TWENTY-FOURTH ANNUAL PROGRESS REPORT

For the Period Through August 31, 2011

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

United States Department of Agriculture

National Institute of Food and Agriculture

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TWENTY-FOURTH 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

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PREFACE

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

Congress envisioned the Centers as focal points in a national program of cooperative research, extension, and development activities that would be developed in association with colleges and universities, state Departments of Agriculture, federal facilities, and non-profit private research institutions with demonstrated excellence in aquaculture research and extension. Eventually, five such Centers were established—one in each of the northeastern, north central, southern, western, and tropical Pacific regions of the country. Funding for the Centers was reauthorized in subsequent Farm Bills (the Food, Agriculture, Conservation, and Trade Act of 1990 [P.L. 101-624]; the Agriculture Improvement and Reform Act of 1996 [P.L. 104-127]; the Farm Security and Rural Investment Act of 2002 [P.L. 107-171]; and the Food, Conservation, and Energy Act of 2008 [P.L. 110-246]).

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-fourth 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.

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 24 years of operation, the Center has disbursed more than $16 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 ten research projects totaling more than $1.5 million. The Center's "Publications" project is in its sixteenth year of funding and is under the editorial direction of faculty and staff at Texas A&M University. From this project, seven fact sheets and two power point presentations were completed this year with 13 fact sheets in progress. To date, the "Publications" project has generated 213 fact sheets and species profiles, six project summaries and 20 DVDs with contributions from 225 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-fourth Annual Progress Report covers the activities of the Administrative Center during the past year. Progress reports on the ten 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, 2011.

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
Dwight Landreneau, Louisiana State University
John Liu, Auburn University
Wondi Mersi, Virginia State University
David Morrison, Louisiana State University
W. David Smith, North Carolina State University
Joe Street, Mississippi State University Extension Service
Tony Windham, University of Arkansas Cooperative 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
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
Tom Murray, VA
Cortney 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
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, 2011

Funding Level

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
	Year 16	73,974
	Total	$1,050,213

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 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...

- *Over 225 authors have contributed to SRAC publications since the project's inception.*
- *Seven new fact sheets and two PowerPoint presentations were completed this year. Thirteen more fact sheets and one power point are in some stage of review.*
- *Twenty-five scientists from across the Southern Region contributed to completed publications this year.*

PROGRESS AND PRINCIPAL ACCOMPLISHMENTS

During this current project year, seven new fact sheets, and two educational power points 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. Eighteen fact sheets are in some stage of writing, production, or revision. Ten fact sheets currently do not have drafts 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://srac.msstate.edu> and <http://srac.tamu.edu>.

WORK PLANNED

During the next project year, ten new fact sheets, four revisions, and three, 1-page informational sheets will be produced.

The new fact sheets will address: 1) water use for aquaculture, 2) algae for biofuels, 3) partitioned pond culture systems, 4) Lacey Act and aquaculture, 5) herpes viruses in fish, 6) nutritional aspects of seafood, 7) four papers on financial management in aquaculture, and 8) three, 1-page nutritional information sheets.

IMPACTS

This is a highly productive project with significant regional, national, and international impact. Fact sheets and videos are requested and used by clientele in all 50 states on a regular basis. Fact sheets generated within the Southern Region are also widely distributed by RACs and extension personnel in other regions. In addition to direct requests for printed material, fact sheets and other informational materials are accessed daily from the SRAC web site by people searching for technical information. In the period from September 2010 through August 2011 29,717 visitors with 25,918 unique visitors came to the SRAC Publications web site and accessed 107,786 pages. These visitors came from 161 countries/territories. Since the fact sheets are also accessible through numerous other university research and extension web sites, the total usage and impact is undoubtedly several times greater. The AQUAPLANT web site from September 2010 through August 2011 had 305,816 visitors with 259,044 unique visitors that accessed 1,229,385 pages. These visitors came from 190 countries/territories.

Results at a glance...

- *In the months from September 2010 through August 2011, the SRAC web site was accessed by 29,717 users of which 25,918 were unique visitors and they accessed 107,786 pages on the site.*

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

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

The impact on consumers of aquaculture products is also likely significant, although 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.

Results at a glance...

Titles of some recent SRAC publications:

- *Phytoplankton Culture for Aquaculture Feed*
- *Site Selection of Levee Ponds*
- *Transport of Warmwater Fish*
- *Emerging Non-Native Species Issues for Aquaculture*
- *Post-Harvest Handling of Freshwater Prawns*
- *Amylodinium ocellatum, an Important Parasite of Cultured Marine Fish*
- *Species Profile: Atlantic Croaker*
- *Aquaponics – An Integrated Fish and Plant Production System*
- *Largemouth Bass Production – Production Technologies for Aquaculture*

PUBLICATIONS, MANUSCRIPTS OR PAPERS PRESENTED

Fact Sheets Completed (9/1/10 - 8/31/2011)

Phytoplankton Culture for Aquaculture Feed, by LeRoy Creswell, SRAC Publication Number 5004
Site Selection of Levee Ponds, by Jimmy Avery, SRAC Publication Number 100 (Revision)
Transport of Warmwater Fish, by Forrest S. Wynne and William A. Wurts, SRAC Publication Number 390 (Revision)
Emerging Non-Native Species Issues for Aquaculture by Jeffrey E. Hill, SRAC Publication Number 4305
Post-Harvest Handling of Freshwater Prawns, by James H. Tidwell and Shawn Coyle, SRAC Publication Number 4831
Amylodinium ocellatum, an Important Parasite of Cultured Marine Fish by Ruth Francis-Floyd and Maxine R. Floyd, SRAC Publication Number 4705

Species Profile: Atlantic Croaker by Todd Sink, SRAC Publication Number 7208

PowerPoint Completed

Aquaponics – An Integrated Fish and Plant Production System by Jason Danaher
Largemouth Bass Production – Production Technologies for Aquaculture by James T. Tidwell

Manuscripts in press

Species Profile: Black Sea Bass by Wade Watanabe SRAC Publication Number 7207
Species Profile: Pigfish by Cortney Ohs
Species Profile: Pinfish by Cortney Ohs
Mycobacterium Infections of Fish by Ruth Francis-Floyd
Soft Shell Crab Shedding Systems by Albert "Rusty" Gaude and Julie A. Anderson

Manuscripts in review

Diagnosing Fish Kills by Bill Hemstreet
Production of Hybrid Catfish by Rex Dunham, SRAC #190 (Revision)
Nutritional Aspects of Seafood by Beth Reames
Non-Commercial Oyster Culture or Oyster Gardening by Mike Osterling
Biosecurity in Aquaculture, Part 1: *An Overview* by Roy Yanong
Biosecurity in Aquaculture, Part 2: *Recirculating Aquaculture Systems* by Roy Yanong
How to Start a Biofilter by Dennis DeLong
Herpesviruses in Fish by Andy Goodwin
Aquaculture and the Lacey Act by Elizabeth R. Rumley
Introduction to Financial Management of Aquaculture Business by Carole R. Engle
Assessing the Financial Position of an Aquaculture Business: the Use of Balance Sheets by Carole R. Engle
Determining Profitability of Aquaculture Businesses: the Use of Income Statements and Enterprise Budgets by Carole R. Engle
Evaluating the Cash Position and Liquidity of Aquaculture Business: the Use of Cash Flow Statements by Carole R. Engle

On-going project

Updating of the AQUAPLANT web site on aquatic weed management - 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

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IMPROVING REPRODUCTIVE EFFICIENCY OF CULTURED FINFISH

Reporting Period
February 1, 2009 - August 31, 2011

Funding Level	Year 1	$222,530
	Year 2	$195,693
	Year 3	$78,456
	Total	$496,679

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.*

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

USDA-ARS Catfish Genetics Research Unit

Channel catfish farming is the largest sector of the U.S. aquaculture industry. Production of catfish fry relies on placing mature male and female catfish in brood ponds with spawning containers and allowed to randomly spawn. Spawning success 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 to late in the year) is important to farmers since early spawning allows earlier stocking of fry and production of larger fingerlings by the end of the first growing season. The inability to identify parentage of pond-spawns has hindered determination of factors influencing spawning in catfish. However, the advent of molecular marker techniques for parentage determination allows evaluation of factors influencing spawning in pond-spawned catfish. Understanding factors influencing spawning could 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 catfish farms in the spring of 2006 as part of a project to establish a diverse population of catfish for selection of an improved catfish line. Full-sib families were maintained in separate tanks until fish were large enough to be individually tagged (> 4 inches), 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 (~ 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 marker analysis. Each broodfish was scored for a series of highly polymorphic microsatellite loci and inheritance patterns at these loci were used to determine parentage of spawns. 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

Figure 1. Ultrasound image of catfish ovary.

ovaries were also recorded for females at this time. Following sampling, 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 cans were placed in each pond in early April and checked for spawns through the end of August each year. 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.

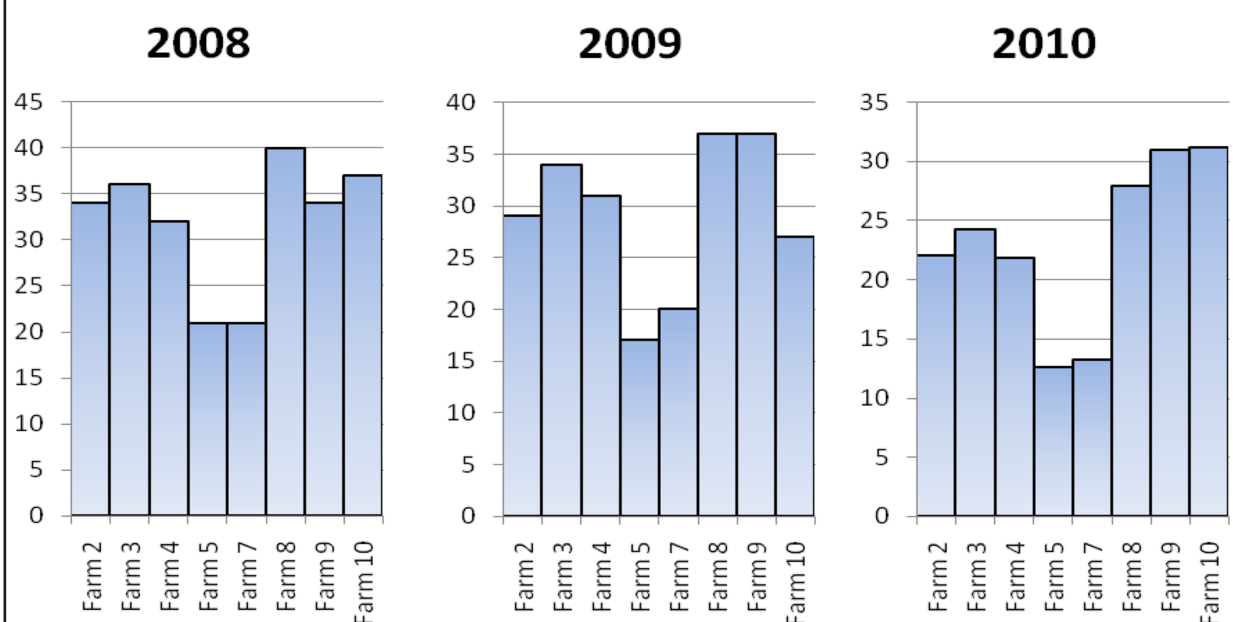
In March of 2010, 4-year-old broodfish were categorized based on their previous spawning history: spawning males, spawning females, non-spawning males and non-spawning females. Two, 0.1-acre ponds were stocked with each possible combination of males and females (previously spawning males with previously spawning females, previously spawning males with previously non-spawning females, previously non-spawning males with previously spawning females, and previously non-spawning males with previously non-spawning females) to determine if spawning history was predictive of future spawning success for either gender. Broodfish were stocked at 1.5:1 female to male ratio and six spawning cans were placed in each pond in early April and checked for spawns through the end of August. Data were analyzed to determine effects of previous spawning history and farm of origin on spawning incidence and farm of origin on spawning time.

Spawns were collected over a 103-day period in 2008, a 98-day period in 2009, and a 75-day period in 2010; however, over 60% of the spawns were collected within 35 days of the first spawn each year. Spawning percentages were 27.4%, 48.3% and 60.3% for 2-, 3-, and 4-year-old females, respectively; and 25.7%, 37.7%, and 46.6% for 2-, 3-, and 4-year-old males, respectively. Due to frequent multiple spawning by males, over 60% of spawns were 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 lbs) were larger than non-spawning females (1.6 lbs), but there was no difference in weight of spawning and non-spawning 3-year-old females (3.2 lbs). Spawning males and non-spawning males were not different for weight as 2-year-olds (2.1 lbs), but spawning males were larger than non-spawning males as 3-year-olds (3.5 lb and 3.0 lbs, respectively) and 4-year-olds (4.7 lbs and 4.1 lbs, respectively). Previous spawning incidence was not predictive of future spawning incidence for males or females. There was no difference in spawning percentage of 4-year-old fish for the various stocking combinations based on previous spawning sucess.

Our data suggest variation in female spawning date has a genetic component. Average spawning date of females from the same two farms-of-origin (farms 5 and 7) was significantly earlier than other farms by 9 days in both 2008 and 2009, and 12 days in 2010 (Figure 2). Farm-of-origin and family-of-origin were significant predictors of female spawning date; combined these factors accounted for 26% and 16% of variation in female spawning date in 2008 and 2009, respectively. There was a positive correlation among spawning date for individual females across years, and for mean spawning date of full-sib sisters across years for the 2008 and 2009 data. There were insufficient numbers of females per family in 2010 to provide accurate estimates for effects of family-of-origin on female spawning date or correlation of female spawning date across years. Analysis and interpretation of male spawning date was precluded due to the high proportion of males that spawned multiple times over each spawning season. We also observed multiple spawning by female channel catfish. Approximately 20% of spawning females produced more than one egg mass during a spawning season each year. These were not interrupted spawning events as the egg masses were collected greater than 7 days apart and typically the second egg mass was collected 20 to 50 days after the first egg mass. Most multiple-spawning females produced 2 separate egg masses, although 3 females produced 3 separate egg masses. To our knowledge, this is the first report of female channel catfish producing multiple egg masses over a spawning season. Plasma hormone levels and ultrasound estimates of ovary size were not predictive of female spawning date for 2008 and 2009.

Figure 2. Mean spawning day for female channel catfish from eight commercial farms in 2008, 2009, and 2010.



Spawning incidence of females appears to be 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 did the majority of spawning, indicating that the number of males typically 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.

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.*

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

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. Ultrasonography 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. During 2010-2011 we captured digital images from 170 fish cataloging more than 6000 digital images. We have begun the process of collecting information regarding ovary characteristics (diameter, cross sectional area, perimeter) using image analysis software (Image-Pro Plus Version 4.5.1.22, Media Cybernetics, Inc., Silver Spring, Maryland). Our initial efforts have included developing a standardized assessment for determining cross sectional surface area. Multiple technicians are involved with this process. Quality control steps include the evaluating agreement between data collected from different personnel. The consistency of the 'rule-set' for interpreting the image and defining the perimeter of each ovary is evaluated for each worker evaluating images. To further optimize training we have collected ultrasound images from three white bass that were then sacrificed. The animals were then frozen and cross sections of the peritoneal cavity were exposed. Photographs of the cross section of the fish are being compared to data gathered using ultrasound. Finally, during April-

May, 2011, 24 wild female white bass were also collected during their spawning migration in Caney Bayou, a tributary of the Arkansas River. Nine of these fish had mature ovaries and the remaining fish were in varying post-spawning stages. Ultrasound images were captured from each of these fish. Ovaries of each fish were removed and length and diameter measurements were recorded so that a cross sectional area of the ovary determined. The average cross-sectional area determined for the nine gravid fish was 1078 ± 74 mm^2 (average ± standard error). Cross sectional areas were also determined using the image analysis program. Mean cross sectional area determined using ultrasound and image analysis was 966 ± 104 mm^2.

A standardized approach to collecting images has been developed. During 2010 and 2011 images were collected over 16 different dates from female white bass. Fish were anesthetized and held upright, submerged in a holding tank. Images were collected from the body region between the posterior insertion of the pelvic fin and the anterior insertion of the anal fin. Whether or not the female responded to hormone injection, and the time to ovulation (if spawning occurred) was recorded. Multiple images of cross sections of the peritoneal cavity were captured. Length and weight of each fish was recorded and age data were gathered from hatchery passive integrated transponder (PIT) tag records. The female white bass were held for about 24 hours before initial inspection for ovulation. The 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 of these samples 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. The digital images of these 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. This procedure does have the potential to guide hatchery decisions and improve reproductive efficiency during production of hybrid striped bass seed stock.

Texas A&M University-Corpus Christi and Auburn University

Steroid analysis was conducted for channel catfish and blue catfish. The objective was to determine if the steroid analysis can be used as a predictor for sexual maturity and ripeness of the fish or as a predictor for future reproductive performance. Steroids were also measured as an indicator of the relative effectiveness of different diets supplemented with vitamin C when fed to brood fish.

Blood and serum samples were collected during three periods corresponding to spring (March-prior to visual spawning activity), early summer (June-during spawning activity), and after spawning (July). Additional studies included exposure studies of blue and channel catfish to vitamin C treatments, and establishment of baseline data for immature 2-3 year-old blue catfish males. Serum samples were immediately frozen and stored at -80 degrees C until processed. Samples were purified, concentrated, and analyzed by high-performance liquid chromatography (HPLC). Eight steroids were targeted: estradiol (E2), 11-ketotestosterone (11-KT), 11β-hydroxyandrostenedione (11β-OHA), 11β-hydroxytestosterone (11β-HT), 17,20β-dihydroxypregn-4-en-3-one (17,20β-P), estrone (E1), testosterone (T), and 17α-hydroxyprogesterone (17-OHP).

Several trends were evident from comparing female blue versus channel catfish. E2 and T were more strongly expressed/accumulated in blue catfish compared to channel catfish, whereas E1 was found in higher concentration in channel catfish post-spawn (June). Male catfish had a larger number of steroids represented in the samples than females. Blue catfish males had higher total steroid content than channel catfish during pre- and spawning periods. 11KT was highest in pre-spawning for both catfish species and decreased over the study period. T was below detection threshold for most of the study period in both species, peaking in channel catfish post-spawn. 17-OHP concentrations peaked during spawning period for both channel and blue catfish. 11β–P was not present in male catfish of either species.

Steroids of female blue and channel catfish shows several expected observations. Peaks in T and E2 occurred during spawning, whereas 17,20β–P was most abundant after this period.

Species differences were observed for steroid levels. This may help explain the differences in the success of open pond spawning and for induced spawning observed between these two species. Data from the vitamin C supplementation of the brood stock and for the immature blue catfish males are still being analyzed.

Sub-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. In addition, nothing is known of nutritional requirements for Atlantic croaker broodfish, which must be known to ensure quality spawns. Four studies were undertaken to resolve these problems. Study 1 examined the feasibility of conditioning and inducing Atlantic croaker to spawn during the spring/summer utilizing 90- or 120-day abbreviated conditioning cycles and hormones. Due to failure to spawn in suitable quantities during study 1, study 2 was conducted to determine the feasibility of delayed spawning through photoperiod and temperature manipulation. Study 3 examined the effects of dietary lipid source and inclusion rate on reproductive performance of Atlantic croaker. Study 4 is currently underway with spawning to take place in November and December of 2011. Study 4 is examining the effects of fish meal replacement and alternative protein sources, as well as dietary lipid percentage and protein source interactions on reproductive performance of Atlantic croaker.

Study 1: Accelerated spawning cycles

The biology of Atlantic croaker dictates they spawn during the autumn months, but baitfish production relies on availability of small fish throughout the year, especially during spring and summer. Atlantic croaker broodstock were spawned in November, 2009, and then maintained under static winter conditions. Broodstock were measured (mean = 11.9 inches), gender determined (male:female ratios of 3:5 or 4:4) and fish were stocked into eight experimental tanks, in two systems 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 light/14 hours dark, water temperature 66 degrees F). The broodfish were then injected with a 75-microgram salmon gonadotropin-releasing hormone analogue implant (sGnRHa; Ovaplant®). Fish were allowed to spawn within the tanks and eggs were collected. No spawning occurred during the 90-day cycle treatment and only two small spawns were collected from fish in the 120-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 and discolored. Egg incubation was not attempted due to poor egg quality. Two plausible explanations for low reproductive output are 1) annual cycles compressed to 90 or 120 days were too short a duration to allow adequate deposition of nutrients to gametes; and 2) spawning twice in a 6-month period does not allow proper physiological preparation through environmental cues. Abbreviated 90- or 120-day cycles are ineffective for out-of-season conditioning and spawning in Atlantic croaker that have previously spawned.

Study 2: Effects of delayed spawning

Due to the poor reproductive success experienced during study 1, a second study was conducted that examined the effects of delayed spawning on the reproduction of Atlantic croaker. Atlantic croaker broodstock were *not* spawned during their natural spawning season in November of 2010, and instead maintained under static summer conditions of 82-86 degrees F and a photoperiod of 15 hours light and 9 hours dark. Histological examination revealed approximately 80% of females developed immature ova during this period, but only 10% demonstrated advanced stage ova development. In February, 2010, the un-spawned broodstock were measured (mean = 12.8 inches), gender determined (male:female ratios of 3:5 or 4:4), and stocked into eight tanks in two systems. Each system underwent a 90-day cooling period with a reduction in photoperiod simulating natural autumn conditions. After the water temperature and photoperiod reached conditions conducive to spawning for Atlantic croakers, the fish in one system were injected with Ovaprim® (sGnRHa and a dopamine inhibitor; 0.23 cc/pound), followed by a second injection 2 days later. The fish in the second system received a single 75 μg sGnRHa implant (Ovaplant®), and all fish were allowed to spawn naturally within the tanks. No spawning occurred from fish administered the implant although egg hydration occurred and several females died due to over-hydration of eggs. All males receiving the 75-μg implant did not express milt upon application of pressure to the abdomen. Although spawning was irregular among the tanks administered the aqueous Ovaprim® injections, 1.1 million eggs were produced. The mean number of eggs produced per tank was 275,530 with fertilization rates ranging from 42 to 88%. At the conclusion of spawning, all males receiving the injection expressed milt upon application of abdominal pressure. Although both treatments resulted in egg production by females, only the injection treatments resulted in viable spawns. The limiting factor of successful spawning appears to be milt production by the males. Only males receiving the Ovaprim® injections successfully produced milt, indicating that a dopamine blocker is required for males to produce milt outside on the natural spawning season. The results of this study indicate Atlantic croaker can be spawned out-of-season for year round production.

Results at a glance...

- *Atlantic croaker can be spawned out-of-season for year-round production. Hormone implants (sGnRHa) improved spawning success, egg production, fecundity, and synchronized spawning events for commercial production. Only males receiving sGnRHa and a dopamine inhibitor successfully produced milt, indicating that a dopamine blocker is required for males to produce milt outside on the natural spawning season.*

Study 3: Lipids in broodfish diets

No information is currently known on the nutritional requirements of Atlantic croaker broodstock. Broodstock nutrition is vital to producing good quality eggs in sufficient quantities to support commercial production while keeping costs down. Atlantic croaker broodstock (4 males:4 females) were stocked into each of 12 tanks in three experimental systems in September, 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. In November 2010, all fish received a single 75 microgram sGnRHa implant (Ovaplant®), and all fish were allowed to spawn naturally within the tanks. Fish fed the 6 and 10% fish oil diets produced more spawns per tank (3.0-3.7 per tank), a greater percentage of floating eggs (64.3-73.2%), larger egg diameters, greater number of eggs produced (879,320-1,470,215 eggs), greater fertilization rates (37.5-65.3%), and better hatching rates (15.3-29.3%) than fish fed the 10% soybean oil or poultry fat diets. While fish fed the 10% soybean oil or poultry fat diets did produce eggs, fertilization rates were extremely poor (< 4.9%) and no egg hatching occurred. While it appears that fish oil cannot be entirely removed from broodstock diets, it can at least be reduced as the 6% fish oil diet produced more spawns, more eggs, and greater fertilization and hatch rates than the 10% fish oil diet. This study provides the first step in determining the nutritional requirements of Atlantic croaker to support commercialized production, and it provides a good basal diet for producers wanting to undertake Atlantic croaker production immediately.

Results at a glance...

- *These studies provide a good basal diet for producers wanting to undertake Atlantic croaker production. Fish oil cannot be entirely removed from broodstock diets, but it can be reduced to an inclusion rate of 6%, or possibly lower.*

Study 4: Protein in broodfish diets

Broodstock nutrition is vital to producing good quality eggs in sufficient quantities to support commercial production. Now that some information is known on lipid sources and inclusion rates to sustain Atlantic croaker production, more information is needed on the protein requirements for broodstock. This study is examining the effects of fish meal replacement and alternative protein sources, as well as dietary lipid percentage and protein source interactions on reproductive performance of Atlantic croaker. Atlantic croaker broodstock (2 males:4 females) were stocked into each of 12 tanks in three experimental systems in October, 2011. Four experimental diets were formulated and manufactured to contain 45% protein and either 6 or 10% lipid. Lipids sources and contents were either 10% or 6% menhaden fish oil. Protein sources included combinations of menhaden fish meal, poultry by-product meal, meat, bone and blood meal, and soybean meal. No results are currently available for this study as the fish will not be spawning until November 2011. The fish are in the feeding period of this study and will receive a single 75-μg sGnRHa implant (Ovaplant®). The fish will then be allowed to spawn naturally within the tanks, the eggs will collected, incubated, and hatched, and biochemical analyses will be conducted.

University of Florida

Ornamental fish production, like all of aquaculture, relies heavily on the successful spawning, hatching, and survival of larval fish. The complexity of this industry, which produces hundreds of species of fish, makes reproduction a critical challenge to improve efficiency. Very little information is available to formulate science-based recommendations for producers and their suppliers.

Research has shown that inclusion of highly unsaturated fatty acids (HUFA) in fish diets can lead to increases in hatch and survival of larval fish. To provide HUFAs in the diet to ornamental fish, current practices rely heavily on feeding a wide variety of foods, often at an extremely high cost which include frozen feeds (e.g. ground beef heart, adult *Artemia*, blood worms, shrimp, and squid). Formulation of an artificial diet which provides proper levels of HUFAs, and is designed to feed smaller broodstock typical to the ornamental industry, could lead to considerable savings in production costs and increased performance of broodstock.

