CHAPTER 1

REVIEW OF YELLOW PERCH (*Perca flavescens*) CULTURE.

TAXONOMIC CLASSIFICATION

The yellow perch (*Perca flavescens*, Mitchell) is classified in the family Percidae, subfamily Percinae, and tribe Percini (Nelson, 1994). Percidae is the second most diverse family of North American freshwater fishes and includes darters, perches, walleye, and sauger. The native range of yellow perch includes the Atlantic, Arctic, Great Lakes, and Mississippi River basins from Nova Scotia and Quebec west to the Northwest Territories and south to Ohio, Illinois, and Nebraska. In the Atlantic drainage, the native range extends south to the Santee River in South Carolina and has been widely introduced elsewhere in the United States (Page and Burr, 1991).

"Historically, the North American yellow perch (*Perca flavescens*) and the Eurasian perch (*Perca fluviatilis*) were considered distinct species. A study by Stetovidov and Dorofeeva (1963) concluded that there was a single, circumpolar species with three subspecies. That taxonomic status was accepted by some North American authors (Scott and Crossman 1967; McPhail and Lindsey 1970), but not by others (Robins 1991). Collette and Banarescu (1977) found that the predorsal bone in the *Perca flavescens* extends between the first and second neural spine while it is anterior of the first neural spine in *Perca fluviatilis*, that morphological difference clearly separates the two species."(Heidinger and Kays, 1993)

Thorpe (1977), however, concluded that the two species are biologically equivalent, and as a result of this, both species will be considered in this literature review.

YELLOW PERCH MARKETS

In the upper Midwest, Friday night fish fries are a long-standing social institution. Historical abundance of the Great Lakes yellow perch made the mild tasting, and relatively inexpensive perch a particular favorite at these weekly affairs (Lesser and Vilstrup, 1978). A serious decline in the Great Lakes fishery began in the early 1970s and has never reversed itself (Riepe, 1998). Commercial perch landings in the Great Lakes peaked at 16.3 million kg in 1969, but dropped to 4.7 million kg in 1976. Traditionally, Lake Erie (85%) and Lake Michigan (12%) accounted for most of the total commercial catch of yellow perch (Lesser and Vilstrup, 1978). However, commercial harvest has been completely banned in Lake Michigan since 1996. In Lake Erie, there are no signs that the yellow perch fishery will be restored to levels experienced in the late 1980s (Ontario Ministry of Natural Resources, 1996).

Declines in the catch of Great Lakes yellow perch have led to high prices for perch fillets. In 1996, wholesale fillet prices varied in the $13 to $17 per kg range (Reipe, 1998), and retail fillet prices have risen to more than $24 per kg (NCRAC, 1996). Wholesale prices for yellow perch in the round range from $2.30-3.00/lb ($5.07-6.61/kg: Malison, 1999c). Despite elevated prices, consumer preference for yellow perch persists and has resulted in yellow perch becoming one of the focal points of aquaculture research in the Great Lakes region of the United States (Brown et al., 1996).

An emerging yellow perch aquaculture industry presently contributes less than 90,720 kg per year. One large food distributor (Great Lakes Marketing, Inc., Waukesha, WI) believes the existing market could readily absorb 23-45 million kg per year (Malison, 1999c). Because of the limited supply, yellow perch is often replaced with imported products. This includes the Eurasian perch (*Perca fluviatilis*) and pike-perch (*Stizostedion lucioperca*) from Europe, walleye

(*S. vitreum*) and sauger (*S. canadense*). Frequently, these alternative products are illegally sold as yellow perch (Malison, 1999b).

Traditionally, Wisconsin has consumed 9 to 11 million kg of yellow perch per year, accounting for 75% of the annual U.S. yellow perch harvest (Calbert and Huh, 1976). A survey of states in the North Central region found that over two-thirds (70%) of responding restaurants that sold yellow perch were located within 50 miles of the Great Lakes (Riepe, 1998).

Several recent studies suggest a potentially large market for farm-raised yellow perch. In a survey of wholesale and retail fish buyers, 72.1% rated farm-raised fish as “somewhat better or superior” versus wild caught fish. The high rating of cultured fish was due to its increased availability, size uniformity, freshness and quality. A vast majority (80.6%) of the buyers indicated they would increase their utilization of farm-raised fish in the future (Hushak, 1993). Aquaculture products may also have a marketing advantage over wild caught products as a result of concerns about microcontaminants in wild fish (Malison, 1999a). Another survey found that, although less than 10% of the restaurants in the North Central region indicated they were purchasing farm-raised yellow perch, over half (56%) reported interest in doing so (Reipe, 1998). Thus, yellow perch was identified as a species with a high potential for aquaculture development based on market presence and buyer demand
(Hushak, 1993).

