ADVANCEMENT OF YELLOW PERCH AQUACULTURE

Chairperson: Jeffrey A. Malison, University of Wisconsin-Madison

Industry Advisory Council Liaison: Forrest Williams, Bay Port, Michigan

Extension Liaison: Donald L. Garling, Michigan State University

Funding Request: $200,000

Duration: 2 Years (September 1, 1997 - August 31, 1999)

Objectives:

1. With the goal of larval intensive yellow perch feeding in tanks from the onset of first feeding, continue to develop methods to produce fingerlings.

2. Increase growth rates of yellow perch greater than 150 mm (6") by evaluating diets, feeding strategies, environmental manipulation, and mono-sex/bi-sex comparisons.

3. Develop out-of-season spawning methods for yellow perch.

Proposed Budgets:

Institution	Principal Investigator(s)	Objec-tive(s)	Year 1	Year 2	Total
Michigan State University	Donald L. Garling	1 & 2	$20,000	$19,360	$39,360
Ohio State University	Konrad Dabrowski	1	$10,000	$9,200	$19,200
Purdue University	Paul B. Brown	1 & 2	$24,300	$23,700	$48,000
University of Missouri-Columbia	Robert S. Hayward	2	$12,000	$12,000	$24,000
University of Wisconsin-Milwaukee	Fred P. Binkowski	3	$10,932	$3,468	$14,400
University of Wisconsin-Madison	Jeffrey A. Malison	1-3	$29,000	$26,040	$55,040
		TOTALS	**$106,232**	**$93,768**	**$200,000**

Non-funded Collaborators:

Facility	Collaborators
Bay Port Aquaculture Systems, Inc., West Olive, Michigan	Forrest Williams, Chris Starr
Ohio Valley Fish Hatchery Inc., Mineral City, Ohio	Marty Domer
U.S. Fish and Wildlife Service, Bozeman, Montana	Frederick Barrows

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JUSTIFICATION

The yellow perch (*Perca flavescens)* is a highly valued food fish having many 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 of perch 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. Its delicate flavor and relative lack of cooking odor make the yellow perch a favorite among restauranteurs and homemakers.

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). Increasingly, regulatory constraints designed primarily to protect recreational sport fishing are limiting commercial perch fishing in all Great Lakes waters, including Lake Michigan, Lake Erie, Green Bay, and Saginaw Bay (e.g., Belonger 1986). Another factor impacting the supply of perch is that recruitment of perch in Lake Michigan has been virtually non-existent since 1989 (M. Keniry, Wisconsin Department of Natural Resources, personal communication). The cause of this problem is unknown, but its threat to the Lake Michigan perch population has led the Wisconsin Natural Resources Board to recommend that commercial perch fishing be closed indefinitely and recreational bag limits be decreased from 50 to 5 fish/day.

The imbalance between supply and demand of yellow perch fillets has resulted in prices that have remained high for over a decade and continue to climb. For example, in 1990-91 fresh yellow perch fillets retailed for $17-25/kg in most markets and by 1994 had increased to $22-32/kg. The reduction of domestic supplies of yellow perch, together with the constant concern over microcontaminant levels in Great Lakes fish (Downs 1985; Smith 1988), has resulted in a tremendous growth of interest in the feasibility of yellow perch aquaculture (Calbert 1975; Downs and Smith 1983).

Studies on yellow perch conducted in the 1970s and 1980s demonstrated that this species 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 perch under laboratory conditions have been known for some time (Huh 1975; Kocurek 1979), as are methods for raising perch to sexual maturity under natural photoperiod/temperature conditions, so that they can be successfully spawned (see Malison et al. 1986).

Over the last several years the commercial production of yellow perch fingerlings and food-size fish has become a reality, and many regional aquaculturists and scientists believe that commercial perch aquaculture is poised to undergo exponential growth in the coming years. Producers can now be found in many states and provinces including Indiana, Ohio, Nebraska, Wisconsin, Michigan, and Ontario. At the present time, almost all fingerlings are raised in ponds and food-size fish are being grown in ponds as well as flow-through and recirculation systems. The comparative costs of raising food-size perch using these different systems is not known, but all appear to be profitable under current market conditions.

Since its inception, the North Central Regional Aquaculture Center (NCRAC) has focused a significant percentage of its research and extension efforts on yellow perch. This proposal is a cooperative regional research effort and involves investigators with appropriate expertise from six different institutions: Michigan State University (MSU), Ohio State University (OSU), Purdue University (Purdue), the University of Missouri-Columbia (UMC), the University of Wisconsin-Madison (UW-Madison), and the University of Wisconsin-Milwaukee (UW-Milwaukee). The project targets the three areas deemed highest priority for research by the Industry Advisory Council (IAC) of the NCRAC.

First, these studies will continue to develop methods for producing perch fingerlings, with the goal of rearing larval perch in tanks from the onset of first feeding. Fingerling costs constitute a significant proportion of the total operating costs for the commercial culture of most fish species (e.g., see Landau 1992) and are especially important for the culture of species like perch that are marketed at a relatively small size (perch are

normally marketed in "the round" at 6-11 fish/kg). Newly-hatched larval yellow perch do not readily accept conventional starter diets and currently most perch fry are reared in ponds on live food and later habituated to formulated feeds. Studies conducted under this project will evaluate live feeds as well as existing and new formulated larval feeds for rearing perch fry in tanks.

Second, these studies will evaluate methods for improving the growth rate of perch larger than 150 mm (6") total length (TL). Compared to other fish species important to commercial aquaculture, perch grow slowly when reared under intensive culture conditions, particularly as they approach market size. To some extent this problem is linked to the inherent small size of perch. It is also related to sexual development and a sexually related dimorphic growth pattern in which female perch grow faster and reach a larger ultimate size than males (Scott and Crossman 1973; Schott 1980; Malison et al. 1986). Investigations conducted under this project will evaluate diets, feeding strategies, environmental manipulations, and mono-sex female versus mixed-sex populations as methods for promoting perch growth.

Third, these studies will develop out-of-season spawning methods for perch, to increase the availability of perch fry throughout the year. In nature, perch spawn once annually in the spring and for this reason the production of fingerlings in ponds is limited to a single crop per year. The availability of fry at multiple times during the year might allow such innovative techniques as the double- or triple-cropping of fry/fingerling ponds. In turn, the availability of fingerlings at multiple times during the year would facilitate a fuller, more efficient use of grow-out facilities and equipment. The availability of fertilized eggs outside the normal spawning season would also greatly facilitate research on the culture of perch fry in tanks. The studies under this project will evaluate the use of environmental and hormonal manipulations for producing perch fry outside of the normal spawning season.

RELATED CURRENT AND PREVIOUS WORK

Continue to Develop Methods to Produce Fingerlings (Objective 1)

The principal advantages of culturing fish fry in tanks are that pond culture facilities are not needed, survival at different stages of fry development can be readily monitored, and environmental and nutritional variables can be manipulated (with the long-term goal of maximizing survival and growth). An additional potential advantage of tank culture is that, if methods can be developed to control the annual reproductive cycle and induce out-of-season spawning, then fry could be raised to fingerling size throughout the year.

The principal disadvantages of fry culture in tanks are that it tends to be labor intensive and typically requires elaborate incubation, rearing, and environmental control systems, all of which can be expensive and rarely have any equity value to help secure financing. A critical disadvantage of existing procedures for tank-culturing perch fry is that, in fish smaller than 20 mm TL, an inverse relationship exists between fish size and survival on conventional formulated diets (Best 1981) and fish below about 17 mm TL generally have poor survival rates using these feeds.

The principal advantages of pond culture are that large numbers of fish can be produced (over 570,000 perch of 25 mm TL/ha, see Manci et al. 1983; Malison and Held 1992) in already existing ponds at a comparatively low cost in labor and supplies, and that ponds and the land they are built on typically have equity value that can be used to secure financing. In addition, skeletal and other deformities often observed in tank-cultured fry and early fingerlings are rarely observed in pond-cultured perch (though emaciation may occur if the forage base in ponds drops below critical levels).

The principal disadvantages of pond culture are that new pond construction can be expensive and is feasible only at certain sites, and that survival, numbers, and condition of fish produced are sometimes difficult to predict and can be quite variable from year-to-year and pond-to-pond. Signs of specific nutritional deficiencies or imbalances are not commonly 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 habituate to formulated diets and are quite susceptible to disease.

At present, it is not clear which exact approach or combination of approaches to producing perch fingerlings will ultimately prove to be the most cost effective and widely accepted by commercial growers. For this proposal, the NCRAC IAC decided to emphasize the goal of "larval perch feeding in tanks from the onset of first feeding."

Ultimately, the preferred method for rearing larval perch in tanks would be to develop a formulated diet which is both accepted by the fry and nutritionally complete. However, perch fry at hatch are normally about 5 mm TL (see Heidinger and Kayes 1986) and Best (1981) concluded that perch fry will accept conventional formulated starter diets only after reaching about 17 mm TL. An alternative approach for rearing larval perch in tanks is to initially feed the fry live food, such as plankton or brine shrimp, until they reach a size at which they accept a formulated diet. In one 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. 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.

Over the past six years, researchers at UW-Milwaukee have developed and employed a system using live food for raising larval perch in tanks. This system uses batch cultures of "green tank water" (GTW) as an initial food until the perch are large enough to consume brine shrimp nauplii. Briefly, GTW is produced in 2.4 m-diameter tanks that are vigorously aerated and illuminated with high intensity metal-halide arc lights suspended approximately 0.5 to 1.0 m above the water surface. Cultures are initiated by fertilizing the tank water with dehydrated alfalfa meal and seeding the tanks with a small amount of a previous culture. Within one week at 18-23°C, large numbers of large ciliate protozoa and rotifers bloom, and within two to four weeks rapidly reproducing populations of copepods with abundant nauplii and copepodites can be produced. The GTW is regularly added as a food source to tanks containing newly hatched perch fry. The GTW is needed for the first 4-6 d after hatch, after which perch are large enough to feed exclusively on brine shrimp nauplii. Beginning on Day 14, the brine shrimp are mixed with increasing amounts of finely chopped beef liver, and by Day 20 the fish are being fed only beef liver. Over the next 10 days a formulated starter feed (Biodiet Starter, Bioproducts, Inc., Warrenton, Oregon) is mixed with the ground liver in increasing proportions, and by Day 30 the perch are consuming 100% formulated feed.

UW-Milwaukee researchers have produced an average of 2,000-4,000 perch fingerlings per cubic meter of rearing space using this system. Despite this success, however, significant problems remain with the tank culture of perch fry. Studies funded by NCRAC have shown that the survival of fry reared in tanks was dramatically lower than those reared in ponds. The high level of mortality of tank-reared fry was associated with cannibalism and a high incidence of spinal deformities and non-inflation of the swim bladder. About 50% of the total mortality occurred when the perch fry were fed brine shrimp nauplii exclusively, suggesting that they (and possibly the GTW organisms) are not nutritionally adequate.

The studies proposed under this objective will evaluate various formulated and live diets for larval perch. Because of the difficulty of keeping newly-hatched yellow perch larvae alive, healthy, and growing in tanks, the studies will use two basic approaches. The first approach will evaluate diets using newly-hatched larvae (~5 mm TL) about to begin first feeding. This approach directly addresses the stated goal of "larval perch feeding in tanks from the onset of first feeding." Past studies using this approach, however, have generally failed to provide useful information on the specific dietary needs of larval yellow perch because larval survival rates have been universally low (<5%) across all tested diets. Accordingly, a second approach will utilize larvae initially reared in outdoor ponds and attempt to habituate larvae to formulated feeds in tanks at progressively smaller sizes. Although this approach does not directly address the stated goal of "larval perch feeding in tanks from the onset of first feeding," it has been successfully used to evaluate different diets and test specific dietary factors important to larval survival and thereby make incremental progress towards the stated goal.

During 1994, workers at Bay Port Aquaculture Systems, with assistance from Don Garling of MSU, intensively raised yellow perch fry on *Artemia* nauplii from first feeding. They collected spawn from wild yellow perch captured from the outer Saginaw Bay of Lake Huron near Bay Port, Michigan. Female brood fish ranged from 200 to 350 mm TL. Over 50% of the females were larger than 250 mm TL. Through experience, workers at Bay Port have observed that smaller and larger females do not produce acceptable spawn. Smaller female

spawners produce eggs of poorer quality as evidenced by lower hatch rates, while larger females often produce flaccid egg masses.

Eggs were incubated in specially designed incubation units that consistently produce high hatch rates. Well water, at approximately 11°C, was used throughout egg incubation. Approximately 165 fry/L were reared in 330-L oval tanks containing approximately 185-L of water. A constant flow of well water was supplied to replicate tanks with either top or bottom inflow at a rate of 5.4 L/min (1.75 turnover/hr). Temperature was increased slowly to approximately 15°C over the next five days.

At 3 d posthatch (initiation of swim up), fry were approximately 5.8 mm TL. Fry were fed newly hatched Great Salt Lake brine shrimp at a density of 7,500/L at 12 d posthatch. This was increased to 15,000/L at 15 d posthatch. These levels of *Artemia* were maintained until the conclusion of the total *Artemia* feeding stage. At approximately 30 d posthatch, the yellow perch larvae were weaned from *Artemia* nauplii to dry feeds, a combination of Biokyowa and AP 100. The amount of dry feed was increased daily and the brine shrimp were reduced daily until approximately Day 40 when only the dry feeds were fed.

Fry reared in tanks supplied with bottom water inflows had extremely low initial survival and were discontinued. Fry reared in tanks supplied with top water inflows had excellent survival (> 50%) over the first 30 d. At Day 33 to 35 posthatch, mortalities increased substantially. Many of the moribund and dead fry had non-inflated swim bladders, a common problem observed in intensively reared walleye (*Stizostedion vitreum*) fry until new tank systems designed to remove surface protein/lipid films were developed to reduce the incidence of non-inflated swim bladders (R. Summerfelt, Iowa State University, personal communication). After the three day period of very high mortalities, survival remained high. Approximately 15% survival was observed at three months posthatching.

The excellent survival of yellow perch fry fed *Artemia* from first feeding by Bay Port Aquaculture may have resulted from a number of factors. First, the relatively low incubation temperatures used by Bay Port could have been responsible. Hokanson and Kleiner (1974) observed that yellow perch subjected to low incubation temperatures over the optimum range (10-20°C) had an increased chance for survival when transferred to higher temperatures. They also survived longer on available yolk reserves. Second, rotifers or other small feed items may have been present in the water supply. Although possible, this seems unlikely since fry were initially maintained on well water. Third, the larvae may have been large enough to consume first hatch *Artemia* nauplii because of the large size of female spawners. Larger female spawners may produce larger eggs and larvae. Mansuetti (1964) has observed that yellow perch egg diameters ranged from 1.6-2.1 mm before water hardening and expanded to 1.7-4.5 mm after water hardening. Newly hatched prolarvae have been observed to range from 4.7 to 6.6 mm TL (Heidinger and Kayes 1986) and fry lengths at hatch have been shown to be extremely variable (Mansuetti 1964). However, no attempts have been made to correlate the average size of perch eggs or prolarvae with the size of the female spawner. The sizes of eggs and fry of some marine fish do, however, increase with the size of female spawner within the same strain of fish (Rothschild 1986). Fourth, the newly hatched *Artemia* used by Bay Port may have produced small sized nauplii. Mansuetti (1964) did have limited success feeding *Artemia* to perch greater than 13 mm TL. However the yellow perch larvae fed *Artemia* by Bay Port Aquaculture did not reach 13 mm TL until Day 25, and nauplii had been observed in their stomachs before this size. The size and nutritional quality of newly hatched brine shrimp has been shown to be a function of the strain and size of cyst (Bengtson et al. 1991; Beck and Bengtson 1982). Raisanen and Applegate (1983) observed that first feeding yellow perch larvae consumed prey items from 0.2 to 0.4 mm when fed mixed wild collected zooplankton. Similar observations have been made when rearing the closely related European perch (*Perca fluviatilis* L.). Wang and Ward (1972) determined that the ratio of mouth gape width to total length of yellow perch fry increases rapidly compared to body length. Based on their observations, a 10 mm TL yellow perch would have a mouth gape width of approximately 0.8 mm while a 15 mm TL yellow perch would have a mouth gape of approximately 1.6 mm. Unfortunately, the ratio was not reported for smaller larvae. Using these estimates, very small *Artemia* nauplii (Beck and Bengtson 1982) should be able to be consumed by larval perch smaller than 10 mm TL. Fifth, fry and prey densities used by Bay Port were much higher than most previous workers have used with yellow perch. Larval densities in laboratory larvae feeding trials have been at or below 5/L (Confer and Lake 1987; Hale and Carlson 1972; Raisanen and Applegate 1983). Prey concentrations have also been lower than that used by Bay Port. Hale and Carlson (1972) recommended feeding 250 lake collected zooplanktonic organisms per larval yellow perch daily over four feedings to obtain 50% survival during the first three weeks

of feeding. At their larval densities, total prey density was only 1,250/L or about one-sixth that used at Bay Port. A. Ostrowski (Oceanic Institute, personal communication) has also observed that larval survival of both mahimahi (*Coryphaena hippurus*) and moi (*Polydactylus sexfilus*) are increased dramatically at higher densities of larvae and *Artemia* nauplii. Sixth, larval yellow perch were reared at cooler temperatures at Bay Port than those normally considered optimum for prolarvae or rearing and feeding larval perch. Hokanson and Kliener (1974) reported that optimum temperatures for these stages range from 20 to 23.9°C.