Redtail black sharks, *Epalzeorhynchos bicolor*, are popular ornamental freshwater fish that has been in production in Florida since the late 1980s. This fish represents a variety of similar species which are spawned in hatcheries using induced spawning procedures. Annual sales of redtail black sharks from Florida farms is estimated to be in excess of 1,000,000/year, with a farm-gate value of $0.25 per fish. Mono sebae, *Monodactylus sebae*, are an ornamental fish species commonly captured from the wild along the western coast of Africa. In recent years their popularity in the ornamental industry has prompted interest in the development of culture methods. No information is available on their nutritional requirements.

Producers identified broodstock nutrition to be a major bottleneck in commercialization and thus served as the impetus for this experiment. These studies were designed to evaluate the effects of altering the fatty acid profiles of diets fed to brood fish on egg and larval quality in these two commercially important ornamental fishes.

Mono Sebae

Brood mono sebae were stocked into three independent systems and held for one year. Spawning was induced by increasing the salinity by 5 g/L every three days until a salinity of 25 g/L was attained. When a salinity of 25 g/L and 24 degrees C was attained, natural volitional spawning initiated. Eggs were collected in an air lift floating egg collector. Fish were fed the various experimental diets daily to apparent satiation. The three formulated diets included an ornamental fish industry standard formulation, a diet fortified with docosahexaenoic acid (DHA) and a dist fortified with DHA plus arachadonic acid (ARA). The formulation of the DHA and DHA+ARA diets was altered by adding commercially available algal additives Algamac 3050 Flake and Algamac-ARA to increase the n-3 and n-6 fatty acid contents, respectively.

The effects that feeding the experimental diets had on spawning performance was measured by quantifying the number of spawns, egg quantity, fertilization percent, hatch percent, egg morphology (egg diameter, oil droplet diameter), larval survival at 24 and 48 hours post-hatch, larval morphology (oil droplet diameter, yolk volume, and notochord length) at hatch, and larval morphology (notochord length) at 24 and 48 hours post-hatch using standard methods. The fatty acid composition of the eggs was determined using standard methods.

A total of 49, 33, and 67 spawning events were recorded over the 88-day experimental period for the control, DHA, and DHA+ARA diets, respectively. The total number of eggs spawned was 758,282 for the control, 521,211, and 1,260,255 for the DHA+ARA diets. The mean total egg production per female was

2160 for the control, 1959 for the DHA diet, and 2813 for the DHA+ARA diet. The mean floating egg percent fertilization were all greater than 93.6% and the mean sinking egg percent fertilization ranged from 70.6 to 88.4%. Mean hatching percentage was 57.4% for the control diet, 55.2% for the DHA diet, and 47.5% for the DHA+ARA diet. The mean 24 hour survival was 62.0% for the control diet, 42.8% for the DHA diet, and 46.4% for the DHA+ARA diet with the control diet being significantly greater than the DHA and DHA+ARA diets. The mean 48-hour survival was 45.3% for the control diet, 30.5% for the DHA diet, and 30.3% for the DHA+ARA diet with the control diet being significantly greater that the DHA and DHA+ARA diets.

The mean egg and oil globule diameters were significantly different among diets with those in the DHA+ARA diet being smaller. At hatch, mean notochord length and oil droplet diameter were significantly different among diets with the DHA+ARA diet being smaller, however, the yolk volume was not significantly different among diets. At 24 hours post-hatch, the notochord length was significantly different among treatments with the DHA+ARA diet being significantly smaller. At 48 hours post-hatch, the notochord length was significantly different among treatments with the DHA+ARA being significantly smaller than the control but not different from the DHA diet.

Results at a glance...

- *Mono sebae broodfish fed increased diest fortified with DHA and ARA produced the greatest number of eggs and greatest number of spawns. Redtail black shark larval survival at 2-days post hatch was significantly lower for the control diet which indicates a possible benefit from incorporation of DHA and ARA in brood diets.*

Redtail Black Sharks

Seven female broodfish were stocked into each of nine 1,000-L concrete tanks in a greenhouse at the University of Florida Tropical Aquaculture Laboratory. Each experimental diet was fed to fish in three tanks. Females were individually weighed at the beginning of the experiment and feed portions were weighed for each feeding. All female fish were fed the brood diets for 27 days at 5% body weight divided into a morning and evening feeding. Males were kept in a tenth tank on the same system and fed the control diet at 5% of their body weight per day. On day 28 the fish were not fed and all female fish were administered Ovaprim injections at a dosage of 1 mL/kg body weight. The injections were divided into a 10% priming dose at midnight and a 90% resolving dose at 6 a.m. Female fish were injected with a 20-minute interval between each tank to allow for the timing of spawning and egg sampling.

Fish were hand-stripped when ovulation occurred using a dry method, mixing eggs and sperm in a bowl and then adding water to initiate fertilization. A combined sample of non-fertilized eggs was taken from females in each tank and placed in a -80 degree C freezer until fatty acid analysis. Fertilization percent was determined by examining a subsample of eggs at the onset of gastrulation, and hatching percent was based on a random subsample taken from spawns from each tank. Survival of larvae was based on a 50 fry sample at day 2 (fully developed gut and functional mouth) and a 100 fry sample at day 30 following standard feeding protocol. Redtail Black Sharks represent a several cyprinid species in commercial production and therefore were a good model candidate for this study. However, due the length of time required to fully mature eggs in their gonad and the seasonality of maturation, we were limited on the number of replications in this trial. Added to the problem were early failures of all treatment eggs to hatch due to elevated water temperatures in the hatchery. Fatty acid profiles of the eggs were determined for both trial but the percent hatch and larval survival data was only for one spawning event in year 2.

Percent fertilization ranged from 89-95%, percent hatch ranged from 82-87.3%, 2-day post-hatch survival ranged from 44-97.3%, and 30-day survival ranged from 42-73.3%. Percent fertilization, percent hatch, percent survival and percent deform at hatch, 2 and 30 days post-hatch were not significantly different among fish fed the different diets. The only statistically significant difference was survival at 2 days post-hatch, which was significantly lowest for eggs for fish fed the control diet. Egg diameters at the onset of the blastomere were not significantly different.

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

USDA-ARS Catfish Genetics Research Unit

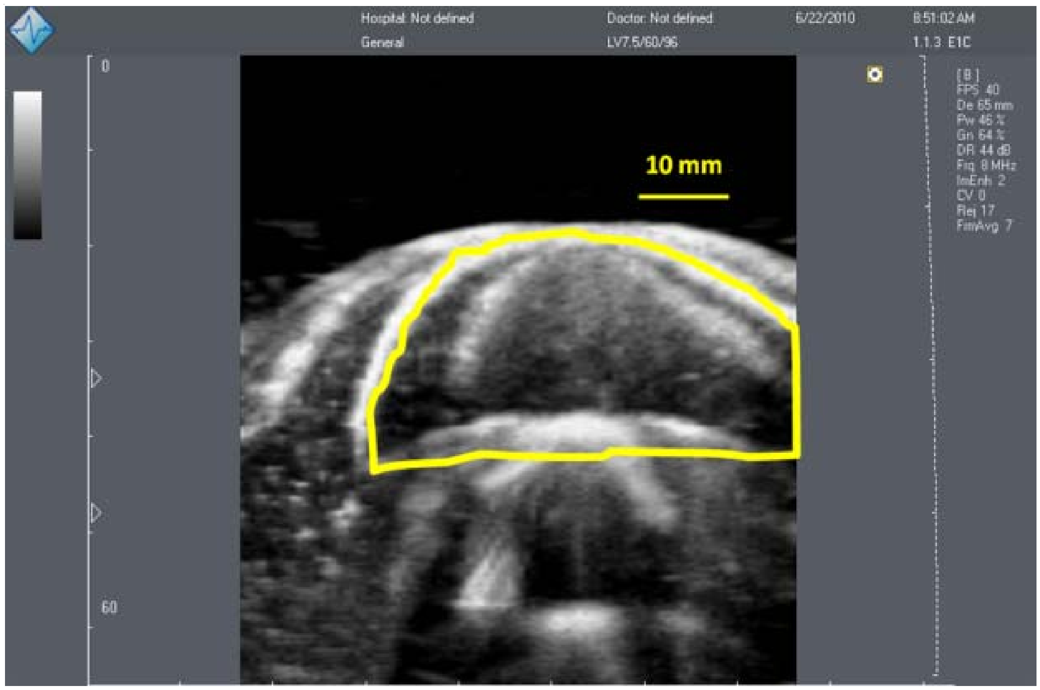
Results of sub-objective 1a showed that ultrasound is not accurate for predicting spawning success of females channel catfish. Therefore, this objective was not addressed, given the labor and time required with no evidence indicating a successful outcome.

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 24-48 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. Quantifying characteristics of the ultrasound 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.

Standardized imaging techniques for female white base developed in the first year of the project were described in sub-objective 1a, above. A database of ultrasound images and corresponding indices of reproductive success has been developed. Image analysis software (Image-Pro Plus Version 4.5.1.22, Media Cybernetics, Inc., Silver Spring, Maryland) is being used to determine several morphometric measures (diameter, cross sectional area, perimeter) to characterize ovaries of fish as they approach ovulation. On four dates in 2010 (March 15, June 6, June 22, and December 6) fecundity measurements (eggs/kg) were calculated for fish (average weight, 0.77 kg; range 0.5 - 1.1 kg) spawned at USDA ARS HKD-SNARC. A linear regression was performed examining the relationship between fish size and number of eggs. A poor observed correlations between fish weight and the number of eggs expressed illustrates the variation in the fish response to hormone treatment. To address this phenomenon we are developing methods using pixel gray-scale analyses to further characterize ultrasound images of ovaries. The wide range in response in reproductive output observed over the course of these studies provide the range in responses necessary to characterize the utility of ultrasound technology as a means identification of suitable fish for artificial spawning of female white bass. Statistical models that include categorical variables such as ovulating/non-ovulating and continuous responses such as fecundity, as well as fertilization success, will be used to determine if variation in ovary images predicts higher or lower reproductive output.

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



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

Sub-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 IU human chorionic gonadotropin (HCG) per kg body weight. The eggs were treated with tannic acid and povidine, and maintained in McDonald hatching jars at 19-24 degrees C. 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 percents were determined. On the day of hatch, approximately 40 larvae from each cross were preserved in 4% buffered formalin. At 5 days post-hatch, 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 (Proc GLM, SAS Inc.) 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 days post-hatch. This study was repeated during year 3 of the project. The procedures for year three were similar to those of year 2. Brood stock were subjected to a 12-month photothermal regime, fed a 45% protein diet twice daily to satiation, and induced to spawn with injections of 330 IU HCG per kg body weight. The eggs were treated with tannic acid and povidine, and maintained in McDonald hatching jars. Larvae were sampled at hatch and at 5 days post-hatch, preserved in 4% buffered formalin, and later individually photographed. Lengths of larvae were determined. Statistical analyses were conducted as before, with the effects of female age and weight on length at hatch and length at 5 days post-hatch examined using analyses of covariance.

Altogether, three 3-year-old, thirteen 4-year-old, and two 5-year-old females were used during the year-2 study. Female weights averaged (SD) 614 (146) g and ranged from 400 to 890 g. Fertilization rates averaged 6 (6)% and ranged from 0% to 25%. Hatch rates were fairly low (< 10%) for most crosses. A total of 11 females had enough hatching to collect adequate sample sizes for length at hatch estimates. Larvae from one of those 11 females all died before 5 days post-hatch. Length at hatch averaged 2.40 (0.27) mm total length (TL). Length at 5 days post-hatch averaged 3.07 (0.31) mm. Neither female weight nor female age significantly influenced length at hatch (Table 1). Likewise, neither female weight nor female age significantly influenced length at 5 days post-hatch (Table 1). During the year-3 study, six 2-year-old, nine 4-year-old, and three 6-year-old females were used. Female weights averaged 581 (170) g and ranged from 370 to 1090 g. Hatch rates varied considerably during the

Table 1. Output from statistical examinations of the effect of female weight and female age or dam on length at hatch and length at 5 days post hatch during the 2010 study (year 2).

Response variable	Effect	Type III SS	F	df	P	R^2
Length at Hatch (mm)	weight	0.071	0.94	1	0.332	0.008
	age	0.182	1.21	2	0.301	
Length at 5 dph (mm)	weight	0.109	1.10	3	0.295	0.005
	age	0.126	0.64	2	0.531	
Length at Hatch (mm)	dam	2.34	3.33	10	0.0004	0.098
Length at 5 dph (mm)	dam	0.710	0.79	9	0.622	0.027

study. Length at hatch averaged 2.66 (0.15) mm TL. Length at 5 dph averaged 3.80 (0.21) mm TL. In this study, female weight and age both significantly influenced length at hatch (Table 2), while female age alone significantly influenced length at 5 days post-hatch (Table 2). The relationship between length at hatch and female weight was positive, suggesting that heavier females produced slightly larger larvae at hatch, but we note that this relationship was no longer significant at 5 days post-hatch. At hatch and at 5 days post-hatch, larvae from 2-year-old females were larger than larvae from 4-year-old or 6-year-old females. The magnitude of the difference in length between larvae from 2-year-old females and 4 or 6-year-old females was a few hundredths of a millimeter at hatch, but was 0.3 mm at 5 days post-hatch.

Earlier work suggested that there was a maternal effect influencing size at hatch and size at 5 days post-hatch. This earlier work was not designed to ascertain whether the maternal effect was genotypic or phenotypic. The results of our year-2 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 days post-hatch. To further examine this possibility, we ran a one-way analysis of variance using female as the independent variable. The effect of female was highly significant for size at hatch, but not for size at 5 days post-hatch. For example, larvae from females 3 and 11 were significantly larger than larvae from females 4 and 7. The results of the year-3 study also indicate a maternal effect, though it is less clear that the effect is genotypic, since age and weight significantly influenced length at hatch and length at 5 days post-hatch. Larvae from two females in particular were larger at hatch than larvae from most other females. However, by 5 days post-hatch, larvae from three completely different females had caught and surpassed the average lengths of larvae from the two stand-out females identified by data collected at hatch. It appears that larvae from the latter three females were more efficient at utilizing endogenous energy reserves (available from yolk). This efficiency could conceivably be carried into latter life stages and might be a characteristic targeted by a selective breeding program.

Table 2. Output from statistical examinations of the effect of female weight and female age or dam on length at hatch and length at 5 days post hatch during the 2011 study (year 3).

Response variable	Effect	Type III SS	F	df	P	R^2
Length at Hatch (mm)	weight	1.671	93.05	1	<0.001	0.192
	age	0.266	7.41	2	<0.001	
Length at 5 dph (mm)	weight	0.001	0.00	1	0.986	0.058
	age	0.842	10.40	2	<0.001	
Length at Hatch (mm)	dam	3.811	19.45	15	<0.001	0.430
Length at 5 dph (mm)	dam	5.463	12.32	15	<0.001	0.334

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.

The difference in results of the two studies is noteworthy. In year 2, ages ranged from 3-5, but in year 3, ages ranged from 2 to 6. Hence, the age range examined was greater in the second study. Likewise, the weight range observed was greater in the second study. The converse conclusions from the two studies, regarding the importance of age and weight to length at hatch and length at 5 days post-hatch, could be due to the greater age and size ranges of the second study. The positive relation between female size and larval characteristics supports earlier research on striped bass, which showed that larger females tended to produce larger larvae. Our results indicate that younger females produce larger larvae. This result should be considered tentative. It is confounded by the fact that a few of the 2-year-old females from year 3 happened to be among the heaviest females in the study. To examine this observation further, we limited the data analysis of larval length at 5 days post-hatch to females weighing between 450 and 650 g. This included five 2-year-old, three 4-year-old, and three 6-year-old females. Even when the weight range is reduced, we still observed that age significantly affected length at 5 dph, and that larvae from 2-year-old females were larger than larvae from 6-year-old females.

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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 and designated as Delta Select. 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, designated as Delta Select, 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 three 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 GSIs. In all three groups, males were heavier than females. Pond raised fish were heavier than both cycled groups and the group fed to satiation were about twice as heavy as fish fed the one-half satiation ration (Table 3).

Fish from the pond raised group and the cycled fish fed to satiation were held through the winter in ponds and 10 males and ten females from each group were stocked in 0.1 acre ponds with spawning containers in April of the following spring. There were not enough fish from the one-half satiation group to attempt spawning in this group. Males in both groups were heavier than females and fish raised in ponds were heavier than the cycled fish.

Table 3. Body weight and gonadosomatic indicies of male and female fish placed in spawning ponds in September when the fish were about 16 months old. Cycled fish were exposed to shortened cold and warm periods shorter than those experienced in the pond raised fish. Two cycled groups were used. One group was fed to satiation and the other was fed a ration one-half that of the fish fed to satiation. Pond raised fish were fed to satiation.

Males		Females	
Body Weight- g	GSI %	Body Weight – g	GSI %
Cycled and Fed to Satiation			
233.2 + 22.0	0.15 + 0.02	113.1 + 14.9	0.53 + 0.09
Cycled and Fed ½ Satiation			
82.3 + 9.7	0.13 + 0.30	60.6 + 7.2	0.53 + 0.02
Pond raised and fed to satiation			
634.6 + 76.4	0.12 + 0.01	334.7 + 23.7	0.30 + 0.04

Only one spawn (10%) occurred in the pond with cycled fish and four spawns (40%) occurred in the pond raised fish (Table 4).

Altering the temperature cycle was not effective in inducing spawning after 12 months or 18 months of age, in spite of their having experienced three cold cycles, the number of cold cycles thought to be necessary to induce precocious puberty. The cold cycles in the 12 month experiment was only one month in length compared to a 2 month cold exposure in previous experiments. Further, even fish exposed for 2 months and attempted to spawn in the fall failed to show any gonadal development or spawning. The only appreciable spawning (40%) occurred in pond raised fish when they were 2 years old and had been exposed to 2 winters in the pond. Fish exposed to 3 artificial (in tanks) cold periods and one winter in a pond only had 1 out of 10 fish spawning.

These data suggest that artificially inducing precocious puberty may be more difficult than originally thought. Regardless of the feeding or temperature regime male fish were heavier than females, which support earlier reports of differential growth in the sexes of channel catfish.

Table 4. Body weights of male and female channel catfish stocked in spawning ponds in April when the fish were about 23 months old. One group had been exposed to four cold periods (Three in indoor tanks and one natural winter in a pond.) One group, identified as pond raised, were raised in a pond and had experienced only two winters. Both groups had been fed to satiation.

Cycled fish		Pond raised	
Males	Females	Males	Females
297.6 $\pm$ 28.6	258.6 $\pm$ 25.3	861.8 $\pm$ 34.1	644.1 $\pm$ 23.3

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-μg 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 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.

The results of this study demonstrate that Atlantic croaker can be spawned passively in a captive environment, but 75-μg sGnRHa hormone implants used to actively induce maturation and spawning in Atlantic croaker can improve spawning success, egg production, fecundity, and synchronize spawning events for commercial production. Optimal spawning of captive Atlantic croaker occurs at a photoperiod consisting of 10 hour daylight/14 hour dark and a water temperature of 19 degrees C. A single 75-μg sGnRHa implant should be injected at 10 hours of daylight and water temperature of 20-21 degrees C in order to control, improve, and synchronize reproduction of Atlantic croaker.

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.*

Sub-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 (Figure 4).

The new incubator, dubbed the "See-Saw" by collaborating farmers, 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

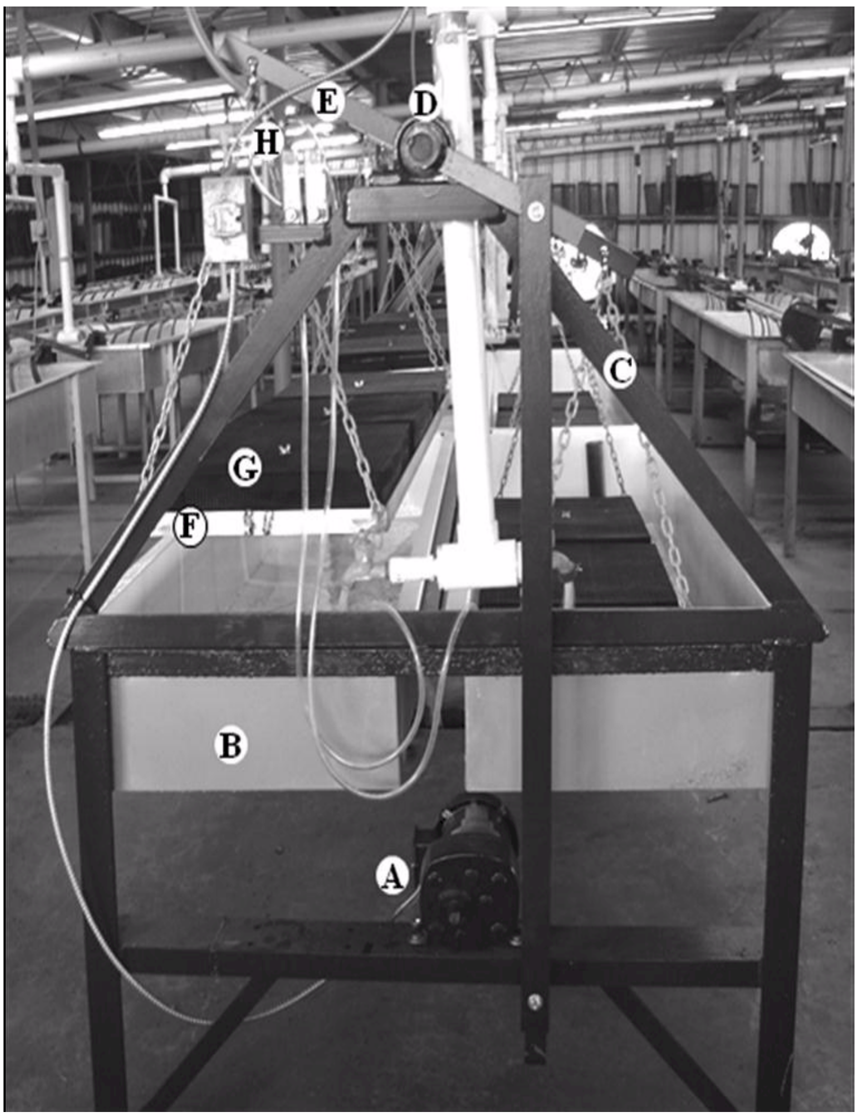

Figure 4. See-Saw incubator prior to loading eggs. Note that as the left rack is up in the air, the right rack is down in the water. Each rack contains three hatching baskets that are secured to the rack. The water supply for these two troughs is in the foreground and the drain is at the far end in each 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 used in Year 3 of this study.

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 10 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 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 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 incubator has 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.

In 2011 (Year 3 of the project) we examined the effect of oxygen supplementation on troughs loaded with 45 pounds of eggs. Fifteen troughs were incubated using no oxygen supplementation and had a mean oxygen saturation of 82.4%; 17 troughs were incubated using additional oxygen added through ceramic diffusers at an average rate of 0.12 liters/min resulting in an average oxygen saturation of 124.1%. Mean swim-up fry production overall was 462,363 fry/trough (10,327 fry/pound of eggs), for a survival from egg to swim-up of 71.2%. There were no significant differences between treatments, confirming that 45 pounds of eggs can be incubated per See-Saw trough without additional oxygen if the hatchery water supply is near air saturation.

We believe that even higher loading densities could be incubated using supplemental oxygen with no impact on hatch rate or survival to swim-up stage. Even without a pure oxygen supplement, the See-Saw incubator can incubate 3 to 4 times as many eggs as traditional paddle-type incubators using half the water, a tremendous savings in both floor space and energy use.

The use of this incubator across the commercial industry would result in considerable savings, 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

Atlantic croaker display asynchronous spawning during a prolonged spawning season, which limits the potential to reproduce this species on a scale capable of sustaining commercial culture. This project has developed reliable hatchery methods to induce and synchronize Atlantic croaker spawning for production creating a new market for farm-raised marine baitfish. These methods could be implemented immediately at several hatcheries in the southern United States. At least two commercial redfish production facilities in Texas have acquired Atlantic croaker broodstock and started the first attempts at commercial production.

Delayed spawning combined with aqueous Ovaprim® injections results in successful spawning of Atlantic croaker out-of-season for year round production. This is a major breakthrough for a marine baitfish industry that relies upon the availability of specific sizes of bait throughout the year. Atlantic croaker is a high value marine baitfish species that can retail for more than $1 for a 2 to 5 inch fish. Current markets for this species rely upon wild-captured juveniles. During the off-season (April to September) Atlantic croaker are subject to limited availability which increases demand and price significantly. This project has provided a means to produce ideal-sized baitfish year round to meet consumer demand and create new markets.

This project has produced the first information on the dietary requirements for Atlantic croaker broodstock in order to improve reproductive performance. While fish oil could not completely be eliminated from the diets to improve sustainability and reduce costs, production was improved by using lower inclusion rates (6% fish oil) than in diets previously used for Atlantic croaker. This will increase profitability over using higher lipid diets while still making moderate advances toward sustainability of the fish feed. The fish oil diets provide good basal diets for producers wanting to undertake Atlantic croaker production immediately while meeting or exceeding the reproductive performance of wild fish.

Over 100 million catfish eggs have been incubated thus far in on-farm trials. Next spring at least 16 four-trough see-saw units will be in commercial operation. Publication of blueprints and assembly instructions is planned. To speed transfer of the technology, a collaborating farmer is considering the manufacture and sale of single four-trough units so potential users can both test the unit in their hatchery and have a physical model to guide fabrication of additional units.

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

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

Participants		
	Mississippi State University	Jimmy Avery (Project Leader)
	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.

    a. Convene a project planning meeting.
    b. Procure store-level scanner data for the most recent 5 years and household-based scanner data for the two most recent years available from 18 markets covering all nine U.S. census regions.
    c. Analyze trends on sales price (dollar per pound), volumes (pounds) and market shares of major aquaculture products.
    d. Prepare fact sheets that summarize price and sales volume data for catfish, crawfish, clams, and shrimp as well as for competing products for distribution to industry stakeholders through extension mechanisms.