Industry research has shown that frozen yellow perch fillets are an acceptable product form for the restaurant market. Restaurants prefer fresh (44%) and frozen (51%) fillets about equally when price and supply are not an issue. When yellow perch is actually purchased, however, about two-thirds (65%) of the restaurants purchase frozen fillets (Riepe, 1998). Yellow perch fillets are low in fat (0.8%) and phospolipids (Kinsella et al., 1977). These attributes result in yellow perch having a long shelf life, resistance to freezer damage, and minimal problems with off-flavor and cooking (Malison, 1999b). The number of production and marketing options broadens considerably once the burden of supplying fresh products is eliminated. Production facilities targeting the restaurant market no longer need to be in close proximity to the Great Lakes. Wherever conditions are most conducive to cost-effective production, yellow perch can be reared and shipped as a frozen product (Riepe, 1998). Accordingly, interest in yellow perch aquaculture has spread from the Midwest throughout much of the United States.

While frozen yellow perch fillets are an acceptable product form for restaurants, other research indicates that this is not the case for perch bought for in-home preparation and consumption (Wesson et al., 1979). Among other species, this study compared fresh yellow perch fillets to that of frozen Eurasian perch fillets imported from Holland. The fresh yellow perch was distinctly less oxidized in flavor, and markedly less dry and tough in texture than the frozen Holland perch product. In-home consumer preference data showed a significant preference for fresh perch, where 85% of the respondents reported a willingness to buy fresh yellow perch compared to 50% reporting a willingness to buy frozen perch (Wesson et al., 1979).

Lindsay (1980) compared fresh cultured yellow perch to fresh wild caught yellow perch. This study found that aquacultured perch fillets were whiter than wild caught perch fillets, and significantly more firm than wild caught perch when prepared as deep-fried fillets. Aquacultured and wild caught perch were equally preferred when environmentally induced off-flavors were absent (Lindsay, 1980). A series of organoleptic evaluations at Purdue University found that cultured yellow perch consistently received the highest preference score when compared to wild caught yellow perch, catfish, walleye, and trout in Indiana, Wisconsin, Illinois, and Kentucky (Cox, 1995).

Fresh yellow perch cultured under controlled environmental conditions commands a higher market price than wild caught perch. This is mainly due to increased fillet yields over wild fish, through the elimination of a 6% loss to freezer shrinkage, and the size uniformity available in cultured fish (Lesser and Vilstrup, 1978). Farm-raised yellow perch have a typical fillet yield of 45%, and average 5% higher yield than wild caught butterfly fillets (Heidinger and Kays, 1993). Restaurant managers prefer standardized portion sizes. Size uniformity of fillets is difficult to achieve with wild caught fish, but aquaculturists have the ability to offer standardized sizes which adds value to their product.

Utilizing fresh perch also reduces the need for frozen storage and eliminates costs of carrying a large inventory. Using costs for the 1975-76 period, the benefits for farm-fresh yellow perch added up to a 47.4 cents per kg price advantage over wild caught fish (Lesser and Vilstrup, 1978). The average 1996/1997 price of fresh fillets ($16.42/kg) purchased by restaurants in the North Central Region was higher than the average price of frozen fillets ($15.19/kg: Reipe, 1998). The premium price that fresh yellow perch demand has unfortunately resulted in previously frozen product being illegally sold as fresh (Malison, 1999a).

YELLOW PERCH CULTURE

Growth & Culture

The current market size for yellow perch is 115-150g, or around 20 cm length (Bennett Fish Inc., Loraine, OH). Calculations from data presented by Carlander (1950) indicate that the mean growth rate of natural populations in North America would produce a 20.4 cm yellow perch after 4 years of life. In southern Wisconsin ponds, approximately 30% of females can reach market size in two growing seasons (Malison, 1999a). Under optimum rearing conditions of 21^{o}C with 16-h light, fed 3 to 4% of body weight daily, Calbert and Huh (1976) predicted that 1.0-1.5 g yellow perch will reach market size in 9 to 11 months. Preliminary research demonstrated that at 20 to 24^{o}C, perch grew at 0.8 to 1.1 cm per month and had monthly feed conversion ratios from 1.3 to 3.5 (Starr, 1991).

Biologically, the yellow perch is well suited for commercial aquaculture. Yellow perch show little aggressive or cannibalistic behavior, readily accept formulated diets, and are highly tolerant of crowding and other conditions associated with intensive culture (Heidinger and Kayes, 1986).

