ATTACHMENT B

PROJECT NAME: Advancement of Yellow Perch Aquaculture

FUNDING LEVEL: Year 1 - $45,822
Year 2 - $46,286

DURATION: 2 Years

ADMINISTRATIVE ADVISOR: Dr. Ira R. Adelman, Department of Fisheries and Wildlife, University of Minnesota, St. Paul, MN 55108

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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 1977). 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, 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 lack of cooking odor make the yellow perch a favorite among restaurateurs and homemakers.

Over the past 2 years, fresh yellow perch fillets have typically 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: (1) the ready acceptance of formulated feeds by perch over 25 mm total length (TL); (2) the perch's lack of aggressive behavior and cannibalism; and (3) its relatively high tolerance of crowding, handling and poor water quality. Procedures for culturing yellow perch from fingerling to adult size 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).

In 1988, the North Central Regional Aquaculture Center (NCRAC) identified two major constraints that currently impede the development of commercial yellow perch aquaculture. They are: (1) the lack of available information on the feasibility of raising perch under a variety of practical rearing conditions, such as 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). In 1989, the NCRAC Yellow Perch Work Group initiated a 2-year research project that is presently examining: (1) the production characteristics (i.e., growth and survival of offspring) of selected wild perch stocks obtained from different geographic locale's, to evaluate their suitability as candidates for potential broodstock development, (2) the applicability of selected conventional production technologies (pond, net-pen and tank culture) to perch aquaculture, and (3) the potential of using chromosomal triploidy induction to enhance growth (for details, see "Program Plan for Grant 1: North Central Regional Aquaculture Center," dated 7 April 1989).

This document constitutes a proposed addendum to the Yellow Perch Work Group's ongoing regional project and focuses on an additional constraint identified by the NCRAC as a priority area for research (NCRAC FY90 Program Development Meeting, 20-23 May 1989, Des Moines, Iowa). This includes the need to compare pond and intensive culture methods for the production of fingerlings. To our knowledge this topic has not yet been systematically investigated in perch.

Two factors that greatly influence the operation and economic feasibility of any intensive aquaculture system are the availability of high-quality fingerlings that are trained (habituated) to formulated feed, and the cost of formulated feeds, particularly during the "grow-out" phase of production. At present, fingerling availability per se is not a major limiting factor in yellow perch aquaculture. This is true because perch fingerlings in some instances can be legally obtained from the wild (e.g., through contract or licensed seining of winterkill lakes) and because they can be readily cultured in ponds by extensive methods similar to those used to produce walleye and striped bass fingerlings (Soderberg 1977; Heidinger and Kayes 1986). However, legal access to fertilized eggs can be a constraining factor, and source of fingerlings, or the way in which they are produced and managed, can have a significant impact on success rates at habituation to formulated feeds, and subsequent survival and growth under intensive culture conditions (T.B. Kayes and J.A. Malison, University of Wisconsin-Madison, and F.P. Binkowski, University of Wisconsin-Milwaukee, unpublished observations). Recently, investigators at the University of Wisconsin-Milwaukee (UW-Milwaukee) have developed procedures for intensively rearing perch fry from hatch in the laboratory, using live-food organisms. To achieve maximum near-term benefits and thereby facilitate the development of a perch aquaculture industry, research is needed on the relative merits of existing pond and intensive culture techniques and how best to improve them. Such a comparative approach should benefit the advancement of both technologies and provide fish farmers with the option of raising perch fry to fingerling size extensively in ponds, or intensively, depending on their production schedule and available resources.

The principal advantage of present pond culture techniques is that large numbers of fish can be produced (over 570,000 perch of 25 mm TL/hectare, see Manci et al. 1983) in already-existing ponds at a comparatively low cost in labor and supplies. The success rate in training healthy pond-raised perch above 25 mm TL to formulated feed is quite high, generally over 90% (Best 1981). In addition, skeletal and other deformaties are rarely observed in pond-cultured fish (though emaciation may occur if forage in the ponds has dropped below critical levels). Principal disadvantages of present pond-culture techniques are that new pond construction can be expensive and is feasible only at certain sites, and that success, in terms of present survival and the number and condition of fish produced, is difficult to predict and can be highly variable from year-to-year and pond-to-pond. Signs of specific nutritional deficiencies or imbalances are generally not observed in pond-raised perch. However, young pond-reared perch that have been subjected to food deprivation (due to forage depletion) or excessive harvesting stress can be difficult to train to formulated feed and highly susceptible to disease. Accordingly, timing and method of harvest can be critical in pond culture (Best 1981).

The principal advantages of existing intensive culture methods are that extensive pond culture facilities are not needed, survival at different stages of fry development can be monitored, and environmental and nutritional variables can be readily manipulated (with the long-term goal of maximizing survival and growth). Also, a potential advantage of intensive culture is that, if methods can be developed to control the perch's annual reproductive cycle and induce out-of-season spawning, then fry could be raised to fingerling size throughout the year. For most types of intensive fry culture, principal disadvantages are that they tend to be labor intensive and often require elaborate incubation, rearing and environmental control systems, all of which can be expensive. An added disadvantage of existing procedures for intensively culturing perch fry is that, in fish smaller than 25 mm TL, an inverse relationship exists between fish size and survival on formulated diets (Best 1981). Accordingly, fish below about 18 mm TL must be fed live-food organisms that have been cultured in the laboratory or collected from wild sources.

Past studies by University of Wisconsin-Madison (UW-Madison) researchers (e.g., Soderberg 1977; Best 1981) and ongoing investigations by UW-Milwaukee workers suggest that the poor survival of yellow perch fry below 18 mm TL on formulated diets is due both to poor diet acceptance and poor nutrition. Typically, these investigators have found that perch of this size ingest live- food organisms more readily than formulated feeds. Using a succession of laboratory-cultured live-food organisms, F.P. Binkowski of the UW-Milwaukee (unpublished findings) has achieved overall success rates of about 40-50% in raising perch larvae to fingerling size. However, perch raised in this manner have exhibited a high incidence (10-15%) of skeletal deformalites. Collectively, these observations suggest that the live-food organisms fed to the perch fry are deficient in one or more critical nutrients essential for normal growth and development. The nutritional quality of live foods is most often attributed to their amino acid (Dabrowski and Rusiecki 1983) and fatty acid composition (Watanabe et al. 1983). However, the high incidence of skeletal deformaties observed by the UW-Milwaukee researchers suggest that vitamin C (ascorbic acid) may also be a critical factor in larval perch nutrition.

