SRAC

TWENTY-THIRD ANNUAL PROGRESS REPORT

For the Period Through August 31, 2010

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

USDA
United States Department of Agriculture
National Institute of Food and Agriculture

December, 2010

TWENTY-THIRD ANNUAL PROGRESS REPORT

SOUTHERN REGIONAL AQUACULTURE CENTER
Dr. Craig S. Tucker, Director
P.O. Box 197
Stoneville, Mississippi 38776
Phone: 662-686-3286
Fax: 662-686-3320
E-mail: srac@drec.msstate.edu
http://www.msstate.edu/dept/srac

TABLE OF CONTENTS

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-third 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 did not increase because stocks of ocean fish were 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. Oddly, 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 2009 the United States imported $13 billion of fish and shellfish products, with a trade deficit of almost $10 billion. This was the largest deficit item for any agricultural commodity.

United States seafood demand continues to increase as a result of population growth and increased emphasis on eating seafood as part of a healthy diet. Although increased seafood demand provides considerable opportunity for growth of domestic aquaculture, production has been level since about 2000. In light of significant economic and food security benefits accruing 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 the largest sector of domestic aquaculture, accounting for more than half of U.S. 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/NIFA 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 23 years of operation, the Center has disbursed more than $15 million to fund multi-state research and extension projects. More than 200 scientists from 30 institutions in the southeast have participated in Center projects.

In the past year, SRAC funded five research projects totaling more than $1.2 million. The Center's "Publications" project is in its fifteenth year of funding and is under the editorial direction of faculty and staff at Texas A&M University. From this project, nine fact sheets, two power point presentations and one project summary were completed this year with nine fact sheets and one power point presentation in progress. To date, the "Publications" project has generated 205 fact sheets and species profiles, six project summaries and 20 DVDs with contributions from 220 authors from throughout the region.

Productivity from SRAC research projects has been excellent since the Center's inception more than two decades ago. Information derived from SRAC-funded projects has been transferred to producers and other scientists in thousands of scientific papers and presentations. Currently funded projects continue this trend of high productivity.

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-third 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, 2010.

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. Regional aquaculture funds are allocated to participants in SRAC projects approved by the Board and NIFA. 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/NIFA. The Center staff also prepares and submits to USDA/NIFA 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
Gregory Bohach, Mississippi State University
John Liu, Auburn University
Wondi Mersi, Virginia State University
David Morrison, Louisiana State University
Gary Palmer, University of Kentucky Extension Service
Gaines Smith, Alabama Cooperative Extension System
W. David Smith, North Carolina State University
Joe Street, Mississippi State University Extension Service

Ex-officio Board members are:

Co-chair, Industry Advisory Council
Co-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
Jim Ekstrom, TX
Shorty Jones, MS
Bill Livingston, SC
Joey Lowery, AR
Bill Martin, VA
Robert Mayo, NC
Sandy Miller, GA
Rick Murdock, KY
Ben Pentecost, MS
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:

Brian Bosworth, MS
Harry Daniels, NC
Sid Dasgupta, KY
Allen Davis, AL
Patricia Duncan, GA
Carole Engle, AR
Delbert Gatlin, TX
Chris Green, LA
Mike Oesterling, VA
Courtney Ohs, FL
Larry Wilson, TN

Members of the TC for Extension are:

Jimmy Avery, MS
Don Bailey, VI
Ron Blair, TN
Gary Burtle, GA
Jesse Chappell, AL
Dennis Delong, NC
David Heikes, AR
Michael Masser, TX
R. P. Romaire, LA
Mike Schwarz, VA
Saul Wiscovich Teruel, PR
Craig Watson, FL
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 efficient use of limited resources and 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

Research and extension activities supported by SRAC are accomplished by work described in *Project Proposals*. Proposals are developed using either the *Work Group Method* or the *Competitive Proposal Method*. In either case, 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 of Directors. Once an area of work has been approved, the Executive Committee appoints a *Project Writing Team* to develop the "Request for Pre-Proposals" and recommend to the Board of Directors which project development process appears to be most appropriate. The Board of Directors has ultimate authority to determine which method will be used to develop project proposals.

In the Work Group Method, the Request for Pre-Proposals is distributed to state, territorial or federal institutions and non-profit private institutions within the Southern Region with demonstrated competence in aquaculture research and development. Interested parties respond by submitting a pre-proposal to the SRAC Adminstrative Office. A *Proposal Review Team* then selects the best pre-proposals to eventually become part of the regional project proposal. The Proposal Review Team consists of three technical and three industry representatives who cannot become funded participants in the project. Once the project participants have been identified, the SRAC Director convenes a meeting of the *Project Work Group*, which consists of individuals selected to participate in the project and members of the Project Writing Team.

The Competitive Proposal Method differs from the Work Group Method in that the Competitive Proposal Method requests that pre-proposals be submitted from multi-state teams of scientists. Each team will submit one proposal addressing all project objectives. Proposals will then be reviewed by a Proposal Review Team, as described above, and one proposal will be selected for funding. After one pre-proposal has been selected for funding, the SRAC Director convenes a meeting of the *Project Work Group*, which consists of individuals collaborating in the selected pre-proposal and members of the Project Writing Team.

The Project Work Group prepares the project proposal, which is reviewed by the 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 NIFA for approval. Pending a successful review of the project plan and budget, NIFA 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

A wide variety of support functions for the various SRAC components, including the Board, TC, IAC, Steering Committees and project Work Groups are provided by the SRAC administrative staff:

- 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/NIFA National Program staff.
- Prepare and submit Grant Application to USDA/NIFA 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/NIFA 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 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 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.
- 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 Requests for Pre-proposals 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, 2010

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	60,466
Year 10	50,896
Year 11	45,723
Year 12	63,764
Year 13	80,106
Year 14	79,913
Year 15	74,077
Total	$976,240

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.

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 direct 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. All SRAC publications are based on research conducted within the region or in surrounding areas.

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 materials 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. DVDs 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 makes access faster and easier, facilitates searching for needed information, and reduces storage space requirements for printed documents. The SRAC publications web site was updated this year.

Results at a glance...

- *More than 220 authors have contributed to SRAC publications since the project's inception.*
- *Nine new fact sheets, two PowerPoint presentations, and one project summary were completed this year. Nine more fact sheets and one power point are in some stage of review.*
- *Thirty scientists from across the Southern Region contributed to completed publications this year.*

PROGRESS AND PRINCIPAL ACCOMPLISHMENTS

During this current project year, nine new fact sheets, two educational PowerPoints, and one project summary were completed. The Aquaplant web site was also updated. All publications have been distributed throughout the Southern Region and to interested Extension Specialists in other regions. Nine fact sheets and one PowerPoint are in some stage of writing, production, or revision. Nine fact sheets have currently not had drafts submitted. One project summary has not been submitted.

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:

- *Basic Aquaculture Genetics*
- *Diseases of Concern in Molluscan Aquaculture*
- *Biological Safety of Fresh and Processed Shellfish*
- *Principles of Fish Nutrition*
- *Mycotoxins in Aquaculture Feeds*
- *Shellfish Handling Practices – Shrimp and Molluscs*
- *Shipping Fish in Boxes*
- *Removing Fish from Ponds with Rotenone*
- *Preventing Hitchhiking Non-Iindigenous Species in Live Shipments*

WORK PLANNED

During the next project year, 12 new fact sheets, one PowerPoint program, and one project summary will be produced.

The new fact sheets will address: 1) pond effluent management, 2) sorting and grading of fish, 3) economics of recirculating systems, 4) heterotrophic/biofloc systems, 5) how to start a biofilter, 6) prebiotics and probiotics, 7) INAD development and drug approval, 8) non-commercial shellfish culture, and 9) species profile on croaker.

The new PowerPoint presentation will address largemouth bass culture.

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 frequently requested and used by clientele in all 50 states. 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 2009 through August 2010, 35,788 visitors with 25,337 unique visitors came to the

SRAC web site and accessed 139,695 pages. These visitors camefrom 97 countries/territories. Since fact sheets are also accessible through numerous other university research and extension web sites, the total usage and impact is undoubtedly several times greater. The AQUAPLANT web site from September 2009 through August 2010 had 244,764 unique visitors that accessed 1,208,211 pages. These visitors came 136 countries/territories.

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.

Results at a glance...

- *In the months from September 2009 through August 2010, the SRAC web site was accessed by 35,788 users of which 25,337 were unique visitors and they accessed 139,695 pages on the site.*

The impact on consumers of aquaculture products is also likely significant, although it has not been 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.

PUBLICATIONS, MANUSCRIPTS OR PAPERS PRESENTED

Fact Sheets Completed (9/1/09 - 8/31/2010)

Basic Aquaculture Genetics by Jason W. Abernathy, Eric Peatman and Zhanjian (John) Liu, SRAC Publication Number 5001.

Diseases of Concern in Molluscan Aquaculture by Ryan Carnegie, SRAC Publication Number 4704.

Biological Safety of Fresh and Processed Shellfish by George J. Flick, Jr., and Linda A. Granata, SRAC Publication Number 4901.

Principles of Fish Nutrition by Delbert M. Gatlin, III, SRAC Publication Number 5003.

Mycotoxins in Aquaculture Feeds by Bruce B. Manning, SRAC Publication Number 5002.

Shipping Fish in Boxes by Craig Watson, Kathy Heym Kilgore, and Carlos Martinez, SRAC Publication Number 3903.

Shellfish Handling Practices – Shrimp and Molluscs by Russell J. Miget, SRAC Publication Number 4902.
Removing Fish from Ponds with Rotenone by Forrest Wynne and Michael Masser, SRAC Publication Number 4101.
Preventing Hitchhiking Non-Indigenous Species in Live Shipments, By Paul W. Zajick, Jeffrey E. Hill, Nathan Stone, Hugh Thomforde, Cortney Ohs, Diane Cooper, Gef Flimlin, Brad McLane and William D. Anderson, SRAC Publication Number 3902.

Project Summary Completed

Optimizing Nutrient Utilization and Reducing Waste through Diet Composition and Feeding Strategies by Kenneth B. Davis, SRAC Publication Number 6003.

PowerPoint Presentations Completed

Constructing a Simple and Inexpensive Recirculating Aquaculture System (RAS) by David J. Cline, Jason Adams and Tiffany Smith.
Techniques for Marine Finfish Larviculture by Michael H. Schwarz, Brendan Delbos, and Steven Craig.

Manuscripts being printed

Phytoplankton Culture for Aquaculture Feed by LeRoy Creswell, SRAC Publication Number 5004.

Manuscripts in review

Amylodinium *Parasites in Fish* by Ruth Francis-Floyd and Maxine R. Floyd
Diagnosing Fish Kills by Bill Hemstreet
Emerging Non-Native Species Issues for Aquaculture by Jeffrey E. Hill.
Transportation of Warmwater Fish by Forrest S. Wynne and William A. Wurts, SRAC Publication Number 390 (Revision).
Site Selection of Levee Ponds by Jimmy Avery, SRAC Publication Number 100 (Revision).
Hybrid Catfish by Rex Dunham, SRAC Publication Number 190 (Revision).
Species Profile – Pigfish by Cortney Ohs.
Species Profile – Pinfish by Cortney Ohs.

On-going project

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

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

◆ ◆ ◆

DEVELOPMENT AND EVALUATION OF POND INVENTORY METHODS

Reporting Period
May 1, 2007 - August 31, 2010

Funding Level

Year 1	$157,818
Year 2	$137,158
Total	$294,976

Participants

Louisiana State University	Ray McClain, Robert Romaire
Mississippi State University	Doug Minchew
University of Arkansas at Pine Bluff	David Heikes, Steeve Pomerleau, Yong-Woo Lee
University of Florida	Craig Watson
University of Mississippi	James Chambers, John Heffington

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, head-count 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. Traditional methods for estimating inventories throughout the ornamental fish production cycle are primarily based on personal knowledge of number of fry per spawn (egg-layers), general productivity of broodfish (live-bearers), general observations during grow-out, and historical production from individual ponds. It was hypothesized that these methods were extremely inaccurate and led to poor management tools within the industry. Very little, if any, record keeping is used. Business planning and comparing results of changes in production methods is, therefore, difficult. Improved techniques for estimating ornamental fish density and size distribution in commercial ponds are needed.

In this project, traditional inventory estimation methods were compared to actual inventory counts from experimental ponds located on 4 commercial facilities and at the University of Florida/IFAS Tropical Aquaculture Laboratory (TAL). Actual inventory counts included physical counts of fry and fish, volumetric estimates of number of fry at stocking, sub-sampling of inventory three times through grow-out using partial seine techniques, and physical counts of fish at harvest. A simple Excel spreadsheet was also employed to record stocking, production observations, and harvest data. This study focused on three species of fish commonly produced in Florida; serpae tetras (*Hyphessobrychon serpae*); blue gouramis (*Trichogaster trichopterus*); and swordtails (*Xiphphorus helleri*).

For serpae tetras and blue gouramis, a similar protocol was developed for comparing estimation and actual counts of number of fry produced per female and number of fry in subsequent pond stocking. With both species, broodstock were selected for health, condition, and similar size. The trials with serpae tetras included 500, 2-gallon spawning tanks, in which one pair of fish were placed. At 96 hours, tanks were numbered and 50 tanks were randomly chosen. The blue gouramis trials included 60 individual 10 gallon spawning tanks, in which one pair of fish was placed. At 96 hours the tanks were numbered and six tanks were randomly chosen. In both cases 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 spawning tanks three times, using a commonly practiced method of holding the spawning tanks up to the light one by one and estimating the number of fry. Serpae tetra fry were then equally distributed into 28 larval rearing vats, except for the 50 randomly selected tanks, which were used to generate an exact count. Counts were conducted by first euthanizing the fry in each spawning tank and transferring 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. For the blue gouramis, the six tanks which were randomly selected were euthanized and then hand counted using the same method. The actual count was then compared to the producer's estimates.

Fry from each remaining tank were then reared for 3 weeks before being stocked into two grow-out ponds (6-feet deep, 0.04-acres). The producer was again asked to estimate the number of juvenile fish stocked into each of the two grow-out ponds, and selected 10 vats for each pond. To generate our count we randomly selected eight vats and counted each juvenile. For the blue gouramis, a simple reduction method was employed to enumerate the fry in two, 10 gallon tubs which are used to transport fry to the ponds. The water was gently mixed to maximize equal distribution of fry in the water volume, and three individual 50-mL samples were counted. These reduction estimates were then compared to the producers visual tub estimates. The fry were then stocked into 2 growout ponds. All grow-out ponds were visually monitored twice daily by the producer and study staff during daily feedings and weekly for the duration of the 4-month grow-out cycle. Actual harvest numbers were supplied by the producer which reflected exact sales receipts. For the swordtail trials, two commercial producers and ponds at the Tropical Aquaculture Laboratory were used. Attempts to assess inventories on two participating commercial facilities were discontinued due to catastrophic losses which occurred on both farms during both summers during this study. Using data collected at the Tropical Aquaculture Laboratory, we were able to evaluate expected production of swordtails in open ponds. Based on previous data from tank studies, predicted production = 1.32 fry/female/day. Five ponds were each stocked with 200 female and 50 male swordtails, and fed a standard diet for 12 weeks (note: 12 weeks is the typical time needed to reach market size for swordtails).

Use of a simple Excel spread sheet to accurately record stocking dates, number stocked, regular observations, and harvest data has proven cost effective and beneficial to farms employing it. An unexpected result is that the local USDA Farm Service Agency is now using the Excel sheets developed as a handout to producers enrolling in the NAP program as an example of the data they are requesting during a disaster program. Numbers of fry generated in hatcheries for serpae tetras and blue gouramis using traditional methods of estimating by sight were grossly underestimated by 3.8 to 4.2 and 8.2 to 8.5 times, respectively. 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. However, the producer's estimate of the amount of juveniles stocked into each pond was more accurate, and exceeded the actual estimate only by 9.78%. This showed that significant losses are incurred during the larval rearing stage. Better nutrition (i.e. simply increasing the amount of artemia fed to the larval rearing tanks) has led to increased survival at this stage and decreased man-hours in setting up breeding tanks. Similarly, the blue gourami trial showed that actual harvest data was significantly less than anticipated. Lowering the stocking rates has

Results at a glance...

- *Improved inventory methods based on this project are being applied by a commercial ornamental fish producer to more than 60 species of fish, resulting in significant improvement in production efficiency. Another producer reports increased revenues of almost $400,000 using improved methods based, in part, on this project.*

resulted in similar harvest numbers indicating that initial larval survival is possible and that fewer broodstock are required.

Physical counts of egg-layer fry are now recommended for all species, at least initially, as opposed to using visual estimates. Savings and increased production have resulted in a 50% reduction in the required broodstock, man-hours, and grow-out time for one farm participating, and they have now employed these methods to 60 varieties of fish. Another producer reports similar percentages and increased revenues of $392,000 based on improved management. Several problems occurred with this project as designed. Periodic sampling of fish in open ponds, during production, using seine nets proved unacceptable and ineffective. Fish captured, counted, and returned to the pond experienced mortalities, and sampling was extremely inaccurate using a partial seine method. Increasing the portion of the pond seined to increase the accuracy resulted in increased mortalities. This method is not recommended for farmers to assess standing crop during production of the species studied. The summer weather in west central Florida during both years of this study resulted in catastrophic losses on both of the commercial swordtail farms studied, which resulted in no usable data. However, work conducted at the Tropical Aquaculture Laboratory has been useful, as previous to this study there was no data available to accurately predict this production in open ponds. Ponds were harvested and all fish counted, resulting in an average total inventory of 20,292 fish, 90% of what was predicted. Based on this, farms can anticipate an average production of 1.18 fry/female/day in open ponds after 12 weeks of production for swordtails. Recommendations based on results of these studies are being implemented in Extension programs for ornamental fish producers.

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 depends upon natural reproduction from indigenous or supplemented broodstock to populate ponds. This subjects growers to great variation in yield and harvest size due to large natural variations in adult survival and reproductive success from year to year and pond to pond. Furthermore, 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. Therefore, this project attempted to eliminate natural recruitment and instead accomplish the task 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 established during the summers of 2006 and 2007 in 12, 1-acre experimental plots at the LSU AgCenter's Rice Research Station. Following rice harvest, the pond was managed for crawfish production according to typical rice-crawfish rotational practices in the region. Ponds were not stocked with brood crawfish and fields were

Results at a glance...

- *Sampling with test traps, dip-net sweeps, and a passive experimental sampler generally were good indicators of relative crawfish recruitment density and potential yield. The most accurate pond inventory methodologies were those that sampled around the pond margin rather than in the pond interior and occurred several months after the simulated recruitment period.*

additionally treated with a pyrethroid insecticide prior to the permanent flood to eliminate migrant crawfish into the field. Ponds were completely drained and re-flooded with fresh water after 3 days. Crawfish populations were subsequently established by stocking of hatchlings, spawned under laboratory conditions, at known densities and at predetermined timing post flooding. Treatments consisted of a low (3 crawfish/m^2) or high (6 to 7 crawfish/m^2) stocking rate and either single or multiple age classes (biweekly over two months) in a factorial arrangement of treatments.

Systematic population sampling was conducted prior to initiation of harvests and 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; Figure 1). 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 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. Crawfish catch,

Figure 1. 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.

total and by size category, were noted for each sampling effort.

Annual yield of market-size crawfish averaged 194 pounds/acre for year 1 and 360 pounds/acre for year 2, which was lower than the state wide average of about 600 pounds/acre. Average overall capture rate based on number of crawfish stocked was 12.8% in year 1 and 26.2% in year 2. This seems low, but without a means to accurately assess recruitment density in commercial ponds, it is unknown how well these numbers represent the percent recovery of commercial operations. Correlation coefficient is a measure of how well one group of data corresponds to a second group of data. Sampling efficacy was highly variable from year to year and from gear to gear in this study; but in general, sampling results using baited large-mesh traps (late in the season) and the passive drop sampler were well correlated to both stocking density and yield.

While these findings provided a basic foundation for better understanding of the relationships between initial recruitment numbers, surviving population density and resulting yields in crawfish aquaculture suggests that timely sampling has merit for assessing relative population inventories. Further research is needed to develop applied management options and recommendations for maximizing profits based on sampling outcomes.

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. Pond production of channel catfish is the largest sector of domestic aquaculture. Pond management strategies can be compromised because of inaccurate inventories resulting in continuous culture for several years without a total harvest. Research was proposed to use an acoustic system to provide the size distribution of a pond to aid management decisions which require inventory information. A current method to determine the size distribution of a pond is to pull a sub-sample seine net across a pond to obtain a sample of the fish and manually weigh them in a time-consuming process. The work presented here still uses a sub-sample seine net to collect a sample of fish but uses acoustic backscatter from the fish as they swim back to the pond to determine the size distribution of the fish in lieu of the manual weight measurements.

A prototype acoustic measurement system (Figures 2 and 3) was assembled and tested in various commercial and research ponds in the Mid-south. The system consisted of a SONAR system operating at 460 kHz placed on top of a PVC floatation system which was attached to a 6-inch PVC pipe extending from the float into the pond. The pipe allowed fish to swim back into the pond after being seined and also acted to restrict fish movement relative to the SONAR's active element, thereby reducing variation in sound reflection due to fish orientation. As fish pass through the pipe, they are pinged by acoustic pulses and the return echo amplitude is recorded and stored on the unit for future analysis. Measurements were made in pens and ponds at the University of Arkansas Pine Bluff as well as commercial ponds at Wilmot, AR. In the preliminary tests, both the acoustic reflections as well as the actual fish weights were collected, on a fish-by-fish basis, to develop an empirical prediction routine relating fish weight to acoustic reflection, also known as the target strength. This prediction routine was later used in blind tests on ponds in Wilmot, AR, Pine Bluff, AR (UAPB) and the National Warmwater Aquaculture Center (NWAC) in Stoneville, MS. The results from the acoustics predictions were compared against actual measured weights to determine efficacy.

