Malison, J. A., and J. A. Held. 1995. Habituating pond-reared fingerlings to formulated feed. Pages 199–204 *in* **R.** C. Summerfelt, editor. Walleye culture manual. NCRAC Culture Series 101. North Central Regional Aquaculture Center Publications Office, Iowa State University, Ames.

Chapter 8

Habituating Pond-Reared Fingerlings to Formulated Feed

*Jeffrey A. Malison and James **A.** Held, University of Wisconsin-Madison Aquaculture Program, Department of Food Science, 123 Babcock Hall, Madison, WI 53706*

The development of a commercial industry that produces food-size walleye is contingent upon a reliable and inexpensive supply of fingerlings that are habituated to formulated feeds. In addition, the use of feed-trained fingerlings would probably reduce the production cost of advanced fingerling walleyes (i.e., fingerlings longer than 2–3 in [50–75 mm] in total length [TL]) that are currently raised by resource management programs using natural foods or forage fish (Nagel 1974).

One way to produce fingerling walleyes habituated to formulated dets is by using intensive tank culture techniques. Another possibility that is currently being tested is to feed-train fingerlings while they remain in ponds. This new method uses lights, sound, or both to attract fingerlings to the vicinity of automatic feeders, and it has met with some success (our unpublished observations). To date, however, the most widely practiced method of producing feed-trained fingerlings has been to rear walleye in ponds until the fish reach 1–3 in (25–75 mm) in TL, and then harvest and stock the fingerlings into tanks for habituation to formulated feeds (Colesante et al. 1986). This method, sometimes called the "tandem pond/tank technique" (Moore et al. 1994), is the focus of this chapter.

Many terms have been used to describe the process of replacing live food organisms with formulated diets, including "habituation," "feed-training," "conditioning," "conversion," or "acclimation". We prefer the term "habituate" because it can be used to describe both the behavioral responses of fish as well as the actions of culturists. "Condition," "acclimation," and "feed-training" are also reasonably accurate terms. The term "conversion," however, is commonly used to describe "a change from one form or use to another". Accordingly, "conversion" does a poor job in describing the habituation process, since fingerlings change neither form nor use. Even more importantly, the use of the term "feed conversion" to describe the habituation of fingerlings can lead to considerable confusion, since feed conversion is also commonly used to describe the ratio of the weight of feed consumed/body weight gain.

Just as there is no clear consensus of the terminology used to describe the habituation process, there is no unanimity among walleye culturists as to protocols that optimize the production of feed-trained fingerlings. The impact of subtle but significant differences in fingerling size and condition at harvest, culture conditions, disease treatments, food types, and feeding strategies are described both in this chapter and in the accompanying case studies. In this chapter, we have also included some of the more recent research findings from our laboratory that pertain to habituating pond-reared walleyes to formulated feeds.

The habituation process begins shortly after walleye fingerlings are harvested from ponds, usually when fish reach 1–3 in (25–75 mm) in TL. Typically, when walleye are harvested at this size, 50,000–150,000 fingerlings/acre (125,000–375,000/ha) can be produced. Harvesting walleye once they have reached larger sizes usually results in lower yields. The most serious problems confronted when rearing walleye fingerlings to larger sizes on natural forage are cannibalism and the depletion of the natural forage base (Dobie 1956).

Alternatively, the number of fingerlings that can be produced in a pond can be maximized by harvesting the fish at a small size. The fragile nature of walleye less than 1 in (25 mm) in TL, however, can make them dfficult to harvest. Additionally, fish harvested at too small a size may not habituate well to conventional starter diets (Cheshire and Steele 1972). In one study undertaken by our laboratory, the habituation rate of walleye harvested at 1.2 in (30 mm) in TL was greater than that of fish harvested at 0.8 in (20 mm) in TL (Figure 1). The overwhelming cause of mortality in the small fingerlings was starvation, Whether this high incidence of starvation resulted from a direct behavioral response of the small fingerlings (e.g., lack of recognition or acceptance of formulated feeds) or from indirect causes (e.g., handling stress) was undetermined.

Stress or injury suffered by fingerlings during harvest, transportation, size-grading, and routine husbandry procedures can result in high levels of mortality during the habituation process. **Box A** in Figure 2 highlights the mortalities that we observed in a group of walleye fingerlings that were subject to stressful conditions during transport from pond to tank. In addition to leading directly to death, stresses caused by careless handling combined with the ordeal of the habituation process provide the perfect opportunity for disease outbreaks (Hussain and Summerfelt 1991: Kuipers and Summerfelt 1994). **A** great deal of vigilance of the fish culturist as well as continuing refinements of fish handling procedures are needed to minimize stress-related problems during this critical time (Nickum 1986).

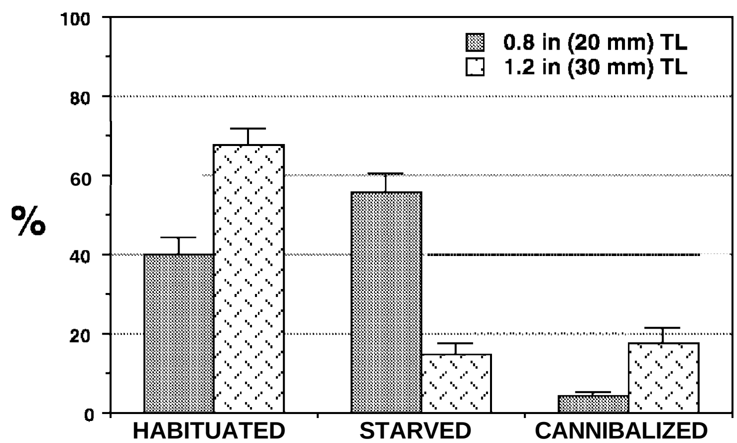

Figure 1. Percentage of walleyes habituated to formulated feeds, or lost to starvation or cannibalism after being harvested from ponds at 0.8 in (20 mm) or 1.2 in (30 mm) in total length. Each bar represents the mean ± sem of 3 tanks/treatment. Both groups of fingerlings were harvested from ponds containing adequate forage bases; condition factors of the fingerlings at harvest were similar; and fish appeared robust and healthy. The diet used for feed-training was Ziegler Bros., Inc. (Gardner, PA) salmon starter.

The decision to harvest a crop of walleye fingerlings and begin the habituation process is usually not as simple as choosing the specific fish size or age to harvest. While the fish must reach a minimum size to accept conventional starter feeds, other variables such as size uniformity, the overall condition of the fingerlings, and environmental conditions (e.g., pond water temperature, dissolved oxygen, zooplankton density, etc.) should have a significant impact on when ponds are harvested.

As a general rule, the better the condition of fingerlings at harvest the more successfully they will adapt to formulated feeds and intensive culture conditions. Poor fish condition at harvest can result from declining forage bases or overpopulated ponds. In some instances we have observed visibly emaciated fingerlings, while still in the pond. Regardless of cause, fingerlings in poor condition rarely have the energy reserves needed to successfully withstand harvest stresses combined with a period of adaptation to a new food source and a novel environment (Figure 2, Box B, opposite page). In our experiences, smaller but more robust fingerlings will habituate more successfully than larger but thinner and weaker fingerlings.

