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INSTANTANEOUS GROWTH RATES AND DISTRIBUTION OF LARVAL FISH IN THE VICINITY OF LOCUST POINT, WESTERN LAKE ERIE

by

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CONTENTS

LIST OF TABLES

Table

LIST OF FIGURES

Figure

INTRODUCTION

Purpose and Objectives

Small and weak swimming organisms such as larval fish, often referred to as ichthyoplankton, are carried into power plants with the cooling water. Inside the plant, they are subjected to physical, thermal, and chemical stresses which often result in mortality. High larval fish mortality rates may be reflected in future year class strengths. Thus, investigation of the time and duration that fish larvae are vunerable to entrainment as well as their spatial distributions in the vicinity of power plants is warranted so that intake and discharge structures can be located to minimize their impact on fish populations.

Extremely high fecundities, yet relatively low numbers of adult fish, indicate high mortality rates. A large part of this mortality is thought to occur during the larval stages (May 1974; Ehrlich 1974; Dahlberg 1979). Small size, lack of physical development, and behaviorial naivity, contribute to the susceptibility of fish larvae to predation, starvation, and physical stresses (i.e. currents, wave action, temperature, and water level). The relative success of these organisms in surviving the inherent vulnerability of the early life history stages will be reflected in the future year-class strength of the species. Therefore, the events that occur in the larval stages are of concern.

Location of fish larvae in the water column may change with increased physical development. For example, larvae possessing a yolk sac may rest on lake bottoms, but swim to the surface after yolk sac absorption. Examination of the lengths of larvae at the surface and bottom levels should reveal such trends if they exist. A comparison of the length of fish found at night versus day can point out movements of larval fish (diel migrations) or inadequacies in sampling equipment (net avoidance).

The duration of the larval stage of development can be predicted when growth rates are known. Because growth rates are dependent on environmental parameters such as temperature and food supply, they can also be used to compare general environmental conditions that are favorable or detrimental to larvae.

The purpose of this study is to determine: 1) the temporal and spatial distributions, and 2) the growth rates of the most abundant larval fish species around Locust Point, Ohio in the Western Basin of Lake Erie 1978-1980. My results will add to the general body of knowledge on larval fish biology as well as provide base line data for comparisons between larval growth rates and distributions.

Literature Review

Spawning and Egg Development

Spawning is controlled by endocrine mechanisms influenced by external conditions such as seasonal changes of photoperiod and temperature. Some fish spawn over a long period of time, ie. several months, while others spawn over an interval of a few weeks. The majority of freshwater fish produce demersal (non-buoyant) eggs. An exception to this are the buoyant eggs of the freshwater drum (Bagenal and Braum 1978). Ecological features of the spawning sites like temperature, water flow, oxygen concentration, suitable substrate, and protective cover are very important to egg survival and development (Martin et al. 1981; Bagenal and Braum 1978). The rate of development is directly related to temperature, yet varies considerably between species (Bagenal and Braum 1978). The above factors will determine the temporal distributions of fish larvae.

Spatial Distribution

Larval fish do not have the physical development for long range motility and therefore are said to drift. Drifting consists of being passively carried by water currents. For example, Houde (1969) found yellow perch to be widely distributed in Oneida Lake because of constant exposure to strong surface currents.

Vertical distributions of many species appear to vary with age. The prolarval stages of clupieds and bloaters were found to remain near or resting on lake bottoms (Seliverstrov 1974; Cada et al. 1980; Faber 1980; Blaxter et al. 1969; Wells 1966). After the transition to active feeding or postlarval stage, many species (eg. herring, golden shiners, emerald shiners) exhibit a positive phototaxis which causes a migration to the illuminated layer of water rich in zoo- and phytoplankton (Seliverstov 1974; Faber 1980; Flittner 1964). Phototaxis varies with species, temperature, light intensity, and age.

Differences in day versus night densities of ichthyoplankton have been widely noted. The vertical distributions of some fish larvae seem to vary between day and night. Overall, net avoidance, especially by larger postlarvae, decreases at night. This is seen as a greater mean total length in the night versus day samples, and often a greater night versus day density value. This has been observed with larval *Perca flavescens*, *Clupea pallasi*, and fresh water clupeids (Faber 1967; Stevenson 1962; Cada, *et al*. 1980).

Movement of larvae upward off the bottom at night has been recorded for bloaters, yellow perch, striped bass, and shad (Wells 1966; Cole 1978; Wallace 1978; Gallagher and Corner 1980). Likewise, larval plaice and sand-eel larvae become more widely dustributed at night due to a downward dispersion from the surface (Gallagher and Corner 1980). These types of movements are referred to as diurnal or diel vertical migrations and can also contribute to greater night versus day densities. Larval herring (*Clupea harengus*), stripped bass (*Morone saxatilis*), and golden shiners (*Notemigonus crysoleucas*) do not start diurnal migrations until initiation of active feeding. The newly hatched prolarvae remain near the bottom (Seliverstov 1974; Wallace 1978; Faber 1980).

Growth

Growth of fish larvae is often reported in terms of increase in total length over time. Length measurements, however, give no indication of the condition, or fatness, of the larvae. Farris (1959) divided growth of pelagic fish larvae into three phases: 1) an early rapid phase after hatching; 2) a slow phase near the completion of resorption of the yolk sac; and 3) a subsequent phase dependent on food availability. If Farris is correct, growth is not linear over time; ie.

growth rates of fish larvae are not constant. Cushing (1977) states that growth of fishes from the postlarval stage onward is an exponential function that is modified towards an asymptote at an infinite age.

The major factors influencing growth are temperature, food supply, change of diet with age, and feeding success. In the prolarval stages, efficient yolk utilization and mobilization of nutrient reserves will influence growth rates (Blaxter 1969). This suggests a possible change in growth rate when external food sources are ingested ie. active feeding commenses.

METHODS

Site Description

Locust Point, located approximately 10 miles west of Port Clinton, Ohio, is a gently curving headland on the south shore of the western basin of Lake Erie (coordinates 41 35'57"N and 83 05'28"W). The Davis-Besse Nuclear Power Station is located on a 954-acre tract of land on this point. The terrain is flat and contains about 600 acres of marshland. An extensive rip-rap dike was placed on the berm of the beach during the record-high water levels of 1972 and 1973.

Hydrographic surveys show a very gentle slope of the lake bottom from the shore out for a distance of at least 4000 ft. Two sand bars lie in the nearshore zone, one 120 ft offshore and the other at 280 ft from the beach. The deep area between the beach and the first sand bar has a thin bottom layer of lightly compacted silt and shell fragments over the sand. The same bottom, generally medium-to fine-grained, extends to 800 ft offshore (5.0 ft water depth, IGLD 1955). At this point, the bottom deepens by 0.5 ft and is composed of hard glaciolacustrine clay which forms a 500 to 700 ft wide strip around the point. Lakeward, the bottom again becomes sandy and the sand layer increases in thickness in a lakeward direction. The lake reaches a depth of 10 ft at a distance of 200 ft offshore and 12 ft at 4000 ft offshore. The sand and gravel bottom, underlain by hard clay persists lakeward to the rocky reefs about three miles offshore (Reutter and Herdendof 1980).

Description of the Data Base

The data for this study were gathered as part of a monitoring program designed to investigate the response of fish and invertebrates to the heated discharge from the Davis-Besse Nuclear Power Station, Lake Erie, Ohio. The overall assessment concluded that the thermal effects on all components of the aquatic ecosystem were so localized as to be insignificant to the lake as a whole (Reutter and Herdendorf 1980). This study, therefore, is most concerned with larval fish ecology and not so much with the impact of the power plant on larval fish.

Samples were collected at four stations every year from 1978 to 1980 (Figure 1). These were station 13, 2000 ft (610 m) from shore located at the power plant discharge, station 29, 3000 ft (910 m) southeast of station 13, station 3, northwest of station 13, and station 8, 3000 ft (910 m) from shore located at the power plant intake. Stations 3, 13, and 29 were approximately equidistant from shore. In 1978, two additional stations, 26 and 28 were sampled. Station 26 was 3000 ft (910 m) southeast of station 8, but also equidistant from shore. The depth of the stations were approximately 3-6 meters (Reutter and Herdendorf 1980).

Larval fish were collected using a 0.75-meter diameter oceanographc plankton net (no. 00, 0.75 mm mesh) equipped with a calibrated General Oceanics flowmeter. Each daytime sample consisted of a 5-minute circular tow at 3 to 4 knots. Two replicate samples were collected in duplicate at the surface and bottom at each site. Night samples were taken at the intake (station 8). These consisted of four

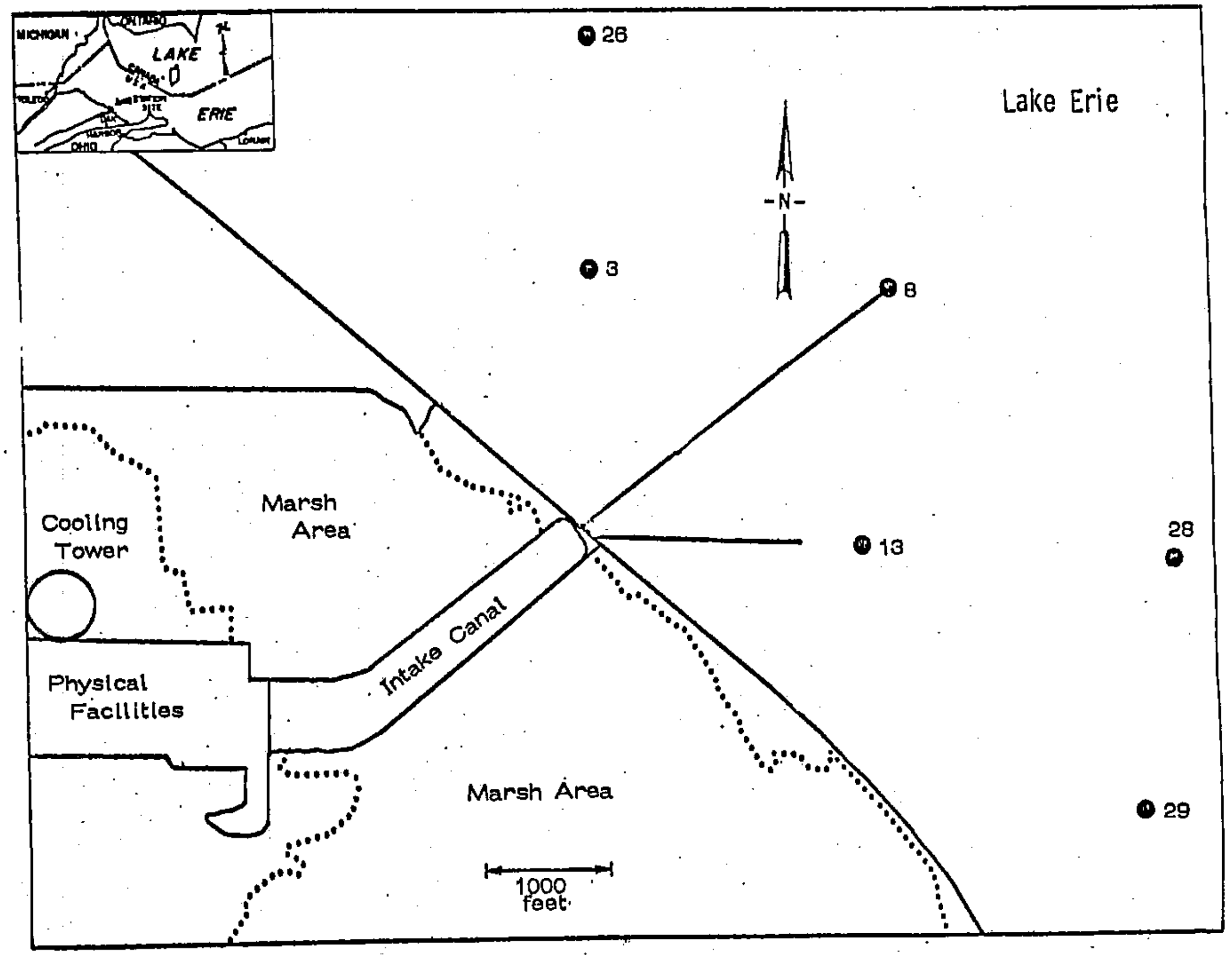


Figure 1

SAMPLING STATIONS AT THE DAVIS-BESSE NUCLEAR POWER STATION

3-minute oblique tows at 3-4 knots. Samples were collected at approximately 10-day intervals from April through August and more frequently in 1980 (Table 1).

