CULTURE TECHNOLOGY OF SUNFISH

Chairperson: Robert J. Sheehan, Southern Illinois University-Carbondale

Industry Advisory Council Liaison: Charlie Stevens, Knoxville, Iowa

Extension Liaison: Joseph E. Morris, Iowa State University

Funding Request: $200,000

Duration: 2 Years (September 1, 1996 - August 31, 1998)

Objectives:

1. Compare feeding trials for grow out of locally available 5.1-10.2 cm (2-4") black crappie and bluegill male × green sunfish female hybrids:
   a. in ponds at dissimilar latitudes in the region, and
   b. in recirculating systems using compensatory feeding strategies.

2. Establish baseline physiological measures for small 2.5-7.6 cm (1-3") black crappie subjected to handling stressors and to test the effect of salt and temperature on stress reduction.

3. Update the sunfish culture manual that had been developed for sunfish produced in the North Central Region.

Proposed Budgets:

Institution	Principal Investigator(s)	Objec-tive(s)	Year 1	Year 2	Total
Purdue University	Paul B. Brown	1a	$19,000	$0	$19,000
Southern Illinois University-Carbondale	Robert J. Sheehan	1a	$19,000	$19,000	$38,000
University of Missouri-Columbia	Robert S. Hayward Douglas B. Noltie	1b	$24,500	$24,500	$49,000
Pittsburg State University	James R. Triplett	1b	$15,500	$8,500	$24,000
Univ. of Wisconsin-Milwaukee	Fred P. Binkowski	1b	$10,000	$10,000	$20,000
Iowa State University	Joseph E. Morris Robert C. Summerfelt	1b & 3	$17,258	$17,742	$35,000
University of South Dakota	Bruce A. Barton	2	$4,083	$4,417	$8,500
Univ. of Wisconsin-Madison	Jeffrey A. Malison	2	$3,250	$3,250	$6,500
		TOTALS	**$112,591**	**$87,409**	**$200,000**

Non-funded Collaborators:

Facility	Collaborator
Gavins Point National Fish Hatchery, Yankton, South Dakota	U.S. Fish and Wildlife Service
Kloubec Fish Farms, Amana, Iowa	Myron Kloubec

TABLE OF CONTENTS

JUSTIFICATION

Sunfish of the genera *Lepomis* and *Pomoxis* already have significant economic impact in the North Central Region (NCR). For example, 51% of the sportfish harvest in Illinois consists of fishes 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 0.23 kg (0.5 lb) crappie indicates that sunfish are about double the value of the two major aquaculture species rainbow trout (*Oncorhynchus mykiss*) and channel catfish (*Ictalurus punctatus*). The significance of the market potential for sunfish has not been lost on others; in some cases 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 brood stocks are easy for culturists to acquire in abundance. Even inexperienced culturists can readily spawn sunfish in ponds. *Lepomis* and *Pomoxis* sunfish are not inclined to be cannibalistic, unlike striped bass (*Morone saxatilis*) and walleye (*Stizostedion vitreum*). A number of sunfish species and hybrids are known to readily accept pelleted feeds. Habituation of larger juveniles and adult centrarchids to commercial diets has been proven feasible; but further improvements and specialized diets for sunfish are needed. Sunfish exhibit fast initial growth and grow at lower temperatures than channel catfish; an important characteristic for production in our region. The suitability of crappies as an alternative aquaculture species is undergoing continued and expanded investigation by the NCRAC Sunfish Work Group.

In general, crappie have proven to be much less tolerant to handling, more difficult to train to prepared diets, and more susceptible to disease-related mortalities than have all the lepomids evaluated in a similar manner. However, black crappie (*Pomoxis nigromaculatus*) have, in general, survived better and been more easily trained to accept prepared feeds than white crappie. Crappie may have advantages in the market as compared with *Lepomis*; crappie may command a higher price, and they may be better suited for the production of a larger fish, but neither possibility is a certainty at this time. Thus, there is a need to compare crappie to *Lepomis* in side-by-side comparisons under practical fish-culture conditions. Also, a number of impediments to successful crappie food fish culture have already been identified. Crappie, more so than *Lepomis*, require basic research on their biology to gain insight into how these impediments might be overcome. More information on their stress physiology and feeding ecology is especially needed at this time to overcome the problems of reduced survival under intensive fish-culture conditions and poor acceptance of feeds, respectively.

Methods of centrarchid production rely on extensive pond production techniques (Snow 1975; Simco et al. 1986; Willis and Flickinger 1980). These techniques have not proved as reliable for the production of crappies. Recruitment of crappies is highly variable and "capricious" (Hooe 1991) and they are generally not recommended for stocking in small impoundments for fishing. Populations may either overpopulate, which results in a “stunted” population, or, on the other hand, reproduction may fail entirely. As noted by Smeltzer and Flickinger (1991), published information on culturing both black and white crappies is limited, yet interest in these species continues to be high. In their brief 1991 survey they found 60 private, state and federal culture facilities producing crappies. To intensify crappie production to levels suitable for commercial food fish production, supplemental feeding of formulated diets will be necessary. Development of indoor intensive rearing strategies as alternatives to pond and cage rearing of sunfishes could offer improved control over rearing conditions. Practical commercial techniques for controlled rearing of crappies through their complete life cycle are desirable industry goals. Modern recirculating aquaculture systems may provide a feasible alternative to outdoor production, circumventing the climatic conditions that limit growth in much of the NCR. The evaluation of the growth performance and the cost effectiveness of rearing centrarchids in outdoor ponds as well as indoor recirculating systems are identified as priorities of the regional industry.

Although experimental methods for artificially spawning sunfishes (Childers and Bennett 1961; Childers 1967) have been employed to produce and evaluate crappie and their hybrids (Hooe and Buck, 1991; Hooe et al. 1994) hatched fry are most often stocked into ponds for early feeding. Commercially practical techniques for intensively rearing crappie from hatching in tanks have yet to be developed. The most problematic barrier to divorcing sunfish production from pond techniques remains in the critical first-feeding fry stage. Generally the gape of the mouth in larval fish limits the size of prey they can accept. There is some evidence that black crappie with a gape size similar to that of yellow perch may select prey even smaller than can be explained by gape size alone (Schael et al. 1991). First feeding black crappie require small-sized live foods for which there is currently no acceptable commercial substitute. Siefert (1968) found that nauplii were the principal first feeding food of 4.5-4.6 mm white crappie larvae, which then principally shifted to Cyclops at 6-7 mm, and Daphnia became significant in the diet at larval sizes of 10.0-13.9 mm. Pond rearing provides the necessary small zooplankters, but is subject to the limitations of the pond's natural productivity. The University of Wisconsin-Milwaukee (UW-Milwaukee) has overcome similar size-related first-feeding difficulties in rearing yellow perch and other larval fish under intensive tank conditions, by using small live foods cultured in "green tanks" and gradually habituating the fish to non-living foods. Green tank foods consist of small sized nauplii, rotifers and protozoans of the appropriate size for first feeding larvae. Following "green tank" foods, UW-Milwaukee switchs larvae to artemia nauplii, then to a ground mixture of beef heart and liver and finally habituates them to a commercial diet. The "green tank" food is easily produced on a commercially applicable scale in lighted and aerated 2.4-m (8-ft.) diameter tanks using alfalfa meal as a nutrient source. UW-Milwaukee has habituated groups of >50,000 yellow perch to Biodiet® (Bioproducts Inc., Warrenton, Oregon) starter feed in around 25 d using this technique at densities of 2,000-6,000 fish/m^3. Applying this method to crappies, as proposed by UW-Milwaukee herein, may provide a viable alternative to pond rearing. The cost effectiveness of such methods needs to be compared and contrasted with the alternative of harvesting juvenile crappies from ponds and habituating them to commercial feeds. Smeltzer and Flickinger (1991) were able to habituate black crappies (25-35 mm) to a commercial diet using carp eggs as an intermediate food as had been done previously for largemouth bass (Brandenburg et al. 1979; Willis and Flickinger 1981).

Investigations of male bluegill (*Lepomis macrochirus*) × female green sunfish (*L. cyanellus*) F_1 hybrids (BG × GS hybrids) have been carried out to evaluate the usefulness of this fish in traditional recreational fishing pond stocking programs. However, there is increasing interest in sunfish and their hybrids as a food fish and hence intensive aquaculture species. The BG × GS hybrid 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 their fish; they primarily rely 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 compared with nonfed hybrids. However, Lewis and Heidinger (1971a) supplementally fed BG × GS hybrids Purina Trout Chow® and demonstrated that these hybrids had better growth and more catchable size fish at the end of the first year. Their 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).

Compare Feeding Trials for Grow Out in Ponds at Dissimilar Latitudes in the Region (Objective 1a)

To date, black crappie have proven to be superior to white and hybrid crappie in intensive fish culture (see **PROGRESS TO DATE**), so it is appropriate that crappie production studies focus on the former. Hybrid sunfish have proven to be superior to parental species under intensive fish culture (see **PROGRESS TO DATE**). However, market prices for crappie and *Lepomis* may differ, and one versus the other may be more suitable for certain market niches, such as a niche for a larger centrarchid. Farmers interested in centrarchid food fish culture do not have information on the comparative advantages and disadvantages of producing black crappie versus hybrid sunfish. With this information, farmers will be able to choose which of the two is more economical to produce to exploit a given market niche. Thus, there is a need to conduct side-by-side production studies with black crappie and BG × GS hybrids to gain this information. Pond production is the most widely used technique for warmwater and coolwater production. The most valuable comparative information can be derived from pond-culture studies, the technique that will most often be used in commercial settings.

Crappie appear to require training to accept prepared diets, whereas this does not appear to be the case for BG × GS hybrids, although the latter may benefit from training also. Although a training period increases the cost of production, it is routinely used for certain commercial species, especially ones that command a high price in the market. Largemouth bass, for example, can be much more successfully produced when held in confinement and trained prior to stocking into grow out ponds (Brandenburg et al. 1979). If market prices for crappie are higher than those for BG × GS hybrids or if crappie can more easily be raised to a larger size, then training will be more economically feasible. It is desirable to compare the production characteristics of crappie to BG × GS hybrids with and without a training period. Southern Illinois University-Carbondale (SIUC) proposes to conduct such studies herein.

Maximum efficiency in the production of fish requires use of diets formulated specifically to meet the requirements of the target organism. Formulated diets are easier to store than live foods, deliveries can be scheduled, and prices remain relatively stable. Perhaps most important is the fact that as dietary needs are quantified, rate of weight gain increases and feed conversion ratio (FCR) of the target organism decreases, leading to increased efficiency of production.

Feed costs comprise a significant portion of annual variable costs in aquaculture for most species and culture systems. There are also significant differences in prices of feed from various feed mills. The variability is a response to source and price of feed ingredients and the target nutritional composition of the diet. For example, crude protein (CP) and fat concentrations in diets fed to trout and salmon are much higher than in diets fed to catfish (National Research Council 1993). Needless to say, diets formulated to meet the requirements of salmonids are, therefore, more expensive.

When evaluating the culture potential of new species, the best and most immediate information that can be developed is a recommendation of a feed that is readily available. Several dietary formulations are available in the U.S., all of which are based on the dietary needs of catfish and trout. There are significant differences in growth and FCR of new species fed diets that appear similar in nutritional composition (Brown et al. 1993). In laboratory situations, this has been observed with hybrid bluegill (Brown and Wilson 1994). However, there have been only preliminary comparisons of available diets fed to hybrid bluegill in earthen pond culture systems. Given the recognized differences in price of the various formulations for fish and the desire for maximum efficiency of production, nutritional research offers promise as a means of facilitating development of new culture industries. In the simplest of terms, producers must feed fish a formulated diet for maximum or optimum efficiency and feed costs comprise a significant portion of annual costs. In recognition of these facts, the Industry Advisory Council (IAC) of NCRAC identified feeding trials as an important area in which they need formal recommendations. Further, they ranked the need for feeding trials with BG × GS hybrids and black crappie (Objective 1) as the highest priority research topic in this funding cycle.

Compare Feeding Trials for Grow Out in Recirculating Systems under Compensatory Feeding Strategies (Objective 1b)

A recently completed study (Hayward et al., In preparation) at the University of Missouri (UM) has shown that BG × GS hybrids, fed on a repeated no-feed/refeed schedule which elicited the compensatory growth response, achieved twice the body weight of control counterparts fed daily in a 115- d feeding and growth experiment. This result suggests that grow out times for this fish in aquaculture might be cut by a factor of two. Because the basic capacity for entering a compensatory state of above-normal growth rate has been demonstrated across many fish families (Koppe et al. 1993; Russell and Wootton 1992; Broekhuizen et al. 1994), a broad-scale potential for growth enhancement in aquaculture has been indicated by the findings of the hybrid sunfish study.

The UM study with hybrid sunfish was carried out under highly controlled laboratory conditions which included holding fish individually in small plexiglass test chambers and feeding a natural prey so that daily food consumption by test fish could be accurately measured. The follow-up experiments proposed herein are intended to evaluate whether the growth benefits observed with the hybrid sunfish from compensatory growth feeding, can be readily extrapolated to the commercial production setting which typically involves use of artificial diets of high caloric density, and fish being held in groups at high densities. Effects of growth increases from compensatory growth feeding strategies on flesh weight and composition (e.g., protein:fat ratio) must also be assessed.

Many centrarchids, including black crappie and BG × GS hybrids, have been recognized as marketable fishery products, but efforts toward developing intensive aquaculture techniques to meet this demand have not been adequately explored. Hybrid bluegill have been used in fisheries management where limited reproduction is desired (Childers and Bennett 1961; Childers 1967; Ellison and Heidinger 1978). Hybrid bluegill 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 NCR.

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). Although growth compensation has been observed to occur in wild populations of fishes (Wootton 1990), the application of this concept to aquaculture has not been thoroughly evaluated.

Ideally, it is desirable to have practical strategies for intensive tank rearing of sunfish species for their entire life cycle, but intensive rearing methods for the production of fingerlings habituated to commercial feed is difficult and still under development. Until such techniques can be perfected, habituation of larger sized 51-102 mm (2-4") pond reared crappie to commercial diets seems to offer an expedient source of crappies for tank rearing. Even when pond-reared crappies are available, making the transition from pond-harvested fingerlings to high-density stocks of crappie that are fully habituated to pelleted feed can be difficult for producers. Fish subjected to the stressful handling of harvest and transport and then held at high density are forced to adjust to new conditions and foods. Their new culture environment is more homogeneous in terms of physical conditions and affords less opportunity for avoidance of stressful conditions.

The result of this transition from the pond production systems to intensive tank situations is likely to be a period of non-feeding that is in some ways analogous to the episodes of food deprivation that for some species result in a compensatory growth response. Would crappie that experience food deprivation during the transition from pond production to intensive tank culture show a compensatory growth response? Could such a compensatory response by larger pond harvested sunfish fingerlings outstrip any advantage that could be gained by habituation of crappie to commercial diet at as young a stage as is currently feasible, perhaps even when reared from egg by a “green tank” strategy? Potential crappie culturists need to know which of these alternatives is most cost effective.

Previous NCRAC work with habituation of perch fingerlings produced in ponds suggests that harvesting at smaller size during the summer, rather than at larger fingerling sizes, dramatically increases the numbers produced per acre of pond (Malison and Held 1992). While sunfish of 51-102 mm (2-4") size are considered suitable for transport and stocking into recirculating production systems, perhaps smaller sized individuals would respond differently. Even if rearing black crappie intensively from eggs is unsuccessful, it may be that younger fish 2.5-3.8 cm (1-1.5") are more tractable in their acceptance of commercial diets than older fish that have had longer periods of conditioning on exclusively live foods. Which sizes of sunfish will habituate most rapidly to commercial diets? Will increasingly older pond fish require longer periods of habituation to commercial food than younger fish? Which size of pond harvested fish will exhibit better survival during the transition from pond to intensive tank culture? All of these factors have practical relevance to how regional fish culturists should approach habituating sunfish to intensive culture conditions.

Feeding trials in open ponds, cages and laboratory aquaria have yielded critical information necessary for the development of the aquaculture industry. However, it is nearly impossible to observe feeding activity and interspecific competition and determine the role they play in food conversion efficiency and subsequent growth in open pond or cage culture systems. At the same time, the use of aquaria in laboratories for feeding trials, while maximizing observability, may produce uncharacteristic behavior as a result of reduced volumes and fish densities. Recirculating systems offer a compromise between the open production systems and the highly altered laboratory approach. In recirculating systems, the rearing environment can be controlled to the same level possible in the laboratory, yet fish densities and feeding levels can approach those of open production systems. While the observation of individual behavior is not possible in the recirculating system, general levels of activity, spatial segregation and interactions between size groups can be monitored. The fish are also far more accessible for routine sampling and for tracking disease and mortality.

In the NCR, recirculating systems are becoming increasingly important as commercial production units. Increased demand for quality water supplies, a substantially reduced growing season and widely varying environmental conditions have made the controllability of recirculating systems far more attractive. New technological developments in monitoring, logging, decision processing and adjusting rearing environments using computerized process control systems have permitted year-round production under optimal conditions. Although recirculating systems are inherently more expensive to operate than open systems, the ability to tightly control the rearing environment, eliminate growing season limitations, reduce water consumption requirements and increase the number of locations possible for fish production have also opened the door for the commercial production of higher valued species previously considered not suitable for open production.

In summary, each institution participating in Subobjective 1b will make unique and important contributions to address the use of compensatory feeding strategies in grow out of black crappie and BG × GS hybrids. The UM will continue its promising work on compensatory feeding strategies in BG × GS hybrids. Iowa State University (ISU) will compare compensatory feeding strategies in tank-reared versus pond-reared BG × GS hybrids. Pittsburg State University (PSU) will study compensatory feeding strategies in black crappie in recirculating systems. UW-Milwaukee will use its “green tank” rearing techniques in an attempt to habituate black crappie at a small size to commercial feed, compare compensatory feeding strategies in crappie habituated to commercial feeds at small sizes to those habituated at larger sizes from ponds, and evaluate the cost-effectiveness of using smaller versus larger crappie.

Establish Baseline Physiological Measures for Small Black Crappie Subjected to Handling Stressors and to Test the Effect of Salt and Temperature on Stress Reduction (Objective 2)

The IAC of the NCRAC has defined a need for examining methods for reducing handling stress in black crappie as part of the overall directive for improving the food fish culture of centrarchid species in the region. This need is a consequence of the fact that both producers and haulers (e.g., Charlie Stevens, Knoxville, Iowa, personal communication) frequently observe high levels of mortality in black crappie subsequent to handling and/or transporting these fish. Physiological measurements of blood constituents provide a useful approach for quantifying the degree of stress experienced by fish and assessing the value of mitigative measures (Wedemeyer et al. 1990). Using such methods, the responses of fishes to physical disturbances in aquaculture and their detrimental effects are now well known and understood, especially in salmonid fishes (reviewed by Barton and Iwama 1991). By contrast, limited information is available on centrarchid fishes and most of that concerns smallmouth (*Micropterus dolomieu*) and largemouth (*Micropterus salmoides*) bass (Carmichael et al. 1983; 1984a,b). Similar information on physiological responses of crappies (*Pomoxis* spp.) to stress is minimal (Davis and Parker 1986).

Update the Sunfish Culture Manual (Objective 3)

As part of the current sunfish proposal, a culture guide is scheduled for completion during fall 1995. At the 1995 NCRAC Program Planning Meeting held February 17-10, in Minneapolis, Minnesota, the IAC expressed a strong desire for improvement and subsequent addition to the NCRAC culture manual for sunfish.

RELATED CURRENT AND PREVIOUS WORK

Compare Feeding Trials for Grow Out in Ponds at Dissimilar Latitudes in the Region (Objective 1a)

Several years of NCRAC-funded research at SIUC have focused on studies of the growth of diploid and triploid *Pomoxis* and *Lepomis* parental species and hybrids in tank-culture studies across a range of temperatures. These studies indicate that diploid black crappie and BG × GS hybrids performed as well or better than their congeneric taxa. Further, preliminary data analyses indicate that the BG × GS hybrid performs better than the black crappie under tank-culture conditions. It is likely that early development of commercial centrarchid food fish culture will employ pond production to a great extent. There have been no side-by-side comparisons of crappie versus *Lepomis* production in ponds.

Presently most fingerling hybrid sunfish producers do not feed prepared diets to their 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® 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).

Several groups are currently working on determining nutritional requirements for hybrid bluegill. Those data will be important pieces of information as they develop and may help explain any differences in Purdue University's study proposed herein. This review will focus only on practical diet evaluations.

Hybrid sunfish destined for stocking in farm ponds are rarely fed formulated diets. There is simply little need to spend the additional funds on feed when pond stocking recommendations assume small centrarchids as forage for largemouth bass, or other predators. A small percentage of producers for that market feed a formulated diet, but as more of a supplemental feeding strategy. That is, feed inputs into the culture system are not sufficient to meet the needs of the fish; they must also rely on naturally occurring organisms in the pond. Additionally, several fisheries managers in the NCR are feeding centrarchids in ponds and lakes as a means of increasing the average size of fish caught by anglers. The development of this centrarchid trophy fishery adopted a supplemental feeding strategy. Culturists who desire production of a fish for the human food market must feed diets that are near complete for the target organism and at feed rates that approach satiation. A supplemental feeding strategy will simply increase the time to harvest and delay economic return on investment.

Very little is known about the nutritional requirements of lepomids. Tidwell and co-workers (1992) evaluated the protein requirements of 4.7-g green BG × GS hybrids using practical feeds. They found that fish fed the highest protein diet used in their study (37%) exhibited significantly higher weight gain than fish fed diets with lower protein levels, which seems to confirm the previous research with lepomids fed supplemental feeding rates. Unpublished data from Purdue University (Purdue) also confirmed the developing concerns that hybrid bluegill require relatively high levels of CP. In a study conducted in a controlled laboratory setting, juvenile hybrid bluegill gained significantly more weight when fed two of the available diets formulated for trout than when fed a third diet formulated for trout or either of two diets formulated for catfish. The two diets formulated for catfish contained 36% and 32% CP, respectively. Again, these data seem to support the idea the optimal concentration of CP for juvenile hybrid bluegill is relatively high.

