Southern Regional Aquaculture Center

TWENTY-FIRST ANNUAL PROGRESS REPORT

For the Period Through August 31, 2008

Supporting research and extension projects based on industry needs and designed to directly impact commercial aquaculture development.

In cooperation with the USDA, Cooperative State Research, Education, & Extension Service

December, 2008

TWENTY-FIRST ANNUAL PROGRESS REPORT

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PREFACE

In 1980, Congress recognized the opportunity for making significant progress in domestic aquaculture development by passing the National Aquaculture Act (P.L. 96-362). The Act established USDA as the lead agency for aquaculture coordination and called for development of a National Aquaculture Plan. The next year, Congress amended the National Agricultural Research, Extension, and Teaching Policy Act of 1977 (P.L. 95-113) by granting, in Title XIV, Subtitle L, Sec. 1475(d) of the Agriculture and Food Act of 1981 (P.L. 97-98), authority to establish aquaculture research, development, and demonstration centers in the United States.

Congress envisioned the Centers as focal points in a national program of cooperative research, extension, and development activities that would be developed in association with colleges and universities, state Departments of Agriculture, federal facilities, and non-profit private research institutions with demonstrated excellence in aquaculture research and extension. Eventually, five such Centers were established—one in each of the northeastern, north central, southern, western, and tropical Pacific regions of the country. Funding for the Centers was reauthorized in subsequent Farm Bills (the Food, Agriculture, Conservation, and Trade Act of 1990 [P.L. 101-624]; the Agriculture Improvement and Reform Act of 1996 [P.L. 104-127]; and the Farm Security and Rural Investment Act of 2002 [P.L. 107-171]).

Projects that are developed and funded by the Regional Centers are based on industry needs and are designed to directly impact commercial aquaculture development in all states and territories. The Centers are organized to take advantage of the best aquaculture science expertise, education skills, and facilities in the United States. Center programs insure effective coordination and a region-wide, team approach to projects jointly conducted by research, extension, government, and industry personnel. Inter-agency collaboration and shared funding are strongly encouraged.

ACKNOWLEDGMENTS

The Southern Regional Aquaculture Center (SRAC) acknowledges the contributions of the Project Leaders and Participating Scientists involved in the projects reported in this Twenty-first Annual Progress Report. Members of the SRAC Board of Directors, Industry Advisory Council, and Technical Committee have provided valuable inputs to the successful operation of SRAC during the past year. We particularly appreciate the assistance of the chairs of our Board, IAC and TC, and those serving as Administrative Advisors.

We also thank the scientists and aquaculturists from across the country who contributed their expertise and valuable time to review SRAC project proposals and publications. Without their help, it would be impossible to maintain the high quality of this program.

INTRODUCTION

The Need for Aquaculture in the United States

Population growth, rising per capita incomes, and increased appreciation of the role of seafood in human health have caused global demand for seafood to triple since 1990. Over the same period foodfish output from capture fisheries was stagnant as stocks of ocean fish became fully exploited or, in many cases, over-exploited. The difference between the non-expanding supply from capture fisheries and rapidly expanding seafood demand was derived from aquaculture—the farming of aquatic plants and animals in oceans and inland waters.

Global aquaculture has grown at a phenomenal rate over the last 30 years to meet the expanding demand for seafood. However, the United States, which is the third largest consumer of edible fisheries products in the world, lags behind many countries in aquaculture development, accounting for less than 2% of world aquaculture production. Aquaculture nevertheless plays a significant role in United States trade and agriculture, and there is considerable incentive for further development. Important in this regard, the United States is second only to Japan as the world's largest importer of edible fishery products, resulting in a significant international trade deficit. In 2006 the United States trade deficit in fish and shellfish products was $8.8 billion, making it the largest deficit item for any agricultural commodity and the 24th largest trade deficit item for all commodity groups.

United States seafood demand will continue to increase as a result of population growth and increased emphasis on eating seafood as part of a healthy diet. Although this provides considerable opportunity for an enhanced domestic aquaculture industry, production has been essentially level since about 2000. Because significant economic and food security benefits accrue from producing fishery products rather than importing them, domestic aquaculture production must grow to meet the increasing demand for seafood by consumers.

Aquaculture in the Southeast

The farm-gate value of United States aquaculture exceeds $1 billion. The farm-raised catfish industry—centered in the three deep south states of Alabama, Arkansas and Mississippi—is a mainstay of domestic aquaculture, accounting for more than half of all U.S. aquaculture production. The southeast is also home to other large aquaculture sectors, such as farming of crawfish, hybrid striped bass, oysters, clams, and bait and ornamental fish.

Overall, about 70% of the $1 billion domestic aquaculture crop is produced in the southeast, and the regional economic impact goes far beyond the farm gate. Many of the support functions for the industry—such as feed manufacture and equipment fabrication—also take place in the region, and the total economic impact of aquaculture is many times the value of production alone. Further, if the overall economic value of aquaculture is viewed against a generally depressed agricultural economy, it is clear that aquaculture is a critical factor in the economy of the southeastern United States. However, the profitability of catfish farming and other aquaculture activities have declined to historic lows because of competition from imported products and higher production costs.

The Role of the Regional Aquaculture Centers

Technologies that improve production efficiency can help restore profitability to United States aquaculture and provide a reliable domestic source of seafood for the domestic consumers. Technology development is, however, costly, and support for research and development in aquaculture differs radically from that for traditional agricultural sectors such as poultry, cotton and soybeans. Farmers of those commodities rely on a vast infrastructure of private-sector agribusinesses to conduct most of the research needed to sustain industry growth. Aquaculture, on the other hand, receives little private-sector R&D support, relying instead almost entirely on public-sector funds for technology development.

Although government agencies, particularly the United States Department of Agriculture, have provided significant support for aquaculture research and development, much of that funding is earmarked for specific use by specific institutions. The USDA-CSREES Regional Aquaculture Center program is the only funding activity with the flexibility to stay abreast of industry development, identify problems on a region-wide scale, and implement cooperative, interstate projects to solve those problems.

Since its inception in 1987, the Southern Regional Aquaculture Center has become the most important regional aquaculture activity in the southeastern United States. In its 21 years of operation, the Center has disbursed more than $14 million to fund multi-state research and extension projects. More than 186 scientists from 30 institutions in the southeast have participated in Center projects.

In the past year, five research projects funded at almost $2 million were in progress. The Center's "Publications" project is in its thirteenth year of funding and is under the editorial direction of faculty and staff at Texas A&M University. From this project, eight fact sheets and seven other publications are in various stages of production. To date, the "Publications" project has generated 188 fact sheets and species profiles, 5 project summaries, 19 research publications and 20 videos with contributions from 186 authors from throughout the region.

The most important measure of the impact of projects funded by the Southern Regional Aquaculture Center is the extent to which the results have influenced or improved domestic aquaculture. As one example, our "hybrid catfish" project has already contributed to a dramatic change in catfish farming culture practices. The hybrid catfish produced by crossing the female channel catfish with the male blue catfish is a superior fish for catfish aquaculture but hybrid eggs and fry are difficult to produce. Until this obstacle is overcome the promise of this fish cannot be realized. Nine scientists at five institutions conducted research to improve the efficiency of hybrid production and allow economical delivery of the hybrid technology to the catfish industry. At the beginning of this project, only about 4 to 5 million hybrid catfish fry were being hatched per year. Research results from this project have been important in increasing hybrid catfish production to more than 30 million fry hatched in 2007.

Beginning with the first projects funded by the Southern Regional Aquaculture Center, interest among aquaculture research and extension scientists in Center activities has been excellent. In fact, funding and project coordination provided by SRAC has become so embedded in the fabric of southeastern aquaculture research and extension that it is difficult to envision what these activities would be like without the program. We are pleased with the participation by our research and extension scientists in the Southern Region in ad hoc Work Group meetings and Steering Committees, and their willingness to serve as Project Leaders and Principal Investigators for the projects. We believe this broad-based representation has resulted in strong, cooperative research that will be of long-lasting benefit to aquaculture producers and consumers, and to the growth of the aquaculture industry in the Southern United States.

This Twenty-First Annual Progress Report covers the activities of the Administrative Center during the past year. Progress reports on the five multi-year research and extension projects supported by SRAC during this reporting period cover the life of the projects from their initiation date through August 31, 2008.

ORGANIZATIONAL STRUCTURE

The Agriculture Acts of 1980 and 1985 authorized establishment of aquaculture research, development and demonstration centers in the United States. With appropriations provided by Congress for the 1987 and 1988 FYs, efforts were undertaken to develop the five Regional Aquaculture Centers now in existence. Organizational activities for SRAC began in 1987, with the first research and extension projects initiated in 1988.

Research and extension problem areas for the southern region are identified each year by the Industry Advisory Council (IAC), which consists of fish farmers and allied industry representatives from across the region. The Technical Committee (TC), consisting of research and extension scientists from all states within the region, works with the IAC to prioritize problem areas. The two groups then work together to develop "Problem Statements" describing objectives of work to solve problems with the highest priority. Using inputs from industry representatives, regional Work Groups of the most qualified research and extension scientists are formed. The Work Groups then plan and conduct the work in conjunction with an Administrative Advisor appointed by the Board. Regional aquaculture funds are allocated to participants in SRAC projects approved by the Board and CSREES. Reviews of project proposals, progress reports, and recommendations for continuation, revision, or termination of projects are made jointly by the TC and IAC and approved by the Board.

The thirteen states and two territories represented by SRAC are Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, Oklahoma, Puerto Rico, South Carolina, Tennessee, Texas, U.S. Virgin Islands, and Virginia.

ADMINISTRATIVE CENTER

The Administrative Center is located at the Delta Research and Extension Center, Stoneville, Mississippi. Mississippi State University serves as the Host Institution. All necessary support services for the Board, IAC, TC, Steering Committees and project Work Groups are provided by the Administrative Center. This includes monitoring status and progress of projects, preparing and executing Letters of Agreement, tracking administrative and project expenditures, reviewing progress reports, and assisting Project Leaders and participating institutional Grants Offices as needed.

Operation and funding are approved by the Board for inclusion in the Grant Application submitted annually to USDA/CSREES. The Center staff also prepares and submits to USDA/CSREES an Annual Plan of Work covering Center activities and projects to be funded. Following final approval, Letters of Agreement are prepared and executed with all participating institutions. The Center acts as fiscal agent to disburse and track all funds in accordance with the provisions of the grants. Additional Administrative Center responsibilities are detailed in the "Administrative Activities" section of this report.

BOARD OF DIRECTORS

The Board is the policy-making body for SRAC. Membership provides an appropriate balance among representatives from State Agricultural Experiment Stations, Cooperative Extension Services, 1890 Institutions, and the Administrative Heads Section (AHS) of the Board on Agriculture Assembly (BAA) of the National Association of State Universities and Land Grant Colleges (NASULGC).

The structure of the Board is as follows:

Three members of the 1862 Southern Extension Service Directors Association
Three members of the 1862 Southern Experiment Station Directors Association
One member of the 1890 Association of Research Administrators
One member of the 1890 Association of Extension Administrators
One AHS administrator from the host institution

Members of the Board are:

Harold Benson, Kentucky State University
Richard Guthrie, Auburn University
Melissa Mixon, Mississippi State University
David Morrison, Louisiana State University
Gary Palmer, University of Kentucky Extension Service
James Rakocy, University of the Virgin Islands
Gaines Smith, Alabama Cooperative Extension System
Joe Street, Mississippi State University Extension Service

Ex-officio Board members are:

Chair, Industry Advisory Council
Vice-chair, Industry Advisory Council
Co-chair for Extension, Technical Committee
Co-chair for Research, Technical Committee
Director, SRAC

The Board is responsible for 1) overall administration and management of the regional center program; 2) establishment of overall regional aquaculture research and extension goals and allocations of fiscal resources to ensure that the center develops strong programs in both research and extension; 3) establishment of priorities for regional aquaculture research and extension education activities based on inputs from the TC and IAC and guidance from the National Aquaculture Development Plan; 4) review and approval of annual plans of work and accomplishment reports; and 5) final selection of proposals for funding by SRAC.

INDUSTRY ADVISORY COUNCIL

The IAC, which meets at least annually, is composed of representatives of state and regional aquaculture associations, federal, territorial and state agencies, aquaculture producers, aquaculture marketing and processing firms, financial institutions, and other interests or organizations as deemed appropriate by the Board of Directors.

The IAC provides an open forum wherein maximum input from private and public sectors can be gained and incorporated into annual and ongoing plans for SRAC. The chairman serves for two years and is elected by IAC members.

Members of the IAC are:

Neal Anderson, AR
Lynn Blackwood, VA
Bill Cheek, LA
David Teichert-Coddington, AL
Jane Corbin, TN
Paul Dees, MS
Shorty Jones, MS
Bill Livingston, SC
Joey Lowery, AR
Bill Martin, VA
Robert Mayo, NC
Sandy Miller, GA
Steve Minvielle, LA
Rick Murdock, KY
Fernando Rodriquez, PR
Robert Schmid, TX
Dan Solano, FL
Marty Tanner, FL
Butch Wilson, AL

IAC members serve up to four-year appointments having staggered terms with options for reappointment.

The IAC 1) identifies research and extension needs; 2) works with the TC to prioritize research and extension needs; 3) works with the TC to develop problem statements and recommend funding levels for projects addressing priority research and extension needs; 4) reviews project proposals, progress reports, and termination reports; and 5) recommends to the Board, jointly with the TC, actions regarding new and continuing proposals, proposal modifications and terminations.

TECHNICAL COMMITTEE

The TC consists of representatives from participating research institutions and state extension services, other state or territorial public agencies as appropriate, and private institutions. Membership of the TC includes research and extension scientists representing essentially all states in the region. The TC meets as needed, but at least annually, and has a co-chairman for research and a co-chairman for extension. Co-chairmen serve for two years and are elected by TC members.

Members of the TC for research are:

David Brune, SC
Louis D'Abramo, MS
Jason Danaher, VI
Sid Dasgupta, KY
Allen Davis, AL
Patricia Duncan, GA
Carole Engle, AR
Delbert Gatlin, TX
John Kubaryk, PR
Tom Losordo, NC
Ray McClain, LA
Mike Oesterling, VA
Courtney Ohs, FL
Larry Wilson, TN

Members of the TC for Extension are:

Jimmy Avery, MS
Ron Blair, TN
Gary Burtle, GA
Jesse Chappell, AL
Dennis Delong, NC
David Heikes, AR
Greg Lutz, LA
Michael Masser, TX
Mike Schwarz, VA
Saul Wiscovich Teruel, PR
Craig Watson, FL
Jack Whetstone, SC
Forrest Wynne, KY

Technical Committee members serve up to four-year appointments having staggered terms with options for reappointment.

The TC 1) works with the Industry Advisory Council to prioritize research and extension needs; 2) works with the Industry Advisory Council to develop problem statements and recommend funding levels for projects addressing priority research and extension needs; 3) reviews proposals, progress reports, and termination reports; and 4) recommends to the Board, jointly with the IAC, actions regarding new and continuing proposals, proposal modifications and terminations.

PROJECT CRITERIA

Projects developed within SRAC should meet the following criteria:

- Addresses a problem of fundamental importance to aquaculture in the Southern Region;
- Involves participation by two or more states in the Southern Region;
- Requires more scientific manpower, equipment, and facilities than generally available at one location;
- Approach is adaptable and particularly suitable for inter-institutional cooperation, resulting in better use of limited resources and a saving of funds;

- Will complement and enhance ongoing extension and research activities by participants, as well as offer potential for expanding these programs;
- Is likely to attract additional support for the work which is not likely to occur through other programs and mechanisms;
- Is sufficiently specific to promise significant accomplishments in a reasonable period of time (usually up to 3 years);

PROJECT DEVELOPMENT PROCEDURES

The IAC initiates the project development process by identifying critical problems facing aquaculture in the region. The TC and IAC then jointly prioritize problem areas and recommend the most important research and extension needs to the Board. Writing teams selected from the TC-IAC membership develop "problem statements" for each of the selected priority areas. Problem statements briefly describe the problem area and general objectives of the work to be conducted. The problem statement also includes a recommended funding level and project duration. Draft problem statements are then forwarded to the Board for approval to release project development funds.

Once an area of work has been approved, the Executive Committee (the SRAC Director, the co-chairs of the TC, and the chair and vice-chair of the IAC) appoints a Steering Committee to develop the "Call for Statements of Interest" and oversee development of the project proposal and the conduct of the regional project. The "Call for Statements of Interest" is distributed to state, territorial or federal institutions and private institutions within the Southern Region with demonstrated competence in aquaculture research and development. Interested parties respond by submitting a "Statement of Interest" to the SRAC Adminstrative Office. After careful review of the Statements of Interest, the Steering Committee recommends a Work Group consisting of selected project participants and the Steering Committee. The Work Group is responsible for preparing the regional project proposal and conducting work outlined in the proposal.

Project proposals are reviewed by the Steering Committee, IAC, TC, all project participants and designated peer reviewers from within the region and from outside the region. The SRAC Director submits the project proposal and peer reviews to the Board of Directors for review and approval. Proposals not approved by the Board are returned for revision or eliminated from consideration.

The Director prepares an annual plan of work, including all project proposals approved by the Board, and submits the plan to CSREES for approval. Pending a successful review of the project plan and budget, CSREES notifies SRAC of final approval. Letters of Agreement (subcontracts) between SRAC and participating institutions are then prepared and forwarded for approval and execution by the authorized institutional official. At that point, formal work on the project begins.

ADMINISTRATIVE ACTIVITIES

The SRAC administrative staff consists of the Center Director and Administrative Assistant. A wide variety of support functions for the various SRAC components, including the Board, TC, IAC, Steering Committees and project Work Groups are provided:

- Center Director serves as an ex-officio member of the Board, TC, and IAC.
- Monitor research and extension activities sponsored by SRAC.
- Solicit and receive nominations for memberships on the TC and IAC.
- Coordinate submission of written testimony to the U.S. House Agriculture, Rural Development, and Related Agencies Subcommittee on Appropriations regarding RAC support.
- The Director of SRAC serves as a member of the National Coordinating Council for Aquaculture which consists of the Directors of the five Regional Centers and appropriate USDA/CSREES National Program staff.
- Prepare and submit Grant Application to USDA/CSREES entering into funding agreement for each fiscal year, Annual Plan of Work and Amendments.
- Develop and execute appropriate Letters of Agreement with participating institutions in each funded proposal for the purpose of transferring funds and coordinating and implementing projects approved under each of the grants.
- Serve as fiscal agent to review and approve invoices and distribute funds to participating institutions as approved under the grants and as set forth in the Letters of Agreement.
- Prepare budgets for the Administrative Center, track administrative expenditures, and obtain USDA/CSREES approval for project and budget revisions.
- Prepare budget reports for the Board of Directors, tracking expenditures and status of funded projects and the Administrative Center.
- Assist Steering Committees and Work Groups with preparation and revision of proposals for technical and scientific merit, feasibility and applicability to priority problem areas.
- Solicit and coordinate national reviews of project proposals.
- Distribute fact sheets and videos to research and extension contacts throughout the Southern Region, other RACs, and USDA personnel.
- Produce and distribute the "SRAC Annual Progress Report," which includes editing and proofreading the project reports and producing camera-ready copy.
- Produce and maintain the web site for SRAC which provides downloadable copies of all SRAC fact sheets, the Operations Manual and Annual Reports, as well as lists of other research publications and extension contacts in the Southern Region.
- Prepare and distribute Calls for Statements of Interest to research and extension directors and other interested parties throughout the Southern Region.
- Respond to requests from aquaculture producers, the public, and research and extension personnel for copies of fact sheets, research publications and videos produced by SRAC and the other Centers, as well as requests for general aquaculture-related information.

PROGRESS REPORTS

The following cumulative reports detail the progress of research and extension work accomplished for the duration of the respective projects through August 31 of the current year. These reports are prepared by the Project Leaders in conjunction with the institutional Principal Investigators.

PUBLICATIONS, VIDEOS AND COMPUTER SOFTWARE

Reporting Period
March 1, 1995 - August 31, 2008

Funding Level

Year 1	$ 50,000
Year 2	60,948
Year 3	45,900
Year 4	60,500
Year 5	67,000
Year 6	77,358
Year 7	82,205
Year 8	77,384
Year 9	84,113
Year 10	78,700
Year 11	78,115
Year 12	74,100
Year 13	80,106
Total	$916,429

Participants Texas A&M University System serves as Lead Institution, with Dr. Michael Masser as Project Leader. Participants in this project include authors and co-authors from all states in the region as shown in the listing of publications at the end of this report.

PROJECT OBJECTIVES

1. Review and revise, as necessary, all SRAC extension printed and video publications.

2. Establish an ongoing project location to develop and distribute new SRAC educational publications and videos for Southern Region aquaculture industries. This project will be responsible for preparation, peer review, editing, reproduction, and distribution of all Extension and popular-type publications for all SRAC projects.

3. Place current, revised, and new publications in electronic format (e.g., Internet or compact disk) for more efficient use, duplication, and distribution.

ANTICIPATED BENEFITS

The primary benefit from this project to the aquaculture industry is the widespread and ready availability of detailed information on production and marketing of aquacultural products. SRAC fact sheets, videos, and other publications are distributed worldwide to a diverse clientele.

Extension Specialists. When this project was initiated, fewer than half the states had educational materials covering the major aquacultural species in their state. The concept of using the SRAC program to produce timely, high-quality educational materials is based upon the benefits of centralizing the production process while using a region-wide pool of expertise to develop materials. Distribution is then decentralized through the nationwide network of Extension Specialists and County Agents. This process assures an efficient publication process that makes use of the best available talent in specific subject areas. The result is widespread availability of high-quality educational material for scientists, educators, producers, and the general public.

Educators. Many high schools, colleges, and universities in the United States and around the world use SRAC technical fact sheets as reference material in aquaculture and fisheries courses. Educational institutions at the elementary and secondary level use SRAC extension materials in the classroom to make students aware of aquaculture production and associated trades as a possible vocation.

Consumers. Information is readily available for consumers who are seeking background information on aquaculture.

Producers. Information on the use of therapeutants, pesticides, methods of calculating treatment rates, and possible alternative crops and marketing strategies is in constant demand by aquaculturists. Videos that demonstrate such techniques are a ready source of "how-to" information.

Potential investors. Detailed information on production and marketing constraints and ways to alleviate or manage those constraints are particularly helpful to people making decisions about entering the aquaculture business. Economic information is used by lending agencies and potential investors, as well as established producers who use the information to help make day-to-day decisions on farm management.

Internet access. Availability of SRAC publications via the Internet and compact disk makes access faster and easier, facilitates searching for needed information, and reduces storage space requirements for printed documents.

Results at a glance...

- *186 authors from across the United States have contributed to SRAC's publication projects.*
- *Eight fact sheets were completed this year with seven fact sheets, one PowerPoint presentation, and one DVD in progress.*
- *Fourteen scientists from across the Southern Region contributed to publications completed by SRAC this year.*
- *SRAC has now published 188 fact sheets and species profiles, 5 project summaries, 19 research publications, and 20 videos.*
- *SRAC has now converted all VHS videos to DVD format.*

PROGRESS AND PRINCIPAL ACCOMPLISHMENTS

During this current project year, three new fact sheets and five fact sheet revisions were completed and the Aquaplant website was updated. One Final Project Report was also completed. All publications were distributed throughout the Southern Region and to interested Extension Specialists in other regions. Five fact sheets are in some stage of writing, production, or revision. Two other fact sheets and two project summaries are in preparation but drafts have not yet been submitted. One DVD on Water Quality is in review. Eight of the SRAC videos in VHS format have been converted to DVD format. All SRAC publications are based on research conducted within the region or in surrounding areas.

Research funding from universities within the region, as well as funding from private sources, has been used to support the work on which the fact sheets are based. Copies of all SRAC fact sheets are available at <http://www.msstate.edu/dept/srac> and <http://srac.tamu.edu>.

Results at a glance...

Titles of some recent SRAC publications:

- *Avian Predators at Aquaculture Facilities in the Southern United States*
- *Feeding Catfish in Commercial Ponds*
- *What is Cage Culture?*
- *Baitfish Production Enterprise Budget*
- *Forage Fish: Introduction and Species*
- *Managing High pH in Freshwater Ponds*
- *Oyster Hatchery Techniques*
- *Disease Prevention on Fish Farms*

WORK PLANNED

During the next project year, ten new fact sheets/ species profiles will be produced , five fact sheets will be revised, two power point programs will be produced, and one project summaries will be produced. The new fact sheets will address: 1) pond effluent management, 2) building crawfish traps, 3) introduction and risk of non-native species, 4) shellfish diseases, 5) diagnosing fish kills, 6) shellfish handling practices, 7) basic aquacultural genetics, 8) shipping fish and invertebrates, 9) pre- and post-harvest seafood safety, and 10) phytoplankton culture.

Revised fact sheets will address: 1) site selection for levee ponds, 2) cage culture problems, 3) cage culture harvesting and economics, 4) small-scale marketing, 4) hybrid striped bass growout, 5) tank culture of tilapia.

Two power point presentations will be produced addressing 1) techniques of marine larviculture and 2) development of classroom recirculating aquaculture systems.

A final project summary from the project "Management of Aquaculture Effluents" will be developed.

IMPACTS

This is a highly productive project with significant regional, national, and international impact. Fact sheets and videos are requested and used by clientele in all 50 states on a regular basis. Fact sheets generated within the Southern Region are also widely distributed by RACs and extension personnel in other regions. In addition to direct requests for printed material, fact sheets and other informational materials are accessed daily from the SRAC web site by people searching for technical information. In the period from September 2007 through August 2008, more than 37,868 unique visitors came to the SRAC web site and accessed over 249,611 pages. Since the fact sheets are also accessible through numerous other university research and extension web sites, the total usage and impact is undoubtedly several times greater.

Publications and videos produced by SRAC are increasingly used in educating high school and college students about aquaculture. In recent years there has been a rapid expansion of aquaculture curricula in high schools. These programs heavily utilize our publications and videos for educational purposes but usage is impossible to measure because many people access the information from Internet sites. Aquaculture and fisheries courses taught at many colleges and universities also use SRAC technical fact sheets as part of their course reference material.

Another important impact is the education of local, state, and federal regulators about the aquaculture industry. This impact is difficult to measure but feedback from personnel in two states indicates that the fact sheets are recommended reading for all new employees dealing with aquaculture water quality, exotic species, and other permitting duties. This should be a positive influence toward making aquaculturists better understood and the development of more enlightened regulations.

The impact on consumers of aquaculture products is also likely significant, although this impact cannot be quantified. Consumers are primarily interested in a wholesome, safe, and inexpensive product, and it has been reported that the consumer-oriented fact sheets and videos developed within SRAC have generated more interest than the producer-directed materials. The fact sheets are in demand in both the English and Spanish versions and, as more information becomes available, extension materials on food safety will be in increased demand by health conscious consumers.

Results at a glance...

- *In the months from September 2007 through August 2008, more than 37,800 unique visitors came to the SRAC web site and accessed over 249,600 pages from the SRAC web site.*
- *All fact sheets completed by this project to date are available on the Internet at <http://www.msstate.edu/dept/srac> and <http://srac.tamu.edu>.*

PUBLICATIONS, MANUSCRIPTS OR PAPERS PRESENTED

Fact Sheets Completed (9/1/07 - 8/31/2008)

Avian Predators at Aquaculture Facilities in the Southern United States, SRAC 400 (revision), by Scott Barras.
Baitfish Production Enterprise Budget, SRAC 122 (revision), by Nathan Stone, Carole Engle, and Eric Park.
Disease Prevention on Fish Farms, SRAC 4703, by Jo Sadler and Andrew Goodwin.
Feeding Catfish in Commercial Ponds, SRAC 181 (revision), by Menghe Li and Edwin Robinson..
Forage Fish: Introduction and Species, SRAC 140 (revision), by Nathan Stone.
What is Cage Culture? SRAC 160 (revision), by Michael Masser.
Managing High pH in Freshwater Ponds, SRAC 4604, by Craig Tucker and Louis D'Abramo.

Oyster Hatchery Techniques, SRAC 4302, Rick Wallace, Phillip Waters, and F. Scott Rikard.

Manuscripts in review

Small-Scale Marketing of Aquaculture Products, Revision of SRAC 350, Sid Dasgupta and Robert Durborow.
Introduction to Non-Native Species in Aquaculture, by Jeff Hill.
Risk Analysis for Non-Native Species in Aquaculture, by Jeff Hill.
Hybrid Striped Bass Hatchery Phase, Revision of SRAC 301 by Andy McGinty and Ron Hodson.
Cage Culture: Harvesting and Economics, Revision of SRAC 166, by Peter Woods and Michael Masser.

Manuscripts being printed

Algal Toxins in Aquaculture, by John Rodgers.
Cage Culture: Problems, Revision of SRAC 165, by Peter Woods and Michael Masser.

DVD in review

Water Quality Testing and Management, by Michael Masser

Power Point Presentation in review

Techniques for Marine Finfish Larviculture, by Michael H. Schwarz

On-going project

Updating of the AQUAPLANT web site on aquatic weed management, by Michael Masser.

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INNOVATIVE TECHNOLOGIES AND METHODOLOGIES FOR COMMERCIAL-SCALE POND AQUACULTURE

Reporting Period
March 1, 2004 - August 31, 2007

Funding Level	Year 1	$314,409
	Year 2	$287,451
	Year 3	$213,168
	Year 4	$170,096
	Total	$985,124

Participants	Auburn University (Lead Institution)	Claude Boyd
	Clemson University	David Brune, T. E. Schwedler
	Louisiana State University	John Hargreaves, Robert Romaire
	Mississippi State University	Doug Minchew, Charles Mischke, Filip To
	University of Arkansas at Pine Bluff	Carole Engle, David Heikes
	USDA/ARS (Stuttgart)	Bart Green
	USDA/ARS (Stoneville)	Les Torrans

Administrative Advisor
Dr. Kenneth J. Roberts, Associate Vice Chancellor
LSU Ag Center
Baton Rouge, Louisiana

PROJECT OBJECTIVES

1. Evaluate new or improved production systems for channel catfish.
   a. Continuous production and inventory control with the partitioned aquaculture system.
   b. Installation of low-cost, semi-confinement systems in commercial-scale, earthen ponds.
   c. Fry and food fish production using in-pond raceways with the option for culturing supplemental species in open-pond areas.
   d. High-intensity production in heterotrophic-based culture units.

2. Improve equipment to enhance culture.
   a. Motor-powered U-tube aerator for commercial-scale channel catfish ponds.
   b. Low-head, low-speed paddlewheel aerator for crawfish ponds.
   c. Low-power, electrically-enhanced seine to harvest market-sized channel catfish from commercial-scale ponds.

3. Assess energy, material, and economic efficiency of production systems.

a. Quantify energy, protein, and water use in traditional systems for channel catfish culture.
b. Develop and evaluate economic and financial models of existing and improved production practices and technologies.

ANTICIPATED BENEFITS

Aquaculture operations in the southeastern United States find it increasingly difficult to maintain profitability as production costs increase and farm gate prices remain relatively low. Solutions to the problem are complex and multifaceted, but improved production efficiency can decrease production costs and improve the prospects for profitability. This project will provide new technology for production systems, aeration and harvesting techniques, and use of energy, materials, and capital. These technologies will be valuable in improving the profitability of aquaculture in the southeast.

PROGRESS AND PRINCIPAL ACCOMPLISHMENTS

Objective 1. *Evaluate new or improved production systems for channel catfish.*

Objective 1a. *Continuous production and inventory control with the partitioned aquaculture system.*

Clemson University. The experimental trials in 2005 focused on 1) physical holding and handling of fry and fingerlings, 2) stocking density and required water flow rates, 3) feed presentation and food consumption, and 4) growth response under raceway culture conditions as opposed to an "accelerated" fingerling culture pond.

