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ABUNDANCE AND DISTRIBUTION OF LARVAL FISHES OF THE FAMILY PERCIDAE IN MAUMEE RIVER AND MAUMEE BAY OF LAKE ERIE

By

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PREFACE

The following report was prepared by William C. Bartholomew as fulfillment of the thesis requirement for the Master of Science degree at the Ohio State University. Dr. Charles E. Herdendorf served as adviser and Drs. John Disinger and James Triplett served as members of the reading and examination committee. The research conducted for this project was coordinated by the Center for Lake Erie Area Research (CLEAR) and was supported by the U.S. Environmental Protection Agency (Large Lakes Field Station, Grosse Ile, Michigan), Toledo Edison Company and White Brothers Sand and Gravel Company. On behalf of the Center for Lake Erie Area Research and the Ohio Sea Grant Program I am pleased to make this report available to the scientific community.

Charles E. Herdendorf
Director

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INTRODUCTION

Fundamental Considerations

This study attempts to determine distribution and abundance of larval fishes of sport and commercial interest of the family Percidae, namely the walleye, sauger and yellow perch (Table 1). Also the effects of power plants, water movements and other environmental factors which influence the early life histories of these species in the Maumee River and Bay are examined.

In recent years the importance of the Maumee River as a major spawning area for fish has become apparent. Formally the western basin of Lake Erie, with its many reefs and over-all shallow environment, was believed to be the major breeding ground for most species of commercial and sport interest (Hartman, 1970). Further studies by Herdendorf and Cooper (1975), Heniken (1977) and Snyder (1978) have shown that the Maumee River and Maumee Bay are very important spawning and nursery areas for various species of fish. Some species which are abundant and reside in the river throughout the year are the gizzard shad, carp and channel catfish. However, species such as the walleye, sauger, white bass, white sucker and freshwater drum are anadromous and move into the river from the lake and bay to spawn (Trautman, 1957).

Both Maumee Bay and, particularly, the Maumee River are used extensively for various types of industrial usage and

TABLE 1

COMMON AND SCIENTIFIC NAMES OF
SPECIES OF FISH MENTIONED IN THIS REPORT*

Common Name	Scientific Name
Alewife	*Alosa pseudoharengus*
Blue pike	*Stizostedion v. glaucum*
Carp	*Cyprinus carpio*
Channel catfish	*Ictalurus punctatus*
Cisco	*Coregonus artedii*
Emerald shiner	*Notropis atherinoides*
Freshwater drum	*Aplodinotus grunniens*
Gizzard shad	*Dorosoma cepedianum*
Goldfish	*Carassius auratus*
Lake trout	*Salvelinus namaycush*
Sauger	*Stizostedion canadense*
Walleye	*Stizostedion v. vitreum*
White bass	*Morone chrysops*
Whitefish	*Coregonus clupeaformis*
White sucker	*Catostomus commersoni*
Yellow perch	*Perca flavescens*

*Names are according to Bailey et al., 1970.

cooling purposes. Examples are industrial cooling, dredging, shipping and pleasure boating. These uses threaten the spawning success and larval survival of fishes. The larval period of fish represents a critical period during which they are especially vulnerable to the industrial and commercial pursuits of mankind.

Large water-using industries such as electrical power plants are especially hazardous to larval fish. Larvae are taken in with the cooling water and often killed or injured by temperature shock, mechanical damage or chemical poisoning or a combination of these factors (Heniken, 1977). This process is termed "entrainment," which is defined as the capture and inclusion of aquatic organisms (smaller than the mesh of the intake screens) in the cooling water (Schubel and Marcuy, 1978). Older and larger fish may also be affected. When this happens, it is termed "impingement" and may be defined as organisms too large to pass through the intake screens which are drawn into the cooling water and become trapped on the screens. Impingement often leads to the organisms being killed or injured (Schubel and Marcuy, 1978). Knowledge of a fish's life cycle, its distribution in the waters of an area and the circulation of those waters are prerequisites to assessing the potential for entrainment and impingement.

The passage of Public Law 92-500 (Federal Water Pollution Control Act Amendments of 1972) has been responsible for most recent investigations of fish larvae. This law was enacted to clean up the United States' waterways and to prevent further pollution and degradation of these valuable natural resources. Section 316(b) of the law requires all thermal electric power plants to demonstrate that their cooling water intake structures either have nonsubstantial adverse environmental effects or that the intake structures reflect the best available technology for minimizing adverse environmental effects.

Data obtained for this thesis was, in large part, related to a 316(b) study for the Toledo Edison Company. Two sites were studied, the Acme and Bay Shore Power Plants, located on the Maumee River in Toledo, Ohio. The objectives of the 316(b) study were to quantify entrainment and impingement losses at the power plants and to attempt to predict impacts upon the environment. Larval fish samples were taken both in the river and directly in front of the intake structures at both plants to estimate the effects of the plants on the total populations inhabiting the river. Impingement studies were also done at each power station to determine impacts upon older and larger fish.

Additional information utilized in this thesis was obtained while researching a project for White Brothers Sand, Incorporated. This project was conducted to assess the environmental impacts of commercial sand and gravel dredging from the Maumee River and Bay. This research is part of an ongoing study initiated in 1975 (Herdendorf and Cooper, 1975; Herdendorf et al., 1977).

To obtain a permit from the United States Army Corps of Engineers to dredge these areas, companies must submit an impact assessment, as required by the National Environmental Policy Act of 1969, to demonstrate that adverse effects to the ecosystem are minimal or nonsubstantial when compared to the benefits of the proposal itself.

Both of the projects were designed and conducted by the Center for Lake Erie Area Research (CLEAR) of The Ohio State University.

Recent summers have marked the return of high-quality walleye sport fishing to the western end of Lake Erie. Catches during this period have been the best since the 1950's (Scholl, 1978, and this author's personal observations). The walleye is one of the major species of sport and commercial interest in this lake. This species is one of the few remaining high-order predators found in significant quantities in western Lake Erie. Walleyes are long-living, general predators that can tolerate a fairly wide range of environmental conditions (Regier et al., 1969). Walleyes are usually found in middle-aged lakes that are fairly rich in species and somewhat turbid, with sufficient clean-bottom areas and relatively high dissolved oxygen concentrations (Carlander et al., 1949).

The walleye is an anadromous species. Formerly, each spring many walleyes ascended the Huron, Maumee, Raisin and Sandusky Rivers. However, most of these runs had been destroyed by 1945. This destruction was due to construction of dams, plus siltation, excessive pollution and irregularity of stream flow due to human activities (Langlois, 1954). Spawning runs still continue in two of these tributaries--the Maumee and Sandusky Rivers (Snyder, 1977).

Much recent interest of fishermen and biologists has been generated by the reintroduction of sauger into Lake Erie. During the period from the late 1950's through the 1960's the sauger became nearly biologically extinct in this lake. Between 1974 and 1976 there were 882,000 fry and fingerling sauger released into the lake. Recapture by commercial and research vessels have indicated good survival rates from each of the stockings (Rawson and Scholl, 1978).

The sauger is similar to, although somewhat smaller than, the walleye. Saugers are most often found in somewhat silty rivers and large lakes (Trautman, 1957). In Lake Erie the sauger was more tolerant of a silted bottom and turbid waters than the walleye (Doan, 1941).

Another important member of the family Percidae is the yellow perch. The perch supplies the backbone for both the sport and commercial fisheries in Lake Erie. In 1977 an estimated 541,547 pounds were taken by anglers while 2,317,060 pounds were taken by commercial fishermen (Scholl, 1978). Scholl also estimated that 49 percent of all sport fishing effort was devoted to yellow perch.

Perch are general predators, feeding on a variety of small fish and benthic organisms, and prefer living in fairly clean water where rooted plants exist (Scott and Crossman, 1973). Areas of Maumee Bay around Turtle Island are used extensively by sport fishermen seeking yellow perch (personal observation of the author).

After spawning and subsequent hatching the larvae of these percids and other species become planktonic (which means they are floating organisms) and are thus termed ichthyoplankton. The larvae have some movement capabilities, but these skills are very limited. Most movements of larval fishes are controlled by currents or other water movements rather than swimming ability. Houde (1969) studied the swimming ability of larval walleye and perch and determined that both species swam poorly as newly-hatched larvae, but as growth continued with the absorption of the yolk sac, development of the fins and increased development of muscle tissue made swimming ability increase substantially.

The distinct physical and biotic features of the Maumee River and Bay system make this area a unique habitat. By being a freshwater estuary (Brant and Herdendorf, 1972), the mixing of its waters and currents have a definite impact on the movements of ichthyoplankton. Maumee Bay is very important as a nursery area for different species, and many fish reside there throughout their first summer before moving out into the lake (Herdendorf and Cooper, 1975; Fraleigh et al., 1974).

It is important to study the distribution and abundance of fish during the larval period (when they are most vulnerable) to insure proper protection for future propagation of the species. Even though fish spend only a small portion of their life cycle in the planktonic phase, it is a critical period. As mentioned previously, this study concentrates mainly upon the walleye, sauger and perch and their utilization of the Maumee River and Bay during their early life histories.

Historical Aspects and Life Histories

Walleye. The population strength of this species in the western basin has fluctuated drastically during the past two-and-a-half decades as indicated by commercial catch records. Prior to 1970, this species had supported a fishery for approximately 140 years. Fishery exploitation, pollution, eutrophication and the introduction of new species all have affected the walleye population strength (Regier et al., 1969). Commercial production of walleyes from western Lake Erie declined from 5.9 million pounds in 1956 to 140,000 pounds by 1969 (Busch et al., 1975).

Prior to 1940, the walleye fishery of Lake Erie was of secondary importance. Traditionally, Lake Erie had produced the greatest variety of commercially-important fish of any of the Great Lakes. In the mid-1800's the major species of commercial importance were the cisco, whitefish and lake trout. These were taken primarily in the deeper waters of the central and eastern basins. Beginning around 1914-1930, the United States' and Canadian catches of these species began to decline. The diminishing abundance of these species was offset by generally upward trends in the production of walleyes, blue pike and white bass. The walleye was one of the most abundant and valuable commercial species between 1940 and the late 1950's. The walleye fishery was first dominated by Ohio fishermen using pound nets. Large numbers of these nets were set, but fishing intensity never became overbearing or led to a marked depletion of stocks.

In the early 1900's there was little fishing in Canadian waters, which provided a sanctuary for migratory species like the walleye. In 1948 Canadian fishermen began testing nylon mesh gill nets instead of using the traditional cotton mesh. They compared catches made with the nylon and cotton, and found the nylon to be several times more efficient. In the early 1950's, fishing intensity greatly increased as Canadian fishermen began converting from cotton to nylon netting. They also began using other items such as sonar and ship-to-ship radios. According to Regier et al. (1969), these improvements in technology, coupled with a "laissez-faire management policy," enabled the gill-net fishermen (particularly in Ontario waters) to increase their effectiveness in taking walleyes approximately 50-fold. Larger and larger catches were taken during the 1950's, mainly in Ontario waters, until the fishery collapsed in 1957.

Parsons (1970) and Regier et al. (1969) speculate that over-exploitation of the weak year classes from 1953-1961, along with the deteriorating water quality and habitat conditions, led to the collapse. As year classes declined in strength, the growth rate of the walleyes increased and the average age of the fish caught by fishermen decreased. Many of these faster growing walleyes were caught and removed from the lake shortly after they reached legal size; thus fewer and fewer females reached sexual maturity before they were captured (Hartman, 1972).

The commercial walleye fishery was closed in American waters of western Lake Erie in 1970. It was found that adult walleyes contained more than 0.5 ppm of mercury, which is considered unsafe for human consumption by the U.S. Food and Drug Administration. However, this ban was lifted when levels of mercury content decreased. Later, the State of Ohio enacted a commercial harvest moratorium (1972 to present) on walleyes to try to build up the stocks. Also during this period there has been little intensive fishing pressure in Canadian waters on walleye as most commercial fishermen have concentrated on catching the more abundant yellow perch. To date, the commercial ban on taking walleyes in American waters is still in effect.

The walleye has always been a popular sport fish in Lake Erie. Throughout the 1950's they were sport-fished extensively with excellent angler success. When the populations decreased, so did sport fishing success and subsequently fishermen began concentrating on other species--mainly the yellow perch. The recent increase in stocks has brought about the return of high quality sport fishing for walleyes. Today they are sport-fished extensively and have become a major economical boost for the area through sales of tackle, licenses, boating supplies, charter service and increased tourism.

The major area of walleye spawning activity in the Maumee River is in the riffle zones beyond the Maumee-Perrysburg Bridge (Figure 1). Walleyes spawn commonly over a rock, rubble or gravel-type bottom (Regier et al., 1969).

Walleye spawning in western Lake Erie and its tributaries usually begins when the water temperature rises to about 40°F. Peak spawning usually occurs when temperatures reach approximately 45°F (Wolfert et al., 1975). For this study that would be about 5 April. The fertilization process has been described by Langlois (1954). Walleye spawning takes place nocturnally; the female sits on the bottom, where she is surrounded by four to seven males. She slowly rises, releasing the eggs which are then fertilized by the males. After this they resume their original positions and spawn again. Females can spawn out completely in one night, whereas males have the potential for spawning over a longer period (Ellis et al., 1965). Ellis also states that males arrive at the spawning grounds before the females and may remain as long as two weeks, while females usually only stay for a day or two before returning to the lake.

Walleyes are not territorial during spawning, and no type of nests are established. Walleyes broadcast their eggs and exhibit no parental care. The spawned eggs are very adhesive. After several hours in the water, the external egg membrane

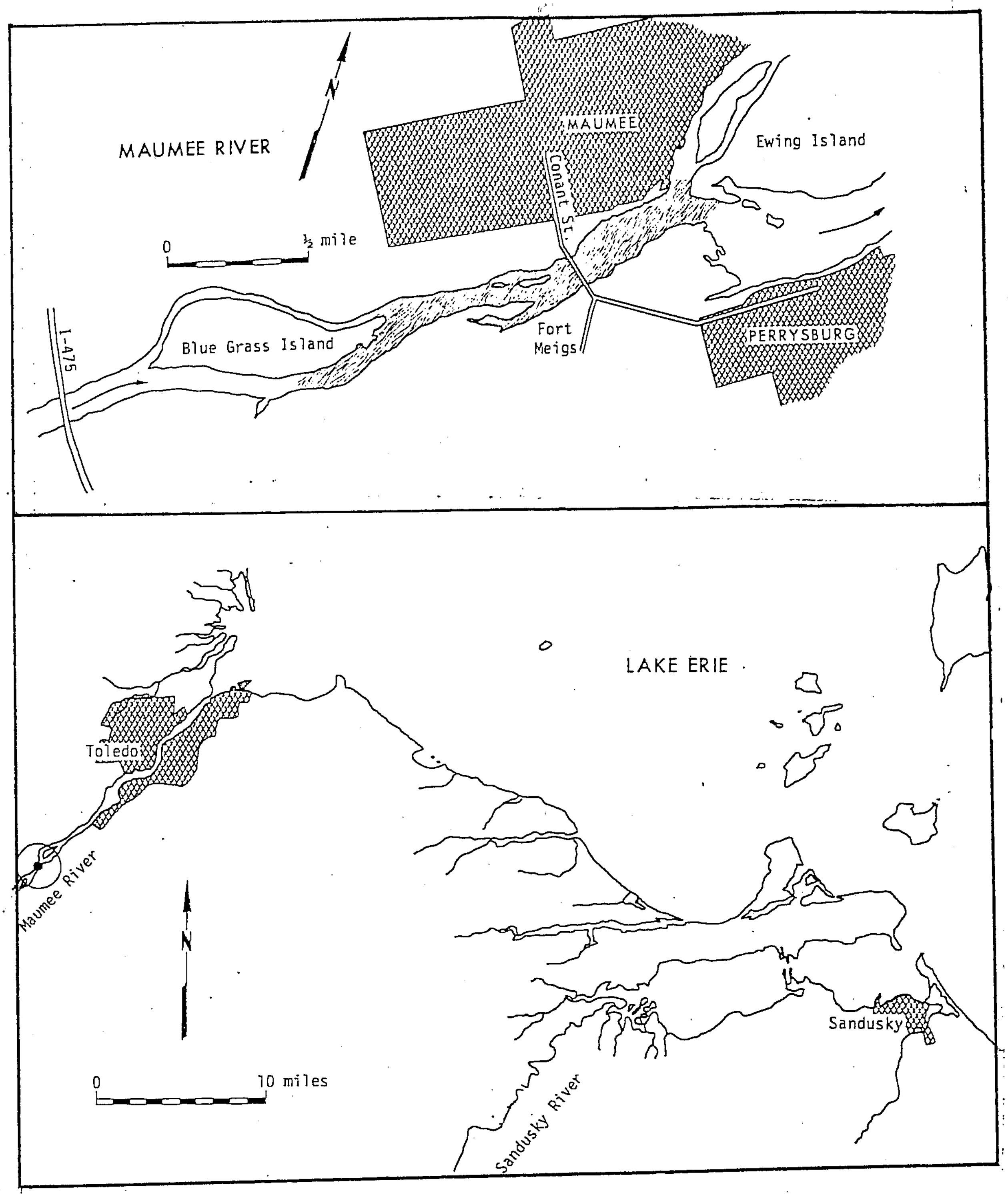


Figure 1. Riffle areas of the Maumee River (A) and its location in relation to the western basin of Lake Erie.

hardens and loses its adhesive quality (Priegel, 1970). After losing their adhesiveness, the eggs lie loose in the substratum. This is one of the main reasons the walleyes need a gravel-type bottom to have a successful spawn. The eggs, after they lose their adhesiveness, do best if they fall into cracks and crevices. If the eggs fall upon a mud bottom, they are easy prey for other species; if they become covered with silt, a fungus will often develop.

The female walleyes of the western basin of Lake Erie have a high fecundity rate. Wolfert (1969) found that females contained between 48,000 and 614,000 eggs per individual. This usually varies with weight. Wolfert also states that in western Lake Erie stocks, 85 percent of the females are sexually mature at age 3, while 96 percent of the male walleyes were mature at age 2. In view of their high fecundity, it follows that the first-year mortality is very high (Regier et al., 1969).

A problem that has puzzled biologists for a long time is trying to determine the percentage of eggs deposited that actually are fertilized and hatched. Estimates by Baker and Manz (1967) ranged between 19 and 49 percent for walleye in the reef areas of western Lake Erie. The fact that from four to seven males spawn with one female is probably a behavioral adaptation to compensate for a relatively low chance of fertilization due to area involved, currents and short-lived viability of the egg and sperm. Stranahan (1900) reported that walleye sperm dies in two minutes, and eggs can't be impregnated after six minutes' exposure to water. These conditions make simultaneous spawning by large numbers of walleyes over a small area advantageous to increasing the probability of fertilization.

Weather conditions appear to be the critical factor affecting survival and subsequent year class strength. Reproductive success is most clearly related to the rates of water warming during the spawning and incubation periods. According to Busch et al. (1975), the spawning and incubation temperatures are strongly related to hatching success. It appears that if the water warms rapidly after most spawning is completed, the number of fingerlings produced is above average (Regier et al., 1969). When water warms quickly and steadily throughout the main spawning and incubation periods, then both the spawning period and embryological developmental time of the eggs are shortened considerably. Thus, exposure of the eggs to unfavorable conditions, such as siltation, disease, low oxygen or storm-generated turbulence, is reduced substantially. In the study done by Busch et al. (1975), incubation periods varied from 16 to 25 days.

The spring of 1977 was a warm, mild season following a very cold winter. The report by Busch et al. (1975) states that in all years of their study where there was a good or excellent year class, the rate of water warming was steady and rapid. In the years where there was poor year class strength, the rate of water warming was slow. Derlack (1947) reports that in some extreme cases female walleyes may reabsorb their eggs if the spawning delay is great or numerous temperature reversals occur. The spring of 1976 was a cold spring in which several relatively large temperature reversals occurred and the subsequent walleye hatch was poor (Snyder, 1978). Fluctuating temperatures tend to disrupt spawning in that fish might spawn intermittently over a period of several weeks instead of a shorter period if temperatures rise steadily.

Busch et al. (1975) determined that the rate of water warming just prior to spawning, during spawning and incubation and immediately after hatching is critical. They state that in years where year class strength is good to excellent, the rate of water warming for this period was generally above 0.50°F per day. In this study the rate of water warming from the last week in March to mid-May for the Maumee River was 0.54°F per day.

Other factors affecting the reproductive success would be water quality, spring storms and the amount and rate of water moving downstream. Regier et al. (1969) states that if conditions are right, a relatively small brood stock can produce a strong year class. The inverse is also true--where conditions are bad, a large brood stock may have a very poor hatch.

Upon hatching, walleye prolarvae drift downstream. Studies done by Snyder (1978) and Priegel (1970) indicate that these fry are at the mercy of the current. A relatively steady, somewhat strong current is needed for required levels of dissolved oxygen and to carry the larvae to the lake. Prolarval walleyes need to stay in the main current of the river to insure survival. Those which get in areas or pockets without currents may perish if their yolk sac is absorbed before they are carried downstream to areas of high zooplankton abundance.

On the journey down the river, prolarval walleye are not able to search for their own food since their fins are not developed enough to allow the fry to swim about freely. Heniken (1977) states that fish larvae pass through a critical period following the absorption of yolk until the first feeding. Larvae require the correct type, correct concentration and correct size of food for successful feeding. Aquarium tests have shown that walleye prolarvae, upon hatching, will absorb their yolk sacs within approximately a five-day period (Priegel, 1970). A relatively greater amount of yolk is present in walleye prolarvae than in perch (Houde, 1969). This may be an adaptation to habitats utilized by adults when spawning. Houde (1969) states that some yolk may be present in walleyes in lengths of 9.5 mm.

Postlarval and juvenile walleyes in the 10 to 50 mm size range were found to feed primarily on copepods, cladocerans and some diatoms (Priegel, 1970; Hahn, 1966). Zooplankters commonly eaten by this size class were _Diaptomus_ spp., _Cyclops_ spp., _Leptodora_ sp. and _Daphnia_ spp. Herdendorf and Cooper (1975) found zooplankton abundance to be low in the upper estuary portion of the Maumee River during spring months. There was a general increase in abundance of zooplankton near the mouth of the river and especially at the bay stations. It is imperative then that walleye larvae be carried down the river by the current and reach the bay area where the food supply is readily available and abundant. In the 50 mm to 75 mm size range walleyes are still considered primarily plankton feeders; over 75 mm in length, they feed primarily on fish. Forage fish appear to be eaten in proportion to their abundance (Priegel, 1970).

Sauger. This species, although never as commercially important as walleye, was still much sought after. Commercial harvest peaked in 1916 when the catch was over 2.3 million pounds (Applegate and Van Meter, 1979). The most important sauger fishery was at Toledo, although catches were common along the entire south shore up to and through the central basin (Rawson and Scholl, 1978). However, soon after this the commercial annual yields of sauger began to fluctuate widely. Between 1946 and 1958 commercial production declined steadily and by 1960 less than 1,000 pounds were taken (Applegate and Van Meter, 1970). Soon after this the sauger became nearly extinct in Lake Erie. Suggested reasons for the population collapse are combined effects of environmental pollution, habitat degradation, heavy fishing pressure and possible interspecific competition with the walleye; however, no one is really sure of the exact cause or causes (Hartman, 1972).

Historically the sauger was also an important sport fish. With the hopefully successful reintroduction of the species into

Lake Erie, the sport fishery will be reestablished. Since the reintroduction, sport-caught sauger have been taken primarily from the Sandusky and Maumee Rivers and Sandusky Bay. The 1977 harvest from the rivers was estimated at 1,900 saugers taken (Rawson and Scholl, 1978). This number may be conservative due to the fact that saugers are easily confused with small walleye.

The sauger in Lake Erie, prior to their reintroduction, received little scientific attention or study. The successful walleye hatches in 1970 and 1972 prompted the Ohio Department of Natural Resources, Division of Wildlife, to attempt the reintroduction program of the sauger (Rawson and Scholl, 1978). The success of this program would be very significant. Studies in the past have shown that there is no positive evidence that stocking or artificial propagation programs have ever been successful in maintaining or increasing yield of a native species in the Great Lakes over an extended period of time (Dymond, 1957).

The sauger in Lake Erie had historically spawned in the same areas as the walleye. Sauger prefer to spawn over areas of rubble, gravel or sand (Priegel, 1969). Like the walleye, the sauger is an anadromous species. Early spring spawning concentrations of sauger have been found in the Sandusky and Maumee Rivers while electrofishing in 1976 and 1977 (Rawson and Scholl, 1978).

The literature states that sauger spawn over a temperature range of 43°F to 52°F. Spawning takes place for approximately a two-week period, often immediately after the walleye with some periods of overlap (Scott and Crossman, 1973). The males are the first to arrive on the spawning grounds and remain in the area longer than the females. The female sauger may completely spawn out in a single night and return to the lake immediately. Spawning occurs at night in shallow water (2 to 12 feet deep), and also, like the walleye, a single female sauger will spawn with several males simultaneously.

Upon deposition the eggs are adhesive, but after water hardening they become semibuoyant and nonadhesive (Priegel, 1969). Fecundity estimates (in the literature) range from approximately 9,000 to 96,000 eggs per female. Mature two-year-old sauger from the reintroduced Lake Erie stock averaged 64,854 eggs per female (Rawson and Scholl, 1968). The sauger does not build a nest or exhibit any parental care. Ripe eggs are reported to be 1.0 to 1.5 mm in diameter, somewhat smaller than those of the walleye (Scott and Crossman, 1973). The incubation period of the eggs has been reported to range from approximately 21 days at an average water temperature of 47°F to 9 to 14 days at a water temperature of 55°F (Nelson, 1968b). Here again, it should be pointed out that the faster incubation rate is advantageous in that eggs are exposed to fewer environmental hazards. Because the eggs are semibuoyant, strong winds causing extreme and prolonged wave action may be a major factor in egg mortality (Priegel, 1969).

Upon hatching, the larvae are 4.5 to 6.2 mm long (Scott and Crossman, 1973). The sauger prolarvae are also at the mercy of the current and need to get to areas of zooplankton abundance before or shortly after absorption of the yolk. The yolk sac is usually absorbed in a seven- to nine-day period.

Nelson (1968b) states that feeding usually begins before the yolk sac is absorbed, when the average length of the larvae is 9.5 mm. Sauger larvae between 9.5 mm and 17 mm appear to prefer *Cyclops* spp. With increasing size they begin to feed upon *Diaptomus* spp., *Bosmina* sp. and *Daphnia* spp. The switch between feeding upon zooplankton and fish occurs between the 50 mm and 70 mm range (Priegel, 1969). Even at this young age sauger show preference for more turbid waters than the walleye. This factor would help eliminate interspecific competition, although this may not be a limiting factor due to the abundance of forage species in Lake Erie.

Yellow perch. The population of this species in Lake Erie has fluctuated widely over the past fifty years as evidenced by commercial catch records and field surveys (Patterson, 1978). The yellow perch commercial fishery is similar to that of the walleye in that it was of secondary importance until populations of cisco, whitefish and lake trout began to decline. There were good year classes of perch throughout the 1950's, with an excellent hatch in 1959. Since this time year class strength has fluctuated greatly. However, the 1965 hatch was also exceptional, and this, combined with heavy Canadian fishing pressure, led to a record catch of 33.7 million pounds in 1969 (Hartman, 1972). Scholl (1978) reports that 1977 was an excellent year for Ohio commercial fishermen when 2,317,060 pounds were taken. The 1973 and 1974 year classes provided the bulk of this catch.

Yellow perch continue to be the backbone of the commercial and sport fishing industry in Lake Erie. Biologists are concerned about the current instability of the perch population in the lake. Strong year classes have repeatedly occurred; however, rendering reasons or causes for these fluctuations in year class strength is lacking or tentative at best. Along with the variability of year class strength, there has been a reduction in growth rates of this species (Hartman, 1972). At the present time, stocks are being monitored closely.

The yellow perch in Lake Erie display a somewhat different reproductive strategy than the walleye or sauger. Yellow perch spawning activity begins when water temperatures reach 44^{o}F to 54^{o}F. At this time adults migrate to nearshore areas of the lake (Waybrant and Shauver, 1978). Like the walleye and sauger, perch males arrive at the spawning grounds first and remain longer than the females. Most spawning occurs from late April into May and may even extend into June.

Habitat for spawning is reported to range from areas over rooted vegetation, submerged brush, fallen trees or areas of sand and gravel (Scott and Crossman, 1973). Peak spawning is reported to occur at water temperatures of about 53°F (Brazo, 1975). Spawning occurs at night or during early morning hours. Like the walleye and sauger, a single female is attended by a group of males during the spawning act.

The eggs are deposited as an accordian or ribbon-like mass. This mass may be as long as seven feet and two to four inches wide (Scott and Crossman, 1973). These egg masses are semi-buoyant, and aeration is accomplished by water circulation through holes and canals in the mass. These egg masses move about with water movements and adhere to become attached to vegetation, submerged articles or the bottom. Also, like the walleye and sauger, no nest is built and no parental care is exhibited toward the eggs or young. The egg masses are very susceptible to adverse or severe weather conditions, and can be easily cast ashore by wind, waves or water currents.

Fecundity rates have been reported to range from 11,000 to 109,000 eggs per fish (Brazo, 1975; Scott and Crossman, 1973). The number of eggs per individual is proportional to body weight of the female. Hatching usually takes approximately 8 to 10 days, but may take as long as 27 days if cold water temperatures persist. Forney (1971) reports that climatic factors during this period may have a definite impact upon year class strength. Here again, a shortened incubation period is advantageous in that eggs are exposed to adverse environmental conditions and predation for a shorter period of time. The eggs after exposure to water are about 3.5 mm in diameter.

Upon hatching, the larvae drift with the currents or remain relatively inactive. The newly-hatched prolarvae are from 4 mm to 5.5 mm in length and are transparent. The absorption of the yolk occurs over approximately a five-day period, and the perch larvae enter the postlarval stage at a length of about seven mm. As mentioned previously, there is a relatively smaller amount of yolk found in perch prolarvae than in the walleye.

Young perch feed almost entirely on zooplankton until they attain a length of approximately 40 mm to 50 mm (Pycha et al., 1954). Zooplankters found to be eaten by young perch were <u>Daphnia</u> spp., <u>Cyclops</u> spp., <u>Bosmina</u> spp., <u>Leptodora</u> sp. and <u>Hycibella</u> sp. Pycha found that there appeared to be no significant selection of these food types, and that occurrence in the stomachs was generally related to abundance of the organisms. In the 40 mm to 80 mm size range perch were found to feed mainly upon zooplankton, fish, benthic amphipods and insect larvae. Here again, and throughout their entire life cycle, it has been found that perch are very general feeders and usually prey upon whatever suitable items are most abundant.

METHODS

Study Area

Maumee River. The Maumee River is a low gradient stream which drains primarily flat farmlands. Although not a large river when compared to some others on the North American continent, it is the largest tributary to the Great Lakes (Reutter et al., 1978). The river begins in Fort Wayne, Indiana, with the merger of the St. Joseph and St. Marys Rivers. The main stream of the Maumee River then flows in a generally northeast direction from Fort Wayne to Toledo, Ohio, where it enters Lake Erie. This is a total distance of about 135 miles. Greater Toledo is an industrialized community with a population of over 700,000 people. Toledo area industries are the major source of industrial pollution to the river.

The average gradient of the river is 1.3 feet/mile with a mean discharge of 4,700 cfs; this ranges from a high of 94,000 cfs to a low of 32 cfs (Herdendorf and Cooper, 1975). The Maumee carries a very heavy silt and sediment load primarily from the farmland drainage of northwestern Ohio and northeastern Indiana. Although the Maumee River provides only three percent of the flow into Lake Erie, it accounts for over 37 percent of the suspended solids entering the lake annually. This is approximately 1.2 million tons of suspended solids per year (Reutter et al., 1978).

The lower 15 miles of the Maumee River is considered to be a freshwater estuary. To be a freshwater estuary, a system must meet three criteria: 1) it must be a semi-enclosed basin; 2) it must be a mixing zone between the incoming stream and the main receiving body of water; and, 3) it must have a tidal influence from the main body of water (Brant and Herdendorf, 1972).

The estuary portion of the Maumee River begins slightly above the Maumee-Perrysburg Bridge. Upstream from the estuary portion is the riffle zone where the majority of walleye spawning in the river is believed to occur (Fig. 1). As the water flows down the river into the estuary zone from the riffle area, its velocity drops off sharply. Various riffles are found from the Maumee-Perrysburg Bridge upstream to Grand Rapids, Ohio, where a dam is located. Primary spawning areas are the Buttonwood riffles and the area just upstream from the Interstate 475 Bridge. Local fishermen, however, catch walleye and white bass in the riffle zones all the way upstream to the dam at Mary Jane Thurston State Park in Grand Rapids. Therefore, it seems likely that some spawning is also taking place in these areas, although no sampling has been conducted this far upstream. Almost the entire area from the Maumee-Perrysburg Bridge to Mary Jane Thurston State Park is sport-fished heavily from late March to early June. The principal species of interest are the walleye and white bass which are entering the river to spawn.

Maumee Bay. Maumee Bay is a shallow body of water located at the western end of Lake Erie and is approximately 12 square miles in size. The bay is separated from Lake Erie by two spits: the Woodtick Peninsula, extending southerly from the Michigan shoreline, and Little Cedar Point, which extends northwesterly from the Ohio shoreline. Contained within the bay and upstream into the Maumee River estuary is a 500-foot-wide navigation channel which has been dredged and is maintained at 28 feet below low water datum (LWD) (Herdendorf and Cooper, 1975). The mean depth of Maumee Bay is five feet (excluding the navigation channel). On both sides of the navigation channel, and parallel to it, shoals have been constructed from the materials dredged to keep the channel at the proper depth. These shoals have been found to have a definite influence on water mixing and current patterns within the Maumee Bay and estuary (Fraleigh et al., 1974).

The bay floor is covered with sediment deposited from the tributaries entering it. Semifluid mud, sandy clay and sand compose 95 percent of the lake floor in Maumee Bay, with 5 percent gravel (Pinsak and Meyer, 1976). The bay shoreline is characterized by low clay shores and marsh (Reutter et al., 1978).

Sampling Locations

316(b) Project. The Acme Power Plant is located on the Maumee River near the heart of downtown Toledo. It is 3.7 miles upstream from the mouth of the river. The geographic coordinates for all sampling stations are listed in Table 2. The Acme plant has five steam electric units, and has a maximum rated capacity of 322 megawatts (MWe). When generating at its full capacity, the plant utilizes cooling water from the river at a rate of 605.7 cfs with an associated heat increase of 15.3°F above the ambient temperature (Reutter et al., 1978). However, Reutter also pointed out that this is a peaking plant, and the average output from 1971-1975 was only 104.3 MWe, with a mean temperature increase across the condensers of 9.4°F above ambient.

Station A - located in front of the traveling screens in the intake canal at the Acme Power Plant. The cooling water intake is a 270-foot-long canal through which water is drawn from the river to cool the condensers. Heated water is then discharged through a canal and put back into the river at a point approximately 660 feet downstream of the intake.

Station 1 - located on the east side of the river, slightly upstream and in front of the Acme intake canal. Approximate depth was 8-10 feet.

Station 2 - located in the navigation channel, and was slightly upstream from the Acme plant. Approximate depth here was 28-30 feet.

TABLE 2

GEOGRAPHIC COORDINATES FOR MAUMEE RIVER
AND BAY FISH LARVAE COLLECTION STATIONS

		Coordinates	
Station	River/Bay	Latitude (N)	Longitude (W)
D-4	River	41°37.1'	83°34.0'
D-3	River	41°37.3'	83°33.3'
D-2	River	41°37.4'	83°32.9'
D-1	River	41°37.6'	83°32.2'
A	River	41°39°.0'	83°31.0'
1	River	41°39°.2'	41°31.1'
2	River	41°39°.2'	83°31.3'
3	River	41°39.2'	83°31.4'
B	River	41°41.0'	83°26'.0'
4	River	41°42.3'	83°26'.6'
5	River/Bay	41°42.3'	83°26.7'
6	River	41°42.2'	83°26.8'
7	Bay	41°45.0'	83°22.8'
8	Bay	41°43.5'	83°21.8'
9	Bay	41°44.2'	83°20.5'
10	Bay	41°43.1'	83°20.8'
11	Bay	41°43.7	83°25.7'
12	Bay	41°42.2'	83°24.6'
13	Bay	41°43.0'	83°27.4'

Station 3 - located near the west shore of the river, again slightly upstream from the Acme plant. Approximate depth here was 20 feet.