Researchers participating in this proposal and previous sunfish proposals are quantifying the nutritional requirements of key essential amino acids (lysine) and phosphorus (Purdue), optimum protein to energy ratio (D.L. Garling, Michigan State University), and the optimum ratio of carbohydrate to lipid within the optimum protein to energy ratio (Purdue). Those data are being incorporated into experimental diets fed to hybrid bluegill at SIUC (C. Kohler). Thus, while the necessary data for developing a diet specifically for hybrid bluegill are being developed, new producers need recommendations they can use now. This proposed project will provide that information.

Colleagues at Kentucky State University are also continuing their research efforts on practical feeds for overwintering (Tidwell and Webster 1993) and diets for hybrid bluegill reared in cages. Thus, there is no apparent overlap with research efforts elsewhere. Indeed, the complimentarity among research lines will facilitate development of the pertinent information in the most expeditious manner without excessive expense.

Compare Feeding Trials for Grow Out in Recirculating Systems under Compensatory Feeding Strategies (Objective 1b)

Compensatory growth refers to the capacity of animals to grow at higher-than-normal rates when food is replenished after a period (usually more than one day) of its low supply. Compensatory growth occurs in many animal classes including mammals, birds and fishes (Jobling et al. 1993), with proximate mechanisms associated with the rapid growth state being hyperphagia and increased growth efficiency (Koppe et al. 1993; Broekhuizen et al. 1994). Compensatory growth in mammals has received substantial attention in agricultural research (Ryan et al. 1993). Fewer, but a growing number of such studies have been completed on fishes from the perspectives of fish ecology (e.g., Russell and Wootton 1992; Wieser et al. 1992) and aquaculture (Grayton and Beamish 1977; Dobson and Holmes 1984; Jobling et al. 1993). Among such studies aimed at aquaculture, efforts have focused on exploiting the compensatory growth response to improve fish growth rates and growth efficiency as well as to influence maturation rate and tissue composition (Jobling et al. 1993).

Regarding fish growth rate improvement, studies have shown that elevated growth rates from compensatory growth do occur in various life stages of many fish families, when food is resupplied *ad libitum* or to satiation after days or weeks of its total deprivation or restriction. In nearly all cases, however, the duration of this rapid compensatory growth elicited by prior food deprivation ceases, once these fish "catch up" to the size of control counterparts that have been fed without interruption (e.g., Miglavs and Jobling 1989; Russell and Wootton 1992). Consequently, there has been little success in fish growth rate improvement using compensatory growth. Results from compensatory growth studies to date have supported the "set-point" hypothesis (Russell and Wooton 1992; Strube 1994) which suggests that better growth in fish cannot be attained through regulation of the food supply.

Whereas the majority of compensatory growth studies in fishes have involved a single period of food restriction followed by unrestricted refeeding (single feeding cycle), a very few studies have employed repeating restriction/refeed cycles (repeated feeding cycles) (Kindschi 1988; Quinton and Blake 1990; Jobling et al. 1993). Repeated feeding cycles are potentially valuable because they may allow successive reactivation of the compensatory growth state (by successive food restriction bouts) each time the compensatory growth state decays. In this way, the total time fish spend in the compensatory growth state may be extended relative to single feeding cycles.

<u>Compensatory Feeding Strategies in BG × GS Hybrids</u>

The published studies which have used repeated feeding regimes to increase fish growth rates with compensatory growth have caught up to, but have not significantly surpassed the growth achieved by daily-fed controls. The study with BG × GS hybrid sunfish at UM did produce significant growth in excess of controls using a repeated feeding regime, primarily because refeeding periods were linked to the duration of the compensatory growth response. Findings demonstrate that compensatory growth can be used for significant growth enhancement in fishes.

Centrarchid production has historically relied on extensive pond production techniques (Snow 1975; Simco et al. 1986; Willis and Flickinger 1980). To intensify production of sunfish to levels beneficial to commercial production for human consumption, producers will probably use hybrid and other sunfish that have good growth rates in intensive culture, and supplemental feeding of formulated diets. 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. 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 culture in ponds where the fish utilize natural foods (i.e., zooplankton).

Successful transition from pond culture to intensive tank culture requires suitable training diets for the culture of fry; nutritionally adequate diets are not yet available for these early stages (<25 mm total length [TL]). The

4-9 d post hatch interval is considered the most critical period in development, as bluegill larvae switch from endogenous to exogenous feeding (Toetz 1966; Smith 1976). During this critical period, nutrients from the yolk sac are used up and the sunfish's mouth opens. Larval fish will starve if they do not begin feeding at this stage. Proper feed for larvae must be digestible and small enough so that the fish can consume it. Toetz (1966) reported the mouth gape of larval bluegill at the onset of exogenous feeding to be 230-270 µm; the first food items must be smaller than this.

In a NCRAC-funded project, Mischke (1995) evaluated feeding protocols for larval bluegill involving 3, 7 and 14 d feeding of brine shrimp, *Artemia franciscana*, (additional 3 d weaning period) prior to using Fry Feed Kyowa® B-250 (FFK-B250). Larvae 24 d post hatch fed brine shrimp for 14 d were significantly longer and heavier than the groups of larvae fed brine shrimp for 3 d or 7 d. There was a significant difference in survival rates between the treatment groups with the 14 d protocol having the greatest survival, 42%.

Compensatory Feeding Strategies in Black Crappie

Efforts to use crappie as an aquaculture species have had limited success (Leary 1908, 1909; Harper 1938). Mortalities related to handling stress and difficulty in training crappie to commercial diets have thwarted efforts to use traditional production approaches. Smeltzer and Flickinger (1991) were most successful in handling fingerling black crappies at night and at water temperatures less than 21°C. They also were able to train these fingerlings to Biodiet® with a success rate of 85 - 95% in raceways. Amspacker (1991) was able to maintain white crappie (*Pomoxis annularis*) in a recirculating system but had variable success in training them to commercial diets. Fish greater than 150 mm showed a 100% training rate to Mesa #4 Crumbles® when preceded by krill. On the other hand, fish less than 150 mm would not accept the Mesa diet. Training success improved to 46 - 65% when fish density was increased to 4 kg/m^3 as recommended by Simco et al. (1986) and 1.5 mm Biodiet® was preceded by brine shrimp. Both wild caught and commercially produced white crappie were used in this study. Throughout the feeding trials mortality was very low and appeared to be from starvation rather than capture or handling.

As a result of Amspacker's (1991) work, PSU initiated an effort to study the use of cage culture technology in rearing crappie as a part of NCRAC Grant #92-38500-6916 (Read 1994). The initial effort to use large numbers of wild caught white crappie to study various densities in cages was met with the same capture and handling problems experienced by earlier workers. Variations in capture, transport and handling produced a reduction in mortality from 100% to 51% with one exception. Fish collected by electrofishing had 0% mortality, which was the method used previously to collect fish for Amspacker's work. Since insufficient numbers of fish could be collected by electrofishing to produce the densities needed in cages and most of the growing season was gone, fish were moved indoors to the recirculating system to evaluate training and success at the mid-range density of 4 kg/m^3. Numerous feeding trials were conducted and the fish were maintained in the system for over 20 months. During that time, mortalities were limited to nonfeeders (starvation) and system failure (dechlorination). These white crappie were fed Biodiet® 2.5 mm semimoist pellets for all trials. Growth was highly variable between individuals suggesting the formation of feeding hierarchies, which was reinforced by observations during feeding. Feeding small amounts of food many times a day appeared to heighten the impact of the hierarchy, resulting in greater growth differentials. Temperatures around 20°C produced the best growth response, while those around 26°C produced the worst growth. Fatty livers and fat packed into the abdominal cavity suggested that Biodiet® may not be nutritionally balanced for crappie.

During the second year of the cage study, over 4,000 crappie (whites, blacks and hybrids) were hauled in two trips from Kinmundy, Illinois to Pittsburg, Kansas without a single mortality (Read 1994). They were loaded and hauled at night with oxygen and water treatments of Polyaqua, Amquel and 0.5% salt at water temperatures less than 20°C. Although mortalities were high for blacks, whites and hybrids throughout the growing season in the cages, it was apparent that the blacks were the most aggressive feeders. Again, fish were fed Biodiet® 2.5 mm pellets throughout the project, and those fish that fed exhibited fatty livers and surplus fat in the abdominal cavity like those in the recirculating system.

As a result of the observations during the feeding trials in the recirculating system at PSU, aquaria studies were initiated during the summers of 1994 and 1995 as part of a National Science Foundation-funded Science Academy to investigate the feeding hierarchies formed by crappie. During 1994, results suggested that a strong nip-right hierarchy forms very quickly among blacks, a bit less quickly among whites and very slowly, if at all, among hybrids. Fish learned feeding sequences for numbers of food items offered quickly if not randomized, and the number of food particles present needed to exceed the number of fish by two to three times in order for all fish to feed. During 1995, experiments were designed to evaluate the relative importance of individual aggressiveness, size, sex and density in aggressive/submissive behavior. Within certain ranges, individual differences appear to be most important. While somewhat tangential, this work has contributed to our understanding of feeding activity and why some feeding strategies may not work.

Establish baseline physiological measures for small 2.5-7.6 cm (1-3") black crappie subjected to handling stressors and to test the effect of salt and temperature on stress reduction (Objective 2)

The use of salts to improve the survivorship of cultured fish has long been of interest and it is now becoming accepted practice in fish transportation (Piper et al. 1982). Many investigators have documented the benefits of using salts to reduce the stress or mortality associated with transport (Long et al. 1977; Carmichael et al. 1984a; Mazik et al. 1991; Weirich and Tomasso 1991; Weirich et al. 1992). Barton and Peter (1982) found that the presence of 0.5% salt in the tank water resulted in a much reduced level of plasma cortisol, the major stress hormone, in rainbow trout compared with that in control fish after 4 h of transport. Similarly, Mazik et al. (1991) reported a dramatic suppression of the characteristic increase in plasma cortisol in striped bass (*Morone saxatilis*) during transport with 1.0% salt water compared with freshwater-transported fish. In a study with walleye (*Stizostedion vitreum*), Barton and Zitzow (1995) showed that the use of 0.5% salt did not attenuate the 1-h elevation in plasma cortisol caused by handling, but evidently allowed the fish to recover from the disturbance more quickly.

The beneficial effect of salt additives may be to prevent losses of blood ions that can occur when fish experience acute stress (Wedemeyer 1972; Carmichael et al. 1984a). Barton and Zitzow (1995) found that using 0.5% NaCl in the recovery medium completely eliminated the handling-induced decline in plasma osmolality seen in freshwater-held walleye. The addition of salt provided conditions that were less hypotonic to the fish than fresh water, thus reducing the osmotic gradient between water and plasma. Similarly, Weirich and Tomasso (1991) and Weirich et al. (1992) found in stressed red drum (*Sciaenops ocellatus*) and hybrid striped bass (*Morone chrysops* × *M. saxatilis*), respectively, that the smallest change in plasma osmolality occurred when the environmental salinity was about 0.8%. Those authors concluded that the least amount of osmoregulatory dysfunction occurred when the external salinity was nearly isosmotic with the fish's plasma. Reduction of the energetic cost of osmoregulation by making the medium near-isotonic with fish blood is also considered as a possible explanation, although this view has been questioned (Morgan and Iwama 1991; Toepfer and Barton 1992). Moreover, the return of fish to salt-free water after a short-term adjustment to isotonic conditions may be stressful (Barton and Peter 1982).

There is a metabolic cost associated with handling and transport of fish that is reflected in increased oxygen consumption (Korovin et al. 1982; Barton and Schreck 1987; Fletcher 1992). Lowering water temperature in handling or transport water has often been suggested or used as a way of reducing post-handling delayed mortality. The value of such a practice appears to be the reduction of the fish's metabolic rate, thereby reducing oxygen consumption and ammonia production. Fish culturists have known about the dramatic increase in metabolic rate in handled fish and the effect of reducing water temperature for some time. For example, more than 50 years ago Haskell (1941) clearly documented a drop in ambient dissolved oxygen (DO) levels at four different temperatures in fish transport tanks for the first hour after the fish were loaded into the tank, with the extent of the decline in DO directly related to increases in tank water temperature. However, Barton and Peter (1982) concluded that chilled water alone was not effective in reducing responses of rainbow trout to transport stress, and that a sudden drop in water temperature (from 9 to 1°C) in itself acted as a stressor on the fish.

Update the Sunfish Culture Manual (Objective 3)

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 exists 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 been 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). In the current sunfish proposal, a Sunfish Culture Manual has been funded and is scheduled for completion in fall 1995.

ANTICIPATED BENEFITS

Compare Feeding Trials for Grow Out in Ponds at Dissimilar Latitudes in the Region (Objective 1a)

NCRAC has funded several years of research evaluating various centrarchid taxa in regard to their potential for food fish production. Taxa that appear to be promising for this application are the BG × GS hybrid and the black crappie. The BG × GS hybrid shows many of the characteristics sought in a commercial food fish, except that it appears to be difficult to economically grow to a size larger than about 0.11 kg (0.25 lb). The black crappie appears to perform better than the white or hybrid crappie under culture conditions, and it may be more suitable than the BG × GS hybrid for production to a larger size, but it has not performed as well as the BG × GS hybrid in tank culture studies. The black crappie has been difficult to habituate to commercial feeds, and it has shown poorer survival in tank and cage culture than is typical of the BG × GS hybrid. It is uncertain at this time whether one versus the other might enjoy any advantages in the market place.

Farmers interested in centrarchid food fish production need to know whether they should choose the black crappie or the BG × GS hybrid to meet a given market niche. Black crappie and BG × GS hybrid, side-by-side pond production studies offer the best approach for providing the information farmers need to make an informed choice. Most warmwater and coolwater commercial-scale aquaculture is conducted in ponds. Pond studies will provide information on the relative costs of production and potential for grow out for the two taxa under practical fish-culture conditions.

Although the BG × GS hybrid has performed better than the black crappie under cage and tank culture conditions, the performance of the latter may improve under pond culture conditions. Black crappie may require habituation to commercial feeds prior to stocking into grow out ponds. This will add to the cost of production, but if black crappie are better candidates for grow out to a larger size than BG × GS hybrids, or if their market value is greater, then employing a period of habituation to commercial feeds in black crappie production may be economically feasible.

Should the proposed black crappie/BG × GS hybrid pond production study be funded, farmers will know the relative economic advantages and disadvantages of producing one taxon versus the other. This study will also provide information on whether stocking density and the inclusion of a period of habituation to commercial feeds in the production cycle affects the performance of either of the two taxa.

Producers throughout the NCR are interested in culturing hybrid sunfish. However, the technical information necessary for producing hybrid sunfish for the human food market is lacking. Data developed for production of hybrid bluegill for pond stocking is beneficial, but often misleading for more intense production in which maximum efficiency is necessary. The data developed in Objective 1a are crucial for producers. The proposed Purdue study will identify the appropriate diets that can be purchased immediately. Further, growth rates, FCRs, survival and final weight at the end of a growing season at two different latitudes will be available. Those data will be important components for development of business plans.

Compare Feeding Trials for Grow Out in Recirculating Systems under Compensatory Feeding Strategies (Objective 1b)

Recent evidence from the UM study with hybrid sunfish (Hayward et al. In preparation) indicates that a capacity exists for substantially reducing grow out times for fish in aquaculture. Other possible benefits associated with compensatory growth include increased fish growth efficiency, influences on proximate composition of flesh, and delayed maturation (Jobling 1993).

This project will provide guidelines on appropriate sizes, and timing of feeding for aquaculturists who wish to intensify centrarchid culture for human food production. Feeding strategies to obtain compensatory growth (i.e., better growth rates with less food) is an easily-applied low-cost/cost-saving technique that both increases growth rates and improves food conversion efficiency in these fishes, which would clearly be beneficial to commercial 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 this region.

An additional benefit that may be associated with feeding strategies that invoke the compensatory growth response 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.

Understanding the impact of compensatory growth on production in recirculating systems is very important to commercial producers. Improved growth efficiency and reduced feed costs are of obvious value. Reduced wastage is important to any production system, but is very critical to recirculating processes. On the other hand, fluctuations in ammonia levels from feeding and nonfeeding periods may result in perfomance problems by creating instabilities in the bacterial communities in the biofilter. The application of process control technology in feeding trials for compensatory growth at PSU will demonstrate the importance of continuous management on optimization of system performance and will have direct application to commercial systems.

Clarifying the factors that influence the transition of pond harvested crappies to intensive tank rearing conditions can provide a foundation for industry efforts toward intensification of crappie production for human food. Practical strategies of habituating large numbers of fingerlings to commercial diet and high rearing densities require that this transition be achieved cost effectively. Either intensive rearing from egg or the habituation of pond reared crappies to commercial feed could prove to be viable alternative strategies. UW-Milwaukee will explore both the biological hurdles that need to be overcome and determine the comparative costs of both methods. This information is needed for the regional industry to intensify crappie production. The development of techniques for crappie production for human food will open up new opportunities for the diversification of aquaculture in our region.

Establish Baseline Physiological Measures for Small Black Crappie Subjected to Handling Stressors and to Test the Effect of Salt and Temperature on Stress Reduction (Objective 2)

The initial experiments described herein are needed to determine the physiological responses of black crappie to handling stress, as this aspect of crappie physiology has not been documented to date. Subsequent studies will determine whether salt addition or temperature reduction can be used to mitigate stress and the mortalities associated with handling and transporting small black crappies. As the proposed experiments are preliminary in nature, optimum treatments probably will not be defined. To do so, subsequent studies will be needed in order to define the optimum timing and level of NaCl and temperature treatment, and also to investigate the effects of other types of treatments for reducing stress, such as the use of anesthetics or other salt additives, notably calcium chloride ($CaCl_2$), alone or in combination.

Update the Sunfish Culture Manual (Objective 3)

NCR 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 for the NCR will provide research based materials for information transfer to commercial producers and individuals interested in production of sunfish to meet these market demands.

PROGRESS TO DATE

Overview

The initial centrarchid culture technology project funded through NCRAC 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 d 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.

In 1990, SIUC workers 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 (Wills et al. 1994).

In 1992, researchers at SIUC 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 (7,000 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 (Wills et al. 1994). 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 (8,000 psi) for 5 minutes begun 1.5 minutes after fertilization.

Also at SIUC, irradiated spermatozoa (to destroy the DNA) have been used to fertilize bluegill eggs. Eggs from each female were divided into three lots. One lot (controls) was fertilized with normal spermatozoa. The other two lots were activated with irradiated spermatozoa. One lot of eggs activated with the irradiated spermatozoa was then subjected to pressure shock to induce polar body retention. These treatments were intended to produce gynogens, fish with exclusively the female genetic complement. The pressure-shocked individuals (putative diploid gynogens) showed poorer survival than the controls and abnormalities, but several hundred lived long enough to be stocked into a pond at SIUC. The controls developed normally, but the non-pressure shocked eggs all died, indicating that they were haploid, and that the irradiation treatment was successful. Seven sexually mature gynogens were recovered from the pond and all were female. The probability of obtaining seven fish which are all females from a fish population with a 50:50 sex ratio is 0.008. Thus, SIUC's results suggest that bluegill have an XY genetic sex-determination system, since all of the gynogens were female.

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.

The methodology developed for triploid sunfish production at SIUC will benefit those producers who wish to control reproduction in culture ponds. Although analysis is incomplete, the triploid sunfish appear to be functionally sterile, and they do not complete gametogenesis, preventing much of the fish's energy from being diverted to the production of gonadal products. Histological and flow cytometric analyses of the gonads of male and female triploids by SIUC, in a collaborative study with Dr. Stan Allen at Rutgers University, showed that Meosis I is not completed during gametogenesis, and that the process stops when germ cells are in the hexaploid stage.

If tetraploid bluegill stocks can be produced and raised to maturity using improved cold or pressure techniques, as MSU is attempting to do, 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.

In 1991 and 1992 work began on evaluating the production characteristics of sunfish. SIUC researchers evaluated densities for cage culture of BG × GS hybrids. 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 1995 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.

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.

Investigators at SIUC 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

ISU researchers have been able to both spawn and feed larval bluegills in an enclosed recirculating system. During a six-month period (December 1994 - May 1995), 40 spawns averaging 20,000 larvae each were obtained from 24 females. This NCRAC-sponsored research demonstrated that it is possible to induce bluegill to spawn in the laboratory out-of-season by manipulation of temperature and photoperiod without the use of hormones. A feeding protocol involving the use of brine shrimp and a commercial diet has also been established that allows for more than 40% survival and good growth rates of larvae through the first 30-d posthatch. This protocol allows for the production of bluegill larvae, regardless of season, for both laboratory studies and intensive culture of sunfish. A Master's thesis describing these protocols has been prepared (Mischke 1995). Research into production of hybrid bluegill is progressing using this same protocol at ISU.

Research progress specifically addressing the objectives of the current Sunfish Work Group proposal is as follows:

Compare Feeding Trials for Grow Out in Ponds at Dissimilar Latitudes in the Region (Objective 1a)

Objective 1a is new for the Sunfish Work Group. It is designed to compare the performance of BG × GS hybrids to black crappie in an intensive pond culture situation. Thus, there is no progress to date *per se* on this objective. However, SIUC is currently comparing the black crappie to BG × GS hybrids in side-by-side tank-culture feeding trials at five water temperatures. Preliminary analysis of the data indicates that the sunfish hybrids grew better under the conditions of the trials. However, these trials do not address the question of whether or not the black crappie can grow as well or perhaps better than the sunfish hybrid in production ponds. Crappie have not grown or survived well in previous studies in the region at PSU and SIUC under highly artificial conditions, such as in cages or tanks. This objective is a logical continuation of that work, since it is reasonable to suggest that the black crappie, a species known to be susceptible to stress-induced mortality when handled and held in confinement (see Objective 2 **JUSTIFICATION**), may show its best performance in ponds, where an environment more similar to natural conditions can be provided.

