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Intensive Culture of Walleye Fry and Fingerlings in Michigan, 1972-1979

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INTENSIVE CULTURE OF WALLEYE FRY AND FINGERLINGS IN MICHIGAN, 1972-1979[1]

By George B. Beyerle

Abstract

Attempts to raise walleye fry intensively on a variety of natural and formulated foods were unsuccessful. A varying percentage of fry did accept several of the foods; however, almost no fry survived beyond 10 days following the beginning of exogenous feeding. A stress syndrome, characterized by continuous, aimless swimming, was associated with mortality of both feeding and non-feeding fry.

Survival of intensively cultured walleye fingerlings varied from 0.3 to 61.3%. Growth rate varied from 0.61 to 0.99 mm per day and surviving walleyes attained mean lengths of 100 to 115 mm. High survival (high acceptance of pelleted food) was related to large initial size of fingerlings (50 mm), covered troughs with a lighted feeding station in the center of each trough, and no disease problems. Low survival (low acceptance) was related to relatively small initial size of fingerlings, open or covered rearing units with feeding stations extending the length of the unit, and problems with various diseases. Recommended procedures are presented for future attempts to culture walleye fingerlings intensively.

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[1] Contribution from Dingell-Johnson Project F-35-R, Michigan.

Introduction

Although the walleye (Stizostedion vitreum vitreum) is recognized as one of the most desirable of coolwater sport fishes, relatively few significant populations are found in the inland waters of lower Michigan. Attempts to rejuvenate diminishing walleye stocks, or to introduce walleyes to new waters by stocking fry, have been generally unsuccessful. Better success is obtained when fry are raised to fingerling size in ponds, using minnows as forage, and then stocked. However, high cost of production and scarcity of suitable high quality rearing facilities make large scale culture of 100-mm and larger fingerlings in ponds infeasible.

It has been theorized that walleyes, as well as other coolwater predatory fishes, can be raised from fry to advanced fingerling size intensively in hatchery troughs, using formulated food. If successful intensive rearing of walleyes can be accomplished, then millions of walleye fingerlings could be produced for the same cost as thousands of fingerlings raised extensively in ponds.

This report describes attempts to intensively raise walleye fry in 1972-76 and 1979, and walleye fingerlings in 1972 and 1974-76. The 1972 fry test was conducted at the former Hastings Fisheries Research Station; all other tests were at the Wolf Lake State Fish Hatchery.

Fry tests

1972

In spring 1972, a series of nine 56- or 68-liter aquaria with bottom drains and stand pipes were prepared so that heated water could be run through them at a rate of 0.75 liter per minute. A vertical fish screen was installed in each aquarium to provide a usable volume of 42 liters. On May 16, the nine aquaria were stocked with 496 walleye fry per liter.

By May 21, some fry had absorbed their yolk sacs and were ready to feed. Automatic drip feeders, operating on a 24-hour schedule, dispensed Oregon Moist Pellet (OMP) starter mash into three aquaria and Spearfish W-3 fine starter pellets into three other aquaria at a daily rate of 5% of the fish biomass. There was also some supplemental hand feeding. Brine shrimp (Artemia salina), raised in hatching jars, and Daphnia, collected from a local lake, were added to the three control aquaria.

Daily water temperature varied from 16 to 19 C. No disease or water quality problems were observed.

A few fry fed on the Spearfish W-3 fine starter pellets on May 21 and 22. They seemed to be more interested in the larger pellets, so a mixture of 50% fine starter and 50% starter was fed beginning May 22. However, no additional feeding was noted until May 25, when about 20 fry in one aquarium began feeding rather heavily. Although these fry continued to feed, they also exhibited signs of stress. They swam constantly, with no apparent purpose, until they became exhausted and sank to the bottom of the aquarium for a brief rest. By May 30, only one of these fry remained alive. No fry were observed feeding on the OMP.

Because of poor success at raising brine shrimp during the critical first days of feeding, the control fry initially were fed mostly ungraded Daphnia. Very few fry were observed feeding on the Daphnia, and when more brine shrimp became available, they were utilized very little by the fry.

After May 21, the incidence of cannibalism increased rapidly in all nine aquaria and it soon became impossible to continue a planned removal of cannibalistic fry. By May 30, essentially all of the fry had died, including the cannibals. It is estimated that 20% of the fry were eaten by cannibalistic fry and the remaining 80% died of starvation. Obviously, no evaluation could be made of the relative usefulness of pelleted food for intensive culture of walleye fry. All the fry in this test, regardless of diet, exhibited the stress "syndrome" described above.

1973

Two experiments on raising walleye fry were completed in 1973. In experiment No. 1, 18 C water was run through each of 10 56-liter aquaria at 0.75 liter per minute. Automatic feeders dispensed Oregon Moist Pellets (starter mash) into six of the aquaria 24 hours per day. Since the previous test showed that walleye fry would swarm to a light source, 150-watt flood lights were installed over two aquaria and regulated to turn on immediately before, during, and for 1 minute after pellets were dispensed from the feeders. In these two aquaria the fry were initially fed brine shrimp. After 3 days the ration of brine shrimp was gradually decreased and feeding of OMP was begun and gradually intensified. In two other aquaria with automatic feeders, the water flow was regulated so that many of the dispensed pellets were kept in constant motion throughout the aquaria. Thus, the pellets were constantly being presented to the fry. In two aquaria without automatic feeders, attempts were made to induce fry to feed on salmon pellets, egg yolk, an egg yolk and farina slurry, and a liver slurry. The final two aquaria were designated as controls, and fry in them were started on brine shrimp and gradually shifted to plankton 3 or 4 days after feeding began. On April 9, each aquarium was stocked with 12,000 walleye swim-up fry (286 fry per liter).

Feeding on brine shrimp was first observed in the control aquaria on April 12. On April 13, fry were observed feeding on OMP in several aquaria. During the period from April 13 through April 21, some intermittent feeding on OMP was observed in all six aquaria with feeders, but, despite a maximum effort by personnel (e.g., much supplementary hand feeding, efforts to keep pellets in suspension as long as possible by stirring), by April 21 all fry in these six aquaria had died of starvation, exhaustion, or cannibalism. On April 15, attempts to feed egg yolk, liver, etc., were discontinued because of lack of success. Fry in the two control aquaria were more cooperative, and despite a rather high incidence of cannibalism, a total of 96 fry (0.5%) remained alive when the experiment was ended on April 26. During the 14-day feeding period these fry grew from 7.1 mm to 14.7 mm. The same stress syndrome noted in 1972 was very evident in all aquaria (constant, purposeless swimming followed by exhaustion and sinking to the bottom of the aquarium).

