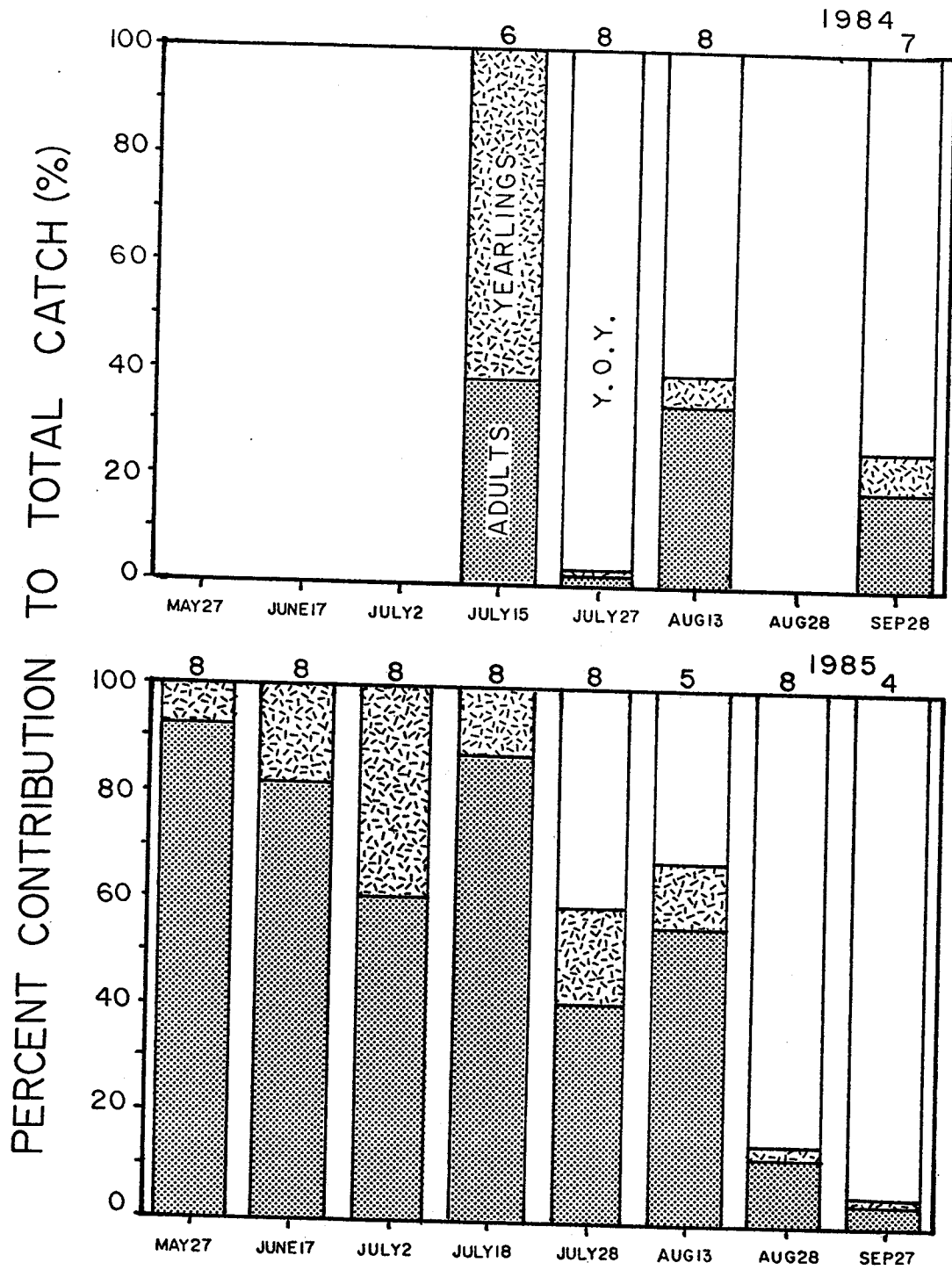
DISCUSSION

Evaluation of selected study methodologies

1) Age determination

    Age determination of emerald shiners has in the past
been based solely on length-frequency analysis (Fuchs 1966)
and scale ageing (Flittner 1964, Campbell and MacCrimmon
1970). Recently, there has been renewed interest in the
validity of ageing methodologies, particularily with regard
to the accuracy of scale readings (Beamish and McFarlane
1987). It is now generally accepted that scale ageing is
less accurate than ageing by other structures. Fishery
workers have indicated that otoliths are more accurate and
reliable for ageing than the scales of herring (Watson 1964),
brown trout (Jonsson and Stenseth 1977), arctic grayling
(Sikstrom 1983), freshwater drum (Goeman et al. 1984),
crappies (Boxrucker 1986), alewives (O'Gorman et al. 1987),
smallmouth bass, striped bass and walleye (Heidinger and
Clodfelter 1987) and other species. For periods when fish
are growing rapidly, scale ageing is probably accurate and
may be as reliable as otolith age determination (Maraldo and
MacCrimmon 1979). As fish growth rate decreases, however, so
does the reliability of this ageing method.

    In most fish, growth rates decline with the onset of
sexual maturity. For small, short-lived fishes like many
cyprinids this usually occurs within their first few years of

life. Dauphin Lake emerald shiners reach sexual maturity at age 2+ and at 1+ in more southerly water bodies (Table 8). Ageing using scales may therefore be subject to error when emerald shiners are greater than the age-at-maturity. Length-frequency analysis is only valuable when length-frequency distributions of various year classes do not overlap. Sexual dimorphism and the prolonged nature of the emerald shiner spawning season lead to overlapping distributions and limit the usefulness of length-frequency analysis. When shiner otolith and scale ages were compared, and descrepancies were found, otoliths yielded higher ages for two of five fish. Other authors have found otoliths to produce higher estimates of age more frequently than ages determined from scales (Erickson 1979, Sikstrom 1983).

The implications of improper ageing are significant. Estimates of growth, annual survivorship, and recruitment may be falsely measured and lead to improper estimates of stock production and therefore, incorrect management strategies.

2) Preservative effect

All shiners collected, except those to be used for ageing, were preserved in 5% formalin. Changes in shiner weight and length of +3.47% and -3.45%, respectively were consistent with literature values. Billy (1982) reviewed the conflicting results of several studies which reported increases and decreases in weight following preservation.

Table 8. Emerald shiner age and size at sexual maturity
in four lakes.

Age-at-sexual-maturity	Minimum female length at maturity	Location	Author
1	78 mm	Lake Erie	Flittner(1964)
1	60 mm	Lewis & Clark	Fuchs(1966)
1(a few)	63 mm	Lake Simcoe	Campbell & MacCrimmon(1970)
2	55 mm	Dauphin Lake	This study

All authors reviewed reported shrinkages in fish length following preservation. Billy (1982) however, and recently Leslie and Moore (1986), reported increases in fish length after preservation. Parker's (1963) study on three salmon species included an analysis of length and weight measurement precision. He concluded that changes greater than 1.2% of the original weight were real, while changes less than 1.2% could be attributed to experimental error. Length measurements were reproducible to within 1 mm.

Parker (1963) concluded that formalin decreased fish length soon after preservation to approximately 97% of the original length and stabilized at approximately 96%. Leslie and Moore (1986) reported an average decrease of 4.1% in the total length of the bluntnose minnow after 53 days in 4% formalin. The average decrease of 3.5% (96.5% of the original) obtained for the emerald shiner preservative study is in good agreement with these findings.

The dramatic increase in emerald shiner weight over the first 48 hours in formalin has also been observed by Billy (1982) and Parker (1963). They noted initial increases of 16-22% and 16-27%, respectively. In this study the maximum measured increase was 12.4%. The stabilized average of 3.4% was similar to the 5-11% range of increase suggested by Parker (1963) for long-term preservation.

While the measured changes in shiner length and weight were not applied to measurements reported in this study, the investigation provided information necessary to ascertain confidence in the data. If this preservative had affected

emerald shiner morphology to a greater extent corrections would have been necessary. Had the investigation not been undertaken, confidence in length and weight measurements, and parameters based on these measurements, would have been unknown.

3) Stomach content analysis

The numerical method of stomach content analysis was employed to determine the feeding habits of emerald shiners. It normally provides little indication of the relative volumes of prey organisms consumed. However, for emerald shiners collected offshore, prey sizes were similar so relative numbers were proportional to relative prey volumes consumed. Inshore, the fish ate a wider range of sizes and shapes of food organisms, and these contributed differentially to the volume of stomach contents.

The electivity index of Chesson (1983) is a convenient means of displaying predator preference. It improves on Ivlev's (1961) index of electivity by being density independent. A more intricate examination of ambient predator and prey movements and abundance, and prey physiology and behavior would be required to examine shiner prey selection (Eggers 1977), however the included index provided a rapid and effective method for determining prey preference.

Emerald shiner ecology

1) Growth and age structure

The physical proportions of the Dauphin Lake emerald shiners, measured by their weight-length relationship, are compared to emerald shiners from other lakes in Figure 29. The general relationship determined for Lake Erie shiners (Flittner 1964) was exactly the same as the regression equation calculated for the Dauphin Lake shiners. The regression coefficient (b) of 3.114 indicated that growth of shiners in these lakes was isometric, or in other words, body shape did not change. The regression coefficient was higher for Lake Simcoe (4.142) indicating that small fish were initially thinner but gained weight faster over changes in length (allometric growth) than the Dauphin/Erie populations. Growth differences between these populations is assumed to be associated with nutritional fitness (Ricker 1975). The weight-length relationship given by Fuchs (1966, 1967) was in error, and therefore could not be considered.

Measurements of emerald shiner condition factor revealed seasonal and yearly variation occurring at all ages. Significantly higher condition factor of young-of-the-year and yearling shiners in 1984 may have resulted from warmer climatic conditions which occurred in that year (Schaap 1987). The warmer conditions may have stimulated plankton production, and contributed to increased fish condition,

Figure 29.   Comparison of emerald shiner weight-length

relationships for three lakes.

LAKE SIMCOE

LAKE ERIE/
DAUPHIN LAKE

DAUPHIN LAKE
$LogW = 3 \cdot 114 \, LogL - 5 \cdot 377$
$r^2 = 0 \cdot 99 \quad n = 5293$

LAKE SIMCOE
$LogW = 4 \cdot 142 \, LogL - 7 \cdot 237$

WET WEIGHT (g)

TOTAL LENGTH (mm)
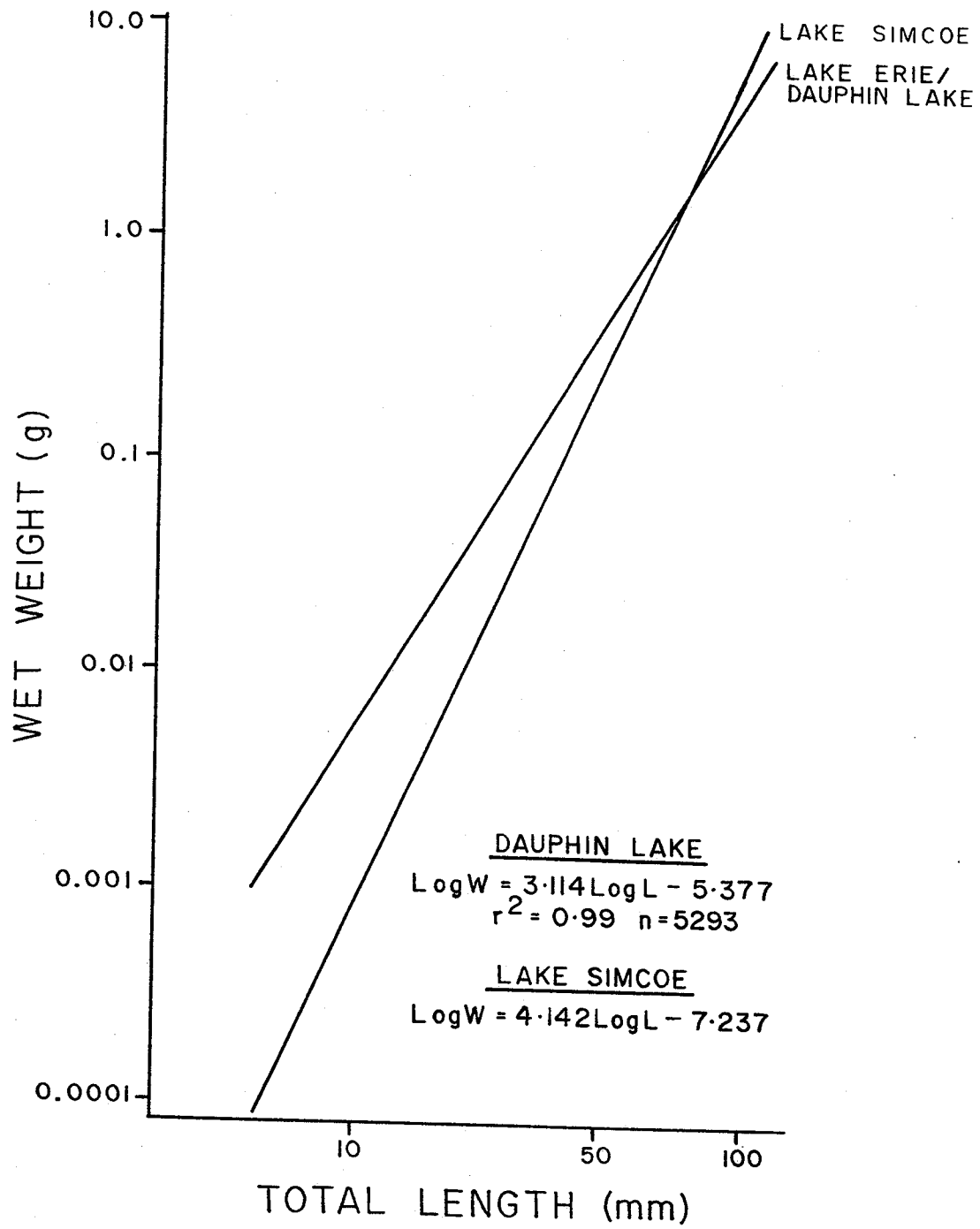
particularly for the younger age groups which were growing rapidly. If environmental conditions during early summer had been optimal for shiner health, condition factor measurements presumably would have increased substantially from early May values when emerald shiner condition is at a minimum (eg. yearling and adults, 1985). These data were not available for 1984. High yearling condition in 1984 may also be the result of high young-of-the-year shiner condition in 1983 and/or a small reduction of condition over the winter of 1983/84. The higher condition factor of young-of-the-year and yearling shiners in 1984 was corroborated by higher growth rates of these age groups between the two years of study.

The condition factor of adult emerald shiners peaked during July of both years and is likely due to the maturation of sexual products. Condition factor of this age group declined steadily over the spawning season. Variation of condition factor between years was not evident probably because energy resources are directed towards reproduction rather than somatic increase at this age.

The emerald shiners of Dauphin Lake live longer than other populations reported in the literature. Five year classes were well represented in both years of the study although 4+ fish were captured only in the spring and summer. In both South Dakota and southern Ontario only three year classes occur with a brief overlap of 0 and 3+ shiners (Fuchs 1966, Campbell and MacCrimmon 1970). In Lake Erie, Flittner

(1964) reported the presence of a 4+ year class made up of only females. Fuchs (1967) made a similar observation in Lewis and Clark Reservoir. Shiners belonging to the 4+ year class in Dauphin Lake were both males and females.

Although capable of living to an older age, the emerald shiner population of Dauphin Lake is very slow growing. Table 9 summarizes shiner growth for examined populations. Mean total lengths of young-of-the-year emerald shiners from Lake Erie and Lewis and Clark Reservoir were more than twice the size of 1985 Dauphin Lake young-of-the-year in mid-September. Similarily, 1+ Dauphin Lake emerald shiners were between 54-61% of the size attained by the shiners of other water bodies.

Table 10 summarizes morphometry and trophic status information for various emerald shiner lakes. Dauphin Lake is located further north than the other lakes suggesting growth differences may be related to the length of the growing season. Due to the shallow depth of Dauphin Lake, however, water temperatures warm quickly in spring with daily mean values reaching 20+°C inshore by mid-June (Schaap 1987). Inshore temperatures in 1984 remained above 20°C until the end of August with 1985 daily means several degrees cooler throughout the summer. Water temperatures were suitably warm to initiate shiner spawning in early July of both years, several weeks earlier than the initiation of spawning in Lake Simcoe (Campbell and MacCrimmon 1970). The growth of young-of-the-year fish in Lake Simcoe, however, was 45% higher than the growth of Dauphin Lake young-of-the-year less

Table 9. Comparison of emerald shiner growth by age in four lakes.