Compare Feeding Trials for Grow Out in Recirculating Systems under Compensatory Feeding Strategies (Objective 1b)

In 1994-1995 researchers at the UM conducted a laboratory study on compensatory growth of the BG × GS F_1 hybrids. Major objectives were to test various feeding schedules that elicited the compensatory growth response in these fish, for their capacity to increase growth rates and improve growth efficiency relative to fish fed every day. BG × GS hybrids were subjected to one of five treatment feeding regimes (N = 10 fish per treatment) involving repeated cycles of food deprivation followed by *ad libitum* refeeding. Each treatment group's food deprivation periods were fixed at either 2, 4, 6, 10 or 14 d (designated as the D2, D4, D6, D10 and D14 treatment groups, respectively); refeeding periods in all cases were continued until hyperphagia ceased. Hyperphagia was considered to be present whenever a treatment group's daily consumption rate was significantly greater than that of the control group which was fed *ad libitum* every day. The treatment feeding schedule involving the shortest food deprivation period (i.e., D2) was hypothesized to yield the greatest growth and growth efficiency benefits. This was hypothesized because the greatest number of days in growth compensation (TGC) per day of food deprivation (TFD), was expected to result from the shortest food deprivation period that was sufficient to produce hyperphagia.

Originally, use of a commercial diet in this study was planned. However, it was decided that daily food consumption rates of the test fish (essential to monitoring hyperphagia) could not be readily measured with sufficient accuracy when using a pellet diet. This was because uneaten food disintegrated and so could not be weighed after 24 hours. For this reason a natural prey (mealworm *Tenebrio molitor*) was used; this was readily accepted by the hybrids and also remained intact for 24-h periods thus allowing accurate determinations of daily food consumption.

Hyperphagia was observed following all food deprivation periods over all treatment groups. Fish in D2 and D14 significantly outgrew (wet weight) control fish (ANCOVA; $P < 0.0001$); D2 outgrew control fish two-fold (2.01), while D14 outgrew controls by a factor of 1.45 over the 115-d experiment. The high growth rate of fish in the D2 group was associated with this group having the greatest total days of hyperphagia; the D14 group had fewer total days of hyperphagia but the magnitude of the hyperphagia was stronger. To our knowledge this is the first documentation of statistically significant outgrowing of daily-fed control fish of any species using compensatory growth. Although growth efficiency significantly exceeded controls during refeeding periods for treatment groups, growth efficiency was no different than controls over the full experiment (which included both no-feeding and refeeding periods).

UW-Milwaukee is currently engaged in a collaborative study, as part of the ongoing NCRAC Sunfish Work Group investigations on feeding strategies for the culture of larval sunfish, through a cooperative aquaculture development project with the Red Lake Band of Chippewa Indians, Red Lake, Minnesota and the Aquaculture Institute, at the University of Wisconsin Great Lakes Research Facility. This group has obtained pond reared black crappie brood fish and young of the year black crappie. The smaller fish accepted adult frozen brine shrimp as a transitional food and were habituated to commercial starter feed within 14 d. The adult fish accepted adult frozen brine shrimp and other transitional foods after about 14 d and eventually habituated to Biodiet® within approximately 3 months. These stocks of crappies were then overwintered at the Aquaculture Institute. UW-Milwaukee attempted to spawn the adult fish by manipulating temperature and photoperiod this spring, but were unsuccessful in bringing the group of approximately 40 adult fish into spawning condition. They then attempted to bring in spawning fish from the wild and hired an experienced individual full time for a month to locate spawning adults or nests with eggs in order to obtain larvae for feeding trials. This effort focused on an area from the Lake Winnebago region northward into the vicinity of Hayward in northwestern Wisconsin; however all these efforts failed to reveal spawning fish, eggs or sac fry. Unusual temperature conditions this spring contributed to the unpredictable spawning activity. UW-Milwaukee will attempt to laboratory spawn their captive brood fish again, if necessary using spawning induction substances, and they will conduct field collection efforts to obtain adults in spawning condition in 1996. From these spawnings UW-Milwaukee will attempt to intensively rear black crappie using "green tank" organisms as first feeding foods.

This "green tank" procedure involves the use of batch cultures ("green tank") of live infusoria, brine shrimp nauplii and ground beef heart and liver for first feeds. Over the last 5-7 years UW-Milwaukee has 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 d post first feeding, and starter diet habituated fry can be produced at levels between 2,000 - 6,000 fry/m^3 of rearing volume. Techniques for intensive rearing of crappie larvae are not available. UW-Milwaukee hopes to bridge this information gap using the “green tank” procedure. Although it is debatable whether the “green tank” method will be feasible in commercial crappie food fish production, UW-Milwaukee will use it to facilitate its evaluations of procedures for habituating crappie to formulated starter diets. Should the “green tank” method fail with crappie, UW-Milwaukee will use the smallest size of pond reared fish that are available from commercial producers and habituate them to commercial feeds at the smallest feasible size.

Through an Iowa producer UW-Milwaukee has obtained a small group of 20-35 mm pond reared young of the year black crappie and are currently habituating these fish to commercial diet.

Work at PSU has shown that white crappie can be held in recirculating systems, trained to feed on commercial pellets and grown under those conditions. Early work indicated that trainability for smaller crappie, less than 150 mm TL was similar to largemouth bass in terms of the approach required and overall success of around 40 to 50%. Larger fish, however, appeared to require less conditioning with most, and in some cases nearly all, of the fish switching to pellets. Later work has focused on the persistent presence of fish that are classified as nonfeeders based on their emaciated appearance and a condition-factor of less than 0.9 K TL. Based on tank observations, aggressive interactions appeared to play a role in the continual development of nonfeeders.

The presence of feeding hierarchies in crappie was demonstrated in competition experiments in the laboratory at PSU. Although crappie are centrarchids, their relative timidity when compared to other members of the family made the levels of intraspecific aggressiveness surprising. Feeding strategies that made food appear scarce, or permitted dominant fish to prevent feeding aggravated the differences in feeding activity in the hierarchy and thereby the differences in growth. Saturation feeding when all fish were hungry produced the best feeding response. The number of food particles available had to exceed the number of fish by two to three times before all fish would feed. This observation was reinforced in the results of the recirculating system trials. Feeding strategies to promote compensatory growth should greatly reduce the impact of the feeding hierarchy.

Feeding trials at PSU in cages and in the recirculating system using the Biodiet® semimoist pellets produced fatty livers and much surplus fat in the gut cavity. While this may primarily result from a feed not well balanced for this species, it could also represent overfeeding by dominant individuals in the hierarchy. Again, feeding strategies that promote compensatory growth may greatly reduce, if not eliminate this development of excess fat. In all trials, growth was highest when temperatures were maintained around 20°C. Growth was poorest when temperatures reached or exceeded 26°C.

Establish Baseline Physiological Measures for Small Black Crappie Subjected to Handling Stressors and to Test the Effect of Salt and Temperature on Stress Reduction (Objective 2)

This is a new objective for the Sunfish Work Group, so there is no progress to date. However, a number of other similar studies, using a variety of species including other centrarchids, are available for comparison (see **RELATED CURRENT AND PREVIOUS WORK**).

Update the Sunfish Culture Manual (Objective 3)

The previously funded manual has been drafted and will be reviewed by regional and national experts. The initial issue is scheduled to be completed by August 1996.

OBJECTIVES

1. Compare feeding trials for grow out of locally available 5.1-10.2 cm (2-4") black crappie and bluegill male × green sunfish female hybrids in:
   a. ponds at dissimilar latitudes in the region, and
   b. recirculating systems using compensatory feeding strategies.

2. Establish baseline physiological measures for small 2.5-7.6 cm (1-3") black crappie subjected to handling stressors and to test the effect of salt and temperature on stress reduction.

3. Update the sunfish culture manual that had been developed for sunfish produced in the North Central Region.

PROCEDURES

Compare Feeding Trials for Grow Out in Ponds at Dissimilar Latitudes in the Region (Objective 1a)

Purdue and SIUC are participating in Objective 1a. Collectively, they will address five important questions regarding grow out of sunfish in ponds in our region. These are:

1. How does latitude affect grow out?
2. How does protein content in commercially available diets affect grow out?
3. How do BG × GS hybrids and black crappie compare during grow out?
4. How does stocking density affect the relative performance of BG × GS hybrids and black crappie during grow out?
5. How does a training (habituation to prepared diets) period affect the relative performance of BG × GS hybrids and black crappie during grow out?

Purdue will address questions 1 and 2 in its one-year study. SIUC will address questions 1, 3, 4, and 5 in its two-year study. Researchers from Purdue and SIUC collaborated to develop the experimental design regarding test diets, feeding rates, and stocking densities for the latitudinal comparison. A readily available commercial feed will be utilized at both locations so that the results will be directly transferable to commercial growers in the region.

Purdue

Procedures at Purdue will be as follows. Juvenile BG × GS F_1 hybrids will be obtained from Clear Creek Hatchery, Martinsville, Indiana, and transported to the Purdue Aquaculture Research Facility. The Martinsville facility has been used as the source of BG × GS hybrids for the past four years. In all cases, sex ratios matched expectations for a true hybrid.

Fish will be stocked into 0.1-ha earthen culture ponds at Purdue at a density of 8800 fish/ha. Fish stocking will be as early in the year as practicable. Purdue anticipates using fish from a late summer spawn which will be overwintered at Clear Creek. That will provide the desired size of fish and the maximum study duration. The target time period for conducting this study will be April through early November.

Three separate diets will be fed to triplicate groups of fish. The three diets will be commercially available feeds containing graded levels of CP (32%, 36% or 40%). To achieve this gradation, Purdue anticipates using a standard catfish diet, a catfish cage diet and a regionally available diet formulated for trout. This approach will also result in varying levels of dietary lipid, but the practical nature of the evaluation demands this concession. Given the proposed studies that will be conducted prior to this one, it may be possible to minimize any confounding effect of varying lipid levels. All fish will be fed once per day to apparent satiation. Feed intake will be monitored on a daily basis.

Pertinent water quality variables will be monitored regularly. DO and temperature will be monitored daily. Ammonia, nitrite, and pH will be monitored at least weekly. Hardness and alkalinity will be monitored monthly. Standard equipment (YSI DO meter, benchtop pH meter and a Hach DREL 1C Water Quality Test Kit) is available and in working order.

At the end of the Purdue study, all ponds will be partially drained and all fish removed by seine. Fish will be counted and weighed in groups for calculation of survival, weight gain and FCR. Feed consumption will be plotted as a function of water temperature over the course of the study. Additionally, dress out percentage of fish from each replicate will be determined by hand. At least 20 fish from each replicate will be used for both dressed yield (gutted and gilled, heads on) and fillet yield. All data will be statistically analyzed as a completely randomized design.

SIUC

SIUC will compare black crappie to BG × GS hybrid sunfish in pond production trials at the Illinois Aquaculture Research and Demonstration Center. The trials will be initiated with 5.1-10.2 cm (2-4") fingerlings obtained from local producers. Two stocking densities will be tested, 4,400 and 8,800 fingerlings per ha. The higher stocking density is the same as that which will be used by Purdue in its feeding trials (see above) to make the results of the two studies more comparable. Each experimental condition will be replicated five times. Thus, a total of 20 ponds will be used in each year of the study, five ponds for each taxon at each density.

In the first year of the study at SIUC, fingerlings will be obtained in the spring and stocked directly into the ponds. The fingerlings will be fed a 40% protein trout diet to make feeding trials conducted at SIUC more comparable to feeding trials at Purdue. Purdue will evaluate three diets, 32%, 36%, and 40% protein diets, in its feeding trials with BG × GS hybrid sunfish (see below). The fingerlings will be fed daily to apparent satiation (as in the Purdue study) through the summer and fall at SIUC until water temperatures decline to about 10°C.

Water quality (DO, pH, temperature, and ammonia) will be monitored each week in at least two ponds for each taxon and density. Continuous-recording thermographs will be placed in two ponds, one for each taxon, to obtain water temperatures over the production period. The ponds will be harvested at the end of the production season, and mean growth, feed conversion efficiency, survival, and production will be determined for the two taxa at each density. Mean condition (K) and dress-out percent will be determined from subsamples of 50 fish from each pond. ANOVA will be used to compare the two taxa at the two stocking densities.

Methods in the second year of the SIUC pond study will be similar to that of the first year with the following exceptions. A training or habituation period, designed to promote acceptance of commercial feeds, will be used at the beginning of the second year of the SIUC pond study. Black crappie may accept commercial feeds in the pond better, if they are first trained (habituated) to prepared feeds in tanks. UW-Milwaukee, PSU, and SIUC have or are currently evaluating methods to habituate black crappies to prepared feeds. Black crappie will be held by SIUC in tanks and habituated to commercial feeds prior to stocking into the production ponds, using the most promising method identified by the three institutions. BG × GS hybrids will also be habituated to commercial feeds in tanks prior to stocking. However, work at SIUC and elsewhere indicates that a brief period of feeding Biodiet®, followed by a gradual shift to dry feeds is sufficient to promote good acceptance of commercial feeds for the hybrid.

Both taxa will be trained for as long as deemed necessary prior to stocking into the production ponds in the second study year; thus, one taxon may be stocked out prior to the other. Mean growth, condition, and survival will be determined at the end of the training period, as well as an estimate of the percent of fish accepting the commercial feed for both taxa. ANOVA will be used to compare the two taxa. Data collection and analyses at the end of the pond-production season in Year 2 will be the same as in Year 1.

Compare Feeding Trials for Grow Out in Recirculating Systems under Compensatory Feeding Strategies (Objective 1b)

UM

Experiments will be conducted in five areas at UM. The first two are follow-up in nature and relate directly to the previous experiment on compensatory growth with BG × GS hybrid sunfish. The latter three experiments are intended to clarify whether hybrid sunfish growth rate improvements observed in the initial experiment are readily reproducible in the commercial aquaculture setting. If not, specific problem areas will be identified.

Feeding schedules in the previous work at UM involved food deprivation periods ranging from 2 to 14 d. Growth in excess of control fish resulted from only the two extreme compensatory growth feeding schedules, the D2 and D14 treatment groups. Because the D2 feeding schedule involved the minimum food deprivation time for elicitation of compensatory growth, this treatment was essentially bracketed (hybrid growth response from feeding schedules involving food deprivation times both greater than and less than 2 d were evaluated). Treatments involving food deprivation times greater than 14 d were not evaluated. Therefore, experimentation with repeated feeding cycles involving food deprivation times in excess of 14 d is warranted to determine if such schedules will produce even higher growth rates than was previously observed; in this way, compensatory growth feeding schedules that produce maximum growth benefits can be fully defined.

Previous studies of change in fish body composition in association with compensatory growth (e.g., Koppe et al. 1993) suggest that protein:fat ratios will not differ substantially between fish fed daily versus those fed on schedules to induce compensatory growth. Nonetheless, as follow-up work to the preliminary study, proximate composition of hybrid sunfish fillets should be compared among fish fed on compensatory growth inducing schedules and those fed daily. All fish from the previous experiment were killed and frozen immediately after the study terminated and can be used for such analyses.

To assess the applicability of previous findings to the commercial production setting, it is also necessary to determine how observed compensatory growth benefits respond when a commercial feed (versus a natural prey item) is used. Also, because fish in the previous experiment were held solitarily in enclosures (so that individual's daily food consumption could be measured), it is necessary to determine whether and how observed compensatory growth benefits change when fish are held in batch settings, as occurs in commercial aquaculture. Here, the primary interest is in whether or not dominance hierarchy effects on hybrid food consumption and growth will be accentuated due to elevated appetites caused by compensatory growth feeding schedules, which may negatively influence mean hybrid growth rates. Finally, information on how compensatory growth feeding affects DO uptake rates, ammonia production and dissolved solids concentration in the culture water is needed, as water quality conditions may be differentially influenced relative to more standard feeding regimes (daily feeding).

1. Longer Food Deprivation Periods

This experiment will be designed for comparability to UM's previous study. BG × GS hybrid sunfish will be secured from a local producer and acclimated to laboratory conditions for three weeks. Laboratory conditions will include water temperature of 23°C in a 945-L water recirculation tank with biofiltering and reaeration capabilities, a 15-h light/9-h day photoperiod regime, and being fed *ad libitum* rations of mealworms once daily while held in 3.25-L clear plexiglass aquaria with perforations, which are submerged within the 945-L tanks. Experimentation will involve four groups of 10 fish (13 g mean live weight). One group (controls) will be fed *ad libitum* every day. Three treatment groups will be fed on repeating cycles of food deprivation (for a fixed number of days), followed by *ad libitum* refeeding for as many days as hyperphagia persists. Fixed food deprivation periods for the three treatment groups will be 14 d (for comparison to the previous experiment), 20 d, and 30 d. The experiment will continue until the longest feeding schedule (30 d food deprivation) has completed two cycles. Growth and daily consumption will be measured for each fish in each group. Results from this experiment in combination with those from the previous study, will allow identification of an optimal feeding schedule for compensatory growth of hybrid sunfish fed mealworms at 23°C. After its completion, the seven compensatory growth feeding schedules having been evaluated will include food deprivation times of 2, 4, 6, 10, 14, 20 and 30 d.

2. Proximate Composition

From UM's previous experiment, all fish were killed at experiment's end via anesthetic overdose (MS-222) in water of 1°C to prevent tissue composition changes. Each specimen was then individually sealed in an air-tight Zip-Loc® plastic freezer bag, and stored at -20°C. To assess whether differences in proximate composition exist across the various treatment groups (control, D2, D4, D10, D14), samples of somatic musculature (flank fillets) and liver will be obtained in equal sizes from all specimens. Within each group, the specimens will be homogenized, and then subjected to standard proximate analyses to determine moisture, protein, lipid, carbohydrate, and mineral ash composition, with the liver samples being subjected to an additional glycogen analysis. Should treatment-associated differences be evident, additional analyses by individual fish will be executed, as funds permit.

3. Using Commercial Feed

This experiment will evaluate how the use of a commercial pellet feed will influence compensatory growth results observed in the previous study. Use of a commercial pellet diet (versus mealworms) may substantially alter the magnitude of the compensatory growth response. In addition, a distinct feeding schedule may produce maximal growth benefits from compensatory growth (versus when mealworms are provided), and weight and composition of fillets may be differentially affected.

UM's previous experiment (see **PROGRESS TO DATE**) will be mimicked with a preferred commercial pellet diet, using a daily-fed control group plus four compensatory growth feeding schedules: D2, D4, and two of the longer cycles, one being the upper-end optimum for growth rate to be determined in Experiment 1 (above). Each fish's daily consumption of the commercial feed will be estimated by capturing uneaten food from each fish's container and subtracting its weight from the known weight provided during feedings to satiation over the previous 24-h period. Each fish's body weight will be determined weekly as in the previous study. Periods of refeeding will continue as long as hyperphagia persists, as was done previously. The experiment will run until the longest feeding regime has completed at least two cycles. Growth, consumption, growth efficiency and fillet proximate composition in each treatment group will be compared to those resulting from the identical feeding schedules in the previous study (where mealworms were used), to determine any differences associated with food type.

4. Batch Versus Solitary Holding

This study will use only the single compensatory growth feeding regime indicated as optimal for growth with commercial feed by Experiment 3. Growth rates of hybrids held solitarily in plexiglass test chambers and provided commercial feed, will serve as the controls. Three treatment groups will be tested in large water-recirculation tanks and will differ from controls in that fish will be held as a batch (i.e., not individually in the small plexiglass chambers). Fish in batch settings will be individually marked so that growth rates of individuals can be determined; in this way, replication of each treatment will result from the ability to measure individual growth responses. Treatment groups will differ in fish holding density with the highest density approaching the carrying capacity of the recirculation system. Experiments will be run approximately 50 d. Means and variances of hybrid final weight in treatment groups will be compared to those in the control group to evaluate whether compensatory growth advantages previously observed for solitary fish are diminished when fish are held in batches. It will also be determined whether any growth loss from behavioral interactions among individuals is minimized at certain holding densities.

5. Water Quality

This experiment is intended to provide only preliminary indication of the extent to which compensatory growth feeding regimes may create water quality problems in culture settings in general. Because fish are fed, consume food, and grow at above-normal rates with compensatory-growth feeding regimes, the potential for increased DO uptake and ammonia production rates exists, as does the potential for increased production of settled and suspended solids. The focus here will be on DO and ammonia only.

In conjunction with Experiment 3, DO uptake and total ammonia nitrogen (TAN) production will be estimated in the control (fish fed daily) and each of the four treatment groups. Measurements will be made early and late in the experiment to consider effects of different fish sizes. Early and late measurements will each be made on six consecutive days for the control group. For treatment groups, early and late measurements will each span a single feeding cycle (measurements on 2 d throughout food deprivation and on 3 d during refeeding). On any measurement day, water samples for DO and TAN from both influent and effluent water will be taken every 30-min for 3 h. Sampling times within a day will be determined from preliminary experiments to define 24-h patterns of DO and TAN concentration. Differences between DO and TAN concentrations in the effluent and influent water will be used to assess uptake and production rates, respectively. Results from compensatory growth treatment groups will be contrasted against those from the control group.

Water samples for DO determinations will be collected in 300-mL biological oxygen demand (BOD) bottles and analyzed using the Azide modification to the Winkler method (APHA et al. 1989). Water samples for TAN will be collected in 150-mL polyethylene bottles, acidified to pH <2.0 and analyzed using the specific ion electrode method (APHA et al. 1989).

PSU

The proposed UM study (above) focuses on compensatory feeding strategies with the *Lepomis* hybrid. In order to evaluate the impact of compensatory growth mechanisms on black crappie in a recirculating system, PSU will conduct two sets of feeding trials. The first will be used to characterize compensatory growth for individual crappie on commercial feed (Biodiet® 2.5 mm, semi-moist pellets). PSU's efforts will focus on the short cycle schedules of D2, D3, and D4 and will follow an approach similar to that described above by UM for evaluating commercial feed with hybrid sunfish (#3).

