ATTACHMENT B

PROJECT NAME:	Advancement of Yellow Perch Aquaculture
FUNDING LEVEL:	Year 1 (91-92) - $77,394 Year 2 (92-93) - $22,603
DURATION:	2 Years
CHAIRPERSON:	Dr. Terrence B. Kayes, Department of Forestry, Fisheries and Wildlife, 12 Plant Industry Building, East Campus Mall, University of Nebraska-Lincoln, Lincoln, NE 68583-0814, Telephone (402) 472-8183

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JUSTIFICATION

The yellow perch is a highly valued food fish having numerous biological characteristics that make it an excellent candidate for commercial aquaculture in the North Central Region (Calbert 1975). The market demand for yellow perch has always been high, reflecting a strong consumer preference for seafood products derived from this fish (Lesser 1978; Lesser and Vilstrup 1979). The basis for this demand is tied to long-standing uses in the region, such as Friday-night fish fries. Advantages to the fish processing and restaurant industries include the perch's firm flesh and low fat and phospholipid content. Such characteristics are conducive to products having a long shelf life, resistance to freezer damage and minimal problems with off-flavor and cooking odor (D.A. Stuiber, Fisheries and Seafood Processing Extension Specialist, University of Wisconsin-Madison, personal communication). Its delicate flavor and relative lack of cooking odor make the yellow perch a favorite among restaurateurs and homemakers.

In 1988-89, fresh yellow perch fillets retailed for $17-25/kg ($8-11/lb) in most markets. For many years, commercial harvests of yellow perch from the Great Lakes and Canada have failed to keep pace with market demands (Calbert 1975; Lesser and Vilstrup 1979). Additional regulatory constraints presently in force on commercial perch fishing in all Great Lakes waters, including Lakes Michigan and Erie, Green Bay and Saginaw Bay (e.g., Belonger 1986), are further reducing domestic supplies of yellow perch, thus forcing the market to purchase imported fish products as substitutes. One clear alternative to this growing reliance on imported fish is the increased development and growth of aquaculture. Aquaculture also provides a means of controlling and reducing microcontaminant levels in fish products, which have been a constant concern with fish originating from the Great Lakes (Downs 1985; Smith 1988).

Over the past decade in the North Central Region, there has been a tremendous growth of interest in the feasibility of yellow perch aquaculture (Calbert 1975; Downs and Smith 1983). In addition to yellow perch being in short supply and having an already established niche in the marketplace, research to date has demonstrated that the perch has many biological characteristics that recommend it for commercial culture (see review by Heidinger and Kayes 1986). Among them are its (1) ready acceptance of formulated feeds; (2) lack of aggressive behavior and cannibalism; and (3) relatively high tolerance of crowding, handling and marginal water quality. Procedures for culturing yellow perch at high densities under laboratory conditions are presently known (Huh 1975; Kocurek 1979), as are methods of raising perch to a size and age at which, under natural photoperiod/temperature conditions, they can be successfully spawned (see Malison et al. 1986).

Two major constraints that currently impede the development of commercial yellow perch aquaculture are (1) the lack of available information on the feasibility of raising perch under a variety of practical rearing conditions, such as in ponds, net-pens or raceways, and (2) the comparatively slow growth of the perch (above 50-80 g body weight) due, in part, to its inherent small size (Heidinger and Kayes 1986). One potential method of offsetting the problem of slow growth is to identify wild stocks of yellow perch with superior growth and performance characteristics, then to improve on this base through broodstock development and selective breeding. Another possible method is to utilize specific endocrine and genetic manipulations, such as sex control and chromosomal triploidy induction, to enhance growth.

This proposal describes an ongoing project by the North Central Regional Aquaculture Center (NCRAC) Yellow Perch Work Group, and involves investigators with appropriate expertise from five different institutions in four states: Purdue University, Michigan State University, University of Nebraska-Lincoln, University of Wisconsin-Madison and University of Wisconsin-Milwaukee. The principal goal of the project is to develop practical strategies for commercial yellow perch aquaculture under the diverse environmental conditions that exist in the North Central Region. Specifically, the project is examining: (1) the suitability of selected wild perch stocks, obtained from different geographic locales, as candidates for potential broodstock development, (2) the applicability of selected conventional production technologies to perch aquaculture, and (3) the potential of using chromosomal triploidy induction to enhance growth. Significant progress on these problem areas has been made during the first 2 years of the project. However, a third year and fourth year of effort and funding are needed for the proposed lines of research to reach full fruition and thus yield maximum benefits.

RELATED CURRENT AND PREVIOUS WORK

Comparison of Yellow Perch Stocks From Different Geographic Locales

1. Background

Currently, there are no domesticated broodstocks of yellow perch; perch used as broodfish for aquaculture are generally obtained from wild populations. The offspring of various wild stocks of perch may differ in their ability to survive, grow and perform well under intensive culture conditions. Information on such differences would provide important baseline data for future efforts at broodstock development and selective breeding.

Significant variations in growth rate have been observed between genetically distinct stocks of both wild and cultured fishes (Leggett and Carscaddin 1978; Dunham and Smitherman 1983). Abundant evidence exists for differences in growth rate between geographically isolated stocks of yellow perch (Deedler 1951; Jobes 1952; El-Zarka 1959; Grice 1960; Warnich 1966; Noble 1975; Weatherley 1977). Typically, these differences have been associated with environmental variance in such factors as temperature, length of growing season, photoperiod and food availability. The extent to which genetic variance is responsible for the reported differences in perch growth rate is unknown.

Genetic differences in specific biochemical traits (e.g., isozyme patterns) between yellow perch stocks have not, as yet, been identified (Leary and Brooke 1982). However, discrete spawning populations of perch are known to exist, (Nakashima and Leggett 1975; Kelso and Ward 1977), and empirical evidence for genetic differences between populations has often been cited (e.g., see Eshenroder 1977; Johnson 1977). Regardless of whether different perch stocks exhibit distinct biochemically-detectable traits, genetic variance between stocks may influence their ability to grow and perform well under different culture conditions (e.g., temperature), and could potentially be exploited as part of a broodstock development program.

Stock-related differences in temperature optima have been observed in largemouth bass (Venables et al. 1977). Such differences have not been specifically reported for yellow perch, but studies on the thermal requirements of perch have yielded variable results. McCormick (1976) reported maximum growth for juvenile yellow perch on unrestricted rations at 24-28 °C, while Schneider (1973) reported the thermal optimum for growth and food consumption by yearlings to be 23 °C. Variations in upper incipient lethal temperatures from 29-34 °C have also been observed in perch (Hokanson 1977). Such variability between studies has typically been attributed to differences in fish age and testing conditions, but may have also been due, in part, to genetic differences between perch stocks. Stocks identified as having different temperature requirements and limits could be extremely useful to aquaculturists rearing perch under different thermal conditions.

One approach to identifying intraspecific differences between stocks of fish is to compare the response patterns and performance of their offspring under carefully controlled environmental conditions. Our project is comparing the survival, growth and performance of offspring from selected northern, southern and Great Plains stocks of yellow perch, at different life history stages and at different temperatures. Such investigations could greatly facilitate yellow perch aquaculture by providing baseline information on differences between wild stocks and their suitability for broodstock development.

2. Progress

In 1989 and 1990, comparisons were made between selected strains of yellow perch from different sources. An inland Wisconsin strain (Lake Mendota) and a Great Lakes strain (Green Bay) were hatched and raised to an early-fingerling size (40-50 mm total length [TL]), employing a rearing procedure developed at the University of Wisconsin-Milwaukee (UW-Milwaukee) to insure that fish used in (subsequent) growth studies have similar environmental and cultural histories. This rearing scheme (as detailed under Procedures and in previous reports), insures uniform incubation, rearing temperature and water-quality parameters, and utilizes an identical progression of live-to-formulated foods, thereby providing a baseline for growth comparisons.

University of Wisconsin-Madison (UW-Madison) investigators provided the fertilized spawn of Lake Mendota fish for this study. UW-Milwaukee personnel obtained the fertilized spawn of Green Bay fish, in cooperation with the Wisconsin Departments of Natural Resources. Juvenile perch (40-50 mm TL) were successfully reared and habituated to a formulated diet by the standardized scheme. In the second year of the study, progress was made toward broadening the geographic range of strain comparisons by hatching and rearing two batches of Pennsylvania-strain perch, provided to the UW-Milwaukee through the efforts of Southern Illinois University (SIU) cooperators. In both years, sufficient numbers of 40-50 mm TL fish were made available to Purdue University researchers to conduct growth comparisons.

To date, observations on the survival and development of young perch using the standardized rearing scheme at one station (UW-Milwaukee) have revealed little variation between strains, at least under optimal conditions during the early rearing stages. This uniformity of results suggests that geographic strain differences are small compared to the influence of incubation and rearing conditions. Operationally, the standardized rearing scheme utilized proved to be an effective method of producing fingerling perch for "grow-out", and we believe constitutes a significant advance in the technology of larval perch culture.

In contrast to the situation with larval perch, studies by Purdue University investigators have revealed clear variations between strains in the growth of fingerlings raised at different temperatures. In the first year of the project, perch from Lake Mendota and Green Bay were reared at 28, 22, and 16ºC, and fed slightly in excess of what they would eat in 5-10 min (3.5%, 3.0%, and 2.0% of body weight per day, respectively). After 10 weeks, overall mean weight gains and feed conversion ratios (FCR) were 254% and 2.7, 417% and 1.6, and 165% and 1.6, respectively, for fish reared at 28, 22, and 16 ºC. Weight gain by the Green Bay strain was significantly higher than Lake Mendota fish when reared at 16 ºC, but weight gain between strains was not significantly different at the other two experimental temperatures.

The weight gain depression observed in Lake Mendota fish at 16 ºC was not obvious until 6 weeks into the study. Accordingly, this result appears to be a true characterization and not an artifact of poor feed acceptance or inability to adapt to the experimental conditions. Both strains appeared chronically stressed when reared at 28 ºC, and survival was reduced in these fish (81% survival compared to 100% and 95% in fish reared at 22 and 16 ºC, respectively). All mortalities were the result of fish jumping out of tanks. Evaluation of the Pennsylvania strain compared to the Lake Mendota strain is currently underway.