Age	Lake		Mean total length (mm) on the 15th day of each month				
			May	June	July	August	September
0	Simcoe		–	–	–	18	38
	Erie		–	–	–	17	52
	Lewis & Clark		–	–	24	30	44
	Dauphin	1984	–	–	10	22	28
		1985	–	–	10	18	21
1	Simcoe	Male	50	58	66	73	79
		Female	53	60	69	78	84
	Erie	M	57	63	69	75	82
		F	57	60	72	80	85
	Lewis & Clark	M	–	51	58*	70*	75
		F	–	51	63*	77*	83
	Dauphin	1984	–	–	40	46	47
		1985	32	33	37	44	46
2	Simcoe	Male	84	84	85	86	88
		Female	86	85	89	93	96
	Erie	M	85	85	86	88	94
		F	90	93	94	95	98
	Lewis & Clark	M	80*	80*	86*	–	–
		F	88*	87*	95*	–	–
	Dauphin	M⊛	–	61	62	–	61
		F⊛	–	60	64	–	63

* Estimated from available data
⊛ Based on otolith data

Table 10. Location, morphometry and trophic status of four emerald shiner lakes.

Lake	Latitude	Depth (m) Max.	Mean	Area (sq. km)	Trophic Status	Author
Erie (Western Basin)	41°45'N	*	17.7	3300	Mesotrophic/ Eutrophic	Flittner
Lewis & Clark	42°52'N	16.8	*	*	Mesotrophic	Fuchs
Simcoe	44°30'N	44.0	17.0	725	Mesotrophic	Campbell and MacCrimmon
Dauphin	51°17'N	3.5	2.0	522	Eutrophic	

* Not Reported

than two months after hatch (Table 9).

High productivity in Dauphin Lake (Heise 1985) presumably provides an abundance of food organisms throughout the growing season and would not appear to limit shiner growth. Physical and thermal lake stability may play a role in regulating growth. The greater mean and maximum depths of the three lakes summarized would result in a more stable environment in Lakes Erie, Simcoe and Lewis and Clark. The basin morphometry and lake orientation of Dauphin Lake renders it physically unstable as light winds are able to induce waves, resulting in frequent water column mixing and resuspension of bottom sediments. During periods of calm, hot weather the shallow depth of the lake may result in extreme temperatures. Inshore temperatures monitored in the shallow margins of the lake exceeded 30°C in 1984 on numerous occasions (Schaap 1987). Diurnal temperature fluctuation inshore peaked at 14.5°C (Schaap 1987). Together, the physical and thermal instability of the lake may create conditions which negatively affect shiners and/or their prey, resulting in reduced shiner growth.

Alternately, the differential allocation of limited energy resources to maintenance, growth and reproduction may be responsible for observed growth differences between emerald shiner populations. Undoubtedly, energy resources are initially channeled into somatic growth in Lakes Erie and Simcoe. In Dauphin Lake, however, energy resources may be limited as growth is slow, and allocation to reproduction takes place later in life history.

2) Reproductive ecology

Fish inhabiting habitats of distinct climatic variability have concise spawning periods which are often coordinated with favorable conditions such as an abundance of suitable food or the absence of predators (Wootton 1984). The characteristics of the food supply was examined at the time of larval emerald shiner appearance to assess this ecological strategy. Larval emerald shiners were first collected on July 10, both in 1984 and in 1985. First food of larval emerald shiners has been reported by Siefert (1972) to include rotifers, nauplii, cyclopoids and cladocerans. Rotifers, copepod nauplii and the cyclopoid Cyclops bicuspidatus were the preferred food for 5-6 mm fish, 8-12 mm fish and fish larger than 12 mm, respectively (Siefert 1972). Zooplankton abundance and composition in Dauphin Lake were measured throughout the open water seasons of 1982, 1983 and 1984 (M. Friesen, unpublished data). Rotifer populations reached maxima on May 28, June 21 and May 2 in the three years, respectively. Rotifer densities occurring throughout July and August of 1982 and 1984 were over 100 per litre, but dropped to only 10 per litre during this period of 1983. In all three years rotifers, nauplii and copepodid abundance reached maxima well before the appearance of larval emerald shiners. However, the availability of zooplankton for larval shiners was obviously adequate, as suggested by the high

production of young-of-the-year fish in 1983 when rotifer densities were relatively low. The initiation of emerald shiner spawning and subsequent larval hatch therefore appears unrelated to food availability, and suggests that other factors may be responsible.

The hatching of emerald shiners in Dauphin Lake does not appear to be timed in order to avoid predation by piscivorous species. On the contrary, Table 11 shows that at the end of July emerald shiners are of a suitable size to be preyed upon by young-of-the-year yellow perch, walleye and northern pike. It is possible that all forage species, however, are adapted to spawn concurrently in order that the aggregate density of their larvae is sufficient to saturate the predatory demand of the piscivorous fish.

Exogenous factors, such as water temperature and photoperiod, are largely responsible for the timing of sexual maturation and spawning of cyprinids (Davies and Hanyu 1986) and most other fishes (Stacey 1984). Water temperature, in particular, has the greatest influence on cyprinids (Bye 1984) affecting gonadal development (Stacey 1984), the initiation of spawning (Bye 1984), and the development of eggs and larvae (Herzig and Winkler 1986). The literature indicates that the emerald shiner commences spawning at water temperatures of 20.0°C to 22.0°C (Table 12). These temperatures corresponded to the months of June through late July for the various reported studies, and were influenced by

Table 11. Modal total lengths of young-of-the-year
           fishes collected on July 29, 1985 in
           beach seines from Dauphin Lake.

Species	Total Length (mm)
Forage	
Logperch	25
Iowa Darter	16
Johnny Darter	25
River Darter	12
Common Shiner	14
Emerald Shiner	15
Spottail Shiner	20
Fathead Minnow	20
Piscivores	
Yellow Perch	45
Walleye	65
Northern Pike	79*

NOTE: * Collected on July 2, 1985

Table 12. Initiation and duration of spawning by the emerald shiner in several lakes.

Initiation	Duration	Water temp. at Initiation (°C)	Location	Author
mid-June	mid-June - late Aug.	*	Lake Erie	Fish (1932)
mid-June	mid-June - mid-Aug.	22.2	Lake Erie	Flittner (1964)
June	June - late Aug.	*	Lewis & Clark	Fuchs (1966)
late June	late June - mid-Aug.	*	Lake Erie	Gray (1942)
early July	early July - early Aug.	22.0	Dauphin Lake	This study
late July	late July - late Aug.	20.1 - 23.2	Lake Simcoe	Campbell and MacCrimmon (1970)

geographic location and lake morphometry. During the two years of investigation on Dauphin Lake, offshore surface water temperatures through late June were similar and, by early July, both reached the 22.0°C threshold suggested by Flittner (1964). Emerald shiner larvae were collected from the lake on July 10 of both years with mean total lengths of 5.9 and 6.4 mm for 1984 and 1985, respectively. Based on Flittner's estimates of early life history these lengths correspond to an age of 90-96 hours. This confirms that emerald shiner spawning in Dauphin Lake commenced in early July of both years despite different warming conditions earlier in spring and appeared to adhere closely to the 22.0°C threshold temperature proposed by Flittner (1964).

Finally, physiological factors, tied closely to exogenous factors, may regulate the onset of maturation and spawning by Dauphin Lake emerald shiners. Spawning in both years, took place after the condition factor of shiners had reached its maximum (Fig. 11).

Variation of fecundity can be used by fishes as a regulating mechanism of population density (Bagenal 1978a). Fecundity differences observed between Dauphin Lake emerald shiners and data for Lake Erie (Flittner 1964) indicated that the Lake Erie population produces more eggs per unit of female body weight. An estimate of the number of eggs per gram of fish (relative fecundity) was calculated to illustrate the difference between populations. Egg production per gram of Lake Erie fish was 11% higher than for

1984 Dauphin Lake shiners. Higher fecundity may be the
result of abundant food supply (Serns 1982) or increased
growth which may be associated with the level of mortality,
including exploitation (Healey 1978). Higher shiner
fecundity occurring in Dauphin Lake in 1985, may have
resulted from an abundance of food in 1984, the warmer of the
two summers.

Higher fecundity may have important ecological
implications for a population of shiners. In Lake Erie, for
example, a female has the potential to spawn four times,
based on the age-at-sexual-maturity and maximum age. Growth
and fecundity data from Flittner (1964) suggest that a first
spawning female is able to produce over 2,200 eggs, and
following her fourth year could have produced almost 15,000
eggs in total. In contrast, a Dauphin Lake shiner has the
potential to spawn three times but cannot do so until the
third summer (age 2+). In its first year of spawning the
Dauphin Lake fish would produce 1,040 eggs, and after three
years would have produced a cumulative total of 4,440 eggs,
only 30% of the Lake Erie potential. Emerald shiner
populations able to produce large numbers of eggs over small
changes in fish weight are initially able to devote more
energy towards growth, then increase egg production quickly
following sexual maturity. This strategy would be
ecologically beneficial as larger, healthier fish would
annually, and substantially, increase the potential
production of progeny. The production of large numbers of
eggs is characteristic of pelagophils (Balon 1975) like

emerald shiners, whose life expectancy is short and potential for mortality (natural and predation) is high. Conversely, egg production is substantially lower for piscivorous fishes. Serns (1982), for example, reported the relative fecundity of walleye from a Wisconsin lake to vary from 12.2-14.8 eggs per gram of body weight over the three years of investigation. This represents only 2.8% of Dauphin Lake emerald shiner egg production. Table 13 summarizes emerald shiner fecundity and reproductive data reported in the literature.

Egg diameters of emerald shiners from various geographic locations exhibited similar variability as Dauphin Lake eggs. Mean egg diameters of Dauphin Lake shiner eggs were 0.75 and 0.79 in 1984 and 1985, respectively and compared favourably with estimates from shiners of other lakes. Mean egg diameters and ranges for 1+ and 2+ Lake Erie emerald shiners were 0.56 (0.24-0.76) mm and 0.49 (0.24-1.05) mm, respectively (Flittner 1964). In Lake Simcoe egg diameters ranged from 0.21-0.67 mm (Campbell and MacCrimmon 1970). Becker (1983) reported mean egg diameters for a 69 mm and 75 mm specimen at 0.90 mm and 0.80 mm, respectively. Coburn (1986) summarized egg diameter variation for 12 genera and 71 species of eastern North American cyprinids. For 48 species of the genus Notropis, egg diameters of mature ova ranged from 0.60-1.60 mm. Egg size variation within a species is thought to be biologically controlled, most importantly by the seasonal and/or geographic availability of food resources (Bagenal 1971, Ware 1977). Egg diameter is often correlated

Table 13. Emerald shiner reproductive data from four lakes.

Parameter	DAUPHIN	ERIE	SIMCOE	LEWIS & CLARK
Age-at-Maturity	2	1	1(a few)	1
Mean egg diameter (mm)	0.67	0.50	Not Reported	Not Reported
Egg diameter range (mm)	0.56-1.12	0.24-1.05	0.21-0.67	Not Reported
Maximum age	4	4	3	3
Maximum body size (g)	5.8	7.0	2.5-8.9	106mm
Max. Number of eggs	3054	4365*	868-8733	Not Reported
Average number of eggs/gram of fish	1984 563 1985 554	623	664*	Not Reported
Author	This study	Flittner	Campbell and MacCrimmon	Fuchs

NOTE: * = Calculated for a 7g fish from Flittner's (1964) fecundity relationship.
　　 * = Calculated as the average number of eggs for only two shiners.

with female size, but relationships are frequently
non-existent. Smaller egg diameters reported for Lakes Erie
and Simcoe are doubtfully affected by food availability,
since shiner growth exceeds Dauphin Lake shiner growth.
Perhaps the reduced age-at-maturity in these lakes, coupled
with the correlation of egg size with female size, may be
responsible for smaller egg sizes. This correlation was not
reported for either study. It was positive, but weak, for
the Dauphin Lake investigation.

The spawning modes of North American species of the
genus Notropis have recently been summarized by Heins and
Rabito (1986). A mode characterized by multiple spawning
during one reproductive season is based on the evidence of
protracted spawning seasons (Hankinson 1930, Harrington 1947,
Heins and Bresnick 1975 and Matthews and Heins 1984) and the
presence of several classes of egg sizes in the ovaries of
mature females (Wallace and Ramsey 1981, Heins and Rabito
1986). Multiple spawning of Notropis has been observed in
the field (Raney 1947, Gale and Gale 1977) and in aquaria and
artificial ponds (Harrington 1951, Gale and Buynak 1978, Gale
1986).

Evidence provided in the literature and data obtained in
this study suggest that emerald shiners of Dauphin lake are
multiple spawners. Studies describing emerald shiner
reproduction reported spawning seasons of similar, or
greater, lengths (Fish 1932, Gray 1942, Flittner 1964, Fuchs
1966). Flittner (1964) concluded that Lake Erie shiners were

capable of repeated spawning, citing the distribution of egg diameters and observations of spawning shiners as evidence. Fuchs (1966) suggested that the emerald shiner population of Lewis and Clark Lake were also multiple spawners based on bimodal frequency distributions of egg diameters. Nikolsky (1963) warned that the presence of large and small eggs in the ovaries were not always indicative of multiple spawners and suggested that some may be resorbed. The stages of development of Dauphin Lake shiner eggs were easily distinguished, and followed the description of Bagenal (1978a). Residual eggs examined in females following the spawning season were dark yellow, or brown and easily identified as those to be resorbed. Further, as no other eggs were observed in the ovaries of females collected in late August, egg production for the following reproductive season did not occur. Campbell and MacCrimmon (1970) observed similar results.

Prolonged spawning seasons and multiple spawning are characteristic of tropical and subtropical fish populations (Nikolsky 1963). The lack of distinct seasonal variation of larval food resources, temperature and photoperiod are chiefly responsible. In temperate areas, examples of populations exhibiting these characteristics are few although recent investigations in the southern United States have yielded evidence that species of Notropis have adopted these strategies (Wallace and Ramsey 1981, Matthews and Heins 1984, Heins and Rabito 1986). The spawning of multiple egg clutches is ecologically advantageous as it ensures survival

during unfavorable spawning conditions (Nikolsky 1963). As well, it enables each female to produce more eggs, and thus offspring in one reproductive season than the coelomic cavity can hold at any one time. Consequences of the increased reproductive effort expended by multiple spawners include reduced longevity (Mann et al. 1984) and a decrease in the age-at-maturity (Heins and Bresnick 1975).

3) Feeding ecology

The analysis of emerald shiner stomach contents from specimens collected offshore revealed an almost exclusively planktivorous diet. Food preferences suggested size-selective predation by planktivorous emerald shiners in Dauphin Lake.

Feeding modes of planktivores has been described, most fully for selective predation (Brooks and Dodson 1965, Galbraith 1967, Brooks 1968 and others). Janssen (1976) described two other feeding modes of the alewife which he termed "filtering" and "gulping". "Filtering" feeders were not size-selective, while "gulping" feeders were. The feeding mode was related to differences in fish size. The largest alewives were "filterers", medium-sized fish were "gulpers" and the smallest alewives were "particulate" feeders or selectors.

Preference differences observed between age groups of emerald shiners collected from open water were not the result of feeding mode differences. Filter feeding could not have

occurred, as evidenced by the high negative preference values of both yearlings and adults for nauplii (Table 6), the most abundant plankter. "Gulping" or "particulate" feeding appears to have occurred for both age groups in open water. Hall et al. (1979) found that predation by the golden shiner was size-selective.

Prey selection is regulated by prey visibility (shape, size, colour and motion), prey evasion and predator behaviour (Eggers 1982). Although aspects of prey visibility and prey evasion were not addressed, the "gulping" feeding mode, combined with the abundance of large-bodied organisms in the shiner stomachs, suggests that shiners were maximizing foraging efficiency by preferentially feeding on the largest available plankton fraction. Large-bodied zooplankters were also observed in emerald shiner stomach contents by Gray (1942) and Fuchs (1966). The preference of adult shiners collected in open water for Keratella spp. however, is difficult to resolve. Their small size and immobility would presumably render them less conspicuous than other available prey. Keratella were not preferred by yearling shiners at this location or shiners analyzed from the river mouth collection. All emerald shiners showed no preference for "other rotifers" at both locations. Perhaps these organisms were preferred due to their dark coloration or their inability to evade predators (Pennack 1953). Possibly, a reduced rate of digestion of their thick cuticle resulted in concentrated numbers in the gut. Finally, the abundance of Keratella in adult shiner stomachs may be indicative of the

"gulping" feeding mode, while their absence in yearling stomach could suggest "particulate" feeding. "Gulping" and particulate" feeding modes were adopted by medium- and small-sized alewives, respectively in Janssen's (1976) study.