Size uniformity within a group of walleye fingerlings is another important determinant for deciding when to harvest a pond. The opportunity for differential growth increases with an extended pond phase of production, particularly in the face of a declining forage base (Nickum 1986; McIntyre et al. 1987). Large variations in size can lead to high incidences of cannibalism (Cuff 1977) during the habituation period when starving cohorts may be a more attractive food source than formulated feed. Li and Mathias (1982) attributed a decline in cannibalism rates among juvenile walleye (longer than 0.75 in [20

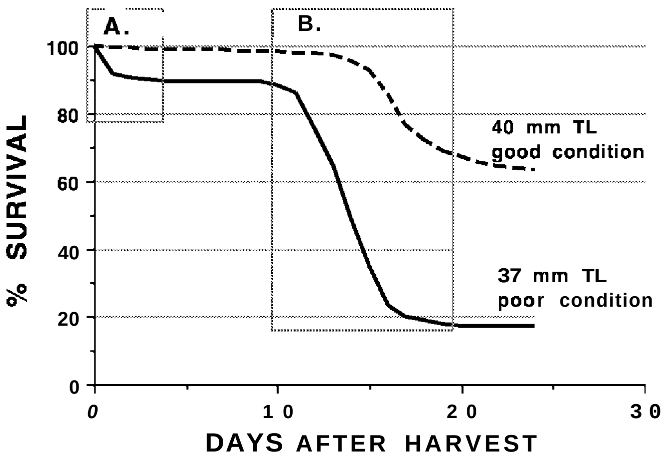

Figure 2. Percent survival of walleye fingerlings harvested at 1.6 in (40 mm) or 1.5 in (37 mm) total length and habituated to intensive culture conditions and formulated feeds. Fingerlings identified as being in good condition were harvested from a pond containing an adequate forage base; those identified as being in poor condition were harvested from a pond containing a depleted forage base, and were visibly emaciated at harvest. The diet used for feed-training was Ziegler Bros., Inc. (Gardner, PA) salmon starter.

mm] in TL) to minimal size differences among the fish. Nagel (1974) and Nickum (1986) suggested that size-grading fingerlings prior to and during the habituation period will help control cannibalism. While this practice does reduce cannibalism, the stress and injuries caused by frequent size-grading can also be detrimental to survival.

The environmental conditions under which fingerlings are habituated have a significant impact on the habituation success. Starvation generally stems from nonacceptance of the formulated diet, but has also been attributed to sub-optimal environmental conditions (Cuff 1977; Masterson and Garling 1986). Corazza and Nickum (1983) found that light-colored tanks had a negative effect on the feeding response of juvenile walleye. Similarly, Masterson and Garling (1986) found that color contrast between the feed and tank improved feed acceptance. Using walleye fry, Bristow and Summerfelt (1994) recently reported that increased water turbidity improved feed acceptance of tank-reared fry, but whether turbidity improves habituation of fingerlings has not been determined.

Several environmental variables can improve feed acceptance by increasing the frequency or duration that the fingerlings are exposed to food. Working with walleye fry, Howey et al. (1980) suggested that light could be used to concentrate fish under automatic feeders and reduce the length of time required for fish to begin actively feeding. In yellow perch, we demonstrated that habituation could be improved by using in-tank lighting to attract fingerlings to feeders (Malison and Held 1992). Upwelling water flows that suspend food in the water column can also improve habituation (Masterson and Garling 1986). Nickum (1986) recommended lighting for at least 16 h daily, and our laboratory and others (Beyerle 1975) routinely use continuous lighting (24 h/day) during the habituation process.

Observations made by ourselves and others (Nagel 1976, 1978) indicate that walleye are easily disturbed by shadows and movement. These disturbances can interrupt feeding for several hours. Nagel (1985) suggested that tank covers and in-tank lighting can minimize such disturbances. We have observed behavioral differences between fingerlings habituated using in-tank versus overhead lighting and, in general, walleye reared using in-tank lighting seem to be less disturbed by routine husbandry procedures. However, the results of several experiments in our laboratory have been inconsistent, and we have found no conclusive evidence that in-tank lighting results in improved habituation rates.

Cannibalism in walleye reared in tanks can be greatly affected by environmental conditions. High cannibalism rates have been directly related to population density (Polis 1981; Li and Mathias 1982; Malison and Held 1992). In one study (unpublished data), we found that losses due to cannibalism increased as stoclung densities were increased from 1 to 5 fish/L. Because of differential losses due to starvation, however, overall habituation success was not different between 1 and 3 fish/L. In fry, Loadman et al. (1989) suggested that the pattern of water flow was an important factor in reducing cannibalism in walleye by reducing frontal or lateral encounters. Similarly, using fry, Bristow and Summerfelt (1994) suggested that turbidity decreased cannibalism by reducing the number of cohort encounters. In general, procedures that limit potentially cannibalistic encounters may prove beneficial to culturists habituating walleye fingerlings.

Many of the losses during the habituation period that are attributed to disease can often be traced to stress incurred during harvest, transportation, or routine husbandry (Hussain and Summerfelt 1991). The most prevalent diseases occurring during the habituation process are myxobacterial infections, particularly those due to ***Flexibacter*** *columnaris*. Additionally, fin rot, furunculosis, bacterial gill disease and fungal infections have all been reported (Hnath 1975; Nagel 1976). "White tail syndrome", an apparent response to severe stress at harvest, has also been observed by ourselves and others (A. Kaas, Wisconsin Department of Natural Resources, personal communication). To date, we are not aware of any studes documenting the clinical pathology of this usually fatal condition.

Sub-optimal environmental conditions, particularly high water temperature and low flushing rate, have also been blamed for increased incidences of disease. To reduce disease problems, Nickum (1986) recommended high water quality and rapid flush rates, along with minimal handling when water temperatures exceed 68°F (20°C). Nagel (1976) suggested lowering water temperatures to the low 60s° F (approximately 15°C) after walleyes have been habituated to formulated feeds, in order to reduce disease problems. Growth rates will normally decline, however, at these lower temperatures.

Prior to the recent increased level of regulation of the aquaculture industry by the **U.S.** Food and Drug Administration, a number of compounds were used to alleviate stress and prophylactically and therapeutically treat diseases in walleye fingerlings. The use of many of these compounds is no longer permitted. Accordingly, we suggest that the reader refer to the chapter in this manual that discusses diseases and chemotherapeutic use in walleye. We have found that disease outbreaks can be minimized by the use of least-stress harvesting and husbandry procedures, combined with prophylactic static salt baths (0.7% for 4h) administered after unavoidable stressful procedures such as weighing and measuring.

Many formulated dets have been tested to habituate walleye fingerlings, including the W series diets developed at the **U.S.** Fish and Wildlife Service laboratories, various salmon and trout starters, and Oregon moist pellets (see Kuipers and Summerfelt 1994). The most important characteristics of a formulated diet used for habituation are its nutrient composition, palatability, and cost. To some extent, these characteristics are interrelated. Generally, most diets that have been successfully used have contained relatively high percentages of protein (40–60%). Palatability can be affected by many characteristics including size and size uniformity, shape, taste and texture. Nagel (1985) attributed high rates of habituation (80–90%) in part to the palatability of the krill flake diet that was used. Unless excessive, the cost of a diet used to habituate walleyes may be relatively unimportant, given the small amount of feed used during tlvs interval.