By the end of the second year of the project, only three strains (Lake Mendota, Green Bay and Pennsylvania) of yellow perch will have been examined. The Pennsylvania fish clearly do not represent a truly southern strain. Accordingly, the full geographic range of potentially different perch strains has not yet been tested. Given the wide range of thermal optima reported for perch (21 to 28 ºC), continuing these evaluations with a Great Plains strain (e.g., Nebraska) and a southern strain (e.g., Maryland) may identify stocks that are capable of maximum weight gain and survival when reared under the diverse environmental temperature conditions that occur in the North Central Region.

Evaluation of Aquaculture Production Technologies for Yellow Perch

1. Background

Growth studies conducted over a decade ago indicated that yellow perch can be raised from fry to market size (150 g total weight) in 9-11 months under optimum environmental conditions (Huh 1975; Stuiber 1975; Calbert and Huh 1976; Kocurek 1979). However, for commercial aquaculture, the maintenance of environmental conditions, such as water quality and temperature, at optimal levels can be prohibitively expensive, particularly in the North Central Region where groundwater temperatures are typically cold (8-15 ºC) and surface-water temperatures can fluctuate seasonally from 0 to over 30 ºC. For yellow perch, the temperature optimum for growth has been reported to be between 21 and 28 ºC, depending, in part, on fish size or age (Huh 1975; McCormick 1976; Hokanson 1977; Heidinger and Kayes 1986).

Two production strategies that could provide stable warm-water temperatures throughout the year in the North Central Region would be to rear fish in tanks or raceways equipped either for water heating, treatment and recirculation, or for single-pass heating of flow-through water. To our knowledge, the economics of large-scale water recirculation systems in aquaculture remain to be proven, and several reports have indicated that the economics of such systems for perch culture do not appear favorable (West and Leonard 1977; Kocurek 1979; Heidinger and Kayes 1986). Alternatively, heating water for flow-through tank or raceway culture would be feasible only if the cost of heating the water were extremely low.

Little is known about the water-flow and spatial requirements of yellow perch in intensive flow-through culture systems. Such systems depend primarily on water flow to provide oxygen and remove metabolic wastes. Westers (1979) developed an operational model that relates water-exchange rates with kilograms of fish present in a culture system. In practice, loading rates (kilograms of fish/L per minute of water flow) may vary, depending on species and culture conditions. Optimum loading rates for yellow perch being reared under intensive culture conditions have not been determined.

The principal environmental factor determining the maximum loading rate of fish in a culture system is dissolved oxygen. Because of increased metabolic rate related to food digestion (Brett and Groves 1979), dissolved-oxygen levels in most culture systems decline shortly after feeding, then return to normal several hours later. Yellow perch are relatively tolerant of low dissolved oxygen, down to about 3.8 mg/L (Carlson et al. 1980). Stress caused by low oxygen may result in reduced growth rates or increased occurrence of disease . When water is aerated to maintain or restore adequate dissolved oxygen, the level of unionized ammonia (NH_3), produced as a metabolic waste product, becomes the primary environmental factor that limits loading rates.

As outlined by Piper et al. (1982), the spatial requirements of intensively cultured fish can be characterized in terms of a "density index" (calculated by dividing pounds of fish/ft^3 of rearing water by fish length in inches). The maximum recommended density index for salmonids is 0.5, a figure based largely on experience and empirical considerations. Even with sufficient water flow, excessive crowding may cause behavioral problems and stress in fish. The optimum density index for yellow perch is presently unknown.

Pond or net-pen culture of yellow perch is an alternative to culture in flow-through or water-recirculation systems that also has not been adequately investigated. One potential limitation of rearing perch in ponds in the North Central Region is that, similar to pond culture of catfish in the South, optimum temperatures for growth do not exist throughout the year. However, a bioenergetics growth model by Kitchell et al. (1977) predicts that perch should reach market size in 15-18 months under ambient temperature conditions (including winter) in the North Central Region, if food is not restricted. Data on fast-growing wild populations of perch, presumably where food is not a major limiting factor, tend to confirm this model (e.g., see Thorpe 1977).

Although wild yellow perch survive and grow well in many lakes and ponds in the North Central Region, the temperature extremes of both summer and winter pose potentially serious problems to the intensive culture of perch in ponds or net-pens. Pond water temperatures throughout much of the region reach 25-30 °C or more for at least part of the summer. In an unpublished study, University of Wisconsin-Madison researchers found that perch held in net-pens at high densities (e.g., 20-40 kg/m^3) exhibited serious bacterial disease problems (primarily *Flexibacter* and *Aeromonas* sp.) and high mortality at temperatures above 24 °C. These problems probably resulted from an interaction of the warm water temperature with high fish densities, because wild perch populations often flourish (at much lower densities) in lakes and ponds whose maximum summer temperatures are warmer than 24 °C (Hokanson 1977; Becker 1983). Fish held in net pens in static or stagnant ponds may also be subject to dissolved oxygen depletion under certain conditions (e.g., during prolonged periods of very hot or cloudy weather).

At the other extreme, winter temperatures result in a reduction (LeCren 1958; Kitchell et al. 1977) though not a total cessation of yellow perch growth (J.A. Malison, University of Wisconsin-Madison, unpublished data). In addition, under normal conditions, heavy ice formation on ponds can (1) damage or destroy piers, net-pens and other equipment at or near the water surface (Wortley 1982), (2) result in fish kills due to dissolved-oxygen depletion, and (3) make fish husbandry (e.g., feeding) difficult or impossible.

Many locales in the North Central Region have abundant groundwater resources that are at or near ground level (e.g., artesian wells). These waters are typically too cold (e.g., 8-15 °C) to be used directly for yellow perch aquaculture. Some are presently being utilized for salmonid culture by both private and public fish hatcheries. For the culture of perch in ponds, groundwater could be employed to moderate the temperature extremes of both summer and winter. Alternatively, in summer such water could be passed through warming ponds, then used in tanks or raceways. In winter, perch could be maintained in tanks or raceways supplied directly with groundwater. Perch overwintered at groundwater temperatures may show improved growth and survival compared to perch overwintered in colder pond waters.

Our project is evaluating the influence of loading and rearing density on the survival, growth and feed conversion of perch reared under flow-through intensive culture conditions. We are also examining the feasibility of culturing perch in net-pens in ponds where groundwater is available for temperature moderation.

2. Progress

For studies on intensive flow-through culture, yellow perch fingerlings (100-130 mm TL) were harvested by Michigan State University (MSU) investigators from ponds that had been stocked with fry during the spring of 1989 by Bay Port Aquaculture, Inc. Fish were graded in order to obtain a uniform size of approximately 115 mm TL. On 1-15-90, fish (53-57 fish per tank) were stocked into experimental 210-L fiberglass tanks (three replicate tanks per treatment) at the MSU Aquaculture Laboratory. Flow rates were adjusted to provide flow indices of 1.4, 1.1, 0.85, 0.55, 0.28 kg/L per min (2.5, 2.0, 1.5, 1.0, and 0.5 pounds/gallon per min per inch) according to Piper (1970). Optimal conditions for growth of perch (21 °C, 16 h light/8 h dark photoperiod; Huh et al. 1976) were maintained throughout the 10 week study period. The fish were fed at a rate of 2% body wet weight, divided into three equal feedings daily of "Trout Grower Diet" (Zeigler Bros. Inc., Gardners, Pennsylvania).

Dissolved oxygen profiles were performed on three randomly selected dates (2-17-90, 3-3-90, and 3-24-90). Using a YSI Model 58 dissolved oxygen meter, readings were taken 1 h prior to feeding and every hour thereafter. Final readings were taken at least 4 h after the last feeding of the day. In order to minimize disturbance of the fish, the probe was placed in the external standpipe that carried effluent water from each individual tank.

In order to estimate maximum ammonia levels, water samples (one sample per tank) were taken 3 h after feeding on a randomly selected date (3-22-90) and analyzed for total ammonia using the nesslerization-following-distillation method at the MSU Limnological Laboratory. Un-ionized ammonia levels were calculated according to Trussell (1972).

Although statistical analyses of the data have yet to be done, it appears that on the basis of fish growth and feed conversion, (there were no mortalities during the study), optimal loading is between 0.85 and 1.1 kg/L per min (1.5 and 2.0 pounds/gallon per min per inch) under our laboratory rearing conditions (Table 1).

Results of the dissolved oxygen profiles indicate that approximately 3.5 mg/L dissolved oxygen is necessary to maintain optimal growth, although fluctuations of 2.0-4.5 mg/L during feeding periods do not appear to hinder growth (Table 2). Un-ionized ammonia levels in the tanks on the sample date were well below that considered to limit growth for other species of freshwater fish (Table 3).

TABLE 1. Weight gain, feed conversion, and gain in length of yellow perch reared at five loading rates (kg/L per min).

Treatment	Mean weight gain (g fish/tank)	Mean feed conversion	Mean gain in total length (mm/fish)
1.4 kg/L per min	399.7	2.77	126
1.1 kg/L per min	669.7	1.77	188
0.85 kg/L per min	744.3	1.60	225
0.55 kg/L per min	744.3	1.60	219
0.28 kg/L per min	782.7	1.57	226

TABLE 2. Mean dissolved oxygen (D.O.) and oxygen ranges in tanks of yellow perch reared at five loading rates (kg/L per min).

Treatment	Mean D.O. (mg/L)	Range (mg/L)
1.4 kg/L per min	1.96	1.0-3.2
1.1 kg/L per min	2.55	1.5-3.7
0.85 kg/L per min	3.42	2.0-4.5
0.55 kg/L per min	4.64	3.5-5.5
0.28 kg/L per min	5.99	4.7-6.9

TABLE 3. Ammonia levels in tanks of yellow perch reared at five loading rates (kg/L per min).

Treatment	Mean un-ionized ammonia (mg/L)
1.4 kg/L per min	0.00243
1.1 kg/L per min	0.00177
0.85 kg/L per min	0.00210
0.55 kg/L per min	0.00170
0.28 kg/L per min	0.00220

Optimal density-index evaluations will be conducted at the MSU Aquaculture Laboratory from October 1990 to December 1990. Two experiments will be done in Year 3. The first experiment will test laboratory-generated optimum loading and density rates under commercial-scale conditions. The second experiment will test the use of baffles to improve water quality and increase rearing densities. Baffles have been used successfully to improve waste-solids control in Michigan Department of Natural Resources (MDNR) fish hatchery raceways (Boersen and Westers 1986). The MDNR rears salmonids and esocids at three to four times the densities used by other state and federal hatcheries because of the improved water quality and flow characteristics provided, in part, by baffle systems.

