# IV. PROGRESS REPORTS

## A. IMPROVING PRODUCTION EFFICIENCY OF WARMWATER AQUACULTURE THROUGH NUTRITION

Progress Report
for the period
January 1, 1994 to August 31, 1997

**FUNDING LEVEL:**

Year 1 ..... $280,310
Year 2 ..... $249,485
Year 3 ..... $234,705
Total ..... $764,500

**PARTICIPANTS:**

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**PROJECT OBJECTIVES:**

1. Determine minimum effective levels of vitamin and protein/amino acid supplementation to maximize feed efficiency in commercial-scale channel catfish production.

2. Evaluate feeding strategies and their effects on commercial-scale channel catfish production. Of particular concern will be the effects of feeding time, frequency, and rate (satiation or restricted) on production efficiency. Feeding regimes to achieve maintenance of body weight and compensatory growth also will be addressed.

3. Investigate nutritional aspects that are most limiting production of baitfish and hybrid striped bass. This will include determining digestible energy and availability of amino acids in practical feedstuffs for hybrid striped bass and the relative contribution of natural foods and prepared feeds to growth of baitfish under conditions of commercial production.

**ANTICIPATED BENEFITS:**

The results of this project have lead to several improvements in the cost-effectiveness of diet formulations and feeding schedules for channel catfish. Advancements in these areas will significantly improve production economics by reducing diet costs and increasing the efficiency of feed utilization. The benefits obtained from these advancements will be substantial because over one-half of the variable production costs associated with channel catfish aquaculture

relate to diets and feeding. The efficiency and profitability of baitfish production also should be improved by integrating information obtained in this project on nutritional requirements of these fish with pond management and feeding strategies to meet those requirements most economically. Additional information from this project concerning nutritional requirements of hybrid striped bass and their utilization of feedstuffs also will facilitate the development of improved formulations that will reduce diet costs and increase production efficiency of these fish which constitute a growing sector of aquaculture in the United States.

**PROGRESS AND PRINCIPAL ACCOMPLISHMENTS:**

**Objective 1:**

Several feeding trials in aquaria and experimental ponds have been completed which evaluated vitamin and protein/amino acid supplementation of practical diets for channel catfish. At the Mississippi State University Delta Research and Extension Center, a series of pond feeding trials (1994 to 1997) have been conducted to evaluate the need to supplement typical commercial catfish feeds with vitamin C, thiamin, riboflavin, niacin, pantothenic acid, pyridoxine and choline. Weight gain, feed conversion, feed consumption, survival, hematocrit and liver vitamin storage data indicated that supplemental thiamin, riboflavin, niacin, pantothenic acid, pyridoxine and choline may not be necessary in commercial catfish diets. Data from fish fed vitamin C test diets also indicated that the requirement appears to be less than 15 mg/kg which is much less than previously reported. Based on production data and liver vitamin analyses, it appears that supplemental riboflavin and pyridoxine are not needed in typical commercial catfish feeds used for growout. There also appears to be enough endogenous niacin in commercial catfish feeds to meet the requirement of channel catfish. Stress responses of catfish fed diets with various vitamin supplements were measured by associates at the University of Memphis. Data on plasma chloride, osmotic pressure, and cortisol levels during acute confinement stress did not indicate any consistent difference due to reduced dietary vitamin levels. The stability of several B-complex vitamins in extruded catfish feeds also were determined. These vitamins are fairly to very stable during the extrusion process with relative retention of thiamin, riboflavin, niacin, pantothenic acid, and pyridoxine being 65, 100, 96, 100, and 70%, respectively.