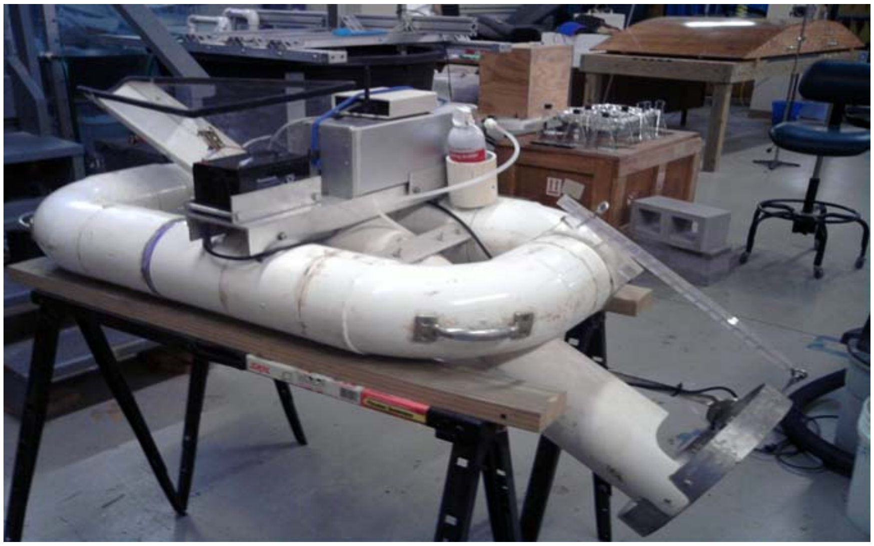


Figure 2. The catfish sizing system with electronics and battery mounted on board and bubbler system in place to provide calibrated signal in data.

Figure 3. Modified Aquascanner Catfish SONAR system being used to measure individual fish.

Measurements show a trend of increasing reflectivity, or target strength, with increasing weight of fish, but the variances between predicted and measured weights for individual fish are larger than expected. For instance some small fish (0.5 pound) returned echo amplitudes comparable to larger (5 pound) brood fish. It is supposed that fish movement, changes in orientation or entrained air bubbles as fish swim back into the pond from the flotation device may be responsible for the variations. The data also showed a point of diminishing returns in that larger and larger fish return a diminishingly smaller increase in target strength (Figure 4). Echoes from fish weighing 8 pounds, for example, were are not markedly different than 4-pound fish. Such a scenario, in an inversion process which uses the acoustic echo

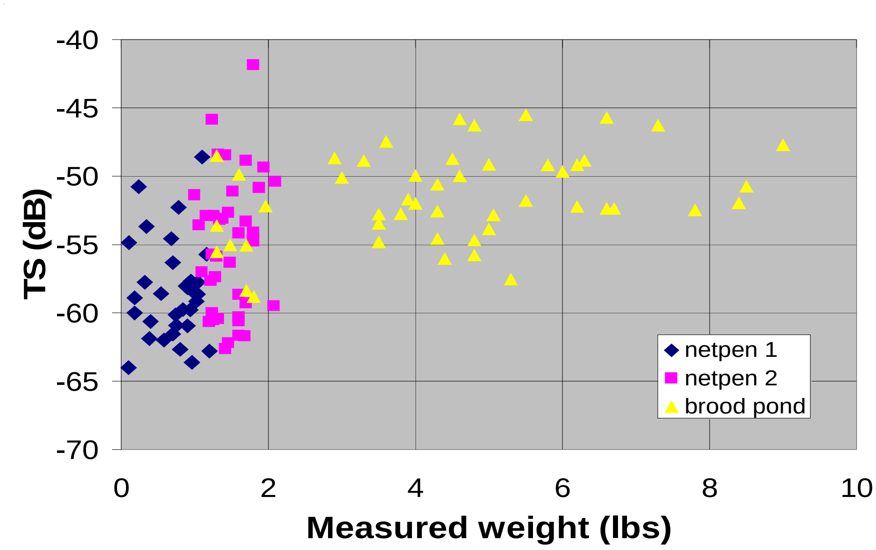


Figure 4. Relationship between target strength (TS) and measured fish weight from a pond at Pine Bluff, Arkansas.

to predict the weight of the fish, makes electronic errors problematic in potentially predicting large fish weights. The use of the data, in a statistical sense however, may have value. While predicted fish weights differ from actual weights for individual fish (mitigating the technology for use in say vaccine delivery), the errors may cancel so that predictions for a large enough sample, may be useful.

Two blind tests were taken at Pine Bluff and Wilmot, AR. The model predicted average fish weights of 1.42 pounds/fish and 2.15 pounds/fish for populations that had measured average weights of 1.43 and 2.34 pounds/fish, respectively, giving errors of -0.5% to -8%. Four additional blind measurements were later taken at Stoneville, MS. These tests consistently under-predicted measured fish weight by an average of 30%. It is unclear if this discrepancy is due to local pond-specific issues, the distribution of sizes in the fish population, an equipment-specific issue or some other factor. The prediction model used was developed to minimize errors of both the average weight and standard deviation in weight of a sample. It may well be that improvements can be made in estimating the average weight of a sample but presumably this will come at the expense of the accuracy of the standard deviation. It is also possible that improvements (and consistency) in how the fish move through the pipe may reduce variations in the reflectivity of the fish which should improve predictions. Data and the prediction algorithm are being investigated further as part of a graduate thesis.

Results at a glance...

- *An acoustic backscatter system has been built to measure the target strength of individual fish from a harvested population. A relationship between fish weight and acoustical target strength was developed into a model that can be used 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. Previous work with custom-fabricated side-scanning SONAR showed that the technology may have application for pond-scale counting of fish as part of inventory assessment in catfish farming. Advances in the private sector on other applications of side-scanning SONAR showed further promise, with the possibility of not only assessing fish numbers, but also individual fish weights, which could then be combined to provide population size distributions and total fish biomass.

Initial research focused on testing a 997c Humminbird® side-imaging SONAR. The transducer has down-looking as well as side-scanning capabilities. The side-imaging SONAR must be moving to operate properly; therefore, it was mounted on a boat with a trolling motor. Testing showed that the side-scan mode produced excellent images of the pond bottom and various structural features in both shallow and deep water but must be operated at 455 kHz in shallow water because the higher frequency saturates the water column making imaging impossible. The down-looking mode worked well in deeper water but not in water as shallow as most catfish ponds. This preliminary work showed that side-scanning SONAR can be used to image fish, and therefore may have the potential to be calibrated to obtain data on fish sizes.

Further work used a DIDSON 300M unit with associated hardware and software. The DIDSON 300M can be operated at either a high- (1.8 MHz) or low- (1.1 MHz) frequency. The DIDSON unit was deployed using a custom-made, adjustable system that allows quick deployment to the desired depth and rapid re-deployment for multiple sampling. Details of the deployment system and data-processing options for the DIDSON unit can be obtained from Dr. C.D. Minchew at Mississippi State University.

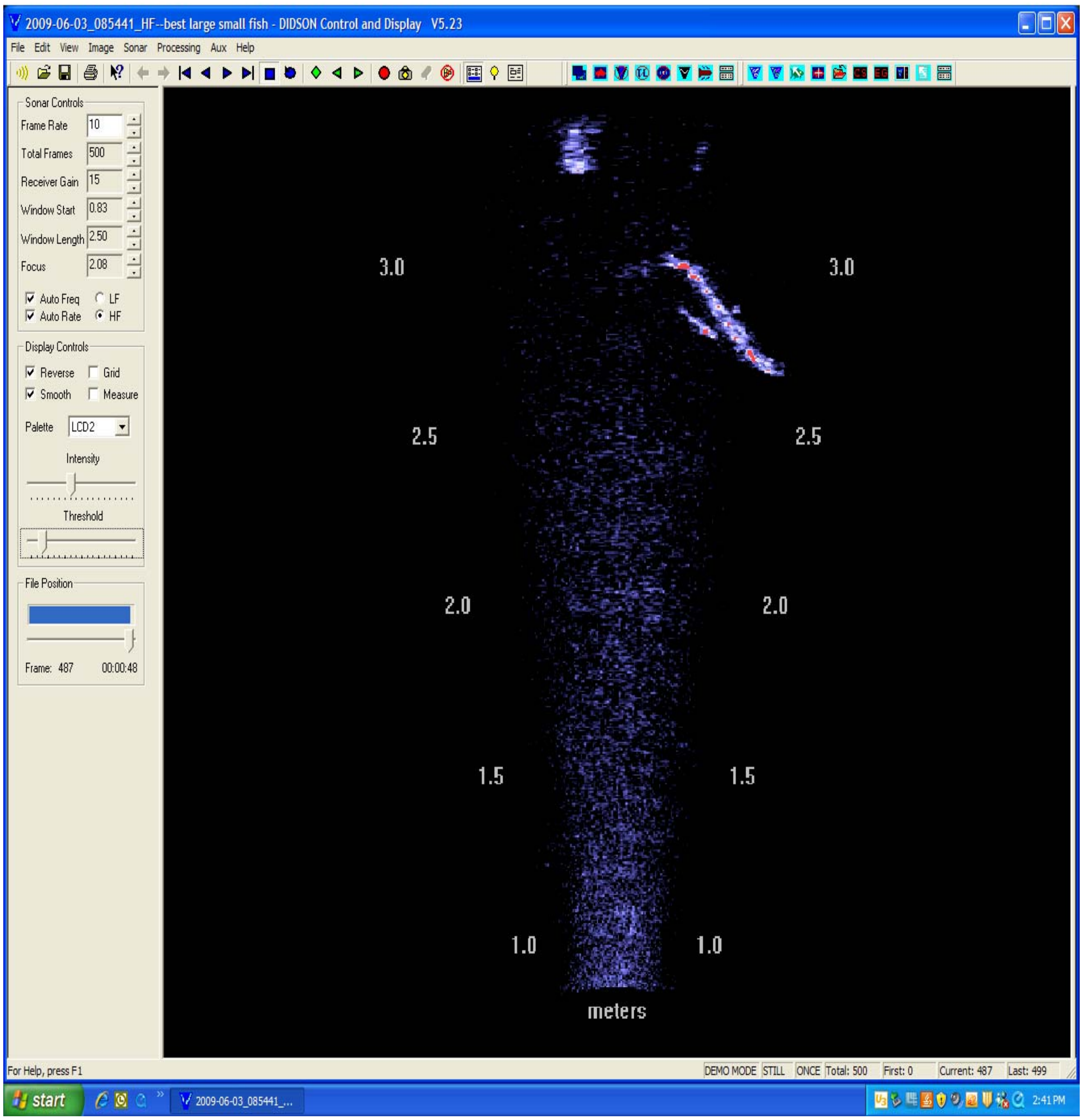
The strength of the DIDSON sonar for studying catfish in shallow production ponds is its ability to record recognizable images of fish in turbid ponds and process that data to obtain estimates of fish size. Useable images have been taken with both the low- and high-frequency beams. Under ideal conditions, ranges of the high- and low-frequency beams are 1 to 15 m and 1 to 35 m, respectively. However, in the present study, the useful range of the two sonar beams was limited to about 8 m (high frequency) and 16 m (low frequency). While the low frequency beam has a longer range, it is limited in its ability to image small fish. Therefore, the high-frequency setting was used to image obtain the following images. Figure 5 shows a large and small catfish swimming together. Fish were sized using the DIDSON "measure tool." The fingerling was 16 cm (6.3 inches) and the larger fish was 58 cm (22.8 inches).

Although not a part of this study, it is clear that the DIDSON has the potential to be useful in studying catfish behavior. It could be used to observe the behavior of pond cultured catfish in response to

Results at a glance...

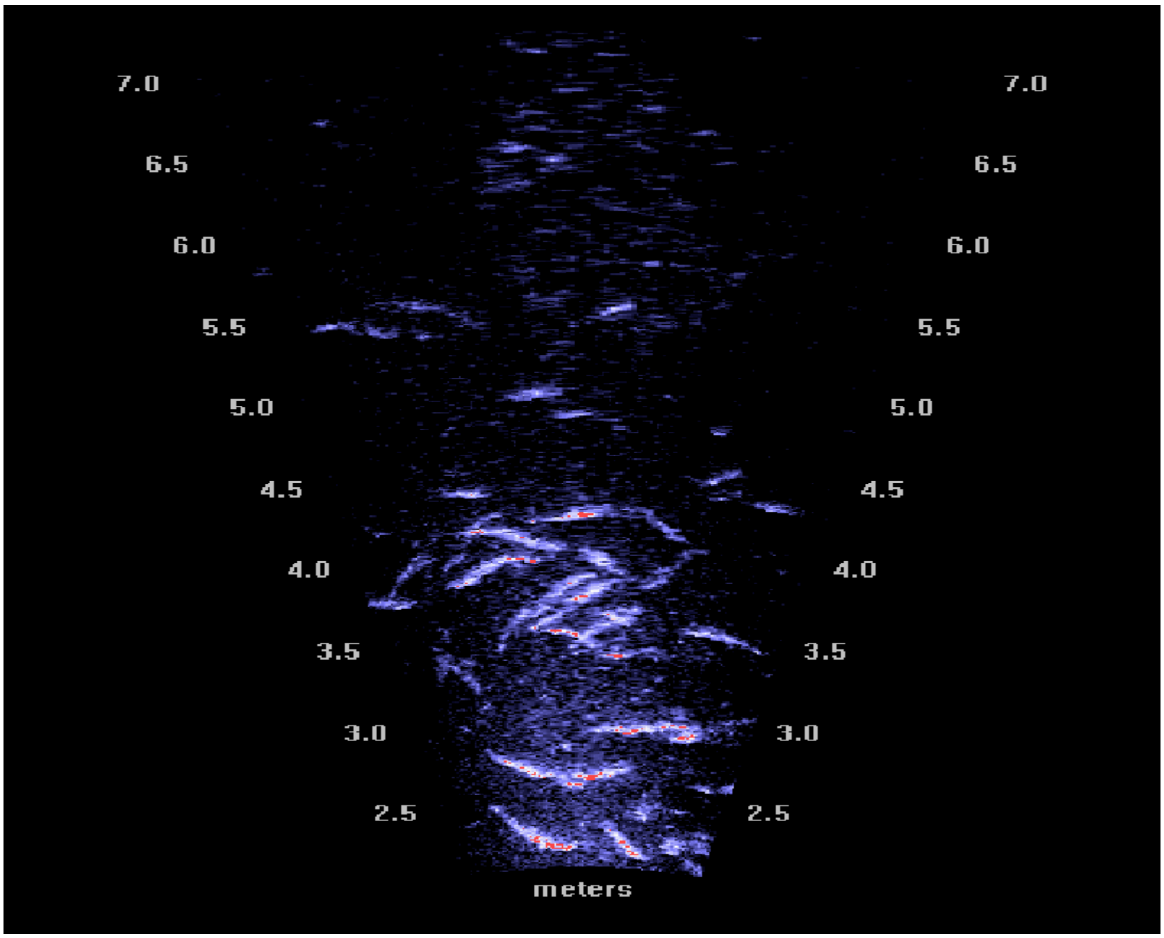
- *The DIDSON sonar with its sophisticated software can detect, identify, and measure catfish cultured in shallow, turbid waters. Catfish as small as 4 inches and as large as 30 inches have been detected, imaged, and measured using sonar data files collected at multiple sampling sites in culture ponds stocked with mixed sizes of fish. Such data could be used to develop population size distributions for commercial ponds.*

Figure 5. A sonar image of a large (58 cm) and small (16 cm) catfish swimming near each other. The sonar image was taken at a sampling station at Delta Research and Extension Center on August 3, 2009. The pond had recently been stocked with two size classes of catfish as a part of a growth study.



seining, grading, low oxygen, and feeding. For example, Figure 6 shows an image collected while catfish were being fed fed using a tractor-pulled feeder. Additional images were collected during a severe dissolved oxygen depletion. Both events (feeding and response to low oxygen) are more impressive when examined while running the video of each event rather than as still pictures.

Figure 6. Raw data image of feeding fish.



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

University of Arkansas at Pine Bluff. Estimating biomass and size distribution of catfish in earthen production ponds has always been difficult. Accurate inventory estimates are often needed for management considerations, business planning, and operation financing. New inventory tools and methodologies are needed to help catfish producers obtain accurate inventory data from large earthen pond systems. The objective of this study was to develop a commercial-scale sampling apparatus and then determine if it could be used to collect accurate inventory data.

We started with two standard pieces of equipment that are commercially available; a hydraulic seine reel, and a standard "otter trawl." The idea was to devise a mechanism that would allow us to lay the otter trawl on the levee on one side of pond, and then pull it through the pond with a rope to the opposite levee to collect our sample. Previously published data indicated that the trawl would need to move through the pond at about 5 feet/second in order to catch catfish consistently. With that in mind, we made several modifications to the seine reel to ensure the trawl would travel at that speed. First, we outfitted the seine reel with a hydraulic system that could be powered by the 540-rpm PTO of any 30-hp (or larger) tractor. This was necessary because the standard hydraulic systems on most fish farm tractors were not designed to deliver the amount of power necessary for this application. We also increased the center drum diameter by welding cross bars to the inside of the spool and decreased the size of the primary drive sprocket to increase the rotational speed. We used an otter trawl, which is a funnel-shaped net with a 30-foot-wide mouth, and "otter boards" that are designed to pull the net open as it moves through the water. Several modifications were made to the original trawl design, including reducing the size and weight of the otter boards, adding mud rollers to the mud line, and removing the trap at the head of the cod end (Figures 7 and 8). Detailed equipment design specifications for the catfish sampling rig can be obtained from David Heikes, Aquaculture and Fisheries Center, University of Arkansas at Pine Bluff.

The sampling trawl was tested in a series of trials conducted in large commercial ponds in Arkansas and Mississippi and also under controlled, replicated conditions at the National Warmwater Aquaculture Center, in Stoneville, MS. In the first commercial pond trials, we wanted to document the performance of the trawl both with and without the use of feeding to attract fish to the trawls path. Each pond was pulled one time without feeding in the morning and then pulled again after feeding in the afternoon. Following the trawl events in each pond, the entire pond was seined three times using a small mesh fingerling seine to determine the actual inventory. Fish captured by the trawl were returned to the pond before seining in each trial. Fish caught by the trawl were individually weighed and the size distribution compared to samples taken from the actual population caught in the seining events. Results of this trial showed us that the frequency distribution of sizes of catfish caught in the trawl pulls was not significantly different from that obtained from seining. A second trial with a similar protocol was conducted in six, 4-acre ponds at Stoneville. While trawling with feeding caught more fish in each pull, there was no difference in average weight or size distribution between the two trawling methods. These results also indicated that a single trawl pull, either with or without feeding, resulted in an accurate size distribution. However, a single trawl pull, which is similar to the technique known in fisheries as the "swept area method", was inadequate for estimating total pond biomass. These results led to a third trial in the same 4-acre ponds at Stoneville to determine if multiple trawl pulls (without feeding) could lead to a better estimate of total biomass. When the inventory was estimated from pooling the catches

Results at a glance...

- *The sampling trawl techniques developed in this project have been adopted commercially on a limited basis. Using fish-size distribution data generated from fish captured by trawling, managers are able to more accurately identify ponds that are ready for harvest and to schedule harvest dates for ponds that are not currently ready.*

from more than one trawl pull (and using the total area swept from the pulls in the calculation), the estimated inventories were similar to that of the base inventory. This indicates that at least under these conditions, the catfish sampling trawl can be used to generate size distribution information as well as an estimate of total biomass.

An additional study was conducted to systematically evaluate the traditional methods of estimating pond inventories that are based on daily feeding response of catfish. Daily feed data from experimental (0.25-acre and 4-acre) and commercial (10-acre) ponds were used to characterize feed response of catfish and to compare the accuracy and precision of feeding response methods used to estimate fish inventories. Daily feed consumption of catfish was highly variable. Inventories estimated with feed response methods had errors of 16% to 37% in single-batch production and 28% to 49% in multiple-batch production. Inventories estimated with feed response methods were too inaccurate and variable for reliable use in management, by lenders, or by the court system.

Figure 7. The "otter trawl" is shown here laid out and ready to be pulled across a pond.

Figure 8. Tractor (43hp) used to pull the trawl using a power take-off driven hydraulic pump.

PUBLICATIONS, MANUSCRIPTS, OR PAPERS PRESENTED

Heffington, J.D., J.P. Chambers, D. Heikes, S. Pomerleau, and N. Stone. 2006. Using acoustic backscatter to determine the size distribution of channel catfish in a commercial pond. Proceedings of the 3rd Joint Meeting of the Acoustical Society of America and Japan 120:3106.

Heffington, J.D., J.P. Chambers, B. Goodwiller, R. Beecham and D. Heikes. 2010. Development and use of an acoustic device to estimate size distribution of catfish in commercial ponds. Proceedings of the 160th Meeting of the Acoustical Society of America, Cancun, Mexico.

Heffington, J.D., J.P. Chambers, B. Goodwiller. 2010. Development and evaluation of an acoustic device to estimate size distribution in catfish production ponds. Proceedings of the 6th Meeting of the Mid-South Chapter of the Acoustical Society of America, Conway, Arkansas.

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.

McClain, W.R., R.P. Romaire, and J.J. Sonnier. 2008. Assessment of sampling and harvest yields when crawfish ponds are populated only by stocking hatchlings. LSU Agricultural Center, Rice Research Station Annual Research Report 100:188-201.

Sudhakaran, P.O. 2009. Improved inventory techniques in commercial catfish (*Ictalurus punctatus)* ponds. Master's Thesis. University of Arkansas at Pine Bluff, August 2009.

Sudhakaran, P.O., D. Heikes, C. Engle and S. Pomerleau. 2010. Evaluation of a trawl to estimate the inventory of catfish in commercial ponds. Aquaculture America 2010, 1-6 March 2010, San Diego, California.

◆ ◆ ◆

ECONOMIC FORECASTING AND POLICY ANALYSIS MODELS FOR CATFISH AND TROUT

Reporting Period
August 1, 2007 - August 31, 2010

Funding Level	Year 1	$73,577
	Year 2	74,758
	Total	$148,335

Participants	University of Arkansas at Pine Bluff	Carole Engle
	Louisiana State University	P. Lynn Kennedy, Jeffrey Gillespie
	Mississippi State University	Terry Hanson, Darren Hudson, John Anderson, and Andrew Muhammad
	North Carolina State University	Jeffrey Hinshaw
	University of Florida	Charles Adams

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 frame-work to ensure model applicability.

ANTICIPATED BENEFITS

U.S. 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.

The demand and supply models estimated will provide an indication of changes in catfish/trout prices and quantities demanded, effects on production/marketing channels, who will bear the costs, and to what extent demand would need to change to compensate for detrimental price shocks. The international trade models will estimate the effect of the import supply of catfish and trout on the domestic price. The effects of policy options such as tariffs, direct or countercyclical payments, feed assistance, crop disaster, export assistance, loan programs, or others as recommended by the industry panel will be identified, summarized, and made available to industry through trade associations. The team will develop a matrix of data requirements and availability for development of these types of models for: catfish, trout, crawfish, clams, tilapia, ornamental fish, prawns, hybrid striped bass, baitfish, alligators, and oysters. This matrix will be provided to the SRAC Industry Advisory Council and to trade associations.