Because of the limited success with raising fry in aquaria in experiment No. 1, fiberglass troughs were tested in experiment No. 2. Food was the same--brine shrimp and plankton. Since there was some question of the detrimental effect on fry of heated, aerated spring water, it was decided to use only water obtained from a local lake in the troughs.

During the experiment, half of the 277 liters of water in each trough was exchanged for fresh lake water each day. Aeration was provided and electric heaters were used to maintain a temperature of 18 C in the troughs. On May 7, 12,000 walleye fry (53 per liter) were introduced into each of the four troughs. Fry in troughs 1 and 2 were started on graded plankton, while fry in troughs 3 and 4 were started on brine shrimp and switched to plankton after 6 days of feeding. Considerable effort was expended keeping troughs clean and maintaining a surplus of food at all times.

Inadvertently, the troughs were located so that trough No. 1 received the greatest amount of natural light (through a window) while trough No. 4 received the least amount of light. A week after feeding began it was noticed that size of fry was directly proportional to the amount of light being received by each trough. A 100-watt incandescent light was immediately installed over troughs 3 and 4 and burned from 8 AM to 5 PM each day for the remainder of the experiment, seemingly with good effect on the feeding intensity of the walleyes. The more intense light in troughs 1 and 2 during the first week may have stimulated feeding, and therefore also cannibalism. This theory is supported by the fact that the walleyes in the troughs with more light were larger but had a lower survival rate than walleyes in the darker troughs (Table 1). The surviving walleyes in all troughs were generally healthy and could conceivably have been raised to a larger size. During the last 2 weeks of the experiment mortality was less than 3% per day.

1974

In 1974, food items smaller than young Daphnia or brine shrimp, which commonly vary from 0.35 to 0.50 mm in length, were tested. Various combinations of hay, manure, and Torula yeast were introduced into several troughs to produce "infusoria". The dominant infusorians were Paramecium sp. and Stylonychia sp., ranging in size from 0.1 to 0.3 mm. One hundred walleye sac fry were stocked in each of six 56-liter aquaria containing aerated water at 18 C. An abundance of infusorians were stocked in two aquaria, brine shrimp were stocked in two aquaria, and an equal mix of infusorians and brine shrimp were placed in the remaining aquaria.

The results of the test are shown in Table 2. An estimated 75% of the walleye fry in aquaria 1 through 4 fed on brine shrimp at one time or another. Conversely, there was no evidence that walleye fed to any extent, if at all, on the infusoria. Walleye fry, like other fishes, usually seem to be most attracted to the largest of the food items available to them. Thus, the infusorians in aquaria 3 and 4 may have been ignored on the basis of size alone. The absence of feeding by walleyes in aquaria 5 and 6 may indicate a size factor (infusoria too small to be noticed) and/or a taste factor (infusoria not palatable) associated with the infusoria used. On May 14 (the last day of the experiment), all surviving fry in aquaria 6 were emaciated and lying on the bottom of the aquarium. An estimated 10% of the fry in aquaria 1-4 appeared to be strong and healthy. The remaining 90%, although they contained food, appeared weaker and unable to easily escape the plastic tube used to collect the fry. It is assumed that these weak fry would soon have died, had the test continued. Constant swimming apparently was the major factor in producing exhaustion and weakness in the feeding fry. The results of this test provide evidence that young walleye fry do not require food items smaller than newly hatched brine shrimp.

1975

In 1975, the objective was to compare the survival of walleye fry fed various sizes of plankton (primarily *Daphnia pulex*) and brine shrimp. In preliminary investigations it was determined that the mean length of newly hatched brine shrimp (0.48 mm) was larger than the length of the smallest *Daphnia pulex* (0.22-0.45 mm) found in plankton samples collected from ponds at Wolf Lake Hatchery in early May 1975. The width of young brine shrimp was 0.20 mm. All newly hatched brine shrimp passed through nylon fabric with 0.400-mm mesh, 97.0% passed through 0.280-mm mesh, 92.4% passed through 0.202-mm mesh, and no shrimp passed through 0.118-mm mesh.

In the feeding test, two 56-liter aquaria with aerated 19 C water were used for each mesh size (0.202-, 0.280-, or 0.400-mm) and food type (brine shrimp or plankton). The walleye fry stocking rate was 150 per aquarium. When the walleyes began exogenous feeding activity on May 18, each aquarium was stocked with at least 750 mg of food items that had passed through the appropriate size mesh. However, the tests with plankton had to be discontinued because the pump used to collect plankton broke down and contaminants from the redwood frames on the screens killed a large number of the newly stocked walleyes. After 4 days, fry being fed 0.202-mm and smaller brine shrimp were switched to 0.280-mm and smaller brine shrimp. After 4 additional days, these fry were switched to 0.400-mm and smaller shrimp. Fry that were started with brine shrimp 0.280-mm and smaller were switched to 0.400-mm and smaller shrimp after 8 days. The "control" fry were fed brine shrimp 0.400-mm and smaller for the entire experiment. The test was ended on May 27, after 10 days of feeding began.

Survival of fry was directly proportional to the size of the mesh through which the brine shrimp were passed, although the only statistically significant (95% level) difference in survival was between the 0.202-mesh lot and the 0.400-mesh lot (Table 3). However, there was no significant difference in final mean length of fry fed the three different complements of brine shrimp. This test provided evidence that young walleye fry selected the larger brine shrimp. Since newly hatched brine shrimp are larger in size than the smallest _Daphnia pulex_, it is logical to conclude that young walleye fry, when they begin feeding, are capable of ingesting newly hatched _Daphnia pulex._

1976

The 1976 test compared survival of walleye fry raised on plankton in rearing units of three different sizes. In April 1976, a mixture of pond and well water was introduced into three aquaria, three troughs, and three circular tanks. Water was added to the rearing units as needed to maintain levels. Aquarium heaters could not keep water temperatures constant because of exceptionally cool weather and an unheated building, thus water temperatures varied from 9 to 21 C in the various rearing units. Similar variations in temperature often occur in ponds where walleye fry are raised successfully. A mix of fluorescent and incandescent lights were turned on from

8 AM to 8 PM everyday. On April 29, walleye fry were stocked at densities equal to stocking rate for extensive walleye rearing ponds in 1975 (0.094 fry per liter). Starting on May 3, and continuing until the end of the test on May 15, plankton (mainly Daphnia pulex) collected from Wolf Lake was added so as to produce a density equivalent to that found in "good" walleye ponds in 1975 (approximately 20 Daphnia per liter).