Samples were preserved in 5% formalin, and returned to the laboratory for sorting and analysis. All specimens were identified and enumerated using the works of Fish (1932), Norden (1961a and b), and Nelson and Cole (1975). Results were reported as the number of individuals per 100 m^3 of water calculated from the volume filtered (flow meter) and the number of individuals within the sample. After the fish in each sample (i.e. specimens in each individual tow) were identified, the smallest and the largest fish of each stage (pro- and post-larvae in 1978, and proto-, meso-, meta-larvae in 1979-1980) were measured in millimeters, and the abundance of larvae in this range was noted. (See Appendix A for explanation of terms). I examined only the larval fish species that composed 5% or more of the collections.

Statistical Methods

Temporal distributions were obtained by plotting the density of each abundant species with time. Temperature data from the intake (station 8) was also plotted, and first appearance of a species was marked to estimate initiation of spawning.

The data were analyzed using the Statistical Analysis System (SAS) parametric procedures (Helwig and Council 1979). Each year, differences in the densities between stations, and differences in the lengths of larvae at the surface, bottom, and night at each station were tested. No significant differences between the stations were found (2-way ANOVA p=0.05). Given no significant differences among

TABLE 1: ICTHYOPLANKTON SAMPLING DATES 1978 - 1980

Year	April	May	June	July	August
1978	30	22	8, 20	5, 19	1, 11, 23
1979	--	1, 9, 31	5, 21	5, 12, 20	3, 15
1980	13, 18, 25	2, 9, 16, 23	6, 14, 21, 27	10, 17, 29	8, 19, 27

stations, I chose to consider collections from the various stations as replicates.

To determine if there were differences between larval fish length with position in the water column, and between those caught during day versus night, average total lengths were calculated for the surface and bottom at each station for day and night samples. Because only length ranges were available, averaging consisted of: 1) taking the midpoint for each size range; 2) multiplying the midpoint by the number of fish in that range; 3) summing the values of each replicate (2 day or 4 night) for all larval stages at a station, and 4) dividing by the total abundance of the species for that date. The surface and bottom lengths were also similarly averaged to give a mean length of a species at each station. In 1979, individual clupeid and yellow perch larvae were measured. In 1980, only yellow perch were measured. The actual mean total lengths of larvae captured were used for these groups. Thus, these species were examined in greater detail during those years.

Length distributions were examined over time to determine if a meaningful growth rate could be calculated, that is, if only a single cohort was sampled during a particular year. If so, instantaneous growth rates were calculated using the expontential growth equation (Ricker 1975).

RESULTS AND DISCUSSION

Temperature

The intake water temperatures over the sampling season were available for each year 1978-1980 (Figures 2 - 4). The coldest April temperatures were in 1978, while the warmest were in 1980. The steadiest rate of temperature increase was in 1978. Occasional steep temperature declines occurred in 1979 and 1980. Every year from late June to August, the water temperatures ranged between 21-27 C. The highest water temperatures were in 1980 during this time.

Abundant Species

To facilitate discussion, I have divided the fish up into two groups: 1) single year species, those that comprised at least 5% of the collections during one year only; emerald shiner and walleye in 1978, and freshwater drum in 1980; and 2) multiple year species, those abundant for more than one year; yellow perch in 1979 and 1980, and clupeids in 1978, 1979, and 1980 (Table 2).

Walleye and yellow perch larvae are found early in the season April to September for a short period of time. Emerald shiners and freshwater drum are found in the middle of the season for a short period of time. Clupleids are found over the whole season at fluctuating densities (Figures 5-7).

Time and frequency of sampling each year could have had an influence on those species found to be the most abundant. For example, yellow perch larvae typically are numerous at Locust Point in May. If collections were made on only one day in May, as in 1978, perch may not have been in sufficient abundance to make up at least 5% of the species