The second set of feeding trials will consist of 10, 50- d feeding trials. Each trial will be replicated between the two rearing tanks and each combination of days off/on feed will be repeated once. This will allow a comparison of five different combinations of days off/on feed. All 10 trials will be randomized in sequence to remove any training, sequence or growth effects. The combinations of days off/on feed will include repeated trials of the short cycle schedule that produced optimal growth in the previous set of trials with individuals. That combination will be bracketed by ± one day on feed and compared to a constant daily feeding trial. During the days on feed, fish will be fed Biodiet® 2.5 mm, semimoist pellets twice daily for a total of 5% of their body weight daily. At the beginning of the feeding trials, 150 black crappie that average 100 mm will be acquired locally and divided between the two rearing tanks. The working volume of water will be adjusted to provide an initial density of 4 kg/m^3 for the 75 fish in each rearing tank. Fish will be acclimated to the conditions of the rearing tanks and to the pellets before the trials are started. Fish will be individually weighed and measured at the beginning and end of each 30 d trial. In order to evaluate the impact of feeding combinations, comparisons will be made between changes in biomass, conversion efficiencies and size distributions.

All feeding trials at PSU will be conducted in the recirculating system in the basement of Heckert-Wells Hall (Biology Building). A closed-loop, process control system will be installed and used to monitor, store and adjust system parameters to ensure optimal performance. Photoperiod will be set at 15-h light/10-h dark. Water temperature will be maintained at 20°C for all trials. Other water quality parameters will be maintained at optimal levels for fish production.

UW-Milwaukee

The overall goal of the UW-Milwaukee proposed investigation is to compare the practicality and cost effectiveness of a black crappie rearing strategy that habituates them to commercial feed and intensive rearing conditions at the smallest feasible size (from egg if possible) versus a strategy of pond harvesting and habituating them to commercial feed and intensive rearing at the more typical 5.1-10.2 cm (2-4") pond harvest size.

1. Production of Black Crappies Habituated to Commercial Feed as Early as Possible

UM-Milwaukee's primary approach will be to use our "green tank" rearing techniques to intensively rear black crappies from hatching and to habituate them to commercial feeds as early as possible. Laboratory spawning efforts in the spring of 1996 would utilize the black crappies that UW-Milwaukee currently has in house as brood fish and include both the manipulations of photoperiod and temperature to stimulate the maturation and attainment of spawning condition and the use of induction substances to stimulate final maturation and release of the gametes. Additional effort will be made to obtain adults in spawning condition from the field during the 1996 spawning season. Several thousand fish reared in this fashion would provide a group for comparison in performance to the larger pond harvested fish by early fall of 1996. Recognizing the difficulty of accomplishing this goal, if necessary we would alternatively habituate several thousand pond reared black crappie at the smallest harvestable size (approximately 2.54 cm; 1"). These would be purchased from commercial growers in the region during the summer of 1996. UW-Milwaukee would habituate these fish to commercial feed using artemia nauplii and other transitional foods and then rear them intensively to 5.1-10.2 cm (2-4") by the fall for comparison to pond fish harvested in the fall.

2. Source of 5.1-10.2 cm (2-4") Pond Produced Group

This group of fish would be purchased from cooperating regional commercial producers in the fall of 1996. Information on the past rearing conditions of the group would be obtained from the producer concerning the previous thermal history and approximate stocking density of the ponds that the fish are harvested from.

3. Investigation of Possible Compensatory Growth Following Transition from Pond to Intensive Tank Rearing

The survival and growth of crappies with a longer history of habituation at the smallest feasible size under intensive tank rearing will be compared to that of black crappie transferred from ponds to intensive tank conditions at the 5.1-10.2 cm (2-4") harvest size. For these trials a recirculating aquaculture system, commercially available feeds and rearing conditions simulating a potential commercial operation will be employed.

Triplicate groups of 200-300 fish each for both the 5.1-10.2 cm (2-4") pond harvested fish and the 5.1-10.2 cm (2-4") intensively reared crappies will be stocked into rearing tanks of approximately 400-L capacity. Rearing densities during the trial are anticipated to be equivalent to 2-3 kg/m^3, approximating the densities of the larger fish used by Smeltzer and Flickinger (1991). These six rearing tanks will be connected to a centralized recirculation system with a solids clarification system and a conditioned biofiltration system. Prior to this trial the recirculating system would be preconditioned from mid-summer 1996 to similar loadings using other fish (perhaps perch) in order to ensure the proper performance of the biofiltration system during the fall experimental trial.

Growth of the experimental groups will be monitored by subsampling 25 to 30 fish from each tank at startup and at approximately bi-weekly intervals through the period of habituation to commercial feed, and for four weeks following their habituation to commercial feed.

Rearing temperatures would be 23-25°C, and daily records would be kept of the amounts of food fed, and the number and weight of mortalities removed. Transitional foods like adult frozen brine shrimp will be used to induce initial feeding of the pond harvested fish. UW-Milwaukee will use automatic feeders to deliver the commercial feed during the habituation process. These will be adjusted to deliver as much food as the fish would consume during the day. Records would be kept of the daily food usage. From these feeding records along with measurement of growth, food conversions will be estimated. Observations will be made concerning the timing of habituation to commercial diet. Records of costs associated with the production of both groups would be kept in order to compare the cost effectiveness of these alternative strategies of providing crappies for grow out in recirculating systems.

Descriptive statistics of growth would be used to compare and contrast the performance of 5.1-10.2 cm (2-4") pond-harvested black crappies during habituation to the recirculation system to the group habituated at the smallest possible size to determine which of these two strategies produced better survival and growth.

4. Cost Effectiveness of Alternative Strategies of Habituating Crappies to Recirculating Culture Systems

The production costs associated with the two strategies for habituating crappie fingerlings to recirculating system culture will be compared. The costs of labor, equipment, fish, fish food, system operation, supplies, etc. that are necessary to habituate crappies at the smallest feasible size will be gathered during laboratory rearing of experimental fish. The cost of habituating 5.1-10.2 cm (2-4") pond reared fish will be estimated based on information obtained from regional growers, and costs encountered during the trial. These costs will be compared on a cost per fish and cost per weight of fish basis to determine which method could be most cost effectively used by regional culturists.

5. 2nd Year Investigation of Pond to Intensive Transition

In order to address possible variation in seasonal pond performance at UW-Milwaukee, the first year's trial would be repeated in the fall 1997; spawning and habituating laboratory stocks at the earliest feasible size, obtaining pond reared 5.1-10.2 cm (2-4") crappies from regional producers, tracking growth changes and costs through one month following the habituation of the 5.1-10.2 cm (2-4") fish to commercial feed.

ISU

ISU personnel will evaluate grow out of both tank- and pond-reared BG × GS hybrids in a recirculating system using compensatory feed strategies. Hybrids will be prepared by spawning fish out-of-season in April 1997 using methods described by Mischke (1995) for out-of-season spawning. A pooled population of newly hatched fry from 10-20 females (500-1,000 fry per female that are collected from multiple spawns over a 2-3 week interval) will be divided, 75% of which will be stocked by May 1 into ponds at the Myron Kloubec fish farm, located in eastern Iowa. These fry will be stocked into two 0.05 to 0.1 hectare ponds, and the other 25% of the fry will be tank-reared at ISU. From the time they are hatched, the fry raised in tanks will be fed brine shrimp until day 14 and then gradually habituated to formulated feed (Fry Feed Kyowa® [FFK] B-250). By August 1, both pond-reared and tank-reared fish will be moved to the grow out facility at ISU, which uses a recycle system. From August 1 to September 1, the pond-reared fish will be habituated and acclimated to the culture system. The tank-reared fish, which were moved from the fry facility to the grow out facility on August 1, will be acclimated to the grow out faculty for the same interval. Both tank- and pond-reared fish will be gradually habituated to FFK-C series feed, starting with C-700.

Starting September 1, the experimental design will be a 2 (two stocks) × 2 (two feeding strategies) factorial. There will be three replicates for each treatment (two treatments for each factor) for a total of 12 experimental units. Fish will be stocked into the 150-L rearing tanks at an initial density of 50 fish/tank. Fish densities will be reduced to 25/tank in the final grow out interval (November 1 to February 1). The stocks are pond- and tank-reared hybrids, and the feeding strategies are a control group with eight daily feedings (CF), and a group with restricted feeding regime (RF) to obtain a measure of compensatory growth. A 3:3 feeding strategy will be used for the RF group, a feeding cycle of 3 weeks of starvation and 3 weeks of feeding *ad libitum*. Both groups will be fed 5 to 7% of their body weight per day (7% from September to November 1, and 5% from November 1 to February 1). Both feeding rates are calculated to be in excess to make sure the fish are fed to satiation.

During the designated feeding period, fish will be fed a 36% protein commercial diet, 8 times/d using an automatic feeder. Determination of feeding rates will be done by bi-weekly subsample of 20 fish per tank, and the increased total length used to predict gain as described by Westers (1987) to calculate feeding rates. Rates will be adjusted weekly.

The parameters to be measured are survival and growth. Growth will be expressed in mm/ d, unit growth rate (mm/ d per °C) and specific growth rate (SGR), as defined by Hopkins (1992): $SGR = ((\ln[w_2] - (\ln[w_2])/t) \times 100$. Statistical differences among treatments will be determined by analysis of covariance with initial size as the covariate to adjust for expected initial size differences between the pond- and tank-reared fish (uncontrolled variable). Statistical significance will be determined with $P < 0.05$.

Water quality during the two grow out intervals will include daily measurement of temperature, DO, and total chlorine. Twice weekly measurements will be made of TAN, pH, and temperature collected together. Nitrites and chlorides, total alkalinity, pH, and CO_2 and temperature will be determined as a suite of parameters once per week.

Establish Baseline Physiological Measures for Small Black Crappie Subjected to Handling Stressors and to Test the Effect of Salt and Temperature on Stress Reduction (Objective 2)

University of South Dakota (USD) and University of Wisconsin-Madison (UW-Madison)

In both years of this project, juvenile black crappie will be obtained from the Gavins Point National Fish Hatchery, Yankton, South Dakota, transported to the fish holding facilities at USD, Department of Biology, and held for suitable acclimation at 25°C. To evaluate the responses of black crappie to stress, blood will be collected from test fish sacrificed at the selected time points during the following described experiments. Because of the small size of the fish to be used, it is likely that blood samples will be small. Thus, physiological indicators of stress will be analyzed by priority, as follows: (1) plasma cortisol (primary endocrine response), (2) plasma chloride (indicator of hydromineral imbalance), (3) plasma glucose (characteristic metabolic response), (4) plasma osmolality (supplemental indicator of hydromineral imbalance), and (5) hematological features such as hematocrit, leucocrit, and differential blood cell counts (characteristic hematological response). In addition, it may be necessary to pool serum from several fish to obtain samples of sufficient size for analysis.

Year 1: Characteristic Stress Response of Black Crappie

To establish resting values for physiological constituents and determine the characteristic stress response of black crappie to handling, 60 fingerling fish (50-70 mm) will be removed from one stock tank and subjected to a standardized handling stressor, which will consist of holding the fish as a group in a dipnet in the air for 30 s. Such a standardized stressor has been used effectively in the past for eliciting an acute physiological response in both salmonids and other temperate freshwater species (e.g., Barry et al. 1993; Barton and Zitzow 1995; reviewed by Barton and Iwama 1991). Thus, the results will serve as a useful reference point to interpret the pattern of the stress response in black crappie in comparison to a variety of previously tested species.

After being subjected to the stressor, the fish will be placed into covered opaque tanks in lots of 15 for blood sampling; a separate tank will be used for each sampling time to avoid the possibility of causing stress to fish remaining in the tank from the sampling. Fish will be sampled at 1, 3, 6 and 24 h post-stress to determine the magnitude and duration of selected physiological responses (N = 10 per time). The remaining fish in each recovery tank will be left undisturbed for up to 72 h post-stress to assess delayed mortality each day. Fish will also be sampled from the stock tank before the experiment to provide initial (t = 0) values, and at 6 and 24 h to ensure constancy of resting physiological constituents. To evaluate the consistency of the response, this experiment will be replicated with a duplicate batch of fish held in a second stock tank. Additional tanks of 60 fish each for the handling treatment and a control will also be established and used to monitor mortality through time only (no blood sampling) as space permits.

Year 2: Effects of Salt and Temperature Reduction During Recovery from Stress

To establish the potential benefit of using salt or reducing water temperature to minimize handling stress and related mortalities, black crappie will be subjected to the same handling stress and recovery protocol as in Year 1. After acclimation, groups of 60 fish for each treatment will be handled as in Year 1 experiments and placed into separate tanks for recovery containing water at 25°C (ambient) or 20°C (5°C reduction), both with and without 0.7% un-iodized NaCl (a concentration approximately isotonic with freshwater fish blood). The fish will be held under these conditions for a standardized period of time representative of typical transport durations (e.g, 4 h) and then gradually returned to original ambient conditions (25°C, no NaCl). Post-stress sampling for each treatment will be carried out as described for the Year 1 handling experiments, except that sampling will be done only at those times identified to be critical by the previous year's study. As in the Year 1 study, groups of fish from each treatment remaining in the tanks will be monitored to assess survival at 24, 48 and 72 h. Additional tanks of 60 fish per treatment plus a control will be used to monitor mortality through time only (no blood sampling) for the respective treatments as space permits.

Sample and Data Analysis

To collect blood, fish will be sacrificed immediately by placing them into a lethal concentration (200 mg/L) of tricaine methane sulfonate. This method has been shown to effectively arrest physiological stress responses in salmonids (Wedemeyer et al. 1990) provided that sampling is completed relatively quickly. Blood will be obtained from the caudal vasculature within 5 min by severing the caudal peduncle. At least four people will be needed to work simultaneously to collect the blood samples over this short period. To meet this need, two technicians from the UW-Madison Aquaculture Program will travel to USD to assist USD personnel with blood sample collection. After a hematocrit sample is taken and a blood smear is prepared on a glass slide, plasma will be separated by centrifugation and stored at <-60°C for later analysis of cortisol, chloride, glucose and osmolality. Blood smears will be air dried, fixed with methanol, and later treated with Wright's-Giemsa stain for differential cell counting.

Plasma cortisol will be determined using a microtiter plate ELISA that has been validated at UW-Madison for use in several fish species including rainbow trout, lake trout (*Salvelinus namaycush*), yellow perch, and walleye (e.g., Barry et al. 1993). Plasma glucose will be measured by colorimetrically with a spectrophotometer using ortho-toluidine reagent. Plasma chloride will be assayed with a chloridometer and plasma osmolality will be determined with a freezing-point depression osmometer.

Hematocrit will be measured as % packed cell volume after centrifugation. Differential leukocyte cell counts from blood smears will be made under an oil-immersion lens microscope at 1,000x power. Counts will made in five separate fields on each smear to provide an average ratio of the number of lymphocytes, neutrophils, and thrombocytes per 10^3 erythrocytes. For consistency, fields will be selected from the same general areas on every smear. Yasutake and Wales (1983) will used as a guide for cell types, but some preliminary screening of smears will be required to identify lymphocytes, as their appearance may be somewhat different than salmonid lymphocytes using this stain. If hematocrit values vary, differential blood cell counts will be adjusted accordingly to compensate for possible changes in erythrocyte numbers.

Data from experiments will be subjected to analyses of variance, if appropriate, followed by multiple-range tests at $P < 0.05$ to determine differences among means.

Update the Sunfish Culture Manual (Objective 3)

<u>ISU</u>

The development of educational materials on the aquaculture production of sunfish will be done by Morris of ISU, working with other appropriate members of the NCRAC Sunfish Work Group and cooperating fish farmers with demonstrated experience in culturing sunfish. Morris is the editor of the current sunfish culture manual funded in the previous NCRAC proposal; Garling of MSU, and Kayes of the University of Nebraska-Lincoln (UNL) also participated. Morris has an extension appointment and is a member of the NCRAC Extension Work Group.

The current version of the NCRAC Sunfish Culture Manual is scheduled for publication by August 1996. Morris will guide the updating process by involving both researchers and extension contacts associated with the current NCRAC Sunfish Work Group. Materials will be distributed through the North Central Regional Extension network contacts.

New	Revision	Topic Areas
	√	Brood Stock Management -hormonal injections (pending INAD approval)
	√	Intensive Culture of Fry and Fingerlings -feeding strategies
	√	Industry Status
	√	Induction of Triploidy and Tetraploidy
	√	Fish Health -list of approved and "low regulatory priority" chemicals
√		Feeding Strategies for Food Fish Production
√		Role of Stress in Handling Crappies
√		Nutritional Aspects

FACILITIES

Compare Feeding Trials for Grow Out in Ponds at Dissimilar Latitudes in the Region (Objective 1a)

Purdue

Construction of earthen culture research ponds at Purdue began September 1995 and will be completed well before initiation of this study. Each pond will be equipped with water supply, drain and electrical outlet. Ponds are being located immediately behind the Aquaculture Research Facility, Purdue. Thus, daily care of fish will not be a limitation.

SIUC

The Illinois Aquaculture Research and Demonstration Center at SIUC's Touch of Nature Facility has 90 fillable and drainable 405 m^2 (1/10 acre) aquaculture ponds and other equipment used in pond aquaculture, such as tractors, paddle-wheel aerators, hauling tanks, seines, etc. The SIUC campus also has an aquaculture pond complex consisting of 18, 578 m^2 (1/7 acre) ponds. SIUC also has two buildings and several rooms in other buildings which house tank culture systems which provide more than 1,115 m^2 (12,000 ft^2) of space for holding fish. Other SIUC aquaculture resources include fully equipped fish genetics, nutrition, feed preparation, and water quality labs.

Compare Feeding Trials for Grow Out in Recirculating Systems under Compensatory Feeding Strategies (Objective 1b)

UM

For the experiments involving individually-held fish, the specimens will be maintained in separate 3.25-L clear numbered plexiglass aquaria (20 cm long × 12.5 cm wide × 13 cm high; Fritz Pet Products, Dallas, Texas) supplied with finely slatted removable tops. Water circulation will be increased by drilling about 20, 3.5-mm holes in the two long sides of each container, and the tops will be shrouded in 1 mm square nylon mesh to prevent the escape of meal worms, where used. Where commercial feeds are used, these small tanks will be inverted, allowing any uneaten pellets to precipitate onto collection trays stationed beneath.

These negatively buoyant containers will be maintained in a wet lab at UM in adjacent 950-L water recirculation tanks with painted green interiors that reduce light reflectivity. For each tank, a recirculation system pumps bottom-drawn water into an elevated biofilter; a gravity return then trickles the conditioned water back into the tanks. To reduce potential tank-to-tank variation, the plumbing systems of adjacent tank pairs can be linked, allowing for continuous water exchange. Room photoperiods will simulate that which occurs over much of the growing season in the Midwest. Temperatures will be maintained at 23°C using a combination of room-wide air heating/conditioning, in combination with chiller and heating units located in head tanks.

PSU

PSU currently has a fully operational recirculating system which was used for feeding trials during a previous NCRAC-funded project to assess the trainability, conversion efficiency and growth of white crappie at a selected production density of 4 kg/m^3. White crappie have been successfully maintained and grown in this system for over 20 months. The system consists of two rearing tanks (568-L capacity each), a water treatment/conditioning tank (379-L), and a biofilter (379-L). All tanks are insulated, stainless steel vats that were used in milk processing. The rearing tanks are isolated by black plastic and photoperiod is regulated by a timer. Food is supplied to the rearing tanks by automatic, adjustable feeders that can be programmed for up to 20 events per day. About 10% of the total working volume is eliminated each day by an automated solids removal system. Water lost from evaporation and solids removal is replaced by an automatic make-up system which dechlorinates the city water before adding it. Circulation is provided by a single fountain pump (60-L/h). The water is aerated and ammonia is converted by a trickle-down biofilter. The working capacity for the system is flexible and can go as high as 1,327-L. The system is located in the basement of the biology building (Heckert-Wells Hall), the newest building on campus. Technical support for the project is high. The

Department of Biology has a fully-equipped water quality laboratory, and the College maintains a full-time science support technician to assist with installation and repair of electronic and mechanical systems.

UW-Milwaukee

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 brood fish either through cooperating producers or through collection in the wild. UW-Milwaukee has 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 conducting these trials. The water supply for the rearing facilities is dechlorinated Milwaukee tap water derived from Lake Michigan as its original source. The facility has water heaters capable of supporting intensive flow through rearing in large capacity tanks.

Large circular fiberglass rearing tanks (1.2 m-diameter) would be available for replicated rearing groups that would be hooked up to a centralized recirculating system for the habituation trials. A wide assortment of other tanks and aquaria are also available ranging in size from 2.4 m diameter (4,000-L) fiberglass tanks down to less than 20-L. These tanks are fitted with the required screened mesh and water supply hardware for specialized larval rearing.

In addition, there are a wide variety of supporting facilities and analytical laboratories at the Great Lakes Research Facility that can provide refrigerated storage, instrument shop capabilities, etc. which will enhance the conduct of the proposed activities.

ISU

The brood stock will be held in a recirculating culture system consisting of eight 640-L round tanks measuring 0.55 m deep and 1.22 m in diameter. All tanks are connected to a common biofilter. After hatching, fry will be removed and cultured in ten 50-L tanks connected to a common biofilter. This hatchery has controlled lighting and temperature.

After August 1, fish will be reared in a recirculating aquaculture system which presently consists of an upflow rock roughing filter, both rock and random packed media biofilters, pressured sand filter, and UV disinfection. The upflow rock roughing filter is outdated, and the system will be modified by removal of the rock filter and replacing it with a microscreen (drum) clarifier, which has become the most common type of clarifier in commercial recycle aquaculture systems. The rooms have controlled lighting and precise temperature control (± 0.5°C). In this study, 12, 150-L tanks will be used for habituation of the pond-reared fish and grow out phases.

Establish Baseline Physiological Measures for Small Black Crappie Subjected to Handling Stressors and to Test the Effect of Salt and Temperature on Stress Reduction (Objective 2)

USD and UW-Madison

The fish holding facilities at USD include a 12-tank, 3,000-L recirculating system employing a rotating paddlewheel biofilter, and use treated city water at an ambient temperature of ≈19-20°C. The Department of Biology at USD also houses a Beckman LS-6500 scintillation counter, a Beckman DU-7400 spectrophotometer, a Corning Model 925 chloride analyzer and a Precision Systems Model 5004 micro-osmometer for conducting physiological assays on blood. An ELISA system and all of the necessary related equipment (e.g., microtiter plate reader) is set up and operational at the laboratories of the UW-Madison Aquaculture Program. Laboratories at both USD and UW-Madison are equipped with all the necessary materials for collecting, processing and storing blood samples, and have modern computer hardware and software for routine statistical analyses.

