A WHITE PAPER
ON THE STATUS AND NEEDS OF
YELLOW PERCH AQUACULTURE
IN THE NORTH CENTRAL REGION

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INTRODUCTION AND JUSTIFICATION OF THE DOCUMENT

The yellow perch (*Perca flavescens*) has been designated as a high priority species by the North Central Regional Aquaculture Center (NCRAC) Industry Advisory Council (IAC). Research on yellow perch has been supported by NCRAC since its inception in 1988/89. Each year, priority research and extension topics have been identified by the NCRAC IAC and presented to the NCRAC Board of Directors (Board). Recently, concerns have developed among NCRAC participants as to the priorities and direction of NCRAC-funded yellow perch research and extension. One expressed concern is that the long-term focus of research goals and priorities may be lost because the NCRAC Board and IAC memberships change over time. A second concern is that the two-year operating cycle of NCRAC can make it difficult to pursue objectives that need a longer time period to reach fruition. Accordingly, the Board decided that a white paper should be developed on yellow perch. The Board directed that the white paper should clearly outline the current state of yellow perch aquaculture technology, critical factors limiting economical and sustainable commercial production, and recommendations for research and extension that should be considered in future work plans. The Board further directed that this white paper be a “living document” that can be updated based on advancements and new developments within the industry.

CURRENT STATUS OF THE INDUSTRY

MARKETING

In the Great Lakes Region, the market demand for yellow perch has always been high, reflecting a strong consumer preference for this fish. Almost 70% of the yellow perch sales in the U.S. occur within 50 miles (80 km) of the Great Lakes, a region that holds over 40 million residents. An additional substantial market exists in Canada along the Great Lakes and St. Lawrence River, including the metropolitan areas of Toronto, Ottawa, Montreal, and Quebec. The basis for this demand is tied to long-standing uses of this product, its firm flesh, and low fat and phospholipid content. These last two characteristics are conducive to products having a long shelf life, resistance to freezer damage, and minimal problems with off-flavor and cooking.

Supply

For many years, virtually the entire supply of yellow perch came from capture fisheries in the U.S. and Canada, principally the Great Lakes. Markets readily absorbed the peak harvests of >33 million lb/yr (>15 million kg/yr) in the 1950s and 1960s (data from the Great Lakes Fisheries Commission, Ann Arbor, Michigan), but since that time wild harvests have declined to 11–18 million lb/yr (5–8 million kg/yr) or less during the 1980s and 1990s. Because of the changing ecology and management of the Great Lakes, most fisheries biologists predict that the peak wild harvests of the 1950s and 1960s will never return. Today, a fledgling aquaculture industry is beginning to add to the supply, but presently it contributes less than 200,000 lb/yr (90,720 kg/yr). Aquaculture products may have a marketing advantage over wild caught products because of their (real and perceived) superiority in terms of freshness, and concerns over microcontaminants in wild caught products from the Great Lakes and elsewhere. Furthermore, on a seasonal basis, aquacultured yellow perch may have higher fillet yields than wild caught fish, and processors have paid a premium for this benefit.

Demand

Even in face of the declining supply, the demand for yellow perch has remained high. One supplier (Bennet Fish, Inc., Lorain, Ohio) has indicated that they have stopped looking for new customers and are now in the business of ensuring product to their regular customers. Another large food distributor (Great Lakes Marketing, Inc., Waukesha, Wisconsin) has suggested that the existing market could readily absorb 50–100 million lb/yr (23–45 million kg/yr). Today, typical wholesale prices for yellow perch in the round range from $2.30–3.00/lb ($5.07–6.61/kg). Almost all yellow perch are eventually sold to retailers and restaurants as scaled, skin-on fillets (fillet yield ranges from 34–48%). Wholesale prices for fillets range from $6.50–9.00/lb ($14.33–19.84/kg), and retail prices normally range from $9.00–15.00/lb ($19.84–33.07/kg). One interesting byproduct of the imbalance between supply and demand is that other products, such as baby walleye, sauger, and European pike perch (zander), are now being illegally marketed as yellow perch.

BIOLOGY/AQUACULTURE TECHNOLOGY

Brood Stock Management and Fry Propagation Methods

The brood fish used by a significant number of yellow perch producers are captured from the wild just before or during the spawning season. Some producers also harvest fertilized egg ribbons from the wild. The regulations regarding the wild harvest of yellow perch brood fish and eggs vary greatly from state to state.

The brood fish used by other producers are fish that they have raised to reproductive maturity. When raised under ambient temperatures, most yellow perch females reach maturity by year 2 at a size of >2.0 oz (57 g). Males can reach sexual maturity by year 1 at a size as small as 0.5 oz (14 g). No specialized diets for yellow perch brood stock currently exist, and many producers are apparently obtaining adequate results with conventional grower diets (such as trout feeds).

