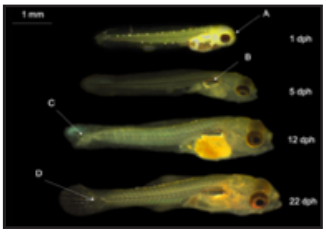
March 2023

33rd ANNUAL PROGRESS REPORT

SRAC

PR VI

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









For the period through December 31, 2020

USDA NIFA

United States Department of Agriculture
National Institute of Food and Agriculture

THIRTY-THIRD ANNUAL PROGRESS REPORT

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EXECUTIVE SUMMARY

This Thirty-Third 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 multi-year research and Extension projects supported by SRAC during this reporting period are available at https://www.srac.msstate.edu/annualprogressreports.html. In the past year, SRAC funded projects totaling more than $2 million. During the past year, these projects have resulted in 1 journal article, 6 Extension/Outreach publications, 13 oral presentations, 2 poster presentations, 5 digital products, and has supported 12 students.

Publications, Videos, and Computer Software

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, 358 technical fact sheets (248 in the current catalog), 102 update revisions, 7 web presentations, 7 software programs or web tools, and 31 videos have been produced. In the current reporting year alone, 36,678 unique users from 140 countries and territories used the SRAC Publications website, https://srac.tamu.edu/, to view or download SRAC publications 98,620 times. SRAC videos were viewed on the SRAC YouTube channel 18,763 times during the current reporting period. The AquaPlant website, created with funding from the SRAC PVCS Project, had 196,909 unique users that viewed 527,612 webpages during the reporting period. These users were from 200 countries/territories. These analytics demonstrate that the SRAC Publications, Videos, and Computer Software project truly has worldwide reach and impact.

Economic Impact and Technology Adoption in U.S. Catfish Industry

The catfish industry continues to be a leading and sustained economic segment in the tri-state regional economies of Alabama, Arkansas, and Mississippi. The economic contribution of the catfish industry to the tri-state region totaled $1.9 billion in 2019. The industry contributed over 9,100 jobs to the regional economy and generated more than $78 million in federal and state tax revenue. The state of Mississippi, with farms, processing plants, and feed mills, is the greatest contributor to the regional economy ($1.3 billion) followed by the state of Alabama ($0.5 billion). The catfish industry was found to support more than 97% of the industries listed in the IMPLAN database for the tri-state regional economy. The study also found that the catfish industry is evolving through the increased adoption of more intensive productivity-enhancing technologies such as intensively aerated ponds and split-pond systems. More than 33% of the catfish production area in 2019 was under intensive-system production. The average aeration rate in the industry in 2019 was 4.2 hp/acre. More than 96% of the surveyed farms had adopted automated oxygen monitoring systems. About 53% of the catfish production area was using hybrid catfish. Over two-thirds of the fingerling production area was vaccinated against ESC at the time of the survey.

Evaluation of Commercial Tilapia Feeds in Recirculating Aquaculture Systems

There is limited information regarding tilapia nutrition in production in recirculating aquaculture systems (RAS) under intense commercial grow out conditions. Furthermore, there is no consensus in the industry that exists whether farmers should use a low protein/lipid (e.g. 36/6) and or high protein/lipid (e.g. 40/10) feed. The project seeks to understand how these different diets impact fish production, water quality and waste management, and the overall economics will help farmers in the Southern region of the U.S. to be successful. The data suggests that there are no significant advantages for

purchasing a more expensive 40/10 feed over the 36/6 feed for the variables evaluated. However, the economic model has not been applied and it is still possible that one diet may prove to me more advantageous over the other. Overall, the outcomes and impacts are not clear.

Evaluation of Probiotics and Prebiotics in Finfish Hatcheries

This project has focused on the evaluation of two commercially available probiotics (Aquaculture Blend from Bio-Cat and Bactocell from Lallemand) and two commercially available prebiotics (GroBiotic®-A from International Ingredient Corporation and SiLO Health® from BASF, Germany). These supplements have been evaluated by administering individually during hatchery production trials of domesticated striped bass, red drum, and Southern flounder. Several different lines of investigation have been pursued in this project and have provided assorted results, some which related directly to prebiotic and probiotic administration, and others to different aspects of larval fish rearing. The administration of prebiotics and probiotics to rotifers was developed such that changes in the microbial composition of the foods was achieved. Significant improvements in swimbladder inflation of domesticated striped bass was necessary to accomplish the feeding trials and has been partially achieved through a combination of techniques. In addition, advances in automated feeding systems for administering Artemia have been made and will enhance the precision by which feeding occurs.

Management Strategies for ESC in Ornamental Fish

The results of this work demonstrate that the isolates from ornamental fish are largely a clonal population with negligible genetic variability. Further, native plasmids among ornamental isolates were also consistent and harbored no recognized antibiotic resistance genes. This would indicate management practices (vaccines; probiotics; antimicrobial regimes) should be consistent across multiple isolates from different facilities and geographic regions. Live attenuated mutant strains which were not harmful to zebrafish in preliminary challenges could be developed successfully. Enrofloxacin and florfenicol drug studies using a closely related species, the giant danio, will help producers more accurately dose medicated feeds for effective disease treatment. Probiotics added to pond water will shift the intestinal bacterial communities of zebrafish, can enhance numbers of “good bacteria” and may help reduce losses from *E. ictaluri*.

Implications of Changes in Federal Authority under the Lacy Act

Due to changes in interpretation of the Lacey Act following a recent court ruling, the regulatory environment for the trade in live aquaculture organisms grown in the Southern region could shift for important markets. This research will bring clarity to how states plan to respond to these Lacey Act changes, including any anticipated regulatory changes impacting Southern region aquaculture. Focus was placed on the trade in live fish/crawfish and other aquatic organisms, where prohibitions, or adoption of U.S. Fish and Wildlife Service approaches and tools could lead to unwarranted prohibitions and lost markets. Identifying anticipated changes at the state level, the strengths and weaknesses (economic, environmental, and sociological) of these and other identified policy/regulatory approaches, can provide clarity to producers. Results will be disseminated to stakeholders so that they can remain informed of regulatory changes and further disseminated to the states so that they can make informed regulatory decisions.

Epidemiology of *Edwardsiella piscicida*

Genotypic profiling established genetic variability among catfish-derived *E. piscicida* isolates and identified five discrete *E. piscicida* phyletic lineages exhibiting group-specific associations with several virulence genes. Plasmids from the studied *E. piscicida* isolates significantly varied in plasmid content

and organization and the unique plasmid sequences have been submitted to GenBank (MZ098222–MZ098227). Phenotypic profiling of representative *E. piscicida* isolates revealed alterations in growth characteristics with respect to incubation temperatures, salt concentrations, and nutrient types. However, there were no phenotypic variations among the studied *E. piscicida* isolates from different genotypes. Challenge studies using *E. piscicida* representatives from each phylogroup indicated significant mortalities in hybrid catfish compared to channel catfish. Histopathological assessment of the infected fish did not reveal any specific trends with respect to *E. piscicida* genotypes. The cross-protective potential of the *E. ictaluri* vaccine against *E. piscicida* in catfish was confirmed abating the need for an *E. piscicida*-specific vaccine. *Edwardsiella piscicida* susceptibility study in Nile tilapia (*Oreochromis niloticus*) reported significant differences in mortality with respect to bacterial isolates from different genetic clades suggesting an underlying genetic basis for strain virulence and potential host associations. The *E. ictaluri* vaccine did not confer protection in immunized tilapia upon exposure to *E. piscicida* (S11-285). So far there are no results to report from the economic analysis.

