TWENTY-NINTH ANNUAL PROGRESS REPORT

For the Period Through August 31, 2016

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

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

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TWENTY-NINTH ANNUAL PROGRESS REPORT

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EXECUTIVE SUMMARY

This Twenty-ninth Annual Progress Report seeks to provide a summary of work completed and outreach activities of the Administrative Center during the past year. Full progress reports on the 9 multi-year research and Extension projects supported by SRAC during this reporting period are available at http://www.srac.msstate.edu/annualprogressreports.html. In the past year, SRAC funded projects totaling more than $2.2 million. During the past year, these projects have resulted in 10 journal articles, 7 Extension/Outreach publications, 30 oral presentations, 1 poster presentation, 3 digital products, and has supported 20 students.

The Center's Publications project is in its twentieth year of funding. Seven new fact sheets and the new SRAC Aquaponics website were completed while several fact sheets are in the process of review or revision. The SRAC publications and AquaPlant websites were also updated with new materials. To date, the project has generated 294 technical fact sheets (276 in the current catalog), 89 update revisions, 7 web presentations, 7 software programs or web tools, and 31 videos through the SRAC PVCS Project. In the current reporting year alone, 47,492 unique users from 170 countries and territories used the SRAC Publications website to view or download SRAC publications 233,342 times. SRAC videos were viewed on the SRAC YouTube channel 43,099 times during the current reporting period. The AquaPlant website, created with funding from the SRAC PVCS Project, had 312,349 unique users that viewed 2,507,344 webpages during the reporting period.

The "Intensive, Pond-based Culture Systems" project evaluated the production efficiencies of three new catfish production systems; smaller conventional earthen ponds with increased aeration rates, split-pond systems, and in-pond raceways. The comprehensive database that is emerging from this project will be a valuable guide for farmers considering investing in the new systems. The intensive monitoring of this project has documented extremely high fish production but also high variability. In most cases net production exceeded 12,000 lbs/acre with FCRs better than 2.0:1, with production up to 17,000-19,000 lbs/acre in the best cases. This dataset provides a more complete picture of the comparative production and economic benefits of these systems than has previously been available, and enables Extension personnel to better assist farmers to make informed decisions related to adoption of these new technologies. There have been 31 presentations (most with published abstracts) to scientific and industry groups, with many more planned.

The "Split-Pond Aquaculture Systems" project is evaluating important design or management options for producing catfish, including pumping systems and oxygen management, and has developed engineering design criteria for baitfish aquaculture. Since project initiation, many farmers have toured the Stoneville facility specifically to observe the four pumping systems installed in the split-ponds. At least two farmers from Arkansas have decided to use a paddlewheel aerator pumping system to circulate water in split-ponds that are currently being constructed on their farms. Five additional split-ponds have been constructed in addition to 13 split-ponds at three cooperating catfish farms in Arkansas. Currently, a baitfish farm has built a commercial size split-pond to raise fathead minnows and harvested the first crop this year. Split-pond technologies have been further expanded to largemouth bass culture. A largemouth bass farm in McCrory, AR is planning to install split-ponds for largemouth bass food-fish production in conjunction with in-pond raceway technologies for largemouth bass stocker production in 2016. Outreach has been extensive. Twenty-five presentations have been made at producer and professional meetings on technologies developed in this project. An additional 8 publications have been published or are accepted for publication.

The objectives of the “Blue Catfish Germplasm” project are to develop a repository of cryopreserved sperm from diverse blue catfish populations to initiate genetic improvement of hybrid catfish and to develop a database for efficient storage and retrieval of cryopreserved blue catfish sperm and associated information. During the spring of 2016 sperm samples from 60 mature blue catfish males from 3 strains were collected. Cryopreserved sperm samples were successfully used to produce full- and half-sib families of blue catfish and hybrid catfish progeny that will be the basis for estimating genetic effects of blue catfish males on purebred blue catfish and hybrid catfish progeny. Progeny have been stocked in earthen ponds and will be measured for growth and carcass yield. The data will be evaluated to identify mating strategies that will involve use of cryopreserved sperm samples to produce superior purebred blue catfish germplasm for release to catfish farmers. Thus far there have been 4 formal presentations to scientific and industry groups, with many informal discussions with individual hybrid catfish fry producers.

The “Control of Virulent *Aeromonas hydrophila*” project will help identify the environmental and human factors that contribute to its spread, develop effective disinfection and management practices that can result in improved biosecurity, and develop control measures for farms afflicted with this epidemic. Quantification of vAh in pond water, sediment, and aquatic invertebrate or fish samples revealed the sampling protocols employed are sufficient to detect vAh in the system. This analysis suggested that a carrier state can occur in fish that have survived vAh outbreaks. It is possible for Great Egrets that have consumed fish with vAh to spread the bacteria to naïve ponds and initiate a disease outbreak. The bacterium was also able to attach and form biofilm in man-made material although there were significant differences in terms of biofilm formation between the different substrates tested. The vAh ymcA deletion mutant was determined to be highly attenuated in its virulence in the same batch of fingerling catfish used for a production pond study, and both the vaccinated fish and the probiotic-fed fish showed a significant increase in survival relative to naïve control fish in aquaria disease challenges. Results of this research will be the foundation of more targeted field sampling to provide more resolute evaluations of pond conditions associated with disease outbreaks.

The “Integrated Approaches to Reducing Individual Variability and Providing Year Round Harvest of Channel-Blue Hybrid Catfish” project seeks to evaluate the impact of culture system, harvest technology, fingerling size and variability, grading, genetics, time and rate of stocking and feeding rate on size variability at harvest and the ability to accomplish year-round harvest. The results are quite preliminary and additional replication is needed. At this point in time the data indicates that the genetic strain of the parent species affects variability in the hybrid. Both sire and dam effects were significant. Genotype-environment interactions affect the body weight variability. However, environment was more important than genetics in causing variability. The coefficient of variability for body weight was significantly affected by whether the pond was partially or completely harvested, the length of the culture period, the amount of aeration, feeding rate, stocking density, production, genetics, grading of fingerlings, and the number of feeding days. Stocking density, production, pond depth, pond size, and stocking weight had the largest effects on the percentage of undersized fish. The amount of aeration, grading of fingerlings, satiation feeding, feeding days per week and protein level of the feed had the largest effects on the oversized fish. Traditional ponds, both single batch and multi batch, split-pond and raceway culture systems produced hybrid catfish with similar body weight variability, percentage of under-sized fish, and percentage of oversized fish. The percentage of undersized and oversized fish has a very large impact on farm profitability. Assuming various price structures for undersized and oversized fish and different observed percentages of each, the cost of production can be affected by as much as 40-70%.

The “Evaluation of Probiotic and Prebiotic Supplements” project is designed to evaluate a commercially available prebiotic and probiotic under conditions simulating commercial production with prominent fish cultures in the southern region including hybrid catfish, golden shiners, and hybrid striped bass in ponds and tilapia in recirculating aquaculture systems. Neither of the prebiotic or probiotic supplements either singularly or in combination significantly altered weight gain, feed conversion ratio, or survival of those species. However, the microbiota of the gastrointestinal tract of hybrid striped bass was affected by the supplements, as were several innate immune responses. The prebiotic supplement had a greater influence on these responses than the probiotic. The controlled bacterial challenges conducted with each of those fish did not result in significant mortality, even in fish fed the basal diet. This was likely do to the non-invasive manner in which the fish were exposed to the pathogens. Additional disease challenges are planned with hybrid striped bass and golden shiners to more stringently evaluate the diet supplements.

The overall goal of the “Improved Reproduction in Foodfish (Catfish and Largemouth Bass), Baitfish, and Ornamentals Using a New Spawning Aid (cGnRH IIa)” project is to identify an effective dosage(s) GnRH IIa which will successfully induce spawning, result in higher female spawning occurrence than currently observed, and potentially lead to increased larval output compared to current hormonal induction strategies for each species. At the end of the reporting period, this project was less than 3 months along. Therefore, participants were not asked to provide summary results/outcomes.

The “Predation Risk and Economic Impact of Lesser Scaup and Piscivorous Waterbirds on Commercial Baitfish and Catfish Production” project will improve understanding of utilization of baitfish ponds by lesser scaup, species and sizes of fish consumed, and will ultimately generate an economic analysis of baitfish losses. This project will also generate contemporary information on cormorant roost locations, numbers of birds per roost, and roost distance from active and inactive catfish ponds in Mississippi as well as reveal how cormorants modify their use of roost sites as commercial aquaculture decreases. Ultimately, results from this study will allow researchers to estimate economic losses of fish caused by these birds, and generate management recommendations for producers to ameliorate depredation of fish by waterbirds. At the end of the reporting period, this project was less than 2 months along. Therefore, participants were not asked to provide summary results/outcomes.