Yellow perch brood stock must be held outdoors in ponds or indoors under conditions that mimic the normal seasonal changes in temperature and day length, as these changes are needed to induce normal sexual maturation. Females must be exposed to a "chill period" for normal yolk deposition and final maturation to occur. The optimum chill period of yellow perch from northern Minnesota was determined to be 185 days at temperatures of 43°F (6°C) or lower (Hokanson 1977). Yellow perch from more southern latitudes, however, probably do not need such a long or cold chill period to complete maturation (Kolkovski and Dabrowski 1998).

Yellow perch spawn once each year in the spring concurrent with increasing photoperiod and water temperature. The spawning season begins as early as January in North Carolina, and may not commence until June in Canada. In the North Central Region (NCR) most yellow perch spawn from late March through May. The fish in any given lake or region normally spawn over a two to three week period.

One line of previously funded NCRAC research is to develop methods for inducing out-of-season spawning so that yellow perch eggs would be available at multiple times of the year. The method being tested is to hold groups of adult yellow perch under environmental conditions in which the chill period is shifted to occur at different times of the year. The successful commercial application of this method has not yet been demonstrated.

Yellow perch eggs are interconnected in a concertina-shaped tube or ribbon. Each female produces one ribbon per year. The number and size of eggs in a ribbon is affected by several factors including fish size, age, and nutrition. Ribbons collected from females 7–10 in (18–25 cm) in length normally contain 7,000–30,000 eggs that range in size from 100,000–200,000/qt (106–212 eggs/mL). The high fecundity of yellow perch means that a large number of offspring can be produced from relatively few brood fish.

The simplest method of producing yellow perch fry is to stock several male and female brood fish in a pond containing suitable spawning substrate (such as brush piles), and allow the fish to spawn and the eggs to hatch naturally. Although simple, this method provides little control over when the fish spawn or the number of fry that are eventually released into the pond. The fry may vary in age by two to three weeks, leading to a significant disparity in size that promotes cohort cannibalization. Additionally, brood fish that are not removed from the pond will eventually begin to cannibalize their offspring.

Another method of fry production is to collect fertilized egg ribbons from a pond or the wild, incubate, and hatch them in tanks. Yellow perch can also be allowed to spawn in tanks if males and females are stocked together at low densities. It is difficult, however, to harvest intact yellow perch ribbons from either ponds or tanks, and even more difficult to incubate small, broken pieces of ribbons.

The most sophisticated method of fry production is to hold brood fish in tanks during the spawning season, manually strip the eggs from ripe females into a bowl, fertilize them, and incubate the eggs in tanks until hatch. Obtaining milt from males is a simple process, and semen extenders can be used to dilute semen and allow it to be stored for 5–10 days after collection (using an extender developed for walleye, see Moore 1987). Alternatively, yellow perch sperm can be cryopreserved (Glogowski et al. 1999). In contrast to stripping milt from males, stripping intact, ripe egg ribbons from females is an art that requires some experience. In order to successfully strip the eggs from a high percentage of captive female brood fish, the fish need to be frequently handled and visually inspected during the spawning season to determine if they have ovulated. Once ovulation has occurred, a female will expel the egg ribbon within several hours if it is not manually stripped.

The repetitive handling of individual female brood fish over the course of a three-week spawning season is extremely stressful to the fish, and severe bacterial infections and significant mortality can occur. Human chorionic gonadotropin (hCG) can be used to synchronize the spawning of a group of female brood fish, and shorten the spawning season from three weeks to three to four days. By using this strategy, the fish are handled much less frequently, and a large number of fry of uniform age can be produced. This past year the Food and Drug Administration (FDA) approved the use of hCG in fish when the drug is obtained through a veterinarian’s prescription. The efforts of the National Aquaculture INAD/NADA Coordinator (which is partially funded by NCRAC) were key to gaining this approval.

Routine (wet or dry) spawning methods can be used to achieve fertilization rates greater than 95%. For successful fertilization, eggs and sperm must contact one another within 30 sec after contacting water. The physical characteristics of the yellow perch egg strand makes egg incubation difficult using standard hatchery equipment, e.g., trays or jars. Instead, egg strands are usually incubated by suspending the ribbons in tanks on wires or racks. Incubation time from fertilization until hatch is temperature dependent, ranging from 5–25 days or longer. Under a thermal regime that rises gradually from 50–59°F (10–15°C), hatch begins about 12 days after fertilization. Some producers move egg ribbons into ponds or tanks shortly prior to hatch. This practice, however, makes it difficult to enumerate the number of hatched fry that are ultimately released. Eggs can be allowed to hatch on their own, but hatch rates can be improved by exposing them to physical agitation. If hatched in buckets or small tanks, the number of fry can be estimated by volumetric sub-sampling, and the fry can be directly stocked into production ponds or tanks.

