CULTURE TECHNOLOGY OF CENTRARCHIDS (SUNFISH)

Chairperson: Donald L. Garling, Michigan State University

Extension Liaisons: Fred P. Binkowski, University of Wisconsin-Milwaukee

Funding Request: $174,999

Duration: 2 Years (September 1, 1994 - August 31, 1996)

Objectives:

1. Produce a production manual, accompanying videos and other information as necessary to demonstrate the technology for culturing centrarchids.
2. Determine the major nutritional requirements for centrarchids and to compare their growth and performance using available commercial feeds in laboratory and field settings.
3. Determine the best feeding management strategies for culturing centrarchids in laboratory and field settings.

Proposed Budgets:

Institution	Principal Investigator(s)	Objec-tive(s)	Year 1	Year 2	Total
Univ. of Nebraska-Lincoln	Terrence B. Kayes	1	$5,650	$2,350	$8,000
Michigan State University	Donald L. Garling	1 & 2	$19,600	$21,400	$41,000
Southern Illinois University	Christopher C. Kohler	2	$15,000	$16,000	$31,000
Iowa State University	Joseph E. Morris	1 & 3	$21,331	$2,669	$24,000
Purdue University	Paul B. Brown	2	$20,000	$20,000	$40,000
University of Missouri - Columbia	Robert S. Hayward Douglas B. Noltie	3	$13,000	$0	$13,000
Univ. of Wisc. - Milwaukee	Fred P. Binkowski	3	$12,969	$5,030	$17,999
		TOTALS	**$107,550**	**$67,449**	**$174,999**

Non-funded Collaborators:

Facility	Collaborator(s)
Little Grassy Fish Hatchery, Carbondale, Illinois	Illinois Department of Conservation
Jim Frey Fish Hatchery, West Union, Iowa	Jim Frey
Kloubec Fish Farms, Amana, Iowa	Myron Kloubec
	Missouri Department of Conservation
National Fisheries Contaminant Research Lab	U.S. Fish and Wildlife Service
Spruce Creek Fish Farm, Minnesota	Ron Johnson
Red Lake Band Chippewa	Tribal Council

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JUSTIFICATION

Sunfish of the genera *Lepomis* and *Pomoxis* already have significant economic impact in the North Central Region. For example, 50.9% of the sportfish harvest in Illinois consists of these two genera (Baur 1988). The potential for marketing sunfish as food fish is considerable because of this popularity. As an example, Michigan consumers want locally produced, farm raised, fresh fish products (Chopak 1992a). Michigan brokers, wholesalers, retailers and restaurants listed the bluegill as one of the top three species that they would like to purchase for their customers (Chopak 1992b). Representatives of the Chicago Fish House, one of the major seafood suppliers in the Midwest, have indicated during North Central Regional Aquaculture Center (NCRAC) meetings a strong interest in obtaining an aquaculturally produced supply of sunfish because of their marketability. A June 1992 price quote from the Chicago Fish House (Bob Rubin, personal communication) of $4.41-5.51/kg ($2.00-2.50/lb) to producers for crappie indicates that sunfish are about double the value of the two major aquaculture species: rainbow trout and channel catfish. The significance of the market potential for sunfish has not been lost on others; tilapia have been marketed in parts of the Midwest through major retail outlets as "bluegill."

A number of factors make sunfish strong candidates for commercial food fish production in the Midwest. Sunfish broodstocks are easy for culturists to acquire in high numbers in contrast to species such as the walleye and striped bass. Even inexperienced culturists can readily spawn sunfish in ponds. *Lepomis* and *Pomoxis* sunfish are not inclined to be cannibalistic, unlike striped bass and walleye. A number of sunfish species and hybrids are known to readily accept pelleted feeds. Sunfish exhibit fast initial growth (see **PROGRESS TO DATE**) and grow at lower temperatures than channel catfish; an important characteristic for production in our region.

Investigations of F_1 male bluegill (*Lepomis macrochirus*) × female green sunfish (*L. cyanellus*) hybrids have been skewed toward the usefulness of this fish in traditional pond stocking programs. However, there is increasing interest in sunfish and their hybrids as a food fish and hence intensive aquaculture species. The bluegill × green sunfish (BG × GS) has several desirable attributes which make it a prime candidate for intensive aquaculture production. This hybrid readily accepts formulated feed (Lewis and Heidinger 1971a), exhibits rapid growth (Childers 1967; Ellison and Heidinger 1978), produces mostly males (Childers and Bennett 1961; Laarman 1973; Brunson and Robinette 1986), and exhibits reduced reproductive ability (Ricker 1948; Childers 1967).

Presently most fingerling hybrid sunfish producers do not feed prepared diets to thier fish, primarily relying on natural productivity. Brunson and Robinette (1986) supplementally fed BG × GS hybrids a channel catfish diet. Hybrids stocked alone did not grow better when supplementally fed versus nonfed hybrids. However, Lewis and Heidinger (1971a) supplementally fed BG × GS hybrids Purina Trout Chow[tm] and demonstrated that these hybrids had better growth and more catchable size fish at the end of the first year. This study suggests that the BG × GS hybrid may need a diet with higher protein. Diets formulated for channel catfish would be less expensive but are not suitable for the BG × GS hybrid (Tidwell et al. 1992).

Production Manual/Videos (Objective 1)

At the 1992 NCRAC Program Planning Meeting held February 14-16, in Columbus, Ohio, the NCRAC Industry Advisory Council (IAC) expressed a strong desire for the production of techniques-centered educational tools that can help fish farmers culture those species identified by NCRAC as having significant potential for commercial aquaculture. At the 1993 Program Planning Meeting held February 19-21, in Madison, Wisconsin, the NCRAC IAC specifically requested the development of extension educational materials in the form of a production manual and accompanying video tapes, as a high priority need for demonstrating the commercial feasibility of centrarchid sunfish aquaculture in the region. The proposed project addresses this stipulated priority need.

Nutritional Requirements (Objective 2)

The Industry Advisory Council of the North Central Regional Aquaculture Center identified development of feeds for centrarchids as a high priority objective. Therefore, this proposal will address quantification of the key nutritional requirements for centrarchids so that dietary development can proceed at a relatively rapid rate. The typical first studies in this line of research are protein and energy needs, maximum level of dietary lipid to supply the energy requirement (or more commonly expressed as the ratio of lipid to carbohydrate), and indispensable amino acid (IAA) and phosphorus requirements. The IAA requirements are currently being quantified at Purdue University (Purdue) in a separate project through NCRAC. Thus, this proposal will address the remaining high-priority nutritional studies and a field study using the information developed in this and previous proposals.

Since protein is often the most expensive feed component and since feeds represent a large portion of aquaculture operation costs, knowledge of the protein requirements of centrarchids will be of great benefit to the sunfish culture industry. The gross protein requirements will vary with size and age of fish, the environmental temperature and the composition of the diet. Gross protein requirements may be overestimated if inadequate consideration is given to indispensable amino acid (IAA) requirements, energy concentration of the diet, and digestibility of the dietary ingredients (Wilson 1989).

Phosphorus (P) is also one of the most important nutritional requirements for fish. It has become the focal point of a great deal of research interest in the past four years because of it's pollutional nature in fish farm effluents (see Culture Technology of Salmonids, this proposal, for a review of phosphorus) and is considered a limiting nutrient in fish diets that contain a high percentage of plant feedstuffs. High quality plant ingredients typically contain a high percentage of P in the form of phytin-P, which is not biologically available to fish (Riche and Brown 1993). If we are going to make high quality , yet low cost diets available to producers of centrarchids in the North Central region, we need to incorporate a higher percentage of plant protein feedstuffs in those diets. The ingredients are readily available in the region, but the dietary restrictions needed for maximum use of those ingredients is lacking.

Feeding Strategies (Objective 3)

Many centrarchids including, black crappie (*Pomoxis nigromaculatus*), and hybrid sunfish (F1 hybrid of male bluegill *Lepomis macrochirus* × female green sunfish *L. cyanellus*) have been recognized as marketable fishery products, but efforts toward developing intensive aquaculture techniques to meet this demand have not been adequately explored. Hybrid sunfish have been used in fisheries management where limited reproduction is desired (Childers and Bennett 1961; Childers 1967; Ellison and Heidinger 1976). Hybrid sunfish also have been noted to have greater growth during cold temperatures than bluegill (Brunson and Robinette 1986) and channel catfish (Heidinger 1975), a definite advantage in the North Central Region.

One possible means of increasing aquaculture production at low or reduced costs involves eliciting the compensatory growth response in the species under culture. Growth compensation is manifested in animals as the elevation in growth rate that occurs when food is resupplied following a period of food deprivation. Studies of this phenomenon in traditional agriculture species suggest that it is a complex physiological response involving hyperphagia, reduced standard rates of metabolism, and reduced costs of assimilating ingested food (Greeff et al. 1986; Mersmann et al. 1987; Williams and Sheedy 1987; Miglavs and Jobling 1989). The improvements in growth potential associated with the higher observed levels of food intake, coupled with lower energy costs, lead to accelerated growth rates and higher production: consumption ratios (Miglavs and Jobling 1989; Quinton and Blake 1990; Russell and Wootton 1992). While growth compensation has been observed to occur in fishes (Wootton 1990), application of this concept to aquaculture has been limited.

RELATED CURRENT AND PREVIOUS WORK

Production Manual/Videos (Objective 1)

While much is known about the life histories and basic biology of centrarchid sunfishes and their management in lakes and recreational fishing ponds (Bennet 1970; McClarney 1984; Brunson and Robinette 1986), little research-based information exist on their culture, particularly beyond the fingerling size for stocking (Davis 1956; Snow 1964; Dupree and Huner 1984; Simco et al. 1986; Engelhart and McCarty 1990). With some notable exceptions (Lewis and Heidinger 1971a; Brunson and Robinette 1982), most of the information on sunfish culture, particularly beyond fingerling size or by intensive methods, has been experimental or anecdotal in nature and has been summarized primarily in certain standard reference books, trade magazines, and the "gray literature" (see above references and Lewis and Heidinger 1971b, Bardach et al. 1972, Lewis 1981). Until the establishment of the NCRAC Centrarchid Work Group in 1990, remarkably little controlled research had ben done on intensive sunfish aquaculture. Few extension oriented materials are available on production of these fishes for recreational fish stocking (Engelhardt and McCarty 1990; Texas Aquaculture Association, 1988 see Publication numbers AO301 through AO308) or as forage species (Higginbotham 1988a,b,c).