On 10 June 2005, channel catfish fry were stocked in six cells (1.83 m × 2.89 m × 1.22 m deep) located within the 0.81-ha PAS system (Figures 1, 2, and 3). Three cells were stocked with 5,000 fry and three cells with 10,000 fry. Fry were held in bins (46 cm × 76 cm × 30 cm deep) with 0.16-cm (1/16-inch) mesh screens for 1 week and then transferred to bins with 0.32-cm (1/8-inch) mesh screens for an additional week. After having reached an average size of 1.2 to 1.4 g, fingerlings were released into 0.63-cm (1/4-inch) mesh net-pens held within the 6.5-m^3 PAS cells. Each cell was supplied with water delivered by a 0.56-kW submerged aerator providing between 280 to 720 L/min to individual cells (Figures 2 and 3). After initial stocking, fish were fed starter feed of 52% to 56% protein supplied using automated feeders (Figure 4).

After 6 weeks, fingerlings had reached 11 to 14 g and hand feeding was initiated. At 7 weeks, fish in cells containing 10,000 fingerlings had reached 14 to 15 g, and were moved to grow-out raceways in the 0.1-ha PAS units (9.1 m × 2.1 m × 1.22 m deep). At the end of 8.5 weeks, fingerlings had reached 27 to 32 g in units stocked at 5,000 per cell, and 20 to 22 g in cells stocked at 10,000 per cell.

In addition to the fingerling culture trials conducted within cells and raceways, experiments were initiated to study the possibility of using PAS cells and raceways to provide a growth acceleration, or "boost" before stocking and grow-out in conventional fingerling ponds. A conventional, 0.20-ha fingerling culture pond was stocked with 34,000 fry (0.03 g/fish), while 17,000 fry of the same cohort were held in bins for 2 weeks with automated feeding until reaching 1.4 g. The "boosted" fry were stocked into a conventional, 0.12-ha fingerling culture pond. At

Figure 1. Overview of the 0.8-ha Clemson PAS unit with fingerling production cells.

Figure 2. Six, 4.5-m^2 fingerling production cell with aerator-driven water flow.

Figure 3. Individual fingerling production cell with aerator-driven water flow.

Figure 4. Automatic feeders used to feed fingerlings during initials stages of culture.

the end of culture trials fingerlings in both ponds were observed to be of similar size, reinforcing the importance of converting the boosted fry or fingerlings to floating feed as quickly as possible. Growth response in the "accelerated" pond was delayed as a result of slow initial response of the fish to hand feeding after being stocked in the pond.

On 10 October 2005, fingerlings in the cells, raceways and control ponds were harvested, sorted, counted and weighed (Table 1; Figure 5). After 120 days of culture, the net-pen cultured fingerlings grew from an initial weight of 0.10 g/fish (3- to 7-days-old) to an average harvest weight of 122 to 158 g (Figure 6). Feed uptake for the pooled net-pen fingerlings was fit to a power law (Figure 7) yielding the relationship:

Feed application rate (% body weight) = 0.3223 $X^{-0.551}$ where X = fish weight (g). The coefficient of determination (R^2) was 0.846.

Table 1. Average fingerling weight, density (in cells and ponds) and feed application rates in 2005.

Unit #	Size (g/fish)	Density (kg/m^3)	Loading/ feed(kg/ha)
Cell 1	122	112.9	2,576/63
Cell 2	139	136.7	2,576/63
Cell 3	124	111.3	2,576/63
Cell 4	158	47.7	2,576/63
Race 1	73	28.6	3,696/112
Race 2	77	28.6	9,072/215
Race 3	56	19.1	9,072/215
Pond 1	38	0.95	5,600/78
Pond 2	49	0.64	3,808/56

Figure 5. Fry stocking and fingerling harvest sizes.

On 1 June 2006, channel catfish fry were stocked into nine, 1.83 m × 2.89 m × 1.22 m deep cells located within the Clemson 0.8-ha PAS system. The experimental trials for 2006 focused on, 1) physical holding and handling of fry and fingerlings, 2) required water flow rates, 3) comparison of fingerling growth at base feed application rate (from 2005), +25% feed application, and at +50% feed application rate, 4) growth response under raceway culture conditions as compared to net-pen culture.

Figure 6. Final harvest fingerling size distribution in cell 2 (average wt = 139 gm) in 2005.

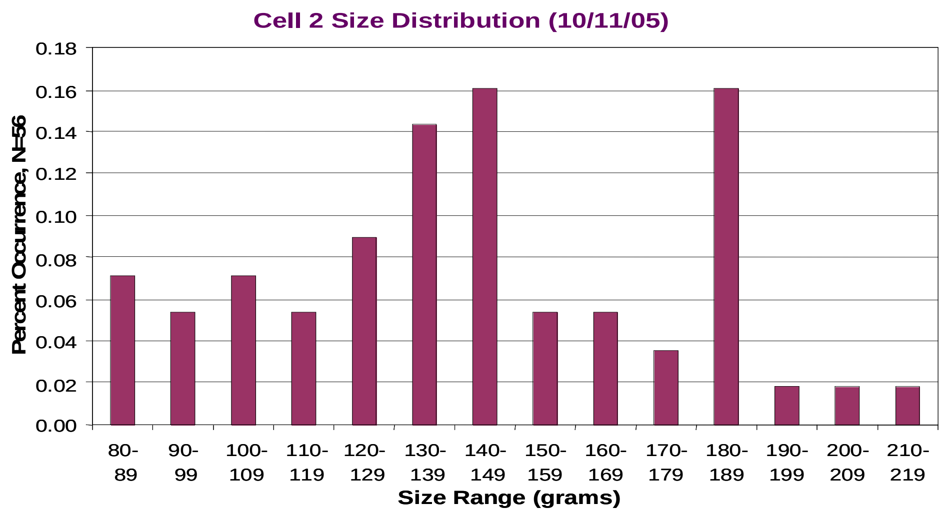
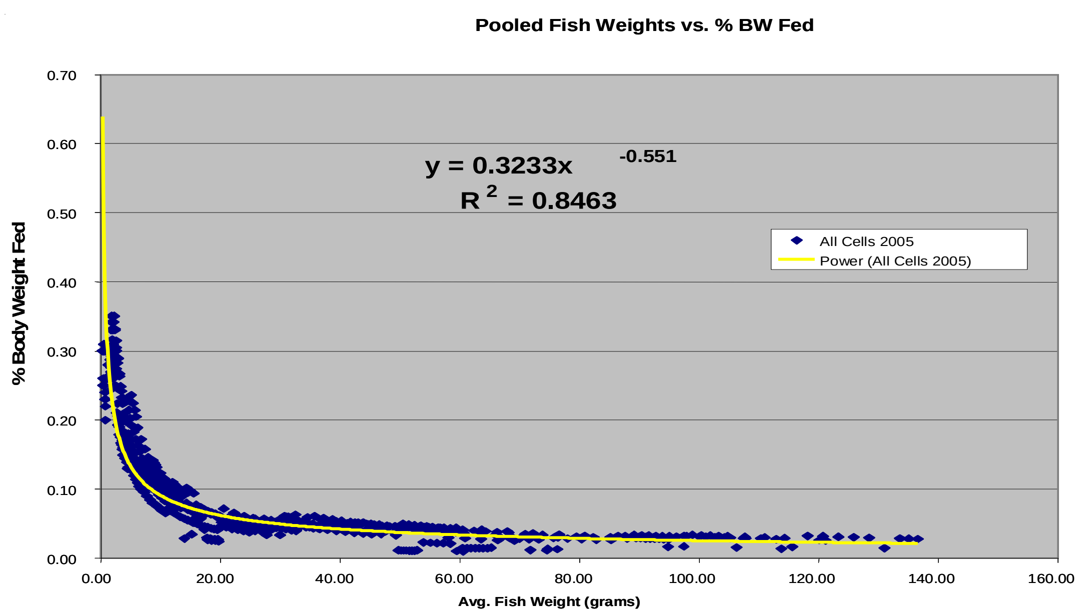


Figure 7. Observed, pooled fry/fingerling feed application rate vs fingerling wt. in 2005.



The nine, 6.5-m^3 cinder block cells were stocked with 3,000 fry in each cell (Figure 8). The fry were held in 1,050-cm^3 bins for 2 weeks, transferred to 3,710-cm^3 bins for two additional weeks, and after having reached 1.8 to 2.0 g in size, the fingerlings were released into a 0.63-cm (1/4-inch) mesh net-pens held within the cells. Each cell was supplied with water flow delivered from two 0.56-kW submerged aerators providing between 280 to 946 L/min flow to the individual cells. From the initial stocking, the fish were fed starter feed supplied with automatic feeders. After 8 weeks the fingerlings had reached 14 to 17 g in size. At 8 weeks, 14 to 15 g fingerlings were stocked into the 0.12-ha PAS raceways units (9.1 m × 2.1 m × 1.22 m deep) at a stocking rate of 74,130 fingerlings/ha.

Fish were harvested on 26 October 2006. End-of-season fingerling weight after 148 days of culture ranged from 126 to 133 gm/fish. Data suggested no statistical difference between fish harvest weight at base, +25, and +50% feed application rates. Overall food uptake rate and fish growth was pooled from the 2005 and 2006 fingerling culture trials and re-fit to a power law yielding the relationship:

Feed application rate (% body weight) = $0.2855X^{0.4818}$ where X = fish weight in grams.

In 2006 culture trials, system-wide feed application rate to the two acre PAS peaked at a maximum of 118 kg feed/ha per day. Overall survival of fingerlings averaged 90%. In all cases observed fingerling growth was significantly reduced in raceways as compared to net-pen culture.

Beginning 15 June 2007, channel catfish fry were stocked into nine, 1.83 m × 2.89 m × 1.22 m deep cinder-block cells located within the Clemson 0.8-ha PAS system. At this time each of the nine cells were stocked with 5,000 fry. The fry were initially stocked (at 0.04 g) in the smallest bins with 0.16-cm (1/16-inch) mesh screens for 9 days of growth (reaching 0.32 g), after which time, they were transferred to larger bins with 0.32-cm (1/8-inch) mesh screens for an additional week until reaching 0.9 gm when they were transferred to 0.48-cm (3/16-inch) mesh bin where they were cultured until reaching an average size of 3.2 g (at 34 days), at which point, the fingerlings were released into 0.63-cm (1/4-inch) mesh net-pens held within the PAS cell. Each cell was supplied with water flow delivered with either 5-cm airlift pumps, or with 0.56-kW submerged aerators providing an initial flow-rate of 150 L/minute, with increased flow (at 5 g fingerling weight) of 1,250 liters per minute to the individual cells (Figure 7). At initial stocking the fish were fed

Figure 8. High density PAS catfish fingerling culture in 6.5 m^3 (1720 gallon) cells with 63-cm (1/4-invh) mesh net cages.

starter feed of 52-56% protein, supplied with automated feeders. After 6 weeks of culture the individual fingerling weight averaged 7.3 to 8.6 g. The fingerlings were harvested after 143 days of culture at an overall combined average fingerling weight of 114 g/fingerling.

In the 2007 season, stocking rates and cell number were adjusted to target a system-wide fingerling carrying capacity approaching expected commercial production levels. Final maximum daily feed application rates exceeded 135 kg/ha of 40% protein feed with maximum fingerling carrying capacity of 4,200 kg/ha. Fingerling feed uptake rates were pooled from all three seasons (2005, 2006 and 2007) suggesting a final feed application relationship of:

Feed application rate (% body weight) = $0.3233X^{0.551}$ where X = fish weight in gms.

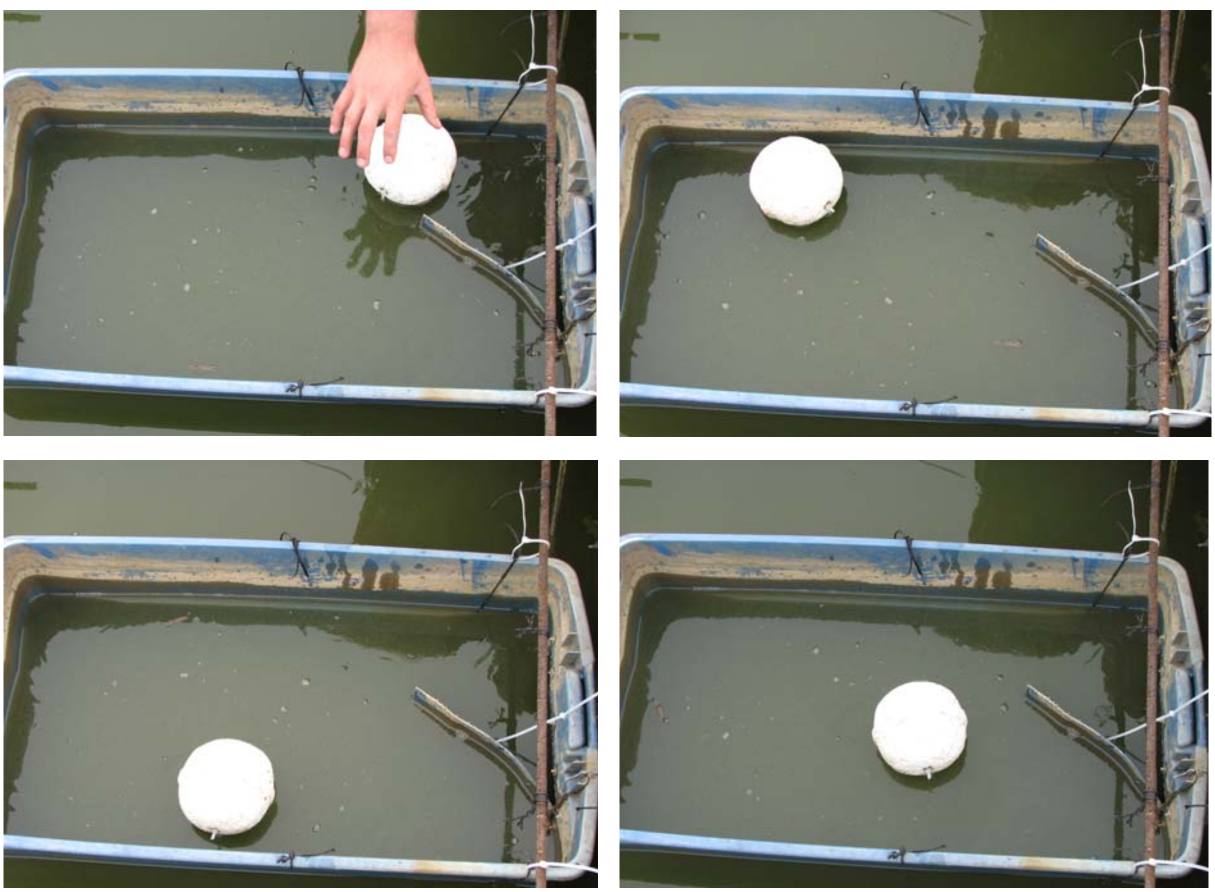
Results from the earlier 2005 and 2006 seasons suggested that fingerlings were extremely sensitive to variations in un-ionized ammonia concentrations resulting from water TAN concentration ranging between 1.0 to 2.0 mg/L at pH values ranging from 8.0-9.0. During 2007 trials, pH-values in four of the nine fingerling culture cells were continually suppressed 0.5 pH units with carbon dioxide supplemental to investigate the potential to increase fingerling feed uptake and growth through reduction in un-ionized ammonia concentrations. At the end of the season average fingerling sizes ranged from 96 to 126 g, and there was no statistically significant differences in fingerling growth attributable to pH adjustment.

In the 2008 season, three of the PAS fingerling growth cells were reconfigured to allow for passive water flow through the cell by utilizing the raceway-paddlewheel (Figure 9), in contrast to using airlifts or aerators to provide water flow as in the 2005, 2006 and 2007 seasons (Figure 8). The goal of these experimental trials was to investigate the possibility of using a lower cost system design, expected to be

Figure 9. 2008 PAS fingerling-cell configuration with paddle-wheel driven flow.

more economically viable for commercial application. The best configuration providing a controllable high flow rate through the cells consisted of combinations of baffles in the water delivery channel and "angled flaps" in the individual fry bins and fingerling net-pens directing water flow into a circular path within the fingerling cells and net pens (Figure 10). Maintaining a circular flow regime within the bins and net-pens was critical to keep feed from washing out at increased flow velocities. Fingerlings were placed into 0.16-cm (1/16-inch) mesh bins, 0.53 m × 0.46 m × 0.38 m at 5,000 fry/bin on June 2, 2008. On 13 June, fry were transferred to 0.32-cm (1/8-inch) mesh bins measuring 0.6 m × 0.53 m × 0.36 m. Finally on July 8 (36 days), fry were transferred to the 0.63-cm (1/4-inch) mesh net-pens, 2.74 m × 1.22 m × 0.91 m in size. Water velocities into bins and net pens ranged from 0.27 to 0.15 m/sec, yielding average water flow rates of 1,514 L/minute (400 gpm) in the bins (contrasted to 151 L/min using airlifts in 2007) and 7,570 L/min (2,000 gpm) in the net-pens (contrasted to 1,362 L/min using aerators in 2007). Bin and net-pen hydraulic detention times were reduced to 0.85 - 0.4 minutes using passive flow in 2008 as opposed to "pumped-flow" detention times of 2 to 5 minutes in the 2006/2007 growth trials.

Figure 10. Demonstration of flap use to direct water flow into circular pattern in 2008 fry-bin providing capture zone for fine mesh fry-feed (0 sec, 2 sec, 8 sec, and 10 sec).



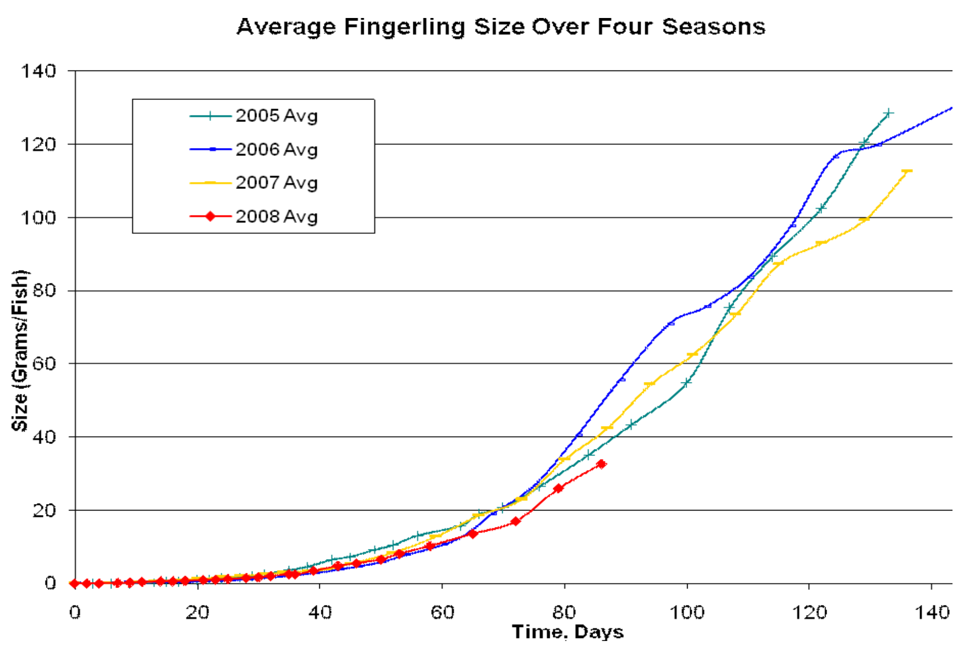
Results at a glance...

- *The Clemson University Partitioned Aquaculture System (PAS) has proven to be particularly well-suited for production of channel catfish fingerlings. Growth is excellent, with fingerlings reaching approximately 140 g/fish (300 pounds/100 fish) in 4 months of growth. The semi-confinement units tested at the University of Arkansas at Pine Bluff also increased the yield of fingerling catfish in ponds.*

As of 27 August 2008 the fingerlings in the three cells averaged 32.6 g/fish. Fry and fingerling densities ranged from 4.2 kg/m^3 to 80 kg/m^3 (0.26 pounds/ft^3 - 5 pounds/ft^3). Overall average fry to fingerling growth rates in the 2008 PAS configuration were statistically compared to fingerling growth observed in 2005, 2006 and 2007 growth trials (Figure 11).

Mississippi State University. The PAS as currently configured in the Clemson system consists of an extensive, shallow algal growth basin (representing about 95% of the total system water surface area), and an intensive fish-confinement area in which fish are confined at about 20 to 40 times the density of traditional ponds. In this objective, a modified PAS system has been constructed that confines fish at a lower density than the Clemson system. The "extensive PAS" was built with a lower proportion of the total system area in the algal growth basin (about 80% of the total area) and a higher percentage of area in the fish-holding area (fish will be held at only 5 times the density of traditional ponds). The overall concept is to take advantage of the fish confinement benefits of the PAS (facilitation of inventory, harvest, health management, and protection against predation) while avoiding the need for intensive system management. A parallel goal of this objective is to design and evaluate a

Figure 11. Fingerling growth in 2005, 2006, 2007 and 2008 seasons.



PAS-type system that can be constructed by retrofitting existing earthen ponds, rather than requiring new construction. This is accomplished by simply dividing an existing earthen pond into two sections with an earthen levee and then hydraulically connecting the two sections.

In year 2004, one system was constructed in an existing 0.324-ha earthen pond at the National Warmwater Aquaculture Center, Stoneville, Mississippi (Figure 12). A 2-m-high earthen levee was constructed to separate the pond into two sections: a 0.227-ha algal basin and 0.073-ha fish confinement area. Two, 3-m concrete-block sluiceways were constructed at either end of the cross-levee. One sluiceway was equipped with a six-bladed, 3-m long paddlewheel to induce water flow out of the fish confinement area and into the algal basin. The paddlewheel is 2 m in diameter and was installed to provide minimal clearance (less than 3 cm) with the sluiceway bottom and side walls. The paddlewheel can be operated at 1 to 6 rpm via a variable-speed, 3.7-kW hydraulic motor. The other sluiceway accommodates return flow from the algal basins into the fish confinement. Both sluiceways were fitted with double barriers of 2.54-cm expanded metal to prevent fish escape out of the confinement area. Aeration in the fish confinement area is provided by eight, highly efficient deep-water release membrane diffusers. Air to the diffuser array will be provided by a 3.7-kW blower through a manifold of PVC pipe. The aeration system is designed to provide a field oxygen transfer rate of approximately 4.5 kg oxygen/hour at a water temperature of 30°C and 2 mg/L ambient dissolved oxygen. That rate should be adequate to meet the respiratory needs of at least 8,000 kg of fish.

The system was stocked with approximately 4,000 kg of catfish to optimize operating parameters. A paddlewheel speed of 1 rpm resulted in a water flow of 15.2 m^3/minute through the fish-confinement basin. This flow rate was adequate to prevent accumulation of waste ammonia in the fish-confinement area at fish feeding rates of 150 kg/ha per day. At fish feeding rates of 175 to 200 kg/ha per day, total ammonia concentrations did not exceed 0.5 mg/L and dissolved oxygen concentrations remained above 3 mg/L.

In spring 2005, the system was stocked with 7,400 stocker-sized hybrid channel × blue catfish (24,710

Figure 12. The split-pond system at Stoneville, Mississippi. An existing 0.32-ha earthen pond was split into a waste-treatment basin (foreground) and a fish-holding section (barely visible over the dividing levee). The two basins are hydrologically connected by a low-speed paddlewheel (at the right) and a return-flow sluiceway (at the left).

fish/ha). Fish grew from an initial average weight of 0.08 kg/fish to an average of 0.78 kg/fish in a 6-month growing season. Total harvest weight was 5681 kg (18,940 kg/ha), for a net fish production of 5089 kg (16,960 kg/ha). Fish survival was 99% at a feed conversion efficiency of 1.87 kg of feed/kg of fish produced.

In spring 2006, the system was stocked with 11,100 hybrid channel × blue catfish (37,065 fish/ha at an average weight of 50 g/fish). As of August 23, 2006 fish averaged 0.43 kg/fish, giving a standing crop of approximately 16,000 kg/ha. In early September, a mechanical problem with the aeration system resulted in an acute nighttime dissolved oxygen depletion in the system and about half the fish standing crop was lost. The system was restocked with an equal number and weight of channel catfish to continue growout.

Results at a glance...

- *A version of the PAS system, called the split-pond, can be constructed by modifying existing earthen ponds. Net annual fish production in the system has ranged from 17,000 to almost 20,000 kg/ha (15,000 to 18,000 pounds/acre) at feed conversion ratios less than 2.0.*

In spring 2007, the system was stocked with 9500 stocker-sized hybrid channel × blue catfish (29,320 fish/ha; average weight 80 g/fish). Fish were harvested in mid-November, 2007. Approximately 98% of the standing crop was harvested on the first seine haul. Total harvest weight was 7,275 kg (22,742 kg/ha) for a net fish production of 6,253 kg (19,479 kg/ha). Average fish weight at harvest was 0.91 kg/fish. Significant fish loss to *Edwardsiella tarda* infections in the last three weeks of growout reduced fish survival to 85% and feed conversion to 1.99. If those late-season losses are added to the final production (that is, if fish had been harvested 3 weeks earlier), net production would have been approximately 23,000 kg/ha with a feed conversion ratio of approximately 1.7. Maximum daily feeding rates averaged approximately 300 kg/ha in August and early September, yet total ammonia-nitrogen rarely exceeded 1.5 mg/L.

The system was renovated in winter 2008 to repair eroded embankments. The re-built system in 2008 consisted of a 0.065-ha fish confinement area and a 0.219-ha waste-treatment area, providing a total system area of 0.283 ha. In spring 2008, the system was stocked with 8750 stocker-sized hybrid channel × blue catfish (30,887 fish/ha; average weight 88 g/fish). Fish were offered feed to satiation daily starting 9 April. Fish were harvested 30 October 2008. Total harvest weight was 6,933 kg (24,432 kg/ha) with an average weight of 0.82 kg/fish. Net production was 6,153 kg (21,686 kg/ha). Survival was 97% with an feed conversion ratio of 1.90. Once again, maximum daily feeding rates averaged more than 300 kg/ha for several weeks in August and early September, yet total ammonia-nitrogen rarely exceeded 1.5 mg/L. The mechanism for efficient nitrogen removal from the system is not known.

In addition to good fish production and few water-quality problems, the Stoneville "split-pond" system offers advantages related to confining the fish into a smaller area than in traditional ponds. The fish-confinement area can be isolated from the rest of the pond, making it easier and far less expensive to use certain disease therapeutants because only about 15 to 20 percent of the total pond water volume is treated. Fish in the confinement area are also easier to protect from bird predation and harvesting is quicker and more efficient. These attributes, combined with fish production characteristics that exceed those achieved in traditional ponds, make the split pond an attractive alternative for commercial catfish culture. Construction of a commercial-sized, 2.4-ha split-pond system at Stoneville is complete and will be operational in the summer of 2009.

Objective 1b. *Installation of low-cost, semi-confinement systems in commercial-scale, earthen ponds.*

University of Arkansas at Pine Bluff. Five confinement systems were installed in research ponds at the UAPB Aquaculture Research facility to determine whether physically separating fish by size group with a pond confinement system would result in improved yield, survival, feed conversion ratio, and growth compared to normal multiple-batch culture. This study consisted of ten, 0.1-ha ponds; five were control ponds and did not have barriers. The five treatment ponds had a 1.27-cm × 2.54-cm PVC-coated wire mesh barrier that partitioned off a third of the pond. In the treatment ponds, fingerling catfish were reared in the smaller portion of the pond and larger carryover fish were stocked in the remaining larger portion of the pond. The fish in the control ponds were allowed to co-mingle as in traditional multiple-batch culture. Ponds were seined every 2 months during the growing season and average weights were calculated to estimate growth. After harvest, survival and FCR were calculated. The facility was stocked on April 28, 2005 and the study terminated on October 18, 2005.

Mean net yield of the fingerlings, total feed fed (kg/ha), and mean daily feeding rate (kg/ha/d) were greater in the confinement system than in the control ponds (Table 2). However, there were no differences in net yield of carryover fish, overall feed conversion ratio, or survival of either size of fish in the confinement system as compared to the control ponds. There were no significant differences in total ammonia, un-ionized ammonia, nitrite, nitrate, total nitrogen, and total phosphorus concetrations. The confinement system appears to offer potential to increase yield of fingerling catfish because of greater feed consumption in the system when the barrier is used to separate size classes. A partial budget analysis with price sensitivities was completed for the first study of raising fish in the confinement system. When fingerlings were physically separated from larger, carryover fish, significantly greater yields of fingerling (stocker) fish were achieved. There were no significant differences in survival, feed conversion ratio, or growth. The partial budget analysis revealed a positive net change of $367/ha or $38,125 for a 104-ha catfish farm at a market price of $1.54/kg of additional stockers produced (Table 3).

Another study was initiated in the spring of 2006 to compare production of catfish within the barrier system to open pond culture. This will help determine if there are any potential culture advantages to confining catfish to one-third of the total pond area. Stocker-sized catfish (136 g) were stocked into the smaller section of the confinement ponds and in the open ponds at a rate of 11,115 fish/ha. Yields, feed

Table 2. Selected data of fingerling and carryover fish in control and confinement ponds. Values with the same letter in the row are not significantly different. All values are mean ± SD.

	Control	Confinement
Net Yield (kg/ha)		
Fingerlings	1,788 ± 448a	2,391 ± 158b
Carryover	4,882 ± 490a	4,712 ± 679a
Total Feed Fed (kg/ha)	11,095 ± 541a	12,189 ± 579b
Mean Daily Feeding Rate (kg/ha/d)	62 ± 3a	67 ± 3b
Feed Conversion Ratio	1.67 ± 0.2a	1.68 ± 0.1a

conversion ratios, and daily growth of food fish were significantly lower in the confinement system than in the open ponds, but there were no differences in survival (Table 4). However, seining efficiency was significantly greater for the confinement system.

The partial budget analysis (Table 5) showed a change in revenue of -$2,186/ha (-$227,334 across

Table 3. Partial budget analysis for the confinement system on a 104-hectare catfish farm, Study 1.

Parameter	Description	Unit Cost($)	Quantity	Benefit/Cost ($)/Farm	Benefit/Cost ($)/ha
Additional costs					
Variable Costs					
	Feed	250/ton	107	26,750	257
	Interest	0.10	1	2,675	26
Fixed Costs					
	Depreciation	179,336	10 yrs	17,934	172
	Interest			11,253[a]	108
Reduced revenue[b]				0	0
Total additional costs and reduced revenue				58,612	563
Additional revenue					
	Stockers	1.54/kg	62,816	96,737	930
Reduced costs[c]				0	0
Total additional revenue and reduced costs				96,737	930
Net change in profit				38,125	367

[a] Average annual interest based on a loan amortized for 10 years at 10% interest.
[b] There are no reduced costs from adopting the barrier system.
[c] There is no reduced revenue since there is an increase in yield resulting from the confinement system.

Table 4. Yield, survival, growth, mean weight and percent of the population that is sub-marketable at harvest of stocker catfish stocked in the confinement system and in open control ponds, Study 2. Values with the same letter in the row are not significantly different. All values are ± SD.

Production parameter	Unit	Confinement	Open
Gross yield	kg/ha	6,783 ± 345a	8,315 ± 254b
Net yield	kg/ha	5,274 ± 345a	6,806 ± 254b
Survival	%	80 ± 0.05a	85 ± 0.02a
Growth	g/d	3.69 ± 0.3a	4.29 ± 0.2b
Mean weight at harvest	g	759± 62a	884 ± 34b
Sub-marketable	%	22 ± 8a	13± 5a

a 104-ha farm) at a food fish market price of $1.54/kg. Single-batch grow out of catfish stockers, under the conditions of this study, was not economically feasible in spite of the improved seining efficiency. Additional research is needed to determine whether refinements to the system can achieve yields similar to those in open ponds.

To evaluate scale-up issues, a commercial size barrier system was constructed on a catfish production

Table 5. Partial budget analysis for the confinement system on a 104-hectare catfish farm, Study 2.

