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Intensive Culture of Largemouth Bass and Walleye Fry in Experimental Systems

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INTENSIVE CULTURE OF LARGEMOUTH BASS AND WALLEYE FRY IN EXPERIMENTAL SYSTEMS

BY

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This thesis is approved as a creditable and independent investigation by a candidate for the degree Master of Science, and is acceptable for meeting the thesis requirements for this degree. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

Thesis Adviser

Wildlife and Fisheries Sciences

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Abstract

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Six genera of invertebrates were made available to largemouth bass (Micropterus salmoides) fry for 25 days. Brachionus spp. was selected for during both day and night (1100 and 2300 h) for the first seven days. Cyclops vernalis was selected on days 1 - 14; it was selected for more during the day for days 1 - 7. Daphnia pulex and D. magna were selected for during days 15 - 25. As the fry grew during the study they ate significantly ($P < 0.05$) larger D. pulex and D. magna. Moina brachiata was not selected for; it was eaten throughout the study in approximately the same proportion as available. Diaptomus spp. and Ceanestheriella setosa were not eaten. The fry increased in mean length from 6.5 mm on day 1 to 29.8 mm on day 25 of the study. Mean daily length increase was 0.93 mm.

Newly hatched walleye (Stizostedion vitreum vitreum) fry were intensively cultured on a diet of live zooplankton under three conditions for 48 days. The fry were reared in tanks under constant illumination (375 lux), in tanks under reduced illumination (105 lux), and in tanks which contained visual interceptors (400 lux). Mean survival of walleyes was 14.0% in tanks under constant illumination, 11.6% in tanks under reduced illumination, and 4.7% in tanks which contained visual interceptors. Mean unaccountable mortality of walleyes was 21.8% in constant illumination tanks, 35.7% in reduced illumination

tanks, and 27.4% in tanks with visual interceptors. The fry increased in mean length from 8.6 mm at the start of the study to 36.3 mm (0.76 mm/day) in constant illumination tanks, 36.6 mm (0.76 mm/day) in reduced illumination tanks, and 33.7 mm (0.70 mm/day) in tanks with visual interceptors after 48 days of intensive culture.

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INTRODUCTION

The practice of rearing larval fish on a live diet is not a recent innovation. Beeman (1924) reared young smallmouth bass (Micropterus dolomieui) for three to six weeks in concrete tanks on a diet of live zooplankton. Daphnia magna was cultured in 10.8 m^3 concrete ponds and fed to largemouth bass (Micropterus salmoides) reared in ponds (Hayford 1927; Langlois 1931). Meehan (1939) gave recommendations on fertilization of ponds to stimulate growth of D. magna to be used as food by young largemouth bass.

Recent studies have focused on the use of prepared foods for young-of-year fish. Snow (1960) found that 38 mm was the best length at which to start largemouth bass on a diet of ground fish. Ground carp (Cyprinus carpio) and commercial trout food were used to feed 57 mm largemouth bass under an intensive culture situation (Snow 1963). Largemouth bass 50 mm long have been trained to take Oregon Moist Pellets (OMP) while being reared in tanks or ponds (Snow 1968; Snow and Maxwell 1970). Nelson et al. (1974) trained largemouth bass, 38 - 51 mm long, to eat a dry diet and reared the fish in outside raceways. Some more recent studies have examined the use of carp eggs or a combination of carp eggs and dry food to feed largemouth bass, 10 - 20 mm long, in intensive culture systems (Brandenburg et al. 1979; Willis and Flickinger 1981).

Municipal sewage lagoons produce large quantities of invertebrates which can be used as food to culture fish. It has already been demonstrated that larval muskellunge (Esox masquinongy) (Applegate 1981), walleyes (Stizostedion vitreum vitreum), and yellow perch (Perca flavescens) (Raisanen 1982) can be reared on live zooplankton obtained from municipal sewage lagoons. This study was done to document: (1) the growth of largemouth bass intensively cultured on a live zooplankton diet, (2) the selection of food organisms by largemouth bass during light and dark periods of the day, and (3) selection by largemouth bass for size of food organisms.

MATERIALS AND METHODS

Experimental Fish

Larval largemouth bass were obtained on 5 June 1981 from the Gavins Point National Fish Hatchery, Yankton, South Dakota. The young fish, after rising from the nest, were collected by seining the hatchery ponds. Four-thousand larvae were counted into each of four 1.2 m diameter circular tanks containing 632 liters of water (6.3 larvae/liter). Water temperature during the study was 20 $\pm$1 C, except on days 23 and 24 when the water temperature rose to 22 C. Each tank received 1 liter/minute flow of charcoal filtered city water.

