WALLEYE

Project Component Termination Report for the Period
September 1, 1993 to October 31, 1995

NCRAC FUNDING LEVEL: $150,000 (September 1, 1993 to October 31, 1995)
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Ohio Department of Natural Resources (DNR)	London State Fish Hatchery	Ohio
Wisconsin DNR	Lake Mills State Fish Hatchery	Wisconsin

REASON FOR TERMINATION

The objectives for this work on Walleye were completed.

PROJECT OBJECTIVES

(1) Measure genetic parameters required for efficient combined selection of sub-adult and adult traits, using a pedigreed population of walleye.

(2) Conduct field trials that compare effectiveness and costs of different pond and tank culture strategies for producing advanced fingerlings.

PRINCIPAL ACCOMPLISHMENTS

OBJECTIVE 1

Commercial production of walleye as a food fish has been constrained by a lack of genetically-selected, high-performance domesticated strains. When this study began, only one "domesticated" stock (London State Fish Hatchery, Ohio DNR) was available that was more than four generations removed from the wild. To overcome this deficiency, a comparative evaluation of walleye stocks from the North Central Region (NCR) and a performance evaluation of family groups, had begun in the second and fourth Walleye projects.

Those evaluations provided a foundation for this fifth Walleye project study of quantitative inheritance in this species by University of Minnesota (UM) investigators. Quantitative traits are described by measurements, such as length and weight. UM researchers founded a pedigreed population from gametes collected from a wild population, then obtained performance data of sub-adult and adult traits from the progeny of crosses from this population. The traits were length and weight at different ages, specific growth rate, survival rate, and incidence of deformities of fish belonging to 12 full-sibling families nested in four half-sibling families and a control group reared at the UM and at Aurora-Aqua, Inc., a commercial walleye aquaculture enterprise.

Sire and dam heritabilities were obtained for length and weight at 25 different ages (from day 1 to day 375). Heritability values, which can range from 0 to 1, were sufficiently high that selective breeding should produce a good response in the next generation: 0.41 for day-47 weight, and 0.93 for day-247 weight. Crosses between adults which had high weights when they were 47-days old would yield progeny with increased weights at 47 days of age. Such results and projections suggest selective breeding of walleye can improve this species' performance in captive environments for the potential benefit of commercial aquaculture.

OBJECTIVE 2

Field trials were conducted in 1993-1995 at sites in: (1) northern Illinois by personnel of the Max McGraw Wildlife Foundation in collaboration with researchers from Iowa State University (ISU); (2) west-central Nebraska (North Platte State Fish Hatchery) by personnel of the University of Nebraska-Lincoln (UNL); and (3) south-central Wisconsin at the Lake Mills State Fish Hatchery by University of Wisconsin-Madison (UW-Madison) investigators.

Fish culturists at the Max McGraw Wildlife Foundation raised walleye from fry to fingerlings in ponds and by intensive methods, and they habituated pond-reared fry to formulated feed for rearing to advanced fingerlings. A commercial-scale facility was developed to intensively raise walleye from hatch to advanced fingerlings (150 mm; 5.9 in). This culture system was single-pass (i.e., not reuse or recycle), with three 650-L (171.7-gal), and three 1,200-L (317.0-gal) tanks. The same facility was used in both 1994 and 1995 culture seasons for fry culture and for habituating pond-raised fingerlings to formulated feed.

An artificial turbid-water culture system was used to raise fry on formulated feed. This system was effective in reducing the clinging of fry to the sidewalls of tanks. Fry grew from 7.7 mm (0.3 in) long at day 2 posthatch to 13 mm (0.5 in) by day 11, when 95% of the fry had food in their stomachs and 94% had fully inflated gas bladders. Problems occurred with bacterial disease in 1994 and gas supersaturation in 1995. But the technology transfer of the fry culture system seems to have been successful, inasmuch as the problem with bacterial disease is commonplace with walleye culture everywhere. The mean length of intensively cultured fish that survived to day 49 were similar to mean lengths of pond-reared fingerlings of about the same age.

Pond culture of walleye at the Max McGraw Wildlife Foundation was done in two 0.4 ha (1.0 acre) ponds, stocked with 2-4 day-old fry at a rate of 275,000/ha (111,293/acre). When zooplankton populations declined, a light-harvesting technique was used to harvest fish for the tank feed habituation and rearing study. In 1994, 41% of the fingerlings in the ponds were captured with the light-harvesting technique. In 1995, with additional experience and some improvements in the technique, more than 80% of the fingerlings in the two ponds were captured by light-harvesting.