Preference of Dauphin Lake emerald shiners for copepodids, daphnids and Keratella spp. coincide well with the analysis of feeding habits of other lake populations. Emerald shiners preyed almost exclusively on zooplankton (Daphnia and Diaptomus) during December and March in Lake Erie (Gray 1942). Fuchs (1966) also indicated that the emerald shiner population of Lewis and Clark Lake fed primarily on zooplankton and selected Daphnia and Diaptomus. Although no indication of preference was presented, Manny (1928) found copepods, oligochaetes, ostracods, cladocerans and chironomids, listed in decreasing order of frequency, in Lake Erie emerald shiner stomachs. Rotifers occurred in only 10% of the stomachs examined.

The importance of terrestrial insects to the shiner diet was second to zooplankton in Lewis and Clark Lake (Fuchs 1966) and Lake Simcoe (Campbell and MacCrimmon 1970). In two stream populations emerald shiners also preyed extensively on terrestrial insects (Minkley 1963, Mendelson 1975). Insects were only important components of the diet in Dauphin Lake shiners collected near shore.

Based on stomach content analysis, the emerald shiner is a generalist feeder which maximizes utilization of the Dauphin Lake food resource. Although based on a

planktivorous diet, emerald shiners ingested a wide variety of prey items. This broad niche width was evident for both yearling and adult age groups.

During their pelagic planktivorous larval stage, walleye have been reported to initially feed on rotifers (Smith and Moyle 1945) and cladocerans and copepods (Bulkley et al. 1976). Mathias and Li (1982) suggested that rotifer and nauplii ingestion was incidental and noted an affinity by postlarvae for small copepods and daphnids. The utilization of copepodids by emerald shiners in Dauphin Lake therefore appears to put them in direct competition with larval walleye for preferred food organisms. The timing of larval walleye apprearance in the lake also coincides with the seasonal maximum abundance of adult and yearling shiners. To assess the effect of zooplankton cropping by the shiner population, and thus the degree of competition with larval walleye for food resources, an estimate of daily copepodid consumption was calculated. The estimate was based on gastric evacuation time and feeding periodicities of fingerling yellow perch of a similar size to the shiners (Noble 1975).

Food consumption by yearling and adult emerald shiners was calculated to be 2.5% of available copepodids per day (Table 14). This compares favourably with a second estimate based on the assumption that emerald shiners consume 3.0% of their body weight per day. The importance of this rate of copepod consumption becomes evident when compared to copepodid mortality. Total copepodid mortality, estimated

Table 14. Consumption of copepodids by emerald shiner, June 6, 1985.

Species/ Age	Fish Density (#/ha)	Daily Consumption per fish	Total Daily Consumption per m3	Copepodid Density (#/m3)	Copepodids Consumed per day(%)	N
Adult Shiners	1232	1740	107	32716	0.3	11
Yearling Shiners	9190	1581	726	. 32716	2.2	8
					2.5	
Fingerling Perch *	30760	445	201	5600	3.6	

NOTE: The daily consumption of copepodids by emerald shiners, based on a
      daily ration of 3% body weight per day, was 2.3%

* Data of Noble (1975) for fingerling yellow perch (1 g) feeding on
  daphnia in Oneida Lake, New York.

from the decline in numbers between nauplii, copepodid and
adult copepods, was calculated from 1982 Dauphin Lake
plankton tows to be 3.8% per day. Thus, emerald shiner
predation is estimated to account for 66% of total copepodid
mortality per day. Since copepodids at this time are below
the density required for optimum walleye feeding (100 L^{-1},
J.A. Mathias, unpublished data) their consumption by emerald
shiners is considered to be in direct competition with larval
walleye and other species utilizing this food resource at
this time of year in Dauphin Lake.

4) Emerald shiner abundance in Dauphin Lake

Fluctuations in abundance of emerald shiners may be
explained by changes in shiner distribution, or mortality.
During the spring of 1984 a sharp decline in adult and
yearling abundance was measured in offshore trawl
collections. Statistically significant differences between
daily mean abundance estimates occurred suggesting that this
decline was "real". Changes in emerald shiner distribution,
illustrated by the percent of maximum contagion (Fig. 27),
may have contributed to the observed decline in abundance.
It is postulated that, by increasing the size of schools or
concentrating in a particular area of the lake, adult and
yearling shiners became less vulnerable to the bongo trawls,
which in turn was reflected by the decrease in abundance.
Minimum offshore abundance estimates in July of both years

corresponded to maximum values of contagion for adult
shiners. Abundance thereafter remained low in each year
however as the degree of contagion dropped sharply suggesting
that some other factor(s) may be responsible for the observed
decline in abundance.

The abundance of young-of-the-year fish in August 1984
compared to yearling fish in June 1985 also suggested that a
substantial decline in numbers of shiners occurred in the
spring of 1985, as it had in 1984. Young-of-the-year mean
abundance in mid-August 1984 was over 62,000 ha^{-1}, while the
1985 spring estimate of yearling abundance was under 2,000
ha^{-1}. Major mortality of young-of-the-year shiners must
occur between these two periods, and based on the evidence of
1984, early spring may be particularily critical. Production
of young-of-the-year fish was calculated, using the density
and fecundity data of this study, to assess the observed
mortality. A density of 150 females per hectare in early
July (1984), with 1000 eggs per female could have produced
150,000 young-of-the-year shiners per hectare. Thus the
62,000 ha^{-1} young-of-the-year shiners measured in August 1984
represents 41% survival from egg to 1 month old and 1.3%
survival from egg to 11 months old (mid-June 1985).
Mortality occurring between August and June therefore must be
approximately 97%. A similar calculation for 1985 using
early July adult densities yielded the potential production
of 75,000 young-of-the-year per hectare. Based on
young-of-the-year densities measured offshore, survival to
late August was only 3% in 1985. This dramatically lower

survival in 1985 may be attributed to cooler air and water temperatures occuring in July and August of 1985 (Schaap 1987).

Whole-lake densities of yearling and adult shiners ranged during summer months from 100-500 ha^{-1}, and 150-600 ha^{-1}, respectively. Densities measured on the two dates of 1984 are considered underestimates as percent contagion was high for both age groups on both dates.

Estimates of emerald shiner abundance have rarely been attempted due to the inability of suitable collection techniques. Gray (1942) found that by summer, emerald shiners were no longer collected in a drag net. Fuchs (1966) was unable to collect I and II age groups effectively in Lewis and Clark Lake from July to November. Campbell and MacCrimmon (1970) noted that otter trawl catch-per-unit-effort dropped from 140 emerald shiners/trawl hour in spring to 29 shiners/trawl hour in summer. Similarily, in Dauphin Lake the bongo trawls were unable to effectively capture emerald shiners under certain trawl conditions.

Flittner (1964) suggested that high mortality occurred over the first two seasons of growth in Lake Erie, particularily from October to April (0+) and July to September (1+). In Dauphin Lake, high mortality from egg to juvenile is also thought to occur. As well, mortality of young-of-the-year and yearling fish is high between August and June, most probably in spring. The mortality of yearling shiners observed by Flittner (1964) during summer was not

observed in Dauphin Lake. Flittner also suggested that post-spawning mortality of adult shiners was substantial. Whole-lake abundance data for Dauphin Lake was too variable to determine whether post-spawning mortality of adult shiners was significant at this time.

Summerkills, although infrequent, do occur in Dauphin Lake (W. Howard, Man. Dept. Nat. Res., pers. comm.). The lake is usually oxygen saturated (Babaluk and Friesen 1988), however during calm periods when algae are concentrated, oxygen concentrations are insufficient for fish which inhabit inshore areas at night. A major summerkill occurred on June 30/July 1 of 1984. Large numbers of emerald shiners were found washed up on the south shore of the lake.

Parasites may also contribute to natural mortality in Dauphin Lake. Several specimens in poor condition were examined for parasite infection. All were encysted with Centrovarium lobotes (20-50 per fish)(A. Szalai, Univ. of Manitoba, pers. comm.) but their affect on these specimens was not determined.

5) Distribution and movements

Numerous factors limit the distribution of fishes within a lake, however in Dauphin Lake the distribution of emerald shiners has few limitations. This shiner inhabits nearly all available habitats in the lake. Cobble and sand habitats supported the highest shiner biomass in both years of

investigation. Only silt or detritus inshore habitats, or
associated with submergent vegetation, supported few emerald
shiners, although several were usually collected. All
offshore trawling locations, regardless of substrate or water
depth, contained abundant emerald shiners. They were also
observed in the lower reaches of several large tributaries
(W. Franzin, Can. D.F.O., pers. comm.).

The distribution of the Dauphin Lake emerald shiner
population was similar in the two years of study. Changes in
distribution appeared to be correlated with water temperature
and may have therefore been related to predator activity.
Walleye, for example, feed most intensively during summer and
fall (Colby et al. 1979). As schooling is a defense
mechanism which decreases the likelihood of detection by a
predator (Shaw 1978), changes in school size or degree of
contagion may be beneficial for survival. During spring,
emerald shiners were distributed evenly throughout the lake
suggested by large inshore and offshore collections and low
values of degree of contagion. Emerald shiner abundance
estimates revealed that, in both years and both strata of the
lake, the shiners increased their degree of contagion as
water temperatures increased, this being particularily
evident in the distribution of adults (Fig. 27). This
change in distribution contributed to the decreased offshore
abundance estimates in summer by reducing the population's
vulnerability to the nets. Flittner (1964) observed similar
distributional changes and noted the annual scarcity of
emerald shiners in bait fish collections in Lake Erie. He,

and Campbell and MacCrimmon (1970), reported the return of
emerald shiners to a more random distribution in the fall.
Decreased contagion and increased abundance in late August
and September collections in Dauphin Lake support these
observations.

Inshore, the effect of water temperature on shiner
contagion was particularily evident. In 1984, mean shiner
biomass dropped by an order of magnitude between July 16 and
July 27. Biomass estimates remained low for the mid-August
sample then, in late September, returned to a value similar
to that on July 16. Mean inshore water temperature on July
16 was 20.8°C and increased gradually to 24.8°C on July 28
(Schaap 1987). Water temperatures generally remained above
22°C until late August and dropped to 10°C by late September.
The diurnal range of inshore temperatures during this period
was up to 12°C (Schaap 1987). In 1985, a gradual decrease in
shiner biomass was noted throughout the summer when water
temperatures were cooler and more consistent. Variation of
biomass estimates between dates in 1984 therefore reflected
mortality and distributional changes caused by diurnal and
seasonal temperature changes.

Movements of shiners between inshore and offshore areas
of the lake could not be documented by the sampling regime
utilized. Abundance estimates offshore, for example, were
never able to account for decreasing densities inshore. If
such migrations had occurred, resulting in the observed
decline in offshore abundance, inshore estimates would have
increased 20-30 times.

Emerald shiner distributions in Dauphin Lake were
separated loosely by age groups. Adult shiners were always
more abundant inshore than yearlings, although differences
between estimates were rarely significant. Conversely,
yearling shiners were most always more abundant offshore than
adults. Differences were significant only in spring.
Young-of-the-year emerald shiners were first collected
offshore in both years as expected, due to pelagic spawning
behavior (Balon 1975). Larvae which hatched early moved
inshore while larvae hatched later remained pelagic. By
fall, young-of-the-year emerald shiners dominated seine
collections.

6) The emerald shiner as forage

The emerald shiner dominates the forage fish assemblage
of Dauphin Lake. In offshore trawls emerald shiners were
almost exclusively the only prey species collected.
Occasionally, yearling yellow perch, yearling ciscoes,
trout-perch and spottail shiners were captured, most
frequently in spring trawls. Inshore, forage fish
composition varied by habitat (seine location) and season but
the emerald shiners always dominated the catch in biomass and
in numbers. This shiner contributes significantly to the
bait fish industry of Dauphin lake and lakes throughout
Manitoba (see appendix 3).

The emerald shiner is an important prey item for

numerous fish species of Dauphin Lake. Stomach content analysis of walleye and northern pike indicate that the emerald shiner is preyed on extensively by all age groups of these species (J.F. Craig, Can. D.F.O., F.W.I., pers. comm.). Other piscivorous inhabitants of the lake presumably prey on the emerald shiner, as well. In other lakes, this shiner has been acknowledged as prey for numerous predatory species. Flittner (1964) reviewed studies of predation on emerald shiners in Lake Erie. Predators included yellow perch, walleye, burbot, sauger, smallmouth bass and white bass. Campbell and MacCrimmon (1970) listed Lake Simcoe predators as yellow perch, smelt, burbot, rockbass, pumpkinseed and lake trout. Numerous other piscivores of other lakes undoubtedly prey on the emerald shiner. As well, Dauphin Lake emerald shiners are preyed upon by many resident and migrant aquatic birds. Significant avian predators at Dauphin Lake include white pelicans, double-crested cormorants, and common terns. All possess diets made up chiefly of small fish (Peterson 1980).

Parsons (1971) examined prey size preference of young walleyes. He estimated the maximum and minimum limits of prey length and noted that the range of acceptable prey size increased with predator size. In Dauphin Lake, walleyes aged 1+ or greater can utilize all ages of the emerald shiner population as a nutritional source (Fig. 30). Young-of-the-year walleyes are only able to consume young-of-the-year shiners. Yearling emerald shiners have growth rates high enough to narrowly exclude them from the

Figure 30.   Prey size preference of young walleyes

(from Parsons) showing mean prey lengths

(dots), prey length ranges (vertical lines),

calculated mean length (solid line) and

estimated maximum and minimum limits (dashed

lines). The range of Dauphin Lake emerald

shiners lengths, by age group, is shown by

hatched areas.
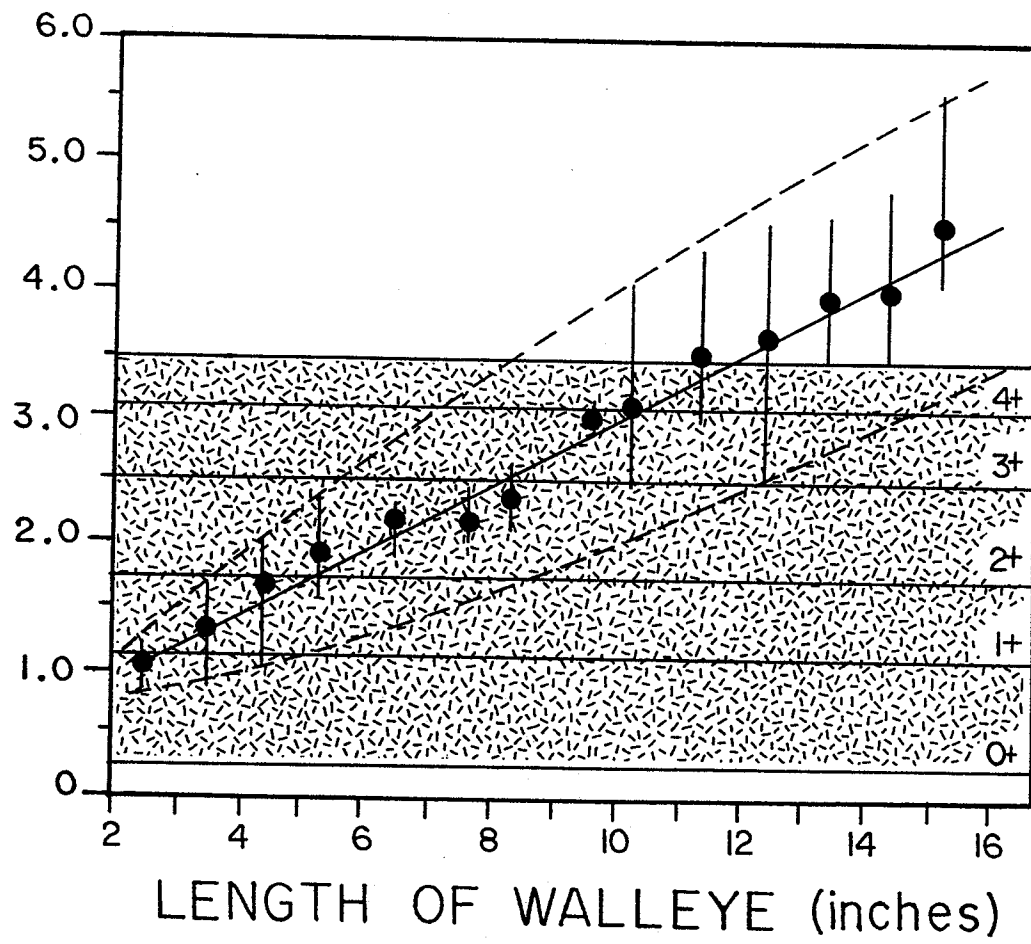
young-of-the-year walleye diet based on Parson's study (Fig. 30). The widespread distribution of the emerald shiner in Dauphin Lake makes it particularily susceptible to predation by walleyes and other piscivorous fishes.