Eight fish, two from each of the four tanks, comprised a sample taken daily at 1100 and again at 2300 hours for 25 days. Fish taken at 2300 hours were dipped from the tanks during darkness. All fish were anesthetized with 0.1% tricane methanesulfonate (MS-222) before being preserved in 10% formalin. Fish were measured to the nearest 0.5 mm total length.

The tanks were cleaned once daily by siphoning the tank bottoms; dead fish were counted. Dissolved oxygen levels were measured two to four times each week with a Hach DR/EL1 water quality test kit. The tanks were illuminated from 0800 to 2000 hours and in darkness from 2000 to 0800 hours. Measurements of light intensity were taken with a Lambda L1 185 photometer. No chemical disease control was used during this study.

Experimental Food

Live zooplankton was collected each day with a 153 µm mesh dip net from a local municipal sewage lagoon (Volga, South Dakota). The zooplankton was filtered through a 1050 µm mesh net during the first 12 days to remove detritus, large zooplanktors, and predatory insects and not thereafter. After 12 days the fish had grown large enough to eat the larger zooplanktors and avoid predatory insects. The zooplankton from the sewage lagoon was largely monospecific and of uniform size. To obtain more species of a larger size range, zooplankton was also collected during days 3 - 25 from six experimental ponds located at the South Dakota Cooperative Fishery Research Laboratory approximately 3 km north of the South Dakota State University campus. The ponds had been fertilized with various inorganic or organic fertilizers and seeded with zooplankton from the sewage lagoon. Zooplankton collected from the experimental ponds was not filtered. All food was mixed by aeration in a 100 liter tank. A 15 ml sample of food was taken at 0800 and 2000 hours and preserved in 4% formalin. Food was added to each experimental fish tank six times daily in sufficient quantity to make swarms of zooplankton visible.

Identification of food organisms was made with a circular plankton counting chamber and a stereomicroscope (14-60X) equipped with a calibrated Whipple disk. The first 600 individuals of a food sample were identified and the percent composition was calculated to the nearest 0.1%. Additional counts did not appreciably change the percentages. One-hundred Dahpnia spp. per sample were measured for days 3 - 25 and one-hundred Moina brachiata per sample were measured for

days 4 - 25. Cladocerans were measured lengthwise from the anterior edge of the head to the posterior edge of the carapace. The diameter was measured from the dorsal edge to the ventral edge of the carapace. One-hundred copepods per sample were measured for all 25 days of the study. Copepods were measured from the anterior edge of the head to the posterior edge of the caudal ramus. The diameter was measured from one lateral edge of the metasome to the other lateral edge. All measurements were made to the nearest 0.07 mm, which was the smallest interval on the Whipple disk under 20x.

Digestive tracts were dissected from five fish from each 1100 hour sample and from five fish from each 2300 hour sample. The food organisms from the esophagus to the pyloric sphincter were identified to genus or species. Organisms which were crushed or partially digested, and therefore unidentifiable, were deleted from the data. All identifiable organisms from each gut were measured as previously described. At least 25 M. brachiata, 20 C. vernalis, or 20 Daphnia spp. were measured when a gut contained more than 50 of each of the respective organisms.

Data Analysis

A linear forage ratio:

$$L = r - p \qquad \text{(Strauss 1979)}$$

where

r = the relative proportion of an organisms in the gut

p = the relative proportion available in the food

was used to determine selectivity by largemouth bass for a food organism. Values of L range from -1 to +1 (-100 to +100 when expressed as percentages). Positive values indicate selection for a particular food type and negative values indicate selection against.

Confidence intervals (95%) were placed around each L - value to determine if the value was significantly different from zero. A t-test was used to determine if the 1100 and 2300 hour L - values were significantly different from each other. Relationships between the size of a food type ingested and the mean fish length were also examined by simple linear regression.

RESULTS

Growth and Survival

Approximately 5,000 largemouth bass were alive at the end of the 25 day study. All fish in one tank had died by day 4 and disease problems were evident in another tank on day 23. No diseased fish were used for food selectivity analysis or growth measurements. Fish in the remaining two tanks appeared to be healthy for the duration of the study. Dissolved oxygen levels were greater than 5.0 mg/liter and light intensity above the tanks ranged 340 - 420 lux during lighted hours.