INTRODUCTION

Mission

The mission of the USDA NIFA Southern Regional Aquaculture Center (SRAC) is to support aquaculture research, development, demonstration, and education to enhance viable and profitable U.S. aquaculture production to benefit consumers, producers, service industries, and the American economy. Projects that are developed and funded are based on industry needs and are designed to directly impact commercial aquaculture development in the southern region and the nation.

Background

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.

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. 95113) 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.

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, SRAC has become the most important regional aquaculture activity in the southeastern United States. In its 29 years of operation, the Center has disbursed more than $18.2 million to fund multi-state research and Extension projects. More than 200 scientists from 30 institutions in the southeast have participated in Center projects.

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 SRAC, 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.

Acknowledgments

The Southern Regional Aquaculture Center acknowledges the contributions of the Project Leaders and Participating Scientists involved in the projects reported in this Twenty-ninth 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 these vital committees.

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.

ORGANIZATIONAL STRUCTURE

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 states within the region, works with the IAC to prioritize problem areas. The two groups then work together to develop "Requests for Pre-proposals" describing objectives of work to solve problems with the highest priority. The best proposals submitted by individuals or teams are used to form a regional Work Group that plans and conducts 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.

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 of the Board on Agriculture Assembly of the Association of Public and Land Grant Universities.

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; 4) review and approval of annual plans of work and accomplishment reports; and 5) final selection of proposals for funding by SRAC.

Members of the Board for the reporting period were:

Gregory Bohach, Mississippi State University
Phil Elzer, Louisiana State University
Steve Lommel, North Carolina State University
Steve Martin, Mississippi State University Extension Service
Ed Jones, Virginia Cooperative Extension, Virginia Tech
Gary Lemme, Auburn Cooperative Extension Service
Wes Burger, Mississippi State University

Industry Advisory Council

The IAC 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. 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 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.

Members of the IAC for the reporting period were:

J. Neal Anderson, AR
Vaun Cummins, KY
Ben Pentecost, MS
Martha Campbell, FL
Rob Ellis, NC
Marty Tanner, FL
Travis Wilson, AL
Townsend Kyser, AL
Ralph Babin, TX
Anthony Marchetti, VA
Chris Bently, VA
Kim Edge, GA
Stephen Sagrera, LA
Shorty Jones, MS
Chase Holub, TX
Frank Roberts, SC
Joey Lowery, AR
Jenny Davis Fagan, TN
Wes Hardin, OK

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 1) works with the IAC to prioritize research and Extension needs; 2) works with the IAC 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.

Members of the TC for research for the reporting period were:

Brian Bosworth, USDA-ARS Warmwater Aquaculture Research Center
Harry Daniels, North Carolina State University
Ken Semmens, Kentucky State University
Allen Davis, Auburn University
Herbert Quintero, University of Arkansas at Pine Bluff
Delbert Gatlin, Texas A&M University
Terry Tiersch, Louisiana State University
Cortney Ohs, University of Florida
Dan Kauffman, Virginia Tech University
Mike Denson, South Carolina Department of Natural Resources
Brian Alford, University of Tennessee

Members of the TC for Extension for the reporting period were:

Lance Beecher, Clemson University
Mike Frinsko, North Carolina State University
Ron Blair, University of Tennessee
Gary Burtle, University of Georgia
Jesse Chappell, Auburn University
Todd Sink, Texas A&M University
Greg Lutz, Louisiana State University
Michael Schwarz, Virginia Tech University
Craig Watson, University of Florida
Forrest Wynne, Kentucky State University
Anita Kelly, University of Arkansas at Pine Bluff
Mark Peterman, Mississippi State University
Marley Beem, Oklahoma State University
Don Bailey, University of the Virgin Islands

PROGRESS REPORTS

Publications, Videos, and Computer Software

Reporting Period: September 1, 2015 – August 31, 2016
Length of Project: Ongoing
Current Project Year: 20
Total Funds Committed: $41,430
Principal Investigator: Todd Sink, *Texas A&M University*

Relevance: 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 including the National eXtension Initiative. This process assures an efficient publication process that makes use of the best available talent in specific subject areas.

Response: A committee of Extension Specialists and researchers solicit input on publication and digital product needs from their counterparts across the region. These suggestions are prioritized during an annual meeting of the committee based on need and available funding. The best talent from within and outside the region are then recruited to submit proposals to develop these products.

Results: The result is widespread availability of high-quality educational materials for scientists, educators, producers, students, and the general public which in turn leads to increased or improved efficiency aquaculture production, improved awareness of aquaculture products and the nutritional benefits of seafood, and increased aquaculture investment.

Outreach Overview: SRAC fact sheets and videos are distributed electronically, by direct request, and via Extension Specialists, County Extension Agents, and other RACs. These products are used regularly by clientele in all 50 states as well as internationally in 206 countries and territories. Fact sheets, videos, and web presentations are accessed daily from the SRAC Publications website and YouTube by people searching for technical information.

Targeted Audiences: The target audiences for this project are educators, consumers, producers, potential investors, students, and the general public.

Outputs: Seven new fact sheets and the new SRAC –aquaponics website were completed for this reporting period. The SRAC publications and AquaPlant websites were also updated with new materials. All completed publications have been distributed electronically throughout the Southern Region and to

interested Extension Specialists in other regions. Four additional fact sheet manuscripts were submitted to be published after the reporting period concluded.

Outcomes/Impacts: Publications and videos produced by SRAC are increasingly used in educating high school and college students about aquaculture. These programs heavily utilize SRAC publications and videos for educational purposes but usage is impossible to measure because access to the information is gained from many different Internet sites, through file sharing, and digital downloads of PDFs.

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 have indicated 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. 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.

The Southern Regional Aquaculture Center commenced the Publications, Videos, and Computer Software Project in order to provide these materials in a timely and relevant manner. Since that time, more than 294 technical fact sheets (276 in the current catalog), 89 update revisions, 7 web presentations, 7 software programs or web tools, and 31 videos have been produced through the SRAC PVCS Project. In the current reporting year alone, **47,492*** unique users from **170** countries and territories used the SRAC Publications website, https://srac.tamu.edu/, to view or download SRAC publications **233,342*** times. SRAC videos were viewed on the SRAC YouTube channel **43,099** times during the current reporting period. The AquaPlant website, created with funding from the SRAC PVCS Project, had 312,349 unique users that viewed 2,507,344 webpages during the reporting period. These users were from 209 countries/territories. These analytics demonstrate that the SRAC Publications, Videos, and Computer Software project truly has worldwide reach and impact.
*Web-based analytical tracking and reporting methods.

Performance Evaluation of Intensive, Pond-Based Culture Systems for Catfish Production

Reporting Period: October 1, 2012 – February 29, 2016
Length of Project: 3 years
Current Project Year: 3 (extended until 2/29/2016)
Total Funds Committed: $297,412
Participants: Les Torrans, Travis Brown, Craig Tucker, *USDA-ARS Warmwater Aquaculture Research Unit*; Luke Roy, Jesse Chappell, Terry Hanson, Claude Boyd, *Auburn University*; David Wise, Terry Greenway, Matt Griffin, *Mississippi State University*; Carole Engle, Yushun Chen, Matt Recsetar, *University of Arkansas at Pine Bluff*

Relevance: Many farmers feel that intensifying fish production will reduce production costs. They are currently using three production systems to do this; smaller conventional earthen ponds with increased aeration rates, split-pond systems, and in-pond raceways. Intensified production systems will likely continue to draw the interest of catfish farmers in the future but without a thorough economic analysis there can be no definitive recommendations.

Response: This study evaluated the production efficiencies of these new production systems on commercial catfish farms. Based on these findings, a complete economic analysis was performed and will provide the necessary guidance to make recommendations to farmers. In addition, detailed physical descriptions of each culture system were thoroughly investigated and the most efficient and practical designs will be recommended to farmers. Data will be used to identify fish health related risk factors associated with each type of production system. Information will be used to develop disease management programs to complement specific production parameters.

Results: Two commercial catfish farms in Mississippi were enlisted as cooperators on this project. Both split-ponds and intensively aerated ponds were monitored. Additionally, six-commercial-sized ponds

and two split-ponds at the MSU Delta Research and Extension Center were used in this study. Electric monitors were installed on all equipment, production facilities were stocked with either hybrid or channel catfish, and management inputs were monitored. Three commercial catfish farms in Arkansas were enlisted as cooperators on this project. Split-ponds and intensively aerated pond production facilities were stocked with either hybrid or triploid (on three occasions) hybrid catfish, and management inputs were monitored. Two commercial farms in Alabama were enlisted as cooperators. One farm used an in-pond raceway and the other intensively aerated ponds. Data from two complete production cycles were reported from all cooperators in the three states. The framework for the economic analysis of the production systems have been developed and preliminary analyses are reported.