Except for some producers who have raised several successive generations of captive yellow perch, no efforts have been made to genetically select or domesticate yellow perch. There is currently no evidence for the existence of strains that show rapid growth under aquaculture conditions. One technique is currently being developed, however, to produce faster growing fish. Both in the laboratory and in the wild, female yellow perch grow significantly faster than males (Schott 1980; Becker 1983; Malison et al. 1985, 1988). Accordingly, the production of monosex female populations may improve yellow perch growth rates and thereby increase production efficiency. Monosex female yellow perch populations can be produced in the following manner: (1) small fingerlings are treated via the diet with an analog of the sex steroid testosterone (MT), which sex-reverses the genetic females (i.e., fish with a “XX” genotype); and (2) the hormone-treated fingerlings are raised to sexual maturity and 100% “X” sperm is collected from the sex-reversed genetic females and used to fertilize normal (XX) eggs. The resulting fry are all female. Two major advantages of this method of producing monosex females are that the cost is almost insignificant and that no yellow perch destined for the market are treated with hormone analogs (Malison and Garcia-Abiado 1996). Despite the latter fact, one yellow perch distributor indicated that he has received negative consumer reaction to monosex female production (M. Libbin, Paragon Aquaculture, Oshkosh, Wisconsin, personal communication). Any such reaction, however, has not limited the use of monosex production in other large aquaculture industries. For example, 100% of the chinook and coho salmon produced in Canada, more than 90% of the rainbow trout produced in the U.S., and an increasing percentage of the tilapia produced in the U.S. are monosex.

The use of MT in yellow perch diets is not yet approved by the FDA, but in 1996–1998 its use has been available to several producers through an FDA Investigational New Animal Drug (INAD) exemption. NCRAC has sponsored research that is needed to gain FDA approval for using MT in yellow perch diets as described above, and the National Aquaculture INAD/NADA Coordinator is currently working towards this end.

Fingerling Production

Three methods of producing feed-trained yellow perch fingerlings have been evaluated to date: tank culture, tandem pond-tank culture, and pond culture. The tank culture method has focused on feeding yellow perch fry live foods for the first few weeks of life because yellow perch fry do not accept any currently available formulated foods. This method relies on raising progressively larger food organisms (e.g., algae, protozoans, rotifers, copepods, cladocerans, and brine shrimp) indoors and feeding them to larvae that are held in separate indoor tanks. As the fish reach approximately 0.6–0.8 in (15–20 mm) in total length

(TL), a size reached in three to four weeks, they are gradually weaned onto a diet of ground beef liver, and subsequently onto a formulated starter food.

Although successful on a laboratory scale, tank culture of yellow perch fingerlings is not widely practiced commercially. It is highly labor and capital intensive, and there are problems associated with producing live food organisms that meet the basic nutritional needs of the fish at critical early developmental stages. In addition, a significant percentage of tank-raised fry do not undergo normal swim bladder inflation. Research to date on improving tank culture has focused on: (1) identifying the nutritional requirements of yellow perch fry and developing acceptable diets, and (2) evaluating different physical properties of rearing tanks to enhance survival and swim bladder inflation rates.

The tandem pond-tank rearing method used by many commercial producers involves stocking yellow perch larvae into fertilized production ponds where they feed on natural food in the ponds. Optimal fertilization methods can vary widely from location to location (Culver and Dabrowski 1998). Once the fish reach approximately 1.0–2.0 in (25–51 mm) TL, a size reached in five to eight weeks, they are harvested and stocked into tanks where they are trained to accept conventional (e.g., salmonid) starter diets. The principal advantages of this method are that large numbers of fish can be produced in ponds (typically over 80,000/acre [197,677/ha] at a size of 1.5 in [38 mm] TL at a low cost compared to the tank culture method. Normally, 70-90% of the fingerlings of this size harvested from ponds can be habituated to formulated food and tank culture conditions. Skeletal and other deformities associated with nutritional deficiencies or imbalances often observed in tank-cultured fry and early fingerlings are rarely observed in yellow perch reared initially in ponds. Disadvantage to the tandem pond-tank method are: (1) it requires separate pond and tank systems, thereby increasing expenses compared to single-system methods; (2) fingerlings subjected to excessive harvesting stress can be difficult to train to formulated diets and are susceptible to disease; and (3) the tank rearing stage of the tandem strategy requires frequent feeding, tank cleaning, and other husbandry, leading to labor costs that continue to escalate the longer the fish are held indoors.