Studies on pond culture are being conducted by UW-Madison investigators, using yellow perch reared in net-pens in ponds located at Coolwater Farms, a commercial fish farm in Dousman, Wisconsin. One of these ponds is provided with sufficient groundwater additions to moderate seasonal temperature extremes. Initial efforts were focused on the transportation, installation and "de-bugging" of experimental facilities (e.g., floating piers, net-pens and frames, automatic feeders, aeration devices, etc.) at Coolwater Farms. Subsequently, preliminary studies of the net-pen culture of perch in the pond provided with groundwater addition were conducted. The major findings of these studies are as follows: (1) The addition of 75-150 L/min of groundwater (at 11 ºC) to the 0.07-hectare pond was sufficient to keep the maximum (summer) pond water temperature at <24 ºC. (2) Fingerlings stocked into net-pens at 350-1,000 fish/m^3 had survival rates of >80% for a 2-month period. (3) Perch reared in 1.8 m-deep net-pens grew faster and seemed less disturbed by shadows and movements than those reared in 1.2 m-deep net-pens. (4) The sudden increase in light intensity when perch were moved from dimly-lit indoor tanks into outdoor net-pens induced a significant degree of stress and some (related) mortality.

In 1990, UW-Madison investigators initiated an ongoing study that is comparing the survival and growth of yellow perch reared in net-pens in ponds either with or without groundwater addition. The experimental protocols being used are similar to those described in our initial proposal. In mid-April, fertilized perch eggs were stocked just prior to hatch into production ponds at the Lake Mills State Fish Hatchery, Lake Mills, Wisconsin. The fish were reared in ponds until they reached 20-40 mm TL (late June), at which time they were harvested and transferred to the UW Aquaculture Program's main wet laboratory, which is also located at the Lake Mills hatchery.

There, the fish were habituated to a formulated feed ("Salmon Grower Diet", Ziegler Brothers Inc.), in flow-through tanks (750-L tanks, 20-25 L/min of water flow and 3,000-8,000 fish per tank) under environmental conditions that UW-Madison personnel have found to be optimal for this procedure (i.e., 21±1 ºC, 24-h constant light, using internal tank lighting). After about 3 weeks, all of the perch were actively consuming feed, and the fish were gradually (over a 1-week period) acclimatized to brighter lighting conditions and transported to Coolwater Farms. There, perch were randomly assigned and stocked into 12, 1.2-m x 1.2-m x 1.8-m deep polyester mesh net-pens. Six of these net-pens are situated in a 0.07-hectare x 2.2-m-deep pond (Pond A), into which up to 270 L/min of 9 ºC groundwater can be added to provide temperature stability and cooling during summer. The other six net pens are situated in a 0.2 hectare x 2.2-m-deep pond (Pond B), that is not supplied with cooling water.

In each pond, three cages each were stocked with 330 or 1,320 fish per net-pen (i.e., a 2x2 factorial design, with the factors being pond [A or B] and fish density [low or high], with three replicates per treatment). Each net-pen is continuously aerated by a single diffuser. Water temperatures and dissolved oxygen are being measured daily at the pond surfaces and at 1.3 m depth. Fish are being fed two or three times daily, initially at 4% of total body weight/d, declining to 1.0% of body weight/d as fish grow and water temperatures decline. Mortalities are removed and recorded regularly, and fish are counted, weighed and measured monthly. This protocol will be followed until ambient water temperatures fall to 9 ºC this autumn (usually sometime in November).

The summer of 1990 in Wisconsin was characterized by exceptionally cool and cloudy weather. Mid-summer water temperatures in Ponds A and B typically ranged from 17-20 ºC and 21-24 ºC, respectively, or about 4 ºC cooler than temperatures recorded in the same ponds during the four previous summers. These cool water temperatures were probably responsible for the complete lack of any bacterial disease outbreaks during the first year of this study. (We had originally anticipated some bacterial disease problems associated with warm water temperatures in Pond B).

Growth rates of the perch in all four treatment groups has been good, but have probably been reduced somewhat by the cool temperatures. Mean monthly weight gains for the four treatment groups during the summer were as follows: Pond A, low density = 83.2%, high density = 64.3%; Pond B, low density = 82.8%, high density = 62.0%. This compares to typical mean monthly weight gains of 100-130% usually observed by UW-Madison researchers, when juvenile perch are reared in tanks under optimal flow-through conditions (i.e., very low rearing densities and temperatures of 21±1 ºC).

Survival rates of perch reared in Pond A have been excellent (>90%), and those of fish in Pond B were equally good until a severe depletion in dissolved oxygen occurred in late August. Following a prolonged period of cloudy weather (six consecutive days without sunshine), early morning dissolved oxygen concentrations in the net-pens in Pond B fell to <1.5

mg/L, despite the use of an emergency paddlewheel aerator in the vicinity of the net-pens. The low dissolved oxygen levels resulted in the loss of 10-20% and 30-50% of the perch in the low density and high density net-pens, respectively. Such a depletion in dissolved oxygen would probably not have occurred had weather conditions been more typical for Wisconsin. Nevertheless, this incident points to a serious potential problem with net-pen aquaculture in small ponds that are not provided with any flow through or water exchange. During the same period, dissolved oxygen concentrations in Pond A never fell below 3.0 mg/L, a fact that can probably be ascribed to the well water addition maintaining a (comparatively) lower biochemical oxygen demand.

Examination of Potential of Triploidy Induction to Enhance Growth

1. Background

Although yellow perch, like many fishes, are generally considered to be indeterminate growers (i.e., growth continues throughout life), a considerable reduction in their growth rate occurs well before they attain a market size of 140-160 g (Huh 1975; Schott 1980; Malison et al. 1985). In part, this growth pattern is related to the onset of sexual maturation and gonadal development, which in perch occurs in the first year of life (Malison et al. 1986, 1987). Somatic growth and reproduction are widely thought to be antagonistic processes, each competing in the adult animal for available nutrients. Studies on yellow perch and other fish species (Huh 1975; Purdom 1976; Utter et al. 1983; Malison et al. 1985, 1988b) have shown a strong correlation between sexual development and reduced growth and feed consumption and conversion.

In recent years, induction of triploidy has been suggested as a way to sterilize fish and improve their growth (see Thorgaard 1986 for a review). Triploids containing two maternal and one paternal chromosome sets can be produced by inhibiting extrusion of the second polar body of the fertilized egg. Triploid fish often exhibit normal somatic development but are assumed to be functionally sterile (i.e., their gametes cannot be used to produce viable offspring) because proper reduction division can not occur during gametogenesis (Thorgaard 1983).

Triploidy in fish can be induced by shocking eggs shortly after fertilization, to affect retention of the second polar body. Methods used to date include the exposure of fertilized eggs to temperature shock (hot or cold, see e.g., Thorgaard et al. 1981; Wolters et al. 1981; Solar et al. 1984; Cassani and Caton 1985), hydrostatic pressure (Charrout 1984; Cassani and Caton 1986) or chemicals, such as colchicine, cytochalasin and nitrous oxide (Smith and Lemoine 1979; Refstie et al. 1977; Shelton et al. 1986).

In a (separate but related) Wisconsin Sea Grant project (Kayes and Malison 1988), J.A. Malison of the University of Wisconsin-Madison has used thermal shock to induce triploidy in yellow perch. Results to date (unpublished) have revealed substantial variability between eggs from different females on the effects of specific thermal-shock regimes on embryo survival and triploidy induction. Similar results have been observed in rainbow trout (Lou and Purdom 1984; also discussed by Shelton et al. 1986) and Atlantic (Johnstone 1985) and chinook (Levanduski et al. 1988) salmon. The variability observed in perch may be related to the fact that the eggs subjected to thermal shocks have been obtained from wild adults captured from lakes whose ambient temperatures vary from 5-12 °C during the spawning season.

Several investigators have reported that triploid fish outgrow diploids after the onset of sexual maturation in diploids reduces growth and feed conversion (Thorgaard and Gall 1979; Gervai et al. 1980; Lincoln 1981a; Wolters et al. 1982). Growth studies on triploid yellow perch have been conducted only on juvenile fish (Kayes and Malison 1988). In one study (Malison et al. 1988a), triploid perch began to outgrow diploids after fish reached 20 g total weight, a size coincident with the onset of sexual development in diploids. Studies on plaice, rainbow trout, channel catfish, loach, and Atlantic and Pacific salmon have suggested that both morphological development of the gonads and gonadal steroidogenesis are suppressed to a greater degree in females than in males (Lincoln 1981a,b; Wolters et al. 1982; Benfey and Sutterlin 1984; Solar et al. 1984; Suzuki et al. 1985; Johnson et al. 1986; Benfey et al. 1988). Consequently, in some fishes, triploidy may result in improved growth only in females.

Sex control and the subsequent production of all-female yellow perch is an alternative method of improving growth, used either alone or in conjunction with triploidy induction. Schott (1980) showed that female perch reared under intensive culture conditions grow significantly faster than males. A similar difference between the sexes in growth rate has been found in many wild perch populations (Scott and Crossman 1973; Thorpe 1977; Becker 1983). Methods similar to those used for triploidy induction can be used to produce all-female gynogenetic fish.

During the first 2 years of this project, we are evaluating methods of improving the efficiency and reliability of using heat shock to induce triploidy in yellow perch. Differences in the growth and performance of diploid and triploid male and female perch raised to market size are also being characterized.

2. Progress

Research on Objective 3 is being done collaboratively by investigators from SIU and the UW-Madison. Investigators at SIU are responsible for conducting studies that examine the influence of ambient water temperature, at which female broodfish are captured, on triploidy induction by heat shock. Researchers at the UW-Madison are responsible for studies that determine the efficacy of various heat shock regimes to induce triploidy under conditions designed to minimize the influence of ambient water temperatures. Researchers at both SIU and the UW-Madison are responsible for conducting studies that compare survival and growth of diploid and triploid perch.