These stations are considered as mid-estuary and were designed to transect the river slightly upstream from the Acme Power Plant. Figure 2 shows the location of the Acme sampling stations.

The Bay Shore Power Plant is located at the mouth of the Maumee River and on the southern shore of Maumee Bay. This is a baseload plant with four coal-fired steam electric units. It has a maximum capacity of 636 MWe in the winter and 623 MWe during the summer. This plant utilizes river cooling water at the rate of 1149.3 cfs at the 623 MWe level (Reutter et al., 1978). Cooling water is drawn from the river in a 3,000-foot-long, 250-foot-wide intake canal. This canal varies in depth from 15-20 feet. Heated water is discharged into Maumee Bay. Figure 3 shows the locations of the Bay Shore sampling stations.

Station B - located directly in front of the traveling screens at the Bay Shore Power Plant.

Station 4 - located near the east shore of the river, slightly upstream from the Bay Shore intake canal. Approximate depth was 9-12 feet.

Station 5 - located in the middle of the navigation channel, slightly upstream from the intake canal. Approximate depth here was 28-30 feet.

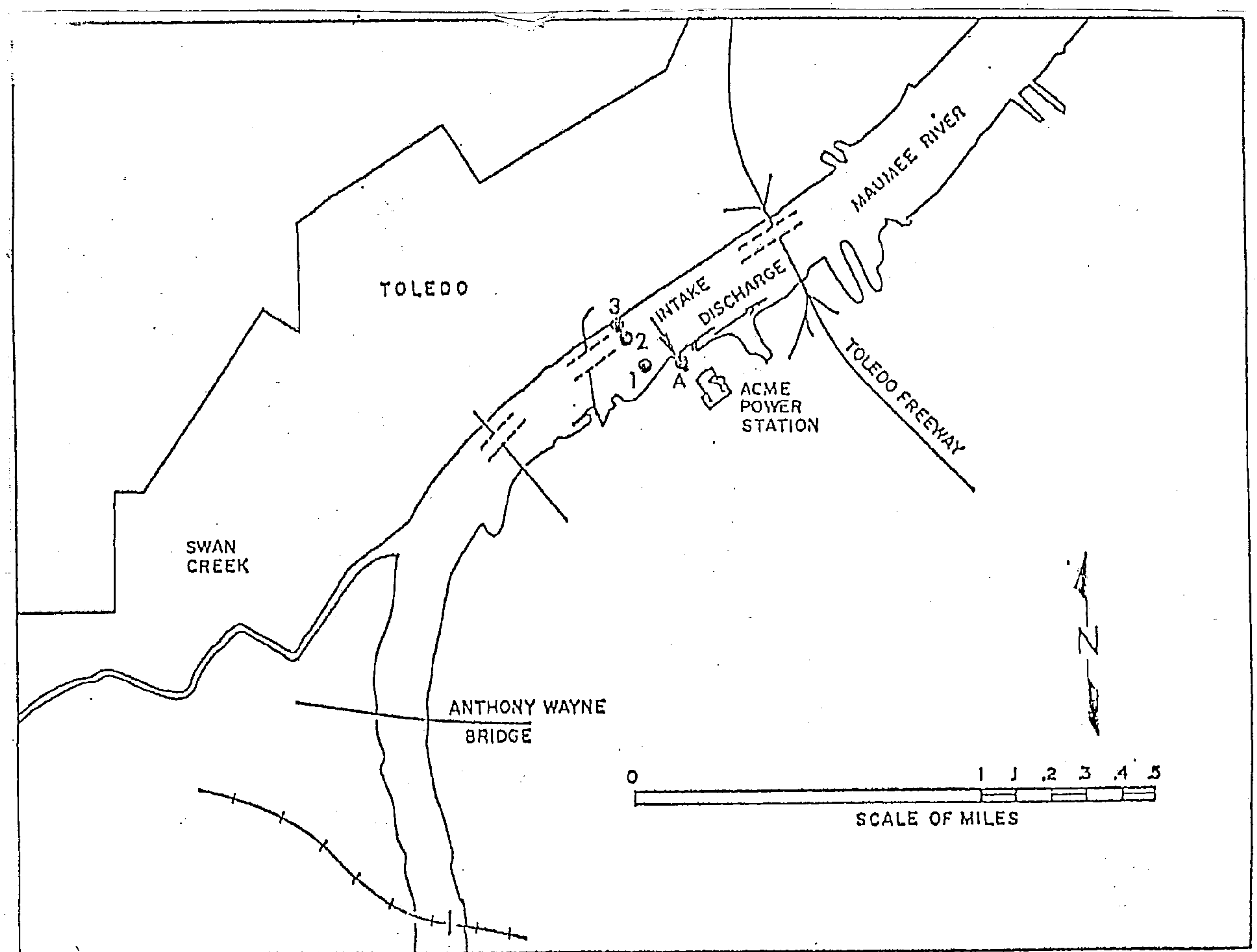


Figure 2. General area near Acme Power Station showing collection stations.

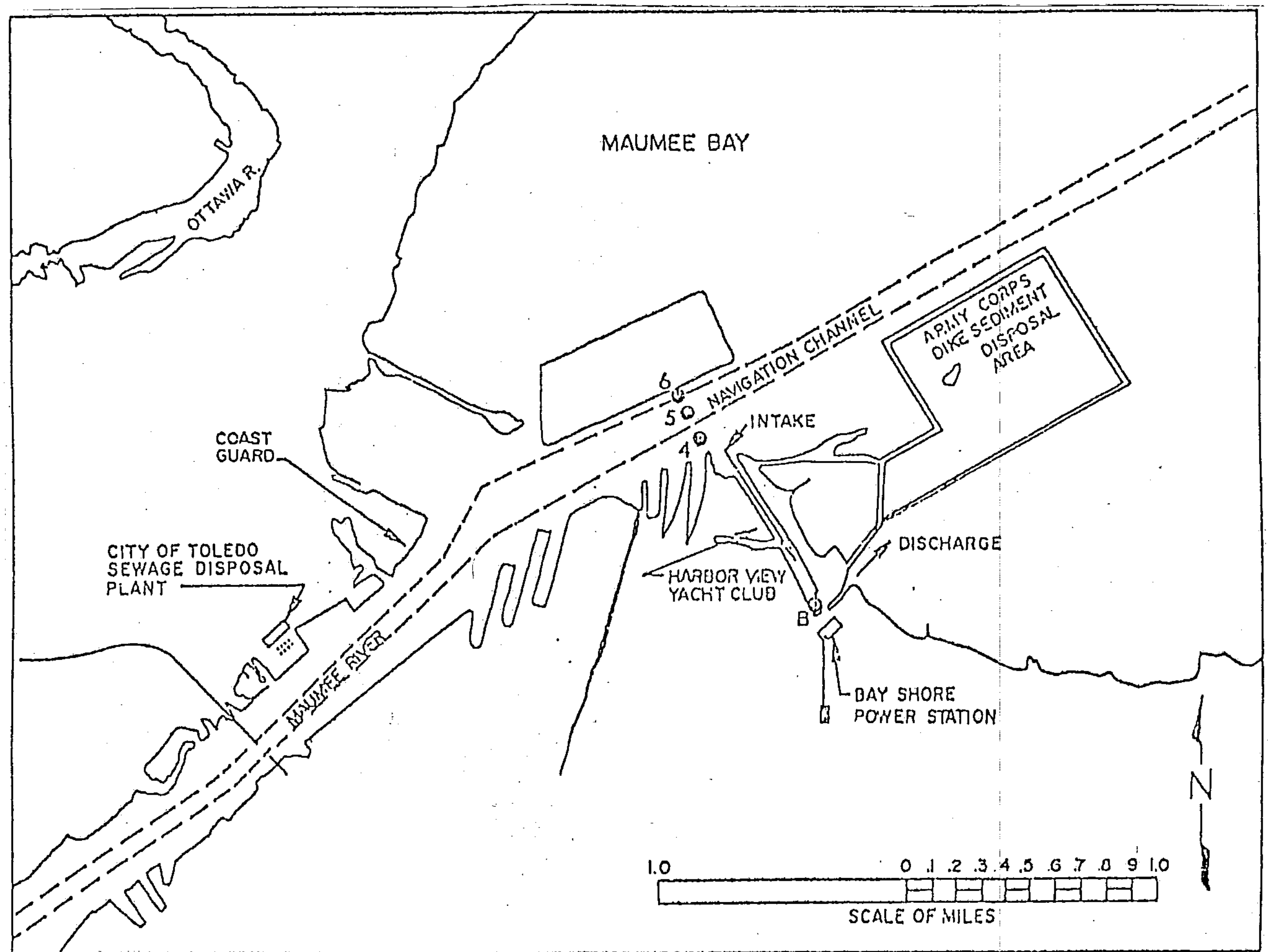


Figure 3. General area near Bay Shore Power Station showing collection stations.

Station 6 - located on the west side of the river along the banks of Toledo Island, which is a man-made island from dredge spoil. Again, it was located slightly upstream from the Bay Shore intake canal and was part of a transect of the river with stations 4 and 5. Approximate depth here was 6-10 feet.

River and Bay Sand Dredging Project. The stations for the White Brothers project were set up in the areas where commercial sand and gravel dredging activity was to be monitored. These stations were designed to evaluate ichthyoplankton movements and the impacts of the dredging operation. Figure 4 shows the location of the stations involved in this project. These stations can be considered mid-estuary.

Station D-1 - represents the downstream dredging area. This region is used by many lake freighters to turn around and is subsequently fairly deep. Approximate depth here was 20-25 feet.

Station D-2 - located upstream of the Interstate 75 Bridge. Approximate depth here was 10-12 feet.

Station D-3 - located in the upstream dredging area. Approximate depth was 15 feet.

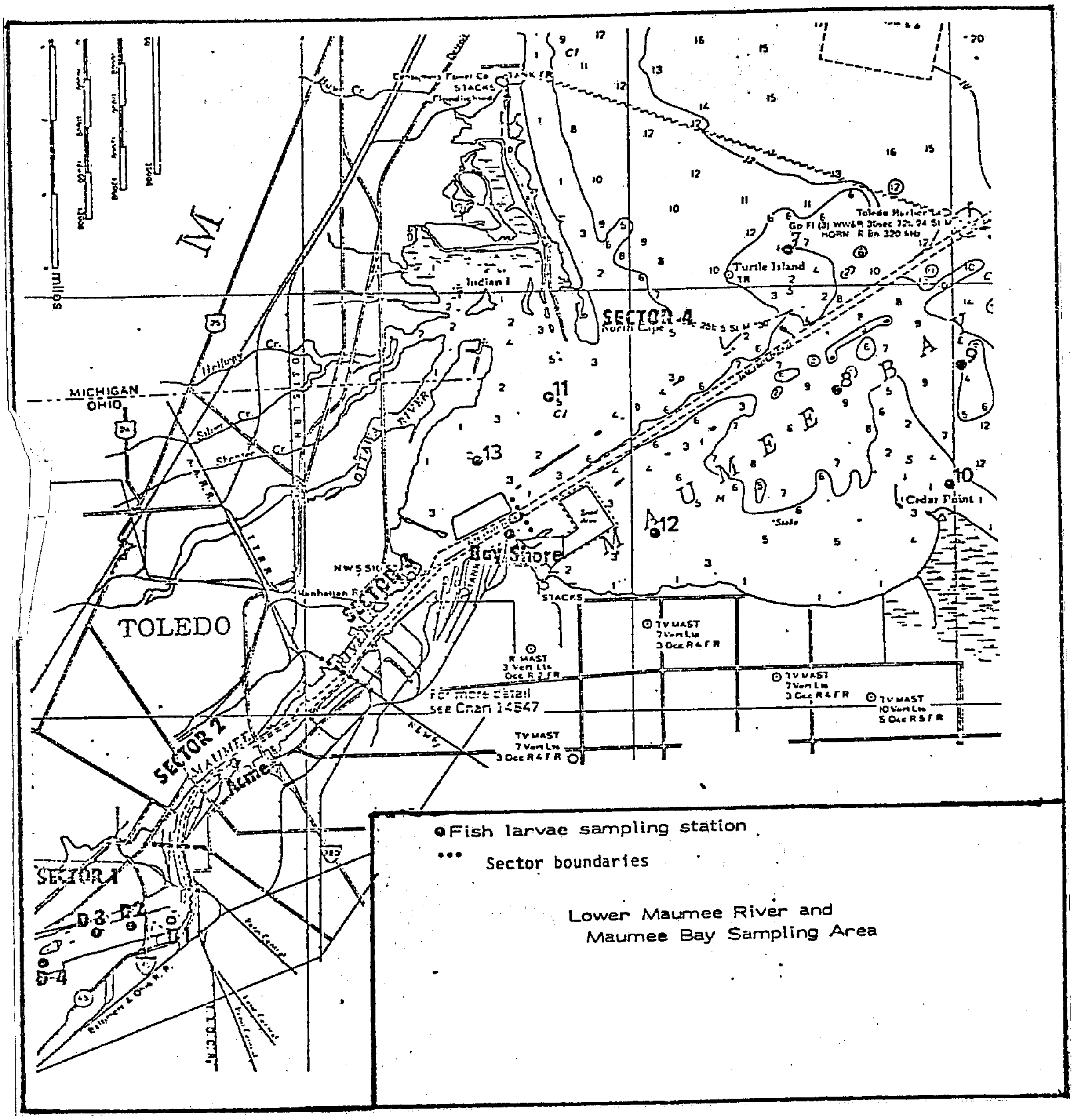


Figure 4. Lower Maumee River and Maumee Bay sampling area.

Station D-4 - designed as an upstream control station. It was located adjacent to Corbutt Island. Approximate depth was 16-20 feet.

The Maumee Bay stations were also set up to monitor dredging impacts and are as follows:

Stations 7-9 - located in the actual dredging zones. Station 9 was a control station in a presently inactive dredging area. Approximate depth was 9-15 feet.

Station 10 - located in the nearshore zone off Little Cedar Point. Approximate depth here was 6-10 feet.

Stations 11-13 - established near the mouth of the river to characterize the river portion of the bay and the interactions between these two systems. Approximate depth here was 6-10 feet.

Field Procedures

316(b) Project. Information was generated from the 316(b) study using the following procedures. Entrainment sampling began on 16 March 1977 and continued once every four days until 16 June, when sampling was then done on a weekly basis until 1 September 1977 (Table 3). Impingement samples were taken on a weekly basis from 15 September 1976 to 16 March 1977, after which they were performed by following the same schedule as the entrainment studies. Most impingement information used in this

TABLE 3

316(b) SAMPLING SCHEDULE
FOR ENTRAINMENT AND IMPINGEMENT

Month	Day	Julian Date	Month	Day	Julian Date
March	16	075	(May)	31	151
	20	079	June	4	155
	24	083		8	159
	28	087		12	163
April	1	091		16	167
	5	095		23	174
	9	099		30	181
	13	103	July	7	188
	17	107		14	195
	21	111		21	202
	25	115		28	209
	29	119	Aug.	4	216
May	3	123		11	223
	7	127		18	230
	11	131		25	237
	15	135	Sept.	1	244
	19*	139		8*	251
	23	143		15*	258
	27	147			

*No Larvae tows taken

report is from the March to September time span when work was done on both aspects simultaneously. Entrainment and larval tows were done for a six-month period to include spawning periods of all species of fish inhabiting the river.

Fish larvae samples for entrainment studies were collected in front of the traveling screens at both power plants. At each power station two Kenco, model number 139, submersible pumps were situated so that one pump sampled the water near the surface, while the other pump sampled water near the bottom. All pumps ran simultaneously for a 24-hour period, which was then subdivided into two 12-hour periods representing night and day collection intervals. The effluent from the pumps was passed through 50 cm diameter, 500 micron mesh plankton nets. Sample contents were preserved for each 12-hour interval. During each collection period the pumps were tested to determine the volume of water passing through. This was done by filling a 32.8-gallon drum five times for each pump and using a stopwatch to determine mean filling time. Approximately 233 cubic meters of water were filtered in a 12-hour period.

River samples were collected using a 17-foot fiberglass trihull boat. The boat was equipped with a 115-horsepower Mercury outboard engine. A backup boat--a 17-foot trihull with a 100-horsepower Johnson outboard--was used from approximately mid-May to mid-June.

River sampling was done using a triplicate surface and near bottom tows at all six stations. A 75 cm diameter, 500 micron mesh oceanographic plankton net was used for the tows. Each tow was three minutes in length, and towing speed was approximately 2-4 knots. Volume of water filtered in a three-minute tow was approximately 72-75 cubic meters. The boat was steered to keep the net at an angle to sample water undisturbed by the action of the boat. However, problems arose sometimes due to the lightness of the boat and how it performed when winds or currents became somewhat strong. To determine the volume of water filtered in each tow, the net was fitted with a General Oceanics flowmeter. The flowmeter was calibrated monthly by towing over a known distance 10 times and then finding a mean number of revolutions.

Upon completion of larval fish tows the net was pulled in and rinsed down. The sample contents taken were then transferred into a prelabeled plastic jar and preserved in a 5-10 percent formalin solution.

The physical parameters measured at each river station were temperature, conductivity and current direction. These parameters were measured at three-foot intervals from surface to bottom. Equipment used was a Beckman, model RB3-3341, temperature/conductivity meter and a Hydro products, model 65, current meter. Anchors were set off both the bow and the stern of the boat to limit movements while taking current measurements.

Temperature and conductivity readings were also taken in front of designated traveling screens of both power stations at one-foot intervals during each collection period. Current readings were taken quarterly in front of these screens throughout the entire year-long 316(b) study.

Impingement studies were taken for a 24-hour period on the same days entrainment work was performed. Like the pump samples, the collection period was divided into two 12-hour intervals representing night and day. Collection of impinged fish was made by placing a 3/8-inch wire mesh basket in the common sluiceway through which effluent of all screen washing passes.

All fish collected were then sorted and identified to species. Fish were then weighed to the nearest 0.1 gram and measured to the nearest millimeter. Standard lengths were used for all impingement length measurements. Due to large catches of some of the more common species such as gizzard shad and emerald shiner subsampling was used periodically (Herdendorf, 1976). However, this procedure was rarely required for walleye and never required for sauger. Perch were subsampled periodically throughout the project.

River and Bay Dredging Project. Collection procedures for the upstream portion of this study were essentially the same as for the 316(b) project. The same boats and nets were used. Collections in the river were made approximately once every four days (Table 4). Upstream stations D-1 to D-4 were sampled with only one surface and one near-bottom tow at each station. No

TABLE 4

SAMPLING SCHEDULE OF LARVAE COLLECTION
FOR DREDGING STUDY

RIVER		
Month	Day	Julian Date
March	31	090
April	2	092
	6	096
	10	100
	13	103
	18	108
	22	112
	26	116
May	1	121
	5	125
	9	129
	11	131
	16	136
	25	145
	28	148
June	3	154
	7	158
	11	162
	15	166

BAY			
Month	Day	Julian Date	No. of Station
April	13	103	5
	21	111	6
	30	120	6
May	12	132	2
June	12	163	7
	21	172	7
July	5	183	7

replicate sampling was conducted. Physical parameters measured at these stations were conductivity and temperature, which were measured at the surface only.

The Maumee Bay sampling consisted of five replicate oblique tows at each station. Seven stations were sampled in the bay, approximately once every 10 days, depending on weather conditions (Table 4). Sampling was performed at night to eliminate net avoidance. Due to the turbid nature of the river and safety factors, this procedure was deemed unnecessary for river sampling stations. Tows were made in the bay using a 21-foot Boston Whaler with twin 70-horsepower Johnson outboard engines. A 75 cm diameter, 760 micron plankton net was used; this slightly larger mesh size was used due to the increased abundance of phytoplankton and zooplankton found in the bay which would foul the net.

Laboratory Procedures

After being taken and preserved in formalin, the field samples were sorted and identified to the species level wherever possible. Larvae were identified using the keys written by Nelson and Cole (1975), Hogue et al. (1976) and Norden (unpublished). Other literature which was very helpful was Fish (1932), Mansueti and Hardy (1967), Norden (1961), Nelson (1968) and The Great Lakes Fish Egg and Larvae Identification Guide, edited by John Boreman (1976).

A binocular microscope was used for identification, and larvae were measured to the nearest 0.5 mm when establishing length ranges. All larvae measurements were expressed in total lengths. Developmental stages of the larvae were classified in the following manner:

1. Prolarvae--larvae still having yolk;
2. Postlarvae--larvae following the time absorption of yolk but before full development of adult characteristics;
3. Juvenile--young stage immediately following acquisition of adult characteristics.

Larvae were then preserved in a mixture of glycerin and 70 percent ethanol and are currently stored in The Ohio State University's research facilities.

During the project no attempt was made to differentiate between larval gizzard shad and alewife, carp and goldfish or walleye and sauger or their respective hybrids. Species of the family Percidae were relatively easy to distinguish from other families due to key characteristics like a very short intestine, anteriorly placed oil globule and preanal length nearly equal to postanal length. Some problems were experienced at first separating larval walleye and perch; however, the paper by Norden (1961) was very helpful, and the problem was eliminated. After studying the paper by Nelson (1968) and conferring with Roger Thoma (former ichthyoplankton specialist for N.U.S. Corporation), the author believes that some of the larvae identified as walleye were in fact saugers. This situation is addressed in the discussion portion of this study.

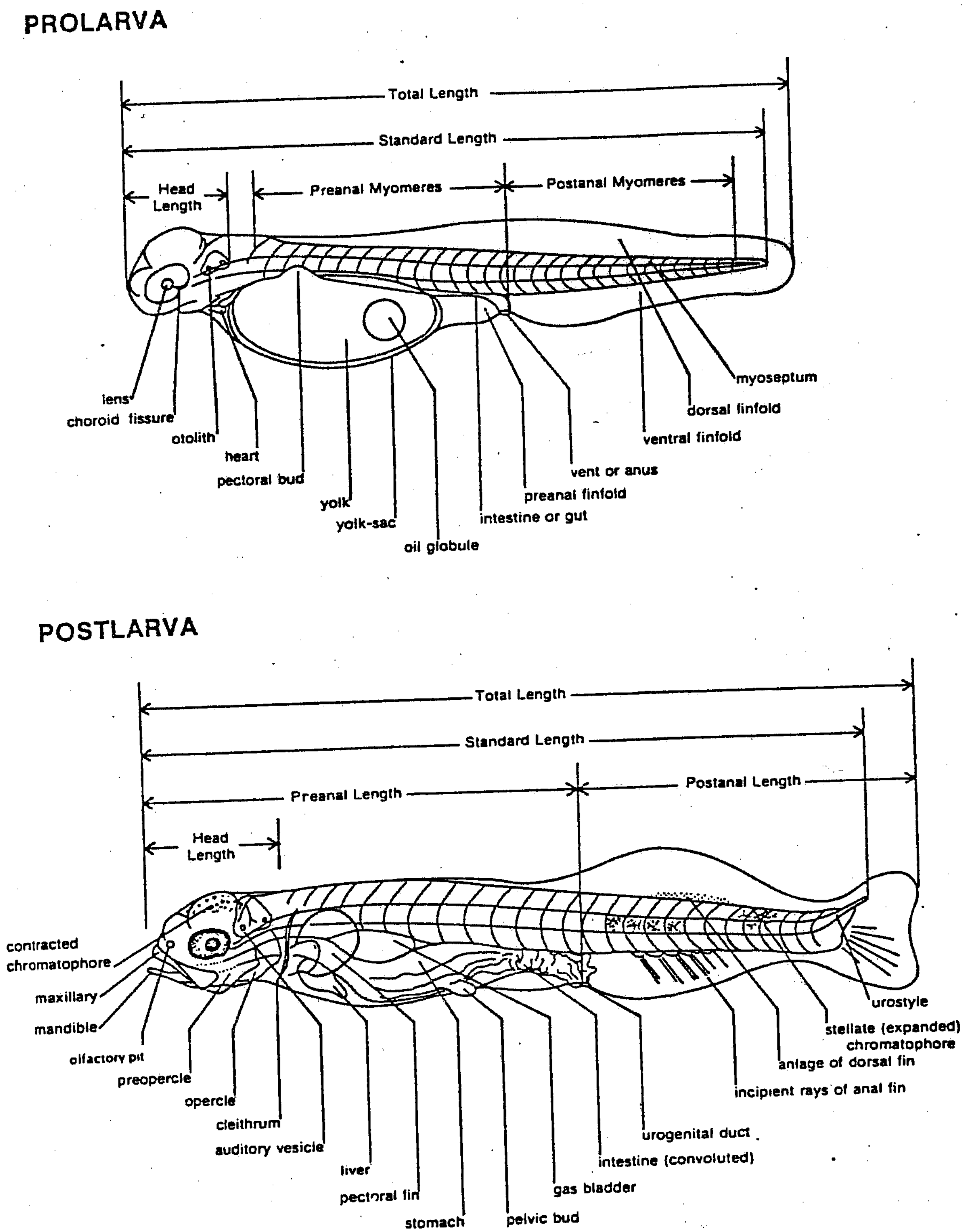


Figure 5. Developmental stages of larval fish (Mansueti et al., 1967).

TABLE 5

CHARACTERISTICS AIDING IN IDENTIFICATION
AND DIFFERENTIATION OF WALLEYE, SAUGER AND PERCH

Species	Size Range (mm)	Pigmentation	Myomere Counts	Special Features
Prolarva				
Walleye	7.0-12.5	Stellate chromatophores on the yolk sac. Have 2 to 4 chromatophores present on the intestine between the anus and the yolk sac.	Preanal, 16-24 (19) Postanal, 22-29 (26)	Larger than perch or sauger during this stage. Yolk sac less oval than sauger. Most pigmentation.
Sauger	4.5-10.00	Similar to walleye, somewhat fewer chromatophores.	Preanal, 16-21 (19) Postanal, 21-26 (24)	Have somewhat deeper bodies than walleye, very hard to differentiate from walleye.
Perch	5.5-7.0	Pigmentation sparse. A small chromatophore at the ventral edge of each postanal myomere.	Preanal, 17-22 (18) Postanal, 17-20 (18)	Smaller than walleye during this stage.

TABLE 5, cont.

CHARACTERISTICS AIDING IN IDENTIFICATION
AND DIFFERENTITATION OF WALLEYE, SAUGER AND PERCH

Species	Size Range (mm)	Pigmentation	Myomere Counts	Special Features
Postlarva				
Walleye	12-30.0	Chromatophores abundant on top of head, cheeks and jaws.	Preanal, 21-25 (23) Postanal, 22-27 (24)	Teeth visible.
Sauger	11-30.0	Similar to the walleye.	Preanal, 19-22 (21) Postanal, 21-24 (23)	Teeth visible, relative head length greater than walleye.
Perch	7-20.0	Few chromatophores on head, cheek or jaws.	Preanal, 17-22 (19) Postanal, 16-21 (19)	Lower jaw articulation different from walleye and sauger.

When the numbers of larvae became excessively high, subsampling was performed. However, larval abundance for walleye and most other early spring spawners was never so high that the subsampler was needed. Perch larvae were only very rarely subsampled.

Problems did arise sometimes with the pump samples as they would occasionally damage larvae beyond identifiable conditions. These fish were then grouped into the unknown category with other unidentifiable individuals or species.

Sources of Field Error

Variability in sampling conditions and sample data can be serious problems when conducting zooplankton or ichthyoplankton studies. Wiebe (1968) lists three distinct sources of error when sampling plankton: 1) active avoidance of the net, 2) mechanical problems inherent with sampling gear and 3) nonrandom spatial distribution of the organisms.

Active avoidance of the net should not have been a major problem here until fish reached at least the postlarval stage. This is mainly due to the turbidity of the water and also to the poor swimming ability of the young fish. The water was extremely turbid in the spring as evidenced by the fact that adult walleye, smelt, gizzard shad and long-nosed gar were taken while doing larval tows. In areas with clearer water, night sampling is recommended (Sameoto, 1975).

Error caused by sampling gear can happen in several different ways. Factors that affect the efficiency of the net include all the structures which provide cues enabling avoidance (McGovern and Fraundorf, 1966). In the present study this would include the towline, cable clamps and the flowmeter preceding the net through the water. Also errors may be caused by zooplankton or algae clogging the net which reduces the filtration efficiency; and, as mentioned previously, the towing speed of the boat could not always be kept constant due to winds or currents. Previous studies show that relatively small changes in net speed through the water result in changes in catch composition (Aron and Collard, 1969).

Error caused by nonrandom distribution or patchiness of the organisms involved is a problem that little, if anything, can be done about at the present time. The effects of patchiness on plankton sampling are still not completely understood, although it is of critical importance (Aron and Collard, 1969). Replicate sampling can help to reduce the effect of nonrandom distribution (McGovern and Fraundorf, 1966). Often many replicate tows must be taken to provide substantial results, and the turbulence caused by the boat engine and net can decrease the accuracy of replicate samples taken at a certain station (Brown and Langford, 1975).

Larval fish tows are selective in that they sample species inhabiting the more open mid-water areas. They do no accurately represent species which inhabit very shallow or very deep zones. Also species such as channel catfish, which receive some parental care, or species which hide between rocks or other structures are

are not sampled successfully. Larvae lying on the bottom are also difficult to sample due to irregularities in the bottom which snag or foul the net. When sampling or conducting a fish larvae project, these problems and inconsistencies must always be considered. The factors that lead to net avoidance lead to underestimates of populations, and the effects of patchiness can lead to either over- or underestimates of abundance.

Statistical Analysis

After the larvae were identified and counted, the information was keypunched, placed on magnetic tape and then analyzed using an IBM model 370-165 computer at The Ohio State University. Larvae and eggs were expressed as numbers per 100 cubic meters (m^3) of water. All surface and bottom tows at each station for each date were averaged and multiplied by the corresponding flowmeter reading and constant to obtain these densities. With the help of Mr. Robert Lahr (The Ohio State University, Department of Statistics) the data were analyzed. Tests were run using the Statistical Analysis System (SAS) program (Burr et al., 1976). This program supplied estimates and subsequent plots of these estimates.

Total abundance estimates were made by multiplying the average densities of all stations in a certain sector, on a particular date, by the estimated volume of that sector. Estimated volumes were taken or calculated from information provided by Herdendorf et al. (1977) and Snyder (1978). The areas of these sectors can be seen in Figure 4.

A Wilcoxon signed rank test was used to test for significant distributional tendencies between surface and bottom tows for walleye and perch taken in the river. This is a nonparametric test used to test the hypothesis that observations have come from symmetrical populations with a common specified median (Dixon and Massey, 1969). Sign tests are often used to compare two distributions or treatments in experimental investigations. Differences in surface/bottom concentrations were tested for both species in the four different sectors. Tests were also run on surface/bottom concentrations for larval perch and juvenile perch. Only larval walleye were taken, so this part of the test was not applicable in this case.

RESULTS

During the 1977 sampling a total of 20 species of larval fishes were taken in the Maumee River and Bay. Common species such as gizzard shad, white bass, freshwater drum and yellow perch were collected in prolarval, postlarval and juvenile stages of development. Walleye were taken primarily in the prolarval stage; some postlarval walleye were taken at the Bay Shore (sector 3) and bay (sector 4) stations. Seven juvenile walleye, two juvenile sauger and four prolarval sauger were taken at bay stations also.

A total of 974 walleye and 3,145 perch were taken by ichthyoplankton sampling during these studies in the river and bay. All these individuals were captured between the dates of 17 April and 7 July 1977.

Sector Designation

For more accurate analysis, the estuarine portion of the river sampled was divided into three sectors. Maumee Bay was treated as a separate sector.

Sector 1. This area represents the White Brothers dredging study. Stations D-4, D-3, D-2 and D-1 are included. This is the farthest upstream portion sampled, and the estimated volume of this sector is 1.3210×10^7 cubic meters (m^3). The boundaries of this sector are Corbutt Island to the High Level Bridge in Toledo.

Sector 2. This sector represents the area sampled around the Acme Power Plant. Stations 1, 2 and 3 were used. The estimated volume of this sector is 1.5476×10^7 m^3. The boundaries are the High Level Bridge to the Norfolk and Western Railroad Bridge in Toledo.

Sector 3. This sector represents the area sampled around the Bay Shore Power Plant. Stations 4, 5 and 6 are used here. The estimated volume of this sector is 1.3619×10^7 m^3, and its boundaries are the Norfolk and Western Railroad Bridge to the mouth of the bay.

Sector 4. This sector represents all the stations of the bay dredging study, which includes stations 7, 8, 9, 10, 11, 12 and 13. The volume of the bay is estimated to be approximately 1.500×10^8 m^3.

Species Abundance

The density estimates of larvae per 100 m^3 were calculated for each species, station and date. Only dates where either walleye or perch were taken are represented. The density estimates can be found in Appendix A.

These density estimates are also represented graphically. The graphs were drawn from computer printouts, and to be compared properly it must be noted that numbers on the vertical axis change between different stations. These results can be seen in Appendix C.

The average species density for each sector and date are plotted together graphically for comparisons in Figures 6 and 7.

The total number of estimates for each sector, species and date which, again, were calculated by multiplying mean density by volume are listed in Tables 6-8.

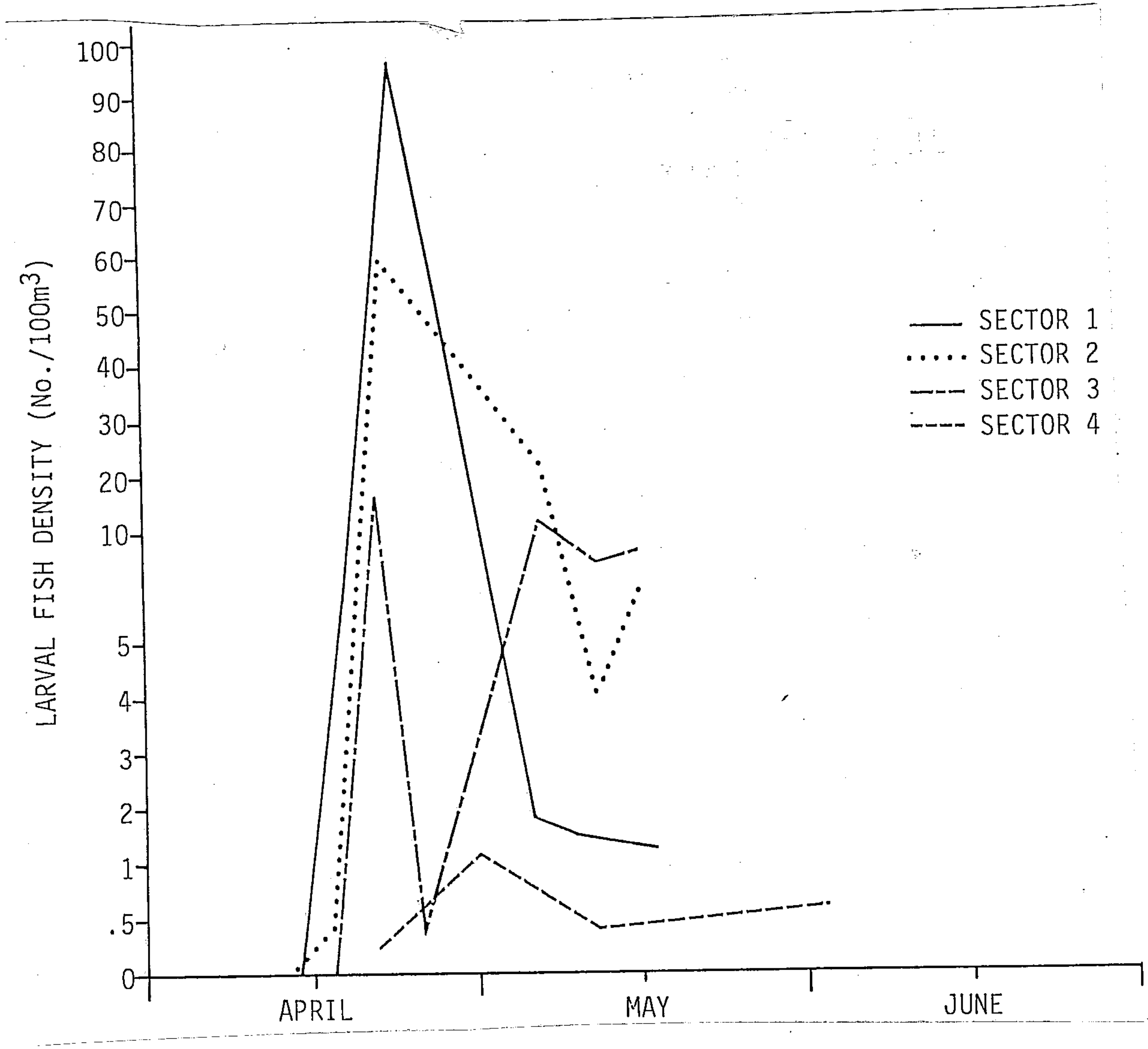


Figure 6. Mean density of walleye for each sector.