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.

    a. Estimate retail pricing models for various fresh and frozen farm-raised catfish, crawfish, clam, and shrimp products based on store level data.
    b. Estimate retail sales response models for various fresh and frozen farm-raised catfish, crawfish, clam, and shrimp products based on store level data.
    c. Estimate disaggregated demand functions for various fresh and frozen farm-raised catfish, crawfish, clam, and shrimp products using discrete-choice models based on panel data.

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.

   a. Estimate cross price elasticities of various seafood products consumed in the U.S.
   b. Model consumer demand for type, form, and package size
   c. Construct policy analysis matrices (PAM) and estimate domestic resource costs (DRC) for various aquaculture products of the southern region of the U.S.

ANTICIPATED BENEFITS

Research into consumer understanding and preferences in the food marketing system in the U.S. 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.*

Sub-Objective 1a. *Convene a project planning meeting.*

University of Arkansas at Pine Bluff, Texas Tech University, Auburn University, and University of Florida

A meeting was held on November 17, 2009 with all project participants attending. 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 five 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.

Sub-Objective 1b. *Procure store-level scanner data for the most recent 5 years and household-based scanner data for the two most recent years available from 18 markets covering all nine U.S. census regions.*

The University of Arkansas at Pine Bluff

The University of Arkansas at Pine Bluff 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

Results at a glance...

- *Supermarket sales of frozen and chilled fish and seafood have grown over the past 5 years.*
- *Unbreaded shrimp is the most dominant product amongst frozen products.*
- *Catfish sales have increased as have sales of tilapia, salmon, and basa/tra, while sales of pollock have decreased. Tilapia sales have demonstrated the greatest rates of increase.*
- *Tilapia marketers diversified their products into entrée products over the years.*
- *Crawfish in the unbreaded form consistently saw drops in share, while shares in entrée crawfish increased.*
- *Clams had decreased sales over the last five years, but the reduction in sales was slowing down.*
- *The retail sales modeling study indicates that both basa/tra and tilapia frozen products are substitutes for catfish frozen products.*
- *For future market planning to increase sales in U.S. supermarkets, the U.S. aquaculture industry needs to consider a broader regional approach regarding substitute products. The catfish industry needs to include other major whitefish products, particularly basa/tra and tilapia products.*

references and other possible public databases.

The University of Arkansas at Pine Bluff procured store-level scanner data from the A. C. Nielsen Company following an opening bidding process; the dataset is composed of weekly data covering 52 U.S. markets for the last 5 years, ending on June 12, 2010. The A.C. Nielsen data category reflects the "department" or physical layout of the typical supermarket and divides food-at-home items into different departments: dry grocery, frozen foods, dairy, deli, packaged meats, and perishables. The store-level database purchased from A.C. Nielsen Inc. contains information for all fish/seafood products in "dry grocery" and frozen food categories. The fish and seafood within the "dry grocery" items include products in canned, shelf-stable, and paste forms. The frozen seafood includes all frozen and chilled fish and seafood available in both prepared and unprepared forms found in refrigerated and frozen sections. The term 'frozen' as defined by A.C. Nielsen Inc. includes all chilled/frozen products having Universal Product Codes (UPC) but does not include random weight (or loose) fresh products that have no UPC codes.

The University of Arkansas at Pine Bluff has also signed a contract with the A. C. Nielsen Company to procure weekly household scanner data for the three most recent years available from five markets (Chicago, Houston, Miami, Memphis, and New Orleans). The Project team is expected to receive the household level data from the A. C. Nielsen Company by the end of September 2011.

Sub-Objective 1c. *Analyze trends on sales price (dollar per pound), volumes (pounds) and market shares of major aquaculture products.*

The University of Arkansas at Pine Bluff

Overall Trends in Sales

From 2005-06 to 2009-10, frozen seafood sales in supermarkets increased by an average of approximately 6% per year. Frozen finfish accounted for a significant part of total frozen seafood sales during this period with its share increasing from 39% in 2005-2006 to 42% in 2009-2010. From 2005-2006 to 2009-2010, frozen finfish sales in supermarkets increased by 35%. This indicates that frozen finfish sales (in value) are increasing faster than total frozen seafood sales. A list of the top ten best-selling frozen fish over the past five years is provided in Table 1. Tilapia has been the top seller in supermarkets since 2006-2007. The position of catfish has improved over the years from eighth place in 2005-2006 to fourth place from 2008-2009 onwards.

Results indicate that catfish and shrimp saw consistent increasing sales over the last five years (2005-2006 to 2009-2010), with the former registering high increases; clams had decreased sales in comparison to 2005-2006, but the reduction in sales was slowing down; and crawfish sales increased last year (2009-2010). Unbreaded shrimp is the most dominant product amongst all the finfish and shellfish frozen products.

Trends in Prices

Breaded catfish products were cheaper than most others, since most of them were sold as breaded nuggets. Shrimp prices remained stable over the years, while there was a marginal increase in breaded clam prices. It is interesting to note that breaded clams and crawfish are priced higher than shrimp.

Catfish, as well as crawfish, clams and tuna, were amongst lower-priced entrée products. Entrée clam

Table 1. Top ten best-selling frozen finfish species from scanner data from 2005-06 to 2009-10.

Rank	2005-06	2006-07	2007-08	2008-09	2009-10
1	Whiting	Tilapia	Tilapia	Tilapia	Tilapia
2	Tilapia	Whiting	Salmon	Salmon	Salmon
3	Salmon	Salmon	Whiting	Whiting	Whiting
4	Tuna	Tuna	Tuna	Catfish	Catfish
5	Cod	Flounder	Catfish	Flounder	Flounder
6	Flounder	Catfish	Flounder	Cod	Cod
7	Pollock	Cod	Cod	Pollock	Haddock
8	Catfish	Pollock	Pollock	Tuna	Tuna
9	Haddock	Haddock	Haddock	Haddock	Pollock
10	Perch	Orange Roughy	Orange Roughy	Perch	Perch

prices increased in price over the years and there was decrease in prices of entrée shrimp that could be explained by the introduction of less expensive products (Alfredo, for example) and less costly package sizes (such as 21-oz regular entrée). Results also show that average price of entrée crawfish products decreased over the years.

Prices of unbreaded finfish fillets with or without promotion showed that tilapia, basa/tra, pollock, and whiting were less expensive than catfish. Price differences between catfish and unbreaded tilapia fillets became wider after price promotion, but between catfish and basa/tra the differences became narrower after promotion. Crawfish was priced higher than shrimp, while clam prices fell sharply over the last two years (2008-2009 and 2009-2010).

One key observation from price trends is that the sales performance of the product in a market is positively correlated with the degree of promotional pricing given to that product. This behavior was seen for many products in many markets. Another observation is that there was a tendency to price larger packages at lower unit prices, thereby indicating the presence of "quantity discounts" (for example, "economy packs" in the retail sales).

Results at a glance...

- *Summaries of market trends in 52 cities across the U.S. for the past 5 years have been sent to 19 catfish processing companies. Customized reports have been sent to six catfish processing companies. The total value of these reports provided to industry is more than $5 million.*

Trends in Product-Specific Sales

Catfish Products

Breaded catfish sales rose in general over the last five years (2005-2006 to 2009-2010). Breaded nuggets constitute about 88-94% of breaded catfish sales with the rest shared between fillet and strips. The most popular packaging size of breaded nugget was 80 oz, followed by 32 oz. For fillet and strips, they were 8 oz and 13 oz, respectively.

Catfish in entrée form was not able to penetrate the market. There was a decline in sales of about -25% to -35% annually with respect to 2005-2006, with a corresponding decline in market share. It also received a much lower degree of promotion. Amongst nine types of entrée catfish available, only Cajun catfish registered consistent increases in year-to-year sales, raising its share amongst catfish entrées to almost 62% in 2009-2010 from 4% in 2005-2006.

Unbreaded catfish sales showed impressive year-to-year growth. Nuggets and fillet constitute about 99% of unbreaded catfish sold. Nuggets still formed the largest selling product form, though their share decreased by around 15% over the years. The share of fillet consistently increased during the same period by approximately 14%. Amongst nugget package sizes, 80 oz (5 lb) and 32 oz (2 lb) were the most prevalent, capturing 40-48% of unbreaded catfish sales. Amongst fillet packages, there was an increase in share of 40 oz packages, having replaced 64 oz packages as the most popular package size in the last two years (2008-2009 to 2009-2010).

For breaded catfish products, New Orleans/Mobile is the largest market and accounts for about 11-14% of the sales during 2005-2006 to 2008-2009, while its share increased sharply to 44.6% during 2009-2010. San Antonio and Memphis are important markets for breaded catfish strips and fillets respectively. New Orleans/Mobile is the only city where entrée catfish sales are on the rise with Cajun catfish is mostly sold there.

Memphis is also the largest market for unbreaded catfish, and there are three Pacific cities (Los Angeles, Sacramento, and San Francisco) in the top-five markets. Southern markets are still important as demonstrated by the presence of cities like Little Rock, San Antonio, Houston, Dallas and New Orleans/Mobile.

Crawfish Products

Breaded crawfish is not a major product in terms of sales volume, and its sales mainly takes place in the southern cities like San Antonio, Houston and Dallas. There are about 20 different types of entrée crawfish products of which the top-five account for about 65-86% of all crawfish entrées. The share of entrée crawfish in total entrée seafood market has almost doubled over the last five years.

Amongst unbreaded crawfish products, crawfish tail meat constitutes 76-94% of all unbreaded crawfish sales. Sales of crawfish tail meat dropped over the last five years, while whole unbreaded crawfish and crawfish pieces increased during the last two years. Amongst package sizes, crawfish tail meat packages of 12 oz (decreasing share) and 16 oz (increasing share) account for about 90-94% of total unbreaded crawfish sales.

Amongst the major markets for entrée crawfish, New Orleans/Mobile tops the list but its share of total entrée crawfish sales declined considerably over the years from about 40% in 2005-2006 to 14% in 2009-2010. Sales in Houston, Dallas, Tampa and Washington D.C. increased during the same period. The top-twenty cities account for about 90-92% of sales. It is interesting to note that entrée crawfish products, though sold mostly in southern U.S. cities, saw a sales growth in non-traditional crawfish markets like New York, Detroit, Philadelphia, New England cities, and cities in Ohio.

New Orleans/Mobile is the most dominant market for unbreaded crawfish with about 70% consumption. Houston has about 14% of the share, followed by other two Texas cities of Dallas and San Antonio with about 3-4% market share each. Memphis has about 1.5-2% share. Thus, these five cities together account for about 90-95% of all crawfish consumed through retail supermarkets.

Clam Products

There are five product types that are popular: crunchy clam, regular clam, crispy tender, stuffed and fried Crunchy. The first two types accounted for about 65%, and the first three types accounted for about 85% of the breaded clam products sales. Smaller package sizes (less than 12-14 oz) were observed to be more popular. Amongst twelve types of entrée clam products, "Regular clam entrée" have the largest share of 87-90%. Amongst unbreaded clams, whole unbreaded clams account for about 76-94% of these products, thus being most prevalent product form. Whole clams packed in 50-oz packages have become the most important package sizes, with their shares rising to almost 70% of the total unbreaded clams sold.

For breaded clams, New York and Boston are the largest markets, each accounting for about 10-15% of sales. Top-five cities account for about 40-45% of sales, including Hartford/New Haven and Boston. New York alone consumes about 30-33% of entrée clam products, thus making it largest market for the products. In the last two years, Philadelphia alone consumed about 50% of all the unbreaded clams sold. Sales in Raleigh/Durham and Charlotte have also increased in the last 2 years.

Shrimp Products

Whole breaded shrimp were observed to be the most prevalent products amongst breaded shrimp. In terms of sales growth, whole breaded shrimp in 10-oz, 10.5-oz, 14-oz, 20-oz, and 32-oz (2-lb) packages have sold well. There are more than 600 different types (with respect to dressing style, method of pre-treatments, etc) of unbreaded shrimp products available in the U.S. market. Uncooked types and cooked types have almost equal share.

For breaded shrimp, there are no single markets with a very high share of total sales. The 15 largest markets together have only about 25% of total sales, with the top-two cities (Washington DC and Chicago) consuming about 5% each. New York is the top market for entrée shrimp products, with a share of 7.5-8.4% of all entrée shrimp sold. New York and Philadelphia are the largest two markets for unbreaded shrimp products, while Miami, Tampa and Orlando have also registered high growth amongst the top-ten cities.

Sub-Objective 1d. *Prepare fact sheets that summarize price and sales volume data for catfish, crawfish, clams, and shrimp as well as for competing products for distribution to industry stakeholders through extension mechanisms.*

The University of Arkansas at Pine Bluff

Upon advice of key industry representatives, the decision was made not to form a single industry advisory panel, particularly given the competitive nature of processors who will make best use of the results of this project. Instead, a combination of formal presentations to trade associations and individual meetings and consultations has been held. Formal presentations have been made at the Catfish Farmers of America annual convention and at the annual meeting of the U.S. Trout Farmers Association at the Aquaculture America 2011 meeting. These presentations focused on explaining to industry members what the data are, what the possibilities for using the data are, and offering to run customized reports for individual companies. The U.S. Trout Farmers Association has also requested a follow-up presentation at their annual fall meeting on September 29, 2011. Individual meetings were held at the request of 6 catfish processing companies to further discuss the data and the type of reports that can be run with the data. Written reports have been sent to 19 catfish processing companies and detailed follow-up reports to six catfish processing companies at their request.

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.*

Sub-Objective 2a. *Estimate retail pricing models for various fresh and frozen farm-raised catfish, crawfish, clam, and shrimp products based on store level data.*

University of Florida

The goal of this sub-objective was to generate information from revealed preference data (i.e., observed market behavior) on individual product attributes for various types of fish and shellfish products sold in the U.S., with an emphasis on information on products sourced from the Southeast and from culture operations.

A retail price response model and sales response model were previously developed for catfish products only. The effects of product characteristics (product type, form, packaging size, brand identity) and product promotion were modeled. To augment this analysis (e.g., for other species or species groups and to consider other product attributes), an approach was utilized that assumes that retail prices paid by consumers reflect the total of the values of individual product attributes. The approach estimates "implicit prices" or market values of the attributes or characteristics that are commonly used to generate market information. These implicit attribute prices identify premiums and discounts associated with specific attributes and can be beneficial to harvesters/growers, processors and retailers as they make production, processing, packaging and pricing decisions.

Implicit retail prices were estimated for frozen unbreaded finfish and shellfish sold in the U.S. Southeast. The "frozen" category included all frozen and chilled seafood available in both prepared and unprepared forms that are usually found in refrigerated and frozen sections of supermarkets. "Seafood" includes 84 freshwater and marine finfish and shellfish species (or species groups). The analysis excludes shrimp, a large volume and relatively generic product, to better focus on lesser studied species and product attributes.

The product characteristic and form attributes include variables that identify species, flesh color, geographic origin and level of processing. The packaging attributes include package size, whether it is a store branded product (versus name brand), and whether

Results at a glance...

- *In monthly retail sales of frozen unbreaded finfish, the top-three products were salmon (19%), tilapia (12%), and whiting (10%). By comparison, only 5% were catfish products. Saltwater products accounted for 58% of sales.*
- *The regional analysis revealed that the average price in the Southern region was the highest at $3.35 per pound indicating higher-valued finfish products are sold in the South. Products sold in the South were also discounted less. However, the price of salmon was $0.56 per pound less in the Southern region than the price of catfish.*
- *In monthly retail sales of frozen unbreaded shellfish products (excluding shrimp), the top three products were: scallop (30%), squid (25%), and lobster (17%). By comparison, only 7% were clam products.*
- *Shellfish products in tail form received a retail premium of $4.01 per pound.*

the product was registered in the U.S. The promotional information indicates whether the promotion involved a change in price (e.g., price increase, small price decrease, or large price decrease).

Two models were initially estimated: one for finfish and one for shellfish. To better understand the markets for these products, the data were disaggregated to allow for the inclusion of attributes that are only available for a subset of products. For example, approximately 70 percent of the observations in the finfish model are fillets and approximately 50 percent are categorized as "regular." By examining the data and models for these groups separately, we are able to explain the seafood sales in the market and obtain more robust estimates of implicit prices and promotional strategies.

Findings revealed expected premiums and discounts for traditional attributes (size, species, and form). In general, large discounts were estimated for low-valued products versus non-price promotions for higher-valued species, with interesting implications for distributors and retail outlets.

Sub-Objective 2b. *Estimate retail sales response models for various fresh and frozen farm-raised catfish, crawfish, clam, and shrimp products based on store level data.*

The University of Arkansas at Pine Bluff

A retail price response model and sales response model were developed for catfish products. The effects of product characteristics (product type, form, packaging size, brand identity), consumer characteristics (average family size, racial/ethnic background, household income, food-related expenditures, region), and product promotion were modeled.

As expected, the price of unbreaded catfish had significantly negative effects on sales volume. Effects of prices of unbreaded tilapia, basa/tra, salmon, cod, and pollock on unbreaded catfish volume varied with the region (Table 2). In the South, Northeast and Mid-West regions, tilapia had positive cross-price elasticities. Thus, in these regions, catfish sales would rise with increases in tilapia prices. This relationship is a characteristic of substitute products. However, in the West, tilapia has negative cross-price elasticities indicating that tilapia is a complement of catfish. These findings imply that frozen tilapia and catfish may be in the same market in these regions. Cross-price elasticity of tilapia in the South region was positive, but was negative in the West, Mid-West, and Northeast regions. This result implies that, in the South region, breaded products of

Table 2. Retail price and retail sales models: cross-price elasticities for unbreaded catfish products in different regions.

	Northeast	South	West	Mid-West
Tilapia	0.499	0.499	-0.051	0.481
Basa/tra	-0.165	-0.165	0.506	-0.165
Salmon	-0.902	-0.902	-0.902	-0.836
Cod	0.000	0.017	0.000	0.000
Pollock	-0.274	-0.274	-0.550	-0.274

catfish and tilapia are substitutes.

The model indicated Catfish retail price and sales vary with region; so, marketing efforts should take this variation into consideration. Substitutability and complementarity for catfish with other finfish products also vary with the region. Retail level non-price competition strategy should be considered as an effective tool to increase sales in U.S. supermarkets. The model also indicated the positive influence of promotional pricing on sales volume but a negative influence on retail price.

Sub-Objective 2c. *Estimate disaggregated demand functions for various fresh and frozen farm-raised catfish, crawfish, clam, and shrimp products using discrete-choice models based on panel data.*

The University of Arkansas at Pine Bluff

Factors affecting market demand for these aquaculture products were estimated using an Inverse Almost Ideal Demand System (IAIDS). The IAIDS model was modified to account for the effects of season, deepwater horizon oil spill (DHOS), and lagged consumption. The distribution of tilapia and catfish is not similar across the markets in the U.S. and studying substitutability of tilapia for catfish in markets where catfish is having significant market shares (e.g., South and Midwest region of the U.S.) can produce different results. Catfish, tuna, flounder, cod, clam, scallop and squid show seasonality in their marginal consumption value (price).

Region-wise market interaction between different white fish modeled suggested many marketing strategies for the domestic catfish industry. In the Midwest region, catfish is a quantity-substitute to tilapia, and tilapia is a quantity-complement to catfish. The other white fish products (cod, flounder, Pollock, and whiting) are weaker quantity substitutes for catfish in the Midwest region as compared to catfish. Therefore, offering customers high value at a low price and/or short-term reduction in the product's price in the Midwest region of the U.S. can benefit the catfish industry. In the West region cod and whiting are substitute products for catfish in all seasons. Catfish substitutes for flounder in all seasons, and for cod, tilapia, and pollock from November to April. In the Northeast region, catfish demand is own-price inelastic with no stronger substitutes except for tilapia from November to January. Therefore, the catfish industry can increase its revenue by increasing supply of unbreaded frozen catfish products to the Northeast region. Own- and cross-price flexibility estimates show that in the Southern region, price strategies would not help the U.S. catfish industry. However, non-price marketing strategies like non-price promotion (e.g. product placement in the stores), country-of-origin labeling, and generic advertisement would benefit the catfish industry.

Catfish demand is the highest in the Southern region followed by the Midwest, and is the lowest in the Northeast region of the U.S. Catfish demand is the highest during the months of November to January. Tilapia demand is the highest in the West region, while demand for pollock is the lowest in the Midwest region. Demand for frozen whiting is the highest in the Northeast and is the lowest in the South region.

Amongst unbreaded products shrimp and crab, and crab and crawfish were quantity substitutes. Seafood consumers who consumed a product in previous week would prefer to consume its substitute product (for example crawfish and crab, squid and perch, lobster and squid, and scallop and clam) in current week. Clam products exhibit seasonality in sales.

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

Sub-Objective 3a. *Estimate cross price elasticities of various seafood products consumed in the U.S.*

Texas Tech University and Auburn University

One of the biggest challenges facing American aquaculture industries remains the high levels of fish and shellfish imports. According to NOAA, the U.S. imports approximately 84% of its seafood needs, up from 63% ten years ago. Most consumers want processed fish/shellfish products and not live product, putting domestically produced and processed products in direct competition with less expensive imported aquaculture and wild-caught fish products. Therefore, accurate knowledge of demand and substitution among domestic and imported aquaculture products is critical to the U.S. aquaculture industry as well as to public policy evaluation. At the production, processing and marketing levels, understanding consumer demand is a helpful decision-making tool in determining investment and production capacity planning, production allocation, sales, and advertising and promotional activities.

An Almost Ideal Demand System (AIDS) approach was used to estimate the substitutions between fish and shellfish products and assess the impact of promotional activities on sales of fish and shellfish products in the U.S. The objective was to shed light on the substitutability between specific aquatic products produced in the U.S., namely catfish, crawfish, and clams with other potentially competing seafood products, such as imported shrimp, tilapia, and salmon. Additionally, another objective was to provide promotional elasticities that can be used to assess the impact of the promotional activities and developing future marketing strategies.

The estimation of the AIDS model was used to derive demand price elasticities, which are the responsiveness of retail buyer's change in quantity demanded to changes in product price, for aquaculture products (Table 3). For the price elasticities, all the own-price elasticities are negative, as expected, and statistically significant, except for the case of crawfish. In addition, the demands for the considered fish/seafood categories are inelastic. Price inelasticity means total revenue would increase when increasing the price of the product. The results indicate the demand for salmon is the more elastic of the inelastic species, followed by shrimp, clams, tilapia, and catfish. A 10% increase in salmon price would decrease its sales by 9.8%; while for catfish, the same price increase would decrease the sales by only 4.8%. This indicates that American consumers show some "loyalty" towards domestically produced catfish compared to the imported categories, such as shrimp, tilapia, and salmon.

In terms of substitution, it is worth noting that shrimp has all other products as its complement, though they are weak complements. In contrast, shrimp is a strong complement for crawfish (-0.89), tilapia (-0.65), and catfish (-0.59). In fact, a 10% increase in the price of shrimp will reduce the sales of crawfish, tilapia, and catfish by 8.9%, 6.5%, and 6.0%, respectively. Results show that American consumers consider catfish as a strong substitute for tilapia, probably because both have white flesh coloration and similar texture; while catfish and salmon are complements as salmon flesh being pink/red colored is seen in a different light from white colored catfish flesh. Hence, an increase of 10% in the price of tilapia will increase catfish sales

Table 3. Marshallian own-price, promotion and expenditure elasticities*.

	Catfish	Crawfish	Clams	Shrimps	Tilapia	Salmon
Catfish	-0.4804	-0.0590	-0.3283	-0.5985	0.7229	-0.3784
	(-3.26)	(-0.79)	(-4.27)	(-5.55)	(7.29)	(-2.51)
Crawfish	-0.1788	-0.1443	0.5081	-0.8884	0.3898	-0.6939
	(-0.77)	(-0.60)	(3.03)	(-5.65)	(2.27)	(-2.45)
Clams	-0.2900	0.1489	-0.7901	0.0803	-0.6601	0.6029
	(-4.20)	(3.04)	(-5.16)	(0.58)	(-4.91)	(3.89)
Shrimps	-0.0217	-0.0121	-0.0031	-0.8728	-0.1324	-0.0629
	(-5.15)	(-5.80)	(-0.51)	(-28.16)	(-6.68)	(-5.83)
Tilapia	0.1463	0.0249	-0.1498	-0.6472	-0.6905	0.2817
	(7.36)	(2.23)	(-4.97)	(-6.22)	(-8.79)	(5.28)
Salmon	-0.0501	-0.0313	0.1198	0.1242	0.2704	-0.9797
	(-2.13)	(-2.17)	(4.45)	(3.13)	(6.72)	(-16.85)
Expenditure	1.1216	1.0076	0.9079	1.1050	1.0345	0.5466
	(15.40)	(10.47)	(9.90)	(14.61)	(13.83)	(19.90)
Promotion	0.0007	0.0117	0.0082	0.0014	-0.0029	-0.0051
	(0.50)	(4.04)	(12.55)	(14.61)	(-6.77)	(-12.66)

*Figures in parenthesis are t-test values.

by 7.2%; while an increase of 10% in the price of salmon will reduce catfish sales by 3.8%. In contrast, a 10% increase in the catfish price will increase tilapia sales by only 1.5%, suggesting tilapia is not strong substitute for catfish.

On average, American consumers consider catfish, crawfish, shrimp and tilapia as luxury goods (elasticity>1); while they consider clams and salmon as necessity goods (elasticity<1). For instance, an increase of 10% in the consumer's income would increase consumption of catfish, crawfish, shrimp, and tilapia by 11.2%, 10.1%, 11.1%, and 10.4%, respectively. The same income increase would induce a 9.08% increase in the consumption of clams and only a 5.47% increase in the consumption of salmon.

On average, shrimp are the most promoted product by retailers, followed closely by tilapia. In fact, more than 58% of the sales of shrimp are realized using some sorts of promotion efforts such as price reduction, feature, and display. The other imported fish category that is heavily promoted is tilapia, with more than 57% of its sales having been realized in association with promotional activities. For salmon, there were more than 41% of sales occurring with some type of promotion. Catfish promotion level was similar to salmon, at more than 38% of sales having promotions. Promotion elasticities are positive and statistically significant for crawfish, clam, and shrimp. For instance, a 10% increase in the volume sold under any type of promotion would increase budget share by 0.12%, 0.08%, and 0.01% for crawfish, clam, and shrimp, respectively. For tilapia and salmon, which are primarily imported products, promotional activities have a negative and statistically significant impact on the budget share. For catfish, promotional activities have a positive but not statistically significant impact on budget share.