Reduction of Artemia Use and Replacement with Fortified Rotifers or Artificial Feeds

The rearing of larval finfish typically requires the use of live foods. One of the most popular larval foods is *Artemia salina* (hereafter referred to as Artemia), often wild harvested from the Great Salt Lake or other areas. However, there are limits to the wild harvest, so alternatives that can reduce dependency on Artemia could have not only positive ecological but also economic implications. Because Artemia is widely used in the aquaculture industry and serves as an essential first food or transition food, improvements in its use or development of suitable alternatives are needed. This project has pursued a variety of approaches to reduce the dependence on Artemia in the feeding of larval stages of various fish species. The various research approaches are being pursued by several investigators from three institutions.

Improving the Position of Southern Aquaculture Products in the Grocery Marketplace

The U.S. seafood markets are highly competitive and diversified in terms of species sold and product forms. Domestic aquaculture producers have to be highly competitive to survive in this global marketplace dominated by imports. Domestic producers who are at the lower end of the supply chain are often unaware of the dynamic consumer interactions that occur in retail markets. Success in these dynamic and competitive environments can only be achieved by making effective marketing decisions. Such decisions rely on the availability of information about actual consumer behavior in retail markets as proper analysis of such downstream signals could help formulate effective marketing strategies. This is vital for improved positioning of Southern aquaculture products. Seafood retail scanner data is one of the best sources of information that cover the magnitude, dynamism, and diversity of the U.S. seafood grocery markets. These big data are generated by scanning the Universal Product Code or the barcode of the products. This project is aimed at tailoring marketing information relevant to the southern aquaculture industry by focusing on seafood sales in grocery stores and purchases of seafood at the household level in major markets. To examine retail market trends for seafood in the U.S., seafood scanner data (ScanTrack®) were purchased from A.C. Nielsen Consumer LLC.

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 USDA, 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 32 years of operation, the Center has disbursed more than $20.2 million to fund multi-state research and Extension projects. More than 200 scientists from 41 institutions in the southeast have participated in Center projects.

Productivity from SRAC research projects has been excellent since the Center's inception more than three 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 Thirty-Second 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, 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) approval 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:

Reuben Moore, Mississippi State University (Chair)
Phil Elzer, Louisiana State University AgCenter
Gina Eubanks, Louisiana State University AgCenter
Steve Lommel, North Carolina State University
Gary Lemme, Auburn Cooperative Extension Service, Auburn University
Wes Burger, Mississippi State University
Doze Butler, University of Arkansas Pine Bluff
Edmund Buckner, Alcorn University
Steve Martin, 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 and progress 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:

Margie Saul, AR
Steve Sarten, KY
Ben Pentecost, MS
Martha Campbell, FL
Marty Tanner, FL
David Heikes, AR
Richard Eager, SC
Mitt Walker, AL
Wec Terry, VA
Kim Edge, GA
Douglas Kuenz, LA
Rob Ellis, NC
Frank Roberts, SC
Townsend Kyser, AL
Mark Kubecka, TX
Robert Wright, MS

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 and progress 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 Unit
Ben Reading, North Carolina State University
Waldemar Rossi, Jr., Kentucky State University
Allen Davis, Auburn University
Amit Sinha, University of Arkansas at Pine Bluff
Amrit Bart, University of Georgia
Delbert Gatlin, Texas A&M University
Chris Green, Louisiana State University
Cortney Ohs, University of Florida
Chris Bentley, 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
Gary Burtle, University of Georgia
Luke Roy, 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
Ganesh Kumar, Mississippi State University
Marley Beem, Oklahoma State University
Don Bailey, University of the Virgin Islands
Creig Kimbro, University of Tennessee
Herbert Quintero, University of Arkansas at Pine Bluff

PROGRESS REPORTS

Publications, Videos, and Computer Software

Reporting Period: Jan. 1, 2020 – Sept. 30, 2020
Length of Project: March 1, 1995 – Ongoing
Current Project Year: 23
Total Funds Committed: $32,727
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 SRAC publications and SRAC-aquaponics websites, SRAC YouTube channel, and 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.

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 publications committee based on need and available funding. The best talents 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 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 factsheets 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. Factsheet, videos, and web presentations are accessed daily from the SRAC publications and SRAC-aquaponics websites and SRAC YouTube channel by people searching for technical information.

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

Outputs: Four new fact sheets and one fact sheet revision 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.

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

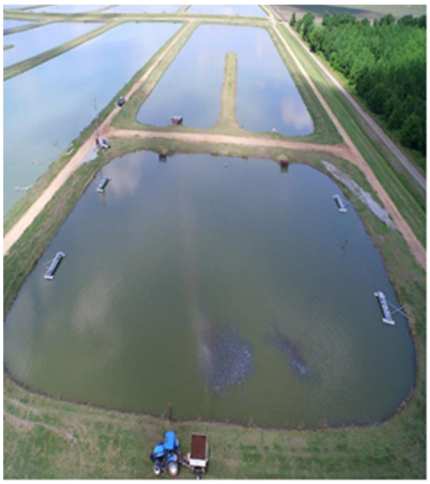
videos for educational purposes, but usage is impossible to measure because access to the information is gained from many different Internet sites, through file sharing, and digital downloads of PDFs.

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 according to usage analytics the consumer information series 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 are experiencing 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 358 technical fact sheets (248 in the current catalog), 102 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, **36,678*** unique users from **140*** countries and territories used the SRAC Publications website, https://srac.tamu.edu/, to view or download SRAC publications **98,620*** times. SRAC videos were viewed on the SRAC YouTube channel **18,763*** times during the current reporting period. The AquaPlant website, created with funding from the SRAC PVCS Project, had 196,909* unique users that viewed 527,612* webpages during the reporting period. These users were from 200* 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.

Economic Impact Assessment and Monitoring Progress of Technology Adoption in the U.S. Catfish Industry



Reporting Period: Aug. 1, 2018 – Sept. 20, 2020
Length of Project: 2 years
Current Project Year: 2
Total Funds Committed: $112,670
Principal Investigators: Ganesh Kumar, *Mississippi State University*; Carol Engle and Jonathan van Senten, *Virginia Polytechnic Institute and State University*; Terry Hanson and Luke Roy, *Auburn University*; Carol Engle, *Engle Stone Aquatics, LLC*

Relevance: The catfish industry has undergone a rapid transformation through adoption of productivity-enhancing technologies to improve profitability. Such dynamic structural changes have many implications for management and for policymakers. This study will produce the most comprehensive, accurate, and current estimates of the economic contribution of the catfish industry along with the progress of on-farm adoption of productivity-enhancing technologies. Accurate estimates of the economic contribution of the catfish industry and technology progress will provide valuable insights for policymakers in making sound policy decisions.