Nutritional Requirements (Objective 2)

Very little is known about the nutritional requirements of centrarchids. Anderson and co-workers (1981) fed 0 and I year largemouth (*Micropterus salmoides*) and smallmouth (*M. dolomieui*) bass semi-purified diets containing gelatin and fish protein concentrate as the protein source. They found that the protein requirement of largemouth and smallmouth bass was 40 and 45 percent of the diet, respectively. Tidwell and co-workers (1992) evaluated the protein requirements of 4.7 gm green BG × GS hybrids using practical feeds. They found that the highest protein diet used in their study (37%) produced significantly greater growth than diets with lower protein levels. Both studies were conducted using essentially isocaloric feeds at one energy level. Since energy levels significantly affect the protein requirements (for review see Wilson 1989), these protein levels may be under or over estimates of the fishes' true protein requirements. A commercial lab determined the whole body amino acid content of the hybrid sunfish used in studies by Tidwell and co-workers (1992). Unfortunately, insufficient information on methodology was presented to determine the usefulness of the measurements of the amino acids cystine, methionine, and tryptophan.

While the total dietary energy concentration of fish diets (most often expressed as a ratio with dietary protein) is critical in practical formulations, the maximum amount of dietary lipid that can be incorporated into diets to satisfy the energy needs is also an important piece of information. Lipid serves as a concentrated source of dietary energy. Practical diets for many species, particularly new aquaculture species, are formulated with a desired level of dietary crude protein and a maximum level of dietary lipid, instead of total energy. Clearly, this is not the case with channel catfish and rainbow trout diets because sufficient nutritional information exists that will allow formulation based on total energy. For example, it is important to know the energy needs, the ability of the target fish to use various ratios of lipid and carbohydrate and their ability to digest and absorb those nutrients. Those data are available for catfish and trout, but no data of this nature exist for centrarchids. A logical initial dietary formulation, therefore, would be based on dietary protein and lipid and allow carbohydrate to "float" or not restrict that component in the diets.

The IAA requirements of fish have been estimated using the IAA composition of the whole fish, muscle, egg and other tissues as a guide (Arai 1981; Ketola 1982; Cowey and Luquet 1983; Ostrowski and Divakaran 1989; Ramseyer and Garling 1994). A strong correlation has been found between whole fish IAA patterns and dietary requirements determined in dose/response studies (Wilson and Poe 1985; Gatlin 1987; Brown 1993). Moon and Gatlin (1991) found that the sulphur AA requirement determined for red drum in a dose/response experiment was 3.03% of the dietary protein. This was very similar to the requirement predicted (2.9% dietary protein) by the A/E ratio [(individual IAA content/total IAA content+Cys+Tyr) x 1000] of red drum muscle when the lysine requirement was known. Similarly, Griffin et al. (In press) found that the dietary total sulfur amino acid requirement for juvenile hybrid striped bass was 0.68-0.73% of the dry diet (in diets containing 35% crude protein) when based on dose/response studies and was 0.75% of the dry diet when predicted based on whole body analysis and a quantitative lysine requirement.

The importance of the ratio of protein to energy (P/E) has been demonstrated in many species of fishes. Garling and Wilson (1976) used a sufficient number of diets to demonstrate that an optimum P/E ratio could be determined for fishes and that estimates of the protein requirement may be over- or under- estimated unless determined over a range of dietary protein and energy levels.

The metabolizable energy (ME) of semi-purified and practical fish feed ingredients has been quantitatively determined for only a few fishes (Smith 1989). However, ME values have been estimated for many species of fish using standard (Garling and Wilson 1976, Zeitoun et al. 1973, El-Sayed and Garling 1988) or modified (Phillips 1972, and others, see Smith 1989) physiological fuel values (PFV). Investigators have modified PFV, primarily to account for differences in the use of proteins and carbohydrates as the preferred starting points for glycolysis. Carbohydrates and lipids have been shown to spare protein in many fish species (Wilson 1989).

Feeding Strategies (Objective 3)

<u>Culture of Larval Sunfish</u>
Methods of centrarchid production rely on extensive pond production techniques (Snow 1975; Simco et al. 1986; Willis and Flickinger 1980). To intensify sunfish production to levels beneficial to commercial production for human consumption supplemental feeding of formulated diets will be necessary. Habituation of larger juveniles and adult centrarchids to commercial diets has been investigated to some extent and appears feasible; further improvements and specialized diets for sunfish are needed. The most problematic barrier for divorcing sunfish production from pond techniques remains in the critical first-feeding fry stage.
Because of the small size of these larvae, acceptable and nutritionally adequate diet formulation are not yet available for these early stages (<25 mm TL). Attempts at intensive feeding have concentrated on training the larval black basses to accept formulated diets (Anderson 1974; Flickinger et al. 1975; Snow 1975; Brandenburg et al. 1979; Willis and Flickinger 1981; Brandt et al. 1987; Loushin and Rushing 1989; Wickstrom and Applegate 1989), following initial feeding in ponds on zooplankton.

The problem still remains of bridging the period from depletion of the yolk sac through sizes large enough to accept substitute live or formulated feeds. This problem with larval centrarchid feeding is common to a wide variety of small-sized spiny-rayed fish. Small-sized organisms like cyclopoid copepoda nauplii and rotifers are initial foods of black bass (Wickstrom and Applegate 1989), crappies (Siefert 1968), yellow perch (Schael et al. 1991) and many other spiny-rayed fish larvae.

Smith (1976) found that a high percentage of bluegill larvae survived when fed a small San Francisco brine shrimp (*Artemia franciscana*) that averaged 394 µm in length as the first exogenous food source. However, Iowa State University (ISU) researchers attempt at duplicating this study using *A. franciscana* that averaged

401 µm produced zero survival. Coyle et al. (1993) also noted low bluegill survival when offered only brine shrimp nauplii upon initiation of exogenous feeding.

Toetz (1966) stated that the mouth gape of bluegill upon initiation of exogenous feeding was 230-270 µm, reaching 330 µm by day 9 post-hatch. He stated that brine shrimp (unknown species) average 470 µm and, therefore, could not serve as appropriate first food for larval bluegill. Siefert (1972) reported the first food of bluegill (5.0-5.9 mm TL) from Grave Lake, MN consisted of the rotifer *Polyartha* spp. and copepoda nauplii, both typically measure less than 200 µm (Thorp and Covich 1991). Similarly, the first exogenous prey selected by wild bluegill larvae (4.5-5.5 mm TL) from Lake Opinicon, Ontario did not exceed 280 µm and 90% did not exceed 140 µm (Keast 1980). Thus, it is clear that brine shrimp nauplii are often too large to be an appropriate first food item for larval bluegill.

In connection with experimental production of yellow perch and other small-sized fish larvae for experimental purposes, University of Wisconsin-Milwaukee (UW-Milwaukee) personnel have repeatedly employed batch cultures ("green tank") of live infusoria, brine shrimp nauplii and ground beef heart and liver to bridge early feeding stages. Over the last 5-7 years they have used and refined these techniques with yellow perch (*Perca flavescens*), to habituate intensively reared fingerlings to formulated starter diets. Perch can be habituated from live rearing foods to formulated starter diets in as little as 30 days post first feeding, and starter diet habituated fry can be produced at levels between 2,000 - 6,000 fry/m^3 of rearing volume.

UW-Milwaukee personnel propose to apply their larval perch feeding technology to the intensive production of black crappie fry to achieve the earliest possible habituation to formulated starter diets.

Growth Compensation

Studies of compensatory growth in traditional agriculture animals have historically used a single protracted period of food deprivation to activate the compensatory growth response, with the length of time in growth compensation usually being directly related to the length of the food deprivation period (Norman 1966; Benet et al. 1970; Thornton et al. 1979; Weiser et al. 1992). In practice, however, single episodes of food deprivation have resulted in a rapid growth phase that often decays too quickly to produce benefits that are significantly greater than the results shown by animals fed continuously on standard rations. In addition, the benefits from eliciting the growth compensation response this way appear to differ substantially among animal species. As such, relatively few species are reared routinely in this fashion.

While being a subject of interest in terrestrial agriculture, growth compensation has received little attention in relation to aquaculture. Most studies of growth compensation in fishes have been ecological in nature (Pedersen et al. 1990; Patoureau 1991; Russell and Wootton 1992) and have sought to understand how fish respond to periodic food scarcity in natural environments. The relatively few studies that have explored the potential benefits of growth compensation for aquaculture have employed experimental designs similar to those used historically in traditional agriculture, involving a single, protracted period of food deprivation followed by a period of feeding to excess (e.g., Miglavs and Jobling 1989). The results from these studies, like those from typical agriculture species, reveal that an acceleration in growth also occurs in fishes but that the benefits over continuous, normal feeding levels are again not striking.

If a way could be found to extend the duration of the growth compensation response in fishes, significant benefits to aquaculture could be anticipated. Recent work in the University of Missouri-Columbia (UM-Columbia) laboratory using white crappie, *Pomoxis annularis*, suggests that the relative amount of time fish spend in growth compensation (TGC) can be extended relative to the time of food deprivation (TFD) when the food deprivation periods are shortened relative to those used in past agriculture and aquaculture studies. Six to eight days of hyperphagia (indicating a compensatory growth state) have been observed to follow starvation periods of only three days. This ratio of time in growth compensation (TGC) to time of food deprivation (TFD), in excess of 2, appears much higher than TGC:TFD ratios associated with long food deprivation periods (e.g., Miglavs and Jobling 1989, where a 49-day food deprivation period yielded TGC/TFD<1 in Arctic charr *Salvelinus alpinus*). Moreover, the UM-Columbia study indicated that these relatively high ratios of TGC/TFD could be sustained over successive cycles of 3 days deprivation:6-8 days of hyperphagia. These results suggest that increased total growth and higher food conversion efficiencies might be attained in aquaculture operations by using repeated short cycles of food deprivation and ad libitum feeding to extend the relative duration of the growth compensation response.

Also, fish are known to exhibit substantial variation in their food consumption within and across days even when exposed to rather constant water quality and food availability (Smagula and Adelman 1982; Alanara 1992). This variability in feeding rates presents a problem for fish culturalists because rates which deviate from the rates at which food is provided, result in underfeeding and food wastage. Either situation may lower food conversion efficiency, and such food wastage is not economically desirable and can reduce effluent water quality. A satisfactory ability to predict short-term changes in food demand by fishes has not been developed (Alanara 1992). Previous work in the UM-Columbia lab with white crappie showed some evidence of more predictable day-to-day feeding patterns when fish were fed on a schedule that induced growth compensation versus being fed continuously to excess.

