TILAPIA AQUACULTURE IN THE NORTH CENTRAL REGION

Chairperson: Paul B. Brown, Purdue University

Industry Advisory Council Liaison: Gene Watne, Velva, North Dakota

Extension Liaison: Donald L. Garling, Michigan State University

Funding request: $150,000

Duration: 2 years (September 1, 1998 - August 31, 2000)

Objectives:

1. Compare feeds developed through the first NCRAC-funded Tilapia project as well as the Wastes/Effluents project to standard commercial feeds in different commercial scale recirculating aquaculture systems based on growth, performance (survival, health, feed conversion), water quality, and economic impacts. To ensure the applicability of results to commercial systems, the minimum size of an experimental recirculating unit must be 18,927 L (5,000 gal) per biofilter and the minimum replicate tank size must be at least 3,785 L (1,000 gal).

2. Conduct "break-even analysis" for raising tilapia in a recirculating aquaculture system on a commercial scale with a minimum recirculating system size of 18,927 L (5,000 gal) per biofilter, capable of producing a minimum of 11,340 kg/yr (25,000 lb/yr).

Proposed Budgets:

Institution	Principal Investigator(s)	Objective(s)	Year 1	Year 2	Total
Purdue University	Paul B. Brown	1	$30,000	$30,000	$60,000
Southern Illinois University-Carbondale	Christopher C. Kohler	1	$30,000	$30,000	$60,000
Michigan State University	Donald L. Garling	1	$2,500	$2,500	$5,000
Southern Illinois University-Carbondale	Susan T. Kohler	2	$12,273	$12,727	$25,000
		TOTALS	**$74,773**	**$75,227**	**$150,000**

Non-funded Collaborators:

Facility	Collaborator(s)
Kloubec Aquaculture, Amana, Iowa	Myron Kloubec
ADM, Decatur, Illinois	Forest Sawlaw
Grayson Hills Farms, Harrisburg, Illinois	Chris Shimp
Aquaculture Consultants for the Heartland	Dan Selock

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JUSTIFICATION

Internationally, culture of the collective species and hybrids of tilapia increased 2.5 fold from 1985 to 1994 (New 1997). The increase from 2.37 × 10^6 metric tons (MT; 2.61 × 10^6 tons) to 5.99 × 10^6 MT (6.59 × 10^6 tons) moved the production of tilapia from seventh to sixth highest production among the fishes. Growth of this magnitude surpassed global increases in all forms of aquaculture over the same time period, which was 2.3 fold. Increases in consumption and production of tilapia in the United States have also been occurring at a rapid rate, including the North Central Region (NCR). However, new producers face several problems as they initiate new culture operations. Further, the focus of interest among producers in the NCR is on indoor recirculating systems, not on traditional earthen pond production systems.

Most tilapia are grown in earthen ponds in tropical regions of the world, particularly in Taiwan, Thailand, and Indonesia, and more recently in Central America (Anonymous 1995). Total sales of tilapia in the U.S. has steadily increased over the past 20 years and surpassed sales of trout in 1994; higher sales volumes were maintained in 1995. Total sales of tilapia increased 38% from 1993 to 1994 and reached 28.0 million kg (61.8 million lb). Trout sales decreased over the same time period from 24.8 million kg (54.6 million lb) to 23.6 million kg (52.1 million lb). Of the total volume of tilapia sold in the U.S., only 5.9 million kg (13.0 million lb) was raised domestically. Indeed, imports of tilapia in 1996 increased to 28.1 million kg (62.0 million lb) with a value of $43 million, surpassing total sales for the previous year (Anonymous 1997). Thus, tilapia are accepted in the marketplace and are significantly contributing to the trade deficit in edible fish consumed in the United States.

Most of the tilapia grown in the U.S. are from the western region followed by the southern, then the NCR. Total production in the NCR was 0.64 million kg (1.4 million lb) in 1994 and 1.18 million kg (2.6 million lb) in 1995; an 85% increase in one year. The majority of production in the U.S. is in indoor recirculating production systems. Because of the relatively cool climate in the NCR and the warm water requirements of tilapia, the focus of production in the NCR is necessarily indoors. Raising fish indoors in recirculating systems costs more than raising fish in traditional earthen pond production systems; thus, the final product form must be more valuable in the marketplace than fish raised in ponds. Producers in the NCR focused their marketing efforts on live, whole fish and have been receiving premium prices in several niche markets. This marketing approach facilitated increased production.

With the focus in the NCR on indoor production, improvements in tilapia raised in recirculating systems was selected as the only research objective addressed in this proposal. During the Annual Program Planning Meeting held in Indianapolis, Indiana in February 1997, the Industry Advisory Committee (IAC) of the North Central Regional Aquaculture Center (NCRAC) identified production level studies with new feeds and associated economic evaluations as the only objectives in the funding cycle that will begin in September 1998. To address these objectives, a work group coalesced in June 1997 that includes researchers from three states and three separate institutions. The requested objectives focused on tilapia raised in recirculating systems in the NCR; specifically, applications of research findings to practical settings.

Feed Evaluations (Objective 1)

Feed, regardless of species produced or production system, typically comprises 30-60% of annual variable costs in aquaculture. Thus, any decreases in feed cost can improve profitability of new or existing operations. Feed costs alone should not be the primary consideration, but feed costs per unit of weight gain or fillet gain is a better measure of true costs. This measure implies efficiency of feed utilization. For example, if one feed costs $0.55/kg ($0.25/lb) and the feed conversion ratio (FCR) is 1.8:1, then producing a hypothetical 0.45 kg (1.0 lb) fish would cost $0.99/kg ($0.45/lb) in feed costs. However, if feed costs decreased to $0.44/kg ($0.20/lb) and the same FCR was achieved, then feed cost for the hypothetical 0.45 kg (1.0 lb) fish would be $0.36, a savings of $0.20/kg ($0.09/lb) of fish produced. If both feed costs and FCR are reduced, then we have even greater savings. For example, if feed cost decreased from $0.55 to $0.44/kg ($0.25 to $0.20/lb) as described above and FCR decreased from 1.8 to 1.4, then the savings would be $0.37/kg ($0.17/lb) of fish produced. These values may not seem that dramatic, but if they are applied to an operation producing 226,800 kg (500,000 lb) annually, the first example results in a savings or increased profit of $45,000/yr, while the second example provides an increase in returns of $85,000. Given the fact that feed costs are a major annual variable cost, it is logical to place emphasis on that component as a means of increasing efficiency of production and maximizing profits. Decreased feed costs and improved FCR leads to real returns on investment in developing aquaculture industries.

Several tilapia feed formulations are available within the NCR, however, there is no consensus regarding the best one for recirculating systems. Most producers use feeds that are locally available, of generally high quality, and reasonably priced. However, there have been intensive efforts in new dietary formulations and use of locally available feed ingredients in recent years (see **RELATED CURRENT AND PREVIOUS WORK**).

Most tilapia in the U.S. and NCR are raised in recirculating systems. Feeds are intimately tied to the long-term success of recirculating systems. First, excess ingestion of amino acids leads to increased excretion of ammonia that must be oxidized by the bacteria present in the biological filter. This is a recognized oxygen demand on the system. Secondly, solid waste, that portion of the feed that is not retained by the fish and fecal matter, must be trapped and removed prior to entering the biological filter. These two requirements of a recirculating system are often overlooked and rarely receive intense research effort. Crude protein in excess of the animal's requirement or improperly balanced in essential amino acids leads to excess excretion of ammonia from the gill and multiple forms of nitrogen in the feces (Kaushik and Cowey 1991). Nitrogen in the feces can be converted to the typical ammonia-nitrite-nitrate cycle present in recirculating systems by the bacteria present (Liao and Mayo 1974). However, this taxes the system. Thus, dietary formulation must consider maximizing dry matter digestibility to minimize waste in the system and maximizing retention of essential amino acids to decrease ammonia excretion. These factors help maximize profits. Further, most nutritional studies have been conducted in small-scale research systems. Densities are generally low and water quality is maintained at or near optimal for the target species. These conditions, while scientifically appropriate, do not reflect commercial situations in which densities are higher and resulting water quality is less than desirable. There are few data indicating the appropriateness of extrapolating research results from highly controlled research studies to commercial production situations. Those studies that have attempted to be commercially relevant have been focused on macronutrients, such as crude protein, and a logical pattern emerged.