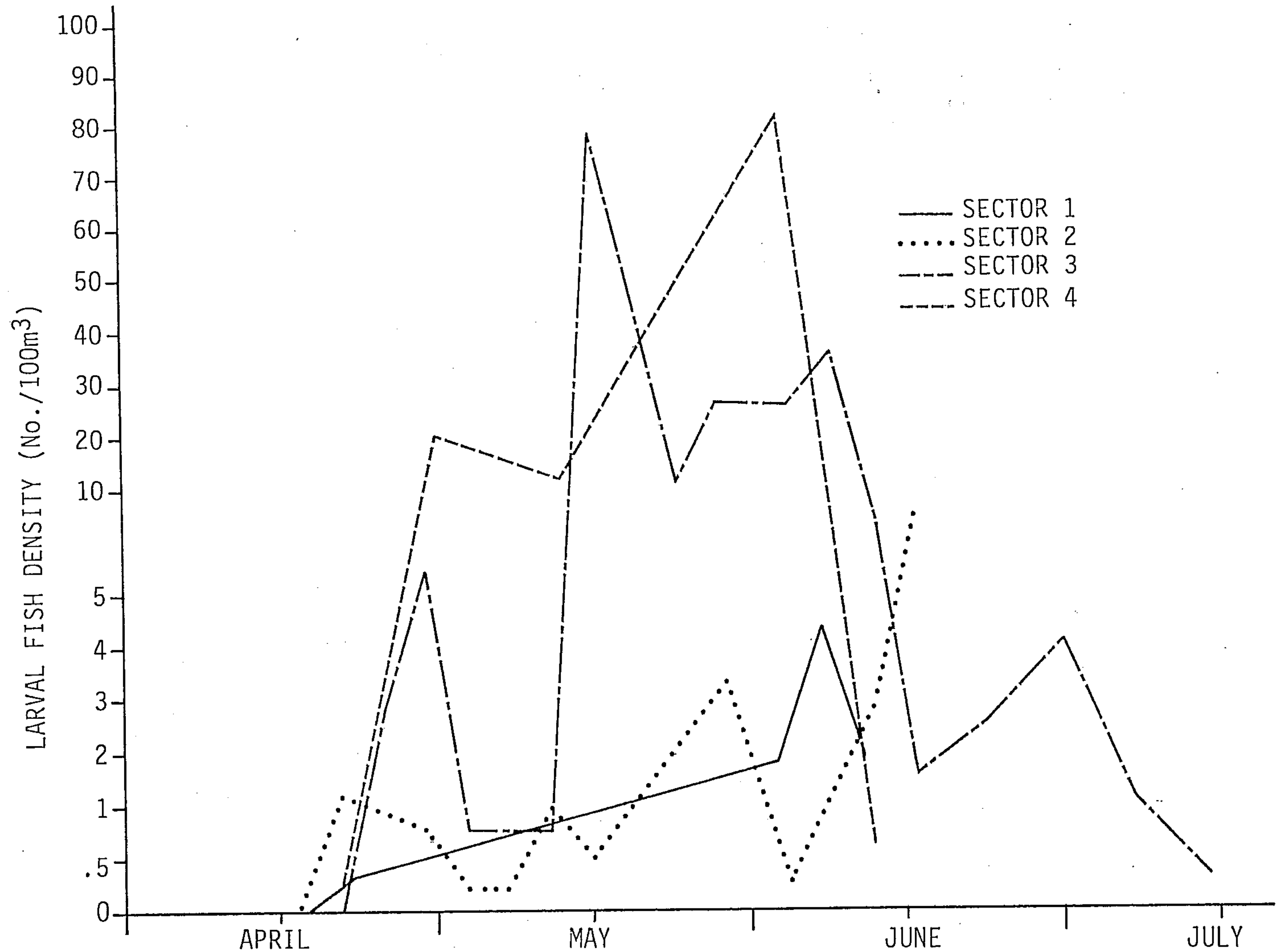


Figure 7. Mean density of perch for each sector.

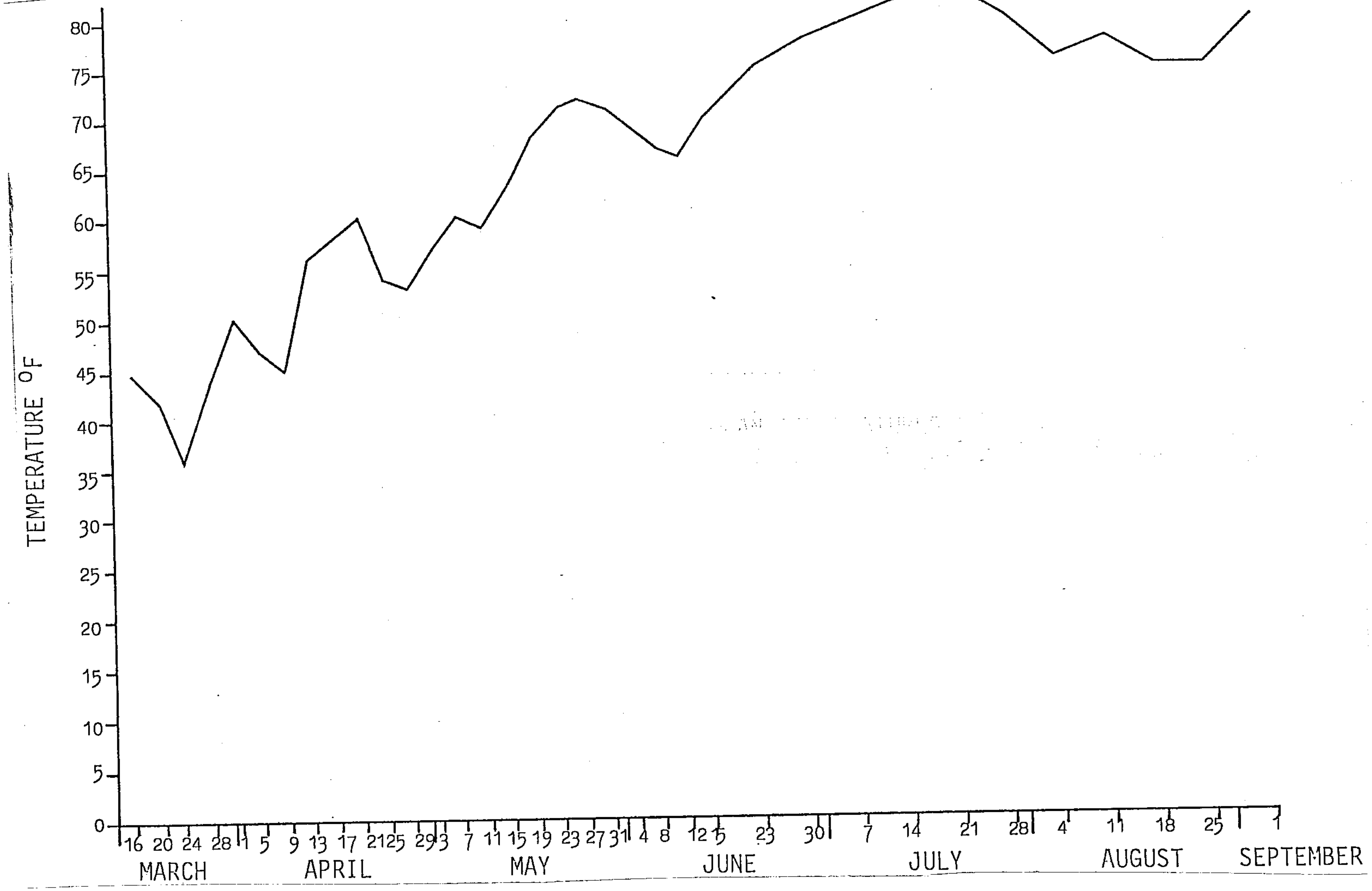


Figure 8. Mean temperatures for the Maumee River in 1977
(March 17 - September 1).

TABLE 6

ESTIMATED TOTAL NUMBERS OF
LARVAL WALLEYE AND PERCH AT SECTOR 1

Species	Date 4/13	4/18	4/22	4/26	5/1
Walleye	-	8.9×10^5	1.3×10^7	-	-
Perch	-	-	3.8×10^4	-	-

Species	Date 5/5	5/9	5/11	5/16	5/25
Walleye	2.3×10^5	2.1×10^5	-	1.7×10^5	-
Perch	-	-	-	-	-

Species	Date 5/28	6/3	6/7	6/11	6/15
Walleye	-	-	-	-	-
Perch	-	2.4×10^5	5.7×10^5	2.4×10^5	-

TABLE 7

TOTAL ESTIMATED NUMBER OF
WALLEYE AND PERCH LARVAE AT SECTORS 2 AND 3

(sector 2)

Species	Date 4/13	4/17	4/21	4/25	4/29
Walleye	-	2.3×10^4	3.1×10^6	-	-
Perch	-	-	3.9×10^4	-	6.1×10^4

Species	Date 5/3	5/7	5/11	5/15	5/23
Walleye	-	1.2×10^6	2.1×10^5	3.7×10^5	-
Perch	1.1×10^4	1.1×10^4	4.9×10^4	2.6×10^4	-

TABLE 7, cont.

TOTAL ESTIMATED NUMBER OF
WALLEYE AND PERCH LARVAE AT SECTOR 2 AND 3

(sector 2)

Species	Date 5/27	5/31	6/4	6/8	6/12
Walleye	-	-	-	-	-
Perch	1.7×10^5	-	1.3×10^4	5.3×10^4	1.4×10^5

Species	Date 6/16	6/23	6/30	7/7
Walleye	-	-	-	-
Perch	7.7×10^5	-	-	-

TABLE 7, cont.

TOTAL ESTIMATED NUMBER OF
WALLEYE AND PERCH LARVAE AT SECTOR 2 AND 3

(sector 3)

Species	Date 4/13	4/17	4/21	4/25	4/29
Walleye	-	-	7.3×10^5	1.8×10^4	-
Perch	-	-	-	1.3×10^5	2.8×10^5

Species	Date 5/3	5/7	5/11	5/15	5/23
Walleye	-	5.7×10^5	3.7×10^5	4.1×10^5	-
Perch	3.3×10^4	-	3.4×10^4	3.5×10^6	5.1×10^5

TABLE 7, cont.

TOTAL ESTIMATED NUMBER OF
WALLEYE AND PERCH LARVAE AT SECTORS 2 AND 3

(sector 3)

Species	Date 5/27	5/31	6/4	6/8	6/12
Walleye	-	-	-	-	-
Perch	1.2×10^6	1.2×10^6	1.4×10^6	1.7×10^6	3.7×10^5

Species	Date 6/16	6/23	6/30	7/7
Walleye	-	-	-	-
Perch	7.0×10^4	1.2×10^5	1.0×10^5	9.6×10^4

TABLE 8

ESTIMATED TOTAL NUMBERS OF
LARVAL WALLEYE, SAUGER, AND PERCH AT SECTOR 4

Species	Date 4/21	4/30	5/12	6/3	6/12	6/21
Walleye	2.0×10^5	1.7×10^6	7.0×10^5	8.0×10^5	-	-
Sauger	-	-	1.0×10^6	2.0×10^5	-	-
Perch	4.0×10^5	3.1×10^7	1.6×10^7	1.2×10^8	5.5×10^6	1.0×10^5

Raw data used to make all calculations and tests can be found in appendix B.

Entrainment and Impingement at the Power Plants

Entrainment estimates for the Maumee River plants were determined by Reutter et al. (1978) by averaging the surface and bottom pump samples and then using the daily pumping rates to calculate densities per 100 m^3 of water at the intake area. This number was then multiplied by the volume of water flowing through the plant during that sampling period to obtain an estimate. Mean larval concentrations from several sampling periods were then averaged and used to estimate entrainment values on nonsampling days based on the flow through the plant on that particular day.

The estimates at the Acme plant indicate that approximately 79,493,000 larval fishes and 178,048,000 fish eggs were entrained during the study (15 March through 15 September). Of this total, an estimated 195,311 walleye larvae were entrained. Table 9 shows when entrainment and capture in the river of these species occurred at the Acme station.

The estimates at the Bay Shore plant indicate that approximately 284,718,000 larval fishes and 426,150,000 fish eggs were entrained here during the study (15 March through 15 September). Of this total, an estimated 441,614 walleye larvae and 2,426,431 perch larvae were entrained. Table 10 shows when entrainment and capture in the river of these species occurred at the Bay Shore sampling stations.

TABLE 9

OCCURRENCE OF LARVAE IN ENTRAINMENT AND RIVER SAMPLES
IN THE VICINITY OF THE ACME PLANT

Collection Period	Conductivity	Inferred Water Mass		Intake	River	Species
		River	Bay			
37	543	X		X	X	Walleye
38	550	X		X	X	Walleye
39	431*		X	X		Walleye[2]
40	457*		X		X	Perch[1]
41	506	X			X	Perch[1]
42	460	X		X	X	Walleye, Perch
43	508	X		X	X	Walleye, Perch[1]
44	532	X			X	Walleye[1], Perch[1]
45	375		X			No Samples Taken, Boat Trouble
47	443		X		X	Perch[1]
49	442		X		X	Perch[1]
50	444		X		X	Perch[1]
51	457	X			X	Perch[1]
52	428		X		X	Perch[1]
55	390		X		X	Perch[1]

1 Found in River Samples only
2 Found in Intake Samples only
* Low conductance may be result of heavy rainfall

TABLE 10

OCCURRENCE OF LARVAE IN ENTRAINMENT AND RIVER SAMPLES IN THE VICINITY OF THE BAYSHORE PLANT

Collection Period	Conductivity	Inferred Water Mass		Intake	River	Species
		River	Bay			
38	508	X		X	X	Walleye
39	397*		X	X	X	Walleye, Perch
40	443*		X	X	X	Walleye[2], Perch[1]
41	521	X			X	Perch[1]
42	464	X			X	Walleye[1]
43	500	X		X	X	Walleye, Perch[1]
44	532	X		X	X	Walleye, Perch
45	658	X				No Samples Taken, Boat Trouble
46	375		X	X	X	Perch
47	377		X	X	X	Perch
48	370		X		X	Perch[1]
49	380		X	X	X	Perch
50	380		X	X	X	Perch
51	385		X		X	Perch[1]
52	427	X				Perch[1]
53	350		X		X	Perch[1]
54	313		X		X	Perch[1]
55	362		X		X	Perch[1]
56	378		X		X	Perch[1]
57	350		X	X	X	Perch[1]

1 Found in River Samples only
2 Found in Intake Samples only
* Low conductance may be due to heavy rainfall

Impingement estimates were also determined by Reutter et al. (1978). Estimated numbers of individuals were calculated by dividing the total weight of each species (or size class) by the mean weight as determined by subsampling a minimum of 50 individuals. Again, several sampling periods were averaged and used to estimate impingement values on nonsampling days based on the flow through the plant on those days.

The impingement estimates for the Acme plant from 1 September 1976 to 15 September 1977 was a total of 5,729,064 fish. Of this total 454 walleye, 15 sauger and 6,063 perch were estimated to have been impinged.

The impingement estimates for the Bay Shore plant over the same time period was approximately 17,810,633 fish. Of this total 12,187 walleye, 194 sauger and 427,260 perch were believed to have been impinged.

Species Distribution

Results of the Wilcoxon signed rank test can be seen in Table 11, where values calculated led to acception or rejection of the hypothesis of equal distribution. The objectives of this test were to predict if there were any significant differences in surface/bottom distributional tendencies of walleye and perch taken while sampling. Tests were run for each species at Sectors 1, 2 and 3. No tests were run for sector 4 since oblique tows were used here instead of surface and bottom tows. In addition, tests were run on both larval and juvenile perch at sectors 2 and 3. Results for perch at sector 1 were not considered due to small sample size. Tests were significant at the 95 percent level of confidence.

TABLE 11

RESULTS OF WILCOXON SIGNED RANK TEST

H_0: Distributions of walleye/perch at a certain sector do not differ for the surface and bottom.

H_1: Distributions do differ.

Species	Sector	N	T*	P< T*	Conclusion
Walleye	1	15	0.74	.459	Accept
Walleye	2	33	-0.063	.952	Accept
Perch (larval)	2	17	-0.32	.749	Accept
Perch (juvenile)	2	12	.32	.749	Accept
Walleye	3	23	3.32	.001	Reject
Perch (larval)	3	29	- .59	.555	Accept
Perch (juvenile)	3	43	3.02	.003	Reject

*T = tabled sum of the positive ranks; P = tabled probabilities (both with different N values).

DISCUSSION

This study was the combination of two projects--a 316(b) study on two power plants in the Maumee River and a study of the impacts of commercial sand and gravel dredging on ichthyoplankton in the Maumee River and Bay. A total of 19 species of larval fish were taken over a six-month period from 15 March to 15 September 1977. Three species of the family Percidae were examined closely--the walleye, sauger and yellow perch. The purposes of this study were: 1) to identify when and where the species prefer to spawn, 2) to determine if the 1977 hatch was successful, 3) to estimate abundance and distribution of larvae and 4) to attempt to examine water movements, entrainment and impingement aspects at the power plants.

Some problems were encountered throughout the study and subsequent analysis. Again, there are certain problems inherent with ichthyoplankton studies, such as variability of sampling conditions, active avoidance of the net, mechanical problems with sampling gear and nonrandom spatial distribution of the larvae. Problems also arose in the data analysis in attempting to compare the different projects due to somewhat different sampling techniques in the three areas examined. It must be recognized that sampling in this study and other fish larvae studies may not adequately sample all larvae inhabiting the area involved.

Estimates of abundance were made by multiplying mean densities by volumes of selected sectors of the estuary. Each segment was represented by at least three stations. The mean densities were determined by averaging all surface, bottom or oblique tows for each station, on each date. These averages were then multiplied by flowmeter readings and a constant to express larval density per 100 m^3 of water. It is the author's opinion that these calculations of mean densities are more representative of actual concentrations than are total estimates of abundance over a larger area. Both these estimates have obvious faults; for example, the assumption of a uniform random distribution throughout the water column. However, this is the state of the art at the present time, and to overcome these factors would be unrealistically expensive and, in many cases, impossible with present technology. The intensive study of larval fish is a new science; more study and improved sampling techniques are necessary in the future.

Power plants can affect fish populations in several ways. The greatest impacts are associated with entrainment and impingement. In addition to these obvious impacts are other factors such as effects on temperature regimes (which may enhance or inhibit spawning of some species) and primary productivity (chlorine added to cooling water for defouling purposes which can inhibit primary productivity) (Nelson and Cole, 1975).

Also, when working with larval fish studies, one must take into account natural mortality factors. Mortality is extremely high during the egg through postlarval stage of young fish. Nature balances this high natural mortality by the high fecundity rates of many species; but it must be remembered that only a very small percentage of the larvae taken or estimated to exist will ever contribute to future adult brood stocks.

Walleye

The estimated adult walleye brood stock utilizing the Maumee River for spawning in 1977 was 540,800 fish (Scholl, 1978). This is believed to be the largest stock in recent years. These walleye are sport-fished heavily during spawning runs, but it has been reported that this has no effect on the success of the hatch (Priegel, 1970). However, all the impacts of this pressure have not been determined. Stricter laws, such as the use of lures with single hooks only (to prevent snagging) and a ban on night fishing in the riffle areas during the walleye spawning period, have been enacted by the Ohio Department of Natural Resources in recent years and should help protect the brood stock somewhat.

The weather conditions in the spring of 1977 were very good, with warm mild temperatures. This type of weather usually indicates that the walleye would have a successful hatch. This was the case, as both our larval estimates and the Division of Wildlife's young-of-the-year population estimates indicate the hatch was excellent. In fact, the Division of Wildlife rates 1977's hatch as "extreme high," which means that the young-of-the-year catch success per hour was the best of any year since the study began in 1969 (Scholl, 1978).

Field sampling in the river began 31 days before any walleye larvae were taken, so it is assumed that the entire period of hatching and subsequent movement down the river was monitored. Larvae were captured during two time spans--17 April to 29 April and 5 May to 15 May.

The first period (17-29 April) yielded the largest estimates in the upstream sectors (1 and 2). In sector 1 maximum density occurred on 22 April, when average abundance was estimated to be 98.75 walleye larvae per 100 m^3. When multiplied by the estimated volume of this segment, a total number estimate of 1.3 x 10^7 larvae were passing through this sector on 22 April. A maximum average density of 58.41 larvae per 100 m^3 occurred on 21 April at the Acme stations (sector 2). Multiplied by the estimated volume of this segment, a total of 3.1 x 10^6 larvae were inhabiting the area on this date.

In the downstream sector 3 (Bay Shore), maximum density was 15.98 walleye larvae per 100 m^3 on 22 April. This yields a total estimate of 7.3 x 10^6 in this segment at that time. These decreasing densities show the downstream movement and subsequent dispersion and mortality of the larvae as they are carried toward the lake.

In a study done in 1976 in the Maumee River, maximum walleye larval density was found to be 3 per 100 m^3 at estuary stations

(Snyder, 1978). However, the weather in the spring of 1976 was cold with numerous temperature reversals. The resulting walleye hatch was very poor (Scholl, 1978). Snyder's results compared with those of this study indicate the differences in year class success between 1976 and 1977. However, it must be pointed out that part of this large difference may be due to a more intensive sampling procedure in 1977.

The second period in 1977 (5-15 May) did not yield estimates as high, with maximum densities being 1.56 larvae per 100 m^3 in sector 1 (5 May), 22.41 per 100 m^3 in sector 2 (7 May) and 12.60 per 100 m^3 in sector 3 (7 May). Larger total lengths and reduced yolk-sac sizes indicated that not all of these larvae were spawned in the riffle area, but in some areas further upstream. Using these same parameters, it is believed that all larvae from the first time period (17-29 April) were from the riffle areas. There is also a good chance that some of the larvae from the second time period may have been sauger or walleye-sauger hybrids; these factors are discussed in more detail in the following section.

Maximum larval abundance for walleye in Maumee Bay (sector 4) occurred on 30 April, when mean density was 1.17 fish per 100 m^3. Total number estimated in the bay for this date was 1.7×10^6. Again, using total length and yolk-sac size as parameters, it is believed that these fish were spawned in this area. This shows that some walleye spawning activity is occurring in the bay, but much greater numbers of larvae are produced in the river. However, this is significant in that with the construction of the dike disposal area and the existing spoil ridges, suitable walleye spawning habitat is thought to exist. However, with the tremendous silt load being discharged into Maumee Bay the likelihood of high spawning success for walleye is low. This study does show that some walleye larvae are being produced in the bay; however, no estimation can be made of the number of adults utilizing this area and subsequent hatching success. There is a very good chance that many of the eggs laid in this area never hatch due to siltation.

The results of the surface/bottom distribution tests showed that there was no significant difference for larval walleyes in sectors 1 and 2. However, the test for sector 3 did show a significant difference with walleyes apparently preferring near bottom areas. This may be due to the fact that walleyes from this area, for the most part, were more developed and possessed greater movement capabilities, thus making it possible to inhabit different levels of the water column and avoiding possible predation by inhabiting near bottom areas where the water is less clear and protective structures can be found.

Sauger

No attempt was made by the author to differentiate between larval walleye or sauger due to their similarities. However, it is believed after consultation and reexamination of some of the samples that some of the larvae may, in fact, have been sauger. Snyder (1978) found a single larvae which was taken from the riffle area in the Maumee River that he determined was a sauger. Roger Thoma, who identified the Maumee Bay larvae used in this report, identified 4 prolarval saugers taken on 12 May at station 8 and 2 juvenile saugers taken at station 10 on 3 June.

Some of the larvae taken in the river on 5 May through 15 May are believed to have been sauger. The fact leading to this assumption is mainly the small size of some of the larvae (five to six mm), which is smaller than any walleye larvae reported by Nelson (1968). Nelson reports newly-hatched walleye ranged in length from 6.13 to 6.88 mm, while saugers ranged from 4.62 to 5.09 mm. These small larvae were differentiated from perch larvae my myromere counts. Since sauger usually spawn near the latter part of the walleye spawning period, the time period also lends credence to this possibility. Thoma also uses head size to distinguish between larval walleye and sauger, but this method did not prove successful for the author. It must be pointed out that not all the larvae taken during the 7 May to 15 May time period are believed to be sauger. The majority are walleyes, with a rough estimate of from 10 to 15 percent sauger.

There is also a very good chance that many of the larvae taken in this period are hybrids between walleye and sauger. These species hybridize frequently, with the offspring usually inheriting most characteristics from the female parent (Nelson, 1968). It has been found by the Ohio Division of Wildlife that mature saugers are often found on the spawning areas with walleyes in the Maumee and Sandusky Rivers; however, sauger are much less abundant during the peak walleye run in March and April (Rawson and Scholl, 1978). It would thus appear that the sauger reintroduction program has been at least partially successful and that some reproduction is occurring.

Plans by the Ohio Department of Natural Resources are to continue the sauger reintroduction program, and further studies of reproductive success will be made (Scholl, personal communication).

Yellow Perch

The yellow perch in Lake Erie displays a somewhat different reproductive strategy than the walleye or sauger. The results of this study show that most perch spawning is occurring in the bay area. However, the study also shows that there is a small or reminant population inhabiting the mid- and upper-estuary portion of the river and that there is some reproduction occurring here. But the vast majority of perch larvae produced are believed to have been spawned in the bay by adults entering this area from regions of deeper water in the lake. Upon hatching, larvae are moved around considerably by the water movements in the area.

Prolarval yellow perch are very rare in sector 1, being found on only a single date--22 April. On this date there was an average of 0.29 perch larvae per 100 m^3 and a total estimate of 3.8×10^4 for this area. There were other perch taken in this area from 6 June to 11 June, but these were juveniles all at least 21 mm in length.

At the Acme stations (sector 2) larval perch reached a maximum density of 1.19 per 100 m^3 on 19 April. This yields a total estimate of 6.1 x 10^4 for this date. Larger numbers of perch were taken from 4 June to 16 June, but again these were juveniles capable of swimming substantial distances. The results from the upstream sectors, 1 and 2, show that there is some perch spawning occurring in this portion of the estuary, but relatively small numbers are being produced. Snyder (1978), in his studies in the springs of 1975 and 1976, found no perch larvae at any upstream stations in the Maumee River. So again it appears that even though perch are a common species in Lake Erie, they do not use the Maumee River to a significant degree for spawning purposes. However, with the capture of the juvenile fish, it appears to be used as a nursery area to some degree.

At the Bay Shore stations (sector 3) perch density was greatest on 15 May when 78.13 were estimated per 100 m^3. This yields a total number of 3.5 x 10^6 for sector 3 on this date. Many of these larvae may have been transported by water movements into this area from the bay. This idea is examined further in a later section.

In the Maumee Bay maximum larval densities were recorded on 30 April, when 20.01 were found per 100 m^3. This yields a total estimate of 3.1 x 10^7 for the bay. However, no sampling was done between 12 May (when only two stations were sampled) and 3 June, and it is the author's opinion that the peak of the perch hatch in this area fell between these dates. On 3 June average density for the bay was 80.57 perch per 100 m^3. Most of these were juveniles between 15 mm to 20 mm in length. When sampling using these techniques, one expects much greater net avoidance by juvenile fish than larvae. This large number of juveniles suggests that the hatch was successful in this area.

Scholl (1978) rates the 1977 hatch of perch in Lake Erie as excellent. Here again this probably is at least partially due to the good weather conditions during the spring. In a study done in 1976, maximum larval densities in Maumee Bay were found to be 30 perch per 100 m^3 (Heniken, 1977). The year of 1976 was rated as a poor year for perch spawning in the lake.

Perch eggs are probably more tolerant of siltation than the walleye eggs in that they are laid in masses which are semi-buoyant and tend to attach to submerged articles where they would receive more water circulation and subsequent dissolved oxygen levels. Perch appear to spawn over a somewhat longer time period than the walleye. This could be, in part, due to the larger population of perch that exists in Lake Erie.

Distribution tests for surface/bottom for the perch showed no significant difference for prolarval and postlarval fish in both sectors 2 and 3. However, conflicting results occurred with juveniles. As in sector 2 the test showed no difference, but in sector 3 there was a significant difference, with perch preferring near-bottom areas. Looking at the raw numbers (Appendix B) for both sectors, one can observe that more juvenile perch were taken at the bottom in both sectors. This indicates to some degree that the juvenile perch prefer the near-bottom zone while inhabiting the river. This preference is probably due to food availability, habitat selection, preditor avoidance or a combination of these factors.

Water Movements and Power Plant Aspects

As discussed previously, being a freshwater estuary means there is a mixing of the waters of the river and bay. The main forces producing the currents which cause the mixing of the waters are wind tides, seiches and river discharge (Pinsak and Meyer, 1976).

Waves are produced initially by wind stress and commonly transport large volumes of water in shallow areas such as Maumee Bay. Northeasterly winds induce an up-river southwesterly current which, at times, may send Lake Erie water as far upstream as the first rapids at Perrysburg (Brant and Herdendorf, 1972). The estuary region and harbor area of the Maumee River and Bay are not significantly affected by longshore currents because of the sheltering effect of the spoil ridges from the dredging and maintenance of the navigation channel. It has been stated that the spoil ridges and islands exert a tremendous influence on the wave characteristics and water movements in the bay (Benson, 1975). Waves crossing these ridges interact with the bottom and break. Seiche activity within this system is also a function of wind along with rapidly moving pressure disturbances (Pinsak and Meyer, 1976). Seiche activity is usually short term, normally not lasting more than 14 hours, but capable of creating significant changes in water levels of between 7.5 feet below to 7.4 feet above low water datum (LWD) (Herdendorf and Cooper, 1975). These water level fluctuations are also a primary factor affecting currents and water movements.

It has been estimated that the flow of the Maumee River estuary is in a downstream direction only 60 percent of the time (Miller, 1968). During walleye, sauger and part of the perch spawning periods, it would be greater than this due to early spring runoff, although spring storms and high winds may cause significant reversals. With the influence of the spoil ridges, it would appear that most water movement and mixing occurs within the navigation channel. The factors creating this situation are the increased current velocity and volume in the channel and the effect of the spoil ridges which inhibit the dispersion of the flow on either side of the channel. When water is moved in an upstream direction there would be greater mixing and dispersion of water due to the lack of these spoil ridges in the river. With many of these water movements of short-term duration, it is the author's opinion that primary impacts of ichthyoplankton survival due to entrainment would occur at the Bay Shore plant.

However, continued current reversal or upstream movement could significantly affect larval survival in that it could prevent young larvae from reaching areas of zooplankton abundance in time for proper feeding.

Power plants, with large water-using capacity, can be very hazardous to ichthyoplankton. As seen in the results section, large numbers of both walleye and perch larvae were entrained.

The Acme plant entrained larval walleye during five sampling periods ranging from 17 April through 15 May. Maximum entrainment occurred on 11 May, when over 8,000 were estimated to have been entrained over the 24-hour period (Appendix D). It was also determined that from 80 to 100 percent of the days when walleye larvae were entrained at Acme the water was of river origin. Conductivity measurements were used to determine the source of the intake water. Conductivity measures can be defined as a measure of the concentration of dissolved salts in the water, and are very useful in tracing mixing patterns in bodies of water (Fraleigh et al., 1974). Normal conductivity measurements for western Lake Erie are $\leq$ 300 umhos per cm, and for the river they are 550-700 umhos per cm (Reutter et al., 1978). Conductivity values for Maumee Bay usually range between these figures, once again showing the effects of being a mixing zone.

The Acme plant entrained perch during only two sampling periods (Figure A-2). However, perch were collected in Acme river samples during 11 sampling periods from 21 April to 12 June.

It must be pointed out that most perch taken after 31 May were juveniles capable of swimming into this region from other areas, possibly Maumee Bay and western Lake Erie. It was determined that from 54 to 72 percent of the time when perch were found here, the water was of bay origin. Thus, it is probable that most of these perch were spawned in the bay and subsequently moved into the river either with the currents or for undetermined reasons which could be factors such as reduced intraspecific competition.

Impingement of walleyes at the Acme plant was light with most occurring from mid-April through May when adults were making their spawning runs (Figure A-3). Maximum impingement occurred on 21 April when just over 30 were estimated to have been caught.

Impingement of perch at the Acme plant occurred throughout the year, with most of these occurring from June through August (Figure A-4). Most of these were young-of-the-year or juvenile fish.

Entrainment and especially impingement were much greater at the Bay Shore plant than at Acme. This has to do with the location of the plant and the greater volume of water utilized. Walleye larvae were entrained here from 21 April to 15 May with maximum entrainment occurring on 11 May. On that date, an estimated 18,000 were taken (Figure A-5). The water was of river origin 67 to 100 percent of the days when walleye larvae were taken at the Bay Shore stations. Also, these stations were the only river stations where any postlarval walleyes were taken; thus again showing movement down the river with subsequent increase in size and absorption of the yolk sac.

Entrainment of perch at Bay Shore occurred from 25 April to 7 July. Maximum entrainment occurred on 15 May when an estimated 110,000 were believed to have gone through the plant (Figure A-6). The water is believed to have been of bay origin 64 to 76 percent of the days when perch were taken at the Bay Shore sampling stations, again showing the tendency of perch to be more of a bay or lake species.

Impingement of walleyes occurred much more at the Bay Shore plant than at the Acme plant. Greatest impingement estimates occurred at the Bay Shore plant on 21 July, when just over 300 walleye were estimated to have been impinged (Appendix D). These were young-of-the-year fish with an average length of approximately 87 mm. Large numbers of juvenile and young-of-the-year walleyes were taken at the Bay Shore plant, while few were taken at Acme. This shows the utilization of the bay area as a nursery grounds for this species. Also, some of these could have been sauger as there was no attempt to differentiate between the species.

Impingement of perch at Bay Shore occurred throughout the entire year. Both adults and large numbers of young-of-the-year were taken during the summer. Maximum impingement occurred also on 21 July, when over 9,000 perch were estimated to have been trapped on the screens. Most of these were young-of-the year or yearling fish. Average length of the young-of-the-year on this date was 46 mm. It is estimated that throughout the summer 116,826 young-of-the-year perch were impinged at Bay Shore. Reutter et al. (1978), using Patterson's mortality estimates, calculated that these could have produced 42,029 to 110,603 age III adults to enter the fishery.

This report makes no attempt to critically evaluate the impacts of the power plants on populations of the species of interest. Obviously, the Bay Shore plant presents a much larger impact than the Acme plant. However, the only method to clearly eliminate the problem would be to convert to a closed cooling system. This would require conversion of the plant and the building of a cooling tower, which would be very expensive; thus causing a subsequent raise in utility rates to the consumer. Another possible alternative is that of a "fish diversion system," now being employed at the Detroit Edison Company's Monroe plant (Pollick, 1978). This involves pumping the fish from areas of congregation in front of the traveling screens and back out into the lake or river. Fish are pumped out through a plastic pipe, and initial studies have shown high survival rates. More studies need to be performed, but this may be a more economically feasible alternative in the future.

CONCLUSIONS

1. The Maumee River and Maumee Bay of Lake Erie are and must be considered important spawning and nursery areas for fishes. The river is used extensively for spawning by the walleye; some spawning also occurs in the bay. The opposite is true for yellow perch in that they use the bay to spawn in to a much greater degree than the river. These factors must be considered when taking into account present and future industrial activities in the area.

2. The spring of 1977, with its warm, mild weather conditions, led to excellent hatches for both walleye and perch in this area. When comparisons are made with other known methods of determining year class success, it appears that ichthyoplankton studies can also be valuable indicators of the success or failure of a year class in certain species.

3. Walleye larvae are carried by the river current in a general downstream movement toward Lake Erie. The young fish absorb their yolk sacs during this time, and it is imperative that they reach areas of zooplankton abundance when they begin active feeding. Maumee Bay, with its high concentrations of zooplankton and suitable forage, is important as a nursery area for young-of-the-year fish. Results indicate that some (although by no means the majority) of the walleye spawning is occurring in areas upstream from the riffle zones in the estuary. Also, it appears that walleye in late larval stages tends to inhabit near-bottom areas more frequently than surface areas.

4. Some larval sauger were captured in both the river and bay, thus proving that some natural reproduction is occurring and that the Ohio Department of Natural Resources sauger reintroduction program is at least partially successful. It is also believed that some walleye-sauger hybrids were captured.