Feeding strategies employed to habituate walleye fingerlings can have a significant impact on habituation. In this regard, many variables such as feeding frequency, rate, and method of feeding have been examined. Beyerle (1975) expressed a preference for automatic feeders, citing their inherent ability to feed on a 24-h basis and lack of the disturbance caused by hand-feeding. Nickum (1986) recommended an initial feeding rate of 10% body weight daily. Nickum (1978) suggested that, since frequent hand feeding is often not practical or possible, automatic feeders may be virtually essential. He also suggested that feeders should supply small quantities of feed either continuously or at frequent intervals (e.g., every 5 min). Nagel (1976) used a combination of hand feeding and a clock-type feeder which "dispensed a few particles of feed continuously for 1–2 h" (Nagel 1974). Additional variables such as particle size, texture, and buoyancy have been tested, but to our knowledge few studies have been published to date.

The interval during which pond-reared fingerlings are habituated is characterized by slow fish growth and poor feed conversion, both of which are due primarily to poor feed acceptance. Accordingly, a short habituation interval should result in an overall improvement of fish growth and feed conversion. A short habituation interval also minimizes the extensive manpower needed during this period for fish husbandry, thereby reducing production costs (Malison and Held 1992). Whether the tandem pond/tank method of producing feed-trained walleye fingerlings will prove to be cost effective when compare with other methods such as intensive fry culture or in-pond habituation remains open to question. Regardless of the production method used, however, a reliable and inexpensive supply of walleye fingerlings habituated to formulated feeds would greatly encourage the development of a commercial industry producing food-size walleye.

Acknowledgments

We thank Thomas Kuczynski, Terence Barry, and Lynne Procarione of the UW-Madison Aquaculture Program for their invaluable assistance. Principal funding for the studies included in this chapter came from the North Central Regional Aquaculture Center with assistance from the University of Wisconsin Sea Grant College Program, National Oceanic and Atmospheric Administration, U.S, Department of Commerce, and the State of Wisconsin (Federal Grant NA90AA-D-SF469, Project No. R/AQ-22).

References

Beyerle, G.B. **1975.** Summary of attempts to raise walleye fry and fingerlings on artificial diets, with suggestions on needed research and procedures to be used in future tests. Progressive Fish-Culturist **37:103-105.**

Bristow, B.T., and R.C. Summerfelt. **1994.** Performance of larval walleye cultured intensively in clear and turbid water. Journal of the World Aquaculture Society 25:454-464.

Cheshire, W.F., and K.L. Steele. **1972.** Hatchery rearing of walleyes using artificial food. Progressive Fish-Culturist 34:96-99.

Colesante R.T., N.B. Youmans, and B. Ziolkoski. **1986.** Intensive culture of walleye fry with live food and formulated diets. Progressive Fish-Culturist 48:33-37.

Corazza, L., and J.G. Nickum. **1983.** Rate of food passage through the gastrointestinal tract of fingerling walleye. Progressive Fish-Culturist 45:183.

Cuff, W.R. **1977.** Initiation and control of cannibalism in larval walleyes. Progressive Fish-Culturist 39:29-32.

Dobie, J. **1956.** Walleye pond management in Minnesota. Progressive Fish-Culturist 18:51-57.

Hnath, J.G. **1975.** A summary of fish diseases and treatments administered in a coolwater diet testing program. Progressive Fish-Culturist 37:106.

Howey, R.G., G.L. Theis, and P.B., Haines. **1980.** Intensive culture of walleye *(Stizostedion vitreum).* U.S. Fish and Wildlife Service Lamar Information Leaflet **80-05,** Lamar, Pennsylvania.

Hussain, M., and R.C. Summerfelt. **1991.** The role of mechanical injury in an experimental transmission of *Flexibacter columnaris* to fingerling walleye. Journal of the Iowa Academy of Science 98:93-98.

Kuipers, K.L., and R.C. Summerfelt. **1994.** Converting pond-reared walleye fingerlings to formulated feeds: effects of diet, temperature, and stocking density. Journal of Applied Aquaculture 4:31-57.

Li, S., and J.A. Mathias. **1982.** Causes of high mortality among cultured larval walleye. Transactions of the American Fisheries Society 111:710-721.

Loadman, N.L., G.E.E. Moodie, and J.A. Mathias. **1986.** Significance of cannibalism in larval walleye *(Stizostedion vitreum).* Canadian Journal of Fisheries and Aquatic Sciences 43:613-618.

Malison, J.A., and J.A. Held. **1992.** Effects of fish size at harvest, initial stocking density and tank lighting conditions on the habituation of pond-reared yellow perch *(Perca flavescens)* to intensive culture conditions. Aquaculture **104:67-88.**

Masterson, M.F., and D.L. Garling. **1986.** Effect of feed color on feed acceptance and growth of walleye fingerlings. Progressive Fish-Culturist 48:306-309.

McIntyre, D.B., F.J. Ward, and G.M. Swanson. **1987.** Factors affecting cannibalism by pond-reared juvenile walleyes. Progressive Fish-Culturist 49:264-269.

Moore, A., M.A. Prange, R.C. Summerfelt, and R.P. Bushman. **1994.** Evaluation of tank shape and a surface spray for intensive culture of larval walleyes fed formulated feed. Progressive Fish-Culturist 56:100-110.

Nagel, T.O. **1974.** Rearing of walleye fingerlings in an intensive culture using Oregon moist pellets as an artificial diet. Progressive Fish-Culturist 36:59.

Nagel, T.O. **1976.** Intensive culture of fingerling walleyes on formulated feeds. Progressive Fish-Culturist 38:90-91.

Nagel, T.O. **1978.** Walleye production in controlled environments. Ohio Department of Natural Resources Division of Wildlife In-Service Note **386,** London, Ohio.

Nagel, T.O. **1985.** Development of a domestic walleye broodstock. Progressive Fish-Culturist 47:121-122.

Nickum, J.G. **1978.** Intensive culture of walleyes: the state of the art. Pages **187-194** *in* R.L. Kendall, editor. Selected coolwater fishes of North America. American Fisheries Society, Washington, D.C.

Nickum, J.G. 1986. Walleye. Pages 115-126 in R.R. Stickney, editor. Culture of nonsalmonid freshwater fishes. CRC Press, Inc., Boca Raton, Florida.

Polis, G.A. 1981. The evolution and dynamics of intraspecific predation. Annual Review of Ecological Systems 12:225-251.

Nagel, T. 1996. Intensive culture of fingerling walleye on formulated feeds. Pages 205–207 *in* R. C. Summerfelt, editor. Walleye culture manual. NCRAC Culture Series 101. North Central Regional Aquaculture Center Publications Office, Iowa State University, Ames.

Intensive Culture Of Fingerling Walleye On Formulated Feeds

Tim Nagel, London Fish Hatchery, Ohio Department of Natural Resources, Division of Wildlife, London, Ohio 43140

Introduction

This case study describes the tandem pond-tank culture method for raising advanced fingerling walleye. These methods were developed at the London Fish Hatchery in the past 20 years. Pond-cultured fingerlings (1.5 in) are brought indoors where they are trained (habituated) to formulated feed then raised to finished size of about 6 in (152 mm).

Methods

Pond-culture

Walleye culture ponds are typically filled in the third week in March. Ponds are stocked with 4-d-old posthatch at 100,000/acre (4,047 ha) about the second week in April. The ponds are fertilized with alfalfa meal to promote and maintain phytoplankton and zooplankton blooms. When the zooplankton population declines, 1.5-in (38.1-mm) walleye fingerlings (1,200/lb, 545/kg) are harvested. Harvest is done with care to minimize handling stress. The culture facilities at the London Hatchery are unique in that the ponds have been constructed to drain directly to a tank within the hatchery building where fingerlings can be harvested for stocking the rearing tanks.