The value or quality of a feed protein to a particular species of fish depends on the amino acid profile and digestibility of the protein, and on the qualitative and quantitative amino acid requirements of the fish. Qualitatively, all fish species so far examined require the same 10 amino acids: arginine, histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan and valine (Mertz 1972; Cowey and Sargent 1979; Cowey et al. 1985). Quantitative estimates of amino acid requirements have been made for a number of economically important

species, including juvenile chinook salmon, Japanese eel, common carp and channel catfish (National Research Council [NRC] 1981).

In fish diets, lysine and the sulfur-containing amino acids (methionine + cystine) are generally considered to be "first limiting." That is, using typical feed ingredients such as high-quality plant or other alternative protein sources, if these amino acids are available in sufficient quantity, levels of the other essential amino acids will probably be adequate. In general, high-quality plant protein sources, such as soybean meal, are much less expensive than fish meal. However, plant protein sources are typically deficient in certain amino acids essential to fish. Before least-cost substitution of such feed ingredients can be achieved, the requirements of a given fish species for these key amino acids must be known. Research efforts along this line on fish species examined to date have typically begun with lysine (e.g., Wilson et al. 1977; Kim and Kayes 1982; Brown et al. 1988), because lysine is generally considered the most limiting amino acid in plant proteins, and because it is a key amino acid in practical feed formulation (Robinette 1984; Crampton 1985). While amino acid and fatty acid nutrition may have a major direct impact on feed costs for aquaculture, the requirements of fish for vitamins and other nutrients can be critical in determining general health and disease resistance, and thus overall profitability. Of the latter nutrients, vitamin E (tocopherol), and especially vitamin C, may be of particular importance because both are essential to proper immune function, are known to be potent immunoenhancing agents (Bendich 1987), and act at the biochemical level as antioxidants (Wayner et al. 1987). Most forms of vitamin C are quite labile. Consequently, the short shelf life and rapid diminution of nutritional quality of fish feeds has often been attributed to a loss of vitamin C. The vitamin requirements of the yellow perch have not yet been studied, and the specific symptoms of vitamin C and E deficiencies in the percid fishes have not been characterized. Given the high level of interest in yellow perch aquaculture, determinations of these critical nutrient requirements need to be made. Also, given the fact that vitamins C and E are in at least some instances functionally related (Hruba et al. 1982; Bendich et al. 1984, 1986; Chen and Taker 1986; Wayner et al. 1987), studies to estimate their requirements are best made in concert. This addendum by the NCRAC Yellow Perch Work Group describes a cooperative regional research effort that will involve investigators with appropriate expertise from three institutions in two states: Ohio State University, the University of Wisconsin- Madison and the University of Wisconsin-Milwaukee. The focus of the research proposed will be on: (1) comparing pond and intensive culture methods for the production of fingerlings. In addition, the amino acid, fatty acid, vitamin C and vitamin E composition of live-food organisms and perch fry raised to different sizes (stages of development) under different culture conditions (different pond sites and laboratories, pond versus intensive culture) will be compared to provide baseline data for the development of nutritionally adequate larval perch diets.

RELATED CURRENT AND PREVIOUS WORK

In general, existing methods of extensively rearing yellow perch fingerlings in ponds are similar to those used to produce walleye and striped bass fingerlings (Soderberg 1977; Heidinger and Kayes 1986). Over the past 10 years, through trial-and-error, UW-Madison researchers have developed procedures for increasing pond production from about 120,000 perch of 40 mm TL/hectare to over 570,000 fish of 25 mm TL/hectare (Manci et al. 1983; T.B. Kayes and J.A. Malison, UW-Madison, unpublished observations). Current (best) procedures, with appropriate explanations, are essentially as follows: Ponds that have been left dry over winter are filled as soon as possible in the spring (generally early April in Wisconsin, 2-3 weeks before stocking). Fertilizers are added to the pond during or soon after filling, and as needed until fish harvest (the timing, exact amounts and types of fertilizers used depend on the prior history of each pond, dissolved O_2 level, Secchi disc reading and visual (subjective) assessment of fertility and general type and abundance of phytoplankton and zooplankton). When fertilization rates are geared to achieve maximum fish production, pond aeration is generally necessary to maintain dissolved O_2 above critical levels. Experience suggests that diffuser aeration systems (e.g., the Aquatic Eco-Systems, Inc., Apopka, Florida "Fat Cat") are best suited for use in perch rearing ponds. Mechanical aerators should be specifically avoided, as they can result in high fry mortality.

Alfalfa in chopped, meal or pelleted form has most often been employed as the primary fertilizer in the pond culture of yellow perch fry (Soderberg 1977). However, recent experience has demonstrated that fertilization with soybean meal gives improved results in terms of plankton production and fewer problems with water quality, competition and predation by crayfish, and the build up of organic fiber on pond bottoms (J.A. Malison, UW-Madison, unpublished observations). In early spring, liquid and soluble fertilizers such as urea and phosphoric acid can be used to enhance phytoplankton production. However, it has not been unequivocally demonstrated that such applications are necessary, particularly in well-established ponds. Regardless, an extremely cautious approach should be employed in using any phosphorus fertilizer, since excessive amounts of this nutrient serve only to promote the growth of filimentous algae and/or rooted macrophytes, which can impair plankton production and make fish harvest extremely difficult.

Yellow perch in the North Central Region typically spawn at about 10-12°C from mid-April to early May (Heidinger and Kayes 1986), and simple procedures for artificially propogating and incubating perch eggs are known (Soderberg 1977). Perch eggs are unique in that they are arranged in a concertina-shaped strand (generally one per female) that is spawned all at one time. The preferred method of incubating these egg strands is to stretch them over plastic-coated wire fencing, or other appropriate media, suspended below the water-surface in an aerated flow-through tank or trough. Incubation is best done on a gradually increasing temperature regime of +0.5-1.0°C/d. Fertilized eggs typically reach the "eye-up" stage of development in 6-8 d and hatch in 8-14 d, depending on temperature. Egg strands at the "eye-up" stage are normally transferred to floating baskets or cages in ponds, where hatching and fry release occurs. This procedure does cause problems with estimating fry survival in ponds (i.e., estimates are generally based on number of eyed eggs stocked). However, methods that involve hatching and then transferring sac fry to ponds are normally best avoided, because such procedures often result in high levels of latent (poststocking) mortality.