Overall, results indicate that the demand for all categories considered are inelastic, suggesting that consumers are less responsive to price changes than previously thought. Interestingly, the consumer price responsiveness for catfish is lower compared to the imported categories of shrimp, tilapia, and salmon. This implies that American consumers can "tolerate" an increase in the catfish price. In addition, American consumers consider catfish as a strong substitute for tilapia; while tilapia, though a substitute for catfish is not a strong one. One strategic implication for catfish producers/processors is to survey tilapia prices and react appropriately. For instance, if tilapia prices increase by 10%, all else held constant, catfish producers/processors could keep the prices unchanged and "enjoy" more than 7% increase in the sale of catfish. In contrast, if they match the price increase, the catfish sales will drop due the own-price effect (4.80% in this case) and loss of sales to tilapia (about 1.50%). However, any price decrease in tilapia should be matched by catfish producers/processors. In fact, if tilapia prices decrease by 10% and catfish producers/processors do not react, catfish sales will be reduced by more than 7.23%. If they match the price decrease (10%), their sales will increase by more than 4.80% due to own-price responsiveness plus an additional 1.50% due to substitution from tilapia. This would bring the decrease in sales to only 0.93%. In addition, this study shows that even though shrimp and salmon have the largest market values in the U.S. seafood market, tilapia is the species that has the most negative effect on domestic aquaculture products, e.g. the US farm-raised catfish industry. Data show that imported products are heavily promoted by retailers; while domestic products lag behind.

Sub-Objective 3b. *Model consumer demand for type, form, and package size*

Texas Tech University

Manufacturers/processors often offer food products in more than one package size, allowing consumers more choices on a given shopping experience. This has implied an expansion of the number of fish and seafood products in last two decades. For example, in the shrimp category, there are more than 400 unbreaded shrimp brands sold under different package size. In the case of fish and seafood products, this differentiation operates in three dimensions:

1. Type: Fish and seafood products come under different types: entrée products, breaded fish and seafood, unbreaded fish and seafood, and canned products;

2. Form: Fish and seafood come under different forms: regular, fillets, nuggets, pop-corn,…;

3. Size: Fish and seafood products are sold in different packaging sizes from few ounces to 5 lbs or more.

Results at a glance...

- *A 10% increase in the price of catfish, will reduce the sales of catfish by 4.8%; while a 10% increase in the price of family size breaded catfish nugget will decrease the sales by 44.2%.*
- *We cannot say that the demand for catfish is more price sensitive than demand for shrimp or vice versa.*
- *Demand for entrée products is more price sensitive than the other forms, regardless of the category of fish or seafood.*
- *U.S. consumers are more price sensitive for catfish fillets than for catfish nuggets.*

According to a previous study, between 16 and 34 % of products available in two or more packages found in retail grocery outlets exhibit a quantity surcharge. The hypothesis here is that consumers do not expect the price for various types, forms, and package sizes of fish and seafood products to be the same. In other words, consumers view these products as imperfect substitutes, that is, shrimp packaged in a 32-oz package may not cost the double of a 16-oz package.

However, when many products are involved, the number of parameters to be estimated in order to analyze demand increases. The development of discrete choice methods offers a very practical alternative to estimate demand parameters at more disaggregate levels. This approach allows estimating taste parameters for product characteristics such as the form, the type, and the package size of the product. For example, unbreaded tilapia fillet, sold in 48-oz pack is treated as a different product than unbreaded tilapia, fillet, sold in 16-oz pack. In doing so, we are able to identify consumers' preferences for the product (tilapia vs. catfish, for example), the coating (breaded vs. unbreaded), the form (fillet vs. nugget), and the package size.In this study, the weekly purchase of fish and seafood products from June 2008 to June 2010 in the U.S. were considered. Six categories of frozen fish and seafood products are considered: catfish, clams, shrimp, salmon, tilapia, and tuna (Appendix 1).

Sub-Objective 3c. *Construct policy analysis matrices (PAM) and estimate domestic resource costs (DRC) for various aquaculture products of the southern region of the U.S.*

Auburn University

The U.S. farm-raised catfish industry has contributed significantly to the economic development of rural economies in the southern U.S. (Hanson et al, 2004). The industry enjoyed a long period of continuous growth for several decades until the early 2000s. Since 2003 the industry has been experiencing reductions in production acres, output, and sales volume and values. The declines are attributed primarily to the competition with substitute catfish-like imports and increases in production input costs, especially for feed and fuel. Knowledge of the comparative advantage and disadvantages of the U.S. catfish industry will help improve policy interventions and provide catfish producers with science-based decisions on ways to improve their profitability.

This research objective constructed an industry budget using both market and shadow prices. The resulting industry budgets are employed to build the policy analysis matrix (PAM), and derive domestic resource cost (DRC) and other economic indicators, such as nominal protection coefficients of inputs and outputs, to evaluate the comparativeness, and efficiencies of resources used in the U.S. farm-raised catfish industry. Data used in this analysis include costs and revenues of catfish farm production in four regions, a black belt soil region in west Alabama and one in east Mississippi, and in the lower and upper delta regions of western Mississippi. Data covered a 5-year production span from 2005 to 2009.

Results in Table 4 show that catfish producers received market prices that were close to its social/ shadow prices. Over the study period, U.S. catfish producers faced an implicit tax on their output sale in 2005 as shown by the nominal protection coefficient of output being less than one. However, the situation improved in the following years. In terms of input use, U.S. catfish producers received small indirect supports from U.S. farm policy through subsidies provided to certain crops such as corn, soybean, and wheat that are ingredients in catfish feed. The industry used to have a comparative advantage in 2005 and 2006 when the domestic resource cost (DRC) ratio was less than one, but due to increases in feed price in later years, U.S. catfish production has demonstrated a comparative disadvantage to foreign competitors.

The U.S. farm-raised catfish industry has become comparatively disadvantaged recently due to low prices paid to producers, both in terms of private and social prices, for the years 2005 through 2009 (in 2011 pond bank prices rose by 66%). The private price paid to catfish producers were determined by interactions in the domestic market and little public price intervention. However, the social price paid to producers could be improved by reducing competition with inexpensive imported aquaculture products through import tariffs. Simulations of different tariff levels on catfish-like imported products were conducted and suggested that a 25% increase in tariff level would have helped the U.S. farm-raised catfish industry in its worst year, 2008, have a comparative advantage.

Table 4: Domestic resource cost (DRC) and protection coefficients of the US catfish industry.

Ratios	2005	2006	2007	2008	2009
Domestic resource cost (DRC)	0.84	0.71	1.31	14.57	1.76
Nominal protection coefficient on tradable output (NPCO)	0.96	1.00	1.05	1.01	1.02
Nominal protection coefficient on tradable inputs (NPCI)	0.95	0.91	0.92	0.93	0.93
Effective protection coefficient (EPC)	0.96	1.17	1.56	6.42	1.62

Sub-Objective 3d. *Preparing fact sheets based on previous results and provide information on how to improve competitive position of aquaculture producers and processors in the southern region of the U.S.*

Auburn University

No accomplishments on this objective to date.

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. Census divisions. The data period is from four weeks (cumulative) ending on July 16, 2005 to four weeks (cumulative) ending on June 16, 2007 and from week ending on June 23, 2007 to week ending on June 12, 2010 (total 156 weeks).

- The cost of an individual report developed from scanner data begins at $200,000. Summaries of market trends in 52 cities across the U.S. for the past 5 years have been sent to 19 catfish processing companies, and detailed customized reports have been sent to six catfish processing companies at their request. Given the 25 reports that have been prepared for individual companies, the total value of these reports provided to industry (at no cost to them) over the past year is $5 million.

- Supermarket and household level scanner data have potential to provide guidance to seafood marketers on trends of specific products, product forms, and product substitutes in specific markets.

PUBLICATIONS, PRESENTATIONS, AND GRADUATE THESES

Manuscripts in Preparation

Chidmi, B., T. Hanson, and G. Nguyen. Substitutions between US and imported fish and seafood products at the national retail level. Marine Resource Economics (in review).

Singh, K., M.M.. Dey and P. Surathkal. Analysis of demand system for unbreaded frozen seafood in the United States using store-level scanner data. Marine Resource Economics (in review).

Singh, K., M.M. Dey and P.Suruthkal. Price and scale flexibilities of white fish products in the United States: a seasonal and regional analysis based on store-level scanner data. Canadian Journal of Agricultural Economics (in review).

Singh, K. and M.M. Dey. Retail level demand for canned seafood in the United States: estimates from almost ideal demand system using scanner data. Journal of Agricultural and Applied Economics (in review)

Abstracts

Dey, M., K. Singh, C. R. Engle, A. Rabbani, and P. Surathkal. 2011. Trends in seafood markets in the United States: reflections from store level scanner data." Page 58 in NAAFE Forum 2011 Program, University of Hawaii at Manoa and NOAA Fisheries, Silver Spring, MD.

Larkin, S., M. Dey, C. Roheim, B. Chidmi, P. Surathkal, and F. Asche. 2011. Hedonic analysis of seafood scanner data: an application to southern U.S. markets. Page 63 in NAAFE Forum 2011 Program, University of Hawaii at Manoa and NOAA Fisheries, Silver Spring, MD.

Rabbani, A.G., M. M. Dey, K. Singh, and P. Surathkal. 2011. Market trends of frozen catfish products at the supermarkets of the USA: an application of national scanner data. Page 51 in NAAFE Forum 2011 Program, University of Hawaii at Manoa and NOAA Fisheries, Silver Spring, MD.

Singh, K. and M. Dey. 2011. Demand for seafood in the United States: econometric analysis for major seafood categories and seafood canned products. Page 208 in 16th Biennial Research Symposium 2011, Association of Research Directors, Atlanta, Georgia, April 9-13, 2011.

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Surathkal, P., M. Dey, C. Engle and K.Singh. 2011. Demand for catfish, crawfish, clam, and shrimp in the United States: effects of demographic and product characteristics. Page 59 in NAAFE Forum 2011 Program, University of Hawaii at Manoa and NOAA Fisheries, Silver Spring, MD.

Surathkal, P., A. Rabbani, M. Dey and K. Singh. 2011. Recent trends in marketing of aquaculture products in the United States: results from store-level scanner data. Page 202 in 16th Biennial Research Symposium 2011, Association of Research Directors, Atlanta, Georgia, April 9-13, 2011.

Presentations

Chidmi, B. 2011. Modeling consumer demand for type, form, and package size in the seafood and fish industry. INFORMS Marketing Science Conference, Houston, Texas.

Chidmi, B., T. Hanson, and G. Nguyen. 2011. Substitutions between US and imported aquaculture products at retail market level. North American Association of Fisheries Economists (NAAFE) Forum 2011, Honolulu, Hawaii.

Dey, M.; K. Singh, C.R. Engle, A.Rabbani, and P.Surathkal. 2011. Trends in seafood markets in the united states: reflections from store level scanner data. North American Association of Fisheries Economists (NAAFE) Forum 2011, Honolulu, Hawaii.

Engle, C.R. 2011. National supply and demand for trout, supermarket sales data, and economic tools for survival. US Trout Farmers Annual Convention, Twin Falls, Idaho.

Engle, C.R. 2011. Supermarket sales of catfish and competing products: what does recent scanner data tell us? Annual Convention of the Catfish Farmers of America, Mobile, Alabama.

Engle, C.R. and M. Dey. 2011. Supply models for trout: industry wide effects of changing costs, prices and international exchange rates. Aquaculture America 2011, New Orleans, Louisiana.

Hanson, T., and G. Nguyen. 2011. Comparative advantage of the U.S. catfish aquaculture sector. North American Association of Fisheries Economists (NAAFE) Forum 2011, Honolulu, Hawaii.

Larkin, S., M. M. Dey, C. Roheim, B. Chidmi, P. Surathkal, and F. Asche. 2011. Hedonic analysis of seafood scanner data: an application to southern U.S. markets. North American Association of Fisheries Economists (NAAFE) Forum 2011,Honolulu, Hawaii.

Rabbani, A. G., M. Dey, K. Singh, and P. Surathkal. 2011. Market trends of frozen catfish products at the supermarkets of the USA: an application of national scanner data." North American Association of Fisheries Economists (NAAFE) Forum 2011, Honolulu, Hawaii.

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Surathkal, P., A. Rabbani, M. Dey, and K. Singh. 2011. Recent trends in marketing of aquaculture products in the United States: results from store-level scanner data. 16th Biennial Research Symposium 2011, Association of Research Directors, Atlanta, Georgia.

Surathkal, P., M. Dey, C. Engle, and K. Singh. 2011. Demand for catfish, crawfish, clam, and shrimp in the United States: effects of demographic and product characteristics. North American Association of Fisheries Economists (NAAFE) Forum 2011, Honolulu, Hawaii.

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Appendix 1: Average prices ($/lb.), volume sales (lb.), and own-price elasticties for frozen fish and seafood products purchased from June 2008 to June 2010 in the United States.

Products	Average Price ($/lb.)	Average weekly volume sales (lb.)	Elastities Average Price ($/lb.)
Catfish			**-0.4804**
Unbreaded fillet <1 lb.	4.5431	8,439	-8.8573
Unbreaded fillet 1 to 3 lb.	4.6570	25,582	-9.0908
Unbreaded fillet > 3 lb.	4.4001	23,998	-8.5981
Unbreaded nugget 1 to 3 lb.	2.2782	16,100	-4.6059
Unbreaded nugget > 3 lb.	2.0085	48,955	-4.0535
Breaded nugget 1 to 3 lb.	2.3642	5,396	-4.7837
Breaded nugget > 3 lb.	2.1872	8,314	-4.4227
Clams			**-0.7901**
Entrée < 1 lb.	6.4632	12,752	-12.4860
Entrée 1 to 3 lb.	3.9936	37,654	-7.8847
Entrée fried breaded < 1 lb.	8.2881	2,667	-15.7426
Entrée New England < 1 lb.	5.9291	2,061	-11.4639
Entrée regular < 1 lb.	4.8802	8,866	-9.5355
Entrée regular 1 to 3 lb.	3.2113	41,271	-6.3803
Canned regular < 1 lb.	3.9703	150,131	-7.8186
Canned regular > 1 lb.	3.0037	3,015	-5.9858
Canned boiled < 1 lb.	3.4788	12,181	-6.8980
Shrimp			**-0.8728**
Entrée < 1 lb.	5.8669	217,144	-11.3179
Entrée 1 to 3 lb.	3.3631	124,837	-6.6428
Breaded < 1 lb.	6.9803	183,991	-13.3678
Breaded 1 to 3 lb.	4.7617	98,472	-9.2821
Unbreaded < 1 lb.	6.6106	1,030,124	-12.6660
Unbreaded 1 to 3 lb.	6.1394	1,637,179	-11.7733
Unbreaded > 3 lb	5.3528	59,121	-10.3676
Salmon			**-0.9797**
Entrée < 1 lb.	6.1673	125,442	-11.8685
Entrée 1 to 3 lb.	9.4050	8,972	-17.7067
Canned < 1 lb.	3.4124	745,264	-6.7467
Unbreaded < 1 lb.	7.5197	107,008	-14.3494
Unbreaded < 1 lb	4.4851	118,540	-8.7619
Tilapia			**-0.6905**
Unbreaded < 1 lb.	4.2119	294,070	-8.2358
Unbreaded 1 to 3 lb.	3.2375	217,982	-6.4100
Unbreaded > 1 lb.	2.2299	70,047	-4.4566
Tuna			
Entrée < 1 lb.	3.7825	65,722	-7.4298
Shelf Stable < 1 lb.	3.3930	5,660,966	-6.6887

EVALUATION OF IMPACTS OF POTENTIAL "CAP AND TRADE" CARBON EMISSION POLICIES ON CATFISH, BAITFISH, AND CRAWFISH FARMING

Reporting Period
January 1, 2011 – August 31, 2011

Funding Level	Year 1	$60,000
	Year 2	$60,000
	Total	$120,000
Participants	Auburn University	Claude Boyd, C. Wesley Wood
	Louisiana State University	Ray McClain, Robert Romaire
	University of Arkansas at Pine Bluff	Carole Engle, Nathan Stone, Madan Dey

PROJECT OBJECTIVES

1. Estimate net carbon balance for channel catfish, bait minnow, and crawfish ponds and propose science-based management practices that may increase net carbon capture by ponds.

2. Estimate the economic effects on U.S. catfish, bait minnow, and crawfish farms of alternative policy options under consideration to reduce carbon emissions, including cap-and-trade programs and carbon taxes.

3. Disseminate results for Objectives 1 and 2 through a general fact sheet that explains the impact of the carbon emissions issue on southern aquaculture, and specific fact sheets for the three species. A special session at a major, national, aquaculture meeting will also be organized.

ANTICIPATED BENEFITS

The study will estimate the carbon emissions balance at the farm level for catfish, baitfish, and crawfish farming in the southern United States. This information will allow an assessment of the possible effects of potential "cap and trade" carbon emissions policies on these three types of aquaculture. It will be possible to ascertain if production ponds can be operated as carbon sinks to develop carbon credits or if farms will be sources of carbon emissions. In addition to allowing predications about effects of possible, future, carbon emissions rules, the findings will allow an estimation of the farm-level carbon footprint of the three types of aquaculture.

PROGRESS AND PRINCIPAL ACCOMPLISHMENTS

Objective 1. *Estimate net carbon balance for channel catfish, bait minnow, and crawfish ponds and propose science-based management practices that may increase net carbon capture by ponds.*

Auburn University

This component of the project is being conducted to determine the amounts of carbon emissions resulting from farm-level activities, and to evaluate the quantities of carbon sequestered in the sediment of ponds on catfish, bait minnow, and crayfish farms. The results will show the carbon emissions balance for the three types of aquaculture. In addition, production methodology will be evaluated and practices for increasing net carbon capture in ponds will be suggested. Carbon dioxide emission balance on farms will be determined as the difference between annual carbon dioxide sequestration rates in pond sediments and amounts of annual carbon dioxide emissions from aquaculture production operations. Direct carbon emissions from fuels (including electricity) will be estimated for pond construction (amortized over expected service life of ponds) and annual management operations. This assessment will be for farm carbon emissions only—carbon emissions for hatchery operation and fingerling delivery, feed manufacturing and delivery, and processing and product delivery will not be included. Data on fuel use for channel catfish production at the farm level are available from several energy use studies done by various investigators. Enterprise budgets also are available for both golden shiner production and crawfish farming that contain estimates of fuel use for pond construction and farm operations. The University of Arkansas at Pine Bluff and Louisiana State University teams will provide any additional information and advice needed by the Auburn University team for estimating amounts of carbon emissions.

Researchers at Auburn University (AU) obtained core samples from 233 aquaculture ponds in nine countries. Samples were subjected to physical and chemical analyses; the resulting database includes channel catfish ponds in Alabama and Mississippi and bait minnow ponds in Arkansas. Sediment accumulation rates and organic carbon concentrations also are available from previous research by the Delta Research and Extension Center in 45 channel catfish ponds in Mississippi. Data referred to above will be used to assess carbon

Results at a glance...

- *Researchers at Auburn University have shown that channel catfish aquaculture at the farm level is essentially neutral with respect to carbon dioxide emissions because considerable carbon dioxide is sequestered in pond sediment.*
- *Researchers at the University of Arkansas at Pine Bluff developed a general framework for simulating potential effects of "cap and trade" carbon emission policies on U.S. aquaculture. The baseline model for catfish and crawfish are called Catfish-CapTrade Policy Model and Crawfish-CapTrade Policy Model, respectively. Researchers compiled baseline data (production/supply, consumption, producer and market prices, input quantity and prices, net carbon balance, etc.) and some of the parameters of these models (own- and cross-price elasticity of demand and supply).*

sequestration rate in channel catfish and bait minnow ponds. Louisiana State University investigators are presently collecting bottom soil samples from crawfish ponds that will be sent to us for estimation of carbon sequestration rate.

Average carbon sequestration rates were 517 g CO_2/m^2/year in catfish ponds and 209 g CO_2/m^2/year in bait minnow ponds. The farm-level carbon dioxide emissions were estimated for channel catfish (Table 1). Each kilogram of fish produced resulted in 0.9405 kg CO_2. The largest contributor to carbon emissions at the farm-level (70.9%) was use of electric paddlewheel aerators. Average channel catfish production in 2010 was 5,553 kg/ha. Thus, carbon emissions were equivalent to about 5,223 kg CO_2/ha or 522 g CO_2/m^2. Thus, at the farm level, catfish ponds sequester roughly as much carbon dioxide as is emitted by production activities.

The work on catfish farm carbon emissions and carbon sequestration show that farms are basically carbon dioxide emissions neutral. We are at present assessing the carbon emissions of bait minnow and crawfish ponds; we anticipate that these systems—to which few management interventions are applied—will also be carbon neutral.

Table 1. Farm-level carbon dioxide emissions for channel catfish production

Activity	CO_2 emissions (kg CO_2/kg fish)
Pond construction	0.0361
Electric paddlewheel aerator operation	0.6668
Tractor use – emergency aeration, feeding, mowing	0.1502
Light truck and boat use	0.0651
Harvesting	0.0223
Total	0.9405

Louisiana State University

The Auburn University investigators met with their counterparts at Louisiana State University and explained the sampling requirements for the sediment samples from crawfish ponds. These samples will be collected during the next few months.

Objective 2. *Estimate the economic effects on U.S. catfish, bait minnow, and crawfish farms of alternative policy options under consideration to reduce carbon emissions, including cap-and-trade programs and carbon taxes.*

University of Arkansas at Pine Bluff

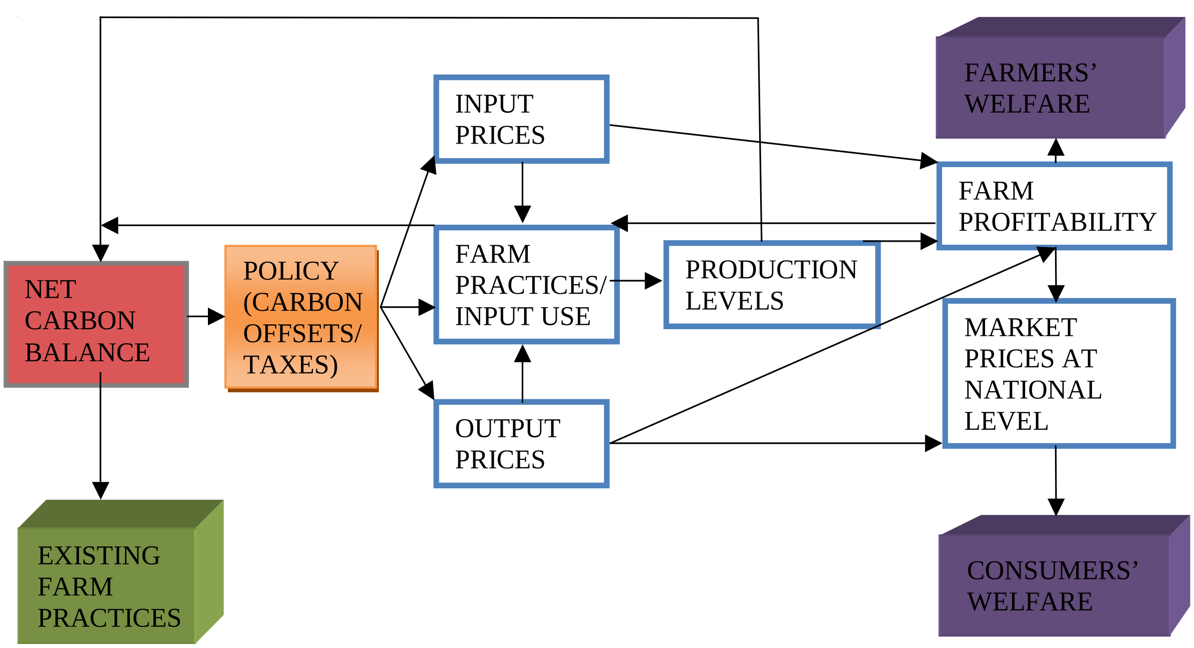
The University of Arkansas at Pine Bluff (UAPB) has developed general framework for simulating potential effects of "cap and trade" carbon emission policies on U.S. aquaculture. The University has developed baseline models for catfish and crawfish referred to as Catfish-CapTrade Policy Model and Crawfish-CapTrade Policy Model, respectively. The researchers at UAPB have compiled baseline data (production/supply, consumption, producer and market prices, input quantity and prices, net carbon balance, etc.) and some of the parameters of these models (own and cross price elasticity of demand and supply).

The general framework of the model developed for simulating effects of "Cap and Trade" carbon emission policies on U.S. aquaculture is given in Figure 1. The models postulate that the carbon offsets/taxes depend on i) net carbon supply of the aquaculture farms and ii) government policies to distribute the revenue generated through the program. The model captures the potential effects of alternative policies on farmers as well as consumers through changes in input prices, output and market prices, and in real per capita income.

Net carbon balance of existing farm practices will determine carbon emission policies (rates of carbon offsets/taxes). The policy will affect input and output prices. Farmers may adjust their farm practices and/or input use according to policy (i.e., carbon offsets/taxes rates). Changes in input and output prices can influence the existing farm practices/input usage. Changes in input and output prices and in farm practices will affect farm profitability, which will potentially affect farmers' as well as consumers' welfare. Changes in farm production levels and farm practices/input usage will result in new net carbon balances.

When completed and used to evaluate the carbon balance data from Objective 1, these models will allow an assessment of the potential economic impacts of possible future carbon emissions regulations on the three types of aquaculture.

Figure 1. Model framework for potential effects of "cap and trade" carbon emission policies on U.S.



Objective 3. *Disseminate results for Objectives 1 and 2 through a general fact sheet that explains the impact of the carbon emissions issue on southern aquaculture, and specific fact sheets for the three species. A special session at a major, national, aquaculture meeting will also be organized.*

Louisiana State University, University of Arkansas at Pine Bluff, and Auburn University

This objective will be addressed when work on Objectives 1 and 2 is complete.

IMPACTS

Channel catfish farming appears to be carbon dioxide emissions neutral with respect to farm-level operations; that is, ponds sequester as much carbon dioxide as farming activities emit.

Models for evaluating the likely economic effects of possible, future, carbon emissions regulations are still being developed. However, the fact that catfish farming is carbon neutral and the likelihood that bait minnow and crawfish farming will contribute less to carbon dioxide emissions than channel catfish farming suggest that the economic impacts of carbon emissions regulations would probably be minor.