PROGRESS AND PRINCIPAL ACCOMPLISHMENTS

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

Sub-objective 1a. *Demand and supply effects.*

Mississippi State University/Auburn University. Demand and supply models were developed by estimating equations that relate the quantity demanded by consumers and supplied by producers at various prices. These models provide an indication of changes in catfish and trout prices and quantities at the domestic wholesale and farm levels. The model also indicates what the effect of negative economic effects would be 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) and raw products used in the manufacture of production inputs. The processing models include different labor wage rates, technologies, price expectations, taxes and subsidies.

U.S. catfish supply and demand model

The model estimated a farm-level price at equilibrium of $0.90/pound and a farm-level quantity at equilibrium of 145 million pounds. 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.

Results at a glance...

A user friendly economic model has been developed for the U.S. catfish market. Some key findings are:

- *Decreased feed prices benefit the U.S. farm-raised catfish industry by increasing product supply and, by reducing the domestic price, increasing consumer demand.*
- *Increased TCI expenditures marginally benefit U.S. farm-raised catfish but would hurt imports significantly.*
- *Increased tariff levels on basa/tra from Vietnam may enhance importation of channel catfish from China without substantially increasing the demand for U.S. farm-raised catfish.*
- *Increased U.S. per capita income would positively impact the catfish industry as a whole, with higher positive impacts on imported channel catfish and imported basa/tra.*
- *Country-of-origin labeling benefits U.S. farm-raised catfish marginally, but hurts channel catfish imports significantly.*

The demand and supply models were then used to estimate the effects of imposing a tariff (at levels of 20%, 28%, and 35%) on imported catfish products. At a tariff rate of 35%, 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. Farm prices increased by $0.04/pound and farm quantity increased by 1.6 million pounds.

U.S. Trout Supply and Demand Model

Trout demand and supply models were not as robust as for the catfish models because there is less data available overall (annual data available from USDA National Agricultural Statistics Service (NASS) for 1988-2008 where monthly data are available for catfish). There also were fewer categories of trout in the NASS data than there were for catfish. The focus of this analysis is solely on food-size trout sold for processing and food use, excluding trout sold for recreational use.

Results indicate that if producers expect farm prices to increase by 10%, then farm production will increase by 4%. A 10% increase in stocker prices will cause production to fall by 3.5%, and a 10% increase in soybean prices will cause production to fall by 2.3%. The model was also used to see how farm prices respond to changes in output and wholesale prices. If farm output would increase by 10% then farm prices would fall by 4.7%. If the price of whole fresh trout increases by 10%, then farm prices rise by 1.2%. Table 1 presents the effects of increases in the prices of fresh trout, trout stockers, and soybean meal on farm prices and production levels.

Table 1. Results of the trout model showing the impact of a 10% increase in processor, stocker or feed prices.

	Before	After	Difference
		10% increase in wholesale price	
Farm price	$1.09	$1.20	$0.11
Farm production (1,000 lbs)	55,130	57,497	2,367
Farm revenue	$60,067,676	$69,049,492	$8,981,816
Buyer surplus	$14,191,604	$15,436,468	$1,244,864
Farmer surplus	$47,449,857	$53,720,727	$6,270,871
		10% increase in stocker price	
Farm price	$1.09	$1.10	$0.02
Farm production (1,000 lbs)	55,130	53,511	-1,619
Farm revenue	$60,067,676	$59,112,586	-$955,090
Buyer surplus	$14,191,604	$13,370,202	-$821,401
Farmer surplus	$47,449,857	$46,142,106	-$1,307,751
		10% increase in soybean meal price	
Farm price	$1.09	$1.10	$0.01
Farm production (1,000 lbs)	55,130	54,062	-1,068
Farm revenue	$60,067,676	$59,443,232	-$624,444
Buyer surplus	$14,191,604	$13,647,089	-$544,515
Farmer surplus	$47,449,857	$46,593,357	-$856,500

Sub-objective 1b. *International trade effects.*

Louisiana State University. International trade models were developed for the domestic catfish and trout industries to estimate the effect of import supply of fish on the domestic prices of catfish and trout. Full details of the models are available from Dr. Lynn Kennedy, Louisiana State University (Lkennedy@agcenter.lsu.edu).

Catfish

The major results of the international trade model for catfish are that the U.S. domestic catfish industry is negatively influenced from imports of major seafood like salmon, tuna, and shrimp in addition to imports of catfish.

Trout

Faced with a change in trout imports, this study attempted to identify how imports affect the U.S. domestic trout industry. During the last two decades, trout imports have changed from primarily that of frozen products to fresh or chilled products. Also, the major exporting country has changed from Argentina to Chile for frozen products and to Canada for fresh trout. According to the results of this study, we found five important facts related to trout imports during this sample period:

- Low farm prices of domestic trout may be due to reasons other than just increased trout imports.

- Domestic trout price decreases with an increase in total trout supply into the domestic market. The increase in imports of Chilean products exert the greatest influence on U.S. domestic trout price.

- Increases in the imports of low priced frozen trout products are a source of concern for the U.S. domestic trout industry because these were found to substitute directly for U.S. product.

- The greatest level of substitution of imported trout is from frozen trout fillets followed in descending order by frozen whole trout, and fresh whole trout.

- Depreciation of U.S. currency in terms of the currencies of the major trout exporting countries has helped to reduce the potentially negative impact of increased trout imports on the U.S. domestic trout price.

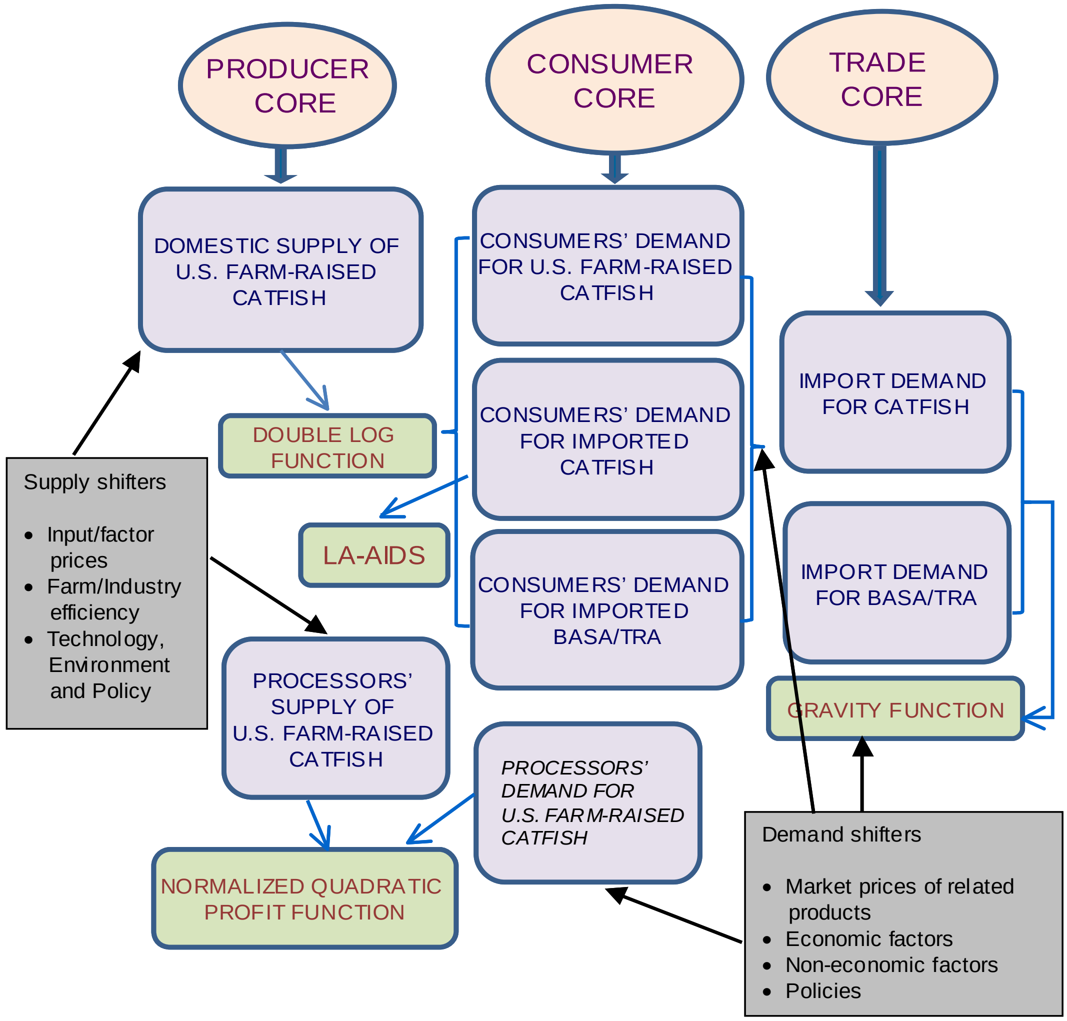
Sub-objective 1c. *Potential effects of various policy alternatives and external economic shocks.*

University of Arkansas at Pine Bluff (UAPB)

Catfish

A model for the catfish market in the U.S. (known as the U.S.-Catfish Model; Figure 1 and Appendix A) was developed, based on the demand-supply and international trade models developed in the previous sub-objectives. The model has been used to conduct simulations to determine the likely impact of changes in catfish feed price, The Catfish Institute (TCI) advertisement expenditures (for promoting U.S. farm-raised catfish), anti-dumping tariff levels imposed by the U.S. on basa/tra imported from Vietnam, and U.S. per capita income. We have also analyzed the effects of Country of Origin Labeling (COOL). A decrease in feed price would benefit the U.S. farm-raised catfish industry along with marginal gains to imported catfish. The decrease in feed price will lower the cost of production, which in turn increases the profitability of farmers, and hence increased supply. This will lower the domestic price of U.S. farm-raised catfish (processed), thereby increasing the demand for the same.

Figure 1. Model Structure



On the other hand, an increase in TCI expenditures would benefit U.S. farm-raised catfish marginally; however, it would hurt imports significantly. Imported channel catfish would benefit more than U.S. farm-raised catfish with an increase in tariff levels on basa/tra imported from Vietnam. An increase in the U.S. per capita income would have a positive impact on the catfish industry as a whole, with a greater positive impact on imported channel catfish and imported basa/tra. The results of the model further showed that COOL has benefited U.S. farm-raised catfish marginally, but has hurt channel catfish imports significantly.

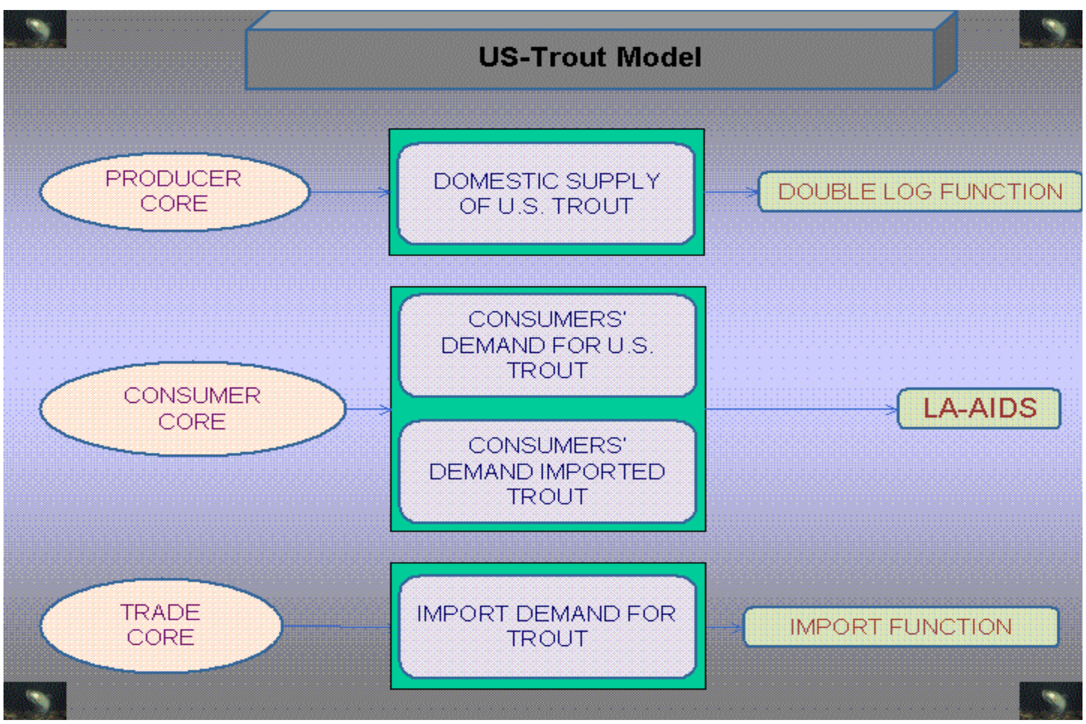
Trout

We have developed and validated an economic forecasting model for the trout market in the United States (US-Trout Model). The basic structure of the US-Trout model is outlined in Figure 2. The model consists of equations describing behaviors of trout farmers, consumers, and importers and exporters (Appendix B). The model differentiates between U.S.-raised trout and imported trout. The model provides links between technology, policy and the market. The imports are related to the non-domestic supply made available to the U.S. market, and the exports are related to the non-domestic market destinations for U.S. produced goods. The present model assumes negligible exports of U.S. trout. After developing a numerical version of the model, the model was solved using the Microsoft Office Excel Solver. Appendices C and D summarize key numerical values used to estimate the equations of the model.

To validate the model, preliminary results of the policy simulation exercise were discussed with different stakeholders in various conferences. Some of the parameters and variables in the model were re-adjusted based on the suggestions of the stakeholders.

The impact of changes in price of trout stockers, price of soybean meal, exchange rate of Chile, national income of the U.S., and national income of Chile on demand for and supply of U.S. domestic trout and imported trout were evaluated (Table 2). Key findings were:

Figure 2. Model Structure of US-Trout Model



- Trout stockers and feed (soybean meal) are important inputs for trout production. The U.S. trout industry would benefit significantly from a decrease in prices of stockers and price of soybean meal.

- Depreciation of the Chilean peso with respect to the U.S. dollar would increase demand of imported trout significantly, but this strategy would have only a marginal impact on the U.S. trout industry.

- With an increase in national income of the U.S., imported trout would gain significantly, whereas the U.S. trout industry would benefit only marginally.

- An increase in national income of Chile would increase the domestic demand for trout in Chile, thereby reducing its supply to the U.S. significantly. This would lead to an increase in demand and supply for domestic trout in the U.S.

Results at a glance...

Results of the model developed for the trout industry include:

- *The U.S. trout industry would benefit significantly from a decrease in prices of stockers and price of soybean meal.*
- *Depreciation of the Chilean peso with respect to the U.S. dollar would increase demand of imported trout significantly, but would have a marginal impact on the U.S. trout industry.*
- *Increased income in the U.S. would benefit imported trout to a greater degree than the U.S. trout industry.*
- *Increased income in Chile would increase the domestic demand for trout in Chile, thereby reducing the supply to the U.S., leading to an increase in demand and supply for domestic trout in the U.S.*

Table 2: Impact of Changes in Policy Variables on Demand for and Supply of Trout

Policy variable	Base line value	Change in policy variable over base	Change in demand/supply over base: Domestic Trout	Change in demand/supply over base: Imported Trout
Price of trout stockers ($/lb)	2.85	-10%	4.27	-0.09
		10%	-3.69	0.08
Price of soybean meal ($/ton)	120.33	-10%	2.80	-0.06
		10%	-2.46	0.05
Exchange rate of Chile (CLP/USD)	535.26	-10%	-1.73	-5.46
		10%	1.60	5.21
Inflation adjusted national income of U.S. ($billions, 2005 base)	12,994	-10%	-0.58	-4.35
		10%	0.53	4.11
Inflation adjusted national income of Chile ($billions, 2005 base)	136	-10%	-1.39	9.27
		10%	1.31	-7.70
Base line value (1,000 lb, average 2007-2009)			61,555	10,956

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.

More specific data requirements for economic forecasting models are:

- Base period demand (consumption) and supply (domestic production and net imports);

- Base period levels of policy variables (prices of inputs, exchange rates, national income levels, quantities/prices of substitute products, etc.);

- Degree of responsiveness of demand and supply to changes in the levels of policy variables. If these responsiveness parameters are not available, then we need to empirically estimate those based on time-series and/or cross section data. We have been able to generate these parameters for catfish and trout, but these are not available for many other species.

While detailed data of the type and scope required for the catfish models are available in various published sources the data on trout are more sparse. Specific data required to enhance the trout models include:

- Monthly data on sales and prices of trout by size and state.

- Data on trout processing (e.g. weight processed, processed weight sold, prices paid to producers, prices received by processors, etc.). No data are available.

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

University of Arkansas at Pine Bluff. We held meetings with representatives of the catfish and trout industries to discuss the results of the models (U.S.-catfish and U.S.-trout model): a) 2009 Annual fall meeting of the USTFA (United States Trout Farmers Association), Harrisburg, Pennsylvania, and b) Annual convention of the Catfish Farmers of Arkansas 2010, Hot Springs, Arkansas. The model structures (U.S.-catfish and U.S.-trout model) and results of simulations have been presented in professional conferences/seminars: a) Aquaculture 2010, San Diego, California, and (b) the International Food Policy Research Institute (IFPRI), Washington DC. These presentations and consultations have identified a list of issues and policy options for consideration in the policy analysis. Accordingly, we have conducted impact analysis for the identified policy variables.

IMPACTS

Results of the simulations and relationships developed in these models have been of interest to both the trout and catfish industry. The U.S. Catfish Model has been used to respond to requests for economic information from congressional offices and is proposed to be used as part of a new SRAC project to examine alternative marketing structures that may provide greater control over the market price of U.S. catfish.

PUBLICATIONS, PRESENTATIONS, AND GRADUATE THESES

Publications

Lee, Y-J and P.L. Kennedy. In review. Measurement of substitutability between U.S. domestic catfish and imported fish. Journal of Agricultural and Applied Economics.

Lee, Y-J and P.L. Kennedy. In review. Theoretical development of implicit price and demand in oligopolistic competition: application to the U.S. trout market. Marine Resource Economics.

Lee, Y-J and P.L. Kennedy. In review. A demand system analysis of the U.S. trout market: imports versus domestic products. Canadian Journal of Agricultural Economics.

Muhammad, A. and K. Jones. 2009. An assessment of dynamic behavior in the U.S. catfish market: an application of the generalized dynamic, Rotterdam model. Journal of Agriculture and Applied Economics 41(3):745-759.

Presentations

Dey, Madan M., Kehar Singh and Carole Engle. 2010. Impact of marketing, trade and exchange rate policies on U.S. catfish and trout markets: results from disaggregated fish sector models. Page 506, Aquaculture 2010 – Meeting Abstracts, San Diego, California (U.S.).

Engle, C.R. 2010. Economic modeling of the U.S. trout industry. U.S. Trout Farmers Association Forum, San Diego, CA.

Dey, Madan M., Kehar Singh, Carole Engle and Abed Rabbani. 2009. Analysis of catfish supply, demand and trade in USA: baseline model, estimation strategy and preliminary results. Page 365, Aquaculture America 2009 - Meeting Abstract, Seattle, Washington (U.S.).

Dey, Madan M., Kehar Singh and Carole Engle. 2009. Analysis of catfish supply, demand and trade in USA: baseline model, estimation strategy and preliminary results. Paper presented at the forth forum of the North American Association of Fisheries Economists, May 17-20, 2009, Newport, Rhode Island (U.S.).

Dey, Madan M. 2009. Food safety standards and U.S.-Asia aquaculture trade: applications of disaggregated fish sector models. Presentation at the International Food Policy Research Institute (IFPRI), Washington DC, Aug 3, 2009.

Lee, Y-J and P.L. Kennedy. 2009. Measurement of substitutability between U.S. domestic catfish and imported fish. Paper presented at the Southern Association of Agricultural Scientists, Atlanta, Georgia.

Lee, Y-J and P.L. Kennedy. 2009. Import demand analysis for U.S. trout. Southern Regional Aquaculture Center Conference Call Meeting.

Lee, Y-J and P.L. Kennedy. 2008. Import demand analysis for U.S. catfish. Southern Regional Aquaculture Center Conference Call Meeting.

Graduate Theses

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.

Appendix A

US Catfish Model: Equations and Identities

A. Model Development

The producer core consists of the supply equation for U.S. farm raised catfish, and supply equations of processed products. We have used double log function to represent the supply U.S. farm raised catfish:

$$\ln\left(Q_{frCatfish}^{FS-dom}\right) = \alpha_0^{FS-dom} + \alpha_1^{FS-dom} \times \ln(P_{frCatfish}^{PBP}) + \sum_{i=1}^{n} \beta_i^{FS-dom} \times \ln(P_i^{dom})$$

$$Where, P_i^{dom} \quad is \quad the \quad factor \quad prices \quad (fingerlings, feed, fuel, electricity, wage)$$

The catfish processing industry uses joint inputs and produces multiproduct. Therefore, we have employed 'normalized quadratic profit function' to derive supply equations for processed products. This approach is widely used in cases of joint agricultural production (e.g., Shumway *et al.*, 1987; Ball *et al.*, 1997). Estimation is undertaken here using the 'dual' approach, which is becoming the preferred method when sufficient price data are available (Jensen, 2003). It is particularly appropriate for multioutput, joint input production, e.g., Squires (1987), Kirkley and Strand (1988), and others have applied it to capture fisheries. Dey *et al.* (2005) have applied this approach in AsiaFish Model. The 'normalized quadratic profit function' is given as follows:

$$\pi = \alpha_0 + \sum_{i=1}^{m-1} \beta_i P_i + \sum_{i=m+1}^{n} \gamma_i X_i + \frac{1}{2}\left(\sum_{i=1}^{m-1}\sum_{j=1}^{m-1} \beta_{ij} P_i P_j + \sum_{i=m+1}^{n}\sum_{j=m+1}^{n} \gamma_{ij} X_i X_j \right) + \sum_{i=1}^{m-1}\sum_{j=m+1}^{n} \lambda_{ij} P_i X_j + e_i$$

Where, π is the normalized profit (normalized by P_m) evaluated at the optimum, P_i's are output and input prices normalized by P_m, X_i is a vector of variables on technology, environment, policy and fixed inputs, e_i is the error term, and α, β, γ, and λ are the parameters of the equation. Then by the 'envelope theorem', the output supply of i[th] product is:

$$\frac{\partial \pi}{\partial P_i} = X_i = \beta_i + \sum_{j=1}^{m-1} \beta_{ij} P_j + \sum_{j=m+1}^{n} \lambda_{ij} X_j + e_i$$

To derive the supply of the numeraire, multiply the expression in (…) by P_m to obtain normal profit; differentiating by P_m yields:

$$QNUM = \alpha_0` + \sum_{i=m+1}^{n} \gamma_i X_i - \frac{1}{2} \sum_{i=-}^{m-i}\sum_{j=1}^{m-1} \beta_{ij} P_i P_j + \frac{1}{2} \sum_{i=m+1}^{n}\sum_{j=m+1}^{n} \gamma_{ij} X_i X_j + e_i$$

The derivation of the supply functions from a profit function entails certain restrictions on the former. A profit function is homogenous of degree one in prices, and should have equal cross-price derivatives; hence, the supply parameters must conform to a homogeneity and symmetry restriction. Homogeneity is already incorporated by normalization, while symmetry can be implemented by imposing $\beta_{ij} = \beta_{ji}$ during estimation.