One problem with extensive pond culture of yellow perch fingerlings in the North Central Region is that rapid weather changes often occur in May and June. Cold snaps in spring, and their detrimental effects on fry feeding and growth, are now widely believed to be a major cause of year-class failures in percids (Colby 1977; Henderson 1985; Henderson and Nepszy 1988), and may be partly responsible for the year-to-year fluctuations in the numbers, size and condition of perch fingerlings produced by extensive pond culture. To date, no systematic studies (involving replicated experimental comparisons of different treatments) have been done on the effects of water temperature, aeration and fertilization methods, and types of fertilizers used, on the production of perch fingerlings in ponds. Furthermore, little is known about how these factors influence the variety, species succession and nutritional quality of forage organisms produced. Knowledge of such information should aid in improving pond culture methods and also facilitate the development of intensive procedures for culturing perch fry.

Until recently, attempts to intensively culture large numbers of yellow perch from hatch through early-fry stages have not been successful. Perch fry at hatch are normally about 5-7 mm TL (Heidinger and Kayes 1986). Mansuetti (1964) identified 13 mm TL as the minimum size at which perch accepted and survived on formulated feed. Best (1981) concluded that perch fry will accept conventional formulated starter diets only after reaching a certain critical size, and that survival rate on these diets is positively correlated with the initial fish size at which these diets are first fed. Best (1981) found that when perch of less than 16 mm TL were fed exclusively on a formulated diet, fewer than 50% survived; at 18 mm TL, more than 80% survived. Survival rates of 90-98% were achieved in perch of 20-31 mm TL. In an earlier study, Hale and Carlson (1972) found that perch larvae could be reared in glass aquaria if copious quantities of lake zooplankton were provided for several weeks in advance of the introduction of a formulated diet. These investigators reported survival rates of 12-73%, depending on such factors as zooplankton density, water flow rate, and whether the aquaria bottoms were dark-covered or transparent. However, major limitations on extrapolating Hale and Carlson's (1972) results to intensive aquaculture are that their study involved few replications, small numbers of fish (50-200/treatment), and the need to collect and process large amounts of zooplankton from the wild.

Live food is presently an important or essential component in rearing the larvae of many fish species, including walleye (Cheshire and Steel 1972; Beyerle 1975; Howey et al. 1980; Colesante et al. 1986; Nickum 1978, 1986), smallmouth bass (Flickinger et al. 1975) and bluegill (Eaton 1974; Smith 1976). Several authors have reported that survival rate of percid larvae, both in nature and under culture conditions, is directly proportional to the abundance of appropriate prey organisms (Kudrinskaya 1970; Priegel 1970; Hale and Carlson 1972; Clady 1977). Eldridge et al. (1978) reported that laboratory-reared striped bass fry required a zooplankton density 50 times greater than that found in nature in order to attain a survival rate comparable to that of wild striped bass populations. The observations of Hale and Carlson (1972) suggest that similar ultra-high densities may be needed for larval perch culture.

As part of an effort to improve the feasibility of yellow perch aquaculture, researchers at the UW-Milwaukee over the past 4 years have developed procedures for intensively culturing large numbers (4,000-8,000/batch) of perch fry on live food, to a size (20-30 mm TL) at which they can be readily trained to conventional formulated feed. At present, the overall success rate, measured by survival, in raising fish to 30 mm TL is about 40%. Details regarding the methods used in achieving such results are described under "PROCEDURES." Briefly, they involve feeding fry a progression of live food organisms, beginning (Weeks 1 and 2) with cultured "green water" (made up of a commercially available mixture of phytoplankton, zooplankton and protozoans) and continuing (Weeks 2 through 5) with brine shrimp nauplii. Subsequently, the young perch are trained (Weeks 3 through 6) to sieved beef liver mixed with a formulated starter diet (Biodiet Starter Nos. 1 and 2; Bioproducts, Inc., Warrenton, Oregon). Soon thereafter (Week 7), they are fed the formulated diet (Biodiet Starter No. 3) exclusively.

Principal problems with this protocol are that it is very time consuming, concurrent culturing of "green water" and brine shrimp nauplii is required, and an unacceptably high percentage (10-15%) of deformed fish are produced.

Also, an overall mortality rate of 60% is probably too high for commercial aquaculture, where egg availability can be a major limiting factor. UW-Milwaukee investigators have found that about 50% of this mortality occurs when the perch fry are being fed exclusively on brine shrimp nauplii (Week 3), which suggests that they (and possibly the "green water" organisms) are not nutritionally adequate. Collectively, the UW-Milwaukee studies indicate that the principal problems in the intensive culture of perch fry are ones of diet acceptance and nutrition.

A major impediment to the development of effective diets for larval fishes is the fact that conventional methods of evaluating nutritional quality, based on differences in growth rate, are often nonefficacious and impractical when applied to fish larvae. This is true because key nutrients are essential not only for growth in fish larvae, but also for critical stages in their development. Thus, nutritional inadequacies or imbalances with larval fishes (unless relatively minor) will most often result not simply in variations in growth, but rather in developmental disfunction and death. Accordingly, alternative methods must often be employed to estimate both the gross and key nutritional requirements of difficult-to-culture larval fishes.

One approach to larval diet development is to formulate diets to approximate the nutrient profiles of live-food organisms that have been successfully used to culture the larvae. Two difficulties with this approach are that: (1) it fails to account for the fact that nutrient content does not necessarily reflect nutrient availability, and (2) both the content and availability of nutrients in live-food organisms can vary widely, depending on the origin of the organisms and/or the conditions under which they are raised. As an example of the latter, Bromley and Howell (1983) found that feeding algae to brine shrimp metanauplii for 2 d significantly enhanced their nutritional value to fish larvae. In turn, the high mortality rates (60%) and incidence of deformaties (10-15%) observed by UW-Milwaukee researchers in yellow perch fry raised on "green water" and brine shrimp nauplii suggest that the nutritional content of these organisms may not be totally adequate for perch.

The nutritional quality of live foods is most often attributed to their amino acid (Dabrowski and Rusiecki 1983) and fatty acid (Watanabe et al. 1983) composition. Dabrowski et al. (1984) and Eckmann et al. (1986) noted that the zooplankton used in rearing larval fishes is often of poor nutritional quality and/or contains toxic substances that cause heavy fish mortality. This may be true in both pond and intensive culture. To optimize survival and growth of fish larvae (when utilizing live food), it is essential to maintain a food chain structure that generates high value zooplankton prey in terms of both nutritional quality and food-item selectivity. In pond culture, this could potentially be achieved by developing fertilization and pond management regimes that optimize microbial plankton communities favorable to the growth and proliferation of those species and life-history stages of cladocerans, copepods and other zooplanktons that are of the greatest food value to larval perch. Similar procedures could be used to enhance the nutritional quality of live-food organisms cultured intensively or under (batch) laboratory conditions.