Tank-culture

The excitable behavior of the fingerlings must be considered in design of the facilities used, or training walleye to formulated feed will not be successful. We have darkened the interiors of the 100-ft^3 (2.8m^3) rectangular troughs by covering them with Styrofoam to eliminate the stress of overhead light and shadows cast from movement in the hatchery (Figure 1). One opening is left in the cover to accommodate a 16-in (40.6 cm) clock-type feeder, The most significant technique factor in the success of the culture techniques is the use of submersed lighting. The troughs were illuminated with a low-intensity, 15W incandescent bulb, located at mid-water depth inside a 6-in (152 mm) clear plastic cylinder (Figure 2). These water tight cylinders are secured to the bottom of the concrete troughs with four brackets and lag screws

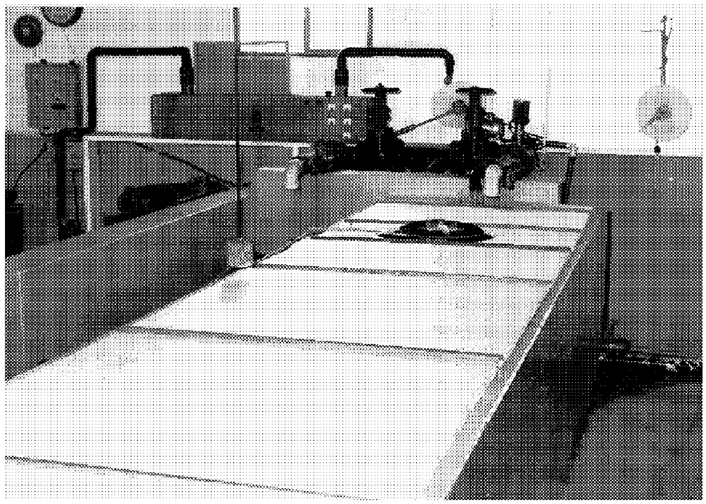

Figure 1. Fish tank used at the London Fish Hatchery for training walleye fingerlings to formulated feed. The tanks are covered with Styrofoam to eliminate overhead light (the feeder is in the background).

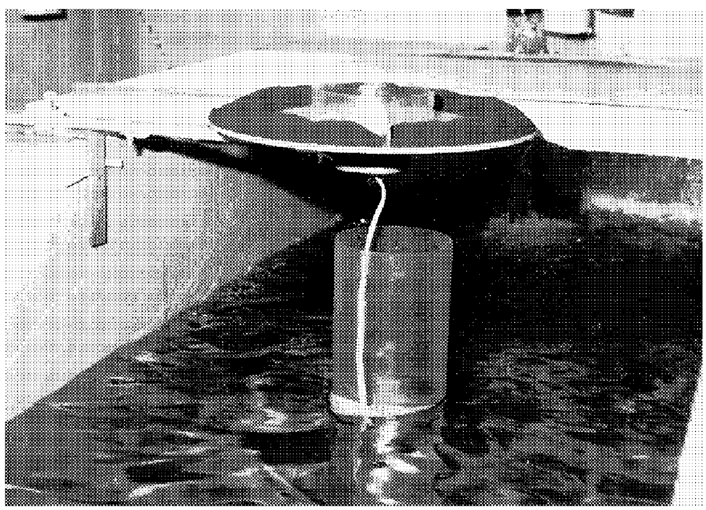

Figure 2. Prospective of homemade feeder that is mounted over a submersed light. Feed falls around the outside of the lighted cylinder.

(Figure 3). The feeder was located directly over the cylinder. Walleyes congregate around the feeders. The internal lighting also reduced shadows and reflections from external sources.

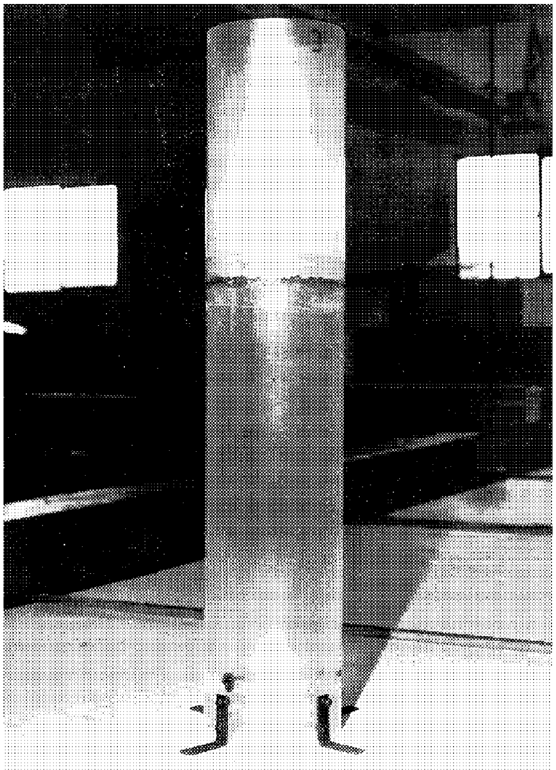

Figure 3. Water tight acrylic cylinder used to house a submerged light. Brackets attach the cylinder to the tank bottom.

The optimal density for training pond-reared fingerlings to formulated feed is 0.33 lb/ft^3 (5.3 kg/m^3) to 400 fish/ft^3 (11.3 fish/m^3). To obtain this density, the 100-ft^3 (2.83 m^3) troughs are divided with a central screen into two sections, and fingerlings are initially confined to only one (upper) of the two sections (Figure 4). A water flow rate of 20 gpm (75.7 Lpm) is used, which is equivalent to an exchange rate of 1.6/h. We consider an optimum water temperature for training fingerlings to be 68°F (20°C). Water temperature plays an extremely important role in this type of culture. Temperatures in the low 70's°F (21–23°C) will stimulate feeding walleye and promote rapid growth, however, temperature greater than 70°F (21.1"C) may increase incidence of disease. Although, decreasing the water temperature to the mid-60's°F (15.5°C) will reduce disease problems, it also reduces growth rate by about one-third.

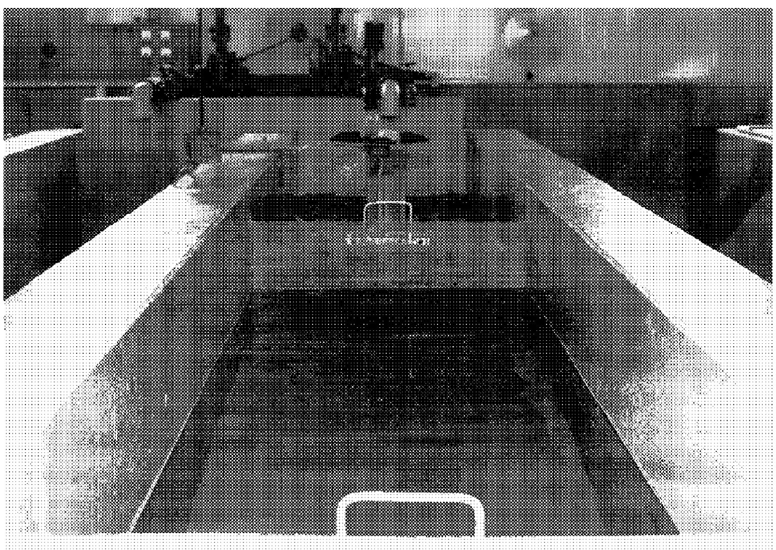

Figure 4. Culture tank with metal divider to crowd fish near feeder during the first 2 weeks of training.