In the baseline model, it is assumed that technology and policy can be modeled as a proportional and factor-neutral shift in quantity. For a given supply function, this may be represented as a distinction between actual and effective prices (see Alston *et al.*, 1995 and Dey *et al.*, 2005). The effective price method is fairly flexible in representing a variety of changing supply conditions.

Consumer core

The consumer core consists of processors' demand equation for inputs and consumers demand for catfish. The processors' demand equation for inputs (live fish) has been derived from 'normalized quadratic profit function' given as follows:

$$\frac{\partial \pi}{\partial P_j} = -X_i = \beta_i + \sum_{j=1}^{m-1} \beta_{ij} P_j + \sum_{j=m+1}^{n} \lambda_{ij} X_j + e_i$$

We have used Almost Ideal Demand System (AIDS) to obtain consumers demand equations (in share forms) for U.S. farm-raised catfish, imported channel catfish and imported basa/tra.

$$w_i = \alpha_i^{CD} + \sum_i \beta_i^{CD} \times \ln(P_i) + \gamma^{CD} \times \ln(X / P) + \sum_j \varphi_j^{CD} X_j + e_{ij}$$

Where, w and P are the expenditure share and price of the products, respectively. X is the vector of exogenous variables, X/P is the real expenditure of the consumers, e is the error term, and α, β, γ and φ are the parameters of the model.

The consumers' demand for i^{th} product has been obtained from share equations as follows:

$$Q_i^{CD-dom} = w_i \times \frac{\sum_i p_i q_i}{P_i}, where \sum_i p_i q_i \text{ is the total expenditure.}$$

Trade core

We have used an augmented gravity model derived by Anderson and Wincoop (2003) from a general equilibrium model. This model differs from commonly used gravity models by including 'multilateral resistance' terms capturing the country i's and country j's resistance to trade with all regions. These variables measure bilateral trade barriers in relation to trade barriers with other trading partners. However, the multilateral resistance terms are not observable. We, therefore, have used exporter and importer fixed effects as proxies of the multilateral resistance terms (Anderson and Wincoop, 2003). Including these fixed effects also allows asymmetric trade flows with symmetric trade barriers, allowing a better fit with the data (Kupier and Tongeren, 2006). The augment gravity model is specified as follows:

$$\ln(Q_i^{S-imp}) = \rho_k + \rho_j + \varphi^{S-imp} + \sum_{i=1} \gamma_i^{dom} \ln(P_i) + \sum_m \gamma^m \ln(\text{EconV})$$
$$+ \sum_n \gamma^n \ln(\text{NEconV}) + \sum_o \gamma^o \ln(\text{PolV}) + e_i$$

Where,

ρ 's are multilateral resistance terms (exporter and importer fixed effects); Subscript 'i', 'j' and 'k' denote the product (imported channel catfish and basa/tra), the exporting country, and the importing country (in our case U.S.), respectively; 'P_i' represents price of i^{th} product which include competing products; e_i is the error term; and γ and φ are the parameters of the model; EconV and NEconV signify economic variables (like gross domestic product, population, x-rates) and non-economic variable capturing cultural and political distances, respectively, effecting trade; and PolV denotes policy variable like promotional activities, antidumping measures, tariffs, etc.

Model identities

Model identities describe the price setting and market clearing conditions. These consist of price transmission functions, relationship between different variables and equilibrium conditions.

Parameterization of equations

The parameterization approach was used to estimate the relevant coefficients of the behavioral equations. Initially, we had estimated the demand, supply and trade elasticities using the approached discussed in the earlier section. Most of the estimated elasticities yielded satisfactory plausible values for the policy analysis. However, some of the elasticities were borrowed from earlier studies. Once obtained, these elasticities were transformed to suit the specification of the equations in the model. The intercept terms of all the relevant equations were then calibrated to ensure that the model replicated the baseline values. The preliminary results of the policy simulation exercise were discussed with different stakeholders in various conferences, and some of the elasticities and variables in the model were readjusted.

B. Consumer Core

Expenditure Share Equations (LA-AIDS)

Expenditure Share Equation for U.S. Farm-Raised Catfish $\left(w_{Catfish}^{fr}\right)$:

$$CC(1) \qquad w_{Catfish}^{fr} = -2.7857 + 0.0260 \times \ln(P_{frCatfish}^{*dom}) + 0.0678 \times \ln(P_{Catfish}^{*imp})$$

$$+ 0.0509 \times \ln(P_{Basa/tra}^{*imp-world}) + 0.0743 \times \ln(P_{Tilapia}^{*imp})$$

$$+ 0.1095 \times \ln(X / P) + 0.2228 \times TCI + +0.0053 \times Pop_{US} + 0.0316 \times COOL$$

Expenditure Share Equation for Imported Catfish $\left(w_{Catfish}^{imp}\right)$:

$$CC(2) \qquad w_{Catfish}^{imp} = -0.1050 + 0.0037\times\ln(P_{frCatfish}^{*dom}) - 0.0105\times\ln(P_{Catfish}^{*imp})$$

$$+0.0039\times\ln(P_{Basa/tra}^{*imp}) + 0.0028\times\ln(P_{Tilapia}^{*imp})$$

$$+0.0020\times\ln(X/P) + 0.0212\times Pop_{US} - 0.0058\times COOL$$

Expenditure Share Equation for Imported Catfish $\left(w_{Basa/tra}^{imp}\right)$:

$$CC(3) \qquad w_{Basa/tra}^{imp} = 0.0986 + 0.0068\times\ln(P_{frCatfish}^{*dom}) + 0.0129\times\ln(P_{Catfish}^{*imp})$$

$$-0.0265\times\ln(P_{Basa/tra}^{*imp}) + 0.0068\times\ln(P_{Tilapia}^{*imp})$$

$$+0.0008\times\ln(X/P) + 0.0015\times Pop_{US} - 0.0520\times COOL$$

Processors' Demand Equation (Normalized Quadratic Profit Function)

Processors' Demand for U.S. Farm-Raised Catfish $\left(Q_{frCatfish-ProcessedWt}^{ProcessorD}\right)$:

$$CC(4) \qquad Q_{frCatfish-ProcessedWt}^{ProcessorD} = -12543.5074 + 761.50\times\frac{P_{R\&GFr}^{PSP}}{P_{steakFroz}^{PSP}} - 378.92\times\frac{P_{WhDressFr}^{PSP}}{P_{steakFroz}^{PSP}}$$

$$+144.03\times\frac{P_{OtherFr}^{PSP}}{P_{steakFroz}^{PSP}} - 151.76\times\frac{P_{FilletFr}^{PSP}}{P_{steakFroz}^{PSP}} + 245.99\times\frac{P_{WhDressFroz}^{PSP}}{P_{steakFroz}^{PSP}} + 98.92\times\frac{P_{OtherFroz}^{PSP}}{P_{steakFroz}^{PSP}}$$

$$+173.86\times\frac{P_{FilletFroz}^{PSP}}{P_{steakFroz}^{PSP}} - 178.23\times\frac{P_{RWP}^{dom}}{P_{steakFroz}^{PSP}} - 54337.78\times\frac{P_{Fuel}^{dom}}{P_{steakFroz}^{PSP}} + 1340.47\times\frac{P_{Eletricity}^{dom}}{P_{steakFroz}^{PSP}}$$

$$+26.16\times\frac{P_{WageRate/hr}^{dom}}{P_{steakFroz}^{PSP}} - 39062.02\times\frac{GDP(2000=100)}{P_{steakFroz}^{PSP}} - 1928.86\times\frac{CPI-F\ \&\ Bev}{P_{steakFroz}^{PSP}}$$

C. Producer Core

Domestic Supply Equation for US Farm-Raised Catfish (Double log Function)

Supply of U.S. Farm-Raised Catfish $\left(Q^{S-dom}_{frCatfish}\right)$:

$$S(1) \qquad \ln\left(Q^{FS-dom}_{frCatfish}\right) = 27.7737 + 1.8235 \times \ln(P^{PBP}_{frCatfish}) - 0.1500 \times \ln(P^{dom}_{Fingerlings})$$
$$-1.7800 \times \ln(P^{dom}_{Feed}) - 0.1000 \times \ln(P^{dom}_{Fuel}) - 0.1000 \times \ln(P^{dom}_{Electricity})$$
$$-5.0550 \times \ln(P^{dom}_{WageRate})$$

Processors' Supply Equations for Different Products (Normalized Quadratic Profit Function)

Processors' Supply of Round and Gutted Fresh $\left(Q^{ProcessorS}_{R\&GFresh}\right)$

$$S(2) \qquad Q^{ProcessorS}_{R\&GFresh} = 1636.3838 + 101.2072 \times \frac{P^{PSP}_{R\&GFr}}{P^{PSP}_{steakFroz}} - 78.4819 \times \frac{P^{PSP}_{WhDressFr}}{P^{PSP}_{steakFroz}} - 135.0662 \times \frac{P^{PSP}_{OtherFr}}{P^{PSP}_{steakFroz}}$$
$$+117.8168 \times \frac{P^{PSP}_{FilletFr}}{P^{PSP}_{steakFroz}} - 20.2359 \times \frac{P^{PSP}_{WhDressFroz}}{P^{PSP}_{steakFroz}} + 10.8645 \times \frac{P^{PSP}_{OtherFroz}}{P^{PSP}_{steakFroz}}$$
$$-121.5899 \times \frac{P^{PSP}_{FilletFroz}}{P^{PSP}_{steakFroz}} - 243.8940 \times \frac{P^{PBP}_{frCatfish}}{P^{PSP}_{steakFroz}} + 9831.9593 \times \frac{P^{dom}_{Fuel}}{P^{PSP}_{steakFroz}} - 329.7612 \times \frac{P^{dom}_{Eletricity}}{P^{PSP}_{steakFroz}}$$
$$-110.8100 \times \frac{P^{dom}_{WageRate/hr}}{P^{PSP}_{steakFroz}} + 3871.2206 \times \frac{GDP(2000=100)}{P^{PSP}_{steakFroz}} + 1878.2037 \times \frac{CPI-F\&Bev}{P^{PSP}_{steakFroz}}$$

Processors' Supply of Whole Dressed Fresh $\left(Q^{ProcessorS}_{WhDressFr}\right)$

$$S(3) \qquad Q^{ProcessorS}_{WhDressFr} = 1407.1287 - 23.8473 \times \frac{P^{PSP}_{R\&GFr}}{P^{PSP}_{steakFroz}} + 52.6020 \times \frac{P^{PSP}_{WhDressFr}}{P^{PSP}_{steakFroz}} + 140.4788 \times \frac{P^{PSP}_{OtherFr}}{P^{PSP}_{steakFroz}}$$
$$+63.2134 \times \frac{P^{PSP}_{FilletFr}}{P^{PSP}_{steakFroz}} - 140.8869 \times \frac{P^{PSP}_{WhDressFroz}}{P^{PSP}_{steakFroz}} - 20.8239 \times \frac{P^{PSP}_{OtherFroz}}{P^{PSP}_{steakFroz}}$$
$$-41.3269 \times \frac{P^{PSP}_{FilletFroz}}{P^{PSP}_{steakFroz}} - 0.1876 \times \frac{P^{dom}_{RWP}}{P^{PSP}_{steakFroz}} - 10474.7926 \times \frac{P^{dom}_{Fuel}}{P^{PSP}_{steakFroz}} - 82.5059 \times \frac{P^{dom}_{Eletricity}}{P^{PSP}_{steakFroz}}$$
$$+104.4400 \times \frac{P^{dom}_{WageRate/hr}}{P^{PSP}_{steakFroz}} + 4538.9238 \times \frac{GDP(2000=100)}{P^{PSP}_{steakFroz}} - 1336.3932 \times \frac{CPI-F\&Bev}{P^{PSP}_{steakFroz}}$$

Processors' Supply of Other Fresh $\left(Q_{OtherFr}^{\Pr ocessorS}\right)$

$$S(4) \qquad Q_{OtherFr}^{\Pr ocessorS} = 499.7585 - 615.0150 \times \frac{P_{R\&GFr}^{PSP}}{P_{steakFroz}^{PSP}} + 723.0623 \times \frac{P_{WhDressFr}^{PSP}}{P_{steakFroz}^{PSP}} + 81.8293 \times \frac{P_{OtherFr}^{PSP}}{P_{steakFroz}^{PSP}}$$
$$-131.9244 \times \frac{P_{FilletFr}^{PSP}}{P_{steakFroz}^{PSP}} - 190.8296 \times \frac{P_{WhDressFroz}^{PSP}}{P_{steakFroz}^{PSP}} - 44.1848 \times \frac{P_{OtherFroz}^{PSP}}{P_{steakFroz}^{PSP}}$$
$$-56.2260 \times \frac{P_{FilletFroz}^{PSP}}{P_{steakFroz}^{PSP}} - 225.4999 \times \frac{P_{RWP}^{dom}}{P_{steakFroz}^{PSP}} - 5004.8605 \times \frac{P_{Fuel}^{dom}}{P_{steakFroz}^{PSP}} + 425.8890 \times \frac{P_{Eletricity}^{dom}}{P_{steakFroz}^{PSP}}$$
$$+113.4300 \times \frac{P_{WageRate/hr}^{dom}}{P_{steakFroz}^{PSP}} - 7129.9032 \times \frac{GDP(2000=100)}{P_{steakFroz}^{PSP}} - 1592.4748 \times \frac{CPI - F\ \&\ Bev}{P_{steakFroz}^{PSP}}$$

Processors' Supply of Fillet Fresh $\left(Q_{FilletFr}^{\Pr ocessorS}\right)$

$$S(5) \qquad Q_{FilletFr}^{\Pr ocessorS} = 4764.6845 + 35.3252 \times \frac{P_{R\&GFr}^{PSP}}{P_{steakFroz}^{PSP}} + 20.1131 \times \frac{P_{WhDressFr}^{PSP}}{P_{steakFroz}^{PSP}} - 65.4681 \times \frac{P_{OtherFr}^{PSP}}{P_{steakFroz}^{PSP}}$$
$$+4.3712 \times \frac{P_{FilletFr}^{PSP}}{P_{steakFroz}^{PSP}} + 38.1056 \times \frac{P_{WhDressFroz}^{PSP}}{P_{steakFroz}^{PSP}} + 5.1619 \times \frac{P_{OtherFroz}^{PSP}}{P_{steakFroz}^{PSP}}$$
$$-104.1733 \times \frac{P_{FilletFroz}^{PSP}}{P_{steakFroz}^{PSP}} - 157.1416 \times \frac{P_{RWP}^{dom}}{P_{steakFroz}^{PSP}} - 17516.3238 \times \frac{P_{Fuel}^{dom}}{P_{steakFroz}^{PSP}} - 323.1987 \times \frac{P_{Eletricity}^{dom}}{P_{steakFroz}^{PSP}}$$
$$+204.5000 \times \frac{P_{WageRate/hr}^{dom}}{P_{steakFroz}^{PSP}} + 12035.0253 \times \frac{GDP(2000=100)}{P_{steakFroz}^{PSP}} - 2059.9643 \times \frac{CPI - F\ \&\ Bev}{P_{steakFroz}^{PSP}}$$

Processors' Supply of Whole Dressed Frozen $\left(Q_{WhDressFroz}^{\Pr ocessorS}\right)$

$$S(6) \qquad Q_{WhDressFr}^{\Pr ocessorS} = 1166.5806 - 128.7214 \times \frac{P_{R\&GFr}^{PSP}}{P_{steakFroz}^{PSP}} - 209.5112 \times \frac{P_{WhDressFr}^{PSP}}{P_{steakFroz}^{PSP}} - 71.6306 \times \frac{P_{OtherFr}^{PSP}}{P_{steakFroz}^{PSP}}$$
$$+104.2277 \times \frac{P_{FilletFr}^{PSP}}{P_{steakFroz}^{PSP}} + 23.1358 \times \frac{P_{WhDressFroz}^{PSP}}{P_{steakFroz}^{PSP}} - 70.8024 \times \frac{P_{OtherFroz}^{PSP}}{P_{steakFroz}^{PSP}}$$
$$+71.1727 \times \frac{P_{FilletFroz}^{PSP}}{P_{steakFroz}^{PSP}} - 197.1554 \times \frac{P_{RWP}^{dom}}{P_{steakFroz}^{PSP}} - 9404.3915 \times \frac{P_{Fuel}^{dom}}{P_{steakFroz}^{PSP}} - 153.5330 \times \frac{P_{Eletricity}^{dom}}{P_{steakFroz}^{PSP}}$$
$$+109.7000 \times \frac{P_{WageRate/hr}^{dom}}{P_{steakFroz}^{PSP}} + 4160.6802 \times \frac{GDP(2000=100)}{P_{steakFroz}^{PSP}} + 1131.9325 \times \frac{CPI - F\ \&\ Bev}{P_{steakFroz}^{PSP}}$$

Processors' Supply of Other Frozen $\left(Q_{OtherFroz}^{ProcessorS}\right)$

$$S(7) \qquad Q_{OtherFr}^{ProcessorS} = 3058.2233 + 11.0722 \times \frac{P_{R\&GFr}^{PSP}}{P_{steakFroz}^{PSP}} - 48.1894 \times \frac{P_{WhDressFr}^{PSP}}{P_{steakFroz}^{PSP}} - 41.6692 \times \frac{P_{OtherFr}^{PSP}}{P_{steakFroz}^{PSP}}$$

$$+17.5451 \times \frac{P_{FilletFr}^{PSP}}{P_{steakFroz}^{PSP}} - 41.0994 \times \frac{P_{WhDressFroz}^{PSP}}{P_{steakFroz}^{PSP}} + 13.0515 \times \frac{P_{OtherFroz}^{PSP}}{P_{steakFroz}^{PSP}}$$

$$+26.5325 \times \frac{P_{FilletFroz}^{PSP}}{P_{steakFroz}^{PSP}} - 185.5772 \times \frac{P_{RWP}^{dom}}{P_{steakFroz}^{PSP}} - 11065.7257 \times \frac{P_{Fuel}^{dom}}{P_{steakFroz}^{PSP}} - 197.8075 \times \frac{P_{Eletricity}^{dom}}{P_{steakFroz}^{PSP}}$$

$$-106.6000 \times \frac{P_{WageRate/hr}^{dom}}{P_{steakFroz}^{PSP}} + 5329.7926 \times \frac{GDP(2000=100)}{P_{steakFroz}^{PSP}} + 2341.1632 \times \frac{CPI - F \;\&\; Bev}{P_{steakFroz}^{PSP}}$$

Processors' Supply of Fillet Frozen

$$S(8) \qquad Q_{FilletFroz}^{ProcessorS} = 2119.2081 - 141.5231 \times \frac{P_{R\&GFr}^{PSP}}{P_{steakFroz}^{PSP}} - 80.6740 \times \frac{P_{WhDressFr}^{PSP}}{P_{steakFroz}^{PSP}} - 52.4991 \times \frac{P_{OtherFr}^{PSP}}{P_{steakFroz}^{PSP}}$$

$$-23.4900 \times \frac{P_{FilletFr}^{PSP}}{P_{steakFroz}^{PSP}} + 85.8179 \times \frac{P_{WhDressFroz}^{PSP}}{P_{steakFroz}^{PSP}} + 7.8158 \times \frac{P_{OtherFroz}^{PSP}}{P_{steakFroz}^{PSP}}$$

$$+51.7524 \times \frac{P_{FilletFroz}^{PSP}}{P_{steakFroz}^{PSP}} - 775.1779 \times \frac{P_{RWP}^{dom}}{P_{steakFroz}^{PSP}} - 16517.6262 \times \frac{P_{Fuel}^{dom}}{P_{steakFroz}^{PSP}} - 264.6949 \times \frac{P_{Eletricity}^{dom}}{P_{steakFroz}^{PSP}}$$

$$-134.9900 \times \frac{P_{WageRate/hr}^{dom}}{P_{steakFroz}^{PSP}} + 12342.4342 \times \frac{GDP(2000=100)}{P_{steakFroz}^{PSP}} - 2252.9332 \times \frac{CPI - F \;\&\; Bev}{P_{steakFroz}^{PSP}}$$

Processors' Supply of Steak Frozen $\left(Q_{SteakFroz}^{ProcessorS}\right)$

$$S(9) \qquad Q_{SteakFroz}^{ProcessorD} = 35.3196 - 0.0967 \times \left(P_{R\&GFr}^{PSP} \times P_{frCatfish}^{PBP}\right) - 0.3667 \times \left(P_{WhDressFr}^{PSP} \times P_{frCatfish}^{PBP}\right)$$

$$-0.1410 \times \left(P_{OtherFr}^{PSP} \times P_{frCatfish}^{PBP}\right) + 1593 \times \left(P_{FilletFr}^{PSP} \times P_{frCatfish}^{PBP}\right)$$

$$+0.1609 \times \left(P_{WhDressFroz}^{PSP} \times P_{frCatfish}^{PBP}\right) + 0.00 \times \left(P_{SteakFroz}^{PSP} \times P_{frCatfish}^{PBP}\right) + 0.1818 \times \left(P_{OtherFroz}^{PSP} \times P_{frCatfish}^{PBP}\right)$$

$$-0.0321 \times \left(P_{FilletFroz}^{PSP} \times P_{frCatfish}^{PBP}\right) - 4.2696 \times P_{Fuel}^{dom} - 41.5902 \times P_{Eletricity}^{dom}$$

$$-12.2761 \times P_{WageRate/hr}^{dom} + 0.8932 \times GDP(2000=100) + 1.5572 \times CPI - F \;\&\; Bev$$

D. Trade Core

Trade Equations (Gravity Function)

Import Demand of Catfish from World $(Q_{catfish}^{imp-D})$

$$TC(1) \qquad \ln(Q_{catfish}^{imp-D}) = -12.5540 + 1.3933 \times \ln(P_{frCatfish}^{*dom}) - 0.5007 \times \ln(P_{catfish}^{*imp,world})$$
$$+ 0.1666 \times \ln(P_{basa/tra}^{*imp,world}) + 1.6888 \times \ln(US - GDP) + 0.9384 \times \ln(US - Pop)$$
$$+ 2.0700 \times \ln(X - rateChina) - 0.6082 \times \ln(TCI - AdvExp.)$$

Import Demand of Basa/tra from World $(Q_{basa/tra}^{imp-D})$

$$TC(2) \qquad \ln(Q_{basa/tra}^{imp-D}) = -21.7634 + 1.6442 \times \ln(P_{frCatfish}^{*dom}) + 0.8059 \times \ln(P_{catfish}^{*imp,world})$$
$$- 0.0872 \times \ln(P_{basa/tra}^{*imp,world}) + 1.4623 \times \ln(US - GDP) + 2.0422 \times \ln(US - Pop)$$
$$+ 1.1115 \times \ln(X - rateVietnam) - 0.9987 \times in(TCI - AdvExp.) - 0.7974 \times \ln(Tariff)$$

Model Identities

Consumers' demand for U.S. farm raised catfish (Processed Weight) $(Q_{frCatfish-ProcessedWt}^{CD-dom})$:

$$\text{MI(1)} \qquad Q_{frCatfish-ProceesedWt}^{CD-dom} = w_{frCatfish} \times \frac{\sum_{i=1}^{n} p_i q_i}{P_{frCatfish}^{*dom}}$$

Consumers' demand for imported catfish $(Q_{Catfish}^{CD-imp})$:

$$\text{MI(2)} \qquad Q_{Catfish}^{CD-imp} = w_{Catfish}^{imp} \times \frac{\sum_{i=1}^{n} p_i q_i}{P_{Catfish}^{*imp}}$$

Consumers' demand for imported basa/tra $(Q_{Basa/tra}^{CD-imp})$:

$$\text{MI(3)} \qquad Q_{Basa/tra}^{CD-imp} = w_{Basa/tra}^{imp} \times \frac{\sum_{i=1}^{n} p_i q_i}{P_{Basa/tra}^{*imp}}$$

Where,

'i' is U.S. farm-raised catfish, imported catfish, imported basa/tra, and imported tilapia.