Update the Sunfish Culture Manual (Objective 3)

ISU

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.

REFERENCES

Amspacker, T.D. 1991. Trainability, growth and conversion efficiency of white crappie *Pomoxis annularis* on an artificial diet. Master's thesis. Pittsburg State University, Kansas.

Anderson R.J. 1974. Feeding artificial diets to smallmouth bass. Progressive Fish-Culturist 36:145-151.

APHA (American Public Health Association), American Water Works Association and Water Pollution Control Association. 1989. Standard methods for the examination of water and wastewater, 17th edition. APHA, Washington, D.C.

Arai, S. 1981. A purified test diet for coho salmon, *Oncorhynchus kisutch*, fry. Bulletin of the Japanese Society of Scientific Fisheries 47:547-550.

Bardach, J.E., J.H. Ryther, and W.O. McLarney. 1972. Aquaculture: the farming and husbandry of freshwater and marine organisms. John Wiley and Sons, New York.

Barry, T.P., A.F. Lapp, T.B. Kayes, and J.A. Malison. 1993. Validation of a microtitre plate ELISA for measuring cortisol in fish and comparison of stress responses of rainbow trout (*Oncorhynchus mykiss*) and lake trout (*Salvelinus namaycush*). Aquaculture 117:351-363.

Barton, B.A., and G.K. Iwama. 1991. Physiological changes in fish from stress in aquaculture with emphasis on the response and effects of corticosteroids. Annual Review of Fish Diseases 1:3-26.

Barton, B.A., and R.E. Peter. 1982. Plasma cortisol stress response in fingerling rainbow trout, *Salmo gairdneri* Richardson, to various transport conditions, anaesthesia, and cold shock. Journal of Fish Biology 20:39-51.

Barton, B.A., and C.B. Schreck. 1987. Metabolic cost of acute physical stress in juvenile steelhead. Transactions of the American Fisheries Society 116:257-263.

Barton, B.A., and R.E. Zitzow. 1995. Physiological responses of juvenile walleye to handling stress with recovery in saline water. Progressive Fish-Culturist 57:267-276.

Baur, R.J. 1988. 1986 Illinois sport fishing survey. Illinois Department of Conservation. Special Fisheries Report Number 53.

Bennett, G.W. 1970. Management of lakes and ponds. 2nd Edition. Van Nostrand Reinhold Co., New York.

Brandenburg A.M., M.S. Ray, and W.M. Lewis. 1979. Use of carp eggs as a feed for fingerling largemouth. Progressive Fish-Culturist 41:97-98.

Brandt T.M., R.M. Jones Jr., and R.J. Anderson. 1987. Evaluation of prepared feeds and attractants for largemouth bass fry. Progressive Fish-Culturist 49:198-203.

Broekhuizen, J., W.S. Gurney, A. Jones, and A.D. Bryant. 1994. Modelling compensatory growth. Functional Ecology 8:770-782.

Brown, P.B., and K. Wilson. 1994. Experimental and practical diet evaluations with hybrid bluegill. 25th Annual Meeting of the World Aquaculture Society. New Orleans, Louisiana.

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.

Brunson, M.W., and H.R. Robinette. 1982. Supplemental feeding of hybrid sunfish in Mississippi. Proceedings of the Southeast Association of Fish and Wildlife Agencies. 36:157-161.

Brunson, M.W., and H.R. Robinette. 1986. Evaluation of male bluegill × female green sunfish hybrids for stocking Mississippi farm ponds. North American Journal of Fisheries Management 6:156-157.

Carmichael, G.J., G.A. Wedemeyer, J.P. McCraren, and J.L. Millard. 1983. Physiological effects of handling and hauling stress on smallmouth bass. Progressive Fish-Culturist 45:110-113.

Carmichael, G.J., J.R. Tomasso, B.A. Simco, and K.B. Davis. 1984a. Characterization and alleviation of stress associated with hauling largemouth bass. Transactions of the American Fisheries Society 113:778-785.

Carmichael, G.J., J.R. Tomasso, B.A. Simco, and K.B. Davis. 1984b. Confinement and water quality-induced stress in largemouth bass. Transactions of the American Fisheries Society 113:767-777.

Childers, W.F. 1967. Hybridization of four species of sunfishes (Centrarchidae). Illinois Natural History Survey Bulletin 29:159-214.

Childers, W.F., and G.W. Bennett. 1961. Hybridization between three species of sunfish (*Lepomis*). Illinois History Survey Biological Notes No. 46.

Chopak, C.J. 1992a. What consumers want: advice for food fish growers. Cooperative Extension Service, Michigan State University Extension Bulletin E-2410.

Chopak, C.J. 1992b. What brokers, wholesalers, retailers and restaurants want: advice for food fish growers. Cooperative Extension Service, Michigan State University Extension Bulletin E-2411.

Davis, H.S. 1956. Culture and diseases of game fish. University of California Press, Berkley, California.

Davis, K.B., and N.C. Parker. 1986. Plasma corticosteroid stress response of fourteen species of warmwater fish to transportation. Transactions of the American Fisheries Society 115:495-499.

Dobson, S.H., and R.M. Holmes. 1984. Compensatory growth in the rainbow trout, *Salmo gairdneri* Richardson. Journal of Fish Biology 25:649-656.

Dupree, H.K., and J.V. Huner. 1984. Third report to the fish farmers. U.S. Fish and Wildlife Service, Washington, D.C.

Ellison, D.G., and R.C. Heidinger. 1976. Dynamics of hybrid sunfish in southern Illinois farm ponds. Proceedings of the Annual Conference of the Association of Game and Fish Commissioners 30:82-87.

Engelhardt, T., and G. McCarty. 1990. Bluegill culture in Texas. Management Data Series 44. Texas Parks and Wildlife, Austin, Texas.

Fletcher, C.R. 1992. Stress and water balance in the plaice *Pleuronectes platessa*. Journal of Comparative Physiology B 162:513-519.

Flickinger S.A., R.J. Anderson, and S.J. Puttman. 1975. Intensive culture of smallmouth bass. Pages 373-379 *in* H.E. Clapper, editor. Black bass biology and management. Sport Fishing Institute, Washington, D.C.

Grayton, B.D., and F.W.H. Beamish. 1977. Effects of feeding frequency on food intake, growth and body composition of rainbow trout (*Salmo gairdneri*). Aquaculture 11:159-172.

Greeff, J.C., H.H. Meissner, C.Z. Roux, and J. Van Rensburg. 1986. The effect of compensatory growth on feed intake, growth rate efficiency and feed utilization in sheep. South African Journal of Animal Science 16:155-161.

Harper, D.C. 1938. Crappie and calico bass culture in Texas. Progressive Fish-Culturist 5:12-14.

Harris, L.E. 1970. Nutrition research techniques for domestic and wild animals, Volume 1. Utah State University Press.

Haskell, D.C. 1941. An investigation on the use of oxygen in transporting trout. Transactions of the American Fisheries Society 70:149-60.

Hayward, R.S., D.B. Noltie, and N. Wang. In preparation. Using compensatory growth in hybrid sunfish to outgrow continuously-fed counterparts.

Heidinger, R.C. 1975. Growth of hybrid sunfishes and channel catfish at low temperatures. Transactions of the American Fisheries Society 104:333-334.

Higginbotham, B. 1988a. Forage species: range description and life history. Southern Regional Aquaculture Center Publication Number 140.

Higginbotham, B. 1988b. Forage species: production techniques. Southern Regional Aquaculture Center Publication Number 141.

Higginbotham, B. 1988c. Forage species: return on investment. Southern Regional Aquaculture Center Publication Number 142.

Hooe, M.L. 1991. Crappie biology and management. North American Journal of Fisheries Management. 11: 483-484.

Hooe, M.L., and D.H. Buck. 1991. Evaluation of F_1 hybrid crappies as sport fish in small impoundments. North American Journal of Fisheries Management 11:564-571.

Hooe, M.L., D.H. Buck, and D.H. Wahl. 1994. Growth survival, and recruitment of hybrid crappies stocked in small impoundments. North American Journal of Fisheries Management 14(1):137-142.

Hopkins, K.D. 1992. Reporting fish growth: a review of the basics. Journal of the World Aquaculture Society 23:173-179.

Jobling, M., H. Jorgensen, and S.I. Siikavuopio. 1993. The influence of previous feeding regime on the compensatory growth response of maturing and immature Arctic charr, *Salvelinus alpinus*. Journal of Fish Biology 43:409-419.

Kindschi, G.A. 1988. Effect of intermittent feeding on growth of rainbow trout. Aquaculture and Fisheries Management 19:213-215.

Koppe, W., J. Pockrandt, K.H. Meyer-Burgdorff, and K.-D. Gunther. 1993. Effects of realimentation after a period of restricted feeding on feed intake, growth, and body composition in *Piaractus brachypomus* (Cuvier 1818), a South American characoid fish. Pages 263-269 *in* T. Braunbeck, W. Hanke, and H. Segner, editors. Fish ecotoxicology and ecophysiology. VCH, New York, New York.

Korovin, V.A., A.S. Zybin, and V.B. Legomin. 1982. Response of juvenile fishes to stress factors associated with transfers during fish farming. Journal of Ichthyology 22:98-102.

Laarman, P.W. 1973. Production from hybrid sunfish populations. Michigan Department of Natural Resources, Federal Aid in Fish Restoration Project F-29-R7, Final Report, Lansing, Michigan.

Leary, J.L. 1908. Description of San Marcos station with some of the methods of propagation in use at that station. Transactions of the American Fisheries Society 37:75-81.

Leary, J.L. 1909. Propagation of crappie and catfish. Transactions of the American Fisheries Society 38:143-148.

Lewis, W.M. 1981. Use of farm ponds for the production of food fish for home use and specialized marketing. Southern Illinois University Fisheries Bulletin 6.

Lewis, W.M., and R.C. Heidinger. 1971a. Supplemental feeding of hybrid sunfish populations. Transactions of the American Fisheries Society 100:619-623.

Lewis, W.M., and R.C. Heidinger. 1971b. Aquaculture potential of hybrid sunfish. The American Fish Farmer 1971(April):14-16.

Long, C.W., J.R. McComas, and B.H. Monk. 1977. Use of salt (NaCl) water to reduce mortality of chinook salmon smolts, *Oncorhynchus tshawytscha*, during handling and hauling. Marine Fisheries Review 39(7):6-9.

Loushin L.L., and J.H. Rushing. 1989. Acceptance by largemouth bass fingerlings of pelleted feeds with a gustatory additive. Progressive Fish-Culturist 51:73-78.

McClarney, W. 1984. The freshwater aquaculture book. Hartley and Marks, Point Roberts, Washington.

Malison, J.A. and J.A. Held. 1992. Effects of fish size at harvest, initial stocking density and tank lighting conditions on the habituation of pond-reared yellow perch (*Perca flavescens*) to intensive culture conditions. Aquaculture 104:67-78.

Mazik, P.M., B.A. Simco, and N.C. Parker. 1991. Influence of water hardness and salts on survival and physiological characteristics of striped bass during and after transport. Transactions of the American Fisheries Society 120:121-126.

Mersmann, H.J., M.D. MacNeil, S.C. Seidman, and W.G. Pond. 1987. Compensatory growth in finishing pigs after feed restriction. Journal of Animal Science 64:752-764.

Miglavs, I., and M. Jobling. 1989. Effects of feeding regime on food consumption, growth rates and tissue nucleic acids in juvenile charr *Salvelinus alpinus* with particular respect to compensatory growth. Journal of Fish Biology 34:947-957.

Mischke, C.C. 1995. Larval bluegill culture in the laboratory. Master’s thesis. Iowa State University, Ames.

Morgan, J.D., and G.K. Iwama. 1991. Effects of salinity on growth, metabolism, and ion regulation in juvenile rainbow and steelhead trout (*Oncorhynchus mykiss*) and fall chinook salmon (*Oncorhynchus tshawytscha*). Canadian Journal of Fisheries and Aquatic Sciences 48:2083-2094.

National Research Council. 1993. Nutrient requirements of fish. National Academy Press, Washington.

Piper, R.G., L.B. McElwain, L.E. Orme, J.P. McCraren, L.G. Fowler, and J.R. Leonard. 1982. Fish hatchery management. U.S. Fish and Wildlife Service, Washington, D.C.

Quinton, J.C., and R.W. Blake. 1990. The effect of feed cycling and ration level on the compensatory growth response in rainbow trout *Oncorhynchus mykiss*. Journal of Fish Biology 37:33-42.

Read, E.R. 1994. Cage culture of black, white, and F_1 hybrid crappie (*Pomoxis* species). Master's thesis. Pittsburg State University, Kansas.

Ricker, W.E. 1948. Hybrid sunfish for stocking small ponds. Transactions of the American Fisheries Society 75:84-96.

Russell, N.R., and R.J. Wootton. 1992. Appetite and growth compensation in the European minnow *Phoxinus phoxinus* following short periods of food restriction. Environmental Biology of Fishes 34:277-285.

Ryan, W.J., I.H. Williams, and R.J. Moir. 1993. Compensatory growth in sheep and cattle. II. Changes in body composition and tissue weights. The Australian Journal of Agricultural Research 44:1609-1621.

Schael D.M., L.G. Rudstam, and J.R. Post. 1991. Gape limitation and prey selection in larval yellow perch (*Perca flavescens*), freshwater drum (*Aplodinotus grunniens*), and black crappie (*Pomoxis nigromaculatus*). Canada Journal of Fisheries and Aquatic Sciences 48:1919-1925.

Siefert, R.E. 1968. Reproductive behavior, incubation and mortality of eggs, and postlarval food selection in the white crappie. Transactions of the American Fisheries Society 97:252-259.

Simco B.A., J.H. Williamson, G.J. Carmichael, and J.R. Tomasso. 1986. Centrarchids. Pages 73-90 *In* R.R. Stickney, editor. Culture of nonsalmonid freshwater fishes. CRC Press, Boca Raton, Florida.

Smagula, C.M., and I.R. Adelman. 1982. Day-to-day variation in food consumption by largemouth bass. Transactions of the American Fisheries Society 111:543-548.

Smeltzer, J.F., and S.A. Flickinger. 1991. Culture, handling and feeding techniques for black crappie fingerlings. North American Journal of Fisheries Management 11:485-491.

Smith, W.E. 1976. Larval feeding and rapid maturation of bluegills in the laboratory. Progressive Fish- Culturist 38:95-97.

Snow, J.R. 1964. Training manual for warm-water fish culture. U.S. Fish and Wildlife Service, Marion, Alabama.

Snow, J.R. 1975. Hatchery propagation of largemouth bass fry. Pages 344-356 *in* H.E. Clepper, editor. Black bass biology and management. Sport Fishing Institute, Washington, D.C.

Strube, J.H. 1994. Regulation of food intake. Pages 142-154 *in* M.S. Westerterp-Plantenga, E.W.H.M. Fredrix, and A.B. Steffens, editors. Food intake and energy expenditure. CRC Press, Boca Raton, Florida.

Texas Aquaculture Association. 1988. Inland aquaculture handbook. Southeastern Regional Aquaculture Center, College Station, Texas.

Tidwell, J.H., C.D. Webster, and J.A. Clark. 1992. Growth, feed conversion, and protein utilization of female green sunfish × male bluegill hybrids fed isocaloric diets with different protein levels. Progressive Fish-Culturist. 54:234-239.

Tidwell, J.H. and C.D. Webster. 1993. Effects of stocking density and dietary protein on green sunfish (*Lepomis cyanellus*) × bluegill (*L. macrochirus*) hybrids overwintered in ponds. Aquaculture 113:83-89.

Toepfer, C., and M. Barton. 1992. Influence of salinity on the rates of oxygen consumption in two species of freshwater fishes, *Phoxinus erythrogaster* (family Cyprinidae), and *Fundulus catenatus* (family Fundulidae). Hydrobiologia 242:149-154.

Toetz, D.W. 1966. The change from endogenous to exogenous sources of energy in bluegill sunfish larvae. Investigations of Indiana Lakes and Streams 7:115-146.

Wedemeyer, G.A. 1972. Some physiological consequences of handling stress in the juvenile coho salmon (*Oncorhynchus kisutch*) and steelhead trout (*Salmo gairdneri*). Journal of the Fisheries Research Board of Canada 29:1780-1783.

Wedemeyer, G.A., B.A. Barton, and D.J. McLeay. 1990. Stress and acclimation. Pages 451-489 *in* C.B. Schreck and P.B. Moyle, editors. Methods for fish biology. American Fisheries Society, Bethesda, Maryland.

Weiser, W., G. Krumschnabel, and J.P. Ojwang-Okwor. 1992. The energetics of starvation and growth after refeeding in juveniles of three cyprinid species. Environmental Biology of Fishes 33:63-71.

Weirich, C.R., J.R. Tomasso, and T.I.J. Smith. 1992. Confinement and transport-induced stress in white bass *Morone chrysops* × striped bass *M. saxatilis* hybrids: effect of calcium and salinity. Journal of the World Aquaculture Society 23:49-57.

Weirich, C.R., and J.R. Tomasso. 1991. Confinement- and transport-induced stress on red drum juveniles: effect of salinity. Progressive Fish-Culturist 53:146-149.

Westers, H. 1987. Feeding levels for fish fed formulated diets. Progressive Fish-Culturist 49:87-92

Wickstrom G.A., and R.L. Applegate. 1989. Growth and food selection of intensively cultured largemouth bass fry. Progressive Fish-Culturist 51:79-82.

Williams, V.J., and J.W. Sheedy. 1987. The efficiency of growth during body weight recovery in young adult female rats. Comparative Biochemistry and Physiology 87A:574-549.

Willis, D.W., and S.A. Flickinger. 1980. Survey of private and government hatchery success in raising largemouth bass. Progressive Fish-Culturist 42:232-233.

Willis, D.W., and S.A. Flickinger. 1981. Intensive culture of largemouth bass fry. Transactions of the American Fisheries Society 110:650-655.

Wills, P.S., J.M. Paret, and R.J. Sheehan. 1994. Pressure induced triploidy in hybrid *Lepomis*. Journal of the World Aquaculture Society 25:507-511.

Wootton, R.J. 1990. Ecology of teleost fishes. Chapman and Hall, New York.

Yasutake, W.T., and J.H. Wales. 1983. Microscopic anatomy of salmonids: an atlas. U.S. Fish and Wildlife Service, Resource Publication 150.

PROJECT LEADERS

State	Name/Institution	Area of Specialization
Illinois	Robert J. Sheehan Southern Illinois University-Carbondale	Fish Culture/Physiology
Indiana	Paul B. Brown Purdue University	Nutrition/Aquaculture
Iowa	Joseph E. Morris Iowa State University	Larval Fish Culture/Water Quality/Extension
	Robert C. Summerfelt Iowa State University	Fish Culture/Larval Fish
Kansas	James R. Triplett Pittsburg State University	Fish Culture/Fish Feeding Strategies and Behavior
Missouri	Douglas B. Noltie University of Missouri	Reproductive and Behavioral Ecology of Fishes
	Robert S. Hayward University of Missouri	Fish Bioenergetics/Feeding Models
South Dakota	Bruce A. Barton University of South Dakota	Stress Physiology in Fish/Fish Culture
Wisconsin	Fred P. Binkowski University of Wisconsin-Milwaukee	Fish Culture/Larval Fish Culture/Ecology Extension
	Jeffrey A. Malison University of Wisconsin-Madison	Aquaculture/Physiology/Endocrinology

PARTICIPATING INSTITUTIONS AND PRINCIPAL INVESTIGATORS

Purdue University (Purdue)
Paul B. Brown

Southern Illinois University-Carbondale (SIUC)
Robert J. Sheehan

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

Pittsburg State University (PSU)
James R. Triplett

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

Iowa State University (ISU)
Joseph E. Morris
Robert C. Summerfelt

University of South Dakota (USD)
Bruce A. Barton

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

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

OMB Approved 0524-0022
Expires 5/31/98

BUDGET

ORGANIZATION AND ADDRESS
Purdue University
Department of Forestry and Natural Resources, 1159 Forestry Building
West Lafayette, IN 47907-1159

USDA AWARD NO. Year 1 - Objective 1a

Duration Proposed Months: 12

Duration Awarded Months: ________

PRINCIPAL INVESTIGATOR(S)/PROJECT DIRECTOR(S)
Paul B. Brown

	CSREES FUNDED WORK MONTHS: Calendar	Academic	Summer	FUNDS REQUESTED by PROPOSER	FUNDS APPROVED BY CSREES (If Different)
A. Salaries and Wages					$
1. No. of Senior Personnel					
a. ___ (Co)-PI(s)/PD(s)					
b. ___ Senior Associates					
2. No. of Other Personnel (Non-Faculty)					
a. ___ Research Associates-Postdoctorates					
b. 1 Other Professional	0.25			$6,930	
c. ___ Graduate Students					
d. 1 Prebaccalaureate Students				$2,000	
e. ___ Secretarial-Clerical					
f. ___ Technical, Shop and Other					
Total Salaries and Wages →				$8,930	
B. Fringe Benefits (If charged as Direct Costs)				$2,290	
C. Total Salaries, Wages, and Fringe Benefits (A plus B) →				$11,220	
D. Nonexpendable Equipment (Attach supporting data. List items and dollar amounts for **each** item.)					
E. Materials and Supplies				$6,000	
F. Travel 1. Domestic (Including Canada)				$1,000	
2. Foreign (List destination and amount for each trip.)					
G. Publication Costs/Page Charges					
H. Computer (ADPE) Costs					
I. All Other Direct Costs (Attach supporting data. List items and dollar amounts. Details of Subcontracts, including work statements and budget, should be explained in full in proposal.) Telephone ($50), FAX ($50), Postage ($50), Photocopying ($75), Repairs ($555)				$780	
J. Total Direct Costs (C through I) →				$19,000	
K. Indirect Costs If Applicable (Specify rate(s) and base(s) for on/off campus activity. Where both are involved, identify itemized costs in on/off campus bases.)					
L. Total Direct and Indirect Costs (J plus K) →				$19,000	
M. Other →					
N. Total Amount of This Request →				$19,000	$
O. Cost Sharing (If Required Provide Details)	$ $21,000				

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

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

Form CSREES-55 (6/95)

BUDGET JUSTIFICATION FOR PURDUE UNIVERSITY

(Brown)

Objective 1a

A. Salaries and Wages. A technician (0.25 FTE) is required for acquisition of fish, coordination of diet acquisition, feeding fish, water quality monitoring and harvesting. A prebaccalaureate student is required for supplementing these activities as fish will be fed 7 days per week.