The significant mortalities that occurred on Days 33 to 35 posthatch in the 1994 trial at Bay Port may have been the result of the quality of *Artemia* used, the failure of the fingerlings to transfer to dry feeds, or the type of feed used. Larval mahimahi survival rates have been improved significantly by including enrichment regimes for *Artemia* nauplii high in n-3 highly unsaturated fatty acids (HUFA, see Brownell and Ostrowski 1989). Mortality of larval mahimahi attributed to unenriched *Artemia* nauplii were observed relatively early during larval development. Consequently, *Artemia* nauplii enrichment may not be required to successfully rear larval perch on *Artemia* nauplii since high levels of early mortalities were not observed. Increased mortality has also been observed to occur a few days after the initiation of the weaning process in other larval fishes (Kim et al. 1993). Best (1981) observed that survival of yellow perch larvae was directly related to size. Less than 50% of 16 mm TL yellow perch survived when started on the Spearfish W-7 starter mash and #1 crumble (600 to 800 µm). F. Binkowski (University of Wisconsin-Milwaukee, personal communication) has been able to feed small yellow perch dry feeds. The Bay Port yellow perch were approximately 15 mm TL when weaning to dry feeds was attempted. Hale and Carlson (1972) were able to wean late postlarvae yellow perch from zooplankton to Oregon Moist Pellets at about three weeks posthatch.

Part of this project is designed to enhance intensive larval rearing at commercially viable levels. MSU is continually working with Bay Port Aquaculture Systems to develop commercially viable, simplified intensive fry culture techniques. The techniques are partially based on Bay Port Aquaculture's limited initial success, techniques developed through previous NCRAC sponsored programs and research completed at the Oceanic Institute (OI). OI has developed successful larval culture methods for the mahimahi that have recently been used successfully for the Pacific threadfin or moi.

Fry of the mahimahi and moi are similar in size to yellow perch fry at first feeding. The principal features of the larval rearing system at OI were outlined by Kim et al. (1993) as: (1) incubation of eggs at low temperature and rearing larvae at high temperature; (2) *Artemia* as the sole food, initially unenriched and later enriched; (3) absence of phytoplankton; (4) carefully regulated feeding rate; (5) daily cleaning of the tank bottom; (6) transfer to a clean tank on about Day 14; (7) high water flow; (8) moderate aeration and water turbulence; (9) transfer of larvae to raceway systems at metamorphosis; (10) weaning to pellets as early as possible; and (11) water current to control aggressive behavior. Many of these features were used by Bay Port in their first attempt to intensively rear larval yellow perch.

In the spring of 1996, the hatching and fertilization rates were compared between size classes of female spawners. Eggs were collected from females of five size classes: 200-225, 226-250, 251-275, 276-300, 301-325, and 326-350 mm TL. Samples of the egg masses were incubated separately to determine female spawner size effects on fertilization rates and hatching characteristics. The samples were also used to determine the effect of female spawners on egg size and size of the mouth at first feeding. The data collected during this research period is currently being analyzed using the Optimas imaging system.

In 1996, MSU in cooperation with Bay Port Aquaculture, continued with the work on fry starter diets. Four diet regimes were selected for evaluation. Both newly hatched *Artemia* and decapsulated *Artemia* cysts were used as diets for first feeding fry that were later weaned to dry diets. Culture tank design was based on those used initially by Barrows et al. (1993) with conical bottoms as used at OI. Poor fry survival was observed during the 1996 feeding trials relative to previous results obtained by Bay Port. Reduced survival may have resulted from the conical bottoms of the culture system. Fry were concentrated on the bottom instead of their normal pelagic behavior. In addition to modifying culture conditions by adding a false bottom to the tanks and improved tank current patterns, 1997 research efforts will focus on improved diets. Combinations of decapsulated *Artemia* cysts, newly hatched *Artemia* nauplii, and rotifers will be compared. Additionally, gas bladder inflation rates will be determined.

Numerous chemical compounds have been identified as feed flavors in diets fed to fish. Feed flavors are defined as chemical compounds that elicit a feeding response when incorporated into diets for the target species. Crystalline amino acid diets have been readily accepted by juvenile hybrid striped bass (Brown et al. 1993), yellow perch (unpublished data from Purdue University), and several other species. These have been the focus of numerous studies (Caprio 1975; Caprio and Byrd 1984; Mearns 1985; Jones 1989; Pavlov and Kasumyan 1990; Sveinsson and Hara 1990; Crnjar et al. 1992; Hughes 1993). Commercial supplies of feed grade amino acids are just now becoming available.

Most recently, there has been interest in betaine as a flavor additive in diets fed to fish. Betaine is commercially available from a number of suppliers and in the free base form is a known flavor additive (G.L. Rumsey, formerly of the Tunison Laboratory of Fish Nutrition, personal communication). It has less of a response in the hydrochloride form (Hughes 1993). There are also several new compounded flavor additives that are available, but the composition is proprietary. Both betaine and the compounded additives can be legally used at the present time, if labeled properly. According to sources within the U.S. Food and Drug Administration (FDA), if chemical compounds added to fish diets are labeled as flavor additives, then they would not be a concern to FDA. If they are labeled as gustatory stimulants, then that implies a physiological response and the compounds would have to be labeled as drugs. The swine and poultry industries use a number of flavor additives in diets without undergoing FDA scrutiny and petitions.

The legal use of betaine at the present time is as a partial substitute for the choline requirement. Biochemical pathways in fish are similar to other vertebrates. The essential amino acid methionine is catabolized to a number of metabolic products including cyst(e)ine, the water soluble vitamin choline, and betaine. Supplying any of these compounds in the diet spares some of the dietary requirement for methionine (Combs 1992). Thus, the interrelationship among nutrients becomes quite complex, but the bottom line is that there are legal mechanisms for using the flavor additive betaine in diets fed to fish. This will be one of the focal points in this line of research. If flavor additives can be identified that elicit a feeding response in first-feeding yellow perch, then there will be the capability of uniform, predictable growth and survival of this new aquaculture species.

Production techniques for freshwater larval fish have been considerably improved in the last decade (Dabrowski 1984; Dabrowski and Culver 1991). However, the variable mortality encountered during larval fish "metamorphosis" (this definition excludes freshwater salmonids, acipenserids, and ictalurids, which have large, precocious larvae) continuously impairs a steady supply of hatchery-reared juveniles. Houde (1994) argued, based on comparison of weight-specific metabolic rate, that oxygen consumption of marine fish larvae was nearly twice that of freshwater larvae, and concluded that the former are unlikely to suffer from starvation but rather from variation or sudden changes in their habitat. However, freshwater percids, yellow perch specifically, have larvae size and appearance resembling the marine fish. The probability of episodic mortalities due to incomplete, nutritionally unbalanced diets in association with high metabolic demand in intensive, high density conditions, is increased. Therefore, taxa-specific, as well as related to the metamorphosis of this species, systematic studies on the formulated diet acceptance and utilization are required. Despite the overall lack of information on nutritional requirements of percids, the findings in the previously funded projects of this work group established the amino acid and fatty acid profiles of yellow perch body during early ontogeny (Dabrowski et al. 1991). This data is essential in providing guidance in dry diet formulations for the proposed, detailed study.

Improvements in larval diet formulation to be tested include the following: (1) additives acting as attractant as well as of nutritional value to fish, such as freeze-dried zooplankton, krill, fish tissues, and soluble fish protein concentrate; (2) enzyme additives (partly purified pancreatic enzymes which include proteases and amylase; Carter et al. 1994; Kolkovski et al. 1993); (3) attractant additives (betaine, free amino acids); and (4) technical aspects of diet preparation (micro-particulated diets, protein-bounded, etc.).

Research at Purdue is designed to provide critical data for the use of one of the more potent and legal flavor additives identified for fish. According to the FDA, betaine is Generally Regarded as Safe (GRAS) if used as a partial replacement for the choline requirement of animals (J. Machado, FDA Center for Veterinary Medicine, personal communication). Betaine is also a potent flavor additive in diets fed to fish (cf, Mackie et al. 1980; Jones 1989; Hughes 1993). Studies are underway at Purdue that will establish the dietary choline requirement of juvenile yellow perch and the interaction of choline and the sulfur-containing amino acids

methionine and cyst(e)ine. This will enable the formal evaluation of betaine in diets fed to yellow perch. However, flavor compounds in diets may not be the sole source of poor feed acceptance.

One of the more difficult aspects of feeding small larval fish is the limitation of mouth gape. Larval feed for yellow perch should be in the range of 100-200 µm. Given current feed manufacturing technologies, it is difficult incorporating all essential nutrients into a feed pellet that small. A new experimental feed pelleting apparatus is available for exploring various larval feed formulations. Rick Barrows pioneered the use of marumerization for production of small feed pellets and has agreed to collaborate on this project. Feed manufacturing capabilities such as the marumerizer enable evaluation of flavor additives in diets for larval fish and evaluation of ingredient composition for this critical life history stage.

Until recently, little was known about the nutritional requirements of larval perch. Two years ago, however, researchers at OSU began a series of studies to estimate the nutrient profiles of larval perch, as well as their natural live-food organisms, with the ultimate aim of using this information to develop and test larval perch diets. One notable finding was that perch larvae have much higher levels of docosahexaenoic (22:6w3) and eicosapentaenoic (20:5w3) fatty acids than *Daphnia*, one of their major natural foods. Other studies on several species of marine fish have recently shown that fatty acid composition and the supplementation of diets with highly unsaturated fatty acids have important influences on the performance of intensively reared larvae (Koven et al. 1990; Dhert et al. 1990; Eda et al. 1990; Webster and Lovell 1990). The same may be true for yellow perch. In the current study funded by NCRAC, experimental diets under investigation at OSU are based on freeze-dried fish, soluble fish protein concentrate and involve testing supplemented pancreatic enzymes and gastrointestinal hormones.

Radünz-Neto et al. (1993) had already showed that addition of casein hydrolysates and sodium caseinate increased the performance of common carp (*Cyprinus carpio*) larvae, indicating that either hydrolysed or soluble forms of protein might increase the utilization of dietary nitrogen supply. These options were not tested in starter diet formulations for yellow perch. The addition of phospholipids to semi-purified diets has been shown to considerably improve the survival and growth performance of carp larvae (Radünz-Neto et al. 1994; Geurden et al. 1995). The addition of a commercial lecithin source to a diet containing high levels of soybean protein concentrate was also found to increase the survival of carp larvae but without any beneficial effect on growth. However, supply of some phospholipids such as purified phosphatidyl-choline has been shown to lead to skeletal deformities in carp larvae fed casein-based diets (Geurden et al. In press).

Another area of interest in intensive culture of yellow perch is the properties of the physical environment, light intensity and ionic strength (salinity). Although European perch (*Perca fluviatilis* L.) larvae require light to feed (Dabrowski and Jewson 1984), the optimum threshold is unknown for yellow perch, and it would not be surprising that tank-reared fish would perform significantly better when the habitat is optimized.

In addition to developing new formulated feeds for perch larvae, further testing is needed to fully evaluate the best currently available larval feeds in perch fry at different sizes. Perch fry at hatch are normally about 5 mm TL (see Heidinger and Kayes 1986) and Best (1981) concluded that perch fry will accept conventional formulated starter diets only after reaching about 17 mm TL. Malison and Held (1992) subsequently showed that perch could be successfully habituated (> 50% survival) to salmonid starter diets at mean sizes as small as 16.9 mm TL when appropriate stocking densities (<14 fish/L) and internal tank lighting were used. As part of a recently completed NCRAC-funded study (unpublished), UW-Madison researchers found that perch as small as 15 mm TL could be successfully habituated to Fry Feed Kyowa (Kyowa Hakko Kogyo Company, Ltd., Tokyo, Japan) B-400 diet. Additional preliminary observations at UW-Madison have indicated that perch from 10-15 mm TL show a significant response to some krill-based feeds, both in ponds and tanks. To our knowledge, however, no scientific evaluations have been conducted with krill diets or with the smallest Kyowa diet (A-250).

Increase Growth Rates of Yellow Perch Greater Than 150 mm (6") TL (Objective 2)

Compared to other fish species important to commercial aquaculture, perch grow relatively slowly when reared under intensive culture conditions, particularly as they approach market size. Perch have several growth and maturational characteristics that may restrict their growth . First, the overall growth potential of this species is limited by its inherent small size. Second, although perch 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 marketable size of 140 to 160 g (Huh 1975; Schott 1980; Malison et al. 1985). Third, male perch grow significantly slower and do not reach as large a size as females (Scott and Crossman 1973; Schott 1980; Malison et al. 1986). These three problems may be related. The second and third, at least, are associated with the onset of sexual maturation and gonadal development, which in perch can occur in the first year of life (Malison et al. 1986). Many authorities have hypothesized that growth and reproduction are antagonistic processes, each competing in the adult animal for available nutrients. Studies on perch as well as other species (Huh 1975; Purdom 1976; Utter et al. 1983; Malison et al. 1985) have shown a strong correlation between sexual maturation and reduced growth, food consumption, and food utilization efficiency. The investigations conducted under this project will evaluate diets, feeding strategies, environmental manipulations, and mono-sex female versus mixed-sex populations as methods for promoting perch growth.

Diet Evaluations

The basal metabolic energy needs, efficiency of diet utilization, and maximum theoretical responses to feeds of male, female, and mixed sex populations of yellow perch can be determined using a saturation kinetics model (Morgan et al. 1975). The saturation kinetics model provides a continuous response curve which is described by the equation:

$$r = (bKi + R_{max}I^n)/(Ki + I^n)$$

where r = the observed response of the organism (body weight gain or nutrient deposition at specific intake levels per day), I = nutrient intake, b = ordinate intercept, R_{max} = maximum response, n = slope factor (apparent kinetic order of the response with respect to I as I^n becomes negligible compared to Ki), and Ki = nutrition constant.

The quantitative predictive curves can be computer generated by a non-linear regression analysis method (Drapper and Smith 1966) refined by Mercer (1982) and Mercer and Gustafson (1984, with Morgan et al. 1975). The model is similar to the commonly used enzyme saturation kinetics model (Michaelis and Menton 1913). Parameters of importance to the estimation of energy and nutrient needs of yellow perch are: $I_{r=0}$, the dietary energy intake required for the maintenance of the original fish body content; E_{mx}, an efficiency parameter that measures the greatest response with the smallest intake value (developed by Mercer 1982); and I_{emx}, the maximum response.

This type of analysis has been used at MSU to evaluate natural (Annett 1985) and practical feeds (Belal et al. 1991) for *Oreochromis niloticus* and to establish energy requirements for male, female, and mixed sex stocks of *O. niloticus*, and mixed sex stocks of sunfishes (unpublished data). Belal et al. (1991) were able to demonstrate that the maximum theoretical energy deposition of fish fed different diets was not significant ($P < 0.05$) which is in agreement with the nutrition concept that animals eat to meet their energy needs. Researchers at MSU propose to conduct similar studies with yellow perch.

Betaine is one of several compounds that can act as a potent flavor additive in diets fed to fish (cf, Mackie et al. 1980; Jones 1989; Hughes 1993). According to the FDA, betaine is GRAS if used as a partial replacement for the choline requirement of animals (J. Machado, FDA Center for Veterinary Medicine, personal communication). Studies are underway at Purdue that will establish the dietary choline requirement of juvenile yellow perch and the interaction of choline and the sulfur-containing amino acids methionine and cyst(e)ine. This will enable the formal evaluation of betaine in diets fed to yellow perch. However, flavor compounds in diets may not be the sole source of decreased food consumption in perch.