The minimal dietary crude protein concentration for tilapia varies with production system, age, and numerous other factors. Current production systems can be viewed as a continuum, starting with earthen culture ponds, then cages, then raceways and indoor recirculating systems. Feeds for tilapia reared in earthen culture ponds often contain lower levels of crude protein than feeds fed to fish reared in cages, with higher protein needs for fish reared in tank culture. Fish raised in outdoor settings can have significant sources of available food in the normal pond biota. The amount is usually greater in ponds than in cages because of the obvious limitation of space and access to natural pond biota. In tank culture, feeds must be more nutritionally complete due to the lack of other food items. As an example of this continuum, current estimates of the minimal level of crude protein that supports maximum weight gain in tilapia raised in ponds can be as low as 20-25%, while the minimum for cage culture is approximately 28%. The optimal crude protein concentration for tilapia raised in tanks is thought to be closer to 30-35% (Luquet 1991). Most of the estimates developed did not balance essential amino acid concentrations to meet the recently established requirements (Santiago and Lovell 1988).

To maximize efficiency, animals should be fed a diet that provides all required nutrients in adequate amounts. Ingredients used to formulate the diet should be low cost, yet high quality. In diets fed to fish, one of the typical goals is to reduce the concentration of fish meal in diets for the target species by incorporating high-quality feedstuffs of plant origin. This has been accomplished with tilapia (Wu et al. 1994, 1995a,b,c; Twibell and Brown 1998). Diets containing no fish meal have been developed and are fed in commercial settings in this region. However, those diets represent only preliminary attempts and the critical factors listed above have only been evaluated in laboratory settings. Similarly, fecal pellet stability is a critical factor in recirculating systems. Waste material must be removed from the system before it enters the biological filter.

Fiber is generally considered to have no functional value in fish feeds except possibly to control rate of movement through the digestive tract (Lovell 1989). Fiber is a generic term that refers to all indigestible plant matter such as cellulose, lignins, and other complex carbohydrates. Fish diets are usually formulated so as to avoid excessive levels of fiber because high fiber serves to inhibit feed intake, increase fecal waste production, and, consequently, pollute the culture water (NRC 1993). However, the use of high fiber content (>5%) in fish diets as a means to increase fecal stability in water to facilitate mechanical removal in intensive rearing systems is being examined in an existing NCRAC Tilapia project.

A common strategy in the pet food industry is to formulate diets high in certain fiber sources to produce firm stools (D. Hughes, Feed Division, Farmland Industries, Inc., Kansas City, Missouri, personal communication). These diets are formulated with high quality protein sources with the added fiber being offset by reduction in carbohydrates. Fat is added as needed to retain sufficient caloric content. Beet pulp is a fiber source commonly used in diets for dogs that has an effective complement of viscous and nonviscous structural carbohydrates (Fahey et al. 1990). Dried beet pulp is the dried residue from sugar beets, which have been cleaned and freed from crowns, leaves, and sand, and then extracted to manufacture sugar. To our knowledge, it has not been used in commercial fish diets. Beet pulp is currently in stable supply and available at a reasonably low price ($0.09-0.16/kg; $85-$150/ton). It would likely provide some limited nutritional benefits by virtue of being about 8% crude protein and 0.5% lipid. Some non-structural carbohydrates are likely present, but most would be expected to be lost from the sugar extraction process. Beet pulp is considered essentially fiber for formulation purposes. Its relatively low cost and potential for some boost in nutrient levels offers clear advantages to more inert sources of fiber such as cellulose, agar, carrageenan, guar gum, etc. There is clearly a need to examine the utility of beet pulp in practical fish diets on a commercial scale to determine if fecal water stability can be improved without significant loss in fish growth.

In addition to nutritional manipulations to alter physical properties of feces, other strategies can be taken to reduce the major elemental components of the feces, namely nitrogen and phosphorus. An extract of the *Yucca shidigera* plant has shown promise in the control of ammonia with various terrestrial livestock animals. It is not known if the reduction is due to urease inhibition, increased use of ammonia (Jacques and Bastien 1989), or direct binding of ammonia (Headon and Dawson 1990). The utility of using this extract for fish needs further examination (see **RELATED CURRENT AND PREVIOUS WORK**). Previous studies (Tidwell et al. 1992; Kelly and Kohler, Southern Illinois University-Carbondale, unpublished data) utilized channel catfish and two different commercial sources of *Y. shidigera* extract. These extracts can contain at least three steroid saponins (Kaneda et al. 1987), but the exact extraction procedures utilized by different companies conceivably can result in significantly different levels of active compounds in the end products. Specifically, it appears that the saponin component of the extract can be removed without eliminating its ammonia reduction capabilities (D.R. Headon, University College, Galway, Ireland, personal communication to Tidwell et al. 1992). Accordingly, the extract used in the Kelly and Kohler study may prove highly useful in reducing nitrogen content in tilapia feces. Moreover, the long intestinal tract of tilapia compared to channel catfish may be more conducive for nitrogen reduction. The studies described above have only been conducted on a laboratory scale, not on a production scale.

There has been increasing concern about the usefulness of studies conducted in small scale laboratory systems. Specifically, members of the IAC question how well laboratory data extrapolate to large-scale production systems. A component of this project will be a comparison of laboratory and production studies that will provide important information for future data sets.

The other major factor identified by the IAC was economics of tilapia production in recirculating systems. Given the scope of laboratory studies on feeds, and application of those findings in this project, economic evaluations seems a complementary objective.

Economic Evaluations (Objective 2)

The number of individuals exploring aquaculture as a business continues to grow. However, an alarming number of aquaculture business failures are accompanying this increase in aquaculture production (Jolly and Clonts 1993). Increased emphasis on farm management is needed to reduce this failure rate. Farm management involves both planning and operation; a business is likely to fail if planning decisions, particularly economic decisions, are overlooked (Jolly and Clonts 1993). For an aquaculture business to be successful, information on economic conditions and constraints is as important as research on scientific and technological advances. To remain in business, an aquaculture enterprise must be profitable, i.e., revenues must exceed costs over the relevant time period. A break-even analysis, which analyzes all production costs and potential revenues, determines the minimum cost per unit of production to cover all expenses. Many factors affect profitability. Producers need to know which factors affect profitability the most and what measures can be taken to reduce costs or increase revenues.

RELATED CURRENT AND PREVIOUS WORK

Feed Evaluations (Objective 1)

Nutritional research with various species and hybrids of tilapia has been conducted for many years (Luquet 1991; Lim 1989; NRC 1993). Indeed, tilapia nutrition should be considered similar to catfish and trout in that a great deal is known about their nutritional needs and ability to utilize various feedstuffs. However, the majority of those studies have been conducted with juvenile fish, usually with an initial weight of 1-10 g (0.035-0.352 oz). There are limited evaluations of optimal grow-out diets for tilapia raised in recirculating systems.

In the most recent tilapia project funded by NCRAC, researchers at Purdue University (Purdue) determined that tilapia with an initial weight of 20 g (0.705 oz), which is the beginning of the grow-out cycle for many producers in the NCR, grew maximally when fed an all-plant diet containing 28% crude protein (Twibell and Brown 1998). However, that study was conducted in small aquaria and has not been tested in large production tanks. A subsequent study designed to quantify the optimal protein to energy ratio in tilapia fed all-plant diets is underway at Purdue, but also on a laboratory scale. Results from that study, and others funded by private companies, will serve as the basis for these evaluations.

Work completed at Michigan State University (MSU) as part of the current Tilapia project has shown that tilapia fed to satiation three times per day increases feed utilization compared to feeding to satiation five times per day. Preliminary results from studies of gastric evacuation rates have shown that in tilapia fed five times per day, feed remains in the stomach from first feeding while feed from later feedings bypass the sac-like extension of the gastrointestinal tract. Again, these studies have been conducted on a laboratory scale.

Work is in progress to determine if phytase treatment of soy products improves utilization when incorporated into feeds for tilapia. Work with salmonids has shown that phytase treated soy products increased protein utilization (Cain and Garling 1995).