Outreach Overview: Results from this project will be disseminated through presentations at scientific and producer meetings, through trade publications, and publications in peer-reviewed journal articles. Outreach efforts have increased dramatically in 2015 as more data has been collected. There should be enough information synthesized in 2016 to reach valuable conclusions and largely complete outreach efforts.

Targeted Audiences: Catfish producers and the aquaculture scientific community.

Outputs: Thus far there have been four refereed journal publications and six Extension/trade publications. More important, there have been 31 presentations (most with published abstracts) to scientific and industry groups, with many more planned for this winter. The research participants are not waiting for final publication in research journals before informing the industry of results to date. These industry presentations also stimulate further discussion among the researchers and farmers interested in the new technologies.

Outcomes/Impacts: The final impact of this project cannot be determined at this point as the data is incomplete. However, the comprehensive database that is emerging from this project will be a valuable guide for farmers considering investing in the new systems. The intensive monitoring of this project has documented extremely high fish production but also high variability. In most cases net production exceeded 12,000 lbs/acre with FCRs better than 2.0:1, with production up to 17,000-19,000 lbs/acre in the best cases. This dataset provides a more complete picture of the comparative production and economic benefits of these systems than has previously been available, and enables Extension personnel to better assist farmers to make informed decisions related to adoption of these new technologies.

Partnerships Developed: Formal partnerships were established between the research collaborators and eight commercial farms in Arkansas, Mississippi, and Alabama. Without the support and cooperation of these farmers this on-farm economic study obviously would not have happened. Their partnerships have greatly strengthened the working relationship between research and industry in these states.

Split-Pond Aquaculture Systems: Design Refinements for Catfish Production and Evaluation for Culturing Other Species

Reporting Period: February 1, 2014 – August 31, 2016
Length of Project: 3 years
Current Project Year: 3 (extended until 6/30/17)
Total Funds Committed: $460,366
Principal Investigators: Craig Tucker, Travis Brown, Les Torrans, *USDA-ARS Warmwater Aquaculture Research Unit*; Charles Mischke, *Mississippi State University*; Greg Whitis, Claude Boyd, *Auburn University*; Kevin Schrader, *USDA-ARS Natural Products Utilization Research Unit*; Jeonghwan Park, Nathan Stone, *University of Arkansas at Pine Bluff*

Relevance: In an effort to remain competitive in the face of adverse economic conditions, some catfish farmers have started using intensive, outdoor culture systems called split-ponds. Despite widespread adoption, optimum split-pond design is unknown and commercial systems vary widely in pump type, water exchange rate, and management of the two basins. Further, the apparent success of split-ponds for growing catfish has generated interest in the possibility of culturing other species, especially baitfish.

Response: Nine scientists at five institutions are collaborating to improve split-pond design for warmwater aquaculture. The project is evaluating important design or management options for producing catfish, including pumping systems and oxygen management, and will develop engineering design criteria for baitfish aquaculture.

Results: Four, 7-acre earthen ponds at the National Warmwater Aquaculture Center at Stoneville, Mississippi have been modified into split-ponds. Four pumping systems were installed: a) 6-hp slow-turning paddlewheel, b) a 10-hp fast-turning paddlewheel, c) a 10-hp high-speed screw-type pump, and d) a 15-hp high-speed axial flow turbine. Engineering test of pump performance showed wide ranges of tradeoffs among the different pump types. The slow-turning paddlewheel was dependable, much more efficient than the other pumps, produced the highest pumping rates (up to 20,000 gallons per minute, gpm) but was by far the most expensive system to install. Pumping efficiency for the slow-turning paddlewheel was strongly dependent on rotational speed, with increasing efficiency up to a point (2 rpm) and then decreasing efficiency after that. The screw pump was the least expensive system to install (about 5-times less expensive than the slow-turning paddlewheel) but had the lowest pumping rate (up to 9,000 gpm) and the second-lowest pumping efficiency. The axial-flow pump was developed for sewage treatment plants and will be very dependable, but was the least efficient pump tested and had the second lowest pumping rate (up to 12,000 gpm). The fast-turning paddlewheel had the second best pumping efficiency and pumping rate (up to 15,000 gpm) but the large-diameter culverts required in the systems made it the second most expensive system to install.

Ponds were stocked with hybrid catfish for production studies in spring 2015 and 2016 and harvested in autumn of each year. In both years, ponds with the highest pumping rates (slow- and fast-turning paddlewheels) had higher net fish production (average = 16,158 lb/acre) and the best feed conversion (average = 1.92) and survival (average = 92%). Split-ponds with the lowest pumping rates (screw and turbine pumps) had lower production (average = 13,970 lb/acre) and worse feed conversion (average = 2.11) and survival (average = 87%).

A commercial catfish farm in Alabama is cooperating to determine benefits of aeration in the waste-treatment section (lagoon) of split-ponds. Water quality data collection have been collected since January 2016 from the waste treatment cells and the fish production cells of split-ponds. The control ponds did not have aerators in the waste treatment cells, while the test ponds did.

Average concentrations of total ammonia, un-ionized ammonia, and dissolved organic matter (measured as soluble chemical oxygen demand) were higher in control ponds but the differences probably have little biological significance. There were no differences in quality of water flowing into and out of the waste-treatment lagoon in either control or treated ponds. In other words, additional aeration in the waste-treatment lagoons did not markedly improve water quality as water flowed through the lagoon.

Fish were stocked and harvested at various intervals in a multiple-batch culture system. There were no differences in fish production, with annual net yields of 8030 ± 4250 lb/acre in control ponds and 7080 ± 4225 lb/acre in ponds with aerated waste cells. Poor production was likely caused by the design of these split-ponds; they were large, lacked adequate circulation and mixing, and used a low-volume pump to circulate water. Feed conversion ratios exceeded 4.0 for treatment and control ponds and was most likely the result of poor feed management, and disease and mortality.

Water and fish samples were collected from four split-pond systems in west Mississippi and seven in west Alabama to study development of algae-related off-flavors in fish grown in split-ponds. Phytoplankton community structures in the split-ponds were not different from those commonly seen in traditional catfish ponds and, as a consequence, both earthy (geosmin) and musty (2-methylisoborneol) off-flavors occur in catfish raised in split-ponds, and flavors are as intense as those seen in traditional catfish ponds. Therefore, off-flavor management practices in split-ponds should be similar to those used by catfish farmers for traditional ponds.

Work in Arkansas focuses on improving pump efficiency for a culvert-based modular paddlewheel systems developed at the University of Arkansas at Pine Bluff and modifying split-ponds for baitfish production. Paddle blade design is an important design feature for the modular, culvert-based paddlewheel pump designed at the University of Arkansas at Pine Bluff. In engineering studies, blades with greater surface area provided greater efficiency than those with less surface area. Designs which added walls, enclosing the side of the paddle wheel to reduce water slip behind the paddle, did not translate to increased efficiency. However, a simple flat, solid blade had better energy transfer rate than the other shapes, and a model was developed to predict water flow rate, power consumption, and pumping efficiency for that blade design. As with testing in Stoneville, all combinations showed an initial increase in pumping efficiency with increased rotational velocity followed by a drop in efficiency as rotational velocity reached maximum levels. Also, larger open areas in both screen and culvert sizes

performed better with respect to power consumption and water flow rate. A model was developed to predict culvert sizes to optimize pumping efficiency.

A newly developed rotary fish barrier appears to be effective at preventing movement of small fish between sections of split-ponds. Based on measurements and field observations on the performance of fish barriers installed in an 8.5-acre pond for fathead minnow production, continuous slow rotation (1-2 rpm) of fish barriers was appropriate to avoid biofouling and/or mechanical failures, allowing for extended use of the fish barrier with less maintenance.

The largemouth bass is emerging as a promising aquaculture species and there is interest in using split-pond systems to raise the fish. Overall bass production was significantly higher in the split-ponds compared to traditional ponds due to increased initial stocking density. Survival rates and feed conversion rates tended to be better in the split-ponds compared to the traditional ponds but condition factor did not differ. Fathead minnows and golden shiners are important baitfish grown in the southern United States. In a field production study with a split and traditional pond for fathead minnow production, final biomass was somewhat higher in split-pond than traditional pond. Survival rate was higher in the split-pond than the traditional pond. However, fish in the traditional pond were bigger than those in the split-pond. Fish appeared to be affected by crowding in the split-pond. A study is also underway to examine the effect of crowding and water flow on golden shiners using a flow tank model.

Outreach Overview: Outreach has been extensive. Twenty-five presentations have been made at producer and professional meetings on technologies developed in this project. An additional 8 publications have been published or are accepted for publication. As additional results become available, results will be disseminated through presentations at scientific and producer meetings, through trade publications, and publications in peer-reviewed journal articles.

Targeted Audiences: Catfish and baitfish producers and the aquaculture scientific community.