5. It is believed that the main period of perch spawning in Maumee Bay was not sampled and fell between the dates of 12 May through 3 June 1977. Large numbers of juveniles taken tend to indicate very good spawning success. Substantial concentrations of juveniles were also taken at some estuary stations; this area may also be employed as a nursery zone for perch. The juvenile perch found in the estuary appeared to prefer near-bottom regions.

6. The Bay Shore Power Plant has a greater impact upon ichthyoplankton populations than the Acme Power Plant. This is due to its location and the greater volume of cooling water utilized. The waters around this plant, in particular, are a mixing zone with many current reversals and often water from Maumee Bay is found to predominate.

7. Ichthyoplankton studies as they are currently conducted can be selective and have certain inherent problems associated with them, such as gear-related problems and nonrandom distribution of larvae. However, they are very valuable to study and attempt to protect fish during the larval period when they are extremely vulnerable to the commercial and industrial pursuits of mankind. Studies should continue to attempt to improve the techniques now being employed.

APPENDIX A

MEAN LARVAL DENSITIES PER 100 m^3

TABLE A1

MEAN LARVAL DENSITIES PER 100 m^3
FOR SECTOR 1

Species	Date (Julian)	Station	Mean per 100 m^3
Walleye	April 18 (108)	D-4	4.31
		D-3	20.28
		D-2	1.10
		D-1	1.21
	April 22 (112)	D-4	37.90
		D-3	36.90
		D-2	27.70
		D-1	292.58
	May 5 (125)	D-3	2.95
		D-2	2.46
		D-1	1.52
	May 9 (129)	D-4	0.72
		D-3	1.29
		D-2	4.23
	May 16 (136)	D-1	1.96
		D-4	0.76
		D-3	2.36
Perch	April 22 (112)	D-4	1.15
	June 3 (154)	D-1	7.29
	June 7 (158)	D-1	17.19
	June 11 (162)	D-2	0.75
		D-1	6.68

TABLE A2

MEAN LARVAL DENSITIES PER 100 m^3 FOR THE 316(b) STUDY (SECTORS 2 AND 3)

Species	Date (Julian)	Station	Mean per 100 m^3
Walleye	April 17 (107)	2	0.45
	April 21 (111)	1	1.14
		2	12.61
		3	44.65
		5	1.10
		6	14.88
	April 25 (115)	4	0.40
	May 7 (127)	1	6.26
		2	9.04
		3	7.12
		4	1.06
		5	3.85
		6	7.69
	May 11 (131)	1	1.52
		2	0.76
		3	1.72
		4	3.23
		5	1.71
		6	3.25
	May 15 (135)	1	3.72
		2	1.28
		3	2.15

TABLE A2, cont.

Species	Date (Julian)	Station	Mean per 100 m^3
Walleye	May 15 (135)	4	3.08
		5	0.81
		6	5.06
	May 19 (139)	no samples - boat trouble	

TABLE A3

MEAN LARVAL DENSITIES PER 100 m^3 FOR THE 316(B) STUDY (SECTORS 2 AND 3)

Species	Date (Julian)	Station	Mean per 100 m^3
Perch	April 21 (111)	2	0.40
		3	0.36
	April 25 (115)	4	2.22
		5	0.63
	April 29 (119)	2	1.19
		4	5.78
		5	0.36
	May 3 (123)	1	0.22
		4	0.50
		6	0.25
	May 7 (127)	2	0.23
	May 11 (131)	1	0.48
		3	0.48
		4	0.27
		5	0.25
		6	0.24
	May 15 (135)	1	0.26
		3	0.25
		4	44.06
		5	28.04
		6	6.03

TABLE A3, cont.

Species	Date (Julian)	Station	Mean per 100 m^3
Perch	May 19 (139)	no samples - boat trouble	
	May 23 (143)	4	2.54
		5	8.73
	May 27 (147)	1	3.24
		4	11.92
		6	16.41
	May 31 (151)	6	25.18
	June 4 (155)	1	0.25
		5	3.44
		6	27.81
	June 8 (159)	2	1.03
		4	11.92
		5	15.77
		6	10.57
	June 12 (163)	1	2.32
		2	0.23
		3	0.23
		4	3.43
		5	2.26
		6	2.53
	June 16 (167)	1	7.71
		2	3.86
		3	3.38

TABLE A3, cont.

Species	Date (Julian)	Station	Mean per 100 m^3
Perch	June 16 (167)	6	1.54
	June 23 (174)	4	0.55
		5	0.24
		6	1.88
	June 30 (181)	4	2.60
		5	1.42
		6	0.21
	July 7 (188)	4	0.28
		5	1.04
		6	0.80

TABLE A4

MEAN DENSITIES PER 100 m^3 FOR
THE MAUMEE BAY STATIONS (SECTOR 4)

Species	Date (Julian)	Station	Mean per 100 m^3
Walleye	April 11 (111)	7	0.20
		8	0.20
		12	0.17
		13	0.35
	April 30 (120)	7	2.24
		8	0.38
		9	0.38
		10	0.34
		11	3.57
		12	(No sample taken)
	May 12 (132)	7	0.29 } only stations sampled
		8	0.60 } only stations sampled
	June 3 (154)	7	1.50
		9	1.47
		10	0.89
Sauger	May 12 (132)	8	1.35

TABLE A5

MEAN LARVAL DENSITIES PER 100 m^3 FOR THE MAUMEE BAY STATIONS (SECTOR 4)

Species	Date (Julian)	Station	Mean per 100 m^3
Perch	April 21 (111)	7	0.20
		8	0.22
		9	(no sample taken)
		10	0.74
		12	0.33
		13	0.23
	April 30 (120)	7	50.90
		8	7.20
		9	15.92
		10	9.86
		11	36.71
		12	(no sample taken)
	May 12 (132)	7	10.45 } only stations sampled
		8	11.35 } only stations sampled
	June 3 (154)	7	377.41
		8	15.70
		9	29.90
		10	37.82
		11	5.72
		12	58.23
		13	39.23

TABLE A5, cont.

Species	Date (Julian)	Station	Mean per 100 m^3
Perch	June 12 (163)	7	1.431
		11	0.02
		12	1.03

APPENDIX B

RAW DATA, NUMBERS NOT CONVERTED TO DENSITY PER 100 m^3

(INCLUDES ONLY TOWS IN WHICH WALLEYE, SAUGER OR PERCH WERE TAKEN)

TABLE B1

316(b) DATA

Date	Station	Depth	Tow	Species	Number	Length Range (mm)
April 17	A	S	N	Walleye	5	7-10.0
	2	B	2	Walleye	1	10.0
		B	3	Walleye	1	10.0
April 21	A	S	N	Walleye	6	7.5-8.5
		B	N	Walleye	5	8-8.5
	1	S	1	Walleye	2	8.0
		S	3	Walleye	1	8.0
		B	1	Walleye	1	8.0
	2	S	1	Walleye	4	7-9.0
		S	2	Walleye	9	8-9.0
		S	3	Walleye	13	8-8.5
		B	1	Walleye	5	8-9.0
		B	1	Perch	1	5.0
		B	3	Walleye	3	8.5-9.0
	3	S	1	Walleye	33	7.5-9.0
		S	2	Walleye	42	7.5-9.0
		S	3	Walleye	28	8-9.0
		S	3	Perch	1	4.5
		B	1	Walleye	5	7-9.0
		B	2	Walleye	4	8-9.0

TABLE B1, cont.

Date	Station	Depth	Tow	Species	Number	Length Range (mm)
April 21	3	B	3	Walleye	1	8.5
	B	S	N	Walleye	1	8.0
		S	D	Walleye	1	8.5
	5	B	2	Walleye	1	7.0
	6	S	1	Walleye	3	7-8.0
			2	Walleye	2	9.0
			3	Walleye	10	8-9.0
	6	B	1	Walleye	8	7-9.0
		B	2	Walleye	5	8-9.0
		B	3	Walleye	14	8-9.0
April 25	A	S	N	Walleye	1	7.0
	B	S	N	Walleye	1	9.0
		S	D	Walleye	1	8.0
		S	D	Perch	2	6-7.0
		B	D	Walleye	1	8.0
		B	D	Perch	2	6-7.0
	4	S	1	Perch	1	5.0
		B	1	Walleye	1	8.0
		B	2	Perch	4	5.5-6.0
		B	3	Perch	1	5.5
	5	B	1	Perch	1	6.0

TABLE B1, cont.

Date	Station	Depth	Tow	Species	Number	Length Range (mm)
April 29	2	B	1	Perch	2	5.0
		B	2	Perch	1	9.0
	B	S	N	Walleye	1	9.0
	4	S	1	Perch	2	5-5.5
		S	2	Perch	7	5-5.5
		S	3	Perch	4	5-6.0
		B	1	Perch	3	5-6.0
May 3	1	B	1	Perch	1	6.0
	4	S	2	Perch	1	6.5
		S	3	Perch	1	6.0
	6	B	3	Perch	1	6.0
May 7	A	S	N	Walleye	1	6.0
		B	N	Walleye	1	7.0
		B	N	Perch	1	8.0
		S	D	Walleye	4	5.5-6.0
	1	S	1	Walleye	2	6.5-7.0
		S	2	Walleye	1	6.0
		S	3	Walleye	2	5-5.5
		B	1	Walleye	7	6-6.5
		B	2	Walleye	8	5.5-6
		B	3	Walleye	6	6-7.0
	2	S	1	Walleye	6	6-6.5
		S	2	Walleye	3	6-6.5

TABLE B1, cont.

Date	Station	Depth	Tow	Species	Number	Length Range (mm)
May 7	2	S	3	Walleye	4	6.0
		S	3	Perch	1	6.0
		B	1	Walleye	8	6-6.5
		B	2	Walleye	2	6.0
		B	3	Walleye	14	6-6.5
	3	S	1	Walleye	3	6-6.5
		S	2	Walleye	3	5-6.0
		B	1	Walleye	2	6.0
		B	2	Walleye	10	6-6.5
		B	3	Walleye	9	6-6.5
	4	B	1	Walleye	2	6.0
		B	3	Walleye	1	5.5-6
	5	S	1	Walleye	1	7.0
		B	1	Walleye	4	5-6.0
		B	2	Walleye	4	5.5
		B	3	Walleye	6	5-6.0
	6	S	1	Walleye	2	5-6.0
		S	2	Walleye	6	5-6.5
		S	3	Walleye	1	6.0
		B	1	Walleye	7	5-6.5
		B	2	Walleye	16	5-6.5
		B	3	Walleye	7	5-6.0

TABLE B1, cont.

Date	Station	Depth	Tow	Species	Number	Length Range (mm)
May 11	A	S	N	Walleye	5	7-7.5
		S	D	Walleye	8	8-9
	1	S	1	Walleye	1	8.0
		S	1	Perch	1	5.0
		S	2	Walleye	1	7.0
		S	2	Perch	1	5.0
		B	2	Walleye	3	7.5-8.0
		B	3	Walleye	1	8.0
	2	S	1	Walleye	1	7.5
		S	2	Walleye	1	6.5
		B	2	Walleye	1	6.5
	3	S	3	Perch	1	7
		B	1	Walleye	2	7-7.5
		B	2	Walleye	3	6.5-7.5
		B	3	Walleye	2	7.5
		B	3	Perch	1	5.0
	B	S	N	Walleye	7	7-8.0
		B	N	Walleye	3	7.5-8.5
		S	D	Walleye	2	7.0
		B	D	Walleye	2	9-10.5
	4	S	1	Walleye	1	11.0

TABLE B1, cont.

Date	Station	Depth	Tow	Species	Number	Length Range (mm)
May 11	4	S	2	Walleye	2	7.5
		S	2	Perch	1	4.5
		B	1	Walleye	1	7.0
		B	2	Walleye	5	6-8.0
		B	3	Walleye	4	6-5.8
	5	S	1	Walleye	4	8-9.0
		S	1	Perch	1	4.0
		S	2	Walleye	3	8-9.5
	6	S	3	Walleye	2	8.0
		B	1	Walleye	1	7.5
		B	2	Walleye	9	6-8
		B	3	Walleye	1	7.0
May 15	1	S	1	Walleye	1	8.0
		S	2	Walleye	2	8.0
		S	3	Walleye	6	8-9.0
		S	3	Perch	1	6.0
		B	3	Walleye	4	7.5-9.0
	2	S	1	Walleye	2	7-7.5
		S	2	Walleye	2	7.5-8.0
		B	3	Walleye	1	9.0
	3	S	1	Walleye	1	8.5
		S	2	Walleye	1	8.5
		S	2	Perch	1	6.0

TABLE B1, cont.

Date	Station	Depth	Tow	Species	Number	Length Range (mm)
May 15	3	S	3	Walleye	4	8-8.5
		B	1	Walleye	1	8.0
		B	2	Walleye	1	8.5
	B	S	N	Walleye	1	8.5
		S	N	Perch	20	6-8.0
		B	N	Walleye	1	12.5
		B	N	Perch	16	7-9.0
		S	D	Walleye	4	9-12.0
		S	D	Perch	27	6-11.0
		B	D	Walleye	3	8-10
		B	D	Perch	12	7-8.5
	4	S	1	Perch	45	7-8.0
		S	2	Walleye	2	9-10.0
		S	2	Perch	23	7-8.0
		S	3	Perch	56	7-8.0
		B	1	Walleye	2	9.0
		B	1	Perch	11	7-9.0
		B	2	Walleye	4	7-9.0
		B	2	Perch	8	7-8.0
		B	3	Walleye	3	9-10.0
		B	3	Perch	20	7-7.5
	5	S	1	Walleye	1	8.5
		S	1	Perch	12	7-9.0

TABLE B1, cont.

Date	Station	Depth	Tow	Species	Number	Length Range (mm)
May 15	5	S	2	Perch	12	7.5-8.5
		S	3	Perch	4	7-8.0
		B	1	Perch	2	6-8.0
		B	2	Walleye	2	9.0
		B	2	Perch	48	6-8.0
		B	3	Perch	28	6-8.5
	6	S	1	Walleye	5	8-10.0
		S	1	Perch	8	6-8.0
		S	2	Walleye	2	8.0
		S	3	Perch	1	7.0
		B	1	Walleye	1	9.5
		B	1	Perch	5	6-8.0
		B	2	Walleye	3	9-10.0
		B	2	Perch	6	7-8.0
		B	3	Walleye	11	8-10.0
		B	3	Perch	8	6-8.5
May 19	B	S	N	Perch	20	7.0
		B	N	Perch	20	8.0
	No River Samples - Boat Trouble					
May 23	B	B	N	Perch	60	9-10.0
	4	B	1	Perch	10	10.5
	5	B	2	Perch	10	12.5
		B	3	Perch	10	12.0

TABLE B1, cont.

Date	Station	Depth	Tow	Species	Number	Length Range (mm)
May 27	1	S	1	Perch	10	5.0
	4	B	2	Perch	20	16.5
		B	3	Perch	20	14.0
	6	B	1	Perch	40	13-17.0
		B	2	Perch	20	14.0
May 31	6	S	1	Perch	20	19.0
		B	1	Perch	100	16.0
June 4	1	S	3	Perch	1	20.0
	B	B	D	Perch	15	20.0
	5	B	1	Perch	10	16.0
	6	S	1	Perch	40	17-18.0
		S	3	Perch	20	19.0
		B	1	Perch	10	17.0
		B	2	Perch	20	13-17.0
		B	3	Perch	10	16.0
June 8	1	S	2	Perch	2	22.0
		S	3	Perch	3	19.5-20.0
		B	1	Perch	2	15-18.0
		B	2	Perch	2	23-27.0
		B	3	Perch	1	25.0
	2	B	3	Perch	1	25.0
	3	S	1	Perch	1	19.5

TABLE B1, cont.

Date	Station	Depth	Tow	Species	Number	Length Range (mm)
June 8	B	S	D	Perch	1	23.0
	4	S	1	Perch	1	27.0
		S	2	Perch	2	20-27.0
		S	3	Perch	1	26.5
		B	1	Perch	5	20-25.0
		B	2	Perch	1	21.0
		B	3	Perch	5	20-27.0
	5	S	1	Perch	3	17.5-21.0
		S	2	Perch	3	18.5-23.0
		S	3	Perch	1	25.5
		B	2	Perch	1	20.5
	6	S	3	Perch	5	22-25.5
		B	1	Perch	1	21.0
		B	2	Perch	3	18-21.0
June 12	1	S	1	Perch	4	15-23.0
		B	1	Perch	11	21-23.0
		B	2	Perch	3	24-25.0
		B	3	Perch	9	21.5-29.0
	2	S	2	Perch	5	21.0-24.0
		S	3	Perch	2	24.0
		B	1	Perch	4	21-23.0
		B	2	Perch	3	21-24.0

TABLE B1, cont.

Date	Station	Depth	Tow	Species	Number	Length Range (mm)
June 12	3	S	1	Perch	1	25.0
		S	2	Perch	2	21-24.0
		S	3	Perch	1	22.0
		B	1	Perch	2	26-30.0
		B	3	Perch	1	23.0
	6	S	2	Perch	1	21.5
		B	2	Perch	3	21-27.0
		B	3	Perch	2	20-25.0
June 16	4	B	3	Perch	2	30-37.0
	5	B	3	Perch	1	30.0
	6	S	1	Perch	1	33.0
		B	1	Perch	1	35.0
		B	2	Perch	4	28-34.0
		B	3	Perch	1	38.0
June 23	4	S	3	Perch	2	30-35.0
		B	1	Perch	3	33-37.0
		B	2	Perch	6	34-40.0
		B	3	Perch	3	35-40.0
	5	S	2	Perch	1	42.0
		B	1	Perch	1	40.0
		B	2	Perch	2	35-45.0
		B	3	Perch	3	17-40.0
	6	B	1	Perch	1	35.0

TABLE B1, cont.

Date	Station	Depth	Tow	Species	Number	Length Range (mm)
June 30	4	B	1	Perch	1	50.0
	5	S	2	Perch	1	44.0
		S	3	Perch	2	42-43.0
	6	S	2	Perch	1	38.0
		S	3	Perch	1	47.0
		B	1	Perch	1	38.0
July 7	6	S	1	Perch	1	10.0
		S	3	Perch	1	8.5
	B	S	N	Perch	1	56.0

TABLE B2

RIVER DREDGING STUDY DATA

Date	Station	Depth	Species	Number	Length Range (mm)
April 18	D-1	B	Walleye	1	9.0
	D-2	S	Walleye	1	9.0
	D-3	B	Walleye	18	7-9.0
	D-4	S	Walleye	1	7.0
		B	Walleye	3	7-8.0
April 22	D-1	S	Walleye	23	8-9.5
		B	Walleye	238	8.5-9.0
	D-2	S	Walleye	20	8-9.0
		B	Walleye	4	9.0
	D-3	S	Walleye	23	8-9.0
		B	Walleye	10	8-9.0
	D-4	S	Walleye	19	7-9.0
		S	Perch	1	5.5
		B	Walleye	14	8.5-9.0
April 26	No Walleye or Perch Taken				
May 1	No Walleye or Perch Taken				
May 5	D-1	B	Walleye	2	4.5-5.0
	D-2	S	Walleye	3	6-6.5
	D-3	S	Walleye	2	5.5
		B	Walleye	2	6.0

TABLE B2, cont.

Date	Station	Depth	Species	Number	Length Range (mm)
May 9	D-1	B	Walleye	3	6-7.0
	D-2	S	Walleye	1	6.5
		B	Walleye	5	6-8.0
	D-3	B	Walleye	2	6.0
	D-4	B	Walleye	1	6.0
May 16	D-4	B	Walleye	1	8.0
June 7	D-1	S	Perch	20	24.0
June 11	D-1	S	Perch	10	21.0
	D-2	B	Perch	1	23.0

TABLE B3

MAUMEE BAY DREDGING STUDY DATA

Date	Station	Tow	Species	Number	Length Range (mm)
April 21	7	3	Walleye	1	7.0
		3	Perch	1	4.5
	8	3	Walleye	1	5.5
		4	Perch	1	5.5
	10	1	Perch	1	4.5
	12	1	Walleye	1	6.0
		1	Perch	1	5.0
		4	Perch	1	4.0
	13	1	Walleye	1	8.0
		2	Walleye	1	8.5
		4	Perch	1	4.5
April 30	7	1	Walleye	3	7-9.0
		1	Perch	19	5.5-6.0
		2	Walleye	3	7.5-8.5
		2	Perch	27	5-6.5
		3	Walleye	1	8.0
		3	Perch	31	5-6.5
		4	Walleye	3	7.5-8.5
		4	Perch	74	4.5-7.0
		5	Walleye	1	8.0

TABLE B3, cont.

Date	Station	Tow	Species	Number	Length Range (mm)
April 30	7	5	Perch	73	5-7.0
	8	1	Walleye	1	8.5
		1	Perch	16	4.5-7.0
		2	Walleye	1	8.5
		2	Perch	3	5.5-6.0
		3	Perch	5	17-18.0
		4	Perch	6	5-6.0
		5	Perch	5	5-6.0
	9	1	Perch	45	5-6.0
		2	Perch	5	6.0
		3	Walleye	1	8.5
		3	Perch	21	5.5-7.0
		4	Walleye	1	7.5
		4	Perch	13	5.5-7.0
	10	1	Perch	6	5-7.0
		2	Perch	16	6-6.5
		3	Perch	11	4.5-6.5
		4	Walleye	2	8.5-10.5
		4	Perch	7	5-6.5
		5	Perch	13	5-6.5
	11	1	Walleye	2	8-9.0
		1	Perch	16	6.0-6.5

TABLE B3, cont.

Date	Station	Tow	Species	Number	Length Range (mm)
April 30	11	2	Walleye	2	8.5
		2	Perch	39	5-6.5
		3	Walleye	5	7.5-9.0
		3	Perch	28	6-6.5
		4	Walleye	4	8-8.5
		4	Perch	37	5-6.5
		5	Walleye	7	7.5-10.5
		5	Perch	93	5-6.5
May 12	7	1	Perch	23	7-10.5
		2	Walleye	1	11.0
		3	Perch	7	6.5-8.0
		4	Perch	3	6.5-7.0
		5	Perch	6	4.5-7.0
	8	1	Perch	7	6.5-8.5
		1	Sauger	1	9.0
		2	Walleye	2	9-13.0
		2	Perch	7	6.5-7.5
		2	Sauger	1	8.5
		3	Perch	11	6.5-8.5
		3	Sauger	1	8.5
		4	Perch	4	6.5-7.0
		4	Sauger	1	7.5

TABLE B3, cont.

Date	Station	Tow	Species	Number	Length Range (mm)
May 12	8	5	Perch	4	7-10.0
	Only Stations Sampled				
June 3	7	1	Perch	12	14-20.5
		2	Perch	17	12-19.0
		3	Perch	350	14-19.0
		4	Perch	190	16-21.0
		5	Walleye	2	16-22.0
		5	Perch	13	14-18.0
	8	2	Perch	8	16-24.0
		4	Perch	13	15-24.0
		5	Perch	5	17-18.0
	9	1	Perch	36	16-22.0
		2	Walleye	1	24.0
		2	Perch	11	13-22.0
		3	Perch	16	16-19.0
		4	Perch	8	15-22.0
		5	Walleye	2	21-31.0
		5	Perch	2	18-20.0
	10	1	Perch	16	19-21.0
		1	Sauger	2	27-28.0
		2	Perch	10	11-18.0
		3	Walleye	2	25-28.0
		3	Perch	5	17-18.0

TABLE B3, cont.

Date	Station	Tow	Species	Number	Length Range (mm)
June 3	10	4	Perch	1	18.5
		5	Perch	50	16-18.0
	11	3	Perch	4	12-21.0
		4	Perch	4	13-21.0
		5	Perch	1	19.0
	12	1	Perch	40	20-24.0
		2	Perch	32	15-25.0
		3	Perch	80	16-23.0
		4	Perch	10	20.5
		5	Perch	9	17-21.0
	13	2	Perch	13	18-25.0
		3	Perch	13	18-25.0
		4	Perch	26	20.0
		5	Perch	26	8-23.0
June 12	7	1	Perch	6	20-24.0
		5	Perch	3	20-23.0
	9	1	Perch	1	22.0
		5	Perch	1	16.0
	10	1	Perch	3	23-24.0
		2	Perch	5	21-29.0
		3	Perch	4	21-25.0
		4	Perch	1	23.0

TABLE B3, cont.

Date	Station	Tow	Species	Number	Length Range (mm)
June 12	10	5	Perch	1	22.0
	11	1	Perch	125	20-25.0
		2	Perch	23	22-30.0
		3	Perch	20	21-22.0
		5	Perch	175	22-30.0
	12	3	Perch	2	20.0
	13	3	Perch	14	20-28.0
		5	Perch	3	20.0
June 21	8	2	Perch	1	28.0
	10	5	Perch	1	25.0
	13	2	Perch	3	20-29.0
		3	Perch	3	24.0-35.0
July 5	9	1	Perch	1	14.0
	10	3	Perch	1	15.0
		5	Perch	1	14.0
	11	3	Perch	1	17.0
	13	1	Perch	1	9.0

APPENDIX C

PLOTS FOR INDIVIDUAL STATIONS OF
WALLEYE AND PERCH DENSITIES

(NOTE--NUMBERS ON THE VERTICAL
AXIS VARY)

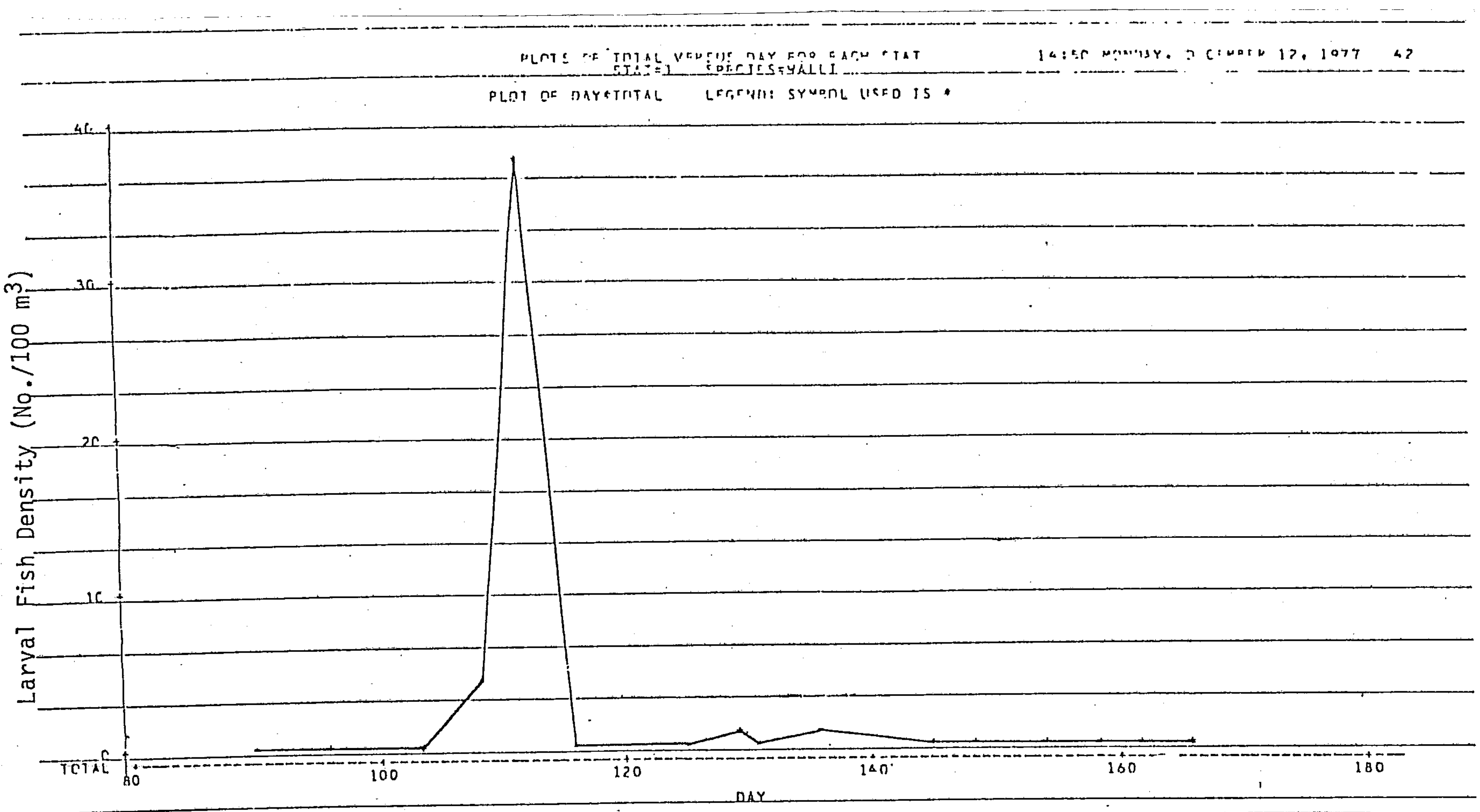


Figure C1. Walleye larvae density at station D-4.

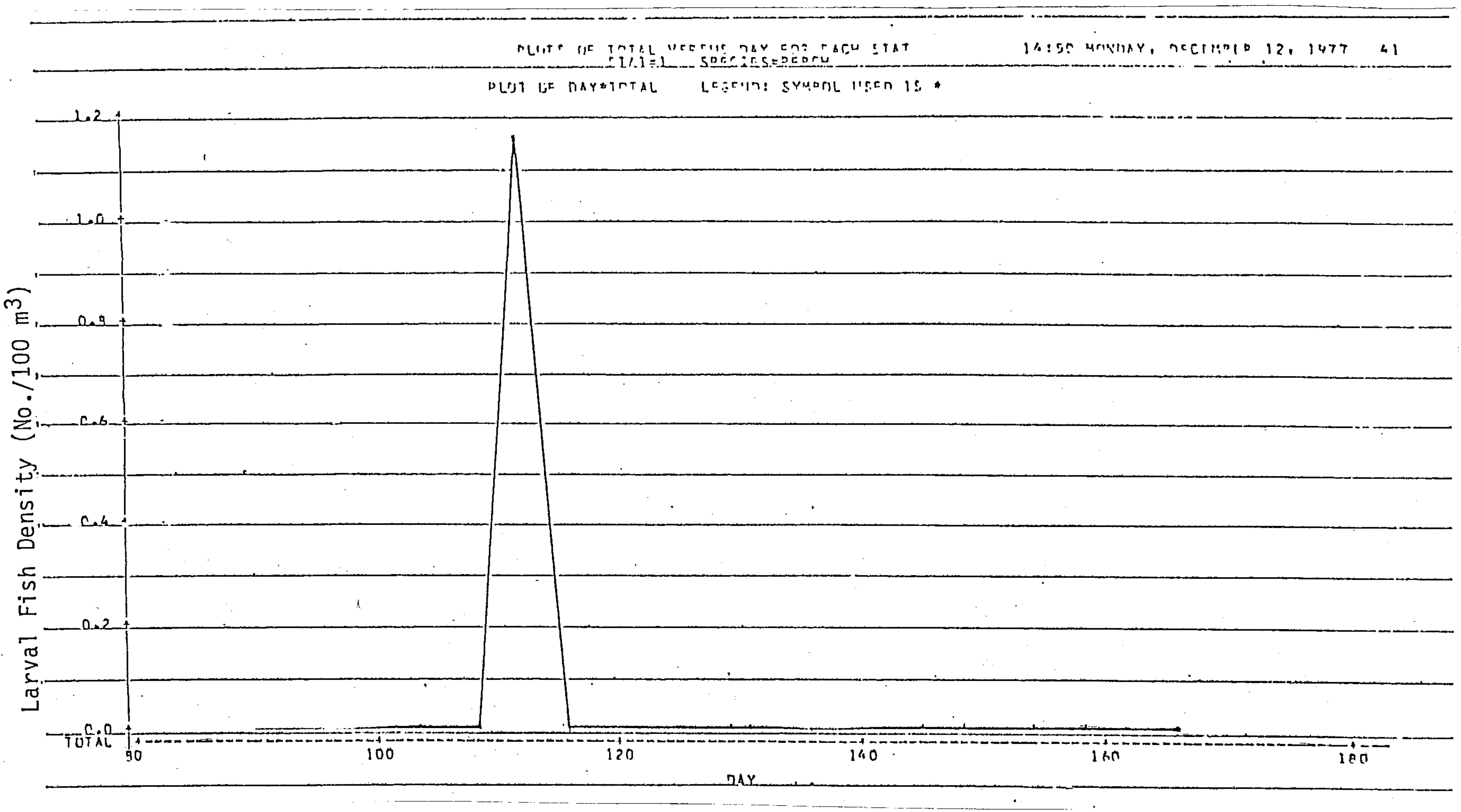


Figure C2. Yellow perch larvae density at station D-4.

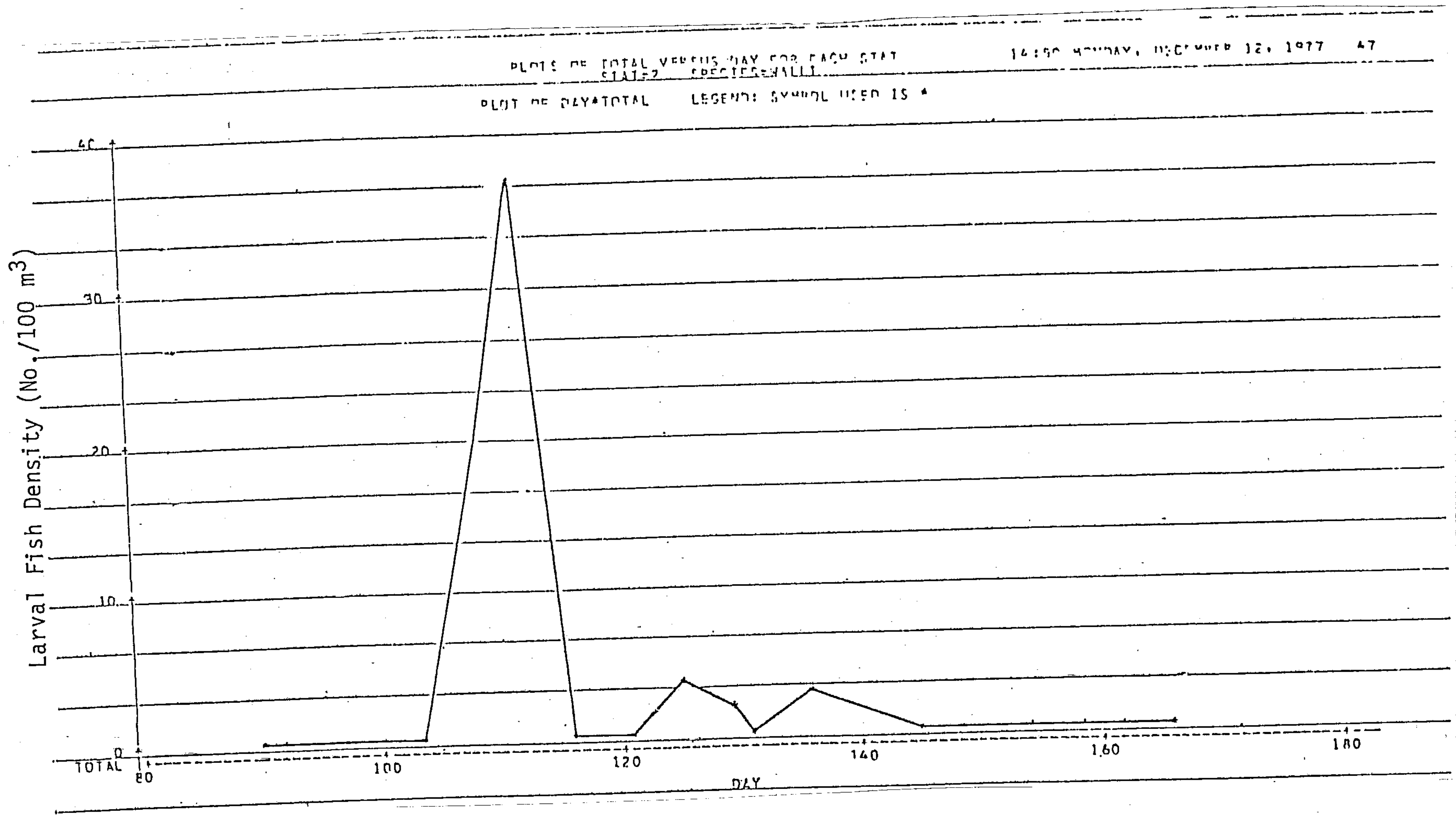


Figure C3. Walleye larvae density at station D-3.