During the period May 5 to May 15, some walleye fry were observed in various rearing units with plankters in their stomachs. No attempt was made to quantify the number of feeding fry at any particular time, but it is estimated that less than 20% of all fry fed on the plankton. By May 15, survival was as follows: 0.0% (0 of 48) in aquaria, 1.6% (3 of 186) in troughs, and 1.5% (9 of 600) in tanks. Obviously, the size of the rearing units tested had no effect on survival of walleye fry.

1979

In 1979, the objective was to create an "intensive" environment that closely approximated the "extensive" pond environment in which walleye fry have been raised successfully at the hatchery. The glass end panels were removed from three aquaria (30 × 48 × 122 cm) and replaced with Nitex screening. The aquaria were placed on wooden bases in hatchery pond 11 so that pond water could pass through them. The water volume in each aquaria was 110 liters. On April 20, each aquarium was stocked with 100 walleye fry, still with conspicuous yolk sacs, and an estimated 10,000 plankters (mostly copepods and cladocera) from Wolf Lake. The density of plankters was maintained throughout the test. As a control, pond 11 was stocked with walleye fry.

By April 24, 4 days after stocking, some walleye fry in the three aquaria were feeding on plankton. No cannibalism was observed. On April 25, some dead and dying walleyes were observed in all aquaria. By April 26, the remaining walleyes appeared to be thin and swimming constantly. On April 27, only a few thin, non-feeding fry remained alive. Finally, by April 30, all test walleyes were dead. Some control walleyes were recovered when the pond was drained in July.

In a related test, Wolf Lake Hatchery personnel installed four standard rearing troughs (680-liter capacity) outside the intensive rearing facility so that walleye fry would be exposed to sunlight rather than artificial light. Four identical troughs were set up inside the rearing facility under fluorescent lights. Each trough was stocked with 10,000 fry and two different formulated foods (Spearfish W-13 and Bioproducts Stabilized Moist) were fed. Walleye fry that were stocked in troughs exposed to sunlight did not accept either of the formulated foods and after 10 days of feeding the test was concluded. Similar results were obtained with the fry stocked in troughs under fluorescent lights.

Discussion

Walleye fry raised extensively in ponds at Wolf Lake Hatchery consumed *Daphnia pulex* almost exclusively and survival to fingerling size (38-50 mm) ranged from 50% to over 90% (Beyerle unpublished data). In contrast, fry confined in rearing units fed to some extent on several live or formulated foods, including *Daphnia pulex*, but their survival beyond the first 3 weeks was only 0 to 4%. All feeding and non-feeding fry displayed what appeared to be a stress syndrome, characterized by constant, aimless swimming, followed by exhaustion and eventual death.

Some investigators (Nickum 1978) believe that malnutrition may be the reason why walleye fry that accept formulated foods do not survive and grow. However, this does not explain why fry in rearing units did not thrive on a diet of the same plankters that produced 90% survival and relatively rapid growth in pond-reared walleyes. We observed that walleye fry in ponds did not swim constantly and aimlessly, but moved about mainly for the purpose of searching out food items.

Two factors come to mind that may be important in producing the stress syndrome in intensively cultured walleye fry. One factor may be the rearing unit itself. Perhaps the young fry feel confined and react by constantly attempting to get away to an area of non-confinement. Another factor may be that something in the natural environment has been chronically lacking under conditions of intensive culture. Whatever the ingredients that are missing, the odds are that sooner or later some fish culturist will create the right mix of conditions and solve the riddle of how to raise walleye fry intensively.

Fingerling tests

All tests with fingerlings were conducted at the Wolf Lake Hatchery with small fingerlings which had been reared in the hatchery's ponds from the fry stage.

1972

Hatchery personnel raised walleye fingerlings on pelleted food in three outdoor tanks, each with a capacity of 3,300 liters, June 28-October 11, 1972. Water from an adjacent pond flowed through each tank at 18.9 liters per minute. Walleye fingerlings (41.7 mm mean length) were stocked as follows: 4.2 g per liter in tank 1, 4.5 g per liter in tank 2, and 2.5 g per liter in tank 3. Fish in tanks 1 and 3 were started on Oregon Moist Pellets (OMP); fish in tank 2 on Spearfish W-3 dry pellets. Tanks were cleaned and dead fish were noted and removed daily. Each week the mean length, number of fish per pound, and total mortality were determined.

During the test the water supplied to the tanks was of poor quality. It had a green color, probably due to an algae bloom, and was so turbid that fish on the tank bottom could not be seen. Water temperature varied from 17 to 20 C, except for the period July 18-26, when the temperature rose gradually to 29 C. During this warm period the walleye fingerlings contracted an apparent systemic bacterial infection that produced symptoms similar to furunculosis. Terramycin (TM-50) fed at the 4% level for 10 days, starting July 25, seemingly caused the infection to disappear. However, mortality of fingerlings remained high and, in retrospect, since relatively little of the medicated food was eaten, the disease may have run its course naturally. The walleye fingerlings were also treated with a 1:6,000 formalin solution, which was effective in eliminating external parasites, and Hyamine 3500, which was used to control gill bacteria.

Very high mortalities occurred during the first week of the feeding trials (Table 4). It is assumed that most of this mortality was the result of starvation caused by unwillingness to eat pelleted food. During the first 28 days, growth of walleyes on the OMP diet averaged 22.9 mm, while walleyes feeding on W-3 pellets grew only 17.0 mm. On July 26, only 66 walleyes remained alive in tank 2. Feeding of the W-3 diet was discontinued and the 66 walleyes were transferred to tank 1.