FIGURE 2: WATER TEMPERATURES AT DAVIS BESSE INTAKE -- 1978

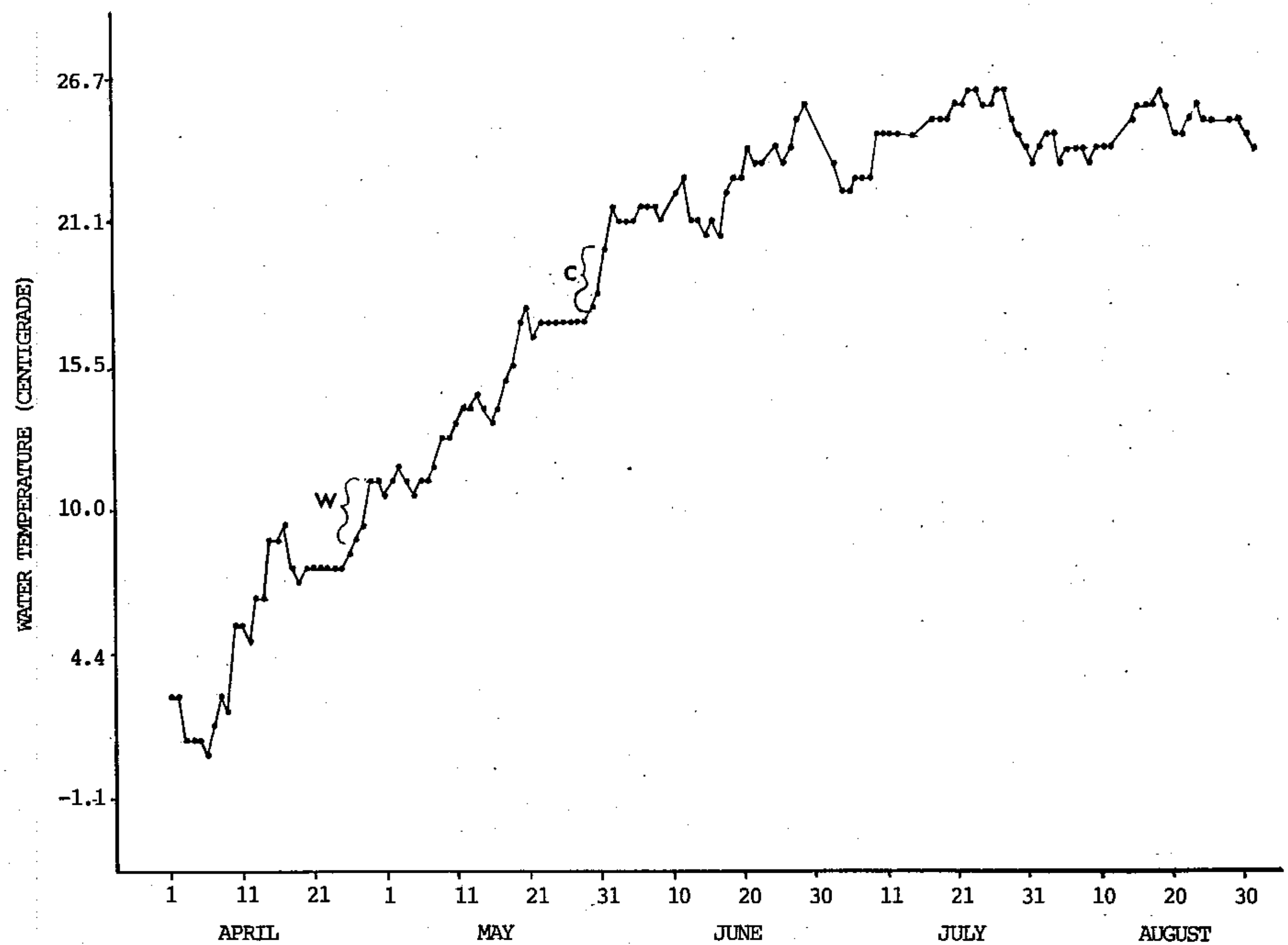


FIGURE 3: WATER TEMPERATURES AT DAVIS BESSE INTAKE — 1979

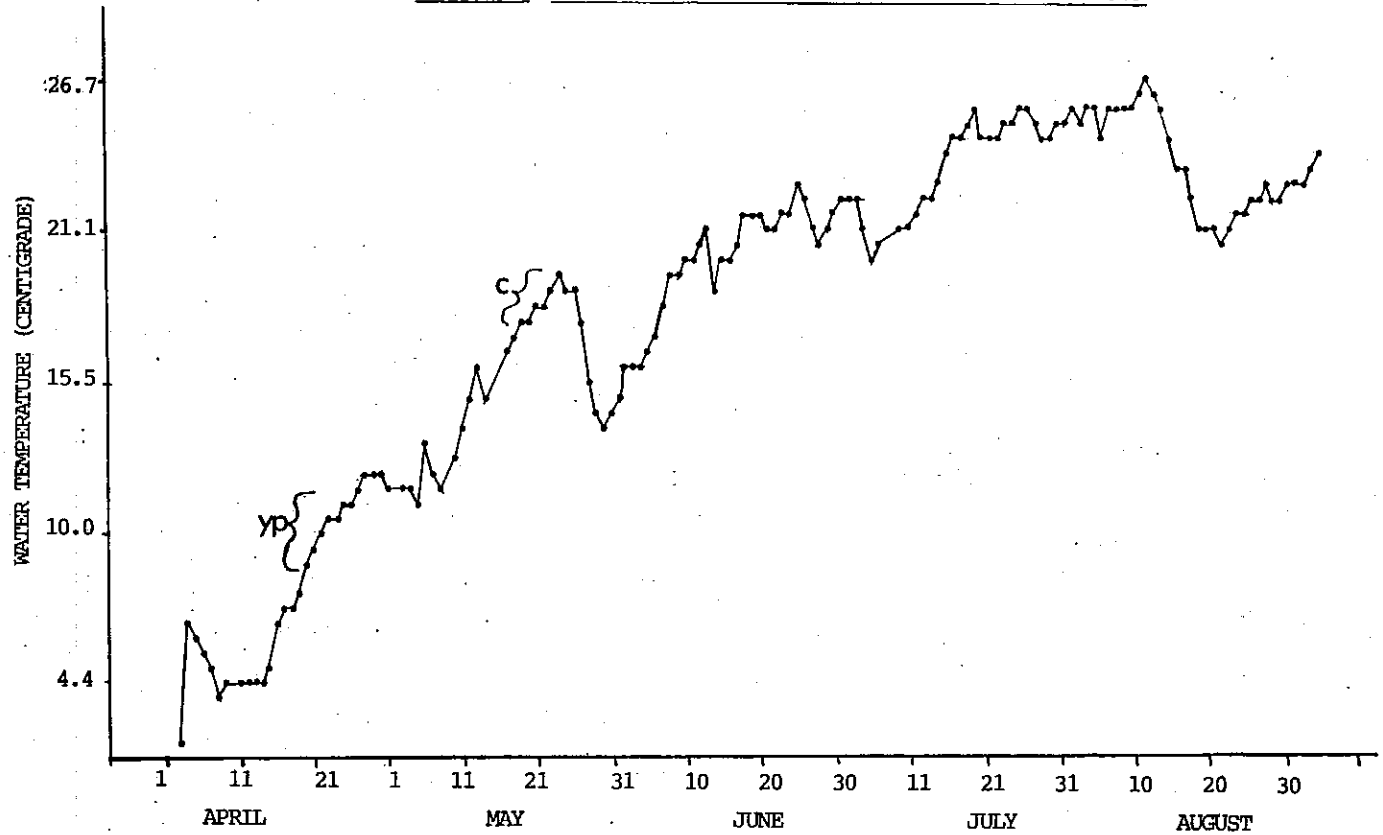


FIGURE 4: WATER TEMPERATURES AT DAVIS BESSE INTAKE — 1980

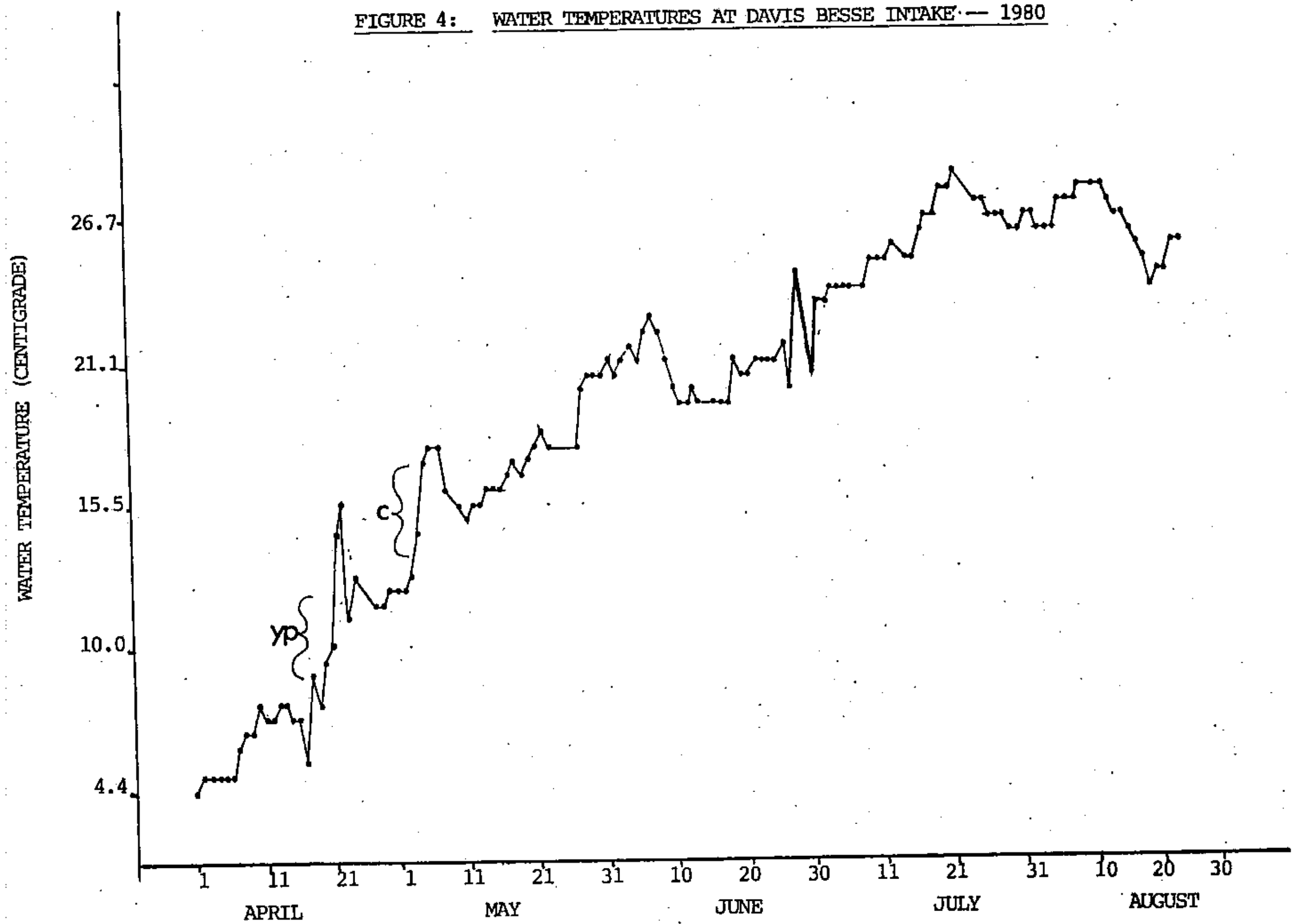
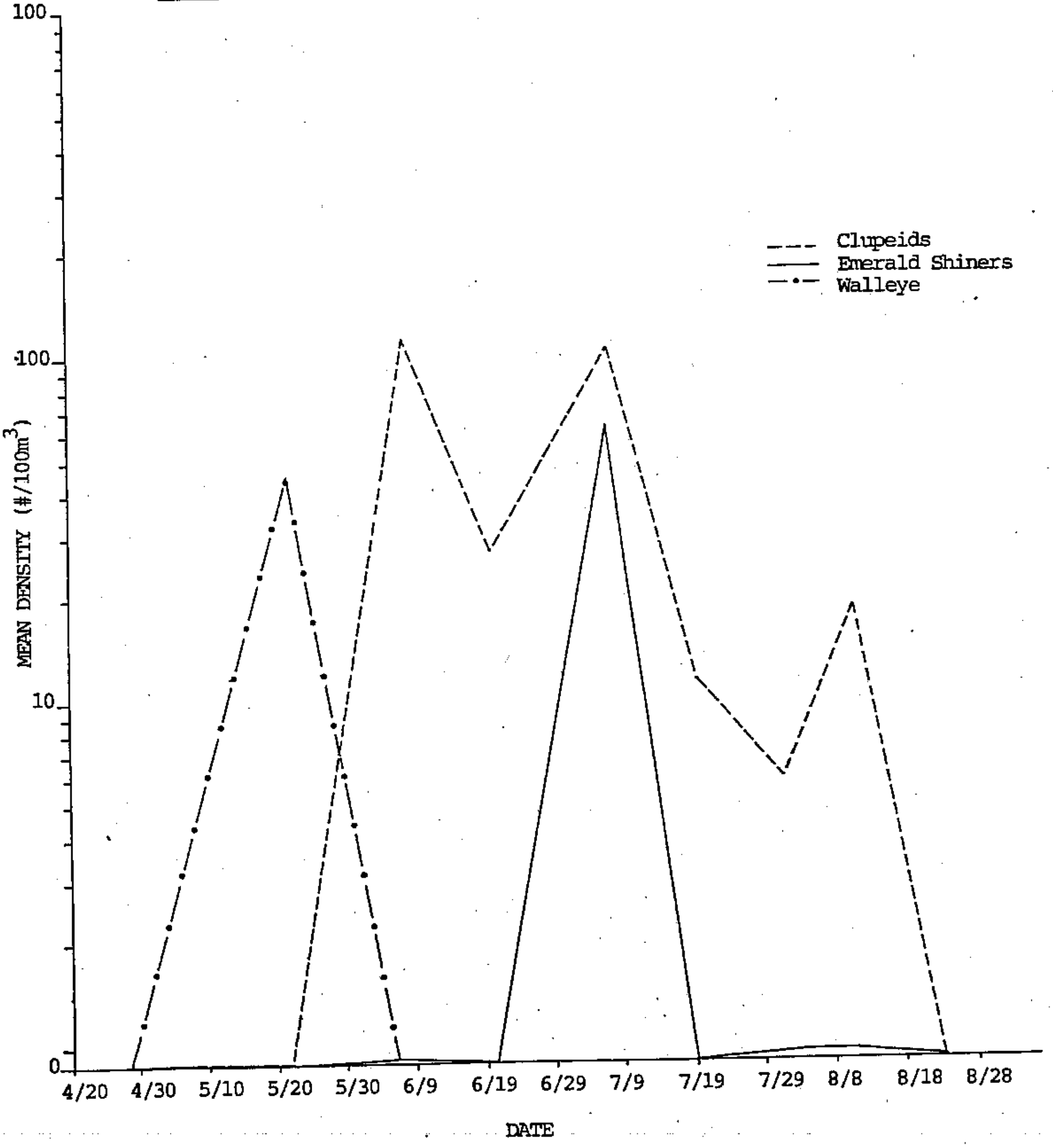


TABLE 2

MOST ABUNDANT SPECIES (Reutter, *et al*. 1980)

Year	Common Name	Species Name	Percent of Capture
1978	Walleye	*Stizostedion v. vitreum*	11
	Emerald Shiners	*Notropis atherinoides*	14
	Clupeids	*Dorosoma/Alosa*	69
1979	Yellow Perch	*Perca flavescens*	11
	Clupeids	*Dorosoma/Alosa*	82
1980	Yellow Perch	*Perca flavescens*	6
	Freshwater Drum	*Aplodinotus grunniens*	16
	Clupeids	*Dorosoma/Alosa*	75