A large number of studies have shown that various hormones, including gonadal steroids, can promote growth in teleosts (see Donaldson et al. 1979). Androgens are known to have anabolic effects in many animals including teleosts and have been shown to promote growth in rainbow trout (*Oncorhynchus mykiss)*, coho salmon (*O. kisutch*), and goldfish (*Carassius auratus)* (Hirose and Hibaya 1968; Fagerlund and McBride 1975, 1977; McBride and Fagerlund 1976). In contrast, in other fish species including plaice *(Pleuronectes platessa*, Cowey et al. 1973) and yellow perch (Malison et al. 1985), estrogens such as estradiol-17ß (E_2) have been found to promote growth. Estrogens improve growth in perch by increasing food consumption (Malison et al. 1985), but the physiological mechanism by which estrogens increase food consumption is not well understood.

It has been shown, however, that endogenous estrogens and androgens are factors responsible for the marked difference in growth between female and male perch (Malison et al. 1987).

Clearly, one simple way to improve perch growth would be to supplement perch diets with compounds having estrogenic activity. Malison et al. (1985, 1986) showed that perch larger than 100 mm TL fed diets containing E_2 at 2-20 mg/kg of feed grew 50-80% faster than perch fed untreated diets. Presently, however, FDA regulations do not permit the incorporation of synthetic E_2 into perch diets.

As an alternative, some natural feed ingredients contain compounds having estrogenic activity and could be used in perch diets to promote growth. Many leguminus plants including clovers and soybeans contain phenolic compounds, known as isoflavones, that can exert estrogenic effects. The major isoflavones in red clover are formononetin and biochanin A, and genistein is the primary isoflavone in soybeans. The estrogenic activity of these compounds has been repeatedly demonstrated by their wide-ranging effects on reproduction in ruminants (Obst and Seamark 1970; Adams and Sanders 1988) and other mammals (Wong and Flux 1962; Perel and Lindner 1970).

In fish, one potent action of estrogen is the induction of hepatic vitellogenin synthesis, and the vitellogenic activity of isoflavones has clearly been demonstrated. For example, both male and female Siberian sturgeon (*Acipenser baeri*) fed an experimental diet in which soybean meal was the primary protein source had higher plasma vitellogenin levels than sturgeon fed a casein-based diet (free of estrogenic compounds; Pelissero et al. 1991a). In the same study, sturgeon fed a commercial trout diet containing soybean meal also had elevated vitellogenin levels compared to sturgeon fed diets without soybean meal. Subsequently, Pelissero et al. (1991b) showed that it was in fact the isoflavones in the soy products that were responsible for the induction of vitellogenin synthesis. Estrogenic activity of isoflavones (vitellogenin synthesis) has also been demonstrated in cultured rainbow trout hepatocytes (Pelissero et al. 1991c).

In general, isoflavones have relatively weak estrogenic activity, being from 0.05-2.00% as potent as E_2 (Pelissero et al. 1991c; Verdeal and Ryan 1979). However, they have been found in concentrations as high as several mg/g in soybean meal (Setchell 1985). These findings, taken together with the fact that good quality commercial fish diets can contain relatively high amounts of soy-based protein components, suggest that it may be possible to develop a prepared fish food which contains sufficient isoflavone levels to promote growth in perch. Preliminary studies at the UW-Madison (unpublished) suggest that isoflavones may have estrogen-like effects in perch, but further studies are needed to evaluate the direct effects of isoflavones on growth.

Feeding Strategies

One promising approach for increasing yellow perch growth rates during the grow-out phase of aquaculture is to use feeding schedules that elicit this fish's compensatory growth response. In addition to increasing growth rates, such feeding schedules also hold the potential to cause yellow perch to attain larger sizes than have been achieved through more standard approaches used in the culture of this species.

Compensatory growth refers to an animal's capacity to grow abnormally fast after periods of food shortage or reproductive weight loss, in order to recover an original body weight or growth trajectory (in the cases of fishes which show indeterminate growth) (Broekhuizen et al. 1994; Jobling 1994). Compensatory growth occurs in both vertebrate and invertebrate animals (Russell and Wootton 1992; Broekhuizen et al. 1994) and is achieved through elevated rates of food consumption (hyperphagia) coupled with growth efficiency improvements that may arise from reductions in metabolic demand (Ryan et al. 1993a, b).

Efforts to use compensatory growth to increase fish growth rates and achieve larger-sized individuals in aquaculture have been largely unsuccessful. This is because rapid, compensatory growth phases elicited by multi-day periods of food deprivation have tended to wane as soon as re-fed fish reach normal weight (that of controls fed continuously without food restriction, Russell and Wootton 1992; Jobling 1994). Finding ways to keep fish in the compensatory growth phase for longer time periods appears necessary, therefore, in order for this natural physiological response to be used for fish growth improvements in aquaculture.

A recent study completed at the UMC (Hayward et al. In press) has effectively increased the time spent in the compensatory growth state by hybrid sunfish and has caused a doubling of body weight in these fishes relative to controls fed every day without restriction (the latter being similar to current feeding practices in aquaculture). Increasing the amount of time that the fish spent in the compensatory growth state was achieved through exposure to repeating cycles of no-feeding followed by re-feeding. Although such cyclic feeding schedules have been used previously without significant growth increases in fishes (Kindschi 1988; Quinton and Blake 1990; Jobling et al. 1993), the study with hybrid sunfish evaluated different no-feed periods and gauged the duration of re-feeding periods according to the persistence of significant hyperphagia which indicated when the compensatory growth state was active. Once hyperphagia ceased, this indicated that the compensatory growth state was in need of reactivation by another round of no-feeding.

The study by Hayward et al. (In press) provided a means to determine the feeding schedule in fishes that produces that maximal growth benefits through compensatory growth. It is expected that the maximal feeding schedule for compensatory growth can be similarly determined for yellow perch and growth improvements produced.

Environmental Conditions

Initial research on yellow perch at Purdue focused on strain or stock evaluations of juvenile yellow perch collected from different geographical locales throughout the country. Results from those studies clearly identified differential responses of fish reared at 16, 22 or 28°C and differential responses of the various stocks at the three temperatures (Brown et al. 1994). Estimated maximum consumption of feed was 2, 3, and 4% body weight/d at 16, 22, and 28°C, respectively. The effects of temperature on consumption by larger yellow perch, however, has not been evaluated.

Develop Out-of Season Spawning Methods (Objective 3)

The reproductive cycles of many annually spawning fishes, including yellow perch, are regulated by several environmental factors, of which temperature and photoperiod are of primary importance (Lam 1983). Environmental cues (as well as other factors) are perceived by the brain, which in turn stimulates the endocrine system to control reproductive cycles. The hypothalamus produces gonadotropin-releasing hormones and (at least in some species) release-inhibiting hormones that regulate the secretion of one or more gonadotropins from the pituitary glands (Peter 1983; Peter et al. 1986; Sherwood 1987). Gonadotropin (GTH), in turn, stimulates the production of sex steroid hormones from the gonads and possibly the interrenal (Idler and Ng 1983; Fostier et al. 1983, 1987; Fontaine and Dufour 1987; Kunimasa et al. 1988). E_2 is the primary steroid hormone responsible for ovarian growth and development in female fishes (Fostier et al. 1983; Lazier et al. 1987). Testosterone (T) and 11-ketotestosterone (11-KT) are the primary steroid hormones responsible for testicular growth and development in males (Fostier et al. 1983; 1987).

Reproductive cycles in fish can be divided sequentially into periods of spawning, gonadal involution and quiescence, gonadal growth and recrudescence, final gonadal maturation, and gamete release (ovulation or spermiation), which again leads to spawning (Billard and Breton 1978, Lam 1983; Lam and Munro 1987). During the period of gonadal quiescence, circulating levels of sex steroids are usually quite low (Idler and Ng 1983; Fostier et al. 1983, 1987; Fontaine and Dufour 1987). During the period of gonadal growth and recrudescence in females, increasing concentrations of E_2 stimulate vitellogensis (yolk protein formation and deposition) and oocyte growth (Fostier et al. 1983; Nagahama 1983; Idler and Ng 1983; Lazier et al. 1987; Wallace et al. 1987). In males, increasing levels of T and/or 11-KT stimulate spermatogenesis (Idler and Ng 1983; Fostier et al. 1983, 1987).

Sometime after completion of the gonadal growth phase in most species examined to date, a GTH rise (or surge) triggers final maturation and subsequent gamete release (Billard and Breton 1978; Idler and Ng 1983; Goetz 1983; Fostier et al. 1987). In females, final maturation typically involves migration of the oocyte nucleus (termed the germinal vesicle) to the cell periphery, followed by dissolution of the nuclear membrane and dispersal of the chromosomes (collectively termed germinal vesicle breakdown or GVBD), and by a resumption of meiosis. Concurrently, during final maturation, yolk globules and oil droplets in the cytoplasm of the oocytes coalesce, the degree of coalescence depending on species (Goetz 1983). The stimulatory effects of the GTH surge on final maturation and ovulation is at least partially mediated by C-21 steroids

produced in the ovaries (Goetz 1983). In the species examined to date, the principal steroids identified as functioning in this role are 17α,20β-dihydroxy-4-pregnen-3-one (17,20-DHP) and 17α,20β,21-trihydroxy-4-pregnen-3-one (17,20,21-THP, see Goetz 1983; Trant et al. 1986; Goetz et al. 1987; Scott and Canario 1987; Patiño and Thomas 1990). In some species, both 17,20-DHP and 11-KT have been implicated as playing major roles in spermiation in males (Fostier et al. 1983, 1987).

Exogenous hormones have been used in a wide range of fish species to either induce or synchronize GVBD and spawning in females (for review see Donaldson and Hunter 1983). Hormones tested in this regard include gonadotropin-releasing hormones such as luteinizing hormone-releasing hormone analog (LHRHa), and gonadotropins such as carp pituitary extract (CPE) or human chorionic gonadotropin (hCG). In perch, LHRHa was reported to effectively induce spawning when administered at doses of 10-100 μg/kg in combination with the dopamine antagonist pimozide (Dabrowski et al. 1994) . Kayes (1977) found that CPE at 1 mg/kg body weight successfully synchronized tank spawning of yellow perch four days after injection. Similarly, spawning in perch has also been synchronized with hCG using single injections ranging from 150-1000 IU/kg (Dabrowski et al. In press; Malison et al. unpublished). The use of such hormone treatments is tightly regulated by the FDA. Fortunately, in 1996 the FDA permitted the limited commercial use of hCG to induce spawning in many fish species including perch and it appears that hCG will gain approved new animal drug application (NADA) status in the very near future.

In yellow perch, the annual reproductive cycle is characterized by a period of gonadal quiescence in the summer, followed by a period of gonadal development in the autumn and winter, and spawning activity in spring. Early work indicated that a protracted cold period is necessary for normal maturation of perch gonads and that the duration and intensity of cold influence many aspects of perch gonadal development. In perch from northern Minnesota, water temperatures of less than 6°C for at least 185 days were required to induce normal ovarian development and spawning in 100% of females (Hokanson 1977a). In general, however, the minimum "chill" period for perch seems to be 160 days at 10°C or less (Hokanson 1977b). Spawning is then triggered by increasing temperature and/or photoperiod in the spring. Kayes and Calbert (1979) concluded that temperature was more important than photoperiod in modulating the time of spawning. Depending on latitude, spawning occurs between late February and early July, with optimal spawning temperatures of 10-12°C (Hokanson 1977a; Thorpe 1977; Craig 1987). The spawning season of perch typically spans two to three weeks in any given location or body of water.

Several attempts have been made to induce out-of season spawning in yellow perch using photoperiod and temperature as environmental cues. Kayes and Calbert (1979) failed to advance or delay spawning by advancing or delaying only the time at which temperature and photoperiod was increased following the chill period (i.e., the onset of the chill period was not changed). Dabrowski et al. (1994), however, were able to advance spawning in perch by one month by advancing both the chill period and the time at which temperature and photoperiod was increased following the chill period. Recently, Dabrowski et al. (In press) and Malison et al. (unpublished) successfully delayed spawning in perch by two to four months by delaying both the chill period and the time of temperature/photoperiod increase following the chill period. In both of these studies, hormone injections were used to induce or synchronize spawning.

Despite the successes of the work described above, further studies are needed to develop methods for inducing spawning year-round in yellow perch. From the studies described above, it appears that a change in the onset of the chill period as well as the ensuing increase in temperature and photoperiod is needed to alter the time of spawning in perch (i.e., in order to maintain the length of the chill period at 160-185 days). Furthermore, Kayes (1977) suggested that it may not be possible to alter the time of spawning in wild perch by more than one or two months if the fish have been "pre-conditioned" to an annual spawning period based on prior reproductive history. Accordingly, the induction of spawning in perch year-round may be best accomplished by using fish raised entirely in captivity, or alternatively by using juveniles reared under constant near-optimal temperature/photoperiod conditions until they are of sufficient age and size to undergo reproductive maturity, and then exposing them at different times during the year to the environmental changes needed to induce gonadal development and spawning.

ANTICIPATED BENEFITS

This project will address priority needs identified by the NCRAC IAC for advancing yellow perch aquaculture in the North Central Region (NCR). The proposed research on Objective 1 will improve larval rearing techniques by developing and evaluating different starter diets and environmental conditions. The information generated by these studies will greatly assist perch producers in their efforts to reliably raise the large numbers of perch fingerlings needed by the industry. Research on Objective 2 will develop and evaluate methods for improving growth of perch as they approach market size. The use of these methods by commercial perch producers will decrease the time needed to raise perch to market size and thereby increase the efficiency of production facilities and reduce production costs. One of the most promising strategies in this regard is the production of mono-sex female stocks of perch. A method for producing 100% female perch has been developed (Malison et al. 1985) and is currently being used by several regional perch producers under an investigational new animal drug (INAD) exemption granted by the FDA. Current research under another NCRAC project entitled "Target Animal Safety Studies for Walleye Fed 17α-Methyltestosterone" is aimed at gaining universal NADA approval for using this method in percids. The proposed research on Objective 3 will develop methods to induce out of season spawning in perch. The resultant availability of perch fry at different times during the year will increase the efficiency of existing pond and tank fry culture systems, by allowing multiple cropping of these systems. In turn, the availability of fingerlings at multiple times during the year would facilitate a fuller, more efficient use of grow-out facilities and equipment. The availability of fertilized eggs outside the normal spawning season would also greatly facilitate research on the culture of perch fry in tanks. Additional benefits of using the procedures developed in these studies include greater predictability of gamete production and reduced incidence of failed spawning, gamete resorption, and subsequent brood fish losses.

OBJECTIVES

1. With the goal of larval intensive yellow perch feeding in tanks from the onset of first feeding, continue to develop methods to produce fingerlings.

2. Increase growth rates of yellow perch greater than 150 mm (6") by evaluating diets, feeding strategies, environmental manipulation, and mono-sex/bi-sex comparisons.

3. Develop out-of-season spawning methods for yellow perch.

PROCEDURES

Continue to Develop Methods to Produce Fingerlings (Objective 1)

MSU

Research at MSU will be under the direction of Donald Garling. Yellow perch brood stock will be obtained from Bay Port Aquaculture, Inc. Spawning and egg incubation will be done at Bay Port's facilities. The size of spawners used will be based on current research to determine the effect of spawner size on survival to hatch and mouth size of first feeding fry.

Sac fry will be transported to the MSU Aquaculture Laboratory. Larvae will be reared under standardized conditions (Moore et al. 1994) in an area designed to control photoperiod, 16-h light/8-h dark light intensity (100 lux), and tank temperature (21±1°C). Larvae will be reared in flow-through tanks specifically designed and tested during the previous perch study.

First feeding yellow perch larvae will be fed in quadruplicate groups using the follow feeds:

1. The live feeds that produced the best survival and growth in previous studies.
2. A feed provided by Rick Barrows who has pioneered the use of marumerization for production of small feed pellets.

3. Fry Feed Kyowa B-200-800, varying diet size with fish size.
4. A microdiet produced with enzymatically pretreated ingredients to enhance feed utilization. Ingredients may include soy protein concentrates, sunflower meals, wheat gluten meal, and fish meal concentrates. The ingredients will be pretreated with pancreatin, Natugrain®, and/or Natuphos® using protocols recommended by the manufacturers and freeze dried prior to incorporation into larval feeds. Feeds will be supplemented with vitamin and mineral mixtures. Diets will be freeze-dried and appropriate particle sizes produced to accommodate mouth sizes as determined in previous studies.

Critical water quality values (temperature, dissolved oxygen, ammonia-N, and nitrite-N) will be monitored daily and maintained within appropriate ranges for yellow perch.

