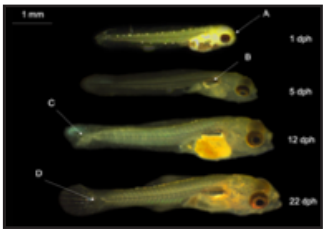
June 2021

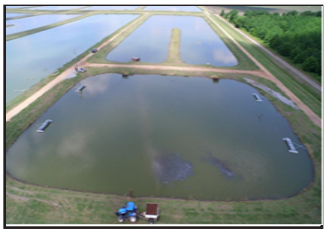
32nd ANNUAL PROGRESS REPORT

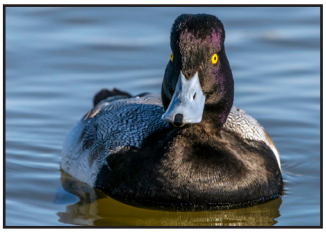
SRAC

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, 2019

USDA NIFA

United States Department of Agriculture
National Institute of Food and Agriculture

THIRTY-SECOND ANNUAL PROGRESS REPORT

USDA NIFA SOUTHERN REGIONAL AQUACULTURE CENTER
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EXECUTIVE SUMMARY

This Thirty-Second 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 http://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 10 journal articles, 12 abstracts, 14 Extension/Outreach publications, 37 oral presentations, 5 poster presentations, 6 digital products, and has supported 14 students.

Publications, Videos, and Computer Software

The Southern Regional Aquaculture Center commenced the "Publications, Videos, and Computer Software Project" to provide these materials in a timely and relevant manner. Since that time, more than 350 technical fact sheets (246 in the current catalog), 100 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, 64,554* unique users from 168* countries and territories used the SRAC Publications website, https://srac.tamu.edu/, to view or download SRAC publications 232,965* times. SRAC videos were viewed on the SRAC YouTube channel 44,676* times during the current reporting period. The AquaPlant website, created with funding from the SRAC PVCS Project, had 278,896* unique users that viewed 687,862* webpages during the reporting period. These users were from 180* countries/territories. These analytics demonstrate that the SRAC Publications, Videos, and Computer Software project truly has worldwide reach and impact.

Impact of Piscivorous Waterbirds on Commercial Baitfish and Catfish Production

The updated economic costs reported from the "Predation Risk and Economic Impact of Lesser Scaup and Piscivorous Waterbirds on Commercial Baitfish and Catfish Productions" project have been and continue to be disseminated to commercial producers. This information will be extremely valuable in tracking the cost of controlling piscivorous birds on baitfish, sportfish, and catfish farms over the next few years. As these costs are documented by individual farm operations, they will assist commercial producers in developing management schemes to better control and increase farm efficiencies at managing the risk associated with pisciviorous waterbirds. Furthermore, the data collected on this project further provides justification for the inclusion of lesser and greater scaup on U.S. Fish and Wildlife depredation permits as their role in consuming fish and causing economic damage has now been fully substantiated. The data pertaining to double-crested cormorants is also extremely valuable to the commercial industry as it clearly documented recent damage and economic impact on catfish farms. This data is being used by the National Aquaculture Association, politicians, lobbyists, and other entities in the current debate between commercial fish farmers and U.S. Fish and Wildlife Service regarding the extent to which commercial producers will be allowed to exercise lethal take of double-crested cormorants on their farms.

Commercial Production of Selected Native Freshwater Ornamental Species

The establishment of culture protocols is important for bringing new candidate species into commercial ornamental fish production. The objectives of the Commercial Production of Selected Native Freshwater

Ornamental Species project aim to define effective culture protocols for nine species of freshwater fishes endemic to the U.S. Culture methods for experimental species developed during this project are a solid foundation for the commercial production of select native North American ornamental fishes, which may be transferable to close congeners. Recommendations on Golden Topminnow broodfish size and expected egg output will help producers with production goals for this species as fecundity is low compared to many other ornamental species. Metallic shiner production has been commercialized by an ornamental producer in Florida, diversifying his business and providing new revenue streams.