An approach being studied by the current NCRAC Aquaculture Wastes and Effluents Work Group is the addition of fiber to the diet to influence fecal durability in water and permit easier removal. Fiber has received relatively little attention in fish nutrition studies. It is generally believed to be of little benefit to fish and may at high levels depress growth and lead to fouling of water. Buhler and Halver (1961) observed depressed growth rates in chinook salmon (*Oncorhyncus tschawytscha*) reared on diets with increasing levels of α-cellulose. Conversely, Dupree and Sneed (1966) found that channel catfish (*Ictalurus punctatus*) exhibited improved growth rates when fed purified diets with 21% cellulose. The fiber may have slowed the rate of the purified ingredients passing through the digestive tract, thus allowing for improved digestion and growth. However, Leary and Lovell (1975) observed growth depression in channel catfish fed practical diets with 8% or more of cellulose. Likewise, Hilton et al. (1983) showed that rainbow trout (*Oncorhynchus mykiss*) had decreased growth when 10 and 20% α-cellulose was incorporated in a practical diet. Similar results were found for Nile tilapia (*Oreochromis niloticus*) as α-cellulose was increased from 0 to 40% in semi-purified diets (Anderson et al. 1984). Shiau and Kwok (1989) followed up on this study by examining various fiber sources (cellulose, agar, carrageenan, guar gum, carboxymethylcellulose) in diets of hybrid tilapia (*O. niloticus* × *O. mossambicus*). Their results were consistent with those of Anderson et al. (1984), but the degree of decrease in weight gain percentage and feed conversion ratio were not the same among the different fiber sources. Moreover, the diets were not isocaloric. Shiau and Kwok (1989) used glucose as a control, while Anderson et al. (1984) used various non-structural carbohydrate sources (glucose, sucrose, and starch). Alternatively, Hilton et al. (1983) and Leary and Lovell (1975) utilized basal diets, which were then diluted with cellulose. The quantity of nutrients was held constant by assigning proportionally higher feed allowances in relation to fiber content.

An extract of the *Yucca shidigera* plant has been used successfully to control ammonia accumulation with various livestock animals (Berg 1977; Rowland et al. 1979; Jacques and Bastien 1989). It also appears to improve growth when incorporated into feeds for poultry (Johnston et al. 1981, 1982), swine (Foster 1983; Cromwell et al. 1985; Mader and Brumm 1987), and cattle (Goodall and Matsushima 1980). However, Tidwell et al. (1992) found that although *Y. shidigera* may have value as a preconditioning agent for water recirculating systems, it decreased growth rates of juvenile channel catfish when used as a feed additive. That study utilized a powdered extract commercially sold under the trade name De-Oderase (Alltech Biotechnology

Center, Nicholasville, Kentucky). Studies conducted at Southern Illinois University-Carbondale (SIUC) with a *Y. shidigera* extract sold under the commercial name Micro-Aid (Distributors Processing Inc., Porterville, California) were more positive (SIUC, unpublished data). While juvenile channel catfish (9.0±1.0 g [0.317±0.035 oz] mean initial weight) fed 0.5 and 1.0 g Micro-Aid/kg feed (0.008 and 0.016 oz/lb) did not grow significantly different than controls, channel catfish fry (0.2±0.1 g [0.007±0.003 oz] initial mean weight) fed 1.0 g Micro-Aid/kg (0.016 oz/lb) feed grew significantly faster than controls and the 0.5 g Micro-Aid/kg (0.008 oz/lb) feed treatment. Moreover, nitrogen content of feces from channel catfish fed 1.0 g Micro-Aid/kg (0.016 oz/lb) feed was significantly lower, possibly indicating improved protein digestion/utilization. No adverse effects in feeding or growth were noted when catfish were fed up to 5 g Micro-Aid/kg (0.008 oz/lb) feed. It appears that Micro-Aid is a *Y. shidigera* product that offers considerably more potential for use in aquaculture than De-Oderase. Preliminary laboratory studies are in progress.

Economic Evaluations (Objective 2)

Recycle systems in general are new technology; thus, there are few economic data from production-scale recirculating systems (Engle 1997). Further, economic analyses based on hypothetical fish production systems do not project risks (Engle 1997). Researchers at Illinois State University (O'Rourke and Tudor Undated) provided costs of production and revenue estimates for fish produced in a hypothetical recirculating aquaculture system utilizing RISK software. RISK allows for relatively easy analysis of investments when sources of uncertainty are multiple. No specific species were analyzed and certain assumptions were made on fixed and variable costs. The authors recommended this type of analysis prior to investing in a commercial recirculating aquaculture system. Losordo and Westerman (1994) estimated the cost of producing 0.45 kg (1.0 lb) of tilapia to be $1.27. Edon (1994) completed a Master's thesis on the economic viability of advanced walleye production in intensive recirculating systems. A computer model was generated integrating input and investment costs collected from surveys and the literature to estimate the expected economic viability. Results indicated economic feasibility, particularly in conjunction with improved rearing techniques.

The economics of catfish production in earthen ponds in the southern United States have been thoroughly evaluated (Waldrop and Dillard 1985; Dellenbarger and Vandeveer 1986; Pomeroy et al. 1987; Nerrie et al. 1990). However, production of catfish is an established industry. If we examine economic evaluations of newer aquaculture species, we find much of the early data focused on hypothetical situations. For example, much of the costs of production and break-even analysis for hybrid striped bass are based on cost estimates as opposed to real production costs (Brown et al. 1988; Strand and Lipton 1989; Gempesaw et al. 1993). Hodson and Jarvis (1990) obtained commercial data from a commercial hybrid striped bass farm in North Carolina. Break-even price for second year production was $2.13. There is a paucity of information available on production costs for tilapia, particularly in indoor recirculating systems. Bailey and Rakocy (1992) reported a high rate of return (259%) for tilapia raised in freshwater cages in the U.S. Virgin Islands.

ANTICIPATED BENEFITS

Producers throughout the NCR are raising tilapia, and a significant amount of research has occurred in the past four years. However, those data have not been applied in practical settings. Diets fed to tilapia are most often modified catfish diets, but are generally more expensive than feeds for catfish in the southern United States. The goal of research programs in the NCR has been development of diets for tilapia that meet the following criteria: use ingredients from the NCR, focus on grow out instead of earlier life history stages, minimize ammonia excretion, and minimize fecal waste. Many of those studies have been completed or are underway and will be applied on a practical scale in these studies. Thus, the benefits of this line of research are continued improvement of diets fed to tilapia in recirculating systems and continued development of all-plant diets that can be easily manufactured in this region, with a continued commitment to product quality for the consumer. Additionally, an extension document will be developed on feed and feed management for tilapia raised in recirculating systems. Extension documents on nutrition are rare.

The use of a pet food nutrition strategy whereby diets are designed to produce firmer stools offers promise for waste management in aquaculture. Removal of feces from the water rather than actual fecal volume is the primary waste management problem in intensive rearing systems. The use of beet pulp in fish diets may significantly and economically improve fecal pellet stability allowing for more efficient mechanical removal. Stickney (1994) cautions that when fish are fed a diet high in fiber, even when fed on an *ad libitum* basis, they may not obtain sufficient food in a day to meet their protein or energy requirements. Apparently no studies have been conducted with fish whereby fiber replaced carbohydrates and fat was increased to retain an isocaloric diet.

We also anticipate development of a comparative data set indicating the degree of difference between laboratory and production-level studies. Studies conducted in smaller scale laboratory settings are typically less expensive than larger scale production evaluations, yet the results may or may not directly transfer to production scale. Development of a "fudge factor" for feeding tilapia in large-scale production systems will be a useful value for future lines of research.

This project will include a comprehensive analysis of the costs involved in commercially raising tilapia in an indoor recirculating system. These figures can then be compared with expectations about market prices to determine if the commercial production of tilapia in indoor recirculating systems is economically viable.

PROGRESS TO DATE

Research on feed evaluations has been funded by a variety of sources including NCRAC, USDA National Center for Agriculture Utilization Research, and several private companies. To date a number of feedstuffs have been evaluated in tilapia raised in recirculating systems (Wu et al. 1994, 1995a,b,c, 1996a,b, 1997; Twibell and Brown 1998) with the goal of developing an all-plant grow-out diet for use in the NCR. Feedstuffs evaluated to date include a variety of processed co-products and distillers grains. Further, the optimal dietary crude protein was established for tilapia of initial weight of 20 g (0.705 oz), which is the beginning of the grow-out phase of production in the NCR. A subsequent study is underway evaluating the optimal protein to non-protein energy ratio in tilapia fed all-plant diets. This study also is focused on the grow-out phase of production.