Response: Researchers from three institutions collaborated to quantify the economic contribution of the catfish industry in the three major catfish-producing states of Alabama, Arkansas, and Mississippi. A comprehensive survey of catfish farms and associated backward- and forward-linked supply-chain elements (i.e., feed mills, processors) was designed and launched to collect detailed firm-level data to estimate the economic impact of the catfish industry. The survey was conducted from 2019 to 2020 and collected responses from 68 farms and 14 supply-chain partners of the catfish industry. An analysis-by-part approach using IMPLAN input-output modeling techniques was employed to detail the contribution of the catfish industry to the three state and tristate regional economies, as well as the specific contribution of farms and supply-chain actors to the regional economy for the year 2019. The survey also collected information on ongoing technological progress on catfish farms by measuring the on-farm adoption of alternative catfish production technologies (split-pond, intensively aerated pond, and in-pond raceway systems), complementary technologies (fixed paddlewheel aeration, hybrid catfish, and oxygen monitoring systems) and the extent of adoption of vaccination technology on fingerling operations.

Results: The catfish industry continues to be a leading and sustained economic segment in the tri-state regional economies of Alabama, Arkansas, and Mississippi. The economic contribution of the catfish industry to the tri-state region totaled $1.9 billion in 2019. The industry contributed over 9,100 jobs to the regional economy and generated more than $78 million in federal and state tax revenue. The state of Mississippi, with farms, processing plants, and feed mills, is the greatest contributor to the regional economy ($1.3 billion) followed by the state of Alabama ($0.5 billion). The catfish industry was found to support more than 97% of the industries listed in the IMPLAN database for the tri-state regional economy.

The study also found that the catfish industry is evolving through the increased adoption of more intensive productivity-enhancing technologies such as intensively aerated ponds and split-pond systems. More than 33% of the catfish production area in 2019 was under intensive-system production. The average aeration rate in the industry in 2019 was 4.2 hp/acre. More than 96% of the surveyed farms had adopted automated oxygen monitoring systems. About 53% of the catfish production area was using hybrid catfish. Over two-thirds of the fingerling production area was vaccinated against ESC at the time of the survey.

Outreach Overview: None to date. However, results of the study will be presented at the 2021 Aquaculture America meeting as well as at various upcoming catfish producer meetings scheduled in Stoneville, MS; Macon, MS; Greensboro, AL; and Hot Springs, AR. The results will also be disseminated to the Extension specialists working with catfish farmers in the tri-state region as well as to National and State aquaculture associations.

Targeted Audiences: Targeted audiences included primarily catfish farmers, policymakers, researchers, industry organizations, congressional members and staff, and the general public.

Outputs: None to date. Two peer-reviewed manuscripts, two popular articles in The Catfish Journal as well as several infographics are planned as outputs from this project.

Outcomes/Impacts: None to date. The ultimate impact of this collective study cannot be estimated at this moment as the analysis has only recently been completed.

Partnerships Developed: Larry Dorman, University of Arkansas at Pine Bluff, Extension Aquaculture Specialist, and Sunni Dahl, Auburn University, Research Assistant III

Evaluation of Protein and Lipid Concentrations in Commercially Available Tilapia Feeds and Their Effect in Intensive Production Systems

Reporting Period: June 1, 2017 – Dec. 31, 2020
Length of Project: 2 years
Current Project Year: 2
Total Funds Committed: $184,844
Principal Investigators: David Kuhn, Carole Engle, Jonathan van Senten, Michael Schwarz, *Virginia Polytechnic Institute & State University*; Rob Ellis, *Astor Farms*; Delbert Gatlin, *Texas A&M University*

Relevance: In the Southern region of the U.S., we have farmers that use feed for intense production of tilapia. Even though we have some understanding of general tilapia nutrition (e.g., in ponds with natural productivity), there is limited information regarding tilapia nutrition in production RAS (e.g., relatively sterile environment) under intense commercial grow out conditions. Furthermore, there is no consensus in the industry that exists whether farmers should use a low protein/lipid (e.g. 36/6) and or high protein/lipid (e.g. 40/10) feed. Both low and high protein/lipid commercial feeds are being used by various farmers. By conducting research under the auspices of this project we will begin to understand how these different diets impact fish production, water quality and waste management, and the overall economics will help farmers in the Southern region of the U.S. to be successful.

Response: During this reporting period the first set of six-month trials was completed, and a second six-month trial started. These trials were designed to compare high protein and lipid (40/10) versus low (36/6). Trials were conducted at two tilapia farms in the southern region of the U.S. using commercially available feeds. The 40/10 feed, on average cost 13% more than the 36/6 feed. For the experiments: a fraction of Farm A was outfitted with four tanks per diet and the other farm (Farm B) three tanks per diet were dedicated to the project. At each farm, feed used (amount of each feed per tank), production data (e.g., survival, growth, and feed conversion rates), whole fish composition (e.g., moisture, protein, lipid, ash) and body indices (e.g., hepatosomatic index, intraperitoneal fat ratio) of fish, water quality parameters (alkalinity, ammonia, chloride, dissolved oxygen, nitrite, nitrate, pH, temperature, dissolved oxygen, etc.), and other inputs added (e.g. water disposed and used, lime, sodium bicarbonate, salt, etc.) were recorded and tracked. Data analysis of the aforementioned data has been completed for Trial one.

Results: Protein and lipid content of the 40/10 and 36/6 feed had actual respective values of 38.6/5.7 and 43.9/9.76. Interestingly, during the first trial there were no statistical differences ($P>0.05$, using tanks as the treatment level) for feed used, production data, whole fish composition, water quality parameters, and other inputs added to the systems at both farms. The only significant differences ($P<0.05$) observed on occasion, from batch to batch, was that the hepatosomatic index was higher in the 40/10 diet compared to the 36/6. The baseline economic models have been completed and are ready for modelling with the experimental from the aforementioned data.

Outreach Activity: Outreach activity during this reporting period was limited to the two farms and the feed company involved directly on the project as we are still collecting data and performing analysis before any concrete conclusions can be drawn from our work.

Targeted Audience: Since we are still in the process of collecting data the target audience has been limited to the two farms and the feed company involved on the project.

Outputs: Nothing to report for this reporting period.

Outcome/Impacts: Remarkably, the data thus far suggests that there are no significant advantages for purchasing a more expensive 40/10 feed over the 36/6 feed for the variables evaluated thus far. However, the economic model has not been applied during this reporting period and it is still possible that one diet may prove to me more advantageous over the other. Overall, the outcomes and impacts are not clear until more data and data analysis is completed.

Partnerships: None.

Evaluation of Probiotics and Prebiotics in Finfish Hatcheries to Improve Larval Production

Reporting Period: Sept. 1, 2018 – Dec. 31, 2020
Length of Project: 2 years
Current Project Year: 2 year
Total Funds Committed: $249,971
Principal Investigators: Delbert Gatlin and Todd Sink, *Texas A&M University*; Mike Frinsko, Steven Hall, Craig Harms, and Harry Daniels, *North Carolina State University*; Robert Vega, *Texas Parks and Wildlife*; Lou D'Abramo, *University of Alabama at Birmingham*

Relevance: Poor and unpredictable hatchery production can be a major impasse to the development and enhancement of marine fish aquaculture in the United States. Due to numerous common challenges in hatchery operation, including undesirable conditions such as overcrowding and poor water quality, elevated fish mortalities are often encountered. Thus, both probiotics and prebiotics were evaluated in an effort to improve early rearing survival, as well as enhance subsequent fish growth and immunity.