Research on improving the tandem pond-tank rearing method has focused on: (1) evaluating different pond fertilization regimes to maximize the quantity and quality of live food organisms in ponds, (2) the effect of different fry stocking densities on pond fingerling production, (3) harvest methods, (4) the influence of fingerling size at the time of pond harvest on the number of fingerlings produced in ponds and the percentage that survive the transition to formulated food, and (5) evaluating different starter diets. Recent studies have demonstrated that, by using a combination of high fry stocking densities and early pond harvest (i.e., harvesting fingerlings when they reach 0.7–1.0 in [17–25 mm]), the number of fingerlings produced in ponds can be increased by 100% or more (to 160,000–200,000/acre [395,354–494,193/ha]), of which 50–70% can be habituated to formulated food and tank culture conditions (Held et al. 1998).

The pond culture method used by a number of commercial producers involves stocking larvae into fertilized production ponds where they initially feed on natural food. When the fingerlings reach approximately 0.7–0.8 in (17–20 mm) TL, they are fed frequently throughout the day with a conventional starter diet. The fish are then fed with increasingly larger food sizes until they are harvested in the autumn. A modification of this method relies on the strong photopositive behavior exhibited by yellow perch smaller than 2.0 in (50 mm) TL (Manci et al. 1983). Automatic feeders are installed adjacent to bright lights along the perimeter of ponds. At night the lights concentrate large numbers of fish in the vicinity of the feeders which then disperse food frequently throughout the night. This modification increases the percentage of fish that initially accept the formulated food and reduces total food usage.

The advantages of the pond culture method are that, similar to the tandem pond-tank rearing method, large numbers of fingerlings can be raised at a relatively low cost. Unlike the tandem pond-tank rearing method, however, separate pond and tank systems are not needed, and labor costs remain low throughout the growing season. One disadvantage to the pond culture methods that are presently employed is that yellow perch fingerlings harvested in autumn show a tremendous variation in size, which leads to significant cannibalism. Typically, the number of fingerlings in ponds declines by approximately 50% between July and October (to approximately 40,000–60,000/acre [98,839–148,258/ha]). A second problem is that total fish production averages only about 700–800 lb/acre (785–897 kg/ha), or 15–25% of the amount of fish that ponds can theoretically produce. A third problem is that fingerlings reared in ponds for an entire growing season sometimes fail to habituate well to tank culture systems. Research to date on pond fingerling production methods has been limited to assessing different types of lights and feeding systems, and documenting production data.

Grow-out Methods

One of the most important factors for the successful grow out of any fish species is the availability of water at the temperature needed to promote good growth. It has long been established that the optimum temperature for the growth of yellow perch is 73–77°F (23–25°C). Yellow perch show little or no growth at temperatures below 50°F (10°C). At temperatures above 79°F (26°C) they show signs of stress and reduced growth, disease, and mortalities can be expected under conventional aquaculture conditions. Yellow perch reared unconfined in ponds seem able to tolerate temperatures up to 79°F (26°C), provided that other water quality parameters are acceptable. Under higher density conditions such as in net-pens and tanks, however, stress and/or disease problems frequently become apparent at temperatures above 70–72°F (21–22°C). These facts greatly impact the four feasible methods for raising yellow perch to market size: (1) flow-through systems, (2) water recirculation systems, (3) net-pens, and (4) open pond culture.

Past research funded by NCRAC has demonstrated that yellow perch can tolerate and thrive at the high loadings and densities needed for the economic production of fish in flow-through systems. One advantage to flow-through systems is that they offer the potential of year-round fish growth if water can be maintained at proper temperatures. At 68–72°F (20–22°C) yellow perch can be expected to grow, on average, from about 0.35 oz (10 g) to 4.60 oz (130 g) in one year, or an average of about 0.01 oz/day (0.33 g/day). Another advantage to flow-through systems is that constant water temperatures do not permit normal reproductive development (see Brood Stock Management and Fry Propagation Methods above). This is advantageous because yellow perch normally mature sexually before they reach a marketable size, and the gonadal growth that occurs with sexual maturity results in a 10–25% decline in fillet yield.

In the NCR, ground water temperatures normally range from 45–59°F (7–15°C), which is too cold to permit good growth in yellow perch. Therefore, flow-through systems for yellow perch in this region require a cost effective method for heating large volumes of water. Thermal effluent from power plants has been the most frequently discussed source of heat in this regard. At the present time there is one commercial yellow perch operation in the NCR using a flow-through system incorporating power plant effluent. There have also been several other attempts in the U.S. to use waste heat from power plants for aquaculture. For a variety of technical reasons, including the consequences of periodic plant shutdowns, such systems have not met with great success. Experts generally believe that the future development and expansion of power plant-based aquaculture remains questionable (e.g., Stickney 1996).