To date, procedures have been developed at SIUC for comparing fecal stability of various semi-purified diets containing beet pulp. Improvements in fecal stability have been observed. Long-term production trials are in progress.

OBJECTIVES

1. Compare feeds developed through the first NCRAC-funded tilapia project as well as the Wastes/Effluents project to standard commercial feeds in different commercial scale recirculating aquaculture systems based on growth, performance (survival, health, feed conversion), water quality, and economic impacts. To ensure the applicability of results to commercial systems, the minimum size of an experimental recirculating unit must be 18,927 L (5,000 gal) per biofilter and the minimum replicate tank size must be at least 3,785 L (1,000 gal).

2. Conduct "break-even analysis" for raising tilapia in a recirculating aquaculture system on a commercial scale with a minimum recirculating system size of 18,927 L (5,000 gal) per biofilter, capable of producing a minimum of 11,340 kg/yr (25,000 lb/yr).

PROCEDURES

Feed Evaluations (Objective 1)

Purdue

The project at Purdue will be under the direction of Paul Brown and focus on the best diets from a series of evaluations already completed or currently underway. The best dietary formulae from those studies will be provided to commercial producers of feeds and cost estimates obtained. It is anticipated that Purina Mills, Zeigler Brothers, Inc., Sterling H. Nelson and Sons, Inc., Rangen, Inc., and several local feed mills in the NCR will be contacted. In addition to the estimates for cost, delivery rates will be ascertained for the two experimental sites. Once these data are generated, feed will be purchased and shipped directly to the two collaborators.

Both ADM, Decatur, Illinois, and Kloubec Aquaculture, Amana, Iowa, agreed to serve as experimental sites for these evaluations. Both have different desires for fish feeds, thus the formulae developed for each will be different. The approach desired by ADM is use of ingredients readily available from other operations within the parent company. These are also the common feedstuffs available within the NCR as ADM is one of the dominant buyers of grain and oil crops, and suppliers of products from those raw commodities. The approach desired by Kloubec Aquaculture is use of readily available waste products available in their local area. Both approaches will result in useful information for all segments of tilapia production in the NCR, as a number of formulae will be developed and tested in each of the two years of this project on a production scale. Together, the approach of using readily available ingredients plus new waste products from other agricultural operations will provide the maximum amount of information in the shortest time period.

In the first year of the project, specific formulae will be developed with the input of Don Garling, MSU, and provided to the feed mill that indicated lowest cost of feed plus delivery. One experimental feed will be developed in each of the two years of this project and compared to a commercially available diet already in use at the respective facilities. All diets will be extruded. Diets evaluated in the second year will be modifications of those evaluated in the first year. The second set of diets will be modified based on results from the production trials as well as continuing studies in the laboratories at Purdue, MSU and SIUC. The diets are obviously difficult to formulate now as a number of evaluations will occur prior to initiation of this project in September 1998. However, the basal ingredients that have demonstrated the most promise include corn gluten feed and meal, soybean meal, distillers grains, and processed wheat products. The xanophyl concentrations in processed corn co-products can cause yellow pigmentation in the fillets of some species of fish, but has not been a demonstrated problem in tilapia fed all-plant diets containing levels of corn gluten meal as high as 45%.

All diets in each year will be fed to triplicate groups of fish in 37,850-L (10,000-gal) culture tanks at ADM, and duplicate tanks of the same size at Kloubec Aquaculture. Both facilities maintain water temperatures of 26-28°C (78.8-82.4°F) and photoperiods of 14-h light/10-h dark. Fish and dietary treatments will be randomly assigned to tanks. Configurations of settling chambers and biological filters at each facility are proprietary, but each has been in production for over three years. Personnel on site will be responsible for feeding fish. Purdue personnel will visit each site weekly during the experimental period for coordination of activities, supplemental sampling of water quality, and coordination of feed acquisition.

At the beginning of each study, fish will be counted and a representative sample weighed. A sample of fish will be collected at the beginning of each study for determination of whole-body and fillet nutritional composition. Stocking densities will be those determined appropriate for the respective systems. Those studies are underway at both facilities. All fish in each facility will be fed at least daily to satiation, beginning immediately after initial stocking. This will allow determination of how rapidly new feeds are accepted in practical settings. Feed frequencies will be the same across dietary treatments. Total consumption of feed and water quality values will be monitored daily. Water quality values will include dissolved oxygen (DO), temperature, pH, ammonia, nitrite, and nitrate. If possible, water quality variables will be monitored hourly during each week. However, this will be a function of available personnel at each site.

At the end of the study, estimated to be minimally 12 weeks, but as long as 16 weeks, final numbers of fish will be determined and final weights will be recorded from a representative sample. Purdue has had success sampling 10% of a population from culture tanks and accurately extrapolating those data to 300 fish, but anticipate sampling closer to 30-50% of the fish from the respective replicates. A sample of fish will be collected for further analyses at the end of the feeding period. Fillet percentages and nutritional composition of fillets will be determined at the end of the feeding study from each replicate. Nutritional composition will be determined by standard AOAC methods (AOAC 1990). Survival, weight gain, FCR, proximate composition, protein efficiency ratio, and protein retention will be calculated and subjected to one-way analysis of variance (ANOVA) using each site as an independent data set. If significant differences are detected, Student-Neuman-Keuls test will be used to separate mean values. Accepted level of significance will be $\alpha \leq 0.05$.

A complementary laboratory study will also be conducted using the same fish and diets. Fish will be acquired from the collaborators and transported to the Purdue University Aquaculture Research Facility, where they will be quarantined prior to experimentation. Fish will be randomly stocked into 120-L (31.7-gal) glass aquaria and dietary treatments will be randomly assigned to triplicate groups of fish. Water temperature and photoperiod will be the same as the collaborators'.

A ten week feeding study will be conducted during the same time as the larger scale feeding study is underway at the production facilities. Fish will be sampled before and after the study and the same data collected as described above. This comparison will provide an indication of the degree of difference between studies conducted in laboratory settings. This portion of the project will be statistically evaluated as a nested analysis of variance. Accepted level of significance will be $\alpha \leq 0.05$.

SIUC

Research at SIUC will be under the direction of Chris Kohler and will focus on fecal characteristics resulting from three 32% crude protein practical feeds designed for channel catfish, but suitable for tilapia (Farmland Industries, Inc., Kansas City, Missouri). The feeds will contain 0, 10, and 20% beet pulp, respectively. Each experiment will be conducted independently in triplicate. As a preliminary study, three 110-L (29.1-gal) glass aquaria will be used, each with a water flow rate of 1.2 L/min (0.3 gal/min) in a recirculating water system with charcoal-filtered municipal water. Water quality variables, particularly temperature, DO, pH, and ammonia will be closely monitored and maintained at appropriate and comparable levels for each experiment and during holding periods. Each aquarium will be stocked with ten juvenile Nile tilapia (about 25 g [0.882 oz] mean weight), and will contain a plexiglass feces collector of sloping walls (Ayala et al. 1993). With the feces collector in place, aquaria will be divided into two chambers: a feeding compartment (about one-third of the aquarium volume) and a fecal collector compartment. A removable screen will separate the two chambers.

For each fish feed/species experiment, fish will be fed the test diet for one week before fecal collections begin. Fish will be fed 3% of their wet body weights once each morning. Prior to feeding, the screen separating the two chambers will be removed and fish will manually be coaxed to swim to the feeding chamber, whereupon the screen will be reset. Feed residue will be siphoned out after each feeding session. Subsequently, the screen will be removed, the fish will be forced to return to the chamber containing the feces collector, after which the screen will be reset. Feces will be collected once each afternoon from a removable plexiglass box at the bottom of the collector.

The following procedures will be used for measuring fecal durability. Feces from each replicate will be placed into a labeled petri dish and left uncovered in a refrigerator at 1-3°C (33.8-37.4°F) for a 24-h drying period. Cold, semi-dry feces from each replicate will be weighed to the nearest 0.01 g (0.0004 oz). A 1.0±0.05 g (0.035±0.018 oz) subsample from each replicate will be placed into a labeled, 250 mL (8.5 oz) Erlenmeyer flask with 100 mL (3.4 oz) of distilled water. The flasks will be continuously agitated on a Lab-Line type orbital shaker set to 500 RPM, and individually timed in seconds until the pellets disintegrate into individual particles. Time-to-disintegration will serve as the measure of relative fecal stability among treatment groups.