Some of the pond-reared fingerlings at the Max McGraw Wildlife Foundation were transferred to 1.2- and 1.5-m (3.9- and 4.9-ft) diameter cylindrical tanks in the hatchery building for habituation to formulated feed and then raised to a target size of 150 mm (5.9 in). Two experimental conditions were examined: tank size (650 and 1,200 L; 171.7 and 317.0 gal) and tank color (light blue and black painted tanks). In both 1994 and 1995, food conversion was lower, growth faster, and percentage of fingerlings that reached the 150-mm (5.9-in) target size higher for fish raised in black tanks than fish raised in blue tanks.

In 1995, total variable costs (labor, feed, chemicals, fertilizer, pumping costs) to produce fingerlings by the tandem production method, averaged $0.42 for 127.8 mm (5.0 in) fingerlings reared in blue tanks and $0.46 for 140.5 mm (5.5 in) fingerlings reared in black tanks. Tank size was less important, but results were better for the smaller tank -- perhaps because a single feeder in both large and small tanks provided fish easier access to feed in the smaller (one feeder per 1.2 m^2 [12.9 ft^2] of tank surface) than the larger (one feeder per 1.8 m^2; 19.4 ft^2) tank.

Field trials conducted by UNL investigators evaluated pond aeration, fertilization, and fry stocking density in ponds at the North Platte State Fish Hatchery. In one seven week study, employing 17 0.4 ha × 1-m-deep (1.0 acre × 3.3-ft-deep) ponds, the effects of no aeration and continuous "Quad-Air" diffuser aeration were compared, as well as two different fertilization rates (150 or 225 kg/ha [133.8 or 200.7 lb/acre] per week of alfalfa pellets, supplemented with liquid phosphoric acid), and stocking rates of 405,000 and 607,000 fry/ha (163,904 and 245,653 fry/acre) rather than a normal stocking rate of 250,000 fry/ha (101,175 fry/acre). This study revealed consistently high levels of dissolved oxygen (DO) in all ponds and no appreciable aeration, fertilization, or stocking-rate effects on survival (71-81%) or on the size (37-44 mm [1.5-1.7 in] total length [TL]) of fish harvested.

In a second UNL study, the effects of stocking rate and continuous aeration on walleye fingerling production in 18 heavily fertilized 0.4-ha × 1-m-deep (1.0 acre × 3.3-ft-deep) ponds were investigated. Walleye fry were stocked at rates of 405,000, 607,500, and 800,600 fry/ha (163,904, 245,855, and 324,003 fry/acre). All ponds were fertilized at a similar rate (340 kg/ha [303.3 lb/acre] per week of alfalfa pellets, supplemented with liquid phosphoric acid). During the sixe and one-half week study, DO levels typically remained near saturation levels and rarely went below 5 mg/L (ppm), irrespective of aeration. At harvest, fish stocked at 405,000/ha (163,904/acre) were significantly longer (40 mm [1.6 in] TL) and heavier (0.47 g; 0.017 oz) than those stocked at either 607,500/ha (245,855/acre) (35 mm [1.4 in] TL, 0.31 g [0.011 oz]), or 800,600 fry/ha (324,003/acre) (34 mm [1.3 in] TL, 0.28 g [0.010 oz]). The size at harvest of fish stocked at the two higher densities did not differ significantly. Neither stocking rate nor aeration had a significant effect on survival (69-79%), or the total biomass of fish harvested per pond (126-166 kg/ha; 112.4-148.1 lb/acre).

Collectively, these results suggest that walleye culture ponds in the NCR are being operated at far below their production potential in terms of harvestable numbers of fingerlings, and that at the tested rates of fertilization, which were comparatively high, the need for supplemental aeration in the Great Plains states of the NCR, except for emergency applications, may be minimal because of the climatically normal windy conditions.

In conjunction with the field trials to evaluate the effects of stocking and fertilization rates on the number of walleye fingerlings that can be produced per unit of pond surface area, UNL investigators also developed and tested various large-scale, low-stress harvesting systems employing lights arranged and operated in a variety of ways to attract fish into specially designed passive-capture gear (i.e., two types of modified, open-topped fyke nets). These trials resulted in 1994 in the repeated capture of 20,000-60,000 fingerling (20-30 mm [0.8-1.2 in] TL) walleye in a 15-20 min interval, from heavily stocked production ponds (400,000 fry/ha; 161,880 fry/acre). Together the results of these field trials and harvesting studies demonstrate that (using appropriate pond stocking, fertilization, and harvesting strategies) the number of walleye fingerlings that can be produced per unit of pond surface area can be increased by 160-320% above presently established standards, with no significant detrimental effect on survival and only a comparatively small reduction in fish size. The success of this approach depends on harvesting before depletion of the forage base and before high summer water temperatures become a problem. Experience has demonstrated that walleye of 34-44 mm (1.3-1.7 in) TL and smaller can be readily harvested and habituated in tanks to conventional starter diets.