FIGURE 5: MEAN LARVAL FISH DENSITIES THROUGH TIME — 1978



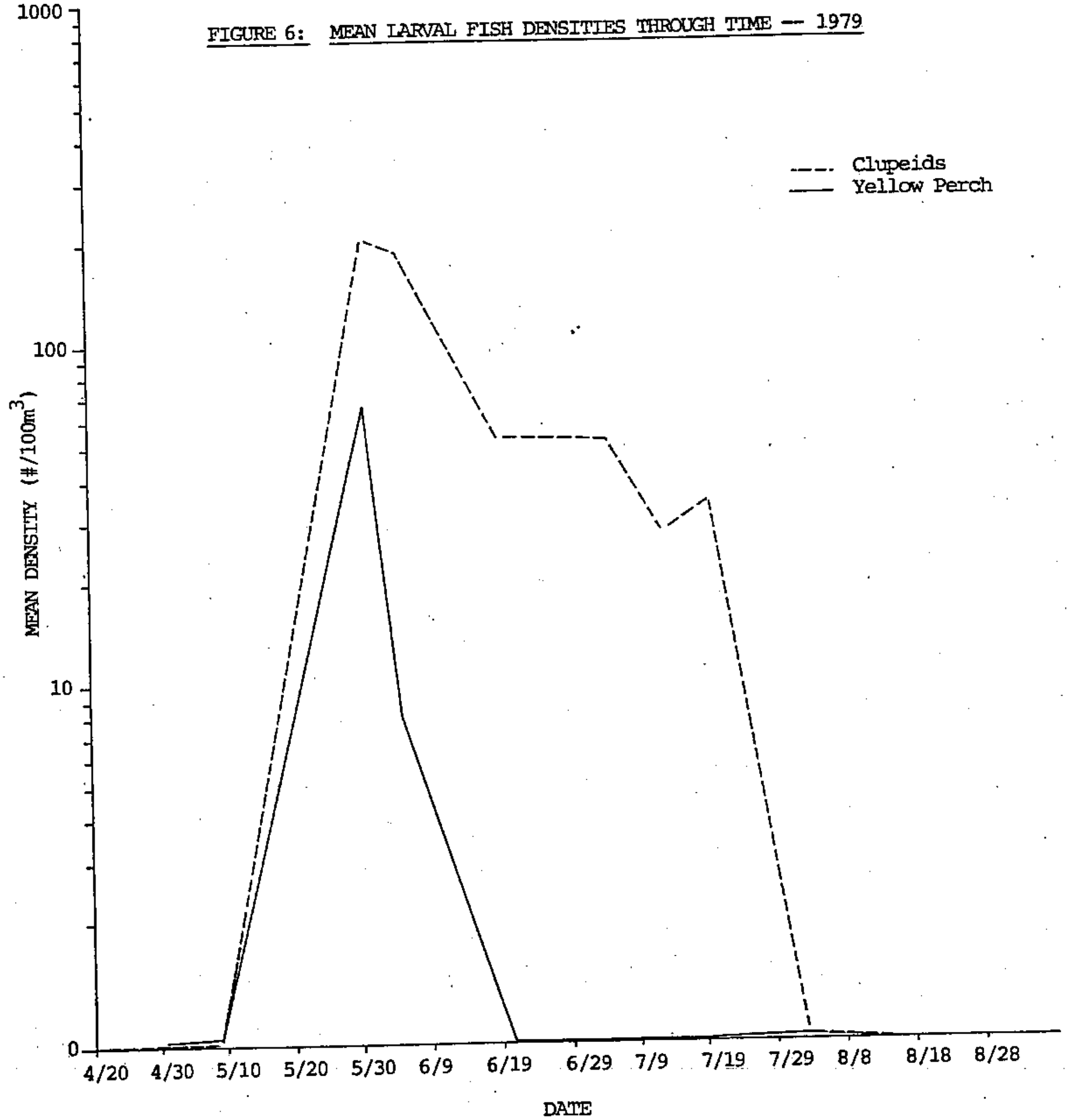
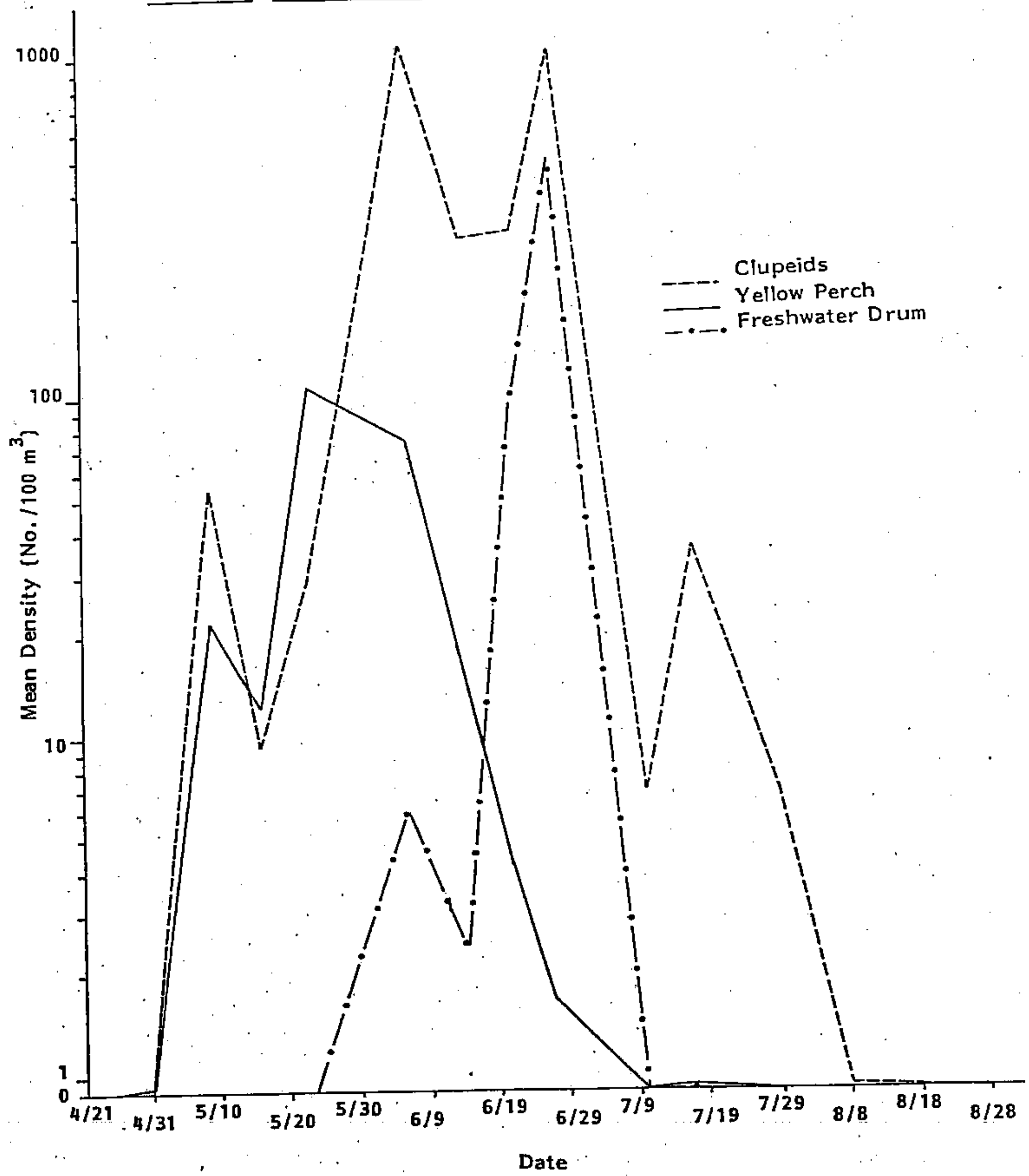


FIGURE 6: MEAN LARVAL FISH DENSITIES THROUGH TIME — 1979
Clupeids
Yellow Perch
1000
100
10
0
MEAN DENSITY (#/100m3)
4/20
4/30
5/10
5/20
5/30
6/9
6/19
6/29
7/9
7/19
7/29
8/8
8/18
8/28
DATE

FIGURE 7: MEAN LARVAL FISH DENSITIES THROUGH TIME -- 1980



in the collections for that year. However, if collections were made often in May, perch could have made up a large percentage of the fish larvae in the collections.

Walleye were abundant in my collections only during 1978. One would theorize that this was a better year for walleye than 1979 or 1980. But, according to the report on the status of Ohio's Lake Erie Fisheries (Ohio Department of Natural Resources, 1982), walleye young-of-the-year in 1978 were less abundant than young-of-the-year in 1979 or 1980. Therefore, I hypothesize that walleye comprised a large percentage of the species in the collections in 1978 because samples were taken when walleye were abundant in the area and not when other species were abundant. Likewise, the status report indicates that gizzard shad young-of-the-year were most abundant in 1978 followed by 1979 then 1980. My data shows the mean densities of gizzard shad (clupeids) to be lowest in 1978. The 1979 and 1980 date were in better agreement with the ODNR young-of-the-year data. Gizzard shad and yellow perch relative abundances correlated with the young-of-the year data for those years. This again points out that infrequent and irregular sampling in 1978 probably did not accurately reflect the percentages of each species in the area.

Single Year Species

Emerald Shiners

Emerald shiners occurred from June 8 through August 23, and peaked on July 5 at 63.0 fish/100m^3 of water in 1980. According to Flittner (1964), emerald shiners spawn after water temperatures reach 22.2 C. Eggs develop in 24 hours, and larvae are approximately 4mm total length upon hatching. The first larvae taken in our samples were 8 to 9mm total length. Therefore, hatching must have taken place several days before July 5; I estimate June 29 to around July 1. Interpolation indicates the water temperature at the estimated spawning time was in the range of 23-25 C. This is close to the reported spawning temperature, and those were the highest temperatures reached previous to July 5.

Fish in night samples tended to be longer than the daytime specimens. Although this was not statistically different, very few fish were found in the bottom samples as compared to the surface samples, and the size of surface versus bottom larvae was not statistically different (1-way ANOVA, p F=0.87). Flittner (1964) noted that most emerald shiner larvae were found close to the surface 94 hours after hatching. The majority of larvae collected in this study were probably older than 94 hours since the average length was over 9 mm. Therefore, in accordance with Flittner's observation, most of these fish were found close to the surface.

Mean total lengths fluctuated over time but did not increase (Table 3). Therefore, a growth rate calculation was not feasible.

TABLE 3: EMERALD SHINER MEAN TOTAL LENGTHS (mm)

Date	Surface	(N)	Bottom	(N)	Night	(N)
July 5	9.9	(645)	8.1	(134)	11.6	(47)
August 1	9.0	(16)	---		12.8	(17)
August 11	15.6	(17)	23	(3)	21.5	(3)
August 23	8.5	(1)	---			

Walleye

With the exception of one 11 mm fish on June 8, larval walleye were only found in the May 22, 1980 samples (density = 45.6/100m^3). Walleye typically spawn in April or May, usually before yellow perch. Peak walleye spawning in the western basin of Lake Erie occurs at 7 C (Wolfert 1963).

The average incubation time for walleye eggs in Lake Erie is 20.8 days (Bush, et al. 1975). The mean total length at hatching has been reported to be 7.5mm (Houde 1969) or between 6 and 8.6mm (Nelson 1968). The first walleye in our samples were around 9mm. Hatching must have occured several days before sampling. Interpolation puts the spawning temperatures of walleye around 10 C. This is somewhat higher than the reported peak spawning temperature, but well within the spawning temperature range (Hardy, 1978).

The narrow temporal occurrence of larval walleye implies a rapid growth rate allowing postlarvae to swim out of the area or that larval walleye are transient through area.

The mean total length of the larvae in the surface, bottom and night samples did not vary more than 0.04 mm (Table 4). Chevalier (1973) also found no difference in the walleye larval lengths in day and night samples.

Freshwater Drum

Freshwater drum occurred from May 16 through June 27 in 1980. Peak abundance was on June 27 at 486.9 fish/100 m^3. The mean length of drum at first occurrence was 4.9 mm. The eggs develop in 24 to 36 hours and newly hatched larvae range from 2.0 to 3.5 mm (Dabier 1950,

TABLE 4: WALLEYE MEAN TOTAL LENGTHS (mm)

Date	Surface	(N)	Bottom	(N)	Night	(N)
May 22	9.19	(379)	9.07	(401)	9.13	(13)
June 8	11.0	(1)	--		--	

1953). Spawning is not believed to take place until water temperatures reach 21 C (Mizera, 1980). Because the intake water temperature did not reach above 17.8 C for the 15 days previous to the date when drum were found, this spawning temperature for drum is in question. Drum have been observed spawning near shore at Locust Point (J.L. Crites, personal communication). Although water closer to shore may be warmer than water offshore, it is doubtful that the temperatures reached 21 C during this time period. I estimate spawning temperature for freshwater drum to be closer to 18 C.

Mean total lengths of drum larvae in the surface, bottom and night samples did not vary significantly (1-way ANOVA, $p > F$-0.97; Table 5). Previous research by Tuberville (1979) found that drum less than 11 mm showed no vertical distrubtion patterns, and that night samples contained greater densities of larvae than the daytime samples, but similar mean lengths. This is in agreement with my data. These results indicate there is no concentration of prolarvae near the bottom, or postlarvae near the surface. This could be related to the pelagic nature of drum eggs. That is, prolarval drum may be buoyant to a degree.

Since the lengths of the drum larvae did not increase over time, a growth calculation was not feasible.

<u>Multiple Year Species</u>

<u>Clupeids</u>

<u>Temporal Distribution</u>

Clupeids were consistently the most abundant group of fish larvae sampled. In 1978, they were taken in samples from June 8 to August 11.

TABLE 5: FRESHWATER DRUM MEAN TOTAL LENGTHS (mm)

Date	Surface	Bottom	Night
June 6	5.25	4.63	--
June 14	9.40	7.64	7.80
June 21	4.72	5.80	7.74
June 27	5.35	5.60	4.90

Peak abundance was reached on June 8 at 110.44 fish/100 m of water. In 1979, clupeids were found from May 31 to August 15 with peak abundance on May 31 at 200.44 fish/100 m^3. In 1980, clupeids occured in samples from May 9 to August 8; peak abundance was reached on June 6 at 1036.93 fish/100m^3 of water.