By September 13, the mean length of the fingerlings was 96.5 mm. On that date the 617 walleyes that remained alive in tank 1 were transferred to tank 3. The experiment was ended on October 11, when the 2,754 surviving walleyes had attained a mean length of 110.7 mm. During the experiment the total loss to cannibalism (all unaccountable losses) was 7,156 walleyes (11.9%). The survival of only 4.6% of the fingerlings was much less than anticipated due to the adverse conditions which developed during the test. Apparently the fingerlings fed somewhat better on the OMP diet than on Spearfish W-3 pellets.

1974

In 1974, fingerling survival and growth on diets of fathead minnows (*Pimephales promelas*) and OMP were compared. Four fiberglass troughs, each with a capacity of 531 liters, were fitted with plywood or masonite covers which extended half the length of the troughs. A small opening was made in the center of two of the covers to permit dispensation of pelleted food from circular automatic feeders. Screens were placed in the middle of the two troughs with automatic feeders to keep the walleye fingerlings in close proximity to the dispensed pellets. Electric heaters kept the water temperature at 21 C throughout the study. Aeration was provided through airstones. Each day the troughs were cleaned and at least half of the water volume was replaced with heated, aerated water. A fluorescent light fixture containing two 40-watt bulbs was suspended 1 m over the water surface in minnow trough 1 and OMP trough 2, while a 150-watt incandescent floodlight was suspended 1 m over OMP trough 3 and minnow trout 4. Both lights were turned on from 8 AM to 8 PM. On June 28, each trough was stocked with 75 walleye fingerlings (mean length 46.5 mm). An abundance of 13- to 25-mm fathead minnows was stocked and maintained in troughs 1 and 4, while OMP (1.2 mm) were dispensed into troughs 2 and 3 every 30 minutes on a 24-hour-per-day basis.

The walleye-minnow experiment continued without a hitch for 31 days, until July 29, when a few "dark" or "sick" walleyes were observed. A few days previously John Hnath, fish pathologist, had detected the parasite Ichthyophthirius multifilis ("Ich") on several walleyes held in a spare aquarium. It was suspected, and later confirmed, that the "sick" walleyes were similarly infected. On August 1, the fish in trough 1 were treated with a 1:6000 formalin solution for 50 minutes, but this resulted in the death of 73 of the 80 walleyes. The fish in trough 4 were then treated with 1:6000 formalin for 30 minutes. During the 24 hours following the treatment, 22 of the 71 walleyes in trough 4 died. By August 7, only one walleye remained alive in the minnow troughs.

The fingerlings raised on minnows grew from 46.5 mm to 89.1 mm in 31 days (1.37 mm per day). Mortality previous to the outbreak of Ich was only 5.3% and resulted entirely from cannibalism. If the Ich infestation had not occurred, it is probable that the walleyes could have been raised to a size of 102 mm (4 inches) by August 15. Thus, the potential of raising walleye fingerlings on minnows in troughs seems very good, if the cost of obtaining minnows of the right size and quantity is not prohibitive. Because of the sensitivity of walleyes to chemical treatments, the water supply and the food fishes must be kept free of fish disease organisms.

The first feeding by walleyes on OMP was observed on June 29. By July 3, about 50% of the walleyes in troughs 2 and 3 were actively feeding. Because the OMP tended to sour if kept in the automatic feeder more than 24 hours, the food was replaced daily. A plastic cover was placed over the feeders to maintain the moisture content of the OMP. Starting July 13, an equal mix of 1.2-mm and 1.6-mm OMP was fed to the walleyes. By August 12, a mix of 2.4-mm and 3.2-mm was being eaten by the walleyes.

During the OMP test, 14.0% of the walleyes died from cannibalism and 24.7% died from starvation. The surviving walleyes (61.3%) grew from

46.5 mm to 85.1 mm in 45 days (0.86 mm per day). One group of these walleyes then grew from 93.5 mm to 102.6 mm in 11 additional days (0.83 mm per day) with no additional mortality. Thus, if the growth and survival obtained in this test could be realized under production conditions, it should be possible to raise walleye fingerlings on OMP to a size of 102 mm (4 inches) by September 1, with a survival of 60%.

1975

In 1975, the objective was to raise the small fingerlings to 102 mm (4 inches) under production conditions in troughs on three different pelleted foods--Oregon Moist Pellets, OMP "spaghetti" (an elongated pellet), and W-7 dry diet. Well water heated to 21 C flowed through each 531-liter fiberglass trough at 0.7 liter per minute. Loudon "North Star" automatic feeders dispensed pelleted food into the troughs 14 hours per day. The rearing units were cleaned twice a day. Black plastic was hung as a drape completely around the troughs to minimize outside disturbances. Fluorescent lighting was reduced to 2-3 footcandles at water level (measured with a photoelectric light meter).

On May 30, walleye fingerlings with a mean length of 29.0 mm were stocked into nine troughs at a rate of 1,600 fish per trough. The nine troughs were divided into three groups. Walleyes in group 1 were started on 1.2-mm OMP, group 2 walleyes were fed OMP spaghetti (1.2 mm in diameter × 7.2 mm in length), and group 3 walleyes were started on W-7 (No. 2 and No. 3 crumbles). The initial daily feeding rate for each trough was 910 g, 279% of the fish body weight.

The walleyes showed immediate interest in all three pelleted foods; however, very little feeding occurred for about 5 days. The onset of active feeding coincided with the onset of heavy mortalities due to starvation. By June 4, mortalities in all troughs due to starvation or cannibalism reached 3 to 10% per day. On June 5, the surviving fish in each group of three troughs were combined into one trough to facilitate feeding and cleaning operations. By June 10, all mortality due to starvation had occurred. Losses were greatest among the fish fed OMP spaghetti (Table 5), probably because the food particles were relatively large. We had not anticipated starting walleyes less than 38 mm long and had no OMP spaghetti smaller than 1.2 mm × 7.2 mm on hand. The survival of walleyes on regular OMP might have been higher also if they had started on 0.8-mm rather than 1.2-mm pellets. On July 7, it was discovered that our remaining stock of OMP spaghetti had spoiled because of a freezer malfunction. Consequently, the walleyes being fed spaghetti were switched to regular OMP beginning July 8.