Repeatability of Channel Catfish Females induced to Ovulate

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. It is not known if channel catfish females exhibiting good reproduction in one year continue to do so in subsequent years. Our overall goal of the "Repeatability of Incidence and Time of Ovulation, Fecundity and Fertility in Channel Catfish Females Induced to Ovulate for Production of Hybrid Catfish Fry" project is to determine the repeatability of reproduction in channel catfish females to make hybrid catfish fry over two consecutive years. There was no relationship between year 1 performance and year 2 performance, so no strategy development is possible. Using best performing strains is the best strategy at this point. Heavy mortality occurred for females that were induce spawned and stripped. This could result in the brood pond having too low of density. Females should be inventoried in the fall and late winter to ensure that adequate numbers of females are present for final preparation for spawning. Procedures need to be developed that will enhance brood stock survival post-spawning.

Production of Off-bottom Cultured Oysters

This project seeks to fine tune methods to control biofouling to grow high value single oysters. The specific objectives of this project are to: 1) Determine the impacts of cage manipulation to decrease biofouling, and evaluate the effects on time to harvest, survival, and morphometric factors, such as meat weight and shell shape (height, length, depth); 2) Determine the impacts of antifouling agents to decrease biofouling, and evaluate the effects on time to harvest, survival, and morphometric factors, such as meat weight and shell shape (height, length, depth); and 3) Determine the economic impact of each methodology on production costs. Trials conducted on the south Atlantic sea cost (North Carolina, South Carolina, and Georgia) suggest that aerial drying frequency and bag coating treatments provide little difference among fouling coverage, ratios, and occurrences, there are many factors that could have altered the findings. Oysters in Louisiana and Florida reached market size quicker than those in Mississippi and Alabama. In FL and LA, oysters were ready for harvest after 24-30 weeks while in MS and AL they required 32-38 weeks of grow out time. Florida experienced the highest degree of fouling which impacted profit. Although flipping every three weeks is most profitable it is important to consider product quality, impact of fouling on the longevity of the cage and associated rigging, and the fact that meat quality was poorer in those oysters which were in cages flipped only every three weeks. In Alabama, mortality was higher than in other states and did not correlate with air drying frequency but was the biggest factor impacting profit. The shortened grow-out time in FL and LA could lead to higher profits overall and help off-set the cost of a more frequent flipping routine because the crop can be turned over more frequently. It is important to keep in mind that these models represent an experiment conducted at one site in each state.

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

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 project will produce 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. A comprehensive survey of catfish farms and associated backward- and forward-linked sectors (i.e., hatcheries, feed mills, processors) was designed and launched to collect detailed firm-level data to estimate the economic impact of the catfish industry. Surveys were well underway by early 2019, but COVID-19 and the ensuing economic shutdowns resulted in the suspension of survey efforts. Surveys have resumed and are expected to be completed by the end of 2020.

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

Evaluation of Probiotics in Finfish Hatcheries

To improve early rearing survival, as well as enhance subsequent fish growth and immunity, investigations into early exposure to both probiotics and prebiotics are being pursed with red drum, domesticated striped bass and southern flounder. This project has the following objectives

1) Conduct *in-vitro* clinical trials to determine effectiveness of two selected commercially available probiotics and two commercially available prebiotics at inhibiting important bacterial fish pathogens.
2) Evaluate the two commercially available probiotics and two commercially available prebiotics under *in-vivo* conditions that adhere to commercial hatchery production.
3) After metamorphosis to juveniles, conduct an in-vivo challenge of each fish species with problematic bacterial pathogens to determine their ability to resist disease using methods that simulate natural routes of infection.
4) Evaluate the economy of the additives based on observed improvements in fish production and disease resistance relative to costs associated with including the additives.

Closures of labs at North Carolina State University forced delaying the disease challenge. Texas A&M University researchers were able to complete a short series of experiments to expose rotifers to the

prebiotic and probiotic supplements in large-scale production. Impacts related to domesticated striped bass (DSB) have been productive. They report the following:

1) Fry cannot see any feeds, including Artemia, when cultured in clear plexiglass Zebrafish tanks. When sides and bottoms are painted with black epoxy, fry readily find both Artemia and microdiets.
2) Regardless of attraction to feed, fry have not been found to ingest any commercial or laboratory diets of similar size to Artemia that are readily consumed.
3) DSB fry at 4 dph that are placed into 10-L plexiglass aquaria with modest water flow and gentle aeration do not develop inflated swim bladders. Fry placed in 530-L tanks with upwelling and strong surface agitation show >75% SBI.
4) Oil-mist application of probiotics failed as unwanted particle clumping results
5) Fry are sensitive to physical stimulation from 12-18 dph.
6) Fry digest feed approximately every 3-4 hours at 20C and become weakened when feeding occurs more than 2 hours past clearing the gut of feed.