Response: This collaborative project, involving researchers at four different Southern regional institutions, has focused on the evaluation of two commercially available probiotics (Aquaculture Blend from Bio-Cat and Bactocell from Lallemand) and two commercially available prebiotics (GroBiotic®-A from International Ingredient Corporation and SiLO Health® from BASF, Germany). These supplements have been evaluated by administering individually during hatchery production trials of domesticated striped bass, red drum, and Southern flounder.

Results: Several different lines of investigation have been pursued in this project and have provided assorted results, some which related directly to prebiotic and probiotic administration, and others to different aspects of larval fish rearing. The administration of prebiotics and probiotics to rotifers was developed such that changes in the microbial composition of the foods was achieved. Significant improvements in swimbladder inflation of domesticated striped bass was necessary to accomplish the feeding trials and has been partially achieved through a combination of techniques. In addition, advances in automated feeding systems for administering Artemia have been made and will enhance the precision by which feeding occurs.

Outreach Activity: It is anticipated that results of these various project activities will be of particular interest to anyone culturing larval fish species. Results of this project will be distributed to aquaculturists through refereed journal publications, articles in trade journals, conferences, and a Southern Regional Aquaculture Center fact sheet.

Targeted Audience: Aquaculturists working at state and federal fish hatcheries, as well as commercial facilities in which culture of fish species through larval stages is conducted.

Outputs: Specific outputs from this project have not been realized to date.

Outcome/Impacts: Outcomes/impacts have not been achieved to date because many of the techniques evaluated at experimental scale have not been extended to hatchery production at larger scale. However, such activities are planned although they were largely curtailed by the COVID-19 pandemic.

Partnerships: Texas Parks and Wildlife Department; Pamlico Aquaculture Field Laboratory

Increasing Understanding of and Developing Management Strategies for *Edwardsiella ictaluri* in Ornamental Fish

Reporting Period: Oct. 1, 2018 – Dec. 31, 2020
Length of Project: 2 years
Current Project Year: 2 year
Total Funds Committed: $212,036
Principal Investigator: Matt Griffin, David Wise, Suja Aarattuthodiyil, *Mississippi State University*; Roy Yanong, Chris Martyniuk, *University of Florida*; John Hawke, *Louisiana State University*

Relevance: Variants of the catfish disease-causing bacteria *Edwardsiella ictaluri* have been reported in the tilapia and ornamental fish industries. Researchers will determine biological differences and similarities between the catfish and ornamental fish strains and evaluate effectiveness of vaccines, antibiotics, natural gut antibacterials, and probiotics to manage the disease.

Response: Archived *E. ictaluri* isolates were obtained from the collections of the MSU-TCNWAC in Stoneville, MS, the LSU-LADL in Baton Rouge, LA, and UF-TAL in Ruskin, FL. Presumptive identification of the isolates was conducted by colony morphology and growth characteristics, which was confirmed using *Edwardsiella ictaluri*-specific PCR. A rifampicin resistant mutant strain of *E. ictaluri* was developed using a zebrafish isolate (LADL 11-194) for vaccine work. Zebrafish were obtained to screen for potential probiotic bacteria producing bacteriocins. Giant danios were obtained for use as a proxy for pharmacokinetic (drug dosing) studies. Commercial probiotic companies were contacted for product testing and delivery.

Results: Catfish and ornamental fish-derived isolates represent two discrete phyletic lineages**.** Within groups, isolates from catfish and ornamental fish were largely clonal, with few exceptions, indicating a high degree of genetic stability among *E. ictaluri* populations within each discrete industry. Live attenuated vaccines for *E. ictaluri* developed at LSU, ΔureG and ΔesrC, were prepared for inclusion in the study. Preliminary challenge trials with the disease-causing strains were unsuccessful with the initial population of zebrafish from Florida, potentially due to previous exposure to the disease or another vaccine. Optimal dosing with a good probability of successful treatment of an infection ranged from 2 to 4 mg/L for 60 mg/kg oral florfenicol, from 0.125 to 0.5 mg/L for 8 mg/kg oral enrofloxacin, and from 0.016 to 0.0625 mg/L for bath dosing (10 mg/L for 5 h) of enrofloxacin. We also demonstrate that the concentration of probiotics used in the dosing regimen are important in achieving microbiome shifts in the gastrointestinal system as Probiotic A (at a lower concentration) did not influence the species richness.

Outreach Overview: Five presentations to fish health and culture professionals and veterinary and graduate students were provided at four different meetings: the 46th Annual Meeting of the Mississippi Chapter of the American Fisheries Society (February 2020), the 45th Annual Meeting of the Mississippi Chapter of the American Fisheries Society (February 2019), the Virtual Conference of the International Association for Aquatic Animal Medicine (May 2021), and the American Fisheries Society Fish Health Section Summer Student Seminar Series (June 2021). An additional presentation on probiotic studies is scheduled for the Eastern Fish Health Workshop, April 2022. Refereed publications are currently in

preparation. Outreach has occurred through some discussions with individual farms, but outreach is also currently planned through industry newsletters and farmer meetings, additional one-on-one industry contacts, and extension publication updates.

Targeted Audiences: Catfish and ornamental fish producers, fish health professionals, extension agents, broad scientific community

Outputs: Nothing to report

Outcomes/Impacts: The results of this work demonstrate the isolates from ornamental fish are largely a clonal population with negligible genetic variability. Further, native plasmids among ornamental isolates were also consistent and harbored no recognized antibiotic resistance genes. This would indicate management practices (vaccines; probiotics; antimicrobial regimes) should be consistent across multiple isolates from different facilities and geographic regions. Live attenuated mutant strains which were not harmful to zebrafish in preliminary challenges could be developed successfully. Enrofloxacin and florfenicol drug studies using a closely related species, the giant danio, will help producers more accurately dose medicated feeds for effective disease treatment. Probiotics added to pond water will shift the intestinal bacterial communities of zebrafish, can enhance numbers of "good bacteria" and may help reduce losses from *E. ictaluri*.

Partnerships: Nothing to report.

Policy Analysis of the Implications of Changes in Federal Authority Under the Lacey Act to Prohibit Interstate Movement of Injurious Wildlife

Reporting Period: Oct. 1, 2019 – Dec. 31, 2020
Length of Project: 1 year
Current Project Year: 1
Total Funds Committed: $116,975
Principal Investigators: Jeffrey E. Hill and Quenton, *IFAS – University of Florida*; Christopher Green. *Louisiana State University*; Carole Engle and Jonathan van Senten, *Virginia Tech University*

Relevance: Scientists at the University of Florida, Louisiana State University, University of Tennessee, and Virginia Polytechnic Institute and State University will work in collaboration to analyze the policy implications of the recent changes in federal authority under the Lacey Act. Following a recent court ruling the Lacey Act can no longer be used by the U.S. Fish and Wildlife Service (USFWS) to prohibit interstate transport of injurious wildlife. These recent changes to the Lacey Act bring uncertainty for producers which trade in live fish/crawfish and other aquatic animals because the regulatory approaches adopted by southern region states or market states may be detrimental to commercial, stock enhancement, and conservation aquaculture. The project staff will determine for southern region states and territories and other states with important markets for Southern region aquaculture commodities their current and probable future regulations and practices used to evaluate potentially prohibited/invasive aquatic species, especially those listed as injurious wildlife by the USFWS using a standardized questionnaire. The strengths and weaknesses (economic, environmental, and sociological) of these and other identified policy/regulatory approaches will be evaluated relative to southern regional aquaculture. Project staff will provide management recommendations to federal and state agencies and aquaculture groups within and outside the Southern region and actionable information for extension personnel to further educate agency staff and producers. Project results will be disseminated through peer-reviewed journal and extension documents, workshops (including a webinar), and presentations at professional conferences (e.g., Association of Fish and Wildlife Agencies).