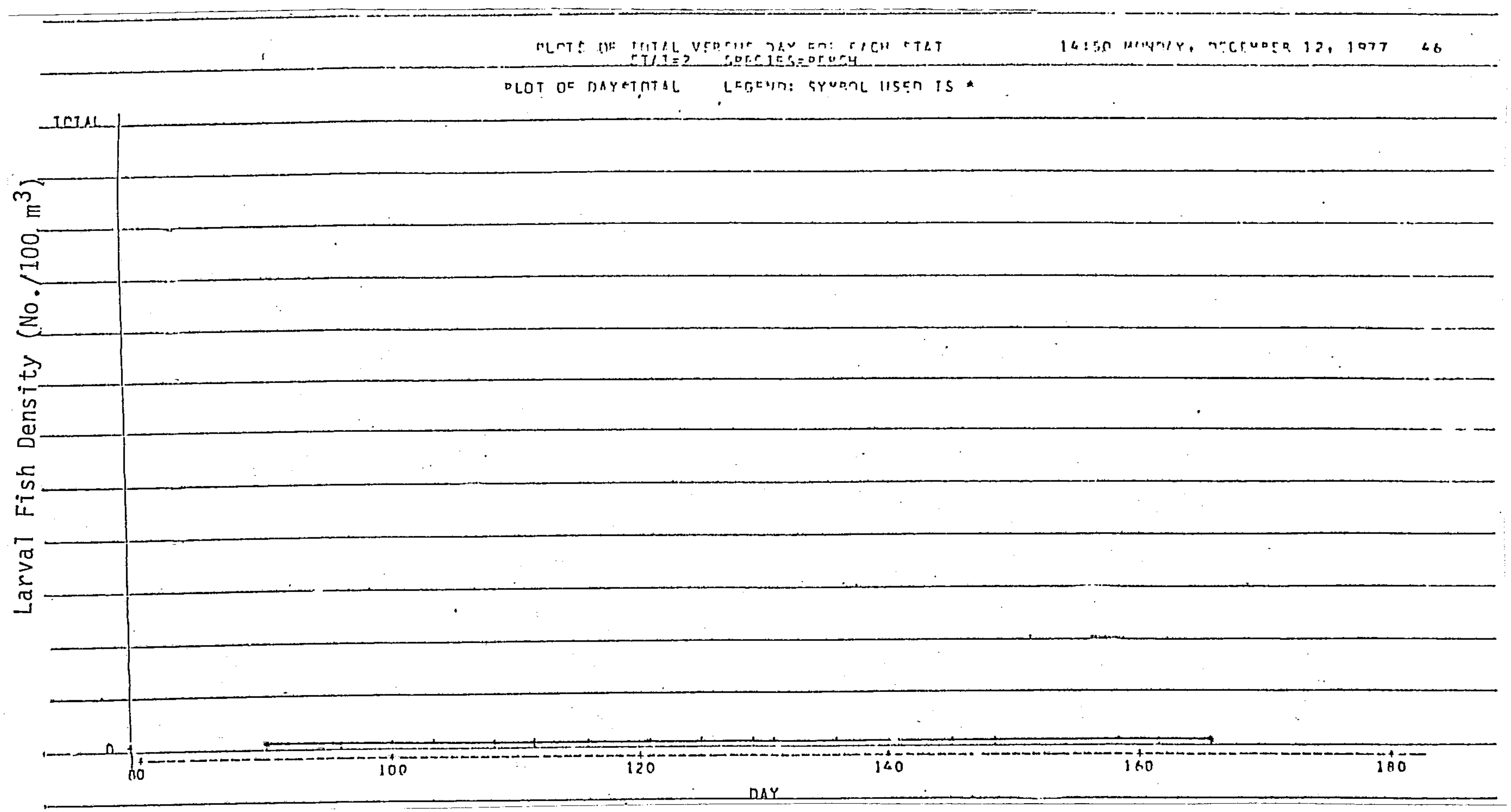


Figure C4. Yellow perch larvae density at station D-3.

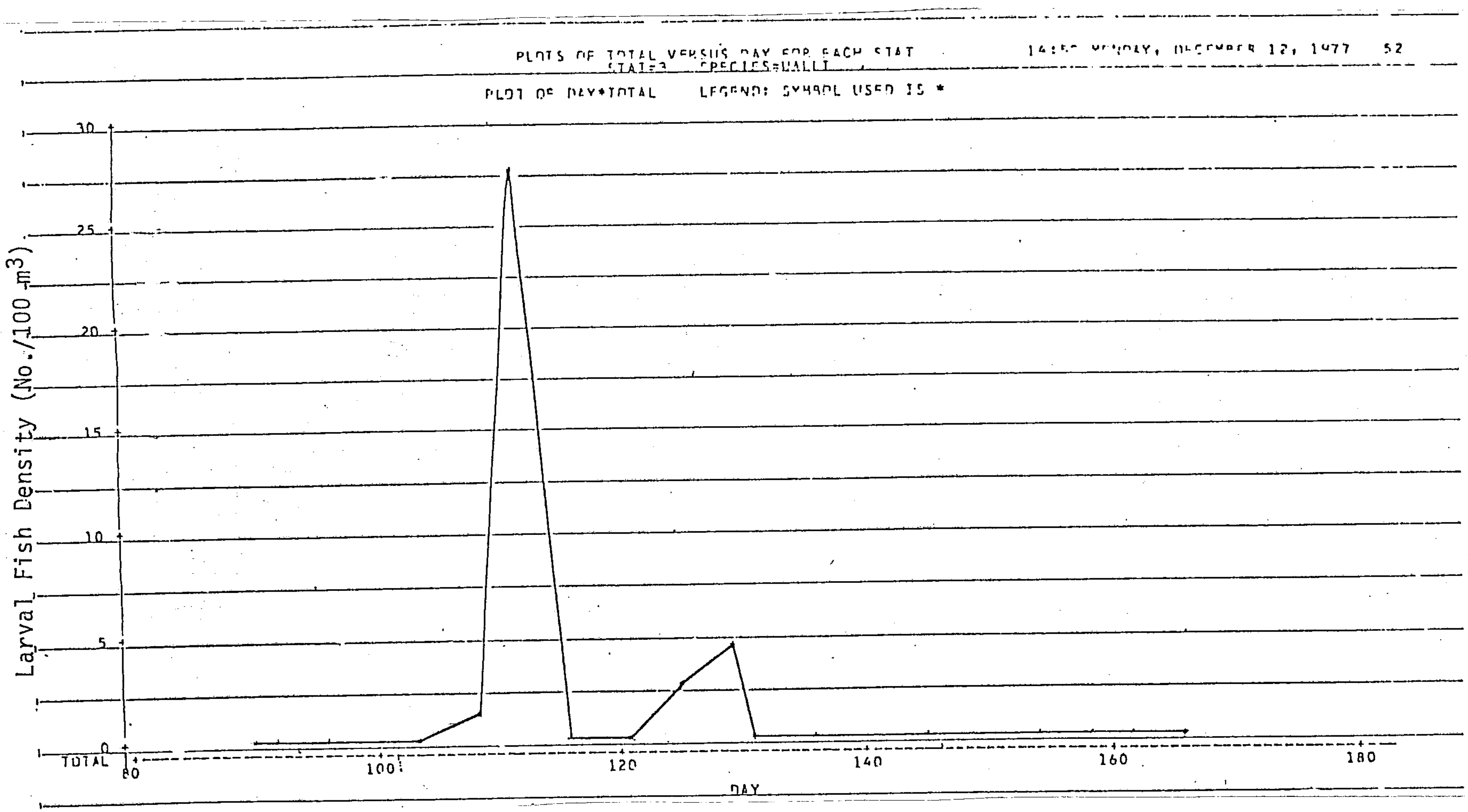


Figure C5. Walleye larvae density at station D-2.

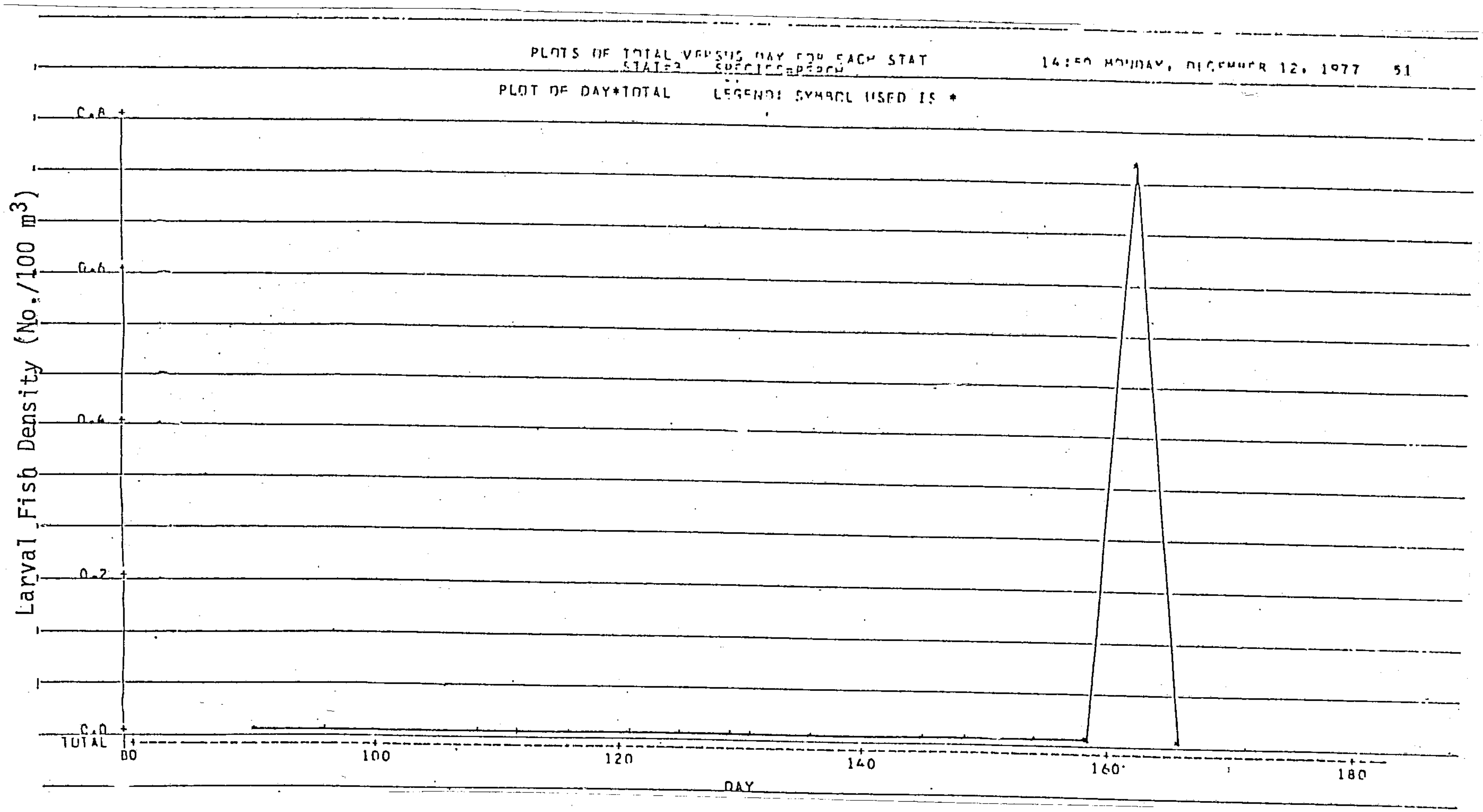


Figure C6. Yellow perch larvae density at station D-2.

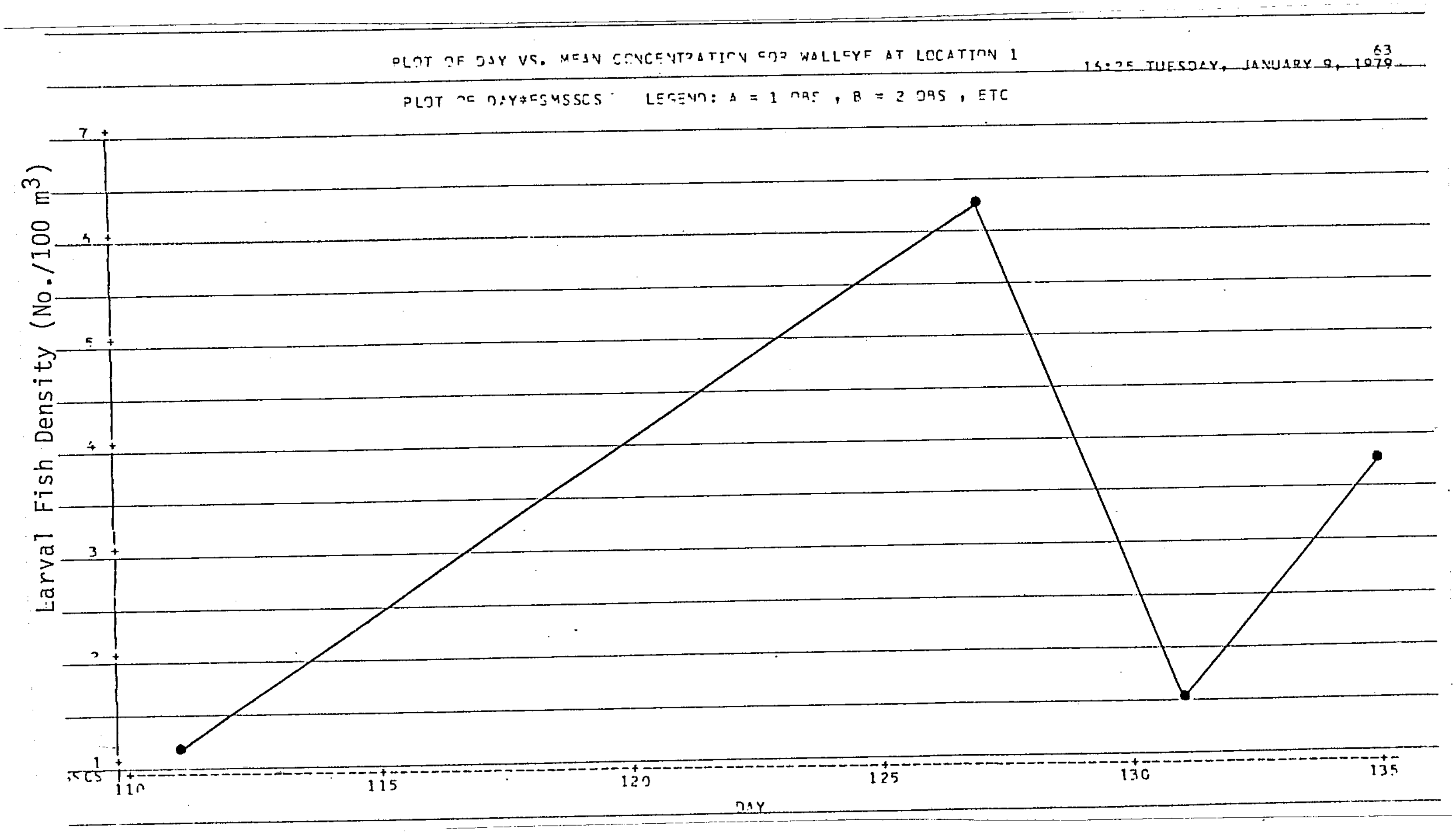


Figure C7. Walleye larvae density at location 1.

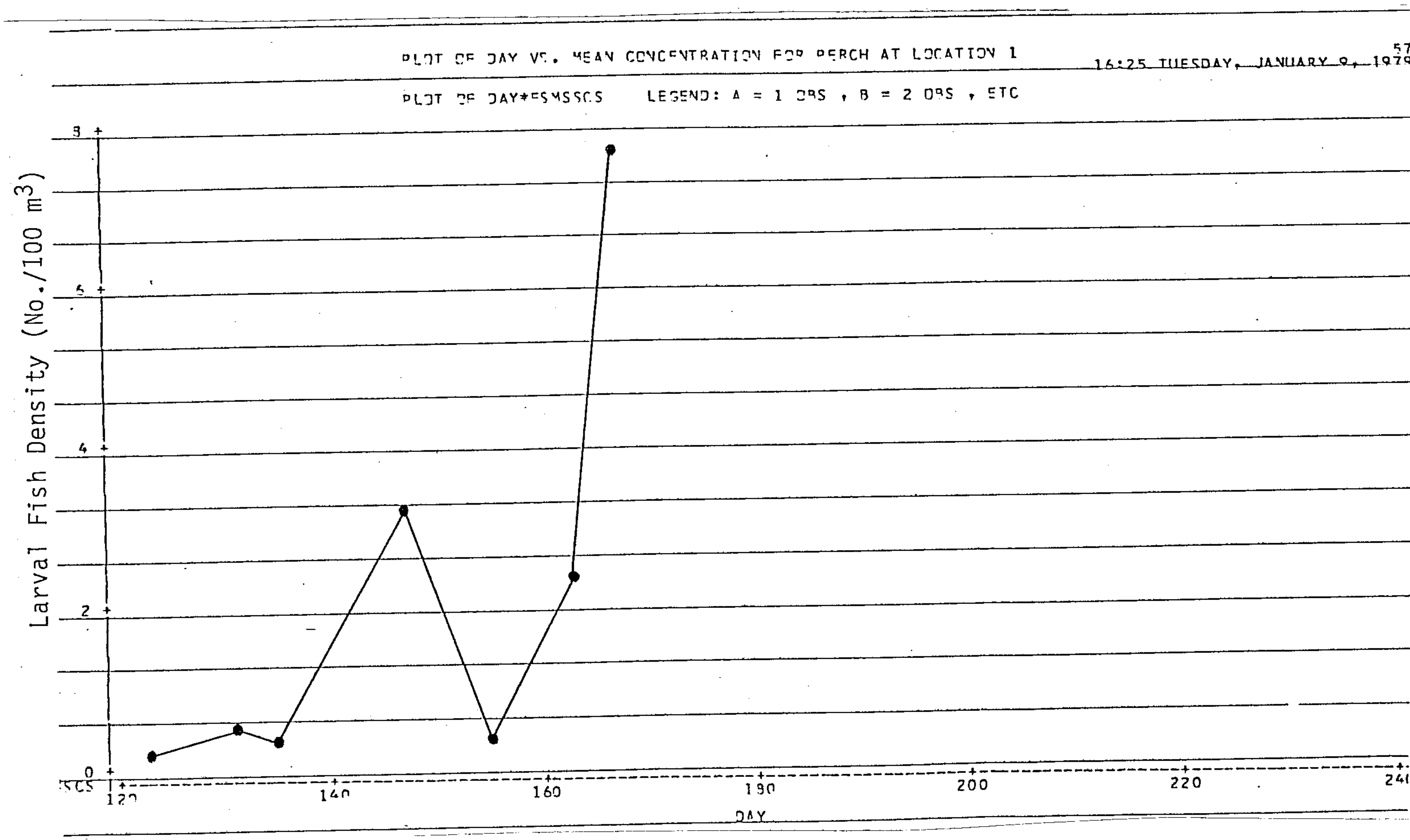


Figure C8. Yellow perch larvae density at location 1.

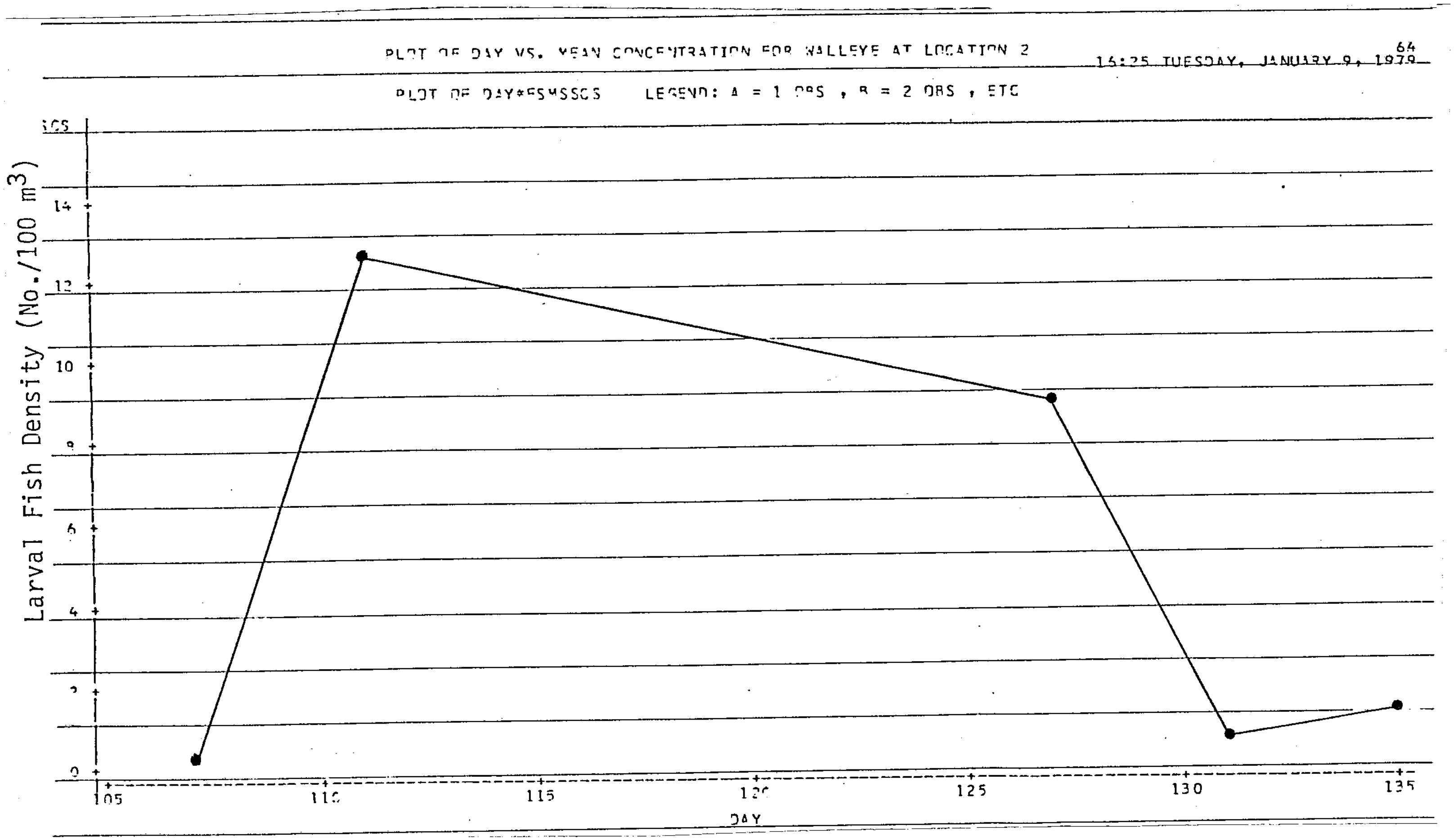


Figure C9. Walleye larvae concentration at location 2.

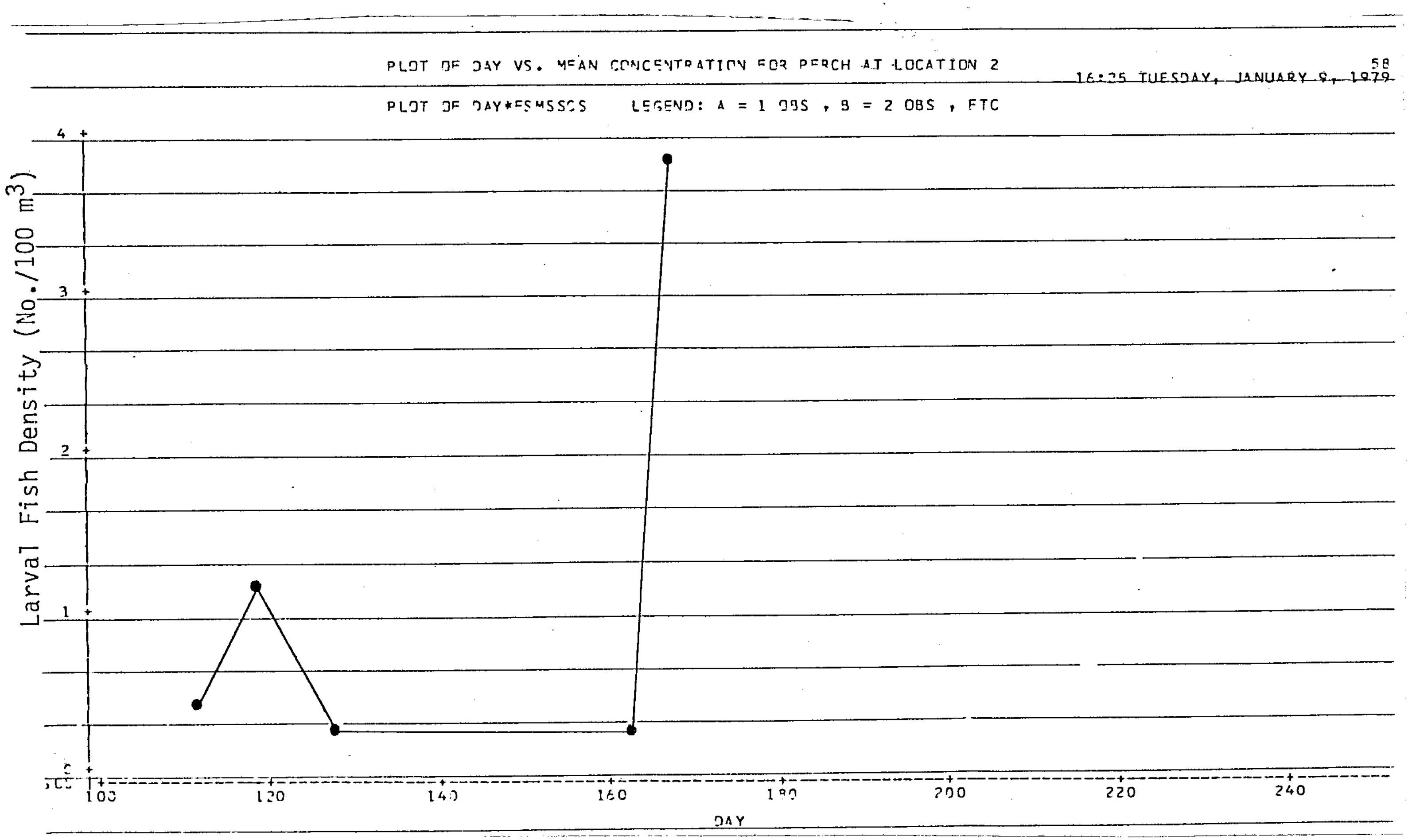


Figure C10. Yellow perch larvae density at location 2.

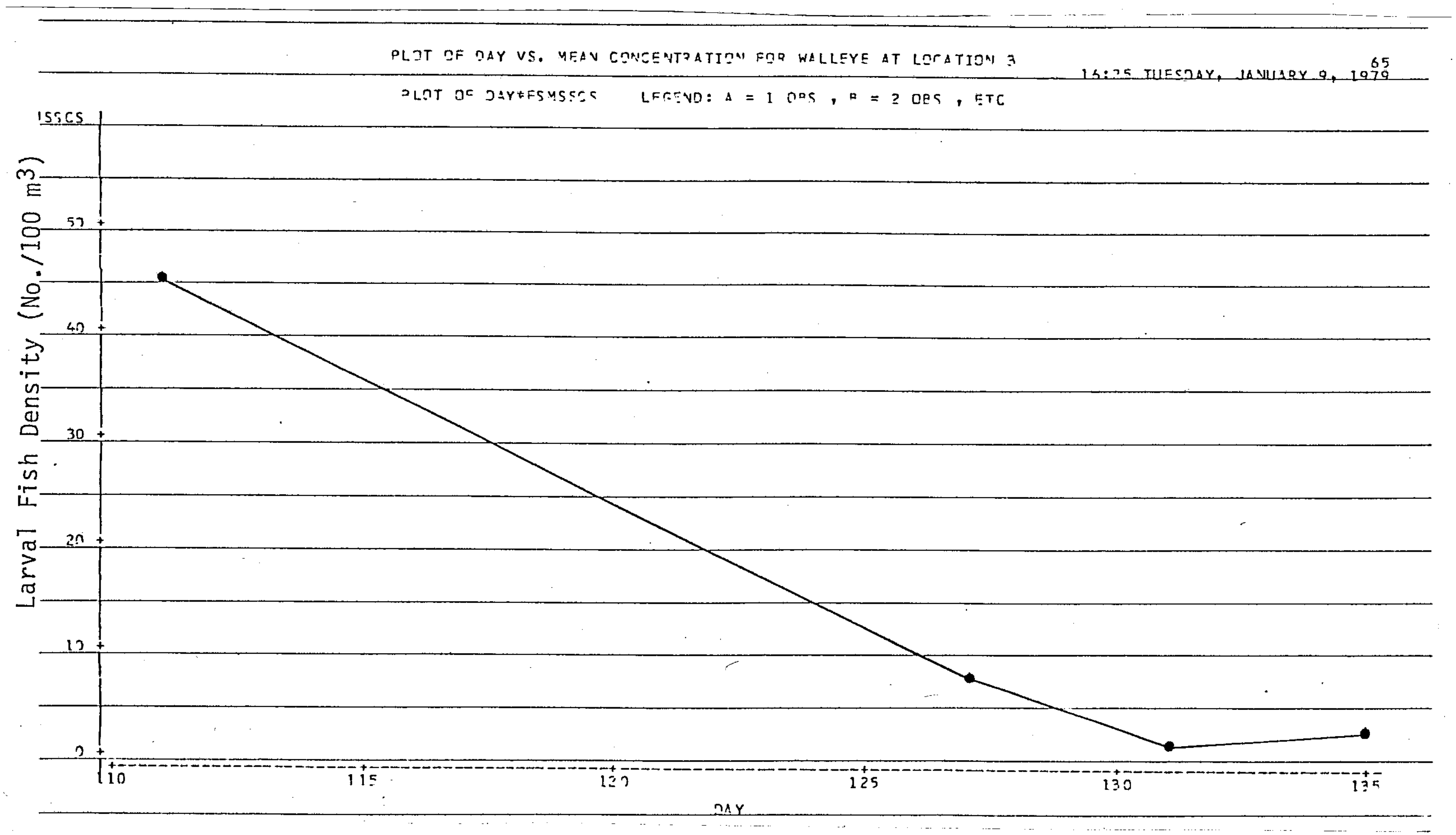


Figure C11. Walleye larvae density at location 3.

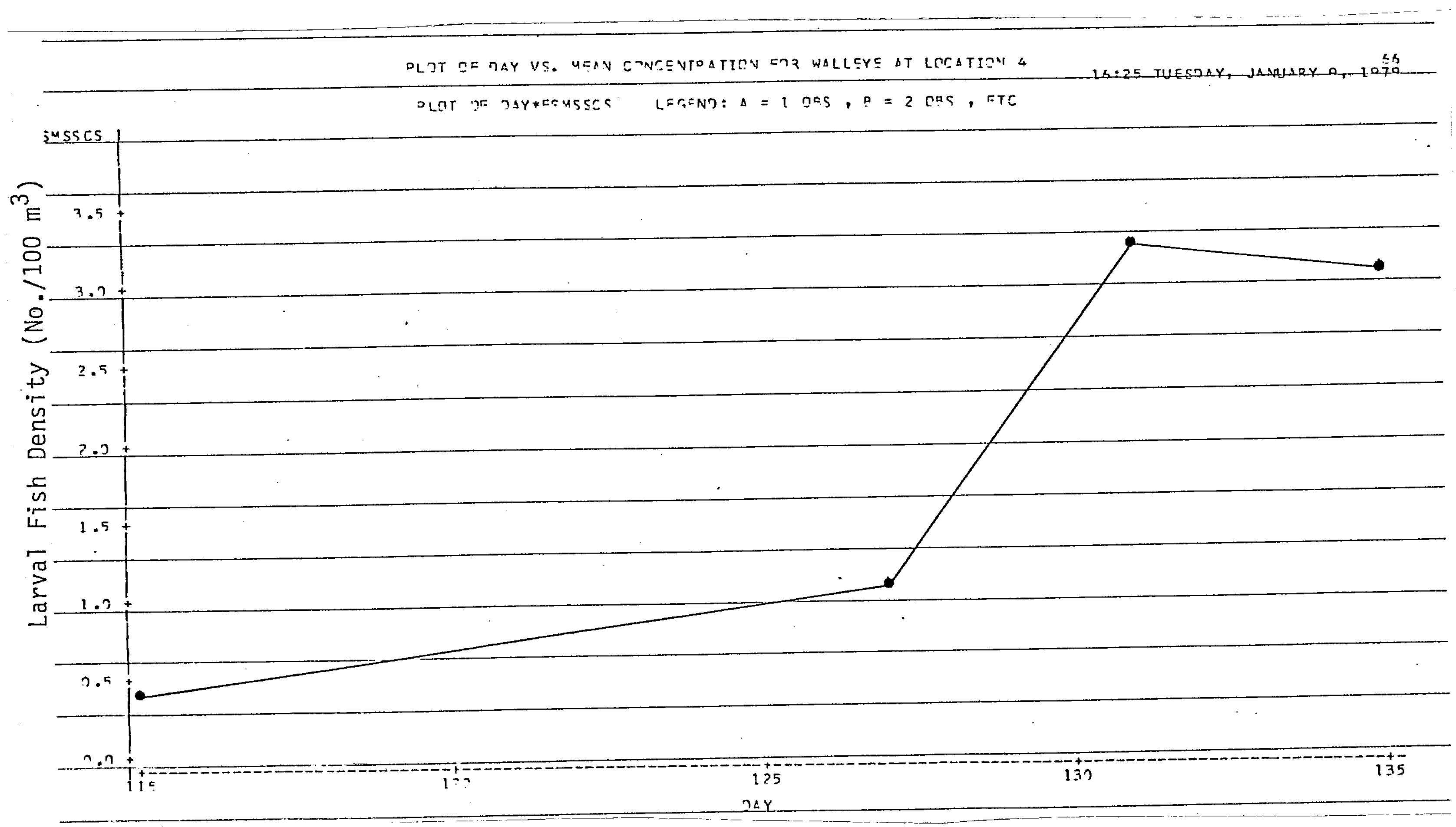


Figure C13. Walleye larvae density at location 4.

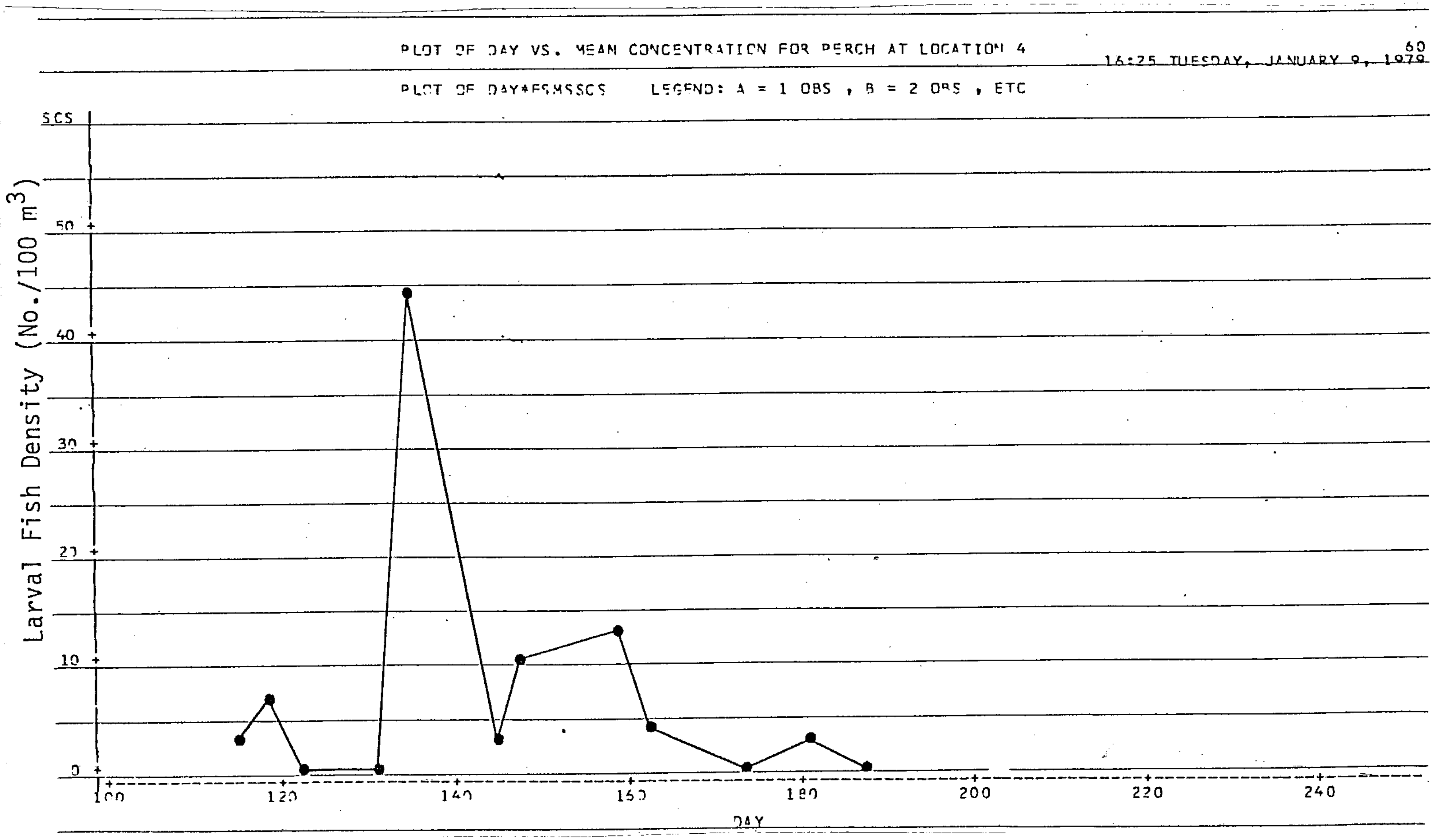


Figure C14. Yellow perch larvae density at location 4.