Outputs: Twenty-five presentations have been made at producer and professional meetings and 8 papers have been published.

Outcomes/Impacts: Split-pond technology continues to be adopted at a rapid rate in the catfish industry. Since project initiation, many farmers have toured the Stoneville facility specifically to observe the four pumping systems installed in the split-ponds. Several farmers in Arkansas and Mississippi have decided to build split-ponds for catfish production, and a baitfish farmer has built a commercial size split-pond to raise fathead minnows and harvested the first crop. Split-pond technologies have been further expanded to largemouth bass culture. A largemouth bass farm in McCrory, is installing split-ponds for largemouth bass food-fish production.

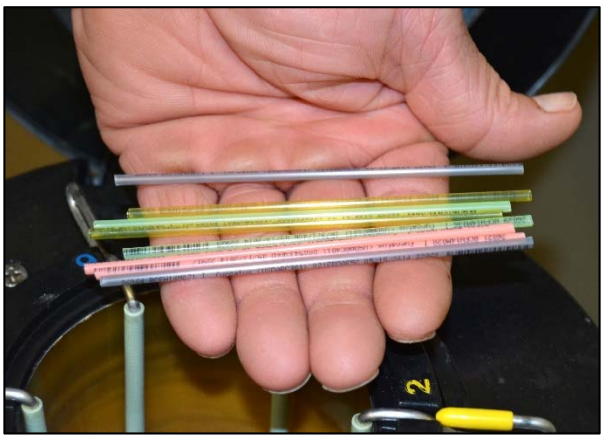
Partnerships Developed: None.

Improvement of Blue Catfish Germplasm for Hybrid Catfish Production

Reporting Period: September 1, 2015 – August 31, 2016
Length of Project: 3 years
Current Project Year: 3
Total Funds Committed: $44,982
Principal Investigators: Brian Bosworth, *USDA-ARS Warmwater Aquaculture Center;* Terry Tiersch, E Hu, *Louisiana State University*

Relevance: Production of channel catfish female x blue catfish male hybrids by U.S. catfish farmers has increased dramatically in the last 10 years and now is estimated to comprise 50 to 60% of total U.S. catfish production. Further improvements in hybrid performance are possible through genetic selection of purebred parents that will produce superior performing hybrid offspring. Male blue catfish must be killed and their testes removed to obtain sperm used to produce hybrid offspring. Therefore, evaluation of blue catfish genetic effects on hybrid performance requires development of a repository of cryopreserved sperm from a genetically diverse group of blue catfish. This project addresses that issue and is therefore important to genetic improvement of hybrid catfish and competitive ability of the U.S. catfish industry in a global market.

Response: The objectives of this project are to develop a repository of cryopreserved sperm from diverse blue catfish populations to initiate genetic improvement of hybrid catfish, and to develop a database for efficient storage and retrieval of cryopreserved blue catfish sperm and associated information.



Results: During the spring of 2016 sperm samples from 60 mature blue catfish males from 3 strains (D&B, Rio Grande, Mississippi River, 20 males per strain) were collected at the USDA-ARS Warmwater Aquaculture Research Unit, Stoneville, MS. This concludes the sperm collection and cryopreservation aspects of the project. A working repository of blue catfish cryopreserved sperm samples is stored at the WARU facility in Stoneville, MS and an archival repository of samples is stored at the National Animal Germplasm Program in Fort Collins, CO.

Cryopreserved sperm samples are being used to produce full and half-sib families of purebred blue catfish progeny and hybrid catfish progeny. Performance data from these progeny is being used to determine the genetic basis for performance differences in hybrid catfish progeny and to expand selection programs to develop and release improved blue catfish germplasm to the U.S. catfish industry. The repository of cryopreserved samples developed from this project is critical to WARU efforts to develop improved blue catfish germplasm.

Cooperation with personnel at the USDA-ARS National Animal Germplasm Program (NAGP, Fort Collins, CO) have resulted in adoption of their database, named Animal GRIN (http://nrrc.ars.usda.gov/A-GRIN/main_webpage/ars?record_source=US), for use with the blue catfish sperm samples collected in this project. Modifications to the data collected specific to blue catfish samples were incorporated. Adoption of the NAGP database provides a comprehensive framework for data collection, storage and retrieval. In addition, use of the NAGP database will allow efficient tracking and data retrieval of the blue catfish samples that are stored at that location.

Outreach Overview: Results from this project have been disseminated through presentations at scientific and producer meetings, through trade publications, and publications in peer-reviewed journal articles. We plan to meet with commercial hybrid catfish hatchery owners during year 3 to discuss the implications for commercial use of germplasm developed through this project and potential for development of protocols for use of cryopreserved sperm in commercial hatchery operations.

Targeted Audiences: Catfish producers and the aquaculture scientific community.

Outputs: Thus far there have been 4 formal presentations to scientific and industry groups, with many informal discussions with individual hybrid catfish fry producers. These industry presentations also stimulate further discussion among the researchers and farmers interested in the new technologies.

Outcomes/Impacts: Although impacts of this project will take time to be realized, the potential benefit to improving production efficiency and profitability of U.S. hybrid catfish production is tremendous.

Partnerships Developed: Formal partnerships were established between researchers at the USDA-ARS Warmwater Aquaculture Research Unit and Louisiana State University.

Studies to Improve the Control of Virulent *Aeromonas Hydrophila* and Evaluate the Impact of Environmental Factors on its Abundance in Catfish Aquaculture Ponds

Reporting Period: June 1, 2014 – August 31, 2015
Length of Project: 2 years
Current Project Year: 2
Total Funds Committed: $ 354,287
Principal Investigators: Mark Liles, Cova Arias, Jeffery Terhune, Joseph Newton, *Auburn University;* Matt Griffin, Henry Wan, Larry Hanson, Charles Mischke, *Mississippi State University;* Fred Cunningham, *USDA National Wildlife Research Center*

Relevance: A highly virulent and clonal population of *Aeromonas hydrophila* is the causative agent of an ongoing epidemic of motile Aeromonas septicemia in farmed catfish. Originally with an epicenter in western Alabama, this disease epidemic has now spread to Mississippi and Arkansas. This research will help identify the environmental and human factors that contribute to its spread, develop effective disinfection and management practices that can result in improved biosecurity, and develop control measures for farms afflicted with this epidemic. The project seeks to:

1) Determine the environmental factor(s) and animal vector(s) that are correlated with epidemic *A. hydrophila* abundance and dissemination.
2) Determine the disinfection method(s) that will allow removal of *A. hydrophila* from seines.
3) Determine the efficacy of vaccine and/or probiotics delivered orally in preventing mortality due to *A. hydrophila* in farmed catfish.

Response:

Objective 1**:** Production ponds in the Mississippi Delta and eastern Mississippi have been sampled for pond water, sediment, aquatic organisms, and fish samples to quantify vAh. Sample processing and analysis has been conducted for Year 1 sampling. The survival of vAh within copepods, cladocerans, dero worms, and larval midges has been assessed. The potential for animal dissemination of vAh was evaluated using a piscivorous bird (Great Egret) model in experimental aviary ponds.

Objective 2**:** The ability of vAh to grow and form a biofilm on seines was determined. The assay for biofilm formation was standardized in order to quantify vAh on seines with and without different disinfection methods.

Objective 3: The vAh vaccine was evaluated in controlled aquaria to prevent MAS. Biofilm formation on chitin flakes or powder was evaluated as an oral delivery mechanism. In-pond raceways systems were constructed in production ponds in western Alabama, and a replicated trial of vaccinated or probiotic-fed fish was conducted in three production ponds.

Results:

Objective 1: Quantification of vAh in pond water, sediment, and aquatic invertebrate or fish samples revealed the sampling protocols employed here are sufficient to detect vAh in the system. In addition, this analysis has suggested that a carrier state can occur in fish that have survived vAh outbreaks. That is, fish from ponds with a history of vAh outbreaks may be positive for vAh, but show no outward signs of disease. In Year 1 sampling, this carrier state was not evident in ponds that received medicated feeds in response to an outbreak, as within 1 month of receiving treatment no fish were positive for vAh. Analysis of resident fish populations from Year 2 sampling is still ongoing. Initially, it was thought that vAh did not persist in the environment prior to, or following a disease outbreak, or if it does, it persists at concentrations below our detectable limits. However, Year 2 results have demonstrated contradictions in this finding, as high levels of vAh were found to persist in the environment in some ponds following an outbreak, while in others vAh dissipated quickly. The conditions that facilitate persistence of vAh in the environment have not been identified, although this analysis is pending. Water chemistry analysis did not identify significant differences between ponds with vAH outbreaks and ponds without, although field sampling did identify differences in zooplankton and phytoplankton communities of ponds positive for vAh (vAh detected in environment or resident fish). In general, the composition of the phytoplankton communities differ, and zooplankton diversity and overall abundance is reduced in vAh ponds. The significance of this finding is unclear, but would suggest that vAh ponds undergo a reorganization of their phytoplankton and zooplankton communities prior to the onset of disease, suggesting an environmental trigger may be involved. That said, the mechanisms at play are currently unknown and caution must be employed when attempting to identify corollary relationships in biological systems. These findings may simply be coincidental. Attempts to colonize copepods and cladocerans with vAh have thus far been unsuccessful. *Dero Digitata* a common oligochaete found in catfish ponds was also resistant to colonization. However, we found that midge larvae (chironomids also called blood worms) had natural flora of *A. hydrophila* and when exposed to vAh maintained the bacterium internally for over 6 days. Lastly, it is possible for Great Egrets that have consumed fish with vAh to spread the bacteria to naïve ponds and initiate a disease outbreak. Both aviary treatment ponds had positive qPCR results for vAh, and vAh was detected in pond water and sediment for at least one of the aviary ponds. Moreover, chironomids, invertebrates, snails or mud were positive for vAH up to 21 days after feeding the birds infected fish.