A second approach to larval diet development is to formulate diets to approximate the nutrient profile of the species of fish larvae being cultured. This approach is based on the observation that the quantitative essential amino acid requirements of a given fish species correlates well with the essential amino acid content of the whole body (Cowey and Luquet 1983; Wilson and Poe 1985). Difficulties with this approach are that: (1) amino acids are not the only essential nutrients, (2) static measures of nutrient content do not necessarily account for potential differences in the metabolic turnover rate of nutrients, and (3) as with zooplankton, the nutrient content of fish larvae may vary widely, depending on the source and nutritional quality of the food they consume. Furthermore, the nutrient content of fish larvae may vary with stage of development. One possible way of addressing these difficulties is to compare the nutrient content of fish raised to different stages of larval development under different culture conditions and feeding regimes, and to compare their nutrient content with that of their food. Such comparisons should provide close estimates of both the dietary needs and the nutrient content of fish larvae on nutritionally adequate diets.

The functional availability of nutrients in foods during the early life history stages of fishes can be linked to morphological and biochemical changes in their digestive tract (Stroband and Dabrowski 1981). In turn, there are strong indications that enzymes contained in zooplanktonic food participate in the digestion and release of nutrients in the gut of larval fishes (Dabrowski and Glogowski 1977; Lauff and Hofer 1984). If external food is lacking, the pancreas and pancreatic duct in young fish start to degenerate (O'Connell 1981), and levels of proteolytic enzymes decline (Dabrowski 1982). The pattern of development of proteolytic enzymes during fish metamorphosis and differentiation of the digestive tract varies considerably among species. To our knowledge, no studies on the digestive enzymes of yellow perch have been done.

From the practical standpoint, vitamin C is a particularly important nutrient in finfish aquaculture because it is essential to proper connective tissue growth and immune function, and because many forms of vitamin C degrade rapidly during feed processing and storage (Halver 1985). Vitamin E is also essential to proper immune function and plays a key role in maintaining the integrity of biological membranes (Bell and Cowey 1985). At the biochemical level,

in vertebrate animals so far studied, both vitamins C and E function as antioxidants (Wayner et al. 1987). Oxy-radicals, which are released into tissues as a consequence of normal metabolism, can cause mutations, cell lysis, enzyme inactivation, inflammation and inhibition of lymphocyte proliferation. A functional relationship between vitamins C and E, in which they act in concert as scavangers of these free-radicals, has recently been established in vivo (Hruba et al. 1982; Bendich et al. 1984). Dietary supplementation with vitamin C can increase circulating and tissue concentrations of vitamin E (Chen and Taker 1986), and both vitamins are known to be potent immunoenhancing factors (Bendich 1987). Vitamin C is also involved metabolically in restoring the antioxidant properties of vitamin E (Bendich et al. 1986).

The vitamin C requirements of several fish species have been evaluated, but with highly variable results. Salmonids (most of the published information pertaining to rainbow trout) require 40-100 mg of vitamin C/kg of diet, depending on fish size and measurement criteria (Halver et al. 1969; Hilton et al. 1978). According to Lim and Lovell (1978), channel catfish require 60 mg of vitamin C/kg of diet to avoid deficiency symptoms. In contrast, using similar criteria, Soliman et al. (1986) and Jauncey et al. (1985) concluded that tilapia require 1,250 mg of Vitamin C/kg of diet. To achieve optimum growth, Mahajan and Agrawal (1980) found that with Indian carp 700 mg vitamin C/kg of diet was needed. In species examined to date, fish deficient in vitamin C typically exhibit lordosis, scoliosis, hemorrhage within the vertebral column, hyperplasia of cell nuclei in cartilage supporting the eyes, and gill arch distortion (Wilson and Poe 1973; Lim and Lovell 1978; Dabrowski et al. 1988).

Vitamin E has been shown to be an essential nutrient for salmonid fishes and may be particularly important in fish requiring high levels of polyunsaturated fatty acids in their diet (Cowey et al. 1981, 1983; Bell and Cowey 1985). For example, in rainbow trout the published requirement of 20-30 mg of vitamin E/kg of diet was found to be inadequate when the oil content of the diet was increased (Boggio et al. 1985). Channel catfish (Wilson et al. 1984; Lovell et al. 1984) and tilapia (Satoh et al. 1987) have been reported to require 50 and 100 mg of vitamin E/kg of diet, respectively. Watanabe and Takashima (1977) found that common carp displayed muscular distrophy when fed 100 mg of vitamin E/kg of diet, but not when fed 300 mg/kg of diet. Symptoms of vitamin E deficiency include: reduced growth and food conversion, muscular dystrophy, depigmentation, fatty liver, anemia, and atrophy of pancreatic tissues.

Hung and Slinger (1980) indirectly touched on the subject of vitamins C and E interaction in rainbow trout, when they found that increased levels of oxidized oil in the diet resulted in decreased concentrations of vitamin C in the liver. To our knowledge, dietary vitamin C and E interrelationships have not yet been specifically investigated in any species of fish. At present, the vitamin C and E requirements of the yellow perch are unknown, and the specific deficiency symptoms for these vitamins in perch have not been characterized.

OBJECTIVE

Compare pond and intensive culture methods for the production of yellow perch fingerlings.

PROCEDURES

Research comparing pond and intensive culture methods for the production of yellow perch fingerlings will involve investigators from the University of Wisconsin-Milwaukee (UW-Milwaukee), University of Wisconsin-Madison (UW-Madison), and Ohio State University (OSU). Principal rearing studies comparing the survival, growth, and adaptability to intensive culture conditions of pond- reared and intensively cultured (on live food) perch fry will be the responsibility of the UW-Milwaukee and UW-Madison. Comparison studies that contrast the survival and growth of pond-reared perch fry, at different latitudes and sites, utilizing a different pond-fertilization strategy will be the responsibility of OSU. Studies on developmental morphology, the nutrient compositions of perch fry and diets, and on the development of enzymatic activity of the digestive tract of larval perch will be conducted by OSU investigators. Because of year-to-year and site-to-site variability in both pond and intensive culture of perch fry, most of the following studies will be replicated 2 years in a row to validate and confirm results. When appropriate, information collected from Year 1 studies will be used to focus Year 2 studies on specific crticial time periods or critical stages of larval development.