ANTICIPATED BENEFITS

North Central Region consumers and marketers, as indicated in a Michigan survey, want locally produced, farm raised, fresh fish products (Chopak 1992a). Additionally, fish marketers listed the bluegill as one of the top three species that they would like to purchase for their customers (Chopak 1992b). A Sunfish Production Manual and accompanying videos for the North Central Region will provide research based materials for informtion transfer to commercial producers and individuals interested in production of sunfish as a food fish to meet these market demands.

This research project will address quanitification of the key nutritional requirements for centrarchids so that dietary development can proceed at a relatively rapid rate. Since protein is often the most expensive feed component and since feeds represent a large portion of aquaculture operation costs, knowledge of the protein requirements of centrarchids will be of great benefit to the sunfish culture industry. Results from this study will be used to make high quality, yet low cost diets available to producers of centrarchids in the North Central region using a higher percentage of plant protein feedstuffs. The ingredients are readily available in the region, but the dietary restrictions needed for maximum use of those ingredients is lacking.

This project would transfer feeding strategies for "intensive" rearing of larval fish that have been successfully used on other small sized larvae, to use on sunfishes. This project will provide guidelines on appropriate sizes, and timing of feeding for aquaculturists who are desirous of intensifying centrarchid culture for human food production, through earlier habituation to formulated feeds, replacing or supplementing natural food production. These techniques will expand control over a portion of the life cycle which is currently limited to natural climatic cycles in ponds. Removal of this limitation would enable culturists to rear "out of season" batches of centrarchid fingerlings from egg if brood stock spawning manipulations can be employed.

In addition, developing an easily-applied low-cost/cost-saving technique that both increases growth rates and improves food conversion efficiency in these fishes would clearly be beneficial to aquaculture. While such a procedure would potentially benefit producers of all sizes, small-scale rural operators would be the most likely to profit because of their typically limited operations budgets. Advances of this type could serve as catalysts to significantly increase fish production from small-scale fish farmers in the United States.

An additional benefit that may be associated with feeding strategies that invoke the compensatory growth mode, is an increase in the predictability of the amounts of food that fish will consume from day to day. An improved capacity to predict short-term changes in daily food demand would result in less food wastage and, in turn, would improve conversion efficiencies as well as effluent water quality.

PROGRESS TO DATE

The initial centrarchid culture technology project sought to control sunfish reproduction through selective breeding and chromosome manipulation and to determine optimum rearing conditions for various sunfish and their hybrids. Modifications of techniques used to manipulate ploidy in other groups of fish were evaluated to develop optimal means of controlling sex determination and producing sterile sunfish. These evaluations are still in progress.

The techniques used involved the application of temperature or pressure "shocks" to induce the retention in the developing eggs of additional sets of chromosomes that would normally be split off with the polar bodies during the process of oogenesis.

In 1990 Michigan State University (MSU) produced the first verified triploid bluegills through temperature shock induced polar body retention. The MSU workers also improved on the rearing time required before treated fish could be evaluated for ploidy level by devising a technique that uses 5-7 day old larvae rather than 3 month old fish. In 1992 a protocol for testing larval fish for ploidy was prepared. In addition, a Master's thesis describing the development of the fertilized bluegill egg was prepared. This information will assist researchers in determining optimum times for the application of shocks for production of polyploids. Pressure shock induction techniques have been extended to commercial sunfish producers.

Southern Illinois University-Carbondale (SIUC) workers in 1990 compared pressure and temperature shocking techniques for the production of triploid hybrid sunfish (bluegill female; green sunfish male). They found that hydrostatic pressure shocks were superior. One hundred percent triploids were produced at several pressure levels with good survival and no deformed individuals. Also at SIU, irradiated sperm has been used to fertilize bluegill eggs. Half of these eggs were treated normally and the other half were subjected to pressure shock to induce polar body retention. These treatments are intended to produce fish with exclusively the female genetic complement. The pressure shocked individuals (putative diploid gynogens) showed higher survival and far fewer abnormalities, and several hundred lived long enough to be stocked in a pond at SIU. When these fish can be reliably sexed in the coming year, if they are all females, it will prove that the sex of bluegills is determined by an XY type chromosomal system.

In 1992, researchers at SIU refined the technique of using pressure shocks to produce triploid hybrid sunfish. They recommend subjecting the fertilized eggs to a pressure of 48,264 kPa (7000 psi) for 4 minutes with the shock initiated 2 minutes after fertilization. Using this protocol they have produced 100% triploids with an actual survival of 30%. The survival rate of the shocked fish was higher than the survival of the unshocked control eggs produced from the same pairing of male and female fish. MSU researchers have also determined that pressure shocks will reliably produce triploid bluegill and have abandoned temperature shocks for the production of triploids. They were able to produce 100% triploidy in bluegill subjected to pressure treatments of 55,158 kPa (8000 psi) for 5 minutes begun 1.5 minutes after fertilization.

Investigators at MSU have also produced the first tetraploid bluegills using cold shock. Tetraploids mated with normal diploid bluegill should absolutely insure 100% sterile triploid offspring. Their results from 1992 suggest that pressure may not be a suitable shock for the production of tetraploids. They have so far achieved 10% tetraploid production using cold shocks.

In 1991 and 1992 work began on evaluating the production characteristics of sunfish. SIU researchers evaluated densities for cage culture of hybrid sunfish (bluegill male × green sunfish female). They are now recommending that culturists stock cages at densities of less than 400 fish/m^3. In 1992 this same hybrid was evaluated in earthen ponds. Although this work is continuing through the end of the growing season, the results of the recent samples suggest that densities of at least 370 fish/ha may be needed to stimulate feeding behavior on practical feeds in these fish.

Investigators at SIU also determined the effects of temperature on the growth and feed conversion of bluegill, green sunfish, their hybrid, and their triploid hybrid (2n bluegill; 1n green sunfish). Their results show that the bluegill, green sunfish and the hybrid have a linear increase in growth rate over the range of 8-23°C and that the best food conversion occurs at 18°C.

The methodology developed for the triploid production of sunfish will benefit those producers who wish to control reproduction in culture ponds. Although analysis is incomplete, the triploid sunfish should be functionally sterile, preventing much of the fishes' energy from being diverted to the production of gonadal products.

If tetraploid bluegill stocks can be produced and raised to maturity using improved cold or pressure techniques, the tetraploid × diploid cross may be used to effectively and economically produce triploids in the future. Other researchers have shown that this cross will produce triploids with higher survival and better overall performance than triploids produced directly by shocks. If tetraploids could be raised to sexual maturity, brood stocks of tetraploids and diploids could be maintained in ponds or at hatcheries. Triploids could be produced from the tetraploid × diploid cross as needed with much less expenditures of time and money.

Based on the results of work that has been completed, a recommendation to producers is to stock culture cages at densities less than 400 fish/m^3. Recommendations on stocking density, anticipated growth rate, and anticipated feed conversion over a range of temperature for the hybrid sunfish and the triploid hybrid sunfish will be developed as part of this project.

OBJECTIVES

1. Produce a production manual, accompanying videos and other information as necessary to demonstrate the technology for culturing centrarchids.

2. Determine the major nutritional requirements for centrarchids and to compare their growth and performance using available commercial feeds in laboratory and field settings.

3. Determine the best feeding management strategies for culturing centrarchids in laboratory and field settings.

PROCEDURES

Production Manual/Videos (Objective 1)

The development of educational materials on the aquaculture production of centrarchid sunfish will be done collaboratively by Joseph E. Morris of ISU, Donald L. Garling of MSU, and Terrence B. Kayes of the University of Nebraska-Lincoln (UN-L), working with other appropriate members of the NCRAC Centrarchid Work Group and cooperating fish farmers with demonstrated experience in culturing sunfish. All three principal collaborators have extension appointments at their respective institutions and are members of the NCRAC Extension Work Group.

Morris and Garling will be primarily responsible for the collection of information and development of a centrarchid sunfish production manual. The manual will consist of a collection of newly developed extension fact sheets and bulletins organized in a three-ring binder so that updates and supplemental information can be added. The text will be well illustrated with photographs, diagrams, charts and tables.

The principal topic areas of responsibility of each of the lead authors will be as presented in the table on the next page.

Topics may be added or deleted through action of the writing committee. Materials will be distributed through the North Central Regional Extension network contacts.

Terry Kayes will coordinate the development of two educational video tapes which will expand on selected topics in the manual that will particularly benefit from audio-video demonstrations of practical procedures or highly specialized techniques. Each video tape will have a duration of 10-20 min; be produced primarily for use in a workshop or classroom setting, or for library loan; and will complement appropriate printed materials in the production manual. The video tapes will be scripted by Kayes, working collaboratively with Morris, Garling or other members of the Centrarchid Work Group as appropriate, as well as with an assigned professional video tape producer of the UN-L Institute of Agriculture and Natural Resources Communications and Computing Services.

Present plans are to do about 70% of the video taping in the first year of the project and about 30% early in the second year. Editing any necessary video graphics and final copying of video tapes for distribution will be completed in the second year. The first video tape will focus on taxonomic identification, sex determination, and differentiating between purebred and hybrid bluegill and green sunfish. The second video tape will demonstrate procedures for artificially propagating bluegill and green sunfish, and various protocols for producing chromosomal triploidy and tetraploidy in these species and/or their hybrids. Practical techniques for verifying ploidy status will also be described. The various procedures will be video taped at the research facilities of SIUC, ISU, MSU, or at cooperating fish farms. Editing and final production of the video tapes will be done at the UN-L.

Extension Specialist	Topic Areas
Joe Morris (ISU)	Historical background and technical literature review Early life history Culture methods Brood Stock Management -field collection methods -species and sex determinations -management -hormonal injections (pending INAD approval) Intensive culture of fry and fingerlings -feeding strategies Hybridization Water temperature Influences on Survival and Growth Contacts for additional information Industry Status
Don Garling (MSU)	Induction of triploidy and tetraploidy Fee fishing -facilities development -pond management -marketing fee fishing operations Fish Health -common sunfish diseases and parasites -list of approved and "low regulatory priority" chemicals -disease treatment methods and calculations

Nutritional Requirements (Objective 2)

Optimum protein/energy levels will be determined at MSU for hybrid sunfish (female green sunfish × male bluegill sunfish) and bluegill sunfish. Both 50 mm and 125 mm initial length fish will be tested if sufficient numbers of the larger fishes can be obtained commercially. Additional studies may be conducted on triploid sunfish or hybrid redear sunfish (female green sunfish × male redear sunfish) if sufficient numbers can be produced or obtained commercially.