Parameter	Description	Unit Cost($)	Quantity	Benefit/Cost ($)/Farm	Benefit/Cost ($)/ha
Additional costs					
Variable Costs		0	0	0	0
Fixed Costs					
	Depreciation	179,336	10 yrs	17,934	172
	Interest			11,253[a]	108
Reduced revenue	Foodfish	1.54/kg	159,328 kg	245,365	2,359
Total additional costs and reduced revenue				274,552	2,640
Additional revenue[b]		0	0	0	0
Reduced costs					
	Feed	250/ton	171.7	42,925	413
Interest			0.1	4,293	41
Total additional revenue and reduced costs				47,218	454
Net change in profit				-227,334	-2,186

[a] Average annual interest based on a loan amortized for 10 years at 10% interest.
[b] There is no additional revenue from adopting the barrier system.

Figure 13. Construction of a commercial-scale confinement system in a 6-ha earthen pond in Chicot County, Arkansas.

facility in Chicot County, Arkansas (Figure 13). The barrier system was constructed in a 6-ha earthen pond that was under renovation. Construction of the barrier system was completed by mid-October 2006. The barrier system was stocked with channel catfish on 21 March 2007. Approximately 2 weeks after stocking, it was evident that catfish were escaping from the barrier system. Within a month, the number of catfish outside the barrier had increased to a critical level and the farm manager had to start feeding fish on both sides of the barrier. We found a 5- to 7-cm gap between the barrier and the pond bottom along a deep depression about mid-way across the pond where the fish were congregating. This area was the deepest part of the pond along the transect where the barrier was constructed. Due to the escapement problem, the barrier was removed from the pond and the study was terminated.

Several factors may be responsible for barrier failure, and these factors may seriously affect the usefulness of this practice. First, poor compaction of the soil during pond renovation resulted in low spots being filled with loose fill material. Second, the barrier was not buried deep enough to get at least 15 cm below the hard-pan bottom of the deepest section of the pond. After all the loose fill material was swept clean from this area by fish activity, the bottom of the fence was exposed. In smaller research ponds over two separate seasons of production we never had a fish escape. However, because the fencing material was only 1.8 m, we had to decrease the height of the standpipe and thus the pond depth to keep fish from going over the top. If we would have buried the commercial pond barrier deep enough to prevent this problem, we would have had to drop the level of the standpipe by at least 0.3 m.

An alternative confinement system was designed and constructed in two, 0.-ha research ponds during the spring and early summer of 2008 to address the escapement issue and to take advantage of the benefits related to segregating fish by size. The current design (Figure 14) includes two, 18-cm

Figure 14. Overview of the circular production units constructed in a 0.25 acre pond at the University of Arkansas at Pine Bluff, Aquaculture Research Facility.

(7-inch) diameter confinement systems constructed of 1.8-m-high PVC-coated wire mesh fastened to steel fence posts and imbedded in a circular concrete slab. Each production unit (pen) was fitted with a sliding gate mechanism that provides for the attachment of a standard harvesting sock for fish movements. Also, each pen includes a simple feeding tube to direct blown feed to the pen, a feed containment ring, and protective bird netting. Standard paddlewheel aeration was positioned so that aerated water would circulate through both the pens (Figure 14). Construction of the pens was completed in mid-July, 2008.

Channel catfish (1,500 fish, 69 g/fish) were stocked into one pen in each pond on 21 July 2008. This corresponds to a fish density of approximately 350 fish/m^3 (10 fish per cubic foot) and a stocking density of 13,400/ha of pond. These fish have responded well to the system and production data is currently being collected. The second pen in each pond was stocked with larger channel catfish (1,500 fish weighing 350 g/fish) on 21 August 2008. These fish have also responded well to the system. Production data will be collected through the remainder of the 2008 growing season.

Objective 1c. *Fry and food fish production using in-pond raceways with the option for culturing supplemental species in open-pond areas.*

Louisiana State University. As part of an effort to improve the efficiency of intensive pond aquaculture systems, the potential for double-cropping freshwater prawns in Louisiana was evaluated. Juvenile prawns were stocked into twelve, 400-m^2 ponds at a nominal density of 2.5/m^2 on 7 May and fed a 32%-protein sinking feed at a daily rate of 25 kg/ha. Vertical substrate at 25% of pond surface area was installed in each pond. Ponds were aerated nightly. Prawns in six ponds were harvested between 3-4 August (after 88-89 d) and subsequently re-stocked with prawn juveniles that were cultured until November 7-9 (91-93 d); prawns in six ponds were cultured from early May until early November (184-186 d). Prawns harvested in the single-crop treatment were 55 g each, whereas prawns harvested from the first (early) crop were 24 g each and the prawns from the second (late) crop were 29 g each. In aggregate, production from double-cropped ponds was 822 kg/ha and production from single-cropped ponds was 568 kg/ha. An economic evaluation of the two cropping systems is being conducted. More prawns were produced in the double-crop treatment, but the prawns were of lower average weight than the prawns produced in the single-crop treatment. The additional biomass in the single-crop treatment will be evaluated relative to the price premium that can be obtained for larger animals. Also during 2007, development of the Partitioned Aquaculture System (PAS) continued, including automation of data acquisition. In particular, development of a cost effective system to monitor and manage critical water quality parameters, including dissolved oxygen, pH, and nitrite nitrogen continued. Development of linkage between this project and a related project in which autonomous vehicles were used to capture water quality in ponds and natural water bodies is in progress.

A 0.3-ha (0.75-acre) Partitioned Aquaculture System, with three fish-culture raceways, were stocked with channel catfish, blue catfish, and channel × blue catfish hybrid fingerlings in separate raceways between 29 June and 19 July. Average stocking size and density were as follows: channel catfish, 29 g and 5,000 fish/raceway; channel × blue catfish hybrids, 32 g at 5,000 fish/raceway; and blue catfish, 36 g and 4,683 fish/raceway. The collective stocking density of catfish was 14,683 fish (48,300/ha). Catfish were fed daily, generally as much as they would consume. In July 1,396 Nile tilapia weighing 391 kg (average weight = 272 g) were stocked into the open pond area of the system for algal control. After 533 days of culture, catfish were harvested.

Production of blue catfish and channel × blue hybrids were 2.4 times higher than for channel catfish (Table 6). Total catfish production of 4,570 kg equated to a yield of 15,014 kg/ha. Recovery rates of channel catfish from the PAS were low compared to blue catfish and channel × blue hybrids. No disease-related mortality was observed although wading birds were able to predate on some catfish. Feed consumption and subsequent growth of blue catfish and channel × blue catfish hybrids were 2 to 3 times higher than channel catfish which verifies finding from other studies that blue catfish and channel × blue hybrids appear to be better suited for high density cultivation. Feed conversion ratio of the system as a whole was 1.59. The presence of tilapia as biological filter-feeders in the open area of the PAS stabilized oxygen concentrations, and odiferous species of blue-green algae were rarely observed in the PAS. All tilapia died from cold water temperatures in January indicating that probably Nile tilapia overwintering in south-central Louisiana is remote.

Table 6. Recovery, size, and yield of channel, blue, and channel × blue catfish hybrids in three raceways in a 0.75-acre (0.3 ha) partitioned aquaculture system (PAS), Aquaculture Research Station, LSU AgCenter, Baton Rouge, LA.

Species	Number Stocked	Number Recovered	% Recovered	Total Weight of Fish (kg)	Average Size after 533 days (g)
Channel Catfish	5,000	2,126	43	783	368
Blue Catfish	4,683	3,088	66	1,824	590
C × B Hybrids	5,000	3,482	70	1.963	563
Total	14,683	8,696	59	4,570	

Objective 1d. *High intensity production in heterotrophic-based culture units.*

Louisiana State University. The performance of a heterotropic-based "biofloc" system consisting of eight 1.5-m^3 tank mesocosms stocked with tilapia (3.0 kg/m^3, 41 g/fish) was investigated in an indoor wet laboratory. Vigorous diffused aeration was provided to maintain solids in suspension, provide oxygen, and remove carbon dioxide. Settleable solids concentration was measured daily in each tank and maintained at eight different nominal concentrations (5, 10, 15, 20, 25, 50, 75, 100 mL/L) through intermittent operation of 80-L settling columns and removal of solids. The range of settleable solids concentration was equivalent to a range of total suspended solids concentration of about 250 to 1,000 mg/L. Daily feeding rate was increased weekly by 25 g/m^3 and water quality was measured weekly before feeding rate adjustments. The biofloc system operated effectively within arbitrarily established water quality limits for ammonia, nitrite, carbon dioxide, and dissolved oxygen concentrations across a broad range of solids concentration and feed loading. After 11 weeks and a daily feeding rate of 275 g/m^3, total ammonia concentration exceeded the pre-established criterion of 2 mg N/L in all tanks. For these indoor tank mesocosms, the sustainable maximum daily feeding rate is about 200 g/m^3. At daily feeding rates greater than 200 g/m^3, control of solids concentration became more difficult and water quality became more variable. Process instability was related to the development of filamentous bacteria that produced severe foaming associated with flocs with poor settling characteristics. As solids concentration increased, water respiration rate, nitrification rate, and solids retention time increased, and hydraulic retention time decreased. Increases in water respiration and nitrification rates were also related to increases in daily feeding rate. There was no effect of solids concentration on specific growth rate (1.27 %/day), final biomass density (9.8 kg/m^3), and feed conversion ratio (1.83). After a cumulative feed loading of about 12 kg/m^3 and a cumulative feed burden of about 130 kg/m^3, tilapia in all tanks displayed signs of respiratory distress and stopped feeding. All tilapia in one tank died. This loading limit was independent of solids concentration. Hypotheses offered to explain this effect include combined metal toxicity related to low hardness, nitrate toxicity, or some factor associated with the accumulation of dissolved organic matter. Within three days of a 50% dilution of tank volume, fish resumed feeding, indicating that dilution sufficiently reduced the concentration of the factor that caused cessation of feeding.

Based on the findings of 2006 biofloc study, the effect of cumulative feed burden (CFB) on the performance of a recirculating biofloc (a combination of suspended solids and attached microorganisms) tilapia system was investigated in eight 1.5-m3 indoor tanks stocked with tilapia (5.1 kg fish/m^3, 183 g/fish) and cultured for 21 weeks. All tanks were vigorously aerated to provide oxygen (DO, 6.4-6.8 mg/L), homogeneous mixing of solids, and CO_2 stripping. Each tank was managed at one of eight CFBs. CFB is a measure of water use intensity and is calculated as the daily feeding rate (g/day) divided by daily effluent (water replacement) rate (L/day). Culture tanks were managed with a CFB of 1, 2.5, 5, 10, 15, 25, 50, or 100 g/L. CFB was managed by increasing the daily water exchange rate with the increase in daily feeding rate. The daily feeding rate was initially 85 g/m^3, increased weekly by 15 g/m^3, and ended at 325 g/m^3. Water quality (TAN, NO_2-N, NO_3-N, TSS, pH, total alkalinity, CO_2, water respiration, temperature and DO) was measured weekly. Settleable solids were controlled at concentrations less than 100 mL/L by intermittent operation of an 80-L settling column. Alkalinity was maintained near a targeted level of 150 mg/L as $CaCO_3$ by weekly additions of $NaHCO_3$.

The NO_2-N, pH, and alkalinity increased with a decrease in CFB, and NO_3-N, TSS, water respiration, and CO_2 decreased. Higher mean NO_2-N concentrations were observed in tanks with CFBs of 2.5 and 1. Nitrite concentration was negatively correlated with a decrease in TSS. The increased water exchange rate (i.e. shorter solids retention time, SRT), associated with low CFBs, likely resulted in a loss of nitrifying bacteria in the effluent that exceeded the ability of remaining nitrifying bacteria to process substrate inorganic nitrogen, thus resulting in significant accumulation of nitrite in tanks with a CFB of 2.5 and 1. Findings of this study indicated that a CFB of 5 or higher was needed to maintain satisfactory water quality conducive to fish production in biofloc recirculating systems.

United States Department of Agriculture-Stuttgart (formerly at Pine Bluff). An intensively-managed, microbial-based production system has been used successfully to culture penaeid shrimp and tilapia, and appears to have potential application in growing catfish. When used for penaeid shrimp or tilapia production, the microbial floc that develops in the culture unit serves as a sink for ammonia-nitrogen and as a supplemental food source for the culture species. While it is unlikely that catfish will derive nutritional benefit from the microbial floc, bacterial control of ammonia-nitrogen may permit increased catfish stocking and feeding rates.

Nine raceways (4.6 m × 9.2 m × 0.9-m water depth) with semi-circular ends that are equipped with a center divider and lined with HDPE were filled with well water on 6 April 2005 and each fertilized with 0.32 kg 18-46-0 fertilizer. Stock salt (5 kg/tank) was added on 12 April 2005 and 12 August 2005. Each raceway was equipped with a 0.37-kW electric paddlewheel aerator that operated continuously. Well water was added periodically to replace evaporative losses.

In 2004, stocker channel catfish (un-vaccinated) stocked in the raceways suffered high mortality from ESC (*Edwardsiella ictaluri*). Channel × blue hybrid catfish were stocked in 2005 because they appear more resistant to ESC. Hybrid catfish (mean weight 0.085 kg/fish), obtained from the ARS Catfish Genetics Research Unit, Stoneville, Mississippi, were stocked on 13 April 2005 at 25, 50, 75, 100, 125, 150, 175, 200, or 225 fish/raceway. A stocking error was detected for the 125-fish treatment, so that treatment was excluded. Fish were fed a 32% protein floating feed daily to apparent satiation. Beginning on 14 July 2005, white flour (0.7 kg/kg feed), as a flour-water slurry, was added daily as an additional source of carbon to raceways. Agricultural limestone (250 mesh) was added to raceways as needed beginning in mid-August to mitigate low water pH. All raceways were harvested by draining on 17 October 2005.

Hybrid catfish survival after 188 days ranged from 61.3 to 79.1%, with an average of 71.0% (Table 7). Mean individual weight at harvest appeared independent of stocking rate up to a stocking rate of 100 fish/raceway (2.4 fish/m^2), and decreased linearly ($y = 0.0017x + 0.6988$; $R^2 = 0.9835$) at stocking rates of 100 to 225 fish/raceway (2.4 to 5.5 fish/m^2) (Table 7; Figure 15). Fish biomass at harvest increased linearly with stocking rate (Figure 16). Feed conversion was variable, ranging from 1.8 to 6.3, and averaged 2.8. Daily feed rates ranged from 13 to 331 kg/ha. The feeding response by hybrid catfish in the raceways was variable and appeared unpredictable.

Mean weekly nitrite-nitrogen concentrations were low and independent of fish stocking rate (or the total amount of feed fed; Table 8). Nitrite-nitrogen concentrations remained low throughout the experiment except between days 60-80 when concentrations spiked as high as 5.78 mg/L NO_2-N. Mean weekly nitrate-nitrogen concentrations were high and increased as fish stocking rate increased

Table 7. Mean weight at harvest, gross and net yields, and survival of channel × blue hybrid catfish after 188 days. At stocking, mean fish weight was 0.085 kg/fish.

Fish/Raceway	Mean Weight (kg/fish)	Yield (kg/m^3) Gross	Net	Survival (%)
25	0.53	0.22	0.18	64.0
50	0.50	0.47	0.38	78.0
75	0.54	0.66	0.52	61.3
100	0.54	0.86	0.67	77.0
150	0.44	0.94	0.66	70.7
175	0.40	1.16	0.84	73.7
200	0.35	1.08	0.69	64.0
225	0.34	1.34	0.86	79.1

Figure 15. Mean individual weight at harvest of channel × blue hybrid catfish stocked at 25 to 225 fish in 41-m² raceways.

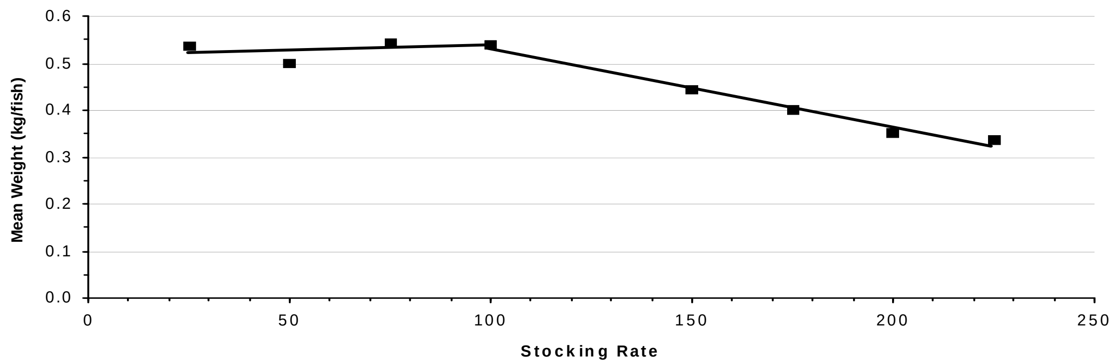
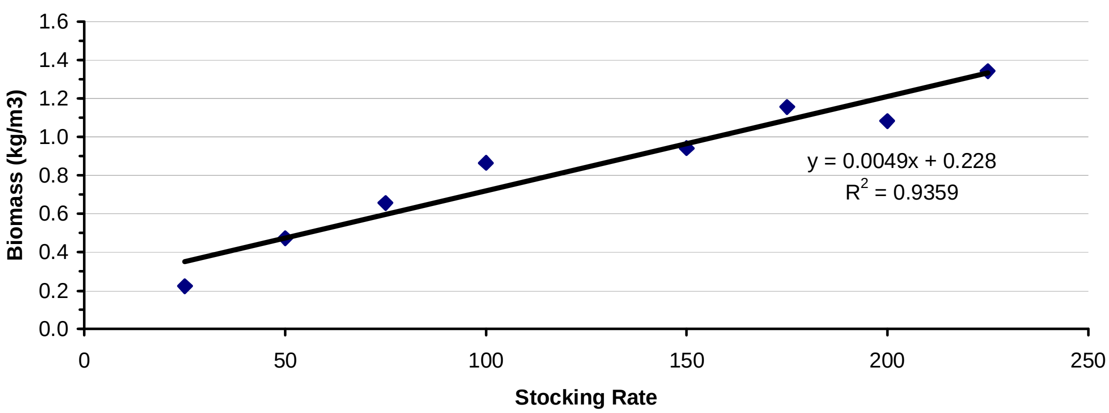


Figure 16. Relationship between final biomass and stocking rate of channel × blue hybrid catfish in 41-m² raceways.



(Table 8). Concentrations of NO_3-N were 0.30 mg/L or less through about day 60, after which concentrations increased. Mean weekly total ammonia-nitrogen (NH_3-N) concentrations were low and independent of fish stocking rate (Table 8). There were several spikes in total NH_3-N concentration, generally in the raceways stocked with greater than 150 fish. The concentration spikes were short-lived and likely inconsequential to stocked fish because pH values were less than 7.9, and often less than 7.0. A maximum of about 5% of the total NH_3-N would be present as un-ionized ammonia at the water temperatures when the concentration spikes were observed. Mean weekly total nitrogen (N) and organic N concentrations were high and each increased linearly as fish stocking rate increased ($R^2 = 0.855$ and $R^2 = 0.909$, respectively; Table 8). Total N and organic N concentrations increased throughout the experiment. Organic N was, on average, 59% of the total N concentration.

Table 8. Mean weekly concentrations of dissolved inorganic nitrogen and phosphorus, total nitrogen and phosphorus, organic nitrogen, pH, and chlorophyll *a* in raceways stocked with 25 to 225 channel × blue hybrid catfish.

Fish/ Raceway	NO_2-N	NO_3-N	NH_3-N	Total N	Organic N	PO_4-P	Total P	pH	Chlorophyll *a*
	mg/L								mg/m^3
25	0.390	13.88	0.03	30.91	16.60	0.26	1.07	7.30	1,241.6
50	0.056	7.19	0.29	22.57	15.03	0.16	0.93	7.50	908.1
75	0.197	9.66	0.01	25.77	15.90	0.08	0.74	7.29	1,264.4
100	0.108	12.31	0.01	32.08	19.65	0.24	1.03	7.28	803.2
150	0.225	16.83	0.02	43.13	26.06	0.27	1.38	7.07	1,223.8
175	0.289	18.75	0.03	45.23	26.15	0.15	1.11	7.01	1,126.8
200	0.106	21.60	0.35	53.08	31.04	0.57	1.50	6.74	1,461.0
225	0.205	28.82	0.38	67.43	38.02	0.76	2.00	6.64	1,454.5

Mean, weekly soluble reactive phosphorus was low and independent of fish stocking rate (or total amount of feed fed) below about 150 to 175 fish/ mean weekly concentrations increased linearly with increased fish stocking rate. Total phosphorus mean weekly concentrations ranged from 0.93 to 2.00 mg/L PO_4-P and increased linearly as stocking rate increased (R^2 = 0.809; Table 8).

Mean weekly early morning pH was 7.50 or less and decreased linearly as fish stocking rate increased (R^2 = 0.869; Table 8). During the first 100 days, mean, weekly early morning pH values were similar among raceways, and ranged from pH 7 to 8. After day 100, weekly early morning means became more variable and trended lower at stocking rates 150 fish/raceway and greater. Afternoon pH generally was 0.5 to 1.0 pH units greater than the morning pH.

Mean, weekly chlorophyll *a* concentrations were high and increased linearly (R^2 = 0.425; Table 8). Chlorophyll *a* concentrations increased throughout the experiment in all raceways, attaining concentrations of 1,000 to 2,500 mg/m^3 at the end of the experiment. A combined photoautotrophic-autotrophic bacteria system appeared to control raceway water quality. Phytoplankton (photo-autrotrophic) removed dissolved inorganic nitrogen and inorganic carbon as alkalinity or carbon dioxide. Autotrophic bacteria involved in nitrification oxidize ammonia to nitrate in a two-step process mediated by bacteria of two distinct genera. The populations of nitrifying bacteria appear to have become established in two stages beginning with increasing populations of ammonia oxidizing bacteria around days 60 to 80 that produced a spike in nitrite-nitrogen concentrations. Populations of nitrite oxidizing bacteria lagged slightly, with concentrations of nitrate beginning to increase around day 80. Total ammonia-nitrogen remained low throughout the experiment.

Nitrification results in decreased pH values, which were more apparent in raceways with the higher stocking rates. Applications of agricultural limestone

Results at a glance...

- *A prototype bio-floc production system capable of producing up to 3.7 kg of fish/m^2 was developed at the ARS Aquaculture Systems Research Unit. This production is more than 10 times that possible per unit volume of water in traditional channel catfish ponds.*

were necessary in all raceways to mitigate the decrease in pH.

The 2006-2007 trial continued to investigate the effect of stocking rate on production of catfish in heterotrophic-based raceway units. Three stocking rates were selected based on the 2005-2006 results.

On 28 March 2006, raceways were stocked with stocker hybrid channel × blue hybrid catfish obtained from the ARS Catfish Genetics Research Unit, Stoneville, Mississippi. Stocking rate was 100, 300, or 500 fish/raceway (2.6, 7.9, or 13.1 fish/m^3). Treatments were assigned randomly to raceways. There were three replicates per treatment. At stocking, fish averaged 0.069 kg/fish. Fish were fed daily to apparent satiation (20 min.) with a 32% protein floating extruded feed. Fish that died during the first 6 weeks were replaced from excess fish from the original population that were held in a hoop net in a pond. Dead fish were counted and, if intact, weighed. Gross feed conversion was calculated as the total quantity of feed divided by the total weight of fish harvested plus mortalities. All raceways were harvested by draining on 30 October 2006, 216 days after stocking. Specific growth rate (SGR) was calculated using the formula: SGR = $100(\ln W_f - \ln W_i)/t$, where $\ln W_f$ is the natural log of the final individual weight, $\ln W_i$ is the natural log of the initial individual weight, and t is the duration in days.

Hybrid catfish survival and performance was poor (Table 9). Survival did not differ significantly among treatments and averaged 26.7%. Mean individual weight at harvest was independent of stocking rate over the range tested. Gross yield ranged from 0-0.96 kg/m^3, did not differ among treatments, and averaged 0.48 kg/m^3. Gross feed conversions ranged from 0.6-4.7, and did not differ significantly among treatments, and averaged 2.15. There was a curvilinear decline in feed conversion ratio with increased survival. Higher FCR was observed with lower fish survival. It was difficult to track low- level, chronic mortality accurately to use for adjusting feeding rates. The feeding response by hybrid catfish in the raceways was variable and appeared unpredictable and not as vigorous as with channel catfish. Maximum daily feed consumption (0.2-1.5 kg/raceway) was observed from early June in seven raceways to early July in two raceways. Daily feed consumption decreased thereafter and oscillated between 3-50% of the maximum. The reduction in feed consumption was attributed to reduction in fish biomass caused by mortality and the apparent inability of the channel × blue hybrid to adapt to the raceway environment.

Dissolved oxygen concentrations exceeded 40% of saturation throughout the experiment. Mean water quality variable concentrations (Table 10) did not differ significantly among stocking rates and were independent of feed and flour inputs. The absence

Table 9. Specific growth rate, mean weight at harvest, gross and net yields, and survival of channel × blue hybrid catfish after 216 days. Fish were stocked into raceways at 100, 300, or 500 fish/raceway (2.6, 7.9, or 13.1 fish/m^3). At stocking, mean fish weight was 0.069 kg/fish.

Treatment (fish/m^3)	SGR (%)	Mean Weight (kg/fish)	Yield (kg/m^3) Gross	Net	Survival (%)
2.6	0.60	0.33	0.30	- 0.06	26.7
7.9	0.58	0.24	0.60	0.06	33.2
13.1	0.61	0.27	0.55	- 0.12	20.2

of treatment effects on water quality variables was attributed to the lack of significant differences among treatment total feed input.

The high mortality of the channel × blue hybrid catfish combined with their variable and unpredictable feeding behavior indicates that a raceway production system environment is inappropriate for the channel × blue hybrid catfish. Thus, treatment effects were unable to be expressed. Consequently, fish production characteristics and water quality variable responses were similar among treatments. The high chlorophyll *a* and nitrate concentrations observed in all raceways indicated that a combined photoautotrophic-autotrophic bacteria system controlled raceway water quality. Phytoplankton removed dissolved inorganic nitrogen and inorganic carbon. Autotrophic, nitrifying bacteria oxidize ammonia to nitrate in a two-step process mediated by bacteria of two distinct genera. The populations of nitrifying bacteria appeared to have become established contemporaneously between days 21-49 that produced a transitory spike in nitrite-nitrogen concentration and increased nitrate-nitrogen concentration. Total ammonia-nitrogen generally remained low throughout the experiment, with the exception of several transitory spikes in concentration.

The 2007-2008 trial continued to investigate the effect of channel catfish stocking rate on production and water quality in mixed suspended growth (bio-floc) raceway culture units. Three stocking rates were selected based on the 2005-2007 results.

Nine raceways (35.1 m^2; 28.1 m^3) that have semi-circular ends, are equipped with a center divider, and are lined with HDPE, were filled with well water on 17 Mar 07. On 19 Mar, each raceway was fertilized with 0.32 kg 18-46-0 fertilizer. Salt was added to each raceway to ensure chloride concentration exceeded 100 mg/L. A continuously operating blower system was installed to aerate raceways instead of an electric paddlewheel aerator. One 1.865-kW blower per three raceways provided air through a diffuser grid on the bottom of each raceway. Well water was added only periodically to replace evaporative losses.

Table 10. Mean weekly concentrations of dissolved inorganic nitrogen and phosphorus, total nitrogen and phosphorus, total settleable solids, pH, and chlorophyll *a* in raceways stocked with 2.6, 7.9, or 13.1 channel × blue hybrid catfish/m^3. Means did not vary among treatments ($P > 0.05$).

	Fish/m^3		
Variable	2.6	7.9	13.1
Ammonia (mg NH_4-N/L)	1.36	0.57	1.25
Nitrite (mg NO_2-N/L)	2.74	1.81	2.51
Nitrate (mg NO_3-N/L)	12.75	13.21	11.49
Soluble Reactive Phosphorus (mg PO_4-P/L)	3.37	3.15	1.18
Total Nitrogen (mg/L)	36.20	37.80	36.20
Total Phosphorus (mg PO_4-P/L)	6.97	7.64	4.58
Total Settleable Solids (mL/L)	33.7	44.1	52.4
pH	7.39	7.41	7.43
Chlorophyll *a* (mg/m^3)	1733.50	2421.20	1663.40

On 22 March 07, raceways were stocked with fingerling NWAC 103 strain channel catfish (*Ictalurus punctatus*) that had been vaccinated against *Edwardsiella ictaluri* and were purchased from an Arkansas catfish producer. Stocking rate was 100, 200, or 300 fish/raceway (2.9, 5.7, or 8.5 fish/m^2). Treatments were assigned randomly to raceways. There were three replicates per treatment. At stocking, fish averaged 0.013 kg/fish. Fish were fed daily to apparent satiation with a 32% protein floating extruded feed. Dissolved oxygen and temperature were measured on a daily basis, and water quality variables (pH, TAN, NO_2, NO_3, SRP, total settleable solids, and chlorophyll *a*) were measured on a weekly basis. In mid-June, most of the fish in one replicate of the 5.7 fish/m^2 treatment died overnight; an undiagnosed disease was the suspected cause as dissolved oxygen and water quality variable concentrations were within acceptable limits. Data from this replicate were excluded from analyses and reporting.

At harvest, 238 d after stocking, catfish net yield increased linearly (R^2 = 0.87) from a mean of 1.0 to 3.7 kg/m^3 as stocking rate increased from 2.9 to 8.5 fish/m^2 (Figure 17). Mean final individual weight (semi-log transformed) decreased linearly (R^2 = 0.44) from a mean of 0.57 to 0.50 kg/fish with increased stocking rate (Table 11). However, specific growth rate of fish did not differ among treatments. Fish survival varied among raceways and ranged from 48 to 73%, but did not differ significantly among treatments. Net fish yield was affected by fish survival, increasing linearly as final fish density increased from 0.9 to 6.7 fish/m^2.

Raceway water quality was impacted significantly by channel catfish stocking rate, primarily because feed application increased linearly with stocking rate (Table 12). However, concentrations of water quality variables were within acceptable limits throughout the trial and did not appear to inhibit fish growth. Chlorophyll *a* and total settleable solids mean concentrations did not differ among treatments. Mean nitrite- and total ammonia-nitrogen

Figure 17. Relationship between net yield and stocking rate of channel catfish (*Ictalurus punctatus*) grown in a mixed-suspended growth (bio-floc) system in nine HDPE-lined raceways (35.1 m^2; 28.1 m^3) for 238 days.

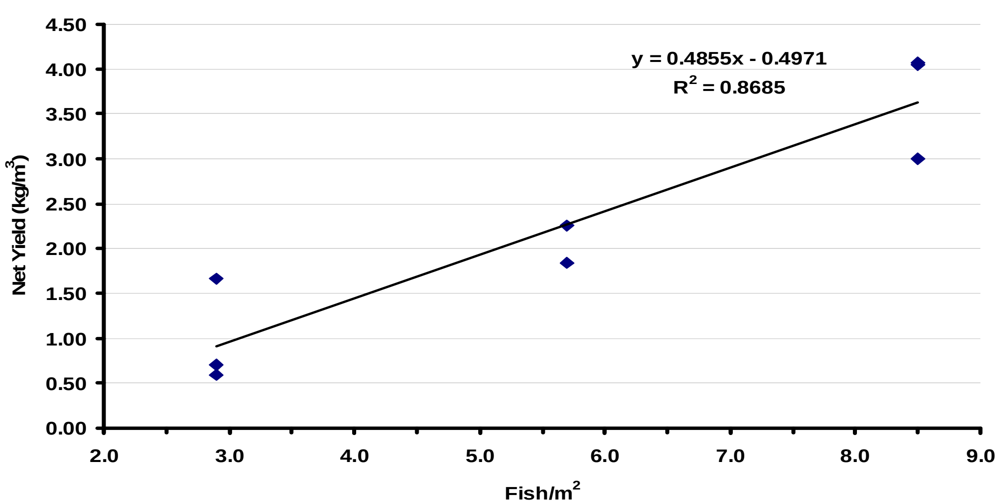


Table 11. Specific growth rate, mean weight at harvest, gross and net yields, and survival of channel catfish after 238 days. Fish were stocked into raceways at 100, 300, or 500 fish/raceway (2.9, 5.7, or 8.5 fish/m^3). At stocking, mean fish weight was 0.013 kg/fish.