Swenson (1977) examined the relationship between walleye consumption rate and prey density. He concluded that consumption rates increased with prey density and stabilized at 30 mg prey per g of walleye per day at a prey density of 400 mg prey per m^3. Figure 31A illustrates Swenson's curve with 1985 densities of Dauphin Lake forage species plotted by month. It is evident that the inshore forage complex is able to support maximum levels of walleye food consumption from May through August. Emerald shiners alone are able to support maximum consumption rates in May and June. Only during September of 1985 were inshore forage densities unable to support maximum consumption rates. Offshore, emerald shiner densities in spring and summer were able to support 50% of maximum consumption rate (Fig. 31B). Fall density estimates were based on only 4 samples.

Figure 31. Densities of A. emerald shiners and all forage
fish estimated from beach seines, and B.
emerald shiners estimated from offshore trawls,
in Dauphin Lake plotted on Swenson's (1977)
curve of walleye consumption rates.

PREY DENSITY (mg/m³)

PREY DENSITY (mg/m³)
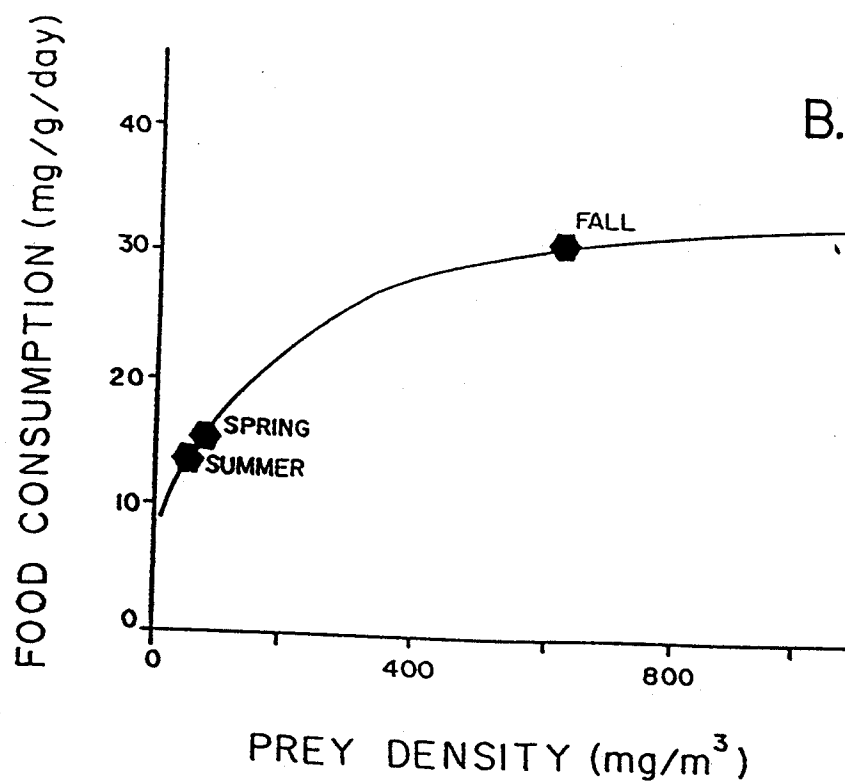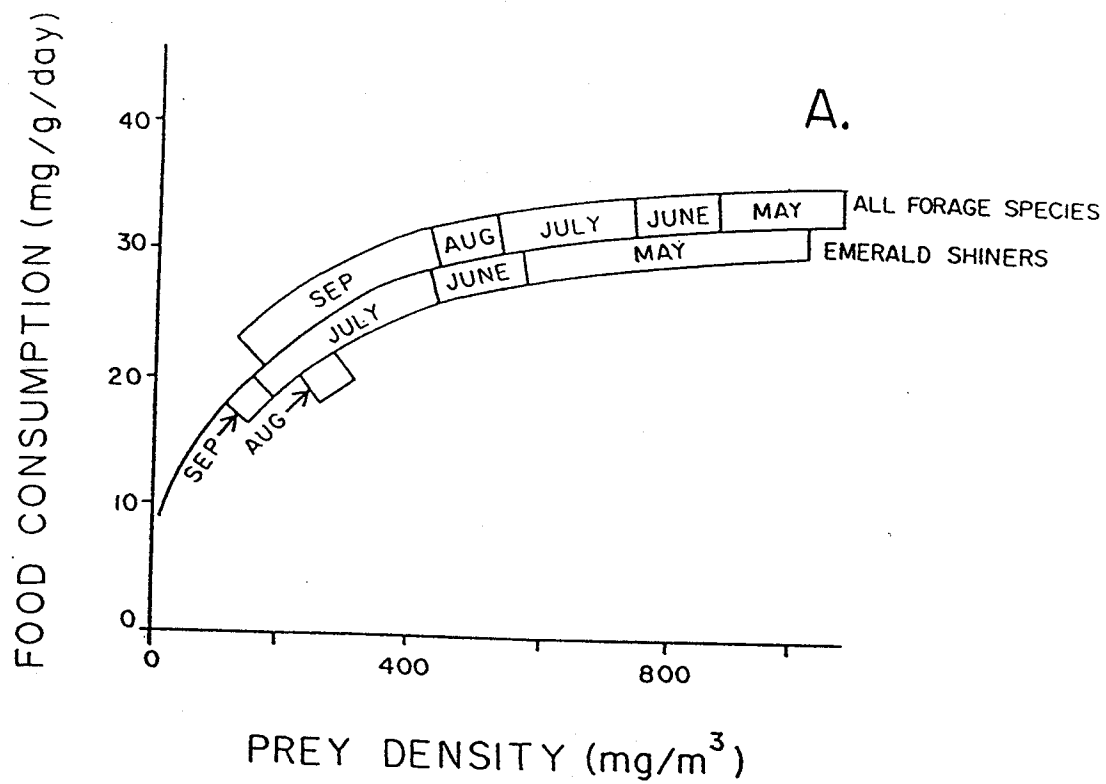
CONCLUSIONS

Should the rehabilitation of the walleye population in Dauphin Lake be successful, increased predation is expected to impact on emerald shiner ecology. Increased walleye abundance in the lake will undoubtedly result in increased predation on emerald shiners, and presumably decrease standing stocks. This prediction is based on the fact that emerald shiners were the largest prey component in the diet of Dauphin Lake walleye and northern pike (J.F. Craig, F.W.I., unpublished data). During the open water seasons of 1984 and 1985, inshore densities of emerald shiners, combined with other forage species, were capable of supporting the maximum food consumption rates of walleye proposed by Swenson (Fig. 31). The availability of forage fish in the lake would therefore promote walleye survival and the potential for rehabilitation. Future abundance of emerald shiners in Dauphin Lake will ultimately depend on survival rates of stocked walleye.

Moderate predation of emerald shiners by walleye may stimulate shiner production, as productivity at a given trophic level is maximized at intermediate biomass levels of its predators (Carpenter et al. 1985). Decreased interspecific competition for food resources, resulting from a moderate reduction in population abundance, may increase specific growth rates. Significant differences in shiner growth were measured between the two years of study and

attributed to climatic differences which occurred. Growth rate changes associated with increased predation should be evident in all age classes, and on a scale greater than observed for climatic differences.

Reduction of emerald shiner biomass through predation by walleye may also be reflected in changes in the zooplankton community of the lake. This prediction is based on the theory of cascading trophic interaction (Carpenter et al. 1985) which proposes that changes in biomass at one trophic level will cascade to lower trophic levels. Presently, high forage fish abundance, including emerald shiners, is responsible for the dominance of rotifers and small crustaceans in the Dauphin Lake zooplankton community. Abundance of large-bodied zooplankters is suppressed through size-selective predation (Fig. 19). A reduction of forage fish biomass would theoretically favour a shift in the size distribution of the lake zooplankton to the dominance of large-bodied species.

Changes in the reproductive ecology of the emerald shiner are also likely to occur as a result of increased walleye abundance. The magnitude of these changes is again dependent on the success of the rehabilitation of Dauphin Lake walleye. Predicted changes may be gleaned from reproductive data of more exploited emerald shiner populations, such as Lakes Erie and Simcoe. In these lakes, energy resources initially channelled to somatic growth when

shiners are young are directed towards reproductive maturation earlier, resulting in the potential for production of offspring at a younger age and larger total contribution of progeny during the fish's lifespan. Predicted changes in the reproductive ecology of Dauphin Lake emerald shiners may therefore include a decrease in age at sexual maturity, a decrease in egg diameter, and an increase in absolute and relative fecundity. Production of larger numbers of juveniles, combined with cropping of adult shiners, would decrease the mean and maximum age of the Dauphin Lake emerald shiner assemblage. Population regulating mechanisms, such as these, are known to function in fish populations in response to community perturbations.

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Appendix 1. List of common and scientific names of fishes
and birds referred to in the text.

Common Name	Scientific Name
FISH	
Alewife	*Alosa pseudoharengus*
Bass, rock	*Ambloplites rupestris*
smallmouth	*Micropterus dolomieui*
striped	*Morone saxatilis*
white	*M. chrysops*
Burbot	*Lota lota*
Ciscoe	*Coregonus artedii*
Crappie	*Pomoxis*
Darters, iowa	*Etheostoma exile*
johnny	*E. nigrum*
river	*Percina shumardi*
Drum, freshwater	*Aplodinotus grunniens*
Grayling, arctic	*Thymallus arcticus*
Herring	*Clupeidae*
Logperch	*Percina caprodes*
Minnow, bluntnose	*Pimephales notatus*
fathead	*P. promelas*
Perch, yellow	*Perca flavescens*
Pike, northern	*Esox lucius*
Pumpkinseed	*Lepomis gibbosus*
Sauger	*Stizostedion canadense*
Shiner, common	*Notropis cornutus*
emerald	*N. atherinoides*
golden	*Notemigonus crysoleucas*
spottail	*Notropis hudsonius*
Smelt, american	*Osmerus mordax*
Trout, brown	*Salmo trutta*
lake	*Salvelinus namaycush*
Trout perch	*Percopsis omiscomaycus*
Walleye	*Stizostedion vitreum*
BIRDS	
Cormorant, double-crested	*Phalacrocorax auritus*
Pelican, white	*Pelecanus erythrorhynchos*
Tern, Common	*Sterna hirundo*

Appendix 2.   Offshore distribution of emerald shiners in
Dauphin Lake, Manitoba for sample dates and age
groups, 1984 and 1985.

Legend

 >30% of maximum emerald shiner collection

 >60% of maximum emerald shiner collection

NOTE: Numbers are percent of maximum numbers of emerald
shiners collected in a a single trawl.