In 1995, catastrophic losses of walleye fry occurred in production ponds across Nebraska because of extremely cold spring and early summer weather. Consequently, the numbers of fish captured per 15-20 min trial run using light-harvesting techniques were significantly lower (1,210-31,900 fish) than in 1994, and highly variable from run to run with each of the systems tested. But despite the production problems in 1995, a sufficient number of trials were done to indicate that the geometries of the different harvesting systems had little significant effect on the numbers of fish captured and that, accordingly, under commercial conditions, operators should employ the system that is least expensive to build and operate.

As a consequence of the catastrophic losses of walleye fry and subsequent stocking needs of the Nebraska Game and Parks Commission in 1995, a field trial to compare the merits of rearing small walleye fingerlings to advanced-fingerling size intensively in tanks versus extensively in ponds was not practicable. Only a small number of pond-reared advanced-fingerling walleye were produced.

UW-Madison researchers completed field trials at the Lake Mills State Fish Hatchery in south-central Wisconsin to identify the minimum size at which pond-reared walleye fingerlings can be successfully habituated to conventional formulated diets in tanks. In these trials about 65% survived the transition from ponds to tanks when fingerlings were harvested at 30 mm (1.2 in) TL, but only 40% survived when harvested from ponds at 20 mm (0.8 in) TL. The increased mortality of the smaller walleye resulted primarily from increased levels of stress and mechanical abrasions during pond harvest.

In addition to length, condition factor (i.e., the ratio of weight to length) of walleye fingerlings is a critical determinant to successful habituation to formulated feeds and intensive culture conditions. Fingerlings with a high condition factor tolerated harvest stress better and habituated more successfully than thin fish. The condition factor of pond-reared fingerlings is directly related to the amount of forage available in ponds prior to harvest. Accordingly, if the amount of forage in a pond declines significantly, it is probably advantageous to harvest ponds early (i.e., harvest relatively short fish with a high condition factor, rather than delaying harvest until the fish are longer but thinner).

Another important consideration in the tandem pond/tank method of culturing fingerlings is that the number of fingerlings which can be produced in a pond declines as harvest size increases. Thus, although the success rate at habituating small fingerlings to formulated feeds may be reduced, harvesting fish at a small size will typically result in higher numbers of fingerlings harvested from ponds and, therefore, may result in more fish surviving the habituation period.

IMPACTS

OBJECTIVE 1

Researchers from UM obtained high heritability estimates of desirable production traits from a pedigreed population. Their findings strongly support a recommendation for a systematic selective breeding program.

OBJECTIVE 2

Field trials conducted at the Max McGraw Wildlife Foundation validated the advantages of turbid water culture technology -- the procedure definitely benefits intensive fry rearing of walleye to 30 days of age. A major benefit of the night-lighting harvest technique was that it eliminated the harvesting of tadpoles and larval salamanders, which had been a chronic problem at the Max McGraw Wildlife Foundation. These studies also demonstrated that survival and growth was improved when fingerlings harvested from ponds were cultured in small black tanks as opposed to large blue tanks, and that tank color was more important than tank size.

Collectively, the UNL findings suggest that walleye culture ponds in the NCR are being operated at far below their production potential in terms of harvestable numbers of fish. The same is probably true for the pond production of other important varieties of fish, such as yellow perch and hybrid striped bass, which NCRAC has identified, along with walleye, as having significant potential for commercial aquaculture development.

The immediate direct impact of the UNL component of the project on the production of walleye fingerlings for stocking by the State of Nebraska can be readily documented. The average estimated number of 25-50 mm (1-2 in) TL walleye fingerlings produced by the Nebraska Game and Parks Commission at the North Platte State Fish Hatchery and statewide for the three-year period 1990 to 1992 was 1,343,316/year (the North Platte hatchery was essentially the state's sole producer of walleye fingerlings). In 1994, the estimated numbers of the same size walleye fingerlings produced at the North Platte hatchery and statewide were 3,403,261 and 4,261,520, respectively. The increased production of walleye fingerlings (by a factor of 2.5), or an increase of about 2,059,945 fish) in 1994 at the North Platte hatchery was directly attributable to the UNL research efforts there. Of the statewide overall increase in walleye fingerling production in 1994, compared to the 1990-1992 average, about 71% was attributable to the UNL research efforts at the North Platte hatchery; about 29% was attributable to walleye fingerling production at the Calamus State Fish Hatchery, which began operating in 1991. Walleye production at the North Platte hatchery was increased by an even larger margin in 1995.