Treatment (fish/m^2)	SGR (%)	Mean Weight (kg/fish)	Net Yield (kg/m^3)	FCR	Survival (%)
2.9	1.58	0.57	1.0	2.2	48.2
5.7	1.50	0.47	2.0	1.8	65.9
8.5	1.52	0.50	3.7	1.7	72.7

Table 12. Least squares mean weekly concentrations of dissolved inorganic nitrogen and phosphorus, total settleable solids, pH, and chlorophyll *a* in raceways stocked with 2.9-8.5 channel catfish/m^2.

	Fish/m^2		
Variable	2.9	5.7	8.5
Ammonia (mg NH_4-N/L)	0.30	0.25	0.49
Nitrite (mg NO_2-N/L)	0.25	0.23	0.42
Nitrate (mg NO_3-N/L)	5.98	7.59	19.20
Soluble Reactive Phosphorus (mg PO_4-P/L)	3.10	4.08	5.65
Total Settleable Solids (mL/L)	20.4	31.6	34.2
pH	7.77	7.72	7.51
Chlorophyll *a* (mg/m^3)	690.8	1,014.5	1,047.2

concentrations did not differ significantly among treatments. Mean nitrate-nitrogen (R^2 = 0.88) and soluble reactive phosphorus (R^2 = 0.81) increased with increasing stocking rate because of increasing amounts of feed fed. Nitrate-nitrogen began to accumulate in raceways beginning in mid-June in response to nitrification. Increased nitrification was inversely related to mean water pH. Fine-mesh agricultural limestone was added to raceways as needed to maintain pH.

In March 2008, the ARS Aquaculture Systems Research Unit, Pine Bluff, AR, was redirected to the Harry K. Dupree Stuttgart National Aquaculture Research Center, Stuttgart, AR. During April-May, nine HDPE-lined 18.6-m^2 (3.05 m × 6.10 m × 0.84 m;15.5 m^3) tanks were constructed to further investigate the effect of channel catfish stocking rate on production and water quality in an intensive mixed-suspended growth system. One 1.865-kW blower/three raceways provided air continuously through a diffuser grid on the bottom of each raceway. Tanks were filled on 11-12 June Tanks were stocked on 18 June 2008 with fingerling NWAC 103 strain channel catfish (*Ictalurus punctatus*) vaccinated against *Edwardsiella ictaluri* and purchased from an Arkansas catfish producer. Fingerlings (0.05 kg/fish average weight) were stocked in triplicate tanks at 7.5, 12.5, or 17.5 fish/m^2. Fish are fed daily to apparent satiation with a 32% protein floating extruded feed. Water quality variable concentrations are measured on a regular basis. Well water is added only periodically to replace evaporative losses. In late July, fish were diagnosed with *Edwardsiella ictaluri*; fish in all tanks were fed for 10 d with Aquaflor-treated feed. Observed mortality from this disease outbreak was low. Harvest is planned for October-November 2008.

Objective 2. *Improve equipment to enhance culture.*

Objective 2a. *Motor-powered U-tube aerator for commercial-scale channel catfish ponds.*

United States Department of Agriculture-Stoneville. A prototype U-tube (Figures 18 and 19) was constructed and installed in a 0.4-ha pond at the National Warmwater Aquaculture Center, Stoneville, Mississippi. The U-tube was fabricated from a 91-cm-diameter, corrugated, galvanized culvert that was installed vertically in a 6-m deep bore hole made in the pond bottom. The unit was powered by a 240-volt, 3-phase, 3.72-kW, helical-geared Flender motor. The motor was vertically mounted on a 91-cm-diameter culvert elbow that was attached to the tube with a 25-cm band clamp. The motor turned a three-vane impeller attached to a 61-cm long × 5-cm diameter unsupported, steel shaft. Water level was maintained at the top of the elbow. The impeller speed was controlled by an in-line, general purpose, open-loop vector, AC-drive (Safetronics Model GP10). With an impeller speed of 150 rpm at 60 Hz, the motor drew 12.7 amps and produced 3.99 kW with a water output of 30.6 m^3/min (Table 13).

Figure 18. Prototype U-Tube with pond empty.

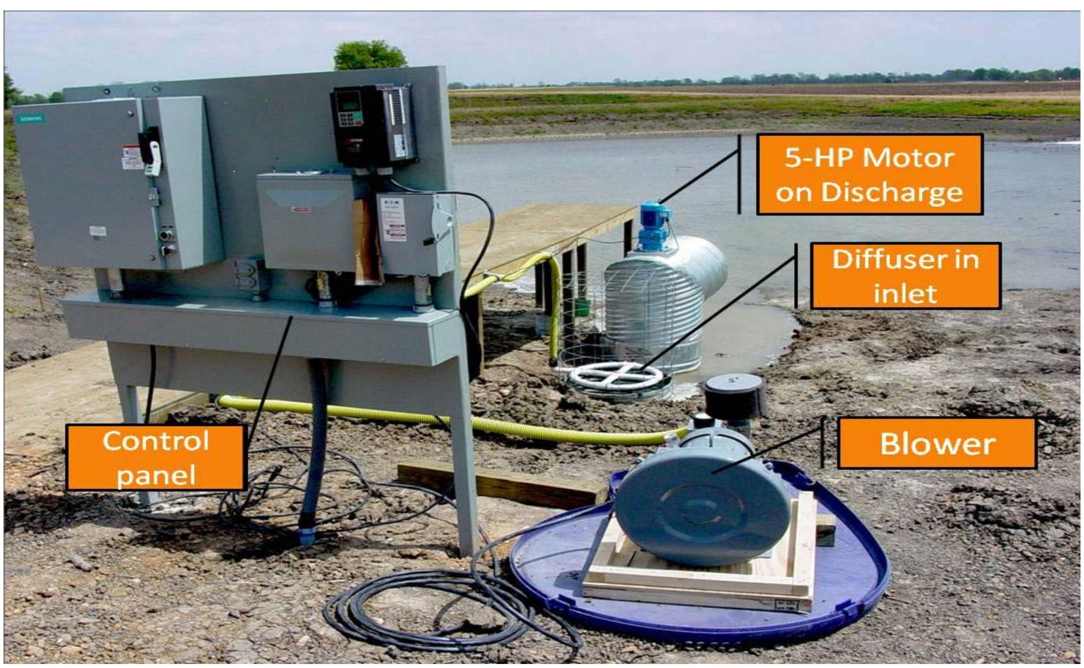


Figure 19. Prototype U-Tube with pond full. Discharge can be seen.

Table 13. Operational data for a prototype motor-powered U-tube aerator.

Impeller (rpm)	Motor Amperage	Volts	kW	Water Velocity (m/sec)	Water Output (m^3/min)	Pump Efficiency (m^3/kW · hr)
150	12.7	230	4.00	0.78	30.6	459
125	10.6	205	2.55	0.60	23.8	560
100	8.1	148	1.43	0.45	18.1	759

Pump efficiency increased as impeller speed decreased, but both total output and water velocity decreased. It was determined that the higher velocity was necessary to entrain the volume of air needed to optimize performance. Air was provided by a 3.7-kW, 3-phase blower to diffusers located at or below the mouth of the "down-leg" of the U-tube, which was level with the pond bottom and approximately 1.5 m below the water surface.

Oxygen transfer efficiency tests were conducted using a variety of diffuser types and configurations. The optimum conditions produced an increase in dissolved oxygen of 2.3 mg/L (outflow DO minus inflow DO) and a standard aeration efficiency of 1.01 kg O_2/kW · hr. These results were encouraging but less than desired for commercial application.

Two problems were noted during testing of the initial prototype during Year 1. First, it was desired to eliminate obstructions in the tube to enhance water flow. Thus, the impeller shaft was kept relatively short because it had no lateral support near the end. This resulted in the impeller being located slightly above the bottom of the horizontal (discharge) end of the elbow. As the air:water ratio increased, back-flow from the pond through the mouth of the discharge was observed. This decreased water flow through the tube, and at higher air:water ratios, flow through the tube ceased entirely. Second, using this design, the water level is critical. If the water level dropped below the top of the discharge elbow, flow rate decreased. If the water level rose more than 15 cm above the top of the elbow, the motor could be damaged. For commercial application, the unit should have at least a 60 cm "freeboard" to allow for normal variations in pond water level.

During Year 2 (1 August 2005 – 31 August 2006), two major design modifications were introduced to eliminate the problems identified in Year 1. First, the shaft length was increased to 91 cm. The only concern was the potential for instability with a longer, unsupported shaft. This was not observed. The longer shaft was stable and apparently eliminated the "backflow" problem seen with the shorter shaft. Second, a 60 cm diameter × 41 cm insert was built and installed in the "down" leg of the tube. This did provide a faster water velocity in the "down" leg, allowing for a greater input of air into the system. Tests are now underway to quantify the impact of these modifications. While funding through SRAC ended in July 2006, work on this project is continuing under USDA/ARS funding.

In addition to further testing of the completed modifications, three additional design changes are being considered. First, a submersible motor placed in the mouth of the "down" tube would allow for larger pond water level fluctuations. This would be desirable in commercial applications. Suitable motors are being examined. Second, a venturi will be examined as a means of introducing gas into the water, eliminating the need for a blower. This would both reduce the overall horsepower requirements (increasing efficiency) and eliminate a motor that is a potential cause of failure. Third, the use of pure oxygen (instead of air) will be examined. While the economics may not justify this for routine aeration, the use of pure oxygen in an emergency situation could eliminate the need for a tractor-powered aerator.

Objective 2b. *Low-head, low-speed paddlewheel aerator for crawfish ponds.*

Louisiana State University. A low-speed paddlewheel mixer is being designed and a horizontal circulator/aeration unit was acquired for evaluation in two 1.5 to 2 ha (4 to 5 acre) experimental crawfish ponds at the Aquaculture Research Station in Baton Rouge. Baffle levees are being constructed to configure the ponds so that water can be recirculated. Mixing patterns and water quality will be monitored during the 2006-2007 crawfish production cycle.

Because of rainfall during the summer of 2006 ponds would not sufficiently dry to support heavy equipment required to laser-level ponds and construct internal baffles necessary install paddlewheel mixers. Weather conditions were more favorable in during summer 2007, and baffles were constructed in two large experimental crawfish ponds to accommodate a paddlewheel mixer and a submersible turbine mixer, respectively, in each pond. Mixing patterns, water quality and nutrient budgets will be determined in the mixed and non-mixed control pond during 2007-2008 crawfish production season.

Paddlewheel mixer/blending units were installed in three large experimental crawfish ponds at the Aquaculture Research Station each pond containing earthen baffles to re-circulate and mix water throughout each pond. Spatial distribution of dissolved oxygen (DO) in morning and afternoon was evaluated in March, May and June at 18 sampling stations in each pond. Mixers were operated continuously and DO were measured at each station in the morning and afternoon. Spatial variability in DO concentration throughout the ponds provided an index of the degree of water mixing. In March when significant amounts of cultivated rice forage was present and phtyoplankton density was low, oxygen concentration was more evenly distributed in mixed ponds (coefficient of variation, CV, associated with mean DO = 11%) than in non-mixed ponds (CV = 29%). However, in May and June when rice forage had been depleted and phytoplankton biomass increased, the variability of DO in mixed ponds (CV = 23%) was high as in non-mixed ponds (CV = 25%).

Objective 2c. *Low-power, electrically-enhanced seine to harvest market-sized channel catfish from commercial-scale ponds.*

Mississippi State University. The primary objectives for the first year of research were to design, manufacture, and test the electrical components required to build the individual modules that will power the electrically-enhanced seine. Three models of the power supply and electrical circuitry were designed, manufactured, and tested during this year. Through this process, the total weight of the electrical components needed to build an electrical module has been reduced over 60%. The power supply and electrical circuitry were miniaturized to fit on a 7.6 cm × 12.7 cm circuit board. A safety circuit designed to switch off the electrical power to a panel as it comes out of the water was added to the circuit board of the latest model of the system. The results of tests conducted in concrete vats indicate that the low powered electrical system (electrodes with no net) will repel adult catfish away from the attached electrodes. However, the system currently appears to be underpowered.

The miniature fish stimulator and power supply module was redesigned based on results of the first year. The system was further reduced in weight while maintaining the developed safety features. The output transformer was redesigned to operate at a higher frequency. In addition, the operating power was reduced from 60 to 10 watts. The results of vat tests using production-sized catfish indicated that the unit is only moderately effective as constructed. It was recently determined that the redesigned output transformer had a lower voltage than specified because of a tooling error by the manufacturer. Efforts are currently underway to get the manufacturer to correct this problem. The power supply and electrical circuitry will be re-tested once properly manufactured parts are obtained.

During the fall of 2006, efforts to eliminate manufacturing design flaws in the miniature transformer were unsuccessful; consequently, further development of the miniature transformer has been abandoned. During 2007, two new designs for a miniature fish stimulator were completed and the prototype units are currently being tested. Prototype-I operates without a transformer thus is the lightweight design. It is designed to stimulate catfish using a low voltage current produced by two AA-batteries. Prototype-II uses a power transformer to generate a high voltage AC pulse to stimulate catfish. The strength of the output current produced by both units can be controlled. The objectives of the new designs are to determine the efficacy of low-voltage system and to investigate the extent of the capabilities of the traditional transformer design. The ultimate goal is to develop an optimal design that is both lightweight and effective.

Problems were identified with both prototype-I and Prototype-II fish stimulators when they were tested in concrete vats stocked with varying numbers of adult-sized catfish. Prototype-I (no transformer, low voltage, and light-weight) was not effective. Fish appeared to sense the presences of the electrodes but were able to easily swim past them. The design of this unit is being reevaluated; it will likely be abandoned. Prototype-II (high voltage with a transformer) was only moderately effect in repelling approaching fish. Also, durability issues with the unit must be resolved. The unit is currently being modified and will be retested.

Objective 3. *Assess energy, material, and economic efficiency of production systems.*

Objective 3a. *Quantify energy, protein, and water use in traditional systems for channel catfish culture.*

Auburn University. During 2005, data on electricity and fuel use were obtained monthly from four catfish farmers. However, in early 2006, the graduate student unintentionally caused slight, cosmetic damage to some equipment on one of the farms. All four farmers subsequently refused to cooperate further.

Data on the cost of electricity and fuel used on catfish farms are now being sought by other means. Twelve farmers, two hatchery owner-operators, one processing manager, and one seining crew manager agreed to participate in the study. In early summer of 2006, questionnaires about energy use were sent to the new cooperators. We have received full responses from four farmers, one seining crew manager, one processor, and no hatchery operators. Data collection was delayed by the onset of the peak of the farming season, and will continue again in the fall when people are more accessible. We anticipate full participation except for the two farmers that have been unresponsive.

The questionnaires include items on total use of electrical power and petroleum specific to each aspect of raising channel catfish. The questionnaires make sure that the respondent lists only energy use for catfish. The questionnaires also include items on fish survival, food use, and yields where appropriate.

During late 2006 and early 2007, we obtained the responses to the questionnaire mentioned above. In all, we obtained amounts of gasoline, diesel fuel, natural gas, propane, and electricity used and production achieved over a 12-month period for one pond construction firm, two hatcheries, four farms, a feed mill, a custom harvesting crew, and a processing plant. These data were incomplete and we had to visit the respondents and interview them to obtain sufficient information.

Energy for pond construction was from diesel fuel. The contractor provided data on fuel used and area of ponds constructed in one year. This allowed the calculation of energy use per hectare of pond construction, and the energy expenditure was amortized over 20 years, the estimated service life of a pond. Hatchery operations used only electricity. The feed mill used mainly natural gas as an energy source. About 80% of energy used on farms was

Results at a glance...

- *Indicators of the efficiency of resource use in aquaculture have been developed and are being used by several environmental advocacy groups in assessing the sustainability of aquacultural production. Direct energy use for production of channel catfish in Alabama was 3.059 kW · hr/kg with 44% of energy used on farms.*

from electricity and about 20% from diesel, gasoline, and propane. The harvesting operation relied on vehicles and other machines powered by diesel fuel. Electricity was the sole energy source for the processing plant. The kilocalories of hydrocarbon fuels used were converted to kilowatt ·hours (kW ·hr) so that these inputs could be easily combined with electrical energy.

The energy use estimates allowed calculation of energy expenditures (Table 14) incurred at each stage in the production chain for one kilogram of live catfish (completely processed). The greatest proportion of energy was used on farms and mainly for feeding fish and applying aeration to ponds by mechanical means. Manufacturing enough feed to produce 1 kg of fish required about 62% as much energy as used on farms to grow out 1 kg of fish. Processing required about half as much energy as feed manufacturing. The smallest amount of energy was used for harvesting. Pond construction required a large quantity of energy, but ponds last a long time. Thus, when energy for pond construction was spread over 20 years, it was only slightly greater than the energy used for harvesting. Hatchery operation was similar to pond construction with respect to energy use per kilogram of catfish. Estimation of the energy expended in shipping processed fish and maintaining them in refrigerated storage until used by consumers was not attempted. Moreover, energy consumed indirectly for producing feed ingredients, and for producing machines and fuel used in catfish production was not considered in this study.

One kilogram of live catfish, the production of which required 2,630 kilocalories of energy directly, provides about 600 g or edible meat containing about 912 kilocalories (or 912 calories as referred to in human diets). This is an energy in:energy out ratio of about 3:1. Of course the ratio would be much greater if all indirect energy costs mentioned above were included.

At the farm level, the energy to produce 1 kg of fish costs about $0.127. This is a substantial expense considering the farm gate price of catfish is only $1.30 to $1.60 per kilogram. The total cost of energy for producing and processing 1 kg of live catfish was about $0.251.

It is doubtful that it would be possible to greatly reduce energy use for feed manufacturing or fish processing. About half of the energy use was on farms, and most of this energy went to power aerators. Improvement in the efficiency of aeration appears to be an opportunity for reducing energy use on farms. Moreover, improvement in the feed conversion ratio (FCR) in grow-out ponds could reduce the contribution of feed manufacturing to energy use/kg fish.

Investigations of water use require definitions of water use terminology. Total water use should refer to the amount of water applied to an aquaculture system in

Table 14. Direct energy use in channel catfish farming in Alabama.

Activity	Energy use (kW · h/kg)	Percentage
Pond construction	0.154	5.03
Hatchery	0.185	6.05
Feed	0.843	27.56
Grow-out	1.362	44.52
Harvest	0.092	3.01
Processing	0.423	13.83
Total	3.059	100.0

rainfall, runoff, and other natural processes and by management intervention, such as water added by pumping or other mechanical means.

Consumptive water use should represent the reduction in surface runoff caused by an aquaculture facility on a watershed. Less runoff equates to less stream flow for downstream water users. In addition, all freshwater withdrawn from aquifers by wells should be included as a consumptive use, because this water would not be available to other users of ground water in the area. Although ground water is re-charged by infiltration, it sometimes is removed by wells at a rate exceeding recharge. This diminishes the amount of water available from wells in the area. Ground water depletion usually is more serious in arid than in humid climates, but even in humid climates, availability of water from wells may be reduced during the dry season and especially during droughts. Consumptive water could be determined as follows:

> Consumptive water use = Reduction in stream flow + Water withdrawn from wells

The amount of ground water pumped or derived by artesian flow from wells should be indicated as a separate variable for ground water use. This is a major issue in many regions. Spring flow should not be included, for springs discharge onto the land surface naturally.

Non-consumptive water use should refer to water that passes through aquaculture facilities and is still available to other users downstream. It could be calculated as follows:

> Non-consumptive water use = Total water use – Consumptive water use

A water use index relating the amount of water used in an aquaculture facility to production could be useful. Although this index could be calculated for both total and consumptive water use, the consumptive water use index would be most meaningful. The index could be calculated as shown below (mt = metric tons):

> Water use index (m^3/mt) = consumptive water use (m^3) ÷ production (mt)

An index of the economic value of water used in aquaculture should be available. This variable could be determined with the following equation:

> Water value index ($/$m^3$) = [production (mt) × crop value ($/mt)] ÷ consumptive water use (m^3)

Studies of protein use in catfish farming also will require some indices of protein and fish meal use. The following indices have been developed based upon the feed conversion ratio (FCR):

> Protein conversion ratio (PCR), an index of the amount of feed protein needed per unit of production: PCR = FCR × [feed protein (%) ÷ 100]

> Protein equivalence (PE), the ratio of feed protein to aquaculture protein produced:

> PE = FCR × [Feed protein (%) ÷ protein concentration in live culture species (%)]

> Fish meal conversion ratio (FMCR), the ratio of fish meal in feed to aquacultural production: FMCR = FCR × [fish meal in feed (%) ÷ 100]

> Live fish equivalence of fish meal (LFE), the ratio of live fish needed for the fish meal in feed to aquacultural production:LFE = FMCR × 4.5

The Auburn University component of this project was completed in 2007. However, during 2008, two manuscripts were written and published, and a paper describing the results of the energy study was presented at a scientific meeting.

Objective 3b. *Develop and evaluate economic and financial models of existing and improved production practices and technologies.*

University of Arkansas at Pine Bluff. Cash flow budgets were developed for five farm sizes: 24 ha, 103 ha, 147 ha, and 407 ha. Validation tests were conducted against cash flow budgets of commercial catfish farms. The effect of varying equity levels, from 0% to 100% was measured across the five farm sizes (Figures 20 and 21). Schedules of cash flow and cash flow risk were developed in 10% increments from 0% to 100% equity for each farm size. With 100% equity, monthly cash flows were positive for all months except February for all farm sizes. Cash flow risk ranged from 0.28 to 0.31 when compared with total cash inflow and from 0.39 to 0.44 when compared against operating expenses. With 100% financing, only the larger farm sizes cash flowed, but at very high levels of risk (0.0008 compared to cash inflow and 0.0012 compared against operating expenses).

Figure 20. Cash flow coverage ratio across farm sizes with 30%, 60%, and 90% financing.

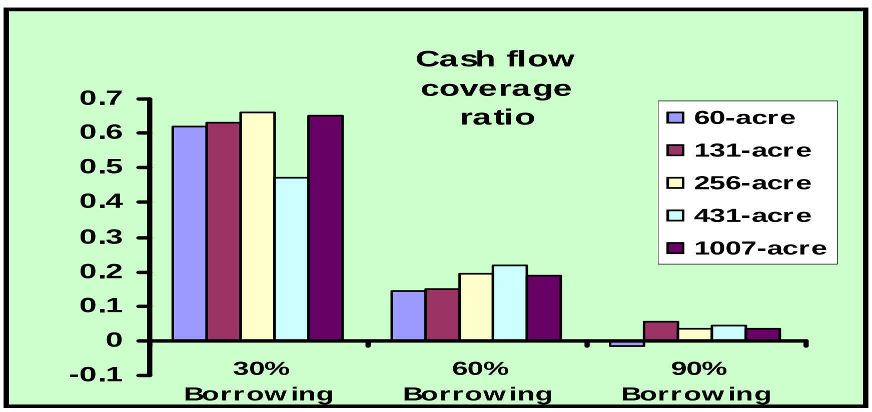
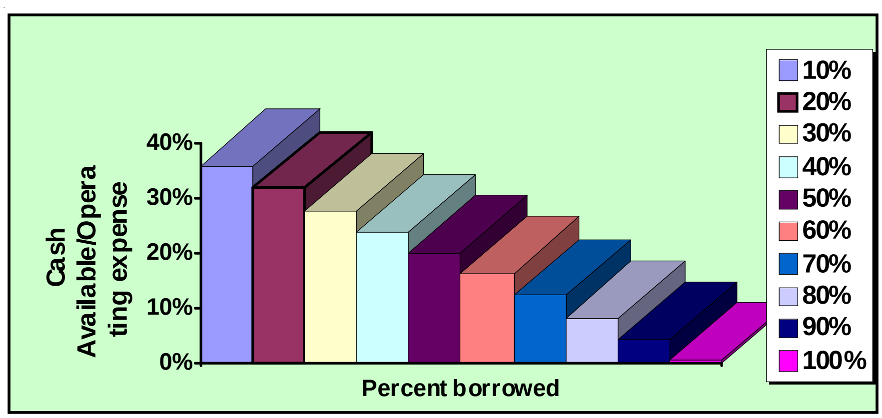


Figure 21. Cash availability compared to operating expenses on a 256-acre farm with levels of financing from 10% to 100%.



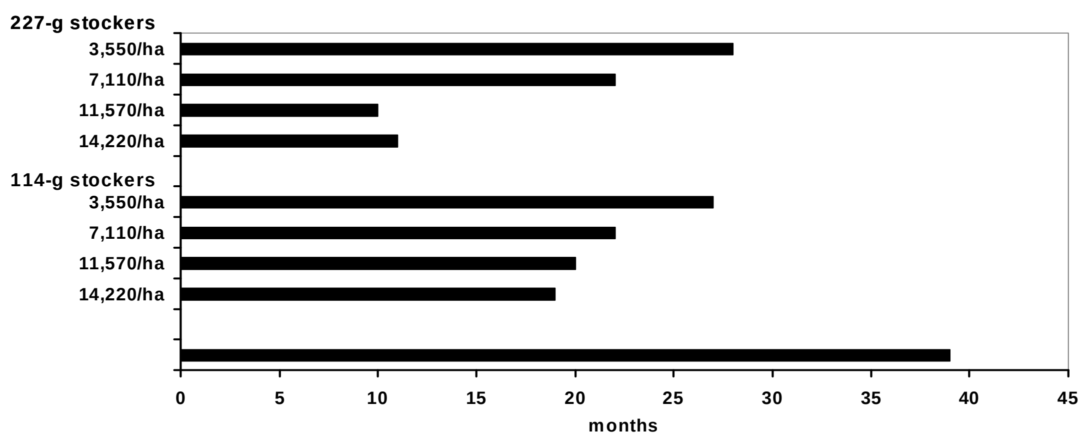
A survey was conducted to gather data from lenders with portfolios in catfish, row crop, and livestock loans. A total of 80 banks (6 in Alabama, 23 in Arkansas, 36 in Mississippi, and 15 in Louisiana) have been included in the sample. Of these, 32 have catfish loans and 48 have agriculture, but not catfish loans. Data obtained from the survey was used to identify the range of lending programs, structures, and repayment plans commonly used for catfish, loans as well as those commonly used in other types of agriculture. These financial lending scenarios will then be applied sequentially to the cash flow budgets to assess the effects on cash flow and repayment capacity.

The initial cash flow budgets were developed for existing farm situations, farms that had been in business for a number of years. However, startup catfish farms require four years to build production to levels that generate adequate cash flow, if initial stockings are based on 12.7-cm fingerlings. Additional cash flow budgets were constructed to measure effects of the use of varying percentages and sizes of stockers on cash flow. The cash flow budgets developed for the 24 ha, 103 ha, 147 ha, and 407 ha catfish farms were further modified to reflect cash flow for startup catfish businesses. The effect of equity position was varied from 0% to 100% in 10% increments to evaluate its effect on startup catfish businesses.

These budgets are multi-year budgets with no revenue in Year 1 because a startup farm that stocks fingerlings will have no revenue in Year 1. These budgets showed that, for all five farm sizes, cash flow did not become positive until Year 4. These results, based on current cash flow conditions, showed a much longer time period to develop positive cash flow than previous cash flow budgets (that are more than 20 years old). This finding explains financial difficulties of farms that entered catfish production in the 1990s. Startup catfish farms require a 4-year cash flow planning period.

Use of stockers improved cash flow and reduced the number of years required to reach adequate cash flow coverage, with the degree of the effect varying with the size of stockers used and the percentage of total stocking devoted to stockers. A startup catfish farm requires 39 months to achieve a positive cash flow (Figure 22). Stocking ponds with 114-g catfish stockers reduces the number of months to achieve

Figure 22. Length of time (months) required to achieve positive cash flow with no stockers and various stocker options.



positive cash flow to 19-27 months. Stocking 14,220 stockers/ha achieved the shortest time, 19 months. Stocking at lower rates lengthens this time to 20 (11,570/ha), 22 (7,110/ha), and 27 (3,550/ha). Stocking 227-g stockers at the higher rates (14,220/ha and 11,570/ha) resulted in positive cash flow in the first year (10 and 11 months). However, the lower stocking rates of 7,110/ha and 3,550/ha did not improve the time to achieve positive cash flow over that of 114-g stockers, but would be more costly. Thus, if a farm must generate positive net cash flow in the first year, 227-g stockers should be used at 11,570/ha. If a positive cash flow is not needed until the second year, 114-g stockers can be used at either 11,570/ha or 14,220/ha. These results were robust across the five farm sizes modeled.

Two mathematical programming economics models have been developed that incorporate grow-out and fingerling production activities. The models maximized net farm income subject to constraints that include: quantity of operating capital, the number of ponds available, farm size, appropriate balance and transfer rows, and non-negativity conditions. Fingerlings were produced either with or without thinning at different stocking densities. Results showed that the optimal size of fingerling to under-stock was 12.7 cm. On-farm production of fingerlings was selected across all farm sizes but the fingerling production technique selected varied with farm size. Models of larger farm sizes began to thin fingerling production ponds, while models of smaller farm sizes produced fingerlings only without thinning. When farm size was treated as endogenous, the optimal size of a catfish farm was 404-water ha. Sensitivity analyses suggested that net returns were sensitive to changes in the key parameters of the model, whereas the optimal size of fingerling to under-stock was robust to variations in the model's parameters. In multiple-batch production, profits were maximized with on-farm production of 12.7-cm fingerlings.

We developed a second multi-period mixed integer-programming model that included six different types of stockers (stockers produced from 6.7-cm fingerlings stocked at 50,000, 100,000, and 150,000/ha, and from 9-cm, 11-cm and 13-cm fingerlings stocked at 100,000/ha) and three different sizes of fingerlings (7.6-cm, 12.7-cm, and 17.8-cm). The results revealed that nearly one-third of the area available for catfish grow-out production should be allocated to foodfish production from fingerlings and two-thirds from stockers. Profits were maximized with on-farm production of 12.7-cm fingerlings, and stockers produced from 9-cm and 11-cm fingerlings stocked at 100,000/ha (Table 15). Sensitivity analyses suggested that the results were sensitive to varying levels of operating capital in that a decrease in the availability of operating capital would result in an increase of foodfish production from fingerlings and a decrease in foodfish production from stockers. Increased availability of operating capital increased on-farm production of

Results at a glance...

- *Detailed cash flow budgets have been developed in this project for both existing and new startup catfish farms under a variety of equity positions. These budgets measure the amount of cash flow risk for varying farm sizes with different levels of financing and for management strategies involving fingerlings only or a mix of fingerling and stockers for grow-out production.*

- *The cash flow budgets showed a much longer time period to develop positive cash flow than previous cash flow budgets (that are more than 20 years old). This finding explains financial difficulties of the farms that entered catfish production in the 1990s. Startup catfish farms require a 4-year cash flow planning period. Purchasing stockers in the first year alleviates cash flow problems. This study identified sizes and stocking densities of stockers that result in positive cash flow in the early years of a catfish farm.*

Table 15. Results of simulations of farm size and pond allocation to stockers and fingerlings.

Farm Size	Pond Allocation: Stockers	Pond Allocation: Fingerlings	Fingerlings Stocked	Fry Stocking Rates (fry/ha) No Thinning: 543,334	Fry Stocking Rates (fry/ha) No Thinning: 1,398,990	Stockers Fingerlings Stocking Rate (100,000/ha): 9-cm	Stockers Fingerlings Stocking Rate (100,000/ha): 11-cm
(ha)	(%)	(%)	(cm)	(%)	(%)	(%)	(%)
40	71	29	12.7	0	100	96	4
80	71	29	12.7	0	100	100	0
120	71	29	12.7	0	100	99	1
160	70	30	12.7	0	100	95	5
200	66	34	12.7	1	100	81	19
240	62	38	12.7	25	75	70	30

stockers for subsequent use in foodfish grow-out. Results of this analysis provide guidelines for farmers related to trade-offs between the use of fingerlings and stocker catfish on farms.