The study was divided into five-day periods to present the mean lengths for small time intervals. The fish increased in mean length from 6.5 mm on day 1 to 29.8 mm on day 25 of the study (Table 1). Mean daily length increase for 25 days was 0.93 mm.

Selection of Food Organisms

Organisms made available to the largemouth bass were the cladocerans Moina brachiata, Daphnia pulex, and D. magna; the copepods Cyclops vernalis and Diaptomus spp.; the rotifer Brachionus spp.; the conchostracod Ceanestheriella setosa; and dipteran larvae of the family Chironomidae. Diaptomus spp., C. setosa, and the chironomids were not included in the data anlaysis because less than 1% of each were contained in any gut sample. Also deleted from the data was 271 (2.2%) unidentifiable organisms from gut samples. For the 25 days of the study, 12,133 organisms were identified, this comprised 97.8% of the total organisms found in the gut.

Table 1. Mean total length, range, and standard deviation (SD) of largemouth bass (Micropterus salmoides) reared intensively for 25 days, 6 June - 30 June 1981.

Days	Number of fish	Mean length (mm)	Range (mm)	SD
1 - 5	40	9.3	6.5 - 10.1	0.96
6 - 10	41	13.2	9.7 - 14.0	1.44
11 - 15	35	16.4	14.3 - 18.4	3.26
16 - 20	30	21.9	20.0 - 23.6	2.21
21 - 25	30	27.4	24.8 - 29.8	3.44

The study was divided into three periods based on developmental changes in the largemouth bass. During period one, days 1 - 7, the yolk sac had been absorbed and no pyloric caeca were present. Period two, days 8 - 14, started at the initial appearance of pyloric caeca; fin folds were present in this period. Period three, days 15 - 25, started at the initial appearance of fin rays which became fully developed by day 25.

All fish were feeding at the beginning of the study. Brachionus spp. was the most abundant organisms made available to and consumed by the largemouth bass for days 1 - 7. It was selected for at both 1100 and 2300 hours (Table 2). The total consumption of Brachionus spp. occurred during the first four days and none were eaten thereafter. Brachionus spp. was not available in the food after day 12. Cyclops vernalis was selected for during days 1 - 14 and was selected significantly more ($P < 0.05$) for days 1 - 7 at 1100 hours. Cyclops vernalis was eaten in approximately the same proportion as made available during days 15 - 25. Moina brachiata was eaten in relatively the same proportion as made available throughout the study. Dahpnia pulex and D. magna were rejected the first seven days but became the most abundantly consumed organisms for days 8 - 25. Daphnia pulex and D. magna comprised over 50% of the organisms eaten for days 15 - 25.

Size of Food Organisms

Brachionus spp. mean length was 0.31 mm for days 1 - 7; further analysis was not done because of the small length range (0.27 - 0.33 mm). There was little variation in sizes of C. vernalis and M. brachiata throughout the study (Table 3). As the fish grew, they consumed significantly larger ($P < 0.05$) D. pulex and D. magna (Table 3).

Table 2. Mean percent composition of organisms fed to largemouth bass (Micropterus salmoides), mean percent composition of organisms in gut, and mean linear forage ratio (L) at 1100 and 2300 hours for 25 days of rearing, 6 June - 30 June 1981.

Days		*Daphnia pulex* and *D. magna*		*Moina brachiata*		*Cyclops vernalis*		*Brachionus* spp.	
		1100h	2300h	1100h	2300h	1100h	2300h	1100h	2300h
1 - 7	% Fed	39.9	28.9	20.4	26.6	8.3	16.3	31.8	28.2
	% Gut	1.2	6.8	19.7	32.2	38.4	24.3	40.7	36.7
	L	-37.7	-22.1	-0.7	5.6	30.1[a]	8.0[b]	8.0	8.5
8 - 14	% Fed	44.2	82.6	33.2	13.1	10.9	3.4	11.7	0.9
	% Gut	37.2	81.7	29.2	7.2	33.6	11.1	0.0	0.0
	L	-7.0	-0.9	-4.0	-5.9	22.7[a]	7.7	-11.7	-0.9
15 - 25	% Fed	46.8	52.4	29.9	29.7	23.3	17.9	0.0	0.0
	% Gut	54.9	52.9	22.4	27.7	22.7	19.4	0.0	0.0
	L	8.1[a]	0.5	-7.5	-2.0	-0.6	1.5	-	-

[a]Significantly different from zero ($P < 0.05$).