The presence of newly hatched larvae over several months indicates that clupeids are wide temporal spawners. The spawning temperature for gizzard shad, which comprise the large majority of this group is between 17.2 C - 26.1 C (Bodola 1955). Peak spawning activity occurs at 18 C (Hardy 1978). The reported lengths at hatching range from 3.25 to 3.5mm. Three days after hatching, the larvae are approximately 6.5mm long (Bodola 1966). The mean lengths of clupeids on the first date they were sampled are approximately 8.7 mm in 1978 (June 8), 9.7 mm in 1979 (May 31), and 5.0 mm in 1980 (May 9). Thus, I estimate that these fish hatched about June 3 in 1978, May 25 in 1979 and May 7 in 1980. Development of clupeid eggs is temperature dependent and usually ranges from 36 hours at 26.7 C to 95 hours at 16.7 C (Miller 1958). The mean temperature of the lake water during the four days previous to the estimated hatching date was 17.2 C in 1978, 18.7 C in 1979 and 15.6 C in 1980. During each of these pre-hatching periods, the water temperatures were ascending. Spawning likely occured during these rising temperatures with the longest time of egg incubation occuring in 1980 due to the lower mean temperature. More precisely, I estimate that spawning occurred on May 31 in 1978 (temperature 18.3 C), May 20 in 1979 (temperature 18.3 C) and May 4 in 1980 (temperature 17.8 C). This allows three to four days for development. These estimations are in total agreement with other reported data on clupeid spawning and development.

It looks as though a rapid water temperature increase triggers spawning. The most rapid temperature increase was in 1980. This explains the earlier spawning time.

Spatial Distribution

Differences in the mean total lengths of clupeid larvae from the surface, bottom and night samples were evident all three years (1-way ANOVA, $p = 0.05$). The overall lengths of the clupeids caught at night were greater than those caught at the surface in the daytime, which were greater than those caught at the bottom in the daytime (Figures 8-10). Duncan's multiple range test indicated that the length of clupeid larvae in the night samples were significantly larger than those from daytime bottom collections ($p = 0.05$) for all three years. However, only in 1979 was the length of fish from daytime surface collections significantly smaller than those caught at night, and significantly larger than those at the bottom ($p = 0.05$). Interestingly, the most accurate length data for clupeids was collected during 1979 (all larvae were measured).

The distribution of prolarvae near the bottom has been well documented for many species. Limited physical development and presence of yolk sac probably keep prolarvae close to the bottom while the more developed postlarvae are feeding in the surface waters.

Because all samples were taken with a non-closing plankton net, fish larvae from the surface were always included with the bottom samples. This sampling problem likely increased the weighted average