When the study was concluded on August 25, only 7.5% of the walleyes remained alive--8.4% fed OMP and 5.7% fed W-7 (Table 5). Final mean lengths were 112.3 mm on OMP and 115.1 mm on W-7. Total mortality from June 10 (end of starvation mortality) to August 25 was 11% for walleyes on OMP and 50% for walleyes on W-7; but this difference resulted mainly from an outbreak of columnaris in the W-7 troughs in early July. Terramycin (TM-50) mixed with the W-7 pellets at a rate of 1.5 g TM-50 to 700 g of pellets controlled the columnaris after 9 days of treatment. If all walleyes that died of columnaris had survived, then total mortality in the W-7 trough from June 10 to August 25 would have been only 9%.

The result of this study stressed the importance of inducing as many walleyes as possible to accept pelleted food during the critical first week following stocking in troughs. Increasing survival from the 10% realized in this study to approximately 50% is one of the two biggest challenges to raising walleye fingerlings intensively. The second challenge is the prevention and/or control of all fish diseases that can decimate walleyes raised in intensive culture. Plans to raise a second group of walleyes intensively had to be abandoned because they became infected with columnaris. Treatments with Terramycin and Diquat did not keep the disease from spreading, and the entire group soon died. However, an external application of Furanace (2.0 mg in 10 liters of water for 1 hour) for 3 consecutive days seemed to control columnaris in a small complement of 12 infected walleyes (8 fish were alive and actively feeding 12 days following the treatment).

<u>1976</u>

Fish diseases, especially columnaris, have been a major problem during intensive culture of walleyes. In 1976, a joint study with John Hnath, the state fish pathologist, Michigan Department of Natural Resources, tested three chemicals known to be effective against <u>Flexibacter columnaris</u>. Walleyes are more sensitive than other fish to many chemicals used to control disease, therefore preliminary tests were made with the three chemicals to determine optimum treatment levels (time and concentration).

The following treatments were chosen for walleye fingerlings in standard rearing troughs containing 283 liters of flowing water at 21 C (Hnath unpublished data):

<u>Copper sulfate</u>: Turn off water flow. Apply as a stagnant bath for 30 seconds at a concentration of 32 ppm copper sulfate. Flush each trough with 19 liters per minute water flow for 30 minutes, then return to normal flow.

<u>Malachite green-formalin mixture</u>: Turn off water flow. Apply as a stagnant bath for 1 hour at a concentration of 0.2 ppm malachite green and 75 ppm formalin. If trough contains walleyes at production levels, oxygen must be provided during the bath. Flush each trough as in the copper sulfate treatment.

<u>Furanace</u>: Turn off water flow. Apply as a stagnant bath for 1 hour at a concentration of 1 ppm Furanace. Provide oxygen if necessary. Flush each trough as in the copper sulfate treatment.

For the intensive rearing tests, well water heated to 21 C flowed through each of 16 283-liter troughs at 7.6 liters per minute. On June 2, each of six troughs were stocked with 2,166 walleye fingerlings (mean length 45.0 mm) from hatchery pond 8. Two troughs were designated as "Furanace, prophylactic", two as "Furanace, therapeutic", and two as "control". Walleyes in "Furanace, prophylactic" troughs were treated every other day as described above. Similar treatments would be given to walleyes in the "Furanace, therapeutic" troughs if an outbreak of columnaris occurred. A Loudon North Star automatic feeder was suspended approximately 7.5 cm above the water surface in each trough. A mix of 0.8-mm and 1.2-mm OMP was fed over a 14-hour period (6 AM-8 PM) at a rate of 450 g per trough per day (27% of fish body weight per day). During the test the size and amount of pellets fed were varied as conditions dictated.

On June 4, each of the remaining 10 troughs were stocked with 1,000 walleyes (mean length, 45.2 mm) from hatchery pond 7. Two troughs, each, were designated "malachite-formalin, prophylactic", "malachite-formalin, therapeutic", "copper sulfate, prophylactic", "copper sulfate, therapeutic", and "control". Fish in the "malachite-formalin, prophylactic" and "copper sulfate, prophylactic" troughs were treated every other day as described above. Walleyes in the respective "therapeutic" troughs were to be treated if columnaris developed. Automatic feeders were set to dispense 225 g of OMP (0.8- and 1.2-mm mix) per day into each trough (29% of fish body weight per day).

A large rectangular opening was cut in each of 16 styrofoam trough covers so that the feeders could be raised and lowered. The combination of covers and feeders seemed to be very effective in minimizing the fright reactions typical of walleyes in intensive culture. Also, the light weight of the covers made for easy removal prior to treatment or cleaning. Troughs were cleaned once or twice daily, as needed. From 8 AM to 4:30 PM lighting was provided by three fixtures, each with two 40-watt fluorescent bulbs. Additional light entered through a large white fiberglass door adjacent to the troughs.

Soon after the test began mortalities due to starvation and cannibalism significantly reduced the number of walleyes in each trough. On June 17, the survivors were combined to reduce the total number of troughs from 16 to 9 (Table 6). Relatively heavy mortalities from starvation continued through June 22. On July 6, an inventory of the remaining walleyes was made, chemical treatments were ended, and fish were combined to further reduce the number of troughs from 9 to 2. On July 22, a final inventory was made (Table 7) and the remaining fish were transferred to a concrete tank and raised through September 8.

Since no disease outbreak occurred during the test, the relative effectiveness of the three chemical formulations for disease control was not determined. However, some apparent effects of each chemical on the growth and survival of walleyes were noted (Table 8). Furanace seemed to have no effect on growth of walleyes, but both copper sulfate and malachite green-formalin seemed to have an adverse effect on growth. Furanace seemed to enhance the survival of walleyes. Malachite green-formalin seemed to have a slightly adverse effect on survival, while copper sulfate seemed to have a definitely adverse effect on survival. Although lighting was not equal for all troughs, there was no obvious variation in growth or survival of walleyes related to light intensity.

Survival through July 6 of non-treatment walleyes originating from pond 7 (36.6%) was different than those from pond 8 (9.5%). The only obvious explanation was that fish from pond 7 were stocked into the troughs at a lower rate--1,000 as compared to 2,166; however, the theoretical maximum loading rate was over 4,000. Loss due to cannibalism was 10.0% for pond 7 walleyes and 10.2% for pond 8 walleyes. Thus, the main difference in mortality was due to starvation. The difference in growth of surviving non-treatment walleyes from pond 7 and pond 8 was not significant.