Problems

Several problem areas have been identified in yellow perch aquaculture, which have impeded the growth of this industry. The yellow perch is a relatively small fish, and even though it can be marketed as small as 115g, it may go through its rapid growth phase before it reaches a harvestable size (Heidinger and Kays, 1993). The yellow perch has a relatively slow growth rate compared to other aquacultured species (Malison, 1999b). The industry advisory council of the North Central Regional Aquaculture Center (NCRAC) has identified the lack of reliable methods of producing perch fingerlings habituated to formulated feeds as a major constraint that presently limits perch aquaculture (NCRAC, 1998). A lack of even the basic understanding of the nutritional needs of yellow perch also may be impeding commercial development (Brown et al., 1996).

Another key problem inhibiting the commercial aquaculture of yellow perch is the growth heterogeneity between male and female perch. Male perch grow much more slowly than females (Schott et al., 1978; Malison et al., 1985; 1986; Malison and Garcia-Abiado, 1996) and female perch reach larger ultimate sizes than males (Leach, 1928; Carlander, 1950; Scott and Crossman, 1973). This sexual dimorphic growth pattern is evident in yellow perch as small as 8-12 g in total weight and 90-120 mm in total length (Schott et al., 1978; Malison et al., 1986). Body weight can range from 7 to 89 g for 7-month-old fish, with a mean of 25.9g (Melard et al., 1996a). It has been suggested that growth heterogeneity is a result of sexual growth dimorphism, genetic variability, and social behavior (Craig, 1987; Melard et al., 1995).

Le Cren (1958) suggested that the onset of sexually dimorphic growth in Eurasian perch is closely associated with the onset of sexual maturity. Schott (1980) however, demonstrated that sex-related size dimorphism can develop in yellow perch under artificial conditions within the first year of life, in fish that were clearly not mature.

Body size in yellow perch, rather than environmental cues or age, may be the major factor controlling the onset of differential growth between the sexes. Two lines of evidence presented by Schott (1980) support this hypothesis. First, the size variations noted developed under artificial conditions among fish that had never experienced a full annual cycle of photoperiod and temperature fluctuation. Second, rapidly growing fish exhibited size dimorphism at an earlier age than slower growing individuals, indicating a size rather than age threshold.

Female growth in Eurasian perch has been reported as 1.5-1.7 times faster than male growth (Melard et al., 1996a) and by the time female yellow perch reach a size of 100-120g they commonly are 25-50% larger than males (Malison, 1985). Females consume greater amounts of food and convert food more efficiently than males (Malison et al., 1988). Perhaps androgens (male hormones) retard and estrogens (female hormones) accelerate the growth of yellow perch (Schott et al., 1978). Since the difference in growth rate expresses itself long before the fish reach marketable size (Best, 1981; Malison et al., 1986), methods of producing monosex female populations of yellow perch may substantially increase production in commercial aquaculture.

Sexual development poses a second problem in yellow perch aquaculture. During this time energy and growth are redirected from somatic elements into gonadal development, and overall growth may be reduced (Ihssen et al., 1990; Mair, 1993). After females reach sexual maturity, approximately 87% of their energy is devoted to egg production under natural conditions (Miller, 1995). Sexual maturation not only reduces somatic growth, but it may markedly reduce the fillet yield, as ovaries may account for up to 35% of the total weight of the fish (Malison and Garcia-Abiado, 1996). Accordingly, methods that sterilize or retard gonadal development in yellow perch also may benefit the aquaculture industry.

Production Data

Though aquaculture often has not been economically feasible due to high per unit costs of feed and technology, advances in fish nutrition and recirculating systems have increased yields. Aquaculture technology is pushing production costs down while fish and seafood prices are going up (Hushak, 1993). Numerous scientific and commercial ventures have demonstrated the technical feasibility of raising a wide variety of aquaculture species in recirculating systems (Broussard and Simco, 1976; Bovendeur et al., 1987; Nunley, 1992). The enhanced quality control offered by recirculating systems, combined with an inherent reduction in water usage and environmental impact, makes it a viable choice for the future of the aquaculture industry (Loyless and Malone, 1997).