In April 1989, Mr. Gary Miller (a graduate student of Dr. J.E. Seeb of SIU), travelled to the UW-Madison to participate in the production of triploid yellow perch. Two groups of triploid perch embryos were produced by heat shocking the eggs for 10 min at 28 °C. The heat shock was initiated at 2 min after fertilization for one group, and at 5 min after fertilization for the other group. Flow cytometry conducted at the UW-Madison indicated that the percentages of triploid embryos for the two groups of eggs were 84% and 90%, respectively.

Both groups of eggs were transported to SIU and stocked into separate fertilized rearing ponds. Approximately 8 weeks later, over 100 perch were harvested from each pond and habituated to formulated feeds and intensive culture conditions. In September 1989, over 200 diploid (control) perch, initially reared by researchers from the UW-Milwaukee, were shipped to SIU. Long-term growth studies comparing diploid and triploid perch are now being conducted at SIU and will soon be completed. However, because Dr. J.E. Seeb, the principal investigator at SIU for Objective 3, has accepted a position outside of the North Central Region, SIU will not conduct any further studies on this objective.

At the UW-Madison, a multi-factorial experiment was conducted that evaluated the efficacy of different heat-shock regimes on inducing triploidy in perch. Wild, "ripe" female broodfish were captured from Lake Mendota during the perch spawning season, during which time ambient water temperatures ranged from 5-14 °C. Regardless of ambient water temperature, broodfish were acclimated to 11 °C (in the laboratory) for at least 2 h prior to stripping the eggs. The experimental factors (variables) were: time of initiation of heat shock (2 or 5 min post-fertilization), duration of heat shock (10 or 25 min), and temperature (24, 26, 28, 30, or 11 °C, the latter as a control). The results were: (1) Temperatures of 28-30 °C were the most effective at inducing triploidy. (2) Embryonic survival was slightly higher at a duration of 10 min, as compared to 25 min. (3) The time of initiation of heat shock (either 2 or 5 min post-fertilization) had no effect on survival or success rates at inducing triploidy.

In two separate studies, UW-Madison researchers have compared growth rates of juvenile triploid and diploid perch. In one study, triploids grew faster than diploids that had been subjected (as embryos) to the same heat shock regime as the triploids (Madison et al. 1988). In a subsequent study (unpublished), juvenile triploids grew slower than diploids that had <u>not</u> been subjected to heat shock. Taken together, the results of these two studies suggest that procedures such as heat or pressure shock may exert deleterious physiological effects on embryos in addition to inducing triploidy. Such deleterious effects, in turn, may mask any potential improvements in growth or performance associated with the triploid state, at least in juvenile perch. Long-term studies comparing the growth and performance of triploid and diploid perch (the former produced by either heat or pressure shock) reared to market size are presently underway at the UW-Madison.

Based on our results, alternative methods of inducing triploids should be investigated. In an ongoing Wisconsin Sea Grant project (Kayes and Malison 1990), UW-Madison researchers are examining methods of inducing tetraploidy in perch. The ultimate goal of the latter project is to produce triploids by crossing tetraploids with normal diploids. The potential of using selected chemicals that block meiosis (e.g., colchicine and cytochalasin) to induce triploidy in perch also needs to be evaluated.

OBJECTIVES

1. Compare weight gain, survival, feed conversion, proximate composition, and protein retention of selected northern, southern, and Great Plains strains of yellow perch.

2. Evaluate survival, growth and feed conversion of yellow perch raised at various loadings or rearing densities in selected flow-through and pond culture systems.

3. Evaluate the efficacy of using chemicals that block meiosis to induce triploidy in yellow perch, and compare the survival and growth of triploids produced in this manner with that of normal diploids.

PROCEDURES

Objective 1

Research to compare selected northern, southern and Great Plains stocks of yellow perch will be done collaboratively by investigators from Purdue University, the University of Nebraska-Lincoln (UNL), University of Wisconsin-Madison (UW-Madison) and University of Wisconsin-Milwaukee (UW-Milwaukee). Obtaining fertilized eggs and/or fish for these investigations will be the responsibility of the UNL and the UW-Madison (Great Plains strain), and the UW-Milwaukee (southern strain), respectively. To ensure that all fish used in critical growth studies have a similar environmental and culture history, the fertilized eggs of all test stocks examined will be directed to one station, the UW-Milwaukee Center for Great Lakes Studies (CGLS). There, the eggs will be incubated and hatched, and the fry raised on live food and later habituated to formulated feed, all under standardized conditions.

After habituation to formulated feed, juvenile yellow perch at about 40-50 mm TL will be transported to Purdue University. All costs and logistics for this activity will be the responsibility of Purdue University. Researchers at Purdue will conduct experiments to compare the survival, growth and feed conversion of different perch stocks at different temperatures. In addition, the Purdue investigators will compare the moisture, crude protein, ash and total lipid contents of fish from the different stocks at the beginning and end of experiments.

Although all yellow perch are spring spawners, time of spawning varies widely between different locales. Thus, perch in the south typically spawn earlier in the year, though often over a more protracted period, than perch in the north (Hokanson 1977). Consequently, experiments in which developing eggs or fish from different perch stocks are compared over exactly the same time period will not generally be possible. To compensate for this, for any given set of comparisons, experimental procedures and conditions will be rigorously standardized across test groups, with each perch stock tested having a minimum of three (generally four) replicate treatment groups per comparison. In addition, rate functions (e.g., rates of survivorship and growth) will be used as primary endpoints in making comparisons. When appropriate, critical comparisons between perch stocks may also be replicated across more than one year.

Present plans are to compare a minimum of two yellow perch stocks from different geographic locales: one from a southern location (Maryland), and one from the Great Plains (Nebraska). If perch from these areas are not available, alternate geographic locales will be considered, (e.g., North or South Carolina for the southern strain, and North or South Dakota for the Great Plains strain).

Studies comparing the early life history stages of different yellow perch stocks will be done by UW-Milwaukee CGLS researchers, using intensive laboratory culture procedures developed over the past 5 years. Principal endpoints will be rates of survivorship and growth through critical developmental and feeding stages--including hatch, first acceptance of live-food organisms (at about 5-6 mm TL), acceptance of brine shrimp nauplii (at 8-12 mm TL) and habituation to formulated feeds (at 25-30 mm TL).

The eggs of yellow perch are arranged in concertina-shaped strands, generally one strand per spawning female (see Heidinger and Kayes 1986). Egg strands will be incubated at the CGLS by suspending them from wire mesh in replicate incubation tanks supplied with temperature-regulated flow-through water from a common head tank. Estimates of numbers of eggs will be made by counting the eggs in subsamples of water-hardened strands and extrapolating to total numbers for each strand, using either a wet-weight or volumetric (water displacement) method. Percent hatch for each replicate tank will be approximated by comparing the estimated number of fry hatched to the estimated number of eggs incubated. Fish size at hatching will be determined by measuring fish subsampled from each replicate tank.

Thereafter, sac-fry will be counted into temperature-regulated static (zero water flow) tanks, equipped for the addition of "green water" originating from parallel static cultures of a commercially-available mixture of phytoplankton, zooplankton and protozoa. The green-water mixture will be added to the tanks several times daily. Water exchanges will be made to maintain water quality, and all tanks will be aerated. Brine shrimp nauplii (BSN) will be added to the feeding regime when the fish reach 8-12 mm TL. After the majority of fish are actively feeding on BSN, they will be counted into flow-through tanks, where BSN will continue to be fed. When the fish reach 25-30 mm TL, they will be habituated to formulated feed. Young perch will be raised on formulated feeds to a size of 40-50 mm TL and then transferred to the Purdue University group for continued grow-out experiments.

All studies at the CGLS will be done using dechlorinated water passed through packed columns, as needed, to ensure total gas supersaturation levels below 102%. Dissolved-oxygen levels will be maintained within 15% of saturation. Water temperature in both static and flow-through systems will be maintained within 1 ºC. During egg incubations, water temperature will be raised 0.5-1.0 ºC/d, following Hokanson and Kleiner's (1974) observation that such a rise results in a shorter hatching period and fewer abnormalities. The total increase in temperature during egg incubation will be 6 ºC from the fertilization or collection temperature. During the early (live-food) rearing period, the water temperature for all stocks will be slowly adjusted (no more than 1 ºC/d) to 21 ºC.

After transport to Purdue, fish will be stocked into 40-L aquaria with supplemental aeration and acclimatized to laboratory conditions and 21 ºC for a minimum of 2 weeks. Temperatures will then be adjusted by 1 ºC/d, with all tanks being brought to the desired experimental temperatures on the same day. All fish will then be acclimated for an additional week prior to the initiation of experiments. At the end of the acclimation period, subsamples of fish will be collected for proximate analyses. Photoperiod will be 16-h light/8-h dark. In experiments during Year 2 of the project, temperature remained within 0.5 ºC of the desired value, dissolved oxygen was 80% saturation or higher, nitrogenous wastes were below 0.05 mg/L, and the pH range was 7.4-8.2.

In the first 2 years of the project, four replicates of each test strain were used per experimental treatment. In Year 3, we propose to evaluate two additional strains (Nebraska and Maryland), and need to incorporate some continuity between years. Thus, the two new strains will be compared to the Lake Mendota strain using three replicates of each per experimental treatment. Duration of the study will be at least 10 weeks, and feeding rates will be slightly in excess of satiation.

All fish will be fed "Biodiet" (Bioproducts, Inc., Warrenton, Oregon), with the daily feed allotment divided into two equal meals per day. Fish will be weighed every 2 weeks, and feed allotments adjusted accordingly. On completion of an experiment, all fish will be counted, weighed, and subsamples collected for analyses. Differences in performance between strains will be assessed by comparing mean weight gain, survival, feed conversion ratio, proximate composition of whole fish, and protein retention. Proximate composition will be determined by standard methods (AOAC 1980), and protein retention will be calculated from weight gain data and proximate values from fish at the beginning and end of the experiment.