The feasibility of raising yellow perch to market size in recirculation systems was demonstrated over 20 years ago (University of Wisconsin Sea Grant College Program 1975). Like flow-through systems, recirculation systems offer the potential of year-round fish growth and limited reproductive development. Unlike flow-through systems, however, there is no need to continuously heat large volumes of flowing water.

The growth of yellow perch in recirculation systems is similar to that in flow-through systems (see above). Yellow perch are moderately tolerant to low levels of dissolved oxygen (levels as low as 3.5 mg/L do not impact growth) and high levels of ammonia and nitrite (specific tolerance limits are not known, but yellow perch are more tolerant than salmonids and less tolerant than tilapia). These factors are major determinants of the production levels that can be expected in recirculation systems. Other important factors that determine production levels are specific to the system components being used. The major system-related factors that limit the productivity of yellow perch recirculation systems are the ability of components to remove fine particulates (suspended solids), ammonia, and nitrite. The temperature requirements of yellow perch allow for adequate but not optimal nitrification using standard biological filtration for the removal of ammonia and nitrite (i.e., biological filtration is temperature sensitive and is more effective at temperatures higher than those tolerated by yellow perch). At the present time the production levels that can be expected from recirculation systems are not widely known.

In the 1970s more than ten yellow perch farms using recirculation systems became operational. All of these eventually closed because they were not economically viable. In the last ten years more than 20 new operations began production, but many of these have already closed for similar reasons.

The growth of all fish species in ponds and net pens is limited by the annual changes in temperature of surface waters. In the middle portion of the NCR, ambient water temperatures are in a range to promote good growth in yellow perch for 180–220 days/yr. This is similar in length to the growing season of channel catfish in the Mississippi delta region. The specific geographic region best suited to raising yellow perch in ponds is not known, but there is some evidence that pond water temperatures south of central Indiana may be too warm for yellow perch culture in the summer. Other information indicates that yellow perch can be successfully raised in ponds throughout the year in southern Wisconsin, and that yellow perch can be expected to gain 2.10–2.80 oz (60–79 g) during the course of a growing season.

Because yellow perch reach sexual maturity before reaching a market size, a 10–25% decrease in fillet yield occurs in net pen- and pond-reared fish harvested from December through April, the time of active gonadal development. To minimize this problem, methods to sterilize yellow perch by inducing triploidy have been developed. Some laboratory studies have shown that triploids may not grow as fast as diploids either as juveniles and/or when reared under constant temperature conditions (Crane et al. 1991; Malison et al. 1993). Such a reduction in growth may limit the commercial potential of triploids. Studies evaluating the growth and fillet yield of triploids raised in net pens or ponds, however, have not yet been conducted.

To date there have been at least three small-scale demonstration projects focused on raising yellow perch in net-pens; one funded by the University of Wisconsin-Madison in the 1980s, another funded by NCRAC in the early 1990s, and a third funded by the Wisconsin Department of Agriculture, Trade and Consumer Protection in the mid-1990s. These studies have shown that stress and disease problems become apparent when water temperatures exceed 70–72°F (21–22°C). Accordingly, given the normal surface water temperatures in the NCR, net-pen culture of yellow perch may not be feasible except at sites having a large supply of cold ground water to reduce maximum summertime temperatures.

To date, the open pond culture method for raising yellow perch to food size has not been the subject of any formal analysis or demonstration project, nor have any significant extension activities occurred in this regard. Evidence from producers in Wisconsin suggest that annual production levels of at least 3,000–4,500 lb/acre (3,362–5,044 kg/ha) are possible (D. Northey, Coolwater Farms, LLC, Cambridge, Wisconsin and M. Schartner, Sunny Meadow Fish Farm, Sturgeon Bay, Wisconsin, personal communications). In one instance the production of 10,000 lb/acre (11,208 kg/ha) was documented in a pond that had sufficient water flow to exchange the water in the pond every three weeks (Coolwater Farms, LLC). Yellow perch readily accept floating foods during the growing season and its use is critical in pond culture for good feed management practices. Presently there are at least ten producers in the NCR (located in Nebraska and Wisconsin) raising yellow perch to food size in ponds, but the profitability of these operations is not known.

PROCESSING

Because of their small size, the processing of yellow perch is expensive compared to other fish species, with total processing costs averaging $0.50–1.00/lb ($1.10–2.20/kg) or more for fillets. Almost all yellow perch are sold as scaled fillets, and most are scaled by machine and filleted by hand. At the present time, machine filleting results in an unacceptable loss of yield. Yellow perch retain very high quality when frozen because of their low fat content but, nevertheless, there are local markets where fresh product commands a premium price compared to frozen fillets. Unfortunately, some product is illegally sold as fresh when in fact it has been previously frozen.