There is very little published data available on the production requirements of yellow perch in recirculating aquaculture systems (NCRAC, 1998). Kocurek (1979) completed part of her thesis work on raising yellow perch in recirculating systems. Two rearing tanks, each containing 8,500 liters, were used in this study. Each system was stocked with 1,050 fingerlings, which were raised for 12 months on a trout diet. After 5 months of growth, the fish in both units were divided into 2 groups on the basis of size, with each group occupying 3,180 liters. In both systems, the fastest growing groups reached market size within 12 months. Mean absolute growth rates over the entire experiment were between 0.29-0.41g/day, with 12.7-40.5% mortality (Kocurek, 1979). This was the first such study to demonstrate the technical feasibility of raising yellow perch to market size within a recirculating system.

Preliminary studies have been conducted on Eurasian perch reared in recirculating systems and in floating cages. For 8 weeks, 22-25g perch were reared in both of these systems on an artificial trout diet. Four trials were conducted in each system, with two replicated feeding treatments of 2 and 4% body weight per day. The specific growth rates (1.1-1.4% day^{-1}) were similar for both culture systems (Fontaine et al., 1996).

Starting from 1 g weaned juveniles, intensive rearing of Eurasian perch resulted in a 50% survival rate and favors growth heterogeneity. Despite some individual fish (10-15%) showing a high growth potential, the perch is generally a slow-growing fish even in optimal rearing conditions (average weight = 120 g in 1 year) (Melard et al., 1996a). In intensive rearing systems (50 kg m^{-3}), 44-day old weaned larvae reached an average body weight of 130-150 g after 1 year of rearing (Melard et al., 1995). Market size was reached about 3 months earlier by faster growing fish, thus allowing a better sharing of the production over the annual cycle, depending on market demand.

In other Eurasian perch experiments (stocking biomass from 30-60 kg m^{-3}), the market size of 120-140g was reached after 1 year by only half of the fish, of which 80% were females.

These fish were started from eggs and were fed optimum rations (see description in "Feeding"). At 23°C, Eurasian perch reached the minimum market size with a specific growth rate (SGR = $(LnW_2\text{-}LnW_1)t^{-1}$) around .086% day $^{-1}$ (1.2g day^{-1} in 140g fish) (Melard et al., 1996b).

These results, though preliminary, demonstrated the feasibility of raising both yellow and Eurasian perch in recirculating aquaculture systems using artificial feed. Growth and productivity in intensive perch rearing may be improved substantially through techniques such as the selection of fast-growing strains, selection of fast-growing individuals as broodstock, all-female or sterile triploid fish production (Melard et al., 1995; Melard et al., 1996a). Scientific experiments have not proven these assertions.

Temperature and Photoperiod

In growth experiments, temperature and photoperiod must be carefully controlled, since these factors can greatly influence yellow perch growth (Huh et al., 1976). The optimum temperature for rearing and feeding larval yellow perch is between 20.0 °C and 23.9 °C (Heidinger and Kays, 1993). According to McCormick (1974; 1976) the optimum temperature for feeding and rearing juvenile perch is 23.9 to 27.8 °C. This is slightly higher than the 20-24 °C range found by Huh (1975). The upper incipient lethal temperature reported for juveniles is 29.1 °C, and for adults is 33 °C (Hokanson, 1977).

In Eurasian perch, maximum growth rates (0.06 to 1.80g fish^{-1} d^{-1} for 1 to 300 g fish) were observed at 23 °C. Rearing at higher (27 °C) or lower temperatures (11-20 °C) resulted in lower growth rates. Perch reared at 20 °C showed a 20% lower growth compared to fish of the same body weight (100g) at 23 °C (Melard et al., 1995).

Maintaining constant temperatures not only optimizes growth, but also functions to inhibit the sexual maturation in females (Melard et al., 1995; 1996a). Reproductive development in both of these species can have a significant negative impact on somatic growth and fillet yield (Malison and Garcia-Abiado, 1996). According to Hokanson (1977), yellow perch from Minnesota require a minimum chill period of 160 d at 10 ^{o}C or less to obtain 100% female spawning participation. Southern strains of yellow perch may require a shorter chill period at slightly warmer temperatures (Kolkovski and Dabrowski, 1998). Just prior to spawning, the gonadosomatic index (GSI) of mature females may reach 35% (Malison and Garcia-Abiado, 1996), while the GSI of male yellow perch ranges from 8 to 15% (Lagler et al., 1962; Brazo et al., 1975).

In addition to temperature, photoperiod appears to have a significant influence on the growth rate in yellow perch (Huh, 1975; Huh et al., 1976). Growth of perch reared at the same temperature, but with a shorter photoperiod (8 h-L) was only about one-third that of fish exposed to photoperiods of 16 or 20 h light (Huh et al., 1976). Apart from temperature, ration size and size of fish, light is probably the most important factor governing metabolic activity, feeding, and growth (Ryder, 1977).