Objective 2: The prevalence of vAh in biofilms naturally occurring in pond environments was monitored by using specific a qPCR protocol. In addition, culture-based techniques were employed to quantify total heterotrophic bacteria and *Aeromonas* sp. Samples were taken monthly at a commercial catfish farm in West Alabama and included water, sediments, and biofilms from three individual ponds (which had experience vAh outbreaks in the past). Numbers of vAh increased, as expected, as warmer temperatures increased and showed a positive correlation with an increase in total heterotrophic counts and total

Aeromonas counts. As temperature decreased in fall, a significant increase in vAh was noticed which suggested the bacterium overwinters in the sediments. Biofilm and sediments contained significantly higher levels of vAh than water samples even during active vAh outbreaks. Biofilms yielded more vAh positive samples than sediments.

Objective 3: The vAh *ymcA* deletion mutant was determined to be highly attenuated in its virulence in the same batch of fingerling catfish used for a production pond study, and both the vaccinated fish and the probiotic-fed fish showed a significant increase in survival relative to naïve control fish in aquaria disease challenges. The ability to introduce the vAh vaccine orally via a biofilm on chitin powder was not found to be a viable option, so the production pond study used an inactivated vaccine that was intraperitoneally injected into catfish. In-pond raceway systems were constructed in three production ponds with a history of MAS outbreaks, and over the course of the summer of 2015 two of these ponds experienced validated MAS outbreaks. A statistically significant difference in the mortality of catfish in a production pond due to vAh was observed, with control fish having a survival of 94.4% whereas the vaccinated fish had a survival of 99.6% ($P < 0.05$). Ongoing studies continue to evaluate vaccine delivery, comparing oral, immersion and IP vaccine delivery in collaboration with the USDA's Aquatic Animal Health Research Unit (Dr. Ben Beck, director).

Outreach Overview: Regular communication with catfish industry stake-holders has been ongoing in Alabama and Mississippi. Catfish industry meetings in Demopolis, AL and Macon, MS were conducted in December of 2015 and 2016, where the results of these studies were presented.

Targeted Audiences: The target audiences are primarily stake-holders in the catfish industry, including catfish farmers, feed mill operators, industry representatives, and aquaculture scientists. We are also inviting animal health industry representatives and biotech industry representatives that have the capacity to mass-produce the vaccine or probiotic, respectively.

Outputs: Outputs are knowledge concerning the 1) distribution and dynamics of vAh within a production pond ecosystem, 2) the possible vectors for vAh transmission, and 3) disinfection methods that are effective in removing vAh biofilms on seines. Additional outputs are the vaccine and probiotics that are being evaluated for MAS prevention. In addition to peer-reviewed publications, these outputs will be communicated via industry-specific newsletters and meetings.

Outcomes/Impacts: This project will result in specific outcomes that can improve management practices in the catfish industry to reduce the transmission, occurrence, and severity of MAS. Results of this research will be the foundation of more targeted field sampling to provide more resolute evaluations of pond conditions associated with disease outbreaks. Improved methods for disinfecting seines, reducing transmission of vAh between ponds, and prevention measures using vaccination and/or probiotic feeding are tangible outcomes of this research.

Partnerships Developed:

1) **Randy Hollingsworth**. Type = industry. Level = local. Provided his farm for production pond trials.
2) **Alabama Catfish Producers**. Type = industry. Level = state. Provided funding ($65k) to expand production pond trials to 3 ponds by building additional in-pond raceways.
3) **Alabama Department of Agriculture and Industries**. Type = industry. Level = state. Provided funding ($55k) to expand production pond trials to 3 ponds by building additional in-pond raceways.

4) **Alabama Catfish Feed Mill**. Type = industry. Level = state. Provided donated feed worth $20k for the pond studies.
5) **Osprey Biotechnics**. Type = industry. Level = regional. Provided donated probiotic spores worth $12k for the pond studies.
6) **Auburn University School of Fisheries, Aquaculture and Aquatic Sciences.** Provided funding ($80k) to expand production pond trials to 3 ponds by building additional in-pond raceways.
7) **Mississippi Catfish Producers.** Type = industry. Level = local. Provided farms for pond sampling.

Integrated Approaches to Reducing Individual Variability and Providing Year Round Harvest of Channel-Blue Hybrid Catfish

Reporting Period: March 1, 2015 - August 31, 2016
Length of Project: 2 years
Current Project Year: 2
Total Funds Committed: $287,911
Principal Investigators: Rex Dunham, Terry Hanson, *Auburn University*; Nagaraj Chatakondi, *USDA-ARS Warmwater Aquaculture Research Unit*

Relevance: The culture of hybrid catfish (channel catfish, *Ictalurus punctatus,* female X blue catfish, *I. furcatus*, male) is expanding, and this is a key component to the survival of the U.S. farm-raised catfish industry. However, the rapid growth, behavior and physical characteristics of the hybrid have presented some unique problems such as variable fish growth, oversized fish, and more difficulty in year-round harvest. This project will explore a holistic approach to identifying the causes and solutions to this problem.

Response: The impact of culture system, harvest technology, fingerling size and variability, grading, genetics, time and rate of stocking and feeding rate on size variability at harvest, and the ability to accomplish year- round harvest will be examined.

Results: The results are quite preliminary and additional replication is needed. At this point in time the data indicates that the genetic strain of the parent species affects variability in the hybrid. Both sire and dam effects were significant. Genotype-environment interactions affect the body weight variability. However, environment was more important than genetics in causing variability. The coefficient of variability for body weight was significantly affected by whether the pond was partially or completely harvested, the length of the culture period, the amount of aeration, feeding rate, stocking density, production, genetics, grading of fingerlings, and the number of feeding days. Stocking density, production, pond depth, pond size, and stocking weight had the largest effects on the percentage of undersized fish. The amount of aeration, grading of fingerlings, satiation feeding, feeding days per week, and protein level of the feed had the largest effects of the oversized fish. Traditional pond, both single batch and multi batch, split-pond and raceway culture systems produced hybrid catfish with similar body weight variability, percentage of undersized fish and percentage of oversized fish. The percentage of undersized and oversized fish has a very large impact on farm profitability. Assuming various price structures for under-sized and oversized fish and different observed percentages of each, the cost of production can be affected by as much as 40-70%.

Outreach Overview: The preliminary results have been presented at three Auburn University seminars, two farmer research meetings involving Alabama and East Mississippi catfish farmers and twice at the annual conference of the U.S. chapter of the World Aquaculture Society, Aquaculture America.

Additional presentations will be made during the coming year after completion of the project, including Auburn University seminars, the West Alabama Farmer research update, Aquaculture America, and the CFA Research Symposium.

Targeted Audiences: The targeted audience includes catfish producers, processors, research scientists, and interested laypersons.

Outputs: Graduate student trainees and scientific presentations.

Outcomes/Impacts: Outcomes and impacts are preliminary. However, initial results indicate that variability of hybrid catfish body weight can be reduced. However, the parameters causing the variability are numerous and complex, and farmers may need to be willing to alter several management strategies to control the variability in the hybrid body weight.

Partnerships Developed: None.

Evaluation of Probiotic and Prebiotic Supplements with Catfish, Golden Shiners, Hybrid Striped Bass and Tilapia under Conditions of Commercial Production

Reporting Period: May 15, 2015 - August 31, 2015
Length of Project: 2 years
Current Project Year: 2
Total Funds Committed: $280,219
Principal Investigators: Delbert Gatlin, Texas A&M AgriLife Research; Todd Sink, *Texas A&M AgriLife Extension Service*; Allen Davis, Jeff Terhune, Terry Hanson, *Auburn University*; Brian Peterson, *USDA-ARS WARU*; Rebecca Lochmann, *University of Arkansas at Pine Bluff*

Relevance: This project is designed to evaluate a commercially available prebiotic and probiotic under conditions simulating commercial production with prominent fish cultures in the southern region including hybrid catfish, golden shiners, and hybrid striped bass in ponds and tilapia in recirculating aquaculture systems. It is anticipated that these functional feed additives may serve as alternative disease prevention and treatment strategies compared to more traditional uses of vaccines and drugs which are expensive, subject to regulatory constraints, and/or associated with inconvenient administration options. This project will provide a thorough evaluation of these commercially available products including economic assessment.