The excitable behavior of the walleye is a factor which must be considered when scheduling cleaning or chemical treatments, because every disturbance causes stress and interrupts feeding, usually for several hours. On a normal feeding day, the troughs are cleaned or treated between 1400 and 1600 hours, but fish are fed in the early morning and evening.

Biotrainer , a krill-based diet, (Bioproducts, Inc., Warrenton, OR) is used as the starter diet. Initial feed sizes for 1.5 to 1.9 in (38 to 51 mm) fingerlings is number 3 and 4 crumbles. Initial feeding rates are 5% of their body weight/d. In this system with these conditions, feeding activity typically begins in less than 1-2 h after the tanks are stocked. A rapid habituation to formulated feed is important because when the fish become even slightly emaciated, cannibalism, tail-biting, and diseases will result in poor survival. Total mortalities are often less than 1% of initial stocking density in the first two weeks and the fish will have doubled in weight.

At two weeks, the fish are inventoried, graded to remove cannibals, and dip-treated prophylactically in a 500 ppm copper sulfate solution for 10 s as a prevention against columnaris, fin rot, and bacterial gill disease. If columnaris was detected, the trough is treated with 30 ppm copper sulfate for 1 min, then quickly flushed. Because the troughs have 8-in (203 mm) tilt-pipe drains, the troughs can be drained in less than 30 s. A short exposure time to 30 ppm copper sulfate is extremely important. Substantial mortalities will occur if walleyes are subjected to this treatment for 2 min, and a 3 4 min exposure will lull all fish.

After 1 month, fingerlings average 2.5-in (63.5-mm) and weigh 210/lb (95.4/kg). They are inventoried, graded, dip treated with copper sulfate, and the center screen removed. This doubles the trough volume and it reduces fish density to 0.50 lb/ft^3 (8.0 kg/m^3). The feed size and type are changed to 1.3-mm BioMoist Grower (Bioproducts, Inc. Warrenton, OR) and the daily feeding rate is reduced from 5 to **3%** of total fish weight.

After about 2 months fish have grown to 4-in (101.6 mm) and 55/b (25/kg). The feed size and type will be changed accordingly and the feed switched to 4.0 mm BioDry 3500 at a feeding rate of 2%/d. **At** this time, the internal lighting and clock-type feeders are removed and modified trough covers are used to accommodate 12 ft (3.66 m) long solenoid-type feeders (Figure 5). The fingerlings are now at a density of 1.0 lb/ft^3 (16.1 kg/m^3). Water flow is increased to 30 gpm (113.55 Lpm).

At the end of 90–100 d growing season, the walleye will be about 6 in (152.4 mm) and 20/lb (9.1/kg). The densities in the troughs will be 2.0 lb/ft^3 (32.1 kg/m^3) with a 40 gpm (151.4 Lpm) flow rate.
The survival rate for the intensive culture phase is about 90% of the initial stock (Table 1).Although 90% is exceptional compared with most published reports, these results have been replicated several times. We think that the success of our procedures is related to both the design of the culture system and the use of London strain fingerlings, which are progeny of a domesticated stock. These fingerlings start feeding within 2 h, while progeny of wild fish may not commence feeding for 2 days. Compared with 90% survival for London strain fingerlings, the survival rates for wild strain progeny normally were only around 50%.

Table 1. Advanced fingerling production statistics.

	English	Metric
Feed conversion	1.12	1.12
Flow rates/trough	40 gpm	151 Lpm
cost	$1.20/lb	$0.54/kg
Cost per fish	$0.06	0.00
Survival	90%	90%
Number	31,506	31,560
Weight	1,575 lbs	715 kg
Initial weight	1,200/lb	545/kg
Final weight	20/lb	9.1/kg
Final length	6 in	152 mm

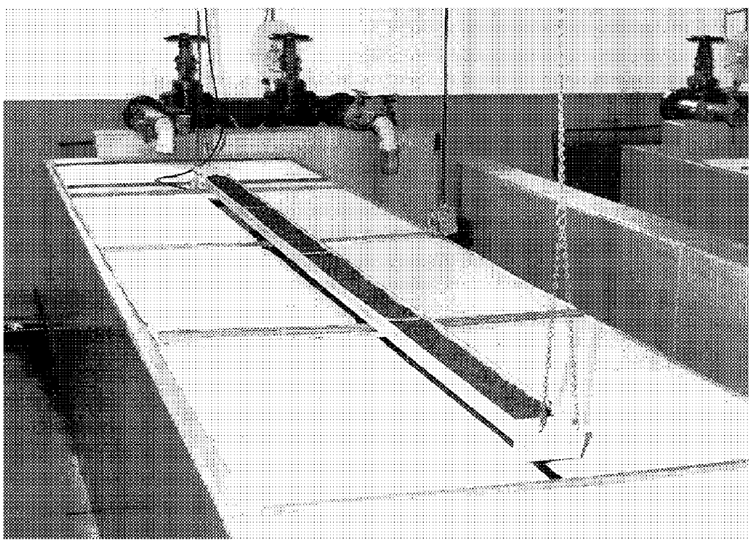

Figure 5. Two months after fish are trained to formulated feed, a long, rectangular tank-feeder is used for the balance of the culture season.

Progeny from domestic broodstock will start swimming on their side looking up towards the feeder. Wild progeny do not exhibit this behavior. The fish that we culture in an intensive culture have about one-third of the ventral lobe of their caudal fin permanently removed by fin erosion. Even ten-year old broodstock still have this marking. Fin clipping or tagging is not necessary with these fish.

In conclusion, when a reliable and good quality of water is available, mass production of walleye 12–14 in (305–356 rnm) could be produced by the end of the second summer. Thus, it seems more practical to raise walleye to 12–14 in (30.5–25.5 cm) than 6–8 in (152–203 mm) yellow perch.

Bristow, B. T. 1996. Extensive-intensive production of advance fingerling walleye at the Spirit Lake State Fish Hatchery. Pages 209–212 *in* R. C. Summerfelt, editor. The walleye culture manual. NCRAC Culture Series - North Central Regional Aquaculture Center Publications Office, Iowa State University, Ames.

Extensive-Intensive Production of Advance Fingerling Walleyes at the Spirit Lake State Fish Hatchery

Brian T. Bristow, Department of Animal Ecology, Iowa State University, Ames, Iowa 5001I

Introduction

Pond-raised walleye fingerlings have been trained to eat formulated feeds in raceways at Spirit Lake State Fish Hatchery, Spirit Lake, Iowa, for the past eight years. Insight from these experiences was incorporated into the current culture protocol of the Spirit Lake walleye program. During the 1993 and 1994 culture seasons, production-scale evaluations of diets for training pond-raised walleye to formulated feed and evaluations of walleye performance when provided several grow-out diets were conducted. For these evaluations we used a tandem culture protocol (pond-to-tank) to produce 26,000–32,000 advanced fingerling walleyes, 5–7 in (127–178 mm), for stoclung Iowa waters. The culture period consisted of three intervals: a pond culture period, when fry were stocked into ponds (see Jorgensen, 1995) and cultured for about 50 d on natural food; a 30-d training period after the fish were brought into the hatchery; and a 60-d grow-out period, which entailed the remainder of the culture season (from about August 1 – October 1). Two to four training- and grow-out diets were evaluated each year, and all but one of these diets were commercially available. This report describes the methods and equipment we used for culturing pond-reared walleyes on formulated feeds to an advanced size, and a brief summary of the results of the diet trials.