PUBLICATIONS, MANUSCRIPTS OR PAPERS PRESENTED

Publications

Boyd, C.E. 2010. Aquaculture ponds hold carbon. Global Aquaculture Advocate 13(2):23-24.

Boyd, C.E., C.W. Wood, P. Chaney, and J. F. Queiroz. 2010. Role of aquaculture pond sediments in sequestration of annual global carbon emissions. Environmental Pollution 158:2,537-2,540.

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DEVELOPMENT AND EVALUATION OF COOL WATER CRAWFISH BAITS

Reporting Period
January 1, 2011 – August 31, 2011

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

Participants Louisiana State University Ag Center .... Ray McClain, Robert P. Romaire, Charles Gregory Lutz
Texas A&M University .... Delbert M. Gatlin, III
Auburn University .... D. Allen Davis

PROJECT OBJECTIVES

1. Identify attractants, bait formulations, or potential manufacturing processes that increase the efficacy of formulated crawfish bait for use at water temperatures below 70 degrees F.

2. Compare the efficacy of experimental formulated baits or processes with fish baits for increasing crawfish catch and profits under simulated commercial conditions at water temperatures below 70 degrees F.

ANTICIPATED BENEFITS

Crawfish are harvested in over 185,000 acres of aquaculture ponds using baited wire-mesh traps that are lifted 3 to 5 days a week beginning as early as November and continuing through May to July of the following year. Traps are typically baited with manufactured formulated bait in warmer weather but, because formulated baits are inferior at cooler water temperatures, fresh-frozen cut fish is used. Fish for crawfish bait has become expensive, costing twice that of commercially formulated bait, and fish bait is frequently in short supply. More than half of the annual crawfish harvesting effort occurs during cool-water periods (December through late March), and with availability and price issues with fish, as well as the need to transport and store fish baits in a frozen state, this bait has become problematic for the crawfish industry. Development of an effective and economical cool-water formulated crawfish bait will address not only some of the cost and handling/storage issues with fish baits, but also will help conserve the fishery for many of these species.

PROGRESS AND PRINCIPAL ACCOMPLISHMENTS

Objective 1. I*dentify attractants, bait formulations, or potential manufacturing processes that increase the efficacy of formulated crawfish bait for use at water temperatures below 70 degrees F.*

Louisiana State University Agricultural Center

A review of the scientific literature for identified attractants to carnivorous crustaceans revealed that amino acids and related biochemical compounds tend to elicit chemoattraction responses and may act as feeding stimulants for these crustaceans. Although some studies have shown that a feeding response can be elicited by single components, most have shown the response to be greatest with specific mixtures of amino acids or other compounds. Although detection does not equal attraction and an elicited feeding response may not equate to attraction over some distance to elicit entry of crawfish into a baited trap, this review provided creditable information.

Preliminary efforts were undertaken to establish an effective protocol for testing preferences of crawfish to attractants in the laboratory. Those efforts were not successful. The response of crawfish to field-proven attractants in a controlled laboratory environment, even at optimum temperatures with acclimated and/or starved captive stock, proved inconsistent and not predictable. Therefore, research was subsequently directed at developing a suitable technique "in the field" for effectively evaluating the efficacy of attractants in ponds that simulated commercial crawfish aquaculture. A gelatin-based matrix (Figure 1) made without excessive heat or processing was found to be an effective medium to test attractants and could be used to evaluate potential attractants using commercial crawfish traps in experimental or commercial crawfish ponds. Several flesh-based attractants, including fish meal, when incorporated into the gelatin-based matrix, caught as many crawfish as cut gizzard shad (industry standard fish bait) when evaluated at temperatures from 51 to 63 degrees F. In contrast, concurrent field studies evaluated single amino acids, an amino acid mixture, sugar, fish oil and fish solubles incorporated into solid blocks of plaster of Paris (calcium sulfate hemihydrate) as attractants for crawfish. The attractants imbedded in the plaster blocks were not effective when compared to either cut shad or attractants incorporated into the gelatin matrix. Thus, the

Figure 1. Example of one gelatin-matrix bait block prior to use (left bait) and after 17-hours in the trap (right bait).

gelatin matrix proved to be best suitable for identifying and testing potential attractants in experimental baits for crawfish in earthen ponds.

Initial tests during the first year of the project involved baits composed of the gelatin medium and various proteinaceous ingredients as test attractants. The test attractants consisted of selected commercially available ingredients, ground flesh products, and proprietary mixtures of synthetic amino acids. The experimental trials were conducted in either a commercial crawfish production pond or small research pond managed to simulate commercial crawfish ponds. Trials were conducted from January to early March at water temperatures ranging from 47 to 77 degrees F, and consisted of baited wire mesh traps (standard commercial trap of the crawfish aquaculture industry; Figure 2) placed at 45-foot intervals at random locations within the ponds. Trap

Results at a glance...

- *Early testing of potential alternative attractants as crawfish bait in cool water has revealed the limitations for several of the more promising high protein feedstuffs; yet valuable information was gleaned regarding the potential for suspending a suitable attractant in an appropriate medium, which would be necessary for an effective formulated manufactured product.*

soak duration was 24 hours. The response variables consisted of average number and weight of crawfish captured per trap per treatment. Capture rates with experimental baits were compared to cut fish (pogy, an industry standard), no bait, and in one trial, a

Figure 2. Typical 3-funnel "pyramid" crawfish trap used for this study. The bait block was placed in the bait well fastened to the center of the trap.

commercially formulated bait (Purina Mills, Shreveport, LA). Trial results are provided in Table 1.

Of the experimental attractants tested, only minced pogy caught as many crawfish as cut pogy, the industry standard for cool water use. While other baits generally yielded higher catches than traps without bait, few differences were observed among the other proteinaceous attractants. Further testing of other ingredients is planned and an approach to investigate and quantify the component of fish flesh that acts as the primary attractant is planned.

Table 1. Average crawfish catch (by number and total weight of crawfish per trap), average weight of crawfish captured, and average catch (by number and by total weight) expressed as a percentage of that caught with cut pogy (the industry standard) for experimental cool water attractants in 2011.

Treatment	No. Trps	Avg Catch (No/Trp)	Avg Catch (Lb/Trp)	Avg Wt. (g)	% of Cut Pogy (by No.)	% of Cut Pogy (by Wt.)
Trial 1 (temp = 47.2 min / 56.7 max / 52.4 average)						
No Bait	3	1.7	0.04	10.9	35.4	20.0
Gelatin-Minced Crawfish	3	0.5	0.02	15.0	10.4	10.0
Gelatin-Krill Meal	3	1.2	0.05	15.0	25.0	25.0
Gelatin-Squid Meal	3	2.3	0.07	14.1	47.9	35.0
Gelatin-Fish Meal	3	3.5	0.11	14.3	72.9	55.0
Gelatin-Minced Fresh Pogy	3	2.8	0.12	19.4	58.3	60.0
Gelatin-Minced Air-dried Pogy	3	5.5	0.22	17.6	114.6	110.0
Cut Pogy	3	4.8	0.20	17.4		
Trial 2 (temp = 53.2 min / 66.3 max / 60.2 average)						
No Bait	12	5.3	0.16	13.8	29.3	26.7
Gelatin-Amino Acid Mix (1%)	12	10.3	0.31	13.5	56.9	51.7
Gelatin-No Attractant	12	9.3	0.32	15.5	51.4	53.3
Gelatin-Krill Meal	12	10.8	0.38	15.5	59.7	63.3
Gelatin-Squid Meal	12	11.1	0.38	14.8	61.3	63.3
Gelatin-Minced Crawfish	12	11.6	0.41	15.8	64.1	68.3
Gelatin-Fish Meal	12	13.6	0.47	15.9	75.1	78.3
Gelatin-Minced Fresh Pogy	12	21.8	0.69	14.3	120.4	115.0
Gelatin-Minced Air-dried Pogy	12	19.3	0.61	14.3	106.6	101.7
Cut Pogy	12	18.1	0.6	14.9		
Trial 3 (temp = 67.7 min / 76.7 max / 71.3 average)						
No Bait	12	6.3	0.2	14.3	25.3	20.8
Gelatin-Amino Acid Mix (3%)	12	12.8	0.45	16.0	51.4	46.9
Gelatin-Minced Crawfish	12	15.8	0.62	17.9	63.5	64.6
Gelatin-Fish/Squid/Krill Meal	12	16.3	0.62	17.1	65.5	64.6
Gelatin-Minced Fresh Pogy	12	26.2	0.99	17.2	105.2	103.1
Purina Pellets-Southern Pride	12	27.1	1.04	17.4	108.8	108.3
Cut Pogy	12	24.9	0.96	17.6		

Objective 2. *Compare the efficacy of experimental formulated baits or processes with fish baits for increasing crawfish catch and profits under simulated commercial conditions at water temperatures below 70 degrees F.*

Louisiana State University Agricultural Center

While all tests conducted and planned involve a comparison with cut fish (the current industry standard for cool water) as the attractant, capture rate of non-baited traps is also included in every experimental trial. When effective alternative attractants to fish baits are identified, and a suitable process determined for manufacture of those baits, a full scale trial will be conducted to compare the efficacy and cost effectiveness of those baits/ processes under rigorous commercial conditions.

Texas A&M University

Analysis of commercial and experimental baits containing attractants have been subjected to analytical evaluation to determine proximate composition as well and content of water- and lipid-soluble components that may confer attractability to the baits.

IMPACTS

The primary impact of the results to date has provided scientists with valuable information regarding what direction to take the research in an attempt to identify methods and potential attractants for further testing. The recent findings have provided some quantitative assessments of the value of a few common feedstuff ingredients and an amino acid mixture as crawfish attractants, and have provided valuable information regarding physical aspects for a crawfish bait. Specifically, this research indicated that attractant fragments (minced flesh products) were as effective as intact fish flesh when suspended in a suitable medium. This provides the impetus to evaluate decreasing quantities of mince (or similar attractants) to further appraise quantity requirements of attractants in bait.

PUBLICATIONS, MANUSCRIPTS OR PAPERS PRESENTED

None to date.

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IDENTIFYING DETERMINANTS FOR DEVELOPMENT OF LIVE-MARKET GRADING STANDARDS FOR CRAWFISH

Reporting Period
January 1, 2011 – August 31, 2011

Funding Level	Year 1	$50,000
	Total	$50,000

Participants	Louisiana State University Ag Center	Ray McClain, Robert P. Romaire
	University of Arkansas at Pine Bluff	Carole Engle, Madan Dey

PROJECT OBJECTIVES

1. Survey major components of the supply chain for live procambarid crawfish to determine the desire for establishing grade standards, and to define the number of grades desired and potential size or weight limits (or other factors) for each grade.

2. Determine size distribution at harvest for live red swamp crawfish collected with standard commercial wire-mesh traps and graded using various bar spacing parameters over a December through June crawfish harvesting season.

   a. Identify the body dimensions, weight, and maturity of the smallest crawfish captured by 0.75-inch and 0.875-inch coated square wire mesh traps.
   b. Identify grader spacing parameters that will segregate crawfish (captured in 0.75-inch square mesh traps) into 3, 4, 5, and 6 different size grade categories.
   c. Determine cross-sectional width dimensions and weight variances of immature and mature crawfish for each of the spacing parameters used in 2b.

3. Present findings of Objectives 1 and 2 to the crawfish aquaculture industry via workshops, educational programs, newsletters, etc. with recommendations for establishment of industry-wide adoptable grade standards.

ANTICIPATED BENEFITS

A lack of industry adopted grading standards for crawfish sales potentially hampers market expansion and leads to tension among sellers and buyers of crawfish in regards to what constitutes "quality." To improve and expand markets for live crawfish, acceptable grading standards are needed. This research was initiated to ascertain (by industry survey) the desire among the various participants of the supply chain for establishing grade standards, and to determine the need for number of grades and potential size classifications for those grades. The research will also resolve many of questions relating to potential grading standards because of the changing morphology of crawfish as they mature. Crawfish are currently graded by size (i.e., width of the carapace) but are noted by count per pound (as with grades of shrimp). However, the weight of crawfish for a given size is highly dependent on maturity (unlike with shrimp) because weight changes for a given size based on morphology associated with maturity. Therefore, this research will not only identify grader bar spacings necessary for several potential grade classifications, it will determine whether any of these systems will be compatible with grading bar spacing requirements that will not change with seasonal changes in crawfish morphometry. Findings of the survey and field research will be presented to the crawfish industry, with recommendations for potential grading standards that could be adopted by industry.

PROGRESS AND PRINCIPAL ACCOMPLISHMENTS

Objective 1. *Survey major components of the supply chain for live procambarid crawfish to determine the desire for establishing grade standards, and to define the number of grades desired and potential size or weight limits (or other factors) for each grade.*

University of Arkansas at Pine Bluff

It is necessary to identify potential markets and the needs of the consumer before developing a standardized grading system. Increased understanding of trends in supermarket sales of crawfish has potential to assist the crawfish industry to refine grading strategies. The University of Arkansas at Pine Bluff team has analyzed the market trends of the U.S. crawfish retail market, including market shares, price fluctuations, promotional sales, and package size across several major regional cities. The analysis is based on store-level scanner data procured from the AC Nielsen Company. The dataset is composed of weekly data covering 52 U.S. markets for the last 5 years, ending on June 12, 2010, for different seafood products that include freshwater crawfish. A.C. Nielsen data in the category of "frozen" were used to develop this descriptive analysis. The "frozen" category includes all frozen and chilled fish and seafood available in both prepared and unprepared forms usually found in refrigerated and frozen sections of supermarkets.

Crawfish products sold in the U.S. supermarkets can be grouped into three frozen/chilled categories: entrée, breaded, and unbreaded products. Breaded products do not show much product diversity, and their sales are mostly in Southern cities. Entrée products are the most diverse in terms of products sold, though they are sold in fewer cities than are unbreaded products. Cities with no sales of crawfish entrées during the last five years were: Des Moines, Las Vegas, Los Angeles, Omaha, Phoenix, Sacramento, Salt Lake City, San Diego, and San Francisco. Unbreaded products are sold by the largest number of brands, and have the largest regional distribution in terms number of cities with sales.

Unbreaded crawfish product is the main category, contributing about 85% of the total crawfish market in terms of volume and about 70% of the market in terms of value. The market for unbreaded crawfish is concentrated in the southern region of the country. Among the 52 markets we have analyzed, New Orleans/Mobile has the maximum share (about 70%) of unbreaded crawfish sales in supermarkets (Table 1). Three Texas cities, Houston, Dallas and San Antonio, are the other major markets for unbreaded crawfish; with Houston having about 13-14% of sales share and the other two about 3-3.5% each. The only two cities out of 52 cities that did not show sales of unbreaded crawfish in the five-year period were Portland and Seattle. But the sales of crawfish in non-southern cities are very limited. Though crawfish products have been sold in cities other than the traditional markets, they are yet to become established in the Western and Midwestern US. Promotional sale is an important crawfish marketing strategy. About 35% of unbreaded crawfish products were sold under some sort of promotion during the during last five years (Table 1). New Orleans/Mobile also had the highest degree of promotion, with about 28-33% of products sold under promotion.

In terms of grading requirements, the unbreaded crawfish category could present more potential applications than other categories. Tail meat is the most dominant product form, with about 90-96% share of unbreaded crawfish sales. However, in the last two years, there is a gradual increase in the share of whole crawfish. Direct applications of potential grading systems are evident in the case of whole crawfish.

The most popular packaging size is 60-oz packages,

Table 1. Top cities for overall unbreaded crawfish sales

Product/City	Proportion (%) out of Total Sales in Individual cities					Proportion (%) of Promotional Sales out of Total Sales (lb)				
	2005/6	2006/7	2007/8	2008/9	2009/10	2005/6	2006/7	2007/8	2008/9	2009/10
Crawfish						33.3	35.2	38.3	32.0	34.0
New Orleans/Mobile	68.3	70.9	71.9	70.9	69.9	29.2	32.6	33.2	27.5	28.8
Houston	13.5	13.7	13.1	13.8	13.7	1.4	1.0	2.4	2.1	2.6
Dallas	3.3	3.5	3.7	3.5	3.8	0.9	0.8	1.4	1.2	1.5
San Antonio	3.2	3.2	3.1	2.8	2.8	0.0	0.1	0.6	0.4	0.3
Memphis	1.5	1.8	1.8	1.7	1.6	0.4	0.2	0.1	0.2	0.1
Jacksonville	1.2	0.4	0.7	1.3	1.3	0.1	0.0	0.0	0.1	0.1
Little Rock	1.0	0.8	0.8	0.9	0.8	0.3	0.1	0.2	0.2	0.2
Birmingham	0.5	0.5	0.8	0.8	1.2	0.1	0.0	0.0	0.0	0.0
St. Louis	0.6	0.7	0.5	0.8	0.6	0.1	0.1	0.0	0.3	0.2
Atlanta	0.6	0.6	0.5	0.1	0.1	0.0	0.0	0.1	0.0	0.0
Raleigh/Durham	0.2	0.5	0.4	0.3	0.4	0.0	0.0	0.0	0.0	0.0
Chicago	0.5	0.3	0.1	0.3	0.4	0.1	0.0	0.0	0.0	0.0
Orlando	0.5	0.1	0.2	0.4	0.5	0.0	0.0	0.0	0.0	0.0
Tampa	0.4	0.2	0.2	0.2	0.5	0.0	0.0	0.0	0.0	0.0
Kansas City	0.3	0.2	0.2	0.3	0.3	0.0	0.0	0.0	0.0	0.0
West Texas	0.2	0.3	0.3	0.3	0.3	0.0	0.0	0.1	0.1	0.1
Nashville	0.4	0.3	0.2	0.2	0.2	0.0	0.0	0.0	0.0	0.0
Detroit	0.3	0.3	0.2	0.2	0.2	0.0	0.0	0.0	0.0	0.0
New York	0.9	0.1	0.1	0.0	0.0	0.3	0.0	0.0	0.0	0.0
Oklahoma City/Tulsa	0.2	0.4	0.1	0.1	0.2	0.0	0.0	0.0	0.0	0.0

and their share has increased over the years, to almost 90% of whole crawfish sales. The remaining sales is constituted by 80 oz, 48 oz and 20 oz. Among these 3 packages, only 80-oz packages have demonstrated consistent sales in all 5 years. Hence, it can be said that larger package sizes (3.75 lb or 60 oz, and 5 lb or 80 oz) form the most important package sizes.

Average price of whole products has fluctuated over the years, with a dip in the last 2 years. The cheapest pack is the 80-oz package. The most popular package, i.e. the 60-oz package, is priced considerably higher than the 80-oz package.

Fifty-five brands of unbreaded crawfish were sold in the market during the last 5 years, out of which 11 brands sold whole unbreaded crawfish products. Sales of crawfish entrées sales have been growing at a high rate. There were 25 crawfish entrée products in the markets, and they contributed almost 30% of total crawfish sold in 2009-2010.

Objective 2. *Determine size distribution at harvest for live red swamp crawfish collected with standard commercial wire-mesh traps and graded using various bar spacing parameters over a December through June crawfish harvesting season.*

Sub-objective 2a. *Identify the body dimensions, weight, and maturity of the smallest crawfish captured by 0.75-inch and 0.875-inch coated square wire mesh traps.*

Louisiana State University Agricultural Center

Daily harvest data, whereby crawfish were sorted into 3 grade categories (large = <15 count/lb, medium = 16-21 count/lb, and small = >21 count/lb), was organized by trap type when traps were constructed of either 3/4-inch (0.75-inch) or 7/8-inch (0.875-inch) square mesh wire. The daily yield of smallest crawfish within the small grade category harvested with 3/4-inch traps occurred in February and averaged 37.5 count per pound or 12.1 grams (g) each. Yields of the smallest crawfish captured with 7/8-inch traps occurred in June and averaged 31 count per pound or 14.6 grams—a 21% increase in the minimum average size from those captured with the smaller mesh traps. Virtually all crawfish in both cases were immature and were composed of an approximate equal mixture of males and females. These average weights correspond to a carapace width and height of 17.1 and 20.0 mm for crawfish weighing 12 g and a carapace width and height of 17.7 and 21.1 for crawfish weighing 14.5 g. The total length (rostrum to tail) for these two sizes of crawfish is approximately 7.7 and 8.0 cm, respectively.

Results at a glance...

- This research has provided valuable information regarding biological feasibility of establishing size grades in crawfish, and offers insight into possible grade categories for several potential systems of classifying graded crawfish for markets.

Sub-objective 2b. *Identify grader spacing parameters that will segregate crawfish (captured in 0.75-inch square mesh traps) into 3, 4, 5, and 6 different size grade categories.*

Louisiana State University Agricultural Center

Two hundred and twelve crawfish representing various sizes (weights), maturity status, and both sexes were measured for carapace width and height and overall length. Preliminary grading of crawfish at various bar spacings with a variable fish grader (Figure 1) revealed that carapace width was the best indicator for determining grader bar spacing. Arbitrary grade categories for each of 4 grading systems (6-, 5-, 4-, and 3-grade systems) were determined for this study (Table 2) based on observations and discussions of previously used grading categories by some in the industry. These were established to represent a range of possible/practical standards and were used solely for testing purposes. Based on carapace width measurements and measurements of fixed grader bar spacing of the fish grader, settings were established that closely matched the biological data for each grade category within the chosen grade systems.

Figure 1. Size grading of crawfish was accomplished in the boat at harvest with a variable fish grader. Grader was adjusted for different size categories.

Table 2. Target crawfish grade (count per pound) and nearest settings on the fish grader (based on crawfish carapace width measurements) for the categories within each numbered grade system. Also presented are the average size (count per pound) and percentage maturity for crawfish harvested and graded according to the various grader bar spacings for each grade category within the 6-, 5-, 4-, and 3-grade system. Averages were determined for each month of harvest and for the season. Yellow highlight indicates averages that fall outside of the targeted range.

Number of Grades in System	Target Grade (Cnt/lb)	Nearest Setting (mm)	March		April		May		June		Seasonal	
			% Mat	Cnt/ Lb	% Mat	Cnt/ Lb	% Mat	Cnt/ Lb	% Mat	Cnt/ Lb	% Mat	Cnt /Lb
6	< 10	< 26.3	71.7	8.7	84.9	9.8	47.2	9.6	88.9	10.8	72.6	9.6
	10 - 14	23. 0- 26.3	47.7	12.9	55.5	12.4	35.7	13.0	68.6	14.0	49.5	12.9
	15 - 19	20.8 - 23.0	44.1	17.8	63.0	17.1	35.1	16.6	50.7	16.9	47.2	17.1
	20 - 24	19.1 - 20.8	44.9	23.0	41.1	21.2	28.4	20.6	48.2	21.3	40.0	21.9
	25 - 29	17.8 - 19.1	25.9	28.7	41.4	27.7	43.2	24.9	42.3	24.8	39.6	26.5
	> 29	> 17.8	34.4	35.0	27.8	35.7	41.0	32.3	32.7	30.1	33.9	33.0
5	< 12	< 24.6	69.6	11.2	80.4	10.2	48.2	10.6	92.7	10.4	69.9	10.5
	12 - 17	21.5 - 24.6	39.7	17.3	48.4	15.2	60.1	15.1	61.1	14.6	51.4	15.6
	18 - 23	19.9 - 21.5	43.1	18.9	44.7	18.9	54.7	19.8	46.2	19.2	47.4	19.2
	24 - 29	17.8 - 19.9	35.3	25.8	41.0	25.8	44.6	24.1	49.3	23.6	41.5	25.2
	> 29	> 17.8	20.7	36.5	34.1	36.6	43.0	31.4	39.7	31.1	35.8	33.9
4	< 12	< 24.6	77.3	10.5	78.5	10.5	45.8	10.9	76.4	11.1	67.1	10.7
	12 - 18	20.8 - 24.6	39.8	17.3	46.4	17.4	47.1	15.7	53.3	15.7	46.2	16.6
	19 - 25	19.1 - 20.8	39.7	23.5	43.1	23.5	49.9	21.3	41.5	21.1	44.3	22.6
	>25	> 19.1	40.9	26.1	46.1	26.1	48.4	26.0	38.1	26.1	44.7	26.0
3	< 12	< 24.6	58.1	10.7	60.1	10.7	53.2	10.8	73.1	11.2	59.6	10.8
	12 - 21	19.9 - 24.6	50.2	17.0	52.9	16.8	52.7	16.1	43.5	17.0	51.1	16.6
	> 21	> 19.9	24.7	31.9	27.9	29.9	49.8	25.0	40.4	24.2	36.8	27.6

Sub-objective 2c. *Determine cross-sectional width dimensions and weight variances of immature and mature crawfish for each of the spacing parameters used in 2b.*

Crawfish were subjected to each grader bar spacing directly as they were emptied from traps over the course of a production season (Figure 2). For the first part of this sub-objective, a random sample of the smallest crawfish retained by each grader setting and the largest crawfish passing through each setting was collected (on 2-week intervals) and weighed and assessed for sex and maturity. Data was summarized by month and a seasonal average was calculated. Using these data to represent crawfish sizes that fall at either end of the target category when graded, we can determine if a theoretical batch of crawfish, uniform in size and maturity but at the extreme ends of each grade category, might fall outside of the targeted grade. The results indicated that monthly averages were smaller than the targeted minimum size for a category 5 times in the 6-grade system, 3 times in the 5-grade system, 3 times in the 4-grade systems, and 2 times in the 3-grade system. Likewise, there were 1, 4, 1, and 0 monthly category averages that represented averages larger than the targeted grade for the 6-, 5-, 4-, and 3-grade systems, respectively. Only one seasonal grade average was outside (under) the targeted size for a category. It should be noted that all averages outside of the targeted range in this exercise were outside of the range only by small fractions when expressed in count per pound—likely due to the slight difference in actual bar spacings from the desired nominal spacing.

Figure 2. Smaller crawfish dropped through to a tote and larger crawfish were emptied into a tote in front of the grader. Graded crawfish were sorted once more in the laboratory using a similar technique.