[b]Significant difference between 1100 h and 2300 h ($P < 0.05$).

Table 3. Mean diameter, length, and standard deviation (SD) of *Cyclops vernalis*, *Moina brachiata*, *Daphnia pulex*, and *D. magna* ingested by largemouth bass (*Micropterus salmoides*) during 25 days of rearing, 6 June - 30 June 1981.

Days	Diameter (mm)		Length (mm)	
	Mean	SD	Mean	SD
	Cyclops vernalis			
1 - 7	0.35	0.10	1.02	0.22
8 - 14	0.39	0.09	1.03	0.20
15 - 25	0.31	0.10	1.01	0.19
	Moina brachiata			
1 - 7	0.56	0.19	0.82	0.24
8 - 14	0.46	0.20	0.75	0.29
15 - 25	0.56	0.16	0.90	0.21
	Daphnia pulex and *D. magna*			
1 - 7	0.57	0.13	0.95	1.0
8 - 14	0.69	0.23	1.13	0.31
15 - 25	0.94	0.26	1.48	0.39

DISCUSSION

Largemouth bass in this study grew from an initial mean length of 6.5 mm to 29.8 mm in 25 days. The growth was similar to that of largemouth bass which attained lengths of 24.2 mm and 28.1 mm in 30 days in two Michigan ponds (Cooper 1936). Largemouth bass in Lake Powell, Utah, reached a length of only 12.0 mm after 30 days (Miller and Kramer 1971). Kramer and Smith (1960) reported that 28 day-old largemouth bass in Lake George, Minnesota, were 26.4 mm long and in an adjacent slough were 27.9 mm long. Largemouth bass intensively reared on a diet of carp eggs and OMP reached a mean length of 26 mm after 25 days (Willis and Flickinger 1981). Strawn (1961) reared largemouth bass to a length of 26 mm in 20 days in a study of growth rates at various temperatures.

Initial feeding on the rotifer (Brachionus spp.) was similar to that reported in other studies. Rogers (1967) reported that Keratella sp. and Brachionus sp. were found in largemouth bass 5 - 40 mm in length. Rotifers, nauplii, and small cladocerans were found in largemouth bass soon after leaving the nest in Lake George, Minnesota, (Kramer and Smith 1960). Applegate et al. (1966) reported an initial dependence on rotifers and entomostracans by largemouth bass in Bull Shoals Reservoir, Arkansas.

Cladocerans and copepods were the most abundantly consumed food by fish greater than 10 mm long in this study. Rogers (1967) reported that largemouth bass 5 - 10 mm long in ponds near Auburn, Alabama, ate cladocerans; fish longer than 15 mm ate mainly midge larvae and pupae.

Largemouth bass, 10 - 15 mm long, in Ohio waters ate cladocerans; insects were eaten after the bass attained 45 mm in length (Turner and Kraatz 1920). Hodson and Strawn (1968) found that 10 - 19 mm long largemouth bass in Beaver Reservoir, Arkansas, fed on entomostracans. Largemouth bass, 18 - 40 mm in length, from Bull Shoals Reservoir ate cladocerans; largemouth bass, 20 - 25 mm, from Beaver Reservoir ate cladocerans, copepods, and midge larvae (Applegate and Mullan 1967). Applegate et al. (1966) reported cladocerans were the most important food organism and copepods were second most important for 20 - 48 mm largemouth bass in Bull Shoals Reservoir. Other authors have stated that entomostracans are an important component of the food for largemouth bass 38 - 69 mm in length (Murphy 1949; Davis 1953; McCammon et al. 1964; Miller and Kramer 1971; Warden and Lorio 1976).

Species preference may play an important part in selection of a food organism but choice is determined by the availability and size of organisms (Davis 1953; McCammon et al. 1964). In this study fish less than 12 mm long consumed C. vernalis which had a mean length of 1.02 mm and M. brachiata which had a mean length of 0.82 mm. Brachionus spp. consumed during the first four days were 0.31 mm in mean length. Rogers (1967) reported largemouth bass, 5 - 10 mm long, ate 0.36 mm mean length cladocerans and 0.45 mm mean length copepods. Turner and Kraatz (1920) found that 10 - 15 mm largemouth bass consumed cladocerans which were 0.35 mm in mean length.