Grading

Growth heterogeneity constitutes a major constraint in perch culture. Several studies have examined the effect of grading on overall productivity by sorting a population into three non-overlapping, weight-related groups (Melard et al., 1995; 1996b). The grading resulted in similar mean specific growth rates between the three groups, with the emergence of fast growing fish in each group. After 200 days of growth, the heterogeneity was so high in each group that the weight distributions overlapped by more than 60%. Overall, the grading processes caused the productivity to be 5-6% lower than in non-sorted populations of the same origin and body weight (Melard et al., 1995; 1996b).

Stocking Density

Growth patterns are strongly influenced by stocking density in perch populations (Melard et al., 1996b). High stocking densities often inhibit territorial and agonistic tendencies that potentially limit access to food (Melard et al., 1995). In a 74-day rearing experiment with Eurasian perch, coefficients of variation of fish body weight decreased from 98.4 to 57.9% with increasing density (Melard et al., 1996b). A positive relationship between density and growth was evident until fish reached 15-20 g body weight. In larger individuals, growth rate decreased with increasing stocking densities. Final stocking biomass ranged from 24 to 35 kgm^{-3}. Intensive rearing offsets a reduction in individual growth by achieving a higher productivity. Survival was independent of stocking density and averaged 85% (Melard et al., 1995; 1996a). These experiments support the significance of high density rearing for the culture of juvenile perch, since the maximum growth and minimum size heterogeneity were achieved at the highest stocking densities (1430 and 2380 fish m^{-2} respectively) (Melard et al., 1996b).

Habituation

Under current production schemes, yellow perch fingerlings are produced primarily in ponds. Intensive rearing of larval perch is difficult because the fry are very small at hatch, from 4-7 mm total length (Mansueti, 1964; Ney, 1978), and existing dry or semi-moist diets yield poor survival (Brown and Dabrowski, 1995). Larvae often are placed into fertilized culture ponds where they feed on rotifers and other small zooplankton (West and Leonard, 1978).

Young perch are positively phototaxic (Schumann, 1963) and pond harvest can be accomplished at night with the aid of a light and lift net. Manci et al. (1983) successfully removed 61% (23,000) of the fingerlings from a 0.08 ha pond using this method. The size of perch that were attracted to the light ranged from 8-50mm.

Fingerlings that have been trained to accept artificial diets can be placed in ponds or tanks and raised to marketable size. Significant components of feed-training fingerlings include: concentrating the fingerlings, removing the natural food source, elevating the temperature to ensure an aggressive feeding response, feeding frequently, and grading fingerlings to reduce cannibalism (Heidinger and Kays, 1993).

Survival is directly related to fingerling size at the beginning of the training period. Less than 50% of larvae smaller than 16 mm can be expected to survive, while 80% of larvae 18 mm long and 98% of those longer than 31 mm have been shown to survive (Best, 1981). Both growth and survival can be maximized by relocating, size-grading, and introducing prepared feeds soon after perch larvae reach 20 mm. In one experiment on yellow perch, the growth of early-trained (ET) perch was compared to late-trained (LT) perch, those trained three weeks later (Best, 1981). Results indicated that even though ET fish were initially significantly smaller in length and weight ($P < 0.001$), after 45 days ET fish were significantly longer ($P < 0.001$) and heavier ($P < 0.001$) than LT tankmates (Best, 1981).

There has been some success reported for rearing perch larvae on live zooplankton. According to Hale and Carlson (1972), 250 planktonic organisms per larval yellow perch are required daily to obtain 50% survival during the first three weeks of feeding. Those authors recommended feeding at least four times daily using dark-bottomed tanks. Other researchers have successfully reared larval perch in intensive culture tanks using green-water systems with survival as high as 60-80% after 30-45 days (Brown and Dabrowski, 1995).

Feeding

The effect of feeding frequency (1, 3, and 6 feedings/day) on growth has been examined in 30g juvenile Eurasian perch (Melard et al., 1995). At a daily ration of 2% body weight, the highest growth rate was obtained when fish were fed three times a day. A daily ration of 2% body weight corresponded to a feeding level between what was calculated to be the optimum ration and the maximum ration. The maintenance (R_{maint}), optimum (R_{opt}), and maximum (R_{max}) daily food rations were estimated for 1-300g perch reared at 23^{o}C at stocking densities of 20-50 kg m^{-3}as follows: R_{maint}= 1.09$w^{-0.23}$, R_{opt}=3.30 $w^{-0.24}$, and R_{max} = 7.60 $w^{-0.31}$ (Melard et al., 1995), where **w** represents the average weight in grams, and **R** is equal to the ration in body weight per day.