For the second part of this sub-objective, crawfish were subjected at harvest to each grader bar setting every other week. Crawfish that passed through the grader at each setting were then placed in holding tanks and graded again after 3 hours. Each batch of crawfish within the holding tanks was subjected to the next grader setting corresponding to the appropriate target standard and no crawfish were subjected to more than the initial grading and one other after the 3-hour reprieve. Crawfish falling into each grading category encompassed a range of sizes (and maturity status) within the spectrum of the two grader settings at time of harvest. Average weight and % maturity were determined for each grade category and this is presented in Table 2 by month of harvest and as a seasonal average. While there were 3 monthly averages slightly outside of the target range, all of the seasonal averages were within the desired grade ranges for category within each grading system tested. Small adjustments in grader bar settings could possibly reduce or eliminate the undesirable results. It should be noted though that resulting count per pound averages were all within the desired ranges for the 3- and 4-grade system categories. This is likely due to a wider range of individual crawfish sizes contained within each category, which tends to mitigate influences on weight per carapace width as maturity is reached.

In conclusion, these results suggest that setting grader bar spacings to closely correspond with the carapace width of crawfish within the desired size ranges, within reason, can achieve suitable results for sorting crawfish by size, even when weight per given carapace width is influenced by physical changes as crawfish mature (Figure 3). Moreover, it is likely that grading standard results will be easier to achieve and less influenced by morphological differences in crawfish if grade categories encompass a wider range of individual sizes when contrast to a narrow range.

Figure 3. Size grading in crawfish is accomplished according to width of the carapace.

Objective 3. *Present findings of Objectives 1 and 2 to the crawfish aquaculture industry via workshops, educational programs, newsletters, etc. with recommendations for establishment of industry-wide adoptable grade standards.*

This objective will be addressed when work on Objectives 1 and 2 is complete.

IMPACTS

The impact of this research has provided confirmation that dimorphism associated with maturity in crawfish can impact results of grading operations based on exterior measurements (specifically carapace width) of the animal. However, tangible evidence is presented that suggests satisfactory results can be achieve in grading crawfish by size if precise grader bar spacings are used and if grade standards are kept to a manageable number while avoiding narrow ranges in the acceptable sizes within a grade category. This is all predicated on grading crawfish at a time when they are less likely to grab and hold onto one another while grading, thereby giving the cleanest grades possible. This information, including the arbitrary target grade specifications used in this study, should be an asset and basis for discussion for the industry when deciding if and what grading standards are needed industry wide.

PUBLICATIONS, MANUSCRIPTS OR PAPERS PRESENTED

None to date.

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POTENTIAL MARKETING STRUCTURES FOR THE CATFISH INDUSTRY

Reporting Period
January 1, 2011 – August 31, 2011

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

Participants	University of Arkansas at Pine Bluff	Carole Engle, Madan Dey
	Auburn University	Terrill Hanson
	Kentucky State University	Siddhartha Dasgupta
	University of California at Davis	Richard Sexton
	University of Missouri	Michael Cook

PROJECT OBJECTIVES

1. Identify and characterize forms of market organization (including ownership and control of the processing/packing function) that have successfully resulted in higher farm-level prices and rank the forms of market organization that have the greatest likelihood of success for the U.S. farm-raised catfish industry.

2. Develop comprehensive economic analyses to evaluate likely impacts on the U.S. farm-raised catfish industry of implementing proposed structures identified under Objective 1. Results would measure effects on product price, product volume, product characteristics, size of the industry, and competitiveness with imports.

ANTICIPATED BENEFITS

Policy makers in the United States have given producers of agricultural and aquaculture products the opportunity to engage in horizontal integration and undertake collective action. The fundamental pieces of authorizing legislation at the federal level are the Capper-Volstead Act of 1922 and the Agricultural Marketing Agreement Act (AMAA) of 1937. Capper Volstead authorizes farmers to market their products collectively through cooperative organizations, while the AMAA allows industries to self regulate through marketing orders. Many states have passed legislation authorizing farmers within a state to self regulate. Regulations permissible under marketing order statutes include forms of volume control, setting of grades and quality standards, and collection of funds to support research and promotion.

Arguably the need for producer collective action is even more acute today than it was at the time the authorizing legislation was implemented, in light of substantial and rising consolidation in the food manufacturing and retailing sectors. The increasing consolidation in the food processing and retailing sector and the increasing power of dominant food retailers has been well documented. Producers of perishable food products are perhaps most vulnerable to the power of buyers because their products are not storable and must be marketed quickly upon harvest.

Despite opportunities afforded by the aforementioned legislation, the track record of farmer collective action in the U.S. is mixed. As this discussion indicates, tools for horizontal integration and collective action available to farmers are quite varied and flexible, with the potential for complementarities among them. Thus, careful consideration of the appropriate options is required if these tools are going to achieve maximum effectiveness for southern aquaculture producers.

PROGRESS AND PRINCIPAL ACCOMPLISHMENTS

Objective 1. *Identify and characterize forms of market organization (including ownership and control of the processing/packing function) that have successfully resulted in higher farm-level prices and rank the forms of market organization that have the greatest likelihood of success for the U.S. farm-raised catfish industry.*

University of Arkansas at Pine Bluff

Scientists at the University of Arkansas at Pine Bluff (UAPB) worked with representatives of the catfish industry to organize an industry advisory panel (including representatives from Alabama, Arkansas, and Mississippi) for the project and to organize the first meeting of project participants. This first meeting was held August 16, 2011 at UAPB and included the economists on the project and the advisory panel of catfish farmers. This initial project meeting provided an opportunity for participants to discuss overall trends in the catfish industry, those forms of producer collective action that have the greatest potential to be of benefit to the catfish industry, and to lay out specific project assignments and deadlines. Carole Engle presented an overview of the catfish industry and of the project, Joey Lowery summarized industry expectations for the project, Richard Sexton reviewed producer collective action in other agricultural industries and the authorizing frameworks, and Michael Cook an overview of the evolution of cooperative structures and management in agriculture. Much of the meeting was spent in open discussion of the industry and potential for producer collective action.

The UAPB team has reviewed the seafood value chains of major aquaculture products from various counties (including Bangladesh, Canada, Japan, Norway, Spain, Thailand, United Kingdom, USA, and Vietnam). The review indicates that retailers play an important role in the seafood value chain, and their role is increasing over time. So far, very limited research has been undertaken on the retail sector of the U.S. seafood market.

The UAPB team has developed quantitative models linking fish prices at different levels of the value chain (farmers, processors and retailers). The models uses weekly retail prices of seafood obtained from supermarket stores nation-wide; this unique dataset was procured from the AC Nielsen Company with funding from the USDA/NIFA Southern Regional Aquaculture Center. The price of fish is an obvious and important factor in the economic welfare of fish farmers, but the price of fish is set by external factors exogenous to fish farmers. These external factors are certainly dictated by demand and supply forces but can also be influenced by monopoly and strategic pricing behavior in downstream markets. Strategic pricing can impact the magnitude of prices passed through among market segments and the length of time to adjust to price shocks.

The model developed will be able to identify and measure some of the factors important in setting the prices of fish. The empirical strategy is to apply time series techniques to measure price relationships. Recognizing the structural links between different market segments in the fish supply chain, we postulate a long-run price relationship. If the long run exists (long run equilibrium depends on statistical cointegration among the price variables of interest), then there must also exist a short-run model defining the links and behavior of prices to short-run shocks.

An error-correction (EC) model will be used to identify econometrically both the short- and long-run parameters for the farmers (first-hand market), to predict the length of time for price adjustment to regain the long-run equilibrium after shocks to the equilibrium and to simulate price response. The model will also be used to estimate market power at different stages of the catfish value chain in the U.S.

Results at a glance...

- *A summary table of federal marketing orders and quality standards for various segments of U.S. agriculture has been developed as well as a narrative summary of the use of federal marketing orders in U.S. agriculture.*

University of California at Davis

One of the fundamental purposes of this project is to study and recommend forms of producer collective action to the U.S. farm-raised catfish industry. If producers are able to act effectively together they will be better able to countervail market power exercised by processors, combat ills caused by international competitors, and build demand for their product. Enhanced demand in turn will enable U.S. farm-raised catfish farmers to receive higher prices and earn higher incomes.

Federal legislation in the United States affords producers of agricultural and aquaculture products the ability to act collectively to market their production. The Capper-Volstead Act of 1922 authorizes farmers to jointly market through cooperatives, while the Agricultural Marketing Agreement Act of 1937 allows producers of a specific commodity in a given geographic region of the country to establish and maintain a federal marketing order. Cooperatives and marketing orders are not mutually exclusive; they can be used in concert to serve producers' marketing objectives.

The present focus of UC Davis is on federal marketing orders including 1) analyzing the tools and strategies available under marketing orders, 2) evaluating the results of using marketing orders in other U.S. agricultural industries, 3) assessing how establishing a marketing order may benefit the U.S. farm-raised catfish industry, and 4) determining what specific marketing-order provisions should be considered by the industry.

Under the auspices of federal marketing order regulation, producers have a variety of provisions at their disposal including, but not limited to: volume/supply control, generic promotion and advertising, and minimum quality standards. Our research to date suggests that the minimum quality standard and generic promotion provisions offer the most potential to U.S. farm-raised catfish producers, especially given the increased international competition faced by the industry from China and Vietnam (Section 8e of the Agricultural Marketing Agreement Act of 1937, amended in 1954, requires that importers comply with the same minimum quality standards, adopted by the marketing order, that domestic producers face).

These importers are supplying the U.S. market with catfish raised in suboptimal conditions that can directly affect the taste and quality of the fish marketed. Consumers' inability to distinguish quality of catfish ex ante constitutes an adverse selection problem wherein poor quality can drive good quality from the market and reduce consumer demand. Imposing minimum quality standards through a federal marketing order represents one option for U.S. farm-raised catfish farmers to address problems caused by inferior imported products. Under U.S. law, imports must meet the same standards that a domestic agricultural industry imposes upon itself.

Generic commodity promotion programs have an extensive history within U.S. agriculture, and numerous studies have documented their overall effectiveness. Economic evaluation of such programs reveals that they are most effective when commodity markets involve relatively undifferentiated products that, in the absence of a mandatory industry program, would be under-promoted due to free riding. Such conditions are present in the U.S. farm-raised catfish industry. Two small promotion programs are in place presently for promoting U.S. farm-raised catfish. Both operate at the state level and one of them is voluntary, so free riding and under-promotion is a genuine concern under the present structure, creating the potential in our view to achieve producer benefits through a federal program encompassing all major U.S. producing areas and possibly also involving contributions from international competitors.

Details the history and current use of marketing orders and reviews relevant literature are presented in the Appendix, with specific focus upon the minimum quality standard and generic promotion provisions. Table 1, *Federal Marketing Orders and Quality Standards,* shows that each extant federal marketing order contains provisions for generic commodity promotions and indicates the orders that utilize minimum quality standards and the types of provisions that are utilized.

University of Missouri

Project activities of the University of Missouri to date include: 1) Review of conceptual models of alternative marketing cooperatives utilized by agricultural and aquacultural producers before attending the initial August 16, 2011 meeting; 2) Identification of several models and correlations with institutional environments where highest probability of success might emerge; 3) Attendance at initial research meeting in Pine Bluff, Arkansas, August 16, 2011; 4) Presentation at the initial meeting of a Life Cycle Approach to examining the intra-firm challenges to developing collective action among and within the US catfish industry; 5) Engaged in discussions with team researchers and industry participants regarding the advantages disadvantages of alternative marketing options which included: state marketing orders, federal marketing orders, marketing boards, traditional cooperatives, new generation cooperatives and, Limited Liability Companies; 6) Commenced search into background and history of collective action attempts applied to aquaculture industry in the U.S.

Table 1. Federal Marketing Orders and Quality Standards

Commodity	Promotion	Grade	Size	Quality	Section 8e
Florida Citrus Fruit	X	E	E		X
Texas Oranges and Grapefruit	X	E	E		X
Florida Avocados	X	E	E		X
California Nectarines	X	E	E		
California Pears and Peaches	X	E	E		
California Kiwifruit	X	E	E		
Washington Apricots	X	E	E		
Washington Cherries	X	E	E		
Washington-Oregon Fresh Prunes	X	A	A		
California Desert Grapes	X	E	E		
Oregon-Washington Pears	X			X	
Cranberries-10 states	X	E*	E*		
Tart Cherries-7 states	X	A			
California Olives	X	E	E		
Idaho-East Oregon Potatoes	X	E	E		X
Washington Potatoes	X	E	E		X
Colorado Potatoes	X	E	E		X
Virginia-North Carolina Potatoes	X	E	E		X
Georgia Vidalia Onions	X				X
Walla Walla Onions	X	A	A		X
Idaho-Oregon Onions	X	E	E		X
South Texas Onions	X	E	E		X
Florida Tomatoes	X	E	E		X
California Almonds	X			X	
Oregon Hazelnuts	X	E	E		X
California Pistachios	X		E	X	
California Walnuts	X	E	A		X
Far West Spearmint Oil	X				
California Dates	X	E	E		X
California Raisins	X	E	E		X
California Dried Prunes	X	A	A		
Oregon and California Potatoes	X				

Source: USDA, 2007. E=In effect, A=Authorized but not in effect, E*=In effect to withheld or reserve product.

Auburn University

Project activities of Auburn University to date included attending the initial project meeting held at UAPB August 16, 2011 with all project participants, including catfish farmer advisory group members and participating in the discussion of the implications of the Capper-Volstead Act of 1922 and the Agricultural Marketing Agreement Act of 1937 on agricultural producers and potentially for aquaculture producers. The former act authorized farmers to market their products collectively through cooperative organizations, while the latter act allowed industries to self-regulate through marketing orders. Auburn University's role in the discussion was primarily to provide University of California at Davis (Richard Sexton) and University of Missouri (Michael Cook) information about the U.S. farm-raised catfish industry, current and historical and understand better agricultural cooperative option and their potential in the U.S. farm-raised catfish industry. The meeting also reviewed project tasks, responsibilities and time frames.

Kentucky State University

Kentucky State University is engaged in a detailed literature review of agricultural marketing research associated with community supported agriculture (CSA) and their willingness to add aquaculture products on their offering. Additionally, Kentucky State University scientists are compiling a list of CSA that are currently operating in Kentucky, methods for producers to register to CSAs, and government initiatives available to CSAs that can help aquaculture producers. The results of this search will be published as a newsletter article in Kentucky Aquatic Farming, a regional aquaculture industry magazine.

Objective 2. *Develop comprehensive economic analyses to evaluate likely impacts on the U.S. farm-raised catfish industry of implementing proposed structures identified under Objective 1. Results would measure effects on product price, product volume, product characteristics, size of the industry, and competitiveness with imports.*

Much of the work specified in Objective 2 will be carried out in the second year of the project, following the identification of the most promising types of producer collective action.

Kentucky State University

Kentucky State University is searching for cooperating restaurants, farmers' markets, and Hispanic markets for a local catfish sales experiment. These markets will be selling local catfish for a few months and collecting relevant marketing and consumer perception data.

IMPACTS

This is a new project, with no impacts to date.

PUBLICATIONS, MANUSCRIPTS OR PAPERS PRESENTED

None to date.

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APPENDIX

Marketing Orders: Commodity Promotion and Quality Regulations

Federal marketing orders are authorized under the Agricultural Marketing and Agreement Act (AMAA) passed by Congress in 1937 (7 U.S.C. §601 *et seq.*). The AMAA and subsequent amendments provide for five general types of regulatory actions: 1) restrictions on the quantity of a commodity that can be sold, either through marketing allotments or reserve pools, 2) limits on the grade, size, or quality of the commodity, 3) regulation of packaging and container sizes, 4) generic promotion and advertising, and 5) production and health-related research.

The AMAA was amended by Congress in 1954 to include "marketing development projects" and in the 1996 farm bill (P.L. 104-127) wherein Congress granted to the U.S. Department of Agriculture (USDA) the ability to create promotion programs for any commodity if the producers wished to have such programs. This amendment stipulated that advertising conducted under a federal marketing order must be generic in nature and not a benefit to some producers and not others. Promotion programs created under this legislation thus "stand alone" and do not operate under the auspices of a federal marketing order.

Federal marketing order programs must be for specific commodities and in as small a region as possible to further the objectives of the order. The process to create a federal marketing order begins with a producer initiative to the USDA. The USDA will conduct hearings on the proposal and if the industry's rationale seems consistent with the AMAA and subsequent amendments, the proposal is put to an industry referendum. If two-thirds of the producers in an industry (or producers representing two-thirds of the value of production) vote in favor of the regulation, it is set in place and its provisions are legally binding upon all who operate under the order's auspices (a detailed overview of the establishment process is provided at the USDA Agricultural Marketing Service Website by linking to the subject "Marketing Orders and Agreements"). A vote by a simple majority vote by the producers can abolish an extant order.

Federal marketing orders operate under the control of an elected producer board whose appointments are approved by the Secretary of Agriculture. However, ultimate decision authority lies with the Secretary, who must approve board recommendations. An equivalent standard of government approval exists for marketing programs that have state authorization. In these cases approval of board decisions must come from the head of the state's department of agriculture. Programs are funded by assessments on producers and sometimes on handlers of the commodity.

Among the possible functions that can be performed under federal marketing orders, we have focused to date upon two—commodity promotion and minimum quality standards—that seem especially relevant to the U.S. catfish industry. For example, in 1999, the Arkansas Catfish Promotion Board was created to promote growth and development of the state's industry through research and promotion. The Board's funding is collected by an assessment of one dollar per ton on all catfish feed purchased by commercial Arkansas catfish producers. A state-level program with multistate production of catfish and relative product homogeneity across states means that producers from other states benefit as free riders on benefits generated from Arkansas promotions. Volume control programs, although important at the inception of the AMAA (Sexton and Alston 2009), are utilized actively today in only a few industries, and it is generally understood that the USDA will not approve new volume-control programs.

Commodity Promotion Programs

The main justification for generic commodity programs is that agricultural products are, essentially, homogeneous (undifferentiated), and, because benefits of advertising by one firm inure to all firms, free-rider problems create little incentive for unilateral promotion. Opponents of commodity promotion programs have challenged this characterization, arguing that their products were differentiated from those of competitors. Thus, even if total demand increased with generic advertising, the effects would not be consistent among growers. Specifically, opponents have argued that generic promotion reduced the differentiation among products and, therefore harmed producers who had worked to establish a brand identity. These arguments, notably, would appear at present to have little resonance in the U.S. catfish industry where product differentiation seems unimportant. Agricultural industries in the United States spend about $1 billion dollars annually on producer-funded, generic marketing programs. Ninety percent of all U.S. farmers pay assessments to support at least one commodity promotion program (Congressional Research Service 2005, p. 52).

The marketing programs that allow generic advertising and promotion exist under various state and federal statutes in addition to the AMAA, although the goals of the various programs are similar. So-called "stand-alone programs" are authorized by separate legislation or farm bill legislation, and are generally significantly larger in the amount of funding involved than those under marketing orders. Currently 51 agricultural industries are covered by federal programs and many others are promoted under state programs. However, only the federal programs can encompass inter-state industries. A list of federally authorized commodity marketing programs is provided in Table 1.

Nearly 250 research studies including 124 peer-reviewed journal articles and chapters in 14 books have examined the effectiveness of commodity promotion programs. The overwhelming majority of these studies have shown that the benefits outweigh the costs (Alston, Crespi, Kaiser and Sexton 2007). Most studies report a benefit-cost ratio wherein the producer benefit (additional profit) generated from the program is divided by the share of program costs borne by producers. Even if producers pay 100 percent of an assessment, the incidence upon producers will normally be less than 100 percent due to tax shifting. In nearly every study this benefit-cost ratio is higher (and often substantially higher) than one, meaning that the commodity program not only worked but worked very well because a dollar spent on it earned the industry greater than a dollar's worth of revenue. See, for example, the summary of various studies provided in Alston, Crespi, Kaiser, and Sexton (2007)

Given the general consensus on the overall effectiveness of commodity advertising programs, more recent research has focused on distributional issues. Is it true that the rising tide caused by a successful advertising program raises all boats? Scant research has addressed the claim that generic advertising can frustrate firms' attempts to create product differentiation through their own advertising. This concern is of paramount importance given the growth in number of product varieties and amount of branded advertising in modern agricultural markets. One exception is Chakravarti and Janiszewski (2004) who in a lab experiment showed that generic advertisements could reduce consumers' responsiveness to branded advertisements, thus making a firm's own advertising less successful than if the generic program did not exist, just as program opponents have argued.

Another key trend in U.S. agricultural markets that impacts promotion effectiveness is consolidation and increased market concentration in food manufacturing, and retailing. Market power of retailers and food manufacturers, both as buyers from farmers and sellers to consumers, is a legitimate concern in many markets. Only a few commodity-promotion studies have taken these considerations into account when investigating the benefits of generic marketing programs. Norman, Pepall and Richards (2008) showed that when industry concentration is low, generic programs are welfare improving but when concentration is high, there may not be a good reason to have generic advertising. Suzuki and Kaiser (1997), Kawaguchi, Suzuki and Kaiser (1997), Chung and Kaiser (2000), and Wohlgenant and Piggott (2003) looked at the effect of generic advertising by size of firm and/or in imperfectly competitive markets and in markets with differing farm supply elasticities, finding various differential effects among producers.

These studies suggest that outside of the idealized market setting where goods truly are homogeneous and firms are unable to differentiate their products, the market structure of the industry is immensely important to understanding the potential of generic promotions to boost farmers' incomes. Further, while most studies examine what is happening at the production sector, Zhang and Sexton (2002) examined the entirety of the supply chain and showed that at least half of the benefits from an advertising program will not get to the farmers if either the processing or retailing sectors are imperfectly competitive, and will instead be captured by the players holding market power.

What if promotions succeed in raising consumer demand, but downstream sellers such as retailers and food-service establishments capture that demand shift in the form of higher prices? No more farm product is sold in such a case, and, thus, farmers derive no benefit from a program that "worked" in the sense of raising consumer demand. Little research has been conducted into such possibilities. One exception is work by Carman, Li, and Sexton (2009), which used retail-level scanner data to examine both price and quantity impacts of promotions conducted by the Hass Avocado Board. They found no evidence that retailers raised prices in response to avocado promotions.

Relevant directly to the U.S. catfish industry is the comparison of voluntary commodity promotion programs to mandatory programs. For example, the Alabama Catfish Producers Association administers a voluntary catfish commercial feed assessment of 50 cents per ton of feed manufactured, bought, and sold in Alabama to fund the research and promotion activities of Alabama catfish producers. Whereas mandatory programs must have federal or state mandates and supervision, voluntary programs can operate entirely under industry auspices. Messer, Kaiser, and Schulze (2008) examined voluntary programs, noting that many of today's mandatory programs began as voluntary programs. They report that free riding on voluntary programs tends to increase over time, often causing producers to seek to establish mandatory programs. These authors conducted experiments with voluntary promotion programs that tended to replicate the progressive incidence of free riding in successive iterations of the experiment. However, the introduction of a "provision point mechanism", which is a threshold participation rate (70 percent in their base case), substantially reduced free riding. If participation falls below the provision point, all contributions are refunded and no expenditures take place, limiting the opportunity to free ride.

Minimum Quality Standards

Federal marketing orders enable producers to self regulate the quality of their production with approval by the Secretary of Agriculture by choosing whether or not to impose minimum quality standards (MQS) and what standards to set. Through amendments to the AMAA enacted in 1954 (section 8e) imports can be made subject to the same quality standards, regulations, and other provisions as are imposed upon domestic production by a marketing order. Thus federal marketing orders allow industries to influence international competition and protect the domestic market from being downgraded by the receipt of poorer quality product from abroad. Article III of the General Agreement on Tariffs and Trade (GATT) requires that imports not be held to higher standards than domestic production, therefore section 8e requirements can only be effect when domestic production is being produced, regulated, and shipped (USDA, 2007). Yet, since catfish are grown, processed, and sold on a year-round basis, section 8e requirements would apply to imports on a continuous basis.

MQS imposed through federal marketing orders are relatively common for fruit and vegetable commodities in the United States. Currently, 16 of the 31 commodities regulated under federal marketing order statutes are subject to section 8e requirements of the AMAA. A summary of these commodities and the specific product attributes regulated is provided in Table 1 *Federal Marketing Orders and Quality Standards*. Of the 31 marketing orders currently operating under the federal statutes, 29 have some combination of grade, size, quality, or maturity provisions authorized or in effect (USDA, 2007). Twenty-five of the federal marketing orders have minimum grade standards in place, 25 have size regulations in authorized or in effect, and 3 have general "quality" regulations in effect.

Increasing international competition faced by domestic farm-raised catfish producers and growing concerns of U.S. consumers surrounding the safety and quality of fish make the establishment of MQS worthy of U.S. catfish producers' consideration. Since 2003 U.S. farm-raised catfish producers have faced increased international competition, primarily from Vietnam and China. From May 2010 to May 2011, the U.S. has seen a 64 percent increase in the amount of Siluriforme catfish imported (USDA 2011).

Catfish produced in Asian countries are typically raised in floating cages on rivers and ponds while being fed a diet of agricultural by-products consisting of rice bran, soy, and fish by-products (Orban et al. 2008). In addition to being subject to chemical contamination from high anthropic pollution, fish raised in these fresh-water, caged environments also often test positive for organochlorine pesticides and polychlorinated biphenyls (PCBs), which have been banned in the U.S. due to human health concerns (Orban et al. 2008).

Processed catfish cuts and fillets are relatively indistinguishable in terms of their origin. As such, without mandatory country-of-origin labeling and/or safety and quality standards in place, imported fish with inferior quality or taste may compromise domestic demand. The problem as described originally by Leland (1979) is one of adverse selection or Gresham's law. When both high-quality and low-quality products are available on the market and are indistinguishable ex ante to consumers Gresham's law states that the bad product will drive the good product out of the market. One potential solution to this problem is for individual farmers to attempt to voluntarily the quality of their production. Such certification is, of course, costly and often ineffective because consumers are generally skeptical as to the reliability, stringency, and credibility of voluntary certification. Thus, certification of quality at the industry level is often necessary to surmount the adverse selection problem. MQS maintain and/or enhance market demand for commodities by ensuring that the poorest quality product doesn't reach consumers (Carmen and Alston, 2005) and, thus, deter them from making future purchases. MQS in this setting can at once mitigate imports, improve overall product quality, and stabilize or increase consumer demand (international shipments that do not meet the MQS may be reconditioned for re-inspection, re-exported, or sent to an exempt use).