All data will be statistically analyzed as a completely randomized design using the Statistical Analysis System. Survival and gain in length through 45 days will be the primary responses measured.

OSU

Research at OSU will be under the direction of Konrad Dabrowski. Yellow perch brood stock to be used in the proposed study will be the offspring of semi-domesticated fish kept originally in ponds at the St. Mary State Hatchery and then trained to a dry diet indoors at an age of five months. Ten d before intended spawning in April, fish will be transferred from 5-8 to 13°C and injected with 100 mg LHRHa kg^{-1}. This same procedure was previously used to obtain the present brood stock. According to our experience, 100% of females will have ovulated and be ready to be stripped within the next four to five days. Pre-weighed eggs will be incubated in troughs, with strands of eggs hanging over the wires. At the eyed-stage, part of the batch of embryos will be transferred to nursery ponds. At the Research Center at Piketon, three 0.1-ha ponds will be stocked with 100,000 embryos per pond. The other part of the same batch of newly hatched larvae will be stocked in circular tanks (80-L volume), supplied with filtered and aerated well water of 22°C. Perch fry number will be adjusted after preliminary trials where between 20 and 200 fish/L will be tested. Tanks will be equipped with a side water supply, a central drainage pipe surrounded by a 0.3 mm mesh screen (Moore et al. 1994). Some tanks will be equipped additionally with a surface spray directed into the tank with a 180° perimeter nozzle. The other tanks will be supplied only with an underwater side inlet pipe. Only the inlet side pipe will be supplied with or without high turbidity causing clay. The resulting turbidity in the tanks will be maintained at 25 NTU (nephelometric turbidity units) (Bristow et al. 1996). Perch fry raised initially in ponds will also be transferred to an indoor facility and maintained in circular tanks (80 L volume), supplied with filtered and aerated water of desired temperature. Perch fry number will be adjusted based on initial size, between 20 fish/L at 10 mm TL and 5 fish/L at 20 mm TL. Water temperature will be maintained at 22°C and light intensity at 100 lux (Moore et al. 1994).

Experimental diets will be based on single-cell protein (yeast, Protibel, France; Charlon et al. 1986; Geurden et al. 1995), beef liver, freeze-dried zooplankton, and fish tissues. Diets will be supplemented with pancreatin and/or bombesin if the results of the study currently performed will prove their growth/survival enhancing effects.

Three to six diets containing top quality fish meal (as a control), or other major protein sources will be made isonitrogenous, supplemented with vitamin and mineral mixtures, and gelatin (3%) as binder. Diets will be freeze-dried and appropriate particle sizes, adjusted to fish, will be separated. The fish, triplicate per dietary treatment, will be fed at hourly intervals from 9 a.m. to 5 p.m. during the first two weeks. Older fish will be fed by automatic feeders continuously at a nominal ration of 5% body weight per day. Toward the end of the experiment 20-30 fish will be taken from each tank and weighed. Depending on the size of fish at the termination of the experiment, fish will be killed and frozen for further analysis (Dabrowski et al. 1991). *Artemia* nauplii or freshwater rotifer cultured at Piketon Station will be used as control live feeds to triplicate groups. Also, Fry Feed Kyowa B-200-800 (varying diet size with fish size) will be used as a control formulated diet.

The first year of the study will concentrate on perch 15-20 mm TL harvested in ponds and transferred to the indoor tanks. In the second year, formulated diets proved to be the best, will be offered to fish smaller than 15 mm TL including newly hatched larvae.

OSU researchers will collaborate with Marty Domer (Ohio Valley Fish Hatchery, Inc., Mineral City, Ohio) who has 6-8 year old yellow perch brood stock. These females produce considerably larger larvae than females available in Piketon. Large larvae may accept *Artemia* nauplii as the starter live feed and may prove easier to work with dry feeds because this fish has been domesticated for several generations.

Purdue

Research at Purdue will be under the direction of Paul Brown. Several sources of perch eggs and larvae are available for use in this study. Perch have been spawned at Purdue for the past two years from captive brood stock and will be the primary source of larvae for these studies. Perch eggs and larvae have also been acquired from a local producer and will be a secondary source. These studies will be conducted by similar protocols used with juvenile yellow perch in previous studies. An existing experimental system will be modified to accommodate larval fish. The system is composed of 40-L glass aquaria, typically operated at a flow rate of 1.0 L/min. The drain from the tank will be covered with 45 mm screen and the flow rate will be reduced to approximately 0.25 L/min. This reduction should facilitate removal of nitrogenous waste, while not impinging the larvae in the outlet pipe. Flow of water through the tank is considered an advantage over static operation of the tank. The aquaria are connected to waste removal and biological filtration tanks. The water temperature will be maintained at 22°C. These systems have been used in several previous studies with yellow perch.

Quadruplicate groups of larvae will be offered one of four diets. Three commercially available diets and one experimental diet will be evaluated in each year of the project. It is anticipated that in the first year there will be evaluation of a fresh lot of Biokyowa A and B fry feeds, a new larval feed from Moore-Clark, and an experimental larval feed containing a relatively high concentration of amino acids. The experimental diet will be similar to other crystalline amino acid diets fed to juvenile yellow perch at Purdue (Brown et al. 1996). In the second year of the project, the best two commercial diets from the first year and one other commercial feed, most likely Zeigler AP-100 will be used. The experimental diet fed in the second year will be modified based on results from the first year. It is difficult to definitively propose that modification prior to initial results, but it is anticipated that the focus will be on specific amino acids that impart positive flavor attributes to larval perch. In each year of the study, all fish will be offered feed every two hours with automatic feeders. Feeders will be set to dispense feed beginning two hours prior to lights turning on in the morning, then through the day until the lights are turned off in the evening. Photoperiod in the laboratory is regulated to 16-h light/8-h dark.

At the beginning of the study, larvae will be counted into each aquarium by siphoning into a 10 mL pipet. It is anticipated that there will be 50-100 individuals per aquarium. Final numbers will be a function of available larvae. All fish used in these studies will be stocked as yolk sac fry. As larvae absorb their yolk, feed will be offered on the schedule described above. Thus, this is an attempt to train larval yellow perch to accept formulated diets as their first and only source of exogenous food.

Critical water quality values (temperature, dissolved oxygen, ammonia-N, and nitrite-N) will be monitored daily and maintained within appropriate ranges for yellow perch.

All data will be statistically analyzed as a completely randomized design using the Statistical Analysis System. Survival and gain in length through 45 days will be the primary responses measured.

UW-Madison

Research at the UW-Madison will be under the direction of Jeff Malison and will determine whether currently available larval feeds can be used to successfully habituate 11-15 mm TL perch fry. Perch fry will be produced using a locally available domestic brood stock and fingerlings will be reared in fertilized ponds at the UW-Madison Aquaculture Program's main research facility at the Lake Mills State Fish Hatchery, Lake Mills, Wisconsin. Perch will be harvested from the ponds when they reach approximately 11, 13, and 15 mm, and placed into twelve 110-L flow-through tanks at a density of 14 fish/L. Fish in three replicate tanks will be fed one of four starter diets: Fry Feed Kyowa A-250; Fry-Feed Kyowa B-200; BioTrainer #1 (containing krill, Bioproducts, Inc., Warrenton, Oregon); and Silver Cup salmon/trout scientific, (Nelson and Sons, Inc., Murray, Utah); a diet similar to the standard Silver Cup salmon/trout starter except that it contains 50% of the fat content, is vitamin-boosted, and contains three times the amount of vitamin C. UW-Maidson researchers have

found that the scientific starter is much less susceptible to packing and clumping than the standard Silver Cup salmon/trout starter, and, therefore, can be dispensed much more accurately and repeatedly by most automatic feeders.

The general protocols and fish husbandry procedures described by Malison and Held (1992) will be used. In brief, tanks will be provided with tempered water (21±0.5°C at a flow rate of 12 L/min), airstone aeration, and continuous illumination using submerged lights. Fish will be fed continuously throughout the day with automatic feeders, as well as several times daily by hand. The tanks will be cleaned and dead fish removed and counted on a daily basis.

The end points measured in each of these trials will be: (1) habituation, defined as the percentage of fish that survive the transition to formulated feeds and intensive culture conditions; (2) starvation, defined as the percentage of fish that die and are recovered; and (3) cannibalism, defined as the percentage of fish that can not be accounted for at the end of the habituation intervals. Our definition of starvation is substantiated by observations in similar studies that virtually all dead fish recovered are extremely emaciated, and losses which could be attributed to disease or other causes (e.g., mechanical injury) are negligible. Our definition of cannibalism is substantiated by observations of cannibalistic behavior and the fact that fish cannot escape from the tanks through the standpipe screens or by any other means. Trials will be terminated when the number of dead fish recovered daily drops to less than 0.05% of the total initial stocking number and all remaining fish are actively feeding. Growth rates of fish from the different groups will be measured both during the habituation interval and for the following 90 days.

Data will be analyzed using two-way analysis of variance (ANOVA), with main effects being fish size and diet. Data will be published in a timely manner in appropriate peer-reviewed national or international scientific journals.

Increase Growth Rates of Yellow Perch Greater Than 150 mm (6") TL (Objective 2)

UMC

Research at the UMC will be under the direction of Rob Hayward. In the first year of study, efforts will be directed towards identifying the feeding schedule that produces the most growth improvement in yellow perch from compensatory growth. The approach will be similar to that used in a recent study of compensatory growth at UMC (Hayward et al. In press), wherein hybrid sunfish were caused to significantly outgrow (two-fold increase) counterparts fed *ad libitum* rations each day. In the proposed study, however, yellow perch will be evaluated when a commercial diet is fed, rather than a natural food.

Male and female yellow perch (15-20 cm) will be acclimated to laboratory conditions for 25 days prior to beginning experiments. Laboratory conditions will include fish being held solitarily in plexiglass test chambers submerged in larger recirculation tanks, exposure to water temperature of 22±1°C, photoperiod of 14-h light/10-h dark, and satiation feeding (four times daily) with a commercial pellet diet.

One control and five treatment groups of 15 fish each, will be formed. Individual fish within their plexiglass chambers will be randomly assigned to either the control or one of five treatment groups; fish assigned to the different groups will be mixed among four large water recirculation tanks. Control fish will be fed every day to satiation (four feeding times daily) with the commercial feed. Treatment-group fish will experience repeating cycles of days of no-feeding followed by days of satiation feeding. The number of no-feeding days in each cycle will be fixed and distinct for each treatment group. Satiation feeding after each no-feeding period in treatment groups will continue until daily consumption no longer exceeds that of the control group (according to daily t-tests). The fixed number of no-feeding days per cycle which will distinguish the five treatment groups will be 2, 7, 12, 17, and 22. Experiments will continue until the longest-cycle treatment group (22-h dark no-feed periods) completes three no-feed/re-feed cycles.

Growth rates (weight measurements every two weeks), cumulative consumption (daily determinations), and gross growth efficiency (overall growth/food consumed) will be compared among the control and five treatment groups of yellow perch. ANOVA will be used to evaluate whether significant differences occur in the three variables among the six groups. If growth, consumption, and growth efficiency are dependent on fish initial

size (see: Hayward et al. In press), then analysis of covariance (ANCOVA) using initial fish weight as the covariate, will be used to evaluate among-group differences. A second round of experimentation will be completed if a maximal compensatory growth feeding schedule is not identified in the first round of experimentation. After completion of these experiments, fish will be killed, sexes determined, and carcasses deep-frozen to permit subsequent proximate analysis of body composition (not part of this study). ANCOVA will be used to evaluate whether male and female yellow perch responded differently in terms of growth, cumulative consumption, and growth efficiency in each of the six groups.

In the second year of study, yellow perch will be grown for a six-month period (April-September) in the laboratory in water-recirculation tanks without the use of plexiglass chambers (which allow daily consumption to be accurately measured). Fish will be fed according to the best-performing compensatory-growth feeding schedule as identified from work in Year 1. The major objective here is to determine whether the best compensatory growth feeding schedule will continue to produce growth rates significantly in excess of daily fed control fish over long periods, when fish are held in free-swimming fashion in recirculation tanks similar to the case in the intensive culture setting.

Laboratory conditions will be similar to those in Year 1 (temperature of 22±1°C, 14-h light/10-h dark photoperiod) in both the acclimation and experimentation phases. If sex-related growth differences are identified in Year 1 or in parallel studies, the faster growing sex will be used exclusively in Year 2.

Yellow perch will be held in three tanks at equal densities estimated to equate to 75% of tank carrying capacities. Fish in three tanks will receive the best-performing compensatory growth feeding schedule while those in the remaining three tanks will receive daily feeding. On feeding days, fish from both groups will be fed to satiation four times daily. Because fish will be fed by hand, it will be possible to estimate food weights fed to whole groups of fish on each feeding day. In addition, growth rates of individual fish (fish will be marked for individual recognition) will be determined on the basis of weight determinations every two weeks.

ANOVA or ANCOVA procedures will be used to determine whether yellow perch that experienced the best compensatory growth schedule (from Year 1) grew significantly faster than daily fed controls over the six-month period under conditions much like those in intensive culture. Rough measurements of daily food consumption should allow statistical comparisons of food consumption rates and growth efficiency between control and treatment groups. Should growth advantages from compensatory growth feeding diminish during this longer testing period, growth, and feeding data should effectively indicate the point at which growth benefits began to decline. Such information would be useful in learning how to avert possible decays in the compensatory growth response of yellow perch that could arise after many serial cycles of reactivating this physiological response. Fish will also be killed and frozen at the end of this portion of the study for subsequent proximate analysis of body composition.

MSU

Research at MSU will be under the direction of Donald Garling. The basal metabolic energy needs ($I_{r=0}$), efficiency of diet utilization (E_{mx}), and maximum theoretical response (I_{emx}) to feeds of 10 to 17.5 cm male, female, and mixed sex populations of yellow perch will be determined at MSU using a saturation kinetic model based on a multiple non-linear regression analysis. This type of analysis has previously been used at MSU to evaluate natural (Annett 1985) and practical feeds (Belal et al. 1991) for *Oreochromis niloticus*, and to establish energy requirements for male, female, and mixed sex stocks of *O. niloticus*, and mixed sex stocks of sunfishes (unpublished data).

The sex of fish will be determined by external characteristics. The sex of intermediate size yellow perch (10 cm or larger) can be determined with about 80% accuracy using external characteristics as described by Kayes and Malison (J. Malison, UW-Madison, personal communication). The vent is crescent shaped in females and round in males. If pressure is applied to the abdomen of males, the vent forms a V towards the point of pressure application. A similar response to pressure is not observed in females. All-female stocks of yellow perch resulting from crosses of masculinized females and normal females will be included in the feeding trials if they are available before the end of the project from Bay Port Aquaculture, Inc. or Coolwater Farms, LLC. These commercial perch culturists are members of an INAD program testing 17α-methyltestosterone for yellow perch sex reversal and the production of all-female stocks of perch.

Experiments will be conducted in 37- and 120-L tanks with screened bottom drains and external standpipes. Ten 20 cm yellow perch will be stocked in each of three replicate tanks for each gender group and each feeding level. Fish will be fed 0, 0.5, 1, 1.5, 2.0, 3.0, and 4.0% of their total wet weight per day using the following schedule:

Feeding Rate (% wet body weight/day)	(% wet body weight/day) @ time (h)		
	8:00 - 9:00	12:00 - 13:00	17:00 - 18:00
0.5	0.5		
1.0	1.0		
1.5	1.0		0.5
2.0	1.0		1.0
3.0[a]	1.0	1.0	1.0
4.0[a]	1.5	1.0	1.5

[a]Note: Upper feeding levels may be adjusted based on actual consumption levels of yellow perch.

Fish will be weighed weekly to adjust feeding levels. Commercial feeds commonly used by NCR perch culturists at the time of the research or feeds formulated based on recommendations from earlier work group research will be fed to male, female, and mixed sex stocks of yellow perch. Based on past experience at MSU, yellow perch of this size will consume 3-4% of their body weight per day divided into three equal feedings if the fish do not observe the individual presenting the feed. If fish do not consume the upper feeding levels, they will be adjusted based on actual consumption levels by yellow perch.

Experimental duration will depend on the growth rate of the various gender groups. Each gender group experiment will be terminated when the fastest growing groups reach 17.5 cm or at four months, whichever comes first. At the completion of the experiment, all fish will be euthanized using MS 222 and their gonads examined to verify sex. Comparisons between groups will be made on an equal size and an equal time basis, based on growth and energy deposition. Energy deposition will be based on the gross energy intake and gross energy gain of fishes determined by standard AOAC methods.