IAA values for whole body and muscle tissue will be determined for approximately 50 and 125 mm fish (five males and five females for each species) from samples obtained from fish farms in the early spring. Samples will be freeze-dried and pulverized, then hydrolyzed with 6N HCL for 18 hours. Free amino acids will be derivatized with phenylisothiocyanate before analysis with a reversed phase C^{18} HPLC column utilizing the Waters liquid chromatography system (Waters 1986). Cystine will be converted to cysteic acid and methionine to methionine sulfone. Crude protein content will be determined for each sample according to Harris (1970). Tryptophan will be determined separately.

Test feeds will be formulated using semi-purified ingredients. A combination of casein, gelatin, and purified amino acids will be used to balance IAA levels for each species, based on studies outlined above, and to establish varying protein levels. ME will be estimated using physiological fuel values. Nutritionally complete vitamin and mineral premixes will be used in all diets. Test feeds will be fed to groups of fish to determine acceptance. If test feeds are not accepted, fish protein concentrate or fish oils will be added to the diets to improve acceptance. Fish will be fed twice daily on a percent of body wet weight basis. Actual percentages will be determined based on seperate preliminary trials to determine the amount of the different feeds consumed. Fish will be weighed every two weeks to adjust the amount of feed fed.

Initially, an open formula commercial feed and four isocaloric diets with varying levels of protein will be fed for 10 to 12 weeks to establish an optimum P/E ratio. A second set of experiments will be completed with varying levels of protein at the optimum P/E ratio to determine the optimum protein level. The open formula commercial feed and the semi-purified diet producing the best growth and performance in the first experiment will be fed in the second experiment as reference feeds.

All feeding trials conducted at MSU will be in the Fish Culture Research Laboratory in 150-L rectangular or 360-L semi-oval tanks filled to approximately 100 or 200 L, respectively. The culture tanks will be supplied with well water (initial temperature 12.5 ± 1°C) heated to 18 ± 1°C. Heated water will be passed through a packed column to remove excess nitrogen and establish appropriate levels of oxygen (> 7 mg/L). Flow rates for the single pass, flow through system will be adjusted to maintain six exchanges per day.

Feeds will be evaluated based on growth (weight) and performance (feed conversion, protein efficiency ratio) and changes in body composition. Proximate analysis of feeds and fish will be determined using standard AOAC (1990) methods. Data will be analyzed using one-way Analysis of Variance (ANOVA) on all growth and whole body composition data to determine if differences observed between fish fed different diets are statistically significant. Duncans/Newman-Keuls test ($p = 0.05$) will be conducted as a multiple comparison on all growth data for all experiments to identify the treatments that differed from one another (Gill 1978).

Studies at Purdue will be continuations of a current NCRAC project designed to identify the optimal dietary concentrations of IAA. Those data will be transferred to colleagues at MSU for formulation of diets for the determining the optimum P:E ratio. Additional studies conducted at Purdue will be determination of the phosphorus requirement and the optimum ratio of lipid to carbohydrate given an optimum P:E ratio from colleagues at MSU.

Both studies will be conducted with similar protocols that have been used with hybrid bluegill at Purdue. Juvenile fish will either be obtained from a private producer (Clear Creek Fisheries, Martinsville, IN) or spawned in the laboratory. Fish from Clear Creek have been obtained for the past three years and, based on sex ratio, appear to be good-quality hybrids. Purdue researchers are currently holding bluegill, green and redear sunfish broodstock and will attempt to spawn those prior to initiation of these studies. Juvenile hybrid bluegill will be randomly stocked into 40-L glass aquaria in groups of 10-15 depending on initial size and acclimated to standard laboratory conditions prior to initiation of the experiments.

Diets will be randomly assigned to triplicate groups of fish in each study. Initial feed rate will be 4% of body weight per day and that rate will decrease as fish get larger. This feed rate has been used at Purdue in other studies with hybrid bluegill. All replicates will be weighed every two weeks and feed rates adjusted according to weights of fish in each tank. Both studies will be conducted for a minimum of ten weeks.

Water quality parameters will be monitored on a regular basis. Ammonia-nitrogen, nitrite-nitrogen, temperature, and dissolved oxygen will be monitored daily. Temperature will be maintained at 24°C throughout the study.

Diets in the first year of this project (phosphorus requirement) will be formulated to contain 35% crude protein and the IAA pattern of whole fish. The dietary lysine requirement should be completed by the time these studies start and predicted values will be used for other IAAs (Brown 1993). Corn gluten meal will be used as the primary source of crude protein and supplemental crystalline amino acid will be incorporated as needed to achieve the desired IAA pattern. Carbohydrate will be supplied by dextrin and a nutritionally complete vitamin premix will be added to each diet. A P-free mineral premix will be formulated (Robinson et al. 1987) and added to each diet. This formulation approach should provide a basal level of total dietary P of 0.3%, which is below most dietary requirements for P in fish. Lipid will be supplied by fish oil incorporated at a level of 8-10% of the dry diet.

Diets in the second year of this project (optimum ratio of lipid to carbohydrate) will be formulated based on the results from colleagues at MSU. Using the optimum P:E ratio, experimental diets will be formulated with varying ratios of lipid to carbohydrate using fish oil and dextrin as the energy sources. While it is difficult to predict those levels, we anticipate using values well below and above the optimum so that treatment effects will become apparent during the course of the study. We anticipate using corn gluten meal as the dietary protein source in the second year, but may use purified ingredients based on current research at Purdue and results from MSU during the first year of this study. Nutritionally complete vitamin and mineral premixes will be used in all diets.

Response parameters in each study will be weight gain, feed conversion ratio and survival. Additionally, adequacy of dietary P levels in meeting the requirement will be assessed by bone and scale mineral content using standard methods for P, calcium and magnesium (Robinson et al. 1987). Adequacy of dietary lipid:carbohydrate ratios will be assessed by whole body proximate composition, Hepatosomatic Index, and liver glycogen of samples of fish from each replicate (AOAC 1990).

Data from each year will be statistically analyzed as a one-way analysis of variance ($p = 0.05$). If significant differences are observed, Duncan's Multiple Range Test will be used to distinguish differences among treatment means.

SIUC will conduct field trials with at least four practical diets. The practical diets will be formulated in consultation with Paul Brown (Purdue) and Don Garling (MSU), and will be based on results from their initial studies. The experimental diets will be extruded as 0.32 cm (1/8-inch) kibbles by Farmland Industries, Inc., Kansas City, Missouri. Feed from the same lots will be provided to Brown and Garling for use in laboratory studies. Prior to the field study, a preliminary tank study will be conducted at SIUC to determine an appropriate stocking density. Approximately 25-g bluegill will be stocked in quadruplicated 0.1-hectare earthen ponds. Studies will be conducted for 120 days. In Year 2, further refinements in the formulation of practical diets will be made based on results from the first year studies. Field trials will be conducted in Year 2 in a manner similar to the previous year.

Feeding Strategies (Objective 3)

<u>Culture of Larval Sunfish</u>
Although ISU will be funded for objective 3 for only one year (1994), they will start their project in 1993 using bluegill larvae. In 1994, ISU will repeat the project using hybrid sunfish larvae. In 1993, hybrid sunfish will be cultured in cages in association with a private fish farmer in northeastern Iowa, Jim Frey (West Union, IA). Three 1-m^3 round cages will be used to culture hybrid sunfish using commercially available diets (two diets will be investigated).

Brood stock acquisition and preparation -- ISU will either use bluegill and green sunfish broodfish that are already in our laboratory or collect them from local ponds just before the natural spawning season of 1994. ISU currently has approximately 60 bluegill broodfish in the lab that have been sexed and are actively feeding on commercial fish diets. Additional sources for bluegill and green sunfish broodfish are numerous private fish producers that have already been contacted.

Spawning -- ISU will use six 1000-L round tanks to hold the broodfish. Each tank will have two males and four females. Water temperatures will be maintained at 22°C and the photoperiod will be 16L:8D (Banner and Hyatt 1975) . The photoperiod will be maintained through the use of a lighting-control device that simulates sunrise and sunset (Manci et al. 1992). Nests will be made by cutting the bottoms off of 10.5-L plastic buckets, covering the bottoms and 3-cm high sides with silicone caulk and pressing pea-gravel into the caulk. Males will be allowed to defend and aerate fertilized eggs for 12-24 h after which the nest will be removed (eggs adhere to the gravel) and placed into an aerated 37-L aquarium.

If the fish refuse to spawn naturally in artificial nests, mature fish will be hand stripped into petri dishes containing enough water to allow mixing of eggs and milt (Childers and Bennett 1961; Childers 1967). These fertilized eggs will then be placed into an aerated 37-L aquarium.

First feeding trials -- at 4-d post-hatch, yolk-sac fry will be siphoned out of the nest and placed into each of three 114-L larval rearing chambers. Fish will be maintained at approximately 25°C, preferred temperature for growth by bluegill (Beitinger and Magnuson 1979). Fish will be cultured using two different methods. The first method will be to use a diet regime consisting of rotifers, mainly *Brachionus* spp., that have consumed a green algae, mainly *Chlorella* spp. As soon as the fry are large enough (typically 9-d post-hatch), brine shrimp nauplii will be substituted with starter diets being used later.

The second rearing method will be to feed only artificial diets to larval fish. ISU personnel have designed a larval rearing chamber; their design allows the feed to remain in suspension for approximately 15-minutes. Automatic feeders (Sweeny model AF6, Sweeny Enterprises, Inc., Boerne, TX) will be used to feed fish on a regular basis. Commercially available larval diets, such as Artificial Plankton Microcapsules®(AP) (Argent Chemical Industries, Redmond, VA) and diets produced by BioKyowa, Inc. (Chesterfield, MO) will be used in the study. Three larval rearing chambers will be used for each diet (a total of three diets) for direct statistical comparisons. As with the first method, starter diets will be substituted for these larval diets, as soon as they are accepted by the fry.

During the trials, which will be run for 6-8 weeks, subsamples of 30-50 larvae will be measured and weighed weekly from each rearing unit to observe growth and condition. Survival during the trial from hatch through habituation to formulated starter diet will be reconstructed based on counts of mortalities screened from the material siphoned from the rearing units daily and fixed in buffered 10% formalin for later sorting and counting. As soon as fry are fully habituated to a formulated starter diet, a complete count of the fish in each rearing unit will be made and numbers/m^3 of habituated fry calculated. Water quality will be monitored on a regular basis (ammonia-nitrogen, nitrate-nitrogen, temperature, dissolved oxygen, and total phosphorus).