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REPRODUCTION AND LARVAL REARING OF FRESHWATER ORNAMENTAL AND MARINE BAITFISH

Reporting Period
January 1, 2011 – August 31, 2011

Funding Level	Year 1	$167,934
	Year 2	$169,429
	Year 3	$162,637
	Total	$500,000

Participants	University of Florida (Lead Institution)	Cortney Ohs, Craig Watson
	Louisiana State University	Chris Green, Ronald Malone
	Mississippi State University	Louis D'Abramo

PROJECT OBJECTIVES

1. Develop improved technologies for spawning and larval rearing of pinfish

   a. Evaluate efficacy of catfish pituitary extract on spawning induction of pinfish.
   b. Evaluate dosing of catfish pituitary extract on spawning induction of pinfish.
   c. Compare human chorionic gonadotropin and catfish pituitary extract on the spawning induction of pinfish.
   d. Evaluate commercial rotifer enrichments and their effects on larval survival and growth.
   e. Evaluate larval feeding regimes employing copepods and rotifers and their effects on larval survival and growth in pinfish.
   f. Evaluate the effects of stocking density on survival and growth of larval pinfish.

2. Develop improved technologies for spawning and larval rearing of goggle eye.

   a. Evaluate the efficacy of Ovaprim on spawning induction of goggle eye.
   b. Evaluate larval feeding regimes employing copepods and rotifers and their effects on larval survival and growth.
   c. Evaluate the effects of stocking density on survival and growth of larval goggle eye.

3. Evaluate spawning substrate preference for captive ballyhoo.

4. Develop improved technologies for egg hatching and larval rearing of *Fundulus grandis* and *Fundulus seminolis*

   a. Evaluate air incubation of *Fundulus* sp. eggs.

b. Identify a replacement of live feeds for Fundulus.
c. Determine relationship between larval density and performance in *Fundulus*.

5. Develop improved technologies for spawning and larval rearing of Bala shark

a. Improve Bala shark broodstock maturation.
b. Develop technologies for induced spawning of Bala shark.
c. Develop improved technologies for larval rearing of Bala shark
d. Design water treatment technologies for commercial larval rearing of Bala shark

6. Publication, Extension, and Dissemination of results.

PROGRESS AND PRINCIPAL ACCOMPLISHMENTS

Objective 1. *Develop improved technologies for spawning and larval rearing of pinfish*

Objective 1 has not been addressed in this new project.

Objective 2. *Develop improved technologies for spawning and larval rearing of goggle eye.*

Objective 2 has not been addressed in this new project.

Objective 3. *Evaluate spawning substrate preference for captive ballyhoo.*

Objective 3 has not been addressed in this new project.

Objective 4. *Develop improved technologies for egg hatching and larval rearing of* Fundulus grandis *and* Fundulus seminolis

Sub-objective 4a. *Evaluate air incubation of* Fundulus *sp. eggs.*

Louisiana State University

For *Fundulus grandis* and some related coastal species, spawning events are timed to semilunar tidal cycles where embryos are deposited at the high water mark of marsh grasses during spring tide and are exposed to air once the tide recesses. During this period, commonly referred to as terrestrial incubation, embryogenesis occurs at an accelerated rate compared to incubation in typical aquatic conditions. The goal of this work on air incubation was to determine developmental and physiological responses of Gulf killifish embryos to terrestrial incubation and extended incubation at temperatures of 20, 23, 26, and 30 degrees C. Specifically, the objectives of this study were to determine: 1) if air incubation influences the rate of embryo development; 2) embryonic heart rates during terrestrial embryogenesis and; 3) the extent to which delayed hatch can be extended. Embryos were manually removed from the spawning substrate material and dead and pigmented embryos were discarded. Live embryos were quantified and treatments consisted of approximately 1,300 embryos sandwiched between two pieces of polyurethane hobby foamin triplicate for each respective temperature treatment. A solution of saline water (7.6 g/L)was mixed using artificial sea salts and was used to moisten the foam. Embryos and hobby foam were then covered with plastic to prevent desiccation while in the incubation chambers. Incubation chambers were set to nominal values of 20, 23, 26, and 30 degrees C with adjustable thermostats.

Time required for embryos to progress through five stages of development was recorded to determine the rate of embryogenesis. Staging was based upon descriptions detailed for the mummichog. Twelve embryos were randomly selected from each temperature-treatment triplicate to determine stage of development. If more than 75% of embryos were at a target stage, treatments were sampled for heart rate and ammonia, urea, and lactate concentrations. Embryos began terrestrial incubation for this study at stage 15. Stage 35 marked the stage at which embryos attain the ability to hatch when placed in an aqueous medium and therefore the transition into delayed hatch. Replicates were sampled in 48-hour delayed hatch intervals after reaching stage 35 until embryos could no longer be sampled due to mortalities. Embryos were sampled at 48-hour intervals for heart rate, morphometric parameters at hatch, and ammonia, urea, lactate and ATP concentrations.

Temperature did not have a significant influence on percent of viable embryos at stage 25. Percent of viable embryos were 59 ± 2% at 20 degrees C, 62 ± 3% at 23 degrees C, 58 ± 8% at 26 degrees C, and 75 ± 1% at 30 degrees C. Temperature had a significant effect on the longest extent of time that delayed hatch embryos remained viable. Embryos began to hatch spontaneously on the substrate beginning at 96 delayed hatch hours in the 26 degrees C and 30 degrees C, but did not hatch on the substrate in the 23 and 20 degrees C treatments. The longest extent of delayed hatch was 320 hours post stage 35 for the 20 degrees C treatment, followed by 272, 224, and 176 h for 23, 26, and 30 degrees C treatments, respectively. Hours of delayed hatch was significantly related to the total length (TL) of the embryo upon hatch. Size at hatch (TL) and body cavity area were not significantly related to temperature.

An accelerated rate of embryogenesis was observed during air incubation relative to aquatic incubation of this species. Temperature associated stresses were also observed in addition to stresses caused by air incubation. Embryogenesis for the 30 degrees C treatment was relatively brief compared to lower temperatures and first hatch occurred at 96 delayed hatch hours, although embryo viability began to decrease upon the initiation of delayed hatch and high urea concentrations were observed with delayed hatch. Temperature can likely be modified during incubation to custom delay or accelerate embryo development based on the specific need of the culturist to time the hatching of different batches of eggs.

Sub-objective 4b. *Identify a replacement of live feeds for* Fundulus

University of Florida Indian Research and Education Center

Use of amicroparticulate diet for culture of *Fundulusseminolis* larvae saves time, space, and labor associated with live feeds, eliminates the potential of disease introduction from the live feeds, and ultimately should reduce the cost of production of juvenile fish.

The microparticulatemicrobound diet used was previously proven to be an effective and complete substitute for live *Artemia* nauplii in the culture of two species of crustaceans, *Macrobrachium rosenbergii* and *Litopenaeus vannamei*, and zebrafish (*Danio rerio*). The diet served as a partial *Artemia* replacement for 20-days post-hatch pinfish larvae and is being tested with larvae of several different marine fishes. Use of anmicroparticulate diet saves time, space, and labor associated with live feeds, eliminates the potential of disease introduction from the live feeds, and ultimately should reduce the cost of production of juvenile fish.

Larval *Fundulus seminolis* were cultured in consisted of 15-L circular fiberglass tanks with flow-through water providing an exchange of approximately 2 tank volumes/day. Upon hatching, 50 larvae were randomly stocked into a tank and randomly assigned one of three diet treatments: microbound microparticulate diet exclusively for 15 days (MICRO), *Artemia* nauplii exclusively for 15 days (ART), or *Artemia* nauplii for 5 days followed by a mix of *Artemia* and microparticulate diet for 5 days followed by the microparticulate diet exclusively for the remaining 5 days (MIX). There were 5 replicates assigned for each treatment.

The microparticulate diet was developed by L. R. D'Abramo at Mississippi State University. On a dry weight basis, the proximate composition of the microparticulate diet was 46.1% crude protein and 37.4% crude lipid. The microparticulate diet was stored frozen at -20 degrees C. Prior to every feeding, a portion of the microparticulate diet was removed from storage and added to a small volume of culture water. This was done to prevent it from clumping and floating, and to achieve a homogeneous particle size. Larvae were fed the microparticulate diet in excess twice daily.

The proximate composition of *Artemia* nauplii on a dry weight basis was 53.8% crude protein and 16.2% crude lipid. *Artemia* cysts were disinfected prior to hatching by exposing to a 2% hypochlorite solution for 10 minutes and aerated. *Artemia* cysts were disinfected and hatched daily at a salinity of 3 g/L. After harvesting, the concentration of hatched *Artemia* was determined by counting a subsample so each treatment received the same amount of *Artemia*. Larvae were fed in excess twice daily. Before feeding, uneaten microparticulate diet and dead *Artemia* were removed from the bottom of each tank. Excess uneaten live *Artemia* were removed from the surface of the water with a fine-mesh net.

At 0, 5, 10, and 15-days post-hatch, five larvae were removed from each tank. Photographs of larvae were taken using a stereo microscope outfitted with a digital camera to measure total length (TL) of each larva.

There were significant differences in total length of larvae among diet treatments at 5, 10, and 15 days post-hatch (Table 1). ART larvae were the largest during the 15-day experiment. Survival among the treatments was significantly different. The MIX diet larvae had no mortalities during the experimental period. The growth of larvae in the MICRO and MIX treatments were 71.5% and 83.9%, respectively, of that of the MICRO treatment after 15 days. However, the feeding schedule used in this experiment most likely affected growth in the

Table 1. Mean TL ± SE of larvae at 0, 5, 10, and 15 days post hatch (dph) and mean survival at the conclusion of the study. Within a row, different letters denote significant differences in TL and survival (*P*#0.05).

	MICRO	ART	MIX
Total length (mm)			
0 dph	8.36 ± 0.09 z	8.36 ± 0.07 z	8.39 ± 0.09 z
5 dph	9.17 ± 0.06 y	9.77 ± 0.34 yz	10.29 ± 0.09 z
10 dph	10.00 ± 0.12 y	13.80 ± 0.20 z	13.29 ± 0.24 z
15 dph	11.58 ± 0.16 x	16.20 ± 0.17 z	13.59 ± 0.15 y
Survival (%)	95.20 ± 0.02 y	99.20 ± 0.01 z	100.00 ± 0.00 z

treatments which received microparticulate diet because live *Artemia* nauplii were available in the water column for a longer period of time than the microparticulate diets. *Artemia* nauplii were present in the appropriate tanks at the next feeding. If the microparticulate diet would have been available in the water column for a longer period of time, the larvae may have been able to increase consumption, thereby increasing growth. If the feeding of the microparticulate diet had been split into more feedings or placed in an automatic feeder, the results may differ. Feeding schedules need additional investigation.

This study was the first evaluation of diets to be used for culturing *F. seminolis* larvae. A 95% survival was achieved in larvae fed the MICRO diet exclusively for 15 days. While the survival was statistically significantly less than the survival in the MIX and ART treatments, survival was very high and can be considered a success in the larval culture of *F. seminolis*. This study demonstrated that *F. seminolis* larvae can be cultured exclusively on a microparticulate diet from 0 to 15 dph.

Results at a glance...

- *This was the first study to show that microparticulate diets can be used to culture* Fundulus *larvae. Survival of fish fed the microparticulate diet alone from 0 to 15-days post-hatch was 95%.*

Sub-objective 4c. *Determine relationship between larval density and performance in* Fundulus.

Sub-objective 4c has not been addressed in this new project.

Objective 5. *Develop improved technologies for spawning and larval rearing of Bala shark.*

Sub-objective 5a. *Improve Bala shark broodstock maturation.*

Sub-objective 5a has not been addressed in this new project.

Sub-objective 5b. *Develop technologies for induced spawning of Bala shark.*

University of Florida Tropical Aquaculture Laboratory

Bala sharks (*Balantiochelios melanopterus*) are a high value and popular freshwater ornamental species but are only available from farms in Asia. Bala sharks have presented unique challenges in broodstock development, spawning techniques, and larval rearingfor the U.S. ornamental aquaculture industry.

Bala sharks (2 g average weight) were purchased from a local importer. Fish were stocked directly into two outdoor ponds. Pond water temperature was 29 degrees C. Six fish were sampled for dissection and histological examination of gonadal development. Fish were removed from the ponds in October and placed in recirculating water tank systems in a heated green-house. Gonadal samples were taken once a month since May 2011 to determine gonad maturation. At each sampling, twelve fish were anesthetized, weighed and measured, and an attempt was made to express sperm or extract eggs. For males, sperm maturation is determined by manually expressing sperm. For female sexual maturation, we are looking for fish that appear to be "fat." When a fish is suspected as a female, a small catheter tube is inserted into the genital opening in an attempt to extract eggs. Subsamples of fish were used to determine the maturational stage on December 23, 2011. Mean weight of the fish was 26.5g and mean length was 14.1 cm. To date, no eggs have been collected and no viable sperm has been expressed. The fish will be returned to open ponds in late March or early April, 2012.

Sub-objective 5c. *Develop improved technologies for larval rearing of Bala shark.*

Subobjective 5c has not been addressed in this new project.

Sub-objective 5d. *Design water treatment technologies for commercial larval rearing of Bala shark.*

Louisiana State University Agriculture Engineering, University of Florida Tropical Aquaculture Laboratory

Eggs of fish are commonly collected and are incubated in a variety of hatching tanks and systems. There is no consistent design and most tanks and filters used are not capable of handling large inputs of ammonia and other compounds released from hatching and decaying egg masses. A design of a water treatment strategy appropriate for use in commercial larval production systems capable of handling shock loading of these compounds is necessary and this type of system has application for many species of fish.

In year 1 of this project the LSU research component focused its efforts on the design of water treatment components capable of responding to shock loading of total ammonia nitrogen and organic matter when a proportion of the egg mass decays in a recirculating system. This effort has been divided into two steps.

The first step was to identify a surrogate to Bala shark eggs that would permit the research team to conduct shock loading response experiments in the LSU laboratory. The research team has also acquired supplies necessary for conducting analysis defining the organic and nitrogen loading for a variety of egg types. Since Bala Shark eggs are not yet available to the team, techniques for freeze drying eggs were developed utilizing trout egg masses. Student workers were trained to conduct the chemical analysis. Freeze dried egg matter from the trout eggs was then used in a preliminary chemical analysis. A no-cost extension has been approved to facilitate completion of this task in the spring semester as the Bala Shark eggs become available to the LSU-AE research team.

The second step was to initiate the design of treatment components for evaluation. In support of this, visits between the LSU and University of Florida research teams were made to observe the current breeding practice and establish system size. The LSU team has constructed and is evaluating appropriately sized prototype floating bead, fluidized sand, and moving bed reactors. Formal testing of the units will be conducted once the waste characterization work is complete.

IMPACTS

There are no impacts from this new project.

PUBLICATIONS, MANUSCRIPTS OR PAPERS PRESENTED

Publications

Brown, C.A., and C.C. Green. Metabolic and embryonic responses to terrestrial incubation of gulf killifish embryos across a temperature gradient. Journal of Experimental Biology. Submitted.

Coulon M.P., C.T. Gothreaux, and C.C. Green. Influence of substrate and salinity on air incubated Gulf killifish embryos. North American Journal of Aquaculture. In press

Presentations

Fisher, C., and C. Green. 2012. Effect of stocking density and potassium ion concentration on growth, survival, and ion regulation in gulf killifish (*Fundulus grandis*). Aquaculture America 2012. Las Vegas, Nevada.

Ohs, C.L., L.M.V. Onjukka, M.A. DiMaggio, and J.S. Broach. 2012. Current status of the culture of the Seminole killifish *Fundulus seminolis* as a freshwater and marine baitfish. Aquaculture America 2012. Las Vegas, Nevada.

Onjukka, L.M.V., J.S. Broach, and C.L. Ohs. 2011. Spawning success of *Fundulus seminolis* in tanks at various densities and salinities. Aquaculture America 2011. March 1-3, 2011, New Orleans, Louisiana. New Orleans, Louisiana.

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EFFECTS OF MOSQUITO ABATEMENT PESTICIDES ON VARIOUS LIFE STAGES OF COMMERCIALLY IMPORTANT SHELLFISH AQUACULTURE SPECIES IN THE SOUTH

Reporting Period
March 1, 2011 – August 31, 2011

Funding Level	Year 1	$40,000
	Year 2	$40,000
	Total	$80,000

Participants	College of Charleston	Dr. Craig Plante, Graduate Program in Marine Biology
	Florida Atlantic University	Dr. Loren D. Coen

PROJECT OBJECTIVES

1. Review the various mosquito abatement pesticides utilized in the Southern United States near the major shellfish hatchery and nursery facilities and select a larvicide and adulticide of most concern, based on application data and available toxicity data, for further bioassay testing.

2. Use standard toxicity testing protocols to assess the potential impacts of the mosquito control larvicide and adulticide pesticides of most concern on larval and post-set (1-3 mm) hard clams, *Mercenaria mercenaria*, and Eastern oysters, *Crassostrea virginica*.

3. Disseminate information to shellfish hatchery operators and agencies responsible for mosquito abatement through SRAC Fact Sheets and meetings.

ANTICIPATED BENEFITS

Developing (larval and juvenile) shellfish may be subject to many environmental and biological stressors, including predation, disease, abiotic variables (temperature, dissolved oxygen, salinity, pH), and chemical contamination. Mosquito control pesticide applications often coincide with both the location of shellfish hatcheries and nurseries, as well as the season(s) when sensitive early life stages are occurring. Shellfish aquaculture facilities are concerned with mosquito spraying activities as they may impact their source water and thereby their larval or juvenile offspring or their algal cultures, potentially causing significant mortality. Currently, toxicity data for mosquito control chemicals and larval clams and oysters are limited (Table 1).

This Southern Regional Aquaculture Center (SRAC)-supported project will establish the concentrations required to cause mortality in early molluscan life stages, and enable us to predict whether these chemicals will have adverse effects on coastal shellfish operations or for that matter, native field populations. The potential impacts of this work are increased knowledge of the effects of mosquito control chemicals on molluscan shellfish, as well as improved management strategies for competing uses of coastal resources.

Table 1. Summary of existing organophosphate and pyrethroid toxicity data for *M. mercenaria* and *C. virginica*.

Active Ingredient	Chemical Class	Species	Life Stage	Toxicity (µg/L)	Source
Chlorpyrifos	Organophosphate	*M. mercenaria*	212 micron	250 (96h LC50)	Chung *et al.*, unpub.
Chlorpyrifos	Organophosphate	*C. virginica*	Juvenile	270 (96h EC50)	Mayer, 1987
Chlorpyrifos	Organophosphate	*C. virginica*	Embryo	2000 (48h EC50)	Mayer, 1987
Malathion	Organophosphate	*C. virginica*	Juvenile	>1000 (48h EC50)	Mayer, 1987
Malathion	Organophosphate	*C. virginica*	Juvenile	>1000 (96h LC50)	Mayer, 1987
Naled	Organophosphate	*C. virginica*	Juvenile	590 (96h EC50)	Mayer, 1987
Dichlorvos	Organophosphate	*C. virginica*	Juvenile	>1000 (96h EC50)	Mayer, 1987
Dichlorvos	Organophosphate	*C. virginica*	Adult	89,000 (96h LC50)	Jones and Davis, 1994
Dichlorvos	Organophosphate	*C. virginica*	Adult	31,620 (96h LC50)	Bolton-Warberg *et al.*, 2007
Resmethrin	Pyrethroid	*M. mercenaria*	212 micron	>100 (96h LC50)	Chung *et al.*, unpub.
Permethrin	Pyrethroid	*C. virginica*	Embryo	>1000 (48h EC50)	Mayer, 1987
Permethrin	Pyrethroid	*M. mercenaria*	212 micron	>100 (96h LC50)	Chung *et al.*, unpub.
Cypermethrin	Pyrethroid	*C. virginica*		370 (96h EC50)	Werner and Moran, 2008
Bifenthrin	Pyrethroid	*M. mercenaria*	1 mm	>100 (96h LC50)	Chung *et al.*, unpub.
Bifenthrin	Pyrethroid	*C. virginica*	Embryo	285 (48h EC50)	Werner and Moran, 2008
Cyfluthrin	Pyrethroid	*C. virginica*		2.69 (96h LC50)	Werner and Moran, 2008
Deltamethrin	Pyrethroid	*C. virginica*		8.2 (96h EC50)	Werner and Moran, 2008
Tralomethrin	Pyrethroid	*C. virginica*		0.006 (EC50)	EPA EFED database

PROGRESS AND PRINCIPAL ACCOMPLISHMENTS

Objective 1. *Review the various mosquito abatement pesticides utilized in the Southern United States near the major shellfish hatchery and nursery facilities and select a larvicide and adulticide of most concern, based on application data and available toxicity data, for further bioassay testing.*

College of Charleston and Florida Atlantic University

Organophosphates used in adult mosquito control include malathion, fenthion, naled, and chlorpyrifos. Some of the pyrethroids used in mosquito control include: permethrin, resmethrin, sumithrin, lambda-cyhalothrin, esfenvalerate, tralomethrin, deltamethrin, cyfluthrin, bifenthrin, cypermethrin, and etofenprox. Commercial and government applicators decide which chemical to use based on several factors such as efficacy (determined by field trials), mosquito species sensitivity, safety, and cost. The pesticide choice is made by each individual mosquito control agency and varies with location because of differences in mosquito species and application requirements. Mosquito species may develop resistance to a given insecticide over time, rendering it less effective and necessitating a change in the chemical used.

A survey (internet and phone) of various Southeastern coastal counties including Charleston, Beaufort, and Georgetown counties of SC, Chatham County, GA, Brevard, Lee, St. Lucie, and Seminole counties, FL, revealed that permethrin, resmethrin, sumithrin, and naled account for the majority of chemical use to control adult mosquitoes. The same survey revealed that methoprene-based products (Altosid) were the most common larvicide applied.

We have selected permethrin/resmethrin and naled as the initial adult mosquito control compounds for toxicity evaluation based on their frequency of use in our coastal county survey (Table 2), number of registered products, and preliminary testing data. These chemicals represent two different classes of mosquito control compounds (permethrin/resmethrin are pyrethroid insecticides, whereas naled is an organophosphate insecticide). By including two different classes of chemical, we will be able to compare organism sensitivity across chemical groups and identify the compounds of most concern to shellfish species. Methoprene will be tested as the larvicide in this project.

Results at a glance...

- *A survey of regional county mosquito abatement programs revealed that organophosphate chemicals, such as naled, and pyrethroid compounds, such as resmethrin, comprise the majority of applications for adult mosquito control. The majority of the chemicals sprayed to control mosquito larvae contain the juvenile hormone mimic, methoprene.*

Table 2. Survey of mosquito control chemicals applied in southern coastal counties.

County	State	Adulticides Used	Active Ingredient	Larvicides Used	Active Ingredient	Website/Contact
Beaufort	SC	Anvil 10+10 ULV	sumithrin	Agnique MMF	monomolecular film	http:/www.co.beaufort.sc.us/about-beaufort-county/public-safety/mosquito-control/index.php
		Biomist 30+30 ULV	permethrin	Altosid Briquets	methoprene	
		Evoluer 30-30 ULV	permethrin	Altosid Liquid Concentrate	methoprene	
		Suspend SC	deltamethrin	Altosid Pellets	methoprene	
				Altosid SBG	methoprene	
				Altosid XR Briquets	methoprene	
				Altosid XR-G	methoprene	
				Aquabac XT	Bti	
				Aquabac 400-G	Bti	
				Bactimos Pellets	Bti	
				GB-1111	petroleum hydrocarbons	
				Summit Bti Briquets	Bti	
				VectoBac 12AS	Bti	
Charleston	SC	Zenivex	etofenprox	Agnique MMF	monomolecular film	http://www.charlestoncounty.org/departments/PublicWorks/MosquitoProgram.htm
		Aqualuer	permethrin	Vectolex CG	Bti	
		Aqua-Reslin	permethrin	Altosid XR Briquets	methoprene	Ed Harne
		Anvil 10+10	sumithrin	Altosid Pellets	methoprene	
		Naled	dibrom			
		5 EC	malathion			

Georgetown	SC		permethrin		methoprene	http://www.georgetowncountysc.org/mosquitocontrol/
		Naled	dibrom		Bti	Tim Chatham, 843-545-3643
		Fyfanon	malathion			tchatman@gtcounty.org
Chatham	GA					
Brevard	FL	Naled	dibrom	Vectolex CG	Bti	http://www.flaes.org/aes-ent/mosquito/reports.html
				GB-1111	petroleum hydrocarbons	
				Altosid SBG	methoprene	
Charlotte	FL	Naled	dibrom	VectoBac 12AS	Bti	http://www.flaes.org/aes-ent/mosquito/reports.html
		Anvil 10+10	sumithrin	Altosid XR-G	methoprene	http://www.charlottecountyfl.com/PublicWorks/PestManagement/Mosquito/HealthIssues.asp
Collier	FL	Naled	dibrom	Aquabac XT	Bti	http://www.flaes.org/aes-ent/mosquito/reports.html
		Zenivex	etofenprox	Altosid Briquets	methoprene	
St. Lucie	FL	Biomist 3+15	permethrin	Agnique MMF	monomolecular film	https://www.stlucieco.gov/mosquito/more_info.htm
		Permanone 30+30	permethrin	Altosid 30-d	methoprene	
		Anvil 10+10	sumithrin	Altosid XR Briquets	methoprene	
		Duet	prallethrin+ sumithrin	Altosid XR-G	methoprene	
		Scourge 4+12	resmethrin	Summit Bti Briquets	Bti	
		Zenivex	etofenprox	Vectobac G	Bti	
				Vectolex CG	Bti	
				Natular T30	Spinosyn	
				Vectolex WSP	Bti	

Seminole	FL	Permanone - RTU	permethrin	Agnique MMF	monomolecular film	http://www.seminolecountyfl.gov/pw/mosquito/msds_labels.aspx
		Aqua-Reslin	permethrin	Altosid 30-d	methoprene	
			dibrom	Altosid Liquid Concentrate	methoprene	
				Altosid Pellets	methoprene	
				Altosid XR Briquets	methoprene	
				Aquabac 200-G	Bti	
				Aquabac XT	Bti	
				Natular T30	Spinosyn	
				Natular XRG	Spinosyn	
				Natular XRT	Spinosyn	
				VectoBac 12AS	Bti	
				Vectobac G	Bti	
				Vectolex CG	Bti	
				Vectolex WDG	Bti	
Lee	FL	Naled	dibrom	Abate 4E	temephos	http://www.flaes.org/aes-ent/mosquito/reports.html
		Fyfanon	malathion	Vectolex CG	Bti	
				GB-1111	petroleum hydrocarbons	
				Altosid	methoprene	
Manatee	FL	Naled	dibrom	Abate 4E	temephos	http://www.flaes.org/aes-ent/mosquito/reports.html
			permethrin	Altosid	methoprene	
		Anvil 10+10	sumithrin	Vectolex CG	Bti	

Sarasota	FL	Anvil 10+10	sumithrin	5% Skeeter Abate	temephos	http://www.flaes.org/aes-ent/mosquito/reports.html
		Naled	dibrom	Agnique MMF	monomolecular film	
				GB-1111	petroleum hydrocarbons	
				Altosid Pellets	methoprene	
				Altosid XR Briquets	methoprene	
				Altosid XR-G	methoprene	
				Vectolex CG	Bti	
				Aquabac XT	Bti	
				Aquabac 200-G	Bti	
Citrus	FL	Naled	dibrom	Abate 4E	temephos adulticide.php	http://citrusmosquito.org/
		Anvil 10+10	sumithrin	Vectolex CG	Bti	http://www.flaes.org/aes-ent/mosquito/reports.html
		Zenivex	etofenprox		Bs	
		Duet	prallethrin+ sumithrin	Natular XRG	Spinosyn	
				Natular XRT	Spinosyn	
				VectoBac 12AS	Bti	
				Vectobac G	Bti	
				Vectolex CG	Bti	
				Altosid XR Briquets	methoprene	
Hampton	VA					http://hampton.gov/publicworks/mosquito/index.html
Carteret	NC	Aqua-Reslin	permethrin	Altosid Pellets	methoprene	Beaufort, Tony Cahoon, 252-728-8595
				Altosid XR Briquets	methoprene	

	% of counties using
dibrom	76.92307692
permethrin	53.84615385
sumithrin	53.84615385
etofenprox	38.46153846
malathion	23.07692308
prallethrin+ sumithrin	15.38461538
resmethrin	7.692307692
deltamethrin	7.692307692
methoprene	100
Bti	92.30769231
monomolecular film	38.46153846
petroleum hydrocarbons	30.76923077
temephos	23.07692308
Spinosyn	23.07692308
Bs	7.692307692

Objective 2. *Use standard toxicity testing protocols to assess the potential impacts of the mosquito control larvicide and adulticide pesticides of most concern on larval and post-set (1-3 mm) hard clams,* Mercenaria mercenaria, *and Eastern oysters,* Crassostrea virginica.