Whenever possible, parametric statistical methods will be used to analyze numerical data. Nonparametric statistics will be employed when the application of parametric methods is found to be inappropriate or unfeasible. Data collected by investigators from the participating institutions will be collated on an ongoing basis, and the findings published in a timely manner in appropriate peer-reviewed journals. Extension information will be published through regional and station bulletins, in collaboration with the NCRAC Aquaculture Extension Work Group.

Objective 2

Research to evaluate selected production technologies for yellow perch aquaculture will be done collaboratively by investigators from Michigan State University (MSU) and the University of Wisconsin-Madison (UW-Madison). Studies on the culture of perch in flow-through systems will be the responsibility of MSU, and studies on the pond culture of perch will be the responsibility of the UW-Madison. The latter will be done in collaboration with Coolwater Farms (Dousman, Wisconsin).

During Year 2 of the project, Dr. Terrence B. Kayes, a principal investigator and the chair of the NCRAC Yellow Perch Work Group, moved from the UW-Madison to the University of Nebraska-Lincoln (UNL). By mutual agreement, Dr. Jeffrey A. Malison is assuming the lead for the research being done at the UW-Madison. Dr. Kayes, at the UNL, will play an active role in Objectives 1 and 3 during Years 3 and 4 of the project, and will continue to coordinate with MSU and UW-Madison investigators on the analysis, interpretation, reporting and subsequent publication of research findings relative to Objective 2. This will be accomplished through close communications and several working visits by Dr. Kayes to the UW-Madison, and possibly MSU.

In Year 3 of the project, MSU investigators will test laboratory-generated optimum loading and density rates for yellow perch under commercial-scale intensive aquaculture conditions. Perch fingerlings will be harvested in August 1991 from ponds stocked by Bay Port Aquaculture Inc, and will be transported to their yellow perch culture demonstration facility at Port Sheldon, Michigan in a fish transport unit equipped with aeration pumps and pure-oxygen injectors, in order to prevent oxygen depletion during transport. The fish will be placed in circular fiberglass tanks (2,830 L each) to be acclimated and feed-trained over a period of approximately 3 weeks.

Using at least six rectangular fiberglass tanks (operational volume of 1,440 L each) with water flows adjusted to provide at least two water exchanges per hour, fish will be stocked at optimal density and loading levels based on data generated during Year 1 and 2 of the project. Baffles will be placed in three of the tanks in order to determine their effectiveness in maintaining water quality and their effect on fish performance. Optimal conditions for growth of yellow perch (21 ºC, 16-h light/8-h dark photoperiod) will be maintained throughout the growing period. Weight and length measurements of samples of fish will be taken every 2 weeks, in order to adjust flows and rearing volume so that optimal loading and density levels are maintained.

To obtain additional data on the metabolic characteristics of yellow perch reared under intensive culture conditions, dissolved-oxygen levels will be monitored for 24-h periods in each tank using a YSI dissolved-oxygen meter and recorder. The data generated will be used to calculate oxygen consumption per kilogram of feed metabolized under intensive rearing conditions. In a similar manner, ammonia probes will be used to monitor ammonia levels for 24-h periods, to calculate ammonia production per kilogram of feed metabolized. These metabolic measurements for perch will enable more accurate regulation of optimum carrying capacities under a variety of rearing conditions. Determination of these metabolic characteristics will depend upon the availability of appropriate instrumentation.

Pond culture studies by the UW-Madison are being conducted using yellow perch raised in net-pens. These investigations address specific potential problems of rearing yellow perch in ponds in the North Central Region. Although parallel studies evaluating the performance of pond-reared perch <u>not confined</u> to net-pens might also have considerable value, such an investigation would require a minimum of six ponds (with three having sufficient groundwater input to moderate summer and winter water temperatures--see experimental protocols described below) to provide an adequate number of replicates for statistical analyses. Raising perch unconfined in six ponds, at densities sufficient to simulate practical aquaculture conditions (i.e., many thousands of fish per hectare of pond surface area), would add greatly to the cost of the project. Our net-pen studies are using existing, readily accessible facilities, while minimizing the costs associated with fish production.

Yellow perch fingerlings needed for the pond culture investigations will continue to be provided by the UW-Madison through the UW Aquaculture Program. The ongoing net-pen studies on juvenile perch during their first growing season will be continued until about November 1, 1990, as described under Related Current and Previous Work. In addition, because of the unusually cool weather conditions that occurred during the summer of 1990, the UW-Madison and Coolwater Farms have agreed to repeat this experiment in either 1991 or 1992, depending on the availability of fingerlings (from the UW-Madison) and facilities (at Coolwater Farms). <u>No additional funding is being requested for repetition of this study.</u>

During winter, survival, growth and feed conversion of Age-0 yellow perch (initially 10-20 g total weight [TW] and 100-120 mm TL) overwintered in tanks at groundwater temperature (9 ºC) will be compared with that of perch overwintered in net-pens in a pond. The pond (Pond A from the previous study) will be supplied with incoming groundwater (at 9 ºC) in such a manner as to keep ice from forming in areas adjacent to the net-pens. The pond water temperature will be <3 ºC for much of the winter.

On or about November 1, 1990 (when the pond temperatures are at or near 9 ºC), fish of similar size will be weighed, measured and randomly distributed into three 1.2-m x 1.2-m x 1.8-m-deep net-pens and three 660-L rearing tanks (located indoors at the Coolwater Farms facility) at 0.3 fish/L (about 9 kg/m^3). Each net-pen and tank will be continuously aerated by a single diffuser, and the tanks will be maintained under a 16-h light/8-h dark photoperiod and supplied with aerated, degassed groundwater at 20 L/min. Dissolved oxygen will be measured regularly and pond water temperature (at a depth of 0.3m) will be monitored continuously with a submerged chart recorder. Fish will be fed once daily at 0.25-1.0% of body weight/d, depending on water temperature and apparent feed consumption. Mortalities will be recorded regularly, and fish will be counted, weighed and measured every 6 weeks. This second experiment will be continued until the pond temperature rises to 9 ºC in the spring (about April 1, 1991). Growth and production data collected will be the same as for the first experiment.

During the second growing season, the effects of stocking density and moderating summer pond temperatures by groundwater addition, on the survival, growth and feed conversion of Age-1 yellow perch (initially 20-40 g TW and 120-140 mm TL) reared to market size (about 150 g TW) will be evaluated. Facilities and test conditions will be similar to those used in the first growing season, with the following exception: To provide greater space for perch stocked at low density, both Pond A and Pond B will contain three 2.4-m x 2.4-m x 1.8-m-deep net-pens and three 1.2-m x 1.2-m x 1.8-m-deep net-pens, each stocked with 200 randomly selected fish of similar size (initially 20-40 g TW). Assuming no mortalities and that the fish will reach 150 g TW by the end of the growing season, final fish densities in the large and small net-pens would be 5.2 and 20.8 kg/m^3, respectively. The experiment will begin on or about April 1, 1991 and end on or about November 1, 1991. Fish will be fed twice daily at 0.5-2% of body weight/d, depending on water temperature and apparent feed consumption. Measurements will be taken and data analyzed as during the first growing season.

Through all the production studies, particular emphasis will be placed on good experimental design and the use of appropriate statistical methods. Data collected will be collated on an on-going basis, and the findings published in a timely manner in appropriate peer-reviewed journals. Extension information will be published through regional and station bulletins, in collaboration with the NCRAC Aquaculture Extension Work Group.

Objective 3

Research to evaluate the potential of using meiotic inhibitors to induce triploidy in yellow perch will be done collaboratively by investigators from the University of Nebraska-Lincoln (UNL) and the University of Wisconsin-Madison (UW-Madison). In general, the responsibilities of UW-Madison researchers will be to capture wild spawning broodfish, perform experiments to evaluate the efficacy of using colchicine and cytochalasin to induce triploidy, and conduct experiments to compare the growth and performance of triploids and diploids. Researchers from the UNL will be responsible for pond-rearing groups of larval and juvenile triploid and diploid perch, and may conduct some short-term studies on growth, depending on the availability of funds and experimental facilities.

In Year 3, UW-Madison investigators will conduct multifactorial experiments to evaluate the efficacy of using colchicine and cytochalasin to induce triploidy in yellow perch. During the spring spawning season, ripe broodfish will be captured from area lakes (principally Lake Mendota, Madison, Wisconsin) and transported to the UW Aquaculture Program's main wet laboratory at Lake Mills, Wisconsin. There, egg strands from females will be stripped, divided into portions of equal size, and fertilized using the standard dry method (Kayes 1977). Each subsample of eggs will be exposed to one experimental treatment. The experimental factors to be tested will include chemical concentration, time of initiation of treatment, and duration of treatment (e.g., 0.05-50 mg/L, 1-10 min post-fertilization, and 5-20 min, respectively). All experiments will be replicated at least three times.

The primary criteria used for broodstock selection will be good health and availability. To the extent possible, Lake Mendota perch will be utilized, since they are also being employed as the control stock for "between-strain" comparisons under Objective 1.

After treatment, the eggs will be incubated in flow-through hatchery jars on a gradually increasing temperature regime (+0.5 ºC per day, from 11 ºC up to 16 ºC). Survival of each group of eggs will be assessed on Days 2 and 8, the latter being the time at which normal embryonic development is characterized by obvious eye pigmentation and a strong, regular heartbeat. The ploidy of sub-samples of 8-12 eggs per treatment will be analyzed by flow cytometry, using instrumentation and technical services available in the UW-Madison's Department of Zoology.

In Year 4, promising treatment regimes identified in Year 3 will be studied in greater detail. To fine-tune procedures, chemical concentrations and the timing of treatments will be varied in small increments around the most successful treatment regimes.

In both Years 3 and 4, groups of fertilized developing eggs containing high percentages of triploids will be shipped together with appropriate diploid controls to investigators of the UNL. After being received in Nebraska, the eyed-eggs and/or sac fry of each group (including diploid controls) will be stocked into separate fertilized ponds at either the North Platte State Fish Hatchery, North Platte or the Calamus State Fish Hatchery, near Burwell, Nebraska, and raised by standard pond-culture procedures (Soderberg 1977). This aspect of the project will be conducted in cooperation with the Nebraska Game and Parks Commission and will be done in Nebraska because of the strong interest in that state in yellow perch aquaculture and because the UW Aquaculture Program's ponds at the Lake Mills State Fish Hatchery, Lake Mills, Wisconsin will probably be undergoing renovation in 1991 and 92.