Facilities and methods

Wafersource

Influent water from Spirit Lake gravity flows into a 1-acre pond, and is then pumped through a gravel filter into the hatchery. Pressurized oxygen was injected into the water between the settling pond and the hatchery at a rate of between 0.5 and 1 gpm (2–4 Wmin); the oxygen content of water flowing into the tanks was about 105% saturation. Water in the culture tanks was generally quite turbid (>10 NTU), and the fish were seldom visible. Water temperature was 70–75°F (21–24°C) for most of the culture season, but the mean temperature in 1993 (70°F) was slightly lower than that in 1994 (73°F).

Culture tanks

Walleyes were cultured in twelve 156-ft^3 (4.4 m^3) concrete raceways that had light blue walls and floors (Figure 1). Water was supplied to each raceway at 20 gpm (76 L/min) for an exchange rate of about once/h.

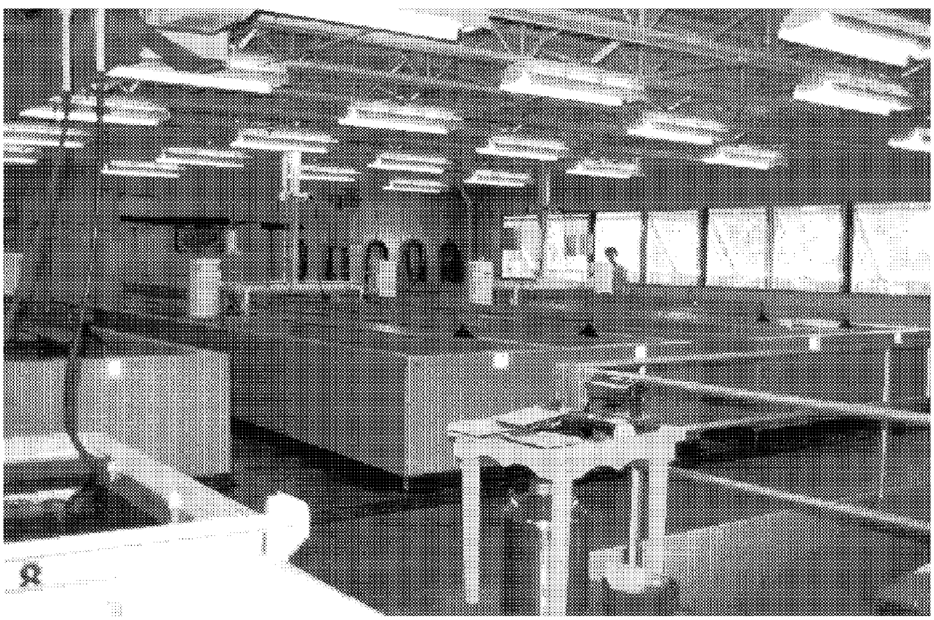

Figure 1. Fingerling culture raceways at the Spirit Lake State Fish Hatchery.

Lighting and feeding

The culture room received natural lighting from nearby windows and skylights. Overhead florescent lights furnished lighting 24 h/d. In 1993, fingerlings were fed 8% of their body weight/d throughout the entire experiment; in 1994, the initial feeding rate was 8%, but this rate was reduced to 6% when the fish were 5 in (127 mm) TL, and reduced to 4% on September 5 when water temperatures fell below 68°F (20°C). Feed was dispensed with automatic feeders every 5 min for 22.5 h/d. The feeders were shut off from 0730 to 0900 hours during tank cleaning. Feeding rates were adjusted weekly in 1993 and daily in 1994 to compensate for changes in tank biomass from fish growth and mortality. As diet type and pellet size were adjusted for fish growth, mixing ratios of 25:75, 50:50, and 75:25 (new: current) were used, and each ratio was fed for 2–3 d. Table 1 shows the pellet size used for various sized walleyes.

Table 1. Pellet size of feed provided to various sized walleyes at the Spirit Lake State Fish Hatchery.

Fish length (in)	Pellet size[1] (mm)
< 2.5	1.0 (3)
2.5 to 3.5	2.0 (4)
3.5 to 4.0	2.5 (4 or 3/32)
4.0 to 4.5	3.0 (3/32)
4.5 to 6.0	3.5 (1/8)

[1] Numbers in parenthesis represent standard feed sizes for crumbles or pellets.

Fish source

1993. Five-day-old walleye fry from Spirit Lake Hatchery were stocked into Welch Lake, a shallow natural lake near Spirit Lake. At 50-d posthatch (June 30), the fingerlings were harvested: they averaged 2.4 in (61 mm) and 230 fish/lb (506/kg). The fish were in good condition with a mean relative weight (W,) (Larscheid 1992)' of 86.8. Fingerlings were stocked into raceways at a density of 0.2 lb/ft^3 (3.2 g/L); (6,500 fingerlings/raceway). Enumeration was done gravimetrically by weighing three 3–5 lb (1.4–2.3 kg) samples, counting the fish, and determining the mean number/lb. The resulting value (230 fish/lb) was then used to calculate the appropriate weight of fish to stock into each raceway (28.25 lb, 12.8 kg).

Following a 30-d training interval, the number of fish in each raceway was calculated, and the populations reduced to 0.18 lb/ft^3 (2.9 g/L); (2,500 fish/raceway) to begin the grow-out phase of the study (August 1 – September 15).

1994. Pond-raised walleye fingerlings (45-d posthatch) were acquired from the Calamus Fish Hatchery, Burwell, NE on June 24. These fish had a mean length of 1.7 in (43 mm), and averaged 989 fish/lb (2,176/kg). The fish were extremely emaciated with a mean W_r (Larscheid 1992) of 66.9. They were stocked into the culture tanks at a density of 0.04 lb/ft^3 (0.64 g/L); (5,900 fingerlings/ raceway). At the end of the 30-d training period, fish numbers were reduced to 2,689 fish/raceway (0.25 lb/ft^3, 4.0 g/L) in preparation for the grow-out phase.

Tank cleaning

Feces and waste feed were flushed down the drain once daily by pulling the standpipe, increasing the water flow, and sweeping the tank bottom. During this process, the water level was lowered to about 5 in (12.7 cm), and the tank walls were sprayed with pressurized water to remove any accumulated fungus or feed residue. Additionally, the tank walls were scrubbed with a coarse brush about once each month. All dead fish were removed and enumerated daily and, when possible, the cause of death was recorded.

Fish sampling

Performance of fingerlings for the training and grow-out phases was evaluated using survival (%), growth, and feed conversion. Samples of 50 fingerlings were removed at 15-d intervals from each raceway and anesthetized in a 75 mg/L Finquel solution. Each fish was weighed to the nearest 0.0005 lb (0.2 g) and measured to the nearest 0.1 in (2.5 mm) and then returned to the tank. At the end of both the training and grow-out phases, lengths and weights were obtained from 100 fish sampled from each tank. All fish in each tank were weighed collectively at the end of the training interval, and populations were calculated by counting the number of fish in three 3–5 lb samples. At the end of the grow-out interval, all remaining fish were hand-counted.