ADULTS

JUNE 3-4, 1984

9.0

10.0

3.4

56.0

21.5

100.0

38.0

13.0   18.6

13.8   7.9

.17.2

3.2

8.2

8.0   11.6

JUNE 5-6, 1984

1.4

4.7   .0.9

7.5   2.5

.3.1

.3.0

7.6   11.9

2.1

2.4   1.2

39.0   70.9   5.8

.46.2

62.6   0.9

23.4

100.0 49.8
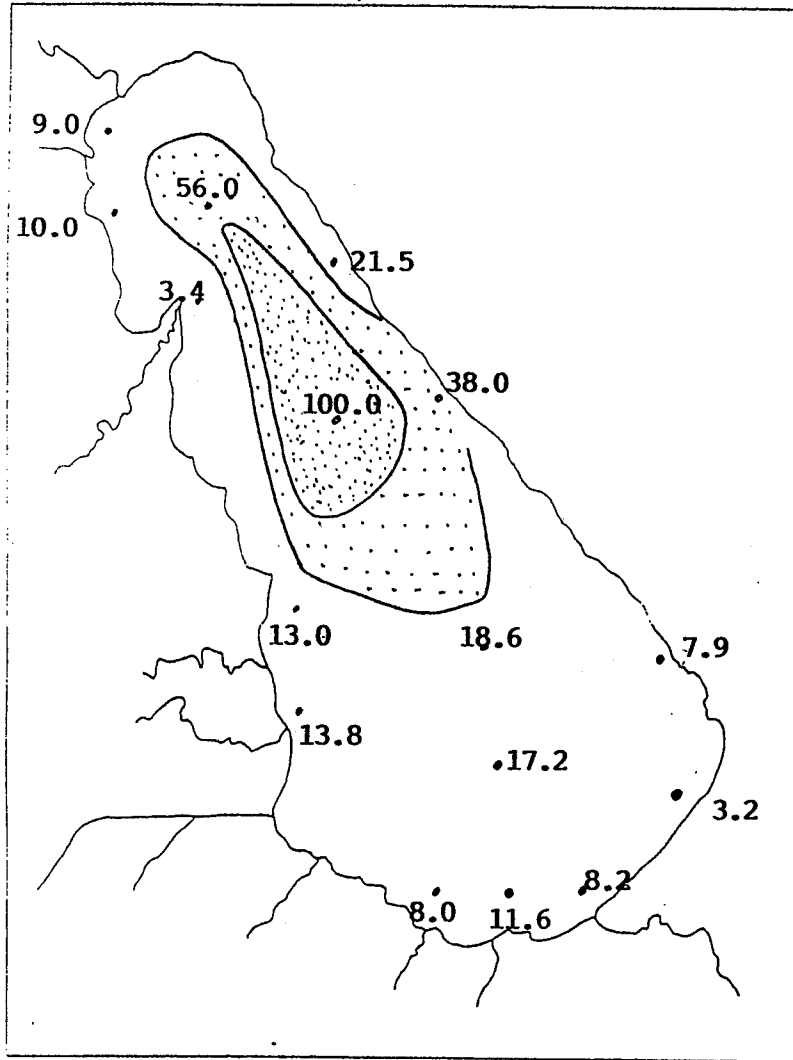
ADULTS

JUNE 11-12, 1984   JUNE 13-14, 1984

160

ADULTS

JUNE 15-16, 1984

23.0

15.3

0.0

100.0

12.5

18.4

5.4

19.7   10.4

8.6

7.3   12.6

0.0   2.4   0.0

0.0   0.0

0.0

0.0   0.0   0.0

JUNE 19-20, 1984

0.0

1.5

0.0   0.0

3.3

4.4

0.0

0.0

4.3   3.5

2.8

11.8   100.0

4.2

73.9

40.9

1.6

5.1

18.7   2.8
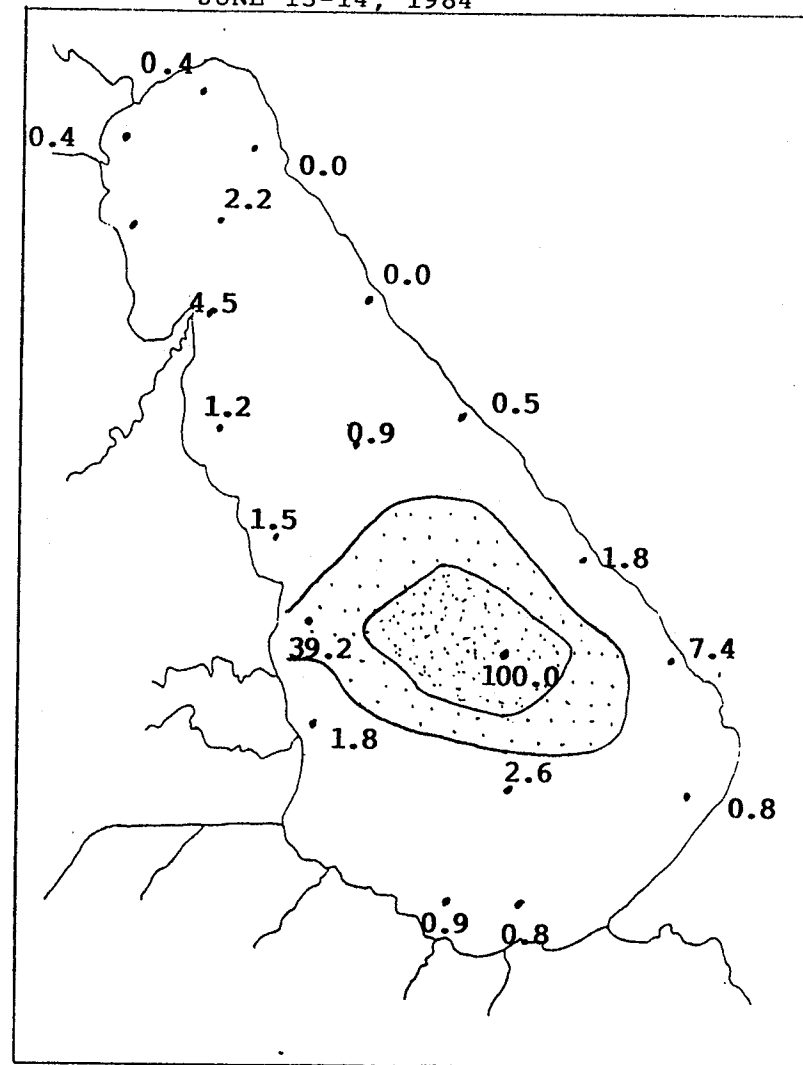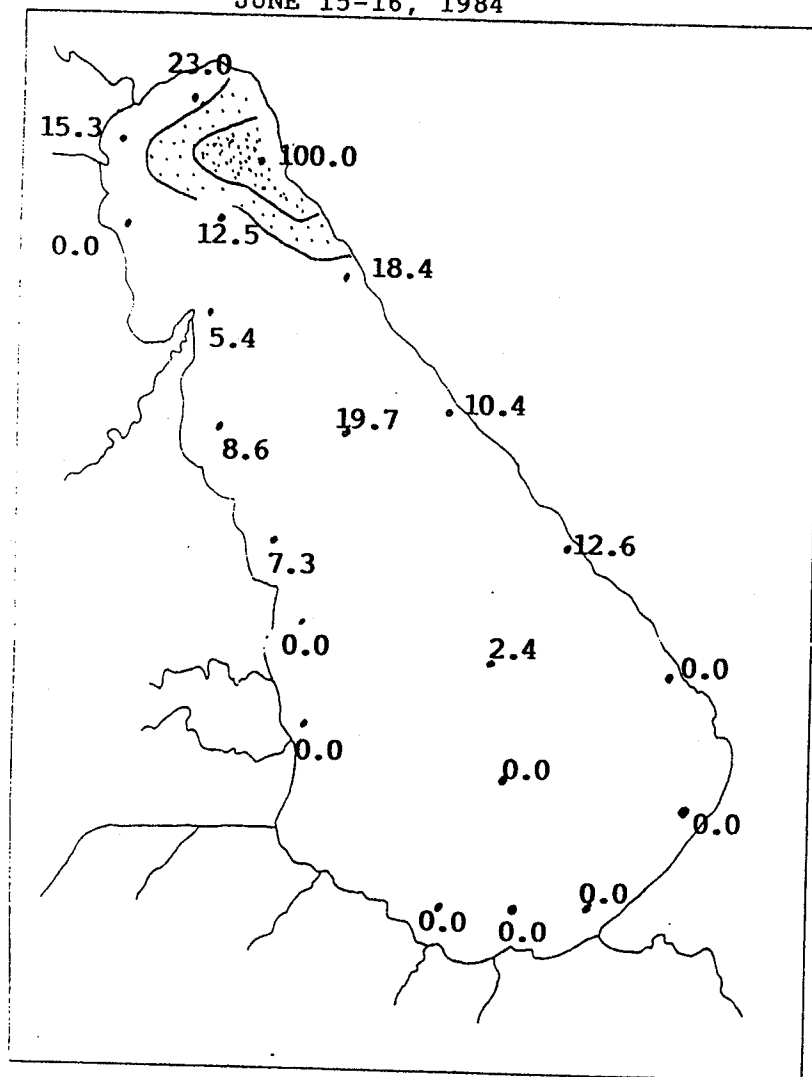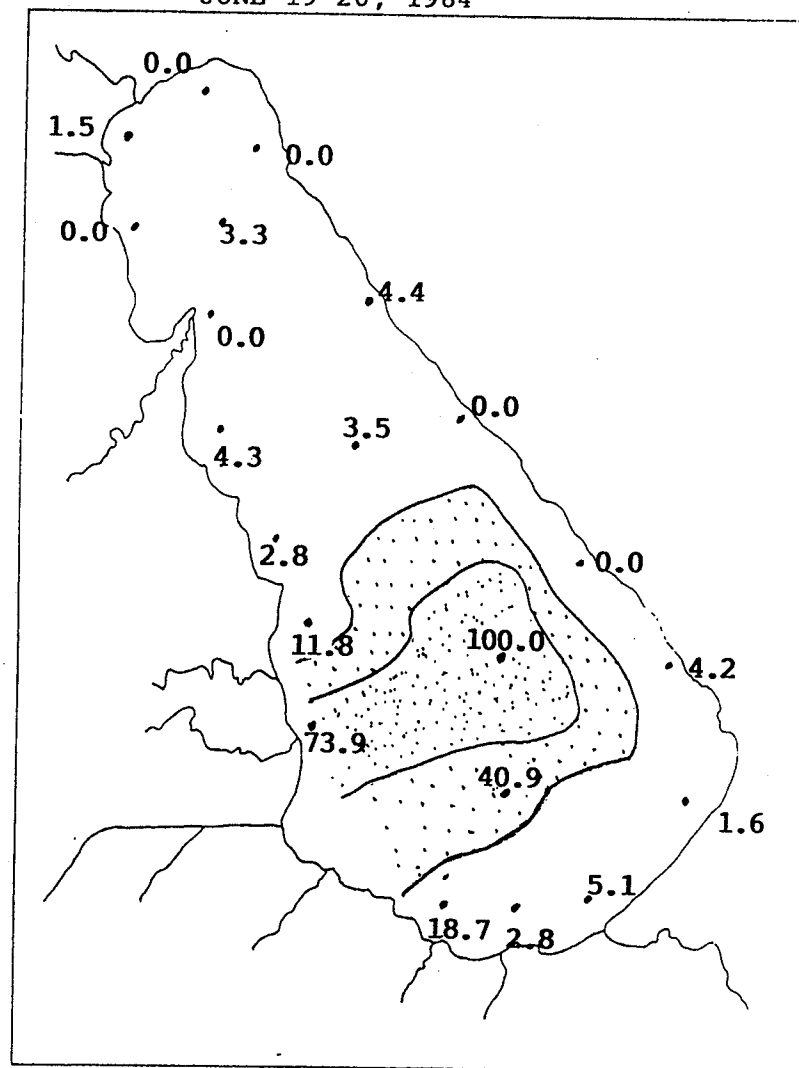
YEARLINGS

JUNE 3-4, 1984

JUNE 5-6, 1984

162

YEARLINGS

JUNE 11-12, 1984

8.6

5.5
38.2
14.5
18.6
39.9
4.7
25.1
15.2
7.0
40.1
20.2
9.5
22.5
100.0
10.4
24.0
13.2
14.0
57.2
58.3

JUNE 13-14, 1984

13.6
60.4
100.0
67.1
69.4
22.5
29.5
35.3
16.0
21.2
22.7
32.4
49.4
49.1
29.3
64.1
32.2
4.7
38.4
5.8

163
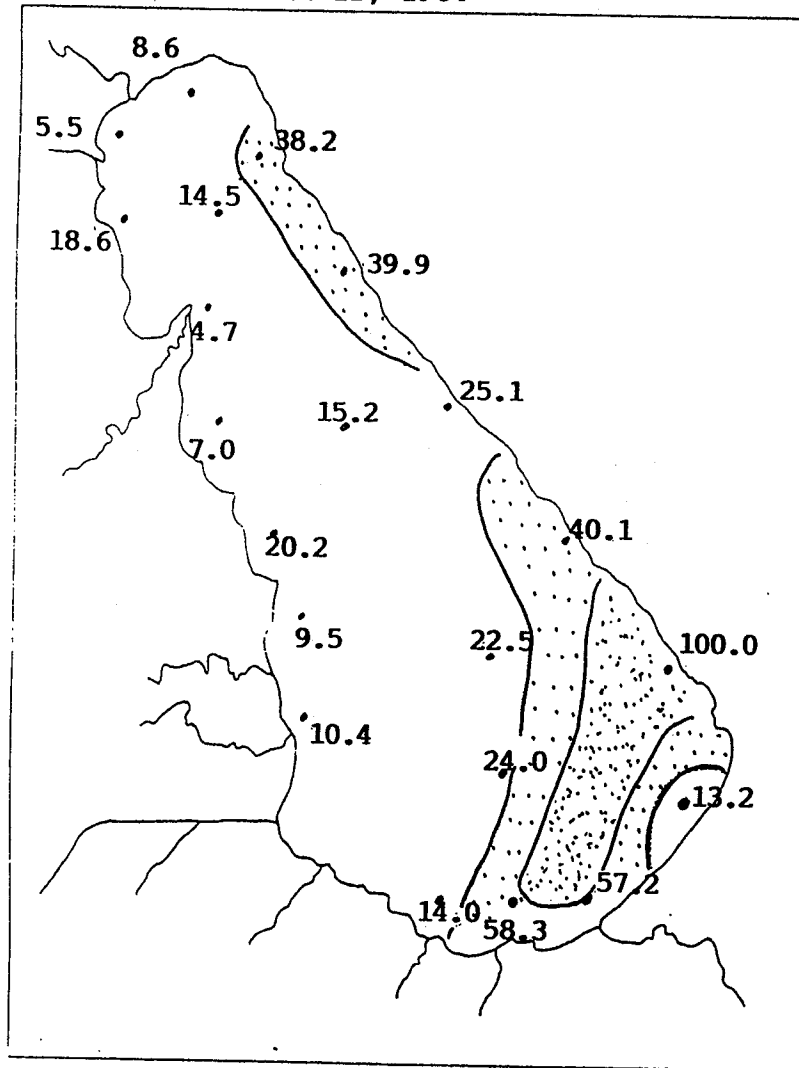
YEARLINGS
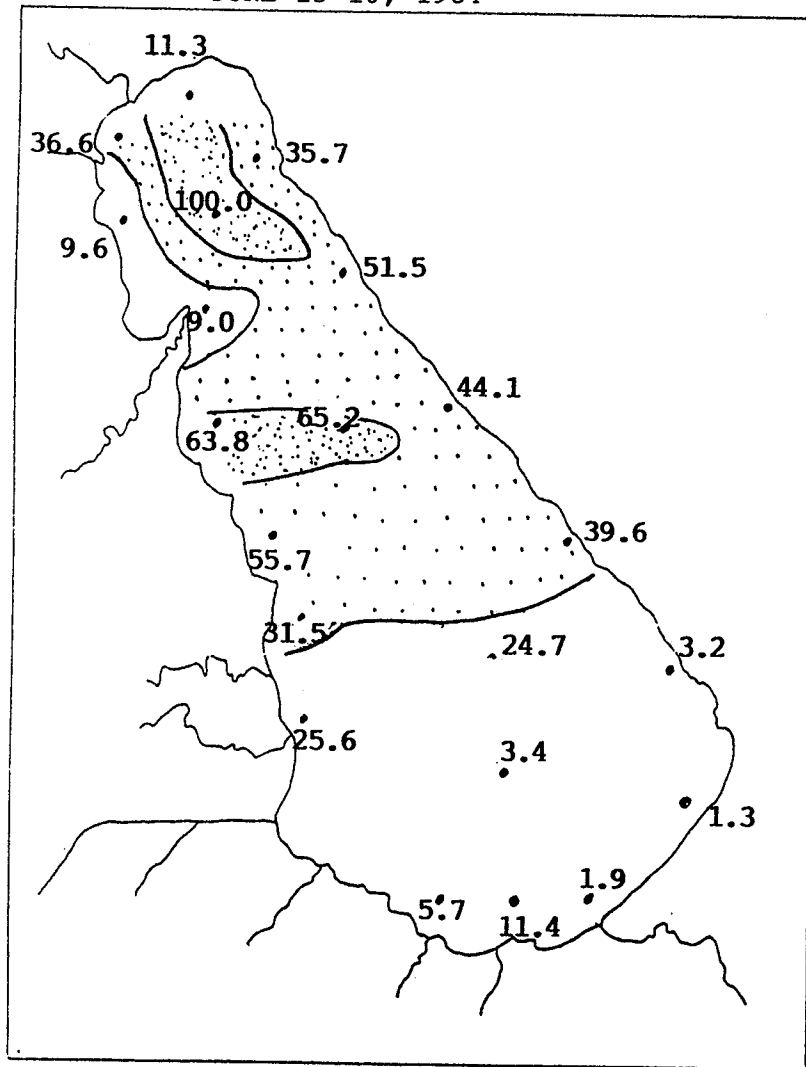
JUNE 15-16, 1984   JUNE 19-20, 1984
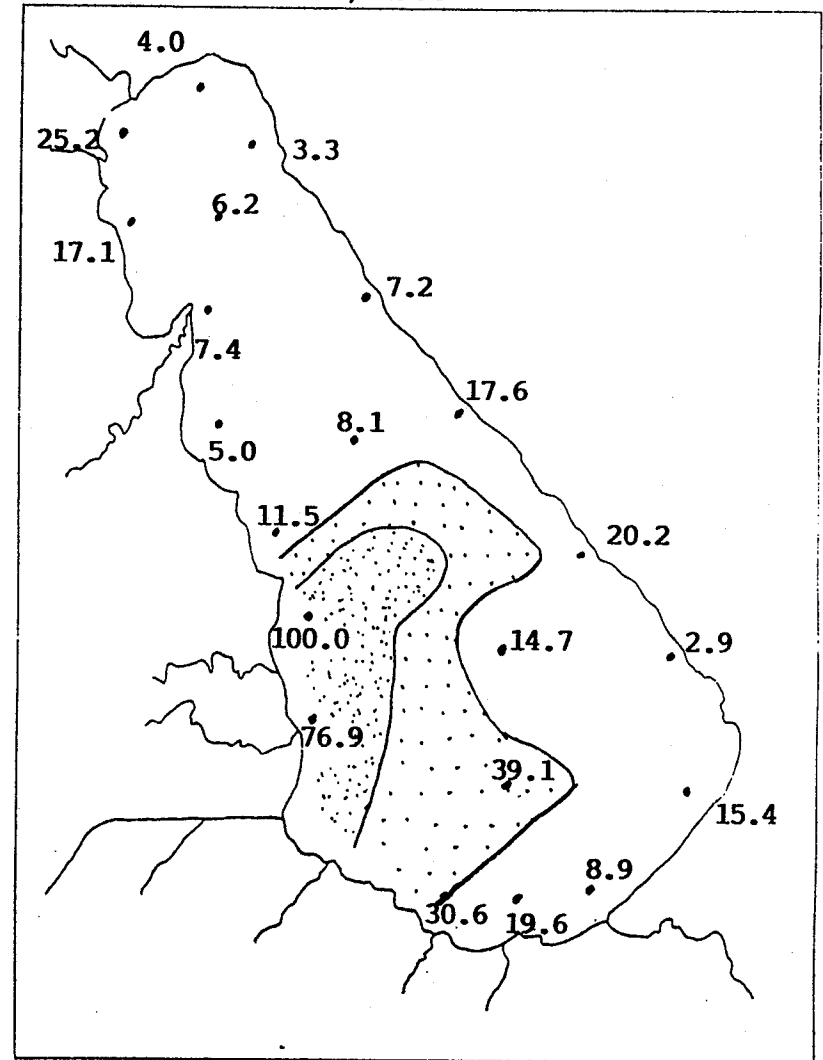
YEARLINGS