Ivlev (1961) stated that the selective ability of a predator depends on the preference shown by the predator and the degree of availability of the food. The availability of a particular food organism was inconsistent throughout this study because of the seven different food sources and the changing nature of zooplankton populations. The sewage lagoon was dominated throughout the study by D. magna while the laboratory ponds contained much smaller organisms such as Brachionus spp., M. brachiata, C. vernalis, and Diaptomus spp. Also, yields of zooplankton were inconsistent per pond per day from the laboratory ponds. Due to the nature of this variability, the preferred organism size may or may not have been available to the fish in any given food sample.

Daphnia pulex and D. magna were apparently too large for the fish to injest during days 1 - 7, but became an important food as the fish increased in length. Initial feeding was on Brachionus spp., the smallest organism available. The second smallest organism, C. vernalis, was probably appropriate during the first 14 days since it was selected for during this period. The reason M. brachiata was not selected can only be speculated upon but it might have been due to the organisms movement, color, or size; this organism was selected for by muskellunge (Applegate 1981), yellow perch (Rainsanen and Applegate 1983), and walleyes (Rainsanen and Applegate, in press). Moyle and Holzhauser (1978) stated that young-of-year largemouth bass are opportunistic feeders and that their diet reflects the abundance of prey items of suitable size.

This study indicated that young-of-year largemouth bass are selective for food organisms. The fish selected for Brachionus spp. the first four days of the study and then C. vernalis was selected for during days 1 - 14. Daphnia pulex and D. magna were selected for as the fish reached greater length. This study demonstrated that acceptable growth rates for largemouth bass can be obtained when they are reared intensively on a live zooplankton diet.

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PART 2. INTENSIVE CULTURE OF WALLEYE FRY IN AN EXPERIMENTAL SYSTEM

INTRODUCTION

The walleye (Stizostedion vitreum vitreum) is a leading game fish throughout the Great Lakes region and in other areas where it has been introduced. In South Dakota the walleye was worth over $16.5 million to the economy in 1980 (United States Department of the Interior, Fish and Wildlife Service and United States Department of Commerce, Bureau of the Census 1982). In many areas walleye populations have been unable to maintain their numbers through natural reproduction, therefore stocking has been necessary to boost or maintain populations. Fry stocking has generally been ineffective, but stocking walleye at a larger size has increased survival.

The traditional method of raising walleyes has been to utilize hatcheries to produce fry and rear them in ponds until late summer or early fall (Smith and Moyle 1943; Walker and Applegate 1966). However, yields from ponds have been both variable and unpredictable (Miller 1952; Dobie 1957). More recent attempts at culturing walleyes have been to rear the fry in ponds for a period of growth and then train the fish to take artificial food in troughs or raceways (Cheshire and Steele 1972; Nagel 1976; Huh et al. 1976; Reinitz and Austin 1980). Some work has been done on rearing walleye fry on invertebrates with little success (Beyerle 1975). Nickum (1978) pointed out that no one has intensively reared a substantial number of walleyes from fry to fingerlings and that few fish survive longer than a few weeks.

Recently, however, encouraging results have been obtained rearing fishes from fry to juveniles on invertebrates collected from sewage lagoons. Applegate (1981) found that Moina brachiata, a common component of sewage lagoons, was the preferred food for larval muskellunge (Esox masquinongy). Raisanen (1982) showed that walleyes can be reared intensively by feeding invertebrates collected from a municipal sewage lagoon. The purposes of this study were to document the survival and growth of walleyes intensively reared to juveniles under three conditions on a live zooplankton diet.

MATERIALS AND METHODS

Experimental Fish

One- to two-day old walleyes were obtained from Valley City National Fish Hatchery, Valley City, North Dakota, on 12 May 1982. The walleye larvae were held at 16 C in a 1.2 m diameter circular tank for two days to allow for delayed mortality from handling, transport, or abnormal fish. On 14 May 5,000 walleye larvae were counted into each of 12, 1100 liter tanks (4.5 larvae/liter). Each tank was aerated and received a 1 liter/minute flow of charcoal filtered city water. Initial water temperature was 15 C which was raised to 19 $\pm$1 C by day 16 of the study. Water temperature remained at 19 $\pm$1 C for the duration of the study except for days 20 and 21 when temperatures decreased to 17 C and 18 C. The tanks were cleaned once daily by siphoning the tank bottoms; dead fish were counted. Dissolved oxygen content was measured at least three times weekly with a Hach DR/EL1 test kit. A composite water sample for each treatment was analyzed for pH and ammonia nitrogen content and used to calculate the un-ionized ammonia nitrogen content (American Public Health Association 1976). No chemical disease control was used in this study.