Purdue

Research at Purdue will be under the direction of Paul Brown and will be an expansion of previous research. Juvenile yellow perch, both all-female and mixed sex groups, will be obtained from Coolwater Farms, LLC (Cambridge, Wisconsin) and the University of Wisconsin-Madison (J. Malison), respectively. Fish will be transported to Purdue, quarantined, then grown to approximately 50-60 g prior to starting the experiments.

These studies will be conducted by similar protocols used with juvenile yellow perch in previous studies. Three separate experimental systems will be established. The systems will be in close proximity to each other and virtually identical in design. The systems will be composed of 40-L glass aquaria connected to waste removal and biological filtration tanks. The three systems will be maintained at either 16, 22 or 28°C with immersion chillers or heaters. These systems have been used in several previous studies with yellow perch and growth of fish has been comparable to published results from other laboratories.

Triplicate groups of each genetic group reared at each of the three temperatures will be offered diets containing one of three flavor additives at selected concentrations of the diet. All diets will be practical diets; thus, results will be directly transferable. In the first year of the project, betaine, alanine, and a proprietary flavor additive from a commercial supplier located in Illinois will be incorporated into diets at concentrations found to be efficacious with other species of fish. All fish will be fed to satiation twice per day for a minimum of eight weeks.

Diets will be similar in ingredient and proximate composition to those identified as promoting the most rapid rates of weight gain in previous studies (Brown et al. 1996). The diets will be based on fish meal and fish oil as the primary ingredients. Vitamin and mineral premixes will be nutritionally complete based on current knowledge of the requirements for fish (NRC 1993). All diets will be mixed and pelleted at Purdue, then stored frozen (-20°C) prior to feeding.

Critical water quality values (temperature, dissolved oxygen, ammonia-N, and nitrite-N) will be monitored daily and maintained within appropriate ranges for yellow perch. Diets for the second year will be either modifications of those used in the first year or, given no response, three new flavor additives. A wide range of nitrogenous compounds have been identified as flavor compounds for fish.

All data will be statistically analyzed as a nested two-way ANOVA. Fish within each temperature treatment will contain the same genetic group of fish and be fed the same three diets, but, because they are not in the same systems, a nested ANOVA, instead of a 3×2×3 factorial, seems appropriate.

UW-Madison

Research at the UW-Madison will be under the direction of Jeff Malison and will: (1) determine the extent to which the isoflavone genistein promotes growth in yellow perch greater than 150 mm TL and (2) compare the growth of male and female yellow perch in outdoor ponds. Perch fry (mixed sex) will be produced using either wild-caught or locally available semi-domestic brood stock from Lake Mendota (Dane County, Wisconsin) and reared in fertilized ponds at the UW-Madison Aquaculture Program's research facility at the Lake Mills State Fish Hatchery, Lake Mills, Wisconsin. Fingerlings will be harvested from ponds when they reach 25-35 mm TL and stocked into 750-L flow-through tanks for habituation to prepared feeds and intensive culture conditions. The general protocols and fish husbandry procedures described by Malison and Held (1992) will be used. In brief, tanks will be provided with tempered water (21±0.5°C at a flow rate of 12 L/min), airstone aeration, and continuous illumination using submerged lights. Fish will be fed continuously throughout the day with automatic feeders, as well as several times daily by hand. After habituation, perch will be fed once or twice daily and reared under culture conditions described above with a 16-h light/8-h dark photoperiod.

Year 1: For the genistein study, approximately 16 fish (120 mm TL, 20 g) will be stocked into each of 15 110-L circular fiberglass tanks. The fish in each tank will be fin-clipped for individual identification. Triplicate groups of fish will be fed one of five diets: standard Silver Cup trout diet, the standard diet treated with E_2 at a rate of 10 mg E_2/kg food, or the standard diet treated with genistein at 0.37, 0.75 or 1.50 mg genistein/g food. In a preliminary (unpublished) experiment, genistein at a rate of 0.75 mg/g diet was found to promote growth in perch. Genistein and E_2 will be administered via the diet. Diets will be prepared by mixing 1 kg of feed with 100 g of ethanol containing the appropriate amount of compound and then evaporating off the alcohol under warm air. The diets will be stored at <0°C. The fish will be fed twice daily to excess.

The genistein will be prepared in the UW-Madison laboratory through conversion of Biochenin A using a slight modification of the method described by Adlercreutz et al. (1986). The conversion involves demethylation at the 4' position of Biochenin A and then attachment of a hydroxyl group at the same position. Briefly, Biochanin A is dissolved in CH_2Cl_2, then a mixture of BBr_3 plus CH_2Cl_2 is slowly added to the solution under argon. The mixture is allowed to sit overnight, then heated to 47°C with oil and refluxed for 2 h to remove the excess boron complex and other reagents. The solvent is then evaporated and the resulting genistein is dissolved in aqueous ethanol and recrystallized. The purity of the genistein will be measured using 1H-NMR spectrum (d_6-DMSO) and HPLC.

Total length and weight of each fish will be measured every three weeks for at least 12 weeks. At the end of the study all fish will be weighed, measured, and necropsied to determine sex. Data will be analyzed using two-way ANOVA, with main effects being diet and sex. Data will be published in a timely manner in appropriate peer-reviewed national or international scientific journals.

Year 2: For the pond study, approximately 1,500 mixed-sex perch (120 mm TL, 20 g) will be stocked into each of two 0.04 ha rearing ponds equipped with airlift circulation located at the Lake Mills Hatchery. This stocking rate is similar to that used at commercial perch facilities and should yield a final production of 4,500 kg/ha (assuming eight fish per kg and 95% survival at harvest). The fish will be fed a floating diet (1.5 mm Silver Cup steelhead, Nelson, and Sons, Inc.) once per day, at either dawn or dusk. The fish will be fed to satiation, rather than a fixed ration, since it has been previously observed that perch may have greater growth and food consumption rates in spring and early summer than in late summer and autumn. Standard pond culture procedures will be followed, including daily measurement of dissolved oxygen concentration. If oxygen levels fall below 3 ppm, feeding will be discontinued and ponds will be flushed.

The ponds will be harvested in mid-October and at least 200 fish from each pond will be weighed, measured, and necropsied to determine sex. Data will be analyzed using a Student's t-test, with the main effect being sex. Data will be published in a timely manner in appropriate peer-reviewed national or international scientific journals.

Develop Out-of Season Spawning Methods (Objective 3)

UW-Madison

Research at the UW-Madison will be under the direction of Jeff Malison and will evaluate the use of temperature/photoperiod manipulations to induce out-of-season spawning in yellow perch which have been reared to mature size under temperature conditions optimum for growth (i.e., not previously exposed to changes in photoperiod and temperature). The work will be conducted at facilities at the Lake Mills State Fish Hatchery. Because the plan is to begin environmental manipulations in the fall of 1997, the fish to be used in this study were already propagated in the spring of 1996. At that time, about 40 semi-domesticated yellow perch brood stock obtained from a local perch producer (Coolwater Farms, LLC, Cambridge, Wisconsin) were spawned and the fry were reared in fertilized ponds. The fingerlings were later harvested and trained to accept formulated starter diets in indoor flow-through tanks and more than 600 individuals are currently being reared under near-optimal growth conditions (21°C, 16-h light/8-h dark photoperiod, low intensity lighting, and sufficient water flow and aeration to provide low loading rates and optimal water quality).

In the autumn of 1997, the fish will be of sufficient size and age to begin environmental manipulations. The fish will be randomly divided into four groups of approximately 150 fish each. Each group of fish will then be subjected to the following "chill" period: the temperature and photoperiod will be reduced from 21°C and 16-h light/8-h dark to 5-8°C and 8-h light/16-h dark over 14 days. These conditions will be maintained for 170 days and then over six days the temperature and photoperiod will be increased to 12°C and 12-h light/12-h dark. The onset of the chill period for the four groups will be as follows: (1) control, similar to ambient temperature/photoperiod conditions with the chill period beginning October 1; (2) three-month delay, beginning the chill period January 1; (3) six-month delay, beginning the chill period April 1; and (4) nine-month delay, beginning the chill period July 1. After the chill period, all females in each treatment group will be given an injection of hCG at 150 IU/kg. Subsequently, females will be checked twice daily for ovulation, which is anticipated to occur 4-8 days following the injection of each group of fish (i.e., about April 18, July 18, October 18, and January 18, respectively).

Eggs from ovulated females will be stripped and fertilized (using the dry method) with fresh semen collected from several males and incubated by suspending each egg ribbon from a wire hanger in flow-through fiberglass tanks. The number, size, and viability of eggs from each female will be measured and hatching rates will be calculated. Samples of newly hatched fry will be evaluated morphologically and histologically. The newly-hatched fry will then be shared with other NCRAC investigators (Paul Brown, Konrad Dabrowski, and Don Garling) for use in studies being conducted under Objective 1. If sufficient fry are produced in July, there will be an attempt to double-crop a fingerling pond at the Lake Mills Hatchery and evaluate the survival and growth of fingerlings raised at that time.

UW-Milwaukee

UW-Milwaukee researchers will conduct out-of cycle spawning of our laboratory brood stock of yellow perch. To shift spawning, only alterations of rearing temperature and photoperiod that are currently accessible to practical aquaculturists will be used. This would be accomplished by segregating three groups of several hundred mature perch each from UW-Milwaukke's domesticated perch brood stock into three 2.44 m diameter circular rearing tanks. Environmental cues in rearing these groups would be adjusted as follows: the first group would be adjusted to advance spawning (target spawning period = February), the second group would be reared with a normal seasonal pattern (target spawning period = late April), and the third group would be adjusted to delay spawning (target spawning period = July).

For the advanced-spawning group the "cold period" for gonadal maturation would be advanced to begin in the mid to late summer rather than the fall and the cues for initiating spawning with increasing photoperiod

followed by spring-like temperature increases beginning in the early winter. They would be fed commercially available brood stock conditioning diet.

Similarly, for the delayed spawning group the "cold period" for gonadal maturation would be delayed to occur from the early winter through the spring rather than the fall and the cues for initiating spawning with increasing photoperiod followed by spring-like temperature increases would begin in the early summer.

As a control to assess the performance of the advanced and delayed spawning groups, the third group of perch derived from the laboratory domesticated brood stock would be spawned following the normal fall through winter cold period, and the spring temperature and photoperiod increases that have been previously used to successfully spawn the laboratory brood stocks during the normal mid to late April spawning period. Following the initiation of the spring-like increases in temperature and photoperiod, each group would be observed daily for behavioral signs of spawning. Eggs spontaneously spawned in the tank would be collected and the volume and number of egg strands released into the tank would be recorded daily. At the target spawning date UW-Milwaukee researchers would evaluate the spawning readiness of the entire group of fish by attempting to artificially strip and collect eggs or milt from each fish in the group. During this examination a fourth 2.44 m diameter tank would be used to temporarily house non-spawning females and handled males. The number of ripe and running fish would be recorded, females that are striped of eggs would be removed from the spawning group and returned to general laboratory brood stock tank. Non-spawning females and males will be returned to the spawning tank and reexamined at successive weekly intervals for the two weeks following the initial target-date sampling, or until the overwhelming majority (75%) of the fish have spawned (whichever is shortest).

The amount and timing of eggs produced by each spawning group would be documented and there would be evaluation of fertility, survival through hatching, and larval survivalthrough seven days posthatch for representative portions of four to five egg strands produced by each of the spawning groups. Replicated portions (20-30 mL) of the selected egg strands will be incubated in separate flow-through aquaria. Estimates of initial numbers per tank will be based on water displacement volume of the pieces of egg strand stocked in each tank and the subsample 1-2 mL counts of the average number of eggs per mL made with a dissecting microscope during determination of fertility. During incubation under a standard rising temperature regime, gross observations will be made of survival through hatching. Following hatching, dead egg material and larvae will be removed daily from each tank and fixed with 10% buffered formalin for later counting. First feeding larvae will be offered green tank organisms and brine shrimp nauplii as foods. At seven days posthatch surviving larvae will be fixed separately from that days' mortalities for later counting. Hatching success will be determined for each tank as the sum of the total survivors at seven days posthatch plus the posthatch daily mortality counts as a percentage of the estimated number of eggs originally stocked in each of the aquaria. The viability and quality of the representative offspring of each of the out-of-cycle (advanced and delayed) groups will be compared and contrasted with the normal spawning period perch.

FACILITIES

MSU has a wet laboratory fully equipped to conduct the growout studies. All studies will be conducted in experimental systems in place at MSU. The system contains 12, 50, 40, and 30 tanks of 20, 40, 120, or 340 -L capacity, respectively. Choice of tank size will be a function of initial size of fish. Density of fish used in all studies will be those found acceptable in previous studies. All experimental systems can be operated flow-through or recirculating. It is anticipated that operation of the systems will be in flow-through mode.

OSU has a wet laboratory in Kottman Hall (167 m^2) equipped with fish rearing tanks, fish egg incubation apparatus, and acclimation chambers. This laboratory includes features for water temperature-control and sterilization systems. The biochemical laboratory in Kottman Hall includes a biofreezer (-85°C), refrigerated centrifuge, freeze-drier, drying ovens, spectrophotometer DU-70, Beckman HPLC system, Varian 3400 gas chromatography system, and other accessories for biochemical research studies. Facilities at Piketon Research and Extension Center include 14 ponds, an aquaculture building equipped with several fish tanks and recirculation system, and temperature and light control rooms. The main building of the field station contains aquaculture, chemical, and biological laboratories.

Purdue has a new wet laboratory complete with experimental systems for conducting this research. Diet manufacturing equipment is on site and available. The nutrition laboratory is fully equipped for conducting proximate analyses, and contains a UV/Visible spectrophotometer, scintillation counter, and liquid chromatograph. Yellow perch have been held at Purdue for the past seven years. All water quality monitoring equipment is available.

UW-Madison has facilities both on-campus and at the Lake Mills State Fish Hatchery. The campus facility has a well-equipped analytical laboratory and a wet laboratory with numerous circular fiberglass tanks (110-L to 3,000-L) and ample supplies of carbon-filtered water which can be maintained at 5-25±1°C by water heaters or chillers. The Lake Mills facility has 32 ponds ranging in size from 0.04-0.5 ha, all of which have high-volume lake water inputs. Many of these ponds also have continuous aeration systems. The facility has over 100 tanks (110-L to 3,000-L), three water sources (dechlorinated city water, high capacity well, and lake water), over 600 L/min of temperature-regulated (5-30±0.5°C) well or carbon-filtered city water and laboratory equipment required to meet the objectives of the proposal.

UW-Milwaukee will conduct experiments at the Aquaculture Institute - University of Wisconsin System Great Lakes Research Facility. A portion of the Aquaculture Institute rearing facilities (>1,900 L/min water supply; >930 m^2 area) would be used for conducting these trials. The water supply for the rearing facilities is dechlorinated Milwaukee tap water derived from Lake Michigan as its original source. The facility has water heaters capable of supporting intensive flow-through rearing in large capacity tanks. A centralized chilled water system is being installed to maintain cold water and sufficient frigid unit type chillers to help control rearing temperatures.

A wide assortment of other tanks and aquaria are also available ranging in size from 2.4 m diameter (4000 L) fiberglass tanks down to less than 20-L. These tanks are fitted with the required screened mesh and water supply hardware for specialized larval rearing. There are suitable covers with lighting and timers for photoperiod adjustment to condition the maturation of the brood stocks and initiate spawning. In addition, there are a wide variety of supporting facilities and analytical laboratories at the Great Lakes Research Facility that can provide refrigerated storage, instrument shop capabilities, etc., which will enhance the conduct of the proposed activities.

UMC will conduct the proposed studies within one of two wet laboratory facilities operated by the School of Natural Resources at UMC. Both are certified animal holding facilities and possess water temperature and photoperiod control. Available are tanks (945-L) equipped with closed, water-recirculation/biofiltration systems. These tanks can be linked for water interchange to ensure homogeneity of water quality.