Processors' Demand in Live Weight Equivalent $\left(Q_{frCatfish-LiveWt}^{ProcessorD}\right)$ and processed weight equivalent $\left(Q_{frCatfish-ProWt}^{ProcessorD}\right)$

MI(4) $$Q_{frCatfish-LiveWt}^{ProcessorD} = 1.9871 \times Q_{frCatfish-ProWt}^{ProcessorD}$$

Farmers' Total Supply (Live Weight) $\left(Q_{frCatfish}^{S-dom}\right)$ and Farmers' Supply to Processor (Live Weight) $\left(Q_{frCatfish-LiveWt}^{FS-Processor}\right)$:

MI(5) $$Q_{frCatfish-LiveWt}^{FS-Processor} = 0.95 \times Q_{frCatfish}^{S-dom}$$

Farmers' Total Supply (Live Weight) $\left(Q_{frCatfish}^{S-dom}\right)$ and Farmers' Supply to Others (Live Weight) $\left(Q_{frCatfish}^{FS-Others}\right)$:

MI(6) $$Q_{frCatfish}^{FS-Others} = 0.05 \times Q_{frCatfish}^{S-dom}$$

Aggregate Processors' Supply (Processed Weight) $\left(Q_{ProcessedWt}^{ProcessorS}\right)$:

MI(7) $$Q_{ProcessedWt}^{ProcessorS} = 1.2789 \times \sum_{j=1}^{n} Q_{j}^{ProcessorS} = \sum_{j=1}^{n} Q_{j}^{ProcessorS} + Q_{Nuggets}^{ProcessorS}$$

Where,

'j' represents processed products namely round and gutted fresh, whole dressed fresh, fillet fresh, other fresh, whole dressed frozen, fillet frozen, other frozen, and steaks frozen.

Consumers' Demand for Farm-raised Catfish in Live Weight Equivalent $(Q_{frCatfish-LiveWt}^{CD-dom})$ and Processed Weight $(Q_{frCatfish-ProcessedWt}^{CD-dom})$:

MI(8) $$Q_{frCatfish-LiveWt}^{CD-dom} = 1.9871 \times Q_{frCatfish-ProcessedWt}^{CD-dom}$$

Price Transmission Functions

Domestic price of farm raised catfish $\left(P_{frCatfish}^{*dom}\right)$ and average price received by processor $\left(P_{frCatfish}^{Processor}\right)$:

PT(1) $$P_{frCatfish}^{*dom} = P_{frCatfish}^{Processor}$$

Where

$P_{frCatfish}^{Processor}$ = *Average Price Received by the Processor*

Model Closure

Equilibrium Between Consumers' Demand $\left(Q_{Basa/tra}^{CD-imp}\right)$ and Import Demand $\left(Q_{Basa/tra}^{imp-D}\right)$ for Basa/tra:

$$Q_{Basa/tra}^{imp-D} = Q_{Basa/tra}^{CD-imp}$$

Equilibrium Between Consumers' Demand $\left(Q_{Catfish}^{CD-imp}\right)$ and Import Demand $\left(Q_{Catfish}^{imp-D}\right)$ for Channel Catfish Imported:

$$Q_{Catfish}^{imp-D} = Q_{Catfish}^{CD-imp}$$

Farmers' Supply to Processor (Live Weight) $\left(Q_{frCatfish-LiveWt}^{FS-\Pr ocessor}\right)$ and Processors' Demand in Live Weight Equivalent $\left(Q_{frCatfish-LiveWt}^{\Pr ocessorD}\right)$

$$Q_{frCatfish-LiveWt}^{FS-\Pr ocessor} = Q_{frCatfish-LiveWt}^{\Pr ocessorD}$$

Market Equilibrium

$$Q_{frCatfish-\Pr ocessedWt}^{\Pr ocessorS} + Q_{Catfish}^{imp-D} + Q_{Basa/tra}^{imp-D} = Q_{frCatfish-\Pr ocessedWt}^{CD-dom} + Q_{Catfish}^{CD-imp} + Q_{Basa/tra}^{CD-imp}$$

Adjustable Variable for Model Closure:

Domestic Price of U.S. Farm-raised Catfish $(P_{frCatfish}^{*dom})$, World Import Unit Value of Channel Catfish $(P_{Catfish}^{*dom})$, World Import Unit Value of basa/tra $(P_{Basa/tra}^{*dom})$, and Processors' sale price for jth product ($P_{R\&GFr}^{j}$)

Where, 'j' represents processed products namely round and gutted fresh, whole dressed fresh, fillet fresh, other fresh, whole dressed frozen, fillet frozen, steaks frozen, and other frozen.

Appendix B

US Trout Model: Equations and Identities

A. Behavioral Equations

The structure of the US-Trout model consists of three cores: producer core, consumer core, and trade core. The model distinguishes between U.S. trout and imported trout.

The producer core consists of the supply equation for U.S. trout. We have used double log function to represent the supply U.S. trout:

$$\ln\left(Q_{trout}^{FS-dom}\right) = \alpha_0^{FS-dom} + \alpha_1^{FS-dom} \times \ln(P_{trout}^{PBP}) + \sum_{i=1}^{n} \beta_i^{FS-dom} \times \ln(P_i^{dom})$$

Where, P_i^{dom} is the factor prices (Stockers, feed, fuel, etc).

The consumer core consists of two equations: consumers' demand for U.S. trout, and consumers' demand for imported trout. We have used Almost Ideal Demand System (AIDS) to obtain consumers demand equations (in share forms) for U.S. trout, and imported trout.

$$w_i^{CD} = \alpha_i^{CD} + \sum_i \beta_i^{TD} \times \ln(P_i) + \gamma^{CD} \times \ln(X/P) + \sum_j \varphi_j^{CD} X_j + e_{ij}$$

Where, w and P are the expenditure share and price of the products, respectively. X is the vector of exogenous variables, X/P is the real expenditure of the consumers, e is the error term, and α, β, γ and φ are the parameters of the model.

The consumers' demand for i^{th} product has been obtained from share equations as follows:

$$Q_i^{CD} = w_i \times \frac{\sum_i p_i q_i}{P_i},$$

$$where \sum_i p_i q_i \text{ is the total expenditure}; i = U.S. \text{ trout, imported trout}.$$

The trade core consists of the U.S. import demand for trout equation. We have used double log function to represent the U.S. import demand of trout.

$$\ln(Q_{imptrout}^{S-\mathrm{imp}}) = \varphi^{D-\mathrm{imp}} + \sum_{i=1} \gamma_i^{ID} \ln(P_i) + \sum_{m} \gamma^{m} \ln(\mathrm{EconV}) + \sum_{o} \gamma^{o} \ln(\mathrm{PolV}) + e_i$$

Where, ' $\mathbf{P}_i$ ' represents price of i^{th} product which include competing products; e_i is the error term; γ and φ are the parameters of the model; EconV signifies economic variables (like gross domestic product, population, x-rates) effecting trade; and PolV denotes policy variable (like promotional activities, antidumping measures, tariffs, etc.).

B. Parameterization of Behavioral Equations

The parameterization approach was used to estimate the relevant coefficients of the behavioral equations. Initially, we had estimated the demand, supply and trade elasticities using the approached discussed in the earlier section. Most of the estimated elasticities yielded satisfactory plausible values for the policy analysis. However, some of the elasticities were borrowed from earlier studies. Appendix C gives the variables and their elasticities used in the model.

Once obtained, these elasticities were transformed to suit the specification of the equations in the model (Appendix D). The intercept terms of all the relevant equations were then calibrated to ensure that the model replicated the baseline values. The preliminary results of the policy simulation exercise were discussed with different stakeholders in various conferences, and some of the elasticities and variables in the model were readjusted.

C. Model Identities

$$Q_{UStrout}^{CD} + Q_{imptrout}^{CD} = Q_{trout}^{FS-dom} + Q_{imptrout}^{S-\mathrm{imp}}$$

Appendix C
Variables and Elasticities for US-Trout Model

Variables	Elasticity
U.S. Trout Supply Equation	
Growers' price of trout (USD/lb)	0.4190
Price of trout stokers (USD/lb)	-0.3510
Price of soybean meal (USD/ton)	-0.2320
Price of fish meal (USD/ton)	-0.0001
Diesel fuel price index (cents/gallon)	-0.0001
Consumer Demand for U.S. Trout Equation	
Domestic trout price (USD/lb)	-1.1186
Imported trout price (USD/lb)	1.5950
Real GDP U.S. ($billions, 2005 base)	0.8567
Exchange rate Chile (CLP/USD)	0.5164
Consumer Demand for Imported Trout Equation	
Domestic trout price (USD/lb)	1.5950
Imported trout price (USD/lb)	-1.5380
Real GDP U.S. ($billions, 2005 base)	0.5567
Exchange rate Chile (CLP/USD)	-0.8982

Variables	Elasticity
U.S. Import Demand Equation	
Import price/domestic price	-0.8527
Real GDP U.S. ($billions, 2005 base)	0.4112
Exchange rate Canada (CAD/USD)	-0.9842
Exchange rate Chile (CLP/USD)	0.5036
Exchange rate Argentina (ARS/USD)	0.3081
Exchange rate Australia (AUD/USD)	1.7942
Real GDP Canada ($billions, 2005 base)	-4.6684
Real GDP Chile ($billions, 2005 base)	-0.8206
Real GDP Australia ($billions, 2005 base)	6.2515
Real GDP Argentina ($billions, 2005 base)	-1.0139

Appendix D
Parameters for US-Trout Model

Variables	Parameters
U.S. Trout Supply Equation	
Growers' price of trout (USD/lb)	0.4190
Price of trout stokers (USD/lb)	-0.3510
Price of soybean meal (USD/ton)	-0.2320
Price of fish meal (USD/ton)	-0.0001
Diesel fuel price index (cents/gallon)	-0.0001
Consumer Demand for U.S. Trout Equation	
Domestic trout price (USD/lb)	0.5362
Imported trout price (USD/lb)	1.3931
Real GDP U.S. ($billions, 2005 base)	-0.1041
Exchange rate Chile (CLP/USD)	-0.3513
Consumer Demand for Imported Trout Equation	
Domestic trout price (USD/lb)	0.8407
Imported trout price (USD/lb)	0.0051
Real GDP U.S. ($billions, 2005 base)	-0.1213
Exchange rate Chile (CLP/USD)	-0.5193

Variables	Parameters
U.S. Import Demand Equation	
Import price/domestic price	-0.8527
Real GDP U.S. ($billions, 2005 base)	0.4112
Exchange rate Canada (CAD/USD)	-0.9842
Exchange rate Chile (CLP/USD)	0.5036
Exchange rate Argentina (ARS/USD)	0.3081
Exchange rate Australia (AUD/USD)	1.7942
Real GDP Canada ($billions, 2005 base)	-4.6684
Real GDP Chile ($billions, 2005 base)	-0.8206
Real GDP Australia ($billions, 2005 base)	6.2515
Real GDP Argentina ($billions, 2005 base)	-1.0139

◆ ◆ ◆

IMPROVING REPRODUCTIVE EFFICIENCY OF CULTURED FINFISH

Reporting Period
February 1, 2009 - August 31, 2010

Funding Level	Year 1	$222,553
	Year 2	$195,693
	Year 3	$78,456
	Total	$496,702

Participants	USDA/ARS Catfish Genetics Research Unit (Lead Institution)	Brian Small, Ken Davis, Les Torrans, Brian Bosworth, Geoff Waldbieser
	Texas A&M University at Corpus Christi	Paul Zimba
	Texas A & M University	Delbert Gatlin
	Auburn University	Allen Davis, Rex Dunham
	University of Florida	Cortney Ohs, Craig Watson
	University of Tennessee	Richard Strange
	University of Arkansas at Pine Bluff	Alf Haukenes, Rebecca Lochmann, Steve Lochmann
	USDA/ARS/Stuttgart National Aquaculture Research Center	Adam Fuller, Jerry Ludwig

PROJECT OBJECTIVES

1. Improve broodfish management protocols for increased reproductive efficiency through:

   a. Developing pre-selection methods of potential broodfish to be included in the broodstock population.
   b. Improving conditioning and preparation of broodfish.
   c. Final identification of broodstock for spawning .

2. Improve spawning protocols to increase reproductive efficiency through:

   a. Managing spawning conditions.
   b. Improving the collection and handling of fertilized eggs.

ANTICIPATED BENEFITS

Captive-bred finfish rarely experience all aspects of natural spawning conditions, and thus dependence on natural reproduction is often unreliable. Consequently, reproductive efficiency is often less than desired, frequently requiring creative management or compensatory protocols to overcome the failure to reproduce spontaneously and at full potential. This project will improve reproductive efficiency of commercially cultured finfish of immediate importance to the Southern Region. Management protocols will be established that address reproductive bottlenecks and result in improved protocols that increase reproductive efficiency for the target species and have the potential for use with other similarly cultured finfish species.

PROGRESS AND PRINCIPAL ACCOMPLISHMENTS

Objective 1. *Improve broodfish management protocols for increased reproductive efficiency.*

Objective 1a. *Develop pre-selection methods of potential broodfish to be included in the broodstock population.*

USDA-ARS Catfish Genetics Research Unit. Production of channel catfish fry relies on pond-spawning, a technique in which mature male and female catfish are placed in brood ponds with spawning containers and allowed to spawn. Spawning incidence for catfish is highly variable, but research and farm data indicate that on average about 40% of females produce a spawn. Little is known about males' contribution to spawning, but most farmers stock a ratio of 1:1 or 2:1 female to male broodfish. In addition to spawning incidence, spawning time (early or late in the year) is important since early spawning fish allow earlier stocking of fry resulting in production of larger fingerlings. Inability to identify parentage of pond-spawns has hindered study of factors influencing spawning in catfish. However, the advent of DNA fingerprinting for parentage determination permits evaluation of factors influence catfish spawning. Understanding these factors can lead to development of improved fish and management techniques for more efficient reproduction of farm-raised catfish.

One hundred channel catfish spawns were collected from eight commercial farms in the spring of 2006 in order to establish a diverse population for selective breeding. Full-sib families were maintained in separate tanks until fish were large enough (> 4 inches) to be individually tagged, and then tagged fish were reared communally in ponds. Fish were fed a 32% protein commercial catfish diet throughout the study. The largest 5 to 9 females and 3 to 7 males from each family (approximately 800 females and 500 males) were selected during the fall of 2007 to be used as future broodfish and blood samples were collected from each fish for DNA fingerprinting. Each broodfish was genotyped at a set of highly polymorphic microsatellite loci. Broodfish were weighed and blood samples were drawn for determination of estrogen and testosterone levels in females and testosterone levels in males in the late winter (February to March) of 2008 and 2009. Ultrasound images (Figure 1) of maximum cross-sectional area of ovaries were also recorded for females at this time. After they were sampled, broodfish were stocked into 0.25-acre ponds at a 2:1 female to male ratio in the spring of 2008 (2-year-old broodfish, 24 ponds) and again in 2009 (3-year-old broodfish, 20 ponds). Eight spawning containers were placed in each pond in early April

Figure 1. Ultrasound image of catfish ovary.

and checked for spawns through the end of August each year. Egg masses were transferred to the hatchery and spawns were hatched in separate tanks. Twelve fry per spawn were genotyped as the broodfish and the patterns of inherited alleles were used to determine parentage of spawns. Data were analyzed to determine relationships among spawning incidence and time; and broodfish weight, farm-of-origin, family-of-origin, spawning pond, hormone levels, and estimated ovary size.

Spawns were collected over a 103-day period in 2008 and a 98-day period in 2009; however, over 60% of the spawns were collected within 35 days of the first spawn each year. Spawning percentages were 27.4% and 48.3% for 2- and 3-year-old females, respectively; and 25.7% and 37.7% for 2- and 3-year-old males, respectively. Due to frequent multiple spawnings by males, over 60% of spawns was attributed to less than 15% of the males each year.

Spawning incidence was influenced by fish weight and spawning pond; but farm-of-origin, family-of-origin, plasma estrogen and testosterone, and ultrasound estimates of ovary size were not predictive of spawning incidence. As 2-year-old fish, spawning females (1.8 pounds) were larger than non-spawning females (1.6 pounds), but there was no difference in weight of spawning and non-spawning 3-year-old females (3.2 pounds). Spawning males and non-spawning males were not different for weight as 2-year-olds (2.1 pounds), but as 3-year-olds spawning males were larger (3.5 pounds) than non-spawning males (3.0 pounds). Spawning incidence at 2 years of age was not predictive of spawning incidence at 3 years of age for females or males.

Our data suggest variation in female spawning date has a genetic component. Average spawning date of females from two farms-of-origin was significantly earlier than other farms by 14 days in both 2008 and

Results at a glance...

- *Timing of female spawning (early or late season, for example) has a genetic component that can be exploited in breeding programs to expand the spawning season. On the other hand, the incidence of females spawning is primarily under environmental control, suggesting that spawning success can be improved by identifying and managing appropriate environmental factors affecting spawning success.*

2009. Farm-of-origin and family-of-origin were significant predictors of female spawning date; these factors combined accounted for 26% and 16% of variation in female spawning date in 2008 and 2009, respectively. There were positive correlations among spawning date for individual females across years and for mean spawning date of full-sib sisters across years. Plasma hormone levels and ultrasound estimates of ovary size were not predictive of female spawning date. Analysis and interpretation of male spawning date was precluded due to the high proportion of males that spawned multiple times over each spawning season.

The data indicated that spawning incidence of females is primarily under environmental control suggesting that future work should focus on identification of environmental factors that influence spawning incidence. Management of environmental factors to promote spawning would reduce the number of broodfish needed and reduce costs. A relatively small proportion of males contributed to the majority of spawns, indicating that the number of males used by farmers (1:1 or 1:2 male to female ratio) is probably excessive. Reducing the number of males could reduce broodfish costs substantially but it will be important to determine how few males can be stocked without reducing spawning incidence. Selection for early spawning date appears to be feasible and could allow farmers to stock fry earlier and potentially produce larger fingerlings at the end of the first growing season.

University of Arkansas at Pine Bluff and USDA-ARS Stuttgart National Aquaculture Research Center. Some female white bass do not respond to changes in the duration of the reproductive cycle (i.e. compression, shifting, or expansion). Females may fail to spawn after being included in groups that are projected to spawn when seed stock is required. Ultranonography has the potential to guide decisions regarding which females to include in a production cycle. Quantification of characteristics of the images collected with an ultrasound machine could be used to determine which females will be most likely to spawn following photothermal manipulation. This would reduce the number of female white bass necessary to hold under controlled photothermal regimes for use in hybrid striped bass seed stock production.

A Tela-Vet portable ultrasound system (Classic Medical, Tequesta, FL) equipped with a 5-8 MHz linear transducer was used for this study. In spring 2009, we evaluated the first ultrasound imaging of white bass ovaries on 35 white bass held at the USDA-ARS Stuttgart National Aquaculture Research Center. Fish were anesthetized and held upright, submerged in a holding tank. The ultrasound transducer was positioned anterior to the gonad, and moved posteriorly along the side of the fish. Three to five digital images of cross sections of the peritoneal cavity were captured along the length of the fish. Each female white bass was injected with a 75-nanogram slow-release GnRHa pellet. The females were held for 24 hours. Response of females to hormone injection and the time to ovulation (if spawning occurred) was recorded. During June, 2010, ultrasound images were collected from 30 female white bass before treatment with hormone to induce ovulation. Images were collected from the body region between the posterior insertion of the pelvic fin and the anterior insertion of the anal fin. Ten to 20 images of cross sections of the peritoneal cavity were captured within the length of this area over the course of 45-90 seconds. Length and weight of each fish was recorded and age data were gathered from hatchery PIT tag records. The female white bass were held for about 24 hours before initial inspection for ovulation. Eggs were visually inspected to determine readiness for spawning. Eggs were then expressed from 'ripe' females into plastic containers. Fish not ready for spawning initially were inspected at several intervals over a 24-hour period. The total mass of eggs expressed was recorded for the females screened using ultrasound imaging. Three small samples of eggs (0.1-0.2 g) were weighed. The number of eggs in each sample was tallied to determine the number of eggs/g. Female fecundity (eggs/kg fish weight) was then determined by multiplying eggs/g by the total mass of eggs expressed. Reproductive output measures were collected from 18 of the 30 females that had been screened with ultrasound.