Response: Four different dietary treatments have been applied in separate production trials conducted under conditions simulating commercial production with the four different fish species. The trials with hybrid catfish and hybrid striped bass were conducted in ponds while the trial with golden shiners was conducted in netpens within ponds. The tilapia trial was conducted in intensive recirculating systems. The dietary treatments evaluated in each trial consisted of: 1) a nutritionally complete basal diet, 2) the basal diet supplemented with 2% Grobiotic®-A (International Ingredient Corporation, St. Louis, MO), 3) the basal diet supplemented with the probiotic Aquablend® (BIO-CAT, Troy, VA), and 4) the basal diet supplemented with both Grobiotic®-A and Aquablend®. Each trial was conducted under conditions to simulate commercial production.

Results: The production trials with hybrid catfish, golden shiners, hybrid striped bass, and tilapia have been reported. Neither of the prebiotic or probiotic supplements either singularly or in combination significantly altered weight gain, feed conversion ratio or survival of those species. However, the microbiota of the gastrointestinal tract of hybrid striped bass was affected by the supplements, as were several innate immune responses. The prebiotic supplement had a greater influence on these responses than the probiotic.

The controlled bacterial challenges conducted with each of those fish did not result in significant mortality, even in fish fed the basal diet. This was likely do to the non-invasive manner in which the fish were exposed to the pathogens or inherent pathogen resistance of the fish such as observed with hybrid catfish. Additional disease challenges are planned with hybrid striped bass and golden shiners to more stringently evaluate the diet supplements. One interesting observation with the hybrid striped bass was both the prebiotic and probiotic supplements significantly improved 7-day survival of fish subjected to handling and temperature stress during transfer from a pond to a holding vat.

A partial enterprise budgeting technique that looks at costs and benefits for the different diets and quantity of fish produced is currently being used to develop benefit cost relationships based on data from the production trials.

Outreach Overview: To date the results from this project have not been extended to intended users. Most of the proposed trials yielded limited results in terms of the ability of the tested products to improve disease resistance of fish. This was due to the inherent resistance of some of the fish species such as hybrid catfish and/or the manner in which the bacterial pathogens were applied. Additional experiments are planned with hybrid striped bass and golden shiners to further evaluate both of the commercial prebiotic and probiotic in terms of their ability to alter disease resistance.

Targeted Audiences: Aquaculturists, feed manufacturers, as well as research and Extension scientists.

Outputs: No specific outputs have been generated to date.

Outcomes/Impacts: Specific impacts have not been generated from this project to date. However, an expanded knowledge base for the potential application of the evaluated products will be available as results from the completed trials are compiled and published. Some additional experiments to further evaluate the products based on findings from the completed trials also are planned.

Partnerships Developed:
International Ingredient Corporation: Type = industry. Level = International. Provided GroBiotic®-A for all feeding trials.
Bio-Cat Microbials: Type = industry. Level = International. Provided Aquablend® for all feeding trials.

Improved Reproduction in Foodfish (Catfish and Largemouth Bass), Baitfish, and Ornamentals Using a New Spawning Aid (GnRH IIa)

Reporting Period: June 1, 2016 - August 31, 2016
Length of Project: 2 years
Current Project Year: 1
Total Funds Committed: $199,982
Principal Investigators: Sylvie Quiniou, Brian Bosworth, *USDA-ARS Warmwater Aquaculture Research Unit*; Chris Green, *Louisiana State University Agricultural Center*; Ken Semmens, Boris Gomelsky, Shawn Coyle, *Kentucky State University Aquaculture Research Center*; Matthew DiMaggio, Craig Watson, *University of Florida Tropical Aquaculture Laboratory*; Cortney Ohs, Jason Broach, *University of Florida*

Relevance: Domestic aquaculture production of teleost fishes primarily encompasses three commercial industries; foodfish, baitfish, and ornamentals. Each segment faces different challenges, but all could improve production and profitability through an increase in reproductive efficiency. Ultimately this investigation will help to assess the viability of GnRH IIa as spawning aid for a wide variety of fish species. In addition, the activities listed have been designed to support an INAD application for GnRH IIa.

Response: The overall goal of this project is to identify an effective dosage(s) GnRH IIa which will successfully induce spawning, result in higher female spawning occurrence than currently observed, and potentially lead to increased larval output compared to current hormonal induction strategies for each species.

Results: At the end of the reporting period, this project was less than 3 months along. Therefore, participants were not asked to provide summary results/outcomes.

Targeted Audiences: Finfish producers.

Outputs: No publications have been generated from this project to date.

Outcomes/Impacts: It is too early in the project to identify any specific impacts.

Partnerships Developed: None.

Predation Risk and Economic Impact of Lesser Scaup and Piscivorous Waterbirds on Commercial Baitfish and Catfish Production

Reporting Period: July 1, 2016 - August 31, 2016
Length of Project: 2 years
Current Project Year: 1
Total Funds Committed: $299,992
Principal Investigators: Luke Roy, Auburn University; Anita Kelly, *University of Arkansas at Pine Bluff*; Brian Davis, *Mississippi State University*; Brian Dorr, *USDA-WS NWRC*; Michael Schwarz, Carole Engle, *Virginia Polytechnic Institute & State University*

Relevance: Lesser scaup and piscivorous waterbirds, such as double-crested cormorants, consume fish raised via aquaculture and result in economic losses on commercial fish farms. This research will improve understanding of utilization of baitfish ponds by lesser scaup, species and sizes of fish consumed, and will ultimately generate an economic analysis of baitfish losses. This project will also generate contemporary information on cormorant roost locations, numbers of birds per roost, and roost distance from active and inactive catfish ponds in Mississippi as well as reveal how cormorants modify their use of roost sites as commercial aquaculture decreases.

Response: Ultimately, results from this study will allow researchers to estimate economic losses of fish caused by these birds, and generate management recommendations for producers to ameliorate depredation of fish by waterbirds.

Results: At the end of the reporting period, this project was less than 2 months along. Therefore, participants were not asked to provide summary results/outcomes.

Targeted Audiences: Finfish producers and natural resource managers.

Outputs: No publications have been generated from this project to date.

Outcomes/Impacts: It is too early in the project to identify any specific impacts.

Partnerships Developed: None.

Products Developed and Students Supported

Journal Articles

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Green, C. and A. Haukenes. 2015. The Role of Stress in Fish Disease. SRAC Publication No. 474 (Revision). Southern Regional Aquaculture Center, Stoneville MS.

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Pickens, J.M. and J. Danaher. 2016. Controlling the Greenhouse Environment for Aquaponics. SRAC Publication No. 5008. Southern Regional Aquaculture Center, Stoneville MS.

Selden, G. 2015. Aquatic Herbicide Mode of Action and Use Implications. SRAC Publication No. 3602. Southern Regional Aquaculture Center, Stoneville MS.

Shirley, M.G. and R.M. Elsey. 2015. American Alligator Production: An Introduction. SRAC Publication No. 230 (Revision). Southern Regional Aquaculture Center, Stoneville MS.

Sink, T. 2015. Investigating a Fish Die-Off and Submitting a Sample for Toxicology or Disease Diagnosis. SRAC Publication No. 472 (Revision). Southern Regional Aquaculture Center, Stoneville MS.

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Brown, T.W., E.L. Torrans, and C.S. Tucker. 2016. Catfish production using intensive, pond-based culture systems in Mississippi. Proceedings, Aquaculture 2016, the Annual Meeting of the World Aquaculture Society, Las Vegas Nevada, February 22-26.

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Cunningham, F., M.M. Jubirt, K.C. Hanson, L. Ford, P.B. Fioranelli, and L.A. Hanson. 2016. Aquatic bird transmission of Virulent strain of *Aeromonas hydrophila*. The International Wildlife Disease Association Annual Meeting. August 3. Courtland, NY.

Cunningham, F., M.M. Jubirt, K.C. Hanson, L. Ford, P.B. Fioranelli, and L.A. Hanson. 2016. Update Aquatic bird transmission of Virulent strain of *Aeromonas hydrophila*. Catfish Farmers East Mississippi Fall Conference. October 30. Macon, MS.