Studies comparing the growth and performance of triploid versus diploid perch will be conducted in Year 3 and 4 at the UW-Madison, and possibly the UNL (depending on the availability of funds and experimental facilities). In either case, pond-reared fish of 20-40 mm TL will be harvested and transported to the laboratory, where they will be habituated to a formulated feed (e.g., "Salmon Grower Diet", Zeigler Bros. Inc.) under intensive culture conditions optimal for this procedure (21±1 ºC; 24 h constant light). When the fish reach 60-80 mm TL, randomly selected perch from each group will be fin-clipped and their ploidy verified by flow cytometry of red blood cells. Four (replicate) tanks each of triploid and diploid perch will be reared under conditions optimal for perch culture (21±1 ºC and 16-h light/8-h dark photoperiod; see Huh 1975). All fish will be fed to satiation or excess two or three times daily, using one of several salmon diets (e.g., "Salmon Grower Diet", Zeigler Bros. Inc.) known to promote good growth in perch. During the course of these experiments, the number of fish per tank (e.g., 8-50), tank size (75-750 L) and rate of water flow (2-20 L/min) will be adjusted to insure good growing conditions and water quality. Fish will be counted and individually weighed and measured on a regular basis (e.g., every 3 weeks).

In all studies, particular emphasis will be placed on good experimental design and the use of appropriate statistical methods. Data collected by UNL and UW-Madison researchers will be collated and published as outlined under Objectives 1 and 2.

ATTACHMENT B

FACILITIES

Objective 1

Obtaining fertilized yellow perch eggs and/or juveniles for the proposed research will be the collective responsibility of all participating institutions. However, F.P. Binkowski of the UW-Milwaukee Center for Great Lakes Studies (CGLS), T.B. Kayes of the UNL, and J.A. Malison of the UW-Madison will play lead roles in coordinating the acquisition and transport of fish eggs and fish. All three organizations either own or have ready access to the boats, motors, fishing and related field gear, transport trucks, live-haul tanks, etc., necessary to achieve Objective 1.

All laboratory studies comparing the early life history stages (including egg, first-feeding fry and post-larval stages) of different stocks of yellow perch will be done at the UW-Milwaukee CGLS, under the direction of F.P. Binkowski. The CGLS has three wet laboratories with a total of about 985 m^2 of floor space. The CGLS has over 200 circular, oval and rectangular fiberglass tanks and glass aquaria ranging in capacity from 100-3,800 L, and has an ample supply (1,100 L/min of flow) of dechlorinated water, a part of which can be heated and mixed to provide flow-through temperature control to within 0.5 ºC.

CGLS backup facilities are available at the Barkhausen Waterfowl Preserve, in cooperation with county government staff, Brown County, Wisconsin. Facilities available there include four to six earthen ponds ranging in size from 0.2-0.35 hectares. The UW Aquaculture Program can also provide backup hatching facilities at its main wet laboratory at the Lake Mills State Fish Hatchery, Lake Mills, Wisconsin.

Experiments comparing the survival, weight gain, and feed conversion of juvenile yellow perch from different stocks will be conducted at Purdue University, under the direction of P. B. Brown. Experimental systems for use in these studies are operational. Proximate analyses will be conducted in the laboratories of the Department of Forestry and Natural Resources.

Objective 2

Experiments during Year 3 on loading and rearing density for flow-through culture of yellow perch will be done under the direction of D.L. Garling of MSU, and performed at the Bay Port Aquaculture Systems, Inc. yellow perch culture demonstration project at Port Sheldon, Michigan. The project is located at the Consumers' Power Company Campbell Electric Plant. At least six 1,450-L tanks will be made available for experiments. Water temperatures and flow rates can be adjusted automatically by a computer-assisted system. Both automated oxygen and ammonia recording systems should be available for these experiments.

Studies on the pond culture of yellow perch will be done by the UW Aquaculture Program of the UW-Madison, under the direction of J.A. Malison. The UW Aquaculture Program has its main wet and analytical laboratories at the Lake Mills State Fish Hatchery, Lake Mills, Wisconsin. The facility has an ample supply of temperature-regulated (10 to 30±0.5 ºC) well or carbon-filtered city water. For this objective, a 0.2-hectare pond will be made available for rearing yellow perch fry up to fingerlings, and several 750-L round fiberglass tanks will be used to habituate the fingerlings to formulated feeds.

The UW Aquaculture Program has the necessary equipment to capture and transport broodfish and fingerlings, collect and incubate eggs, and rear fish in tanks and net-pens. This equipment includes a live-haul truck, two boats, 11 trap nets, over 100 fiberglass rearing tanks, several portable floating piers, over 40 net-pens of assorted sizes and eight temperature chart recorders.

Net-pen studies and overwintering studies in tanks will be conducted at Coolwater Farms, Dousman, Wisconsin. Coolwater Farms personnel have over 7 years experience in yellow perch aquaculture. For these studies, Coolwater Farms has offered the use of two ponds (0.07- and 0.2-hectare) and three 660-L indoor tanks that can each be supplied with aerated, degassed groundwater at 20 L/min. One of the ponds (Pond A) will be supplied with groundwater (9 ºC) at up to 270 L/min for summer cooling and winter ice control. The ponds and tanks are presently supplied with electrical and aeration services adequate to conduct the proposed research.

T.B. Kayes of the UNL will assist MSU and UW-Madison investigators with the analysis and interpretation of research findings and will actively participate in the research on Objective 2 through working visits to the UW-Madison and Coolwater Farms facilities, and possibly to MSU.

Objective 3

Studies on triploidy induction in yellow perch done at the UW-Madison will be performed under the direction of J.A. Malison at the UW Aquaculture Program's main laboratory at the Lake Mills State Fish Hatchery, Lake Mills, Wisconsin. The facility has an ample supply of temperature-regulated (10 to 30 ± 0.5 °C) well or carbon-filtered city water. For this objective, six 110-L, 220-L or 750-L round fiberglass tanks will be used for perch growth studies.

The UW Aquaculture Program has the necessary equipment to capture and transport broodfish and fingerlings, collect and incubate eggs, rear fish in tanks and expose eggs to precise chemical shocks. This equipment includes a live-haul truck, two boats, 11 trap nets, over 100 fiberglass rearing tanks, six water baths, eight experimental hatchery jars capable of holding over 100 separate groups of eggs, and a well-equipped analytical laboratory. Flow cytometry will be done using instrumentation and technical services available in the UW-Madison's Department of Zoology as well as the School of Veterinary Medicine.

Pond production of triploid and (control) diploid yellow perch fingerlings in Nebraska will be done under the direction of T.B. Kayes of the UNL. This work will be performed collaboratively by investigators from the UNL Department of Forestry, Fisheries and Wildlife, and hatchery personnel of the Nebraska Game and Parks Commission, at either the North Platte State Fish Hatchery, North Platte, Nebraska or the new Calamus State Fish Hatchery, Burwell, Nebraska. Resources available include: 40 0.4-hectare ponds, four 0.13-hectare ponds, and a 34,000-L/min reservoir-water supply system at North Platte; 40 0.4-hectare ponds, 11 0.2-hectare ponds, a 60,500-L/min reservoir-water supply system, and a 13,250-L/min well-water supply system at Calamus; and all the equipment needed (boats, motors, trailers, capture gear, nets, live-haul trucks, etc.) to manage these ponds and harvest and transport fish. Present plans are to use six of the 0.2-hectare ponds at Calamus for the production of triploid and (control) diploid perch.

Depending on completion of construction, studies comparing the growth of triploid versus diploid yellow perch will be done either in newly-developed wet-laboratory facilities at the UNL or at the Calamus State Fish Hatchery. By 1991, the latter should have over 900 m^2 of operational wet-laboratory facilities, which by prior agreement will be open and available to UNL researchers. Resources and equipment available will include: three separate water sources (a river reservoir and two different aquafers), water-temperature control and pure-oxygen aeration systems, and a variety of different size raceway and circular rearing tanks. If needed, flow cytometry can be done at the UNL using instrumentation and technical services available at the UNL Center for Biotechnology, Flow Cytometry Facility. Routine analytical procedures will be done in laboratories available in the UNL Department of Forestry, Fisheries and Wildlife and at the Calamus State Fish Hatchery.

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PROJECT LEADERS

State	Name/Institution	Area of Specialization
Indiana	Paul B. Brown Purdue University	Aquaculture Nutrition
Michigan	Donald L. Garling Michigan State University	Aquaculture Production/ Nutrition and Physiology/ Aquaculture Extension
Nebraska	Terrence B. Kayes University of Nebraska-Lincoln	Finfish Aquaculture/ Physiology/Endocrinology
Wisconsin	Jeffrey A. Malison University of Wisconsin-Madison	Aquaculture/Reproductive Physiology/Endocrinology
	David L. Northey Coolwater Farms	Yellow Perch and Walleye Commercial Aquaculture
	James W. Northey Coolwater Farms	Commercial Aquaculture/ Computer Modeling
	Fred P. Binkowski University of Wisconsin-Milwaukee	Finfish Aquaculture/ Larval Fish Culture/ Aquaculture Extension

ATTACHMENT B

INDIVIDUAL BUDGETS FOR PARTICIPATING INSTITUTIONS

Indiana

Purdue University
Paul B. Brown

Michigan

Michigan State University
Donald L. Garling

Nebraska

University of Nebraska-Lincoln
Terrence B. Kayes

Wisconsin

University of Wisconsin-Madison
Jeffrey A. Malison

University of Wisconsin-Milwaukee
Fred P. Binkowski

PROPOSED YELLOW PERCH BUDGET SHEET FOR
PURDUE UNIVERSITY

(Brown)

Objective 1

	Year 1 No.	Year 1 FTEs	Year 2 No.	Year 2 FTEs	Year 1	Year 2
A. Salaries and Wages						
1. No. of Senior Personnel & FTEs[1]						
a. (Co)-PI(s)	1	0.03	0	0	$0	$0
b. Senior Associates						
2. No. of Other Personnel (Non-Faculty) & FTEs						
a. Research Assoc./Postdoc						
b. Other Professionals						
c. Graduate Students	1	0.50	0	0	$10,000	
d. Prebaccalaureate Students						
e. Secretarial-Clerical						
f. Technical, Shop, and Other						
Total Salaries and Wages					$10,000	$0
B. Fringe Benefits (1.8% of 2c)					$180	$0
C. **Total Salaries, Wages and Fringe Benefits**					$10,180	$0
D. Nonexpendable Equipment					$0	$0
E. Materials and Supplies					$2,820	$0
F. Travel - Domestic (*Including Canada*)					$1,000	$0
G. Other Direct Costs					$0	$0
TOTAL PROJECT COSTS PER YEAR (*C through G*)					$14,000	$0
TOTAL PROJECT COSTS					$14,000	

[1] FTEs = Full Time Equivalents based on 12 months.