Response: A combination of internet searches of state statutes and administrative code and a formal phone survey with a standardized questionnaire to identify current regulatory practices was used. The phone survey was directed to state Aquatic Nuisance Species coordinators (ANS coordinators). Project staff examined state regulations (using web searches) pertaining to the possession and sale of non-native aquatic species for all 50 states. Policy/regulatory options were identified which were subsequently analyzed to determine the complex mosaic of strengths and weaknesses to each approach. The goal was to identify how each approach balanced environmental protection and reasonable economic activity. Project investigators assessed the implications of policy and regulatory options identified in terms of overall trade (volume and the types of species), potential for decline/growth, and economic effects.

Results: Based on a national survey of aquatic nuisance species coordinators:

- Following Lacey Act ruling: 43 states made no changes, 3 added species to their prohibited list, and 1 state harmonized regulations with USFWS injurious wildlife lists
- Of the 43 states yet to make changes, 33 had no plan for changes, 9 were in the process of assessing their options, and 1 had plans for harmonization with USFWS lists
- 32 states had no standardized procedure for evaluating invasiveness risk of aquaculture species, 13 had a standardized process, and 2 used common processes but were not standardized
- 31 states had no intention of changing process and 16 were interested in changing or adopting a process
- 10 states used the USFWS ERSS (mainly outputs rather than new assessments), 5 indicated used of FISK or AS-ISK, 5 used an unknown/in-house process; other tools were used by single states
- Most states engaged in risk management activities in addition to risk assessment, but seldom used formal or structured processes
- Most states lacked in-house expertise in risk analysis, with some exceptions in the Midwest, west coast, and Florida
- The extent to which stakeholders were included in risk analysis efforts varied but was unclear and not standardized across states

Policy approaches:

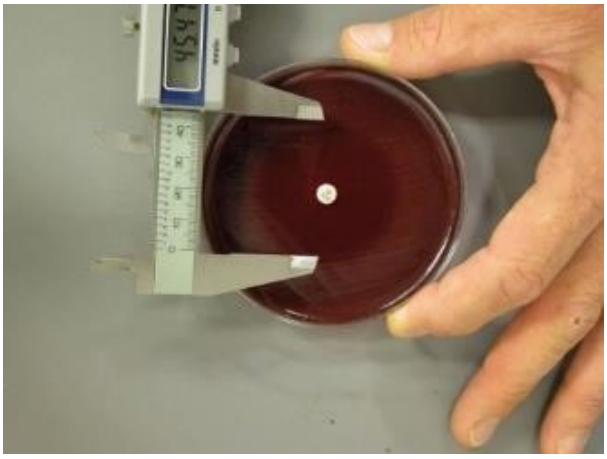
- Most policy options focused on possession, with prohibition on a case-by-case basis and harmonization with surrounding states the most common and balanced options; state laws universally prohibited release of non-native species without a permit; education and outreach were large components of non-native species policy in nearly all states
- Policy most likely to provide a balance between environmental protection and reasonable economic activity relative to southern regional aquaculture included prohibitions on a case-by-case basis using risk-based approaches, coordination with neighboring states, and harmonization with neighboring states if warranted
- Policy most likely to negatively affect southern regional aquaculture includes decision-making without support from risk-based approaches, blanket prohibitions, automatic harmonization with neighboring states, and automatic harmonization with USFWS Injurious Wildlife list

Outcomes/Impacts: Potential economic impacts on Southern regional aquaculture:

- Pending petition of the USFWS to list new species as injurious threatens southern regional aquaculture, especially if the USFWS is granted the authority to prohibit interstate ships of injurious wildlife
- Several species could be impacted but the main southern regional aquaculture species affected would be blue catfish, tilapia (*Oreochromi*s spp.), grass carp, koi carp, red swamp crawfish, and guppy, resulting in economic losses of at least $429,558,935 and loss of 4,298 jobs
- Goldfish, though not listed currently and not petitioned for listing, may have genes of currently listed species (Crucian carp, Prussian carp). Enforcement could result in losses of $15,549,164 and loss of 355 jobs.

Investigating the Epidemiology of *Edwardsiella piscicida* -Septicemia in Hybrid Catfish and Other Commercially Important Fish Species in the Southern United States

Reporting Period: Oct. 1, 2019 - Dec. 31, 2020
Length of Project: 3
Current Project Year: 1
Total Funds Committed: $358,232
Principal Investigators: Suja Aarattuthodiyil, Matt Griffin, Ganesh Kumar, Terry Greenway, Lester Khoo, and David Wise, *Mississippi State University*; Alvin Camus, *University of Georgia*; Carole Engle and Jonathan van Senten, *Virginia Polytechnic Institute and State University*; Larry Dorman and Grace Ramena, *University of Arkansas Pine Bluff*; John Hawke, Louisiana State University; and Esteban Soto, *University of California-Davis*



Relevance: Bacterial septicemia associated with *Edwardsiella piscicida* is an emerging disease in the U.S. catfish industry. Increased incidence and prevalence within the industry has led to laboratory investigations demonstrating a higher susceptibility of hybrid catfish to *E. piscicida* infection than channel catfish. Molecular profiling has confirmed 96% of archived isolates from the Aquatic Research and Diagnostic Laboratory, Stoneville, MS, phenotypically identified initially as *E. tarda* were in fact *E. piscicida*. Moreover, *E. piscicida* is recognized as a virulent pathogen of significant importance in global aquaculture, with a wide host range affecting > 20 economically important fish species. Economic losses on catfish farms can be substantial as outbreaks primarily affect market-size fish during the grow-out phase of production, where significant investments have already been incurred. Preliminary reports indicate fish immunized with *E. ictaluri* are less susceptible to *E. piscicida* and vice versa, suggesting vaccine candidates already developed against *E. ictaluri* may have utility as an effective *E. piscicida* vaccine.

A complete study of the epidemiology of *E. piscicida*-septicemia is warranted to ascertain the gravity of this emerging disease in hybrid catfish and other commercially important fish species. Researchers from six institutions will collaborate on this project for: 1) Disease surveillance of *E. piscicida* in the Southeastern U.S., 2) Phenotypic, serological, molecular and pathological characterization of *E. piscicida* with *E. ictaluri*, evaluation of the cross-protective efficiency of an already developed ESC vaccine and 3) Explore the economic impacts of Edwardsiellosis in channel and hybrid fingerling and foodfish production systems. Comprehending the pathobiology and pathogenesis of *E. piscicida* is critical to develop effective pathogen-specific control strategies and to provide aquaculturists efficient tools to combat this emergent disease.