The principal site of pond-culture studies will be 3 replicate 0.08-hectare ponds at the Barkhausen Waterfowl Preserve, Brown County, Wisconsin, which will be managed by UW-Milwaukee investigators. Here, standard methods for the pond culture of perch fry will be employed. Ponds will be treated with rotenone to eradicate resident fish. Several weeks prior to egg stocking in the spring, the ponds will be fertilized with alfalfa meal at 120 kg/hectare. Because procedures that involve hatching and transferring fragile perch fry to ponds often result in high levels of post-stocking mortality, ponds will be stocked with known numbers of fertilized eggs (counted volumetrically) by suspending egg strands in a floating screened enclosure. The percentage of fry that successfully hatch will be estimated

by enclosing small (25 to 30 ml) portions of egg strands in 360-5m mesh cages in each pond. After hatching is completed, the live fry and dead embryos in each enclosure will be individually counted. Pond water temperatures and dissolved oxygen will be monitored during fish sampling periods.

Using procedures similar to those described above, perch will also be raised in a 0.2-hectare pond at the Lake Mills State Fish Hatchery, Lake Mills, Wisconsin, under the supervision of UW-Madison investigators. In addition, OSU investigators will use two 0.2-hectare ponds provided by the Ohio Department of Natural Resources at the Marysville State Fish Hatchery, St. Mary's, Ohio. Perch raised in Ohio will be the offspring of broodfish captured from Lake Erie. Pond culture methods in Ohio will differ from those in Wisconsin in that liquid inorganic fertilizers (dissolved ammonium phosphate, ammonium nitrate and urea) will be employed to maintain pond concentrations of phosphorus and nitrogen at 30 5g/L and 600 5g/L, respectively. The influence of such procedures on phytoplankton and zooplankton populations, and on fish survival and growth, will be evaluated (see below).

Research will be conducted to: (1) evaluate survival and growth of yellow perch fry using standard (best) methods of pond and intensive culture; (2) compare pond-reared and intensively cultured perch fry for their adaptability to intensive culture conditions and formulated diets; and (3) compare, in pond-reared and intensively cultured perch, developmental morphology, the nutrient compositions of the fry and their (live food) diets, and the development of enzymatic activity in the larval digestive tract.

For studies comparing survival and growth of pond-reared and intensively cultured perch in Wisconsin, perch eggs and sperm will be obtained from wild broodfish from either Lake Mendota, Madison, Wisconsin. Eggs will be stripped, fertilized and incubated using standard methods (Soderberg 1977). Each egg strand will be divided in half, with one half assigned to a pond and the other half to an intensive culture system. This procedure should minimize differences stemming from genetic variations between the individual broodfish.

Several half-strands totaling 200,000 eggs will be stocked into each of the three Barkhausen ponds, and the corresponding half-strands stocked into each of three 1,500-L intensive rearing units at the UW-Milwaukee Center for Great Lakes Studies (CGLS). Standard pond culture methods (previously described) will be employed whenever possible. Beginning at 2 d post-hatch and at weekly intervals thereafter for the 6-week study period, samples of zooplankton and perch fry from each pond will be collected for analysis. Zooplankton will be evaulated by pouring 20 L of pond water through stacked geological sieves (300-um, 150-um and 63-um mesh), washing the contents of each sieve into a jar containing 4% formalin and determining the relative concentrations of the zooplankton in each water sample. Fish will be captured using plankton nets, light traps and/or small mesh seines. Fish will be weighed, measured and fixed for subsequent gut-content analysis. At the end of 6 weeks, all the fish in each pond will be captured by seining, and percent survival will be calculated.

Research involving the three replicate intensive culture systems will rely on techniques previously developed by UW-Milwaukee researchers (described briefly under "RELATED, CURRENT AND PREVIOUS WORK"). During egg incubation, each 1,500-L system will be supplied with 4-5 L/min of dechlorinated water from a head tank and manifold. The supply to the head tank will be temperature regulated on an increasing (about 1°C/d) regime, as recommended by Hokanson (1977). Hatching success will be calculated using the same method as described for pond rearing.

The standard UW-Milwaukee regime for intensively culturing perch fry to fingerlings is as follows.

Number of days (post-first feeding)	Food Available
0-4 d	Green tank water (GTW)
5-12 d	GTW plus brine shrimp nauplii (BSN)
15-22 d	BSN only
22-25 d	BSN plus beef liver mash (BLM)
25-28 d	BSN plus BLM plus formulated starter diet (FSD)[1]
29-42 d	BLM plus FSD
42 d+	FSD only

[1] Starter diet will be Biodiet Starter, Bioproducts, Inc., Warrenton, Oregon

After all fish hatch, the experimental rearing units will be maintained at temperatures of 20-22°C. Water quality will be maintained by adjusting the rate of water exchange in each unit. During the GTW phase of rearing, flow will be held to less than one exchange per day. Beginning with the addition of BSN, water flow will be increased to 7-10 volume exchanges per day. Tank temperatures and flows will be recorded daily. During early feeding phases involving GTW and BSN, the fish will be reared under 24 h constant light. On about Day 28 post first-feeding, they will be switched to a 12-h light/12-h dark photoperiod. Zooplankton and fish will be sampled in a manner similar to that described for pond culture. Percent survival will be determined by counting all fish surviving in each system at the end of 8 weeks. In addition, to accurately pinpoint critical periods of high mortality during intensive culture, mortalities will be regularly (e.g., daily) siphoned into jars and fixed for later enumeration.

Studies comparing pond-reared and intensively cultured perch of different ages for their adaptability to intensive culture conditions and formulated diets, will be done using pond-reared perch from the Lake Mills State Fish Hatchery, Lake Mills, Wisconsin, and intensively cultured fish from a 1,500-L system at the UW-Milwaukee CGLS. These fish will be the offspring of wild broodfish collected from Lake Mendota, Madison, Wisconsin. On Days 10, 20 and 40 post-hatch, groups of 3,000-6,000 fish each will be collected from the pond and intensive culture system. To estimate initial fish size, subsamples of 20-30 fish from each group will be anesthetized and individually weighed and measured. Fish collected on Days 10 and 20 post-hatch will be stocked into six 100-L aquaria (three for each fish type, at 1,000-2,000 fish/aquaria) at the CGLS. Fish in these aquaria will be reared under the standard intensive culture conditions (using live food) employed at the CGLS. Fish collected on Day 40 will be stocked into six flow-through 110-L tanks at the UW-Madison's Lake Mills facility, and habituated to a formulated diet (Biodry, Bioproducts, Inc.) and intensive culture conditions. Environmental conditions used to habituate perch to intensive culture at the Lake Mills facility are similar to those used at the CGLS. To monitor fish growth and survival, the fish in each tank or aquaria will be counted, weighed and measured on Days 70, 95 and 120 post-hatch.