JULY 10-12, 1984
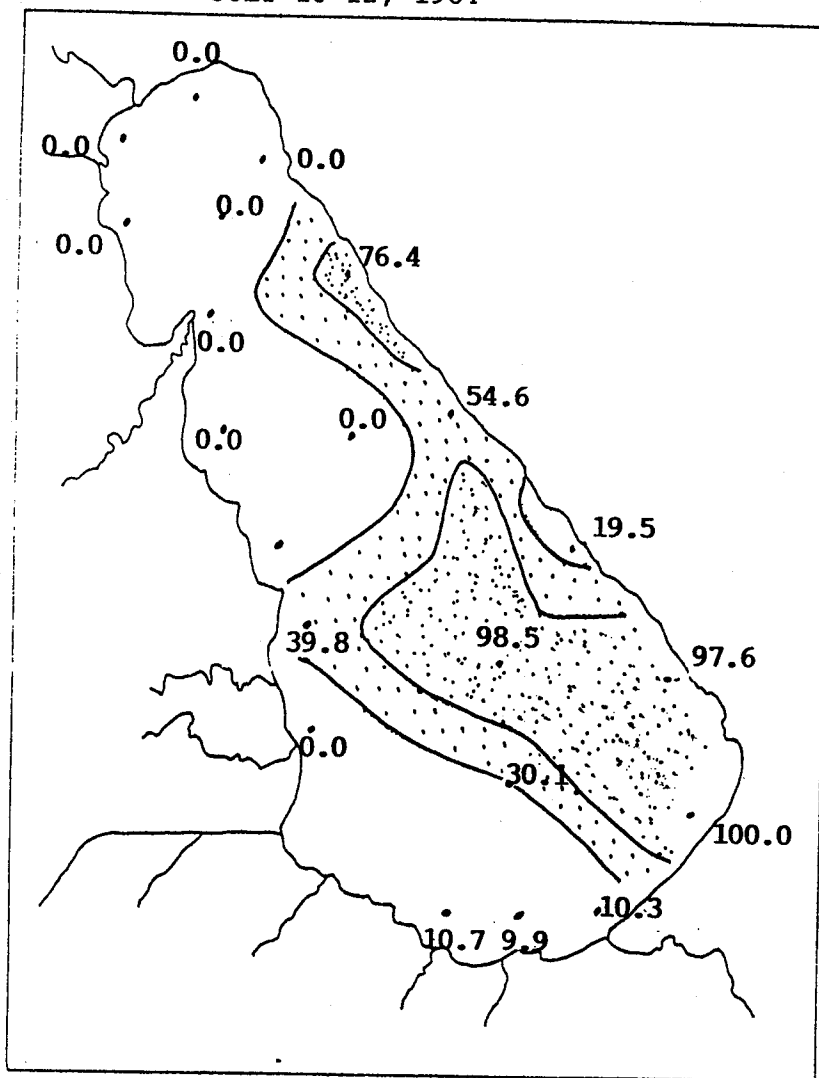
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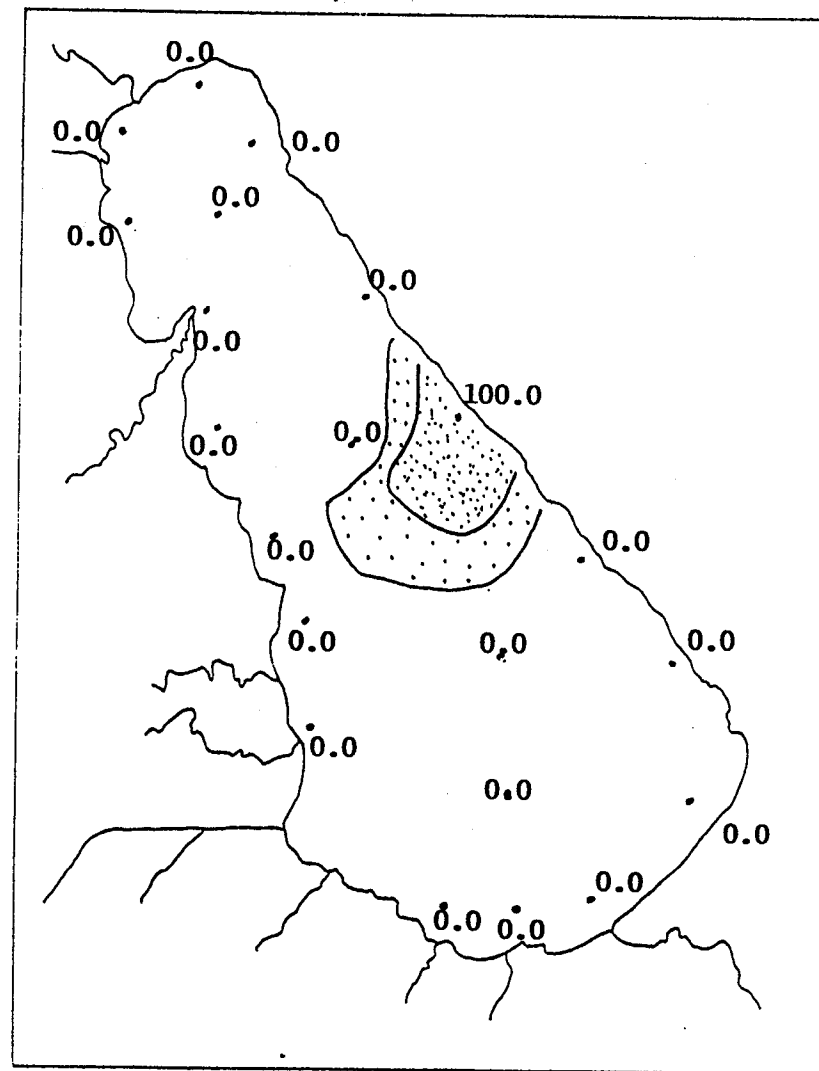
YEARLINGS
AUGUST 10-12, 1984
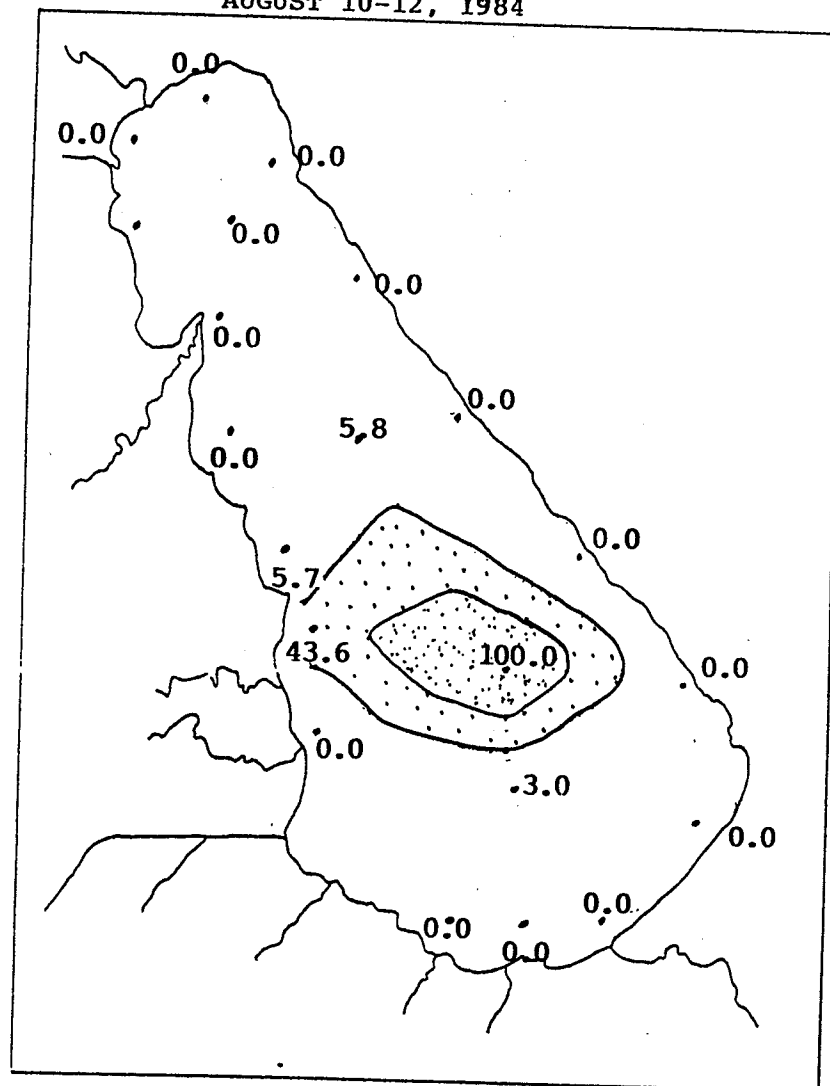
Y.O.Y.

JULY 10-12, 1984

JULY 26-27, 1984

167
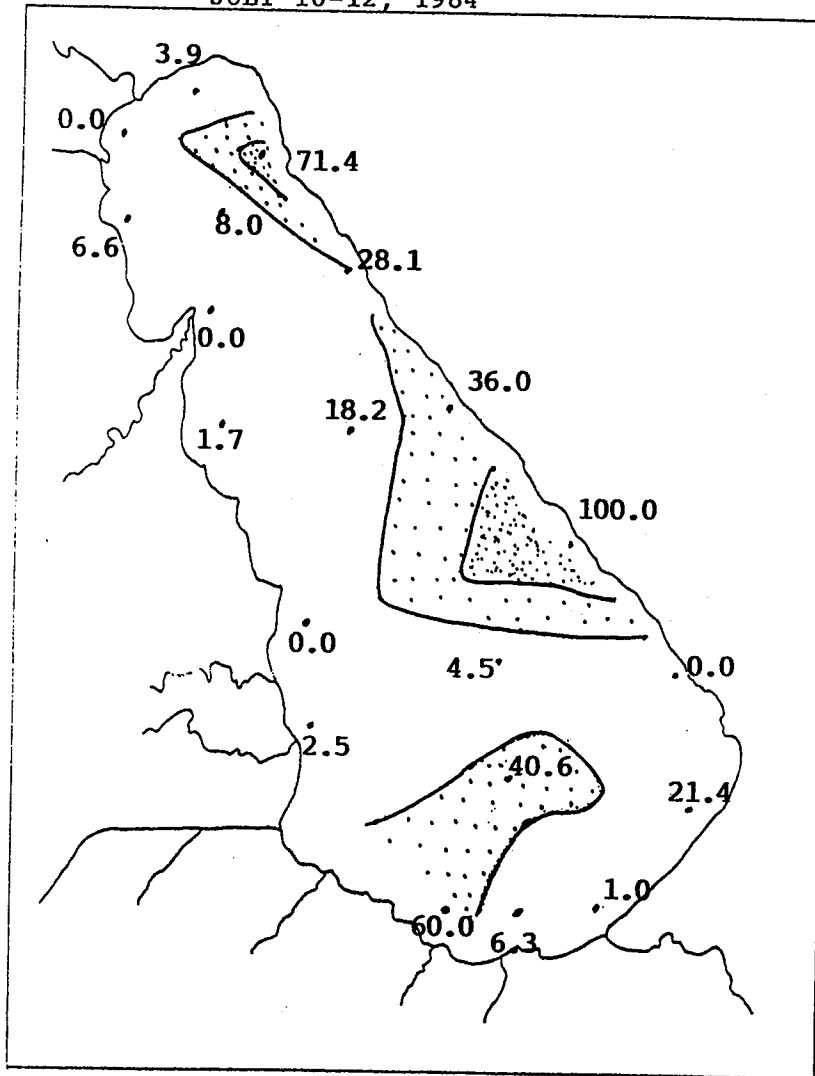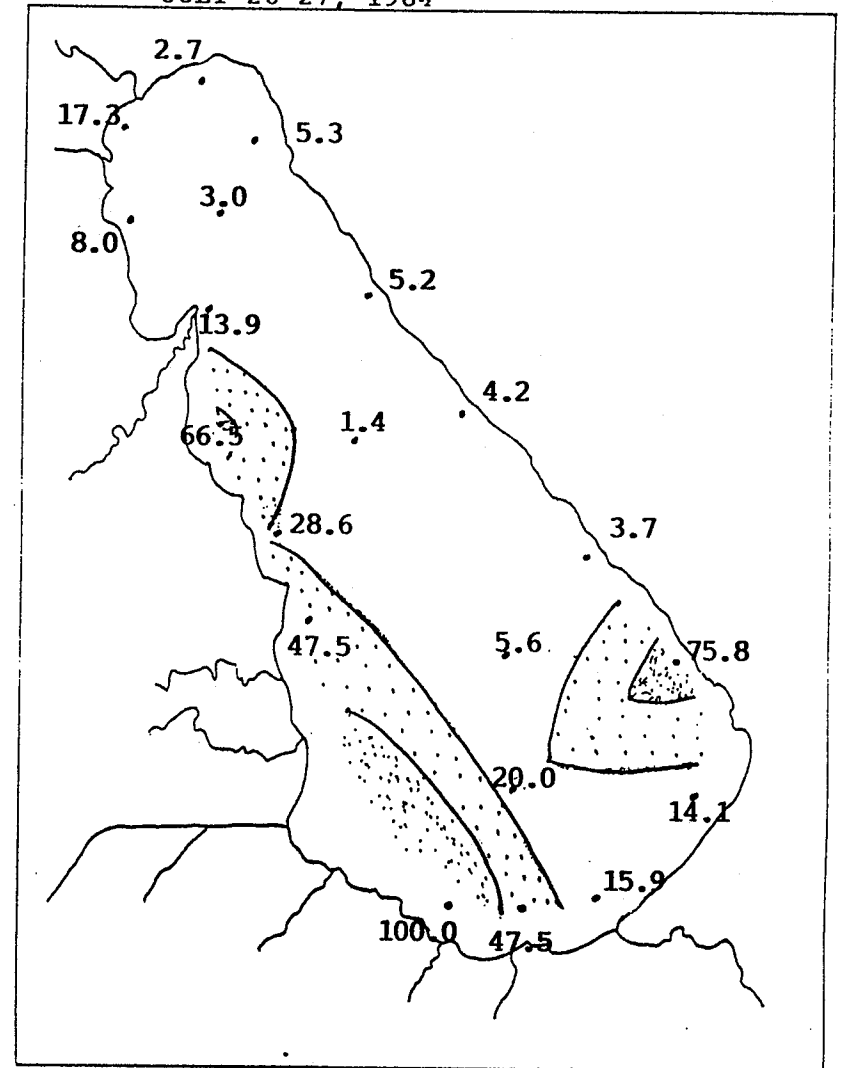
Y.O.Y.