B. Fringe Benefits. Standard fringe benefit rate is 32% for technicians and 3.6% for prebaccalaureate students.

E. Materials and Supplies. These funds will be used for acquisition of fish from Clear Creek Hatchery, Martinsville, Indiana and acquisition of feeds. Feed purchases will be on a regular basis to avoid confounding effects of rancidity or loss of labile nutrients; thus, must be purchased in bags instead of bulk.

F. Travel. These funds will be used for acquisition of fish, feed and dissemination of research results.

I. Other Direct Costs. Telephone ($50), FAX ($50), postage charges ($50) and photocopying charges ($75) associated with this project and unexpected repairs to critical equipment ($555).

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

OMB Approved 0524-0022
Expires 5/31/98

BUDGET

ORGANIZATION AND ADDRESS Southern Illiinois University-Carbondale Fisheries Research Laboratory Carbondale, IL 62901-6511				**USDA AWARD NO.** Year 1 - Objective 1a	
PRINCIPAL INVESTIGATOR(S)/PROJECT DIRECTOR(S) Robert J. Sheehan				Duration Proposed Months: 12 **FUNDS REQUESTED by PROPOSER**	Duration Awarded Months: ________ **FUNDS APPROVED BY CSREES** (If Different)
A. Salaries and Wages	**CSREES FUNDED WORK MONTHS**				$
1. No. of Senior Personnel	Calendar	Academic	Summer		
a. ___ (Co)-PI(s)/PD(s)					
b. ___ Senior Associates					
2. No. of Other Personnel (Non-Faculty) a. ___ Research Associates-Postdoctorates					
b. ___ Other Professional					
c. 1 Graduate Students				$11,332	
d. 1 Prebaccalaureate Students				$2,000	
e. ___ Secretarial-Clerical					
f. ___ Technical, Shop and Other					
Total Salaries and Wages →				$13,332	
B. Fringe Benefits (If charged as Direct Costs)					
C. Total Salaries, Wages, and Fringe Benefits (A plus B) →				$13,332	
D. Nonexpendable Equipment (Attach supporting data. List items and dollar amounts for **each** item.)					
E. Materials and Supplies				$2,800	
F. Travel 1. Domestic (Including Canada)				$1,500	
2. Foreign (List destination and amount for each trip.)					
G. Publication Costs/Page Charges					
H. Computer (ADPE) Costs					
I. All Other Direct Costs (Attach supporting data. List items and dollar amounts. Details of Subcontracts, including work statements and budget, should be explained in full in proposal.) Telephone ($75), FAX ($75), Postage ($75), Photocopying ($75), Computer time ($300), Mowing ($200), Repairs ($568)				$1,368	
J. Total Direct Costs (C through I) →				$19,000	
K. Indirect Costs If Applicable (Specify rate(s) and base(s) for on/off campus activity. Where both are involved, identify itemized costs in on/off campus bases.)					
L. Total Direct and Indirect Costs (J plus K) →				$19,000	
M. Other →					
N. Total Amount of This Request →				$19,000	$
O. Cost Sharing (If Required Provide Details)	$ 18,509				

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

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

Form CSREES-55 (6/95)

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

OMB Approved 0524-0022
Expires 5/31/98

BUDGET

ORGANIZATION AND ADDRESS
Southern Illiinois University-Carbondale
Fisheries Research Laboratory
Carbondale, IL 62901-6511

USDA AWARD NO. Year 2 - Objective 1a

PRINCIPAL INVESTIGATOR(S)/PROJECT DIRECTOR(S)
Robert J. Sheehan

	CSREES FUNDED WORK MONTHS: Calendar	Academic	Summer	Duration Proposed Months: 12 **FUNDS REQUESTED by PROPOSER**	Duration Awarded Months: ________ **FUNDS APPROVED BY CSREES** (If Different)
A. Salaries and Wages 1. No. of Senior Personnel					$
a. ___ (Co)-PI(s)/PD(s)					
b. ___ Senior Associates					
2. No. of Other Personnel (Non-Faculty) a. ___ Research Associates-Postdoctorates					
b. ___ Other Professional					
c. 1 Graduate Students				$11,785	
d. 1 Prebaccalaureate Students				$2,080	
e. ___ Secretarial-Clerical					
f. ___ Technical, Shop and Other					
Total Salaries and Wages →				$13,865	
B. Fringe Benefits (If charged as Direct Costs)					
C. Total Salaries, Wages, and Fringe Benefits (A plus B) →				$13,865	
D. Nonexpendable Equipment (Attach supporting data. List items and dollar amounts for **each** item.)					
E. Materials and Supplies				$2,500	
F. Travel 1. Domestic (Including Canada)				$1,500	
2. Foreign (List destination and amount for each trip.)					
G. Publication Costs/Page Charges					
H. Computer (ADPE) Costs					
I. All Other Direct Costs (Attach supporting data. List items and dollar amounts. Details of Subcontracts, including work statements and budget, should be explained in full in proposal.) Telephone ($75), FAX ($75), Postage ($75), Photocopying ($75), Computer time ($300), Mowing ($200), Repairs ($335)				$1,135	
J. Total Direct Costs (C through I) →				$19,000	
K. Indirect Costs If Applicable (Specify rate(s) and base(s) for on/off campus activity. Where both are involved, identify itemized costs in on/off campus bases.)					
L. Total Direct and Indirect Costs (J plus K) →				$19,000	
M. Other →					
N. Total Amount of This Request →				$19,000	$
O. Cost Sharing (If Required Provide Details)	$ 18,991				

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

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

Form CSREES-55 (6/95)

BUDGET JUSTIFICATION FOR SOUTHERN ILLINOIS UNIVERSITY-CARBONDALE

(Sheehan)

Objective 1a

A. Salaries and Wages. A graduate student (0.50 FTE) is required to conduct and coordinate field activities in the project. A prebaccalaureate student (0.25 FTE) is required to assist in acquisition of fish, feeding fish, water quality monitoring, fish harvesting, and data collection.

E. Materials and Supplies. These funds will be used for acquisition of fish from local fish producers, acquisition of feeds, and the purchase of chemicals and other miscellaneous itesm for pond treatments and water quality analyses.

F. Travel. These funds will be used for the operation of a truck used fpr acquisition of fish and daily travel to the research facility and for travel associated with dissemination of research results.

I. Other Direct Costs. Telephone ($75), FAX ($75), postage charges ($75) and photocopying charges ($75) associated with this project, computer time ($300), levee mowing ($200), and unexpected repairs to critical equipment (Year 1 - $568; Year 2 - $335).

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

OMB Approved 0524-0022
Expires 5/31/98

BUDGET

ORGANIZATION AND ADDRESS University of Missouri-Columbia School of Natural Resources Columbia, MO 65211	**USDA AWARD NO.** Year 1 - Objective 1b	
PRINCIPAL INVESTIGATOR(S)/PROJECT DIRECTOR(S) Robert S. Hayward and Douglas B. Noltie	Duration Proposed Months: 12 **FUNDS REQUESTED by PROPOSER**	Duration Awarded Months: ________ **FUNDS APPROVED BY CSREES** (If Different)

	CSREES FUNDED WORK MONTHS: Calendar	Academic	Summer	Funds Requested by Proposer	Funds Approved by CSREES (If Different)
A. Salaries and Wages 1. No. of Senior Personnel					$
a. ___ (Co)-PI(s)/PD(s)					
b. ___ Senior Associates					
2. No. of Other Personnel (Non-Faculty) a. 1 Research Associates-Postdoctorates	12			$16,000	
b. ___ Other Professional					
c. ___ Graduate Students					
d. ___ Prebaccalaureate Students					
e. ___ Secretarial-Clerical					
f. ___ Technical, Shop and Other					
Total Salaries and Wages . . . . →				$16,000	
B. Fringe Benefits (If charged as Direct Costs)				$4,000	
C. Total Salaries, Wages, and Fringe Benefits (A plus B) . . . . →				$20,000	
D. Nonexpendable Equipment (Attach supporting data. List items and dollar amounts for **each** item.)					
E. Materials and Supplies				$4,500	
F. Travel 1. Domestic (Including Canada) . . . . 2. Foreign (List destination and amount for each trip.)					
G. Publication Costs/Page Charges					
H. Computer (ADPE) Costs					
I. All Other Direct Costs (Attach supporting data. List items and dollar amounts. Details of Subcontracts, including work statements and budget, should be explained in full in proposal.)					
J. Total Direct Costs (C through I) . . . . →				$24,500	
K. Indirect Costs If Applicable (Specify rate(s) and base(s) for on/off campus activity. Where both are involved, identify itemized costs in on/off campus bases.)					
L. Total Direct and Indirect Costs (J plus K) . . . . →				$24,500	
M. Other . . . . →					
N. Total Amount of This Request . . . . →				$24,500	$
O. Cost Sharing (If Required Provide Details)	$ 32,741				

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

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

Form CSREES-55 (6/95)

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

OMB Approved 0524-0022
Expires 5/31/98

BUDGET

ORGANIZATION AND ADDRESS University of Missouri-Columbia School of Natural Resources Columbia, MO 65211				**USDA AWARD NO.** Year 2 - Objective 1b	
PRINCIPAL INVESTIGATOR(S)/PROJECT DIRECTOR(S) Robert S. Hayward and Douglas B. Noltie				Duration Proposed Months: 12 **FUNDS REQUESTED by PROPOSER**	Duration Awarded Months: ________ **FUNDS APPROVED BY CSREES** (If Different)
A. Salaries and Wages	**CSREES FUNDED WORK MONTHS**				$
1. No. of Senior Personnel	Calendar	Academic	Summer		
a. ___ (Co)-PI(s)/PD(s)					
b. ___ Senior Associates					
2. No. of Other Personnel (Non-Faculty) a. 1 Research Associates-Postdoctorates	12			$16,000	
b. ___ Other Professional					
c. ___ Graduate Students					
d. ___ Prebaccalaureate Students					
e. ___ Secretarial-Clerical					
f. ___ Technical, Shop and Other					
Total Salaries and Wages →				$16,000	
B. Fringe Benefits (If charged as Direct Costs)				$4,000	
C. Total Salaries, Wages, and Fringe Benefits (A plus B) →				$20,000	
D. Nonexpendable Equipment (Attach supporting data. List items and dollar amounts for **each** item.)					
E. Materials and Supplies				$4,500	
F. Travel 1. Domestic (Including Canada)					
2. Foreign (List destination and amount for each trip.)					
G. Publication Costs/Page Charges					
H. Computer (ADPE) Costs					
I. All Other Direct Costs (Attach supporting data. List items and dollar amounts. Details of Subcontracts, including work statements and budget, should be explained in full in proposal.)					
J. Total Direct Costs (C through I) →				$24,500	
K. Indirect Costs If Applicable (Specify rate(s) and base(s) for on/off campus activity. Where both are involved, identify itemized costs in on/off campus bases.)					
L. Total Direct and Indirect Costs (J plus K) →				$24,500	
M. Other →					
N. Total Amount of This Request →				$24,500	$
O. Cost Sharing (If Required Provide Details)	$ 32,741				

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

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

Form CSREES-55 (6/95)

BUDGET JUSTIFICATION FOR UNIVERSITY OF MISSOURI-COLUMBIA

(Noltie and Hayward)

Objective 1b

A. Salaries and Wages. A Postdoctorate (1.0 FTE) will be needed to perform experiments (feeding and weighing of fish, data compilation and analysis). PIs will supervise all aspects of the study and will author and submit study reports.

B. Fringe Benefits. Standard fringe benefit rate is 25% for Postdoctorates.

E. Materials and Supplies. Costs associated with routine operations and data collection include: fish feed, chemicals for water quality assessment and fish health maintenance, aquarium nets, buckets, replacement materials for recirculating culture system, thermometers, computer supplies, stationary, phone/FAX charges, proximate analyses, literature search costs.

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

BUDGET

ORGANIZATION AND ADDRESS Pittsburg State University Department of Biology, 1701 S. Broadway Pittsburg, KS 66762-7552				**USDA AWARD NO.** Year 1 - Objective 1b	
PRINCIPAL INVESTIGATOR(S)/PROJECT DIRECTOR(S) James R. Triplett				Duration Proposed Months: 12 **FUNDS REQUESTED by PROPOSER**	Duration Awarded Months: ________ **FUNDS APPROVED BY CSREES** (If Different)
A. Salaries and Wages 1. No. of Senior Personnel	**CSREES FUNDED WORK MONTHS**				$
	Calendar	Academic	Summer		
a. ___ (Co)-PI(s)/PD(s)					
b. ___ Senior Associates					
2. No. of Other Personnel (Non-Faculty) a. ___ Research Associates-Postdoctorates					
b. ___ Other Professional					
c. 1 Graduate Students				$7,450	
d. 1 Prebaccalaureate Students				$500	
e. ___ Secretarial-Clerical					
f. ___ Technical, Shop and Other					
Total Salaries and Wages →				$7,950	
B. Fringe Benefits (If charged as Direct Costs)				$150	
C. Total Salaries, Wages, and Fringe Benefits (A plus B) →				$8,100	
D. Nonexpendable Equipment (Attach supporting data. List items and dollar amounts for **each** item.)				$6,000	
E. Materials and Supplies				$500	
F. Travel 1. Domestic (Including Canada)				$700	
2. Foreign (List destination and amount for each trip.)					
G. Publication Costs/Page Charges					
H. Computer (ADPE) Costs					
I. All Other Direct Costs (Attach supporting data. List items and dollar amounts. Details of Subcontracts, including work statements and budget, should be explained in full in proposal.) Telephone ($50), FAX ($50), Postage ($25), Photocopying ($75)				$200	
J. Total Direct Costs (C through I) →				$15,500	
K. Indirect Costs If Applicable (Specify rate(s) and base(s) for on/off campus activity. Where both are involved, identify itemized costs in on/off campus bases.)					
L. Total Direct and Indirect Costs (J plus K) →				$15,500	
M. Other →					
N. Total Amount of This Request →				$15,500	$
O. Cost Sharing (If Required Provide Details)	$ 17,126				

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

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

Form CSREES-55 (6/95)

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

OMB Approved 0524-0022
Expires 5/31/98

BUDGET

ORGANIZATION AND ADDRESS Pittsburg State University Department of Biology, 1701 S. Broadway Pittsburg, KS 66762-7552				**USDA AWARD NO.** Year 2 - Objective 1b	
PRINCIPAL INVESTIGATOR(S)/PROJECT DIRECTOR(S) James R. Triplett				Duration Proposed Months: 12 **FUNDS REQUESTED by PROPOSER**	Duration Awarded Months: ________ **FUNDS APPROVED BY CSREES** (If Different)
A. Salaries and Wages 1. No. of Senior Personnel	**CSREES FUNDED WORK MONTHS** Calendar	Academic	Summer		$
a. ___ (Co)-PI(s)/PD(s)					
b. ___ Senior Associates					
2. No. of Other Personnel (Non-Faculty) a. ___ Research Associates-Postdoctorates					
b. ___ Other Professional					
c. 1 Graduate Students				$6,093	
d. 1 Prebaccalaureate Students				$500	
e. ___ Secretarial-Clerical					
f. ___ Technical, Shop and Other					
Total Salaries and Wages →				$6,593	
B. Fringe Benefits (If charged as Direct Costs)				$122	
C. Total Salaries, Wages, and Fringe Benefits (A plus B) →				$6,715	
D. Nonexpendable Equipment (Attach supporting data. List items and dollar amounts for **each** item.)				$385	
E. Materials and Supplies				$500	
F. Travel 1. Domestic (Including Canada)				$700	
2. Foreign (List destination and amount for each trip.)					
G. Publication Costs/Page Charges					
H. Computer (ADPE) Costs					
I. All Other Direct Costs (Attach supporting data. List items and dollar amounts. Details of Subcontracts, including work statements and budget, should be explained in full in proposal.) Telephone ($50), FAX ($50), Postage ($25), Photocopying ($75)				$200	
J. Total Direct Costs (C through I) →				$8,500	
K. Indirect Costs If Applicable (Specify rate(s) and base(s) for on/off campus activity. Where both are involved, identify itemized costs in on/off campus bases.)					
L. Total Direct and Indirect Costs (J plus K) →				$8,500	
M. Other →					
N. Total Amount of This Request →				$8,500	$
O. Cost Sharing (If Required Provide Details)	$ 17,177				

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

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

Form CSREES-55 (6/95)

BUDGET JUSTIFICATION FOR PITTSBURG STATE UNIVERSITY

(Triplett)

Objective 1b

A. Salaries and Wages. A graduate research assistant (0.50 FTE) is required to assist with the setup and monitoring of the process control system, establish and conduct the feeding trials, maintain the recirculating system, collect and analyze the data and assist with the preparation of reports. This position is needed for 11 months during the first year and for 9 months of the second year. In addition, a prebaccalaureate student is needed to occasionally assist the graduate research assistant and cover system needs during the GRA's absence ($500 per year).

B. Fringe Benefits. The fringe benefit rate at PSU is 2% for GRAs and less than 1% for prebaccalaureate students.

D. Nonexpendable equipment. The software (Intouch by Wonderware, 64-TAG process control), digital interface (8-channel DASS 800 board and server), and sensors (YSI high-level analog sensor) will cost about $3500. The computer hardware (486DX, 100MHZ, 16MGB RAM, 540MGB Hard Drive) will cost about $2000. An upgrade of the temperature control system (chiller, heater) should be fabricated for about $500. A back-up dssolved oxygen meter will be needed eventually for $385.

E. Materials and Supplies. The bulk of the estimated cost for supplies comes from the feed used in the feeding trials, which could be as much as 200 kg of Biodiet®TM at $3.50/kg (includes shipping) totalling $700. The remaining $300 is needed to replace recirculating pumps ($60 @) and purchase plumbing materials and other supplies to maintain the process control and recirculating systems. We may also need to purchase fish from a local producer ($100).

F. Travel. These funds will be used to help defray the cost of attending professional meetings and presenting papers on the results by the PI and GRA. Plans are to attend the Midwest Fish and Wildlife Conference, the Kansas Academy of Sciences, the Kansas Commercial Fish Growers meeting and any NCRAC work group meetings during the project period ($700 per year).

I. Other Direct Costs. It is anticipated that about $200 per year will be needed to defray telephone, postage and copying costs.

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

OMB Approved 0524-0022
Expires 5/31/98

BUDGET

ORGANIZATION AND ADDRESS University of Wisconsin-Milwaukee - Center for Great Lakes Studies 600 E. Greenfield Avenue Milwaukee, WI 53204	**USDA AWARD NO.** Year 1 - Objective 1b	
	Duration Proposed Months: 12	Duration Awarded Months: ________
PRINCIPAL INVESTIGATOR(S)/PROJECT DIRECTOR(S) Fred P. Binkowski	**FUNDS REQUESTED by PROPOSER**	**FUNDS APPROVED BY CSREES** (If Different)

	CSREES FUNDED WORK MONTHS: Calendar	Academic	Summer	FUNDS REQUESTED by PROPOSER	FUNDS APPROVED BY CSREES (If Different)
A. Salaries and Wages 1. No. of Senior Personnel					$
a. ___ (Co)-PI(s)/PD(s)					
b. ___ Senior Associates					
2. No. of Other Personnel (Non-Faculty) a. 2 Research Associates-Postdoctorates	0.16			$7,498	
b. ___ Other Professional					
c. ___ Graduate Students					
d. 1 Prebaccalaureate Students				$178	
e. ___ Secretarial-Clerical					
f. ___ Technical, Shop and Other					
Total Salaries and Wages →				$7,676	
B. Fringe Benefits (If charged as Direct Costs)				$2,324	
C. Total Salaries, Wages, and Fringe Benefits (A plus B) →				$10,000	
D. Nonexpendable Equipment (Attach supporting data. List items and dollar amounts for **each** item.)					
E. Materials and Supplies					
F. Travel 1. Domestic (Including Canada)					
2. Foreign (List destination and amount for each trip.)					
G. Publication Costs/Page Charges					
H. Computer (ADPE) Costs					
I. All Other Direct Costs (Attach supporting data. List items and dollar amounts. Details of Subcontracts, including work statements and budget, should be explained in full in proposal.)					
J. Total Direct Costs (C through I) →				$10,000	
K. Indirect Costs If Applicable (Specify rate(s) and base(s) for on/off campus activity. Where both are involved, identify itemized costs in on/off campus bases.)					
L. Total Direct and Indirect Costs (J plus K) →				$10,000	
M. Other →					
N. Total Amount of This Request →				$10,000	$
O. Cost Sharing (If Required Provide Details)	$ 25,747				

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

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

Form CSREES-55 (6/95)

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

OMB Approved 0524-0022
Expires 5/31/98

BUDGET

ORGANIZATION AND ADDRESS University of Wisconsin-Milwaukee - Center for Great Lakes Studies 600 E. Greenfield Avenue Milwaukee, WI 53204				**USDA AWARD NO.** Year 2 - Objective 1b	
PRINCIPAL INVESTIGATOR(S)/PROJECT DIRECTOR(S) Fred P. Binkowski				Duration Proposed Months: 12 **FUNDS REQUESTED by PROPOSER**	Duration Awarded Months: ________ **FUNDS APPROVED BY CSREES** (If Different)
A. Salaries and Wages	**CSREES FUNDED WORK MONTHS**				$
1. No. of Senior Personnel	Calendar	Academic	Summer		
a. ___ (Co)-PI(s)/PD(s)					
b. ___ Senior Associates					
2. No. of Other Personnel (Non-Faculty) a. 2 Research Associates-Postdoctorates	0.16			$7,498	
b. ___ Other Professional					
c. ___ Graduate Students					
d. 1 Prebaccalaureate Students				$178	
e. ___ Secretarial-Clerical					
f. ___ Technical, Shop and Other					
Total Salaries and Wages →				$7,676	
B. Fringe Benefits (If charged as Direct Costs)				$2,324	
C. Total Salaries, Wages, and Fringe Benefits (A plus B) →				$10,000	
D. Nonexpendable Equipment (Attach supporting data. List items and dollar amounts for **each** item.)					
E. Materials and Supplies					
F. Travel 1. Domestic (Including Canada)					
2. Foreign (List destination and amount for each trip.)					
G. Publication Costs/Page Charges					
H. Computer (ADPE) Costs					
I. All Other Direct Costs (Attach supporting data. List items and dollar amounts. Details of Subcontracts, including work statements and budget, should be explained in full in proposal.)					
J. Total Direct Costs (C through I) →				$10,000	
K. Indirect Costs If Applicable (Specify rate(s) and base(s) for on/off campus activity. Where both are involved, identify itemized costs in on/off campus bases.)					
L. Total Direct and Indirect Costs (J plus K) →				$10,000	
M. Other →					
N. Total Amount of This Request →				$10,000	$
O. Cost Sharing (If Required Provide Details)	$ 25,747				

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

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

Form CSREES-55 (6/95)

BUDGET JUSTIFICATION FOR UNIVERSITY OF WISCONSIN-MILWAUKEE

(Binkowski)

Objective 1b

A. Salaries and Wages. Research associates will acquire and maintain the 5.1-10.2 cm (2-4") black crappie stocks, spawn habituate, and rear the smallest feasible intensively reared crappies for comparison, install and operate the recirculating aquaculture system and sample rearing trials; collect and enumerate mortalities; evaluate growth, survival, food conversion and rearing costs of alternative crappie habituation strategies over the trial period; analyze the results; and prepare the final report. Also included is a very minimal amount of salary for student hourly help.