Comparisons of developmental morphology, the nutrient compositions of the perch fry and diets, and the development of enzymatic activity of the digestive tract, will be made on perch from Wisconsin (from the Barkhausen ponds and the CGLS intensive culture systems, respectively) as well as Ohio. Ponds in Ohio will be stocked at a density of approximately 300,000 fish/hectare. Fish will be sampled daily during the first week and thereafter at 3-d intervals, using a plankton net (120-5m mesh) or seine. Perch fry will be preserved in 4% formalin for growth and stomach content analyses. Zooplankton and phytoplankton samples will be collected twice per week during a 6-week pond-rearing period and will be analyzed using the methods of Culver et al. (1985). Differences in pond management strategies between Wisconsin and Ohio (especially fertilization regimes) may (very likely) result in differences in the nutrient composition of both the fish and the plankton examined.

Investigators from the UW-Milwaukee will collect 1 g samples of pond-reared and intensively cultured fish for nutrient (composition) analyses. The samples will be frozen in liquid nitrogen, transported to OSU and stored at -80°C for analysis of amino acids, fatty acids, vitamin C and vitamin E. One-gram samples of the zooplankton available to the fish as food will also be collected. Samples will be collected at the following stages of perch development:

embryos 3-5 d before hatch, larvae at hatch, larvae just prior to first feeding (e.g., Day 4-7), and fish when they reach mean TLs of 10, 14 and 18 mm.

As part of the OSU study, preserved samples of pond-reared and intensively cultured perch samples will be analyzed to compare the development of the yolk sac, fins, pigmentation, scales and digestive tract. Contents of entire digestive tracts of both groups of fish will be examined to provide qualitative and quantitative diet analyses. Cladocera and copeopods will be identified to species, and rotifers and insect larvae will be identified to genus. The number of organisms in each gut will be counted with a Bogorov chamber, and their size (length) measured to the nearest 0.01 mm with a calibrated eyepiece micrometer under a microscope.

For amino acid analyses, freeze-dried and pulverized samples of whole fish and live-food organisms (zooplankton) will be hydrolyzed in 6N hydrochloric acid at 110°C for 24 h under vacuum. After acid removal by rotary evaporation, coupling of amino acids with phenylisothiocyanate (PCT) will be carried out. Reverse-phase high performance liquid chromatography (HPLC) separation of PCT-derivatives of amino acids will be run according to the procedure described by Heinrikson and Meredith (1984).

For fatty acid analyses, lipids will be extracted from the samples by homogenization with 20 volumes of chloroform/methanol (2:1 volume), as described by Folch et al. (1957). The extract will then be subjected to acid-catalyzed methylation. Total fatty acid determinations will be carried out on a gas chromatograph with flame-ionization detector (Hewlet Packard 5840A), according to the procedure described by Outen et al. (1976).

Total ascorbic acid and dehydroascorbic acid (vitamin C) concentrations in the samples will be analyzed according to the procedures described by Dabrowski and Hinterleitner (1989). To assess vitamin E concentrations, fish carcasses and zooplankton samples will be prepared for HPLC analysis by the method of Zaspel and Casllany (1983). The HPLC procedure to be used allows separation of tocopherol alpha and gamma forms, and is based on a method described by Cort et al. (1983).

Proteolytic enzymes (trypsin and chymotrypsin) and amylase activities will be analyzed using synthetic substrates, as described by Dabrowski et al. 1989 and Dabrowski and Kock 1989. The entire digestive tract(s) will be separated from one or several fish (depending on fish size) and homogenized in a phosphate buffer at pH 5.5. The supernatant will be used to assay enzyme activities.

Data collected by UW-Milwaukee, UW-Madison and OSU investigators will be collected and/or compared on an ongoing basis (through the NCRAC Yellow Perch Work Group), and the findings published in a timely manner in appropriate peer-reviewed scientific journals. Extension information will be published through regional and station bulletins, in collaboration with the NCRAC Aquaculture Extension Work Group.

FACILITIES

Obtaining yellow perch eggs from Lake Mendota stocks will be the responsibility of J.A. Malison of the UW-Madison. K. Dabrowski and D.A. Culver of OSU will collect perch eggs from Lake Erie stocks. All three institutions have the boats, field gear and/or other resources needed to obtain and transport fish eggs and/or fish.

Rearing studies comparing pond and intensive culture methods for the production of yellow perch fingerlings will be done primarily by UW-Milwaukee investigators under the direction of F.P. Binkowski. Three 0.08-hectare ponds at the Barkhausen Waterfowl Preserve, Brown County, Wisconsin will be utilized for the extensive rearing trials. Research on intensive culture methods will be conducted at the UW-Milwaukee Center for Great Lakes Studies (CGLS). Resources and equipment available at the CGLS include: three wet laboratories with a total of about 985 m^2 of floor space; over 200 cylindrical, oval and rectangular fiberglass tanks and glass aquaria ranging in capacity from <100 to 4000 L; and 1,100 L/min of dechlorinated water, a part of which can be heated and mixed to provide temperature control to within 0.5°C.

UW-Milwaukee investigators will collaborate with UW-Madison researchers (under the supervision of F.P. Binkowski and J.A. Malison, respectively) in one study, which will compare pond and intensively cultured perch fry, raised to different ages (on live food), in terms of success rates of habituation to intensive culture conditions and formulated diets, and subsequent survival and growth. Resources and equipment that will be allocated by the UW-Madison for this study at the UW Aquaculture Program's main research facility at the Lake Mills State Fish Hatchery, Lake Mills, Wisconsin will include: a 0.2-hectare fish production pond, six 110-L cylindrical fiberglass rearing tanks equipped with internal lighting, and sufficient charcoal-filtered temperature-regulated (10.5°C) water to

operate these tanks. As part of this study, the UW-Milwaukee investigators will provide the intensively cultured fry and perform parallel feeding trials (utilizing live food organisms) at the CGLS.

Selected studies comparing pond culture methods for the production of yellow perch fingerlings (involving a different site and different procedures from those used by UW-Milwaukee investigators) will be done by OSU researchers, supervised by K. Dabrowski and D.A. Culver. The extensive-rearing component of this research is contingent on the provision of two (0.2-hectare) ponds by the Ohio Department of Natural Resources at the Marysville State Fish Hatchery, St. Mary's, Ohio.

All analyses of the amino acid, fatty acid, vitamin C and vitamin E contents of the live-food organisms and perch fry sampled for this purpose by both UW-Milwaukee and OSU investigators will be done by OSU researchers, under the supervision of K. Dabrowski.

Analytical studies of fish will be performed on the OSU campus, where D.C. Mahan has the laboratory facilities and equipment (HPLC, etc.) needed to carry out lipid and vitamin E analyses. K. Dabrowski has the necessary laboratory facilities and equipment (spectrophotometer, etc.) to perform vitamin C analyses. When required, amino acid analyses will be done by C. L. Brooks of the OSU Department of Veterinary Pathobiology, using HPLC.