Response: Disease surveillance of *E. piscicida* in the Southeastern U.S. Case records from the disease diagnostic laboratories (Stoneville, MS; Baton Rouge, LA, and Lake Village, AR) were collected to determine trends associated with *E. piscicida*-septicemia in catfish and other fish species. Pond water samples from hybrid catfish farms were collected twice monthly from April - October and processed for *E. piscicida* detection. Data collection on foodfish production losses due to *E. piscicida* primarily on hybrid catfish ponds will be collected in the third year of this project.

Results: Genotypic profiling established genetic variability among catfish-derived *E. piscicida* isolates and identified five discrete *E. piscicida* phyletic lineages exhibiting group-specific associations with several virulence genes. Plasmids from the studied *E. piscicida* isolates significantly varied in plasmid content and organization and the unique plasmid sequences have been submitted to GenBank (MZ098222–MZ098227). Phenotypic profiling of representative *E. piscicida* isolates revealed alterations in growth characteristics with respect to incubation temperatures, salt concentrations, and nutrient types. However, there were no phenotypic variations among the studied *E. piscicida* isolates from different genotypes. Challenge studies using *E. piscicida* representatives from each phylogroup indicated significant mortalities in hybrid catfish compared to channel catfish. Histopathological assessment of the infected fish did not reveal any specific trends with respect to *E. piscicida* genotypes. The cross-protective potential of the *E. ictaluri* vaccine against *E. piscicida* in catfish was confirmed abating the need for an *E. piscicida*-specific vaccine. *Edwardsiella piscicida* susceptibility study in Nile tilapia (*Oreochromis niloticus*) reported significant differences in mortality with respect to bacterial isolates from different genetic clades suggesting an underlying genetic basis for strain virulence and potential host associations. The *E. ictaluri* vaccine did not confer protection in immunized tilapia upon exposure to *E. piscicida* (S11-285). So far there are no results to report from the economic analysis.

Outreach Overview: Nothing to report. After completion of studies, outreach will ensue via Extension agents and specialists with industry members and researchers.

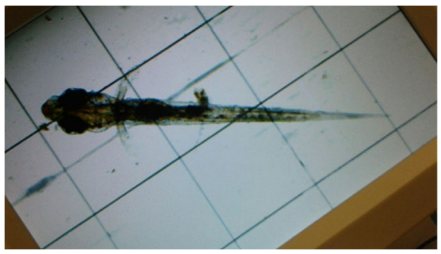
Targeted Audiences: Fish producers, fish health professionals, extension agents, and researchers.

Outputs: Nothing to report

Outcomes/Impacts: Study findings identified five discrete *E. piscicida* phyletic groups exhibiting group-specific association with several virulence genes. Though the growth characteristics of catfish-derived *E. piscicida* isolates differed with respect to incubation temperatures, salt levels in media, and nutrient types, these were not linked to different genotypes. Challenge studies using representative isolates indicated *E. piscicida* to be more virulent in hybrid catfish than in channel catfish. A live-attenuated *E. ictaluri* vaccine conferred cross-protective immunity in channel and hybrid catfish against *E. piscicida* isolates confirming the multivalent nature of the vaccine and its potential utility in commercial operations.

Partnerships: Nothing to report

Managing Larval Feeding for Improved Survival by Reduction of Artemia Use and Replacement with Fortified Rotifers or Artificial Feeds



Reporting Period: Sept. 1, 2020 – Dec. 31, 2020
Length of Project: 3 years
Current Project Year: 1
Total Funds Committed: $294,533
Principal Investigators: Delbert Gatlin, Todd Sink, *Texas A&M University*; Mike Frinsko, Steven Hall, Michael Joseph, Kimberly Livingston, Ben Reading, *North Carolina State University*; Jason Broach, *Waddell Mariculture Center SCDNR*; Michael Denson, Aaron Watson, Erin Levesque, *Marine Resources Division SCDNR*

Relevance: The rearing of larval finfish typically requires the use of live foods. One of the most popular larval foods is *Artemia salina* (hereafter referred to as Artemia), often wild harvested from the Great Salt Lake or other areas. However, there are limits to the wild harvest, so alternatives that can reduce dependency on Artemia could have not only positive ecological but also economic implications. Because Artemia is widely used in the aquaculture industry and serves as an essential first food or transition food, improvements in its use or development of suitable alternatives are needed.

Response: This project has pursued a variety of approaches to reduce the dependence on Artemia in the feeding of larval stages of various fish species. The various research approaches are being pursued by several investigators from three institutions.

Results: Three distinct objectives are being pursued in this project as follows:

1) Define effective feeding mechanisms and strategies to reduce Artemia use in the hatchery.
   Automation of Artemia Feeding. Significant improvements have been made to the automated North Caroline State University (NCSU) *Artemia* feeding system initially developed in a prior project. This has resulted in the creation of a state-of-the-art tablet-mounted GUI control system which has provided the ability to adjust: 1) feeding rate (based on concentration), 2) time of feeding, 3) feeding interval, and 4) concentration, for each treatment associated with *Artemia* feeding experiments.
   Alternative live foods production. Another component of the project has evaluated a refined, simple technology of live foods production for hatcheries that eliminates the high costs and rigorous equipment and labor requirements of intensive larval culture, as well as removes the water waste, uncertain timing of fertilization, and high fish mortality due to predators and temperature fluctuations of extensive larval culture.
2) Evaluate commercially available artificial diets and alternative live food organisms for fresh and saltwater species that are effective replacements to Artemia.
   To date, such evaluations of commercially available artificial diets and alternative live food organisms for freshwater and saltwater fish have been conducted with larval zebrafish and red drum, respectively, at Texas A&M University (TAMU). Additional trials will be conducted with southern flounder (TAMU) and domesticated striped bass larvae (NCSU) when those fish are available. Preparations were made at the South Carolina Department of Natural Resources, Marine Resources Division, to conduct feeding trials with three marine baitfish, namely spot, pinfish, and

pigfish. During the reporting period, mature fish of the three species were obtained from the Broad River estuary to serve as broodfish for provision of eggs and larvae for experimentation which is set to begin in 2021.

3) Evaluate enrichments of rotifers and other live food organisms to increase their nutritional composition as suitable Artemia replacements.
   To date research under this objective has included the development of regimes in which rotifers can be effectively enhanced with either taurine or vitamin C. Replicated assays have been conducted at TAMU to refine the level and duration of exposing rotifers to these supplements while maximizing resulting concentrations.
   The NCSU component of this objective include the following:
   Incorporation of INVE "Sep-Art" *Artemia* has greatly enhanced the purity of Artemia hatches compared to traditional methods involving decapsulation. This process uses the same GSL cysts that we used before, however, the Sep-Art cysts are coated with a ferrous material that allows magnetic removal following hatching.

Outreach Overview: This is the first progress report for this project and thus most of the anticipated results have not been extended to the intended users. However, it is anticipated that the various activities associated with this project will be of interest to anyone culturing larval fish species or producing live foods or larval feeds. As such, results of the project will be distributed to aquaculturists and other groups through refereed journal publications, articles in trade journals, conferences, and a Southern Regional Aquaculture Center fact sheet.