Survival of all walleyes through July 22 was 20.0%. They had achieved a length of 77.5 mm by then. Mortality rate during the 2 weeks prior to July 22 was three fingerlings per day. If this rate continued through the summer, then survival would have been 19.4% as of September 8. Mean length was 110.5 mm on September 8.

Results obtained in the 1976 experiments were more encouraging than in 1975. The walleyes reached a length of 110-115 mm in both years, but survival was significantly greater in 1976. Better success in 1976 is attributed to larger initial size of fingerlings and the absence of fish disease problems.

Discussion

From 1972 through 1976, survival of walleye fingerlings in intensive culture varied from 0.3 to 61.3%. Growth rates varied from 0.61 to 0.99 mm per day and surviving walleyes reached lengths of 100 to 115 mm (Table 9). Nickum (1978) reported similar survival rates (as high as 60%) and growth (to 100-125 mm in 10-15 weeks) for walleye fingerlings raised intensively in other hatcheries in the United States and Canada.

When individual tests over the study years were compared, survival of walleyes was considerably higher on OMP (mean 20.6%) than on two dry diets (mean 3.0%). However, in the only test where the two formulated food types were compared in the same year, the difference in survival was not as great (7.2% for OMP and 5.7% for W-7). In New York, growth on the W-7 diet was comparable to growth on other diets and fingerlings of 100-125 mm were produced by mid-September. In other studies, daily feeding rates have varied from 3% of body weight to "feeding to excess" (Nickum 1978). In my studies, initial daily feeding rates were 279% of body weight in 1975 (probably equivalent to "feeding to excess") and 27 to 29% in 1976 (feeding rates were not recorded in 1972 and 1974).

No particular type or size of rearing unit has proved to be superior for culture of fingerling walleyes (Nickum 1978). The rectangular fiberglass troughs used in Michigan in 1974-1976 seemed to be of optimum dimensions for such things as feeding, cleaning, lighting, and observing. In all my tests in troughs the initial loading rates and stock densities were well below the maximum values for fingerling walleyes proposed by Nickum (approximately 0.7 kg per liter per minute and 24 kg per cubic meter, respectively).

Initial size of fingerlings seems to be important to the success realized in intensive culture. Fingerlings of 45 to 50 mm accepted formulated food more readily than smaller fingerlings. In Michigan, extensive pond culture techniques have evolved to the extent that walleye fry can be grown to 50 mm mean length on plankton with survival rates from 50 to 95% (Beyerle unpublished data). But all walleye fingerlings, regardless of size, went through an initial "starvation period" of up to 10 days. Refusal to eat formulated food in this period was the main reason for low survival in my experiments. Nickum (1978) reported that survival of fingerling walleyes was increased by first feeding brine shrimp and zooplankton to the fingerlings, then gradually reducing the abundance of live food while increasing the ration of formulated food.

Unlike fry, walleye fingerlings were negatively phototrophic. Fingerlings in troughs tended to seek out shaded areas, although they moved to lighter areas to feed if necessary. The highest survival occurred in 1974 when walleyes had to move from a dark area under a cover into a lighted area in the center of the trough to feed. There was lower survival in 1975 and 1976 when troughs were dimly lit and food was dispensed more or less evenly over the entire surface.

Water temperatures of 20 to 22 C are considered to be best for maximizing growth of fingerling walleyes while minimizing disease problems (Nickum 1978). In my 1972 test, water temperatures as high as 29 C were associated with the onset of an unidentified bacterial infection that decimated fingerling walleyes. In other years water temperatures were kept at or near 21 C. Nevertheless, a serious outbreak of Flexibacter columnaris occurred in 1975. Of the three fish disease control chemicals tested in 1976, two may no longer be legally used. Furanace, the most effective chemical, still has not been approved for use. Malachite green, which was mixed with formalin, has been banned from use in fish disease control (John Hnath personal communication). Thus, the only acceptable compound is copper sulfate, the least effective one.

Summary

Walleye fry under intensive culture did not consume any live or formulated food with regularity, and survival beyond the first 3 weeks was extremely low (0-4%). Factors which had no noticeable influence on survival of fry in rearing units included water temperature, loading rate, fry density, size of unit, source of water, natural versus artificial light, and exposure to natural pond conditions. Factors which influenced feeding were light intensity and size of food items. In one test growth of fry was enhanced by increasing light intensity from dim to slightly less than normal daylight. Light intensities greater than daylight seemed to stimulate swimming activity but not feeding. Young fry beginning to feed consumed brine shrimp 0.48 mm and larger but did not feed on 0.1- to 0.3-mm infusorians.

One characteristic common to all walleye fry confined to rearing units was a tendency to swim constantly and, apparently, aimlessly. Although cannibalism caused significant mortalities, the majority of fry seemed to die

from exhaustion caused by lack of feeding and constant swimming. They literally swam themselves to death. Even fry that fed exhibited this same stress syndrome.

Survival of walleye fingerlings raised intensively on formulated food was quite variable (0.3-61.3%) and was primarily dependent on willingness of fingerlings to accept pelleted food. Relatively high survival (high acceptance) was related to large initial size of fingerlings, covered rearing units with feeding station and lighting only in the center of each unit, and no disease problems. Low survival (low acceptance) was related to relatively small initial size of fingerlings, open or covered rearing units with feeding stations and lighting extending the length of unit, and problems with various diseases. Final (September) mean length of surviving walleyes during the four study years ranged from 100 to 115 mm.

Growth rate of fingerling walleyes varied from 0.61 to 0.99 mm per day. Year-to-year variation in growth was much more pronounced than trough-to-trough variation within years. In the 2 years when both OMP and dry diets were fed, there was essentially no difference in growth. Optimum water temperature seemed to be approximately 21 C. Within the range of values used in these tests, the stock densities, loading rates, feeding rates, or sizes of the rearing units had no important effect on survival, growth, or ultimate size of walleye fingerlings.

Recommendations

Based on the experiences gained in these tests, plus information reported by Nickum (1978), the following procedures are recommended for intensive culture of walleye fingerlings:

1. Assuming the walleyes to be cultured intensively will first be raised from the fry stage in extensive ponds on plankton, every effort should be made to produce uniform-size fingerlings approximately 50 mm long. However, to obtain optimum numbers of healthy fingerlings, the walleyes should be harvested, regardless of size, as soon as the pond zooplankton population begins a sharp decline.