A similar investigation concerning vitamin E supplementation of diets for channel catfish was conducted in ponds at Texas A&M University in 1994-95. A typical commercial diet formulation (with approximately 10 mg vitamin E/kg provided endogenously) was supplemented with vitamin E acetate at either 0, 15, 30 or 60 mg/kg diet. No differences in growth, feed efficiency and survival were observed over the 1-year trial; however, plasma tocopherol was directly correlated with dietary vitamin E supplementation. Differences in liver tocopherol also were observed in fish fed the various diets with those fed the highest level of supplemental vitamin E having the highest liver tocopherol concentrations. Based on the lack of overt or histological signs of vitamin E deficiency in fish fed the basal diet, it appears that vitamin E supplementation of practical diets for growout of channel catfish can be reduced considerably.

In the Department of Biochemistry at Mississippi State University, laboratory experiments on the dietary riboflavin and niacin requirements of fingerling channel catfish have been completed. Fish were fed purified diets containing graded levels of dietary riboflavin or niacin for 8 and 12 weeks, respectively. The dietary riboflavin

requirement of channel catfish for optimal growth was determined to be 6 mg/kg diet which is lower than the previously accepted value of 9 mg/kg diet. The dietary niacin requirement for rapidly growing channel catfish was estimated to be 7.4 mg/kg diet which is about half the previously reported value of 14 mg/kg diet. In a separate experiment, it has been confirmed through direct evidence that dietary tryptophan does not serve as an efficient precursor of niacin in channel catfish. Based on the results of two previous niacin studies, a catfish liver NAD bioassay was developed to determine the bioavailability of niacin from feed ingredients commonly used in commercial catfish feeds. Menhaden fish meal (MFM), meat and bone/ blood meal (MBM), wheat middlings (WML), cooked corn (CCO), uncooked corn (UCO), cottonseed meal (CSM) and soybean meal (SBM) were found to contain 105.3, 50.5, 153.3, 21.9, 12.8, 22.5 and 20.3 mg available niacin/kg, respectively. When compared to the total niacin content of each feed ingredient, niacin in animal feed ingredients (MFM, MBM) was found to be completely available to channel catfish. The availability of niacin in the cereals and cereal byproducts, WML, CCO and UCO, was 60, 44 and 28%, respectively. Niacin availability in the two oilseeds, CSM and SBM, was found to be 58 and 57%, respectively. It was concluded that supplementation of niacin may not be needed or can be significantly lowered in typical commercial catfish feeds because of the relatively high amount of available niacin found in the feed ingredients.

An investigation to optimize dietary protein/amino acid supplementation of all-plant-protein diets for channel catfish has been completed at Louisiana State University. Channel catfish were produced continuously in sixteen, 0.08-ha (0.2-acre) ponds at the Aquaculture Research Facility, Baton Rouge, for a 2.5-year period. Ponds were top-harvested multiple times and restocked with fingerlings after top-harvests to maintain a density of 25,000 fish/hectare (10,000 fish/ acre). Fish were fed one of two, custom-formulated, 32% crude protein, extruded diets: one containing animal and plant protein (control) and one containing only plant protein (primarily from cottonseed and soybean meal with supplemental lysine). Each diet was fed to fish in eight randomly selected ponds, once per day. Diet allotments were adjusted daily to provide as much food as the fish would eat. Both diets appeared to be equally palatable to channel catfish. The total amounts of feed consumed, feed conversion ratio values, and production yields did not differ between treatments. However, fish fed the all-plant-protein diet tended to weigh slightly less than those fed the control diet. Fish fed the control diet had more visceral fat and muscle fat, less muscle protein, and lower muscle moisture content than fish fed the all-plant-protein diet. The all-plant-protein diet thus appears to be a suitable, less expensive substitute for diets containing fish meal for long-term production of channel catfish in earthen ponds.