Targeted Audiences: This will include aquaculturists working at state or federal fish hatcheries, as well as commercial facilities in which culture of fish species through larval stages is conducted.

Outputs: No outputs have been generated to date due to the limited reporting period.

Outcomes/Impacts: To date, the outcomes and impacts achieved on this project have been internal in that project participants have been able to adjust and refine experimental protocols based on initial efforts to address the various objectives of this project. It is anticipated that as more results are generated from this project, major impacts on how larval fish are cultured with live foods and/or larval diets will be realized.

Partnerships Developed: Texas Parks and Wildlife Department; Pamlico Aquaculture Field Laboratory

Targeted Marketing Research and Outreach for Improving the Position of Southern Aquaculture Products in the Grocery Marketplace

Reporting Period: July 1, 2020 - December 31, 2020
Length of Project: 3 years
Current Project Year: 1
Total Funds Committed: $299,856
Principal Investigators: Ganesh Kumar, *Mississippi State University*; Jonathan van Senten, *Virginia Polytechnic Inst. and State University*; Madan Dey, *Texas State University*

Relevance: The U.S. seafood markets are highly competitive and diversified in terms of species sold and product forms. Domestic aquaculture producers have to be highly competitive to survive in this global marketplace dominated by imports. Domestic producers who are at the lower end of the supply chain are often unaware of the dynamic consumer interactions that occur in retail markets. Success in these dynamic and competitive environments can only be achieved by making effective marketing decisions. Such decisions rely on the availability of information about actual consumer behavior in retail markets as proper analysis of such downstream signals could help formulate effective marketing strategies. This is vital for improved positioning of southern aquaculture products.

Response: Seafood retail scanner data is one of the best sources of information that cover the magnitude, dynamism, and diversity of the U.S. seafood grocery markets. These big data are generated by scanning the Universal Product Code (UPC) or the barcode of the products. This project is aimed at tailoring marketing information relevant to the southern aquaculture industry by focusing on seafood sales in grocery stores and purchases of seafood at the household level in major markets. To examine retail market trends for seafood in the U.S., seafood scanner data (ScanTrack®) were purchased from A.C. Nielsen Consumer LLC.

Results: The original purchase of the retail scanner data from AC Nielsen Consumer LLC was proposed for Year 1, Quarter 2 of the project (January 2021). However, inadvertent delays were experienced that delayed the purchase of the data for a number of months. Finally, the dataset was purchased and downloaded on September 13, 2021. This big seafood dataset comprised 53 million rows of seafood retail market information. The dataset included weekly sales information from September 2016 to August 2021 for 54 cities, eight regional markets, and the overall U.S. retail market from more than 62,000 retail stores for 53 major seafood categories. The big data acquired comprise more than 1.5 billion cells and careful handling is required for proper aggregation into species groups. Efforts are underway to separate and aggregate this big dataset into major seafood groups including important southern regional aquaculture sectors such as catfish, trout, crayfish, shellfish, shrimp, and salmon.

Outreach Overview: None to date.

Targeted Audiences: The targeted audience includes aquaculture producers and processors in the southern region, policymakers, researchers, industry organizations, congressional members and staff, and the general public.

Outputs: None to date.

Outcomes/Impacts: None to date.

Partnerships Developed: Leslie Noel Sturmer, Shellfish Aquaculture Extension Specialist, University of Florida

Products Developed and Students Supported

Journal Articles and Abstracts

López-Porras A, Griffin MJ, Armwood AR, Camus AC, Waldbieser GC, Ware C, Richardson B, Greenway TE, Rosser TG, Aarattuthodiyil S, Wise DJ. 2021. Genetic variability of *Edwardsiella piscicida* isolates from Mississippi catfish aquaculture with an assessment of virulence in channel and channel × blue hybrid catfish. Journal of Fish Diseases. 44(11):1725-1751.

Extension/Outreach Publications

Cassiano, E.J. 2020. SRAC Publication No. 4607, *Groundwater Treatment Before Use in Aquaculture*. 8 pages

Coyle, S.D., J.H. Tidwell, and M.D. Matthews. 2020. SRAC Publication No. 0201, *Culture of Largemouth Bass Fingerlings*. 9 pages

Hinshaw, J.M., C.R. Engle, and J. van Senten. 2020. SRAC Publication No. 0221, *Enterprise Budgets for Trout Production*. 15 pages

Kumar, G., and S. Hegde. 2019. Economies of scale based on catfish production strategy and farm size. National Warmwater Aquaculture Center- News 16(1):1-4.

Patterson, J.T. and D. Lirman. 2020. SRAC Publication No. 7214, *Species Profile: Stony Corals*. 7 pages

Sink, T.D. 2020. SRAC Publication No. 0324, *Red Drum: Production of Fingerlings and Stockers*. 8 pages

Oral Presentations

Frinsko, Mike. 2020. Update on NCSU Investigations to Improve Larviculture of Domesticated Striped Bass. Tilapia/RAS Producers Meeting, Goldsboro, NC. 10/6/2020.

Frinsko, Mike. 2020. Update on NCSU Investigations to Improve Larviculture of Domesticated Striped Bass. Striped Bass Producers meeting, Washington, NC. 10/29/2020.

Poudel Ashmita, Kumar Ganesh, Khoo Lester, Lawrence Mark, and Aarattuthodi Suja. Phenotypic characterization of Edwardsiella piscicida isolates derived from catfish aquaculture. Marine Biology and Aquaculture. Virtual seminar. September 23, 2021.

Cheatham, M. C., S. Hegde, G. Kumar, C. R. Engle, T. H. Hanson, J. van Senten, and L. Roy. 2021. Adoption of productivity-enhancing technologies in the U.S. catfish industry. Aquaculture America, San Antonio TX, Aug 2021.

Brammer-Robbins, E.M., E. K. Freeman, A. S. Kanarek, J. H. Bisesi, E. J. Cassiano, Q. M. Tuckett, R.P.E. Yanong, C. J. Martyniuk. Evaluating probiotic treatments in the ornamental fish aquaculture industry: implications for managing Edwardsiella ictaluri outbreaks and fish microbiota. International Association for Aquatic Animal Medicine, Virtual Conference, May 2021.

Hegde, S., G. Kumar, C. R. Engle, T. H. Hanson, J. van Senten, and L. Roy. 2021. Economic impact assessment of the U.S. catfish industry. Aquaculture America, San Antonio TX, Aug 2021.

Johnson, D., M. Griffin, L. Khoo, G. Waldbieser, and S. Aarattuthodi. 2020. Biological, Molecular and Serological characterization of *Edwardsiella ictaluri* isolates in the channel and hybrid catfish and ornamental fish species. 46th annual meeting of Mississippi Chapter of the American Fisheries Society. Gulfport, MS.

Johnson, D., M. J. Griffin, L. H. Khoo, G. C. Waldbieser, and S. Aarattuthodi. Molecular characterization of *Edwardsiella ictaluri* isolates and efficacy of *E. ictaluri* vaccine to protect channel catfish fingerlings against the field isolates. 45th Annual meeting of Mississippi Chapter of American Fisheries Society. February 20-22, 2019. Jackson, MS.