Management Strategies for ESC in Ornamental Fish

Variants of the catfish disease-causing bacteria *Edwardsiella ictaluri* have been reported in the tilapia and ornamental fish industries. Researchers seek to 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. 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. Use of the closely related zebrafish proxy, the giant danio for pharmacokinetic studies provide a much more scientifically based regimen for antibiotic dosing of florfenicol and enrofloxacin in infected zebrafish.

Implications of Changes in Federal Authority under the Lacy Act

Following a recent court ruling the Lacey Act can no longer be used by the U.S. Fish and Wildlife Service 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. At the time this report was requested, work has only just begun on this project, so no report was requested from the Principal Investigators.

Epidemiology of *Edwardsiella piscicida*

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. At the time this report was requested, work has only just begun on this project, so no report was requested from the Principal Investigators.

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 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 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 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, 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:

Reuben Moore, Mississippi State University (Chair)
Phil Elzer, Louisiana State University AgCenter
Gina Eubanks, Louisiana State University AgCenter
Steve Lommel, North Carolina State University
Rick Cartwright, University of Arkansas Cooperative Extension Service
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, 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:

Margie Saul, AR
Steve Sarten, KY
Ben Pentecost, MS
Martha Campbell, FL
Rob Ellis, NC
Marty Tanner, FL
Travis Wilson, AL
Townsend Kyser, AL
Richard Eager, SC
Mitt Walker, AL
Wec Terry, VA
Kim Edge, GA
Douglas Kuenz, LA
Shorty Jones, MS
Chase Holub, TX
Frank Roberts, SC
David Heikes, AR
Jenny Davis Fagan, TN
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, 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 Unit
Ben Reading, North Carolina State University
Ken Semmens, Kentucky 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
Anita Kelly, University of Arkansas at Pine Bluff
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: September 1, 2018 – December 31, 2019
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: Two new fact sheets and two fact sheet revisions 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 to provide these materials in a timely and relevant manner. Since that time, more than 350 technical fact sheets (246 in the current catalog), 100 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, **64,554** unique users from **168** countries and territories used the SRAC Publications website, https://srac.tamu.edu/, to view or download SRAC publications **232,965** times. SRAC videos were viewed on the SRAC YouTube channel **44,676** times during the current reporting period. The AquaPant website, created with funding from the SRAC PVCS Project, had 278,896* unique users that viewed **687,862** webpages during the reporting period. These users were from 180 countries/territories. These analytics demonstrate that the SRAC Publications, Videos, and Computer Software project truly has worldwide reach and impact.

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

Reporting Period: September 1, 2018 – December 31, 2019
Length of Project: 2 years
Current Project Year: 2
Total Funds Committed: $286,780
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 and 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. In addition to the losses of fish, there is a financial cost associated with managing piscivorous waterbirds on commercial farms.

Response: 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 generate contemporary information on cormorant roost locations, numbers of birds per roost, and roost distance from catfish ponds in Mississippi as well as reveal how cormorants modify their use of roost sites as commercial aquaculture has changed. 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: During winter 2016-2017, 830 ponds were surveyed over 11 survey trips from mid-November through March on baitfish and sportfish farms. We counted 1,740 scaup during all surveys combined. For our winter 2016-2017 work, average scaup/acre was 0.277, 0.300, 0.005, and 0.026 on golden shiner, fathead minnow, goldfish, and sportfish ponds, respectively. In total, we counted over 14,000 water birds that could potentially be consuming fish from these ponds including great blue herons, great egrets, double-crested cormorants, and ring-billed gulls. We collected 294 scaup in winter 2016-2017. Of those, only 2% (*n* = 6 birds) contained any sign of fish parts, and 5 out of 6 of those scaup only contained fish parts in the gizzard, so there was little fish biomass to quantify. Of the 294 scaup collected, 230 contained identifiable prey items in the esophagus. Of the bird-scaring costs reported by producers, manpower composed 56% of the cost of scaring birds, followed by 32% for the costs of truck usage, 9% for levee upkeep, 2% for firearms and ammunition, and only 1% of costs were for pyrotechnics and exclusion devices. On average, for the 2016-2017 bird-scaring season, baitfish farmers reported an average per-acre cost of $246/acre (range of $24/acre to $956/acre).