At the University of Georgia, a study was conducted to evaluate replacement of menhaden fish meal in channel catfish diets with alcohol-extracted soy protein concentrate. Two experimental diets were formulated to contain either 8 or 16% soy protein concentrate to totally replace menhaden fish meal and some soybean meal which were included in the control diet at 8 and 43%, respectively. Dietary protein, energy, lysine, methionine, and phosphorus were the same among the three diets. Channel catfish in three size classes were stocked at 25,000 fingerlings/ha (10,000/acre) into 0.10-ha (0.25-acre) ponds. Partial harvests were made during the growing season when catfish reached market size for Georgia (about 0.5 pound/fish). After stocking in May, five partial harvests were completed and a final complete harvest was made in

November when all remaining catfish were counted and weighed. Catfish production and conversion efficiency were similar for all three diets and resulted in total production of between 5,736 and 7,390 kg/ha for all ponds. Catfish survival ranged between 73% and 97% because of bird depredation and disease-related mortalities but was not significantly different among treatments. Thus, soy protein concentrate used in an all-plant-protein diet allowed the omission of fish meal without negative effects on catfish production.

**Objective 2:**

Several studies to investigate various feeding strategies in channel catfish production also have been conducted. Laboratory experiments have been completed at Texas A&M University in which effects of feed restriction and dissolved oxygen concentration on growth of channel catfish were investigated. Fish maintained at two levels of dissolved oxygen (60 and 92% of air saturation) were either not fed or fed at 1.5 or 3% of body weight per day for one month after which they were all fed to satiation for another month. Weight gain and feed efficiency of fish subjected to low dissolved oxygen were reduced compared to those of fish maintained at the higher dissolved oxygen concentration. Compensatory gain of fish that were not fed or fed at the restricted rate for the first 4 weeks was limited. Another study was conducted with channel catfish in ponds to evaluate restricted feeding regimes that may illicit compensatory growth responses. Catfish of two size classes were stocked at commercial densities and either fed to satiation every day, fed to satiation every third day, or not fed at all for a 3-week period, alternated with another 3-week period during which fish in all treatments were fed to satiation each day. The effects of these feeding regimes on growth, feed efficiency and body composition were evaluated over a 6-month period. Fish fed to satiation throughout the experiment gained more weight than fish subjected to restricted feeding regimes. Fish which alternated between being fed every third day and being full fed gained more weight than fish alternated between being unfed and full fed. However, during periods when all groups were fully fed, fish which had been previously restricted consumed more feed per body weight and experienced greater increases in weight than fish that had not been restricted.

At Auburn University, two over-winter feeding studies were conducted with channel catfish. Two age-classes of fish, year-1 (43 g; 0.09 lb) and year-2 (660 g; 1.5 lb), were stocked separately in 0.04 ha (0.1 acre) ponds in both studies and subjected to three overwinter management regimes: no feed, restricted feeding (not fed during December, January and February), and continuous feeding. Fish were challenged with *Edwardsiella ictaluri* the following spring, and representative fish in all treatment groups were fed to satiation during the following growing season. Results from these two studies indicate no benefit in terms of weight gain from feeding year-1 and year-2 channel catfish during December, January, or February as fish not fed during that period were able to exhibit compensatory growth if feeding was reintroduced in March and continued through late April. While starvation was immunosuppressive in young channel catfish, it enhanced resistance to bacterial infection in adult (year-2) fish. Possible reasons for the difference in immune responses of the two age groups of starved fish include the following: seriously low serum protein concentrations, reduced antibody production, and/or elevated serum iron in the young fish, and increased antibody production and reduced serum iron level in the adult fish.

In the Department of Wildlife and Fisheries at Mississippi State University, a study of the