The range in weight of these fish was 0.5 to 1.1 kg (1.1 to 2.4 pounds). Among fish yielding eggs, fecundity ranged from 30 to 490 thousand eggs/kg of female (14 to 220 thousand eggs/pound). Digital images of gonads are being currently being examined. Depth, power, gain, frequency and decibel settings and the quality of each image collected by the of the ultrasound system are being summarized to optimize settings for ultrasonagraphy of white bass ovaries.

Results at a glance...

- *Ultrasound images white bass ovaries do not show individual eggs as clearly as ultrasound images from striped bass due to differences in egg size between the species. Images from white bass do, however, show some quantifiable characteristics that are likely to vary between fish during egg development. Ultrasonagraphy may therefore help guide hatchery decisions and improve reproductive efficiency during production of hybrid striped bass seed stock.*

Texas A&M University-Corpus Christi. Physiological markers are being assessed for their usefulness to determine nutritional effects on reproductive traits and to predict testicular development of channel catfish. More specifically, steroid profiles of channel catfish and blue catfish are being assessed as predictors of reproductive readiness and to determine the effects of mega-doses of vitamin C on reproductive development and performance.

Channel and blue catfish were fed three levels of vitamin C (100, 500, and 1,000 mg/kg diet). Preliminary results indicate that increasing levels of vitamin C had positive effects on reproductive output, hatching success, and fry produced per kg of brood fish. One objective is to correlate these results with hormone levels in the brood fish. Currently 50 samples have been analyzed for steroid content by liquid chromatography. We have about 65 more samples for analysis from this experiment. Three- and 4-year-old male blue catfish will be sampled in April, 2011, to determine steroid levels and this will be correlated with sexual characteristics.

Results from this study are important in determining inexpensive and effective methods to improve reproductive performance of males and females selected for producing large numbers of fry destined for growout.

Objective 1b. *Improve conditioning and preparation of broodfish*

University of Arkansas at Pine Bluff, University of Tennessee, Texas A&M University. To achieve maximum Atlantic croaker production efficiency, larvae must be available throughout the year. Nothing is known of nutritional requirements for Atlantic croaker broodfish. Two studies were undertaken to resolve these problems. Study 1 examined the feasibility of conditioning and inducing Atlantic croaker to spawn during the summer utilizing 90- or 120-day abbreviated conditioning cycles and hormones. Study 2 is examining the effect of dietary lipid sources and inclusion rate on reproductive performance of Atlantic croaker.

Study 1. Atlantic croaker were spawned in November, 2009, and then maintained under static winter conditions until March, 2010. Broodstock were measured (11.9 ± 0.2 in), gender determined (male to female ratios of either 3:5 or 4:4) and fish were stocked into the experimental tanks on March 1, 2010. Each system underwent either 90- or 120-day abbreviated cycles that condensed annual photoperiod/water temperatures into the experimental duration. Treatments ended during autumn conditions optimal for spawning of Atlantic croaker (10 hours of daylight/14 hours of dark, water temperature 66 degrees F). The broodfish were then injected with a 75-microgram salmon gonadotropin-releasing hormone analogue implant (sGnRHa; Ovaplant®, Syndel International Inc., Vancouver, British Columbia). Fish were allowed to spawn within the tanks and eggs were collected.

Study 2. Pellet-trained brood Atlantic croaker (4 males and 4 females) were stocked into each of 12 tanks of three experimental systems on September 23, 2010. Four experimental diets were formulated and manufactured to contain 45% protein and either 6 or 10% lipid. Lipids sources and contents were 10% menhaden fish oil, 6% menhaden fish oil, 10% poultry fat, or 10% soybean oil. Fish have been fed experimental diets once daily to satiation since October 1, 2010. The fish will be spawned in autumn 20101 using hormone implants.

In study 1, no spawns were collected from fish in the 90-day cycle. In the 120-day cycle, a single 4,300 egg spawn and a 2,700 egg spawn was collected 4 and 6 days after implantation, respectively. Fertilization was less than 5% for both spawns, and eggs were atypically small (less than 0.02 inches in diameter) and discolored. Egg incubation was not attempted due to poor egg quality. No results have been obtained from study 2, as spawning will take place this autumn.

Study 1 has limited meaningfulness as the treatments were not successful at conditioning Atlantic croaker to spawn out of season. However, another study is planned to delay spawning until the spring. The expected impact of study 2 is to improve fecundity, hatch rate, and larval survival beyond what has been found in other studies through improved broodstock nutrition.

Auburn University. In previous research we have demonstrated that the addition of highly un-saturated fatty acid sources (menhaden oil enhanced with docosahexaenoic, DHA, and arachidonic acid, ArA) to broodfish diets significantly improved fry output of channel catfish females when mated to blue catfish males artificially, and preliminary information regarding mega-doses of vitamin C indicated improved hybrid fry output. The question of whether vitamin C coupled with select lipid sources could further improve fry output remains to be determined. These additives are costly so increases in the diet must be justified through improved performance of the fish. To evaluate these dietary manipulations this year's research compared five diets (manufactured for this study by Melick Aquafeeds Inc): 1) reference diet (RD) with 36% protein, 6% lipid and 100 mg vitamin C/kg diet; 2) RD with 1000 mg/kg vitamin C (RD+C); 3) RD with 2% added menhaden fish oil (RD+FO); 4) RD with 1.5% FO with 0.5% of high DHA and ArA meals (RD+HUFA); 5) RD with 1.5% MFO with 0.5% of high DHA and ArA meals with 1000 mg/kg vitamin C. The test diets were offered to the broodstock starting in the spring until they were harvested for spawning. Brood fish were channel catfish "E strain," obtained from Jubilee Fish Farm, MS.

Females selected for induced spawning were transferred to 200-gallon holding tanks supplied with continuous flow-through water, and placed individually in soft mesh bags. Total length, body weight, and grade were recorded. GMP-grade luteinizing hormone-releasing hormone analogue (LHRHa) from American Peptide (Vista, CA) was utilized to induce ovulation. Hormone injections were administered at a dose of 90 microgram/kg.

Overall, the production of female broodstock was quite successful. Fish were obtained in the fall, stocked into the ponds with limited variation in size or age. The condition factor was good indicating the fish were in good health prior to the initiation of the experiment. After feeding the diets over the course of the spring feeding period the fish were harvested and strip spawned. The spawning success ranged from 70.8 to 80.1% of the total fish that were harvested or 82.3 to 87.5% of the fish were injected and 79.8 to 90.9% of the injected fish were successfully strip spawned.

Overall, there does not seem to be any major trends in the data in terms of positive responses to the presented dietary treatment (Table 1). This is consistent with previous observations in which catfish going into the fall with good condition indices tend not to respond to broodstock diet manipulations or their response is considerably muted. On the other hand, in studies in which the condition factors where poor, there seemed to be very strong responses to dietary manipulations. Although not significantly different, the two treatments with the lowest observed values (Diets 2 and 4) had the highest lipid content. Too much lipid in the diet may harm reproductive performance and this should be evaluated.

University of Florida. The effects of altering the fatty acid profiles of diets fed to broodfish on egg and larval quality in two distinct commercially important ornamental fish species, the Redtail Black Shark (*Epalzeorhynchos bicolor*) and the Mono Sebae (*Monodactylus sebae*). Mono sebae is an ornamental fish species commonly captured from the wild along the western coast of Africa. In recent years their popularity among the ornamental industry has prompted interest in the development of culture methods. Producers identified broodstock nutrition to be a major bottleneck in commercialization and thus served as the impetus for this experiment. Redtail Sharks are a Cyprinid fish, a large group of which are in production in the ornamental industry. Most broodstock within this group are "conditioned" in open ponds where they have access to primary and secondary productivity, and only brought into the hatchery during spawning events. The ability to condition broodstock in indoor tanks would allow much greater control of reproductive efforts, including spawning in winter months. The need for a commercially available broodstock diet with specific characteristics for enhancing egg quality and subsequent larval quality is critical to this effort. While these diets exist for other species, the ornamental industry demands a much smaller particle size broodstock diet, and results of controlled trials to foster change in private farm practices.

The objectives of this study were to feed three diets to mono sebae and red tailed sharks broodstock

Table 1. Spawning success for brood female channel catfish fertilized with male blue catfish. Broodfish were fed one of five test diets in the spring preceding spawning.

Treatment	Percentage ovulation	fry/kg
Diet 1 (RD)	75.5	2,126
Diet 2 (RD +C)	66.1	1,696
Diet 3 (RD + FO)	70.5	2,544
Diet 4 (RD + HUFA)	73.4	1,443
Diet 5 (RD + C + FO + HUFA)	80.1	2,004

and determine the effects on spawning induction, egg quantity and morphology, fertilization rate, hatch rate, and larval morphology and survival. Rick Barrows, USDA-ARS, formulated the three diets with varying levels of essential fatty acids. The three formulated diets include an ornamental fish industry standard formulation containing 52% crude protein and 10% crude lipid, a diet with 52% crude protein and 13% crude lipid with added Algamac ArA to increases n-6 fatty acid content, and a diet with 52% crude protein and 13% crude lipid with added Algamac ArA and Algamac 3050 to increase both n-3 and n-6 fatty acid content. Populations of both red tailed sharks and mono sebae were fed the various experimental formulated diets for approximately one year.

Redtail black sharks were induced to spawn using industry standard methods of 0.5 mL/kg body weight Ovaprim injections, and salinity of culture water for the mono sebae was increased 1.5 g/L per week until 35 g/L was attained (spawning cue). Mono sebae eggs were removed from surface egg collectors after spawning. A subsample of all eggs was used to determine egg quality and will be analyzed for fatty acid content and profile. Redtail shark eggs and sperm were collected by hand stripping. The number of mono sebae eggs spawned was assessed by using egg collectors which were checked daily and all eggs were removed and enumerated volumetrically. Eggs were placed into 100-mL graduated cylinders at ambient treatment temperature and allowed to settle for 30 minutes. The numbers of floating and sinking eggs were recorded. Fertility was calculated from the floating eggs. Percent fertilization for red tailed sharks was determined by examining a subsample of eggs at the onset of the first cell divisions. For both species, a sample of fertile eggs was rinsed and frozen at -80 degrees C for fatty acid analyses. Hatching percent was attained from random subsamples taken from each spawn and stocked into 1-L containers with screen bottoms and suspended into temperature controlled water, three replicate containers for each of hatching percent, 24-hour survival, and 48-hour survival. Survival percentage and size was recorded from each replicate container.

Three populations of mono sebae brood were fed a formulated diet prior to spawning induction triggered by increased temperature and salinity. A total of 39, 30, and 46 spawning events were recorded over the 88-day experimental period for diets 1, 2, and 3, respectively. The mean total egg production per female and the mean floating and sinking egg fertilization percentages are presented in Table 2. Mean hatching percentage ranged from 47.5 “ 35.4% for diet 3 to 57.4 “ 34.8% for diet 1. The highest mean 24-hour and 48-hour survivals, 61.9 “ 41.3% and 45.3 “ 41.2% respectively, were observed in larvae from the treatment fed diet 3. Results of the number of total, floating, and sinking egg produced for each treatment are summarized in Table 2.

Over 4,800 photos of mono sebae eggs and larvae

Table 2. Mean (± one standard deviation) total, floating, and sinking egg production over the 88-day spawning period for mono sebae (C - control diet, ArA - arachidonic acid, DHA - docosahexaenoic acid).

Diet	Mean Total Eggs per Female (±SD)	Mean Floating Egg Fertilization (±SD)	Mean Sinking Egg Fertilization (±SD)
1 C	2160.4 ± 1089.2	96.5 ± 6.1	83.9 ± 24.8
2 C+ArA	1959.4 ± 2001.0	93.6 ± 7.4	70.6 ± 36.5
3 C+ArA+DHA	2813 ± 1859.6	97.2 ± 3.7	88.4 ± 16.7

have been taken (Figure 2). The egg (egg diameter, oil droplet diameter), larval morphology (oil droplet length and width, yolk length and width, notochord length) at hatch, larval morphology (notochord length) at 24 and 48 hours post-hatch are currently being measured. Proximate and fatty acid composition of the diets and fatty acid composition of samples of floating and sinking eggs will be analyzed.

During the spring and summer of 2010, four separate spawning trials of redtail sharks were conducted. In each trial, three females from each of nine tanks were used (three replicates of each of three feed formulations). A sample of eggs was taken for estimating gonadasomal index and number of eggs for each treatment. Separate egg samples have been rinsed and stored for fatty acid profiling from each female, and photographs of eggs at 8-cell stage and late blastomere have been taken and archived as well. Percent fertilization has been recorded for each feed treatment. The results of hatching experiments have been problematic and the data for hatching percent and subsequent larval survival is inconclusive. Modifications in the hatching system for the last of the four spawning trials which was conducted October 13-14, 2010 resulted in a decrease of hatching rates for all treatments with 0% hatch for all treatments and replicates. While it is possible that none of the diets are able to provide nutritional requirements for viable egg production, it is more likely that there is a fatal flaw in the hatching conditions (e.g. water quality, flow, temperature control) and/or handling, and these issues will be addressed in subsequent trials.

Results at a glance...

- *Results of this project should provide the ornamental fish industry with information that can be used to create a commercially available broodstock maturation diet. Use of an ornamental fish specific brood diet should increase the efficiency of broodstock by increasing percent hatch and percent survival, as well as eliminating the need for expensive and labor intensive feeding of live, fresh, and frozen dietary supplements or dependence on pond culture for broodstock conditioning.*

Figure 2. 7-d-old *Monodactylus sebae* fry

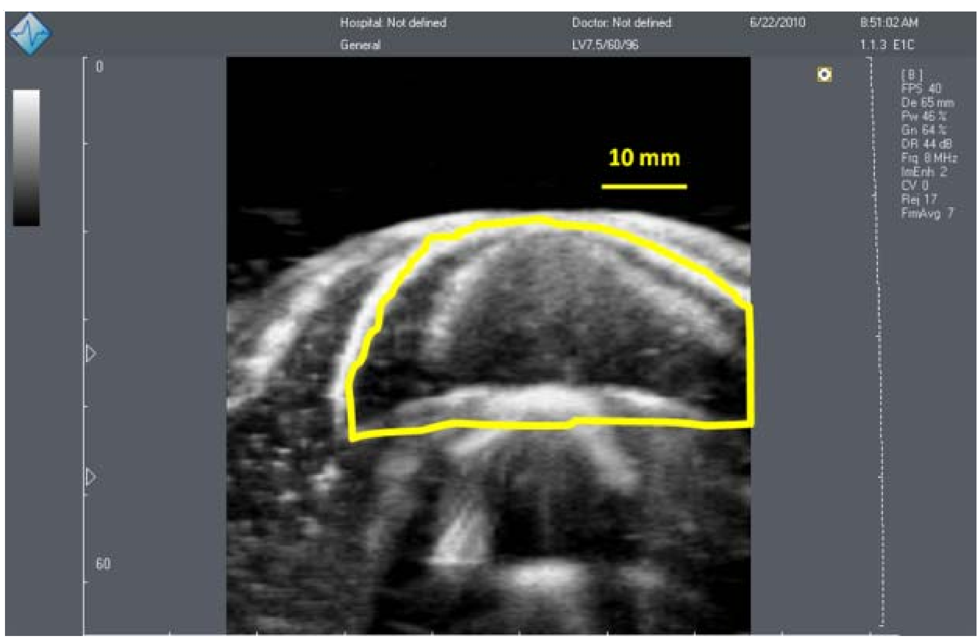
Objective 1c. *Final identification of broodstock for spawning.*

USDA-ARS Catfish Genetics Research Unit. We have communicated with two commercial catfish farms about separating females into brood ponds based on ultrasound estimates of ovary size and then tracking reproductive success. However, we are currently waiting to see the results from the 2009 spawning data to determine if ultrasound has any predictive ability for spawning success of females. Our initial results suggest ultrasound is not accurate for predicting spawning success of females. If there is no ability to predict spawning success from ultrasound examination of ovary size, we will likely drop the commercial farm trials from the study given the labor and time required with no evidence indicating a successful outcome.

University of Arkansas at Pine Bluff and USDA-Stuttgart National Aquaculture Research Center. Often, injection of white bass females with hormone does not result in spawning during the next 24 to 48 hours. Females may fail to spawn at all, or they may spawn later than 48 hours, rendering a spawning effort less successful. Ultrasonography has the potential to guide decisions during the spawning process. Quantification of characteristics of the images collected with an ultrasound machine could be used to determine which females will be most likely to spawn in a fixed period following hormone injection. This would substantially improve the efficiency of hybrid striped bass seed stock production.

A database of ultrasound images and corresponding indices of reproductive success has been developed. A standardized image of a cross section for the ovarian region (Figure 3) is being selected for each

Figure 3. Ultrasound image of pre-spawning white bass female collected during June 2010 spawning activities. Outline indicates area containing the ovary.



fish for image analyses. Image analysis software (Image-Pro Plus Version 4.5.1.22, Media Cybernetics, Inc., Silver Spring, Maryland) will be used to determine several morphometric measures (diameter, cross sectional area, perimeter) to characterize ovaries of fish as they approach ovulation. Additionally we are exploring the use of pixel gray-scale analyses to further characterize ultrasound images of ovaries. All fish identity information will be withheld from individuals performing image analyses so as not to bias the results with a prior knowledge of the reproductive success of the individual female.

Statistical models are under consideration that will use data gathered from image analyses to determine relationships of ovary measurements and indices of reproductive output. These models will include categorical variables such as ovulating/non-ovulating and continuous responses such as fecundity, as well as fertilization success, to determine if variation in ovary images predicts higher or lower reproductive output. This work is being undertaken presently. We will also compare these values from fish maintained under a 12-month reproductive cycle to data gathered from fish during spawning dates scheduled for November, 2010 using fish held in a fashion to compress the spawning cycle.

The wide range of responses in reproductive output observed to date combined with the responses collected from fish sampled during the scheduled out-of-season spawning events should provide the necessary information to characterize the utility of ultrasound technology as a means identification of suitable fish for artificial spawning of female white bass.

Objective 2. *Improve spawning protocols to increase reproductive efficiency.*

Objective 2a. *Manage spawning conditions.*

University of Arkansas at Pine Bluff and USDA-ARS Stuttgart National Aquaculture Research Center. Domestication of striped bass and white bass allows greater control over the reproductive cycle and spawning conditions. Domestication also allows choices related to age, size, and the duration of the reproductive photothermal period. The choices made may effect the success of induced spawning efforts. For example, choosing older or larger individuals might affect fertilization or hatching rates, or size of individuals at hatch or at yolk absorption. Quantifying the importance of these factors should lead to improvements in hatchery efficiency during production of hybrid striped bass.

A combination of 3-, 4-, and 5-year-old white bass were subjected to a 12-month photothermal regimes. During the 12-month period, fish were fed a 45% protein diet twice daily to satiation. At the end of the 12-month period, fish were induced to spawn with hormone injections. Weights and lengths of females were determined prior to hormone injection. Fish were injected with 330 International Units of human chorionic gonadotropin (HCG) per kg body weight (150 IU/pound) Eggs were treated with tannic acid and povidine, and maintained in McDonald hatching jars at 19 to 24 degrees C (66 to 75 degrees F). During year 1, egg development ceased after approximately 19 hours. It appears that povidine treatment of moronid eggs is lethal. During the second year, hatching success was determined. On the day of hatch, approximately 40 larvae from each cross were preserved in 4% buffered formalin. At 5 days post-hatch (dph), approximately 40 larvae from each cross were preserved in 4% buffered formalin. Preserved larvae were photographed individually and larval total length was determined. The effect of female age on length at hatch was examined using an analysis of covariance with female weight utilized as the continuous covariate. The same statistical approach was used to examine the effect of female age on length at 5 dph.

Altogether, three 3-year-old, thirteen 4-year-old, and two 5-year-old females were used during this study. Female weights averaged 614 g (1.4 pounds) and ranged from 400 to 890 g (0.9 to 2 pounds). Fertilization rates averaged 6% and ranged from 0% to 25%. Hatch rates were fairly low (< 10%) for most crosses. A total of 11 females had adequate hatching to collect samples for length at hatch estimates. Larvae from one of those 11 females all died before 5 dph. Length at hatch averaged 2.40 (0.27) mm TL. Length at 5 dph averaged 3.07 (0.31) mm. Neither female weight nor female age significantly influenced length at hatch. Likewise, neither female weight nor female age significantly influenced length at 5 dph.

Earlier work suggested that there was a maternal effect influencing size at hatch and size at 5 dph. This earlier work was not designed to ascertain whether the maternal effect was genotypic or phenotypic. The results of our study point to a genotypic effect, since phenotype (i.e. age and weight of female) did not influence size at hatch or size at 5 dph. To further examine this possibility, we ran a one-way analysis of variance using dam as the independent variable. The effect of female was statistically significant for size at hatch, but not for size at 5 dph. For example, larvae from females 3 and 11 were significantly larger than larvae from females 4 and 7. If heritability of length at hatch is sufficient, then selection for this trait could increase the size of larvae and consequently, their gape. If gape is large enough, hybrid striped bass might be able to consume *Artemia* nauplii at first feeding, eliminating the current requirement for rotifers at first feeding. This might significantly change the economics of tank culture of fingerling hybrid striped bass and lead to year-round availability of fingerlings.

USDA-ARS Catfish Genetics Research Unit. Yearling USDA-403 fingerlings were randomly divided into two groups. Group one was fed to satiation and group two was fed half the amount fed to group one. Both groups were exposed to a compressed annual temperature cycle of 4 months at 79 degrees F and 2 months at 55 degrees F. Exposure to three complete temperature cycles was done over two calendar years and 30 females and 20 males from each group were stocked separately into two, 0.1-acre ponds with 10 spawning containers in April. Male fish fed to satiation weighed 2.2 pounds and females weighed 1.7 pounds. Male fish fed to half-satiation weighed 1.6 pounds and females weighed 1.3 pounds. Spawning cans were checked through the summer, however, there were no spawns produced from either group.