In economic terms (assuming an average market value of $0.05/fingerling), according to existing production statistics, the North Platte hatchery, using traditional methods, has annually reared walleye fingerlings with a total direct market value of about $67,200 or $9,765/ha ($3,952/acre). UNL research efforts increased these amounts to $107,160 (total production) and $24,710/ha ($10,000/acre), respectively. If the "best" methods developed by the project were fully implemented at the North Platte hatchery, as they nearly were in 1995, these figures could potentially reach $204,150 (total production) and $29,652/ha ($12,000/acre). Present estimates suggest the enhanced walleye stockings of 1994 and 1995 may have increased the size and economic value of Nebraska's walleye fishery by as much as 50%. Based on such indicators, the Nebraska Game and Parks Commission has increased hatchery-pond stocking rates for walleye fry from 247,100/ha (100,000/acre) to 308,871/ha (125,000/acre).

Studies conducted at UW-Madison showed that the tandem pond/tank method of producing walleye fingerlings habituated to formulated feeds and intensive culture conditions can be expected to produce 65,000-195,000 habituated fingerlings/ha (26,306-78,917/acre) [100,000-300,000 fingerlings/ha × 65% habituation]. Once the habituation period has been completed, relatively few losses should normally be incurred during grow out to an advanced fingerling size (150-200 mm [5.9-7.9 in] TL). These and other production data are now available for economists for comparisons of the effectiveness and costs of different pond and tank culture strategies for producing advanced walleye fingerlings.

RECOMMENDED FOLLOW-UP ACTIVITIES

OBJECTIVE 1

A long-term commitment is required to commence development of domesticated brood stock and carry out genetic selection. A major reason for large-scale highly efficient commercial production of poultry has been investment by universities, government, and commercial interests in selective breeding. No matter what species is cultured, aquaculture enterprises in the NCR can benefit from genetic improvement of stocks. Because walleye require nearly three years for female fish to reach sexual maturity, it will require many years of combined effort by a team with both genetic and fish-culture expertise to carry out the long-term rearing that is needed. However, based on what has been achieved with the culture of Atlantic salmon, substantial benefits may be gained in only two generations of purposeful selective breeding of carefully chosen founder stocks.

OBJECTIVE 2

Field trials provide opportunities for extending laboratory findings to commercial-scale aquaculture. It may be the most effective way to extend research findings to the industry, as well as develop a cadre of producers who can pass on effective technologies to others. Studies on intensive fry culture indicate that bacterial gill disease (BGD) and columnaris disease are critical factors affecting success of this type of walleye fingerling production. BGD severely constrains intensive fry culture, with or without turbid water; and columnaris disease is invariably a cause of mortality in handling pond-reared fish and in tandem pond/tank culture. The environmental correlates to BGD are not well known, although the incidence of columnaris disease is known to be related to handling damage and stress from high temperatures. There is a critical need for studies of ways to prevent and control these diseases.

Further studies are needed to determine the number of walleye fingerlings that can be produced in ponds when the fish are harvested at different sizes, ranging from 20-30 mm (0.8-1.2 in) TL. Also, research is needed to compare the habituation to formulated feeds and intensive culture conditions of pond-reared walleye fingerlings harvested at different fish condition factors. This information is needed to more closely define the optimum production parameters and the most cost effective use of the tandem pond/tank method of producing walleye fingerlings.

PUBLICATIONS, MANUSCRIPTS, OR PAPERS PRESENTED

See the Appendix for a cumulative output for all NCRAC-funded Walleye activities.

SUPPORT[1]

YEARS	NCRAC-USDA FUNDING	OTHER SUPPORT					TOTAL SUPPORT
		UNIVERSITY	INDUSTRY	OTHER FEDERAL	OTHER	TOTAL	
1993-94	$72,725	$111,029	$11,250[a]	$11,000[b]	$57,420[c]	$190,699	$263,424
1994-95	$77,275	$44,773	$13,080[a]	$11,000[b]	$32,350[d]	$101,203	$178,478
TOTAL	$150,000	$155,802	$24,330	$22,000	$89,770	$291,902	$441,902

[1]This is funding for all three objectives of the fifth Walleye project.
[a]Aurora-Aqua, Inc.
[b]Wisconsin Sea Grant/USDC/NOAA
[c]1993-94: Max McGraw Wildlife Foundation ($14,900), Minnesota Department of Natural Resources ($820), Nebraska Game and Parks Department ($41,700)
[d]1994-95: Max McGraw Wildlife Foundation ($14,900) and Nebraska Game and Parks Department ($17,450)