The mathematical programming models of fingerling and stocker production were extended to incorporate the cash flows required as indicated by the cash flow budgets for the various farm sizes and equity positions. Results show that cash flow position affects the selection of optimal management strategies.

The models demonstrated that, when lenders restrict access to operating capital (for example, when lending limits decrease as the price of fish decreases and the value of assets on the balance sheet falls), and there are cash shortfalls, farms are forced to take ponds out of production. The effect is more pronounced on smaller farms. Across all farm sizes, the financial condition of farms became particularly acute at cash flow restrictions greater than about 30%.

Cash flow problems when total operating capital was not restricted resulted in changes to the management plan on the farm. The optimal strategies in the base models prior to imposing cash flow restrictions, were foodfish production from fingerlings on the smaller farms and foodfish production from stockers on the larger farms. As cash flow was restricted, the smaller farms switched to stocking smaller fingerlings and the larger farms switched to stocking fingerlings instead of stockers. Thus, the feasibility of a stocker phase on catfish farms is affected by both the overall level of operating capital and cash flow limitations.

A Just-Pope catfish production function was used to estimate minimum catfish prices and maximum feed prices at which various feeding rates would be economically efficient. Optimal stocking and feeding rates were estimated for very low catfish price levels. Low catfish prices require lower stocking and feeding rates to operate at profit-maximizing levels. Stocking rates below 10,000/ha will not generate adequate revenue to cover debt-servicing requirements for long-term capital investment loans. Thus, farmers must adopt management strategies that will satisfy the multiple business requirements of servicing debt and meeting fish delivery schedules. The results of this analysis provide guidance on the relationships among prices of catfish and feed, with stocking and feeding rates, to provide a basis for these decisions.

IMPACTS

Studies of Partitioned Aquaculture Systems developed at Clemson University revealed that channel catfish fingerling growth can be significantly intensified and accelerated in these systems, yielding fingerlings in excess of 100 gm in size within a 120 to 140 day growing season at demonstrated carrying capacities of 4200 kg/ha. The extensive PAS systems used at Mississippi State University also allowed excellent grow-out of stocker-sized fish to harvestable size. These systems, which show considerable promise, should be further evaluated for commercial potential.

Net yield of channel catfish in intensively managed earthen ponds ranges from 0.4-0.7 kg/m^3. A prototype combined photoautotrophic-chemoautrophic (bio-floc) production system used by the ARS Aquaculture Systems Research Unit to investigate intensified production at stocking rates of 2.9, 5.7, or 8.5 fish/m^2 resulted in net yields that increased linearly from 1.0 to 3.7 kg/m^3 as stocking rate increased from 2.9 to 8.5 fish/m^2. This research demonstrated that increased channel catfish yield was possible by using the prototype combined photoautotrophic-chemoautrophic production system.

The prototype, motor-powered, U-tube aerator being developed by United States Department of Agriculture-Stoneville can move up to 759 m^3/water/kW · hr, but the oxygen transfer efficiency must be improved for commercial application. Problems with the prototype electric seine have been identified, and progress is being made towards development of an effective unit.

Studies at Auburn University have resulted in a number of indicators of sustainable aquaculture that are already being used by the Global Aquaculture Alliance and the World Wildlife Fund in evaluating the ecological efficiency of different production systems. Studies of energy use indicated that a total of 3.059 kW · hr energy is used to produce and process 1 kg of live catfish. Grow-out of fish on farms account for nearly half of energy use and feed production accounts for another 30% of energy use.

Economic analyses done at University of Arkansas at Pine Bluff revealed that the optimum size of a catfish pond was about 400 ha of water surface area. Cash flow budgets have been developed for five farm sizes, for existing and startup farming operations with no stockers, 114-g and 227-g stockers, stocked at four different rates for 11 different financing options, for a total of 550 budgets. These spreadsheet model budgets have been used extensively to provide direct financial assistance to catfish farmers through the difficult financial times of recent years. A number of workshops on cash-flow based management have been held to aid farmers to make decisions related to survival of their farm businesses.

The semi-confinement units tested at the University of Arkansas at Pine Bluff increased the yield of fingerling catfish in ponds and has commercial potential. A similar system is being tested at a commercial facility for grow-out of fingerlings.

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FEED FORMULATION AND FEEDING STRATEGIES FOR BAIT AND ORNAMENTAL FISH

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PROJECT OBJECTIVES

1. Manipulate diet composition and/or feeding strategy for economical production of "jumbo" golden shiners.

2. Manipulate diet composition and feeding strategy to increase immunocompetence and resistance to stress in bait and ornamental fish during:

    a. Production
    b. Transport and Live Display

3. Determine the relative contribution of natural foods and prepared diets to growth, response to low dissolved oxygen, and other health indices for bait and ornamental fish in different production systems.

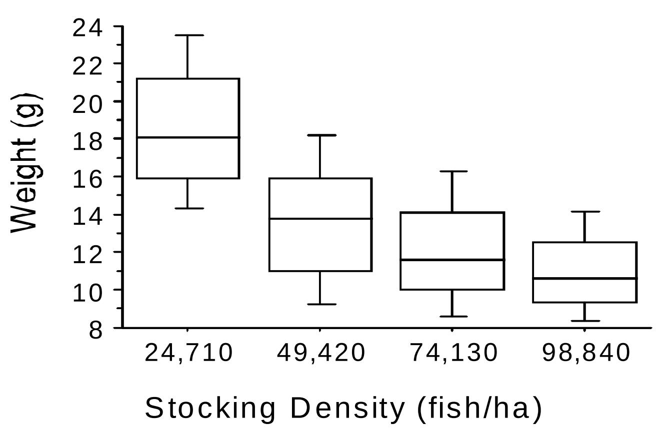
PROGRESS AND PRINCIPAL ACCOMPLISHMENTS

Objective 1. *Manipulate diet composition and/or feeding strategy for economical production of "jumbo" golden shiners*

University of Arkansas at Pine Bluff. The first objective was to determine an appropriate stocking density for juvenile golden shiners to maximize the production of jumbos (12 g and larger) within a single growing season. This density would then be used for a subsequent study evaluating feeding frequency and diet composition. Golden shiner juveniles (0.5 g) were stocked on July 25 into 12, 0.04-ha fenced and netted earthen ponds at four densities (24,710; 49,420; 74,130; and 98,840/ha) and cultured for 105 days. Fish were fed to satiation once daily with a commercial 42% protein extruded pellet. Ponds were aerated 10 hours nightly using 0.37-kW aerators. Secchi disk visibility was measured every 2 weeks, and total ammonia nitrogen, pH, chlorophyll *a*, dissolved oxygen and zooplankton were determined monthly. Recording thermographs were installed in two ponds and recorded water temperature every 6 hours. Fish were sampled monthly. Ponds were harvested November 7-8. Average fish weight and survival were estimated by weighing and counting five subsamples of at least 25 fish. Weights (g) and lengths (mm) of a sample of at least 50 fish per pond were measured to determine condition and size variation. Remaining fish were bulk-weighed.

Average fish weight declined with increasing stocking density (Figure 1). At the lowest density, 98.4% of the weight at harvest was composed of jumbo fish. Survival ranged from 53 to 87% and was not significantly different among treatments. Gross yield increased with density from 366 to 753 kg/ha and was highly variable among ponds. Net yield of jumbos did not differ among the three higher density treatments. The 74,130/ha (30,000/acre) treatment resulted in an average gross yield of 639 kg/ha, of which 54% by weight was comprised of fish that weighed more than 12 g, and this density was selected for the next trial. Advanced fry were found in six ponds by August, documenting previously undescribed sexual maturity at 3 months of age in golden shiners. Juveniles stocked into study ponds had been raised from hatchery fry that were obtained on May 11, at 1 to 2 days of age.

Figure 1. Box plots showing the distribution of fish weights at harvest.



Stocking juvenile golden shiners in late July, as was done in this study, results in lower single-season yields of jumbos when compared to direct stocking of hatchery fry at low densities. Previous work showed that direct stocking of fry in early May resulted in about 650 kg/ha of jumbos in a single season. However, the extra production of jumbos must be balanced against other uses for the ponds; juveniles used in this study were produced by stocking fry at 3.7 million/ha for 9 weeks, resulting in yields of about 900 kg/ha.

A second trial evaluated the effects of diet composition and feeding frequency on the growth and production of golden shiners. Juvenile golden shiners (average weight of 0.46 g) were stocked into 12, 0.04-ha earthen ponds at a rate of 74,100 fish/ha. Fish were fed either once or twice daily with one of two diets (Table 1); a control diet (Diet 1) and an experimental diet (Diet 2), with the intent of matching the performance of fish fed the control diet but at a lower cost. The feed form was an slow-sinking, extruded pellet. Fish were fed at 3% body weight per feeding, adjusted weekly based on an assumed feed conversion ratio (FCR) of 1:1 and by sampling every 2 weeks. Ponds were aerated 10 h nightly (2200 – 0800 hours) with 0.37-kW aerators. Secchi disk visibility was measured every 2 weeks, and total ammonia nitrogen, pH, chlorophyll *a*, dissolved oxygen and zooplankton were determined monthly. Ponds were harvested November 19-20 after 80 days.

Results at a glance...

- *Stocking juvenile golden shiners in late July resulted in lower single-season yields of jumbos when compared to direct stocking of hatchery fry at low densities. However, the extra production of jumbos produced by stocking fry must be balanced against other uses for the ponds. Growout diets with no fish meal fed once daily to golden shiners supported yields similar to those obtained with more expensive diets and more frequent feeding.*

Table 1. Composition of the diets[1] being tested for producing jumbo golden shiners in a single growing season.

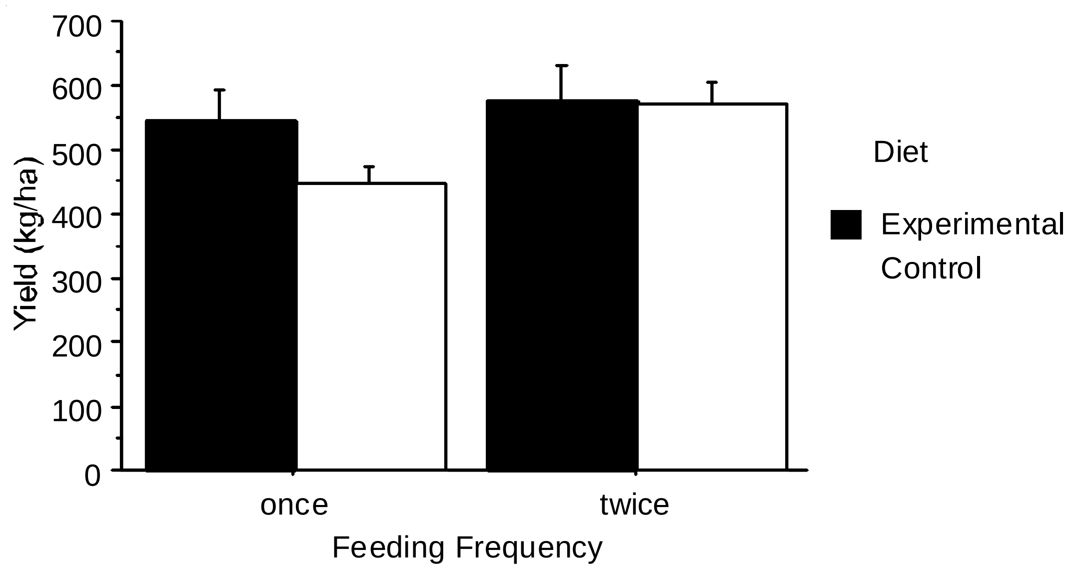
Ingredient	Amount (g/100g as fed) Diet 1 (control)	Amount (g/100g as fed) Diet 2 (no fish meal)
Menhaden fish meal (62%)	26.0	0.0
Poultry By-Product meal (60%)	15.0	34.0
Soybean meal (48%)	30.0	40.0
Corn	7.0	5.0
Wheat midds	13.8	12.8
Vitamin C (Stay-C)	0.146	0.146
Choline	0.58	0.58
Vitamin premix	0.4	0.4
Mineral premix	0.1	0.1
Poultry fat	7.0	7.0

[1] Diets contain approximately 42% total protein and 9-10% lipid by calculation.

Average fish weight and survival were estimated by weighing and counting five sub-samples of at least 25 fish. Weights (g) and lengths (mm) of a sample of at least 50 fish per pond were measured to determine condition and size variation. Remaining fish were bulk-weighed.

At harvest, there was no difference in yield (Figure 2), average weight, or survival due to diet or feeding frequency. Yield averaged 535 kg/ha with a standard error of ± 24 kg/ha. Survival ranged from 57 to 80% and mean weight per fish was 10.2 ± 0.4 g. Results showed that feeding a diet with fish meal did not improve yields over a comparable diet formulated with poultry by-products, and that feeding twice a day instead of once a day provided no benefits.

Figure 2. Yield of golden shiners stocked at 74,100/acre for 80-d and fed either once or twice daily at 3% body weight with a 42% crude protein diet with fish meal (Control) or without fish



Objective 2. *Manipulate diet composition and feeding strategy to increase immunocompetence and resistance to stress in bait and ornamental fish under simulated commercial conditions.*

Objective 2a. *Production*

Texas A&M University in collaboration with University of Arkansas at Pine Bluff. Three feeding trials were conducted at Texas A&M in recirculating systems with golden shiners to evaluate various potential immunostimulatory diet supplements. These trials were largely inconclusive, possibly due to limited utilization of the practical basal diet formulation that was used to standardize methodology among institutions. Extrusion processing or a different method of particle size reduction may be needed to increase the utilization of these experimental diets by golden shiners.

We also supplemented the work originally planned by developing methodologies to quantitatively measure the immunocompetence and stress responses of baitfish under various conditions. A series of evaluations was conducted to define effective biological endpoints and/or physiological indicators of golden shiner health in response to various stimuli for rapid assessment of fish quality, and development of nutritional, pharmacological or husbandry strategies to enhance production efficiency. Some measurements of immunological and physiological responses have been developed for golden shiner including differential blood leucocyte counts, serum complement and cortisol assays. In Year 1, our group (TAMU) demonstrated that serum lysozyme activity of golden shiner and goldfish is very sensitive to the pH of the bacterial suspension (*Micrococcus lysodeikticus*), compared to hybrid striped bass and channel catfish. The optimal pH for lysozyme assay of golden shiner and goldfish was determined to be 5.9 and 6.0, respectively.

Our research team also found that neutrophil oxidative radical production could be analyzed according to a previously described procedure, but the isolation of head kidney from golden shiner is nearly impossible because that organ is almost invisible.

Our laboratory completed a 10-week feeding trial in a recirculating system with goldfish to evaluate potential immunostimulatory supplements including a commercial prebiotic (GroBiotic®-A) at either 1 or 2% of diet, the amino acid arginine, and three different nucleotide preparations. After the 10-week feeding period, none of the supplements conferred increased growth, feed efficiency or immunocompetence as measured by oxidative radical production of blood neutrophils. Representative samples of fish fed each diet also were subjected to low dissolved oxygen (DO) stress as originally proposed. However, the goldfish were so tolerant of low DO conditions that we could not kill fish in any treatments even when lowering the DO concentration to below 0.5 mg/L by bubbling nitrogen into the water.

University of Arkansas at Pine Bluff in collaboration with Texas A&M University. In Year 1, a 14-week feeding trial was conducted at the University of Arkansas at Pine Bluff with golden shiner in aquaria to determine whether practical diets supplemented with GroBiotic®-A, extra lipid, or both could improve growth, survival, feed conversion, body composition, or survival upon exposure to low dissolved oxygen. Six diets similar to a commercial diet (30% protein and 9.6 kg energy/gram of protein) were formulated. Two diets contained the same protein components (primarily fish and poultry meals) and differed only in the amount of added lipid (4 and 10% poultry fat).

The diet with 4% fat was the control. Two other diets were similar to diets 1 and 2 except they contained 2% GroBiotic®-A. Two additional diets contained poultry meal in place of fish meal on an estimated digestible protein basis. Twenty-five fish

Results at a glance...

- *Prebiotics, immune stimulants, and differences in protein or lipid content of diets had only limited impacts on general performance of golden shiners. However, the prebiotic GroBiotic®-A significantly improved survival of golden shiners exposed to the bacterium that causes columnaris disease. In systems with natural foods (pools or ponds), it was necessary to impose a stressor (crowding) on golden shiners before exposure to bacteria to get a statistically significant increase in survival of fish fed diets with prebiotics. Prophylactic use of the prebiotic should be economically feasible based on a partial budget analysis of data from the golden shiner pond trial.*

(1.2 ± 0.001 g average weight) were stocked into each of four replicate 110-L tanks per treatment in a flow-through system. Fish were fed twice daily to apparent satiation and group-weighed every 2 weeks to track growth. Weight gain, survival, and feed efficiency are shown in Table 2. Fish fed diets with GroBiotic®-A or no fish meal +4% poultry fat had slightly lower feed conversion ratio (feed offered/ fish growth) than fish fed other diets. Statistical analysis of fish weight over time showed some transient differences, but final weight gain did not differ by diet. Post-trial fish were exposed to low dissolved oxygen for 24 hours with no mortality.

Whole-body lipid was analyzed and there were no differences among treatments (Table 2). Because the golden shiners were not large enough to obtain blood for health assays at the end of the feeding trial, a subset of fish was maintained on their experimental diets for 12 more weeks. Alternative complement activity in these larger fish did not differ by diet.

Due to the lack of effect from the low-DO stress test, we performed a columnaris disease challenge on a subset of golden shiners fed the control diet (basal + 4% poultry fat), the basal + 10% poultry fat diet, or the GroBiotic®-A + 10% poultry fat diet. GroBiotic®-A significantly enhanced survival of golden shiner relative to diets with 4 or 10% poultry fat and no GroBiotic®-A.

In Year 3, an 8-week feeding trial was conducted at UAPB with goldfish in aquaria to determine whether practical diets supplemented with GroBiotic®-A, extra lipid, or both could improve growth, survival, feed conversion, body composition, or survival upon exposure to the bacteria that causes columnaris disease. Four diets similar to a commercial diet (30% protein and 9.6 kg energy/gram of protein) were formulated. Two diets contained the same protein components (primarily fish and poultry meals) and differed only in the amount of added lipid (4 and 10% poultry fat). The diet with 4% fat was the control. Two other diets were similar to diets 1 and 2 except they contained 2% GroBiotic®-A. Twenty-five fish (0.57 ± 0.002 g average weight) were stocked into each of four replicate 110-L tanks per treatment in a recirculating system. Fish were fed twice daily to apparent satiation and group-weighed

Table 2. Performance of juvenile golden shiners fed diets containing different concentrations of poultry fat (PF), Grobiotic-A® (GROB), or menhaden fish meal (FM) for 14 weeks[1]

Diet	Mean individual weight gain (g)	Feed conversion	Survival (%)	Whole-body lipid (%)
Basal - 4% PF	1.00±0.06	5.7±0.2b	80.0±2.8	4.1±0.7
GROB - 4% PF	1.15±0.04	5.2±0.2ab	78.0±1.2	4.8±0.7
No FM - 4% PF	1.06±0.05	5.0±0.2a	83.0±3.0	5.3±1.3
Basal - 10% PF	1.06±0.05	5.8±0.2b	88.0±2.3	3.7±0.6
GROB - 10% PF	1.18±0.03	5.0±0.1a	85.0±3.4	6.9±1.2
No FM - 10% PF	1.09±0.09	5.7±0.2b	84.0±2.8	5.7±0.6

[1]Means in columns with different letters are significantly different (P<0.10, Fisher's LSD).

every 2 weeks to track growth. Weight gain, survival, and feed conversion are shown in Table 3. Weight gain, feed conversion and survival of goldfish did not differ among diets. Proximate analysis of whole fish is in progress.

After the feeding trial we performed a columnaris disease challenge on goldfish fed each of the diets. Although the goldfish were exposed to higher densities of bacteria than were golden shiners, there were no differences in mortality among goldfish fed different diets. The growth rate of bacteria was so high that it is possible that the nutrients in the broth were depleted, and the bacteria might have been dead at the time of the challenge. To avoid this possibility in the future, fresh broth will be added when the culture is nearing peak optical density for the challenge. Signs of columnaris disease were also seen in some goldfish during the feeding trial. Although infected fish were not used in the challenge, the remaining fish may have been exposed to the bacteria and developed resistance before the challenge.

Table 3. Performance of goldfish in aquaria fed diets containing different concentrations of poultry fat (PF) or GroBiotic®-A (GROB) for 8 weeks. Means were not significantly different (P>0.05, Fisher's LSD).

Diet	Mean individual weight gain (g)	Feed conversion	Survival (%)
Basal - 4% PF	2.13 ± 0.15	1.8 ± 0.1	83.3 ± 4.1
GROB – 4% PF	2.30 ± 0.05	1.7 ± 0.0	85.8 ± 4.2
Basal – 10% PF	2.10 ± 0.09	1.8 ± 0.1	76.7 ± 1.4
GROB – 10% PF	2.31 ± 0.12	1.7 ± 0.1	79.2 ± 4.4

Objective 2b. *Transport and Live Display*

University of Georgia. Whole-cooked soybeans are being compared to soybean meal in diets of golden shiners, feeder goldfish and fathead minnows. Golden shiners were stocked into aquaria in Years 1 and 2 but were subject to excessive mortality within a few days of stocking under a variety of culture conditions. Antibiotics applied to the golden shiners had no significant positive effect on survival. However, increasing salinity of the systems to 3 parts per thousand by addition of artificial sea salts improved survival of the golden shiners.

Subsequent feeding trials with golden shiners in aquaria were improved by the addition of salt to the culture water when using golden shiners from a commercial source or by using golden shiners from a breeding population established on site. Survival of commercial golden shiners was 0% after 14 days in aquaria versus 97% survival for Tifton-reared golden shiners after 56 days in fresh water. When 3,000 mg of sodium chloride was added per liter of water, the commercial golden shiner survival was improved to 85% over 56 days. Fathead minnows obtained from the same commercial source did not show signs of disease and survived at the rate of 95% for 56 days in aquaria in fresh water.

Weight gain for golden shiners fed a complete diet (gain = 0.52 g) or whole-cooked soybeans (gain = 0.57 g) was not statistically different over 56 days when 0.5 gram golden shiners from Tifton ponds were fed to satiation in aquaria. Similarly, weight gain for fathead minnows (1.5 g initial weight) was not significantly different when fed a complete diet (gain = 1.06 g) or whole-cooked soybeans (gain = 1.01 g). Goldfish trials have not been completed.

Pond trials with golden shiners fed roasted full-fat soybean meal show similar growth to golden shiners fed complete diets. Consumption of natural food appeared to provide essential nutrients that are not present in the simple soybean meal diet. Further analyses are in progress.

Economics of feeding for baitfish has changed over the course of this project. Roasted soybeans obtained for $500 per ton in 2006 cost $630 per ton in 2008, FOB Missouri. While 48% protein soybean meal is available for $342 per ton, complete feed costs range from $360 to $640 per ton, depending on quantity and location. At on-the-farm prices of $11 to $12 per bushel, soybean roasting would put feed value between $407 and $444 per ton for whole roasted soybeans. Roasting costs another $25 to $40 per ton. Therefore, baitfish producers, who also raised soybeans, could consider on-the-farm roasting in order to reduce dependence on the feed milling industry during periods of price uncertainty.

Results at a glance...

- *Golden shiners in ponds fed roasted full-fat soybean meal show similar growth to golden shiners fed complete diets. Consumption of natural food appeared to provide essential nutrients that are not present in the simple soybean meal diet. During periods of price uncertainty, baitfish producers who also raise soybeans could consider on-farm roasting to reduce dependence on the feed milling industry.*

Supplemental objective. *Development of methodologies to quantitatively measure the immunocompetence and stress responses of baitfish under various conditions.*

Texas A&M University. An assay of whole-body cortisol has been developed and shown to be quite responsive in measuring stress of shiners subjected to various handling procedures. Samples of golden shiners obtained from a study conducted during year 1 in which fish were subjected to normal harvesting, handling and distribution practices have been analyzed for whole-body cortisol as well as zinc and ascorbic acid as potential indicators of stressful conditions. The whole-body cortisol assay was determined to be a most sensitive measure of stress in golden shiners; whereas, whole-body zinc and ascorbic acid were not readily altered by the various harvesting, grading and transportation stressors.

Objective 3. *Determine the relative contribution of natural foods and prepared diets to growth, response to low dissolved oxygen, and other health indices of bait and ornamental fish in different production systems.*

Bait species

Texas A&M University. Based on the positive responses of golden shiners to GroBiotic®-A observed in the first year of this project year at UAPB, two separate feeding trials with goldfish have evaluated the effects of GroBiotic®-A in the presence or absence of natural productivity. Fish have been fed a commercially prepared basal diet and one supplemented with GroBiotic®-A in both a recirculating system containing well water and an outdoor system receiving a continuous supply of pond water. Significantly increased feed efficiency was noted in both feeding trials for goldfish fed GroBiotic®-A when compared to the basal diet. However, no significant differences were noted in regards to percent weight gain or survival over the course of the feeding trials, nor during a controlled disease challenge with *Aeromonas* spp. Goldfish in the presence of natural foods did exhibit significantly greater feed efficiency and survival during the feeding trial, as well as in the disease challenge. Denaturing gradient gel electrophoresis (DGGE) was performed on 16S ribosomal DNA isolated from digesta samples collected from intestinal sections of representative goldfish after each feeding trial to evaluate the relatedness of the GI tract microbiota. These analyses revealed no difference in the GI tract microbiota in the anterior or posterior intestinal sections regardless of diet, unlike previous studies in this laboratory with other species. Additionally, fish fed the diet supplemented with GroBiotic®-A showed a reduced stress response as measured by whole-body cortisol after net confinement.

Two additional feeding trials are in progress to further evaluate the effects of several diet supplements including arginine, a commercial nucleotide preparation and the prebiotic GroBiotic®-A on production efficiency and disease resistance of goldfish culture in the presence and absence of natural productivity (well water or pond water). After 8 weeks of feeding the various diets, fish will be subjected to a controlled exposure to *Aeromonas* spp. and their disease resistance will be monitored.

University of Arkansas at Pine Bluff. A 10-week feeding trial with golden shiner in outdoor pools was conducted at the University of Arkansas at Pine Bluff using the same diets described in Objective 2a (see Table 2 for list of diets). Methodological differences from the tank trial included less frequent fish sampling (monthly) to avoid mortalities due to handling stress, and monitoring natural food abundance through Secchi depth and chlorophyll a readings. Four hundred (0.46 ±0.002 g in individual mass) fish were randomly stocked into each of four plastic-lined 4.1-m^3 pools that were fertilized 1 week before stocking and maintained static during the study. Fish were fed twice daily to apparent satiation and group-weighed every 2 weeks to track growth. Chlorophyll *a* was measured to assess phytoplankton abundance and other water quality parameters were acceptable for golden shiner. Weight gain and feed conversion did not differ by diet (Table 4). There were slight differences in condition factor and survival that were not consistently associated with diet variables (Table 4). Whole-body lipid was significantly higher in fish fed the 10% poultry fat diets compared to those fed the 4% poultry fat diets, regardless of other diet variables.

Results at a glance...

- *GroBiotic®-A also enhanced performance (growth, survival, condition index, or feed efficiency) of goldfish in systems with natural foods, and reduced cortisol response of goldfish to crowding stress. Interestingly, no differences in gut microflora were detected in fish fed diets with or without prebiotic, and the mechanism of action still needs to be determined.*

After harvest, shiners fed the control diet or the diet with 2% GroBiotic®-A were acclimated to indoor tanks and challenged with *Flavobacterium columnare* (trial 1). In trial 2, shiners from the same treatments were subjected to confinement stress or left unmolested, then exposed to *F. columnare*. Mortality (mean ± SE) was not significantly different for the control diet (23.4 ± 3.4%), GroBiotic®-A diet (10.0 ± 3.3%), or GroBiotic®-A diet with stress (16.7 ± 3.4%) treatments. Mortality for the control diet with stress (50.0 ± 3.3%) treatment was significantly greater than the other treatments. This suggests that prebiotic supplementation in golden shiner feeds prior to a stressful event could reduce associated mortality from *F. columnare* significantly compared to control diets.

We evaluated the performance of juvenile golden shiners in ponds fed a control diet or the same formula with 2% GroBiotic®-A. Golden shiner juveniles (0.1 g) were stocked on June 28, 2007 into 10, 0.04-ha fenced and netted earthen ponds at 21.9 kg/ha. Fish were fed to satiation twice daily (4 to 7% body weight) with custom-made 35%-protein diets extruded as 1.5-mm pellets. The diet formulation was similar to a commercial catfish diet. Temperature and dissolved oxygen concentrations were measured daily, Secchi disk visibility and chlorophyll *a* were measured weekly, and total ammonia nitrogen, nitrite, alkalinity, and pH were determined monthly. Ponds were aerated 10 hours nightly using 0.37-kW aerators. Subsamples of fish (100 per pond) were counted and weighed at 2-week intervals to track growth and adjust feed rations. Due to small initial fish size and the relatively low stocking density, growth was very rapid and the study was harvested after 7 weeks to avoid reproduction. At harvest there were no differences in average fish weight, net yield, or feed conversion ratio between treatments (Table 5).

After harvest, 100 fish per pond were moved to indoor tanks for acclimation prior to a bacterial challenge with *Flavobacterium columnare*. Fish were maintained on their

Table 4. Performance of golden shiners in pools fed diets containing different concentrations of poultry fat (PF), GroBiotic®-A (GROB), or menhaden fish meal (FM) for 10 weeks. Means in columns with different letters are significantly different ($P<0.10$, Fisher's LSD).

Diet	Mean individual weight gain (g)	Feed conversion	Condition index	Survival (%)	Whole-body lipid (%)
Basal - 4% PF	1.32 ± 0.13	2.4 ± 0.2	0.85 ± 0.01^{c}	99.8 ± 0.2^{a}	7.9 ± 0.3^{b}
GROB – 4% PF	1.47 ± 0.10	2.6 ± 0.1	0.88 ± 0.01^{b}	96.6 ± 1.3^{b}	7.8 ± 0.4^{b}
No FM – 4% PF	1.56 ± 0.10	2.4 ± 0.1	0.88 ± 0.01^{b}	98.9 ± 0.5^{a}	8.5 ± 0.3^{b}
Basal – 10% PF	1.50 ± 0.21	2.4 ± 0.1	0.91 ± 0.01^{a}	99.1 ± 0.7^{a}	10.0 ± 0.6^{a}
GROB – 10% PF	1.50 ± 0.12	2.5 ± 0.1	0.89 ± 0.01^{b}	99.2 ± 0.6^{a}	9.6 ± 0.2^{a}
No FM – 10% PF	1.43 ± 0.03	2.4 ± 0.1	0.90 ± 0.01^{a}	99.6 ± 0.4^{a}	9.3 ± 0.3^{a}

Table 5. Performance of golden shiners in ponds fed a control diet or a diet with 2% GroBiotic®-A (GROB) for 7 weeks. Means were not significantly different ($P>0.10$, 1-way ANOVA).

Diet	Average individual weight gain (g)	Net yield (g)	Feed conversion
Control	2.93 ± 0.29	287.0 ± 586.75	1.34 ± 0.08
2% GROB	2.89 ± 0.28	690.3 ± 623.0	1.47 ± 0.10

respective diets during acclimation and the challenge. Each pond replicate received three experimental treatments: confinement stress for 30 minutes prior to *F. columnare* exposure (stressed); left un-molested prior to *F. columnare* exposure (un-stressed); or left un-molested and not exposed to *F. columnare* (control). Stress was induced by netting all 24 shiners in a tank and placing them in a small basket suspended within each aquarium. Pre-stress and post-stress fish samples were frozen for subsequent whole-body cortisol analysis to document stress. Confinement stress induced a significantly higher cortisol response compared to unstressed fish, regardless of diet. After the fish were released into the tank they were exposed to a virulent strain (PB02) of *F. columnare* for 18 hours. Mortality was monitored and recorded for 14 days. Mortality ranged from 0 to 35.0% and was not significantly different for fish in the control or un-stressed treatments fed either the control or 2% GroBiotic®-A diets. The stressed shiners fed the 2% GroBiotic®-A diet also had similar mortality rates compared to control and un-stressed shiners, but the stressed fish that received the control diet had significantly greater mean (± SE) mortality (26.7 ± 4.4%). A partial budget analysis based on the results of the challenge indicate that the increased cost of feed containing 2% GroBiotic®-A would be justified based on increased survival of golden shiners exposed to stress and pathogens.