ISU personnel have had past success in spawning and rearing bluegill using the previously described larval rearing chambers (52-80% survival). The continued success using these techniques should be of assistance to private fish producers.

UW-Milwaukee will use either black crappie broodfish collected form the field just before or during the natural spawning season of 1995 and/or broodfish collected previously and over-wintered in the Aquaculture Institute - University of Wisconsin Great Lakes Research Facility.

UW-Milwaukee currently cooperates with the Red Lake Band Chippewa who are a potential source of these broodfish in addition to possible wild collection from local Wisconsin populations. Potential sources of broodfish would also be explored through other work group cooperators or private producers.

Spawning -- spawning will be attempted using small groups of broodfish in large circular fiberglass tanks. A combination of elevated water temperature and extended photoperiod (West and Hester 1966; Kaya and Hasler 1972) will be used to induce gonadal maturation and spawning in the laboratory. Spawning will be performed either by allowing it to take place over spawning substrates or by manual stripping techniques (West and Hester 1966; Merriner 1971).

First feeding trials -- fry will be incubated and hatched in the lab and set up in replicated experimental rearing groups of several hundred to several thousand fry per tank. At first feeding, green tank water will be offered from cultures prepared several weeks to a month prior to hatching. As soon as the larvae are big enough, brine shrimp nauplii would be substituted for green tank organisms, followed in succession by non-living foods. Ground beef heart and liver would be used as a transitional training tool to habituate the larvae to accept non-living and firmer-formulated feeds.

The duration of each of these transitional foods in this habituation process for black crappie will probably differ slightly from that used with yellow perch due to differences in development and morphology. The timing of the transitions will be adjusted to these differences based on daily observation of feeding behavior. During the trials, which will be run for 6-8 weeks, subsamples of 30-50 larvae will be measured and weighed weekly from each rearing unit to observe growth, gut content fullness, swim bladder inflation and the incidence of gross spinal deformation (which was observed in some groups of yellow perch reared with these techniques).

Survival during the trial from hatch through habituation to formulated diet will be reconstructed based on counts of mortalities which will be screened from the material siphoned from the rearing units daily and fixed in 10% buffered formalin for later sorting and counting.

As soon as fry are fully habituated to formulated starter diet, a complete count of the fish in each rearing unit will be made and numbers/m^3 of habituated fry produced will be determined for comparison to production of yellow perch fry using this technique.

In the 1995 trials, the duration of the transitions between successive foods would be overlapped broadly in an effort to insure better survival.

The trials would be repeated in the 1996 season adjusting the feeding transition more abruptly to minimize the dependence on live foods and ground beef heart and liver and to promote the briefest possible transition to formulated commercial diet.

These investigations will determine a practical larval feeding strategy for tank culturing crappies by defining critical periods for survival, the timing and duration of the transitions of food type and size in relation to larval growth, and the densities of formulated diet-habituated fry that can be produced per volume of rearing unit using a larval feeding strategy that we have successfully used with other small-sized larvae of spiny-rayed fish.

Growth Compensation
UM-Columbia will conduct growth compensation studies. This work will seek to identify feeding schedules that give high TGC:TFD ratios in hybrid sunfish (F1 hybrid of male bluegill *Lepomis macrochirus* x female green sunfish *Lepomis cyanellus*) fed a commercial pelleted diet at a near-maximal growth temperature. Growth rates, conversion efficiencies, gonadal energy investment, as well as the predictability of daily consumption will be compared among fish fed on these schedules, in relation to those fed continuously to excess.

Hybrid sunfish will be secured from a local producer and acclimated over a 3-week period to laboratory conditions at the UM-Columbia. Fish will be held individually in plastic test chambers submerged in 945-L tanks equipped with closed circulation systems and biofilters. Ad libitum rations of commercial diet will be provided. Water temperature will be 23°C and fish will be exposed to a 15-h light: 9-h dark photoperiod.

Following acclimation, three fish will be randomly assigned to one of four primary treatment groups where feeding schedules will involve either 2, 4, 7, or 14 days of food deprivation. This will be followed immediately by refeeding to excess until the median feeding level of a treatment group no longer exceeds that of a control group of five fish fed continuously to excess (C_{max}). At this time the food deprivation period will be resumed for the set number of days, followed again by refeeding. Two secondary treatment groups of three fish will parallel the 4- and 7-d treatment groups differing only in that the food deprivation phase will involve feeding at 10% of C_{max}, rather than feeding no food at all. Values of C_{max} for hybrids will be determined from a regression equation involving body weight and temperature that will be developed prior to the study.

The experiment will continue until the 14-d treatment group has completed three cycles of food deprivation followed by refeeding. All other treatments will continue to cycle up to this time, being allowed to complete any cycle in progress near the experiment's end.

Daily food consumption by individual fish will be determined as the difference between food placed into test chambers and that remaining uneaten. During days of feeding, food will be provided in excess every 4-h. Fish will be weighed every three days for growth rate determinations. Conversion efficiency will be estimated for each fish from information on food consumed and weight gained. The gonadal-somatic index and wet:dry weight ratio of gonads will be used to assess relative energy investment into gonads for each treatment group. Predictability of daily food demand by fish experiencing compensatory growth feeding schedules will be compared to that for fish fed continuously to excess using statistical procedures to be determined.

FACILITIES

Production Manual/Videos (Objective 1)

Final publication of the production manual will be coordinated by Joseph Morris through the ISU publication team that has produced the existing NCRAC factsheets and publications. The production of video tapes will be coordinated by Terrence B. Kayes and key support staff of the UN-L Department of Forestry, Fisheries and Wildlife (FFW), and done in cooperation with extension professionals and researchers at SIUC, ISU, and MSU. This collective effort will be done in collaboration with the professional video and media staff of the UN-L Institute of Agriculture and Natural Resources (IANR) Communications and Computing Services. The UN-L FFW has the necessary "in-house" audio-video equipment and expertise to perform most, if not all, of the routine field video taping required for the proposed project. Any highly specialized video taping required, and all necessary video graphics and final tape editing will be done by the appropriate professionals of the UN-L IANR Communications and Computer Services, which has all the equipment needed to perform these functions.

Nutritional Requirements (Objective 2)

MSU has the necessary wet lab, tanks and water supply to conduct the proposed research. Feeds will be manufactured and phosphorus determinations conducted with the help of MSU's Department of Animal Sciences.

Purdue recently completed a new 687.5 m^2 (7,400 ft^2) aquaculture research facility that will be used for this research. That laboratory currently houses two strains of rainbow trout, as well as chinook, Atlantic, and coho salmon, and three species of sunfish. It is complete with back-up generators on both the dedicated well and the building. The Fish Nutrition Laboratory has all necessary equipment for completing the proximate analysis.

The Fisheries Research Laboratory has 743.2 m^2 (8,000 ft^2) of floor space in the Life Science II Building, located on the SIUC campus. Facilities housed in this building include eight research laboratories; three fully equipped, temperature controlled aquarium rooms; and eight administrative offices.

The on-campus laboratories contain all the necessary equipment for monitoring water quality and evaluating the growth and welfare of experimental fishes. Specific instrumentation includes: nitrogen analyzer, bomb calorimeter, fat extractor, ovens, analytical balances, gas chromatograph, atomic absorption spectrophotometer, specific ion electrodes, osmometers, research grade microscopes, spectrophotometer, sterilizer, etc. The Fisheries Research Laboratory also houses two remote computer terminals, personal computers and a word processor.

Field facilities include eighteen newly renovated 0.06-ha ponds contiguous to campus. At the nearby SIUC Touch of Nature Facility, 90 ponds have recently been constructed. The Touch of Nature site includes a large water retention pond, several deepwater wells, and all-weather roads. Graduate student living quarters and various storage facilities are situated on the site. The old Moroni facility north of DeSoto, consisting of nine 0.10-ha ponds, was reactivated in 1988. Via a long-term agreement, the Laboratory conducts experimental work at a large commercial hatchery that rears catfish, largemouth bass, and hybrid sunfish. A recirculating water system has been established in a greenhouse on the SIUC campus. Studies with freshwater shrimp, walleye, threadfin shad, hybrid striped bass and other species have been conducted in the controlled environment available in that facility. Research is also conducted at the State of Illinois Little Grassy Fish Hatchery located nine miles from campus.

A 771.1 m^2 (8,300 ft^2) wet laboratory building was completed on campus in 1986. This facility features more than 30, 1.8 m-diameter (6 ft) and 12, 1.5 m-diameter (5 ft) fiberglass tanks, approximately 200 flow-through aquaria, feed storage and manufacturing rooms, a water chemistry laboratory and small office. At least 20 recirculating water systems are employed; thus allowing the simultaneous conduct of numerous experiments. The building is heated and insulated to provide year-round operation at any desired temperature.

Feeding Strategies (Objective 3)

<u>Culture of Larval Sunfish</u>
ISU currently has a recirculating aquaculture system that consists of biofilters, controlled lighting and temperature, six 1000-L tanks, two 1200-L isolation tanks and six larval rearing chambers. A complete water exchange occurs hourly in each tank. They also have the capability to culture and maintain both zooplankton and phytoplankton populations for use in the laboratory. A water quality laboratory has been established that will assist in measuring water quality parameters.

UW-Milwaukee will conduct experiments at the Aquaculture Institute - University of Wisconsin Great Lakes Research Facility. Arrangements will be made for the acquisition of black crappie broodfish either through cooperating producers or through collection in the wild. We have the required collecting and transporting equipment to accomplish this task. A portion of the Aquaculture Institute - University of Wisconsin Great Lakes Research Facility rearing facilities (>1900 L/min water supply; >930 m^2 area) would be used for maintaining and spawning these broodfish, incubating the eggs and conducting the intensive rearing trials.

Large circular fiberglass rearing tanks (1.2 - 2.4 m-diameter) would be available for replicated rearing groups and a wide assortment of smaller sized aquaria are also available. These tanks are fitted with the required screened mesh and water supply hardware for specialized larval rearing.

Existing "green tank" facilities at UW-Milwaukee used to produce live foods for their larval feeding strategy will be used for these trials. This apparatus consists of two 2.4 m-diameter tanks with controlled temperature and lighting. These tanks can easily produce enough food to simultaneously feed fish in the four to eight large rearing units.