B. Fringe Benefits. The fringe benefit rate is 31% for Research Associates.

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

OMB Approved 0524-0022
Expires 5/31/98

BUDGET

ORGANIZATION AND ADDRESS Iowa State University Department of Animal Ecology Ames, IA 50011-3221				**USDA AWARD NO.** Year 1 - Objectives 1b & 3	
PRINCIPAL INVESTIGATOR(S)/PROJECT DIRECTOR(S) Joseph E. Morris and Robert C. Summerfelt				Duration Proposed Months: 12 **FUNDS REQUESTED by PROPOSER**	Duration Awarded Months: ________ **FUNDS APPROVED BY CSREES** (If Different)
A. Salaries and Wages 1. No. of Senior Personnel	**CSREES FUNDED WORK MONTHS** Calendar	Academic	Summer		$
a. ___ (Co)-PI(s)/PD(s)					
b. ___ Senior Associates					
2. No. of Other Personnel (Non-Faculty) a. ___ Research Associates-Postdoctorates					
b. ___ Other Professional					
c. 1 Graduate Students				$2,400	
d. 1 Prebaccalaureate Students				$1,500	
e. ___ Secretarial-Clerical					
f. 1 Technical, Shop and Other				$4,500	
Total Salaries and Wages →				$8,400	
B. Fringe Benefits (If charged as Direct Costs)				$520	
C. Total Salaries, Wages, and Fringe Benefits (A plus B) →				$8,920	
D. Nonexpendable Equipment (Attach supporting data. List items and dollar amounts for **each** item.)				$6,800	
E. Materials and Supplies				$1,238	
F. Travel 1. Domestic (Including Canada)				$200	
2. Foreign (List destination and amount for each trip.)					
G. Publication Costs/Page Charges					
H. Computer (ADPE) Costs					
I. All Other Direct Costs (Attach supporting data. List items and dollar amounts. Details of Subcontracts, including work statements and budget, should be explained in full in proposal.) Telephone ($50), FAX ($50)				$100	
J. Total Direct Costs (C through I) →				$17,258	
K. Indirect Costs If Applicable (Specify rate(s) and base(s) for on/off campus activity. Where both are involved, identify itemized costs in on/off campus bases.)					
L. Total Direct and Indirect Costs (J plus K) →				$17,258	
M. Other →					
N. Total Amount of This Request →				$17,258	$
O. Cost Sharing (If Required Provide Details)	$ 16,835				

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

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

Form CSREES-55 (6/95)

OMB Approved 0524-0022
Expires 5/31/98

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

BUDGET

ORGANIZATION AND ADDRESS Iowa State University Department of Animal Ecology Ames, IA 50011-3221				**USDA AWARD NO.** Year 2 - Objectives 1b & 3	
PRINCIPAL INVESTIGATOR(S)/PROJECT DIRECTOR(S) Joseph E. Morris and Robert C. Summerfelt				Duration Proposed Months: 12 **FUNDS REQUESTED by PROPOSER**	Duration Awarded Months: ________ **FUNDS APPROVED BY CSREES** (If Different)
A. Salaries and Wages	**CSREES FUNDED WORK MONTHS**				$
1. No. of Senior Personnel	Calendar	Academic	Summer		
a. ___ (Co)-PI(s)/PD(s)					
b. ___ Senior Associates					
2. No. of Other Personnel (Non-Faculty) a. ___ Research Associates-Postdoctorates					
b. ___ Other Professional					
c. 1 Graduate Students				$2,420	
d. 1 Prebaccalaureate Students				$1,500	
e. ___ Secretarial-Clerical					
f. 1 Technical, Shop and Other				$9,568	
Total Salaries and Wages →				$13,488	
B. Fringe Benefits (If charged as Direct Costs)				$1,027	
C. Total Salaries, Wages, and Fringe Benefits (A plus B) →				$14,515	
D. Nonexpendable Equipment (Attach supporting data. List items and dollar amounts for **each** item.)					
E. Materials and Supplies				$2,577	
F. Travel 1. Domestic (Including Canada)				$550	
2. Foreign (List destination and amount for each trip.)					
G. Publication Costs/Page Charges					
H. Computer (ADPE) Costs					
I. All Other Direct Costs (Attach supporting data. List items and dollar amounts. Details of Subcontracts, including work statements and budget, should be explained in full in proposal.) Telephone ($50), FAX ($50)				$100	
J. Total Direct Costs (C through I) →				$17,742	
K. Indirect Costs If Applicable (Specify rate(s) and base(s) for on/off campus activity. Where both are involved, identify itemized costs in on/off campus bases.)					
L. Total Direct and Indirect Costs (J plus K) →				$17,742	
M. Other →					
N. Total Amount of This Request →				$17,742	$
O. Cost Sharing (If Required Provide Details)	$ 18,149				

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

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

Form CSREES-55 (6/95)

BUDGET JUSTIFICATION FOR IOWA STATE UNIVERSITY

(Morris and Summerfelt)

Objective 1b

A. Salaries and Wages. (1) First year - $6,000: Technician (0.25 FTE) and prebacculaurate student (0.25 FTE) to carryout out-of-season spawning of fish, rearing fry to August 1, monitor water quality, and training two-month old pond-reared fingerlings to formulated feed. In addition, they will modify existing recycle system to replace old clarifier with new microscreen filter. (2) Second year - $11,068: Technician (0.40 FTE) and prebacculaurate student (0.25 FTE) to carry out husbandary of fish during the two grow out intervals, and to monitor water quality.

B. Fringe Benefits. Standard fringe benefit rate is 10% for technicians; there is no rate for prebaccalaureate students.

D. Nonexpendable Equipment. (1) First year - $6,800: microscreen filter, with level control and high pressure sprayer; (2) Second year: No equipment.

E. Materials and Supplies. (1) First year - $1,198: Fish feed (brine shrimp and Fry feed Kyowa®) for fry culture, fish feed for training and grow out, reagents and glassware for chemical analysis, plumbing supplies to revise recycle system. (2) Second year - $2,577: Fish feed (brine shrimp and Fry Feed Kyowa®) for fry culture, fish feed for grow out, reagents and glassware for chemical analysis.

F. Travel. (1) First year: 360 miles for two roundtrips to commercial fish farm, to take fry and pickup pond-reared fingerlings, and for brood fish acquisition. (2) Second year: Funds to attend regional scientific meetings to present results or to attend Sunfish Work Group meeting.

I. Other Direct Costs. First and Second years - $100: Telephone ($50) and FAX ($50) charges associated with this project.

Objective 3

A. Salaries and Wages. A graduate student (0.17 FTE) is needed to assist the principal investigator (Morris) with this component of the project. This individual will assist in writing extension publications on sunfish culture.

B. Fringe Benefits. There is a flat rate of $70 for any graduate assistantship.

E. Materials and Supplies. General office supplies and other miscellaneous supplies ($40) will be needed to produce drafts of the extension publications on sunfish culture in the first year.

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

OMB Approved 0524-0022
Expires 5/31/98

BUDGET

ORGANIZATION AND ADDRESS University of South Dakota Department of Biology, 414 E. Clark Vermillion, SD 57069	**USDA AWARD NO.** Year 1 - Objective 2	
PRINCIPAL INVESTIGATOR(S)/PROJECT DIRECTOR(S) Bruce A. Barton	Duration Proposed Months: 12 **FUNDS REQUESTED by PROPOSER**	Duration Awarded Months: ________ **FUNDS APPROVED BY CSREES** (If Different)

	CSREES FUNDED WORK MONTHS: Calendar	Academic	Summer	FUNDS REQUESTED by PROPOSER	FUNDS APPROVED BY CSREES (If Different)
A. Salaries and Wages 1. No. of Senior Personnel					$
a. ___ (Co)-PI(s)/PD(s)					
b. ___ Senior Associates					
2. No. of Other Personnel (Non-Faculty) a. ___ Research Associates-Postdoctorates					
b. ___ Other Professional					
c. 1 Graduate Students				$3,384	
d. ___ Prebaccalaureate Students					
e. ___ Secretarial-Clerical					
f. ___ Technical, Shop and Other					
Total Salaries and Wages →				$3,384	
B. Fringe Benefits (If charged as Direct Costs)				$474	
C. Total Salaries, Wages, and Fringe Benefits (A plus B) →				$3,858	
D. Nonexpendable Equipment (Attach supporting data. List items and dollar amounts for **each** item.)					
E. Materials and Supplies				$150	
F. Travel 1. Domestic (Including Canada)				$75	
2. Foreign (List destination and amount for each trip.)					
G. Publication Costs/Page Charges					
H. Computer (ADPE) Costs					
I. All Other Direct Costs (Attach supporting data. List items and dollar amounts. Details of Subcontracts, including work statements and budget, should be explained in full in proposal.)					
J. Total Direct Costs (C through I) →				$4,083	
K. Indirect Costs If Applicable (Specify rate(s) and base(s) for on/off campus activity. Where both are involved, identify itemized costs in on/off campus bases.)					
L. Total Direct and Indirect Costs (J plus K) →				$4,083	
M. Other →					
N. Total Amount of This Request →				$4,083	$
O. Cost Sharing (If Required Provide Details)	$ 7,060				

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

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

Form CSREES-55 (6/95)

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

OMB Approved 0524-0022
Expires 5/31/98

BUDGET

ORGANIZATION AND ADDRESS University of South Dakota Department of Biology, 414 E. Clark Vermillion, SD 57069				**USDA AWARD NO.** Year 2 - Objective 2	
PRINCIPAL INVESTIGATOR(S)/PROJECT DIRECTOR(S) Bruce A. Barton				Duration Proposed Months: 12 **FUNDS REQUESTED by PROPOSER**	Duration Awarded Months: ________ **FUNDS APPROVED BY CSREES** (If Different)
A. Salaries and Wages	**CSREES FUNDED WORK MONTHS**				$
1. No. of Senior Personnel	Calendar	Academic	Summer		
a. ___ (Co)-PI(s)/PD(s)					
b. ___ Senior Associates					
2. No. of Other Personnel (Non-Faculty) a. ___ Research Associates-Postdoctorates					
b. ___ Other Professional					
c. 1 Graduate Students				$3,384	
d. ___ Prebaccalaureate Students					
e. ___ Secretarial-Clerical					
f. ___ Technical, Shop and Other					
Total Salaries and Wages →				$3,384	
B. Fringe Benefits (If charged as Direct Costs)				$474	
C. Total Salaries, Wages, and Fringe Benefits (A plus B) →				$3,858	
D. Nonexpendable Equipment (Attach supporting data. List items and dollar amounts for **each** item.)					
E. Materials and Supplies				$359	
F. Travel 1. Domestic (Including Canada)				$200	
2. Foreign (List destination and amount for each trip.)					
G. Publication Costs/Page Charges					
H. Computer (ADPE) Costs					
I. All Other Direct Costs (Attach supporting data. List items and dollar amounts. Details of Subcontracts, including work statements and budget, should be explained in full in proposal.)					
J. Total Direct Costs (C through I) →				$4,417	
K. Indirect Costs If Applicable (Specify rate(s) and base(s) for on/off campus activity. Where both are involved, identify itemized costs in on/off campus bases.)					
L. Total Direct and Indirect Costs (J plus K) →				$4,417	
M. Other →					
N. Total Amount of This Request →				$4,417	$
O. Cost Sharing (If Required Provide Details)	$ 7,350				

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

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

Form CSREES-55 (6/95)

BUDGET JUSTIFICATION FOR UNIVERSITY OF SOUTH DAKOTA

(Barton)

Objtective 2

A. Salaries and Wages. A stipend (0.12 FTE) will support a graduate student for two summers, who will set up and carry out the study under the Principal Investigator's direct supervision at USD.

B. Fringe Benefits. USD fringe benefit rate for part-time staff including graduate assistants is 14%.

E. Materials and Supplies. Immersion heaters will be purchased in Year 2, along with blood chemistry assay replacement reagents and supplies in both years.

F. Travel. Travel to Yankton, South Dakota, using a daily-leased USD vehicle, will be needed twice each year to obtain fish. Additional partial support is provided for NCRAC Sunfish Work Group meeting attenance.

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

OMB Approved 0524-0022
Expires 5/31/98

BUDGET

ORGANIZATION AND ADDRESS University of Wisconsin-Madison Aquaculture Program Department of Food Science, 103 Babcock Hall Madison, WI 53706	**USDA AWARD NO.** Year 1 - Objective 2	
	Duration Proposed Months: 12	Duration Awarded Months: ________
PRINCIPAL INVESTIGATOR(S)/PROJECT DIRECTOR(S) Jeffrey A. Malison	**FUNDS REQUESTED by PROPOSER**	**FUNDS APPROVED BY CSREES** (If Different)

	CSREES FUNDED WORK MONTHS: Calendar	Academic	Summer	FUNDS REQUESTED by PROPOSER	FUNDS APPROVED BY CSREES (If Different)
A. Salaries and Wages 1. No. of Senior Personnel					$
a. ___ (Co)-PI(s)/PD(s)					
b. ___ Senior Associates					
2. No. of Other Personnel (Non-Faculty) a. ___ Research Associates-Postdoctorates					
b. 2 Other Professional	0.7			$1,500	
c. ___ Graduate Students					
d. ___ Prebaccalaureate Students					
e. ___ Secretarial-Clerical					
f. ___ Technical, Shop and Other					
Total Salaries and Wages . . . . →				$1,500	
B. Fringe Benefits (If charged as Direct Costs)				$465	
C. Total Salaries, Wages, and Fringe Benefits (A plus B) . . . . →				$1,965	
D. Nonexpendable Equipment (Attach supporting data. List items and dollar amounts for **each** item.)					
E. Materials and Supplies				$700	
F. Travel 1. Domestic (Including Canada)				$585	
2. Foreign (List destination and amount for each trip.)					
G. Publication Costs/Page Charges					
H. Computer (ADPE) Costs					
I. All Other Direct Costs (Attach supporting data. List items and dollar amounts. Details of Subcontracts, including work statements and budget, should be explained in full in proposal.)					
J. Total Direct Costs (C through I) . . . . →				$3,250	
K. Indirect Costs If Applicable (Specify rate(s) and base(s) for on/off campus activity. Where both are involved, identify itemized costs in on/off campus bases.)					
L. Total Direct and Indirect Costs (J plus K) . . . . →				$3,250	
M. Other . . . . →					
N. Total Amount of This Request . . . . →				$3,250	$
O. Cost Sharing (If Required Provide Details)	$ 7,350				

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

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

Form CSREES-55 (6/95)

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

OMB Approved 0524-0022
Expires 5/31/98

BUDGET

ORGANIZATION AND ADDRESS	USDA AWARD NO. Year 2 - Objective 2	
University of Wisconsin-Madison Aquaculture Program Department of Food Science, 103 Babcock Hall Madison, WI 53706	Duration Proposed Months: 12	Duration Awarded Months: ________
PRINCIPAL INVESTIGATOR(S)/PROJECT DIRECTOR(S) Jeffrey A. Malison	**FUNDS REQUESTED by PROPOSER**	**FUNDS APPROVED BY CSREES** (If Different)

	CSREES FUNDED WORK MONTHS: Calendar	Academic	Summer	FUNDS REQUESTED by PROPOSER	FUNDS APPROVED BY CSREES (If Different)
A. Salaries and Wages					$
1. No. of Senior Personnel					
a. ___ (Co)-PI(s)/PD(s)					
b. ___ Senior Associates					
2. No. of Other Personnel (Non-Faculty)					
a. ___ Research Associates-Postdoctorates					
b. 2 Other Professional	0.7			$1,500	
c. ___ Graduate Students					
d. ___ Prebaccalaureate Students					
e. ___ Secretarial-Clerical					
f. ___ Technical, Shop and Other					
Total Salaries and Wages →				$1,500	
B. Fringe Benefits (If charged as Direct Costs)				$465	
C. Total Salaries, Wages, and Fringe Benefits (A plus B) →				$1,965	
D. Nonexpendable Equipment (Attach supporting data. List items and dollar amounts for **each** item.)					
E. Materials and Supplies				$700	
F. Travel 1. Domestic (Including Canada)				$585	
2. Foreign (List destination and amount for each trip.)					
G. Publication Costs/Page Charges					
H. Computer (ADPE) Costs					
I. All Other Direct Costs (Attach supporting data. List items and dollar amounts. Details of Subcontracts, including work statements and budget, should be explained in full in proposal.)					
J. Total Direct Costs (C through I) →				$3,250	
K. Indirect Costs If Applicable (Specify rate(s) and base(s) for on/off campus activity. Where both are involved, identify itemized costs in on/off campus bases.)					
L. Total Direct and Indirect Costs (J plus K) →				$3,250	
M. Other →					
N. Total Amount of This Request →				$3,250	$
O. Cost Sharing (If Required Provide Details)	$ 8,250				

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

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

Form CSREES-55 (6/95)

BUDGET JUSTIFICATION FOR UNIVERSITY OF WISCONSIN-MADISON

(Malison)

Objective 2

A. Salaries and Wages. Research specialists are needed to assist with the collection of blood samples, the analysis of physiological stress indicators, and analysis and publication of results.

B. Fringe Benefits. UW-Madison benefits rate for technical staff is 31%.

E. Materials and Supplies. Biochemicals, reagents and laboratory supplies are needed to conduct analyses of plasma cortisol, glucose and/or chloride.

F. Travel. Approximately 75% of the travel budget requested will be needed for research specialists to travel once per year to USD to collect and process blood samples. The remainder of the travel budget will be used to attend NCRAC Sunfish Work Group meetings.