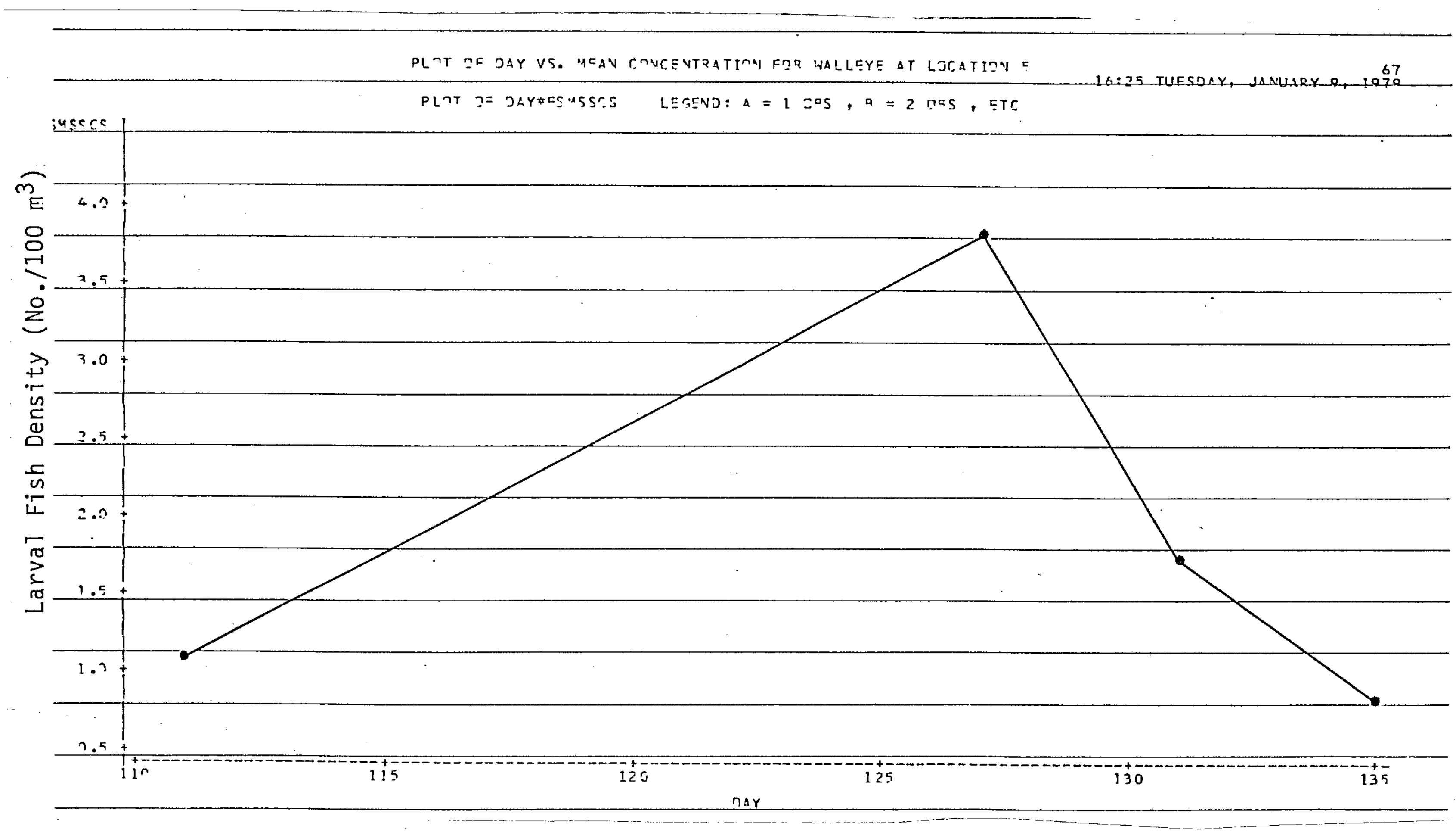


Figure C15. Walleye larvae density at location 5.

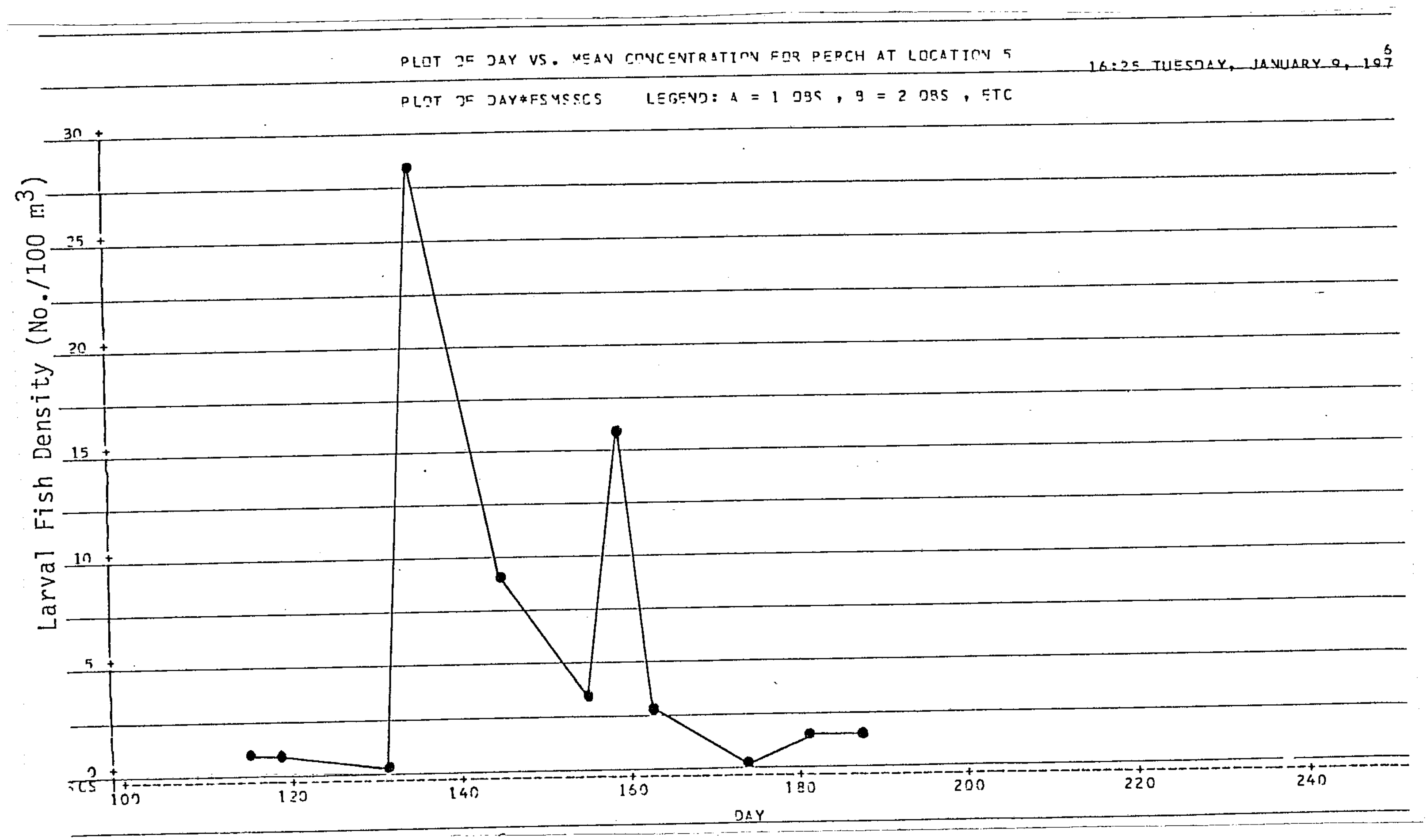


Figure C16. Yellow perch larvae density at location 5.

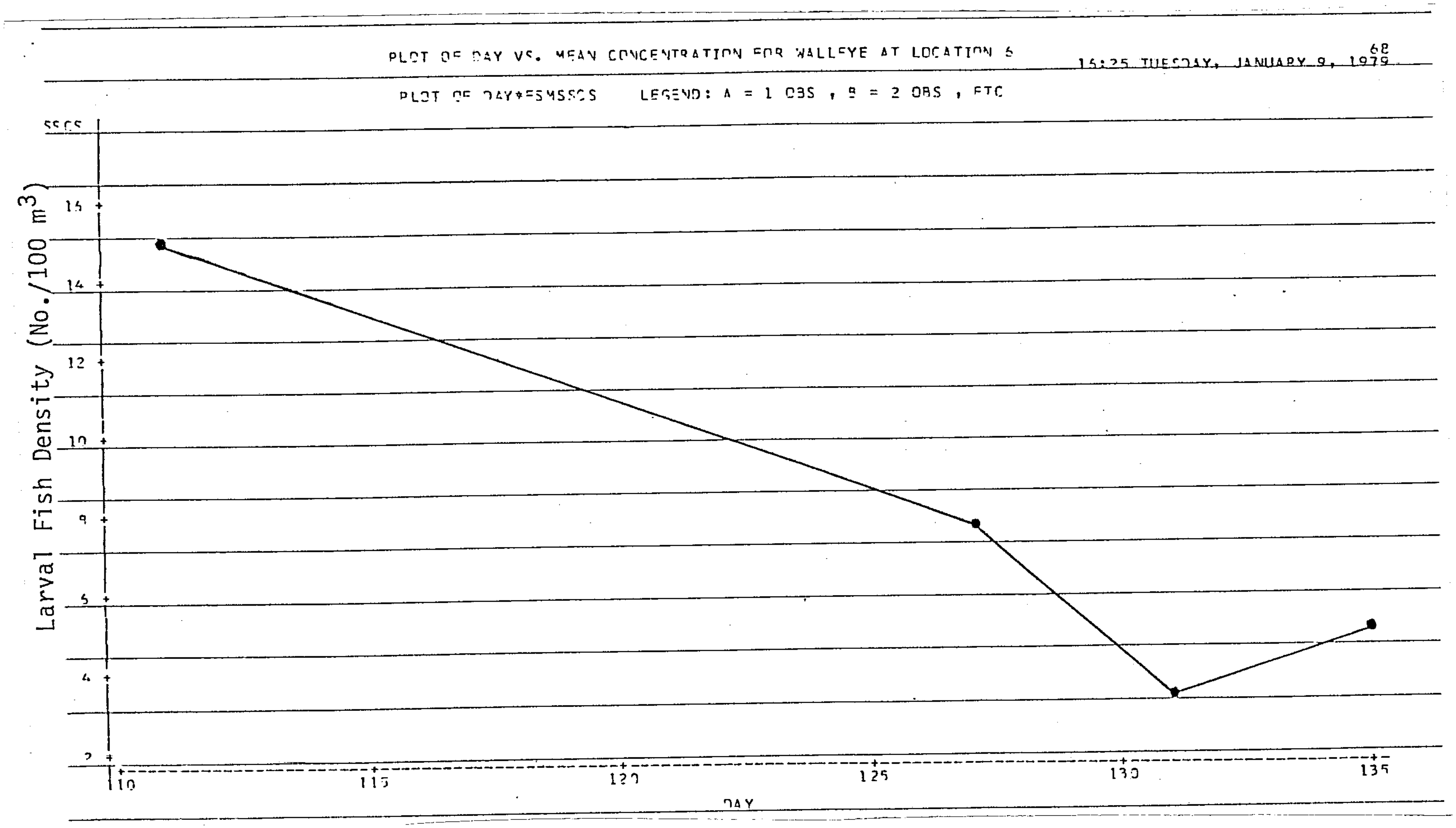


Figure C17. Walleye larvae density at location 6.

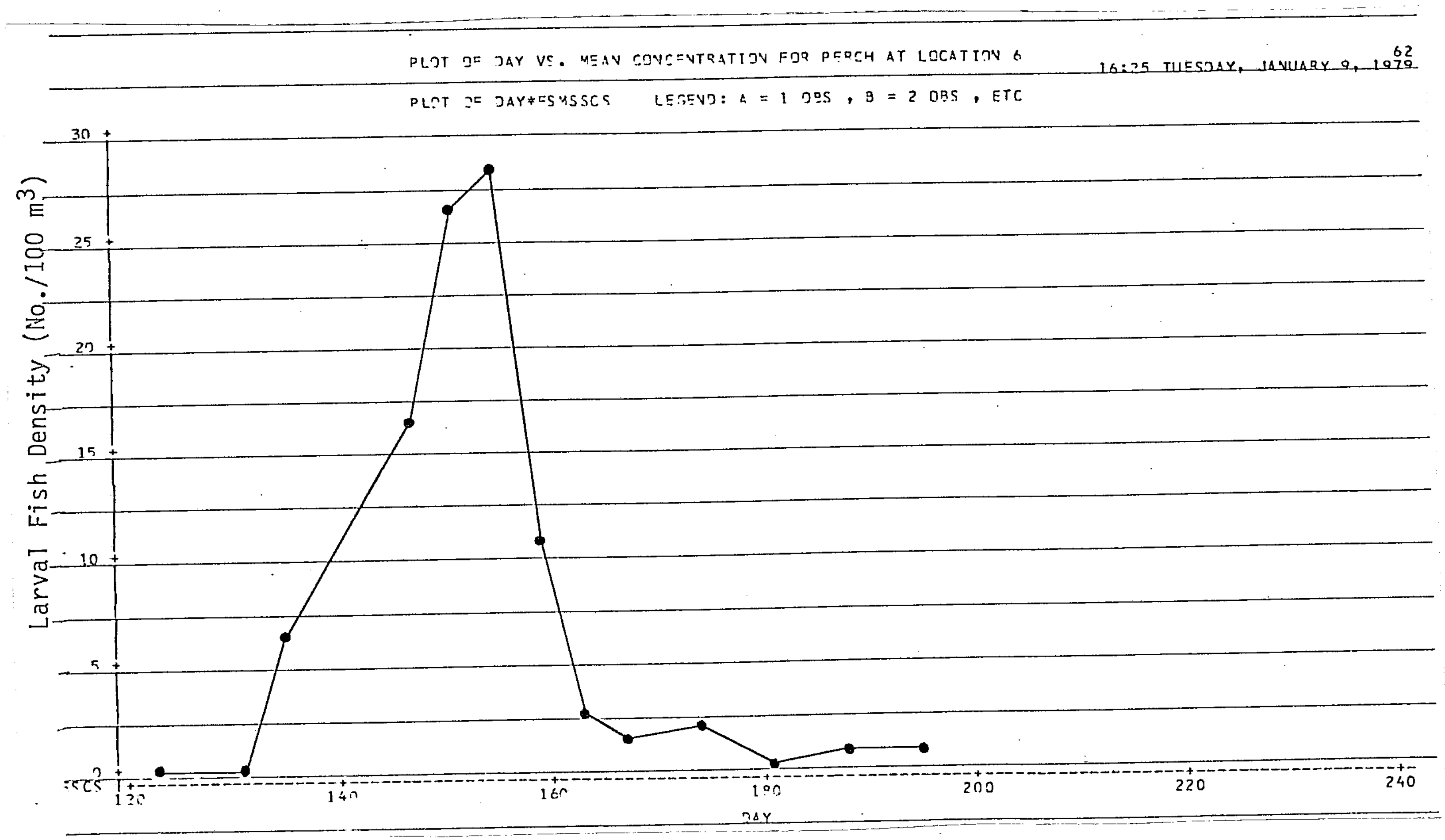


Figure C18. Yellow perch larvae density at location 6.

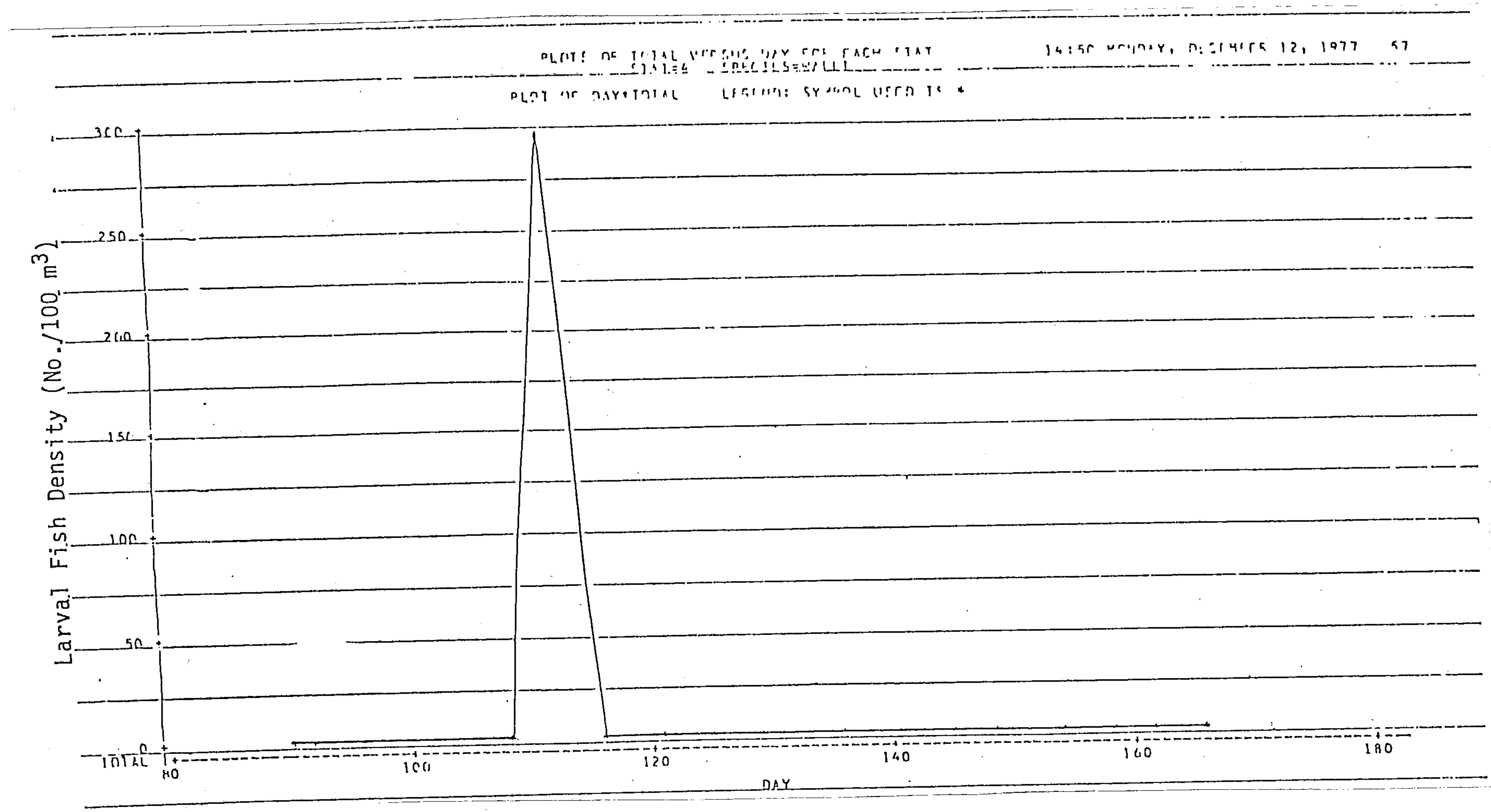


Figure C19. Walleye larvae density at station D-1.

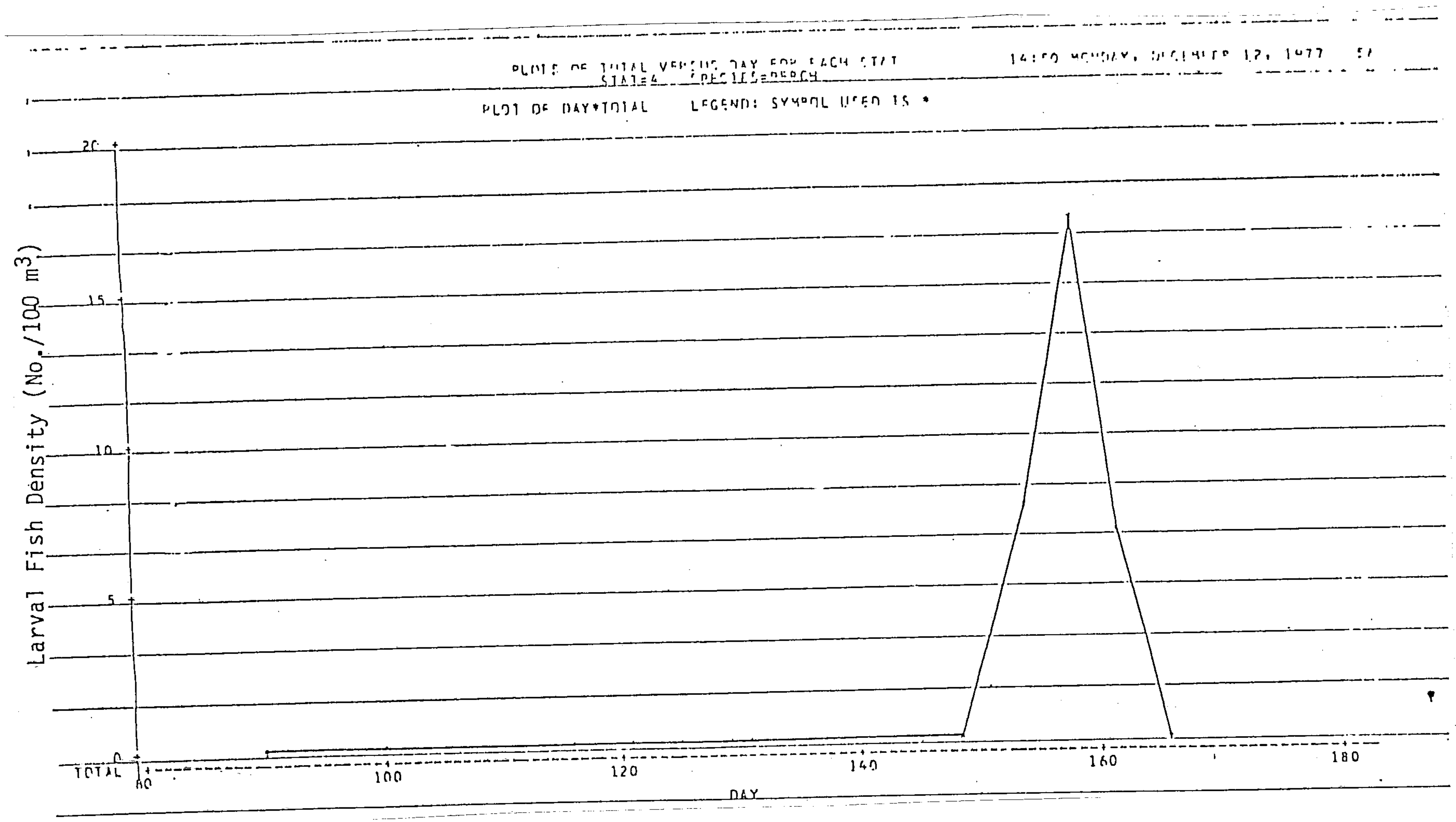


Figure C20. Yellow perch larvae density at station D-1.

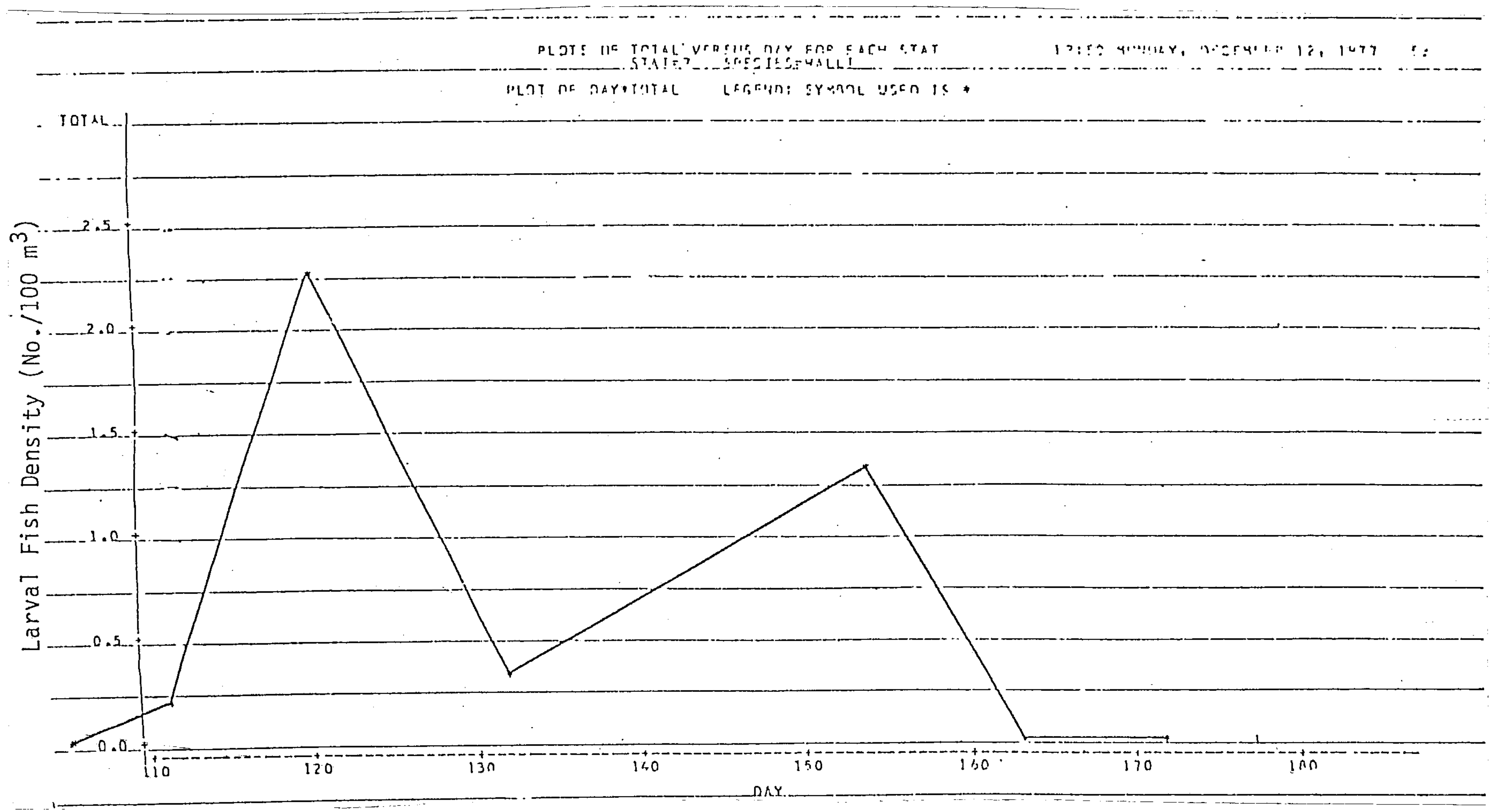


Figure C21. Walleye larvae density at station 7.

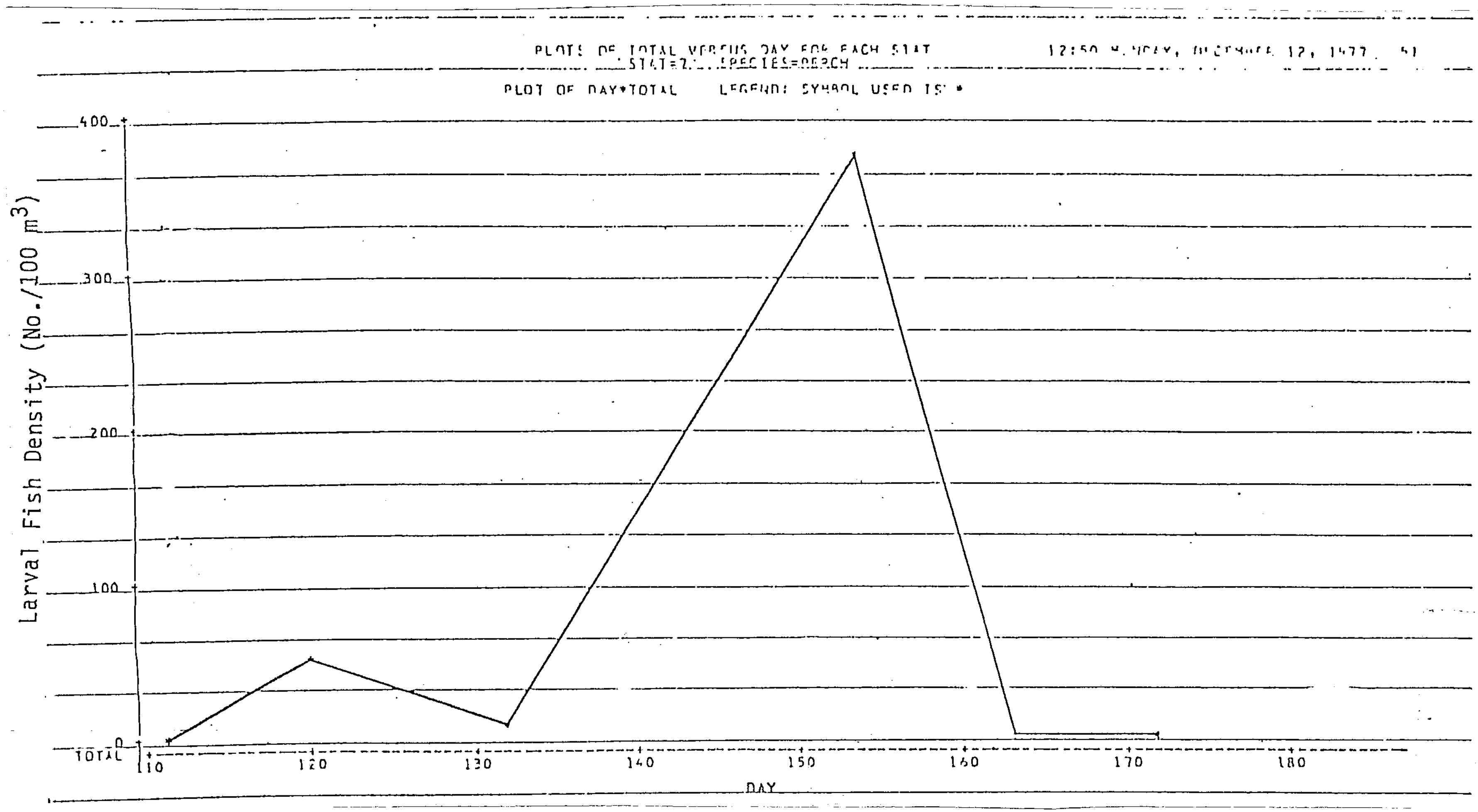


Figure C22. Yellow perch larvae density at station 7.

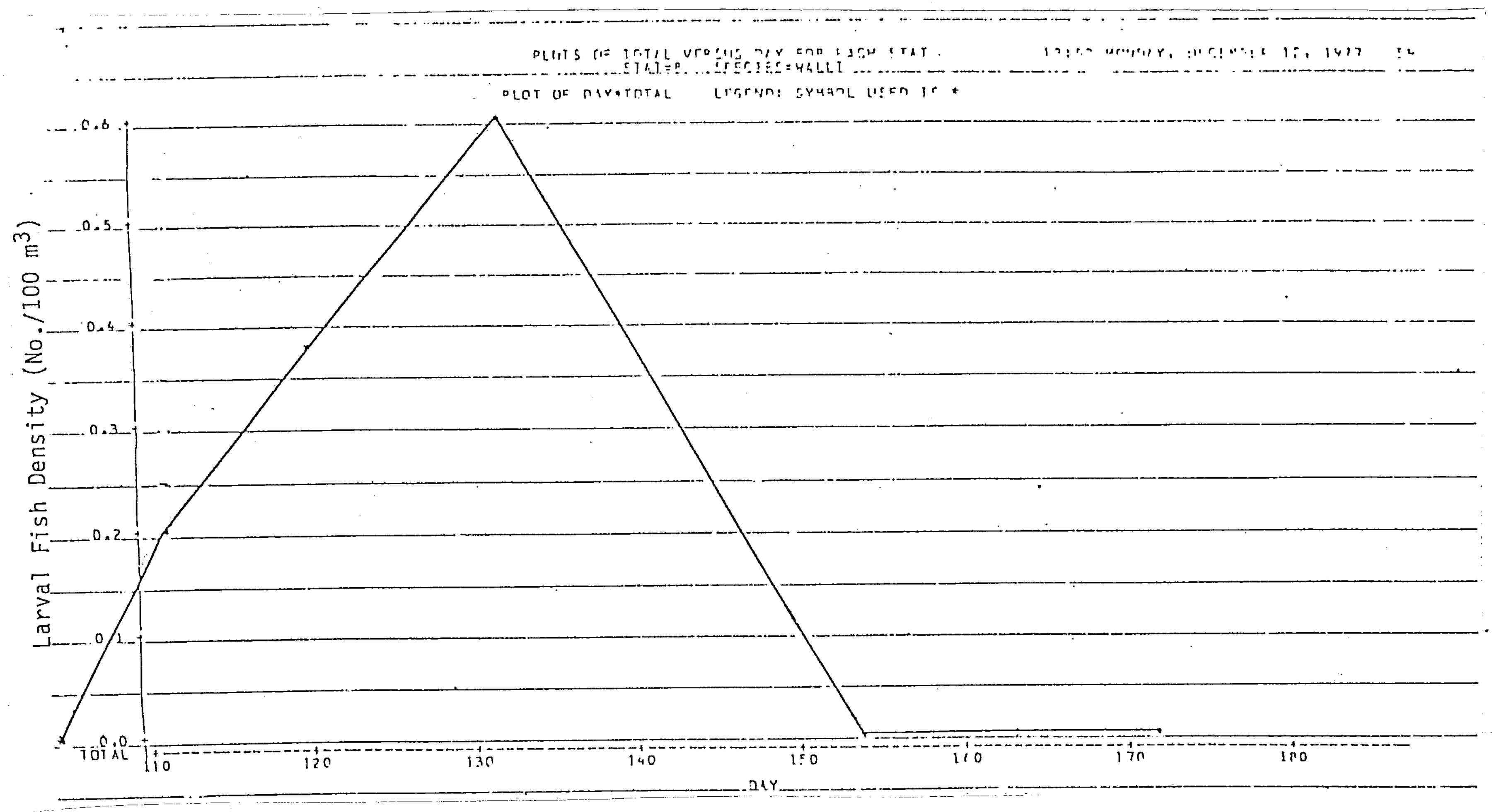


Figure C23. Walleye larvae density at station 8.