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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	Fish Nutrition/Fish Culture/ Extension
Missouri	Robert S. Hayward University of Missouri-Columbia	Fish Bioenergetics/Feeding Models
Ohio	Konrad Dabrowski Ohio State University	Larval Fish Culture/Nutrition/ Physiology
Wisconsin	Fred P. Binkowski University of Wisconsin-Milwaukee	Finfish Aquaculture/Larval Fish Culture
	Jeffrey A. Malison University of Wisconsin-Madison	Aquaculture/Physiology/ Endocrinology

PARTICIPATING INSTITUTIONS and PRINCIPAL INVESTIGATORS

Michigan State University (MSU)
Donald L. Garling

Ohio State University (OSU)
Konrad Dabrowski

Purdue University (Purdue)
Paul B. Brown

University of Missouri-Columbia (UMC)
Robert S. Hayward

University of Wisconsin-Madison (UW-Madison)
Jeffrey A. Malison

University of Wisconsin-Milwaukee (UW-Milwaukee)
Fred P. Binkowski

UNITED STATES DEPARTMENT OF AGRICULTURE
COOPERATIVE STATE RESEARCH, EDUCATION, AND EXTENSION SERVICE

OMB Approved 0524-0022
Expires 5/31/98

BUDGET

ORGANIZATION AND ADDRESS Department of Fisheries and Wildlife Michigan State University East Lansing, MI 48824-1222				**USDA AWARD NO.** Year 1: Objectives 1 and 2	
PRINCIPAL INVESTIGATOR(S)/PROJECT DIRECTOR(S) Donald L. Garling				Duration Proposed Months: 12 **FUNDS REQUESTED by PROPOSER**	Duration Awarded Months: _____ **FUNDS APPROVED BY CSREES** (If Different)
A. Salaries and Wages 1. No. of Senior Personnel	**CSREES FUNDED WORK MONTHS**				$
	Calendar	Academic	Summer		
a. ___ (Co)-PI(s)/PD(s)					
b. ___ Senior Associates					
2. No. of Other Personnel (Non-Faculty) a. ___ Research Associates-Postdoctorates					
b. ___ Other Professional					
c. _1_ Graduate Students				$12,650	
d. ___ Prebaccalaureate Students					
e. ___ Secretarial-Clerical					
f. ___ Technical, Shop and Other					
Total Salaries, and Wages . . . . . →				$12,650	
B. Fringe Benefits (If charged as Direct Costs)				$600	
C. Total Salaries, Wages, and Fringe Benefits (A plus B) . . . . . →				$13,250	
D. Nonexpendable Equipment (Attach supporting data. List items and dollar amounts for **each** item.)					
E. Materials and Supplies				$6,000	
F. Travel 1. Domestic (Including Canada)				$750	
2. Foreign (List destination and amount for each trip.)					
G. Publication Costs/Page Charges					
H. Computer (ADPE) Costs					
I. All Other Direct Costs (Attach supporting data. List items and dollar amounts. Details of Subcontracts, including work statements and budget, should be explained in full in proposal.)					
J. Total Direct Costs (C through I) . . . . . →				$20,000	
K. Indirect Costs If Applicable (Specify rate(s) and base(s) for on/off campus activity. Where both are involved, identify itemized costs in on/off campus bases.)					
L. Total Direct and Indirect Costs (J plus K) . . . . . →				$20,000	
M. Other . . . . . →					
N. Total Amount of This Request . . . . . →				$20,000	$
O. Cost Sharing (If Required Provide Details)	$15,020				

NOTE: Signatures required only for Revised Budget — This is Revision No. →

NAME and TITLE (Type or print)	**SIGNATURE**	**DATE**
Principal Investigator/Project Director		
Authorized Organizational Representative		

Form CSREES-55 (6/95)

UNITED STATES DEPARTMENT OF AGRICULTURE
COOPERATIVE STATE RESEARCH, EDUCATION, AND EXTENSION SERVICE

OMB Approved 0524-0022
Expires 5/31/98

BUDGET

ORGANIZATION AND ADDRESS Department of Fisheries and Wildlife Michigan State University East Lansing, MI 48824-1222				**USDA AWARD NO.** Year 2: Objectives 1 and 2	
PRINCIPAL INVESTIGATOR(S)/PROJECT DIRECTOR(S) Donald L. Garling				Duration Proposed Months: 12 **FUNDS REQUESTED by PROPOSER**	Duration Awarded Months: _____ **FUNDS APPROVED BY CSREES** (If Different)
A. Salaries and Wages 1. No. of Senior Personnel	**CSREES FUNDED WORK MONTHS**				$
	Calendar	Academic	Summer		
a. ___ (Co)-PI(s)/PD(s)					
b. ___ Senior Associates					
2. No. of Other Personnel (Non-Faculty) a. ___ Research Associates-Postdoctorates					
b. ___ Other Professional					
c. _1_ Graduate Students				$13,936	
d. ___ Prebaccalaureate Students					
e. ___ Secretarial-Clerical					
f. ___ Technical, Shop and Other					
Total Salaries and Wages . . . . . →				$13,936	
B. Fringe Benefits (If charged as Direct Costs)				$625	
C. Total Salaries, Wages, and Fringe Benefits (A plus B) . . . . . →				$14,561	
D. Nonexpendable Equipment (Attach supporting data. List items and dollar amounts for **each** item.)					
E. Materials and Supplies				$4,049	
F. Travel 1. Domestic (Including Canada)				$750	
2. Foreign (List destination and amount for each trip.)					
G. Publication Costs/Page Charges					
H. Computer (ADPE) Costs					
I. All Other Direct Costs (Attach supporting data. List items and dollar amounts. Details of Subcontracts, including work statements and budget, should be explained in full in proposal.)					
J. Total Direct Costs (C through I) . . . . . →				$19,360	
K. Indirect Costs If Applicable (Specify rate(s) and base(s) for on/off campus activity. Where both are involved, identify itemized costs in on/off campus bases.)					
L. Total Direct and Indirect Costs (J plus K) . . . . . →				$19,360	
M. Other . . . . . →					
N. Total Amount of This Request . . . . . →				$19,360	$
O. Cost Sharing (If Required Provide Details)	$15,250				

NOTE: Signatures required only for Revised Budget — This is Revision No. →

NAME and TITLE (Type or print)	**SIGNATURE**	**DATE**
Principal Investigator/Project Director		
Authorized Organizational Representative		

Form CSREES-55 (6/95)

BUDGET JUSTIFICATION FOR MICHIGAN STATE UNIVERSITY

(Garling)

Objectives 1 and 2

A. Salaries and Wages. Laboratory studies will be conducted with the assistance of a graduate student (0.50 FTE). Responsibilities of the graduate student will include: diet preparation and analysis, general fish culture. The graduate student will participate in Objective 1 (two months, during Year 1.)

B. Fringe Benefits. MSU requires medical coverage for graduate research assistants estimated to be $600 for Year 1 and $625 for Year 2 of the project.

E. Materials and Supplies. Fish ($2,000), feeds and ingredients ($5,000), chemicals ($1,500), and four additional larval rearing tanks ($1,000) will be required to complete Objectives 1 and 2, and general office supplies as extension liaison ($549).

F. Travel. Domestic travel will be required to obtain larvae and fish to complete Objectives 1 and 2. Costs will include transportation, lodging, and meals.

UNITED STATES DEPARTMENT OF AGRICULTURE
COOPERATIVE STATE RESEARCH, EDUCATION, AND EXTENSION SERVICE

OMB Approved 0524-0022
Expires 5/31/98

BUDGET

ORGANIZATION AND ADDRESS Ohio State University Research Foundation 1960 Kenney Road Columbus, OH 43210-1063				**USDA AWARD NO.** Year 1: Objective 1 Duration Proposed Months: 12	Duration Awarded Months:
PRINCIPAL INVESTIGATOR(S)/PROJECT DIRECTOR(S) Konrad Dabrowski				**FUNDS REQUESTED by PROPOSER**	**FUNDS APPROVED BY CSREES** (If Different)
A. Salaries and Wages	**CSREES FUNDED WORK MONTHS**				$
1. No. of Senior Personnel	Calendar	Academic	Summer		
a. ___ (Co)-PI(s)/PD(s)					
b. ___ Senior Associates					
2. No. of Other Personnel (Non-Faculty)					
a. 1 Research Associates-Postdoctorates		3		$4,000	
b. ___ Other Professional					
c. ___ Graduate Students					
d. ___ Prebaccalaureate Students					
e. ___ Secretarial-Clerical					
f. ___ Technical, Shop and Other					
Total Salaries and Wages →				$4,000	
B. Fringe Benefits (If charged as Direct Costs)					
C. Total Salaries, Wages, and Fringe Benefits (A plus B) →				$4,000	
D. Nonexpendable Equipment (Attach supporting data. List items and dollar amounts for **each** item.)					
E. Materials and Supplies				$4,000	
F. Travel				$500	
1. Domestic (Including Canada)					
2. Foreign (List destination and amount for each trip.)					
G. Publication Costs/Page Charges					
H. Computer (ADPE) Costs					
I. All Other Direct Costs (Attach supporting data. List items and dollar amounts. Details of Subcontracts, including work statements and budget, should be explained in full in proposal.) Telephone ($200), Fax ($300), Equipment repair ($1,000)				$1,500	
J. Total Direct Costs (C through I) →				$10,000	
K. Indirect Costs If Applicable (Specify rate(s) and base(s) for on/off campus activity. Where both are involved, identify itemized costs in on/off campus bases.)					
L. Total Direct and Indirect Costs (J plus K) →				$10,000	
M. Other →					
N. Total Amount of This Request →				$10,000	$
O. Cost Sharing (If Required Provide Details)	$16,200				

NOTE: Signatures required only for Revised Budget — This is Revision No. →

NAME and TITLE (Type or print)	**SIGNATURE**	**DATE**
Principal Investigator/Project Director		
Authorized Organizational Representative		

Form CSREES-55 (6/95)

UNITED STATES DEPARTMENT OF AGRICULTURE
COOPERATIVE STATE RESEARCH, EDUCATION, AND EXTENSION SERVICE

OMB Approved 0524-0022
Expires 5/31/98

BUDGET

ORGANIZATION AND ADDRESS Ohio State University Research Foundation 1960 Kenney Road Columbus, OH 43210-1063				**USDA AWARD NO.** Year 2: Objective 1	
PRINCIPAL INVESTIGATOR(S)/PROJECT DIRECTOR(S) Konrad Dabrowski				Duration Proposed Months: 12 **FUNDS REQUESTED by PROPOSER**	Duration Awarded Months: _____ **FUNDS APPROVED BY CSREES** (If Different)
A. Salaries and Wages 1. No. of Senior Personnel	**CSREES FUNDED WORK MONTHS**				$
	Calendar	Academic	Summer		
a. ___ (Co)-PI(s)/PD(s)					
b. ___ Senior Associates					
2. No. of Other Personnel (Non-Faculty) a. 1 Research Associates-Postdoctorates		3		$5,000	
b. ___ Other Professional					
c. ___ Graduate Students					
d. ___ Prebaccalaureate Students					
e. ___ Secretarial-Clerical					
f. ___ Technical, Shop and Other					
Total Salaries and Wages . . . . . →				$5,000	
B. Fringe Benefits (If charged as Direct Costs)					
C. Total Salaries, Wages, and Fringe Benefits (A plus B) . . . . . →				$5,000	
D. Nonexpendable Equipment (Attach supporting data. List items and dollar amounts for **each** item.)					
E. Materials and Supplies				$3,200	
F. Travel 1. Domestic (Including Canada)				$500	
2. Foreign (List destination and amount for each trip.)					
G. Publication Costs/Page Charges					
H. Computer (ADPE) Costs					
I. All Other Direct Costs (Attach supporting data. List items and dollar amounts. Details of Subcontracts, including work statements and budget, should be explained in full in proposal.) Telephone ($200), Fax ($300)				$500	
J. Total Direct Costs (C through I) . . . . . →				$9,200	
K. Indirect Costs If Applicable (Specify rate(s) and base(s) for on/off campus activity. Where both are involved, identify itemized costs in on/off campus bases.)					
L. Total Direct and Indirect Costs (J plus K) . . . . . →				$9,200	
M. Other . . . . . →					
N. Total Amount of This Request . . . . . →				$9,200	$
O. Cost Sharing (If Required Provide Details)	$17,200				

NOTE: Signatures required only for Revised Budget — This is Revision No. →

NAME and TITLE (Type or print)	**SIGNATURE**	**DATE**
Principal Investigator/Project Director		
Authorized Organizational Representative		

Form CSREES-55 (6/95)

BUDGET JUSTIFICATION FOR OHIO STATE UNIVERSITY

(Dabrowski)

Objective 1

A. Salaries and Wages. Field and laboratory studies will be conducted by a graduate student and a postdoctoral fellow. Their tasks include sampling at two locations, Columbus campus and at Piketon; initial preparation of experimental diets and their analysis; fish and zooplankton sample analysis. Approximately half of the labor in pond and tank experiments will be supported by monies from the Piketon Center.

Additional responsibilities of a graduate student will include: diet preparation and analysis, preparation of daily, weekly, and monthly tables, and graphs of field and laboratory experiments schedule.

E. Materials and Supplies. General laboratory and field supplies will include reagents, glassware, diet ingredients, commercial feeds, and replacement parts for laboratory equipment (homogenizers, spectrophotometer).

F. Travel. These funds will support transportation, and, if necessary, lodging for the collection of samples in Piketon (round trip distance 160 miles). Travel funds will also be used to attend work group meetings and the NCRAC conference to present initial results. Costs will include transportation, lodging, and meals.

I. All Other Direct Costs. Year 1: telephone ($200), fax ($300), and equipment repair ($1,000); Year 2: telephone ($200) and fax ($300).

UNITED STATES DEPARTMENT OF AGRICULTURE
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OMB Approved 0524-0022
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BUDGET

ORGANIZATION AND ADDRESS Purdue Research Foundation Office of Sponsored Programs West Lafayette, IN 47907-1021				**USDA AWARD NO.** Year 1: Objectives 1 and 2	
PRINCIPAL INVESTIGATOR(S)/PROJECT DIRECTOR(S) Paul B. Brown				Duration Proposed Months: 12 **FUNDS REQUESTED by PROPOSER**	Duration Awarded Months: _____ **FUNDS APPROVED BY CSREES** (If Different)
A. Salaries and Wages 1. No. of Senior Personnel	**CSREES FUNDED WORK MONTHS**				$
	Calendar	Academic	Summer		
a. ___ (Co)-PI(s)/PD(s)					
b. ___ Senior Associates					
2. No. of Other Personnel (Non-Faculty) a. ___ Research Associates-Postdoctorates					
b. ___ Other Professional					
c. 1 Graduate Students				$13,450	
d. 1 Prebaccalaureate Students				$3,000	
e. ___ Secretarial-Clerical					
f. ___ Technical, Shop and Other					
Total Salaries and Wages . . . . . →				$16,450	
B. Fringe Benefits (If charged as Direct Costs)				$1,476	
C. Total Salaries, Wages, and Fringe Benefits (A plus B) . . . . . →				$17,926	
D. Nonexpendable Equipment (Attach supporting data. List items and dollar amounts for **each** item.)					
E. Materials and Supplies				$4,874	
F. Travel 1. Domestic (Including Canada)				$1,500	
2. Foreign (List destination and amount for each trip.)					
G. Publication Costs/Page Charges					
H. Computer (ADPE) Costs					
I. All Other Direct Costs (Attach supporting data. List items and dollar amounts. Details of Subcontracts, including work statements and budget, should be explained in full in proposal.)					
J. Total Direct Costs (C through I) . . . . . →				$24,300	
K. Indirect Costs If Applicable (Specify rate(s) and base(s) for on/off campus activity. Where both are involved, identify itemized costs in on/off campus bases.)					
L. Total Direct and Indirect Costs (J plus K) . . . . . →				$24,300	
M. Other . . . . . →					
N. Total Amount of This Request . . . . . →				$24,300	$
O. Cost Sharing (If Required Provide Details)	$26,500				

NOTE: Signatures required only for Revised Budget — This is Revision No. →

NAME and TITLE (Type or print)	**SIGNATURE**	**DATE**
Principal Investigator/Project Director		
Authorized Organizational Representative		

Form CSREES-55 (6/95)

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COOPERATIVE STATE RESEARCH, EDUCATION, AND EXTENSION SERVICE

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BUDGET

ORGANIZATION AND ADDRESS Purdue Research Foundation Office of Sponsored Programs West Lafayette, IN 47907-1021				**USDA AWARD NO.** Year 2: Objectives 1 and 2	
PRINCIPAL INVESTIGATOR(S)/PROJECT DIRECTOR(S) Paul B. Brown				Duration Proposed Months: 12 **FUNDS REQUESTED by PROPOSER**	Duration Awarded Months: _____ **FUNDS APPROVED BY CSREES** (If Different)
A. Salaries and Wages 1. No. of Senior Personnel	**CSREES FUNDED WORK MONTHS**				$
	Calendar	Academic	Summer		
a. ___ (Co)-PI(s)/PD(s)					
b. ___ Senior Associates					
2. No. of Other Personnel (Non-Faculty) a. ___ Research Associates-Postdoctorates					
b. ___ Other Professional					
c. 1 Graduate Students				$12,924	
d. 1 Prebaccalaureate Students				$3,000	
e. ___ Secretarial-Clerical					
f. ___ Technical, Shop and Other					
Total Salaries and Wages . . . . . →				$15,924	
B. Fringe Benefits (If charged as Direct Costs)				$1,276	
C. Total Salaries, Wages, and Fringe Benefits (A plus B) . . . . . →				$17,200	
D. Nonexpendable Equipment (Attach supporting data. List items and dollar amounts for **each** item.)					
E. Materials and Supplies				$5,000	
F. Travel				$1,500	
1. Domestic (Including Canada)					
2. Foreign (List destination and amount for each trip.)					
G. Publication Costs/Page Charges					
H. Computer (ADPE) Costs					
I. All Other Direct Costs (Attach supporting data. List items and dollar amounts. Details of Subcontracts, including work statements and budget, should be explained in full in proposal.)					
J. Total Direct Costs (C through I) . . . . . →				$23,700	
K. Indirect Costs If Applicable (Specify rate(s) and base(s) for on/off campus activity. Where both are involved, identify itemized costs in on/off campus bases.)					
L. Total Direct and Indirect Costs (J plus K) . . . . . →				$23,700	
M. Other . . . . . →					
N. Total Amount of This Request . . . . . →				$23,700	$
O. Cost Sharing (If Required Provide Details)	$27,000				

NOTE: Signatures required only for Revised Budget — This is Revision No. →

NAME and TITLE (Type or print)	**SIGNATURE**	**DATE**
Principal Investigator/Project Director		
Authorized Organizational Representative		

Form CSREES-55 (6/95)

BUDGET JUSTIFICATION FOR PURDUE UNIVERSITY

(Brown)

Objectives 1 and 2

A. Salaries and Wages. One prebaccalaureate student will assist the graduate student with necessary aspects of the project.