The walleye larvae were fed, throughout the study, a diet of zooplankton which was collected daily from a municipal sewage lagoon (Volga, South Dakota). Zooplankton was collected with a 153 µm mesh dip net and filtered for the first 15 days through a 1050 µm mesh net to remove detritus, predatory insects, and large zooplanktors. After 15 days the fish were large enough to eat large zooplanktors and avoid predatory insects. The zooplankton was mixed by aeration in a 100 liter

tank. Zooplankton was added to the treatment tanks five times daily in sufficient quantity to make swarms of zooplankton visible. Approximately equal amounts of zooplankton were added to all tanks at each feeding.

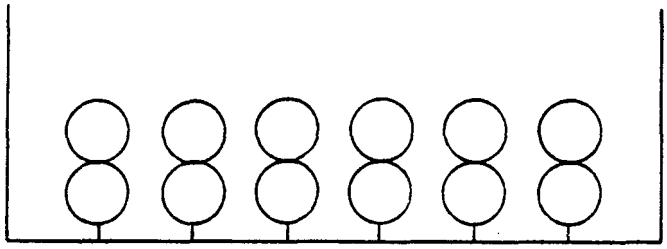
Forty-five walleyes were sampled for initial size measurements and then five walleyes were sampled weekly from each of the 12 tanks; 10 walleyes were sampled from each tank at the end of the study. All fish were preserved in 10% formalin solution. Lengths were determined to the nearest 0.5 mm total length.

Experimental Design

The design used for this study was a randomized complete block of three treatments with four replications. The treatments consisted of constant illumination, constant reduced illumination, and illumination with visual interceptors.

Four tanks were illuminated 24 hours a day at an average of 375 lux (350 - 390) as a control treatment. Measurements were made with a Lambda L1-185 photometer. Two layers of fiberglass window screen covered four tanks which reduced the illumination to an average of 105 lux (100 - 120). This treatment was used to determine the effects of reduced light intensity on survival and growth of walleyes. Visual interceptors were constructed from 20 x 54 cm sheets of 12 x 15 mm mesh Vexar screen. The sheets were rolled into 16 cm diameter cylinders and fastened with plastic tubing. Two cylinders were fastened side by side to form one unit. Since the Vexar was bouyant, 12 units were anchored horizontally along the length of each tank (Figure 1). Visual interceptors were used to determine if visual isolation would increase

View A



View B

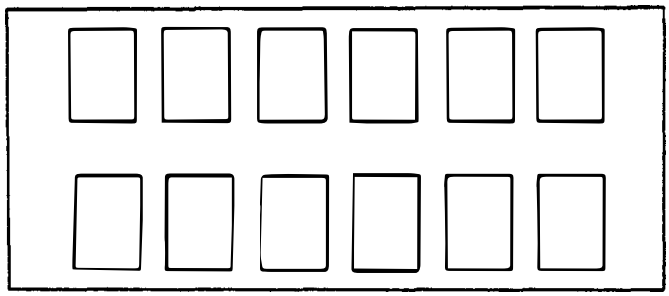


Figure 1. Arrangement of visual interceptor units in tanks used to rear walleyes (Stizostedion vitreum vitreum) for 48 days, 14 May - 30 June 1982. (A) Side view. (B) Top view.

survival. Illumination for the tanks containing visual interceptors averaged 400 lux (350 - 430).

Data Analysis

A chi-square comparison was used to test for differences in survival and mortality among treatments. Orthogonal separations were used to determine which treatments differed. A general linear model was used to test for differences in growth among treatments. The Waller-Duncan K-ratio t-test was used to determine which treatments differed.

RESULTS

Survival of Walleyes

The walleyes remained reasonably healthy throughout the study. Pinheads, fish with a large head and a slender body, were first observed on day 8. On days 34 and 38, fish were observed on their sides on the tank bottom while others were suspended vertically near the surface. Dissolved oxygen levels were always greater than 4.8 mg/liter and the highest un-ionized ammonia nitrogen on day 34 was 0.002 mg/liter.