The maximum daily ration provided feed conversion ratios from 1.1 to 2.0 in fish ranging from 1 to 150g and up to 3.0 in 300 g fish. The corresponding FCRs for R_{opt} were 1.0, 1.7 and 2.0 (Melard et al., 1996a). The person administering feed may empirically adjust food rations based on apparent food consumption at the population level. This would allow adjustment for differences in survival and growth patterns, and also avoids water quality degradation resulting from overfeeding.

OBJECTIVES

Past research has demonstrated that female perch grow faster and ultimately larger than males, both in the wild and in culture conditions. Currently, all-female perch stocks are available for commercial aquaculture producers. Although these stocks seem to have the potential to increase aquaculture production, scientific research has not confirmed this hypothesis. Against this background, the objectives of this study were: (1) to compare production parameters between all-female and mixed-sex yellow perch stocks in production-scale grow-out trials, (2) to track and compare individual growth between and within stocks and assess the implications towards maximizing production through early selection upon the production stock, and (3) to compare fillet yields between stocks under controlled environmental conditions and evaluate the possible effect of gonadal development on fillet yield.

LITERATURE CITED

Best, C.D. 1981. Initiation of artificial feeding and the control of sex differentiation in yellow perch (*Perca flavescens*). M.S. Thesis, University of Wisconsin, Madison. 121 pp.

Bovendeur, J., G.H. Zding, and A.M. Henken. 1987. Design and performance of a water recirculation system for high-density culture of the African catfish (*Clarias gariepinus*). Aquaculture. 63: 329-353.

Brazo, D.C., D.I. Tack, and C.R. Liston. 1975. Age, growth, and fecundity of yellow perch, *Perca flavescens*, in Lake Michigan. Trans. Am. Fish. Soc. 104: 726-730.

Brown, P. and K. Dabrowski. 1995. Zootechnical parameters, growth, and cannibalism in mass propagation of yellow perch. *In*: Kestemont and Dabrowski, Ed's. Workshop on Aquaculture of Percids: Short Communications. Presses Universitaires de Namur, Namur Belgium, pp 25-26.

Brown, P.B., K. Dabrowski, and D.L. Garling. 1996. Nutrition and feeding of yellow perch (*Perca flavescens*). J. Appl. Ichthyology. 12: 171-174.

Broussard, M.C. and B.A. Simco. 1976. High-density culture of channel catfish in a recirculating system. Progressive Fish-Culturist. 38: 138-141.

Calbert, H.E. and H.T. Huh. 1976. Culturing yellow perch (*Perca flavescens*) under controlled environmental conditions for the upper Midwest market. Proc. World Maricult. Soc., 7: 137-144.

Carlander, K.D. 1950. Handbook of Freshwater Fisheries Biology. Wm. C. Brown, Dubuque, Iowa. 281 pp.

Cox, D.R.H., 1995. Chemical and sensory properties of fresh and refrigerated aquaculture and wild yellow perch. M.S. Thesis, Purdue University, West La Fayette, Indiana, 111 pp.

Craig, J. 1987. The Biology of Perch and Related Species. Beckenham, Great Britain: Croom Helm Ltd. 333 pp.

Fontaine, P., L. Tamazouzt, and V. Capdeville. 1996. Growth of the Eurasian perch (*Perca fluviatilis*) reared in floating cages and in water recirculated system: first results. J. Appl. Ichthyol. 12, 181-184.

Hale, J.G. and A.R. Carlson. 1972. Culture of the yellow perch in the laboratory. Progressive Fish Culturist 34(4): 195-198.

Heidinger, R.C. and T.B. Kayes. 1993. Yellow Perch. *In*: R.R. Stickney (Ed.), Culture of Non-salmonid Freshwater Fishes. CRC Press, Inc., Boca Raton, FL. 215-229 pp.

Hokanson, K.E.F. 1977. Temperature requirements of some percids and adaptations to the seasonal temperature cycle. J. Fish. Res. Bd. Can., 34, 1524.

Huh, H.T. 1975. Bioenergetics of food conversion and growth of yellow perch (*Perca flavescens*) and walleye (*Stizostedion vitreum vitreum*) using formulated diets. Ph.D. Dissertation, University of Wisconsin, Madison. 196 pp.

Huh, H.T., H.E. Calbert, and D.A. Stuiber. 1976. Effects of temperature and light on growth of yellow perch and walleye using formulated feed. Trans. Am. Fish. Soc., 105, 254.