B. Fringe Benefits. The fringe benefit rate for Purdue is 1.8% for prebaccalaureate students and 10.6% for graduate students.

E. Materials and Supplies. These funds will be used to acquire fish, feed ingredients, and routine maintenance supplies for the experimental system.

F. Travel. These funds will be used to attend work group meetings and dissemination of research results at international aquaculture meetings. Costs will include transportation, lodging, and meals.

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OMB Approved 0524-0022
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BUDGET

ORGANIZATION AND ADDRESS School of Natural Resources University of Missouri-Columbia Columbia, MO 65211				**USDA AWARD NO.** Year 1: Objective 2 Duration Proposed Months: 12 **FUNDS REQUESTED by PROPOSER**	Duration Awarded Months: _____ **FUNDS APPROVED BY CSREES** (If Different)
PRINCIPAL INVESTIGATOR(S)/PROJECT DIRECTOR(S) Robert S. Hayward					
A. Salaries and Wages 1. No. of Senior Personnel	**CSREES FUNDED WORK MONTHS** Calendar	Academic	Summer		$
a. ___ (Co)-PI(s)/PD(s)					
b. ___ Senior Associates					
2. No. of Other Personnel (Non-Faculty) a. ___ Research Associates-Postdoctorates					
b. ___ Other Professional					
c. 1 Graduate Students				$10,000	
d. ___ Prebaccalaureate Students					
e. ___ Secretarial-Clerical					
f. ___ Technical, Shop and Other					
Total Salaries and Wages →				$10,000	
B. Fringe Benefits (If charged as Direct Costs)					
C. Total Salaries, Wages, and Fringe Benefits (A plus B) →				$10,000	
D. Nonexpendable Equipment (Attach supporting data. List items and dollar amounts for **each** item.)					
E. Materials and Supplies				$1,500	
F. Travel 1. Domestic (Including Canada) 2. Foreign (List destination and amount for each trip.)				$500	
G. Publication Costs/Page Charges					
H. Computer (ADPE) Costs					
I. All Other Direct Costs (Attach supporting data. List items and dollar amounts. Details of Subcontracts, including work statements and budget, should be explained in full in proposal.)					
J. Total Direct Costs (C through I) →				$12,000	
K. Indirect Costs If Applicable (Specify rate(s) and base(s) for on/off campus activity. Where both are involved, identify itemized costs in on/off campus bases.)					
L. Total Direct and Indirect Costs (J plus K) →				$12,000	
M. Other →					
N. Total Amount of This Request →				$12,000	$
O. Cost Sharing (If Required Provide Details)	$8,925				

NOTE: Signatures required only for Revised Budget — This is Revision No. →

NAME and TITLE (Type or print)	**SIGNATURE**	**DATE**
Principal Investigator/Project Director		
Authorized Organizational Representative		

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BUDGET

ORGANIZATION AND ADDRESS School of Natural Resources University of Missouri-Columbia Columbia, MO 65211				**USDA AWARD NO.** Year 2: Objective 2 Duration Proposed Months: 12 **FUNDS REQUESTED by PROPOSER**	Duration Awarded Months: _____ **FUNDS APPROVED BY CSREES** (If Different)
PRINCIPAL INVESTIGATOR(S)/PROJECT DIRECTOR(S) Robert S. Hayward					
A. Salaries and Wages 1. No. of Senior Personnel	**CSREES FUNDED WORK MONTHS** Calendar	Academic	Summer		$
a. ___ (Co)-PI(s)/PD(s)					
b. ___ Senior Associates					
2. No. of Other Personnel (Non-Faculty) a. ___ Research Associates-Postdoctorates					
b. ___ Other Professional					
c. 1 Graduate Students				$10,000	
d. ___ Prebaccalaureate Students					
e. ___ Secretarial-Clerical					
f. ___ Technical, Shop and Other					
Total Salaries and Wages →				$10,000	
B. Fringe Benefits (If charged as Direct Costs)					
C. Total Salaries, Wages, and Fringe Benefits (A plus B) →				$10,000	
D. Nonexpendable Equipment (Attach supporting data. List items and dollar amounts for **each** item.)					
E. Materials and Supplies				$1,500	
F. Travel 1. Domestic (Including Canada) 2. Foreign (List destination and amount for each trip.)				$500	
G. Publication Costs/Page Charges					
H. Computer (ADPE) Costs					
I. All Other Direct Costs (Attach supporting data. List items and dollar amounts. Details of Subcontracts, including work statements and budget, should be explained in full in proposal.)					
J. Total Direct Costs (C through I) →				$12,000	
K. Indirect Costs If Applicable (Specify rate(s) and base(s) for on/off campus activity. Where both are involved, identify itemized costs in on/off campus bases.)					
L. Total Direct and Indirect Costs (J plus K) →				$12,000	
M. Other →					
N. Total Amount of This Request →				$12,000	$
O. Cost Sharing (If Required Provide Details)	$7,523				

NOTE: Signatures required only for Revised Budget — This is Revision No. →

NAME and TITLE (Type or print)	**SIGNATURE**	**DATE**
Principal Investigator/Project Director		
Authorized Organizational Representative		

Form CSREES-55 (6/95)

BUDGET JUSTIFICATION FOR UNIVERSITY OF MISSOURI-COLUMBIA

(Hayward)

Objective 2

A. Salaries and Wages. A graduate student (0.05 FTE) will work the proposed study over two years as partial fulfillment of degree requirements. The PI will supervise all aspects of the study and will complete the annual and final reports.

E. Materials and Supplies. The majority of funds ($2,500) under this category will be used to purchase pelleted fish feeds in both study years. The balance ($500) will be used for water chemicals for water quality maintenance, nets, buckets, replacement materials for water recirculation systems, thermometers, and paper supplies needed for routine operations and data collections.

F. Travel. Travel in both years including student's travel to a professional meeting to present results of the proposed work and miscellaneous travel associated with routine operation of study. Costs will include transportation, lodging, and meals.

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OMB Approved 0524-0022
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BUDGET

ORGANIZATION AND ADDRESS Center for Great Lakes Studies University of Wisconsin-Milwaukee Milwaukee, WI 53204				**USDA AWARD NO.** Year 1: Objective 3	
				Duration Proposed Months: 12	Duration Awarded Months:
PRINCIPAL INVESTIGATOR(S)/PROJECT DIRECTOR(S) Fred P. Binkowski				**FUNDS REQUESTED by PROPOSER**	**FUNDS APPROVED BY CSREES** (If Different)
A. Salaries and Wages	**CSREES FUNDED WORK MONTHS**				$
1. No. of Senior Personnel	Calendar	Academic	Summer		
a. ___ (Co)-PI(s)/PD(s)					
b. 1 Senior Associates	3			$7,200	
2. No. of Other Personnel (Non-Faculty) a. ___ Research Associates-Postdoctorates					
b. ___ Other Professional					
c. ___ Graduate Students					
d. 1 Prebaccalaureate Students				$1,000	
e. ___ Secretarial-Clerical					
f. ___ Technical, Shop and Other					
Total Salaries and Wages →				$8,200	
B. Fringe Benefits (If charged as Direct Costs)				$2,232	
C. Total Salaries, Wages, and Fringe Benefits (A plus B) →				$10,432	
D. Nonexpendable Equipment (Attach supporting data. List items and dollar amounts for **each** item.)					
E. Materials and Supplies				$500	
F. Travel 1. Domestic (Including Canada)					
2. Foreign (List destination and amount for each trip.)					
G. Publication Costs/Page Charges					
H. Computer (ADPE) Costs					
I. All Other Direct Costs (Attach supporting data. List items and dollar amounts. Details of Subcontracts, including work statements and budget, should be explained in full in proposal.)					
J. Total Direct Costs (C through I) →				$10,932	
K. Indirect Costs If Applicable (Specify rate(s) and base(s) for on/off campus activity. Where both are involved, identify itemized costs in on/off campus bases.)					
L. Total Direct and Indirect Costs (J plus K) →				$10,932	
M. Other →					
N. Total Amount of This Request →				$10,932	$
O. Cost Sharing (If Required Provide Details)	$13,125				

NOTE: Signatures required only for Revised Budget — This is Revision No. →

NAME and TITLE (Type or print)	**SIGNATURE**	**DATE**
Principal Investigator/Project Director		
Authorized Organizational Representative		

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BUDGET

ORGANIZATION AND ADDRESS Center for Great Lakes Studies University of Wisconsin-Milwaukee Milwaukee, WI 53204				**USDA AWARD NO.** Year 2: Objective 3	
				Duration Proposed Months: 12	Duration Awarded Months:
PRINCIPAL INVESTIGATOR(S)/PROJECT DIRECTOR(S) Fred P. Binkowski				**FUNDS REQUESTED by PROPOSER**	**FUNDS APPROVED BY CSREES** (If Different)
A. Salaries and Wages	**CSREES FUNDED WORK MONTHS**				$
1. No. of Senior Personnel	Calendar	Academic	Summer		
a. ___ (Co)-PI(s)/PD(s)					
b. 1 Senior Associates	1.2			$2,500	
2. No. of Other Personnel (Non-Faculty) a. ___ Research Associates-Postdoctorates					
b. ___ Other Professional					
c. ___ Graduate Students					
d. ___ Prebaccalaureate Students					
e. ___ Secretarial-Clerical					
f. ___ Technical, Shop and Other					
Total Salaries and Wages →				$2,500	
B. Fringe Benefits (If charged as Direct Costs)				$775	
C. Total Salaries, Wages, and Fringe Benefits (A plus B) →				$3,275	
D. Nonexpendable Equipment (Attach supporting data. List items and dollar amounts for **each** item.)					
E. Materials and Supplies				$193	
F. Travel 1. Domestic (Including Canada)					
2. Foreign (List destination and amount for each trip.)					
G. Publication Costs/Page Charges					
H. Computer (ADPE) Costs					
I. All Other Direct Costs (Attach supporting data. List items and dollar amounts. Details of Subcontracts, including work statements and budget, should be explained in full in proposal.)					
J. Total Direct Costs (C through I) →				$3,468	
K. Indirect Costs If Applicable (Specify rate(s) and base(s) for on/off campus activity. Where both are involved, identify itemized costs in on/off campus bases.)					
L. Total Direct and Indirect Costs (J plus K) →				$3,468	
M. Other →					
N. Total Amount of This Request →				$3,468	$
O. Cost Sharing (If Required Provide Details)	$13, 275				

NOTE: Signatures required only for Revised Budget — This is Revision No. →

NAME and TITLE (Type or print)	**SIGNATURE**	**DATE**
Principal Investigator/Project Director		
Authorized Organizational Representative		

Form CSREES-55 (6/95)

BUDGET JUSTIFICATION FOR UNIVERSITY OF WISCONSIN-MILWAUKEE

(Binkowski)

Objective 3

A. Salaries and Wages. Year 1: senior associate (0.25 FTE) to maintain brood stock, manipulate environmental conditions, and evaluate early life history parameters and student helper (0.09 FTE) to assist in animal husbandry over weekend and holiday breaks; Year 2: senior associate (0.08 FTE) to conduct data analysis and prepare report.

B. Fringe Beneftits. Fringe benefit rate for the senior associate is 31%.

E. Materials and Supplies. Year l: fish foods, aquarium supplies, and hardware supplies; Year 2: computer and office supplies.

UNITED STATES DEPARTMENT OF AGRICULTURE
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OMB Approved 0524-0022
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BUDGET

ORGANIZATION AND ADDRESS Board of Regents, University of Wisconsin System 750 University Avenue Madison, WI 53706				**USDA AWARD NO.** Year 1: Objectives 1-3	
PRINCIPAL INVESTIGATOR(S)/PROJECT DIRECTOR(S) Jeffrey A. Malison				Duration Proposed Months: 12 **FUNDS REQUESTED by PROPOSER**	Duration Awarded Months: _____ **FUNDS APPROVED BY CSREES** (If Different)
A. Salaries and Wages	**CSREES FUNDED WORK MONTHS**				$
1. No. of Senior Personnel	Calendar	Academic	Summer		
a. ___ (Co)-PI(s)/PD(s)					
b. ___ Senior Associates					
2. No. of Other Personnel (Non-Faculty)					
a. ___ Research Associates-Postdoctorates					
b. 1 Other Professional	1.2			$2,166	
c. 1 Graduate Students				$18,200	
d. ___ Prebaccalaureate Students					
e. ___ Secretarial-Clerical					
f. ___ Technical, Shop and Other					
Total Salaries and Wages →				$20,366	
B. Fringe Benefits (If charged as Direct Costs)				$1,967	
C. Total Salaries, Wages, and Fringe Benefits (A plus B) →				$22,333	
D. Nonexpendable Equipment (Attach supporting data. List items and dollar amounts for **each** item.)					
E. Materials and Supplies				$4,800	
F. Travel				$1,400	
1. Domestic (Including Canada)					
2. Foreign (List destination and amount for each trip.)					
G. Publication Costs/Page Charges					
H. Computer (ADPE) Costs					
I. All Other Direct Costs (Attach supporting data. List items and dollar amounts. Details of Subcontracts, including work statements and budget, should be explained in full in proposal.) Fax ($100), Postage ($100), Equipment repair ($267)				$467	
J. Total Direct Costs (C through I) →				$29,000	
K. Indirect Costs If Applicable (Specify rate(s) and base(s) for on/off campus activity. Where both are involved, identify itemized costs in on/off campus bases.)					
L. Total Direct and Indirect Costs (J plus K) →				$29,000	
M. Other →					
N. Total Amount of This Request →				$29,000	$
O. Cost Sharing (If Required Provide Details)	$31,920				

NOTE: Signatures required only for Revised Budget — This is Revision No. →

NAME and TITLE (Type or print)	**SIGNATURE**	**DATE**
Principal Investigator/Project Director		
Authorized Organizational Representative		

Form CSREES-55 (6/95)

UNITED STATES DEPARTMENT OF AGRICULTURE
COOPERATIVE STATE RESEARCH, EDUCATION, AND EXTENSION SERVICE

OMB Approved 0524-0022
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BUDGET

ORGANIZATION AND ADDRESS Board of Regents, University of Wisconsin System 750 University Avenue Madison, WI 53706				**USDA AWARD NO.** Year 2: Objectives 1-3	
				Duration Proposed Months: ___12___	Duration Awarded Months: _____
PRINCIPAL INVESTIGATOR(S)/PROJECT DIRECTOR(S) Jeffrey A. Malison				**FUNDS REQUESTED by PROPOSER**	**FUNDS APPROVED BY CSREES** (If Different)
A. Salaries and Wages	**CSREES FUNDED WORK MONTHS**				$
1. No. of Senior Personnel	Calendar	Academic	Summer		
a. ___ (Co)-PI(s)/PD(s)					
b. ___ Senior Associates					
2. No. of Other Personnel (Non-Faculty)					
a. ___ Research Associates-Postdoctorates					
b. ___ Other Professional					
c. _1_ Graduate Students				$18,600	
d. ___ Prebaccalaureate Students					
e. ___ Secretarial-Clerical					
f. ___ Technical, Shop and Other					
Total Salaries and Wages . . . . . →				$18,600	
B. Fringe Benefits (If charged as Direct Costs)				$1,302	
C. Total Salaries, Wages, and Fringe Benefits (A plus B) . . . . . →				$19,902	
D. Nonexpendable Equipment (Attach supporting data. List items and dollar amounts for **each** item.)					
E. Materials and Supplies				$4,300	
F. Travel				$1,400	
1. Domestic (Including Canada)					
2. Foreign (List destination and amount for each trip.)					
G. Publication Costs/Page Charges					
H. Computer (ADPE) Costs					
I. All Other Direct Costs (Attach supporting data. List items and dollar amounts. Details of Subcontracts, including work statements and budget, should be explained in full in proposal.) Fax($100), Postage ($100), Equipment repair ($238)				$438	
J. Total Direct Costs (C through I) . . . . . →				$26,040	
K. Indirect Costs If Applicable (Specify rate(s) and base(s) for on/off campus activity. Where both are involved, identify itemized costs in on/off campus bases.)					
L. Total Direct and Indirect Costs (J plus K) . . . . . →				$26,040	
M. Other . . . . . →					
N. Total Amount of This Request . . . . . →				$26,040	$
O. Cost Sharing (If Required Provide Details)	$27,382				

NOTE: Signatures required only for Revised Budget — This is Revision No. →

NAME and TITLE (Type or print)	**SIGNATURE**	**DATE**
Principal Investigator/Project Director		
Authorized Organizational Representative		

Form CSREES-55 (6/95)

BUDGET JUSTIFICATION FOR UNIVERSITY OF WISCONSIN-MADISON

(Malison)

Objectives 1-3

A. Salaries and Wages. A graduate student and technical help (Year 1 only) is needed to assist the PI with the conduct of experiments and analysis, and publication of results.