Cunningham, F., M.M. Jubirt, K.C. Hanson, L. Ford, P.B. Fioranelli, and L.A. Hanson. 2016. Potential of fish eating birds to spread virulent Aeromonas hydrophila. The Wildlife Society Annual Meeting. October 14-19. Raleigh, N.C.

Cunningham, F. 2016. Aeromonas Transmission. NWAC Winter Seminar November 30, 2016 in Macon, MS.

Dunham, R. A., N. Chatakondi, T. Hanson, W. Bugg, K. Gosh, D. Drescher, and D. Robinson. 2016. Integrated approaches to reducing individual variability and providing year round harvest of channel-blue hybrid catfish. 2016 Meeting abstracts. Aquaculture America 2016. Las Vegas, NV. World Aquaculture Society.

Dunham, R., K. Gosh, D. Drescher, D. Robinson, T. Hanson and N. Chatakondi. 2015. SRAC Hybrid Catfish Genetics Project 2015 Annual Catfish Update Meeting, Demopolis Convention Center, Alabama, Auburn University – School of Fisheries, Aquaculture and Aquatic Sciences & Aquaculture and Fisheries Business Institute (AFBI). December 15, 2015.

Dunham, R., K. Gosh, D. Drescher, D. Robinson, T. Hanson, and N. Chatakondi. 2016. SRAC hybrid catfish genetics project. 2016 Annual Catfish Update Meeting, Demopolis Convention Center, Alabama, Auburn University – School of Fisheries, Aquaculture and Aquatic Sciences & Aquaculture and Fisheries Business Institute (AFBI). December 13, 2016.

Gosh, K., D. Drescher, D. Robinson, R. Dunham, T. Hanson, and N. Chatakondi. 2015. Integrated Approaches to Reducing Individual Variability and Providing Year Round Harvest of Channel-Blue Hybrid Catfish. School Seminar, School of Fisheries, Aquaculture and Aquatic Sciences, Auburn University. November 6, 2015.

Gosh, K., R. A. Dunham, N. Chatakondi, T. Hanson, D. Drescher, D. Robinson, W. Bugg, and C. Chen. 2016. Studying the growth variability of channel-blue hybrid catfish: an integrated base approach. Auburn University Graduate Student Research Symposium 2016.

Hanson, L.A., L. Ford, K.C. Hanson, and F.L. Cunningham. 2016. Pond Study demonstrates potential of fish eating birds to spread virulent *Aeromonas hydrophila*. American Fisheries Society/Fish Health Section Annual Meeting. June 7-10. Jackson Wyoming. page 20.

Hanson, L.A., M.M. Jubirt, K.C. Hanson, L. Ford, P.B. Fioranelli, and F. Cunningham. 2015. Aquatic bird transmission of Virulent strain of Aeromonas hydrophila. Catfish Farmers East Mississippi Fall Conference. December 3. Macon, MS.

Hanson, L. 2015. Aquatic bird transmission of the Virulent strain of Aeromonas hydrophila. NWAC Fall Seminar, November 19, 2015 in Stoneville MS, NWAC Winter seminar Dec 3, 2015 in Macon, MS.

Jescovitch, L.N. and C.E. Boyd. 2017. Effects of aeration on water quality in waste-treatment sections of split-pond aquaculture, a three-year synopsis. Proceedings, Aquaculture America 2017, the Annual Meeting of the United States Aquaculture Society, San Antonio, Texas, February 19-22.

Ju, M. and D.M. Gatlin III. 2017. Effects of dietary prebiotic and probiotic supplementation on growth performance and disease resistance of hybrid striped bass *Morone chrysops x Morone saxatilis* in ponds. Aquaculture America 2017, San Antonio, TX.

Liles, M.R. 2015. An epidemic of *Aeromonas hydrophila* in farmed catfish and the development of probiotics and a vaccine for disease control. The Volcani Institute, Tel Aviv, Israel.

Liles, M.R. 2015. Virulent *Aeromonas hydrophila*: Detection, origin, and control. Auburn University School of Fisheries, Aquaculture and Aquatic Sciences seminar series, Auburn, AL.

Luna, T.P. and J. Park. 2016. Performance evaluation of a paddlewheel water circulator with different blade shapes in a split-pond test system. Proceedings, Aquaculture 2016, the Annual Meeting of the World Aquaculture Society, Las Vegas Nevada, February 22-26.

Luna, T.P., J. Park, and D. Heikes. 2016. The effect of screen sizes and culvert water return area on pumping performance of a paddlewheel water circulator in a split-pond test system. Proceedings, Aquaculture 2016, the Annual Meeting of the World Aquaculture Society, Las Vegas Nevada, February 22-26.

Luna, T.P., J. Park, L.A. Roy, and A.M. Kelly. 2016. Performance evaluation of split-pond systems operated at two different water turnover rates for production of hybrid catfish *Ictalurus punctatus* x *I. furcatus*. Proceedings, Aquaculture 2016, the Annual Meeting of the World Aquaculture Society, Las Vegas Nevada, February 22-26.

Quintero, H.E., J. Park, L.A., Roy, A.M. Kelly, and D. Heikes. 2016. Comparison of different pond production systems for raising largemouth bass. Proceedings, Aquaculture 2016, the Annual Meeting of the World Aquaculture Society, Las Vegas Nevada, February 22-26.

Robinson, D., R. Dunham, N. Chatakondi, T. Hanson, W. Bugg, K. Gosh, D. Drescher, and N. Backenstose. 2017. Effect of genetics on body weight variability in channel catfish *Ictalurus punctatus* Female × blue catfish *I. furcatus* hybrids. 2017 Meeting abstracts. Aquaculture America 2017. San Antonio, TX. World Aquaculture Society.

Tucker, C.S. and T.W. Brown. 2015. Design and Fish Culture Considerations for Catfish Farming in Split Ponds. Proceedings of the Catfish Farmers of America Research Symposium. Natchez, Mississippi, February 26-28.

Tucker, C.S. and T.W. Brown. 2015. Design and fish culture considerations for catfish farming in split ponds. Proceedings, Aquaculture America 2011, the Annual Meeting of the United States Aquaculture Society, New Orleans, Louisiana, February 28-March 3.

Tucker, C.S., T.W. Brown, J.W. Pote, and C.L. Wax. 2016. Impact of production intensification on water use efficiency in catfish pond aquaculture. Proceedings, Aquaculture 2016, the Annual Meeting of the World Aquaculture Society, Las Vegas Nevada, February 22-26.

Poster Presentations

Thurlow, C.M., M.J. Hossain, D. Sun, J.S. Terhune, and M.R. Liles. 2015. An attenuated *Aeromonas hydrophila* mutant as a vaccine candidate for Motile Aeromonas Septicemia in Channel Catfish (*Ictalurus punctatus*). American Society for Microbiology meeting, New Orleans, LA.

Digital Products

SRAC Website: www.srac.msstate.edu

SRAC YouTube Channel: https://www.youtube.com/channel/UC1VFn_Lef2WdHFEVF1O82jA

AquaPlant Website: http://aquaplant.tamu.edu/

Students Supported

Alexander Gezzar, Louisiana State University, School of Renewable Natural Resources, Undergraduate Researcher, Graduation anticipated Spring 2016.

Barcley Pace, Louisiana State University, School of Renewable Natural Resources, MS student, Thesis Title: Infectivity and Physiological Effects of White Spot Syndrome Virus in Two Louisiana Native Crayfish Species, *Procambarus clarkii* and *Orconectes* spp. Graduation anticipated Spring 2016.

Bradley Richardson, Mississippi State University, PhD student, degree in progress.

Charles M. Thurlow, Auburn University, PhD student, degree in progress.

Dalton Robinson, Auburn University MS student, degree in progress and Auburn University Research Assistant.

David Drescher, Auburn University MS student, degree in progress.

Eric Allison, Auburn University, MS student, degree in progress.

Kamal Gosh, Auburn University, PhD student, degree in progress.

Ken Zachary, Texas A&M University, BS, August 2016.

Min Ju, Texas A&M University, PhD, Anticipated graduation May 2018. Dissertation title: Evaluation of dietary prebiotic and probiotic supplements on hybrid striped bass *Morone chrysops x Morone saxatilis.*

Mohammad Hossain, Auburn University, Postdoctoral scientist, has now taken a postdoctoral position at John Hopkins University.

Nathan Backenstose, Auburn University, MS student, degree in progress.

Oai Chen, University of Arkansas Pine Bluff, PhD.

Oscar Delfin Guillaumin, Mississippi State University, MS student, degree in progress.

Prasant Allaka, University of Arkansas Pine Bluff, PhD.

Priscilla Barger, Auburn University, PhD student, degree in progress.

Ramjie Odin, Auburn University, PhD student, degree in progress.

Tanner Jones, Louisiana State University, School of Renewable Natural Resources, Undergraduate Researcher, Graduation anticipated Spring 2016.

Wenlong (Colin) Cai, Auburn University, PhD student, degree in progress.