After 48 days in tanks which contained visual interceptors, 932 (4.7%) of the 20,000 walleyes remained (Table 4). The greatest number of mortalities occurred on days 8 - 14 when 642 - 1,297 fish died daily. Tanks under constant illumination contained 2,104 (14.0%) of the 15,000 walleyes stocked. One tank of this treatment was deleted from the study because the larvae were miscounted when placed into the tank. The highest mortalities occurred on days 10 and 11 when 834 and 714 fish died. In tanks which received reduced illumination, 2,323 (11.6%) of the 20,000 walleyes remained. The greatest number of mortalities occurred on days 8 - 14 when 507 - 1,063 fish died daily. Survival in tanks containing visual interceptors was significantly less ($P < 0.01$) than that in constant illumination tanks and reduced illumination tanks (Appendix Table 1). Survival under constant illumination was significantly greater ($P < 0.01$) than that in reduced illumination tanks.

Table 4. The number of walleyes (Stizostedion vitreum vitreum) surviving and unaccounted for after 48 days of rearing, 14 May - 30 June 1982. Percentages appear in parentheses.

Treatment	Number Stocked	Number Surviving	Number Unaccounted
Visual Interceptors	5,000	346 (6.9)	1,589 (34.1)
	5,000	103 (2.1)	2,235 (45.6)
	5,000	246 (4.9)	848 (17.8)
	5,000	237 (4.7)	501 (10.5)
Total	20,000	932 (4.7)	5,173 (27.4)
Constant Illumination	5,000	605 (12.1)	1,631 (37.1)
	5,000	694 (13.9)	1,046 (24.3)
	*	-	-
	5,000	805 (16.1)	131 (3.1)
Total	15,000	2,104 (14.0)	2,808 (21.8)
Reduced Illumination	5,000	576 (11.5)	1,829 (41.3)
	5,000	761 (15.2)	1,121 (26.4)
	5,000	762 (15.2)	1,347 (31.8)
	5,000	224 (4.5)	2,019 (42.3)
Total	20,000	2,323 (11.6)	6,316 (35.7)
Grand Total	55,000	5,359 (9.7)	14,297 (28.8)

*Tank miscounted when stocked, not used for analysis.

Unaccountable mortality, fish not accounted for at the end of the study, was 27.4% in tanks containing visual interceptors, 21.8% in constant illumination tanks, and 35.7% in reduced illumination tanks (Table 4). The highest survival and lowest unaccountable mortality occurred in constant illumination tanks. Total unaccountable mortality for the study was 14,297 (28.8%) of the 49,641 total mortalities; 440 fish were removed for length measurements. Cannibalism was undoubtedly a factor in unaccountable mortality. Mortalities with only a head remaining were first observed on day 12. Throughout the remainder of the study, some dead fish appeared to have a tail at each end; these were fish which choked while swallowing a sibling. No estimate of mortalities from cannibalism was made; all would have appeared as unaccountable mortality.

Growth of Walleyes

Walleye larvae mean length was 8.6 mm at time of stocking into the treatment tanks (Table 5). After 48 days walleye mean length was 33.7 mm (0.70 mm/day) in tanks containing visual interceptors, 36.3 mm (0.76 mm/day) in tanks under constant illumination, and 36.6 mm (0.76 mm/day) in tanks under reduced illumination. No significant difference ($P > 0.05$) for growth among treatments was detected (Appendix Table 2).

Differences in the behavior of the walleyes among treatments was noted. After approximately 25 days, fish in the constant illumination tanks were noticeably more excitable than fish in the other treatment tanks. Walleyes under reduced illumination were more sedate. The fish in the tanks containing visual interceptors were somewhat excitable and were not attracted to the visual interceptors.

Table 5. Mean weekly total length (mm) of walleyes (Stizostedion vitreum vitreum) reared intensively, 14 May - 30 June 1982. Standard deviations are in parentheses.

	Treatments		
	Visual Interceptors	Constant Illumination	Reduced Ilumination
Stocked	8.6 (0.4)	8.6 (0.4)	8.6 (0.4)
Week 1	9.5 (0.1)	10.3 (0.2)	9.9 (0.2)
Week 2	11.4 (0.6)	12.9 (0.4)	12.0 (0.4)
Week 3	15.7 (0.7)	17.5 (0.8)	17.2 (0.5)
Week 4	20.7 (0.9)	23.4 (0.3)	23.0 (1.0)
Week 5	21.3 (0.5)	24.1 (1.5)	24.5 (1.4)
Week 6	26.3 (2.8)	29.1 (4.0)	28.2 (3.6)
48 days	33.7 (2.2)	36.3 (2.7)	36.6 (2.2)