Johnson, D., M. J. Griffin, E. T. Woodyard, L. H. Khoo, G. C. Waldbieser, R. P. E. Yanong, J. P. Hawke and S. Aarattuthodi. Phenotypic and genotypic characterization and comparison of *Edwardsiella ictaluri* isolates derived from catfish and ornamental fish species. AFS-FHS Summer Student Seminar Series. Oral Presentation. Online. June 2021.

Kumar, G., 2019. Factors affecting the adoption of aquaculture technologies. Asia Pacific Aquaculture Chennai, India. May 2019.

Kumar, G., and J. Avery. 2018. Effective communication portals for technology transfer. 2017 Delta Research and Extension Center Annual Report.

Kumar, G., C. R. Engle, S. Hegde, J. van Senten, S. Aarattuthodiyil, J. L. Avery. 2019. Assessment of economic impact and cost of regulations on catfish farms. NWAC Fall seminar, Mississippi State University, Stoneville, MS. Nov 2019.

Kumar, G., L. A. Roy, and T. R. Hanson. 2019. Cost of regulations, Technological advances, and Economic impact: Research planned for the catfish industry. Annual producer meeting of West Alabama catfish farmers. Greensboro, AL. Dec 2019.

Poster Presentations

Johnson, D., R. Hu, D.T. Nguyen, M. Griffin, S. Aarattuthodi, A. Camus, E. Henderson, and E. Soto. 2021. Cross protective capabilities of an *Edwardsiella ictaluri* live attenuated vaccine against *E. piscicida* infection in a Nile tilapia (*Oreochromis niloticus*) model of infection. Star summer program symposium. University of California-Davis. August 27, 2021.

Vorbach, B.S., J. Bulitta, J. Zhou, Y. Lang, and R.P.E. Yanong. Pharmacokinetics and pharmacodynamics of enrofloxacin and florfenicol in the giant danio (Devario aequipinnatus) following oral and bath administration. International Association for Aquatic Animal Medicine, Virtual Conference, poster session, May 2021.

Digital Products

SRAC Home Website: www.srac.msstate.edu

SRAC Publications Website: https://srac.tamu.edu/

SRAC Aquaponics Website: https://srac-aquaponics.tamu.edu/

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

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

Students Supported

Shradda Hegde. Mississippi State University, PhD Student, Anticipated date of graduation – December 2021. Dissertation title: *Economic aspects of the U.S. catfish farming: Adoption of technologies, cost of regulations, and economic impact.*

Divya Johnson. Mississippi State University, MS Student Anticipated completion: May 2021. Thesis title: *Phenotypic and genotypic characterization and comparison of Edwardsiella ictaluri isolates derived from catfish and ornamental fish species*.

Ashmita Poudel. Mississippi State University, PhD Student, Anticipated date of completion: 7/31/2023. Dissertation title: *Epidemiology of Edwardsiella piscicida and economic loss assessment due to E. piscicida and E. ictaluri in catfish aquaculture.*

Adrián López-Porras. Mississippi State University, MS Student, Degree completion: 5/31/2020. Thesis title: *Intraspecific variability of Edwardsiella piscicida and cross-protective efficacy of a live-attenuated Edwardsiella ictaluri vaccine in channel and channel × blue hybrid catfish.*

Ruixue Hu. University of California-Davis (visiting student from College of Fisheries, Huazhong Agricultural University, Wuhan, China).

Davida Johnson. University of California-Davis, School of Veterinary Medicine.

Debarshi Bhattacharjee. Texas Tech University, MS Student, Anticipated date of graduation: May 2022. Dissertation title: *Market trends and consumer demand for Southern aquaculture products of USA: An analysis of seafood scanner data.*

Grayson Clark. Texas A&M University, M.S. degree, Degree completed: May 2020. *Thesis title: Evaluating the effect of prebiotics and probiotics on rotifer and juvenile red drum (Sciaenops ocellatus) production*.

Bryan Candelaria. Texas A&M University, M.S. degree, Anticipated date of graduation: May 2021. Thesis title: *Application of prebiotics and probiotics in larval production of Southern flounder*.

Alex Geddie. NCSU Dept. of Bio and Agr. Eng. Assisted in feeding and routine larval system management.

Mason Hancock. NCSU Dept. of Bio and Agr. Eng. Assisted culturing live feeds and routine larval system management.

Garrett Stamport. Texas A&M University, undergraduate.

Appendix 1. List of Completed SRAC Projects to Date

Predation Risk and Economic Impact of Lesser Scaup and Piscivorous Waterbirds on Commercial Baitfish and Catfish Production
Duration: 2016-2018 Funding Level: $286,780
Participants: UAPB, MSU, USDA/WS/NWRC; VPI

Commercial Production of Selected Native Freshwater Ornamental Species
Duration: 2017-2019 Funding Level: $148,890
Participants: UF, LSU, VPI

Repeatability of Incidence and Time of Ovulation, Fecundity and Fertility in Channel Catfish Females Induced to Ovulate for Production of Hybrid Catfish Fry
Duration: 2017-2019 Funding Level: $126,619
Participants: AU, USDA/ARS/WARU, MSU

Techniques to Improve Production of Off-bottom Cultured Oysters
Duration: 2017-2019 Funding Level: $168,576
Participants: SCSGC, UG, UF, LSU, AU, NCSU

Field-Testing of a Rapid LAMP Assay to Detect the Marine Parasite *Amyloodinium ocellatum* in Commercial Aquaculture Facilities
Duration: 2017-2018 Funding Level: $92,018
Participants: AU, UF, USM

Improved Reproduction in Foodfish (Catfish and Largemouth Bass), Baitfish and Ornamentals Using a New Spawning Aid (GNRH IIA)
Duration: 2017- 2019 Funding Level: $192,287
Participants: AU, USDA ARS WARU

Evaluation of Probiotic and Prebiotic Supplements with Catfish, Golden Shiners, Hybrid Striped Bass and Tilapia under Conditions of Commercial Production
Duration: 2015-2017 Funding Level: $274,308
Participants: TAMU, AU, USDA ARS WARU, UAPB, ESA

Improvement of Blue Catfish Germplasm for Hybrid Catfish Production
Duration: 2014-2017 Funding Level: $44,343
Participants: USDA ARS WARU, LSU

Integrated Approaches to Reducing Individual Variability and Providing Year Round Harvest of Channel-Blue Hybrid Catfish
Duration: 2015-2017 Funding Level: $275,232
Participants: AU, USDA ARS WARU

Performance Evaluation of Intensive, Pond-Based Culture Systems for Catfish Production
Duration: 2012-2016 Funding level: $292,891
Participants: USDA ARS WARU, AU, MSU, UAPB

Split-Pond Aquaculture Systems: Design Refinements for Catfish Production and Evaluation for Culturing Other Species
Duration: 2014-2017 Funding level: $452,824
Participants: USDA ARS WARU, MSU, AU, USDA ARS NPURU, UAPB

Studies to Improve the Control of Virulent *Aeromonas hydrophila* and Evaluate the Impact of Environmental Factors on its Abundance in Catfish Aquaculture Ponds
Duration: 2014-2016 Funding level: $354,287
Participants: AU, MSU, USDA NWRC

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