A 32% protein commercial catfish feed (Farmland Industries, Inc., Kansas City, Missouri) will be used as the base diet to determine the efficacy of *Yucca shidigera* extract (Micro-Aid, Distributors Processing Inc., Porterville, California) to reduce N in feces and enhance overall growth performance of Nile tilapia. Treatments of 0, 1.0, and 2.0 g Micro-Aid/kg (0, 0.016, and 0.032 oz/lb) feed will be prepared by mixing the prescribed amounts of dried extract in agar and then coating the feed. Production trials will be conducted in triplicate. Photoperiod (14-h light/10-h dark) will be held constant. Fish will be stocked two weeks prior to trials and fed daily the control diet at a rate of 3% wet body weight, equally divided into two meals (early morning/late afternoon). Treatments will be randomly assigned to triplicate tanks. The same rationing and feeding schedule will be maintained. Samples of fish will be weighed every two weeks and feed rations adjusted accordingly using treatment means. Major water quality parameters (temperature, DO, pH, total ammonia, carbon dioxide, alkalinity, and hardness) will be monitored on a regular basis using standard aquaculture procedures (Hach kits, DO meter, etc.). Specific growth rate (SGR), FCR, protein efficiency ratio (PER), and condition (K) will be determined bi-weekly as follows:

$$SGR = 100 \, [\ln \text{ final live weight (g)} - \ln \text{ initial live weight (g)}]/\text{time (d)}$$

FCR = feed offered (g)/live weight gain (g)
PER = live weight gain (g)/protein offered (g)
K = live weight (g)/length^3 (cm)

At termination of each study (ten weeks), ten fish from each treatment will randomly be selected, taken off feed for a 24-h period, and then frozen pending whole body proximate analysis. Percent moisture, fat, and ash will be determined using standard methods (AOAC 1990). Crude protein will be determined using Hach's modification of the AOAC (1990) standards (Watkins et al. 1987). Fecal samples will be collected from fish receiving each feed treatment to determine relative amounts of N. Each treatment will be tested independently in triplicate. Feces will be collected once each afternoon from a removable plexiglass box at the bottom of the collector. Feces from each replicate will be placed into a labeled petri dish and left uncovered in a refrigerator at 1-3°C (33.8-37.4°F) for a 24-h drying period. Samples of feces will subsequently be dried in a vacuum oven at 95°C (203.0°F) for 5 h and cooled in a desiccator. Feces will be analyzed for N content utilizing Hach's modification of the AOAC (1990) standards (Watkins et al. 1987).

The major emphasis of this study will be to examine the efficacy of fiber (beet pulp) and *Yucca* extract as dietary components to enhance solids removal and reduce fecal nitrogen, respectively, in a commercial setting. Nine 9,085-L (2,400-gal) rectangular tanks will be used in this study. The commercial system will be located at Grayson Hill Farms in Harrisburg, Illinois, about 50 miles east of Carbondale (see **FACILITIES** for description). The exact percentage incorporation of beet pulp and *Yucca* extract to be tested will be based on ongoing trials using semi-purified diets, as well as preliminary laboratory trials using practical diets as described for laboratory studies above.

In Year 1, beet pulp and *Yucca* extract will be independently compared to a control diet (32% crude protein) as described for laboratory studies. The treatments will be triplicated such that in each battery of three tanks, one tank will receive the beet pulp diet, one the *Yucca* extract diet, and one the control diet. Treatments will be randomly assigned within each battery. Each of the three batteries of three tanks will have separate biofilter and rotating-screen filters. All tanks will be stocked with 3,500 fingerling Nile tilapia. Water will be maintained at 28°C (82.4°F). Pure oxygen will be injected, as needed, to maintain DO levels above 5 mg/L. Sodium bicarbonate will be applied to maintain pH near neutrality. Fish will be fed from 3 to 6% of their wet body weight in four to five feedings/day. Fish will be reared to market size (500-600 g; 1.1-1.3 lb). Data on growth rates, feed conversions, water quality, etc., will be collected as described for laboratory studies. The efficiency of solids removal will be assessed based on clarity of water as measured by a turbidity meter. The effect of reduction of nitrogen in feces will be assessed by a detailed analysis of water ammonia, nitrite, and nitrate. The null hypothesis will be that water quality is not affected by feed type. In Year 2 of the study, beet pulp and *Yucca* extract will be combined in the same diet and compared to a control in similar fashion as studies were described for Year 1. Studies conducted in both years will be statistically analyzed as a one-way analysis of variance with $\alpha \leq 0.05$. An attempt will be made to simultaneously conduct the commercial scale and laboratory scale studies so that results can be compared.

Commercial-Scale Study

The major emphasis of this study will be to examine the efficacy of fiber (beet pulp) and *Yucca* extract as dietary components to enhance solids removal and reduce fecal nitrogen, respectively, in a commercial setting. Four 75,708-L (20,000-gal) circular tanks, each attached to a separate packed-column biofilter and rotating screen solids separator, will be used in the study. The commercial system will be located at Grayson Hill Farms in Harrisburg, Illinois, about 50 miles east of Carbondale (see **FACILITIES** for description). The exact percentage incorporation of beet pulp and *Yucca* extract to be tested will be based on ongoing trials using semi-purified diets, as well as preliminary laboratory trials using practical diets as described for laboratory studies above.

In Year 1, the best beet pulp diet based on laboratory studies will be compared to a control diet (32% crude protein). Treatments will be duplicated. Treatments will be randomly assigned to tanks. Each tank will be stocked with 15,000 fingerling Nile tilapia. Water will be maintained at 28±1°C (82.4±1.8°F). Pure oxygen will be injected, as needed, to maintain dissolved oxygen levels above 5 mg/L (ppm). Sodium bicarbonate will be applied to maintain pH near neutrality. Fish will be fed from 3 to 6% of their wet body weight in three to five feedings/day. Fish will be reared to market size (500-600 g; 1.1-1.3 lb)). Data on growth rates, feed conversions, water quality, etc., will be collected as described for laboratory studies. The efficiency of solids removal will be assessed based on clarity of water as measured by a turbidity meter and by a mechanical collection using standard sieves held at the outflow of each tank prior to solids removal and at the inflow after solids removal and biofiltration. These collections will be taken at the same times and for the same duration in each tank once weekly. Suspended solids collected in sieves will be dried and weighed to the nearest 0.1 mg. In Year 2 of the study, the best *Yucca* extract diet will be compared to a control in similar fashion as studies were described for Year 1. The effect of reduction of nitrogen in feces will be assessed by a detailed analysis of ammonia, nitrite, and nitrate in the water. Studies conducted in both years will be statistically analyzed as a one-way ANOVA with $\alpha \leq 0.05$. The null hypothesis will be that water quality is not affected by feed type. An attempt will be made to simultaneously conduct the commercial scale and laboratory scale studies so that results can be compared.

MSU

Research at MSU will be under the direction of Don Garling who will assist in diet development and feed management for the project, as he has been intimately involved in previous tilapia projects funded by a number of sources. He will also prepare an extension publication on new feed for tilapia raised in the NCR and management of feed inputs into recirculating systems.

Economic Evaluations (Objective 2)

SIUC

Break-even analyses will be under the direction of Sue Kohler and conducted with tilapia raised in two indoor recirculating aquaculture systems. As requested by the NCRAC IAC, these data will be based on real numbers collected on systems producing tilapia at a commercial scale. Researchers will work with the proprietors of two operations to collect actual cost and production figures. The analyses will not be based on averages collected from models, projections or survey results. The system from which data will be collected is Grayson Hill Farms, Harrisburg, Illinois (see **FACILITIES** for descriptions). Actual figures for capital, fixed, and variable costs will be collected. These figures will be used to calculate the break-even analysis. Break-even analysis determines the minimum cost per pound that all fish must be sold for to cover all costs (Jolly and Clonts 1993). Break-even analysis also illustrates how production costs are allocated between fixed and operating costs. Additionally, sensitivity analysis will be conducted using the five-step process described by Riepe et al. (1992).