B. Fringe Benefits. The fringe benefit rate for graduate students is 7% (not including tuition waiver) and for professional/technical positions is 32%.

E. Materials and Supplies. Fish food, wet lab supplies, biochemicals, and reagents are needed to conduct the proposed experiments.

F. Travel. Approximately $900 is needed each year to attend an international scientific conference (e.g., American Fisheries Society or World Aquaculture Society) to present research findings. The remainder of the travel budget will be used to attend work group meetings. Costs will include transportation, lodging, and meals.

I. All Other Direct Costs. Year 1: fax ($100), postage ($100), and equipment repair ($267); Year 2: fax ($100), postage ($100), and equipment repair ($238).

ADVANCEMENT OF YELLOW PERCH AQUACULTURE

Budget Summary for Each Particpating Institution for the First Year

	MSU	OSU	Purdue	UMC	UW-Mil.	UW-Madison	TOTALS
Salaries and Wages	$12,650	$4,000	$16,450	$10,000	$8,200	$20,366	$71,666
Fringe Benefits	$600	$0	$1,476	$0	$2,232	$1,967	$6,275
Total Salaries, Wages, and Fringe Benefits	$13,250	$4,000	$17,926	$10,000	$10,432	$22,333	$77,941
Nonexpendable Equipment	$0	$0	$0	$0	$0	$4,800	$4,800
Materials and Supplies	$6,000	$4,000	$4,874	$1,500	$500	$0	$16,874
Travel	$750	$500	$1,500	$500	$0	$1,400	$4,650
All Other Direct Costs	$0	$1,500	$0	$0	$0	$467	$1,967
TOTAL PROJECT COSTS	**$20,000**	**$10,000**	**$24,300**	**$12,000**	**$10,932**	**$29,000**	**$106,232**

Budget Summary for Each Particpating Institution for the Second Year

	MSU	OSU	Purdue	UMC	UW-Mil.	UW-Madison	TOTALS
Salaries and Wages	$13,936	$5,000	$15,924	$10,000	$2,500	$18,600	$65,960
Fringe Benefits	$625	$0	$1,276	$0	$775	$1,302	$3,978
Total Salaries, Wages, and Fringe Benefits	$14,561	$5,000	$17,200	$10,000	$3,275	$19,902	$69,938
Nonexpendable Equipment	$0	$0	$0	$0	$0	$0	$0
Materials and Supplies	$4,049	$3,200	$5,000	$1,500	$193	$4,300	$18,242
Travel	$750	$500	$1,500	$500	$0	$1,400	$4,650
All Other Direct Costs	$0	$500	$0	$0	$0	$438	$938
TOTAL PROJECT COSTS	**$19,360**	**$9,200**	**$23,700**	**$12,000**	**$3,468**	**$26,040**	**$93,768**

RESOURCE COMMITMENT FROM INSTITUTIONS[1]

State/Institution		Year 1	Year 2
Michigan State University			
Salaries and Benefits: SY @ 0.05 FTE		$4,520	$4,650
Waiver of Overhead		$10,500	$10,600
	Total	$15,020	$15,250
Ohio State University			
Salaries and Benefits: SY @ 0.05 FTE		$6,200	$6,200
Equipment and Waiver of Overhead		$6,000	$6,000
Piketon Research and Extension Center Facilities and Utilities		$4,000	$5,000
	Total	$16,200	$17,200
Purdue University			
Salaries and Benefits: SY @ 0.10 FTE		$6,500	$7,000
Supplies, Expenses, Equipment, and Waiver of Overhead		$20,000	$20,000
	Total	$26,500	$27,000
University of Missouri-Columbia			
Salaries and Benefits: SY @ 0.10 FTEs (Year 1 and 2)		$5,565	$5,843
Supplies, Expenses, Equipment, and Waiver of Overhead		$3,360	$1,680
	Total	$8,925	$7,523
University of Wisconsin-Milwaukee			
Salaries and Benefits: SY @ 0.10 FTE		$11,125	$11,275
Supplies, Expenses, and Equipment		$2,000	$2,000
	Total	$13,125	$13,275
University of Wisconsin-Madison			
Salaries and Benefits: SY @ 0.08 FTE		$4,300	$4,400
TY @ 0.08 FTE		$2,100	$2,150
Supplies, Expenses, Equipment, and Waiver of Overhead		$25,520	$20,832
	Total	$31,920	$27,382
	Total per Year	$111,690	$107,630
	GRAND TOTAL	$219,320	

[1]Because cost sharing is not a legal requirement, universities are not required to provide or maintain documentation of such a commitment.

SCHEDULE FOR COMPLETION OF OBJECTIVES

Objective 1: Initiated in Year 1 and completed in Year 2.

Objective 2: Initiated in Year 1 and completed in Year 2.

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

LIST OF PRINCIPAL INVESTIGATORS

Fred P. Binkowski, University of Wisconsin-Milwaukee

Paul B. Brown, Purdue University

Konrad Dabrowski, Ohio State University

Donald L. Garling, Michigan State University

Robert S. Hayward, University of Missouri-Columbia

Jeffrey A. Malison, University of Wisconsin-Madison

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EDUCATION

B.S. University of Wisconsin-Milwaukee, 1971
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POSITIONS

Director (1993-present), Aquaculture Institute, University of Wisconsin System Great Lakes Research Facility
Senior Scientist (1991-present), Associate Scientist (1987-1990), Senior Fisheries Biologist (1984-1986), Associate Fisheries Biologist (1981-1983), and Assistant Fisheries Biologist (1978-1980), Center for Great Lakes Studies/University of Wisconsin Great Lakes Research Facility
Research Specialist (Fisheries) (1975-1978), Department of Zoology, University of Wisconsin-Milwaukee

SCIENTIFIC and PROFESSIONAL ORGANIZATIONS

American Fisheries Society
World Aquaculture Society

SELECTED PUBLICATIONS

Letcher, B.H., J.A. Rice, L.B. Crowder, and F.P Binkowski. 1996. Size-dependent effects of continuous and intermittent feeding on starvation time and mass loss in starving yellow perch larvae and juveniles. Transactions of the American Fisheries Society 125:14-26.

Binkowski, F.P., and L.G. Rudstam. 1994. The maximum daily ration of Great Lakes bloater. Transactions of the American Fisheries Society 123:335-343.

Rudstam, L.G., F.P. Binkowski, and M.A. Miller. 1994. A bioenergetics model for analysis of food consumption patterns by bloater in Lake Michigan. Transactions of the American Fisheries Society 123:344-357.

Binkowski, F.P., J.J. Sedmack, and S.O. Jolly. 1993. An evaluation of *Pfaffia* yeast as a pigment source for salmonids. Aquaculture Magazine 19:1-4.

Miller, T., L. Crowder, J. Rice, and F.P. Binkowski. 1992. Body size and the ontogeny of the functional response in fishes. Canadian Journal of Fisheries and Aquatic Sciences 49:805-812.

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

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EDUCATION

B.S. University of Tennessee, 1981
M.S. University of Tennessee, 1983
Ph.D. Texas A&M University, 1987

POSITIONS

Professor (1997-present), Associate Professor (1993-1997), and Assistant Professor (1989-1993), Department of Forestry and Natural Resources, Purdue University
Assistant Professional Scientist/Field Station Director (1987-1989), Illinois Natural History Survey
Adjunct Assistant Professor (1988-1989), University of Illinois, Department of Animal Sciences
Research Associate (1986-1987), Texas A&M University

SCIENTIFIC and PROFESSIONAL ORGANIZATIONS

American Association for the Advancement of Science
American Institute of Nutrition
American Oil Chemists' Society
International Association of Astacology
Society for Comparative Nutrition
Society for Integrative and Comparative Biology (formerly American Society of Zoologists)
World Aquaculture Society
Gamma Sigma Delta, Sigma Xi

SELECTED PUBLICATIONS

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

Riche, M., and P.B. Brown. 1996. Absorption of phosphorus from feedstuffs fed to rainbow trout. Aquaculture 142:269-282.

Tudor, K.W., R.R. Rosati, P.D. O'Rourke, Y.V. Wu, D. Sessa, and P.B. Brown. 1996. Technical and economical feasibility of on-farm fish feed production using fishmeal analogs. Aquacultural Engineering 15:53-65.

Riche, M., M.R. White, and P.B. Brown. 1995. Barium carbonate as an alternative indicator to chromic oxide for use in digestibility experiments with rainbow trout. Nutritional Research 15:1323-1331.

Brown, P.B. 1995. A review of nutritional research with crayfish. Journal of Shellfish Research 14:20-28.

Griffin, M.E., K.A. Wilson, M.R. White, and P.B. Brown. 1994. Dietary choline requirement of juvenile hybrid striped bass. Journal of Nutrition 124:1685-1689.

Brown, P.B., M.E. Griffin, and M.R. White. 1993. Experimental and practical diet evaluations with juvenile hybrid striped bass. Journal of the World Aquaculture Society 24:80-89.

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EDUCATION

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

POSITIONS

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

SCIENTIFIC and PROFESSIONAL ORGANIZATIONS

Editorial Board Member for Aquaculture and Aquatic Living Resources
Fisheries Society of British Isles
Japanese Fisheries Society
National Research Council, Washington, Subcommittee on Fish Nutrition (1990-1992)
World Aquaculture Society

SELECTED PUBLICATIONS

Matusiewicz, M., and K. Dabrowski. 1996. Utilization of the bone/liver alkaline phosphatase activity ratio in blood plasma as an indicator of ascorbate deficiency in salmonid fish. Proceedings of the Society for Experimental Biology and Medicine 212:44-51.

Matusiewicz, M., K. Dabrowski, L. Volker, and K. Matusiewicz. 1995. Ascorbate polyphosphate is a bioavailable vitamin C source in juvenile rainbow trout: Tissue saturation and compartmentalization model. Journal of Nutrition 125:3055-3061.

Ciereszko, A., and K. Dabrowski. 1994. Some biochemical constituents of fish semen: Relationship between semen quality and fertility changes. Fish Physiology and Biochemistry 12:357-367.

Matusiewicz, M., K. Dabrowski, L. Volker, and K. Matusiewicz. 1994. Regulation of saturation and depletion of ascorbic acid in rainbow trout. Journal of Nutritional Biochemistry 5:204-212.

Dabrowski, K., A. Ciereszko, L. Ramseyer, D. Culver, and P. Kestemont. 1994. Effects of hormonal treatment on induced spermiation and ovulation of yellow perch (*Perca flavescens*). Aquaculture 120:171-180.

Dabrowski, K., G. Krumschnabel, M. Paukku, and J. Labanoski. 1992. Cyclic growth and activity of pancreatic enzymes of Arctic charr (*Salvelinus alpinus* L.). Journal of Fish Biology 40:511-521.

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EDUCATION

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POSITIONS

Professor (1990-present), Associate Professor (1985-1990), and Assistant Professor (1980-1985), Department of Fisheries and Wildlife, Michigan State University

Aquaculture and Fisheries Extension Specialist (1985-present), Department of Fisheries and Wildlife, Michigan State University.

Assistant Professor of Fisheries Science (1976-1980), Department of Fisheries and Wildlife Sciences, Virginia Polytechnic Institute and State University

SCIENTIFIC and PROFESSIONAL ORGANIZATIONS

American Fisheries Society
Comparative Nutrition Society
World Aquaculture Society

SELECTED PUBLICATIONS

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

Cain, K.D., and D.L. Garling. 1995. Pretreatment of soy bean meal for salmonid diets with phytase to reduce phosphorus concentration in hatchery effluents. Progressive Fish Culturist 57:114-119.

Ramseyer, L.J., and D.L. Garling. 1994. Amino acid composition of the ovaries, muscle, and whole body of yellow perch (*Perca flavescens*). Progressive Fish-Culturist 56:175-179.

Belal, I.E., D.L. Garling, and H. Assem. 1992. Evaluation of practical tilapia feed using a saturation kinetic model. Comparative Biochemistry and Physiology 102A:785-790.

Dean, J.C., L.A. Nielsen, L.A. Helfrich, and D.L. Garling, Jr. 1992. Replacing fish meal with seafood processing wastes in channel catfish diets. Progressive Fish-Culturist 54:7-13.

Garling, D.L. 1992. Making plans for commercial aquaculture in the North Central Region. Fact Sheet #101. North Central Regional Aquaculture Center.

Garling, D.L. 1991. NCRAC research programs to enhance the potential of yellow perch aquaculture in the region. Pages 253-255 *in* Proceedings of the North Central Aquaculture Conference. Michigan Department of Natural Resources, Wolf Lake Fish Hatchery, Mattawan, Michigan.

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POSITIONS

Associate Professor of Fisheries and Wildlife (1995-present), Assistant Professor of Fisheries and Wildlife (1988-1995), University of Missouri-Columbia
Aquatic Ecologist (1985-1987), Battelle Memorial Institute
Research Associate (1980-1984), Aquatic Ecology Program, Ohio State University

SCIENTIFIC and PROFESSIONAL ORGANIZATIONS

American Fisheries Society
American Institute of Fishery Research Biologists
Missouri Chapter AFS

SELECTED PUBLICATIONS

Hayward, R.S., D.B. Noltie, and N. Wang. In press. Using compensatory growth for more than catching-up in hybrid sunfish. Transactions of the American Fisheries Society.

Hayward, R.S., and A. Arnold. 1996. Temperature-dependence of maximum daily consumption in white crappie: Implications for fisheries management. Transactions of the American Fisheries Society 126:60-68.

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Hayward, R.S., and F.J. Margraf. 1987. Eutrophication effects on prey size and food available to yellow perch in Lake Erie. Transactions of the American Fisheries Society 116:210-223.

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Ph.D. University of Wisconsin-Madison, 1985

POSITIONS

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SCIENTIFIC and PROFESSIONAL ORGANIZATIONS

American Association for the Advancement of Science
American Fisheries Society
Wisconsin Aquaculture Association
Wisconsin Aquaculture Industry Advisory Council
World Aquaculture Society

SELECTED PUBLICATIONS

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

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Malison, J.A., L.S. Procarione, J.A. Held, T.B. Kayes, and C.H. Amundson. 1993. The influence of triploidy and heat and hydrostatic pressure on the growth and reproductive development of juvenile yellow perch (*Perca flaverscens*). Aquaculture 116:121-133.

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Malison, J.A., and J.A. Held. 1992. Effects of fish size at harvest, initial stocking density, and tank lighting conditions on the habituation of pond-reared yellow perch (*Perca flaverscens*) to intensive culture conditions. Aquaculture 104:67-88.

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.