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ATTACHMENT B

PROJECT LEADERS

State	Name/Institution	Area of Specialization
Ohio	David A. Culver Ohio State University	Limnology/Plankton Ecology/ Fisheries Biology
	Konrad Dabrowski Ohio State University	Fish Nutrition and Physiology/ Larval Fish Culture
Wisconsin	Terrence B. Kayes University of Wisconsin-Madison	Finfish Aquaculture/ Fish Physiology and Nutrition
	Jeffrey A. Malison University of Wisconsin-Madison	Finfish Aquaculture/Fish Physiology and Endocrinology
	Fred P. Binkowski University of Wisconsin-Milwaukee	Finfish Aquaculture/ Larval Fish Culture/ Aquaculture Extension

ATTACHMENT B

INDIVIDUAL BUDGETS FOR PARTICIPATING INSTITUTIONS

Ohio

Ohio State University
Konrad Dabrowski
David A. Culver

Wisconsin

University of Wisconsin-Madison
Terrence B. Kayes
Jeffrey A. Malison

University of Wisconsin-Milwaukee
Fred P. Binkowski

ATTACHMENT B

PROPOSED YELLOW PERCH BUDGET FOR OHIO STATE UNIVERSITY

(Dabrowski and Culver)

	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	0.11	1	0.11	$0	$0
b. Senior Associates	1	0.083	1	0.083	$0	$0
2. No. of Other Personnel (Non-Faculty) & FTEs						
a. Research Assoc./Postdoc						
b. Other Professionals						
c. Graduate Students						
d. Prebaccalaureate Students	1	0.25	1	0.25	$2,860	$3,014
e. Secretarial-Clerical						
f. Technical, Shop, and Other						
Total Salaries and Wages					$2,860	$3,014
B. Fringe Benefits					$0	$0
C. **Total Salaries, Wages and Fringe Benefits**					$2,860	$3,014
D. Nonexpendable Equipment					$0	$0
E. Materials and Supplies					$6,644	$6,559
F. Travel - Domestic (*Including Canada*)					$696	$696
G. Other Direct Costs					$1,500	$1,581
TOTAL PROJECT COSTS PER YEAR (*C through G*)					$11,700	$11,850
TOTAL PROJECT COSTS					$23,550	

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

ATTACHMENT B

PROPOSED YELLOW PERCH BUDGET FOR UNIVERSITY OF WISCONSIN-MADISON

(Kayes and Malison)

	Year 1		Year 2		Year 1	Year 2
A. Salaries and Wages	Year 1 No.	Year 1 FTEs	Year 2 No.	Year 2 FTEs		
1. No. of Senior Personnel & FTEs[1]						
a. (Co)-PI(s)	1	0.04	1	0.04	$0	$0
b. Senior Associates	1	0.04	1	0.04	$1,200	$1,272
2. No. of Other Personnel (Non-Faculty) & FTEs						
a. Research Assoc./Postdoc						
b. Other Professionals	1	0.04	1	0.04	$1,283	$1,360
c. Graduate Students						
d. Prebaccalaureate Students						
e. Secretarial-Clerical						
f. Technical, Shop, and Other	1	0.12	1	0.12	$1,997	$2,116
Total Salaries and Wages					$4,480	$4,748
B. Fringe Benefits (24.2% of 1a and 2b, 8.9% of 2f)					$774	$820
C. **Total Salaries, Wages and Fringe Benefits**					$5,254	$5,568
D. Nonexpendable Equipment					$0	$0
E. Materials and Supplies					$1,600	$1,600
F. Travel - Domestic (*Including Canada*)					$800	$800
G. Other Direct Costs					$200	$200
TOTAL PROJECT COSTS PER YEAR (*C through G*)					$7,854	$8,168
TOTAL PROJECT COSTS					$16,022	

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

ATTACHMENT B

PROPOSED YELLOW PERCH BUDGET FOR UNIVERSITY OF WISCONSIN-MILWAUKEE

(Binkowski)

	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)	2	0.25	2	0.25	$0	$0
b. Senior Associates						
2. No. of Other Personnel (Non-Faculty) & FTEs						
a. Research Assoc./Postdoc						
b. Other Professionals	3	0.25	3	0.25	$15,050	$15,300
c. Graduate Students						
d. Prebaccalaureate Students					$2,076	$2,265
e. Secretarial-Clerical						
f. Technical, Shop, and Other						
Total Salaries and Wages					$17,126	$17,565
B. Fringe Benefits (24.2% of 2b)					$3,642	$3,703
C. **Total Salaries, Wages and Fringe Benefits**					$20,768	$21,268
D. Nonexpendable Equipment					$0	$0
E. Materials and Supplies					$3,000	$2,500
F. Travel - Domestic (*Including Canada*)					$2,500	$2,500
G. Other Direct Costs					$0	$0
TOTAL PROJECT COSTS PER YEAR (*C through G*)					$26,268	$26,268
TOTAL PROJECT COSTS					$52,536	

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

ATTACHMENT B

YELLOW PERCH AQUACULTURE

Budget Summary for Each Participating Institution at 45.8K for the First Year

	OSU	UW-Madison	UW-Milwaukee	TOTALS
Salaries and Wages	$2,860	$4,480	$17,126	$24,466
Fringe Benefits	$0	$774	$3,642	$4,416
Total Salaries, Wages and Benefits	**$2,860**	**$5,254**	**$20,768**	**$28,882**
Nonexpendable Equipment	$0	$0	$0	$0
Materials and Supplies	$6,644	$1,600	$3,000	$11,244
Travel	$696	$800	$2,500	$3,996
Other Direct Costs	$1,500	$200	$0	$1,700
TOTAL PROJECT COSTS	**$11,700**	**$7,854**	**$26,268**	**$45,822**

Budget Summary for Each Participating Institution at 46.3K for the Second Year

	OSU	UW-Madison	UW-Milwaukee	TOTALS
Salaries and Wages	$3,014	$4,748	$17,565	$25,327
Fringe Benefits	$0	$820	$3,703	$4,523
Total Salaries, Wages and Benefits	**$3,014**	**$5,568**	**$21,268**	**$29,850**
Nonexpendable Equipment	$0	$0	$0	$0
Materials and Supplies	$6,559	$1,600	$2,500	$10,659
Travel	$696	$800	$2,500	$3,996
Other Direct Costs	$1,581	$200	$0	$1,781
TOTAL PROJECT COSTS	**$11,850**	**$8,168**	**$26,268**	**$46,286**