An experiment was designed to determine if fish exposed to extreme compressed cycles would spawn when they were 1 year old. One group of fish was USDA-103 and the other group was created from an "industry pool." Both groups of fish were grown 4 months at 79 degrees F then exposed to 55 degrees F for 1 month. A temperature cycle of 2 months at 79 degrees F followed by a month of cold temperature was repeated until the fish had been exposed to three cycles of cold and warm temperatures. The fish were then stocked into 0.1-acre ponds with spawning containers and the cans checked regularly through the summer. No spawns were produced in either group.

Another experiment was performed to determine if fish could be spawned after 18 months of alternating temperature cycles. Fish from an industry pool were raised in the hatchery at 79 degrees F until October 13, 2009. Four groups of 150 fish from an industry pool, mean weight 27.0 g, were stocked into each of four, 300-gallon tanks equipped with chillers. Another group of 300 fish was stocked into a 0.1-acre pond. One group was fed to satiation and a second group was fed one half the satiation amount. Two other tanks were fed an amount less than the group fed to satiation. Fish in the tanks were exposed to 2 months of 55 degrees F water followed by 4 months of 79 degrees F water. Fish were exposed to 3 cycles of 2 months of 13 degree C water and three cycles of 79 degree F water. In early October, 2010, 30 females and 20 males from each group were stocked in each of two, 0.1-acre ponds with 10 spawning containers. Female fish from the fish fed to satiation weighed an average of 0.45 pounds and males weighed 0.50 pounds; female fish fed one-half-satiation weighed 0.22 pounds and male fish weighed 0.28 pounds. Female fish from the ponds weighed 0.74 pounds and males weighed 1.4 pounds. A sample of eight fish from each treatment were weighed, the gonads dissected and weighed and a blood sample taken. Gonadal development was reported as the gonadosomatic index (GSI). Fish fed to satiation were twice as heavy as those fed to half-satiation ; however fish fed in the ponds were over twice as heavy as those fed in tanks. The GSI from both groups fed in tanks were larger than fish from the pond. Spawning cans were checked during October, however, no spawns occurred.

Although the October water temperature was warm enough to support spawning, no spawning occurred suggesting that age of the fish may be an important component of reproductive maturation and that there is a limit on the effectiveness of temperature cycles to advance spawning. Some maturational events may have been advanced suggested by the larger GSI in cycled female fish compared to pond raised fish. However, both female satiation fed and half-satiation fed fish had similar GSI.

University of Arkansas at Pine Bluff, University of Tennessee, Texas A&M University. Atlantic croaker display asynchronous spawning with a prolonged spawning season, which limits the potential to reproduce this species on a scale capable of sustaining commercial culture. Therefore, a study was conducted to determine if 1) Atlantic croaker could be spawned naturally in captivity; 2) hormone implants could induce spawning or improve fecundity; and 3) temperature, photoperiod, and hormone implants could synchronize spawning.

Atlantic croaker broodstock (average total length = 11.3 inches) were captured from Trinity Bay in August, 2009. Two males and three females were stocked into each of twelve, 300-gallon tanks in three recirculation systems with temperature/photoperiod controls. Natural photoperiod and temperature mimicked seasonal temperature fluctuations in Trinity Bay. Tanks were assigned to four treatments; 1) natural spawning (NAT); 2) pre-optimal temp (77 degrees F) hormone implant (PRE); 3) optimal temp (73 degrees F) hormone implant (OPT); or 4) post-optimal temp (70 degrees F) hormone implant (POST). Implants used were Ovaplant® 75-microgram sGnRHa. Egg samples were taken for determination of egg diameter, fertilization rate, and hatch rate. Egg samples from each spawning event were placed into conical, 25-gallon hatching tanks to determine hatch rates at 27-30 hours.

Total egg production was 2.9 million from all treatments (36 females; 24 males). Parameter means were: water temperature at spawning, 67.8 degrees F; photoperiod at spawning, 10.1 hours daylight; eggs/spawn, 97,417; fertilization rate, 42%; hatch rate, 19%; and 3-day larval survival, 37%. The POST treatment produced the greatest quantity of eggs and spawns per tank. Spawning events were highly synchronized for hormone treatments compared to NAT. The shortest to longest latency occurred in the

Results at a glance...

- *Atlantic croaker can be spawned naturally in captivity, but a single 75-microgram sGnRHa implant injected at 10 hours of daylight and water temperature of 69 degrees F will control, improve, and synchronize reproduction of Atlantic croaker for commercial production.*

following order: 1) POST; 2) OPT; 3) PRE. The total egg per spawn was greater in the POST treatment than PRE or OPT. The quantity of eggs per spawn was greater from POST than from fish in PRE or OPT, while the quantity of eggs per spawn from NAT was not different from other treatments. Egg fertilization was greater in the NAT and POST treatments than for PRE or OPT. Overall fecundity for all treatments in the study (36 females) was 81,180 eggs per female. The mean fecundity for females in the POST treatment was greater than fecundity of the NAT, PRE, or OPT treatments.

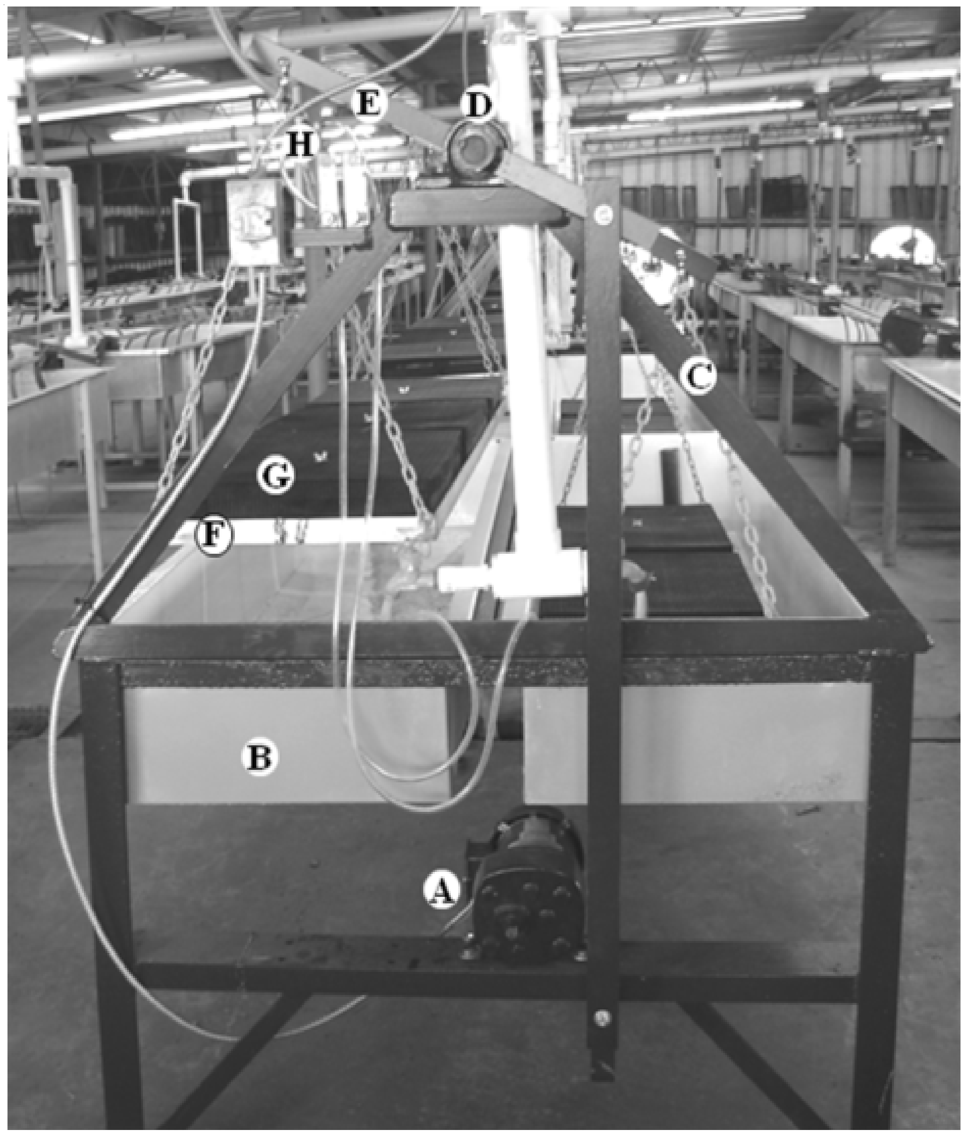
Objective 2b. *Improving the Collection and Handling of Eggs.*

USDA-ARS-Catfish Genetics Research Unit. Channel catfish were first spawned in captivity nearly a century ago and the methods used have changed little. Egg masses are placed in hatchery troughs in baskets made with 0.25-inch-mesh hardware cloth or plastic screen, and are agitated with paddles located between the baskets. The paddles are attached to a shaft running the length of the hatchery trough, and either rotate 360 degrees or oscillate back and forth. Normally 10 to 12 spawns (roughly 18 pounds or 250,000 eggs) are held in each 100-gallon hatchery trough, with a water flow of 5 gallons per minute at 78 to 82 degrees F. This incubation system has proved functional, but it has limitations. If egg loading is increased, as normally happens during the peak of the spawning season when facilities are limited, water circulation between and through the spawns is greatly restricted resulting in a low dissolved oxygen concentration and dead eggs in the center of the spawns. Those areas may serve as foci for fungal and bacterial infection, greatly reducing the hatch rate in the entire trough. We believed that a new incubation system, one in which water (and oxygen) was more thoroughly and efficiently forced through the egg masses, would increase the efficiency of commercial catfish hatcheries.

The new incubator, dubbed the "See-Saw" by collaborating farmers (Figure 4) utilizes an angle aluminum frame slightly smaller the standard hatchery troughs. Three baskets made with 0.25-inch PVC-coated hardware cloth contain the spawns and are held in place by the frame. The baskets have cross-partitions to evenly distribute the egg masses within the baskets, and hinged lids to hold the spawns in place during operation. Agitation is accomplished by raising and lowering the frame up and down through the water. A prototype of the new incubator underwent preliminary testing during the 2007 and 2008 spawning seasons. The first trial (2007) determined the appropriate cycle interval to be approximately ten seconds. In the second trial (2008) the See-Saw was tested with twice the egg density as is recommended. Although a thoroughly replicated comparison with standard incubators was not conducted, the See-Saw operated flawlessly. Those preliminary studies were published (Torrans et al. 2009) and describe the construction and operation of the prototype incubator in more detail. With the initiation of this SRAC project, a non-funded cooperative agreement was initiated with Needmore Fisheries LLC, Glen Allen, Mississippi, to more thoroughly compare the See-Saw with conventional paddle-type incubators and to test and quantify several operational parameters. All studies reported here were conducted at that commercial hatchery using experimental incubators fabricated and operated by the hatchery employees.

Most of the first year (2009 spawning season) was used to design the system, purchase motors and material for fabrication, and preliminary stress-testing of the system without live eggs. Near the end of the spawning season the first comparative trial was conducted. Pairs of troughs (one control and

Figure 4. See-Saw incubator used in Year 2 of this study prior to loading eggs. Note that as the left rack is up in the air, the right rack is down in the water. Each rack contains three hatching baskets that are secured to the rack. The water supply for these two troughs is in the foreground and the drain is at the far end in each trough. The following components are labeled: (A) 6 rpm motor , (B) hatching trough, (C) angle-aluminum frame supporting the See-Saw, (D) steel shaft running the length of the troughs, (E) crossbars, (F) angle-aluminum rack that holds the baskets, (G) hatching baskets, and (H) oxygen supply not used in this study.



one See-Saw, with four troughs for each treatment) were loaded with approximately 26 egg masses per trough (approximately 475,000 and 473,000 eggs per trough, respectively). Water quality was measured in the water supply and in each trough daily. Sac fry were measured volumetrically and sub-sampled to determine total number, then transferred to rearing troughs. When the fry reached swim-up stage, they were measured volumetrically and sampled to determine total number before transfer to rearing ponds. Survival to swim-up stage averaged 54% in the See-Saw and 23% for the control troughs, a 2.3-fold difference.

Results at a glance...

- *A novel catfish egg incubatorhas been designed and tested on two commercial farms. More eggs can be incubated using less water exchange than with conventional incubators, while achieving increased survival to swim-out stage.*

In Year 2 of the project (2010 spawning season) we measured the effect of egg loading density in See-Saw incubators on survival to hatch and swim-up. Further comparisons with the paddle-type incubators were not conducted. We loaded See-Saws (five troughs for each treatment) with approximately 15 pounds (220,000 eggs), 30 pounds (447,000 eggs), 45 pounds (670,000 eggs), and 60 pounds (893,000 eggs) of spawns. Water flow into the troughs averaged 2.1 gallons/minute, roughly half of the rate recommended for commercial hatcheries. The 15, 30, and 45 pound troughs produced an average of 132,700, 263,800, and 429,400 swim-up fry (survivals from egg of 60, 59, 64%, respectively, similar to values reported in commercial hatcheries). However, the 60 pound treatment produced only 417,200 swim-up fry (survival of 46%). The results of this year's study indicate that both hatchery space and water use would be maximized with See-Saw incubators loaded at the 45 pound rate. Year three of the project will aim at further improvements in operational efficiencies.

The results thus far indicate that the See-Saw incubator can be loaded with 45 pounds of eggs per trough without impacting hatch rate or survival to swim-up. The use of this incubator across the commercial industry would result in considerable savings in water alone, particularly for those hatcheries that need to heat their well water. This incubator may have even greater application in the numerous state and federal hatcheries which are tasked with hatching a growing number of fish species. The See-Saw can reduce both the space and water flow needed to meet their channel catfish production quota, making those resources available for other priority species.

IMPACTS

Two commercial hatcheries are currently using the new catfish egg incubator as a part of the on-farm trials. Further technology transfer will follow as the new system is more thoroughly tested.

Other studies have not progressed to the point where information has used commercially.

PUBLICATIONS, MANUSCRIPTS, OR PAPERS PRESENTED

Manuscripts

Davis, K.B. 2009. Age at puberty of channel catfish, *Ictalurus punctatus*, controlled by thermoperiod. Aquaculture 292:244-247.

Sink, T.D., R.J. Strange, and R.T. Lochmann. 2010. Hatchery methods and natural, hormone-implant-induced, and synchronized spawning of captive Atlantic croaker (*Micropogonias undulatus*). Aquaculture 307: 35-43

Sink, T.D., R.J. Strange, and R.T. Lochmann. In press. Bi-Annual cyclic spawning of captive Atlantic croaker (*Micropogonias undulatus*) using abbreviated conditioning cycles and hormone treatments. Aquaculture.

Sink, T.D., and R.T. Lochmann. In press. The Atlantic croaker (*Micropogonias undulates)*: An emerging candidate for multiple purpose aquaculture. World Aquaculture Magazine.

Sink, T.D. In press. Species Profile: Atlantic croaker. Southern Regional Aquaculture Center Fact Sheet.

Torrans, L., B. Ott, R. Jones, B. Jones, J. Baxter, B. McCollum, A. Wargo III, and J. Donley. 2009. A vertical-lift incubator (the "Seesaw") designed for channel catfish egg masses. North American Journal of Aquaculture 71:354-359.

Presentations

Bosworth, B.G., G.C. Waldbieser, S. Quiniou, B.C. Small, and K.B. Davis. Factors affecting spawning success in channel catfish. 2009. In: Research and Review; A Compilation of Abstracts of research on channel catfish. Catfish Farmers of America Catfish Research Symposium, March 5-7, 2009, Natchez, Mississippi.

Bosworth, B.G. 2010. Factors influencing spawning in pond-spawned channel catfish. Annual Texas Aquaculture Association Conference and Trade Show, Jan 27-29, 2010, Bay City, TX.

Ohs, C.L., Ohs, M.A. DiMaggio, S.M. DeSantis, J.S. Broach, L.M.V. Onjukka, A.H. Beany, S.W. Grabe, C.A. Watson, R. Barrows. 2011. Evaluation of spawning performance of *Monodactylus sebae* fed brood diets supplemented with increased levels of essential fatty acids. Abstract: Aquaculture America 2011. New Orleans, Louisiana.

Sink, T., R. Strange, and R. Lochmann. 2010. Natural, induced, and synchronized spawning of Atlantic croaker *Micropogonias undulatus*. Aquaculture America 2010, San Diego, California.

Sink, T. 2010. Introducing the Atlantic croaker *Micropogonias undulatus*: An emerging candidate for multiple purpose aquaculture production. Aquaculture America 2010, San Diego, California.

Sink, T., and R. Lochmann. 2010. Atlantic croaker *Micropogonias undulatus*: An emerging candidate for multiple purpose aquaculture production. UAPB Aquaculture Field Day 2010, Pine Bluff, Arkansas.

Torrans, L., B. Ott, R. Jones, B. Jones, J. Baxter, B. McCollum, A. Wargo III, and J. Donley. 2009. The "See-Saw"–a high-intensity catfish egg incubator designed to save space and conserve water. Catfish Farmers of America Catfish Research Symposium, Natchez, Mississippi, 5-7 March 2009.

◆ ◆ ◆

USING NATIONAL RETAIL DATABASES TO DETERMINE MARKET TRENDS FOR SOUTHERN AQUACULTURE PRODUCTS

Reporting Period
August 1, 2009 – August 31, 2010

Funding Level	Year 1	$125,000
	Year 2	$125,000
	Total	$250,000

Participants	Mississippi State University	Jimmy Avery
	University of Arkansas at Pine Bluff	Madan M. Dey, Carole Engle
	Texas Tech University	Benaissa Chidmi
	Auburn University	Terry Hanson
	University of Florida	Sherry Larkin, Charles Adams

PROJECT OBJECTIVES

1. Compile historical data on retail price and sales volumes of major aquaculture species and competing products in key cities and regions in the United States.

2. Identify factors affecting a) trends in prices and sales volumes and b) consumption of fresh and frozen farm-raised catfish, crawfish, clam, and shrimp products.

3. Measure competitive position and substitutability of frozen farm-raised catfish, clam, and shrimp products with other seafood products, with an emphasis on imported products.

ANTICIPATED BENEFITS

Research into consumer understanding and preferences in the food marketing system in the US and abroad are important in terms of the viability and sustainability of aquaculture businesses. An increasing body of research has demonstrated that market power (i.e. the ability to set price) in the U.S. food market lies at the retail level. National scanner data provide a key opportunity and resource to understand current trends in the retail markets, and to analyze consumer preferences and diversified demand structures. Use of these data has the potential to lead to the design of production and marketing strategies that match market trends and consumer preferences. Though the project will concentrate on catfish, crawfish, clam, and shrimp, the approaches and tools developed will have wider applicability to other species and products.

PROGRESS AND PRINCIPAL ACCOMPLISHMENTS

Objective 1. *Compile historical data on retail price and sales volumes of major aquaculture species and competing products in key cities and regions in the U.S.*

Project planning meeting

University of Arkansas at Pine Bluff, Texas Tech University, Auburn University, and University of Florida. The University of Arkansas at Pine Bluff organized a one-day Project Planning Meeting on November 17, 2009. All project participants attended the meeting. Project stakeholder's expectations, project objectives and methods, sources of national scanner data and characteristics of data, matching data requirements and sources, project methodology, and work plan were discussed. The project team decided to purchase a national database from A.C. Nielsen for the recent 5 years, and considered Information Resources Inc. as an alternative source. Household consumption data using Consumer Expenditure Survey of the Bureau of Labor Statistics, and the USDA National Nutrient Database for Standard Reference were identified as sources for matching data. The University of Arkansas at Pine Bluff was entrusted with the task of obtaining these data.

Acquisition and summary of store-level scanner data

University of Arkansas at Pine Bluff and Auburn University. The University of Arkansas at Pine Bluff procured the store-level scanner data following an open bidding process. Both A. C. Nielsen and Information Resources Inc. were invited to submit bids. Based on the information in the bids, the A. C. Nielsen company was selected to supply the data.

Results at a glance...

- *Retail data acquired in this project covers 133 food chains, 65 convenience chains, 11 drug chains, and 8 mass chains in 52 cities and 19 regions in the U.S.*

During acquisition of A.C. Nielsen store-level data, data samples were shared with all project participants. The project team finalized the characteristics of data and the format of the data report. Once the data were acquired, the project team discussed the details concerning the size of the data, data-sharing alternatives, and data-management issues.

The A.C. Nielsen store-level retail scanner data acquired for this project have the following salient features:

- Outputs and products

  133 'food chains' (except Walmart), 65 'convenience chains', 11 'drug chains', and 8 'mass chains'

  52 U.S. cities and 19 regions, all U.S. Census Divisions and the total U.S.

  84 seafood product categories (species or species groups) classified as 'unbreaded frozen', 30 'breaded frozen' products, 40 'entrée' products, and 5 'canned' product categories, and 'anchovies' and 'tuna shelf-stable' categories

  12,898 products

- Descriptive characteristics: city, chain, product form, UPC barcode, and brand

- Sales information: Sales value, sales unit volume, unit size, average unit price, sales value with promotion, sales unit-value with promotion, etc.

- Frequency: Four weeks cumulative data from four weeks ending on 07/16/2005 to four weeks ending on 06/16/2007 (total 26 four weeks cumulative), and weekly data from week ending on 06/23/2007 to week ending on 06/12/2010 (total 156 weeks).

According to the availability of the data and the objective of the research, the seafood market in the U.S. can be divided or aggregated into different levels. The overview description of the seafood market in the U.S and levels of aggregation/disaggregation that can be analyzed are:

- The entire U.S. seafood market that would provide an overview of the whole seafood market, consumption, and price trends for each region or locations in the U.S.

- The market for some main fish species such as shrimp, crawfish, catfish, clam, and others that can provide an overview of the market for each species.

- The market for different product forms such as fresh, frozen, canned, and paste that can provide information on the product/shelf life.

- The market for different product types such as whole, fillet, steak, slice, piece, nugget, stick, breaded or un-breaded that can provide information on how ready-to-eat the products are, which is important for understanding consumers preference for cooking time savings.

- The market at the product-brand level can provide information about the diversification of brands, competition between brands, level of market concentration, market power of product brands, and pricing behavior of product branders.