FACILITIES

Purdue

Facilities at each of the Purdue collaborators include the necessary 37,850-L (10,000 gal) culture tanks equipped with biological filtration and solids filters. Trained personnel are available at each site including graduates of the undergraduate program in aquaculture at Purdue. Both facilities are commercial operations that have been in operation for a minimum of three years. A complete nutritional laboratory is available at Purdue for completing proximate analyses of tissues from fish raised at each facility. Further, six experimental systems (24-48 tanks per system) are on site and functional. All systems can be operated as either flow-through or recirculating and all have temperature control and supplemental aeration.

SIUC (C. Kohler)

Over 150 glass aquaria with volumes ranging from 38-209 L (10-55 gal) are maintained by the SIUC Fisheries Research Laboratory. Most of these are located in the University Vivarium, a National Institute of Health-approved animal housing facility under the direction of a veterinarian. Most aquaria are arranged in batteries with attachments to biofilters. The systems are highly flexible in terms of numbers that can be attached to a given biofilter. Several large indoor water recycle systems are also available at the University Wetlab. These systems will be used for housing fish prior to initiation of laboratory trials. All necessary equipment for measuring and maintaining water quality, measuring and weighing fish, preparation of feed, and conducting proximate analyses are available. A Lab-Line orbital shaker and all necessary glassware for conducting fecal studies are available.

Grayson Hill Farms, Harrisburg, Illinois, is one of the largest producers of hydroponically-grown tomatoes in the United States. They are currently diversifying their operation to include raising fish, specifically tilapia. The overall facility will contain approximately 378,540-L (100,000 gal) of water. The system will have four 75,708-L (20,000-gal) grow-out tanks. Each tank will be attached to a separate packed-column biofilter and a rotating Hydrotech drum solids separator. Each battery will be identical so that a treatment and control group can be compared in duplicate. The system will be situated inside a heated insulated pole barn located at the main farm complex. Components such as protein skimmers, oxygen supersaturation injection devices, water heaters, alarms system, etc., will be incorporated.

SIUC (S. Kohler)

SIUC is equipped with up-to-date computers and financial software. A Small Business Development Center is also available to assist staff. No special facilities are needed to complete this objective.

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PROJECT LEADERS

State	Name/Institution	Area of Specialization
Illinois	Christopher C. Kohler Southern Illinois University-Carbondale	Aquaculture
Illinois	Susan T. Kohler Southern Illinois University-Carbondale	Business and Economic Development
Indiana	Paul B. Brown Purdue University	Aquaculture/Nutrition
Michigan	Donald L. Garling Michigan State University	Aquaculture/Nutrition/Extension

PARTICIPATING INSTITUTIONS AND PRINCIPAL INVESTIGATORS

Purdue University (Purdue)
Paul B. Brown

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

Michigan State University (MSU)
Donald L. Garling

Southern Illinois University-Carbondale (SIUC)
Susan T. Kohler

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 Research Foundation Hovde Hall West Lafayette, IN 47907-1021				**USDA AWARD NO.** Year 1: Objective 1	
PRINCIPAL INVESTIGATOR(S)/PROJECT DIRECTOR(S) Paul B. Brown				Duration Proposed Months: 12 **FUNDS REQUESTED by PROPOSER**	Duration Awarded Months: ________ **FUNDS APPROVED BY CSREES** (If Different)
A. Salaries and Wages	**CSREES FUNDED WORK MONTHS**				$
1. No. of Senior Personnel	Calendar	Academic	Summer		
a. ___ (Co)-PI(s)/PD(s)					
b. ___ Senior Associates					
2. No. of Other Personnel (Non-Faculty) a. ___ Research Associates-Postdoctorates					
b. 1 Other Professional	3			$5,700	
c. 1 Graduate Students				$12,000	
d. 1 Prebaccalaureate Students				$2,500	
e. ___ Secretarial-Clerical					
f. ___ Technical, Shop and Other					
Total Salaries and Wages . . . . →				$20,200	
B. Fringe Benefits (If charged as Direct Costs)				$3,285	
C. Total Salaries, Wages, and Fringe Benefits (A plus B) . . . . →				$23,485	
D. Nonexpendable Equipment (Attach supporting data. List items and dollar amounts for **each** item.)					
E. Materials and Supplies				$3,500	
F. Travel 1. Domestic (Including Canada)				$2,500	
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 ($150), Fax ($50), Postage ($100), Photocopying ($50), Equipment maintenance ($165)				$515	
J. Total Direct Costs (C through I) . . . . →				$30,000	
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) . . . . →				$30,000	
M. Other . . . . →					
N. Total Amount of This Request . . . . →				$30,000	$
O. Cost Sharing (If Required Provide Details)	$32,750				

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 Purdue Research Foundation Hovde Hall West Lafayette, IN 47907-1021	**USDA AWARD NO.** Year 2: Objective 1	
PRINCIPAL INVESTIGATOR(S)/PROJECT DIRECTOR(S) Paul B. Brown	Duration Proposed Months: 12 **FUNDS REQUESTED by PROPOSER**	Duration Awarded Months: ________ **FUNDS APPROVED BY CSREES** (If Different)

	CSREES FUNDED WORK MONTHS				
A. Salaries and Wages	Calendar	Academic	Summer	FUNDS REQUESTED by PROPOSER	FUNDS APPROVED BY CSREES
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	3			$6,000	
c. 1 Graduate Students				$12,400	
d. 1 Prebaccalaureate Students				$2,500	
e. ___ Secretarial-Clerical					
f. ___ Technical, Shop and Other					
Total Salaries and Wages . . . . →				$20,900	
B. Fringe Benefits (If charged as Direct Costs)				$3,395	
C. Total Salaries, Wages, and Fringe Benefits (A plus B) . . . . →				$24,295	
D. Nonexpendable Equipment (Attach supporting data. List items and dollar amounts for **each** item.)					
E. Materials and Supplies				$3,000	
F. Travel 1. Domestic (Including Canada)				$2,500	
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 ($150), Fax ($5), Postage ($50)				$205	
J. Total Direct Costs (C through I) . . . . →				$30,000	
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) . . . . →				$30,000	
M. Other . . . . →					
N. Total Amount of This Request . . . . →				$30,000	$
O. Cost Sharing (If Required Provide Details)	$32,650				

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 1

A. **Salaries and Wages.** A graduate student (0.50 FTE), technician (0.25 FTE) and one prebaccalaureate student are required for coordination of activities, and acquiring and feeding fish at Purdue. Trips to collaborators' facilities during the year demand several people who can potentially help.

B. **Fringe Benefits.** Standard fringe benefit rate is 1.13% for graduate students, 55.5% for technicians and 0.36% for prebaccalaureate students.

E. **Materials and Supplies.** These funds will be used for acquisition of feedstuffs and diet manufacturing. Additionally, these funds will be used for routine maintenance of experimental and holding systems.

F. **Travel.** These funds will be used for acquisition of feedstuffs, travel to the sites of the study, and dissemination of research results.

I. **Other Direct Costs.** Year 1: telephone ($150); fax ($50); postage ($100); photocopying ($50); and, equipment maintenance ($165). Year 2: telephone ($150); fax ($5); and, postage ($50).

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

OMB Approved 0524-0022
Expires 5/31/98

BUDGET

ORGANIZATION AND ADDRESS Board of Trustees Southern Illinois University-Carbondale Carbondale, IL 62901				**USDA AWARD NO.** Year 1: Objective 1	
PRINCIPAL INVESTIGATOR(S)/PROJECT DIRECTOR(S) Christopher C. Kohler				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				$12,000	
d. ___ Prebaccalaureate Students					
e. ___ Secretarial-Clerical					
f. ___ Technical, Shop and Other					
Total Salaries and Wages →				$12,000	
B. Fringe Benefits (If charged as Direct Costs)					
C. Total Salaries, Wages, and Fringe Benefits (A plus B) →				$12,000	
D. Nonexpendable Equipment (Attach supporting data. List items and dollar amounts for **each** item.)					
E. Materials and Supplies				$8,000	
F. Travel 1. Domestic (Including Canada)				$4,000	
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.) Telecommunications ($200), Equipment maintenance ($200), Computer costs ($100), Report preparation ($500), Graphics ($200), Fiber analysis ($500), Meeting registrations ($300), Consultant ($4,000)				$6,000	
J. Total Direct Costs (C through I) →				$30,000	
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) →				$30,000	
M. Other →					
N. Total Amount of This Request →				$30,000	$
O. Cost Sharing (If Required Provide Details)	$33,400				