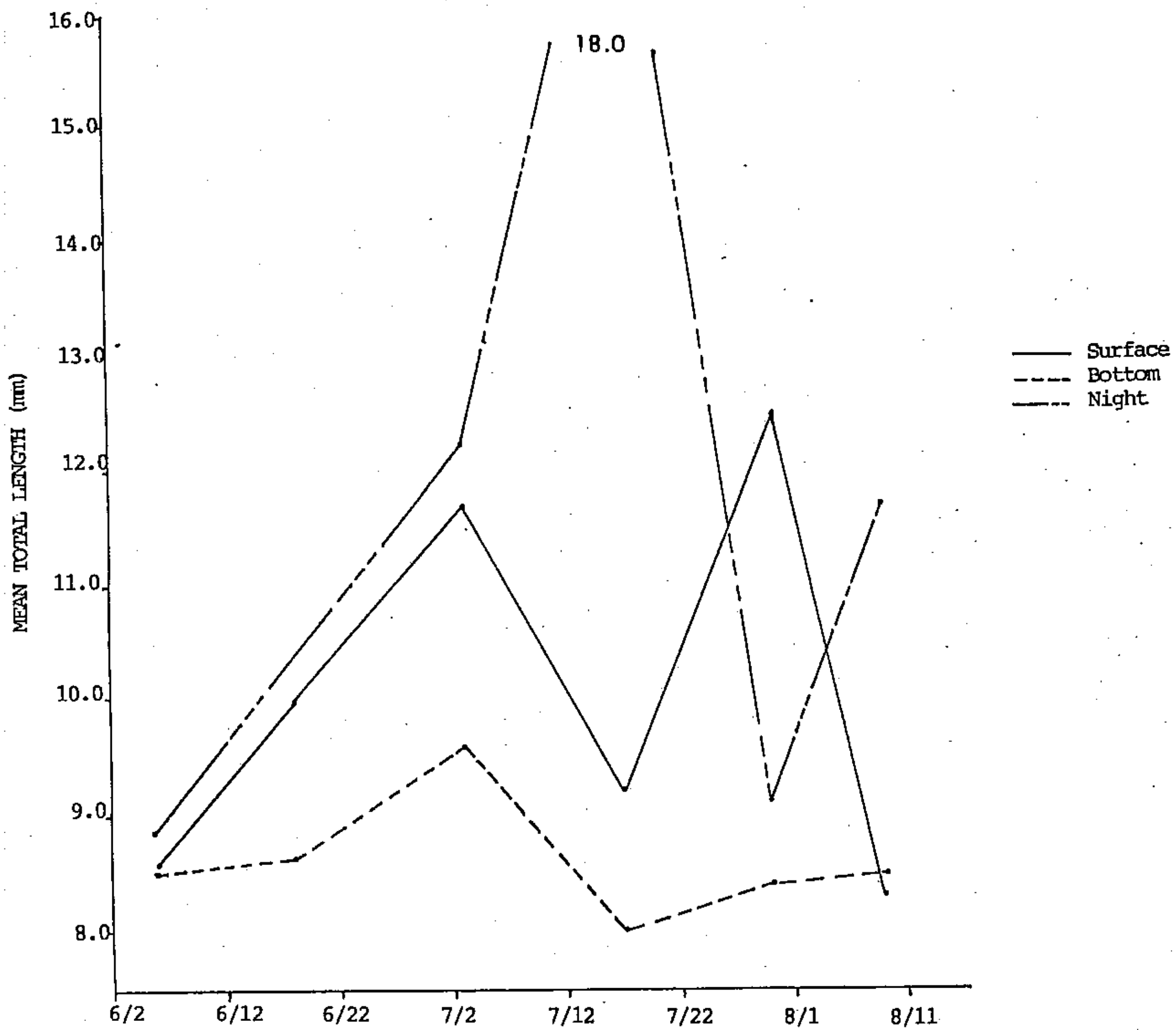


FIGURE 8: CLUPEID MEAN TOTAL LENGTHS IN SURFACE, BOTTOM AND NIGHT SAMPLES -- 1978

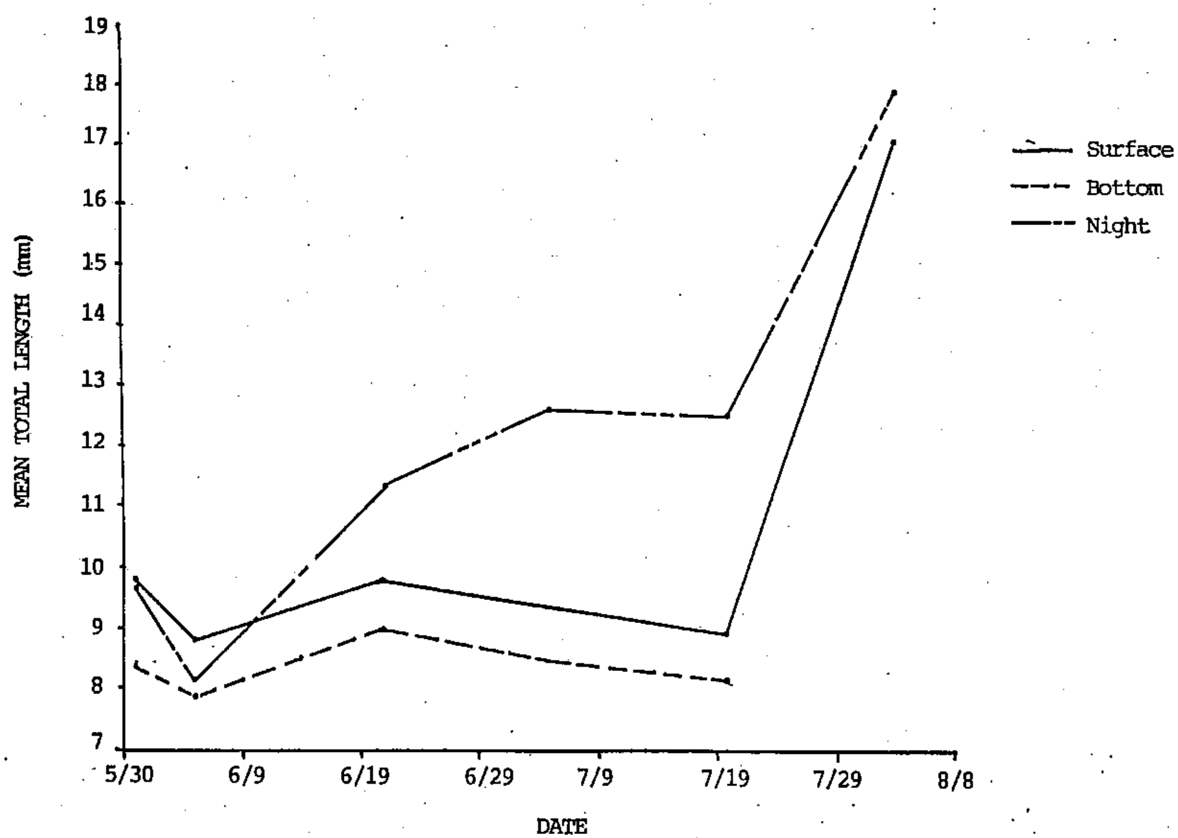


FIGURE 9: CLUPEID MEAN TOTAL LENGTHS IN SURFACE, BOTTOM, AND NIGHT SAMPLES -- 1979

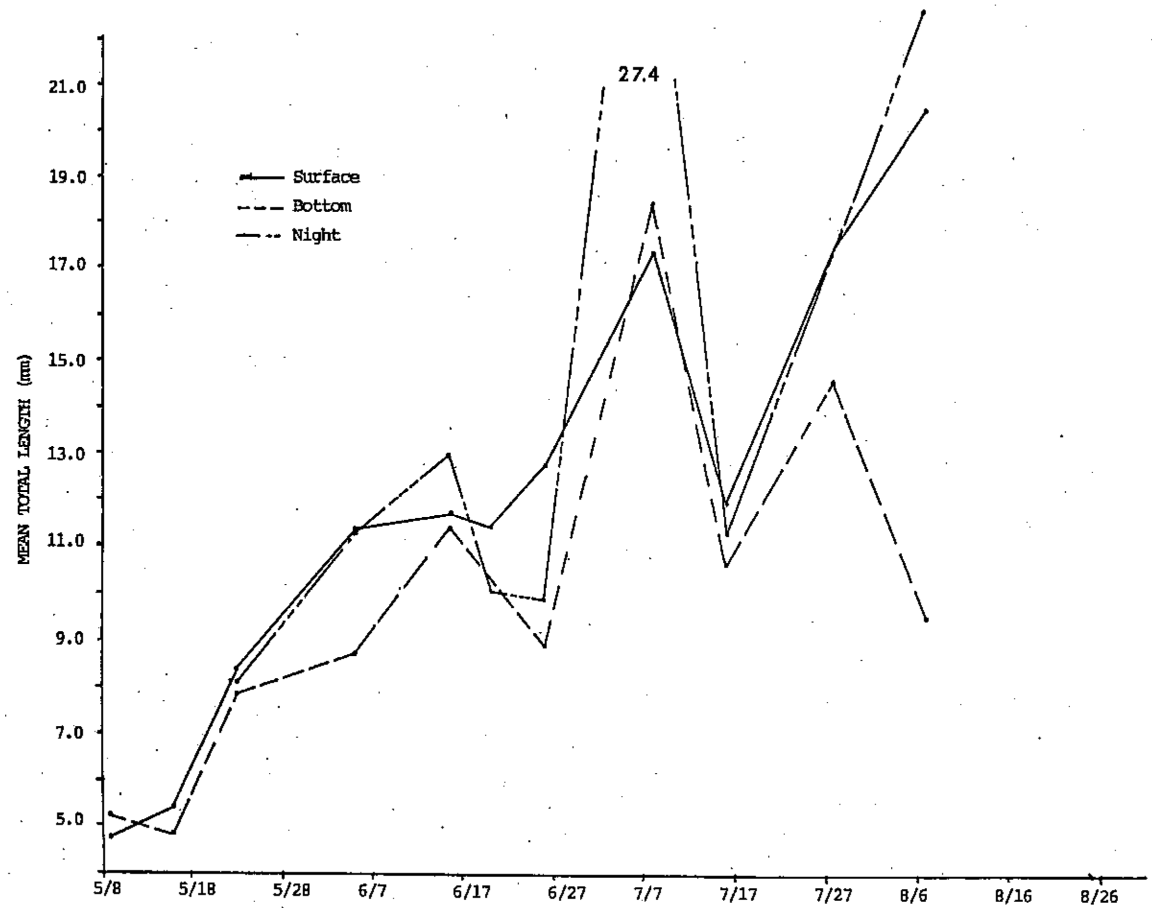


FIGURE 10: CLUPEID MEAN TOTAL LENGTHS IN SURFACE, BOTTOM AND NIGHT SAMPLES — 1980

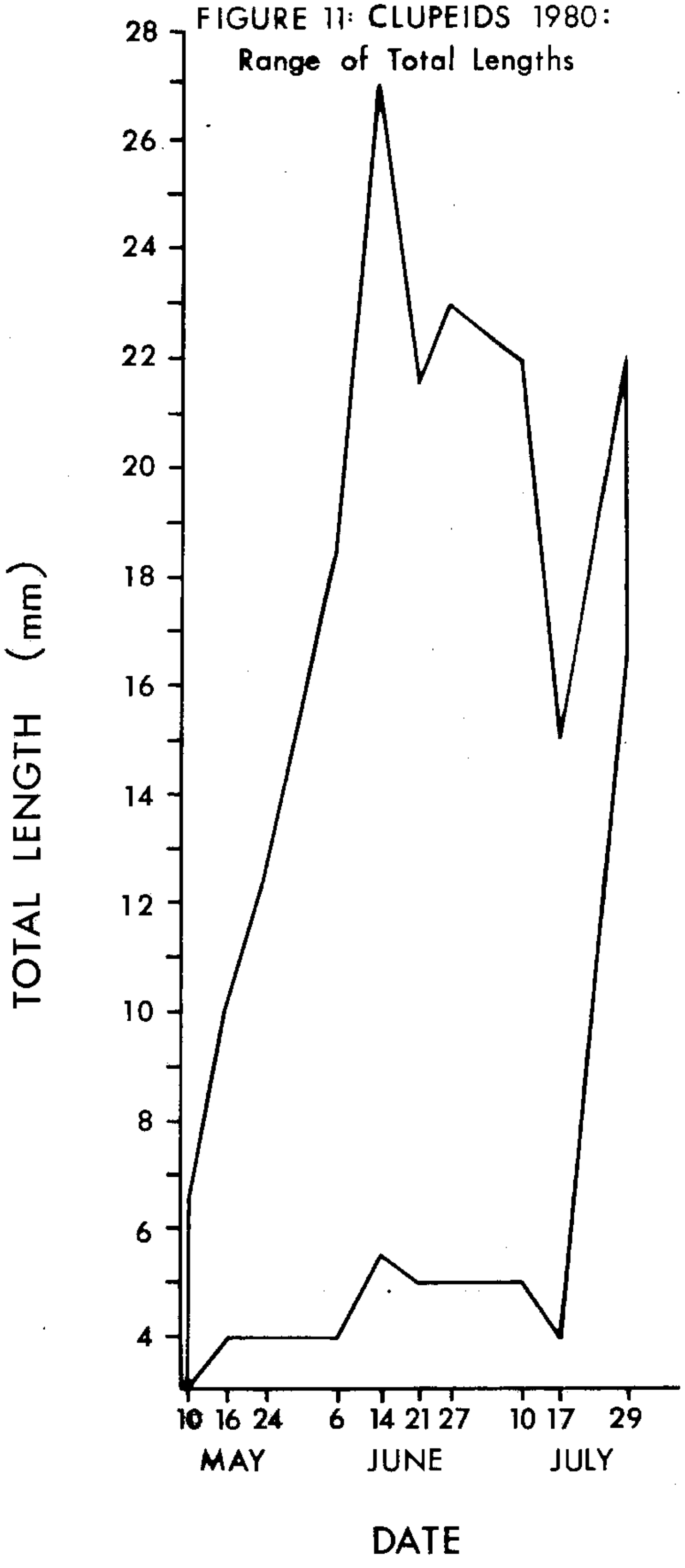
length estimates, based on the midpoints of the smallest and largest larvae. For clupeids, this includes the 1978 and 1980 estimates. The problem being that one large fish from the surface would bias the midpoint estimate, because it is based on the largest and smallest larvae. This probably masked length differences from in the surface and bottom samples collected during 1978 and 1980.

Clupeid larvae in bottom samples were always significantly shorter than those in the night samples. An increase in the mean total length of clupeid larvae at night has been noted due to the absence of prolarvae in night samples (Gallagher and Conner 1980, Graser 1979). This is apparently due to the concentration of prolarvae near the bottom and, therefore, inaccessible to the sampling year. Another explanation is that large larvae actively avoid the net during the daytime, but are unable to see it at night and are captured. These large larvae increase the weighted average length of the larvae at night (Tuberville 1979).

Growth

Determination of growth rate for larval clupeids was difficult due to the constant influx of newly hatched larvae. Growth could not be detected in 1978 and 1979, and could only be seen for a short period in 1980. Using length data from station 3 as an example (all stations had similar results), the size of the smallest larvae collected is constant, indicting continual recruitment of newly hatched clupeids (Figure 11). The size of the largest larvae collected shows an initial increase in total length, providing an instantaneous growth coefficient of 0.034 (Figure 12). This value probably does not represent the

FIGURE 11: CLUPEIDS 1980:
Range of Total Lengths



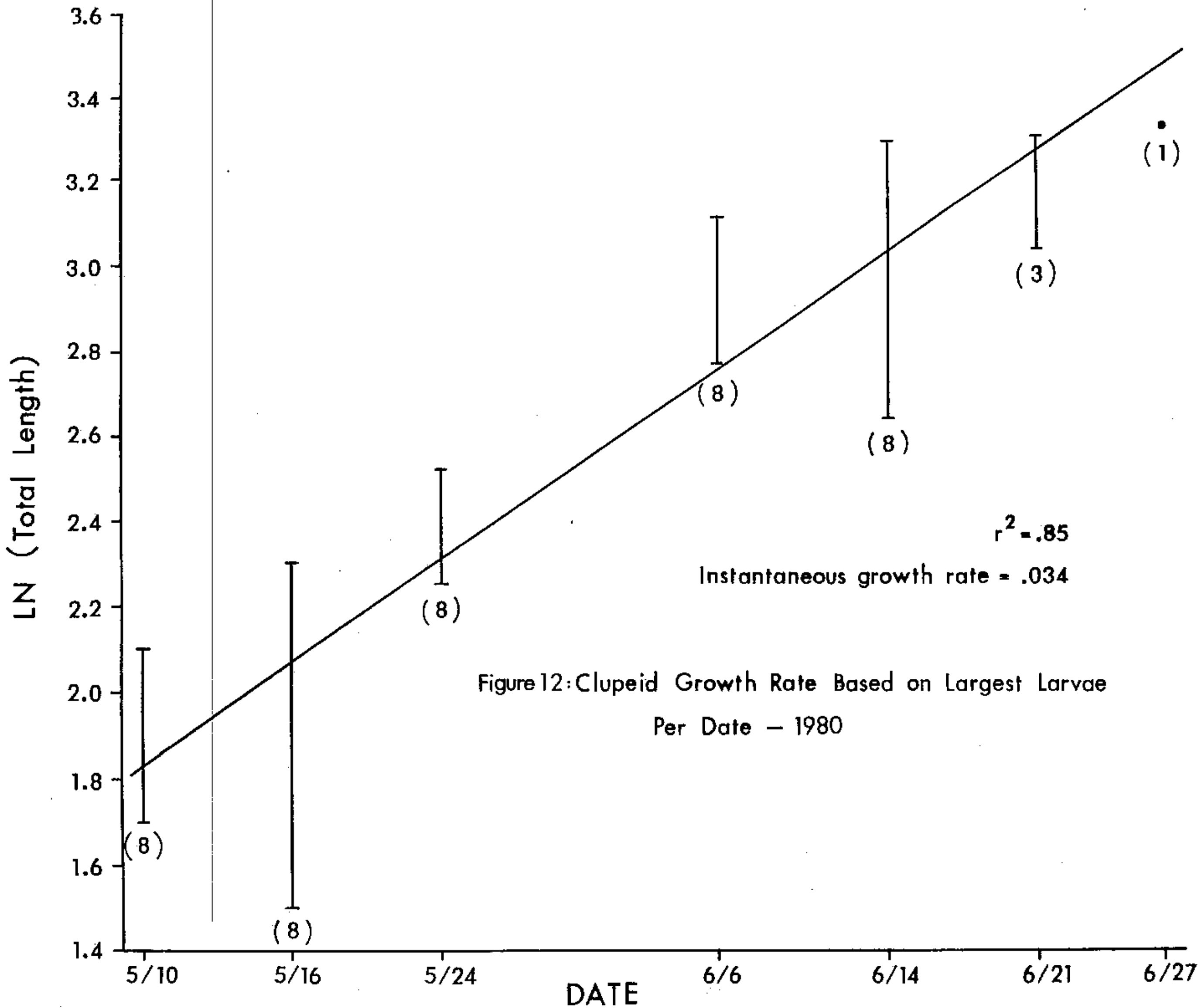


Figure 12: Clupeid Growth Rate Based on Largest Larvae Per Date – 1980

average larval clupeid growth coefficient, but rather the rate of the fastest growing larvae. Therefore, another growth coefficient based on the range of the weighted average lengths was computed (Figure 13). Because the small, newly hatched larvae influence the means, this growth coefficient (referred to as the population growth coefficient) should be less than that calculated for the largest larvae, and probably less than that for the average clupeid. The results did follow this pattern with the population growth coefficient of 0.028 less than the largest larval growth coefficient of 0.034.

The growth rate of the largest clupeids was based upon larvae 6.2 mm to 29.0 mm. Because the average clupeid larvae completes yolk sac absorption at 6.4 mm, this instantaneous growth rate represents that of postlarval (Bodola 1955). Growth rate analysis based upon the average fish lengths did include prolarvae on the first two dates. Lengths ranged from 4.9 mm to 9.0 mm. The data, however, were too sparce to detect differing growth rates for pro- and post-larvae.