Matching the store-level scanner data

University of Arkansas at Pine Bluff. The University of Arkansas at Pine Bluff has procured the household consumption data from the Consumer Expenditure Survey (CES) of the Bureau of Labor Statistics (BLS). The CES data for the years from 2004 to 2008 was obtained in the form of compact discs (CDs) from the BLS. The CES is the most comprehensive and detailed U.S. data source for analyzing demographic effects on household consumption. It collects data on expenditure, income and various household characteristics. It includes two types of survey procedures: the quarterly Interview survey and the weekly Diary survey. Information from approximately 5,000 households is available in each of these surveys. The interview survey collects information pertaining to expenditures on housing, household durables, apparel, transportation, health care, insurance and entertainment. The Diary survey collects information on weekly expenditures on frequently consumed goods like food and beverage, tobacco, personal care products and nonprescription drugs and supplies. In addition, demographic and family characteristics of each consumer unit (CU) are collected. There are five main data files in CES. These are the Consumer Unit Characteristics and Income (FMLY) file, the Monthly Expenditures (MTAB) file, the Detailed Expenditures (EXPN) file, the Income (DTAB) file and the Imputed Income (DTID) file. Overall these files provide information such as age, gender, race, marital status, education and relationships amongst the members of the CU.

Next, the nutritional characteristics of the relevant products were collected from the USDA National Nutrient Database for Standard Reference. Among the four aquaculture species under study in this project, only the information on crawfish is not available. This will be collected from scientific references and other possible public databases.

Trend analysis for major seafood categories

University of Arkansas at Pine Bluff. The University of Arkansas at Pine Bluff analyzed the trends by volume, value, and average prices for major seafood categories at the U.S. level. The trends were analyzed for 'breaded frozen' products (total, finfish, shrimp and others), 'unbreaded frozen' products (total, finfish, shrimp, crab, and others), 'canned' products (total, shrimp, clam, oysters, salmon, sardines, crab, and others), 'entrées', 'anchovies', and 'tuna shelf-stable'.

Tuna shelf-stable has remained the most important contributor to total seafood product sales, however, its share has declined over the study period. The market share of breaded frozen and canned products has also declined continually over the period. Market share of unbreaded frozen seafood products has increased over the period.

Shrimp is the most important contributor (>25% share in total seafood in value terms) to unbreaded frozen products, and its share is almost constant over the study period. Unbreaded frozen finfish market share has increased over the period. The share of shrimp canned and shrimp breaded frozen has also declined continuously. 'Clam canned' contributes less than 2% to total seafood consumption, however, its share appears to have declined during the study period.

Total sales value of breaded and unbreaded shrimp has increased over the period at an increasing growth rate. Canned products have registered negative growth in sales volume over the period. Sales value and volume of canned shrimp has registered negative growth, however, clams increased at a positive rate.

The average prices (nominal) of total seafood products have increased from $3.38/pound during 2005-2006 to $4.69/pound during 2009-2010. In general, nominal prices of seafood under major categories have increased over the period, but this increase is relatively low as compared to increase in consumer price index for food product over the period.

Market trends in catfish (fact sheet information)

University of Arkansas at Pine Bluff. Catfish products in the U.S. market can be grouped into three broad categories: 'Entrée', 'breaded frozen', and 'unbreaded frozen'. There are 12 entrée, 34 breaded and 143 unbreaded catfish products (except in 2007-2008 when there was 146 unbreaded items). Unbreaded products occupy the largest share in the total catfish market ranging from 80-90% in both value and volume. Although changes in catfish sales were not uniform during 2005-2010, sales grew every year. Sales of unbreaded products grew faster than that of breaded and entrée products. Entrée products experienced a decline in sales during 2009-10 from previous year. Unbreaded fillet and nuggets, which have a relatively large share of total catfish sales, have continued to grow since 2005-2006. Since 2005, the price of unbreaded fillets decreased $0.25/pound, but the price of unbreaded nuggets has increased $0.45/pound.

Results at a glance...

- *The New Orleans/Mobile market is the top market for catfish entrée items and breaded items, but for unbreaded items, Memphis is the top market.*

Market share for the unbreaded products has increased from 2005 through 2010 but it has decreased for value added products like breaded and entrée items. Fillets and nuggets are the top products in all three groups. Unbreaded fillet and nugget items have 61% and 37% market share of all catfish products, respectively. In summary, the composition has remained almost the same but the position of specific products has changed over the period.

Among 52 major U.S. markets, about 75% do not sell catfish entrée items, and 35% do not sell breaded catfish items. However, unbreaded products are more or less sold in all 52 markets. The top 5 markets for catfish products are listed in Table 1. In 2009-2010, New Orleans/Mobile market alone has consumed 66% of total catfish entrée products. The New Orleans/Mobile market remained the top market for breaded catfish items, but for unbreaded items, Memphis is the top market.

Since 2005-2006, more products are being promoted. The percentage of volume of products without promotion is decreasing, but percentage of products with promotion is increasing. The average price of the products without promotion is higher than that of the products with promotion.

Market trends in shrimp (fact sheet information)

University of Arkansas at Pine Bluff. Overall, there is an increase in sales volume of shrimp products in 2010 compared to 2006. This increase in sales volume is not associated with corresponding increase in sales value; the value of key shrimp products has decreased overall and in some case the decrease has been substantial (Table 2). Conversely, higher sales have been observed in the unbreaded shrimp category, which also has the highest market share for any given shrimp product category. The increase in sales of unbreaded shrimp is driving the

Table 1: Top Five Markets and Their Market Shares for Catfish Products in the U.S., 2007-08 through 2009-10

	2007-08		2008-09		2009-10	
Category	Market	% Share	Market	% Share	Market	% Share
Entrees	San Antonio	33.58	New Orleans/ Mobile	73.19	New Orleans/ Mobile	65.78
	New Orleans/ Mobile	28.44	San Antonio	13.26	Oklahoma City / Tulsa	28.32
	Houston	17.06	Houston	8.95	Houston	1.64
	Raleigh/ Durham	5.43	Raleigh/ Durham	1.06	Jacksonville	0.96
	Atlanta	3.27	Dallas	0.72	Orlando	0.58
Breaded	New Orleans/ Mobile	11.93	New Orleans/ Mobile	11.87	New Orleans/ Mobile	40.89
	St. Louis	9.85	Memphis	9.08	Memphis	5.49
	Memphis	9.81	Jacksonville	6.52	St. Louis	3.78
Unbreaded	Memphis	13.92	Los Angeles	12.5	Memphis	13.49
	Los Angeles	11.75	Memphis	10.99	Los Angeles	8.58
	Birmingham	9.97	Birmingham	6.19	Jacksonville	4.23
	Orlando	6.93	Orlando	5.67	Chicago	4.23
	Chicago	6.91	San Francisco	4.36	Birmingham	3.93
	Little Rock	3.83			Little Rock	3.19

overall increase in shrimp product sales, and this is also reflected in the decreasing trend in sales value. The overall decrease in sales value in 2010 is likely due to the decrease in average sales price of products in the unbreaded category from \$9.48/pound in 2006 to \$6.41/pound in 2010.

The main characteristics of the top-selling unbreaded shrimp products are container size and product form. There has been no major change in the characteristics of top-selling products between 2006 an 2010. Entrée shrimp products, which constitute the second-highest selling shrimp product category, are mainly composed of two products: shrimp and shrimp-scampi. Together these two products account for approximately 90% of the category. Among the breaded shrimp products, the 8 oz container size was by far the most popular variety. Breaded whole shrimp, breaded butterfly, and popcorn shrimp were the most popular dressing styles. The major share of the top-selling canned shrimp category is comprised of the 'regular' dressing type as opposed to the deveined type. Lastly, domestic brands are sold in higher quantities than imports.

Overall, 58-60% of shrimp products are sold under some sort of promotion. The highest promotional sales were observed for the unbreaded category, and the least promotion for the canned category. There is a discernable change in the average prices during promotional sales in comparison to normal sales.

Table 2. Trends in Sales Volume, Sales Value and Prices of Shrimp Products

Product Category	% Change 2005-06 to 2009-10		Average Price (US$/lb)	
	Sales volume	Sales Value	2010	2006
Entrée	-12.64	-19.29	4.97	5.38
Breaded	8.44	-34.28	3.53	5.82
Canned	-32.41	-27.35	10.26	9.55
Unbreaded	14.98	-22.29	6.41	9.48
Remaining Breaded	-99.97	-99.96	5.10	3.88
All Shrimp Products	10.57	-22.89	6.07	8.70

Objective 2. *Identify factors affecting a) trends in prices and sales volumes, and b) consumption of fresh and frozen farm-raised catfish, crawfish, clam, and shrimp products.*

Finalization of methodology

University of Arkansas at Pine Bluff, Texas Tech University, Auburn University, and University of Florida. The project team finalized the methodology for estimation of 'Market Response' and "disaggregated Demand Models'.

Factors Effecting Demand for Seafood Product

University of Arkansas at Pine Bluff. The University of Arkansas at Pine Bluff has initiated analysis of demand for various seafood products in the U.S. using a 'discrete choice model'. This models uses store-level weekly scanner data from the weeks ending on 06/23/2007 through the week ending on 06/12/2010 (total 156 weeks). Given the complex nature of the data, the University of Arkansas at Pine Bluff team has conducted some preliminary demand analysis using the Almost Ideal Demand System (AIDS) model at two product levels: a) category and b) canned products. Using 'Seemingly Unrelated Regression Equations' in STATA 11 software, the University of Arkansas at Pine Bluff has estimated the models. Effects of own prices, prices of competition products, consumption expenditure and seasonality have been estimated.

Next, a broad category-level analysis was conducted. Equations for finfish breaded frozen, other breaded frozen, finfish unbreaded frozen, others unbreaded frozen, canned, entrée and anchovies have been estimated. The preliminary estimates show that with an expenditure on seafood, the market share in total seafood of breaded products and unbreaded finfish would increase, and that of other product groups would fall. An increase in own prices of breaded products, other unbreaded products, canned and entrée would cause a decline in total sales revenue because of decrease in quantity demanded of the products. Finfish breaded and other unbreaded, and other breaded and other unbreaded were found to be substitutes.

The demand for breaded finfish was found to be highest from July to September and the lowest in January to March. In case of other breaded frozen products, the demand was highest in July to September months and the lowest in October to December months. The demand for finfish unbreaded products rises in July to September and January to March months. The demand for other unbreaded products lowers in July to September period. The demand for entrée and canned products declines during October to December period.

Lastly, the trends in canned products were investigated. Equations for shrimp, clam, salmon, sardines, crab, oysters and others canned products have been estimated. The results show that with an increase in expenditure on canned products, the market share of total canned products of a) oyster will increase, b) salmon, crab and oyster will remain the same, and c) sardines and shrimps will fall. All canned products were found highly responsive to changes in their own prices, that is, with an increase in own prices quantity demanded for these products (and total revenue) would decline. The degree of responsiveness is higher for clam and oysters as compared to salmon, sardines, shrimp and crab. Oysters and clam were found to be complements to each other. Oysters were found to be a strong substitute for shrimp, and salmon. For other products, the degree of substitutability was found to be very low.

The demand for canned shrimp falls in July through September. The demand decreases for canned clams during the July through December period, for canned oysters from January through March, for canned crabs in July to September, and for canned salmon during January to March. The demand for sardines is the lowest during April to June and the highest in July to September.

Objective 3. *Measure competitive position and substitutability of frozen farm-raised catfish, clam, and shrimp products with other seafood products, with an emphasis on imported products.*

Preliminary demand analysis

Auburn University. The primary purpose of this objective is to investigate the substitutability between project specific aquatic products produced inside the U.S., namely farm-raised catfish, crawfish, clam, and shrimp products with other potential competing seafood products, such as imported tilapia, imported channel catfish from China, imported tra and basa from Vietnam, and imported crawfish from China.

Texas Tech University. The preliminary demand analysis is conducted using weekly scanner data provided by AC Nielsen for total U.S. seafood and fish consumption from June 2008 to June 2010 for 18 seafood/fish categories. We conducted a Linear Approximation, Almost Ideal Demand System (LA-AIDS). This resulted in a matrix of price and expenditure elasticities.

Overall, the own-price elasticities are of expected sign except for the crab unbreaded category. The own-price elasticities range from -3.49 for seafood frozen entrée to -0.73 for anchovy paste. In addition, anchovy paste, unbreaded shrimp, and canned clams have an inelastic demand; while seafood entrée, breaded and unbreaded fish, anchovies, tuna shelf, canned salmon, breaded shrimp, and canned shrimp have an inelastic demand. This implies that consumers are very sensitive to price changes. For instance, a 10% price increase in the price of seafood entrée will imply approximately 35% decrease in the sales of seafood entrée. In terms of the pattern of the substitution pattern, there is no consistent pattern of substitution between different seafood categories. In general, the magnitude of the cross-price elasticities is lower than the magnitude of the own-price elasticities.

The demand results indicate also that all the seafood categories considered in this study have positive expenditure elasticities, implying that consumers consider these products as normal goods. In addition, seafood entrées, breaded and unbreaded fish, breaded shrimp, and canned salmon have expenditure elasticities greater than 1, indicating that these products are considered by consumers as luxury goods.

Results at a glance...

- *Consumers are very sensitive to price changes. For instance, a 10% price increase in the price of seafood entrée will imply approximately 35% decrease in the sales of seafood entrée.*

Domestic Resource Costs (DRC) and Policy Analysis Matrices (PAM)

Auburn University. The social profitability of a product will be measured by calculating the Domestic Resource Cost (DRC) of the project's selected aquaculture products based on information contained in farm budgets. This information will be used to construct a Policy Analysis Matrix (PAM). Social profitability will be calculated based on "shadow" prices (i.e., the price reflecting the value of social benefits or costs) instead of market prices. The PAM will then be used to determine which domestic aquaculture industries in the Southeastern U.S. have a comparative advantage (i.e., they increase national social welfare). Collection of data to determine the DRC has already commenced.

WORK PLANNED

There are a number of specific tasks that are planned for completion during the next year of the project. These tasks include:

1. The University of Arkansas at Pine Bluff will pursue the acquisition of the household-based scanner data.

2. Collectively, we will select the level to aggregate/disaggregate for each objective, extracting data

for the correct aggregation level, and aggregating data into product form, product brand, and product species. There is a risk of unbalance in the panel dataset and we will need to drop out some items and locations that cause the panel data to be unbalanced.

3. Further describe the competition dynamics of price, volume, brand, and promotion between domestic and imported seafood products.

4. Additional input is needed from industry regarding the level of aggregation for the key variables in the retail scanner data, and on the policy analysis matric (PAM) indicators.

5. The final design of the quantitative analysis and much of the quantitative analysis under objective 2 in general needs to be agreed upon by the project team.

6. The scanner data at hand offers the advantage to estimate the demand at the brand level. However, traditional demand analysis, such the AIDS model, cannot estimate demand with higher dimensionality. The use of discrete choice models offers the advantage to solve the dimensionality problems as well as to offer a richer substitution pattern, as such, these models will be estimated.

7. Develop budget sheet for interested industries: catfish, crawfish, clams, and shrimp. Modify budget sheet using shadow price to measure cost and benefit to society in general.

8. Following the quantitative analysis, the estimates of the Domestic Resource Cost (DRC) will be used to construct the PAM to assess comparative advantage.

9. Lastly, we envision the development of several fact sheets from the results (e.g., by species, region, and product form).

IMPACTS

The project has acquired store level scanner data for 12,898 seafood products. The data includes information on 84 seafood species (or species groups) of unbreaded frozen products, 30 species of breaded frozen products, 40 species of entrées, and 5 species of canned products. The data covers 209 marketing chains over 52 U.S. cities and all U.S. Censuses divisions. The data period is from 4 weeks (cumulative) ending on 07/16/2005 to 4 weeks (cumulative) ending on 06/16/2007 and from week ending on 06/23/2007 to week ending on 06/12/2010 (total 156 weeks).

The project successfully organized a team of experts to derive lessons from the data obtained to help Southern Region Aquaculture industry of the U.S.

PUBLICATIONS

None to date.

◆ ◆ ◆

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 Computer Software	1	50,000	43,950	-0-	-0-	-0-	43,950	93,950
	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	77,384	47,000	-0-	-0-	-0-	47,000	124,384
	9	60,466	47,000	-0-	-0-	-0-	47,000	107,466
	10	50,896	30,000	-0-	-0-	-0-	30,000	80,896
	11	45,723	30,000	-0-	-0-	-0-	30,000	75,723
	12	63,764	30,000	-0-	-0-	-0-	30,000	93,764
	13	80,106	30,000	-0-	-0-	-0-	30,000	110,106
	14	79,913	30,000	-0-	-0-	-0-	30,000	109,913
	15	74,077	30,000	-0-	-0-	-0-	30,000	104,077
Total		**976,240**	**568,372**	**-0-**	**1,000**	**-0-**	**569,372**	**1,545,612**
Development and Evaualtion of Pond Inventory Methods	1	157,818	75,241	-0-	-0-	-0-	75,241	233,059
	2	137,423	72,420	-0-	-0-	-0-	72,420	209,843
Total		**295,241**	**147,661**	**-0-**	**-0-**	**-0-**	**147,661**	**442,902**
Economic Forecasting and Policy Analysis Models for Catfish and Trout	1	75,000	37,825	-0-	-0-	-0-	37,825	112,825
	2	75,000	38,163	-0-	-0-	-0-	38,163	113,163
Total		**150,000**	**75,988**	**-0-**	**-0-**	**-0-**	**75,988**	**225,988**
Improving Reproductive Efficiency of Cultured Finfish	1	222,633	53,970	-0-	-0-	-0-	53,970	276,603
	2	195,693	58,630	-0-	-0-	-0-	58,630	254,323
	3	78,456	38,166	-0-	-0-	-0-	38,166	116,622
Total		**496,782**	**150,766**	**-0-**	**-0-**	**-0-**	**150,766**	**647,548**
Using National Retail Databases to Determine Market Trends	1	125,000	72,890	-0-	-0-	-0-	72,890	197,890
	2	125,000	72,890	-0-	-0-	-0-	72,890	197,890
Total		**250,000**	**145,780**	**-0-**	**-0-**	**-0-**	**145,780**	**322,890**

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 Reducing Waste 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	$77,384	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	$45,723	2005-38500-15815
	Yr. 12-03/01/07-02/29/08	$63,764	2006-38500-16977
	Yr. 13-05/01/08-04/30/09	$80,106	2007-38500-18470
	Yr. 14-05/01/09-04/30/10	$79,913	2008-38500-19251
	Yr. 15-05/01/10-04/30/11	$74,077	2008-38500-19251
	Project Total	**$976,240**	
*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,	Yr. 1-01/01/01-12/31/01	$287,053	00-38500-8992
Grading and Transport Technology	Yr. 2-01/01/02-12/31/02	$14,259	98-38500-5865
for Finfish Aquaculture. Dr. Ed Robinson,		39,720	99-38500-5865
Mississippi State University, Principal		14,757	00-38500-8992
Investigator		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	11/01/05-10/31/06		
other Regional Aquaculture Centers)	**Project Total**	**$5,000**	2002-38500-11805
*Identification, Characterization, and	Yr. 1-03/01-03-02/28/04	$28,029	2000-38500-8992
Evaluation of Mechanisms of Control of		126,778	2001-38500-10307
Bolbophorus-like Trematodes and		67,298	2002-38500-11307
Flavobacterium columnaris-like Bacteria.	Total Yr. 1	$222,105	
Dr. John Hawke, Louisiana State University,	Yr. 2-03/01-04-02/28/2005	$27,126	2000-38500-8992
Principal Investigator		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	Yr. 1-03/01/04-02/28/05	$1,000	2001-38500-10307
Produce Channel × Blue Hybrid Catfish Fry.		114,935	2002-38500-11805
Dr. Rex Dunham, Auburn University,	Total Yr. 1	$115,935	
Principal Investigator	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	$112,128	2005-38500-15815
	Project Total	**$442,063**	
*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
		38,919	2004-38500-14387
		96,508	2005-38500-15815
	Total Yr. 3	$204,857	
	Yr.4-08/01/07-07/31/08	$62,491	2004-38500-14387
		51,892	2005-38500-15815
		34,760	2006-38500-16977
	Total Yr. 4	$149,144	
	Project Total	**$935,726**	
*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	$66,789	2004-38500-14387
		58,163	2005-38500-15815
	Total Yr. 3	$124,952	
	Project Total	**$335,063**	
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
		18,463	2004-38500-14387
		137,707	2005-38500-15815
	Total Yr. 1	$157,818	
	Yr. 2-05/01/08-04/30/09	$12,917	2004-38500-14387
		6,225	2005-38500-15815
		118,016	2006-38500-16977
	Total Yr. 2	$137,158	
	Project Total	**$294,976**	
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	$53,577	2006-38500-16977
		20,000	2008-38500-19251
	Total Yr. 1	$73,577	
	Yr. 2-08/01/08-07/31/09	$42,502	2005-38500-15815
		32,256	2006-38500-16977
	Total Yr. 2	$74,758	
	Project Total	**$148,335**	

Project	Duration	Funding	Grant No.
Improving Reproductive Efficiency of Cultured Finfish. Dr. Brian Small, USDA/ARS, Principal Investigator	Yr. 1-02/01/09-01/31/10	$34,044	2005-38500-15815
		178,135	2006-38500-16977
		10,374	2008-38500-19251
	Total Yr. 1	$222,553	
	Yr. 2- 02/01/10-01/31/11	$23,887	2006-38500-16977
		171,806	2008-38500-19251
	Total Yr. 2	$195,693	
	Yr. 3-02/01/11-01/31/12	$78,456	2007-38500-18470
	Project Total	**$496,702**	
Using National Retail Databases to Determine Market Trends. Dr. Jimmy Avery, Mississippi State University Extension Service, Principal Investigator	Yr. 1-06/01/09-05/31/10	$1,649	2005-38500-15815
		93,803	2006-38500-16977
		29,548	2007-38500-18470
	Total Yr. 1	$125,000	
	Yr. 2-06/01/10-05/31/12	$1,322	2006-38500-16977
		110,165	2007-38500-18470
		13,513	2008-38500-19251
		$125,000	
	Project Total	**$250,000**	

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.

Work summarized in this report was supported in part by Grant Nos. 2005-38500-15815, 2006-38500-16977, 2007-38500-18470 and 2008-38500-19251from the United States Department of Agriculture, National Institute of Food and Agriculture.