<u>Growth Compensation</u>
UM-Columbia will conduct growth compensation experiments within one of two wet laboratories controlled by The School of Natural Resources at the UM-Columbia. Available are tanks (945-L) equipped with closed-circulation, biofiltration systems. These tank systems can be linked for water interchange to ensure homogeneity of water quality. When necessary, these tank systems can be housed within environmental control chambers for uniformity of temperature, photoperiod, dissolved oxygen, and other environmental parameters. Experimental ponds are available through cooperative arrangements in place with the Missouri

Department of Conservation and the U.S. Fish and Wildlife Service's National Fisheries Contaminant Research Laboratory located near Columbia, Missouri.

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PROJECT LEADERS

State	Name/Institution	Area of Specialization
Illinois	Christopher C. Kohler Southern Illinois University-Carbondale	Fish Culture/Stocking Exotic Fishes/Fish Feeding Strategies
Indiana	Paul B. Brown Purdue University	Fish Nutrition/Fish Culture
Iowa	Joseph E. Morris Iowa State University	Larval Fish Culture/Water Quality/Extension
Michigan	Donald L. Garling Michigan State University	Fish Nutrition/Fish Culture/Extension
Missouri	Robert S. Hayward University of Missouri-Columbia	Fish Bioenergetics/Feeding Models
	Douglas B. Noltie University of Missouri-Columbia	Reproductive and Behavioral Ecology of Fishes
Nebraska	Terrence B. Kayes University of Nebraska-Lincoln	Fish Culture/Fish Endocrinology/ Extension
Wisconsin	Fred P. Binkowski University of Wisconsin-Milwaukee	Fish Culture/Larval Fish Culture/Ecology/Extension

PARTICIPATING INSTITUTIONS AND PRINCIPAL INVESTIGATORS

University of Nebraska-Lincoln (UN-L)
Terrence B. Kayes

Michigan State University (MSU)
Donald L. Garling

Southern Illinois University-Carbondale (SIUC)
Christopher C. Kohler

Iowa State University (ISU)
Joseph E. Morris

Purdue University (PU)
Paul B. Brown

University of Missouri-Columbia (UM-Columbia)
Robert S. Hayward
Douglas B. Noltie

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

PROPOSED CENTRARCHIDS (SUNFISH) BUDGET FOR UNIVERSITY OF NEBRASKA-LINCOLN

(Kayes)

Objective 1

							Year 1	Year 2
A. Salaries and Wages			Year 1		Year 2			
			No.	FTEs	No.	FTEs		
	1. No. of Senior Personnel & FTEs[1]							
		a. (Co)-PI(s)	1	0.08	1	0.08	$0	$0
		b. Senior Associates						
	2. No. of Other Personnel (Non-Faculty) & FTEs							
		a. Research Assoc./Postdoc						
		b. Other Professionals						
		c. Graduate Students						
		d. Prebaccalaureate Students						
		e. Secretarial-Clerical						
		f. Technical, Shop, and Other	1	0.05			$980	$0
		Total Salaries and Wages					$ 980	$0
B. Fringe Benefits (25% of 2f)							$245	$0
C. **Total Salaries, Wages and Fringe Benefits**							$1,225	$0
D. Nonexpendable Equipment							$0	$0
E. Materials and Supplies							$250	$400
F. Travel - Domestic (*Including Canada*)							$2,150	$890
G. Other Direct Costs							$2,025	$1,060
TOTAL PROJECT COSTS PER YEAR (*C through G*)							$5,650	$2,350
						TOTAL PROJECT COSTS	$8,000	

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

BUDGET JUSTIFICATION FOR UNIVERSITY OF NEBRASKA-LINCOLN

(Kayes)

A. Salaries and Wages. A technician (0.05 FTE) is required in Year 1 to assist with the coordination, set-up and staging of field and laboratory operations for video taping at several different demonstration sites in Illinois, Iowa, Michigan, and Nebraska.

B. Fringe Benefits. The UN-L has a standard fringe benefit rate of 25% of faculty and staff salaries.

E. Materials and Supplies. In Year 1 and 2, respectively, $250 and $400 are needed for video tape, and photographic, art and computer graphics supplies.

F. Travel. The production of effective techniques-centered video tapes on sex determination, differentiating between purebreds and hybrids, artificial propagation procedures, and various protocols for manipulating chromosomal ploidy in bluegill, green sunfish and/or their hybrids will require extensive travel from the UN-L to different video taping sites in Illinois, Iowa, Michigan, and Nebraska. Present plants are to do about 70% of the video taping in Year 1 of the project, and about 30% early in Year 2. Estimated travel costs for Year 1 are $810 for fleet vehicle rental, and $1,215 for lodging and meals - calculated on the basis of 15-18 d total time required for two people for vehicle travel, field coordination, set-up, and video taping at the different sites across the region. Estimated travel costs for Year 2 are $224 for fleet vehicle rental, and $666 for lodging and meals - calculated on the basis of 5-7 d total time required for travel and video taping.

G. Other Direct Costs. The production of video tapes will be done in collaboration with professional staff of the UN-L IANR Communications and Computing Services. Projected budget needs for Year 1 are: staff time and equipment use for field production (at $35.00/h) $840; editing and video-graphics production (at $50/h) $1,185. Projected budget requirements in the same categories for Year 2 are $420 and $640, respectively.

**PROPOSED CENTRARCHIDS (SUNFISH) BUDGET FOR
MICHIGAN STATE UNIVERSITY**

(Garling)

Objectives 1 and 2

					Year 1	Year 2
	Year 1		Year 2			
A. Salaries and Wages	No.	FTEs	No.	FTEs		
1. No. of Senior Personnel & FTEs[1]	1	0.05	1	0.05	0	0
a. (Co)-PI(s)						
b. Senior Associates						
2. No. of Other Personnel (Non-Faculty) & FTEs						
a. Research Assoc./Postdoc						
b. Other Professionals						
c. Graduate Students	1	0.50	1	0.50	$12,500	$13,500
d. Prebaccalaureate Students						
e. Secretarial-Clerical	1	0.08	1	0.08	$1,850	$1,850
f. Technical, Shop, and Other						
Total Salaries and Wages					$14,350	$15,350
B. Fringe Benefits (35% of 2e)					$650	$650
C. **Total Salaries, Wages and Fringe Benefits**					$15,000	$16,000
D. Nonexpendable Equipment					$0	$0
E. Materials and Supplies					$1,600	$1,700
F. Travel - Domestic (*Including Canada*)					$750	$1,250
G. Other Direct Costs					$2,250	$2,450
TOTAL PROJECT COSTS PER YEAR (*C through G*)					$19,600	$21,400
TOTAL PROJECT COSTS					$41,000	

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

BUDGET JUSTIFICATION FOR MICHIGAN STATE UNIVERSITY

(Garling)

A. Salary and Wages. A secretarial/clerical staffperson is required for the Work Group Chairperson and for clerical assistance to develop NCRAC extension fact sheets. One level 2 Graduate Research Assistant is needed to assist the PI in the research project.

B. Fringe Benefits. The current rate for fringe benefits a secretarial position at MSU are 35% of salaries.

E. Materials and Supplies. $250/yr are necessary for annual reports and the development of NCRAC extension fact sheets. Materials and supplies needed to accomplish the research objectives include feeds used during acclimation to lab conditions, chemicals for proximate analysis and amino acid analysis, and general lab materials and supplies.

F. Travel. In-state to obtain fish and materials and out-of-state to participate in workgroup meetings

G. Other Direct Costs. Utilities for the MSU off-campus aquaculture wet lab are paid by the PI through grants and contracts. Costs are apportioned to research grants based on the amount of use for the project.

PROPOSED CENTRARCHIDS (SUNFISH) BUDGET FOR SOUTHERN ILLINOIS UNIVERSITY-CARBONDALE

(Kohler)

Objective 2

	Year 1 No.	Year 1 FTEs	Year 2 No.	Year 2 FTEs	Year 1	Year 2
A. Salaries and Wages						
1. No. of Senior Personnel & FTEs[1]						
a. (Co)-PI(s)	1	0.05	1	0.05	$0	$0
b. Senior Associates						
2. No. of Other Personnel (Non-Faculty) & FTEs						
a. Research Assoc./Postdoc						
b. Other Professionals						
c. Graduate Students	1	0.50	1	0.50	$11,500	$12,000
d. Prebaccalaureate Students						
e. Secretarial-Clerical						
f. Technical, Shop, and Other						
Total Salaries and Wages					$11,500	$12,000
B. Fringe Benefits					$0	$0
C. **Total Salaries, Wages and Fringe Benefits**					$11,500	$12,000
D. Nonexpendable Equipment					$0	$0
E. Materials and Supplies					$2,000	$2,000
F. Travel - Domestic (*Including Canada*)					$500	$1,000
G. Other Direct Costs					$1,000	$1,000
TOTAL PROJECT COSTS PER YEAR (*C through G*)					$15,000	$16,000
TOTAL PROJECT COSTS					$31,000	

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

BUDGET JUSTIFICATION FOR SOUTHERN ILLINOIS UNIVERSITY-CARBONDALE

(Kohler)

A. Salaries and Wages. One graduate assistant (0.50 FTE) in years 1 and 2 to assist in nutrition studies.

B. Materials and Supplies. Expendable supplies such as nets, glassware, fish feed, plumbing supplies, chemicals, etc.

C. Travel-Domestic. NCRAC meetings and professional meetings for paper presentations will require travel support.

D. Other Direct Costs. Computer costs, report preparation, graphics, telecommunications, equipment repair, etc.

PROPOSED CENTRARCHIDS (SUNFISH) BUDGET FOR IOWA STATE UNIVERSITY

(Morris)

Objectives 1 and 3

					Year 1	Year 2
A. Salaries and Wages	Year 1 No.	Year 1 FTEs	Year 2 No.	Year 2 FTEs		
1. No. of Senior Personnel & FTEs[1]						
a. (Co)-PI(s)	1	0.05	1	0.05	$0	$0
b. Senior Associates						
2. No. of Other Personnel (Non-Faculty) & FTEs						
a. Research Assoc./Postdoc						
b. Other Professionals						
c. Graduate Students	1	0.50	1	0.50	$15,000	$2,000
d. Prebaccalaureate Students						
e. Secretarial-Clerical						
f. Technical, Shop, and Other						
Total Salaries and Wages					$15,000	$2,000
B. Fringe Benefits (2.9% of 2c)					$431	$58
C. **Total Salaries, Wages and Fringe Benefits**					$15,431	$2,058
D. Nonexpendable Equipment					$0	$0
E. Materials and Supplies					$3,400	$200
F. Travel - Domestic (*Including Canada*)					$1,250	$411
G. Other Direct Costs					$1,250	$0
TOTAL PROJECT COSTS PER YEAR (*C through G*)					$21,331	$2,669
TOTAL PROJECT COSTS					$24,000	

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

BUDGET JUSTIFICATION FOR IOWA STATE UNIVERSITY

(Morris)

A. Salaries and Wages. A graduate student (0.50 FTE) is needed to assist the principal investigator with this project. This individual will assist in writing extension publications on sunfish culture and will also be responsible for coordination of the fish hatchery and its day-to-day operations.