Diets

In 1993, three dets (Fry Feed Kyowa C-Series, Biodry 1000, and Silver Cup Moist) were evaluated during the training interval. Four diets were evaluated during the grow-out interval. Two of the grow-out diets were closed formula commercial fish feeds (Biodry 1000 and Silver Cup Moist), and two were manufactured using the Walleye Grower 9015 open formula (Table 2) (developed by F. T. Barrows of the US Fish and Wildlife Service Fish Technology Center, Bozeman, MT). The two walleye Grower 9015 diets, however, were manufactured using dfferent techniques. One diet was formed into cylindrical pellets under pressurized steam, and then crushed to create smaller particle sizes. For simplicity in this report, this form of the 9015 diet is referred to as "crumble." The other diet was extruded into semi-round pellets of different sizes; this diet is referred to as "round." The crumble diet was produced by Sterling H. Nelson and Sons Inc., Murray, UT. The round diet was manufactured at Kansas State University, Manhattan, **KS.** All diets were analyzed for protein, moisture, fat, and ash (Table 3).

Table 2. Composition of Walleye Grower 9015.

Ingredient	Percent
Herring meal	44.44
Soybean meal	12.00
Fish oil	10.61
Wheat middlings	6.02
Corn gluten	8.30
Alfalfa	10.36
Blood meal	4.18
Lysine	0.51
Methionine	0.35
Binder	2.00
Vitamin premix	0.60
Choline	0.45
Ascorbic acid	0.15
Mineral premix	0.03

In 1994, two training diets (Fry Feed Kyowa and round extruded WG 9015) and three grow-out dets (crumble and round forms of WG 9015, and WG 9206, a newer Barrows formula in which anchovy meal replaced the more expensive herring meal) were evaluated. All but the Fry Feed Kyowa were manufactured by Sterling H. Nelson and Sons Inc., Murray, UT.

Disease diagnosis and treatment

Any time a moribund fish was observed during tank cleaning, the gills were removed and observed microscopically. The only major increases in daily mortality attributed to disease were caused by parasite infestations. *Chilodonella* sp., ich (*Ichthyophthirius multifiliis*), and Costia (*Ichthyobodo sp.*) were microscopically observed, occasionally in high numbers, on the gill tissues of moribund fish. These infestations were chemically treated with either a 1-h bath treatment of **1%** salt, or a 1-h flow-through drip of 100 ppm Paracide F (formalin). For severe ich infections, an 8-hour, 40 ppm formalin drip treatment was used for about 10 consecutive d.

Table 3. Proximate analyses' of the five diets evaluated at Spirit Lake State Fish Hatchery in 1993.

	Diet				
Analysis	Crumble	Round	Biodry	SCM[2]	Kyowa[2]
Protein	50.5	52.5	50.5	50.2	57.5
Moisture	8.4	9.5	13.6	11.9	5.1
Fat	16.0	12.2	18.8	16.3	13.5
Ash	7.4	9.2	9.5	10.2	12.0
Gross energy (Kcal/g)[3]	4.3	4.1	4.6	4.3	4.5

[1] Diet testing was conducted by Woodson-Tenent Laboratories, Inc., Des Moines, IA.
[2] SCM represents Silver Cup Moist and Kyowa represents Fry Feed Kyowa C-Series.
[3] Calculated from proximate analyses using constant values for protein and fat from Piper et al. (1982).

Results

7993

During the training interval, survival and growth were significantly greater for fish fed Fry Feed Kyowa. Survival averaged 59.1% in the six raceways fed Fry Feed Kyowa compared with 30.2 and 27.9% for those fed Biodry 1000 and Silver Cup soft moist, respectively. Over the grow-out phase, differences in survival, growth, and feed conversion among the feed treatments were not significant. However, in comparing only the two forms of WG-9015, fish fed the round pellet form had significantly less mortality than fish fed the crumble diet; possibly because the round pellet was similar in shape to the Kyowa training diet. Overall, mean density was 0.17 lbs/ft^3 (2.7 g/L) and loading was 1.3 lb/gal/min (0.156 kg/L/min) at the beginning of the grow-out interval, and density was 0.56 lbs/ft^3 (9.0 g/L) and loading was 4.3 lb/gal/min (0.516 kg/l/min) at the conclusion of the grow-out interval. In 1993, the water temperature averaged 70°F (21°C), and the fish attained an average size of 5.1 in (130 mm) and 25.1 fishflb (55/kg) with a mean W_r of 96.3%.

7994

Fish trained on Fry Feed Kyowa again showed greater survival. Preliminary analyses of growth and feed conversion data indicate that these factors were not affected by diet type. It seems that fish trained on Fry Feed Kyowa and then switched to the round form of WG 9015 grew significantly faster than those raised exclusively on the round diet. In 1994, the water temperature averaged 73°F (22.8°C), and the fish attained a final mean size of 6.3 in (160 mm) and 13.7 fish/lb (30.1/kg) with a mean W_r of 99.8%.

Conclusions

Under the production protocol used in tlvs study, we recommend training pond-reared walleye fingerlings with Fry Feed Kyowa C-series and then converting them at about 30 d to a round diet with a formulation similar to those developed by Barrows (either 9015 or 9206; Table 3). For 2–5 in walleyes, we fed 8% of their body weight in food/d, but when they are greater than 5 in long (127 mm), *6%* or slightly less may be a more efficient rate. We have developed general guidelines for estimating the amount of feed for fish of different initial sizes (Table 4), but the amount will vary with water temperatures. Further evaluations of optimal loadmg and density of fingerling walleyes would be beneficial, but two guidelines we have developed are: a loading index of 1.6 lb/gpm/in (0.08 kg/Lpm/cm), and a density index of 0.2 lb/ft^3/in (1.26 kg/m^3/cm).

Table 4. Guidelines for estimating the amount (lb/1000 fish) of walleye training and grow-out diets needed for raising pond-reared fingerlings from late June through late September.

Feed size (mm)	Pounds of feed/1000 fish of initial length of	
	1.5 in (38 mm)	2.5 in (64 mm)
Training Diet		
1.0	1.5	0.5
2.0	4.0	4.0
3.0	2.0	5.0
Grow-out diet		
2.0	5.0	2.0
2.5	50.0	30.0
3.0	100.0	120.0
3.5	25.0	25.0

Acknowledgments

This study was conducted at the Spirit Lake State Fish Hatchery, Spirit Lake, Iowa, and funding was provided by the Federal Aid in Sportfish Restoration Program (project F–151–R), Iowa Department of Natural Resources, and Iowa State University. Assistance with the culture of the fish was provided by Wally Jorgensen and the staff of the Spirit Lake State Fish Hatchery.

References

Jorgensen, W. D. 1996. Extensive lake culture of walleye fingerlings. Pages 151–152 *in* R. C. Summerfelt, editor. Walleye culture manual, NCRAC Culture Series 101. North Central Regional Aquaculture Center Publications Office, Iowa State University, Ames.

Larscheid, J. G. 1992. Natural lakes investigations. Iowa Department of Natural Resources, Federal Aid in Sportfish Restoration, Project F-135-R2, Annual Report, Des Moines.

Flowers, D. D. 1996. Intensive walleye culture in Ontario: advanced fingerling production methods. Pages 213–214 *in* R. C. Summerfelt, editor. Walleye culture manual. NCRAC Culture Series 101. North Central Regional Aquaculture Center Publications Office, Iowa State University, Ames.