Yellow Perch

Temporal Distributions

Yellow perch in Lake Erie usually spawn in late April or early May (Sztramki and Teleki 1977). In 1979, yellow perch occurred in samples from May 1 through June 5, and peaked on May 31 at 66.13 fish/100m^3 of water. Large numbers of yellow perch larvae were sampled on only two dates, May 31 and June 5, in 1979 (Figure 14). In 1980, yellow perch occurred from May 9 through June 6 and peaked on May 23 at 106.84 fish/100m^3 of water (Figure 15). The length distribution of yellow perch larvae time in 1980 indicates a single short spawning period:

FIGURE 13: 1980 Clupeid Growth Rate Based on Mean Larval Total Length

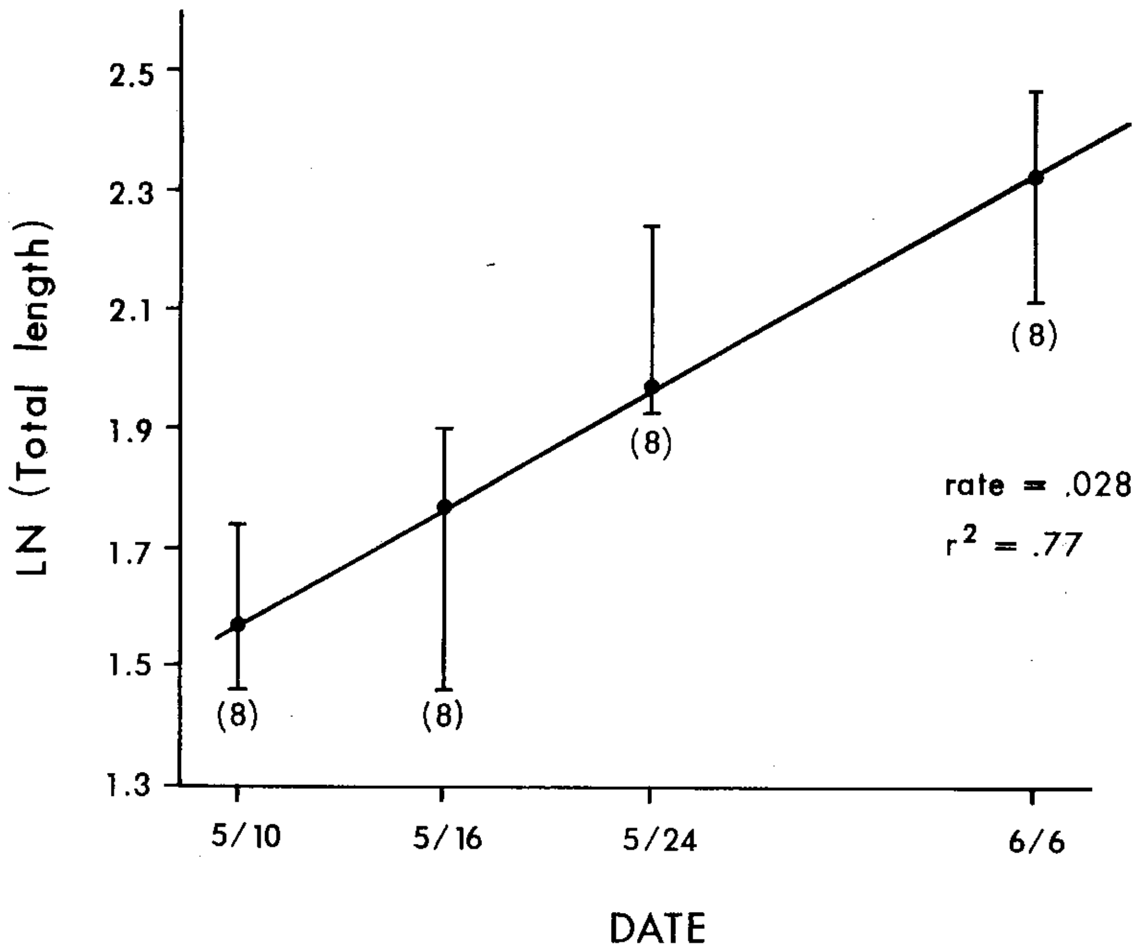


Figure 14: LENGTH DISTRIBUTIONS OF YELLOW PERCH--1979

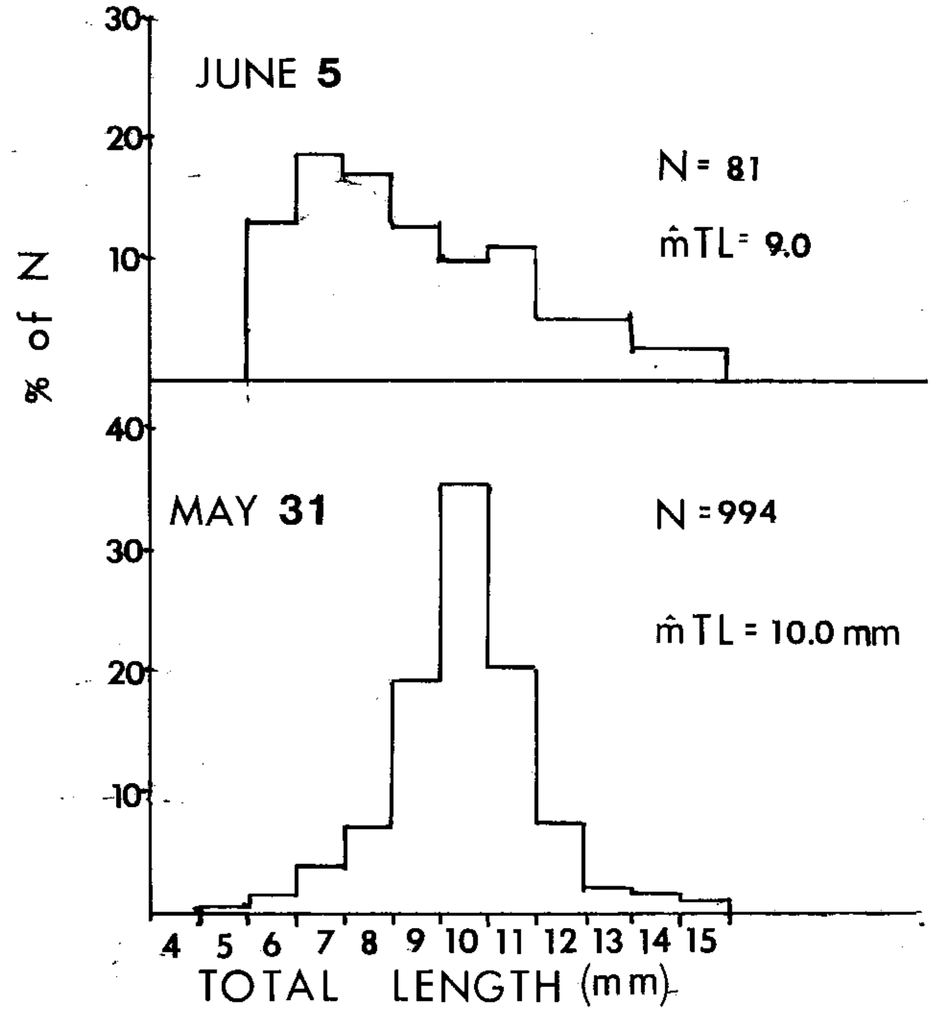
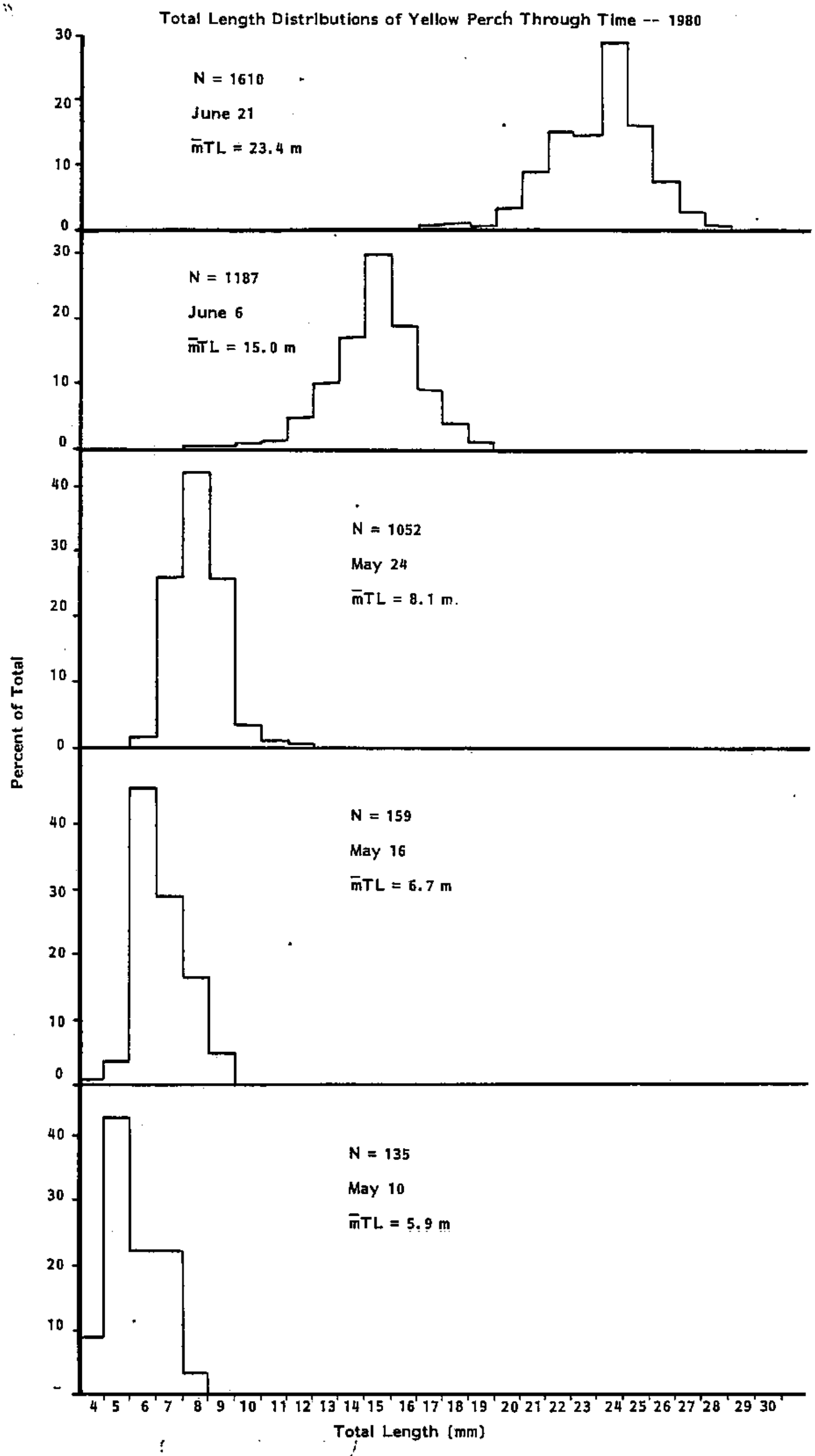


Figure 15


Total Length Distributions of Yellow Perch Through Time -- 1980
N = 1610
June 21
mTL = 23.4 m
N = 1187
June 6
mTL = 15.0 m
N = 1052
May 24
mTL = 8.1 m.
N = 159
May 16
mTL = 6.7 m
N = 135
May 10
mTL = 5.9 m
Percent of Total
Total Length (mm)

i.e. there was no large influx of newly hatched larvae after the first collections. In 1979, however, spawning occurred over a long period of time. One group of perch eggs hatched a few days before May 31. This is indicated by a mean larval total length that is several millimeters above the mean length of yellow perch at hatching. A large influx of 6 mm larvae in the population on June 5 points to another hatch. Yellow perch spawn when water temperatures reach 8.9 C to 12.2 C, with peak spawning activity at 11.7 C (Brazo, et al. 1975, Fish 1932). The rate of lake warm-up has also been noted to influence spawning time (Amundrud, et al. 1974). Therefore, the longer period of spawning in 1979 versus 1980 may be explained by difference lake temperature patterns. The temperature range of yellow perch spawning is bracketed on Figures 6 and 7. There were fewer spawning days and a much sharper increase in water temperatures in 1980 than in 1979. Interpolation from the mean lengths of yellow perch larvae in first samples may give a better estimate of spawning time and temperature at Locust Point. Incuabtion of perch eggs varies with temperatures. Hatching has been observed within 27 days at 8.3 C, 13 to 15 days at 15 C, and 6 days at 19.7 C (Scott and Crossman 1973; Hardy 1978; Hokanson and Kleiner 1974). In 1980, yellow perch larvae first appeared in samples on May 9. The mean size was 5.9 mm. In 1979, the mean size on May 31 was 10 mm. However, an influx of 6 mm yellow perch occurred on June 5, 1979. The mean total length of perch at hatching has been reported to be between 4.7 to 6.6 mm, 4 to 5.5 mm, and 5.5 to 6 mm (Hardy 1978; Hokanson and Kleiner 1979; Scott and Crossman 1973; and Mansueti 1964). Therefore, the average yellow perch larvae on May 9, 1980, and the 6 mm larvae on June 5, 1979 are newly hatched or only a day or two old.