E. Marterials and Supplies. General office supplies and other miscellaneous supplies will be needed to produce drafts of the extension publications on sunfish culture ($500 in Year 1 and $200 in Year 2). Feeds, additional tanks, feeders, and miscellaneous supplies as needed by the project for Objective 3.

F. Travel. At least one trip annually will be taken to confer with work group researchers for input on development of the sunfish culture extension publications. Approximately $500 is needed to attend regional scientific meetings to present results. The remainder of the funds requested are required to partially meet fleet vehicle costs associated with broodfish acquisition.

G. Other Direct Costs. About $650 is needed for telecommunications (telephone, FAX, e-mail), postage, and photocopying. The remainder of the funds will be used to cover costs associated with processing water samples for Objective 3.

PROPOSED CENTRARCHIDS (SUNFISH) BUDGET FOR PURDUE UNIVERSITY

(Brown)

Objective 2

						Year 1	Year 2
A. Salaries and Wages		Year 1		Year 2			
		No.	FTEs	No.	FTEs		
1. No. of Senior Personnel & FTEs[1]							
	a. (Co)-PI(s)	1	0.10	1	0.10	$0	$0
	b. Senior Associates						
2. No. of Other Personnel (Non-Faculty) & FTEs							
	a. Research Assoc./Postdoc						
	b. Other Professionals	1	0.50	1	0.50	$10,400	$11,000
	c. Graduate Students						
	d. Prebaccalaureate Students					$1,000	$1,000
	e. Secretarial-Clerical						
	f. Technical, Shop, and Other						
	Total Salaries and Wages					$11,400	$12,000
B. Fringe Benefits (29.5% of 2b)						$3,040	$3,250
C. **Total Salaries, Wages and Fringe Benefits**						$14,440	$15,250
D. Nonexpendable Equipment						$0	$0
E. Materials and Supplies						$2,500	$2,000
F. Travel - Domestic (*Including Canada*)						$1,500	$1,500
G. Other Direct Costs						$1,560	$1,250
TOTAL PROJECT COSTS PER YEAR (*C through G*)						$20,000	$20,000
					TOTAL PROJECT COSTS	$40,000	

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

BUDGET JUSTIFICATION FOR PURDUE UNIVERSITY

(Brown)

Objective 2

A. Salaries and Wages. One technician is needed for this project (0.50 FTE). The technician will be responsible for acquisition of fish, diet preparation, scientific feeding, and chemical analysis.

E. Materials and Supplies. This budget is for acquisition of feeds for broodstock and juveniles prior to starting the experiments, miscellaneous supplies for the experimental system (airline and airstones) and maintenance of chillers for temperature control.

F. Travel. Travel funds will be used to disseminate experimental results and participate in workgroup meetings.

G. Other Direct Costs. Costs include photocopying, phone, FAX, postage and computer time for statistical analyses.

PROPOSED CENTRARCHIDS (SUNFISH) BUDGET FOR UNIVERSITY OF MISSOURI-COLUMBIA

(Hayward and Noltie)

Objective 3

	Year 1 No.	Year 1 FTEs	Year 2 No.	Year 2 FTEs	Year 1	Year 2
A. Salaries and Wages						
1. No. of Senior Personnel & FTEs[1]						
a. (Co)-PI(s)	2	0.10			$0	$0
b. Senior Associates						
2. No. of Other Personnel (Non-Faculty) & FTEs						
a. Research Assoc./Postdoc						
b. Other Professionals						
c. Graduate Students	1	0.50			$11,440	$0
d. Prebaccalaureate Students						
e. Secretarial-Clerical						
f. Technical, Shop, and Other						
Total Salaries and Wages					$ 11,440	$0
B. Fringe Benefits					$0	$0
C. **Total Salaries, Wages and Fringe Benefits**					$11,440	$0
D. Nonexpendable Equipment					$0	$0
E. Materials and Supplies					$1,560	$0
F. Travel - Domestic (*Including Canada*)					$0	$0
G. Other Direct Costs					$0	$0
TOTAL PROJECT COSTS PER YEAR (*C through G*)					$13,000	$0
TOTAL PROJECT COSTS					$13,000	

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

BUDGET JUSTIFICATION UNIVERSITY OF MISSOURI-COLUMBIA

(Hayward and Noltie)

A. Salaries and Wages. A Research Assistant (0.50 FTE) will be needed to carry out routine fish maintenance procedures as well as the primary experimental protocol including feeding and weighing of fish. PIs will supervise all aspects of the study and will compile and submit reports.

E. Materials and Supplies. Chemicals for water quality maintenance, nets, buckets, replacement materials for circulation system, thermometers, and paper supplies are needed for routine operations and data collection.

PROPOSED CENTRARCHIDS (SUNFISH) BUDGET FOR UNIVERSITY OF WISCONSIN-MILWAUKEE

(Binkowski)

Objective 3

	Year 1 No.	Year 1 FTEs	Year 2 No.	Year 2 FTEs	Year 1	Year 2
A. Salaries and Wages						
1. No. of Senior Personnel & FTEs[1]						
a. (Co)-PI(s)	2	0.12	2	0.06	$0	$0
b. Senior Associates						
2. No. of Other Personnel (Non-Faculty) & FTEs						
a. Research Assoc./Postdoc	2	0.18	2	0.07	$9,900	$3,840
b. Other Professionals						
c. Graduate Students						
d. Prebaccalaureate Students						
e. Secretarial-Clerical						
f. Technical, Shop, and Other						
Total Salaries and Wages					$ 9,900	$3,840
B. Fringe Benefits (31% of a)					$3,069	$1,190
C. **Total Salaries, Wages and Fringe Benefits**					$12,969	$5,030
D. Nonexpendable Equipment					$0	$0
E. Materials and Supplies					$0	$0
F. Travel - Domestic (*Including Canada*)					$0	$0
G. Other Direct Costs					$0	$0
TOTAL PROJECT COSTS PER YEAR (*C through G*)					$12,969	$5,030
TOTAL PROJECT COSTS					$17,999	

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

BUDGET JUSTIFICATION FOR UNIVERSITY OF WISCONSIN-MILWAUKEE

(Binkowski)

A. Salaries and Wages. Research associations will acquire and maintain broodfish; spawn and incubate eggs; prepare "green tanks" and other foods; set-up, maintain and sample rearing trials; collect and enumerate mortalities; evaluate growth and survival of crappies over the trial period; analyze the results; and prepare the final report. Less labor is allocated to Year 2 to reflect the tightened feeding periods and improvement based on Year 1 experimental results.

E. Materials and Supplies. No expenses are listed here since we anticipate that the expense of acquiring and shipping the broodfish, as well as some other supply expenses will be covered through our concurrent work on other aspects of black crappie aquaculture funded through the Red Lake Band of Chippewa (USDI, Bureau of Indian Affairs).

F. Travel. Expenses will be covered through our concurrent work on other aspects of black crappie aquaculture funded through the Red Lake Band of Chippewa (USDI, Bureau of Indian Affairs).

RESOURCE COMMITMENT FROM INSTITUTIONS[1]

State/Institution			Year 1	Year 2
University of Nebraska-Lincoln				
Salaries and Benefits:	SY @ 0.08 FTE		$5,300	$5,450
	TY @ 0.05 FTE		$0	$1,262
Production of Educational Video Tapes			$5,300	$6,712
Supplies, Expenses, and Waiver of Overhead			$0	$0
		Total	$10,600	$13,424
Michigan State University				
Salaries and Benefits	SY @ 0.05 FTE		$3,920	$4,075
	TY @ 0.01 FTE		$10,584	$11,689
		Total	$14,504	$15,764
Southern Illinois University-Carbondale				
Salaries and Benefits:	SY @ 0.05 FTE		$3,000	$3,500
Overhead Waived			$5,500	$6,000
		Total	$8,500	$9,500
Iowa State University				
Salaries and Benefits:	SY @ 0.05 FTE		$2,860	$3,250
Overhead Waived (42%)			$9,181	$1,365
Supplies, Expenses, and Equipment			$3,000	$0
		Total	$15,041	$4,615
Purdue University				
Salaries and Benefits:	SY @ 0.05 FTE		$5,750	$6,250
Supplies, Expenses, and Equipment and Overhead Waived			$15,000	$15,000
		Total	$20,750	$21,250
University of Missouri-Columbia				
Salaries and Benefits			$6,300	$0
Supplies, Expenses, and Equipment and Overhead Waived			$8,350	$0
		Total	$14,650	$0
University of Wisconsin-Milwaukee				
Salaries and Benefits			$11,135	$5,567
Supplies, Expenses and Equipment			$5,000	$5,000
Travel			$1,000	$1,000
		Total	$17,135	$11,567
Farmland Industries, Inc.				
Feeds and Labor			$5,300	$6,712
		Total	$5,300	$6,712
		Total per Year	$106,480	$82,832
		GRAND TOTAL	$189,312	

[1]Since cost sharing is not a legal requirement, some universities chose not to provide resource commitment from institutions.

SCHEDULE FOR COMPLETION OF OBJECTIVES

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

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

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

LIST OF PRINCIPAL INVESTIGATORS

Fred P. Binkowski, University of Wisconsin-Milwaukee

Paul B. Brown, Purdue University

Donald L. Garling, Jr., Michigan State University

Robert S. Hayward, University of Missouri-Columbia

Terrence B. Kayes, University of Nebraska-Lincoln

Christopher C. Kohler, Southern Illinois University-Carbondale

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EDUCATION

B.S. Zoology, University of Wisconsin-Milwaukee, 1971
M.S. Fishery Biology, University of Wisconsin-Milwaukee, 1974

POSITIONS

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

SCIENTIFIC AND PROFESSIONAL ORGANIZATIONS

American Fisheries Society: Early Life History Section, International Association for Great Lakes Research (Associate Editor), World Aquaculture Society,

SELECTED PUBLICATIONS

Miller, T., L.B. 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.