During 2017-2018, 628 ponds were surveyed over 9 survey trips from mid-November through March. We counted 4,746 scaup during all surveys combined which was a substantial increase from the 1,740

scaup counted (173% increase) during all surveys in winter 2016-2017. We collected 267 scaup in winter 2017-2018. Of those, 29% (*n* = 77 birds) contained sign of fish parts, and the majority of those (*n* = 71) contained fish in the esophagus that we could use to estimate total fish consumption. Of the 267 scaup collected, 15% (*n* = 39) contained <5mg of dried identifiable prey items and were not used in subsequent analysis. Much like the first winter collections, midge larvae was the most common prey item found in birds collected during the second winter and made up 40% of the diet by weight in winter 2017-2018. Unlike collections in the first winter, 2016-2017, fish comprised 18% of lesser scaup diet by weight in winter 2017-2018. Mean fish lengths consumed were 44.4, 39.5, and 48.3 for golden shiners, goldfish, and *Lepomis* spp. respectively and the maximum number of fish found in a single bird was 112 identifiable golden shiners.

We used 1,368 individual pond surveys conducted in winters 2016-2017 (year 1) and 2017-2018 (year 2) to model the distribution and abundance of scaup on baitfish and sportfish aquaculture. We ran separate models to examine the influence of individual pond and farm (pond group) level characteristics on scaup distribution and abundance. At the pond level, our top distribution model indicated that year, day, fish species, fish density and pond size were all significant predictors of scaup use and explained 45% of the total variation in scaup distribution. During year 2, there was a significantly greater overall chance of finding birds on ponds than in year 1, which was likely result of colder temperatures driving more scaup to Arkansas during the survey season of year 2. Among fish types, scaup were found on goldfish and 'other' sportfish ponds significantly less frequently than on ponds containing golden shiners or fathead minnows. Fish density significantly improved our model and indicated that overall probability of scaup use increased with stocking density, particularly during year 2. The overall probability of scaup use also increased with increasing pond size.

We used data from our surveys and scaup collections to estimate the total amount of fish consumed by scaup within our survey area during winter 2016-2017 (year 1) and 2017-2018 (year 2). Our survey data was used to estimate the total number of scaup present on golden shiner, fathead minnow, goldfish, and sunfish ponds for each survey day. We then used those total counts to run polynomial regressions for each year in order to estimate the total number of scaup use-days (SUDs) during each winter. Total SUDs are the sum of the number of scaup predicted by our models within our survey area each day of the wintering season (November – March). Monthly totals of SUDs combined with diet data from collected scaup were the bases for estimating total fish loss. We examined scaup diets to estimate the monthly percentages of scaup that consumed fish and, for birds that contained fish, the percentage of their diet obtained from fish. Knowing the percentage of their diet obtained from fish allowed us to estimate the average amount of fish an individual scaup would consume each day. By multiplying the monthly SUDs, percentages of scaup consuming fish, and the amount of fish consumed by an individual scaup, we were able to estimate the total amount of fish lost within our survey area as a result of foraging scaup. Both scaup abundance and diet were variable between our two winters which resulted in substantial differences in fish loss between the two winters. We estimated a total of 292,000 SUDs in year 1 and 875,000 SUDs in year 2. February of year 2 was associated with the greatest percentage (51.3%) of scaup consuming fish, but January of the same year however, was associated with a larger amount of daily fish consumption and therefore was the month that was estimated to have the greatest overall fish loss (52,000 lbs) during our two study winters. Given the variability between winters, total fish loss during year 2 was estimated at 133,000 lbs, while in year 1, just 3,000 lbs was estimated to be

lost. Fathead minnows experienced the greatest total loss (1,900 lbs) in year 1, while golden shiners experienced the greatest total loss (84,000 lbs) in year 2. We attribute the variability in fish loss between the two winters to the differences in weather patterns. We suspect that differences in temperatures increased the overall migration activity of scaup in our colder second winter which resulted in a much greater number of scaup being observed.