AUGUST 10-12, 1984

ADULTS

JUNE 11, 1985

5.2

40.5

13.2

8.3

38.5

100.0

8.9

0.0

0.0

54.0

6.1

5.3

64.8 39.3

JUNE 25-26, 1985

7.4

1.3

0.0

0.0

10.7

30.7

18.7

12.6

10.2

13.0

19.5

14.5 32.9

100.0

45.3 67.2

3.0 47.1

2.0

169
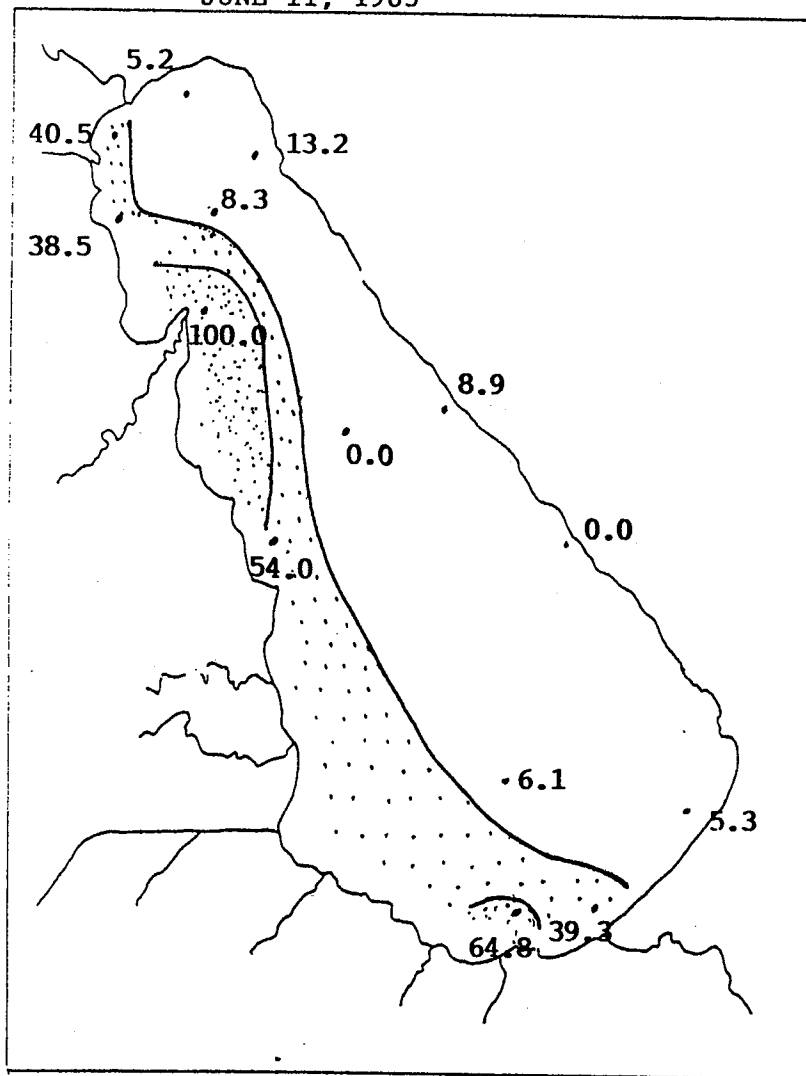
ADULTS

JULY 8-10, 1985

JULY 24-25, 1985
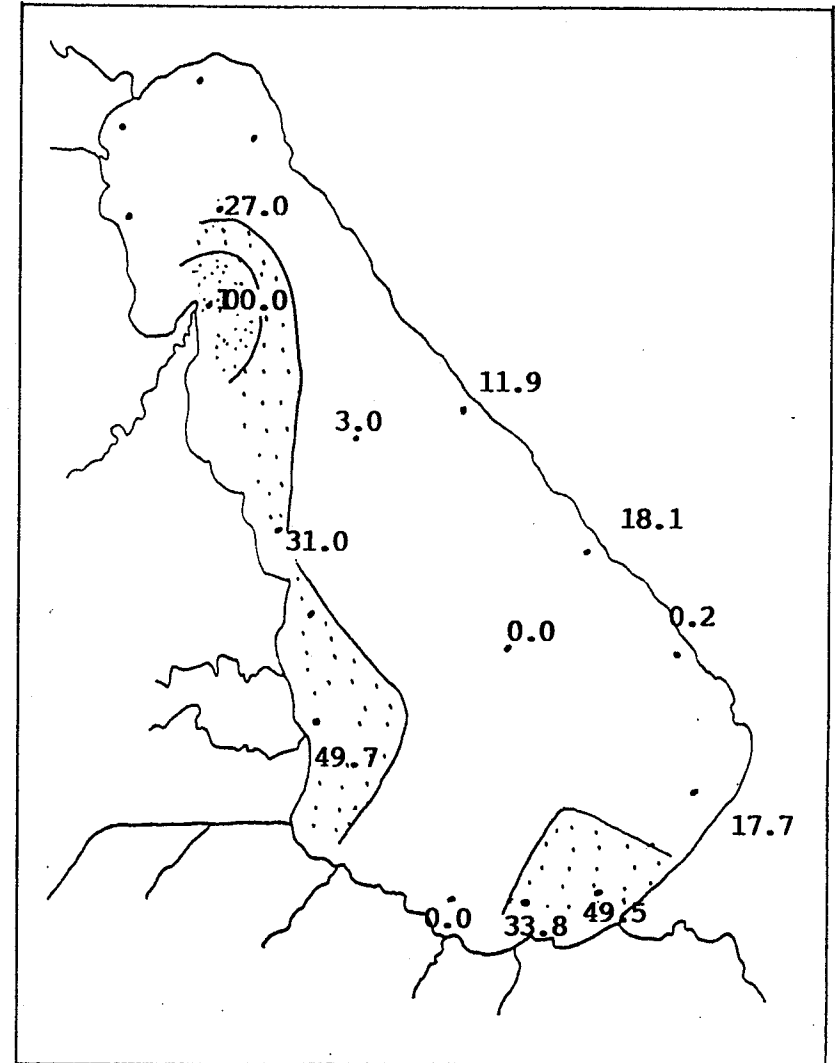
ADULTS
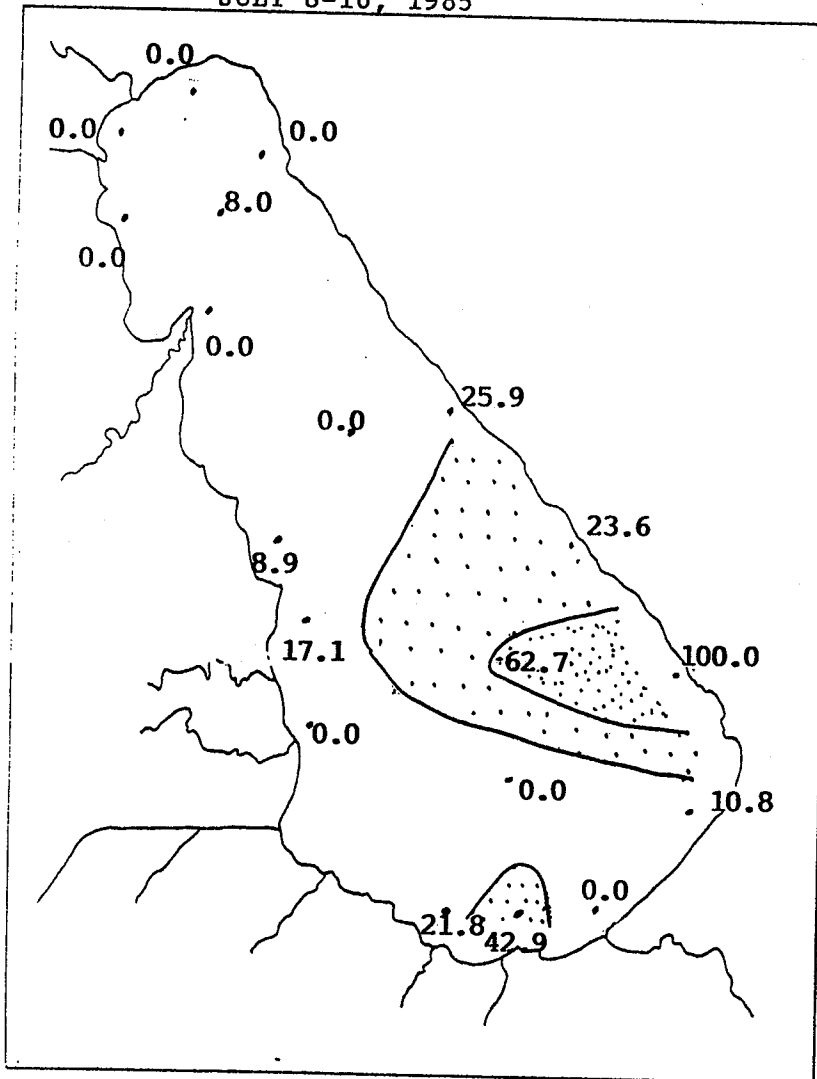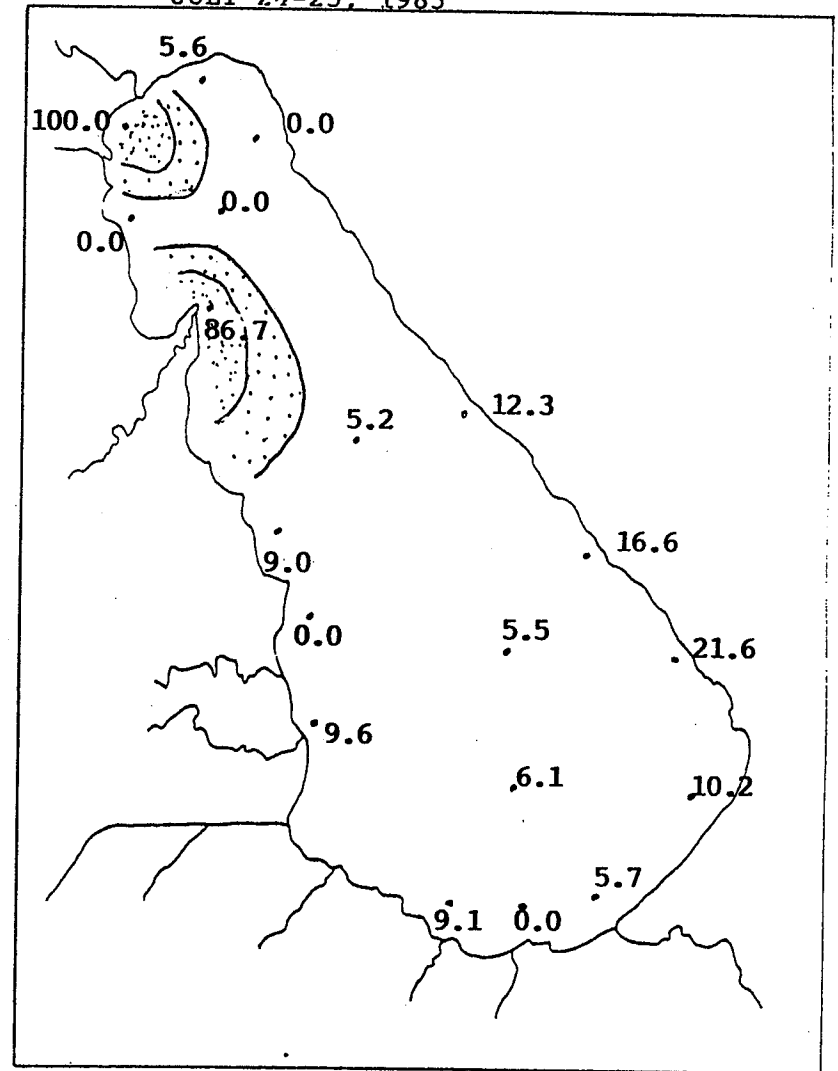AUGUST 20-22, 1985
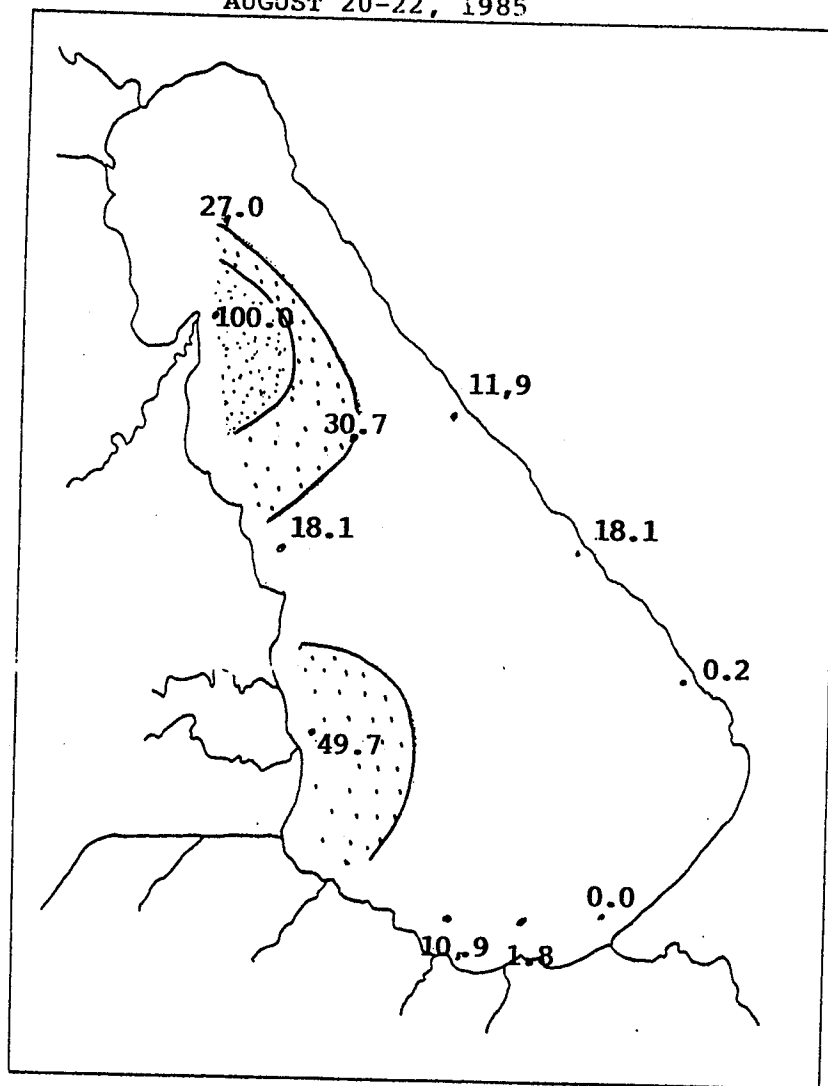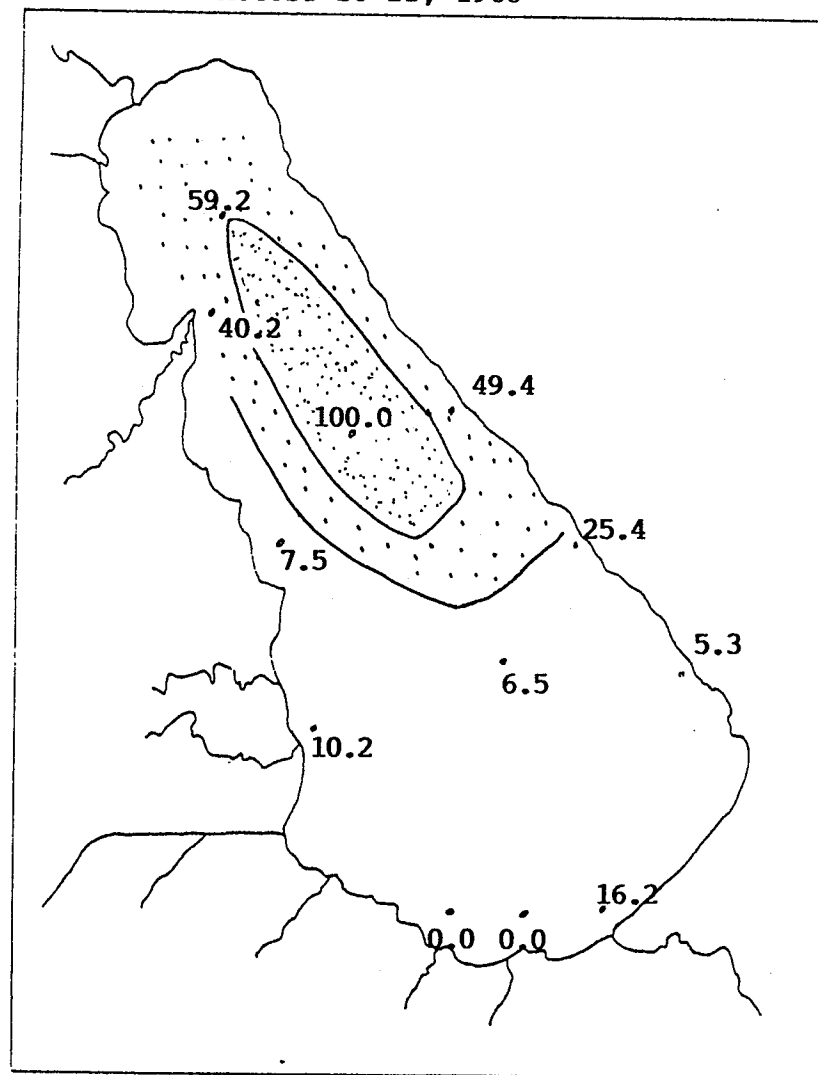
YEARLINGS
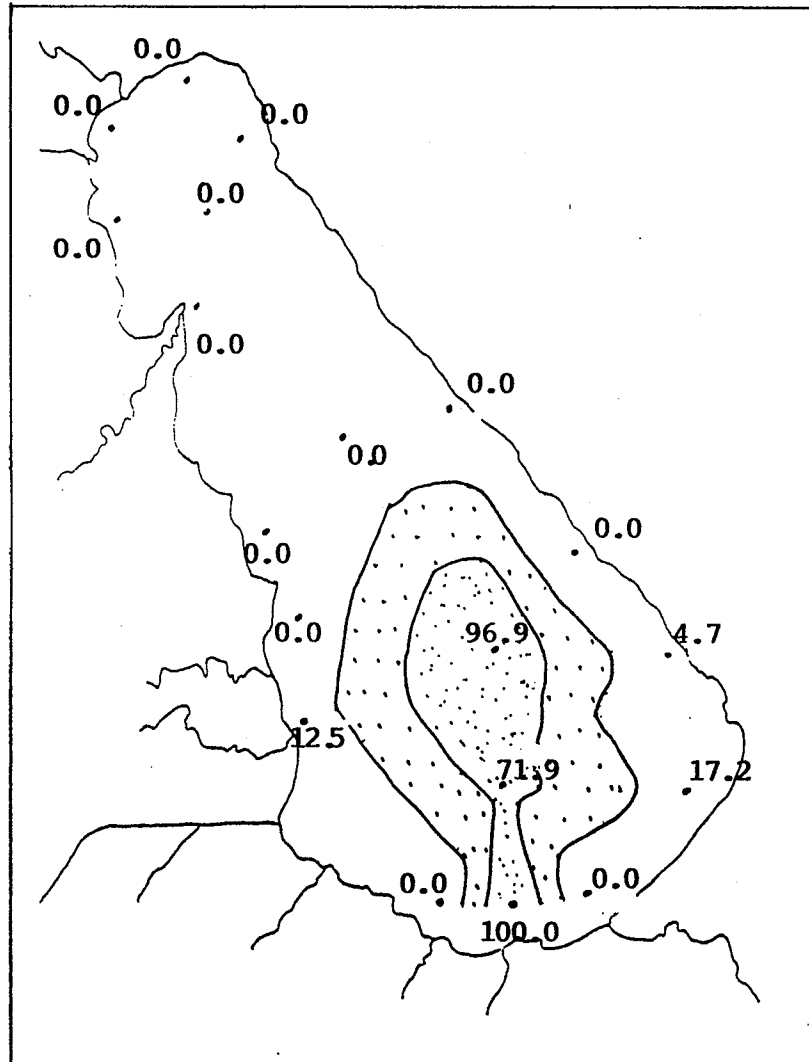
JUNE 11, 1985