William Bugg, Auburn University, MS student, degree in progress.

Appendix 1. List of Completed SRAC Projects to Date

Using National Retail Databases to Determine Market Trends for Southern Aquaculture Products
Duration: 2009-2015 Funding level: $397,845
Participants: UAPB, TTU, AU, UF

Improving Catfish Broodstock Management by Manipulating Diet, Stocking Densities, and Sex Ratios
Duration: 2011-2015 Funding level: $382,463
Participants: UAPB, TAMU, USDA ARS WARU

Identification and Removal of Adhesive Proteins from Goldfish and Baitfish Eggs and Egg Masses
Duration: 2014-2015 Funding level: $32,432
Participants: LSU, UAPB, UF

Implementation of Collective Action Alternatives Identified for the U.S. Catfish Industry
Duration: 2014-2015 Funding level: $121,120
Participants: UAPB, AU, UCD, UMo

Effects of Mosquito Abatement Pesticides on Various Life Stages of Commercially Important Shellfish Aquaculture Species in the South
Duration: 2011-2012 Funding level: $39,973
Participants: Coll. of Charleston, Sanibel-Captiva Conservation Foundation Marine Laboratory

Development of Baitfish, Goldfish and Ornamental Fish Hatchery Methods
Duration: 2011-2012 Funding level: $59,957
Participants: UAPB, LSU, UF

Reproduction and Larval Rearing of Freshwater Ornamental and Marine Bait Fish
Duration 2011-2014 Funding level: $499,400
Participants: UF, LSU, MSU

Potential Marketing Structures for the Catfish Industry
Duration: 2011-2013 Funding level: $244,591
Participants: UAPB, AU, KSU, UCDavis, UMo

Evaluation of Impacts of Potential "Cap and Trade" Carbon Emission Policies on Catfish, Baitfish, and Crawfish Farming
Duration: 2011-2013 Funding level: $119,952
Participants: AU, UAPB, LSU

Development and Evaluation of Cool-Water Crawfish Baits
Duration: 2011-2014 Funding level: $124,326
Participants: LSU, TAMU, AU

Identifying Determinants for Development of Live-Market Grading Standards for Crawfish
Duration: 2011-2012 Funding level: $49,952
Participants: LSU, UAPB

Improving Reproductive Efficiency of Cultured Finfish
Duration: 2009-2011 Funding level: $493,973
Participants: USDA/ARS/CGRU, TAMU-CC, TAMU, AU, UF, UT, UAPB, USDA/ARS NRAC

Economic Forecasting and Policy Analysis Models for Catfish and Trout
Duration: 2007-2009 Funding level: $148,335
Participants: UAPB, LSU, MSU, NCSU, UF, AU

Improving Reproductive Efficiency to Produce Channel x Blue Hybrid Catfish Fry
Duration: 2004-2008 Funding level: $460,000
Participants: AU, LSU, MSU, UMem, USDA/ARS CGRU

Development and Evaluation of Pond Inventory Methods
Duration: 2007-2009 Funding level: $294,976
Participants: UAPB, LSU, MSU, UF, UMiss

Feed Formulation and Feeding Strategies for Bait and Ornamental Fish
Duration: 2005-2008 Funding level: $335, 063
Participants: UAPB, TAMU, UF, UG

Innovative Technologies for Commercial-Scale Aquaculture
Duration: 2004-2008 Funding level: $935,726
Participants: AU, CU, LSU, MSU, UAPB, USDA/ARS CGRU, USDA/ARS NARC

Identification, Characterization, and Evaluation of Mechanisms for Control of Bolbophorus Trematodes and Columnaris-Like Bacteria Causing Disease in Warm Water Fish
Duration: 2003-2006 Funding level: $598,947
Participants: USDA-APHIS-WS, USDA-ARS SNARC, AU, CU, LSU, MSU, NCSU, UAPB, UT

National Aquaculture Extension Conference
Duration: 2002 Funding level: $4,500
Participants: University of Arizona

Development of Improved Harvesting, Grading and Transport Technology for Finfish Aquaculture
Duration: 2001-2003 Funding level: $750,000
Participants: UMem, MSU, NCSU, UAPB, UF, UT

Control of Blue-green Algae in Aquaculture Ponds
Duration: 1999-2001 Funding level: $836,247
Participants: AU, CU, LSU, MSU, NCSU, UAPB, UG, UMiss, UT

Management of Aquacultural Effluents from Ponds
Duration: 1999-2002 Funding level: $555,353
Participants: AU, LSU, MSU, NCSU, UAPB, Waddell MC

National Aquaculture Extension Conference
Duration: 1997 Funding level: $3,700
Participants: Univ. of Maryland

Verification of Recommended Management Practices for Major Aquatic Species
Duration: 1997-2000 Funding level: $160,305
Participants: AU, LSU, NCSU, UAPB

Optimizing Nutrient Utilization through Diet Composition and Feeding Strategies
Duration: 1996-1999 Funding level: $732,804
Participants: AU, LSU, UMem, MSU, NCSU, LSU, TAMU, UAPB, UG

Management of Environmentally-Derived Off-Flavors in Warmwater Fish Ponds
Duration: 1996-1999 Funding level: $866,281
Participants: AU, LSU, LaTech, UMem, MSU, TAMU, UAPB, UMiss, UT

Publications, Videos and Computer Software (Years 1-12)
Duration: 1995-2008 Funding level: $826,000
Participants: TAMU

Improving Production Efficiency of Warmwater Aquaculture Species through Nutrition
Duration: 1994-1996 Funding level: $760,466
Participants: AU, ECU, KSU, LSU, UMem, MSU, TAMU, UAPB, UG

Delineation and Evaluation of Catfish and Baitfish Pond Culture Practices
Duration: 1994-1997 Funding level: $332,993
Participants: AU, LSU, MSU, TAMU, UAPB, UG

Aquaculture Food Safety: Residues
Duration: 1992-1995 Funding level: $351,929
Participants: AU, LSU, MSU, TAMU, TennTech, UF, UG

National Coordination for Aquaculture Investigational New Animal Drug (INAD) Applications
Duration: 1992 Funding level: $2,000
Participants: North Central Regional Aquaculture Center

National Extension Aquaculture Workshop
Duration: 1991 Funding level: $3,005
Participants: UAPB, ACES, TAMU

Educational Materials for Aquaculturists and Consumers
Duration: 1991-1992 Funding level: $133,142
Participants: AU, KSU, LSU, MSU, NCSU, OSU, TAMU, UF, UG, UVI

Characterization of Finfish and Shellfish Aquacultural Effluents
Duration: 1991-1994 Funding level: $442,041
Participants: AU, CU, LSU, MSU, NCSU, TAMU, UAPB, UF, UG, VSU, Waddell MC

Food Safety and Sanitation for Aquacultural Products: Microbial
Duration: 1991-1995 Funding level: $535,338
Participants: UT, AU, LSU, UF, UG

Preparation of Extension Publications on Avian Predator Control in Aquaculture Facilities
Duration: 1990-1992 Funding level: $15,000
Participants: TAMU, MSU, UG, USDA/APHIS/ADC (MS, AR, LA, and S&T Field Station)

Effect of Nutrition on Body Composition and Subsequent Storage Quality of Farm-Raised Catfish
Duration: 1990-1992 Funding level: $822,843
Participants: AU, KSU, LSU, MSU, TAMU, UG

Harvesting, Loading, and Grading Systems for Cultured Freshwater Finfishes and Crustaceans
Duration: 1990-1993 Funding level: $373,952
Participants: LSU, AU, CU, UMem, MSU, UG, USL

Immunization of Channel Catfish
Duration: 1990-1991 Funding level: $99,789
Participants: AU, LSU, UG

Enhancement of the Immune Response to *Edwardsiella ictaluri* in Channel Catfish
Duration: 1990-1991 Funding level: $98,363
Participants: CU, TAMU, UG

Develop a Statistical Data Collection System for Farm-raised Catfish and Other Aquaculture Products in the Southern Region
Duration: 1989-1990 Funding level: $13,771
Participants: MSU, LSU, AU, UA, TAMU, UG, LU, CU, UF, UT, VTU, USDA/NASS

Performance of Aeration Systems for Channel Catfish, Crawfish, and Rainbow Trout Production
Duration: 1988-1990 Funding level: $124,990
Participants: AU, LSU, MSU, NCSU, TAMU

Analysis of Regional and National Markets for Aquacultural Products Produced for Food in the Southern Region
Duration: 1988-1990 Funding level: $346,038
Participants: AU, CU, LSU, MSU, TAMU

Preparation of Southern Regional Aquaculture Publications
Duration: 1988-1990 Funding level: $150,000
Participants: AU, UA, UF, UG, KSU, LSU, MSU, NCSU, UPR, USC, TAMU, UVI