ECONOMICS/BUSINESS PLANNING

Based on laboratory studies, University of Wisconsin-Milwaukee scientists estimated that the production cost of raising yellow perch fingerlings in tanks was $0.084/fingerling not including capital expenses or depreciation (NCRAC 1994). The costs of producing fingerlings using the tandem pond-tank or pond culture methods have not yet been estimated, but typically fingerlings 1.0–3.0 in (25–75 mm) in length sell for 5–84/in (0.2–0.34/mm) in large quantities. For yellow perch grow out, the production cost of the flow-through method has not been determined. Using theoretical inputs, models have been developed for estimating the production costs for net pen culture, pond culture, and recirculation systems. These models have estimated the break-even production costs for ~50,000 lb/yr (22,700 kg/yr) grow-out facilities at $1.92/lb ($4.23/kg) for net pen culture (Riepe 1997), $2.14/lb ($4.72/kg) for pond culture (Riepe 1997), and $2.58/lb ($5.69/kg) for recirculation systems (Hoven 1998). Currently, a NCRAC-funded study is underway which will provide “real cost” inputs from commercial operations for the recirculation model. Similar studies are not being conducted for the net pen or pond models.

CRITICAL LIMITING FACTORS AND RESEARCH/OUTREACH NEEDS

As of March 2000 a large market for yellow perch exists at prices higher than those of most other aquacultured fish species. A yellow perch aquaculture industry is beginning to develop to meet this demand, but its expansion is currently limited by the lack of proven, profitable, and sustainable production technologies. Many new producers are repeating the same mistakes made by more experienced producers because of the paucity of readily available “how to” information.

It is not yet clear which strategies for fingerling production or grow out will prove to be the most cost effective. At the present time most experts feel that either recirculation systems or pond culture will prove to be the most cost effective method for grow out. Accordingly, research and extension activities for yellow perch grow out should be focused on these systems until flow-through or net pen systems show more promise. In this regard, the development of flow-through and net pen systems may be limited in the region by resource management agencies and environmental concerns. Flow-through grow out may be proven feasible in regions having relatively warm (>64°F [18°C]) ground water or geothermally heated water, or in conjunction with power plants that are operated in a manner that prioritize aquaculture. Pond fingerling and/or grow out may meet competition from southern states due to a longer growing season, but high summer water temperatures may limit this expansion.

MARKETING

Riepe (1998) recently provided a detailed summary of yellow perch markets and marketing in the NCR. At the present time, it appears as though the market for yellow perch is both large and capable of considerable expansion if needed. Accordingly, this area seems to present little limitation to expansion of the yellow perch aquaculture industry, and should be considered low priority for research/outreach at the present time. If the price of yellow perch changes, however (as might occur with increased production or supply), this conclusion should be reevaluated.

BIOLOGY AND PRODUCTION TECHNOLOGY

Brood Stock Management and Fry Propagation Methods

At the present time there are few problems with gamete quality or quantity. Methods for spawning yellow perch and incubating and hatching eggs are well developed. One possible advancement that could be made in this area is the development of methods for identifying or producing female brood fish with larger eggs. It has been hypothesized that such females may produce fry having increased survival in some rearing systems. Studies to date, however, have not successfully correlated large egg size with other characteristics of female brood fish (e.g., fish size or age) useful for identification purposes.

The development of methods for producing yellow perch eggs and fry at multiple times of the year would greatly facilitate research on tank fry culture methods. The availability of fry throughout the year may also benefit fingerling producers if the tank culture method of fingerling production is ever successfully employed commercially. For all of the current fingerling producers who use the tandem pond-tank or pond culture methods, however, the availability of out-of-season fry may be of limited value. Theoretically, production ponds could be double-cropped if fry were available in April/May and again in June/July. Fingerling producers would need a market for the small (1.5–2.0 in [38–51 mm] TL), second-crop fingerlings in autumn, however, because such small fish may not survive well in ponds over winter.

Diseases in brood stock, eggs, and fry are almost always the result of outbreaks induced by stress or poor husbandry or management. Currently there are few therapeutic agents that are approved for treating disease outbreaks in yellow perch. Efforts should be made to gain approval for existing treatments known to be effective at controlling bacterial, fungal, and parasitic outbreaks for yellow perch. The availability of such agents would be advantageous for not only brood stock management and fry propagation, but also for fingerling production and grow out. Additionally, the use of MT to produce monosex female populations of yellow perch holds significant promise to improve yellow perch growth rates and thereby increase the production efficiency of producers. Accordingly, efforts aimed at gaining FDA approval for using these compounds should continue.