Hushak, L.J. 1993. Survey of wholesale and retail buyers in the six southern states of the North Central region. USDA Technical Bulletin Series #104.

Ihssen, P.E., L.R. Mckay, I. McMillan, and R.B. Phillips. 1990. Ploidy manipulaton and gynogenesis in fishes: cytogenetic and fisheries applications. Trans. Am. Fish. Soc. 119, 698-717.

Kinsella, J.E., J.L. Shimp, J. Mai and J. Weshrauch. 1977. Fatty acid content and composition of fresh water fin fish. J. Am. Oil Chem. Soc. 54: 424.

Kitchell, J.F., D.J. Stewart, and D. Weininger. 1977. Applications of a bioenergetics model to yellow perch (*Perca flavescens*) and walleye (*Stizostedion vitreum vitreum*). J. Fish. Res. Board Can. 34: 1922-1935.

Kocurek, D. 1979. An economic study of a recirculating perch aquaculture system. M.S. Thesis, University of Wisconsin, Madison. 85 pp.

Kolkovski, S. and K. Dabrowski. 1998. Off-season spawning of yellow perch. Progressive Fish-Culturist 60: 133-136.

Lagler, K.F., J.E. Bardach, and R.R. Miller. 1962. Ichthyology. John Wiley & Sons, New York, New York. 545 pp.

Leach, G.C. 1928. Propagation and distribution of food fishes. Fiscal year 1927, Report to the U.S. Commissioner of Fisheries, U.S. Government Printing Office, Washington D.C. pp 683-736.

LeCren, E.D. 1958. The length-weight relationship and seasonal cycle in gonad weight and condition in the perch (*Perca fluviatilis*). J. Anim. Ecol. 20: 278-334.

Lesser, W. and R. Vilstrup. 1978. The supply and demand for yellow perch. Research Bulletin R3006. University of Wisconsin-Madison. 14 pp.

Lindsay, R.C. 1980. Comparative sensory analysis of aquacultured and wild yellow perch (*Perca flavescens*) fillets. Journal of Food Quality 3: 283-289.

Loyless, J.C. and R.F. Malone. 1997. A sodium bicarbonate dosing methodology for pH management in freshwater-recirculating aquaculture systems. Progressive Fish-Culturist 59: 198-205.

Mair, G.C. 1993. Chromosome-set manipulation in tilapia-techniques, problems and prospects. Aquaculture 111, 227-244.

Malison, J.A. 1985. Growth promotion and the influence of sex steroids on sexually related dimorphic growth and differentiation of yellow perch (*Perca flavescens*). Ph.D. Thesis, University of Wisconsin-Madison. 153 pp.

Malison, J.A., C.D. Best, T.B. Kays, C.H. Amundson, and B.C. Wentworth. 1985. Hormonal growth promotion and evidence for a size-related difference in response to estradiol-17β in yellow perch (*Perca flavescens*). Can. J. Fish Aquat. Sci. 42, 1627-1633.

Malison, J. A., T.B. Kayes, C.D. Best, C.H Amundson, and B.C. Wentworth. 1986. Sexual differentiation and use of hormones to control sex in yellow perch (*Perca flavescens*). Can. J. Fish. Aquat. Sci. 43:26-35.

Malison, J.A., T.B. Kays, B.C. Wentworth, and C.H. Amundson. 1988. Growth and feeding responses of male versus female yellow perch (*Perca flavescens*) treated with estradiol-17β. Can. J. Fish Aquat. Sci. 45, 1942-1948.

Malison, J.A., and M.A.R. Garcia-Abiado. 1996. Sex control and ploidy manipulations in yellow perch (*Perca flavescens*) and walleye (*Stizostedion vireum*). J. Appl. Ichthyology 12: 189-194.

Malison, J.A. 1999a. Current status of yellow perch (*Perca flavescens*) markets and culture. Book of Abrstracts. Aquaculture America Conference. Tampa, FL January 27-30.

Malison, J.A. 1999b. Sex control and ploidy manipulations in yellow *perch Perca flavescens* and walleye *stizostedion vitreum*. Book of Abstracts. Aquaculture America, Tampa, FL January.

Malison, J.A. 1999c. A white paper on the status and needs of yellow perch aquaculture in the North Central Region.[Online]. Available: http://ag.ansc.purdue.edu/aquacic/ncrac/wpapers/ypwhite.html

Mansuetti, A.J. 1964. Early development of yellow perch, *Perca flavescens*. Chesapeake Science 5: 46-66.

McCormick, J.H. 1974. Temperatures suitable for the well-being of juvenile yellow perch during their first summer-growing season. Annual Report, ROAP-16AB1, National Water Quality Laboratory, Duluth, Minnesota.