For catfish, we completed 13 aerial surveys and counted 112,239 cormorants across 67 different night roosts in our first year of study (2016-2017). Roosts ranged from 0.1 to 39 kilometers to the nearest aquaculture facility. A total of 390 cormorants were harvested from 20 different night roosts. Stomach contents contained 3,895 identifiable prey specimens, of which 1,212 were measurable. Catfish (*Ictalurus spp*.) represented 55% of the total prey biomass after length-weight formulas were applied to partially digested fish specimens. Of the costs reported by catfish farmers, manpower composed 48% of the costs of scaring birds, followed by 29% for the costs of truck usage, 15% for levee upkeep, firearms and ammunition 7%, and only 1% of costs were for pyrotechnics and exclusion devices. In our second year of study (2017-2018), we completed 12 aerial surveys and counted 130,684 cormorants across 68 different night roosts. Roosts ranged from 0.1 to 39 kilometers to the nearest aquaculture facility. A total of 338 cormorants were harvested from 22 different night roosts. Stomach contents contained 7,901 identifiable prey specimens, of which 3,333 were measurable. Catfish (*Ictalurus spp*.) represented 33% of the total prey biomass after length-weight formulas were applied to partially digested fish specimens. Other notable species found in the diet included shad (*Dorosoma spp*.), which comprised 57.6% of the total prey biomass, and sportfish, which comprised 9.2% of the diet.

A bioenergetics model was developed using collected data from 2016-2017 and 2017-2018 surveys estimated individual energy demands for cormorants wintering in the Delta. Delta cormorant abundance and distribution were calculated from aerial survey data and partitioned by month. The estimated average daily energy budget for cormorants was 1947.3 kJ/bird/day and the daily fish intake required to meet this when consuming catfish was 434.7 g/bird/day. Monthly bird forage days ranged from 75,082 in April 2017 to 1,156,775 in January 2018 with the peak occurring in January of both winters. The average catfish forage days were estimated to be 209,495 cormorants consuming catfish per month based on the average of the month and area variables. Catfish biomass consumed was an estimated 585.2 and 753 metric tons in winters 2016-2017 and 2017-2018, respectively. The greatest catfish consumption occurred in February of each winter. The average depredation impact for all aquaculture in the Delta was 45.5 kg/ha.

This is the first study to develop on-farm costs of attempts by farmers to prevent losses due to bird depredation. Results demonstrate that the greatest costs are for the trucks and manpower used to chase birds. Fish farmers are spending more money and more time than had previously been thought in efforts to scare birds from their ponds.

The economic effects of depredating scaup on baitfish and sportfish farms were substantial. Results revealed total annual costs of scaring birds from baitfish/sportfish farms were \$622 $\pm$ 742 per ha. Manpower (56%), truck usage (32%), levee upkeep to allow truck access to scare birds (9%), firearms and ammunition (2%), and pyrotechnic devices (1%) were the greatest components of bird-scaring costs documented on farms. When reduced revenue from fish losses to scaup were combined with expenditures associated with scaring birds costs averaged \$683/ha for golden shiners, \$695/ha for fathead minnows, \$663/ha for sportfish, and \$673/ha for goldfish across the two study years. By considering fish losses, scaup alone documented costs averaged \$1.06 million per year (\$0.09 million in

Year 1 and $2.03 million in Year 2) for the Arkansas baitfish industry. Total direct annual economic losses to baitfish farms in Arkansas as a result of depredating scaup averaged $5.5 million, with a range of $4.6 million to $6.3 million.