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

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BUDGET

ORGANIZATION AND ADDRESS Board of Trustees Southern Illinois University-Carbondale Carbondale, IL 62901				**USDA AWARD NO.** Year 2: Objective 1	
PRINCIPAL INVESTIGATOR(S)/PROJECT DIRECTOR(S) Christopher C. Kohler				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				$12,600	
d. ___ Prebaccalaureate Students					
e. ___ Secretarial-Clerical					
f. ___ Technical, Shop and Other					
Total Salaries and Wages →				$12,600	
B. Fringe Benefits (If charged as Direct Costs)					
C. Total Salaries, Wages, and Fringe Benefits (A plus B) →				$12,600	
D. Nonexpendable Equipment (Attach supporting data. List items and dollar amounts for **each** item.)					
E. Materials and Supplies				$8,400	
F. Travel 1. Domestic (Including Canada)				$3,000	
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.) Telecommunications ($200), Equipment maintenance ($200), Computer costs ($100), Report preparation ($500), Graphics ($200), Fiber analysis ($500), Meeting registrations ($300), Consultant ($4,000)				$6,000	
J. Total Direct Costs (C through I) →				$30,000	
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) →				$30,000	
M. Other →					
N. Total Amount of This Request →				$30,000	$
O. Cost Sharing (If Required Provide Details)	$33,600				

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

(C. Kohler)

Objective 1

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

E. Materials and Supplies. Expendable supplies such as fish nets, glassware, fish feed, plumbing supplies, chemicals, etc. ($5,000 is budgeted for experimental feeds each year).

F. Travel. NCRAC meetings and professional meetings for paper presentations will require travel support. Travel from Carbondale to Harrisburg.

I. Other Direct Costs. Annual costs: telecommunications ($200); equipment maintenance ($200); computer costs ($100); report preparation ($500); graphics ($200); fiber analysis ($500); meeting registrations ($300); and, consultant ($4,000). The consultant will be Daniel A. Selock, of Aquaculture Consultants for the Heartland in Goreville, Illinois, who will provide technical assistance, assist in monitoring study protocols, and perform water quality analyses at a rate of $25.00/hour.

UNITED STATES DEPARTMENT OF AGRICULTURE
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OMB Approved 0524-0022
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BUDGET

ORGANIZATION AND ADDRESS Department of Fisheries and Wildlife Michigan State University East Lansing, MI 48824-1222				**USDA AWARD NO.** Year 1: Objective 1	
				Duration Proposed Months: 12	Duration Awarded Months: ________
PRINCIPAL INVESTIGATOR(S)/PROJECT DIRECTOR(S) Donald L. Garling				**FUNDS REQUESTED by PROPOSER**	**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. ___ Graduate Students					
d. ___ Prebaccalaureate Students					
e. ___ Secretarial-Clerical					
f. ___ Technical, Shop and Other					
Total Salaries and Wages →					
B. Fringe Benefits (If charged as Direct Costs)					
C. Total Salaries, Wages, and Fringe Benefits (A plus B) →					
D. Nonexpendable Equipment (Attach supporting data. List items and dollar amounts for **each** item.)					
E. Materials and Supplies				$833	
F. Travel 1. Domestic (Including Canada)				$1,667	
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) →				$2,500	
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) →				$2,500	
M. Other →					
N. Total Amount of This Request →				$2,500	$
O. Cost Sharing (If Required Provide Details)	$2,500				

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

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

Form CSREES-55 (6/95)

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BUDGET

ORGANIZATION AND ADDRESS
Department of Fisheries and Wildlife
Michigan State University
East Lansing, MI 48824-1222

USDA AWARD NO. Year 2: Objective 1

Duration Proposed Months: 12
Duration Awarded Months: ________

PRINCIPAL INVESTIGATOR(S)/PROJECT DIRECTOR(S)
Donald L. Garling

Item	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. ___ Graduate Students					
d. ___ Prebaccalaureate Students					
e. ___ Secretarial-Clerical					
f. ___ Technical, Shop and Other					
Total Salaries and Wages →					
B. Fringe Benefits (If charged as Direct Costs)					
C. Total Salaries, Wages, and Fringe Benefits (A plus B) →					
D. Nonexpendable Equipment (Attach supporting data. List items and dollar amounts for **each** item.)					
E. Materials and Supplies				$833	
F. Travel 1. Domestic (Including Canada)				$1,667	
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) →				$2,500	
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) →				$2,500	
M. Other →					
N. Total Amount of This Request →				$2,500	$
O. Cost Sharing (If Required Provide Details)	$2,500				

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

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

Form CSREES-55 (6/95)

BUDGET JUSTIFICATION FOR MICHIGAN STATE UNIVERSITY

(Garling)

Objective 1

E. Materials and Supplies. These funds will be used for development of fact sheets.

F. Travel. These funds will be used for travel in support of consultation with feed development activities with researchers involved in Objective 1 and commercial tilapia culturists in development of extension fact sheets.

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

OMB Approved 0524-0022
Expires 5/31/98

BUDGET

ORGANIZATION AND ADDRESS Board of Trustees Southern Illinois University-Carbondale Carbondale, IL 62901				**USDA AWARD NO.** Year 1: Objective 2	
PRINCIPAL INVESTIGATOR(S)/PROJECT DIRECTOR(S) Susan T. Kohler				Duration Proposed Months: 12 **FUNDS REQUESTED by PROPOSER**	Duration Awarded Months: ________ **FUNDS APPROVED BY CSREES** (If Different)
A. Salaries and Wages	**CSREES FUNDED WORK MONTHS**				$
1. No. of Senior Personnel	Calendar	Academic	Summer		
a. ___ (Co)-PI(s)/PD(s)					
b. ___ Senior Associates					
2. No. of Other Personnel (Non-Faculty) a. ___ Research Associates-Postdoctorates					
b. 1 Other Professional	2.5			$8,149	
c. ___ Graduate Students					
d. ___ Prebaccalaureate Students					
e. ___ Secretarial-Clerical					
f. ___ Technical, Shop and Other					
Total Salaries and Wages →				$8,149	
B. Fringe Benefits (If charged as Direct Costs)				$2,480	
C. Total Salaries, Wages, and Fringe Benefits (A plus B) →				$10,629	
D. Nonexpendable Equipment (Attach supporting data. List items and dollar amounts for **each** item.)					
E. Materials and Supplies				$250	
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 ($150), Fax ($100), Photocopying ($144)				$394	
J. Total Direct Costs (C through I) →				$12,273	
K. Indirect Costs If Applicable (Specify rate(s) and base(s) for on/off campus activity. Where both are involved, identify itemized costs in on/off campus bases.)					
L. Total Direct and Indirect Costs (J plus K) →				$12,273	
M. Other →					
N. Total Amount of This Request →				$12,273	$
O. Cost Sharing (If Required Provide Details)	$13,402				

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 Board of Trustees Southern Illinois University-Carbondale Carbondale, IL 62901				**USDA AWARD NO.** Year 2: Objective 2	
PRINCIPAL INVESTIGATOR(S)/PROJECT DIRECTOR(S) Susan T. Kohler				Duration Proposed Months: 12 **FUNDS REQUESTED by PROPOSER**	Duration Awarded Months: ________ **FUNDS APPROVED BY CSREES** (If Different)
A. Salaries and Wages	**CSREES FUNDED WORK MONTHS**				$
1. No. of Senior Personnel	Calendar	Academic	Summer		
a. ___ (Co)-PI(s)/PD(s)					
b. ___ Senior Associates					
2. No. of Other Personnel (Non-Faculty) a. ___ Research Associates-Postdoctorates					
b. 1 Other Professional	2.5			$8,473	
c. ___ Graduate Students					
d. ___ Prebaccalaureate Students					
e. ___ Secretarial-Clerical					
f. ___ Technical, Shop and Other					
Total Salaries and Wages →				$8,473	
B. Fringe Benefits (If charged as Direct Costs)				$2,511	
C. Total Salaries, Wages, and Fringe Benefits (A plus B) →				$10,984	
D. Nonexpendable Equipment (Attach supporting data. List items and dollar amounts for **each** item.)					
E. Materials and Supplies				$250	
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 ($150), Fax ($100), Photocopying ($243)				$493	
J. Total Direct Costs (C through I) →				$12,727	
K. Indirect Costs If Applicable (Specify rate(s) and base(s) for on/off campus activity. Where both are involved, identify itemized costs in on/off campus bases.)					
L. Total Direct and Indirect Costs (J plus K) →				$12,727	
M. Other →					
N. Total Amount of This Request →				$12,727	$
O. Cost Sharing (If Required Provide Details)	$13,892				

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 SOUTHERN ILLINOIS UNIVERSITY-CARBONDALE

(S. Kohler)

Objective 2

A. Salaries and Wages. A field representative (0.21% FTE) is necessary to assist in the collection and analysis of data as well as report preparation.