PROPOSED YELLOW PERCH BUDGET SHEET FOR MICHIGAN STATE UNIVERSITY

(Garling)

Objective 2

	Year 1 No.	Year 1 FTEs	Year 2 No.	Year 2 FTEs	Year 1	Year 2
A. Salaries and Wages						
1. No. of Senior Personnel & FTEs[1]						
a. (Co)-PI(s)	1	0.05	0	0	$0	$0
b. Cooperator (Bay Port Aqua)...	1	0.05	0	0	$0	$0
2. No. of Other Personnel (Non-Faculty) & FTEs						
a. Research Assoc./Postdoc						
b. Other Professionals						
c. Graduate Students	1	0.50	0	0	$13,000	
d. Prebaccalaureate Students						
e. Secretarial-Clerical						
f. Technical, Shop, and Other ...						
Total Salaries and Wages					$13,000	$0
B. Fringe Benefits (20% of 2c)					$2,600	$0
C. **Total Salaries, Wages and Fringe Benefits**					$15,600	$0
D. Nonexpendable Equipment					$0	$0
E. Materials and Supplies					$400	$0
F. Travel - Domestic (*Including Canada*)					$0	$0
G. Other Direct Costs					$0	$0
TOTAL PROJECT COSTS PER YEAR (*C through G*)					$16,000	$0
TOTAL PROJECT COSTS					$16,000	

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[1] FTEs = Full Time Equivalents based on 12 months.

PROPOSED YELLOW PERCH BUDGET SHEET FOR UNIVERSITY OF NEBRASKA-LINCOLN

(Kayes)

Objective 1, 2 and 3

	Year 1		Year 2		Year 1	Year 2
A. Salaries and Wages	No.	FTEs	No.	FTEs		
1. No. of Senior Personnel & FTEs[1]						
a. (Co)-PI(s)	1	0.08	0	0.08	$0	$0
b. Senior Associates						
2. No. of Other Personnel (Non-Faculty) & FTEs						
a. Research Assoc./Postdoc						
b. Other Professionals						
c. Graduate Students						
d. Prebaccalaureate Students						
e. Secretarial-Clerical	1	0.12	1	0.12	$1,800	$1,890
f. Technical, Shop, and Other ...	1	0.10	0	0	$1,600	$0
Total Salaries and Wages					$3,400	$1,890
B. Fringe Benefits (25% of 2e and 2f)					$850	$473
C. **Total Salaries, Wages and Fringe Benefits**					$4,250	$2,363
D. Nonexpendable Equipment					$0	$0
E. Materials and Supplies					$600	$420
F. Travel - Domestic (*Including Canada*)					$1,500	$800
G. Other Direct Costs					$200	$100
TOTAL PROJECT COSTS PER YEAR (*C through G*)					$6,550	$3,683
TOTAL PROJECT COSTS					$10,233	

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[1] FTEs = Full Time Equivalents based on 12 months.

ATTACHMENT B

PROPOSED YELLOW PERCH BUDGET SHEET FOR UNIVERSITY OF WISCONSIN-MADISON

(Malison)

Objective 1, 2 and 3

	Year 1 No.	Year 1 FTEs	Year 2 No.	Year 2 FTEs	Year 1	Year 2
A. Salaries and Wages						
1. No. of Senior Personnel & FTEs[1]						
a. (Co)-PI(s)	1	0.07	1	0.07	$0	$0
b. Senior Associates						
2. No. of Other Personnel (Non-Faculty) & FTEs						
a. Research Assoc./Postdoc						
b. Other Professionals	1	0.20	1	0.20	$4,600	$4,830
c. Graduate Students						
d. Prebaccalaureate Students						
e. Secretarial-Clerical						
f. Technical, Shop, and Other	2	0.50	2	0.42	$9,435	$7,925
Total Salaries and Wages					$14,035	$12,755
B. Fringe Benefits (24% of 2b; 8.9% of 2f)					$1,944	$1,865
C. **Total Salaries, Wages and Fringe Benefits**					$15,979	$14,620
D. Nonexpendable Equipment					$0	$0
E. Materials and Supplies					$2,500	$2,200
F. Travel - Domestic (*Including Canada*)					$1,200	$1,600
G. Other Direct Costs					$400	$500
TOTAL PROJECT COSTS PER YEAR (*C through G*)					$20,079	$18,920
				TOTAL PROJECT COSTS	$38,999	

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[1] FTEs = Full Time Equivalents based on 12 months.

ATTACHMENT B

PROPOSED YELLOW PERCH BUDGET SHEET FOR UNIVERSITY OF WISCONSIN-MILWAUKEE

(Binkowski)

Objective 1

	Year 1		Year 2		Year 1	Year 2
A. Salaries and Wages	No.	FTEs	No.	FTEs		
1. No. of Senior Personnel & FTEs[1]						
a. (Co)-PI(s)	1	0.17	0	0	$0	$0
b. Senior Associates						
2. No. of Other Personnel (Non-Faculty) & FTEs						
a. Research Assoc./Postdoc						
b. Other Professionals	2	0.25	0	0	$9,575	$0
c. Graduate Students						
d. Prebaccalaureate Students					$3,500	$0
e. Secretarial-Clerical						
f. Technical, Shop, and Other ...						
Total Salaries and Wages					$13,075	$0
B. Fringe Benefits (28.1% of 2b)					$2,690	$0
C. **Total Salaries, Wages and Fringe Benefits**					$15,765	$0
D. Nonexpendable Equipment					$0	$0
E. Materials and Supplies					$3,000	$0
F. Travel - Domestic (*Including Canada*)					$2,000	$0
G. Other Direct Costs					$0	$0
TOTAL PROJECT COSTS PER YEAR (*C through G*)					$20,765	$0
TOTAL PROJECT COSTS					$20,765	

[1] FTEs = Full Time Equivalents based on 12 months.

ATTACHMENT B

YELLOW PERCH AQUACULTURE

Budget Summary for Each Participating Institution at 77.4K for First Year

	PURDUE	MSU	UNL	UW-MAD.	UW-MILW.	TOTALS
Salaries and Wages	$10,000	$13,000	$3,400	$14,035	$13,075	$53,510
Fringe Benefits	$180	$2,600	$850	$1,944	$2,690	$8,264
Total Salaries, Wages and Benefits	$10,180	$15,600	$4,250	$15,979	$15,765	$61,774
Nonexpendable Equipment	$0	$0	$0	$0	$0	$0
Materials and Supplies	$2,820	$400	$600	$2,500	$3,000	$9,320
Travel	$1,000	$0	$1,500	$1,200	$2,000	$5,700
Other Direct Costs	$0	$0	$200	$400	$0	$600
TOTAL PROJECT COSTS	$14,000	$16,000	$6,550	$20,079	$20,765	$77,394

ATTACHMENT B

YELLOW PERCH AQUACULTURE

Budget Summary for Each Participating Institution at 22.6K for Second Year

	PURDUE	MSU	UNL	UW-MAD.	UW-MILW.	TOTALS
Salaries and Wages	$0	$0	$1,890	$12,755	$0	$14,645
Fringe Benefits	$0	$0	$473	$1,865	$0	$2,338
Total Salaries, Wages and Benefits	$0	$0	$2,363	$14,620	$0	$16,983
Nonexpendable Equipment	$0	$0	$0	$0	$0	$0
Materials and Supplies	$0	$0	$420	$2,200	$0	$2,620
Travel	$0	$0	$800	$1,600	$0	$2,400
Other Direct Costs	$0	$0	$100	$500	$0	$600
TOTAL PROJECT COSTS	$0	$0	$3,683	$18,920	$0	$22,603

ATTACHMENT B

RESOURCE COMMITMENT FROM INSTITUTIONS[1]

(Salaries, Supplies, Expenses and Equipment)

Institution/Item		Year 1	Year 2
Purdue University			
Salaries and Benefits: SY @ 0.15 FTE		$8,582	$0
Supplies, Expenses and Equipment		$4,205	$0
	TOTAL PER YEAR	$12,787	$0
Michigan State University			
Salaries and Benefits: SY @ 0.05 FTE		$5,275	$0
Supplies, Expenses and Equipment		$8,564	$0
	TOTAL PER YEAR	$13,839	$0
University of Nebraska-Lincoln			
Salaries and Benefits: SY @ 0.08 FTE		$6,762	$7,438
Supplies, Expenses and Equipment		$2,760	$1,380
Salaries, Supplies and Equipment Contributed by Nebraska Game and Parks		$18,500	$18,500
	TOTAL PER YEAR	$28,022	$27,318
University of Wisconsin-Madison			
Salaries and Benefits: SY @ 0.07 FTE		$2,700	$3,212
TY @ 0.10 FTE		$2,852	$2,995
Supplies, Expenses and Equipment		$18,421	$17,988
Salaries, Supplies and Equipment Contributed by Coolwater Farms		$7,750	$0
	TOTAL PER YEAR	$31,723	$24,195
University of Wisconsin-Milwaukee			
Salaries and Benefits: SY @ 0.17 FTE		$10,290	$0
Supplies, Expenses and Equipment		$17,210	$0
	TOTAL PER YEAR	$27,500	$0
	GRAND TOTAL	$113,871	$51,513

[1] Since cost sharing is not a legal requirement and due to the difficulty in accounting for small items, documentation will not be maintained.

ATTACHMENT B

SCHEDULE FOR COMPLETION OF OBJECTIVES

Objective 1: Completed in Year 1.

Objective 2: Completed in Year 1.

Objective 3: Continued in Year 1 and completed in Year 2.