A 10-week feeding trial with goldfish in pools was conducted using the same diets described in the goldfish aquarium trial at UAPB (see Table 3). Four hundred (0.36 ±0.002 g in individual mass) fish were randomly stocked into each of four plastic-lined, 4.1-m^3 pools that were fertilized 1 week before stocking and maintained static for most of the study. Fish were fed twice daily to apparent satiation and subsamples of 100 fish per pool were group-weighed every 2 weeks to track growth. Natural food abundance was monitored through Secchi depth and chlorophyll *a* readings. Other water quality parameters were acceptable for goldfish, except for one instance of high pH (> 9) where fish were showing signs of stress. All pools were flushed with fresh water for 2 hours to restore water quality. At 10 weeks all fish were counted and group-weighed by pool. Fifty individual fish per pool were also euthanized for individual measurements of length and weight to calculate condition index (Fulton's K). These fish were frozen and used for proximate analysis (in progress). Weight gain and condition index of goldfish fed diets with 10% poultry fat, 2% GroBiotic®-A + 4% poultry fat, or 2% GroBiotic®-A + 10% poultry fat were higher than those of fish fed the control diet with 4% poultry fat and no prebiotic (Table 6). Feed conversion and survival did not differ among diets. One hundred goldfish per pool were retained live in the pools where they were fed their experimental diets until they could be moved to indoor tanks for acclimation prior to a columnaris challenge. This work is in progress.

Table 6. Performance of goldfish in pools fed diets containing different concentrations of poultry fat (PF) or GroBiotic®-A (GROB) for 10 weeks. Means in columns with different letters are significantly different (P≤0.05, Fisher's LSD).

Diet	Mean individual weight gain (g)	Feed conversion	Condition index	Survival (%)
Basal - 4% PF	2.26 ± 0.12[b]	1.2 ± 0.03	1.47 ± 0.02[b]	84.1 ± 2.0
GROB – 4% PF	2.54 ± 0.09[a]	1.2 ± 0.04	1.53 ± 0.02[a]	82.9 ± 2.4
Basal – 10% PF	2.74 ± 0.07[a]	1.2 ± 0.03	1.58 ± 0.02[a]	85.0 ± 1.5
GROB – 10% PF	2.56 ± 0.07[a]	1.3 ± 0.02	1.54 ± 0.02[a]	86.9 ± 2.6

University of Georgia. Pond feeding trials are in progress using fathead minnows. At that time, transport hardiness will be evaluated.

Ornamental species

University of Florida. During this project we submitted five species of fish (*Brachydanio rerio*, zebra danios; *Xiphophorus helleri*, swordtails; Hypostomus sp., common plecostomus; *Cichlasoma meeki*, firemouth cichlid; and *Moenkhausia sanctaefilomenae*, red-eye tetra) to the treatments outlined in the original proposal. The original objective was to determine the relative contributions to ornamental fish growth of direct consumption of manufactured feed and natural foods produced as an indirect result of feeding. At the time the proposal was submitted there was at least one large feed supplier selling farmers unprocessed meal diets, but at a relatively expensive cost, and this work was designed to determine whether use of a processed (i.e., pelleted and reground) diet would provide better growth and survival. Two fertilization regimes were also added to the tests to determine the ability of these species to utilize primary and secondary productivity. Each trial consisted of 6 replicated ponds of each species, with four treatments: 1) cottonseed meal; 2) liquid fertilizer; 3) unprocessed, 33%-protein meal-type diet; and 4) processed, 33%-protein diet. Ponds were stocked at rates consistent with industry standards, and trials were each conducted for 12 weeks. A similar tank trial was conducted with each species to compare growth and survival using the two diets. Ten replicate tanks of fish were fed each diet for 12 weeks and growth and survival measured and compared. Other measurements included water quality (ammonia, nitrite, pH, temperature, and dissolved oxygen), and weekly chlorophyll *a* samples from pond studies.

A "low dissolved oxygen" stress test was conducted on three of the five species, but was discontinued as it showed no significant measurement of the fish's ability to handle stress due to deprivation of dissolved oxygen.

There were significant differences in the growth and survival of zebra danios produced in ponds receiving treatments of liquid fertilizer, cottonseed meal, an unprocessed meal diet, and a processed diet. Growth on the processed diet was best, followed by unprocessed diet, cottonseed meal, and liquid fertilizer. Although growth was best with the addition of processed diets or organic materials, liquid fertilizer alone produced a good number of market-sized fish with minimal costs. The economics of each level of input need further analysis. Zebra danios fed a processed diet in tanks also outperformed fish fed an unprocessed diet.

Results at a glance...

- *Zebra danios, swordtails, plecostomus, firemouth meeki cichlids, and red-eye tetras performed similarly on processed or unprocessed diets in ponds, while results were generally less favorable for liquid fertilizer or cottonseed meal treatments. In some species, a large number of fish could be produced with fertilizer alone, but fish size was reduced. Except for zebrafish, these species also performed similarly on processed and unprocessed diets in aquaria.*

Survival of swordtails in all pond studies was greater than 100% due to reproduction in the pond during the 12 weeks. Overall survival was based on number of fish at final harvest with the processed diet treatment being highest followed in order by the unprocessed diet, liquid fertilizer and cottonseed meal treatments. Overall weight of fish produced differed among treatments, with highest There was an increase in overall weight of fish produced in each treatment, with the processed diet providing the highest overall weight, followed by the unprocessed diet, cottonseed meal, and liquid fertilizer. No significant difference in production were seen in tanks studies for swordtails.

Yields of plecostomus in pond studies also differed among treatments, with yields decreasing in the following order: unprocessed diets > processed diets > cottonseed meal > liquid fertilizer. Survival varied dramatically, with survival in the liquid fertilizer treatment being only 10%, compared to 65% survival for the unprocessed diet. No significant differences in growth or survival between the unprocessed and processed diet treatments were found in the tank study.

Highest yield of firemouth meeki cichlids in ponds was obtained on the processed diet treatment, followed in order by the unprocessed diet, liquid fertilizer, and cottonseed meal. Firemouth meeki cichlids readily spawn in ponds, and reproduction and survival of offspring was best in the liquid-fertilized ponds, but fish size was significantly smaller than in the ponds receiving either diet. There was no significant difference in growth or survival of Firemouth meeki cichlids fed either diet in the tank study.

The processed diet treatment provided highest yield of red-eye tetras in ponds, followed in order by the unprocessed diet, cottonseed meal, and liquid fertilizer treatments. However, the total weight of fish was less with the unprocessed diet than with cottonseed meal, and the total number of fish was greatest with cottonseed meal, followed by processed diets, unprocessed diets, and liquid fertilizer. Tank studies for red-eye tetras showed no significant difference in growth or survival between the two diets.

Chlorophyll *a* values were consistent throughout the study for all species. A significant difference in primary productivity (based on chlorophyll *a*) was also observed, consistent with anticipated results (i.e. fertilized ponds were high in primary productivity, with unprocessed and processed diet treatments showing a lower level of chlorophyll *a*.)

The small size of most ornamental species allows them to utilize primary and secondary productivity, but the impact of this source of nutrition alone was unknown for most species. This project demonstrated that pond fertilization alone can produce a significant number of fish, and at a relatively low cost, but the size of fish grown on fertilizer alone is significantly smaller than for fed fish. There also was a general trend toward increasing growth and survival in ponds with processing of the diet, but not for all species (e.g., plecostomus fed an unprocessed diet had a 13% increase in survival). Selection of type of "fertilization" from an organic fertilizer such as cottonseed meal to use of an inorganic fertilizer also affected yield, but again there was variation in this trend between species. Survival and total yield of firemouth meeki cichlid was dramatically increased in ponds with inorganic fertilizer relative to ponds fertilized with cottonseed meal. Chlorophyll *a* levels and water quality parameters were consistent with expectations, showing higher productivity in the pond water when fertilization was used rather that a diet.

Several issues related to the overall value and impact of this study should be addressed in future work. All fish except the firemouth meeki cichlids and the danios were procured for the study from local producers. Red-eye tetras were received at a very small size from a local hatchery, and their counting methodology was obviously flawed. We attempted to stock 7,500 fry per pond, and physically counted over 30,000 fish in some ponds at harvest. Future studies should not rely on external parties counting fish, and there is an obvious need to assist farms with how they are enumerating their inventories while stocking.

WORK PLANNED

Texas A&M University (TAMU) is still pursuing supplemental work to that originally planned. The University of Arkansas at Pine Bluff is collaborating on some aspects of this work:

1. Development of methodologies to quantitatively measure the immunocompetence and stress responses of baitfish under various conditions.

We are currently working on procedures to purify the lymphocytes of golden shiners from whole blood for a mitogen-induced proliferation assay. We also are exploring the potential application of methodology for cortisol extraction from beef cattle adrenal gland for assessment of whole-body cortisol in golden shiner. We also have evaluated the dynamics of whole-body minerals and vitamins such as selenium, zinc, and ascorbic acid in response to environmental stimuli such as harvesting, grading and shipping.

2. Investigation of dynamics of whole-body minerals and visceral vitamins and whole-body cortisol of golden shiners in response to handling and transportation stressors.

A study was completed in which these responses were monitored at various stages of harvesting, handling and distribution of golden shiner. A publication from this study is currently in press.

At UAPB, validation of a whole-body cortisol ELISA method for golden shiner was completed and the method has been published. The procedure is being used to assess stress in small fish under a variety of conditions at UAPB, TAMU, and other universities not affiliated with this project. UAPB conducted a partial validation of the method for goldfish to support recent and future work.

IMPACTS

The overall goal of this project is to develop diets, feeding practices, and production strategies that enhance stress resistance and prolong survival of bait and ornamental fishes. Production diets with no fish meal fed once daily to golden shiners support yields similar to those obtained with more expensive diets and more frequent feeding. The use of a dairy/yeast prebiotic has shown consistently positive results in baitfish and the cost should be offset by improved survival under production conditions. The prebiotic was effective in golden shiners in ponds even at a low stocking density, where natural foods typically have a greater impact on performance. The economics of these feed additives look promising, but need further verification due to the small scale of the baitfish industry.

In addition to the positive effects of a commercial dairy/yeast prebiotic on disease resistance of golden shiners observed by co-investigators on this project, this prebiotic improved stress resistance of goldfish based on a reduction in whole-body cortisol after net confinement. Thus, this prebiotic appears to have considerable potential as a feed additive to protect baitfish from stressors and diseases commonly encountered in production.

Performance of golden shiner in ponds fed full-fat soybean meal or a nutritionally complete diet was comparable. Therefore, full-fat soybean meal can be used to reduce production costs when complete diets are more costly. Baitfish producers who also produce soybeans may realize additional profits by roasting the soybeans on-farm.

With ornamental species, pond fertilization alone produced a significant number of fish, and at a relatively low cost, but the size of these fish was significantly smaller than when feeds were used. Several ornamental fish producers have altered their stocking densities and feeding regimes based on the findings of the pond studies in this project. Overall, there was a general improvement in growth and survival of ornamental species using a processed diet. Perhaps most importantly, there were no advantages to using the expensive, unprocessed meal that was used previously by the ornamental fish industry, which should discourage farms from renewing a market for these diets.

PUBLICATIONS, MANUSCRIPTS, OR PAPERS PRESENTED

Publications

Li, P. B. Ray, D. M. Gatlin III, T. Sink, R. Chen and R. Lochmann. 2008. Effect of handling and transport on cortisol response and nutrient mobilization of golden shiner *Notemigonus crysoleucas*. Journal of the World Aquaculture Society, in press.

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DEVELOPMENT AND EVALUATION OF POND INVENTORY METHODS

Reporting Period
May 1, 2007 - August 31, 2008

Funding Level	Year 1	$162,604
	Year 2	137,423
	Total	$300,027

Participants	Louisiana State University	Ray McClain, Robert Romaire
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PROJECT OBJECTIVES

1. Determine the most accurate and reliable methodologies for estimating ornamental fish density and size distribution in commercial ponds.

2. Determine the most accurate and reliable methodologies for estimating crawfish density and size distribution in experimental ponds and develop a means to estimate annual yield and harvest size from sampling methodologies.

3. Modify the Aquascanner Catfish SONAR system to size individual catfish collected from commercial catfish ponds.

4. Develop and evaluate several down-looking and low frequency side-scan sonar technologies to determine numbers of channel catfish in ponds.

5. Develop and evaluate a catfish trawl and portable computing technologiesto estimate size distribution and biomass in catfish production ponds.

ANTICIPATED BENEFITS

Maintaining accurate inventory records in large earthen-pond aquaculture systems has always been problematic. Accurate biomass, headcount and size distribution information is critical for production management, business planning, accounting, and operation financing. This project will enhance current pond inventory methodologies and will foster the development of novel techniques and/or equipment to objectively assess biomass, headcount and size distribution information in aquatic production systems. These technologies will help to improve the long-term sustainability of aquaculture production in the southeast.

PROGRESS AND PRINCIPAL ACCOMPLISHMENTS

Objective 1. *Determine the most accurate and reliable methodologies for estimating ornamental fish density and size distribution in commercial ponds.*

University of Florida. Ornamental fish production varies from extremely intensive indoor recirculating systems to extensive outdoor earthen ponds. Regardless of the culture method, ornamental fish farmers are dependant upon producing their own fry. The farmers that choose egg-layer species generally have much more control over their production then do their live-bearer counterparts. This is due to the fact that production numbers of egg-layers can easily be controlled by varying the number of breeding pairs, whereas most live-bearers are produced by pond spawning. The only control of a typical live-bearer facility occurs during the initial introduction of broodstock as well as in subsequent culling necessary during the production cycle, which can be as long as 3 years.

Traditional methods for estimating stocking, growout, and harvesting (final) inventories are primarily based on personal knowledge of number of fry per spawn (egg-layers), general productivity of broodfish (live-bearers), generalized observations during growout, and historical success of individual ponds. Very little, if any record keeping is employed in these methods. Producers often will simply estimate the number of fish stocked, and maintain a running, mental estimate of how many fish are in each pond. Often there is not even a written record of what ultimately is sold from each pond. These methods make planning production, improving survival, and increasing growth very difficult. In this project, these traditional methods will be compared to actual counts on commercial egg layer and live bearer facilities as well as experimental ponds located at the University of Florida/IFAS Tropical Aquaculture Laboratory (TAL).

Improved methods will include physical counts of fecundity of female broodfish, volumetric estimates of number of fry at stocking, sub-sampling of inventory three times through growout using partial seine techniques, and physical counts of fish at harvest. Both methods (traditional and improved) will be documented and monitored on a simple Excel spreadsheet. Costs also will be estimated for each method based on man-hour requirements, and benefits will be based on the accuracy of each method. Another anticipated positive effect is the use of improved inventory methods to allow for more efficient production planning and increases in total production per pond.

Our first major objective was to increase the accuracy and reliability of methods for determining ornamental fish density and size distribution in commercial ponds and develop a simple computer based record keeping spreadsheet. For the initial portion of the project a very experienced, well-organized ornamental egg-layer producer was chosen. This producer did not represent the majority but rather the minority, reflected by his record keeping. The fish used was a Serpae tetra (*Hyphessobrychon serpae*), commonly know as a Red Minor. All fish used were in excellent health and very well conditioned. The spawning room (climate controlled) was prepared with 500 individual 7.6-L (2-gallon) spawning tanks, each containing roughly 5.7 L (1.5 gallons) of spawning water. The tanks were then equipped with an air line and benthic spawning media. Once prepared each tank received a female, followed later by a male, and then was left alone for 48 hours. On the second day the tanks were inspected for eggs and the breeders removed. On the third day the spawning media was removed as the fry were now free swimming. On the fourth day the tanks were numbered and fifty tanks were randomly chosen (Figure 1). The producer was not told which tanks were chosen. After tanks were labeled, the producer was asked to estimate the number of fry in each of the 500 spawning tanks three times. He did this by holding the spawning tanks up to the light one by one and qualitatively estimated the number of fry (Figure 2). The fry were then equally distributed into 28 larval rearing vats, except for the 50 tanks identified

Figure 1. One rack of 2-gallon spawning tanks.

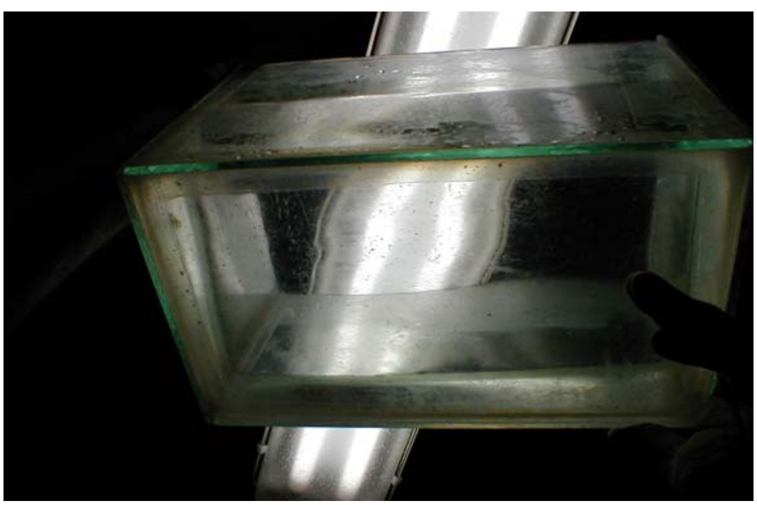


Figure 2. Spawning tank held overhead to the light for fry estimation.

above, which were used to generate our exact count. This was done by first euthanizing the fry in each spawning tank and transferring the fry from one spawning tank at a time into a clean, white bucket. Fry were counted by carefully aspirating each fry into a 1-ml pipette. The actual total was then compared to the producer's estimates. The fry from each remaining tank were then reared for 3 weeks before being stocked into two properly prepared 3-m (6 feet) deep, 0.02-ha (0.04-acre) growout ponds. The producer was again asked to estimate the number of juvenile fish going into each of the two growout ponds. He did this by reviewing his notes regarding his estimates of fry per vat as well as a close inspection of each individual vat. He then selected 10 vats for each pond. In order to generate our count we randomly selected eight vats and swim-counted each juvenile. This was done by first netting all the juveniles in the vat using a large vat net, then dipping into that vat net with a small handnet.

Each dip of the hand net caught roughly 100 juveniles which were then allowed to swim one at a time out of the hand net into a large Styrofoam box. After counting the contents of each dip the juveniles were returned to a separate large vat net within a new vat. This process was repeated until every juvenile was individually counted in each of the eight selected vats. Because the juveniles involved in our count were severely stressed they were ultimately stocked into a separate pond and did not factor into the later results. The actual total was then compared to the producer's estimates.

The two growout ponds were visually monitored twice daily by the producer during daily feedings and weekly for the duration of the 4-month growout cycle. Actual harvest numbers were supplied by the producer which reflected exact sales receipts.

Numbers of Red Minor fry that were in each spawning tank were grossly underestimated by the producer. Actual total count for the 50 tanks was 27,883 fish. The three estimates by the producer were 7,048, 7,265, and 6,615 fish. In other words, the actual counts were 3.8 to 4.2 times higher than the estimates of the producer. In individual tanks, the magnitude of the difference between actual counts and the producer's estimates increased dramatically as the total number of fish in the tank increased. For example, in one tank, the producers's estimates averaged 300 fish although the tank actually contained 1,479 fish, or almost 5 times estimated number.

The producer's estimate of the amount of Red Minor juveniles stocked into each pond was very close to actual counts, and exceeded the actual estimate only by 9.78%. The actual harvest totals for the two ponds were 54.4% and 69.4% of the estimates based on actual counts.

Some early attempts at increasing larval nutrition in order to increase the survival from fry to juvenile have proven favorable. The harvest results for both ponds were considered low for this facility, although harvest values of 50% or more are commonly accepted in the industry. It was observed and recorded that during the 4-month grow out cycle both ponds of Red Minor were treated for external parasites and were also plagued by wading birds.

Objective 2. *Determine the most accurate and reliable methodologies for estimating crawfish density and size distribution in experimental ponds and develop a means to estimate annual yield and harvest size from sampling methodologies.*

Louisiana State University Agricultural Center. Crawfish farming in Louisiana does not rely on a hatchery component for populating grow-out ponds, unlike many aquaculture enterprises around the world. Rather, dependence is upon indigenous and/or supplemented broodstock to reproduce naturally in subsurface burrows as crawfish in the region have evolved to do. Without the reliance on natural reproduction, crawfish farming would probably be non-profitable. While the advantages of natural reproduction are great, there are several drawbacks. Reliance on natural reproduction subjects the grower to great variations in yield and harvest size due to large natural variations in adult survival and reproductive success from year to year and pond to pond. Not only are yield and size variations problematic due to variations in recruitment patterns, but these problems are exacerbated by a lack of predictability and a reliable means of assessing pond inventory. Currently, there is no reliable means of accurately determining the success or failure of young-of-the-year recruitment. Without a means of determining population density and structure prior to initiation of harvesting, economic and business planning and implementation of corrective measures are not viable tools for the producer.

Natural, staggered recruitment and heavily vegetated ponds have limited the development of accurate population assessment techniques in crawfish ponds. Previous efforts to establish population sampling in crawfish ponds as a predictor of yield outcomes, though imprecise, were undertaken mainly in crawfish monocropping systems and were accomplished without the knowledge of actual pond densities. Largely unsuccessful, producers do not routinely attempt precise assessments of population density or structure. Therefore, this project attempted, for the first time, to eliminate natural recruitment and instead accomplish the tasks of populating ponds with stocking of hatchlings at known numbers. This was done so that systematic sampling efforts could be employed with the intent of establishing some kind of relationship between sampling (with different gear) and known populations, and furthermore, to determine if harvest results could be relatively associated with sampling outcomes.

A rice crop was planted and harvested during the summer of 2006 in 12, 0.4-ha (1-acre) experimental plots at the LSU AgCenter's Rice Research Station. The rice stubble was managed for regrowth according to typical rice-crawfish rotational practices in the region. Although the fields (ponds) were not stocked with crawfish broodstock as is customary, the fields were nonetheless flooded on 2 October and Karate™ (a pyrethroid insecticide) was applied at the rate of 4 ounces/acre to minimize natural recruitment from indigenous crawfish that might have happened to wandered into the rice field. After one week, the ponds were completely drained and after 3 days they were reflooded with fresh water for the duration of the crawfish production cycle. Crawfish population was accomplished by stocking of hatchlings, spawned under laboratory conditions, at known densities and predetermined timings.

Five stocking treatments were investigated and consisted of a low stocking rate with one age class (Low-1), low stocking rate with four age classes (Low-4), high stocking rate with a single age class (High-1), high stocking rate with four age classes (High-4), and no stocking of hatchlings (0-Stocking). Crawfish densities of approximately 3 (2.7 to 3) crawfish/m^2 were considered low, and densities of 6.5 (5.9 to 7) crawfish/m^2 were considered high for this study. Timing of the multiple stockings occurred every 2 weeks from 16 October to 28 November.

Population sampling prior to initiation of harvests consisted of employing four sampling gear: large mesh traps, consisting of standard 0.75-inch square mesh pyramid traps, small mesh traps, consisting of common 0.25-inch wire mesh minnow traps with 1.25-inch funnel openings at each end, long handle dip nets (3-mm mesh), and specially constructed drop sampling devices (0.5 m^2 surface area). The drop sampler consisted of a metal cylinder that was rigged to slide up and down on three legs with a trigger that allowed the unit to be "set" in the up position with 15 m (50 feet) of rope, whereby the unit could be placed in the pond some distance and triggered from the levee to prevent disturbing of crawfish during sampling. When "dropped," the sampler formed an enclosure entrapping any crawfish that were captured within the interior of the cylinder. Water was pumped out and crawfish counted and sized.

Sampling was accomplished during six weekly periods (11-15 December, 8-12 January, 22-26 January, 5-9 February, 19-23 February, and 5-9 March). The large- and small-mesh traps were employed with and without bait and were placed both around the pond edge and away from the edge within the interior of the pond (with duplicate traps per pond per location per bait regime). Dip net sweeps were accomplished both around the pond edge and within the pond interior (with 10 random sweeps per pond per location). The drop samplers were operated in the morning (approximately 0830 hours) and afternoon (approximately 1600 hours). Traps and dip net sweeps were accomplished in duplicate ponds of each treatment, while drop samplers were not duplicated by treatment, occurring in only one replicate of each treatment. Crawfish catch, total and by size category, were noted for each sampling effort.

A total of 502 spawns (over 150,000 hatchlings) were stocked for this study. Hatchlings were released with the brood female to more accurately stimulate natural recruitment. The resulting annual average harvest yields for this study were low, even for typical crawfish production scenarios (Table 1). Overall, annual yields averaged 194 pounds/A by weight and 2,216 crawfish/A by number of individuals captured. Highest yielding were those ponds that received multiple introductions of hatchlings at the higher rate, while the lowest yielding ponds consisted of those receiving a single introduction at the low rate, yielding lower even than those ponds that were not intentionally stocked. It is unclear how non-stocked ponds became populated. Perhaps some minimal natural reproduction occurred (even though attempts were made to eliminate that source) and/or some movement of crawfish occurred after stocking. While rare to see small juveniles traversing across levees between ponds, larger crawfish will sometimes migrate at night, and it is possible that some individuals may have moved between ponds via water inflow structures.

The overall capture rate in this study for ponds where crawfish were introduced represents only 12.8% of the total number of crawfish stocked; however, when non-stocked fields are included, the

Table 1. Average annual yield of harvested crawfish. Values within columns with the same superscript were not significantly different (P > 0.05).

Treatment[1]	Yield by Wt. (lb/A)	Yield by No. (No./A)	Avg. Individual Weight (g)	Avg. Count (No./lb)
0-Stocked	112.3^{BC}	$1{,}379^{C}$	36.9	12.3
Low - 4	220.9^{B}	$2{,}567^{B}$	39.1	11.6
Low - 1	98.7^{C}	$1{,}110^{C}$	40.3	11.2
High - 4	397.2^{A}	$4{,}354^{A}$	41.4	11.0
High - 1	148.1^{BC}	$1{,}670^{BC}$	40.3	11.3
	Avg.=195.4	Avg.=2,216		

[1] Stocking treatments consisted of two replicated ponds, while four ponds received no crawfish.

capture rate increases to 16.5% of crawfish stocked (Table 2). This is lower than expected, but it is unknown if this is typical of commercial ponds since little work regarding known populations exist. Recapture rates were greater for the multi-stocking and low stocking density factors. Assuming the residual of remaining crawfish after cessation of all harvests was similar for all ponds, these low retrieval rates indicate greater mortalities at the higher stocking rates and for the single stocking scenarios. The reason(s) for this is unclear but could possibly be associated with either fish and/or insect predators. Some small sunfish and dragonfly naiads were observed during sampling and subsequent harvests but not in uncommon quantities. Recapture rate was especially low for the single stocking factor. This lends credence to the predation theory because later stocking would allow for an increase in fish and insect numbers and size prior to the introduction of crawfish hatchlings, and the later stocking dates would insure that crawfish size remain small for a longer period (due to cooler water temperatures), thus facilitating greater predation opportunity.

Results of the population sampling were general low for all gear and all sampling periods, most likely due to the low stocking rates and apparent low survival rates. Given the low numbers caught per sampling gear though, the greatest catch per sampling period for both large- and small-mesh traps occurred in March, while the greatest catch with dip nets occurred in February and with drop samplers in January (Figure 3). With regard to wire mesh sampling traps,

Figure 3. Average catch with sampling gear by sampling period (Dec, early Jan, late Jan, early Feb, late Feb, and early March).

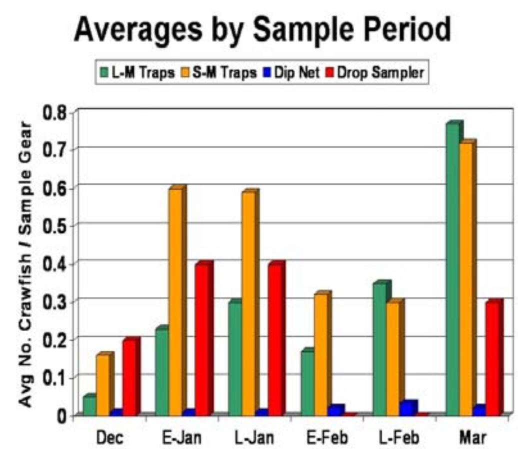


Table 2. Average percent recovery of crawfish per treatment (two replicated ponds per treatment) and individual treatment factors.

Treatment	No. Crawfish Stocked	No. Recaptured	% Recaptured	Treatment Avg. for 1 age class	Treatment Avg. for 4 age classes	Treatment Avg. for Low density	Treatment Avg. for High density
Low - 4	11,033	2,567	23.3%				
Low - 1	12,193	1,110	9.1%				
High - 4	23,847	4,354	18.3%	7.5%	20.8%	16.2%	12.1%
High - 1	28,501	1,670	5.86%				
Overall	151,148	19,402	12.8%[1]				

[1] When harvests from 0-stocked ponds are included, the average percent recovery based on total stocked individuals was 16.5%.

it should be noted that small-mesh traps dominated the catch per unit effort early on, with large-mesh traps gaining a slight edge during late February and March. This reflects the relative abundance of individuals by size in the population. As crawfish grew, more were retained by the large-mesh traps. Sampling efficacy was generally greater for edge of pond sampling as opposed to the pond interior. Sample trap catches for both large- and small-mesh traps mirror the yield data in terms of relationship by treatment from largest to smallest. Although the two highest yielding treatments also had the highest average catches for both dip net and drop sampling gear, the drop sampler was better correlated to yield data (Table 3).

Correlation coefficient is a measure of how well one group of data corresponds to a second group of data and whether the trend is a positive or negative correspondence. Based on the resulting correlations for this study, the best predictor of yield (both in weight and numbers) was the drop sampler (Figure 4). However, sampling results with this gear did not indicate an exceptional relationship to the number of crawfish stocked. Both small- and large-mesh traps also seemed to show a respectable positive correlation to yield. Interestingly, dip net sweep counts, one of the recommended methods for assessing population early on, did not exhibit an especially strong correlation with yields.

Table 3. Correlation coefficients for various yield and sampling protocols.

Correlation	Coefficient
Yield (lb) to total crawfish stocked	0.27623403
Yield (#) to total crawfish stocked	0.25935273
Large trap catch to total crawfish stocked	0.35249102
Large trap catch to yield (lb)	0.86312414
Large trap catch to yield (#)	0.86078803
Small trap catch to total stocked	-0.0749788
Small trap catch to yield (lb)	0.77517418
Small trap catch to yield (#)	0.79616247
Dip net sweep count to total crawfish stocked	-0.00662517
Dip net sweep count to yield (lb)	0.51101328
Dip net sweep count to yield (#)	0.51891547
Drop sampler catch to total crawfish stocked	0.35867357
Drop sampler catch to yield (lb)	0.95017711
Drop sampler catch to yield (#)	0.96752626

Results at a glance...

- *Although simulated population recruitment was poorly correlated to crawfish yield in this study, sampling by test traps generally was a good indication of potential yield. However, the most accurate pond inventory methodology, and best indicator of potential yield, in this study was the passive drop sampler. Additional research is necessary to determine how well these findings apply to large scale commercial operations and whether these methods are accurate enough to have practical applications.*

In other findings, as previously stated, edge of pond sampling was more effective for both test traps and dip net sweeps. Surprisingly, there was little difference between baited and non-baited catches. The 48-hour trap sets generally caught more crawfish but the differences were small.