effects of size-class distribution and dietary protein level on protein utilization and feed conversion of channel catfish was conducted. Fish averaging either 24.1 g (0.05 lb) or 392.1 g (0.86 lb) were stocked in earthen ponds as separate size classes or in a 50:50 ratio in June 1994, and fed either a 28 or 32% protein diet daily to satiation. After 125 days, there were no significant differences in average harvest weight, weight gain, survival, feed conversion, or proximate composition of whole body and filets from fish fed either diet or stocked with only the same size versus mixed sizes. However, large fish stocked with small fish had higher percentage fillet, carcass and fat dressout (32.2, 51.5, and 2.3, respectively) than large fish stocked alone (29.7, 48.3, and 1.6, respectively). Small fish stocked alone had higher percentage carcass dressout (50.3) than small fish stocked with large fish (47.6). Additionally, small fish stocked in mixed-size ponds displayed significantly less average weight gain (148 g; 0.32 lb) than small fish stocked alone (264 g; 0.58 lb). In December 1994, 26-g (0.06 lb) fingerlings were stocked with non-market size fish (remaining from the fall harvest of year-1 fish) to bring fish density to 24,719/ha (10,000/acre) in each of the 18 ponds used in year 1. Thus, the experimental design from year 1 (three fish size groups each fed 28 and 32% protein feeds) was continued into year 2 of the study. However, the treatment consisting of only large fish in year 1 became only small fish in year 2 because all fish reached market size in year 1. The two remaining size treatments were mixed size group ratios of large fish: small fish of approximately 1:2 (mixed-1) and 1:5 (mixed-2). Market size fish were removed by partial harvest in April, July, and October, 1995. Total number and weight of fish in each pond were determined by total harvest in November 1995. Average survival rate in mixed-1 ponds (74.5%) was significantly higher than in mixed-2 ponds (65.9%) or in small-only ponds (63.8%). There was no interaction among the three size groups and two dietary protein levels, and there were no significant differences between diets for average market-size and total production. However, across size groups at final harvest, small fish stocked alone (market size at harvest) displayed significantly greater average visceral fat (2.01%) than fish stocked as mixed-1 (1.4%) or mixed-2 (1.4%) groups. The small-only fish also had significantly greater average fillet yield (29.9%) when compared to fish in the mixed-1 treatment (28.6%).

**Objective 3:**

Several other studies have been completed and are in progress with baitfish and hybrid striped bass to investigate various aspects of their nutrition and feeding. Investigators at the University of Arkansas at Pine Bluff (UAPB) have completed the following: 1) the dietary protein requirement (29%) and optimal dietary energy:protein ratio (9.7 kcal/g) of golden shiners and goldfish in aquaria were established; 2) A series of stable-carbon-isotope-ratio studies has been completed with golden shiners. Isotope analysis of fish and plankton has been used to estimate the relative assimilation of natural and prepared feeds by golden shiners in ponds. Under the conditions of these studies, fish obtained approximately 40-83% of their nourishment from plankton, and the remainder from the prepared feeds. The percentage of plankton consumed by golden shiners was inversely related to the assimilation of the diets which varied with diet composition; 3) A pond feeding trial performed jointly at UAPB and Texas A&M University was conducted to study the effect of different stocking densities (300,000 fish/acre at UAPB vs. 150,000/acre at TAMU) on the relative intake of natural and prepared feeds by golden shiners. Stable carbon isotopes were used to make comparisons. Differences in natural productivity between sites contributed to the unexpected result that fish stocked at the lower density assimilated more of the

prepared feed than fish stocked at the higher density. Stocking density alone was not an adequate predictor of the need for nutritionally complete feeds by golden shiners in ponds; 4) Aquarium studies of the dietary lipid requirement of golden shiners and goldfish were completed. Golden shiners performed well when fed diets containing a wide range of lipid (7-19%), but performance showed a peak when the diet contained around 12% lipid. Goldfish fed diets containing 4.5-7.0% lipid had the highest weight gain. However, survival of goldfish fed the diet with 4.5% lipid was significantly lower than that of fish fed diets containing 7.0-13.3% lipid; 5) A pond trial comparing performance of golden shiners fed diets containing similar energy:protein ratios (10.3 kcal/g) and either high (31%) or low (24%) protein levels was conducted. Diets were fed to golden shiners once daily to satiation. After 4 weeks the average weight of fish fed the diet with 31% protein was higher than that of fish fed the diet with 24% protein. However, weight gain did not differ between fish fed the two diets at 8 weeks or 10 weeks (harvest). There were no differences in total or net yield, or percentage of fish in different size classes. Feed intake did not differ between the two groups.