Intensive Walleye Culture In Ontario: Advanced Fingerling Production Methods

David D. Flowers, Ontario Ministry Of Natural Resources, White Lake Fish Culture Station, RR2 Sharbot Lake, Ontario, CANADA, KOH 2P0

Introduction

In Ontario, over 3.6 billion walleye have been stocked in Ontario waters since 1904, mostly newly-hatched fry. Stocking activity peaked in the 1940's and 1950's when 117 million walleye (largely eggs and fry) were stocked each year. From 1974–1991, inclusive, an estimated 156 million were stocked, 93% of the total were eggs and fry, fingerlings contributed only 6.5%. During the 1960's pond and fingerling research at White Lake Fish Culture Station, hereafter referred to as White Lake, paved the way for culture methods now in use in the Province. White Lake is the only government hatchery in Ontario presently raising walleye, however, in 1982, Ontario initiated a Community Fisheries Involvement Program (CFIP) which furthered the development of many partnerships with local associations. Many of these groups have produced fry and pond fingerlings for local stochng programs and it is through their efforts that most stocking in the Province is presently accomplished.

Objective

This report describes methods for culturing advanced fingerlings based on experiences at White Lake. Considerable research and experimentation has been conducted at this facility aimed at developing practical methods for producing pond fingerlings and also larger advanced fingerlings. In the past 3 years over 100,000 advanced fingerlings have been produced here, mean survival during intensive culture has been 50–60%. Good survival and consistent production of large fingerlings at White Lake has been dependent upon the quality (size and health) of pond fingerlings used for intensive culture. Culture success also depends on good fingerling habituation to formulated diets, following proven culture methods and maintaining a diligent monitoring program.

Production methods

At White Lake, walleye fry are extensively cultured in ponds for 4–8 weeks until they are about 1.4–2.4 in (40–60 mm). At this size they are harvested with seines and either stocked in local lakes or brought indoors for habituation to formulated diets. Intensive culture lasts 10–12 weeks and results in the production of 4 in (10.2 cm) fingerlings that average 45/lb (99/kg).

Culture environment

Fingerlings harvested from ponds are placed in tanks and held for 24 hrs before they are transferred to production units. This allows for easier removal of weak and moribund fish, aquatic insects, tadpoles, algae and organic debris. We select similar-sized fish for each production unit and cull large cannibals. Within 48-h after transfer to production units, the fish are given a 1hr static bath of Diquat™ (10 mg/L, Diquat dibromide) and salt (sodium chloride at 1%). This helps combat columnaris outbreaks attributed to the bacterium *Flexibacter columnaris.*

The production units are cone shaped, 141 ft^3 (4,000L) fiberglass tanks that are approximately 6.6 ft (2 m) across and 6.6 ft (2 m) deep. They are initially filled to half volume and each is stocked at 0.19 lb/ft^3 (3.0 g/L) with 1.5 inch (38 mm, 0.5–1.0 g) fingerlings. Water volumes are increased as walleye grow and no further handling or density reductions are needed. Higher starting densities are used to promote better feed acceptance, but thinning may be required. We monitor oxygen levels daily, and increase tank volumes, flow rates or reduce walleye numbers if oxygen falls below 4 ppm. Larger walleye seem to crowd better than small ones and as a guideline, when fingerlings are approaching 4 in, we keep fish densities below 0.94 lb/ft^3 (15 g/L) at 68°F(20°C).

The water source for all facilities at White Lake is from a natural mesotrophic lake. Blended surface and hypolimnion water is used during intensive culture and temperatures are maintained between 68–72°F(20–22°C) for optimum growth of fingerlings. Flow rates to individual units are between 1 and 2 exchanges per hour which keeps oxygen levels above 4 ppm. We attempt to minimize stress by reducing activity and lighting around rearing units; low lighting (10–20 lux-measured at the surface) is provided 24 hrs/d.

Feeding and nutrition

When fingerlings are transferred from ponds to intensive culture units it is important that inventories and fish measurements are accurate. Loading densities and feeding rates will affect training success to formulated diets. Fingerlings are left alone for the first 72 hrs and not handled, except for routine feeding and maintenance. Automatic feeders are used and are checked throughout the day to make sure feed is available around the clock. It has been our experience that early feed acceptance is crucial to prevent starvation and cannibalistic behavior.

One of the keys to successful habituation of pond-raised walleye to formulated diets is to use high quality “starter” feeds. We have had our best success with Fry Feed Kyowa type C diet (Biokyowa Inc., Chesterfield, MO). FFK is fed exclusively for 2 weeks before fish are fed a 1.5 mm standard trout production diet (MNR 89S) developed by Ontario Ministry of Natural Resources for final grow-out. Early in the training period, all fingerlings are fed only FFKC 1000 (1 mm) and C 2000 (2 mm). During week 3, FFKC is fed in decreasing amounts while the MNR production diet is introduced in increasing quantities. The habituation period from FFKC to the lower-priced MNR diets lasts for approximately 1 week with final transition to trout diets by the end of week 3.

For best training success and least amount of cannibalism we prefer to start with pond fingerlings larger than 908/lb (2,000/kg). Walleye as small as 2270/lb (5,000/kg) at 4 weeks, have accepted dry dets but larger fingerlings seem to train easier with fewer mortalities. We have successfully trained pond fingerlings as large as 227/lb (500/kg).

Inappropriately sized feed can lead to poor training success. We found that FFKC 2000 (2mm) is too large as an initial feed for small pond fingerlings. For fish smaller than 908/lb 2,000/kg) we start with FFK-C 1000 (1mm); and with fingerlings 454–908/lb (1,000-2,000/kg) we feed a 50:50 blend of FFKC 1000 (1mm) and C 2000 (2mm). We use automatic feeders that dispense feed every 15 min, 20 hrs/d. Fish are fed at 12% body weight/day for the first week, but this is reduced by 2%/week for 3 weeks. Feedmg rates are maintained at 4–6% body weight/d during late August and early September or until water temperatures drop below 64°F(18°C).

Disease treatments and routine monitoring

Chemical treatments are essential during the first 4 weeks of intensive culture to control columnaris disease. We use Diquat™ at 10 mg/L (1 h bath) for 3 consecutive d each week. These preventative treatments reduce the risk of acute losses and help maintain fish health, consistent growth and predictable survival rates. If columnaris becomes well established it is often necessary to give the fish a 1% salt bath concurrent with the first diquat treatment of the week. The salt seems to facilitate treatment effectiveness.

To maintain proper water quality and prevent disease, tanks are cleaned at least once daily and mortalities are removed each morning and counted. Record keeping is a priority for all our programs, we monitor water quality, feeding rates, fish mortality, fish behavior and growth.

Conclusion

At White Lake, intensive culture methodology continues to be refined and improved with every production year. The tandem pond culture and intensive culture sequence has proven to be the most reliable and economical way of producing large numbers of advanced walleye fingerlings at White Lake. About 40,000 advanced fingerlings were produced at this facility in 1992. These fingerlings were initially reared in ponds and then intensively reared to the fall at a cost of 27 cents (CDN) each (this includes labor, feed, chemical treatment and initial pond-rearing costs). The production cost for pond-reared fingerlings was 3.4 cents (CDN) (based on annual production of 200,000 summer fingerlings from 10 small ponds with a total surface area of 2.6 acres (0.96 ha).