B. Fringe Benefits. Medical, dental and retirement benefits for the field representative position.

E. Materials and Supplies. These funds will be used for miscellaneous office supplies.

F. Travel. These funds will be used for travel to the commercial facility for collecting data for the break-even analysis. The funds will also be used for dissemination of research results at professional meetings.

I. Other Direct Costs. Year 1: telephone ($150); fax ($100); and, photocopying ($144). Year 2: telephone ($150); fax ($100); and photocopying ($243).

BUDGET SUMMARY FOR EACH PARTICIPATING INSTITUTION

Year 1

	Purdue	SIUC	MSU	TOTALS
Salaries and Wages	$20,200	$20,149	$0	$40,349
Fringe Benefits	$3,285	$2,480	$0	$5,765
Total Salaries, Wages and Benefits	$23,485	$22,629	$0	$46,114
Nonexpendable Equipment	$0	$0	$0	$0
Materials and Supplies	$3,500	$8,250	$833	$12,583
Travel	$2,500	$5,000	$1,667	$9,167
Other Direct Costs	$515	$6,394	$0	$6,909
TOTAL PROJECT COSTS	$30,000	$42,273	$2,500	$74,773

Year 2

	Purdue	SIUC	MSU	TOTALS
Salaries and Wages	$20,200	$21,073	$0	$41,273
Fringe Benefits	$3,285	$2,511	$0	$5,796
Total Salaries, Wages and Benefits	$23,485	$23,584	$0	$47,069
Nonexpendable Equipment	$0	$0	$0	$0
Materials and Supplies	$3,500	$8,650	$833	$12,983
Travel	$2,500	$4,000	$1,667	$8,167
Other Direct Costs	$515	$6,493	$0	$7,008
TOTAL PROJECT COSTS	$30,000	$42,727	$2,500	$75,227

RESOURCE COMMITMENT FROM INSTITUTIONS[1]

Institution		Year 1	Year 2
Purdue University			
Salaries and Benefits: SY @ 0.05 FTE		$7,150	$7,250
Equipment and Waiver of Overhead		$25,600	$25,400
	Total	$32,750	$32,650
Southern Illinois University-Carbondale			
Salaries and Benefits: 2 SY @ 0.10 FTE each		$13,105	$13,298
Supplies, Expenses, Equipment and Waiver of Overhead		$33,697	$34,194
	Total	$46,802	$47,492
Michigan State University			
Salaries and Benefits: SY @ 0.01 FTE		$950	$950
Supplies, Expenses, Equipment and Waiver of Overhead		$1,550	$1,550
	Total	$2,500	$2,500
	Total per Year	$82,052	$82,642
	GRAND TOTAL	$164,694	

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

SCHEDULE FOR COMPLETION OF OBJECTIVES

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

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

LIST OF PRINCIPAL INVESTIGATORS

Paul B. Brown, Purdue University

Donald L. Garling, Michigan State University

Christopher C. Kohler, Southern Illinois University-Carbondale

Susan T. Kohler, Southern Illinois University-Carbondale

VITA

Paul B. Brown
Department of Forestry and Natural Resources
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E-mail: pb@fnr.purdue.edu

EDUCATION

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

POSITIONS

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

SCIENTIFIC and PROFESSIONAL ORGANIZATIONS

American Institute of Nutrition
American Oil Chemists Society
Comparative Nutrition Society
International Association of Astacology
Society for Integrative and Comparative Biology
World Aquaculture Society

SELECTED PUBLICATIONS

Twibell, R.G., and P.B. Brown. 1998. Optimum dietary crude protein for hybrid tilapia (*Oreochromis niloticus* × *O. aureus*) fed all-plant diet. Journal of the World Aquaculture Society 29:9-16.

Brown, P.B., R. Twibell, Y. Hodgin, and K.A. Wilson. 1997. Use of soybean products in diets fed to juvenile hybrid striped bass. Journal of the World Aquaculture Society 28:215-223.

Brown, P.B., K.A. Wilson, Y. Hodgin, and J. Stanley. 1997. Use of soy protein concentrates and lecithin products in diets fed to coho and Atlantic salmon. Journal of the American Oil Chemists Society 74:187-194.

Wu, Y.V., R.R. Rosati, and P.B. Brown. 1996. Effect of diets containing various levels of protein and ethanol coproducts from corn on growth of tilapia fry. Journal of Agricultural and Food Chemistry 44:1491-1493.

Brown, P.B., M.R. White, J. Chaille, M. Russell, and C. Oseto. 1996. Evaluation of three anesthetic agents for crayfish (*Orconectes virilis*). Journal of Shellfish Research 15:433-435.

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

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

VITA

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Southern Illinois University-Carbondale
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Phone: (618) 453-2890
Fax: (618) 536-7761
E-mail: ckohler@siu.edu

EDUCATION

B.S. St. Mary's College of Maryland, 1973
M.S. University of Puerto Rico, 1975
Ph.D. Virginia Polytechnic Institute and State University, 1980

POSITIONS

Professor (1993-present), Associate Professor (1989-1993), Assistant Professor (1982-1988), of Zoology, Southern Illinois University-Carbondale
Associate Director (1991-present), Fisheries Research Laboratory, Southern Illinois University - Carbondale
Assistant Professor (1980), Virginia Polytechnic Institute and State University

SCIENTIFIC and PROFESSIONAL ORGANIZATIONS

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

SELECTED PUBLICATIONS

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.

Ayala, C.E., C.C. Kohler, and R.R. Stickney. 1993. Protein digestibility and amino acid availability of fish meal in largemouth bass infected with *Acanthocephala*. The Progressive Fish-Culturist 55:275-279.

Killian, H.S., and C.C. Kohler. 1991. Influence of 17 alpha-methyltestosterone on red tilapia under two thermal regimes. Journal World Aquaculture Society 22:83-94.

Phillips, P.C., and C.C. Kohler. 1991. Establishment of tilapia spawning families providing a continuous supply of eggs for *in vitro* fertilization. Journal World Aquaculture Society 22:217-223.

Roem, A.J., C.C. Kohler, and R.R. Stickney. 1990. Vitamin E requirements of the blue tilapia, *Oreochromis aureus* (Steindachner) in relation to dietary lipid level. Aquaculture 87:155-164.

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

VITA

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Department of Fisheries and Wildlife
Michigan State University
9A Natural Resources Building
East Lansing, MI 48824-1222

Phone: (517) 353-1989
Fax: (517) 432-1699
E-mail: garlingd@pilot.msu.edu

EDUCATION

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

POSITIONS

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

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

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

SCIENTIFIC and PROFESSIONAL ORGANIZATIONS

American Fisheries Society: Fish Culture and Fisheries Educators Sections
World Aquaculture Society
Gamma Sigma Delta
Sigma Xi

SELECTED PUBLICATIONS

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

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

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

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

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

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

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EDUCATION

B.S. St. Mary's College of Maryland, 1974
M.S. Southern Illinois University, 1984
Ph.D. Southern Illinois University, 1992

POSITIONS

Assistant Director (1995-present), Coordinator, Regional Research and Service (1992-1995), Field Representative (1991-1992), Graduate Research Assistant (1990-1991), Office of Economic and Regional Development, Southern Illinois University-Carbondale

Research Assistant II (1985-1990), Department of Botany, Southern Illinois University-Carbondale

SCIENTIFIC and PROFESSIONAL ORGANIZATIONS

American Fisheries Society
Illinois Development Council
World Aquaculture Society
Rural Partners
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SELECTED PUBLICATIONS AND PRESENTATIONS

Kohler, S.T. 1996. Using census data and geographic information systems to identify target markets for aquaculture products in the USA. World Aquaculture 27:23-35.

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