At East Carolina University, feeding trials have been completed to determine organic matter digestibility coefficients for dextrin, wheat starch, wheat flour, wheat middlings, potato starch and corn starch in diets fed to original cross hybrid striped (palmetto) bass of two sizes (6 g; 0.01 lb) and (95 g; 0.21 lb). Digestibility coefficients for all carbohydrates were generally high (90.5-100%), indicating that simple and complex carbohydrates can be digested by these fish. However, potato starch was not well digested (66.0%) in either small or larger fish. Digestibility determinations also have been conducted at Texas A&M University with reciprocal cross hybrid striped (sunshine) bass. Apparent protein and organic matter digestibility coefficients have been determined for menhaden fish meal, anchovy meal, meat and bone meal, poultry byproduct meal, soybean meal and cottonseed meal.

At Kentucky State University, experiments were conducted with hybrid striped bass to evaluate the effects of diet formulations on growth, body composition and organoleptic qualities. In one experiment, sunshine bass in floating cages were determined to require a diet with 41% protein and a protein to energy ratio greater than 99 mg protein/kcal when fish meal comprised 56% of the dietary protein. In another experiment, juvenile (20 g) palmetto bass in cages were shown to require some fish meal in the diet to provide good growth; however, fish meal inclusion at 15% of diet produced similar growth as diets with higher levels of fish meal. Another study was conducted to determine frozen storage stability, fatty acid composition, and textural quality of sunshine bass. The n-3 fatty acids composed one-third of the total fatty acids in muscle, with eicosapentaenoic acid, 20:3(n-3), and docosahexaenoic acid, 22:6(n-3), being the most prevalent n-3 highly unsaturated fatty acids. Storage of muscle at -20 C for 6 months did not cause increases in lipid oxidation for skin-on fillets; however, skinless fillets exhibited marked increases from month 4 to 6. There was no change in textural quality during 6 months of frozen storage. Flavor quality of sunshine bass fillets stored frozen (-10 C) with skin on for 0, 9, and 18 months also was evaluated by a trained taste-test panel. Diet had little effect on flavor quality, even after 18 months of frozen storage, except for a diet that had 35% fish meal and 10% menhaden fish oil which produced a “fishy” flavor. Frozen storage of sunshine bass fillets for up to 18 months did not greatly affect flavor quality.

**WORK PLANNED:**

Almost all of the project activities have

been completed. One component of this project that is ongoing concerns the development of extension fact sheets that summarize and integrate information obtained from the various studies conducted in association with this project.

**IMPACTS:**

Several benefits to the aquaculture industry have emerged from this project. Based on numerous investigations, it appears that dietary supplementation of several vitamins may be reduced substantially, resulting in as much as a 5% reduction in feed costs which represents a considerable savings to the industry. Research concerning various feeding strategies also has identified means of improving health and increasing production efficiency of channel catfish which will positively impact that industry. Significant advancements also have been made in obtaining specific information on the nutritional requirements of baitfish and hybrid striped bass, and how to meet those requirements most economically. The extent of benefits to be derived from this project appear to be substantial as aquaculturists and feed manufacturers are now implementing many of the suggested dietary manipulations and feeding regimes which were evaluated in this project.

**PUBLICATIONS, MANUSCRIPTS, OR PAPERS PRESENTED:**

**PUBLICATIONS IN PRINT**

Keembiyehetty, C.N. 1995. Amino acid nutrition of sunshine bass (*Morone chrysops* x *M. saxatilis*). Ph.D. Dissertation, Texas A&M University, College Station, TX, 84 pp.

Kim, M.K., and R.T. Lovell. 1995. Effect of overwintering feeding regimen on body weight, body composition and resistance to *Edwardsiella ictaluri* in channel catfish. Aquaculture 134:237-246.