CULTURE TECHNOLOGY OF CENTRARCHIDS (SUNFISH)

Budget Summary for Each Participating Institution for the First Year

	Purdue	SIUC	UM	PSU	UW-Mil.	ISU	USD	UW-Mad.	TOTALS
Salaries and Wages	$8,930	$13,332	$16,000	$7,950	$7,676	$8,400	$3,384	$1,500	$67,172
Fringe Benefits	$2,290	$0	$4,000	$150	$2,324	$520	$474	$465	$10,223
Total Salaries, Wages and Benefits	$11,220	$13,332	$20,000	$8,100	$10,000	$8,920	$3,858	$1,965	$77,395
Nonexpendable Equipment	$0	$0	$0	$6,000	$0	$6,800	$0	$0	$12,800
Materials and Supplies	$6,000	$2,000	$4,500	$500	$0	$1,238	$150	$700	$15,088
Travel	$1,000	$1,500	$0	$700	$0	$200	$75	$585	$4,060
Other Direct Costs	$780	$2,168	$0	$200	$0	$100	$0	$0	$3,248
TOTAL PROJECT COSTS	**$19,000**	**$19,000**	**$24,500**	**$15,500**	**$10,000**	**$17,258**	**$4,083**	**$3,250**	**$112,591**

Budget Summary for Each Participating Institution for the Second Year

	Purdue	SIUC	UM	PSU	UW-Mil.	ISU	USD	UW-Mad.	TOTALS
Salaries and Wages	$0	$13,865	$16,000	$6,593	$7,676	$13,488	$3,384	$1,500	$62,506
Fringe Benefits	$0	$0	$4,000	$122	$2,324	$1,027	$474	$465	$8,412
Total Salaries, Wages and Benefits	$0	$13,865	$20,000	$6,715	$10,000	$14,515	$3,858	$1,965	$70,918
Nonexpendable Equipment	$0	$0	$0	$385	$0	$0	$0	$0	$385
Materials and Supplies	$0	$2,000	$4,500	$500	$0	$2,577	$359	$700	$10,636
Travel	$0	$1,500	$0	$700	$0	$550	$200	$585	$3,535
Other Direct Costs	$0	$1,635	$0	$200	$0	$100	$0	$0	$1,935
TOTAL PROJECT COSTS	**$0**	**$19,000**	**$24,500**	**$8,500**	**$10,000**	**$17,742**	**$4,417**	**$3,250**	**$87,409**

RESOURCE COMMITMENT FROM INSTITUTIONS[1]

State/Institution		Year 1	Year 2
Purdue University			
Salaries and Benefits: SY @ 0.10 FTE		$6,000	$0
Supplies, Expenses, Equipment, and Waiver of Overhead		$15,000	$0
	Total	$21,000	$0
Southern Illinois Univeristy-Carbondale			
Salaries and Benefits: SY @ 0.10 FTE		$7,415	$7,754
Waiver of Overhead (42%)		$11,094	$11,237
	Total	$18,509	$18,991
University of Missouri-Columbia			
Salaries and Benefits: 2 SY @ 0.125 FTE		$14,706	$14,706
Waiver of Overhead (46%)		$18,035	$18,035
	Total	$32,741	$32,741
Pittsburg State University			
Salaries and Benefits: SY @ 0.10 FTE		$9,297	$9,762
Waiver of Overhead (45%)		$7,829	$7,415
	Total	$17,126	$17,177
University of Wisconsin-Milwaukee			
Salaries, Benefits, and Waiver of Overhead		$18,547	$18,547
Supplies, Expenses, and Equipment		$6,200	$6,200
Travel		$1,000	$1,000
	Total	$25,747	$25,747
Iowa State University			
Salaries and Benefits: 2 SY @ 0.05 FTE		$8,441	$9,043
Waiver of Overhead (44%)		$7,594	$7,806
Supplies, Expenses, and Equipment		$800	$1,300
	Total	$16,835	$18,149
University of South Dakota			
Salaries and Benefits: SY @ 0.06		$3,500	$3,600
Supplies, Expenses, Equipment, and Waiver of Overhead		$3,560	$3,750
	Total	$7,060	$7,350
University of Wisconsin-Madison			
Salaries and Benefits: SY @ 0.02		$1,600	$1,800
TY @ 0.08		$2,500	$2,800
Supplies, Expenses, Equipment, and Waiver of Overhead		$3,250	$3,650
	Total	$7,350	$8,250
	Total per Year	$146,368	$128,405
	GRAND TOTAL	$274,773	

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

SCHEDULE FOR COMPLETION OF OBJECTIVES

Objective 1: Initiated in Year 1 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

Bruce A. Barton, University of South Dakota

Fred P. Binkowski, University of Wisconsin-Milwaukee

Paul B. Brown, Purdue University

Robert S. Hayward, University of Missouri-Columbia

Jeffrey A. Malison, University of Wisconsin-Madison

Joseph E. Morris, Iowa State University

Douglas B. Noltie, University of Missouri-Columbia

Robert J. Sheehan, Southern Illinois University-Carbondale

Robert C. Summerfelt, Iowa State University

James R. Triplett, Pittsburg State University

VITA

Bruce A. Barton	Social Security No. 543-04-5736
Department of Biology	Phone: 605-677-5211
University of South Dakota	FAX: 605-677-6557
Vermillion, SD 57069	E-mail: bbarton@charlie.usd.edu

EDUCATION

B.Sc. University of Guelph, 1970
M.Sc. University of Guelph, 1974
Ph.D. Oregon State University, 1987

POSITIONS

Assistant Professor (1993-present), Department of Biology, University of South Dakota
Senior Fisheries Biologist (1991-1993), Environmental Management Associates/Golder
Assistant Professor (1988-1990), Department of Biology, University of North Dakota
Fish Health Manager (Research) (1986-1988), Utah Natural Resources, Division of Wildlife Resources
Fish Culture Assessment Biologist (1980-1982), Ontario Ministry of Natural Resources, Fisheries Branch
Fisheries Research Biologist (1976-1980), Alberta Energy and Natural Resources, Fish and Wildlife Division
Aquaculture Biologist (1975-1976), Alberta Recreation, Parks and Wildlife, Fish and Wildlife Division

SCIENTIFIC AND PROFESSIONAL ORGANIZATIONS

American Fisheries Society
American Institute of Fishery Research Biologists
Canadian Society of Zoologists
Fisheries Society of the British Isles
Society for Experimental Biology (UK)
World Aquaculture Society

SELECTED PUBLICATIONS

Barton, B.A., and R.E. Zitzow. In press. Physiological responses of juvenile walleye to handling stress with recovery in saline water. Progressive Fish-Culturist.

Iwama, G.K., J.D. Morgan, and B.A. Barton. 1995. Simple field methods for monitoring stress and general condition of fish. Aquaculture Research 26:273-282

Barton, B.A., and G.K. Iwama. 1991. Physiological changes in fish from stress in aquaculture with emphasis on the response and effects of corticosteroids. Annual Review of Fish Diseases 1:3-26.

Wedemeyer, G.A., B.A. Barton, and D.J. McLeay. 1990. Stress and acclimation. Pages 451-489 *in* C.B. Schreck and P.B. Moyle, editors. Methods for fish biology. American Fisheries Society, Bethesda, Maryland.

Maule, A.G., C.B. Schreck, C.S. Bradford, and B.A. Barton. 1988. Physiological effects of collecting and transporting emigrating juvenile chinook salmon past dams on the Columbia River. Transactions of the American Fisheries Society 117:245-261.

VITA

Fred P. Binkowski
Center for Great Lakes Studies
University of Wisconsin-Milwaukee
600 E. Greenfield Avenue
Milwaukee, WI 53204

Social Security No. 398-40-1700
Phone: (414) 382-1723
FAX: (414) 382-1705
E-mail: sturgeon@csd.uwm.edu

EDUCATION

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

POSITIONS

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

SCIENTIFIC AND PROFESSIONAL ORGANIZATIONS

American Fisheries Society
World Aquaculture Society

SELECTED PUBLICATIONS

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

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

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

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

Miller, T., L. Crowder, and F.P. Binkowski. 1990. Effects of changes in the zooplankton assemblages on growth of Bloater and implications for recruitment success. Transactions of the American Fisheries Society 119:483-491.

Sommer, C.V., F.P. Binkowski, M.A. Schalk, and J.M. Bartos. 1986. Stress factors that can affect studies of drug metabolism in fish. Veterinary and Human Toxicology 28 (Supplement 1):45-54.

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

VITA

Paul B. Brown
Department of Forestry and Natural Resources
Purdue University
1159 Forestry Building
West Lafayette, IN 47907-1159

Social Security No. 411-11-4004
Phone: (317) 494-4968
FAX: (318) 494-0409
E-mail: pb@forest1.fnr.purdue.edu

EDUCATION

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

POSITIONS

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

SCIENTIFIC AND PROFESSIONAL ORGANIZATIONS

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

SELECTED PUBLICATIONS

Griffin, M.E., M.R. White, and P.B. Brown. 1994. Total sulfur amino acid requirement and cysteine replacement value for juvenile hybrid striped bass (*Morone saxatilis* × *M. chrysops*). Comparative Biochemistry and Physiology 108A:423-429.

Griffin, M.E., K.A. Wilson, and P.B. Brown. 1994. Dietary arginine requirement of juvenile hybrid striped bass. Journal of Nutrition 124:888-893.

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

Swann, D.L., J.R. Riepe, J.D. Stanley, M.E. Griffin, and P.B. Brown. 1994. Cage culture of hybrid striped bass in Indiana and evaluation of diets containing three levels of dietary protein. Journal of the World Aquaculture Society 25:281-288.

Wu, Y.V., R. Rosati, D.J. Sessa, and P. Brown. 1994. Utilization of protein-rich ethanol co-products from corn in tilapia feed. Journal of the American Oil Chemists Society 71:1041-1043.

Wetzel, J.E., II, and P.B. Brown. 1993. Growth and survival of juvenile *Orconectes virilis* and *O. immunis* at different temperatures. Journal of the World Aquaculture Society 24:339-343.

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.

VITA

Robert S. Hayward
School of Natural Resources
University of Missouri-Columbia
112 Stephens Hall
Columbia, MO 65211

Social Security No. 001-46-5460
Phone: (573) 882-2353
FAX: (573) 884-5070
E-mail: ffwgshad@mizzou1.missouri.edu

EDUCATION

B.S. Cornell University, 1977
M.S. Tennessee Technological University, 1980
Ph.D. Ohio State University, 1988

POSITIONS

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

SCIENTIFIC AND PROFESSIONAL ORGANIZATIONS

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

SELECTED PUBLICATIONS

Hayward, R.S., and E. Arnold. In press. Temperature dependence of maximum daily consumption in white crappie: implications for fisheries management. Transactions of the American Fisheries Society.

Hayward, R.S., and M.E. Bushman. 1994. Gastric evacuation rates for juvenile largemouth bass. Transactions of the American Fisheries Society 123:88-93.

Hayward, R.S., and F.J. Hiebert. 1993. Low-effort regression estimation of average daily food weight in fishes. Transactions of the American Fisheries Society 122:834-844.

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

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.

VITA

Jeffrey A. Malison
University of Wisconsin Aquaculture Program
Department of Food Science, 123 Babcock Hall
University of Wisconsin-Madison
Madison, WI 53706

Social Security No. 395-50-7597
Phone: (608)263-1242
FAX: (608)262-6872
E-mail: jmalison@facstaff.wisc.edu

EDUCATION

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

POSITIONS

Director (1995-present) and Assistant Director (1990-1995), University of Wisconsin Aquaculture Program, University of Wisconsin-Madison

SCIENTIFIC AND PROFESSIONAL ORGANIZATIONS

American Association for the Advancement of Sciences
American Fisheries Society
World Aquaculture Society

SELECTED PUBLICATIONS

Barry, T.P., J.J. Parrish, and J.A. Malison. 1995. Ontogeny of the cortisol stress response in rainbow trout. General and Comparative Endocrinology 97:57-65.

Malison, J.A., L.S. Procarione, A.R. Kapuscinski, and T.B. Kayes. 1994. Endocrine and gonadal changes during the reproductive cycle of walleye. Fish Physiology and Biochemistry 13:473-484.

Kohler, C.C., R. J. Sheehan, C. Habicht, J.A. Malison, and T.B. Kayes. 1994. Habituation to captivity and controlled spawning of white bass. Transactions of the American Fisheries Society 123:964-974.

Barry, T.P., A.F. Lapp, T.B. Kayes, and J.A. Malison. 1993. Validation of a microtitre plate ELISA for measuring cortisol in fish and comparison of stress responses of rainbow trout (*Oncorhynchus mykiss*) and lake trout (*Salvelinus namaycush*). Aquaculture 117:351-363.

Kebus, M.J., M.T. Collins, M.S. Brownfield, C.H. Amundson, T.B. Kayes, and J.A. Malison. 1992. Measurement of resting and stress-elevated serum cortisol in rainbow trout *Oncorhynchus mykiss* in experimental net-pens. Journal of the World Aquaculture Society 23:83-88.

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.

VITA

Joseph E. Morris
Department of Animal Ecology
Iowa State University
124 Science II
Ames, Iowa 50011-3221

Social Security No. 506-78-2186
Phone: (515) 294-4622
FAX: (515) 294-7874
E-mail: jemorris@iastate.edu

EDUCATION

B.S. Iowa State University, 1979
M.S. Texas A&M University, 1982
Ph.D. Mississippi State University, 1988

POSITIONS

Fisheries and Aquaculture Specialist/Associate Professor (1995-present), Specialist/Assistant Professor (1988-1995), Department of Animal Ecology, Iowa State University and Associate Director (1990-present), North Central Regional Aquaculture Center
Graduate Research Assistant (1986-1988), Mississippi State University
Aquaculture Manager (1982-1986), Stiles Farm Foundation
Graduate Research Assistant (1981-1982) and Research Technician I (1980-1981), Texas A&M University
Fisheries Biologist Aide (1979), Indiana Department of Natural Resources

SCIENTIFIC AND PROFESSIONAL ORGANIZATIONS

American Fisheries Society: Iowa State Chapter, Fish Culture Section, Educators Section
Iowa Aquaculture Association
Phi Kappa Phi, Iowa State University Chapter

SELECTED PUBLICATIONS

Latka, D.C., J.S. Ramsey, and J.E. Morris. 1995. Selection of tributary confluence habitat by shovelnose sturgeon in the channelized Missouri River. Pages 250-258 *in* A.D. Gershanovich and T.I.J. Smith, editors. Proceedings of the second international symposium on sturgeon. VNIRO PuMoscow, Russia.

Bryan, M., J. Morris, and G. Atchison. 1994. Methods for culturing bluegill in the laboratory. Progressive Fish-Culturist 56:217-221.

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.

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.

VITA

Douglas B. Noltie
School of Natural Resources
University of Missouri-Columbia
112 Stephens Hall
Columbia, MO 65211

Social Security No. 499-02-9860
Phone: (314) 882-9421
FAX: (314) 884-5070

EDUCATION

B.S. Queen's University, 1980
M.S. University of Western Ontario, 1983
Ph.D. University of Western Ontario, 1988

POSITIONS

Assistant Professor (1990-present), Fisheries and Wildlife Program, The School of Natural Resources, University of Missouri-Columbia

Post-doctoral Fellow (1988-1990), Natural Sciences and Engineering Research Council of Canada, Department of Zoology, University of Guelph, Guelph, Ontario, Canada

SCIENTIFIC AND PROFESSIONAL ORGANIZATIONS

American Fisheries Society
American Institute of Fishery Research Biologists
American Sportfishing Association/Sport Fishing Institute
International Association of Fish Ethologists

SELECTED PUBLICATIONS

Johnson, B.L., and D.B. Noltie. In press. Migratory dynamics of stream-spawning longnose gar (*Lepisosteus osseus*). Ecology of Freshwater Fish.

Bye, M.R., and D.B. Noltie. 1993. Differences in allocation of biomass to reproduction and gonad composition in pink salmon (*Oncorhynchus gorbuscha*). McNair Journal, University of Missouri-Columbia 1:24-27.

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(1):174-179.

Noltie, D.B. 1988. Differences in breeding Lake Superior pink salmon (*Oncorhynchus gorbuscha* (Walbaum)) associated with variation in thyroid hyperplasia. Canadian Journal of Zoology 66(12):2688-2694.

Noltie, D.B. 1988. Comparative growth and condition of northern stream-dwelling rock bass, *Ambloplites rupestris* (Rafinesque). Hydrobiologia 160(3):199-206.

Noltie, D.B. 1987. Incidence and effects of sea lamprey (*Petromyzon marinus*) parasitism on breeding pink salmon (*Oncorhynchus gorbuscha*) from the Carp River, eastern Lake Superior. Canadian Journal of Fisheries and Aquatic Sciences 44(9):1562-1567.

VITA

Robert J. Sheehan
Department of Zoology/Fisheries Research Laboratory
Southern Illinois University-Carbondale
Carbondale, IL 62901-6511

Social Security No. 321-42-5628
Phone: (618) 453-6089
FAX: (618) 536-7761
E-mail: bsheehan@siu.edu

EDUCATION

B.S. Northeastern Illinois University, 1973
M.A. Southern Illinois University-Carbondale, 1976
Ph.D. Southern Illinois University-Carbondale, 1984

POSITIONS

Associate Professor (1992-present) and Assistant Professor (1986-1992), Department of Zoology, Southern Illinois University-Carbondale

Associate Director (1995-present) and Assistant Director (1986-1995), Fisheries Research Laboratory, Southern Illinois University-Carbondale

Assistant Professor (1984-1986), Department of Fisheries and Wildlife Science, Virginia Polytechnic Institute and State University

SELECTED PUBLICATIONS

Sheehan, R.J., L.R. Bodensteiner, W.M. Lewis, A.M. Brandenburg, and P.S Wills. In press. Flowing water: an effective treatment for Ichthyophthiriasis. Transactions of the American Fisheries Society.

Woods, III., L.C., C.C. Kohler, R.J. Sheehan, and C.V. Sullivan. 1995. Volitional tank spawning of female striped bass with male white bass produces hybrid offspring. Transactions of the American Fisheries Society 124:628-632.

Kohler, C.C., R.J. Sheehan, C. Habicht, J.A. Malison, and T.B. Kayes. 1994. Habituation to captivity and controlled spawning of white bass. Transactions of the American Fisheries Society 123:964-974.

Wills, P.S., R.J. Sheehan, and J. Paret. 1994. Induced polyploidy in sunfish. Journal of the World Aquaculture Society 25(4):507-511.

Goudreau, S.E., R.J. Neves, and R.J. Sheehan. 1993. Effects of sewage treatment plant effluents on mollusks in the upper Clinch River, Virginia. Hydrobiologia 252:211-230.

Sheehan, R.J., and J.R. Rasmussen. 1993. Large rivers. Pages 443-466 *in* C. Kohler and W. Huber, editors, Inland fisheries management in North America. AFS Special Publication. American Fisheries Society, Bethesda, Maryland.

Bodensteiner, L.R., R.J. Sheehan, W.M. Lewis, and P.S. Wills. 1993. Effects of repetitive formalin treatments on channel catfish fingerlings. Journal of Aquatic Animal Health 5:59-63.

Kohler, C.C., R.J. Sheehan, and J.J. Sweatman. 1993. Largemouth bass hatching success and first-winter survival in two Illinois reservoirs. North American Journal of Fisheries Management 13:125-133.

Krum, H.N., and R.J. Sheehan. 1992. Development of a magnetic activity-detection system. Animal Behaviour 43:688-690.

Sheehan, R.J., R.J. Neves, and H.E. Kitchel. 1989. Fate of freshwater mussels transplanted to formerly polluted reaches of the Clinch and North Fork Holston Rivers, Virginia. Journal of Freshwater Ecology 5(2):139-149.

VITA

Robert C. Summerfelt
Department of Animal Ecology
Iowa State University
124 Science II
Ames, IA 50011-3221

Social Security No. 514-28-4947
Phone: (515) 294-6107
FAX: (515) 294-5468
E-mail: rsummer@iastate.edu

EDUCATION

B. S. University of Wisconsin-Stevens Point, Biology, 1957
M. S. Southern Illinois University, Zoology, 1959
Ph.D. Southern Illinois University, Zoology, 1964

POSITIONS

Professor (1976-present), Department of Animal Ecology, Iowa State University
Associate Director (1988-1990), North Central Regional Aquaculture Center
Chairman (1976-85), Department of Animal Ecology, Iowa State University
Leader (Fishery Research Biologist, U.S. Fish and Wildlife Service, GS-13))1966-76), Oklahoma Cooperative Fishery Research Unit, Oklahoma State University
Assistant Professor (1964-66), Department of Zoology, Kansas State University

SCIENTIFIC AND PROFESSIONAL ORGANIZATIONS

American Fisheries Society: Fish Culture, Fish Health (Charter member), Education (Charter member), Bioengineering, Computer User, and Fisheries Management Sections; Iowa Chapter.
American Institute of Fishery Research Biologists (Fellow)
Aquacultural Engineering Society
Fisheries Society of the British Isles
Iowa Academy of Sciences
North American Lake Management Society
World Aquaculture Society
Sigma Xi, Phi Kappa Phi, Gamma Sigma Delta

SELECTED PUBLICATIONS

Bristow, B.T., and R.C. Summerfelt. 1994. Performance of larval walleye cultured intensively in clear and turbid water. Journal of the World Aquaculture Society 25:454-464.

Yager, T.K., and R.C. Summerfelt. 1994. Effects of feeding frequency on metabolism of juvenile walleye. Aquacultural Engineering 13:257-282.

Moore, A., M.A. Prange, B.T. Bristow, and R.C. Summerfelt. 1994a. Influence of stocking densities on walleye fry viability in experimental and production tanks. Progressive Fish-Culturist 56:194-201.

Moore, A., M.A. Prange, R.C. Summerfelt, and R.P. Bushman. 1994b. Evaluation of tank shape and a surface spray for rearing larval walleye on formulated feed. Progressive Fish-Culturist 56:100-110.

Harding, L.M., and R.C. Summerfelt. 1993. Effects of fertilization and of fry stocking density on pond production of fingerling walleye. Journal of Applied Aquaculture 2 (3/4):59-79.

Hussain, M., M.A. Gabal, T. Wilson, and R.C. Summerfelt. 1993. Effect of aflatoxin-contaminated feed on morbidity and residues in walleye fish. Veterinary and Human Toxicology 35(5):396-399.

Siegwarth, G.L., and R.C. Summerfelt. 1993. Performance comparison and growth models for walleyes and walleye × sauger hybrids reared for two years in intensive culture. Progressive Fish-Culturist 56:229-235.

VITA

James R. Triplett
Department of Biology
Pittsburg State University
1701 S. Broadway
Pittsburg, KS 66762-7552

Social Security No. 499-44-6623
Phone: (316) 235-4730
FAX: (316) 235-4194

EDUCATION

B.A. Kansas State College of Pittsburg, 1966
M.S. Kansas State College of Pittsburg, 1986
Ph.D. University of Kansas, 1976

POSITIONS

Chairman and Professor (1993-present), Department of Biology, Pittsburg State University
Chairman and Associate Professor (1985-1993), Department of Biology, Pittsburg State University
Assistant Professor (1981-1985), Department of Biology, Pittsburg State University
Assistant Professor (1976-1981), Division of Fisheries and Wildlife Management, School of Natural Resources, Ohio State University
Research Assistant (1971-1976), University of Kansas
Lieutenant (1968-1971), U.S. Navy Oceanographic System, Atlantic

SCIENTIFIC AND PROFESSIONAL ORGANIZATIONS

American Fisheries Society: Fish Culture, Fisheries Educators, Water Quality, and Fisheries Management Sections
Kansas Academy of Sciences
Kansas Commercial Fish Growers
Gamma Sigma Delta

SELECTED PUBLICATIONS

Triplett, J.R., D.A. Culver, and G.B. Waterfield. 1981. An annotated bibliography on the effects of water-level manipulations on lakes and reservoirs. Ohio State University, Columbus.

Drenner, R.W., G.L. Vinyard, W.J. O'Brien, J.R. Triplett, and J. Wagner. 1980. The zooplankton community of LaCygne Lake: A cooling pond in Kansas. Southwestern Naturalist 26:243-249.

Gash, S.L., R. Gash, J.R. Triplett, R. Taffanelli, and J.C. Bass. 1972. Helminth parasites of Dry Wood Creek fishes in Bourbon and Crawford counties, Kansas. Transactions of the Kansas Academy of Science 75:245-250.

Bass, J.C., J.R. Triplett, and W.T. Waller. 1970. Fishes in the Kansas segment of the West Ford of Drywood Creek. Southwestern Naturalist 15:138-141.

Branson, B.A., J.R. Triplett, and R. Hartmann. 1969. A partial biological survey of the Spring River drainage in Kansas, Oklahoma and Missouri. Part II: the fishes. Transactions of the Kansas Academy of Science 72(4):429-472.