2. Fingerlings should be transferred with minimum, careful handling from ponds into fiberglass rearing units of approximate 0.5 m^3 capacity, containing water equal in temperature to pond water. The optimal initial stocking rate is 12 kg per cubic meter of water, with at least two water exchanges per hour. Each rearing unit should have medium green or medium blue inside color, a lighted feeding station in the middle third of the unit, and covers over the remaining two-thirds of the unit. During intensive culture water temperatures should be maintained at 20 C.

3. Automatic feeders are a necessity for intensive culture of walleyes. Either OMP or W-7 dry diet can be fed. As new diets are developed, they should be tested on walleyes. If possible, during the first 10 days of intensive culture, Daphnia or other suitable plankters should be added to provide supplemental food while the walleyes are converting to formulated food. Daily feeding of plankton and formulated food should be regulated so that on the first day plankton is the primary food being offered, and on the tenth day the main diet is formulated food. Feeding rates (percent of body weight per day) for formulated food should increase from 1% on the first day to 6% on the tenth day and each day thereafter. If the actual stocking rate of fingerlings was less than the optimal rate, then the feeding rate should be increased proportionally--to as much as 30%. Feeding should be done at regular intervals during a 12- to 16-hour "day", and the feeding station should be lighted by an overhead fluorescent light during each "day" so that the dispensed food pellets can be easily seen by the walleyes. No artificial light should be provided during the hours when no food is being dispensed. The size of food pellets must be varied with the size of the walleyes. Walleyes of 50-mm mean length require pellets of 0.8 to 1.2-mm diameter. Daily cleaning of the troughs is mandatory.

Table 1.--Growth and survival of walleye fry fed brine shrimp and plankton, or plankton only, in fiberglass troughs, May 7-June 15, 1973.

Trough no.[a]	Food	Number of walleyes		Percent survival	Mean length of recovered walleyes (mm)
		Stocked	Recovered		
1	Plankton	12,000	379	3.2	25.9
2	Plankton	12,000	397	3.3	22.9
3	Brine shrimp and plankton	12,000	493	4.1	22.4
4	Brine shrimp and plankton	12,000	583	4.9	20.8
	Total	48,000	1,852	3.9	22.7

[a] Relatively large, potentially cannibalistic walleye fry were placed in trough 5 to minimize predation. The mean length of the 35 recovered was 34.5 mm.

Table 2.--Survival of walleye fry fed three types of food in aquaria, May 5-14, 1974.

Aquarium no.	Food type	Number of walleyes		Percent survival	
		Stocked	Recovered	Per aquarium	Mean
1	Brine shrimp	100	36	36	47.5
2	Brine shrimp	100	59	59	
3	Brine shrimp + infusoria	100	48	48	49.0
4	Brine shrimp + infusoria	100	50	50	
5	Infusoria	100	0	0	8.5
6	Infusoria	100	17	17	

Table 3.--Survival and growth of walleye fry fed brine shrimp passed through three sizes of nylon screen, May 18-27, 1975.

Mesh size and aquarium no.	Number of walleyes		Percent survival	Mean length of recovered walleyes (mm)
	Stocked	Recovered		
Size 0.202 mm				
1	150	13		11.4
2	150	26		12.3
Mean		19.5	13.0	12.0
Size 0.280 mm				
3	150	41		12.3
4	150	18		12.3
Mean		29.5	19.7	12.3
Size 0.400 mm				
5	150	47		11.2
6	150	18		12.5
Mean		32.0	21.7	11.6

Table 4.--Growth and survival of walleye fingerlings raised in tanks on two pelleted food diets, 1972.

Date	Fish alive	Observed mortality during period		Mean length (mm)	Mean water temperature (°C) during period
		Number	Percent		
Tank 1 (OMP diet)					
June 28	25,451	-	-	40.6	-
July 5	8,461	16,990	66.7	43.4	19
July 12	6,585	1,876	22.2	-	19
July 19	5,975	610	9.3	52.8	23
July 26	4,286	1,689	28.3	65.5	23
July 26	4,352[a]	-	-	-	-
August 2	4,311	41	0.9	69.3	17
August 9	4,302	9	0.2	74.7	17
August 16	4,298	4	0.1	80.0	19
August 16	625[b]	-	-	-	-
August 23	620	5	0.8	86.6	18
August 30	618	2	0.3	92.2	20
September 6	617	1	0.2	98.0	18
September 13	0[c]	-	-	-	-
Tank 2 (Spearfish W-3 diet)					
June 28	23,366	-	-	41.7	-
July 5	9,259	14,107	60.4	43.2	19
July 12	5,393	3,866	41.8	-	19
July 19	4,043	1,350	25.0	53.1	23
July 26	3,407	636	15.7	58.7	23
July 26	66[a,d]	-	-	-	-
Tank 3 (OMP diet)					
June 28	11,355	-	-	42.4	-
July 5	7,664	3,691	32.5	48.5	19
July 12	4,480	3,184	41.5	-	19
July 19	3,234	1,246	27.8	60.2	23
July 26	2,374	860	26.6	63.5	23

(continued, next page)

Table 4.--concluded

Date	Fish alive	Observed mortality during period		Mean length (mm)	Mean water temperature (°C) during period
		Number	Percent		
Tank 3 (OMP diet) continued					
August 2	2,211	163	6.9	70.1	17
August 9	2,199	-	0.5	-	17
August 9	2,364[e]	-	-	-	-
August 16	2,352	12	0.5	78.0	19
August 23	2,340	12	0.5	81.8	18
August 30	2,329	11	0.5	88.4	20
September 6	2,319	10	0.4	91.4	18
September 13	2,308	11	0.5	95.0	19
September 13	2,925[c]	-	-	-	-
September 20	2,912	13	0.4	-	18
September 27	2,904	8	0.3	102.9	16
October 4	2,898	6	0.2	-	16
October 11	2,896	2	0.1	110.7	14
October 11	2,754[f][g]	-	-	-	-

[a] Sixty-six fish transferred from tank 2 to tank 1

[b] Inventory disclosed unaccountable loss of 3,673 fish

[c] Six hundred seventeen fish transferred from tank 1 to tank 3

[d] Inventory disclosed unaccountable loss of 3,341 fish

[e] Inventory disclosed unaccountable gain of 165 fish

[f] Inventory disclosed unaccountable loss of 142 fish

[g] End of experiment

Table 5.--Growth and survival of walleye fingerlings fed three pelleted foods, 1975.