College of Charleston and Florida Atlantic University

Shellfish aquaculture facilities are concerned that environmental risk assessments of mosquito control pesticides do not include enough larval and small post-set molluscan shellfish information in the overall data available for assessments. The Eastern oyster, *Crassostrea virginica* forms living subtidal and intertidal reefs in many Atlantic and Gulf coast estuaries. Hard clam populations also are critical species in the ecosystems where they naturally occur. At present hard clam *(Mercenaria mercenaria)* aquaculture undoubtedly occurs in more Eastern U.S. states than any other native bivalve species under culture. Hence these two species are ideal candidates for focused research relating to impacts from spraying for mosquitoes. Specifically, there are few data available regarding the effects of mosquito control compounds on larval and juvenile forms of clams and oysters.

We identified and hired a College of Charleston graduate student to work on the project, Robin Garcia. She completed her candidacy exam in June 2011, and has drafted a thesis proposal which will include aspects of the funded project, as well as a component examining the combined effects of low pH and dissolved oxygen on mosquito control pesticide toxicity.

A commercial shellfish aquaculture company, Bay Shellfish Co., Terra Ceia, FL, was selected as the main source for all lab test animals. They are able to supply both *Mercenaria mercenaria* and *Crassostrea virginica* in the life stages requested.

Newly hatched *M. mercenaria* and *C. virginica* were shipped from Terra Ceia, and larvae were acclimated to laboratory conditions. Larval shellfish exposures to the mosquito control pesticides were conducted based on previously published, static-renewal toxicity-testing methods. Each day of the 96-hour static-renewal exposure, larvae were observed using a dissecting microscope. Mortality was noted and water quality parameters were measured (salinity, temperature, pH, and dissolved oxygen). Median lethal concentrations (LC50) with 95% confidence intervals were determined using the Trimmed-Spearman-Karber method.

Acute (96-hour), static-renewal toxicity tests were also conducted using 1-3 mm post-set clams and oysters. Tests consisted of a control and 5 treatment concentrations, with three replicates per treatment. Juveniles were exposed in aerated, 16-oz glass jars with Teflon-lined lids containing 180 mL of test media. Mortality (indicated by gaping, lack of response to stimuli, and/or shell closure for more than five minutes) was determined and a 96-hour LC50 was calculated.

We completed an initial range-finding test with larval (7-day-old) oysters and resmethrin. We determined that the acute 96-hour LC50 for resmethrin is within the range of 100-1000 μ/L. Larval clams were also

Results at a glance...

- *Acute toxicity testing with the pyrethroid compound, resmethrin, is underway. Preliminary results with 7-day-old clams indicate an median acute toxicity value of 1924 μg/L.*

tested with the compounds permethrin and deltamethrin at a concentration of 1111 μg/L. Greater than 50% mortality was not observed for either permethrin or deltamethrin at 1111 μg/L.

We completed an initial range-finding test with larval (7-day-old) clams and resmethrin. The acute 96-hour LC50 for resmethrin is within the range of 1000-10,000 μg/L. We also completed an acute toxicity test with larval (7-day-old) clams and resmethrin. The concentrations tested were 0, 123, 370, 1,111, 3,333, and 10,000 μg/L resmethrin. A preliminary 96-hour LC50 value of 1924 μg/L was determined. The test will be repeated, increasing the sample size from 24 clams per treatment to 72 clams per treatment.

Currently we are assessing the acute toxicity of resmethrin to juvenile (1mm) clams. We are expecting newly spawned clams and oysters to be available in late September-early October, at which time we will continue the larval testing.

IMPACTS

No impacts to date on this new project.

PUBLICATIONS, MANUSCRIPTS OR PAPERS PRESENTED

Presentations

Garcia, R., and DeLorenzo, M. 2011. Effects of hypoxia and low pH on mosquito control pesticide toxicity in two commercial shellfish species. Poster presentation. College of Charleston, Grice Marine Lab Graduate Student Colloquium. Sept. 23-24, 2011. Charleston, SC.

DEVELOPMENT OF BAITFISH, GOLDFISH, AND ORNAMENTAL FISH HATCHERY METHODS

Reporting Period
March 1, 2011 – August 31, 2011

Funding Level	Year 1	$59,957
	Total	$59,957

Participants	University of Arkansas at Pine Bluff	Anita Kelly, Nathan Stone
	Louisiana State University	Chris Green
	University of Florida	Cortney Ohs

PROJECT OBJECTIVES

1. Develop goldfish and ornamental fish hatchery methods that result in cost-effective methods to de-stick adhered goldfish and ballyhoo eggs from spawning substrate within 24 hours of deposition.

    a. Determine the composition of the egg matrix of goldfish and ballyhoo.

    b. Identify the compounds that will de-stick goldfish and ballyhoo eggs from spawning substrate.
    c. Perform embryo viability and hatch assays to determine toxicity thresholds for selected de-sticking agents.

2. Develop baitfish hatchery methods that result in cost-effective methods to maximize egg collection within 1-2 days of fertilization of fathead minnows.

    a. Determine the optimal nest site to male fathead minnow ratio that will maximize egg number and collection efficiency (egg per unit of substrate).
    b. Determine the effect of pond water temperature, dissolved oxygen, and depth on fathead minnow egg production in earthen ponds.

ANTICIPATED BENEFITS

Removal of eggs from spawning substrate will enable producers to hatch eggs in a controlled environment. They will be able to obtain more accurate counts of the number of fry that are stocked into ponds. Increased production costs have severely affected the profitability of bait, feeder and forage fish farming. New hatchery methods have the potential to reduce production costs and keep farms profitable.

PROGRESS AND PRINCIPAL ACCOMPLISHMENTS

Objective 1. *Develop goldfish and ornamental fish hatchery methods that result in cost-effective methods to de-stick adhered goldfish and ballyhoo eggs from spawning substrate within 24 hours of deposition.*

Sub-objective 1a. *Determine the composition of the egg matrix of goldfish and ballyhoo.*

Louisiana State University

Glycoproteins are large molecules composed of proteins and sugars that are attached to the outer membranes of fish eggs. Glycoproteins are also responsible for the "sticky" nature of eggs developed after fertilization, allowing eggs to adhere to a substrate and preventing river and tidal currents from dislodging eggs. In aquaculture settings, adhesive eggs prevent a speedy harvest of eggs and increase labor. The purpose of this sub-objective is to characterize the nature of goldfish (*Cyprinus carpio*) and ballyhoo (*Hemiramphus brasiliensis*) egg membrane glycoproteins to better identify appropriate de-sticking compounds.

Goldfish eggs were received from the University of Arkansas at Pine Bluff. Isolation of glycoproteins was first attempted using a protocol derived from Mansour, Lahnsteiner, and Patzner (2009, Animal Reproduction Science 114:256-268). The protocol was created with the assistance of Dr. Ted Gauthier and Tamara Chouljenko of the Louisiana State University H.D. Wilson Laboratories Protein Center. The protocol called for removal of the egg membrane using forceps in an isotonic saline solution seated in ice. Egg membranes were then ground in a container that was seated in ice to release the glycoproteins. The saline solution was removed and frozen at -20 degrees C for later analysis and the ground egg membranes were transferred to a new container. The egg membranes were then incubated in a urea and bicarbonate solution for 6 hours at 4 degrees C. The solution was centrifuged to pellet the egg membranes and the supernatant was tested using gel electrophoresis for the presence of proteins. Low concentrations of proteins were detected and were determined insufficient to proceed with glycoprotein staining.

A new protocol was developed from Scapigliati, Fausto, Zega, and Mazzini (1995, Comparative Biochemistry and Physiology Part B: Biochemistry and Molecular Biology 112:169-175) with the assistance of Dr. Gauthier and Mrs. Chouljenko. The new protocol called for the chorion removal over ice and 15-minute incubation in a buffered solution at 4 degrees C. The egg membranes were transferred to a solution similar to the one listed, where it was homogenized. The mixture was centrifuged to pellet the chorions and the supernatant was collected.

The Mansour protocol produced four protein bands at the highest concentration of 20 μL of sample (Figure 1, lanes 1-3). Bands were detected at approximately 125, 105, 70, and 22 kDa. Lanes 5-7 represent a lower concentration of 5 μL of sample. Lanes 8-10 represent the saline solution in which the egg membranes were homogenized. The fourth lane represents the Precision Plus Protein Standard from Biorad. Proteins isolated using the Scapigliati protocol have been measured at total protein concentrations (mean ± standard deviation) of 1,775 ± 62.21, 454.12 ± 41.37, and 1,426.22 ± 573.87 mg/L. These samples have been submitted to the H. D. Wilson protein lab for electrophoresis analysis and glycoprotein staining.

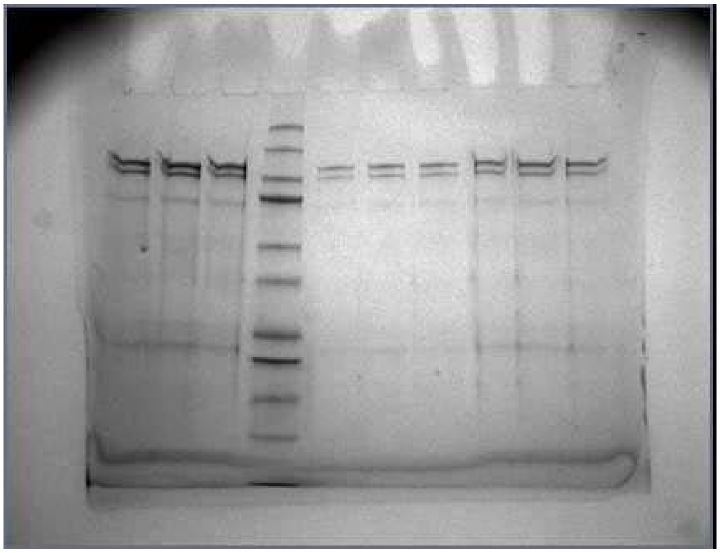

Figure 1. SDS-PAGE electrophoresis of protein samples derived from the Mansour protocol. Numbers identify samples and lanes. Arrows depict protein bands detected using Coomasie Blue staining.

With future processed samples the resulting bands from gel electrophoresis will be excised and purified. These glycoproteins will then be analyzed for composition using mass spectroscopy. The current and future results of this portion of the project are ongoing and will develop as we continue to extract and characterize these proteins.

Sub-objective 1b. *Identify the compounds that will de-stick goldfish and ballyhoo eggs from spawning substrate.*

University of Arkansas at Pine Bluff

The inability of producers to remove goldfish eggs from spawning substrate does not allow for the producer to accurately count the number of fry that are stocked into a pond. Mats are currently placed into ponds where eggs hatch. The number of eggs per mat is usually a guess and the number of fry hatched and produced in the pond is often an inaccurate estimate of the true population. De-sticking eggs from spawning material is also a bottleneck for the commercial efficiency for Ballyhoo (*Hemiramphus sp*). Another bottleneck with ballyhoo is the hatching rates of the eggs have been low. Removal of ballyhoo eggs from the spawning substrate would enable producers to efficiently collect and hatch eggs. By hatching eggs in a controlled environment, hatching rates in goldfish and ballyhoo may also be increased.

Spawning mats containing freshly laid (<12 hours) goldfish eggs were obtained from a local fish farm. Mats were cut into 3- by 3-inch squares and placed into 1-pint beakers containing one of the following concentrations of a selected solution: sodium sulfite, 1.5%, 2.0% and 3.0%; tannic acid 75% and urea 3%, 4%, 6%, and 8%; control in hatchery water; fresh squeezed pineapple juice 1%, 3%, 5% and 10%; bromelain 1%, 3%, 5% and 10%; papaya 1%, 3%, 5% and 10%; papain 1%, 3%, 5% and 10%; 4M urea;

lithium chloride 1 mg/L, 3 mg/L, 5 mg/L and 10 mg/L; cadavarine 1 mg/L, 3 mg/L, and 5 mg/L; lysozyme; acetone; sodium bicarbonate; sodium hydroxide; ammonium chloride; ethylene glycol mono-butyl ether; propolyene glycol n-butyl ether; citric acid; and alcalase, 20 mL/L, 40 mL/L and 80 mL/L. Eggs were placed into treatment solutions for 2 minutes and removed. Loose eggs and eggs still attached to the substrate were counted and the percentage of eggs removed was calculated. The eggs were then placed into a tank and allowed to hatch. Newly hatched fry were counted and the percent survival was calculated.

Significant removal of eggs was only accomplished with the alcalase enzyme. The 20 mL/L alcalase treatment removed 10% of the eggs from the mat, the 40 mL/L treatment removed 78% and the 80 mL/L treatment removed 82% of the eggs in 2 minutes. To increase the number of eggs removed the alcalase was mixed in a 3% salt solution. Removal of eggs exposed to 20 mL/L alcalase with 3% salt was 36%, for 40 mL/L was 99% and for the 80 mL/L was 100 %.

Survival of the eggs to hatch was low with less than 2% surviving. This may have been due to the fact that the eggs were not placed into hatching jars but laid in a single layer on the bottom of an aquarium. Eggs did succumb to fungal infections. Once the egg membrane compounds are identified, other potential compounds will be tested and eggs will be hatched in a hatching jar.

University of Florida

Ballyhoo were collected from the wild and held in quarantine for 21 days. They were treated with five one hour formalin baths (100 mg/L) on alternating days and were fed mysid shrimp soaked in an antibiotic for 10 days. Thereafter, they were fed a combination of mysid shrimp, krill, and pelleted feed.

Ballyhoo maintained in tanks readily spawned onto substrate constructed of pvc and plastic zip ties during late May and early June. However, only small batches of eggs were spawned daily. Three compounds at three concentrations were exposed to egg samples in triplicate. These included sodium sulfite 1.5, 3.0, 6.0%; trypsin 0.05%, 0.25%, 0.5%; and alcalase 20, 40, 80 mL/L of water each for 15 minutes each. Additionally, samples of unexposed eggs were collected to determine the composition of the egg membrane and associated microfibrils which serve to adhere the eggs to substrate.

None of these compounds has been successful at the tested concentrations and exposure time in breaking up the microfibrils which adhere the eggs to substrate and to each other. Continued evaluation of other concentrations, exposure times, and compounds will be conducted when more eggs are naturally spawned. All eggs including those unexposed, and exposed to the various chemicals are stored in a -80 degrees C freezer. The composition of the egg matrix of ballyhoo eggs will be identified in the next few months.

Sub-objective 1c. *Perform embryo viability and hatch assays to determine toxicity thresholds for selected de-sticking agents.*

This objective will be addressed once the egg membrane compounds have been identified.

Objective 2. *Develop baitfish hatchery methods that result in cost-effective methods to maximize egg collection within 1-2 days of fertilization of fathead minnows.*

Sub-objective 2a. *Determine the optimal nest site to male fathead minnow ratio that will maximize egg number and collection efficiency (egg per unit of substrate).*

University of Arkansas at Pine Bluff

A new hatchery method for fathead minnow is based on the collection of eggs from brood ponds for indoor hatching. Egg collection is costly, given the required spawning substrate and labor. The purpose of this study was to improve the efficiency of egg collection by evaluating resulting egg production from four different ratios of substrate area to male fish.

Approximately 121 rosy red fathead minnows (200 g total per pool; average weight per fish of 1.65 g) were stocked into outdoor plastic pools in June 2011. A male: female sex ratio of 1: 2 was determined by visual inspection of 100 fish. Treatments consisted of 1, 2, 3, or 4 sections of 7.6 cm-wide textured plastic geoweb material, each with an underside surface area of ~4,050 cm^2, resulting in substrate area (m^2) to male fathead minnow ratios of 0.01, 0.02, 0.03, and 0.04. Water from a reservoir replenished by a shallow well was added to each pool at a rate of 6 L/min, and constant aeration was provided using a low pressure blower. Fish were fed once daily at 3% of initial body weight with extruded commercial catfish feed (32% protein). Temperature was recorded every four hours and dissolved oxygen concentration and mortalities were recorded twice daily. The number of nests and eggs were determined every two to three days and eggs were removed with 1.5% sodium sulfite. Eggs were collected a total of eight times. Mean temperature was 29 degrees C, close to the upper limit for reproduction. Less than half of the males were actively nesting at any one time and there was no difference in the number of nests collected between treatments (Table 1).

Table 1. Mean (SEM) number of nests for each collection event, mean (SEM) number of eggs per male per day, and number of eggs per kg of fish per day. Means within a row with different letters were significantly different ($P < 0.05$).

	Substrate Area (m^2): Male			
	0.01	0.02	0.03	0.04
Mean (SEM) nests/collection	9.8 ± 4.3	9.7 ± 3.7	10.9 ± 3.2	9.2 ± 4.1
Mean (SEM) eggs $\cdot$ $male^{-1} \cdot day^{-1}$	31 ± 23^{ab}	37 ± 25^{a}	36 ± 17^{ab}	26 ± 16^{b}
Mean eggs $\cdot$ kg $fish^{-1} \cdot day^{-1}$	$6,115^{ab}$	$7,366^{a}$	$7,130^{ab}$	$5,231^{b}$

Sub-objective 2b. *Determine the effect of pond water temperature, dissolved oxygen, and depth on fathead minnow egg production in earthen ponds.*

University of Arkansas at Pine Bluff

Placing spawning substrates within brood ponds in favorable locations for egg deposition should improve egg harvest and reduce the cost per million fry. This study was designed to examine nest location and egg number on spawning substrates in relation to depth, temperature and early morning dissolved oxygen.

Two, small earthen ponds were fertilized and each stocked with adult rosy red fathead minnows with a visually determined male to female sex ratio of 7 to 10. The fish were fed once daily to satiation with extruded commercial catfish feed. Spawning substrate consisted of three, 1-m^2 sections of 7.6 cm-wide textured plastic geoweb material per pond, each suspended between a floating pipe at the surface and a weighed pipe at a depth of 1 m.

Thermographs recorded temperature every 4 hours at 25-cm intervals from the surface to a depth of 1 m, and dissolved oxygen was recorded at 25-cm intervals every morning. The number of nests and eggs were determined every two days and eggs were removed with 1.5% sodium sulfite and collected nine times. Temperature, dissolved oxygen, and other water quality parameters were similar in both ponds and within acceptable ranges for this species. Cumulatively, the number of eggs was greatest on rows 2 and 4. Depth, temperature, dissolved oxygen, and date all had interactive effects on the number of nests per day and the total number of eggs produced per day. Data analysis is continuing.

IMPACTS

None to date in this new project.

PUBLICATIONS, MANUSCRIPTS OR PAPERS PRESENTED

None to date in this new project.

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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	Yr. 1-12/01/96-11/30/97	$241,476	95-38500-1411
Composition and Feeding Strategies.	Yr. 2-12/01/97-11/30/98	$47,105	95-38500-1411
Dr. Kenneth Davis, University of		210,047	96-38500-2630
Memphis, Principal Investigator	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-	Yr.1-06/01/96-05/31/97	$29,349	93-38500-8393
Derived Off-Flavors in Warmwater		34,918	94-38500-0045
Fish Ponds. Dr. Tom Hill, University		186,560	95-38500-1411
of Tennessee, Principal Investigator	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	01/01/97-12/31/97	$3,392	93-38500-8393
Conference (In cooperation with other		308	95-38500-1411
Regional Aquaculture Centers)	**Project Total**	**$3,700**	
*Verification of Recommended Manage-	Yr. 1-01/01/97-12/31/97	$31,410	95-38500-1411
ment Practices for Major Aquatic	Yr. 2-01/01/98-12/31/98	$7,186	95-38500-1411
Species. Dr. Carole Engle, University		58,928	96-38500-2630
of Arkansas at Pine Bluff, Principal	Total Yr. 2	$66,114	
Investigator	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	2000-38500-8992
	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
	Yr. 16-05/01/11-04/30/12	$4,000	2007-38500-18470
		69,973	2008-38500-19251
	Total Yr. 16	$73,973	
	Project Total	**$1,050,213**	
*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 Aquaculture 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
		10,352	2008-38500-19251
	Total Yr. 1	$222,530	
	Yr. 2- 02/01/10-01/31/11	$23,887	2006-38500-16977
		155,213	2007-38500-19251
		16,593	2008-38500-19251
	Total Yr. 2	$195,693	
	Yr. 3-02/01/11-01/31/12	$10,830	2007-38500-18470
		63,626	2008-38500-19251
		4,000	2010-38500-21142
	Total Yr. 3	$78,456	
	Project Total	**$496,680**	
*National Aquaculture Extension Conference-2011 (In cooperation with other Regional Aquaculture Centers)	11/01/10-09/20/11		
	Project Total	**$5,000**	2007-38500-18470
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
		28,478	2007-38500-18470
	Total Yr. 1	$123,930	
	Yr. 2-06/01/10-05/31/11	$1,322	2006-38500-16977
		48,560	2007-38500-18470
		75,118	2008-38500-19251
	Total Yr. 2	$125,000	
	Yr. 3-03/01/12-02/28/13	$73,683	2008-38500-19251
	Projected-Yr. 4	$76,322	
	Project Total	**$398,935**	
Evaluation of Impacts of Potential "Cap and Trade" Carbon Emission Policies on Catfish, Baitfish, and Crawfish Farming. Dr. Claude Boyd, Auburn University, Principal Investigator	Yr. 1-01/01/11-12/31/11	$9,747	2007-38500-18470
		50,253	2008-38500-19251
	Total Yr. 1	$60,000	
	Yr. 2-01/01/12-12/31/12	$60,000	2008-38500-19251
	Project Total	**$120,000**	
Development and Evaluation of Cool Water Crawfish Baits. Dr. Ray McClain, Louisiana State University, Principal Investigator	Yr. 1-01/01/11-12/31/11	$15,108	2007-38500-18470
		22,591	2008-38500-19251
	Total Yr. 1	$37,699	
	Yr. 2-01/01/12-12/31/12	$43,503	2010-38500-21142
	Projected-Yr. 3	$43,798	

Project	Duration	Funding	Grant No.
	Project Total	**$125,000**	
Identifying Determinants for Development of Live-Market Grading Standards for Crawfish. Dr. Ray McClain, Louisiana State University, Principal Investigator	Yr. 1-01/01/11-12/31/11	$34,598	2007-38500-18470
		15,402	2008-38500-19251
	Project Total	**$50,000**	
Potential Marketing Structures for the Catfish Industry. Dr. Carole Engle, University of Arkansas at Pine Bluff, Principal Investigator	Yr. 1-01/01/11-12/31/11	$21,951	2007-38500-18470
		103,049	2008-38500-19251
	Total Yr. 1	$125,000	
	Yr. 2-01/01/12-12/31/12	$73,258	2008-38500-19251
		51,742	2010-38500-21142
	Total Yr. 2	$125,000	
	Project Total	**$250,000**	
Reproduction and Larval Rearing of Freshwater Ornamental and Marine Baitfish. Dr. Cortney Ohs, University of Florida, Principal Investigator	Yr. 1-01/01/11-12/31/11	$56,531	2007-38500-18470
		$111,403	2008-38500-19251
	Total Yr. 1	$167,934	
	Yr. 2-01/01/12-12/31/12	$169,429	2008-38500-19251
	Projected-Yr. 3	$162,637	
	Project Total	**$500,000**	
Effects of Mosquito Abatement Pesticides on Various Life Stages of Commercially Important Shellfish Aquaculture Species in the South. Dr. Craig Plante, College of Charleston, Principal Investigator	Yr. 1-03/01/11-02/29/12	$40,000	2008-38500-19251
	Project Total	**$40,000**	
Development of Baitfish, Goldfish, and Ornamental Fish Hatchery Methods. Dr. Anita Kelly, University of Arkansas at Pine Bluff, Principal Investigator	Yr. 1-03/01/11-02/29/12	$19,022	2007-38500-18470
		40,935	2008-38500-19251
	Project Total	**$59,957**	

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

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