DISCUSSION

Changes in survival and growth of intensively reared walleye fry were obtained by altering the rearing conditions. Tanks containing visual interceptors resulted in the lowest survival and shortest mean length of larval walleyes; although growth was not significantly different from the other treatments. Survival of walleye fry in constantly illuminated tanks was significantly greater than the other treatments. Survival of walleyes in this study (9.7%) compares favorably to that reported by other investigators. Koenst and Smith (1976) obtained 0 - 8% survival for walleyes reared to 40 mm on a brine shrimp and zooplankton diet. Li and Ayles (1981) reported survival of 0 - 18% for walleyes reared for 115 days in ponds near Erickson, Manitoba, Canada. Cheshire and Steele (1972) reported 21% survival of walleyes reared to 50 mm in ponds and 15% survial for walleyes reared to 55 mm in ponds. Smith and Moyle (1943) reported an average of 6% survival for walleyes reared in ponds in Minnesota for 100 days or more. Miller (1952) reported an average of 19.2% survival for walleyes reared in Minnesota ponds until the end of summer but this is somewhat misleading as the ponds were cropped at midsummer when high fish densities became apparent. Total survival of 4 - 5% was reported by Noble (1972) for 10 - 18 mm walleyes collected from Lake Oneida, New York.

Two major factors appear to contribute to high mortality of intensively reared larval walleyes. Mortality is greatest during the critical period when the fish are changing from endogenous feeding to exogenous feeding (Li and Mathias 1982). In this study, the critical

period was apparently days 8 - 14 when the highest mortalities occurred; the fish were 9 - 15 mm in length. Pinheads, evidence of non-feeding, were first observed on day 8 which corresponds with the critical period.

Cannibalism is the other factor which causes high mortality. Smith and Moyle (1943) stated that walleyes begin to eat each other soon after hatching. Li and Mathias (1982) stated that cannibalism is highest 6 - 16 days after hatching. Cuff (1977) stated that cannibalism is found mainly in walleyes less than 20 days old.

Walleyes in this study, from 14 May to 30 June, grew to a mean length of 35.6 mm in 48 days with no difference in growth found among treatments. This is less than walleyes reared to mean length of 46.6 mm in 50 days on a zooplankton diet by Raisanen (1982). Campbell and Rowes (1980) reared walleyes to mean lengths of 68 and 71 mm in 60 days in two ponds near Lake Winnepegosis, Canada. Smith and Moyle (1943) reported that walleyes averaged 48.1 mm in length after 50 days for Minnesota ponds. Walleyes in Clear Lake, Iowa, grew to 33 mm long in 30 days (Spykerman 1974). Walleyes in Red Lakes, Minnesota, grew to 36 - 47 mm long by 1 July (Smith and Pycha 1960). Forney (1966) reported walleyes grew to 36 - 64 mm long by 1 July in Lake Oneida, New York. Beyerle (1975) reported that walleyes averaged 22.9 mm in length after 32 days on a diet of brine shrimp and Daphnia spp.

In past studies, few larval walleyes have survived longer than three weeks of intensive culture. This study demonstrated that larval walleyes can be reared to juveniles on a zooplankton diet. It is concluded from this study that walleye fry reared under constant illumination have higher survival and lower unaccountable mortality than those reared under reduced illumination and visual interception.

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APPENDIX

Appendix Table 1. Chi-square comparison and orthogonal separation of survival among treatments for walleyes (Stizostedion vitreum vitreum) reared 14 May - 30 June 1982.

Treatment	Number of Fish		
	Alive	Dead	Total
1 Visual Interceptors	932	19068	20,000
2 Constant Illumination	2104	12896	15,000
3 Reduced Illumination	2323	17677	20,000
Total	5359	49641	55,000

Chi-square = 980.3095[a] 2 Degrees of Freedom

Chi-square 2 versus 3 = 56.6878[a] 1 Degree of Freedom

Chi-square 1 versus 2, 3 = 923.5804[a] 1 Degree of Freedom

[a]Significant at $P < 0.01$.

Appendix Table 2. Analysis of variance for mean growth among treatments for walleyes (Stizostedion vitreum vitreum) reared 14 May - 30 June 1982.

Source	Degree of Freedom	Sum of Squares	F-Value
Replications	3	97.993	5.44
Treatments	2	66.1285	5.52
Error	5	29.9249	