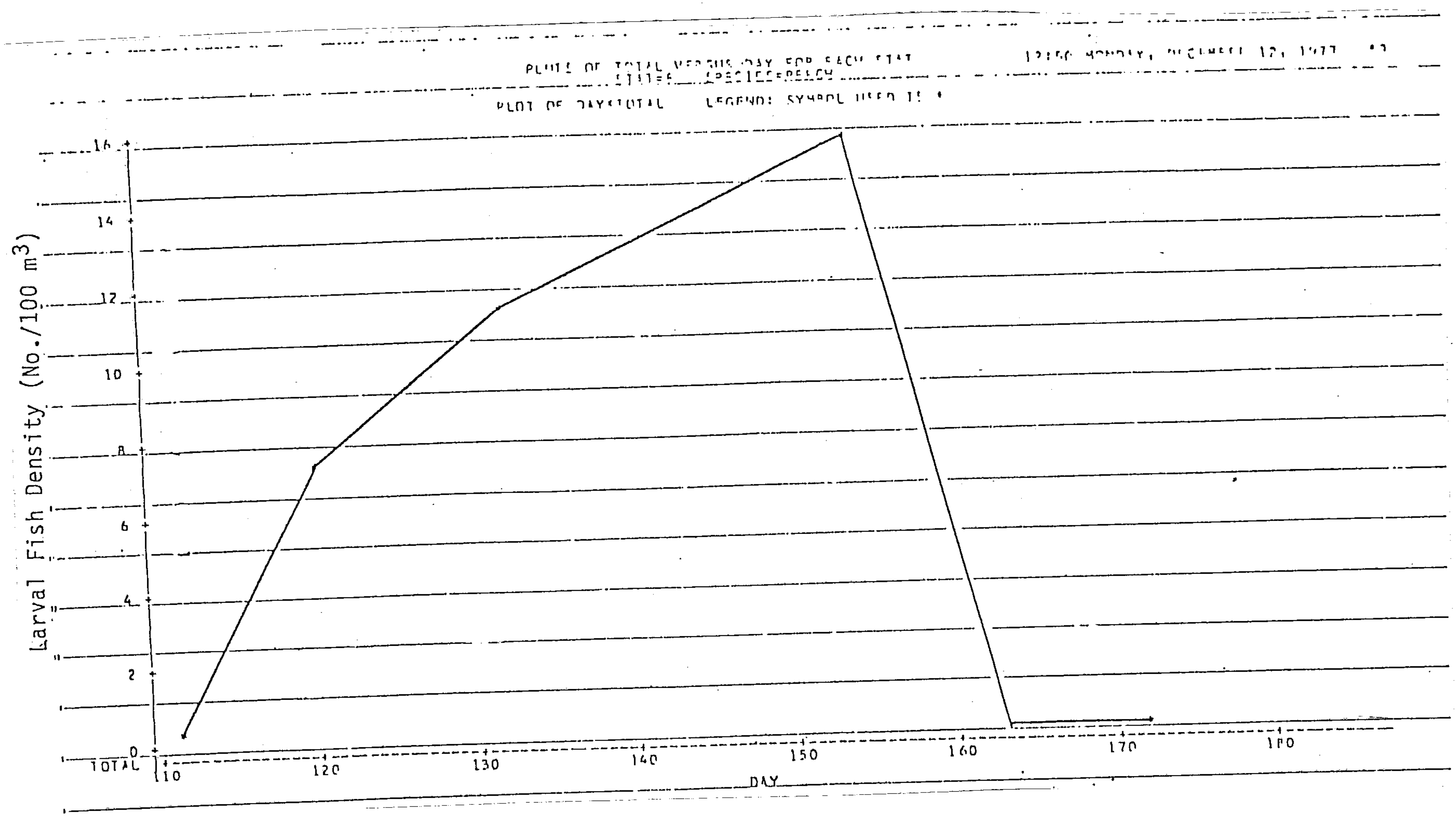


Figure C24. Yellow perch larvae density at station 8.

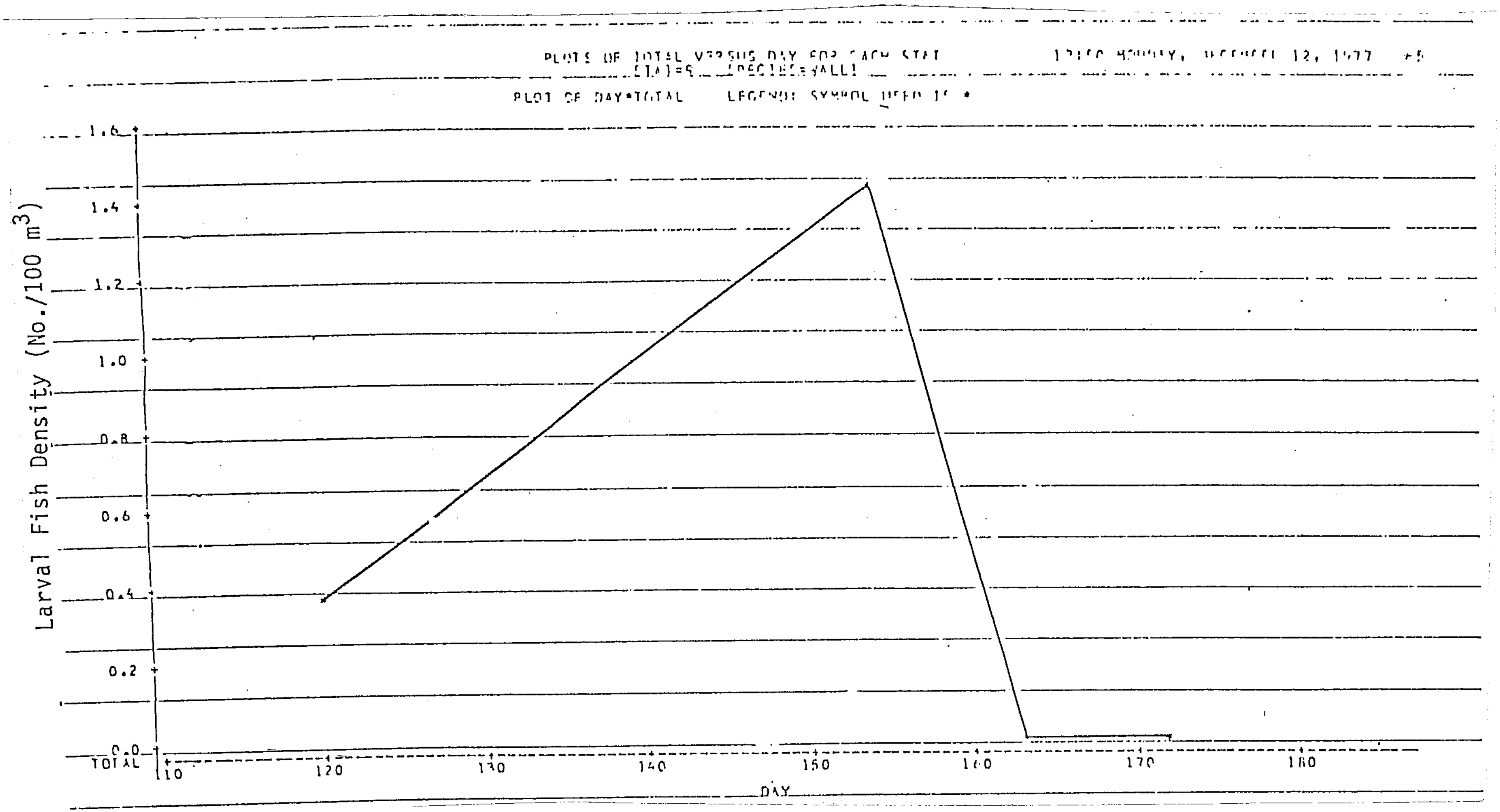


Figure C25. Walleye larvae density at station 9.

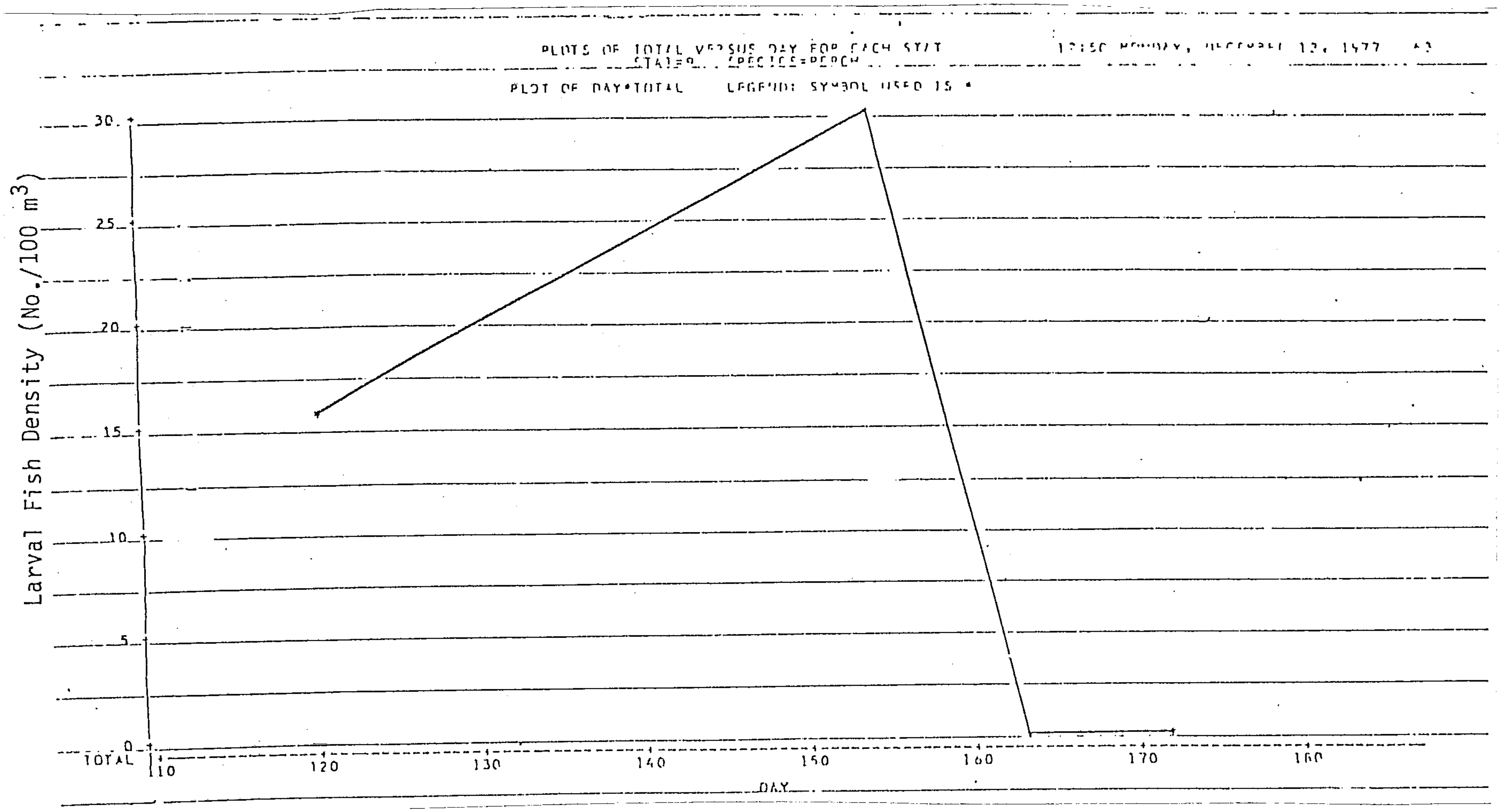


Figure C26. Yellow perch larvae density at station 9.

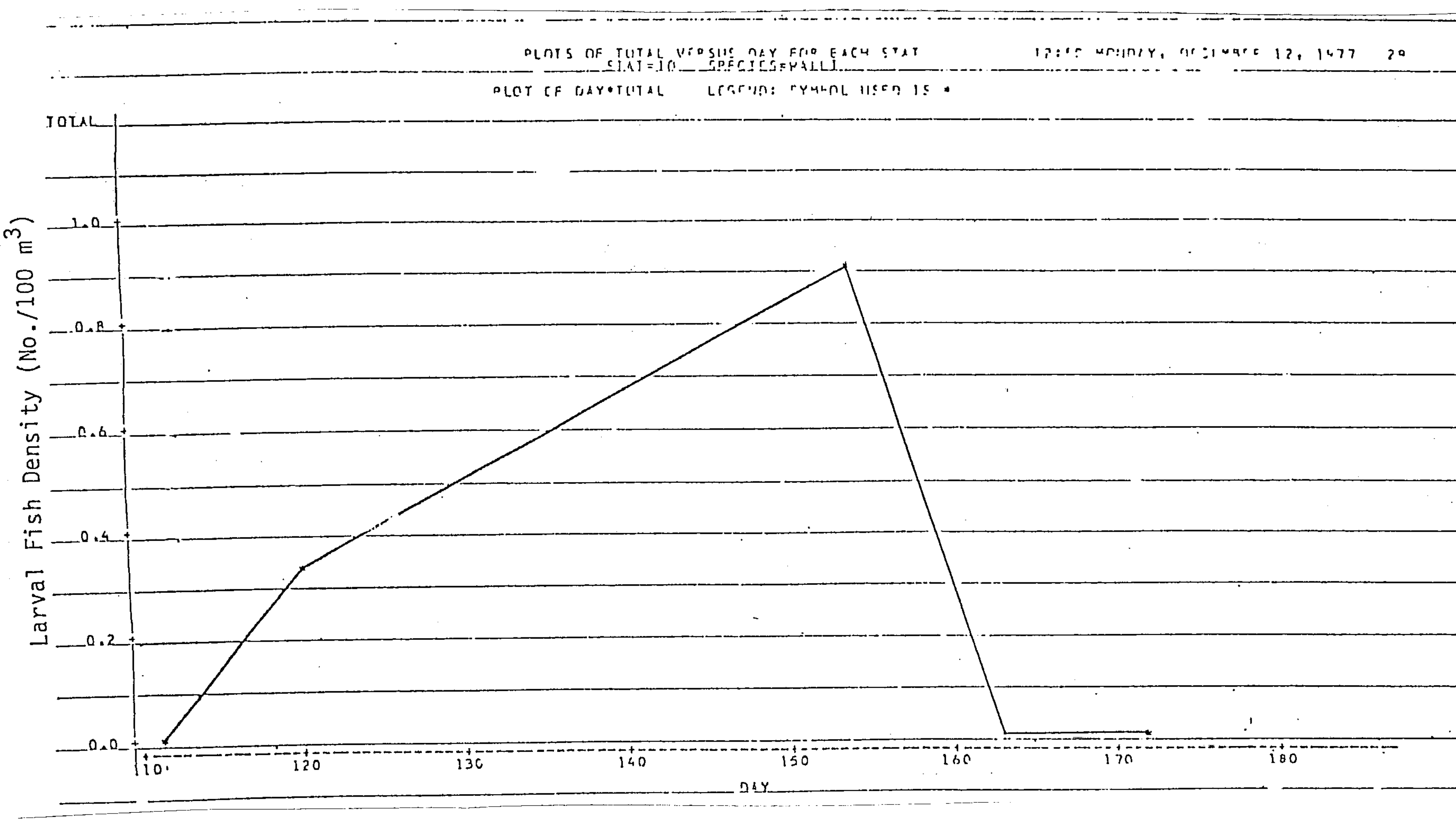


Figure C27. Walleye larvae density at station 10.

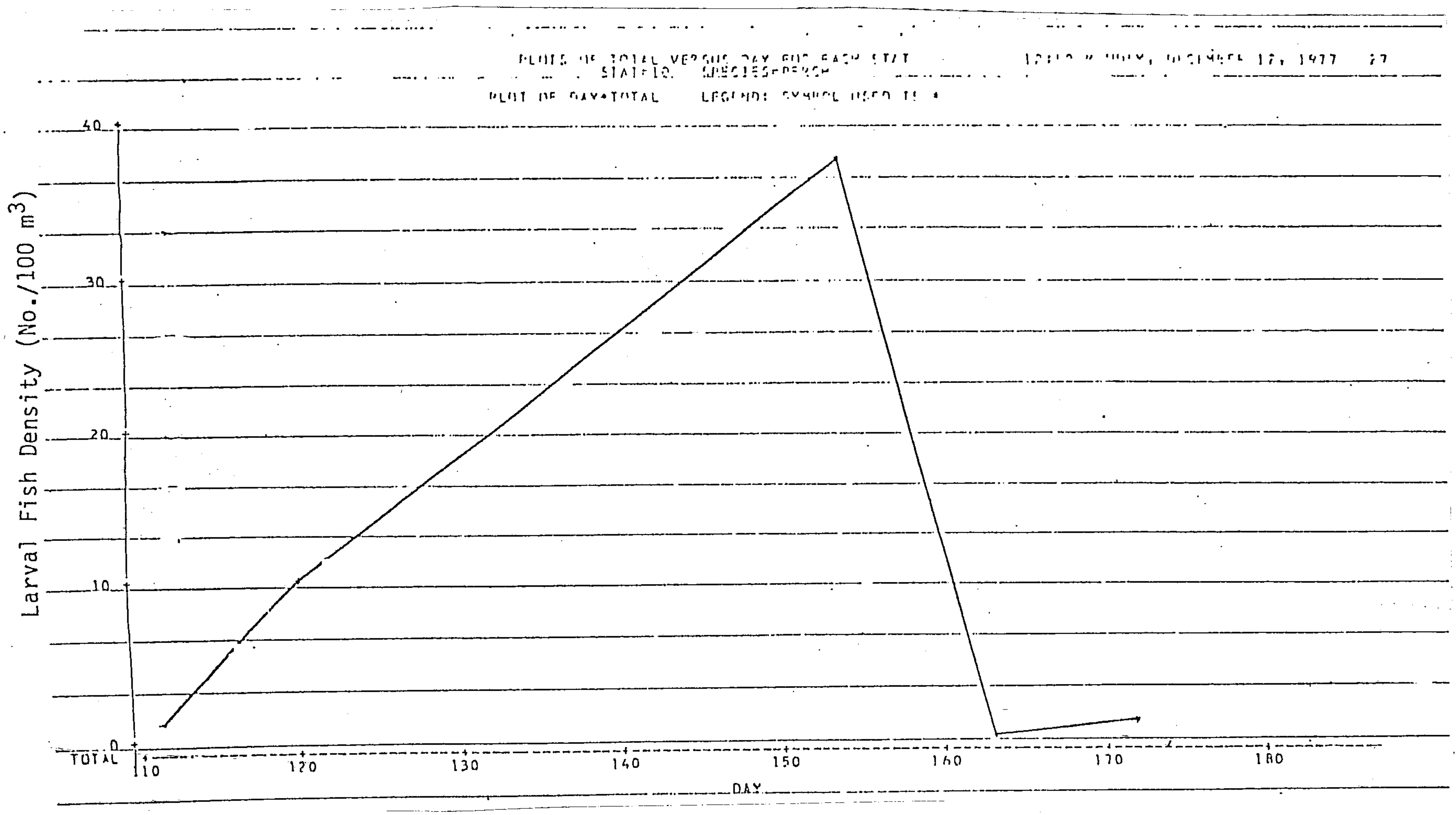


Figure C28. Yellow perch larvae density at station 10.

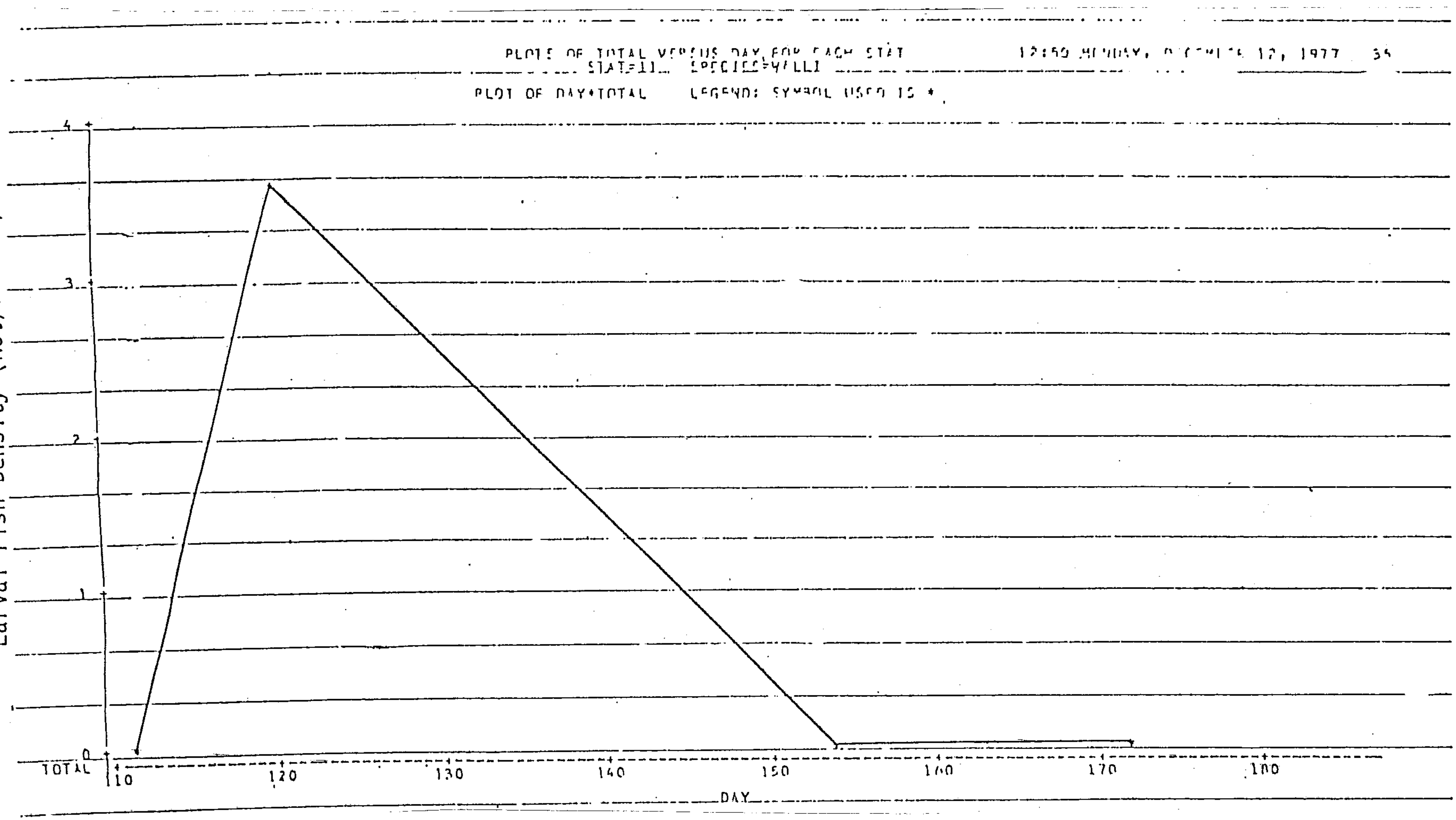


Figure C29. Walleye larvae density at station 11.

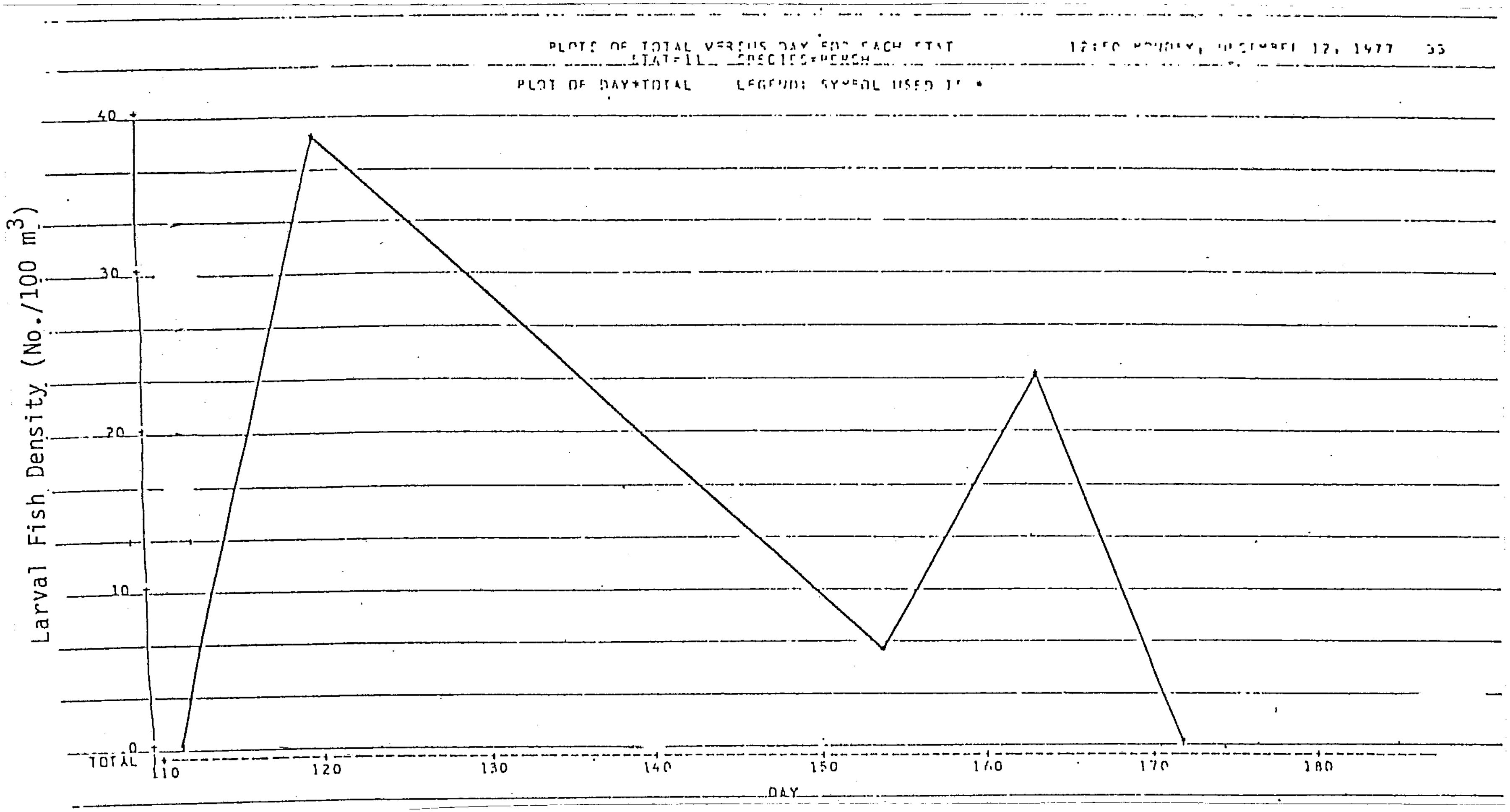


Figure C30. Yellow perch larvae density at station 11.

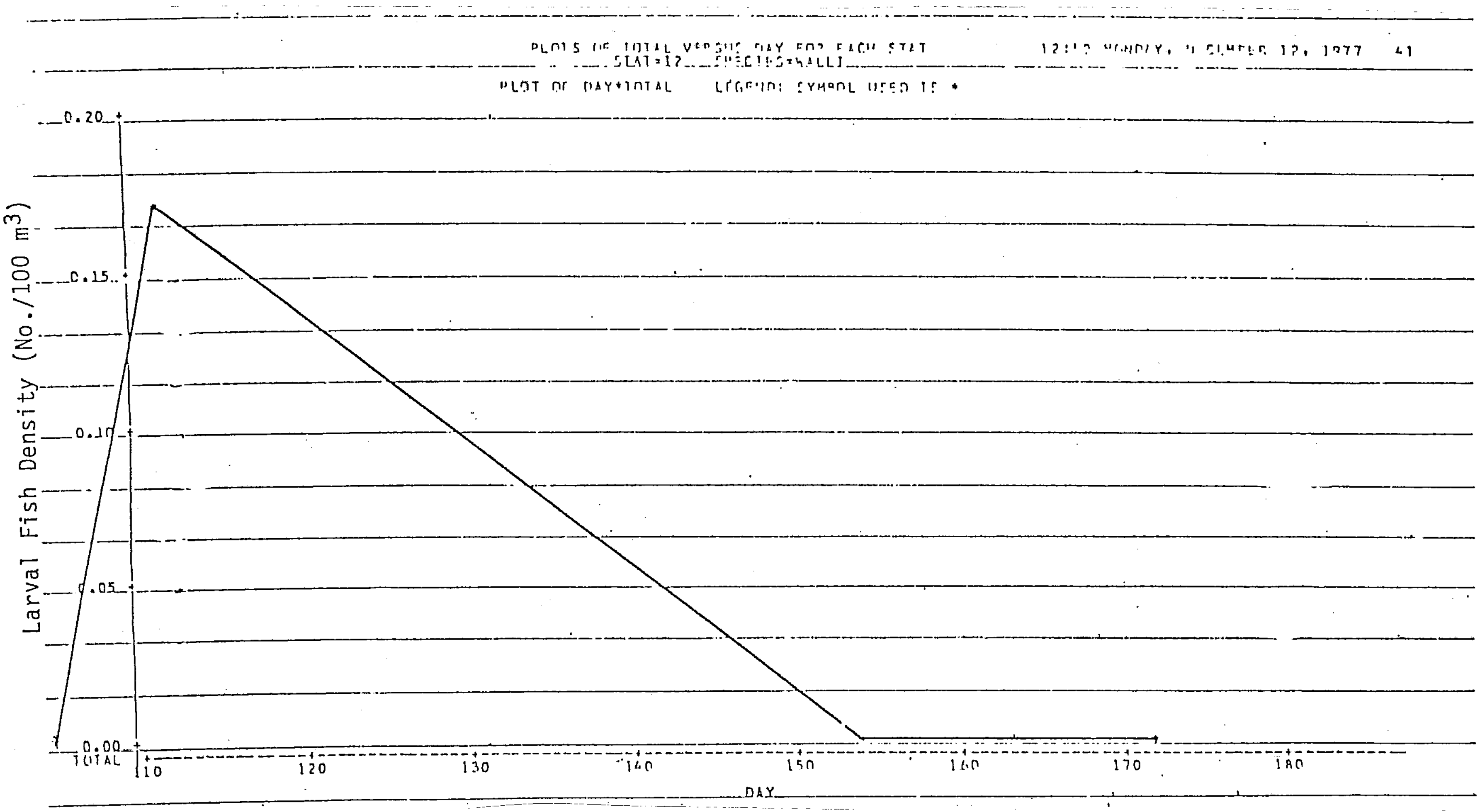


Figure C31. Walleye larvae density at station 12.

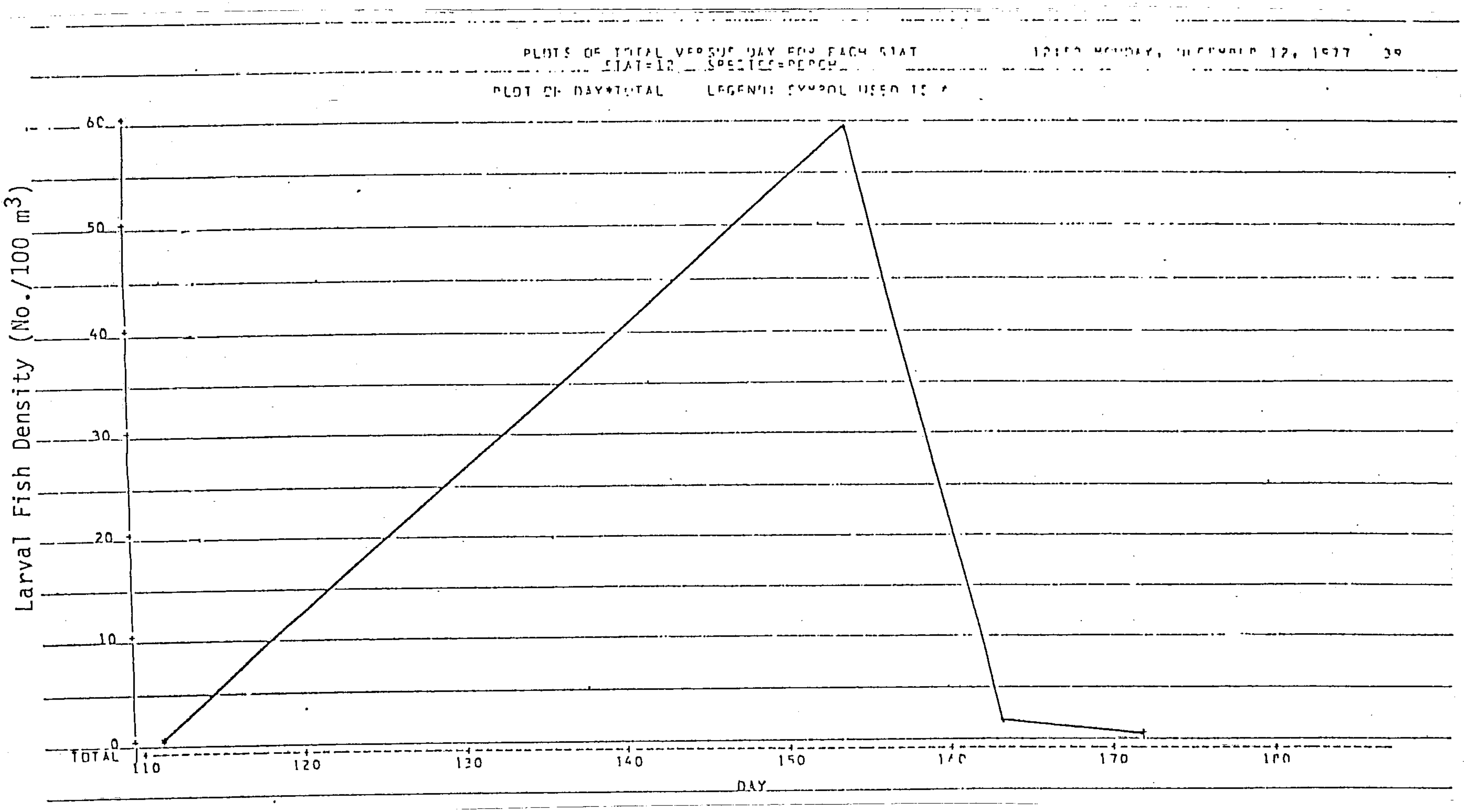


Figure C32. Yellow perch larvae density at station 12.

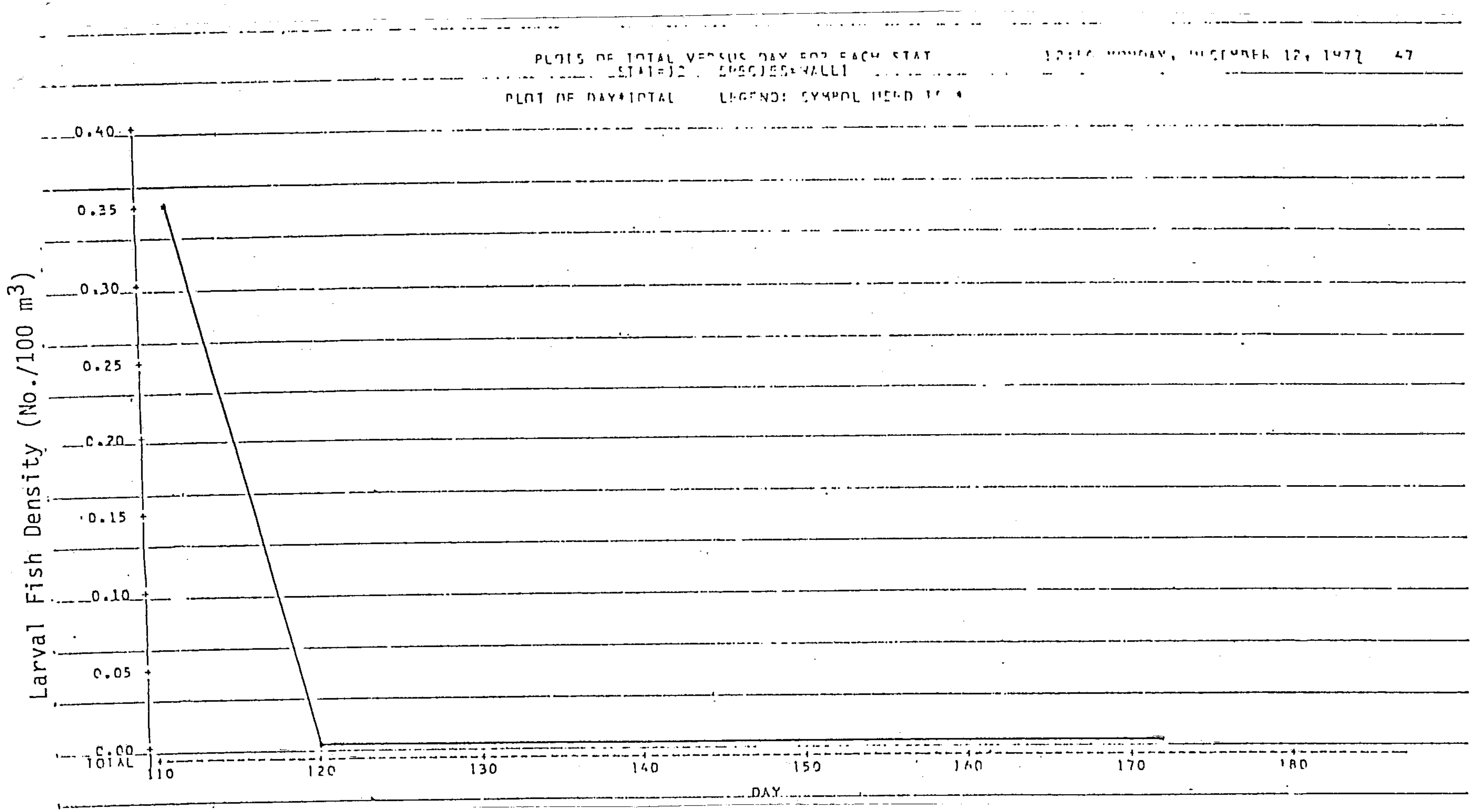


Figure C33. Walleye larvae density at station 13.