In conclusion, while stocking density in this study generally reflected the resulting harvest yields, actual percentage of crawfish retrieved by typical harvesting routines was unexpectedly low. Confounding those results were the single stocking factor as opposed to multiple stocking that presumably reflects more natural recruitment

Figure 4. A drop sampler, set and ready to trip with a slight tug on the rope from the levee. Crawfish are retrieved by pumping out the water from the caisson while the cylinder walls are in contact with the mud bottom, exposing crawfish trapped within.

conditions. However, additional research is necessary to determine whether relatively low capture rates in comparison to initial population density are the norm in crawfish aquaculture. In addition, the sampling data gathered from late December to early March seemed to more accurately reflect trends in actual yield rather than reflect initial population density at recruitment. Thus, it is apparent that much more work of this nature is necessary before any conclusions can be drawn for the utility of population sampling in crawfish aquaculture.

Objective 3. *Modify the Aquascanner Catfish SONAR system to size individual catfish collected from commercial catfish ponds*

National Center for Physical Acoustics at the University of Mississippi. Work has progressed on modifying the Aquascanner Catfish SONAR to provide information on fish size distribution in populations from commercial catfish ponds. If such information is desired in research or commercial settings, the only method currently available is to individually weigh or measure length of fish that in a subsample of the population. The method being investigated involves collecting a population subsample in holding device (a tank, netpen, or other device) and then allowing fish to rapidly pass, one at a time, through the pipe. As fish pass through the pipe, they are pinged by acoustic pulses and the return echo amplitude is used to catalogue and size the fish. This data is then stored on the unit or transmitted wirelessly to the host laptop.

A prototype measurement system was assembled and tested in the summer of 2005 and again in the Fall of 2006. Figure 5 shows the preliminary unit and some testing in pens at the University of Arkansas Pine Bluff.

Figure 6 shows preliminary data from a test run in August, 2005. Fish were collected and were pinged acoustically as they passed through a 6-inch PVC pipe. The large echoes from the back wall of the pipe as well as well as from fish passing by have been identified. The background noise is presumably due to entrained sediment in the test tank. It is worth noting that the original Aquascanner SONAR utilizes a 460 kHz operating frequency with a large transducer

Figure 5. Preliminary prototype system and pen testing.

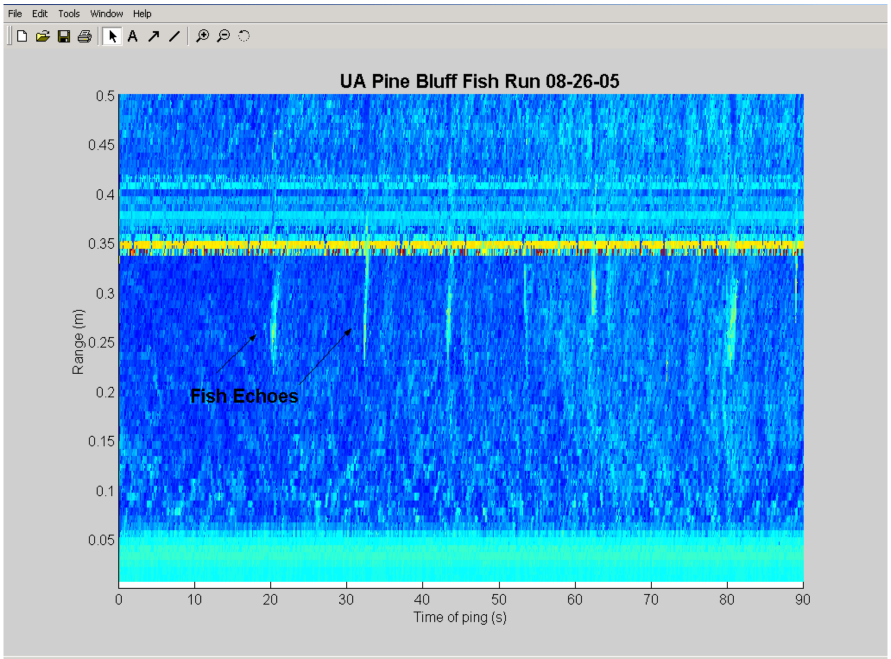


Figure 6. Results of fish passing at controlled 15 sec. (approx.) intervals.

Figure 7. 460 kHz transducer designed for the individual catfish sizing system.

to provide a narrow, 2-degree beam. For these preliminary tests an alternate transducer with a wider beam width was used to minimize beam width effects on the fish which will pass quite close to the transducer. Unfortunately the transducer available had a 1MHz frequency which is more sensitive to entrained sediment.

In the current effort, a 460 kHz transducer with a wider, 18-degree beam-width was designed and manufactured at the NCPA (Figure 7). The wider beam width will help reduce any error associated with fish moving through the return pipe at differing locations. Three acoustic transducers were constructed and calibrated. The preliminary prototype system including the transducer mount and float system was modified and ruggedized to improve ease of use and durability.

The new fish-sizing unit is being lab tested at the NCPA test tank with ping-pong balls being used to mimic the echo return from a fish swim bladder (Figures 8 and 9).

Previous research showed that a 1 MHz side-aspect target strength measurement correlated to catfish length in a manner similar to other species with swim bladders. Their results were modified to compensate for the change from 1 MHz to 460 kHz and the results are shown in Figure 10. Previous research data on fish length-weight relationships were then used to provide a formula to predict the weight of a catfish from the 460 kHz side-aspect target strength. This relation is shown in Figure 11.

A data set incorporating the new 460 kHz transducer is shown in Figure 12. The manually measured fish weights are shown and 9 of the 10 fish scanned are present. The smallest and last fish, 1.3 pounds, is not easily observed and the eighth fish passing through the pipe got stuck or stopped and provided a larger than normal acoustic echo. It is noted as “slow” in the figure.

The data set generated from this work has been used to develop software routines to smooth out acoustical

Figure 8. Current sizing system.

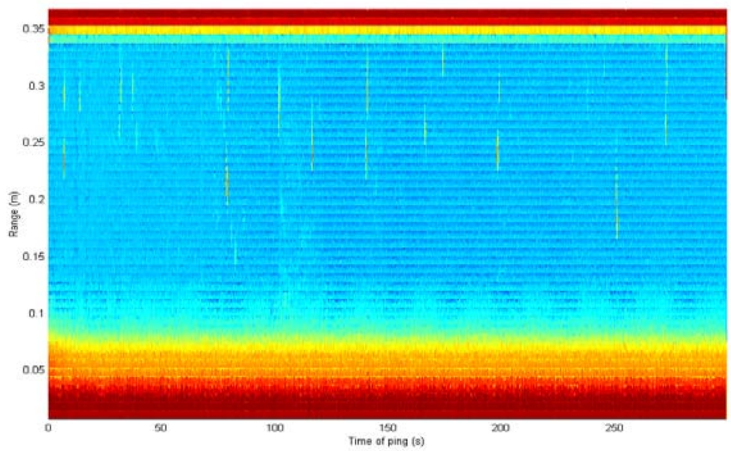


Figure 9. Individual catfish sizing system raw test data using 19 ping pong balls released one or two at a time over a 5 minute period.

Figure 10. 1 MHz side-aspect target strength vs. catfish length.

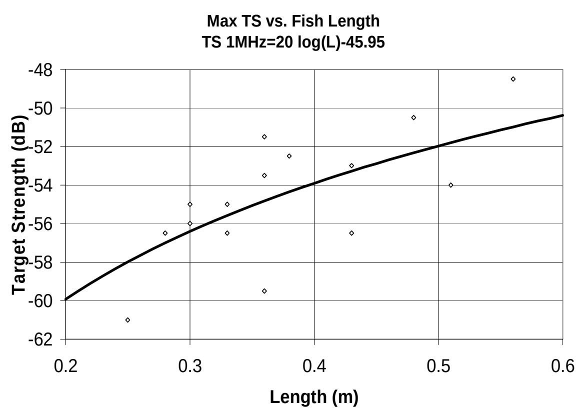
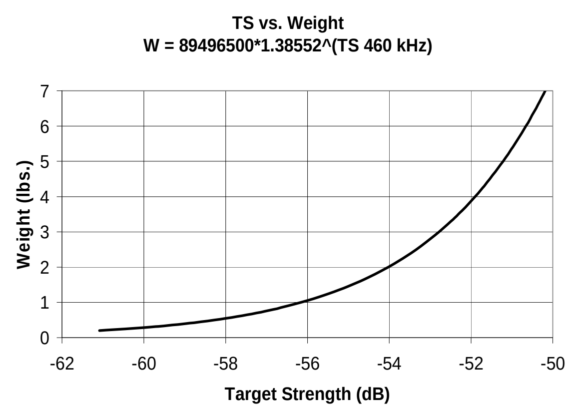


Figure 11. Catfish weight vs. 460 kHz side-aspect target strength.



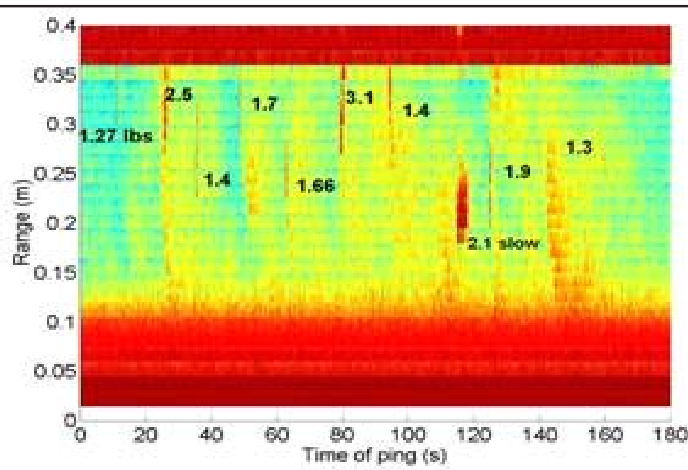
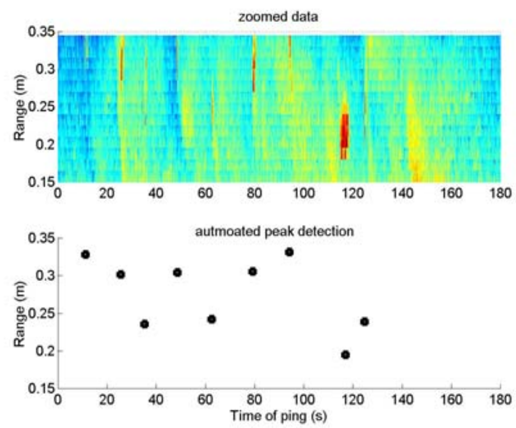


Figure 12. Fish scan data set using 460 kHz transducer.

data, automatically pick out the peak returns (Figure 13) and use these peak returns to provide the target strength information to convert into weight and length.

Figure 13. Fish scan data set with automated peak detector software.



Results at a glance...

- *An acoustic backscatter system has been built to measure the target strength of individual fish from a harvested population. That information can then be processed to predict the population weight distribution of the fish harvested.*

Objective 4. *Develop and evaluate several down-looking and low frequency side-scan sonar technologies to determine numbers of channel catfish in ponds.*

Mississippi State University. First year research focused on obtaining and testing the inventory potential of a 997c Humminbird side-imaging sonar unit. The 997c transducer has both a down looking 83 kHz/200 kHz lobe and a side scanning 455 kHz/ 800 kHz lobe. The side imaging sonar must be moving to operate properly; therefore, it has been mounted on a boat equipped with an electric-start outboard motor, console steering, and a trolling motor. These features make it possible for one person to control both the boat path and the sonar functions (monitoring images and making recordings when appropriate). Initial sonar evaluation trials were conducted in a 64.7-ha lake stocked with bass, bream, crappie, and a 2.4-ha catfish pond stocked with food-sized catfish. The lake has extensive shallow (0.6-1.8 meters) and deep (ranging to 6 meters) areas including a flooded creek. The catfish pond was build with a smooth flat bottom ranging in depth from 0.6 to 1.8 meters. The 997c side-scan lobe produced excellent images of the pond bottom and various structural features in both shallow and deep water; however, the unit must be operated 455 kHz in shallow water because the higher frequency saturates the water column making imaging impossible. The down-looking lobe has an advanced fish-imaging feature that works well in deeper water but not in water as shallow as most catfish ponds. We were able to record and save images as "Screen Snap Shots" on SD memory cards for play back on the 997c or reviewed later after transfer to a computer. This preliminary work indicates that the side-scan lobes can be used to image fish.

Objective 5. *Develop and evaluate a catfish trawl and portable computing technologies to estimate size distribution and biomass in catfish production ponds.*

University of Arkansas at Pine Bluff. A sampling apparatus was constructed with two major components: 1) a commercially available "otter trawl" with a 9-m (30-foot) opening (Figure 14), and 2) a standard seine reel fitted with an increased drum diameter and a PTO-driven, self-contained hydraulic

Figure 14. Preparing a commercially available "otter trawl" for a sampling event.

system. In a preliminary study, the catfish trawl was pulled once across three commercial catfish ponds. All captured fish were individually weighed to assess the size distribution of the fish in the trawl. The day following the trawl pulls, ponds were seined twice with a fingerling seine to capture all the fish in the pond. Seined fish were transferred to a sock and a random sample of fish was captured from the sock with a hoop-net. Sampled fish were individually weighed to assess the size distribution of the fish captured with the seine.

The average weight and the size distribution of the fish obtained from each sampling gear were significantly different for the three ponds tested. The proportion of fish larger than 0.32-kg (0.75 pounds) was significantly larger in the sample collected from the trawl. However, the range of fish sizes (minimum and maximum) caught by each method appeared similar, suggesting that the trawl has the capacity of capturing fish of all sizes (Table 4). Besides, the quantity of fish captured with the trawl did not appear to be related with the quantity of fish in the pond (Table 5).

In a second trial, the trawl was pulled across a commercial catfish pond four successive times over a two day period to test the variability in trawl sampling. The total quantity of fish captured in each trawl pull varied from 280 to 375 kg (656 to 859 pounds; Table 6). Results indicated that the average fish sizes and the fish size distribution were significantly different among trawl pull (Table 6).

The preliminary results suggested that the trawl did not capture a representative fish sample from commercial catfish ponds under the tested

Table 4. Comparison of the average size (± std. dev.) of fish captured with a seine and with a trawl from three different commercial catfish ponds.

		Fish Weight		
Treatment	Fish Sampled	Average (lb)	Min. (lb)	Max. (lb)
Pond A1				
Seine	428	0.80±0.59	0.10	3.64
Trawl	525	0.92±0.61	0.18	4.39
Pond A2				
Seine	474	0.63±0.35	0.04	3.77
Trawl	86	0.97±0.66	0.09	3.99
Pond B1				
Seine	621	0.56±0.33	0.02	2.68
Trawl	142	0.70±0.35	0.16	1.98

Table 5. Comparison between the quantity of fish captured with two seine hauls and a trawl pull across three commercial catfish ponds.

	Seine		Trawl	
Pond	Total (lb)	Sample (lb)	Total (lb)	Sample (lb)
A1	37,090	341	646	484
A2	24,020	297	84	84
B1	36,230	348	100	100

Table 6. Characteristics of four successive trawl samples collected from a single commercial catfish pond.

	Total		Fish size		
Sample	Weight (lb)	Number (fish)	Av. ± SD (lb)	Max. (lb)	Min. (lb)
1	767	1,026	0.75±0.54	2.82	0.02
2	741	1,150	0.64±0.52	2.88	0.03
3	656	752	0.87±0.59	4.35	0.02
4	859	922	0.93±0.59	6.58	0.03

conditions. However, the number of replicates was too limited to draw definitive conclusions. The trawl may still remain a viable sampling technique to assess the size distribution of catfish populations if the limits and biases of the method can be quantified.

Estimating the size distribution of a fish population entails weighing a large number of fish individually on the pond bank. The standard method of recording the individual weight data requires one individual putting the fish on a bench scale and another individual writing the weights on a sheet of paper.

Results at a glance...

- *Preliminary results suggest that the catfish sampling trawl may capture large stockers and foodsize fish more effectively than it does fingerlings. Nevertheless, the trawl may still remain a viable sampling technique to assess the size distribution of catfish populations after these biases are quantified.*

Later, the data need to be typed into a computer spreadsheet for analysis. Unfortunately, it may take several hours or even days to finally get the data into a computer and get a report printed for the farmer. The delay prevents farmers from making timely, well-informed management decisions.

One solution to this problem is to have the bench scale connected by a serial cable directly to a laptop computer at the pond bank. The weight data can be transferred automatically from the scale to the computer and processed in a timely fashion. Unfortunately, laptop computers are not suited for use in harsh, dusty, and wet environments.

Handheld computers (PDA, Palm Pilot, or Pocket PC) appear to be the most efficient tools to use for weight data collection and processing in the field. After numerous field trials, a collection of reliable hardware and user friendly software available commercially have been identified for farmers or researchers desiring collecting and processing fish weight data from the pond bank (Figure 15). The measured weights on a bench scale can be transferred and recorded directly to an Excel spreadsheet on a PDA. The Excel spreadsheet can display the updated overall average fish weight and total fish count automatically after each new data entry. Besides, the data can be safe and protected from PDA malfunctions or breakdown if the Excel file is located on an SD card inserted in the PDA. Reports can also be printed in the field with a wireless portable printer. Later, the Excel file can be easily transferred to a desktop computer for further processing.

Figure 15. Equipment used to efficiently assess the size distribution of large fish samples.

Equipment:

1) Scale: There are two main required specifications for the scale. First it should be water-resistant or waterproof. Second, it should be equipped with a RS232 serial port. There are several models of bench scales available on the market meeting those specifications.

2) Handheld computer.

3) Protective case: The handheld computer should be protected from the environment by a waterproof case. The case tested in this project was the OtterBox 1900 Series PDA case equipped with the Serial POD accessory, which provides a water-resistant serial connection between the handheld computer and the scale.

4) Serial cable and null modem adapter

5) Software: The program CE-Wedge from www.taltech.com was used to input the scale data directly into Excel on the PDA. The program is very simple and designed to interface with any serial device and transfer the data to any PDA programs.

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IMPACTS

Although this project is new, the preliminary results could have a significant impact with producers, especially in the estimation of ornamental fish egg-layer fry. These impacts could not only reduce time spent on spawning tank set-up and subsequent cleaning but could also increase production if the actual fry numbers could be reared through to the juvenile stage.

Another benefit of this project relates to the U.S. Department of Agriculture, Commodity Credit Corporation, Noninsured Crop Disaster Assistance Program (NAP), which now requires ornamental fish producers to maintain an accurate, ongoing inventory as per the following quote: "The State Committee determined to require all producers with NAP value loss crops, to maintain a monthly inventory. These maintained monthly inventory numbers can be used for spot checks, if needed, and in the event of a disaster occurrence. Records are to be kept up to date and readily available upon request." With data obtained in future studies of a second egg-layers species, blue gouramis (*Trichogaster trichopterus*) as well as one live bearing swordtail (*Xiphophorus hellerii*), the eventual completion of a computer-based spreadsheet will not only help the producers with their efficiency but will also provide data for NAP inventory requirements.

While much of these findings on crawfish inventory methods must also be considered preliminary, their usefulness lies in the providing a foundation which can be used to develop a better understanding of the relationship between initial recruitment numbers, surviving population density and structure, and resulting yields. This should lead to better management recommendations and options for maximizing profits.

The new data collection system resulting from this work has already been used by University of Arkansas at Pine Bluff Extension specialists who routinely assess size distribution of large fish samples on commercial catfish farms. The system minimizes labor necessary for data collection and makes processed data immediately available for making management decisions.

PUBLICATIONS, MANUSCRIPTS OR PAPERS PRESENTED

McClain, W.R., R.P. Romaire, and J.J. Sonnier. 2007. Assessment of sampling and harvest yields when crawfish ponds are populated only by stocking of hatchlings. LSU Agricultural Center, Rice Research Station Annual Research Report 99:233-246.

Heffington, J.D., Chambers, J.P., Heikes, D., Pomerleau, S., Stone, E. 2006. Using acoustic backscatter to determine the size distribution of channel catfish in a commercial pond. The 152nd Meeting of the Acoustical Society of America. Honolulu, Hawaii.

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ECONOMIC FORECASTING AND POLICY ANALYSIS MODELS FOR CATFISH AND TROUT

Reporting Period
August 1, 2007 - August 31, 2008

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	Year 2	75,000
	Total	$150,000

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PROJECT OBJECTIVES

1. Identify, develop, and validate economic forecasting models of catfish and trout.
   a. Demand and supply effects,
   b. International trade effects,
   c. Potential effects of various policy alternatives and external economic shocks.

2. Identify data needs necessary to refine the models for these species and to potentially apply to other species.

3. Identify an industry-input framework to ensure model applicability.

ANTICIPATED BENEFITS

United States aquaculture industries and their product markets have matured such that the dynamics of the national economy, federal and state policies, and international trade can have significant and unanticipated effects on the financial health of U.S. aquaculture businesses. Other segments of the agriculture and food sectors rely upon and benefit from econometric models that estimate demand, supply and the relationships among key economic parameters. These models are used to forecast industry trends, effects of anticipated macroeconomic factors, and impacts of proposed policy initiatives. Linking general macroeconomic trends to aquaculture production and market sectors and following the effects through to the resulting impacts on farm price levels will provide guidance on policy initiatives for the catfish and trout industries.

PROGRESS AND PRINCIPAL ACCOMPLISHMENTS

Objective 1. *Identify, develop, and validate economic forecasting models of catfish and trout.*

Objective 1a. *Identify, develop, and validate economic forecasting models of catfish and trout: demand and supply effects*

Mississippi State University. Demand and supply models (Appendix A)were developed to provide an indication of changes in catfish prices and quantities at the domestic wholesale and farm levels. The model generates output related to the effects of detrimental price shocks on the price and quantity demanded of catfish and who will bear the costs.

Demand and supply models were developed based upon quantities and prices of production inputs (such as feed ingredients, fuel, and electricity), prices and quantities of raw products used in the manufacture of production inputs, and competitive markets bidding for these same raw materials or production inputs. Models at the processing sector include different sets of inputs than in the production sector, such as different labor wage rates, technologies, price expectations, taxes and subsidies. An import tariff "shock" was then applied to demonstrate how the model results would be affected.

Wholesale demand and supply results are presented in Table 1 and the farm-level demand and supply results are presented in Table 2. Short and long-run supply and demand elasticities were estimated for important wholesale (Table 3) and farm (Table 4) level variables, using 2007 and 1993-2007 means. These elasticities show the degree of change that will occur in one variable as a result of changes in other variables.

These equations were used to estimate the effects before and after imposing a tariff in terms of welfare changes to buyers and producers at the domestic wholesale level (Table 5). Without any tariff being applied, equilibrium price was $2.74/pound and the equilibrium quantity was over 60 million pounds at the wholesale level. Buyer and producer surpluses were $96 and $84 million, respectively, with revenue of $164 million. Table 5 shows the changes in equilibrium price and quantity, welfare surpluses, and revenue as tariffs are applied. Equilibrium quantity and buyer surplus decrease with each increase in the tariff rate. As prices rise at the farm level, equilibrium quantity and buyer surplus at the wholesale level decrease.

Results of the impact of tariffs on the farm level are reported in Table 6. Without any tariff being applied, the model's equilibrium price at the farm level is $1.00/pound and the equilibrium quantity is 145 million pounds. Buyer and producer surpluses

Results at a glance...

- *Economic models have been developed of demand and supply of catfish at both the farm and wholesale levels. The variables with significant effects on catfish supply and demand were identified for both the farm and wholesale levels.*

Table 1. Wholesale level estimates: three stage least square results. The variable $QD_{P(-1)}$ is the one-period lagged quantity of producer-level catfish demanded by U.S. processors ('000 lb); the variable $QS_{P(-1)}$ is the one-period lagged quantity of producer-level catfish supplied by U.S. producers ('000 lb); all other variables are defined in Appendix A.

Demand Equation			Supply Equation		
Variable	Estimate [a]		Variable	Estimate [a]	
Constant	42,313	(3.34)***	*Constant*	6,214	(0.41)
P_W	-18,718	(-2.82)***	P_W	21,229	(1.61)
$\hat{P}_{MC}$	3,179	(0.85)	P_F	-49,588	(-2.23)**
P_{MT}	643	(0.31)	P_{FUEL}	-25	(-1.41)**
P_{MTR}	-572	(-0.49)	$QS_{P(-1)}$	0.68	(9.80)***
P_{MS}	2,801	(1.67)*	*TREND*	41	(0.76)
P_R	80	(2.19)**	*q1*	15,593	(15.36)***
P_{FUEL}	-23	(-1.74)**	*q2*	217	(0.19)
$QD_{P(-1)}$	0.65	(10.84)***	*q3*	5,272	(5.53)***
q1	15,027	(16.49)***			
q2	853	(0.79)			
q3	5,965	(6.60)***			
R^2 =0.943 Durbin |*h*| = -0.630			R^2 =0.918 Durbin |*h*| = -0.424		

[a] t-values are in parentheses. ** indicates 5% significance.
*** indicates 1% significance. * indicates 10% significance.

Table 2. Farm level estimates: three stage least square results. All variables are defined in Appendix A.

Demand Equation			Supply Equation		
Variable	Estimate [a]		Variable	Estimate [a]	
Constant	-30,479	(0.75)			
P_F	-422,393	(-2.71)***	P_F	40,691	(2.65)**
P_W	211,187	(2.47)**	P_{FUEL}	-92	(-1.26)
P_{FUEL}	-111	(-2.51)**	$\hat{F}S(-7)$	0.07	(-5.55)***
$QD_{F(-1)}$	0.27	(1.78)*	*TREND*	-379	(-1.46)
q1	21,333	(4.95)***	$QS_{F(-1)}$	0.52	(4.43)***
q2	15,301	(1.09)	*q1*	23,599	(6.37)***
q3	-1,690	(-038)	*q2*	-50,508	(-4.28)***
			q3	-379	(-5.88)***
R^2 =0.743 Durbin |*h*| = -0.809			R^2 =10.963 Durbin |*h*| = 0.997		

[a] t-values are in parentheses. ** indicates 5% significance.
*** indicates 1% significance. * indicates 10% significance.

Table 3. Wholesale level price elasticities.

Variable Name	Name	Short-run	Long-run
η_{P_W}	Own-price	-0.718	-0.981
η_{P_R}	Retail fish index price	0.228	0.312
$\eta_{P_{MC}}$	Imported catfish price	0.077	0.106
$\eta_{P_{MS}}$	Imported salmon price	0.134	0.183
$\eta_{P_{MT}}$	Imported tilapia price	0.014	0.02
$\eta_{P_{MTR}}$	Imported trout price	-0.021	-0.03
$\eta_{P_{FUEL}}$	Fuel price index	-0.085	-0.001
ε_{P_W}	Own-price	0.815	2.95
ε_{P_F}	Farm price	-1.90	-2.16
$\varepsilon_{P_{Fuel}}$	Fuel price index	-0.092	-0.332

Table 4. Farm level price elasticities.

Variable Name	Name	Short-run	Long-run
η_{P_F}	Own-price	-2.61	-3.56
η_{P_W}	Processed catfish price	4.16	5.68
$\eta_{P_{FUEL}}$	Fuel price index	-0.21	-0.29
ε_{P_F}	Own-price	0.25	0.52
$\varepsilon_{P_{FUEL}}$	Fuel price index	-0.66	-1.39
ε_{FS}	Fingerling supply	0.71	1.50
ε_{SP}	Soybean price	-5.78	-12.12

Table 5. Equilibrium price and quantity and changes from the impacts of tariffs at the wholesale (domestic) level, 2007 prices.

Tariff (%)	Equilibrium Price ($/lb)	Equilibrium Quantity ('000 lb)	Buyer Surplus ($'000)	Producer Surplus ($'000)	Revenue ($ million)
2007	$2.74	60,026	96,250	84,774	164
20.35	+0.05	-81	-258	+148	+3
28.05	+0.08	-111	-356	+225	+4
35.20	+0.10	-139	-445	+306	+4

are $25 and $125 million, respectively, with revenue of $145 million. Table 6 shows the changes in equilibrium price and quantity, surpluses, and revenue as tariffs are applied at increasing levels. All categories increase with the application of a higher tariff. As prices rise at the farm level, equilibrium price and quantity, buyer and producer surplus, and revenue at the farm level increase.

The results of the impact of tariffs on the wholesale and farm-level data from 1993-2007 are reported in Table 7. Average tariff rates of 20.35%, 28.05% and 35.20% were considered. Without any tariff imposed, the weighted U.S. wholesale price for processed frozen products and frozen quantity sold to wholesalers was estimated to be $2.52/pound and 65 million pounds, respectively. Buyer and producer surplus are $114 and $97 million, respectively. Revenue was estimated to be $165 million. The price paid to producers and the quantity produced (and sold to U.S. processors) was estimated to be $0.90/pound and 145 million pounds respectively. Buyer and producer surpluses at the farm level were estimated to be $27 and $121 million, respectively. Revenue was estimated to be $138 million.

At the maximum average tariff rate of 35.2% on imported catfish products, the U.S. wholesale price was estimated to increase by $0.08/pound and the quantity sold was estimated to decrease by 120,000 pounds, a relatively small change. Farm prices increase by $0.04/pound and farm quantity increases by 1.6 million pounds. The changes in surplus (welfare) and revenue due to the tariff are also reported in Table 7.

Table 6. Equilibrium price and quantity and changes from the impacts of tariffs at the farm (domestic) level, 2007 prices.

Tariff (%)	Equilibrium Price ($/lb)	Equilibrium Quantity (‘000 lb)	Buyer Surplus ($’000)	Producer Surplus ($’000)	Revenue ($ million)
2007	1.00	145,285	24,985	124,994	145
20.35	+0.02	+1,073	+371	+3,849	+5
28.05	+0.04	+1,482	+513	+5,320	+7
35.20	+0.05	+1856	+643	+6,672	+9

Table 7. The impact of tariffs on the U.S. catfish industry.

Vietnam Tariff (%)	Price ($/lb)	Quantity (‘000 lb)	Buyer Surplus ($’000)	Producer Surplus ($’000)	Revenue ($million)
Wholesale Level	$2.52	65,427	$ 114,348	$97,449	165
20.35	+0.05	-69	-240	+391	+3
28.05	+0.07	-95	-348	+520	+4
35.20	+0.08	-120	-417	+642	+5
Farm Level	$0.90	153,276	$27,810	$121,190	138
20.35	+0.02	+919	+335	+3,472	+4
28.05	+0.03	+1,260	+459	+4,763	+5
35.20	+0.04	+1,599	+584	+6,058	+7

Objective 1b. *Identify, develop, and validate economic forecasting models of catfish and trout: international trade effects*

Louisiana State University. An international trade model for the domestic catfish industry was developed to estimate the effect of import supply of catfish and related fish on the domestic price of catfish (Appendix B). Co-integration analysis and inverse demand models were developed to evaluate international trade effects related to catfish and trout. This study used monthly data ranging from January 1993 to December 2004 and examined seven finfish species (catfish, trout, tuna, tilapia, salmon, flatfish, and groundfish) and four crustacean species (shrimp, crabs, crawfish and oysters). Data of imported quantities and value of these fish were obtained from the National Marine Fisheries Service (NMFS). The unit prices of imports were obtained by dividing total value by volume of imports and were used to identify the long-term equilibrium relationship between domestic catfish and individual imported fish prices.

This work examined the interdependence between the domestic catfish price and imported fish prices in the U.S. fish market with cointegration analysis. A second analysis quantified the level of substitutability among the domestic catfish and imported fish through development of inverse demand system analyses including the Rotterdam model, the Central Bureau of Statistics (CBS), the AIDS model, National Bureau of Research (NBR), and Generalized Demand System (GDS).