ATTACHMENT B

LIST OF PRINCIPAL INVESTIGATORS

Fred P. Binkowski, University of Wisconsin-Milwaukee

Paul B. Brown, Purdue University

Donald L. Garling, Michigan State University

Terrence B. Kayes, University of Nebraska-Lincoln

Jeffrey A. Malison, University of Wisconsin-Madison

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EDUCATION

B.S.	University of Wisconsin-Milwaukee 1971
M.S.	University of Wisconsin-Milwaukee 1974

POSITIONS

Associate Scientist, Center for Great Lakes Studies/University of Wisconsin Great Lakes Research Facility (1987-present)
Senior Fisheries Biologist, Center for Great Lakes Studies/University of Wisconsin Great Lakes Research Facility (1984-1986)
Associate Fisheries Biologist, Center for Great Lakes Studies/University of Wisconsin Great Lakes Research Facility (1981-1983)
Assistant Fisheries Biologist, Center for Great Lakes Studies (1978-1980)
Research Specialist (Fisheries), Department of Zoology, University of Wisconsin-Milwaukee (1975-1978)

SCIENTIFIC AND PROFESSIONAL ORGANIZATIONS

American Fisheries Society: Early Life History and Fish Culture Sections
International Association for Great Lakes Research (Associate Editor)
World Aquaculture Society

SELECTED PUBLICATIONS

Luecke, C., J.A. Rice, L.B. Crowder, S.E. Yeo, and F.P. Binkowski. 1990. Recruitment mechanisms of bloater in Lake Michigan: an analysis of the predatory gauntlet. Canadian Journal of Fisheries and Aquatic Sciences 47:524-532.

Seale, D.B., and F.P. Binkowski. 1988. Vulnerability of early life intervals of *Coregonus hoyi* to predation by freshwater mysid, *Mysis relicta*. Environmental Biology of Fishes 21:117-125.

Doroshov, S.I., and F.P. Binkowski. 11986. Sturgeon culture: an evolution of the techniques and concepts. Presented at the 1986 Annual Meeting of the World Aquaculture Society, Reno, Nevada. (Received best paper award: Technical Sessionon Fin Fish and Freshwater Disease Technology.)

Sommer, C.V., F.P. Binkowski, M.A. Schalk, and J.M. Bartos. 1986. Stress factors that can affect studies of drug metabolism in fish. Veterinary and Human Toxicology 28(Supplement I):45-54.

Binkowski, F.P., and S.I. Doroshov. 1985. North American sturgeons: biology and aquaculture potential. Kluwer Academic Publications, Dordrecht, Netherlands.

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EDUCATION

B.S.	University of Tennessee	1980
M.S.	University of Tennessee	1983
Ph.D.	Texas A&M University	1987

POSITIONS

Assistant Professor, Purdue University (1989-present)
Assistant Professional Scientist/Field Station Director, Illinois Natural History Survey (1987-1989)
Research Associate, Texas A&M University (1986-1987)

SCIENTIFIC AND PROFESSIONAL ORGANIZATIONS

American Fisheries Society: Membership Concerns Committee (National, 1985-present), Walleye Technical Committee (North Central Division, 1988), Fish Culture Section, Indiana Chapter
World Aquaculture Society: United States Chapter
International Association of Astacology
American Institute of Fishery Research Biologists
American Association for the Advancement of Science
Sigma Xi, Gamma Sigma Delta

SELECTED PUBLICATIONS

Brown, P.B., A. Emery, A. Lawrence, and E.H. Robinson. (In Press). Digestible energy values for red swamp crayfish and evaluation of dietary associative effects in practical feeds. Journal of the World Aquaculture Society.

Brown, P.B., D.A. Davis, and E.H. Robinson. 1988. An estimate of the dietary lysine requirement of juvenile red drum. Journal of the World Aquaculture Society 19:109-112.

Robinson, E.H., D. LaBomascus, P.B. Brown, and T.L. Linton. 1987. Dietary calcium and phosphorus requirements of *Oreochromis aureus* reared in calcium-free water. Aquaculture 64:267-276.

Robinsin, E.H., S.D. Rawles, P.B. Brown, H.E. Yette, and L.W. Green. 1986. Dietary calcium requirement of channel catfish *Ictalurus punctatus*, reared in calcium-free water. Aquaculture 53:263-270.

Hubbard, D.M., E.H. Robinson, P.B. Brown, and W.H. Daniels. 1986. Optimum ratio of dietary protein to energy for red crayfish (*Procambarus clarkii*). Progressive Fish-Culturist 48:233-237.

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EDUCATION

B.S.	University of Dayton	1970
M.S.	Eastern Kentucky University	1972
Ph.D.	Mississippi State University	1975

POSITIONS

Professor, Department of Fisheries and Wildlife, Michigan State University (1990-present)
Associate Professor, Department of Fisheries and Wildlife, Michigan State University (1985-1990)
Aquaculture and Fisheries Extension Specialist, Department of Fisheries and Wildlife, Michigan State University (1985-present)
Assistant Professor, Department of Fisheries and Wildlife, Michigan State University (1980-1985)
Assistant Professor of Fisheries Science, Department of Fisheries and Wildlife Sciences, Virginia Polytechnic Institute and State University (1976-1980)

SCIENTIFIC AND PROFESSIONAL ORGANIZATIONS

American Fisheries Society: Fish Culture and Fisheries Educators Sections, Michigan Chapter
World Aquaculture Society
Beta Beta Beta
Sigma Xi
Gamma Sigma Delta

SELECTED PUBLICATIONS

Machado, J.P., T.G. Bell, A.L. Trapp, D.L. Garling, Jr., and N.R. Kevern. 1989. Effect of carbon monoxide exposure on gas bubble disease in rainbow trout (*Salmo gairdneri*). Canadian Journal of Fisheries and Aquatic Sciences 46:74-80.

Westerhoff, R., D.L. Garling, and H.A. Tanner. 1988. Development of techniques to produce triploid chinook salmon for stocking the Great Lakes. Journal of the World Aquaculture Society 19:73A.

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

Ostrowski, A.O., and D.L. Garling. 1986. Dietary androgen-estrogen combinations in growth promotion in fingerling rainbow trout. Progressive Fish-Culturist 48-268-272.

Garling, D., and M. Masterson. 1985. Survival of Lake Michigan chinook salmon eggs and fry incubated at three temperatures. Progressive Fish-Culturist 47-63-66.

ATTACHMENT B

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EDUCATION

B.S.	Chico State College	1968
M.A.	California State University at Chico	1972
Ph.D.	University of Wisconsin-Madison	1978

POSITIONS

Associate Professor, Department of Forestry, Fisheries and Wildlife, University of Nebraska-Lincoln (1990-present)
Assistant Director and Associate Scientist, University of Wisconsin Aquaculture Program, University of Wisconsin-Madison (1979-1990)
Project Biologist, Aquaculture Research Laboratory, University of Wisconsin-Madison (1974-1979)
Teaching Assistant, Department of Zoology, University of Wisconsin-Madison (1972-1974)
EPA Trainee, Laboratory of Limnology, University of Wisconsin-Madison (1970-1972)
Instructor, Department of Biological Sciences, Chico State College (1968-1970)

SCIENTIFIC AND PROFESSIONAL ORGANIZATIONS

American Society of Zoologists: Divisions of Comparative Endocrinology, Comparative Physiology and Biochemistry, Ecology and Comparative Immunology
American Fisheries Society: Fish Culture, Bioengineering, Fish Health, Water Quality and Early Life History Sections
World Aquaculture Society

SELECTED PUBLICATIONS

Malison, J.A., T.B. Kayes, J.A. Held, and C.H. Amundson. 1990. Comparative survival, growth and reproductive development of juvenile walleye (*Stizosedion vitreum*), sauger (*S. canadense*) and their hybrids reared under intensive culture conditions. Progressive Fish-Culturist 52:73-82.

Malison, J.A. T.B. Kayes, B.C. Wentworth, and C.H. Amundson. 1988. Growth and feeding responses of male versus female yellow perch (*Perca flavescens*) treated with estradiol-17β. Canadian Journal of Fisheries and Aquatic Sciences 45:1942-1948.

Kim, K.I., T.B. Kayes, and C.H. Amundson. 1987. Effects of dietary tryptophan levels on growth, feed/gain, carcass composition and liver glutamate dehydrogenase activity in rainbow trout (*Salmo gairdneri*). Comparative Biochemistry and Physiology 88B:737-741.

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EDUCATION

B.S.	University of Wisconsin-Stevens Point	1976
M.S.	University of Wisconsin-Madison	1980
Ph.D.	University of Wisconsin-Madison	1985

POSITIONS

Assistant Director, University of Wisconsin Aquaculture Program, University of Wisconsin-Madison (1990-present)
Associate Researcher, University of Wisconsin Aquaculture Program, University of Wisconsin-Madison (1987-1990)
Project Associate, University of Wisconsin Aquaculture Program, University of Wisconsin-Madison (1985-1987)

SCIENTIFIC AND PROFESSIONAL ORGANIZATIONS

American Association for the Advancement of Science
American Fisheries Society
American Society of Zoologists
World Aquaculture Society

SELECTED PUBLICATIONS

Malison, J.A., T.B. Kayes, J.A. Held, and C.H. Amundson. 1990. Comparative survival, growth and reproductive development of juvenile walleye (*Stizostedion vitreum*), sauger (*S. canadense*) and their hybrids reared under intensive culture conditions. Progressive Fish-Culturist 52:73-82.

Malison, J.A., T.B. Kayes, B.D. Wentworth, and C.H. Amundson. 1988. Growth and feeding responses of male versus female yellow perch (*Perca flavescens*) treated with estradiol-17β. Canadian Journal of Fisheries and Aquatic Sciences 45:1942-1948.

Malison, J.A. C.D. Best, T.B. Kayes, C.H. Amundson, and B.C. Wentworth. 1986. Sexual differentiation and the use of hormones to control sex in yellow perch (*Perca flavescens*). Canadian Journal of Fisheries and Aquatic Sciences 43:26-35.

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

Malison, J.A., C.D. Best, and T.B. Kayes. 1983. Hormonal control of growth and size dimorphism in yellow perch (*Perca flavescens*). American Zoologist 22:955.