ATTACHMENT B

RESOURCE COMMITMENT FROM INSTITUTIONS[1]

(Salaries, Supplies, Expenses and Equipment)

Institution/Item		Year 1	Year 2
Ohio State University			
Salaries and Benefits: SY @ 0.50 FTE		$34,300	$34,300
Supplies, Expenses and Equipment		$75,000	$75,000
Resource Commitment from the Ohio DNR		$50,000	$50,000
	TOTAL PER YEAR	**$159,300**	**$159,300**
University of Wisconsin-Madison			
Salaries and Benefits: SY @ 0.08 FTE SY @ 0.08 FTE		$3,260 $2,476	$3,460 $2,624
Supplies, Expenses and Equipment:		$4,956	$5,093
	TOTAL PER YEAR	**$10,692**	**$11,117**
University of Wisconsin-Milwaukee			
Salaries and Benefits: SY @ 0.16 FTE TY @ 0.08 FTE		$8,304 $5,632	$8,304 $5,632
Supplies, Expenses and Equipment:		$16,131	$16,131
	TOTAL PER YEAR	**$30,067**	**$30,067**
	GRAND TOTAL	**$200,059**	**$200,484**

[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 OBJECTIVE

Research on all aspects of this objective will be initiated in Year 1 and should be completed by the end of Year 2.[1]

[1] It is presently anticipated that all of the proposed research will be completed by the end of Year 2. However, if difficulties arise or critical experiments must be repeated, a third year of effort may be needed to fully achieve the proposed objectives and thus yield maximum benefits.

ATTACHMENT B

LIST OF PRINCIPAL INVESTIGATORS

Fred P. Binkowski, University of Wisconsin-Milwaukee

David A. Culver, Ohio State University

Konrad Dabrowski, Ohio State University

Terrence B. Kayes, University of Wisconsin-Madison

Jeffrey A. Malison, University of Wisconsin-Madison

ATTACHMENT B

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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, University of Wisconsin-Milwaukee (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

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

Stewart, D.J., and F.P. Binkowski. 1986. Dynamics of consumption and food conversion by Lake Michigan alewives: an energetics-modeling synthesis. Transactions of the American Fisheries Society 115:643-661. (Received most significant paper award for 1986.)

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

A.B. Cornell University 1987
M.S. University of Washington 1969
Ph.D. University of Washington 1973

POSITIONS

Associate Professor, Ohio State University (1981-present)
Visiting Scientist, University of Adelaide, South Australia (1984-1985)
Assistant Professor, Ohio State University (1975-1981)
Assistant Professor, Queen's University, Ontario, Canada (1973-1975)

SCIENTIFIC AND PROFESSIONAL ORGANIZATIONS

American Society of Limnology and Oceanography
International Society for Theoretical and Applied Limnology
Ecological Society of America
International Association for Great Lakes Research

SELECTED PUBLICATIONS

Phipps, T.L., and D.A. Culver. In Press. Genetics of seasonal changes in cladoceran size at maturity. Clonal replacement in two species of Daphnia. Limnology and Oceanography 35

Culver, D.A. 1988. Plankton ecology in fish hatchery ponds in Narrandera, NSW, Australia. International Association of Theoretical and Applied Limnology. Proceedings 23:1085-1089.

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Culver, D.A., R.M. Vaga, and C.S. Munch. 1984. Evidence for size-selective fish predation on the reproductive output of Cladocera in hatchery ponds. International Association of Theoretical and Applied Limnology. Proceedings 22:1636-1639.

Munch, C.S., R.M. Vaga, and D.A. Culver. 1984. Evidence for size-selective grazing of phytoplankton species by zooplankton in fish hatchery ponds. International Association of Theoretical and Applied Limnology. Proceedings 22:1640-1644.

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EDUCATION

M.Sc. Agriculture and Technical University, Olsztyn, Poland 1972
Ph.D. Agriculture and Technical University, Olsztyn, Poland 1976
D.Sc. Agricultural University, Szczecin, Poland 1984

POSITIONS

Visiting Professor of Aquaculture, Ohio State University (1989-present)
Visiting Professor, University of Innsbruck, Austria (1987-1989)
Visiting Professor, Tokyo University of Fisheries, Japan (1984-1985)
Associate Professor, Agriculture and Technical University, Olsztyn, Poland (1972-1985)

SCIENTIFIC AND PROFESSIONAL ORGANIZATIONS

Fisheries Society of British Isles
Japanese Fisheries Society
World Aquaculture Society

SELECTED PUBLICATIONS

Dabrowski, K., and G. Kock. In Press. Absorption of ascorbic acid and ascorbic sulfate and their interaction with minerals in digestive tract of rainbow trout. Canadian Journal of Fisheries and Aquatic Science 45

Dabrowski, K. 1989. Formulation of a bioenergetic model for coregonine early life history. Transactions of the American Fisheries Society 118:138-150.

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Dabrowski, K., F. Takashima, and Y.K. Law. 1988. Bioenergetical model of planktivorous fish feeding, growth and metabolism. Theoretical optimum swimming speed in fish larva. Journal of Fish Biology 32:443-458.

Georgopoulou, U., K. Dabrowski, M.F. Sire, and J.M. Vernier. 1988. Absorption of intact proteins by the intestinal epithelium of trout. Demonstration by luminescence enzyme immunoassay and cytochemistry. Cell and Tissue Research 251:145-152.

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EDUCATION

B.A. Chico State College 1968
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POSITIONS

Assistant Director, University of Wisconsin Aquaculture Program, University of Wisconsin-Madison (1979-present)
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 State College (1968-1970)

SCIENTIFIC AND PROFESSIONAL ORGANIZATION

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, 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.

Malison, J.A., T.B. Kayes, B.C. Wentworth, and C.H. Amundson. 1987. Control of sexually related dimorphic growth by gonadal steroids in yellow perch (*Perca flavescens*). Page 206 *in* D.R. Idler, L.W. Crim and J.M. Walsh, editors. Proceedings of the third international symposium on the reproductive physiology of fish. Memorial University of Newfoundland, St. John's, Newfoundland.

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B.S. University of Wisconsin-Stevens Point 1976
M.S. University of Wisconsin-Madison 1980
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POSITIONS

Associate Researcher, University of Wisconsin Aquaculture Program, University of Wisconsin-Madison (1987-present)
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, 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.

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Malison, J.A., C.D. Best, T.B. Kayes, C.H. Amundson, and B.C. Wentworth. 1985. Hormonal growth promotion and evidence for a size-related difference in response to estradiol-17'in yellow perch (*Perca flavescens*). Canadian Journal of Fisheries and Aquatic Sciences 42:1627-1633.

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.