The combined effect of increased bird-scaring costs and continued catfish losses to cormorant predation resulted in reduced profitability on catfish farms. Costs of production (measured as breakeven price above total costs) increased by 4% to 23% for the various catfish farm management scenarios analyzed, with the greatest percentage increase in costs on the smallest farm scenarios. One-third of the farm size and production scenarios analyzed changed from being unprofitable to showing a profit in the absence of the negative economic effects associated with bird depredation. Increased costs of production from catfish losses to cormorants increase financial risk on catfish farms by reducing the financial safety margin for times when market price decreases. Industry-wide, the value of catfish losses averaged $47.2 million (range of $25.8 million to $65.4 million). Total direct economic effects (including both the increased costs to scare birds and the revenue lost from fish consumed by cormorants despite bird-scaring attempts) averaged $64.7 million (ranging from $33.5 million to $92.6 million). Overall, the combined effects of increased farm expenditures to scare birds from farms and the value of the catfish lost to predation by cormorants caused substantial negative economic effects on catfish farms.

Outreach Overview: Results from this project are being disseminated through a number of different outlets including state aquaculture association meetings, national aquaculture and wildlife society meetings, trade publications, extension publications, and peer-reviewed scientific journal articles. Stakeholders are being informed of data and progress made on the project through presentations at state aquaculture association meetings and extension publications.

Targeted Audiences: Baitfish, sportfish, and catfish producers, the aquaculture scientific community, and state/federal agencies are the main targeted audiences for this work.

Outputs: To date there have been five extension articles (2 fact sheets, 3 articles) published on this work. There has been one journal article published, with two articles in press and three articles currently under review. In addition, 19 abstracts and 18 presentations have been delivered to aquaculture association and scientific meetings since the beginning of this project. Timely delivery of pertinent information gained through this study is being shared with stakeholders and interested parties as it becomes available. Lastly, aerial survey data of cormorant roost counts were provided to USDA APHIS Wildlife Services within 24 hours of collection during the project period to support their roost dispersal programs that provide a direct benefit to producers in reducing cormorant depredation.

Outcomes/Impacts: The updated economic costs reported from this project have been and continue to be disseminated to commercial producers. This information will be extremely valuable in tracking the cost of controlling piscivorous birds on baitfish, sportfish, and catfish farms over the next few years. As these costs are documented by individual farm operations, they will assist commercial producers in developing management schemes to better control and increase farm efficiencies at managing the risk associated with pisciviorous waterbirds. Furthermore, the data collected on this project further provides justification for the inclusion of lesser and greater scaup on U.S. Fish and Wildlife depredation permits as their role in consuming fish and causing economic damage has now been fully substantiated. The data pertaining to double-crested cormorants is also extremely valuable to the commercial industry as it clearly documented recent damage and economic impact on catfish farms. This data is being used by the National Aquaculture Association, politicians, lobbyists, and other entities in the current debate

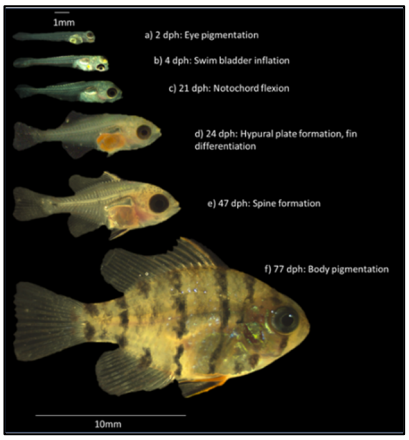
between commercial fish farmers and U.S. Fish and Wildlife Service regarding the extent to which commercial producers will be allowed to exercise lethal take of double-crested cormorants on their farms.

Partnerships Developed: none

Commercial Production of Selected Native Freshwater Ornamental Species

Reporting Period: September 1, 2018 – October 31, 2019
Length of Project: 2 years
Current Project Year: 2
Total Funds Committed: $148,867
Principal Investigators: Matthew DiMaggio, Joshua Patterson**,** Quenton Tuckett, *University of Florida;* Christopher Green, *Louisiana State University;* Donald Orth, Eric Hallerman, Michael Schwarz, *Virginia Polytechnic Institute and State University*

Relevance: Increasing interest in native North American fishes for ornamental use provides opportunities for novel aquaculture endeavors. Scant biological information on this group exists, let alone culture protocols for these species. Currently, native ornamental species sold in the aquarium trade are generally wild caught. The establishment of culture protocols is important for bringing new candidate species into commercial ornamental fish production. Once established, culture protocols can be transferred to industry partners, as well as applied and adapted to related species, including those of conservation concern. The objectives of the proposed research aim to define effective culture protocols for nine species of freshwater fishes endemic to the U.S. Species specific protocols will be immediately transferred to stakeholders within the southern region to aid in commercialization.