Miller, T., L.B. Crowder, and F.P. Binkowski. 1990. Zooplankton size dynamics and recruitment success of bloater in Lake Michigan. Transactions of the American Fisheries Society 119:483-491.

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

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

Rice, J.A., L.B. Crowder, and F.P. Binkowski. 1987. Evaluating potential sources of mortality for larval bloater (*Coregonus hoyi*): starvation and vulnerability to predation. Canadian Journal of Fisheries and Aquatic Sciences 44:467-472.

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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

Associate Professor of Fisheries and Aquatic Sciences, Department of Forestry and Natural Resources, Purdue University (1993-present)
Assistant Professor of Fisheries and Aquatic Sciences, Department of Forestry and Natural Resources, Purdue University (1989-1993)
Assistant Professional Scientist/Field Station Director, Illinois Natural History Survey (1987-1989);
Adjunct Assistant Professor, University of Illinois, Department of Animal Sciences (1988-1989)

SCIENTIFIC AND PROFESSIONAL ORGANIZATIONS

World Aquaculture Society
American Institute of Nutrition
American Fisheries Society
International Association of Astacology
American Association for the Advancement of Science
American Society of Zoologists

SELECTED PUBLICATIONS

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.

Brown, P.B., and E.H. Robinson. 1992. Vitamin D studies with juvenile channel catfish (*Ictalurus punctatus*) reared in calcium-free water. Comparative Biochemistry and Physiology 103A:213-219.

Griffin, M.E., P.B. Brown, and A. Grant. 1992. Dietary lysine requirement of juvenile hybrid striped bass. Journal of Nutrition 122:1332-1337.

Brown, P.B., W.H. Neill, and E.H. Robinson. 1990. Preliminary evaluation of whole body energy changes as a method of estimating maintenance energy needs of fish. Journal of Fish Biology 36:107-108.

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EDUCATION

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

POSITIONS

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

SCIENTIFIC AND PROFESSIONAL ORGANIZATIONS

World Aquaculture Society
American Fisheries Society
Sigma Xi
Gamma Sigma Delta

SELECTED PUBLICATIONS

Ramseyer, L.J., and D.L. Garling. In press. Amino acid composition of ovaries, muscle, and whole body of yellow perch (*Perca flavescens*). Progressive Fish-Culturist.

Cain, K., and D. Garling. 1993. Trout culture in the north central region. North Central Regional Aquaculture Center, Fact Sheet #108.

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.

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.

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

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EDUCATION

B.S. Cornell University, 1977
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Ph.D. Ohio State University, 1988

POSITIONS

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

SCIENTIFIC AND PROFESSIONAL ORGANIZATIONS

American Fisheries Society
Missouri Chapter of American Fisheries Society

SELECTED PUBLICATIONS

Hayward, R.S., F.J. Margraf, Jr., D.L. Parrish, and B. Vondrack. 1991. Low-cost field estimation of yellow perch daily ration. Transaction of the American Fisheries Society 120:589-604.

Hayward, R.S. 1991. Bias associated with using Eggers' model for estimating fish daily ration. Canadian Journal of Fisheries and Aquatic Sciences 48:1100-1103.

Hayward, R.S. 1990. Comment on Boisclair and Leggett: Can eating really stunt your growth? Canadian Journal of Fisheries and Aquatic Sciences 47:228-233.

Hayward, R.S., F.J. Margraf, C.T. Knight, and D.J. Glomski. 1989. Gear bias in field estimation of the amount of food consumed by fish. Canadian Journal of Fisheries and Aquatic Sciences 46:874-876.

Hayward, R.S., N.G. Reichenbach, L.A. Dickson, and T.J. Wildoner, Jr. 1988. Variability among bluegill ventilatory rates for effluent toxicity biomonitoring. Journal of Water Research 22:1311-1315.

Hayward, R.S. 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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EDUCATION

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Ph.D. University of Wisconsin-Madison, 1978

POSITIONS

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

SCIENTIFIC AND PROFESSIONAL ORGANIZATIONS

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

SELECTED PUBLICATIONS

Barry, T.P., A.F. Lapp, T.B. Kayes, and J.A. Malison. In press. Validation of an ELISA for measuring cortisol in fish and comparison of stress responses of rainbow trout (*Oncorhynchus mykiss*) and lake trout (*Salvelinus namaycush*). Aquaculture.

Heidinger, R.C., and T.B. Kayes. 1993. Yellow Perch. Pages 215-229 *in* R.R. Stickney, editor. Culture of nonsalmonid freshwater fishes. CRC Press, Boca Raton, Florida.

Malison, J.A., T.B. Kayes, J.A. Held, T.P. Barry, and C.H. Amundson. 1993. Manipulation of ploidy in yellow perch (*perca flavescans*) by heat shock, hydrostatic pressure shock, and spermatozoa inactivation. Aquaculture 110:229-242.

Kebus, M.J., M.T. Collins, M.S. Brownfield, C.H. Amundson, T.B. Kayes, and J.A. Malison. 1992. Effects of rearing density on the stress response and growth of rainbow trout. Journal of Aquatic Animal Health 4:1-6.

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POSITIONS

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Assistant Director, Fisheries Research Laboratory, Southern Illinois University-Carbondale (1988-1991)
Assistant Professor, Department of Zoology, Southern Illinois University-Carbondale (1982-1988)
Research Associate, Department of Zoology, Southern Illinois University-Carbondale (1980-1981)
Assistant Professor, Virginia Polytechnic Institute and State University (1980)

SCIENTIFIC AND PROFESSIONAL ORGANIZATIONS

American Fisheries Society,(Culture, Management, Introduced, Education and International Sections)
World Aquaculture Society, (Charter Member of USA Chapter)
Sigma Xi
Phi Kappa Phi

SELECTED PUBLICATIONS

Ayala, C.E., C.C. Kohler, and R.R. Stickney. In press. Protein digestibility and amino acid availability of fish meal in largemouth bass infected with intestinal Acanthocephala. Progressive Fish-Culturist.

Roem, A.J., R.R. Stickney, and C.C. Kohler. 1991. Dietary pantothenic acid requirement of the blue tilapia. Progressive Fish-Culturist 53:216-219.

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Roem, A.J., R.R. Stickney, and C.C. Kohler. 1990. Vitamin requirements of blue tilapia in a recirculating system. Progressive Fish-Culturist 52:15-18.

Stickney, R.R., and C.C. Kohler. 1990. Maintaining fishes for research and teaching. Pages 633-663 *in* C. Schreck and P. Moyle, editors. Methods for fish biology. American Fisheries Society.

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POSITIONS

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Associate Director, North Central Regional Aquaculture Center (1990-present)
Graduate Research Assistant, Mississippi State University (1986-1988)
Aquaculture Manager, Stiles Farm Foundation (1982-1986)
Graduate Research Assistant, Texas A&M University (1981-1982)
Research Technician I, Texas A&M University (1980-1981)
Fisheries Biologist Aide, Indiana Department of Natural Resources (1979)

SCIENTIFIC AND PROFESSIONAL ORGANIZATIONS

American Fisheries Society: Iowa State Chapter, Fish Culture Section, Educators Section, Early Life History Section, Computer Users Section
Iowa Aquaculture Association
Phi Kappa Phi, Iowa State University Chapter
Sigma Xi, Iowa State University Chapter,

SELECTED PUBLICATIONS

Bettoli, P.W., J.E. Morris, and R.L. Noble. 1991. Changes in the abundance of two atherinid species following aquatic vegetation removal. Transactions of the American Fisheries Society 120:90-97.

Morris, J.E., L.R. D'Abramo, and R.J. Muncy. 1990. An inexpensive marking technique to assess ingestion of artificial diets by larval fish. Progressive Fish-Culturist 52:120-121.

Morris, J.E. 1989. Supplemental feeding of hybrid striped bass fry. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 43:96-105.

Morris, J.E. 1988. Role of artificial diets and feeding regimes on the culture of hybrid striped bass fry. Doctoral dissertation. Mississippi State University, Starkville, MS.

Campbell, J.M., J.E. Morris, and R.L. Noble. 1983. Spatial variability and community structure of littoral microcrustacea in Lake Conroe, Texas. 86th Annual Meeting Texas Academy of Science, Stephen F. Austin University, Nacodoches, TX.

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POSITIONS

Assistant Professor, Fisheries and Wildlife Program, The School of Natural Resources, University of Missouri-Columbia (1990-present)
Post-doctoral fellow, Natural Sciences and Engineering Research Council of Canada, held at Department of Zoology, University of Guelph, Guelph, Ontario, Canada (1988-1990)
Contract biologist, Ontario Ministry of Natural Resources, Fisheries Branch, Toronto, Ontario, Canada (1986-1988)

SCIENTIFIC AND PROFESSIONAL ORGANIZATIONS

American Fisheries Society: Canadian Aquatic Resources, Computer User, Early Life History, Education, Fish Culture, Genetics, Introduced Fish Sections; Missouri and Southern Ontario Chapters; North Central Division Rivers & Streams and Great Lakes Technical Committees
American Institute of Fishery Research Biologists
American Society of Ichthyologists and Herpetologists
Animal Behavior Society

SELECTED PUBLICATIONS

Bye, M.R., and D.B. Noltie. In press. Differences in allocation of biomass to reproduction and gonad composition in pink salmon (*Oncorhynchus gorbuscha*). McNair Journal, University of Missouri-Columbia.

Noltie, D.B. 1990. Migratory dynamics and characteristics of breeding pink salmon (*Oncorhynchus gorbuscha*) from the Carp River, eastern Lake Superior. Canadian Journal of Zoology 68:684-693.

Noltie, D.B. 1990. Intrapopulation variation in the breeding of male pink salmon (*Oncorhynchus gorbuscha*) from a Lake Superior tributary. Canadian Journal of Fisheries and Aquatic Sciences 47:174-179.

Noltie, D.B. 1988. Spawning site utilization by Ontario brook charr (*Salvelinus fontinalis*) in relation to groundwater and susceptibility to acidification. Ontario Ministry of Natural Resources Report.

Noltie, D.B. 1988. Differences in breeding Lake Superior pink salmon (*Oncorhynchus gorbuscha* [Walbaum]) associated with variation in thyroid hyerplasia. Canadian Journal of Zoology 66:2688-2694.