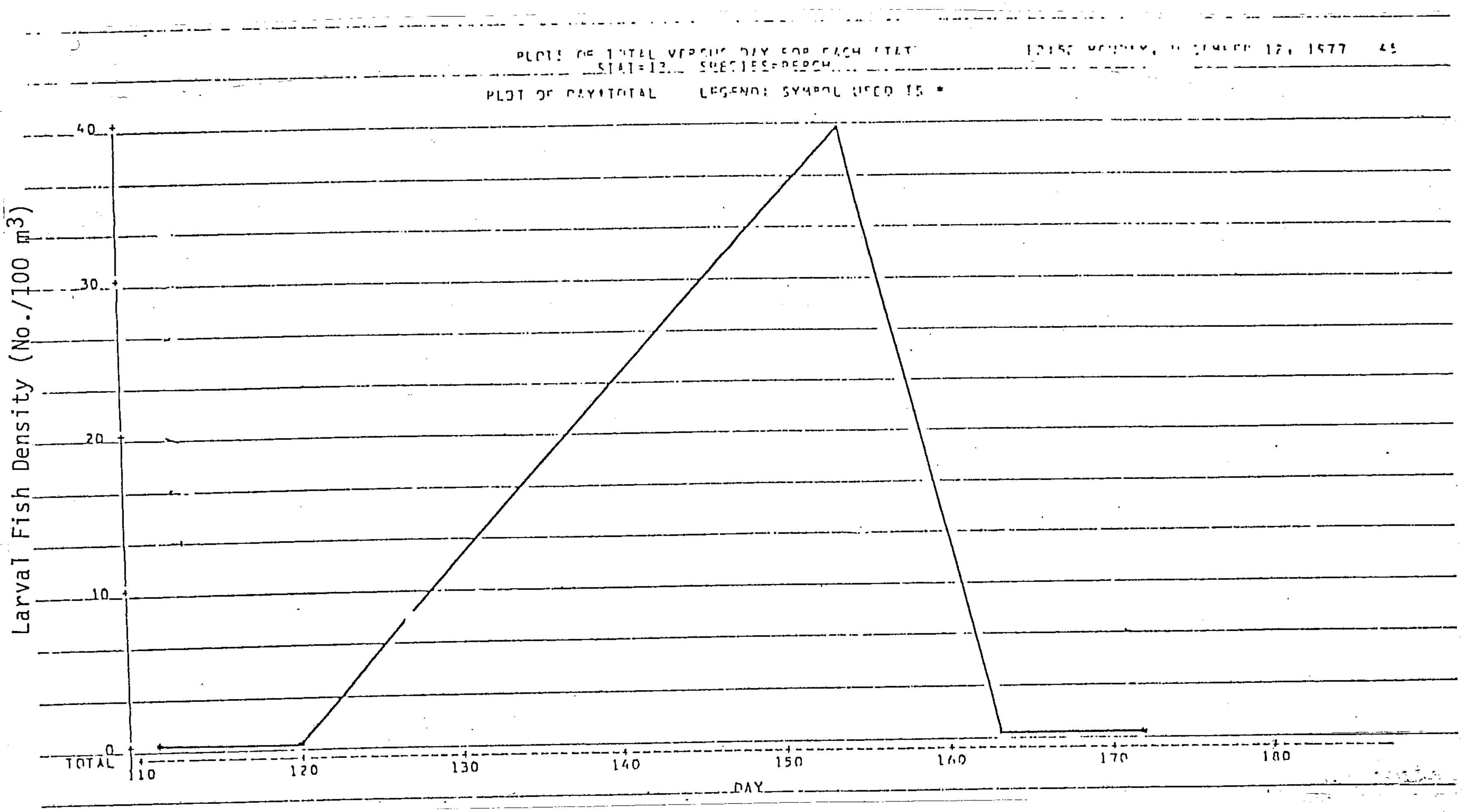


Figure C34. Yellow perch larvae density at station 13.

APPENDIX D

PLOTS OF ESTIMATED NUMBERS OF WALLEYE AND PERCH ENTRAINED AND IMPINGED AT THE ACME AND BAY SHORE POWER PLANTS

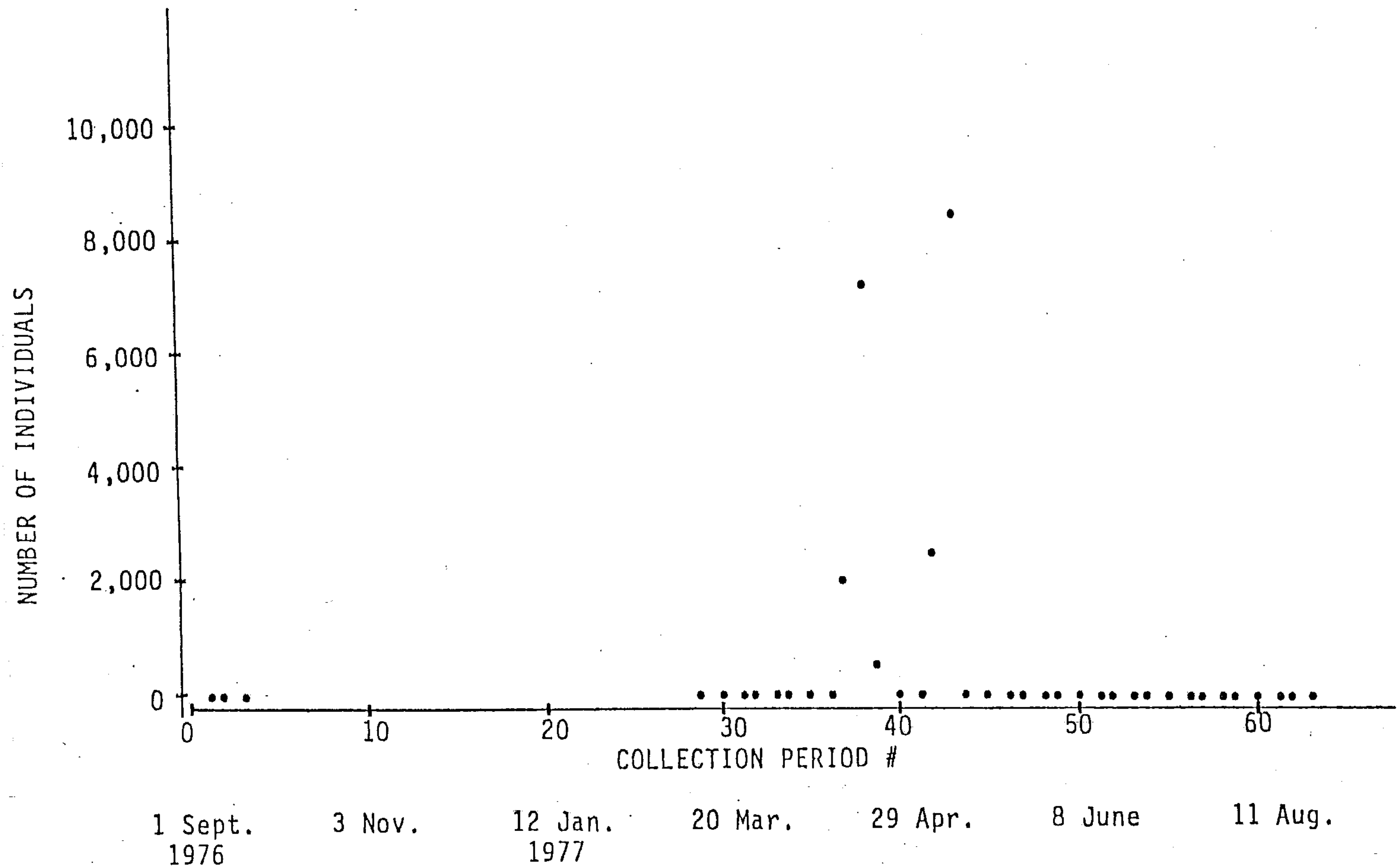


Figure D1. Number of walleye larvae entrained at the Acme Power Station from 1 September 1976 - 1 September 1977.*

*These estimates are based on concentrations observed in the intake canal (with pump samplers) multiplied by the flow through the power station.

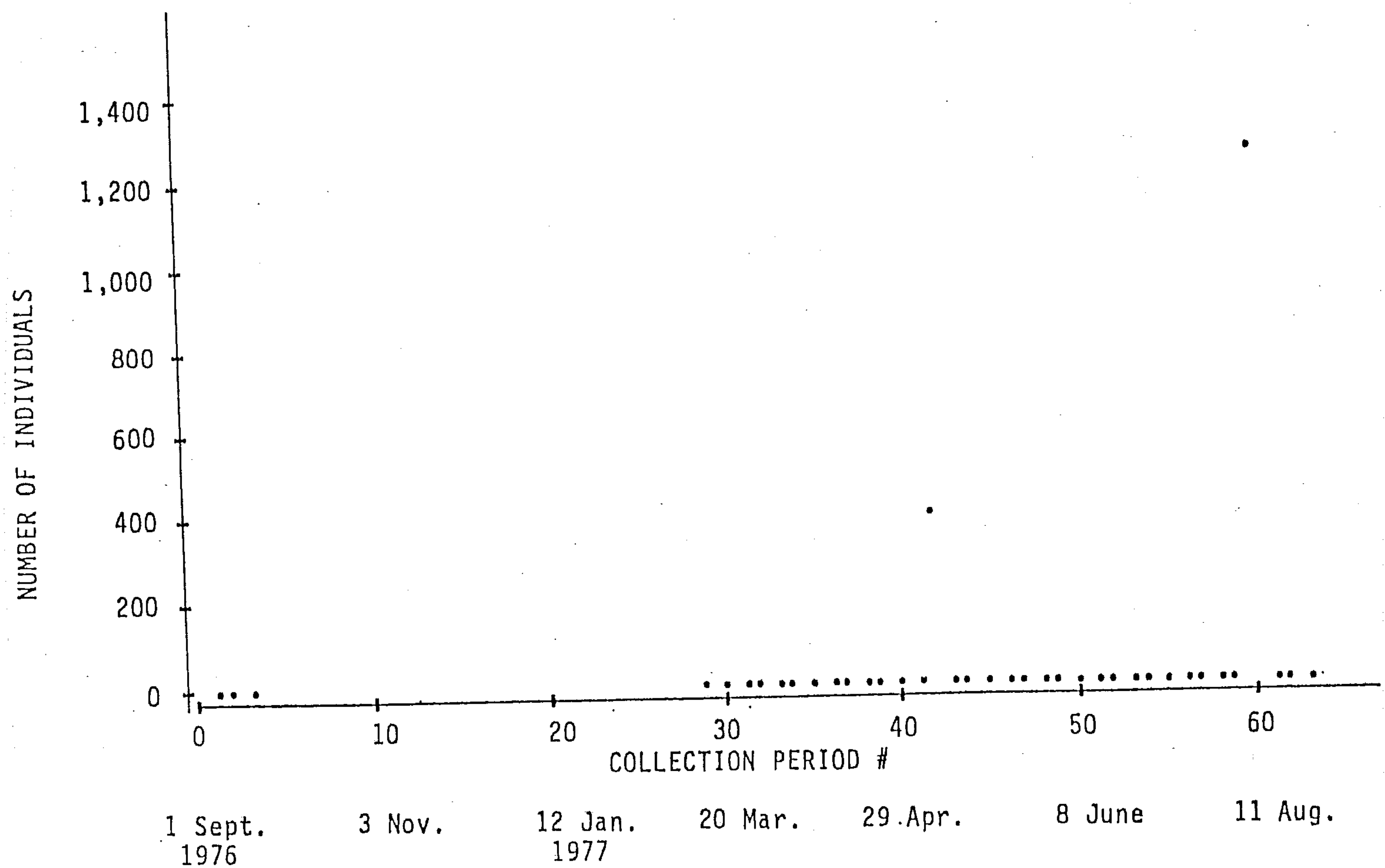


Figure D2. Number of yellow perch larvae entrained at the Acme Power Station from 1 September 1976 - 1 September 1977.*

* These are estimates based on concentrations observed in the intake canal (with pump samplers) multiplied by the flow through the power station.

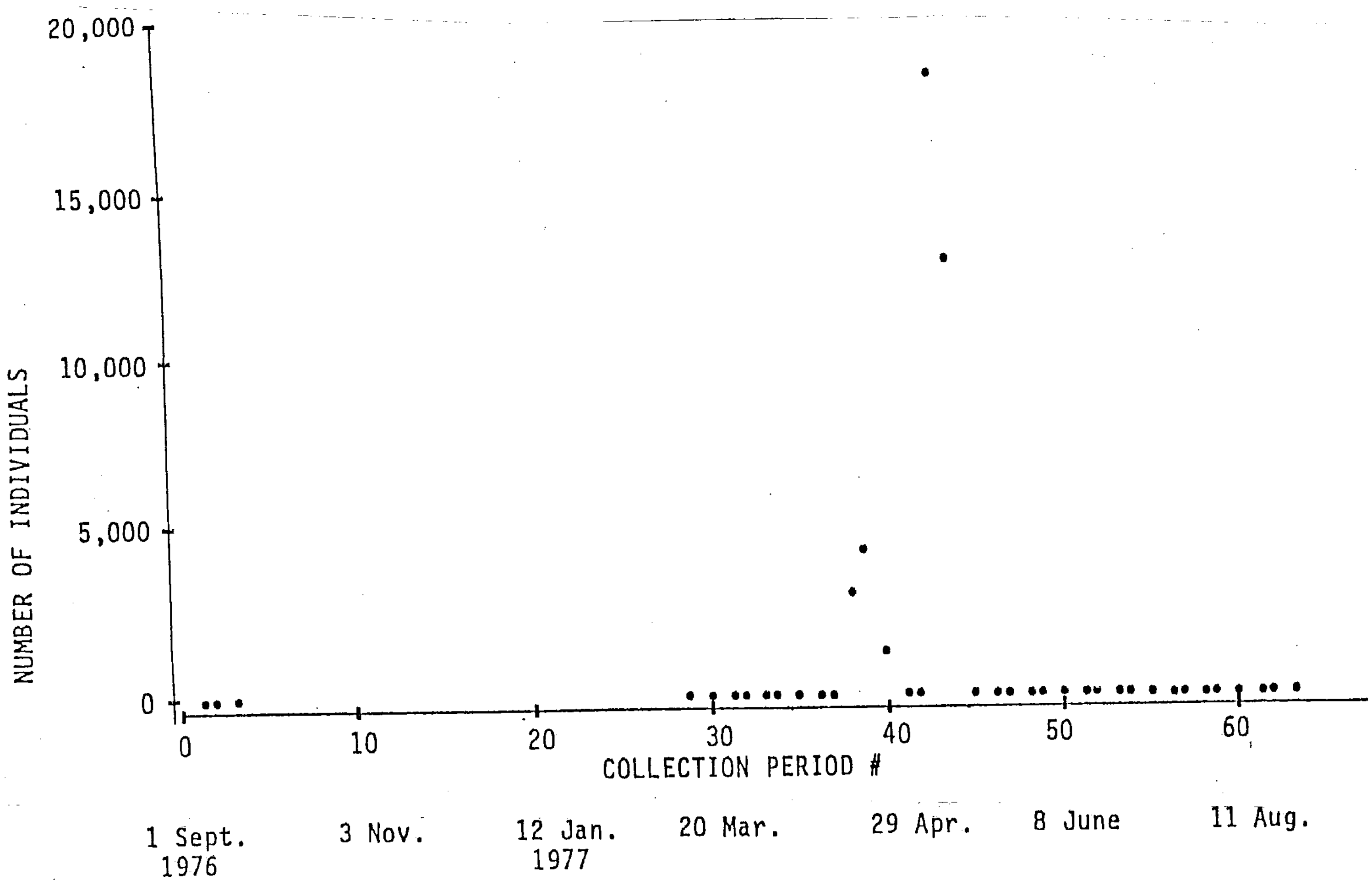


Figure D3. Number of walleye larvae entrained at the Bay Shore Power Station from 1 September 1976 - 1 September 1977.*

*These are estimates based on concentrations observed in the intake canal (with pump samplers) multiplied by the flow through the power station.

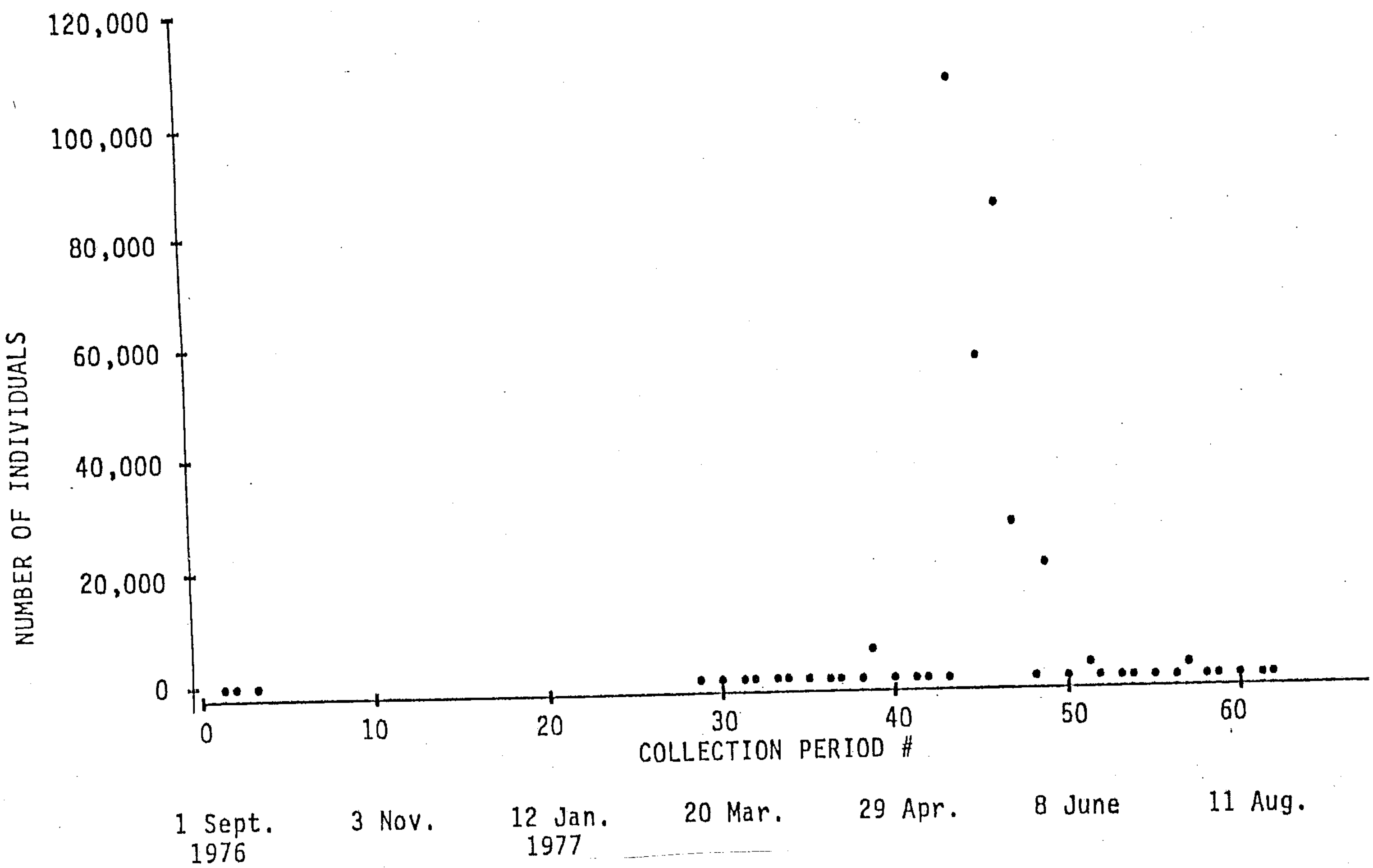


Figure D4. Number of yellow perch larvae entrained at the Bay Shore Power Station from 1 September 1976 - 1 September 1977.*

*These are estimates based on concentrations observed in the intake canal (with pump samplers) multiplied by the flow through the power station.

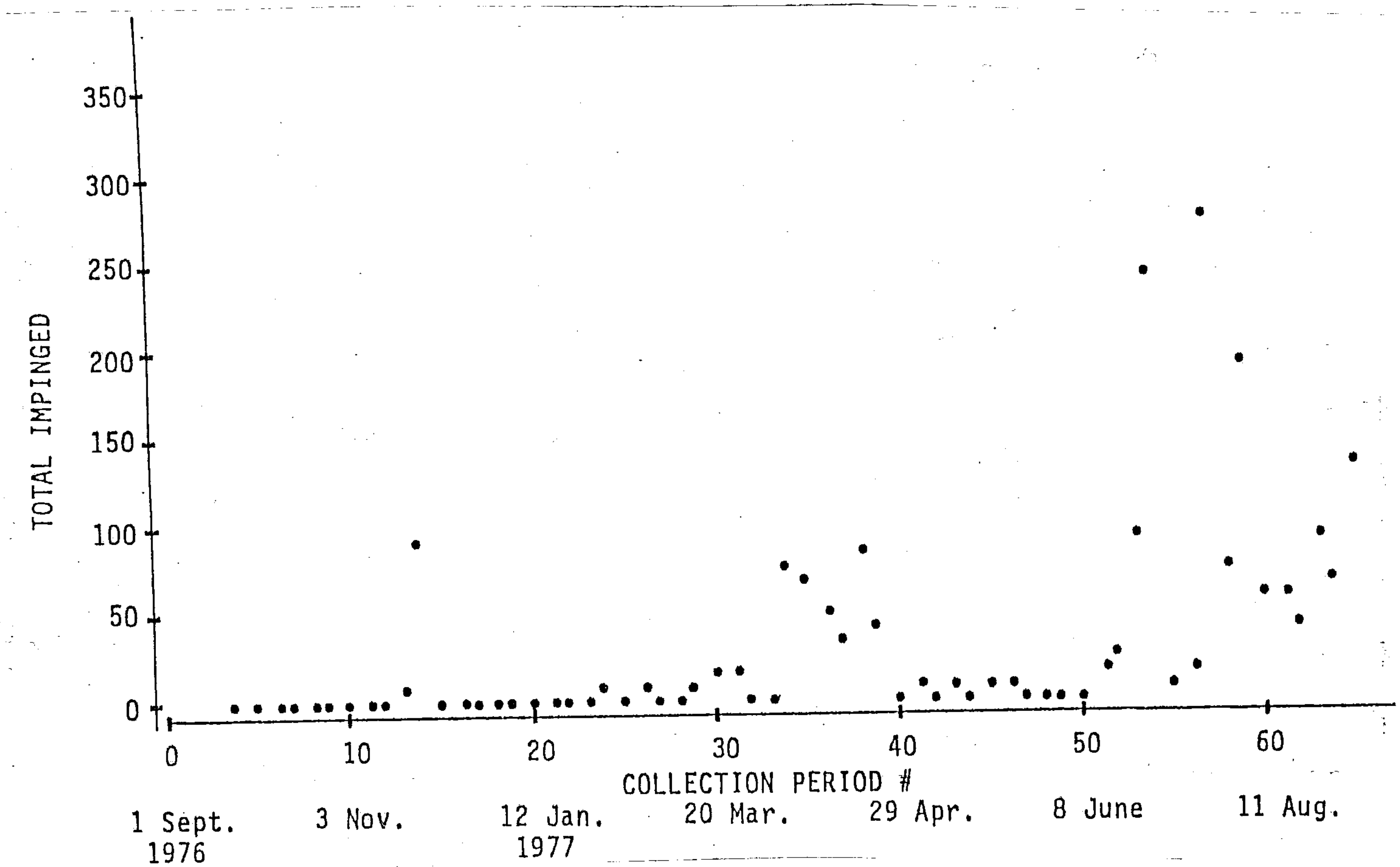
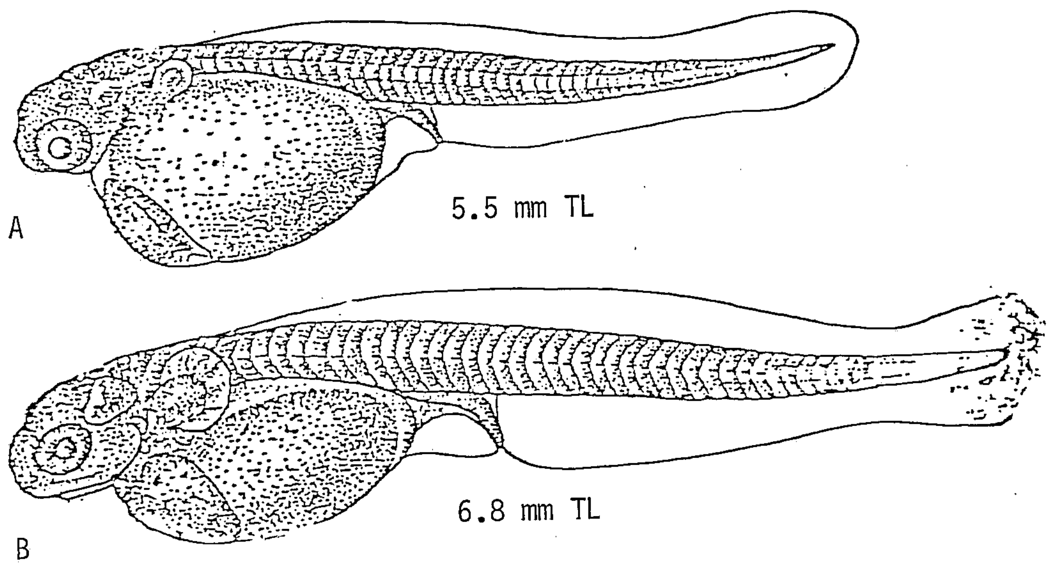
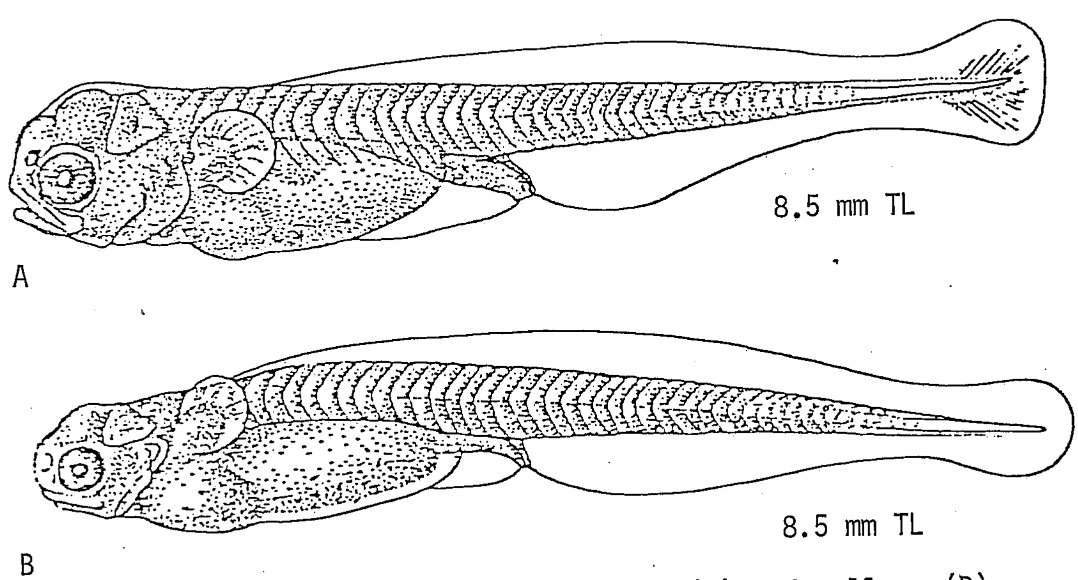


Figure D7. Number of walleye impinged at the Bay Shore Power Station from 15 September 1976 - 15 September 1977.*

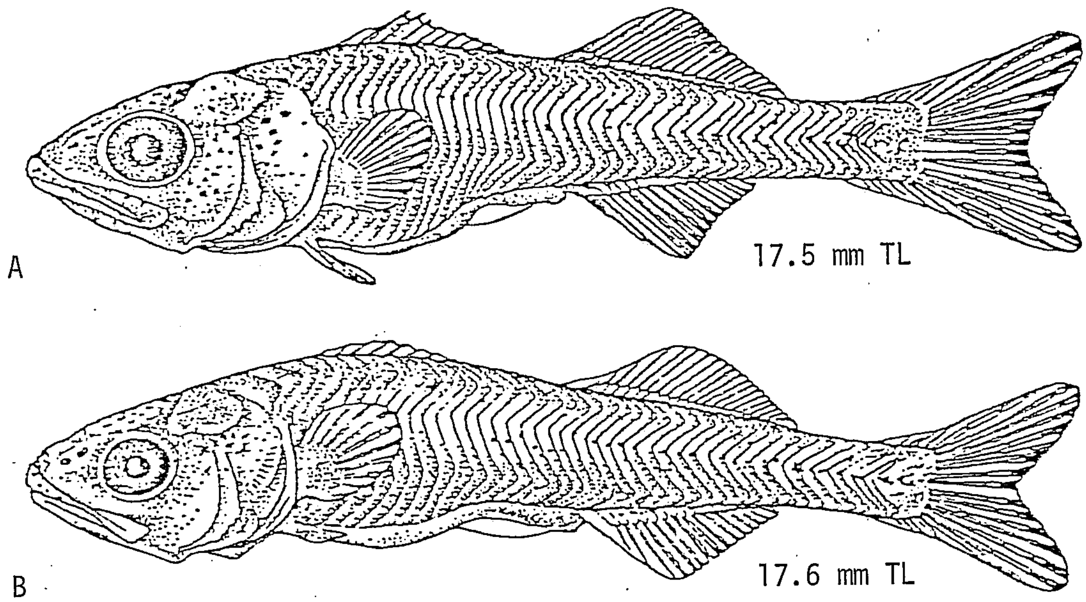
*Estimates projected over the entire year based on the results of 62 24-hour collections.



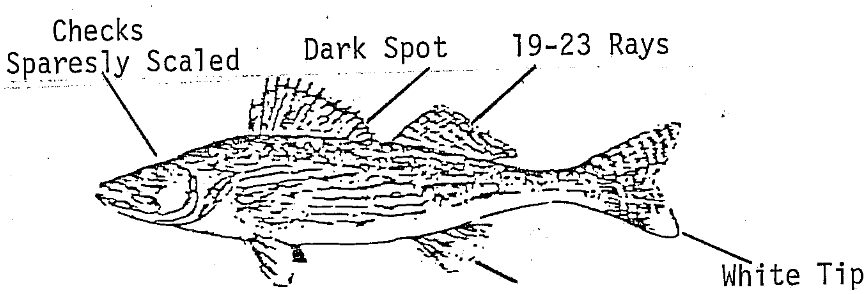
---Early prolarval stage of a sauger (A) and walleye (B).



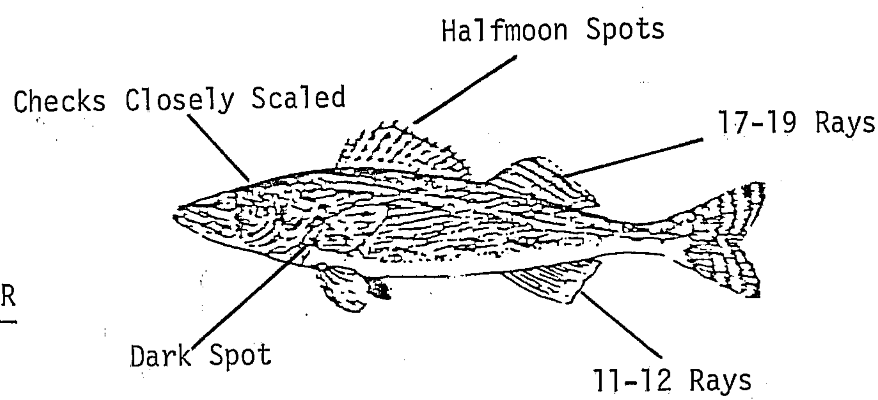
--Late prolarval stage of a sauger (A) and walleye (B).



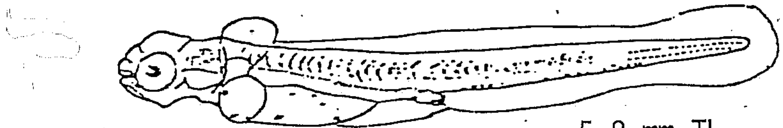
--Late postlarval stage of a sauger (A) and walleye (B).



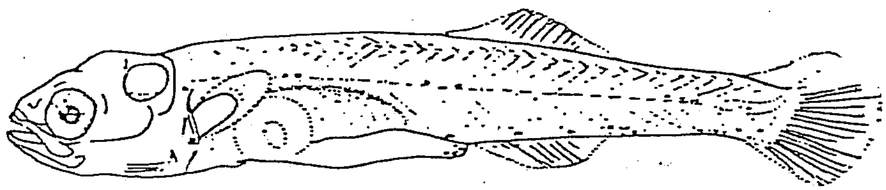
WALLEYE



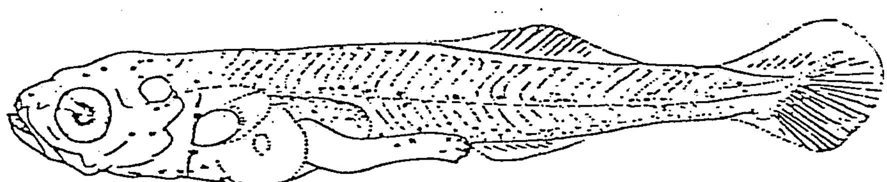
SAUGER



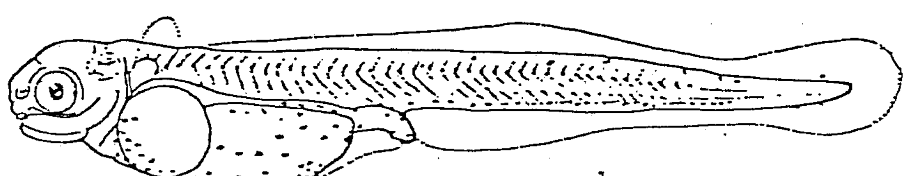
Yellow Perch 5.8 mm TL



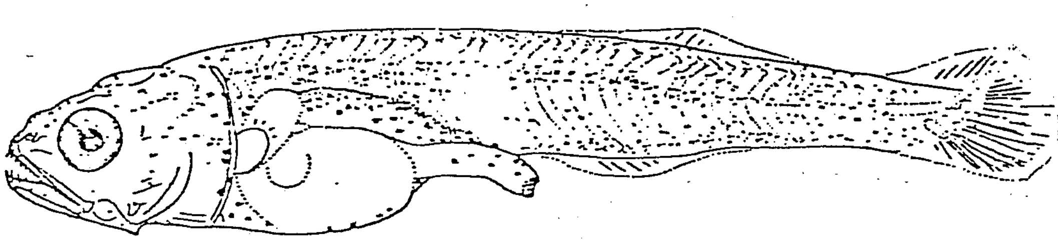
Yellow Perch 13.0 mm TL



Yellow Perch 13.0 mm TL



Walleye 8.0 mm TL



Walleye 14.8 mm TL

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