Response: ***Develop commercial production techniques and protocols for Black Banded Sunfish Enneacanthus chaetodon, Gulf Coast Pygmy Sunfish Elassoma gilberti, Sailfin Shiner Pteronotropis hypselopterus, and Flagfin Shiner Pteronotropis signipinnis (UF).*** A series of experiments with Black Banded Sunfish, Gulf Coast Pygmy Sunfish, Flagfin Shiner, and Metallic Shiner were carried out to asses spawning substrate preference, embryo incubation techniques, egg disinfection protocols and larval feeding regimes. Descriptive trials evaluating growth and development were also completed to facilitate development of commercial culture protocols.

Develop commercial production techniques and protocols for Bluenose Shiner Pteronotropis welaka and Bluehead Shiner Pteronotropis hubbsi (LSU). Sub-objective 1g. Develop commercial production techniques and protocols for Golden Topminnow Fundulus chrysotus (LSU). A study was conducted on Golden Topminnows to determine size related fecundity and egg production metrics to provide recommendations for female broodfish size (Small: 5.7 ± 0.19g; Medium: 8.53 ± 0.16g; Large: 12.2 ± 0.47g). Golden Topminnow embryos and newly hatched larvae were measured for length at hatch and yolk volume morphometrics. Bluenose Shiner (10) were stocked in three 1,400-L outdoor mesocosms with 4-5 Longear Sunfish. Each tank was stocked with a sandy/pebble substrate and several species of submerged vegetation. In addition to natural prey items, fish were fed bloodworms twice a week.

Develop commercial production techniques and protocols for Rainbow Darter Etheostoma caeruleum and Mountain Red-belly Dace Chrosomus oreas (VT). Various environmental manipulations were assessed to elicit volitional spawning in captive populations of Rainbow Darter and Mountain Red-belly

Dace. Opportunistic work was also completed with other candidate native ornamental species, Logperch *Percina caprodes,* Redline Darter *Etheostoma rufilneatum,* Fantail Darter *Etheostoma flabellare,* and Creek Chub *Semotilus atromaculatus*.

Results: Gulf Coast Pygmy, Flagfin Shiners, and Metallic Shiners all preferred a floating yarn substrate for spawning. Commercial microparticulate diets are a viable replacement for *Artemia* during larviculture of the Gulf Coast Pygmy Sunfish, Flagfin Shiner, and Metallic Shiner. Safe egg disinfection protocols were elucidated for these three species. A mandatory period of live feed inclusion is required for successful larviculture of Blackbanded Sunfish. Aquaculture production protocols established during this project are directly transferable to the commercial ornamental aquaculture industry and will circumvent costly research and development associated with new species production.

The number of Eggs female^{-1} day^{-1} (including all females each day) produced by Golden Topminnows were 1.1 ± 0.70, 2.0 ± 0.69, and 5.2 ± 1.40 for small, medium, and large female broodfish, respectively. This results in potential daily egg production from the two larger sized females groups at approximately 230 and 415 eggs per day for every 1000 g of female broodfish stocked. The use of outdoor tanks stocked with sunfish as a potential spawning cue for Bluenose Shiners resulted in Bluenose Shiner spawning within the early summer. Predation of larval and juvenile shiner by sunfish spawned at the same time was anticipated to limit the production of larvae from these initial outdoor trials.

Thermal manipulation of Rainbow Darter spawning tanks yielded volitional reproduction, with 722 eggs and 23 larvae collected over the experimental period. Photo-thermal manipulation and introduction of artificial “chub mounds” has been unsuccessful for captive spawning of Mountain Red-belly Dace. Redline Darters produced eggs, although the larvae did not survive. For Logperch, no spawning was observed and no eggs or larval fish were found.

Outreach Overview: Results of completed experiments have been disseminated through various presentations at professional meetings. Farm visits and tours of research facilities have also allowed for education of stakeholder groups. Interested commercial clientele are periodically informed of pertinent research develops.