Kim, M.K., and R.T. Lovell. 1995. Effect of restricted feeding regimens on compensatory weight gain and body tissue changes in channel catfish *Ictalurus punctatus* in ponds. Aquaculture 135:285-293.

Li, M.H., J.B. Rushing, and E.H. Robinson. 1996. Stabilities of B-complex vitamins in extruded catfish feeds. Journal of Applied Aquaculture 6(2):67-71.

Lochmann, R.T., and H. Phillips. 1994. Dietary protein requirement of juvenile golden shiners (*Notemigonus crysoleucas*) and goldfish (*Carassius auratus*) in aquaria. Aquaculture 128:277-285.

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Serrini, G., Z. Zhang, and R.P. Wilson. 1996. Dietary riboflavin requirement of fingerling channel catfish (*Ictalurus punctatus*). Aquaculture 139: 285-290.

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Unprasert, P. 1996. Influence of dietary protein level and mixed-size stocking on production characteristics of channel catfish, *Ictalurus punctatus* Ph.D. Dissertation, Mississippi State University, Mississippi State, MS, 103 pp.

**MANUSCRIPTS**

Brett, K.L., P.B. Johnsen, C.D. Webster, L.G. Tiu, Y.L. Xiong, and E.A. Decker. In press. Sensory evaluation and lipids oxidation of sunshine bass (*Morone chrysops* x *M. saxatilis*) fillets frozen for various periods of time. Journal of Applied Aquaculture.

Davis, K.B., B.A. Simco, M.H. Li and E.H. Robinson. In preparation. Effect of supplementary dietary vitamins on the stress response of channel catfish. Journal of the World Aquaculture Society.

Gallagher, M.L. In press. Apparent digestibility coefficients for carbohydrates in diets for hybrid striped bass (*Morone saxatilis* x *M. chrysops*). Journal of the World Aquaculture Society.

Gaylord, T.G., S.D. Rawles and D.M. Gatlin, III. In press. Reevaluation of vitamin E supplementation of practical diets for channel catfish (*Ictalurus punctatus*) production. Aquaculture Nutrition.

Li, M.H., D.J. Wise and E.H. Robinson. In review. Effect on dietary vitamin C on weight gain, tissue ascorbate concentration, stress response, and disease resistance of channel catfish *Ictalurus punctatus*. Journal of the World Aquaculture Society.

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Ng, W.K. and R.P. Wilson. In press. Chromic oxide inclusion in the diet does not affect glucose utilization or chromium retention by channel catfish, *Ictalurus punctatus*. Journal of Nutrition.

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Effects of various degrees of feed deprivation on growth and body composition of channel catfish. Progressive Fish-Culturist.

Reigh, R.C. In preparation. Production characteristics of pond-reared channel catfish fed diets with and without animal protein for three growing seasons.

Robinson, E.H. and M.H. Li. In preparation. Practical vitamin nutrition of channel catfish. Technical Bulletin, Mississippi Agricultural and Forestry Experiment Station.

Sealey, W.M., J.T. Davis and D.M. Gatlin, III. In review. Refinement of vitamin supplementation in diets for pond-raised channel catfish. Extension Fact Sheet.

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Stahl, C.J., T.G. Gaylord, and D.M. Gatlin III. In review. Influence of feeding time and dissolved oxygen on growth performance and body composition of channel catfish. Fish Physiology and Biochemistry.

Webster, C.D., L.G. Tiu, and J.H. Tidwell. In press. Effects of replacing fish meal in diets on growth and body composition of palmetto bass (*Morone saxatilis*) x *M. chrysops*) raised in cages. Journal of Applied Aquaculture 7(1).

**PAPERS PRESENTED**

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Gatlin, D.M., III. An overview of fish nutrition research supported by the Southern Regional Aquaculture Center. Aquaculture America, February 1996 (Abstract).

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February 1996 (Abstract).

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