Two of the most important factors that currently constrain the expansion of the yellow perch aquaculture industry are that, compared to most aquacultured species, yellow perch are small and grow slowly. Consequently, efforts aimed at improving the growth rate of yellow perch should be high priority. There are different possible approaches to meet this goal. Some of these involve grow-out strategies and will be discussed under Grow Out below. Others involve brood stock and will be mentioned here.

Replicated and statistically valid studies are needed to document the extent to which monosex females grow faster than mixed sex populations in systems having constant and ambient temperature/photoperiod regimes (i.e., flow through or recirculation systems, and net pen or pond culture systems, respectively). Recent results from NCRAC-funded studies from 3 laboratories indicate that female yellow perch grow faster than males when raised under a variety of aquaculture conditions. In contrast, however, a study conducted at Virginia Polytechnic Institute and State University was not able to demonstrate that monosex female yellow perch grow faster than mixed sex yellow perch when raised in water recirculation systems (Schmitz 1999). The latter study suffered from a number of technical problems, however, including having only two replicate tanks of monosex females. Studies are also needed to document the growth of triploid yellow perch in ponds, and to evaluate the extent to which triploidy may improve the fillet yield of pond-raised yellow perch.

In several aquacultured species (e.g., rainbow trout and Atlantic salmon), traditional genetic selection has been a useful approach for developing fish strains having markedly improved growth. Accordingly, such an approach would have a high likelihood of success with yellow perch. If NCRAC chooses to fund a traditional genetic selection program for yellow perch, however, it should recognize that such a project will be costly and will demand <u>continual</u> funding for a minimum of 10–15 years or more before tangible results are obtained. In addition to traditional selection, alternative genetic technologies, including but not limited to transgenics and interspecific (e.g., *Perca flavescens* × *P. fluviatilis*) and intraspecific hybridization, may be useful in developing rapidly growing strains of yellow perch.

Regulatory agencies and environmentalists have expressed concerns that the development of genetically selected domesticated strains, hybrids, or transgenic yellow perch for aquaculture may harm wild populations of fish including yellow perch. Unbiased studies are needed to document the extent of this possible threat.

<u>Fingerling Production</u>

One of the primary factors constraining the expansion and profitability of the yellow perch aquaculture industry is the high price of feed-trained fingerlings to grow-out producers. Compared to other aquacultured species, food-size yellow perch are harvested and marketed at a small size. For example, rainbow trout, channel catfish, and hybrid striped bass are usually marketed at a size of 1.5 lb/fish (0.7 kg/fish), whereas yellow perch are marketed at 0.25–0.33 lb/fish (0.11–0.15 kg/fish). As a consequence, four to six times as many fingerlings are needed to produce a given weight of yellow perch compared to other fish species. Because of this, fingerling purchases represent 35–50% of the total operating costs of yellow perch production, regardless of the method used for grow out (Riepe 1997; Hoven 1998).

Clearly, research to develop methods for improving the cost-effectiveness of yellow perch fingerling production should be high priority. Such research could be focused on any or all of the three methods described above (tank culture, tandem pond-tank culture, and pond culture), or on new, innovative methods. If tank culture research is conducted it should focus on improving swim bladder inflation and the development of viable feeds for yellow perch larvae, because significant breakthroughs are needed in these areas in order for this method to ever have any commercial potential. Research on improving the tandem pond-tank and pond culture methods should focus on the continued development of new and innovative culture strategies. For pond culture, efforts should be directed at increasing the average fish size at harvest, decreasing the variation in the size of fish harvested, improving the overall productivity of ponds, and developing methods that improve the habituation of pond-raised fingerlings to tank culture conditions. For both the tandem pond-tank and pond culture methods, evaluations of the large number of existing formulated starter diets are needed, and the development of diets having increased palatability and acceptance should be high priority (e.g., see Kolkovski et al. In press).

Grow Out

Regardless of the grow-out system used, research aimed at developing least-cost diets for yellow perch would decrease production costs and is, therefore, warranted. The growth rate of yellow perch could be improved by the use of dietary growth enhancers (including hormones and hormone analogs), but the likelihood of FDA approval and the impact on consumer acceptance of such compounds should be evaluated prior to funding any studies along these lines.

For recirculation systems, most of the research needed on yellow perch grow out is not unique to one fish species but rather has broad applicability across species. Improvements are needed in filter technology, specifically the removal of ammonia, nitrite, and suspended solids. With regards to the latter, the development of diets that reduce fine particulate fecal matter is also a priority.