Tables 8 and 9 summarize the complete sets of elasticity forms for the parameters of domestic catfish equations in the five inverse demand systems developed. The results of these analyses showed that the supply of domestic catfish and imported trout and crawfish have negative effects on the domestic catfish price in all five models. The supply of imported tuna and crab are also shown to have negative effects on the domestic catfish for all models except the GDS model. Contrary to expectations, imported catfish did not show a negative effect on domestic catfish price in structural demand analyses as it did in the co-integration analyses. Table 5 shows own- and cross-uncompensated quantity elasticities of domestic catfish in terms of imported catfish, trout, tuna, tilapia, salmon, flatfish, groundfish, shrimp, crab, crawfish, and oysters. The own-elasticities ranged from -0.22277 to -0.65316. The cross-elasticities ranged from -0.01401 to 0.00831 for imported catfish, from -0.00799 to -0.01441 for imported trout, from -0.00035 to 0.10498 for imported tuna, from 0.00828 to 0.03611 for imported tilapia, from 0.02440 to 0.15542 for imported salmon, from -0.00416 to 0.04687 for imported flatfish, from -0.02094 to 0.15974 for imported groundfish, from 0.00243 to 0.23930 for imported shrimp, from -0.01734 to 0.02350 for imported crab, from -0.00514 to -0.03559, and from 0.00137 to 0.03109 for imported oysters.

Co-integration analyses showed that there were long-run price equilibriums between the domestic catfish price and different species of imported fish such as tuna, tilapia, salmon, groundfish, shrimp, crab, crawfish, and oysters in the U.S. fish market. As expected, these imported fish were negatively related with the domestic catfish price except for salmon. The inverse demand system analyses showed the U.S. fish import demand structure in terms of degree of substitutability. The results of these analyses showed that the supply of domestic catfish and imported trout and crawfish have negative effects on the domestic catfish price in all five models. The supply of imported tuna and crab showed a negative effect on the domestic catfish price except for the GDS model results. Contrary to our expectations, imported catfish did not show negative effects on the domestic catfish price.

Table 8. Elasticity parameter estimation[a].

	Catfish(D)	Catfish(M)	Trout	Tuna	Tilapia	Salmon	Flatfish	Groundfish	Shrimp	Crab	Crawfish	Oyster
Rott.	-0.01362	0.00032	-0.00061	-0.00008	0.00167	0.00235	-0.00001	0.00952	0.00375	-0.00119	-0.00224	0.00014
	(-4.65)	(0.43)	(-1.12)	(-0.55)	(1.09)	(0.79)	(0.00)	(3.74)	(1.28)	(-0.48)	(-3.73)	(0.10)
CBS	-0.01513	0.00054	-0.00049	-0.00285	0.00070	0.00338	0.00334	0.00930	0.00152	-0.00015	-0.00188	0.00172
	(-5.15)	(0.72)	(-0.89)	(-1.37)	(0.46)	(1.08)	(1.47)	(3.37)	(0.52)	(-0.06)	(-3.42)	(1.19)
AIDS	0.02075	-0.00091	-0.00065	-0.00221	0.00078	0.01050	-0.00116	-0.00342	0.00047	-0.00368	-0.00037	0.00184
	(8.83)	(-2.09)	(-2.17)	(-1.21)	(0.68)	(-4.43)	(-0.73)	(-1.44)	(-0.16)	(-1.63)	(-0.84)	(1.75)
NBR	0.02076	-0.00097	-0.00070	-0.00293	0.00193	0.01231	-0.00265	-0.00119	0.00265	-0.00524	-0.00061	0.00125
	(8.11)	(-2.15)	(-2.26)	(-1.52)	(1.49)	(-4.81)	(-1.56)	(-0.47)	(0.88)	(-2.19)	(-1.28)	(1.17)
GDS	-0.01392	0.00026	-0.00100	0.00019	0.00037	0.00026	0.00077	0.00395	0.01312	-0.00330	-0.00234	0.00056
	(-2.58)	(0.37)	(-1.90)	(0.89)	(0.26)	(-0.08)	(0.34)	(1.36)	(-2.39)	(-1.28)	(-4.03)	(0.41)

[a]t-ratios are in the parentheses.

Table 9. Marshallian quantity elasticity.

	Catfish(D)	Catfish(M)	Trout	Tuna	Tilapia	Salmon	Flatfish	Groundfish	Shrimp	Crab	Crawfish	Oyster
Rott.	-0.22277	0.00494	-0.00980	-0.01533	0.02441	0.02440	-0.00416	0.13664	0.00243	-0.02917	-0.03559	0.00137
CBS	-0.25012	0.00831	-0.00799	-0.06516	0.00828	0.03504	0.04687	0.12721	0.06449	-0.01734	-0.03004	0.02594
IDS	-0.65316	-0.01401	-0.00979	-0.00035	0.01679	0.13437	-0.00837	-0.02094	0.14336	-0.03248	-0.00514	0.03109
NBR	-0.64811	-0.01487	-0.01047	-0.00341	0.03611	0.15542	-0.02947	0.02213	0.22883	-0.05094	-0.00876	0.02224
GDS	-0.22416	0.00515	-0.01441	0.10498	0.01937	0.08802	0.04152	0.15974	0.23930	0.02350	-0.03483	0.01487

Objective 1c. *Identify, develop, and validate economic forecasting models of catfish and trout: potential effects of various policy alternatives and external economic shocks*

University of Arkansas at Pine Bluff. The policy analysis phase will be a three-step procedure: 1) development of a baseline model; estimation of behavioral systems; and 3) impact analysis under alternative policy scenarios. The baseline model consists of a producer core (output supply and input demand equations), a consumer core (demand equations for products), a trade core, and identities (price setting and market clearing). The model links technology, policy, and the market. The behavioral systems include fish supply functions, input demand functions (such as feed), fish demand functions, and fish import functions. Now that the demand and supply and international trade models for catfish have been developed, the policy models can be completed and analyses of policies finalized.

Results at a glance...

- *Economic models have been developed of international trade effects. The variables with significant effects on domestic catfish prices were identified.*

Objective 2. *Identify data needs necessary to refine the models for these species and to potentially apply to other species.*

All Project Participants. Data required for the demand and supply models include: quantities and prices of production inputs (feed ingredients, fuel, and electricity), prices and quantities of raw products used in the manufacture of production inputs, price and quantity of domestic product, and prices and quantities of competing products. Data requirements for the international trade model are monthly domestic price and quantity data. These data are required for a number of years. Generally, the more years of data available, the more accurate the results. Data are required not only for the species in question, but also for the major substitute products.

Objective 3. *Identify an industry-input framework to ensure model applicability.*

Preliminary meetings have been held with representatives of the catfish and trout industries. The first sets of meetings are being organized to show the models developed to date with the available data. The meetings planned are expected to result in feedback from industry on the specific types of output that would be most useful to industry and on the policy options to be analyzed.

WORK PLANNED

Work planned for the second year will focus on completing the policy analyses for catfish and development of the models for trout.

IMPACTS

Models of demand and supply and international trade effects of catfish have been developed.

PUBLICATIONS

Publications in Print

Neal, S. J. 2008. The Impact of Imported Catfish on U.S. Wholesale and Farm Sectors. Master's Thesis, Department of Agricultural Economics, Mississippi State University.

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Appendix A
Development of the Demand and Supply Models

The following six linear equations were used to model the U.S. catfish industry:

(1) $$QD_W = a_0 + a_1 P_W + a_2 \hat{P}_{MC} + a_3 P_{MT} + a_4 P_{MS} + a_5 P_{MTR} + a_6 P_R + a_7 P_{FUEL} + a_8 QD(-1) + a_9 q1 + a_{10} q2 + a_{11} q3 + eD_W$$

(2) $$QS_W = b_0 + b_1 P_W + b_2 P_F + b_3 P_{FUEL} + b_4 TREND + b_5 QS(-1) + b_6 q1 + b_7 q2 + b_8 q3 + eS_W$$

(3) $$QD_F = c_0 + c_1 P_F + c_2 P_W + c_3 P_{FUEL} + c_4 QD(-1) + c_5 q1 + c_6 q2 + c_7 q3 + eD_F$$

(4) $$QS_F = d_0 + d_1 P_F + d_2 P_{FUEL} + d_3 \hat{F}S(-7) + d_4 TREND + d_5 QS(-1) + d_6 q1 + d_7 q2 + d_8 q3 + eS_F$$

(5) $$P_{MC} = \alpha_0 + \alpha_1 P_W + \alpha_2 P_{MT} + \alpha_3 P_{MS} + \alpha_4 P_{MTR} + \alpha_5 P_R + \alpha_6 TREND + e$$

(6) $$FS = \beta_0 + \beta_1 P_{FE} + \beta_2 SP + \beta_3 TREND + \beta_4 FS(-1) + \beta_5 q1 + \beta_6 q2 + \beta_7 q3 + e$$

where the variables are defined as:

QD_W	Quantity of wholesale-level catfish demanded by wholesalers (000 lbs)
P_W	Price of domestically processed catfish ($/lb)
$\hat{P}_{MC}$	Predicted imported catfish prices ($/lb)
P_{MT}	Imported tilapia prices ($/lb)
P_{MS}	Imported salmon prices ($/lb)
P_{MTR}	Imported trout prices ($/lb)
P_R	Retail price index for all processed fish and seafood
P_{FUEL}	Fuel price index throughout all levels
$QD_W(-1)$	Lag quantity of wholesale-level catfish demanded by wholesalers
q1, q2, q3	Quarterly dummy variables to account for seasonality
QS_W	Quantity of the wholesale-level catfish supplied by processors
P_F	Price of farm raised catfish
TREND	Accounts for technological changes or time
$QS_W(-1)$	Lag quantity of wholesale-catfish supplied by processors
QD_F	Quantity of farm-level catfish demanded by processors (000 lbs)

$QD_F(-1)$	Lag quantity of farm-level demanded by processors
QS_F	Quantity of the farm-level catfish supplied by producers
$\hat{F}S(-7)$	Lagged predicted fingerling supply (number of fish)
$QS_F(-1)$	Lag quantity of farm-level supplied by farmers
P_{MC}	Imported catfish prices ($/lb)
FS	Fingerling supply (number of fish)
P_{FE}	Expected price of farm raised catfish ($/lb)
SP	Soybean futures price (cents/bu)
$FS(-1)$	Lag fingerling supply (number of fish)

The a's, b's, c's, d's, α's, and β's in equations 1 through 6 are parameters that were estimated. Equations 1 and 2 were the demand and supply, respectively, at the wholesale level. Equations 3 and 4 were the demand and supply, respectively, at the farm level. Equation 3 is the demand for farm-raised catfish by processors, and equation 4 is the supply of farm-raised catfish by farmers. Equation 5 is an import price transmission equation that links imported fish prices to wholesale demand, and equation 6 is the stocker equation that links the supply equation at the farm level to producer production decisions. In equation 1 through 6, lagged terms are used to account for dynamic adjustments at each level. The quarterly dummy variables (q_1, q_2, and q_3) account for seasonality and the trend terms (*TREND*) account for technology changes.

The three-stage least squares (3SLS) estimation procedure was used to jointly estimate equations 1 through 4. The 3SLS method accounts for P_W and P_F being endogenous in the system. If the equations are specified correctly, 3SLS yields more accurate results than the Ordinary Least Squares (OLS) procedure would, because the OLS procedure assumes prices are given or exogenous. The OLS estimation procedure is used to estimate equations 5 and 6. First-order autocorrelation (AR1) was tested for and because lagged dependent variables were present in these equations, the Durbin-Watson test could not be used so the Durbin-H test was used instead to determine if AR1 is present.

Appendix B
Development of Inverse Demand System Models of International Trade Effects

In order to consistently quantify the substitutability of the cointegrated fish with micro-economic theory, this study used inverse demand system models rather that single equation models. The inverse demand systems can be conveniently summarized into one nesting equation and is as follows:

(1) $w_i d\ln\pi_i = g_i d\ln Q + \sum_j g_{ij} d\ln q_j$,

where $g_i = h_i - \theta_1 w_i$ and $g_{ij} = h_{ij} - \delta_{ij}\theta_2 w_i - \theta_2 w_j$ (θ_1 and θ_2 are nesting parameters, δ_{ij} is the Kronecker delta), w_i is the budget share for good *i*, π_i is the normalized price of good *i*, $d\ln Q = \sum w_j d\ln q_j$ is the Divisia volume index, and $d\ln P = \sum w_j d\ln p_j$ is the Divisia price index. The other nested models can be obtained by restricting none, one, or both nesting parameters as follows:

(2) $w_i d\ln\pi_i = h_i d\ln Q + \sum_j h_{ij} d\ln q_j$ RDS for $\theta_1 = 0$ and $\theta_2 = 0$,

(3) $w_i d\ln\frac{p_i}{P} = c_i d\ln Q + \sum_j h_{ij} d\ln q_j$ CBS for $\theta_1 = 1$ and $\theta_2 = 0$,

(4) $dw_i = c_i d\ln Q + \sum_j c_{ij} d\ln q_j$ AIDS for $\theta_1 = 1$ and $\theta_2 = 1$,

(5) $dw_i - w_i d\ln Q = h_i d\ln Q + \sum_j c_{ij} d\ln q_j$ DINBR for $\theta_1 = 0$ and $\theta_2 = 1$,

where price elasticity parameters, g_{ij} , h_{ij} and c_{ij} , and expenditure elasticity parameters, g_i , h_i and c_i , can b $c_i = h_i + w_i$ and $c_{ij} = h_{ij} + w_i\delta_{ij} - w_i w_j$. The estimated parameters can be converted into the forms of elasticity.

SUPPORT OF CURRENT PROJECTS

Title	Yr	SRAC Funding	Other Support: University	Industry	Other Federal	Other	Total Other Support	Total SRAC+ Other Support
Publications, Videos and	1	50,000	43,950	-0-	-0-	-0-	43,950	93,950
Computer Software	2	60,948	30,737	-0-	-0-	-0-	30,737	91,685
	3	45,900	35,710	-0-	1,000	-0-	36,710	82,610
	4	60,500	41,000	-0-	-0-	-0-	41,000	101,500
	5	67,000	47,000	-0-	-0-	-0-	47,000	114,000
	6	77,358	52,975	-0-	-0-	-0-	52,975	130,333
	7	82,205	43,000	-0-	-0-	-0-	43,000	125,205
	8	77,383	47,000	-0-	-0-	-0-	47,000	124,383
	9	60,466	47,000	-0-	-0-	-0-	47,000	107,466
	10	75,700	30,000	-0-	-0-	-0-	30,000	105,700
	11	78,115	30,000	-0-	-0-	-0-	30,000	108,115
	12	74,100	30,000	-0-	-0-	-0-	30,000	104,100
	13	80,106	30,000	-0-	-0-	-0-	30,0000	110,106
Total		**889,781**	**508,372**	**-0-**	**1,000**	**-0-**	**508,372**	**1,399,153**
Innovative Technologies and	1	314,409	193,931	-0-	-0-	-0-	193,931	508,340
Methodologies for Commercial-	2	287,135	217,676	-0-	-0-	-0-	217,676	504,811
Scale Pond Aquaculture	3	213,168	163,173	-0-	-0-	-0-	163,173	376,341
	4	170,096	106,405	-0-	-0-	-0-	106,405	276,501
Total		**984,808**	**681,185**	**-0-**	**-0-**	**-0-**	**681,185**	**1,665,993**
Feed Formulation and	1	103,118	39,363	-0-	-0-	-0-	39,363	142,481
Feeding Strategies for Bait	2	139,603	50,345	-0-	-0-	-0-	50,345	189,948
and Ornamental Fish	3	130,525	52,363	-0-	-0-	-0-	52,363	182,888
Total		**373,246**	**142,071**	**-0-**	**-0-**	**-0-**	**142,071**	**515,317**
Development and Evaualtion	1	162,604	75,241	-0-	-0-	-0-	75,241	273,845
of Pond Inventory Methods	2	137,423	72,420	-0-	-0-	-0-	72,420	209,843
Total		**300,027**	**147,661**	**-0-**	**-0-**	**-0-**	**147,661**	**447,688**
Economic Forecasting and	1	75,000	37,825	-0-	-0-	-0-	37,825	112,825
Policy Analysis Models for	2	75,000	38,163	-0-	-0-	-0-	38,163	113,163
Catfish and Trout								
Total		**150,000**	**75,988**	**-0-**	**-0-**	**-0-**	**75,988**	**225,988**

SRAC RESEARCH AND EXTENSION PROJECTS

Project	Duration	Funding	Grant No.
*Analysis of Regional and National Markets for Aquacultural Products Produced for Food in the Southern Region. Dr. J. G. Dillard, Mississippi State University, Principal Investigator	04/01/88-06/30/90		
	Project Total	**$346,038**	87-CRSR-2-3218
*Preparation of Southern Regional Aquaculture Publications. Dr. J. T. Davis, Texas A&M University, Principal Investigator	01/01/88-12/31/90		
	Project Total	**$150,000**	87-CRSR-2-3218
*Performance of Aeration Systems for Channel Catfish, Crawfish, and Rainbow Trout Production. Dr. C. E. Boyd, Auburn University, Principal Investigator	03/01/88-10/31/90		
	Project Total	**$124,990**	87-CRSR-2-3218
*Develop a Statistical Data Collection System for Farm-Raised Catfish and Other Aquaculture Products in the Southern Region. Dr. J. E. Waldrop, Mississippi State University, Principal Investigator	06/01/89-11/30/90		
	Project Total	**$13,771**	88-38500-4028
*Immunization of Channel Catfish. Dr. J. A. Plumb, Auburn University, Principal Investigator	Yr. 1-05/02/89-04/30/90	$50,000	88-38500-4028
	Yr. 2-05/01/90-04/30/91	49,789	89-38500-4516
	Project Total	**$99,789**	
*Enhancement of the Immune Response to *Edwardsiella ictaluri* in Channel Catfish. Dr. J. R. Tomasso, Clemson University, Principal Investigator	Yr. 1-05/02/89-04/30/90	$46,559	88-38500-4028
	Yr. 2-05/01/90-10/31/91	51,804	89-38500-4516
	Project Total	**$98,363**	
*Effect of Nutrition on Body Composition and Subsequent Storage Quality of Farm-Raised Channel Catfish. Dr. R. T. Lovell, Auburn University, Principal Investigator	Yr. 1-05/02/89-04/30/90	$274,651	88-38500-4028
	Yr. 2-05/01/90-04/30/91	274,720	89-38500-4516
	Yr. 3-05/01/91-12/31/92	273,472	90-38500-5099
	Project Total	**$822,843**	

*Project Completed

Project	Duration	Funding	Grant No.
*Harvesting, Loading and Grading Systems for Cultured Freshwater Finfishes and Crustaceans. Dr. R. P. Romaire, Louisiana State University, Principal Investigator	Yr. 1-05/02/89-04/30/90	$124,201	88-38500-4028
	Yr. 2-05/01/90-04/30/91	124,976	89-38500-4516
	Yr. 3-05/01/91-04/30/93	124,711	90-38500-5099
	Project Total	**$373,888**	
*Preparation of Extension Publications on Avian Predator Control in Aquaculture Facilities. Dr. James T. Davis, Texas A&M University, Principal Investigator	05/01/90-12/31/92		
	Project Total	**$15,000**	89-38500-4516
*National Extension Aquaculture Workshop. Dr. Carole Engle, University of Arkansas at Pine Bluff, Principal Investigator	10/01/91-09/30/92		
	Project Total	**$3,005**	89-38500-4516
*Educational Materials for Aquaculturists and Consumers. Dr. J. T. Davis, Texas A&M University, Principal Investigator	Yr. 1-05/01/91-04/30/92	$3,971	87-CRSR-2-3218
		35,671	88-38500-4028
	Total Yr. 1	$39,642	
	Yr. 2-06/01/92-05/31/93	$58,584	91-38500-5909
	Yr. 3-06/01/93-12/31/94	34,500	92-38500-7110
	Project Total	**$132,726**	
*Characterization of Finfish and Shellfish Aquacultural Effluents. Dr. J. V. Shireman, University of Florida, Principal Investigator	Yr. 1-05/01/91-04/30/92	$45,131	88-38500-4028
		65,552	89-38500-4516
		34,317	90-38500-5099
	Total Yr. 1	$145,000	
	Yr. 2-06/01/92-05/31/93	$168,105	91-38500-5909
	Yr. 3-06/01/93-12/31/94	$128,937	92-38500-7110
	Project Total	**$442,042**	
*Food Safety and Sanitation for Aquacultural Products: Microbial. Dr. J. L. Wilson, University of Tennessee, Principal Investigator	Yr. 1-04/01/92-03/30/93	$12,649	89-38500-4516
		71,608	90-38500-5099
	Total Yr. 1	$84,257	
	Yr. 2-06/01/93-05/31/94	$213,106	92-38500-7110
	Yr. 3-06/01/94-05/31/95	$237,975	93-38500-8393
	Project Total	**$535,338**	

*Project Completed

Project	Duration	Funding	Grant No.
*Aquaculture Food Safety: Residues. Dr. George Lewis, University of Georgia, Principal Investigator	Yr. 1-09/11/92-09/30/93	$99,393	91-38500-5909
	Yr. 2-10/01/93-09/30/94	$44,631	90-38500-5099
		107,050	91-38500-5909
	Total Yr. 2	$151,681	
	Yr. 3-10/01/94-09/30/95	$89,463	93-38500-8393
	Yr. 4-10/01/95-09/30/96	$11,392	93-38500-8393
	Project Total	**$351,929**	
*National Coordination for Aquaculture Investigational New Animal Drug (INAD) Applications. (In cooperation with other Regional Aquaculture Centers and USDA)	Yr. 1-09/01/93-08/31/94		
	Project Total	**$2,000**	90-38500-5099
*Improving Production Efficiency of Warmwater Aquaculture Species Through Nutrition. Dr. Delbert Gatlin, Texas A&M University, Principal Investigator	Yr. 1-01/01/94-12/31/94	$28,148	90-38500-5099
		123,705	91-38500-5909
		128,444	92-38500-7110
	Total Yr. 1	$280,297	
	Yr. 2-01/01/95-12/31/95	$38,059	92-38500-7110
		175,450	93-38500-8393
		32,397	94-38500-0045
	Total Yr. 2	$245,906	
	Yr. 3-01/01/96-12/31/96	$23,907	93-38500-8393
		210,356	94-38500-0045
	Total Yr. 3	$234,263	
	Project Total	**$760,466**	
*Delineation and Evaluation of Catfish and Baitfish Pond Culture Practices. Dr. Michael Masser, Auburn University, Principal Investigator	Yr. 1-04/01/94-03/31/95	$75,530	92-38500-7110
		43,259	93-38500-8393
	Total Yr. 1	$118,789	
	Yr. 2-04/01/95-03/31/96	$113,406	94-38500-0045
	Yr. 3-04/01/96-03/31/97	$28,517	93-38500-8393
		72,281	94-38500-0045
	Total Yr. 3	$100,798	
	Project Total	**$332,993**	

*Project Completed

Project	Duration	Funding	Grant No.
*Optimizing Nutrient Utilization and Waste Control through Diet Composition and Feeding Strategies. Dr. Kenneth Davis, University of Memphis, Principal Investigator	Yr. 1-12/01/96-11/30/97	$241,476	95-38500-1411
	Yr. 2-12/01/97-11/30/98	$47,105	95-38500-1411
		210,047	96-38500-2630
	Total Yr. 2	$257,152	
	Yr. 3-12/1/98-11/30/99	$34,365	96-38500-2630
		199,811	97-38500-4124
	Total Yr. 3	$234,176	
	Project Total	$732,804	
*Management of Environmentally-Derived Off-Flavors in Warmwater Fish Ponds. Dr. Tom Hill, University of Tennessee, Principal Investigator	Yr.1-06/01/96-05/31/97	$29,349	93-38500-8393
		34,918	94-38500-0045
		186,560	95-38500-1411
	Total Yr. 1	$250,827	
	Yr. 2-06/01/97-05/31/98	$68,718	94-38500-0045
		97,393	95-38500-1411
		84,031	96-38500-2630
	Total Yr. 2	$250,142	
	Yr. 3-06/1/98-05/31/99	$154,621	96-38500-2630
		74,645	97-38500-4124
	Total Yr. 3	$229,266	
	Yr. 4-06/01/99-05/31/00	$80,900	98-38500-5865
	Yr. 5-06/01/00-05/31/01	$55,146	99-38500-7375
	Project Total	**$866,281**	
*National Aquaculture Extension Conference (In cooperation with other Regional Aquaculture Centers)	01/01/97-12/31/97	$3,392	93-38500-8393
		308	95-38500-1411
	Project Total	**$3,700**	
*Verification of Recommended Management Practices for Major Aquatic Species. Dr. Carole Engle, University of Arkansas at Pine Bluff, Principal Investigator	Yr. 1-01/01/97-12/31/97	$31,410	95-38500-1411
	Yr. 2-01/01/98-12/31/98	$7,186	95-38500-1411
		58,928	96-38500-2630
	Total Yr. 2	$66,114	
	Yr. 3-01/01/99-12/31/00	$62,781	99-38500-4124
	Project Total	**$160,305**	

*Project Completed

Project	Duration	Funding	Grant No.
Publications, Videos and Computer Software. Dr. Michael Masser, Texas A&M University, Principal Investigator (Continuing project)	Yr. 1-04/01/95-03/31/96	$50,000	94-38500-0045
	Yr. 2-04/01/96-03/31/97	$13,405	93-38500-8393
		47,543	94-38500-0045
	Total Yr. 2	$60,948	
	Yr. 3-04/01/97-03/31/98	$45,900	96-38500-2630
	Yr. 4-04/01/98-03/31/99	$60,500	97-38500-4124
	Yr. 5-04/01/99-03/31/00	$67,000	98-38500-5865
	Yr. 6-07/01/00-06/30/01	$77,358	00-38500-8992
	Yr.7-07/01/01-06/30/02	$82,205	2001-38500-10307
	Yr.8-01/01/03-12/31/03	$77,383	2002-38500-11805
	Yr.9-04/01/04-03/31/05	$916	2002-38500-11805
		59,550	2003-38500-12997
	Total Yr. 9	$60,466	
	Yr. 10-03/01/05-02/28/06	$50,896	2004-38500-14387
	Yr. 11-03/01/06-02/28/07	$72,065	2005-38500-15815
	Yr. 12-03/01/07-02/29/08	$74,100	2006-38500-16977
	Yr. 13-05/01/08-04/30/09	$80,106	2007-38500-18470
	Project Total	**$858,927**	
*Control of Blue-green Algae in Aquaculture Ponds. Dr. Larry Wilson, University of Tennessee, Principal Investigator	Yr. 1-01/01/99-12/31/99	$25,147	96-38500-2630
		105,167	97-38500-4124
		177,260	98-38500-5865
	Total Yr. 1	$307,574	
	Yr. 2-01/01/00-12/31/00	$975	96-38500-2630
		17,394	97-38500-4124
		158,608	98-38500-5865
		98,993	99-38500-7375
	Total Yr. 2	$275,970	
	Yr. 3-01/01/01-12/31/01	$26,186	97-38500-4124
		7,202	98-38500-5865
		188,550	99-38500-7375
		24,277	00-38500-8992
	Total Yr. 3	$246,215	
	Project Total	**$829,759**	
*Management of Aquacultural Effluents from Ponds. Dr. John Hargreaves, Mississippi State University, Principal Investigator	Yr. 1-04/01/99-03/31/00	$100,000	97-38500-4124
		127,597	98-38500-5865
	Total Yr. 1	$227,597	
	Yr. 2-04/01/00-03/31/01	$221,146	99-38500-7375
	Yr. 3-04/01/01-03/31/02	$106,610	2000-38500-8992
	Project Total	**$555,353**	
*Project Completed			

Project	Duration	Funding	Grant No.
*Development of Improved Harvesting, Grading and Transport Technology for Finfish Aquaculture. Dr. Ed Robinson, Mississippi State University, Principal Investigator	Yr. 1-01/01/01-12/31/01	$287,053	00-38500-8992
	Yr. 2-01/01/02-12/31/02	$14,259	98-38500-5865
		39,720	99-38500-5865
		14,757	00-38500-8992
		189,955	01-38500-10307
	Total Yr. 2	$258,691	
	Yr. 3-01/01/03-12/31/03	$47,937	00-38500-8992
		139,390	01-38500-10307
	Total Yr. 3	$187,327	
	Project Total	**$733,071**	
*National Aquacultue Extension Conference-2007 (In cooperation with other Regional Aquaculture Centers)	11/01/05-10/31/06		
	Project Total	**$5,000**	2002-38500-11805
*Identification, Characterization, and Evaluation of Mechanisms of Control of *Bolbophorus*-like Trematodes and *Flavobacterium columnaris*-like Bacteria	Yr. 1-03/01-03-02/28/04	$28,029	2000-38500-8992
		126,778	2001-38500-10307
		67,298	2002-38500-11307
	Total Yr. 1	$222,105	
	Yr. 2-03/01-04-02/28/2005	$27,126	2000-38500-8992
		47,498	2001-38500-10307
		151,614	2002-38500-11805
		778	2003-38500-12997
	Total Yr. 2	$227,016	
	Yr. 3-03/01/05-02/28/06	$24,074	2001-38500-10307
		15,417	2002-38500-11805
		104,918	2003-38500-12997
	Total Yr. 3	$144,409	
	Project Total	**$593,530**	
*Improving Reproductive Efficiency to Produce Channel × Blue Hybrid Catfish Fry. Dr. Rex Dunham, Auburn University, Principal Investigator	Yr. 1-03/01/04-02/28/05	$1,000	2001-38500-10307
		114,935	2002-38500-11805
	Total Yr. 1	$115,935	
	Yr. 2 -03/01/05-02/28/06	$99,000	2003-38500-12997
	Yr. 3-03/01/06-02/28/07	$14,549	2002-38500-11805
		28	2003-38500-12997
		100,423	2004-38500-14387
	Total Yr. 3	$115,000	
	Yr. 4-03/01/07-02/29/08	$115,000	2005-38500-15815
	Project Total	**$444,935**	
*Project Completed			

Project	Duration	Funding	Grant No.
Innovative Technologies and Methodologies for Commercial-Scale Pond Aquaculture. Dr. Claude Boyd, Auburn University, Principal Investigator	Yr.1-08/01/04-07/31/05	$1,053	2000-38500-8992
		167,433	2002-38500-11805
		145,923	2003-38500-12997
	Total Yr. 1	$314,409	
	Yr. 2-08/01/05-07/31/06	$39	2002-38500-11805
		116,043	2003-38500-12997
		151,234	2004-38500-14387
	Total Yr. 2	$267,316	
	Yr.3-08/01/06-07/31/07	$120	2002-38500-11805
		69,310	2003-38500-12997
		40,349	2004-38500-14387
		103,299	2005-38500-15815
	Total Yr. 3	$213,078	
	Yr.4-08/01/07-07/31/08	$17,000	2004-38500-14387
		82,788	2005-38500-15815
		70,308	2006-38500-16977
	Total Yr. 4	$170,096	
	Project Total	**$964,900**	
Feed Formulation and Feeding Strategies for Bait and Ornamental Fish. Dr. Rebecca Lochmann, University of Arkansas at Pine Bluff, Principal Investigator	Yr. 1-05/01/05-04/30/06	$102,913	2003-38500-12997
	Yr. 2-05/01/06-04/30/07	$107,198	2004-38500-14387
	Yr. 3-05/01/07-04/30/08	$21,148	2004-38500-14387
		109,332	2005-38500-15815
	Total Yr. 3	$130,480	
	Project Total	**$373,246**	
Development and Evaluation of Pond Inventory Methods. Dr. David Heikes, University of Arkansas at Pine Bluff, Principal Investigator	Yr. 1-05/01/07-04/30/08	$1,648	2003-38500-12997
		58,290	2004-38500-14387
		101,872	2005-38500-15815
	Total Yr. 1	$161,810	
	Yr. 2-05/01/08-04/30/09	$24,018	2004-38500-14387
		113,405	2006-38500-16977
	Total Yr. 2	$137,423	
	Project Total	**$299,233**	
Economic Forecasting and Policy Analysis Models for Catfish and Trout. Dr. Carole Engle, University of Arkansas at Pine Bluff, Principal Investigator	Yr. 1-08/01/07-07/31/08	$75,000	2006-38500-16977
	Yr. 2-08/01/08-07/31/09	$821	2005-38500-15815
		74,179	2006-38500-16977
	Total Yr. 2	$75,000	
	Project Total	**$150,000**	

Southern Regional Aquaculture Center, P.O. Box 197, Stoneville, Mississippi 38776

Visit our web site at http://www.msstate.edu/dept/srac to obtain SRAC publications and other information.

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