JUNE 25-26, 1985

172

YEARLINGS

JULY 8-10, 1985

0.0

0.0   0.0

.8.0

0.0

0.0

0.0   25.9

23.6

8.9

17.1   62.7   100.0

0.0

0.0   10.8

0.0

21.8
42.9

JULY 24-25, 1985

5.6

100.0   0.0

0.0

0.0

86.7

5.2   12.3

9.0   16.6

0.0   5.5   21.6

9.6

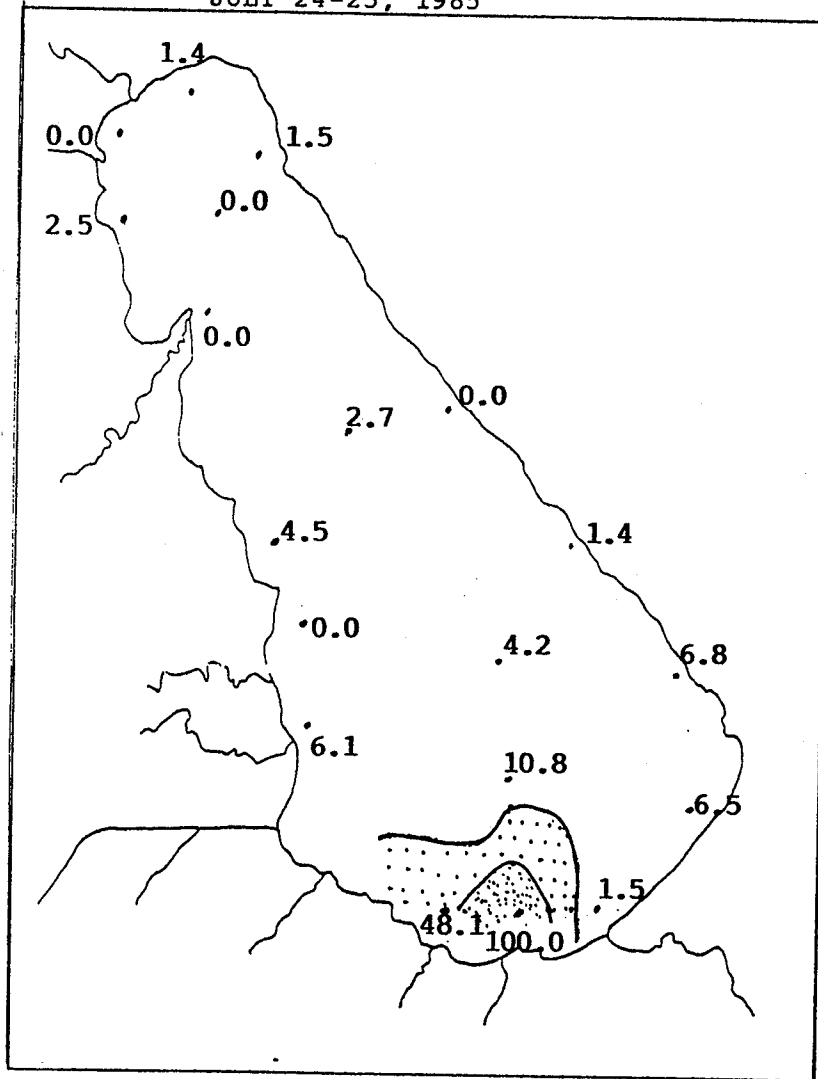.6.1   10.2

5.7

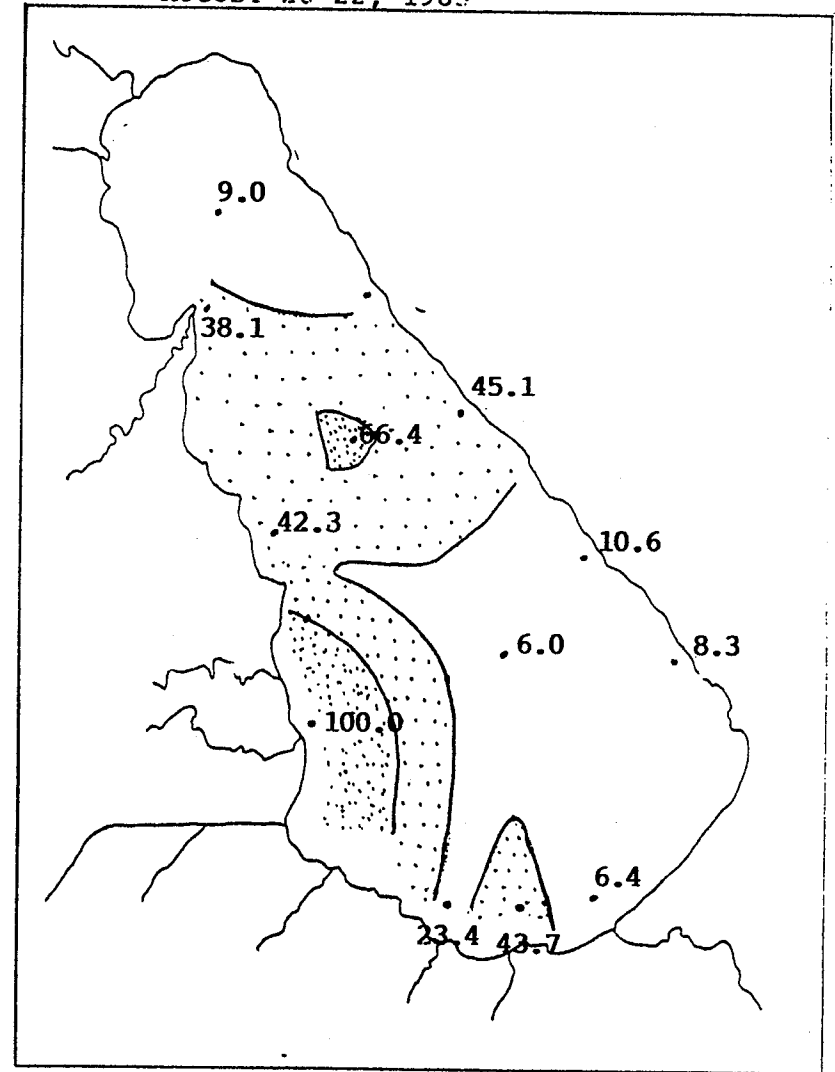9.1   0.0
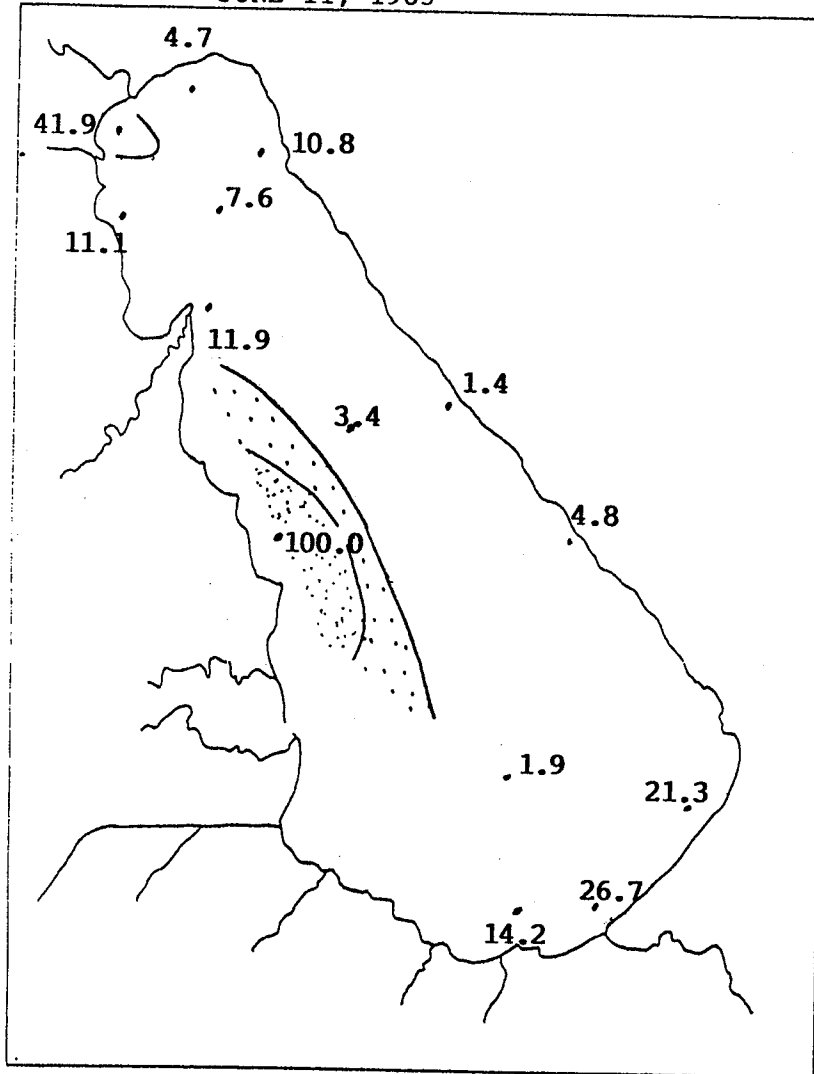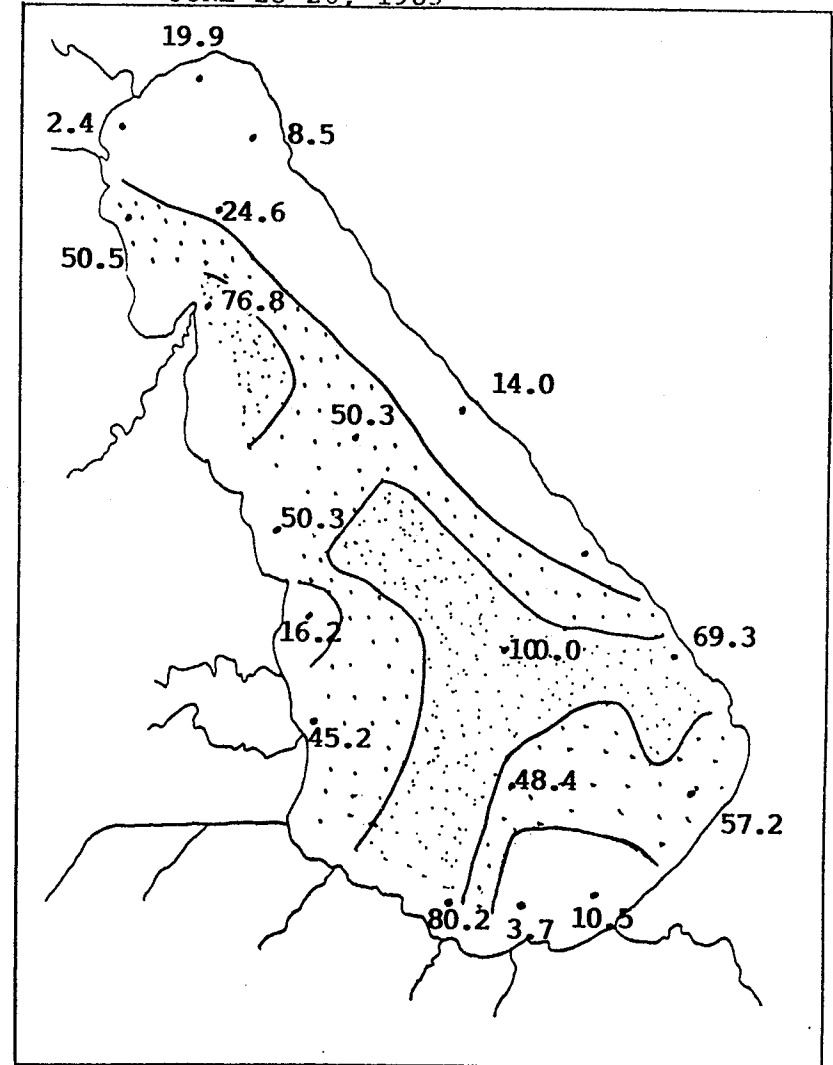
YEARLINGS
AUGUST 20-22, 1985

Y.O.Y.
JULY 8-10, 1985

JULY 24-25, 1985

AUGUST 20-22, 1985

Appendix 3.   Importance of the emerald shiner to the bait
fish industry

The emerald shiner contributes significantly to the
total bait fish production of the province of Manitoba.
Lysack (1987) estimated this contribution at 99%, with about
80% of all bait fish collected from the lower Red River being
emerald shiners. Maximum production for the Red River over
the past 7 years occurred in 1985 (183,000 cartons) and for
the province, in 1986 (459,613 cartons)(Lysack 1987). As
standard bait cartons of emerald shiners average 105 fish and
weigh 202 g (Lysack 1987), the above production numbers
represent 19.2 million (36,966 kg) and 48.2 million shiners
(92,842 kg), respectively.

Presently, there is only one licenced bait fisherman on
Dauphin Lake. Past production has been estimated at
1,200-1,400 cartons of which approximately 20% were emerald
shiners (Z. Sklepowich, pers. comm.). Based on Lysack's
estimates of carton contents, the Dauphin Lake harvest
represents a total of 242-283 kg of minnows and 48-56 kgs of
emerald shiners. Increased fishing effort on Dauphin Lake is
projected for 1987, with a predicted harvest of 25,000-30,000
cartons or 4,250-5,100 kg of bait fish (Z. Sklepowich, pers.
comm.). If the proportion of emerald shiners remains
constant at 20%, this species will yield approximately
850-1,020 kg in 1987. To date, the Dauphin Lake harvest has
been restricted to the lower reaches of several tributaries
during spring when large aggregations of bait fish are

found.

Wholesale prices of minnow cartons range from $0.80 - $1.20 in Manitoba (W. Lysack, pers. comm.). Dauphin Lake bait fish wholesaled for $1.15 per carton in 1986 (Z. Sklepowich, pers. comm.) and thus, the value of the bait fishery was estimated at about $2,000.00. Predicted wholesale value, based on projected landings for 1987 will be $28,750.00 - $34,500.00 for all bait fish. Retail value of the maximum provincial bait fish catch (1986) was estimated at $459,613.00 - $689,420.00 (W. Lysack, pers. comm.). As the emerald shiner contributes overwhelmingly to this production, their importance and economic value as a bait fish in Manitoba is evident. In other areas of North America their importance is also acknowledged (Wallace 1976) as the most common bait fish used, retailing for $0.75 - $6.50 per dozen (Magnotta's Live Bait Specialists, Toronto, Ontario, pers. comm.).