For pond culture, the documentation of production parameters (e.g., fish growth rates and the kg/ha [lb/acre] that can be produced) should be high priority. Also, the specific geographic region best suited to raising yellow perch in ponds needs to be determined. Subsequently, the testing of various strategies known to affect the production efficiency of raising other fish species in ponds (e.g., feed management practices, aeration/water circulation, water addition, frequency of harvest) needs to be conducted.

Processing

Compared to hand filleting, machine filleting of yellow perch could lead to a significant reduction in the cost of processing yellow perch. In this regard, the yellow perch aquaculture industry may benefit from improvements in fillet machine technology.

ECONOMICS

Economic information that documents the true production costs of raising yellow perch fingerlings is greatly needed. Although price information on fingerlings is readily available, the comparative costs of using different methods to raise yellow perch fingerlings are unknown, at least to the general public. It may be difficult to procure such information for tank culture, since little or no commercial production is presently underway. Such information should be attainable, however, for the tandem pond-tank and pond culture methods of fingerling production.

For grow out, there currently exists a divergence of opinion among experts as to which system(s) will prove to be the most cost-effective method of producing yellow perch. An ongoing NCRAC study should be helpful at determining the true production costs using recirculation systems. A similar determination is greatly needed for pond culture. Such studies aimed at flow-through and net pen culture, however, should be lower priority until the feasibility and/or broad applicability of these methods is proven.

EXTENSION

Hopefully, the NCRAC yellow perch manual that is currently being developed will help to alleviate the current problem of the lack of practical information on yellow perch aquaculture. The completion of this document should be high priority. In addition, an historical documentation of successes and failures of commercial yellow perch aquaculturists may help new producers from repeating past mistakes. Conferences and “short courses” targeting specific areas of yellow perch aquaculture seem to be in high demand and are, therefore, warranted. Current yellow perch producers would benefit from an education program aimed at customers (e.g., distributors, restaurateurs, and consumers) regarding the illegal marketing practices that currently exist. To date, extension activities have been focused to a far greater extent on recirculation systems as opposed to pond systems, and as a consequence more effort should be aimed at pond fingerling and grow-out methods.

SUMMARY OF RESEARCH AND EXTENSION PRIORITIES

It is difficult to rank research and extension priorities, and there is always the potential for subjective bias. The following prioritized list was presented at the 2000 NCRAC Annual Program Planning Meeting (February 25-27, 2000, Kansas City, Missouri), and I believe that a general consensus existed with regards to this list among the commercial producers, researchers, and extension personnel in attendance.

The most important research and extension needs for the development of yellow perch aquaculture are ranked numerically into categories in order of priority (categories having the same numerical ranking are equivalent). In addition, within each category specific research topics are ranked alphabetically (topics having the same alphabetical ranking are equivalent).

RESEARCH

1. Document the production parameters and costs of raising perch to market size in recirculation systems and ponds.
   A. Complete the ongoing NCRAC-funded study for recirculation systems including several producers.

   A. Conduct a study documenting the production parameters and costs of raising perch to market size in ponds.
   B. Evaluate different geographic regions for raising perch to market size in ponds.
2. Develop methods for improving growth rates and fillet yields of yellow perch in ponds and recirculation systems.
   A. Compare the growth and fillet yields of monosex female and mixed sex populations of yellow perch in pond and recirculation systems.
   A. Continue efforts aimed at gaining approval for using MT (to produce monosex females) and therapeutics in yellow perch.
   B. Compare the growth and fillet yields of diploid and triploid yellow perch in ponds.
   B. Use traditional genetic selection between and within families (not simply mass selection) to develop fast growing strains of yellow perch, recognizing that useful results will take a sustained effort of at least 10 years.
   B. Test alternative strategies (feeding strategies, hybridization, transgenics, etc.) to improve growth in yellow perch.
2. Improve recirculation and pond systems for raising perch to market size.
   A. Develop least-cost diets and evaluate dietary growth enhancers.
   A. Develop improved filters for recirculation systems that remove ammonia, nitrite and solids, and develop diets that reduce fine particulates.
   A. Test and improve on pond management strategies.
2. Improve fingerling production methods.
   A. For pond and pond/tank culture: Develop methods to increase average fish size and total productivity of ponds, decrease variation in fish size, and improve habituation of pond-reared fish to tanks. Also, develop starter diets having increased palatability.
   A. Tank culture: Develop larval feeds and methods to increase swim bladder inflation.
   A. For all methods, continue to develop methods for inducing out-of-season spawning.
   B. Document the costs of raising fingerlings using different methods.
3. Develop methods for reducing processing costs.

EXTENSION

1. Complete the yellow perch manual.
2. Develop an historical record of successes and failures of commercial producers.
2. Conduct conferences targeting specific topics.
2. Increase emphasis on pond fingerling and grow out.
2. Educate consumers regarding illegal marketing practices.

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