McCormick, J.H. 1976. Temperature effects on young yellow perch, *Perca flavescens*. EPA-600/3-76-057, U.S. Environmental Protection Agency Ecology Research Service, Washington D.C.

Melard C., P. Kestemont, and J.C. Grignard. 1995. Intensive ongrowing of juvenile perch (*Perca fluviatilis*): zootechnical parameters and growth. *In*: Kestemont and Dabrowski (Ed's), Workshop on Aquaculture of Percids: Short Communications. Presses Universitaires de Namur, Namur, Belgium, 25-26.

Melard, C., P. Kestemont, and J.C. Grignard. 1996a. Intensive culture of juvenile and adult Eurasian perch (*P. fluviatilis*): effect of major biotic and abiotic factors on growth. J. Appl. Ichthyology. 12: 175-180.

Melard, C., Baras, E., Mary, L., and P. Kestemont. 1996b. Relationships between stocking density, growth, cannibalism and survival rate in intensively cultured larvae and juveniles of perch (*Perca fluviatilis*). Ann. Zool. Fennici 33:643-651.

Miller, W.W. 1995. Yellow Perch Aquaculture Curriculum Guide. Iowa State University, Ames, Iowa. 99 pp.

Nelson, J.S. 1994. Fishes of the World, 3rd Edition. John Wiley and Sons, Inc. New York, NY. 600 pp.

Ney, J.J. 1978. A synoptic review of yellow perch and walleye biology. *In*: Selected Coolwater Fishes of North America, Special Publ. No. 11, Kendall, R.L., Ed., American Fisheries Society, Washington D.C. pp 1-11.

North Central Regional Aquaculture Center. 1988. Annual progress report for the period September 1, 1993 to August 31, 1996. 58 pp.

Nunley, C.E. 1992. Production of hybrid striped bass (*Morone chrysops* x *Morone saxatilis*) in a recirculating Aquaculture System. M.S. Thesis: Virginia Polytechnic Institute and State University, Blacksburg, VA. 193 pp.

Ontario Ministry of Natural Resources. 1996. Lake Erie fisheries report: 1995. Queen's Printer for Ontario. Ontario, Canada. 55 pp.

Page, L.M. and B.M. Burr. 1991. A Field Guide to Freshwater Fishes. Houghton Mifflin Co. New York, NY. 432 pp.

Riepe J.R. 1988. Yellow perch markets in the North Central Region: results of a 1996/97 survey. Bulletin No. 756. Purdue University, West La Fayette, Indiana. 48 pp.

Ryder, R.A. 1977. Effects of ambient light variation on behavior of yearling, sub-adult, and adult walleyes (*Stizostedion vitreum vitreum*). J. Fish. Res. Board Can. 34(10): 1481-1491.

Schott, E.F., T.B. Kays, and H.E. Calbert. 1978. Comparative growth of male versus Female yellow perch fingerlings under controlled environmental conditions. *In:* Selected Coolwater Fishes of North America, Special Publ. No. 11, Kendall, R.L., Ed., American Fisheries Society, Washington D.C. pp 181-186.

Schott, E.F. 1980. Sexually dimorphic growth in young-of-the year yellow perch (*Perca flavescens*) under controlled environmental conditions. M.S. Thesis, University of Wisconsin, Madison. 222 pp.

Schumann, G.O. 1963. Artificial light to attract young perch: a new method of augmenting the food supply of predacious fish fry in hatcheries. Progressive Fish-Culturist 25: 171-174.

Scott, W.B. and E.J. Crossman. 1973. Freshwater Fishes of Canada. Fish. Res. Bd. Can. Bull., 184 pp.

Starr, C.J. 1991. Commercial production of yellow perch (*Perca flavescens*), in proc. North Central Regional Aquaculture Conference, Kalamazoo, MI, March 18 to 21.

Thorpe, J. 1977. Morphology, physiology, behavior and ecology of *Perca fluviatilis* L. and *P. flavescens* Mitchill. J. Fish. Res. Board Can. 34: 1504-1511.

Wesson, J.B., R.C. Lindsay and D.A. Stuiber. 1979. Discrimination of fish and seafood quality by consumer populations. Journal of Food Science 44: 878-882.

West, G. and J. Leonard. 1978. Culture of yellow perch with emphasis on development of eggs and fry. . *In*: Selected Coolwater Fishes of North America, Special Publ. No. 11, Kendall, R.L., Ed., American Fisheries Society, Washington D.C. pp 172-176.