Examining the 1980 data, the sampling date before to May 9 was May 2, and the water temperature was 12.2 C. No perch were present in the May 2 samples. This implies that the eggs were incubating. If peak spawning occurs at 11.7 C, then the majority of perch would have spawned around April 21. Assuming larvae hatched on May 8, the eggs would have incubated 18 days at a mean water temperature of 13.7 C. This is in reasonable agreement with the reported data.

For the 1979 data, I assume the 6 mm group of larval yellow perch in the June 5 samples hatched on June 4, 1979. If the reported incubation times are correct, then yellow perch spawned at a higher temperature than has been reported (approximately 16 C). Perhaps the ascending water temperatures triggerred a few late spawners. The majority of the perch spawned previous to the first sampling date.

Spatial Distribution

The mean weighted average length of larval yellow perch in the surface, bottom and night samples were not statistically different (1-way ANOVA, P=0.42 in 1979, p=0.63 in 1980). Ney and Smith (1975) found similar results on young-of-the-year yellow perch in the Red Lake, Minnesota. However, in 1980, the overall means indicted that the longest weighted average length was in the night samples followed by the surface, followed by the bottom larvae. Here, yellow perch are showing the same tendencies as the clupeid larvae.

Growth

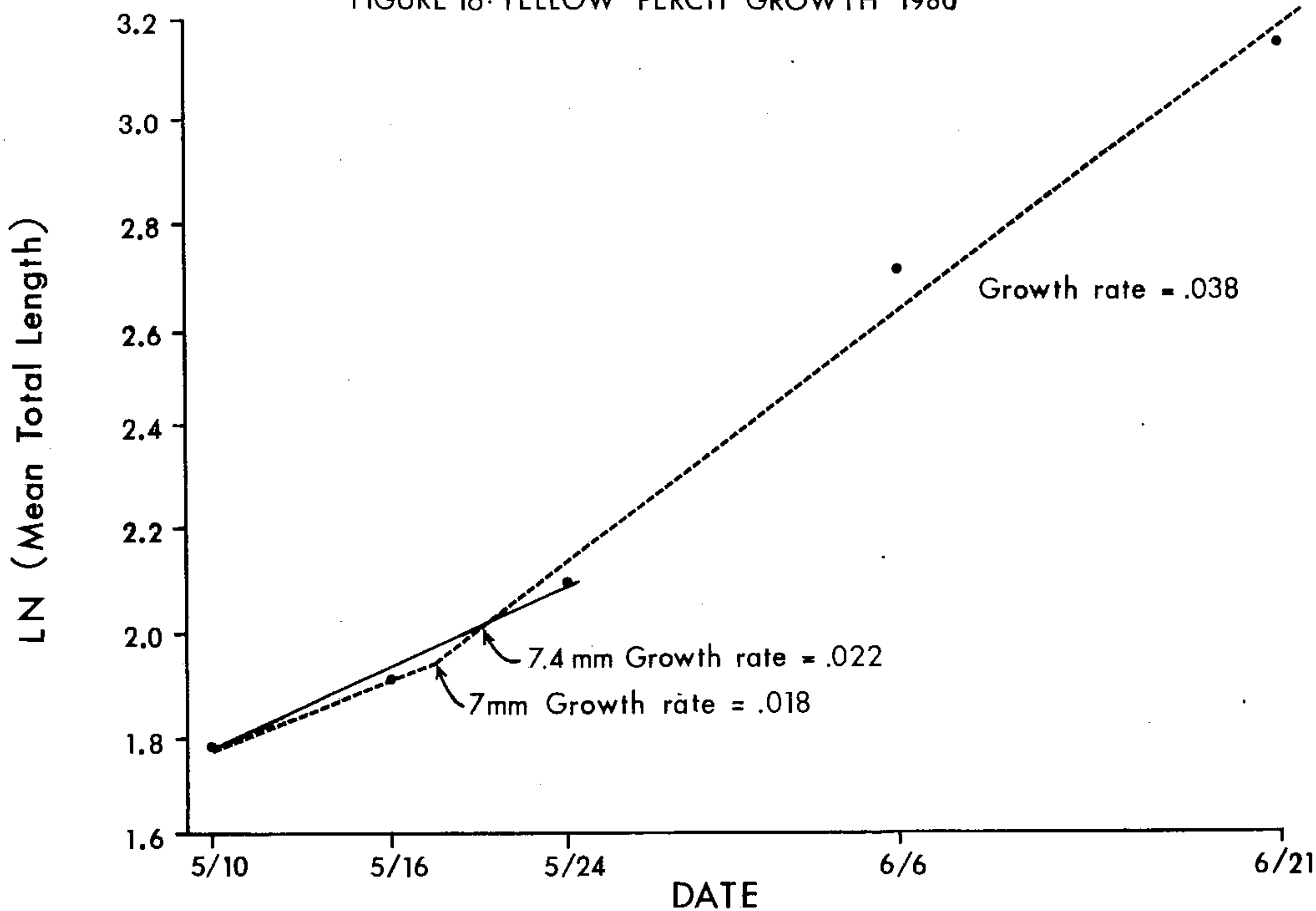
A growth rate for 1979 could not be determined since the weighted average length decreased from 10.0 mm on May 31 to 9.0 mm on June 5. Very few large larvae (10mm TL) were collected in the June 5 samples. This could be due to: 1) a high larval mortility after May 31; 2) movement of postlarvae out of the area; or 3) sampling technique simply missed the big larvae. The 1979 data points out the importance of frequent sampling if growth rates are to be determined for yellow perch. It is not reasonable to make inferences based upon only two data points.

A single analysis was not sufficient to explain the 1980 yellow perch data. Therefore, three different growth coefficients were calculated. These were 0.018 from the first two data points, 0.022 from the first three data points, and 0.038 from the last three data points (Figure 16).

The two slow growth coefficients (0.018 to 0.022) were calculated on fish measuring 5.9 mm to 7 and 7.4 mm. The fast rate (0.038) was for larvae 7.4 mm to 23.4 mm. The length where growth started to increase (7 to 7.4 mm) corresponds to complete absorption of the yolk sac nutrients; hence, the length where active feeding has commenced (Mansueti 1964, Siefert 1972; Bartholomew 1979; Houde 1969). Therefore, the slow instantaneous growth rate, which is between 0.018 and 0.022, represents the growth of prolarval (yolk sac stage) yellow perch. The faster growth rate (0.038) represents the growth of postlarval yellow perch.

Growth following yolk sac absorption is dependent on food abundance and availability, the ability of the larvae to capture food, and water temperature (Farris 1959; Mansueti 1964; Ney and Smith

FIGURE 16: YELLOW PERCH GROWTH 1980



1975). My results imply favorable food supply and water temperatures in 1980. Comparing my results to those of Clady (1976), it is evident that larval yellow perch in Lake Erie near Locust Point were growing at a much faster rate than those in Oneida Lake. The mean length of the yellow perch in Oneida Lake were 6.0 mm on May, 6.2 mm on May and 6.8 mm on May 20, as compared to 5.9 mm on May 10, 6.7 mm on May 16 and 8.1mm on May 23 at Locust Point. Clady (1976) described yellow perch larval growth as linear whereby it is exponential in my data.

This data set further points out the value of frequent sampling in determining ichthyoplankton growth rates. The change in growth rate at 7-4 mm would not have been detected if the samples were taken less than weekly. The 1978 and 1979 data are examples of inadequate frequency of sampling. No growth rate determinations were even attempted for those years. When studying an early spawner like yellow perch, it is also important to start sampling early in the season (end of April) or the data for prolarvae will be missing.

SUMMARY

The mean lengths of emerald shiners, freshwater drum, and yellow perch in 1979 fluctuated over time. This indicates that several cohorts were being sampled. Spawning over several weeks and net avoidance by large larvae and juveniles accounts for these length variations.

With the exception of clupeids, no differences were found in the mean lengths of larvae in the surface, bottom, or night samples. This implies that a representative sample of larvae can be obtained for mean length estimates by either surface or bottom daytime tows or oblique night tows with a plankton net. However, actual differences in mean larval lengths at the surface, bottom and during the night may exist, but they may not be detected by this sampling technique.

The instantaneous growth rate technique is appropriate for 1980 yellow perch and clupeid data. Frequent sampling from April through August provided sufficient data for these calculations.

CONCLUSIONS

1) Five different species comprised at least 5% of the larval populations in 1978 to 1980. These were clupeids, emerald shiners and walleye in 1978, clupeids and yellow perch in 1979, and clupeids, freshwater drum and yellow perch in 1980. Clupeids were consistently the most abundant group comprising over 65% of the population each year.

2) Clupeids are wide temporal spawners spawning over several months (May to August). Walleye and yellow perch are narrow temporal spawners, apparently spawning over only a week or two.

3) The mean length of larvae on the first date they occurred in samples and water temperature data can be used with appropriate references to back calculate time of spawning.

4) With the exception of clupeids, the lengths of larvae in the surface, bottom and night samples were not statistically different (1-way ANOVA, $p = 0.05$). The longest clupeids were found in the night samples followed by those fish in the surface samples and then in the bottom samples. Non-closing plankton nets are not recommended to take bottom tows since larvae at the surface are included in collections upon retrieval of the net. These surface larvae could have an influence on the mean larval length estimates.

5) For growth studies on larval fish in Lake Erie, it is recommended that collections be made no less than once every

ten days. Sampling should be underway by mid-April depending on water temperatures and species concerned with.

6) Instantaneous growth rates can be calculated on yellow perch and on the first hatch of clupeids if collections are made early and often enough. The growth coefficient of clupeids in 1980 was between 0.028 and 0.034. Two growth rates were detected with the 1980 yellow perch data. It appears as though the yolk sac larvae were growing at a rate between 0.018 and 0.022, and actively feeding larvae were growing at a rate of 0.038.

APPENDIX A

Larval Terminology

Hubbs (1943) defined the following terminology:

prolarvae - larval fish with a yolk sac (stage 1).

postlarvae - larval fish no longer possessing a yolk sac (stage 2).

juvenile - acquiring adult characteristics.

Snyder (1976) introduced another set of terminology to describe stages of larval fish development. There were:

protolarvae - any larvae with no spine development in the principal median fins (all fins excluding the pelvic and pectorials).

mesolarvae - when first spines appear in the median fins. Spines usually appear in the caudal fins first.

metalarvae - first appearance of pelvic fin buds.

juvenile - when segmentation occurs in all 3 median fin spines.

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