Date and food type	Mean length (mm)	Survival	
		Number	Percent
May 30 (start)			
OMP regular	29.0	4,800	100
OMP spaghetti	29.0	4,800	100
W-7	29.0	4,800	100
Total	29.0	14,400	100
June 10			
OMP regular	-	597	12.4
OMP spaghetti	-	304	6.3
W-7	-	548	11.4
Total	-	1,449	10.1
July 7			
OMP regular	67.6	587	12.2
OMP spaghetti	64.8	286[a]	6.0
W-7	62.7	457	9.5
Total	65.3	1,330	9.2
July 31			
OMP regular	90.4	853[a]	8.9
OMP spaghetti	-	-	-
W-7	91.9	305	6.4
Total	90.9	1,158	8.0
August 25			
OMP regular	112.3	802	8.4
OMP spaghetti	-	-	-
W-7	115.1	274	5.7
Total	113.0	1,076	7.5

[a] On July 8, walleyes being fed OMP spaghetti were switched to OMP regular.

Table 6.--Survival and growth of walleye fingerlings fed OMP, June 2-July 6, 1976.

Source pond and trough no.[a]	Treatment[b]	Mean length (mm)		Percent		
		Start	Finish	Cannibalism[c]	Starvation[c]	Survival
Pond 8						
21⟶ 19	FN	45.0	64.8	7.1	68.4	24.5
22⟶ 23	Control	45.0	65.0	14.9	75.0	10.1
18⟶ 20	Control	45.0	65.3	5.6	85.5	8.9
Mean, control		45.0	65.0	10.2	80.3	9.5
Mean, Pond 8		45.0	65.0	9.2	76.3	14.5
Pond 7						
26⟶ 17	M-F	45.2	59.7	2.6	67.6	29.8
27	$CuSO_4$	54.2	60.7	12.1	70.0	17.9
29⟶ 30	$CuSO_4$ + control	45.2	56.1	2.2	85.2	12.6
32	Control	45.2	66.8	17.5	50.4	32.1
28⟶ 31	Control	45.2	62.2	10.5	48.8	40.7
24⟶ 25	Control	45.2	62.0	2.0	61.0	37.0
Mean, control		45.2	63.8	10.0	53.4	36.6
Mean, Pond 7		45.2	60.7	6.4	64.6	29.0
Ponds 7 and 8						
Mean, all troughs		45.1	62.5	8.0	71.2	20.8

[a] Arrow (⟶) indicates that walleyes in these troughs were combined on June 17. Inadvertently, the fish in trough 29 ($CuSO_4$) were combined with those in trough 30 (control).

[b] Treatments: FN = Furanace, M-F = Malachite green-formalin, $CuSO_4$ = copper sulfate. Because no disease problems occurred, the various "therapeutic" troughs became a second set of controls.

[c] Loss of walleyes to starvation was the number of fish found dead in the troughs; loss to cannibalism was the difference between the total number of fish which failed to survive and the number which starved.

Table 7.--Survival and growth of walleye fingerlings fed OMP, July 7-22, 1976.

Trough no.	Fingerlings		Mean length (mm)		Percent		
	Stocked	Recovered	Start	Finish	Canni-balism	Starva-tion	Survi-val
21	2,478	2,419	63.8	77.5	1.2	1.2	97.6
23	2,308	2,186	62.0	77.5	1.4	3.9	94.7

Table 8.--Survival and growth of treated and control walleye fingerlings, June 6-July 6, 1976.

Treatment	Treated		Control	
	Mean length (mm)	Survival (percent)	Mean length (mm)	Survival (percent)
Furanace	64.8	24.5	65.0	9.5
Malachite green-formalin	59.7	29.8	63.8	36.6
Copper sulfate	60.7	17.9	63.8	36.6

Table 9.--Summary of growth and survival of intensively cultured walleye fingerlings, 1972-76.

<table>
<tr><th rowspan="2">Year</th><th rowspan="2">Initial stock density kg/m^3</th><th rowspan="2">Initial loading rate kg/ℓ/min</th><th rowspan="2">Food</th><th colspan="2">Mean length (mm)</th><th rowspan="2">Growth rate mm/day</th><th rowspan="2">Survival (percent)</th></tr>
<tr><th>Start</th><th>Finish</th></tr>
<tr><td>1972</td><td>2.5-4.2</td><td>0.44-0.74</td><td>W-3</td><td>41.7</td><td>58.7</td><td>0.61</td><td>0.3</td></tr>
<tr><td>1972</td><td>4.5</td><td>0.79</td><td>OMP</td><td>41.5</td><td>110.7</td><td>0.66</td><td>7.5</td></tr>
<tr><td>1974</td><td>0.12</td><td>-</td><td>Minnows</td><td>46.5</td><td>89.1</td><td>1.37</td><td>94.7</td></tr>
<tr><td>1974</td><td>0.12</td><td>-</td><td>OMP</td><td>46.5</td><td>85.1</td><td>0.86</td><td>61.3</td></tr>
<tr><td>1975</td><td>0.61</td><td>0.47</td><td>OMP</td><td>29.0</td><td>112.3</td><td>0.96</td><td>8.4</td></tr>
<tr><td>1975</td><td>0.61</td><td>0.47</td><td>OMP spaghetti</td><td>29.0</td><td>64.8</td><td>0.94</td><td>6.0</td></tr>
<tr><td>1975</td><td>0.61</td><td>0.47</td><td>W-7</td><td>29.0</td><td>115.1</td><td>0.99</td><td>5.7</td></tr>
<tr><td>1976</td><td>5.8</td><td>0.22</td><td>OMP</td><td>45.0</td><td rowspan="2">77.5</td><td rowspan="2">0.65</td><td rowspan="2">20.0</td></tr>
<tr><td>1976</td><td>2.7</td><td>0.10</td><td>OMP</td><td>45.2</td></tr>
</table>

Literature cited

Nickum, J. G. 1978. Intensive culture of walleyes: The state of the art. Am. Fish. Soc. Spec. Publ. 11: 187-194.

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