Targeted Audiences: Commercial producers.

Outputs: Within the reporting period for this project, 12 oral presentations and two posters have been delivered at conferences and professional meetings. Five graduate students have been trained.

Outcomes/Impacts: Culture methods for experimental species developed during this project are a solid foundation for the commercial production of select native North American ornamental fishes, which may be transferable to close congeners. Recommendations on Golden Topminnow broodfish size and expected egg output will help producers with production goals for this species as fecundity is low compared to many other ornamental species. Metallic shiner production has been commercialized by an ornamental producer in Florida, diversifying his business and providing new revenue streams.

Partnerships Developed: None to date.

Repeatability of Incidence and Time of Ovulation, Fecundity and Fertility in Channel Catfish Females Induced to Ovulate for Production of Hybrid Catfish Fry

Reporting Period: September 1, 2018 - April 30, 2019
Length of Project: 2 years
Current Project Year: 2
Total Funds Committed: $126,619
Principal Investigators: Rex Dunham, *Auburn University*; Nagaraj Chatakondi, Brain Bosworth, *USDA-ARS Warmwater Aquaculture Research Unit*; Peter Allen, *Mississippi State University*

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. It is not known if channel catfish females exhibiting good reproduction in one year continue to do so in subsequent years. If they do not have consistently good reproductive performance over time, a significant economic loss and inefficiency may occur. Our overall goal is to determine the repeatability of reproduction in channel catfish females to make hybrid catfish fry over two consecutive years.

Response: There was no relationship between year 1 performance and year 2 performance, so no strategy development is possible. Using best performing strains is the best strategy at this point. Heavy mortality occurred for females that were induce spawned and stripped. This could result in the brood pond having too low of density. Females should be inventoried in the fall and late winter to ensure that adequate numbers of females are present for final preparation for spawning. Procedures need to be developed that will enhance brood stock survival post-spawning.

Results: *USDA* - In 2017, a total of 280 catfish were selected, forty fish per week for 7 weeks during the spawning season. The percentage of fish gravid was quite low as 635 fish were evaluated to find the 280 spawnable fish, 37.9% gravid. Percent ovulation of channel catfish ranged from 65 to 95% with an average of 80% ovulation. Percent neurulation ranged from 8 to 32% with an average of 16%. This lower percent neurulation may be attributed to our hatchery water, which could not be stripped of gasses. The estimated fry/kg (ovulation % X relative fecundity X neurulation) was 839 fry/kg female body weight.

Percentage of gravid channel catfish females was much better in 2018, perhaps because of better weather patterns, as 59.8% of the fish evaluated were gravid, and of these, ovulation rate, 78.1%, was similar to 2017. Of the 68 females injected with LHRHa in 2018 that spawned in 2017, 75.0% ovulated, which was not different, 79.6%, for 133 virgin (injected for the first time) females. Observed means for relative fecundity, neurulation, and estimated fry/kg female body weight was also higher in 2018 compared to 2017 and may be related to better weather patterns and brood stock preparation.

Percent neurulation increased from 23.1 in 2017 to 38.6% I 2018, and fry/kg female body weight from 839 to 1.525. Females that ovulated and did not ovulate 2017 had similar reproductive output in 2018

with 75% and 79.6% ovulation, 5715 and 4,706 eggs/kg, 36.8 and 39.5% neurulation and 1,587 and 1,480 estimated fry/kg female body weight, respectively.

Hypothetically, sexual development, hormone induction and/or handling stress affected survival post-spawning season. Females that ovulated, gravid and did not ovulate, and non-gravid females had 34.9, 69.5 and 59.5% survival, respectively, in 2017, which was similar to results at Auburn University (see below). In 2018, gravid, gravid and injected in both 2017 and 2018, and non-gravid females had 37.3, 26.5 and 63.7% post-spawning survival, respectively.

Auburn University - A total of 300 channel catfish females were injected over 6 spawning runs in 2017. The weather was unusually cold for the entire spawning season and appeared to adversely affect the spawning preparation and spawning at Auburn University. Ovulation rates ranged from 38-69% with a mean of 59.6%. This had a major impact on fry output, but some runs produced as many as 2,000 fry/kg.

In 2018, ovulation was much better with 89.3% of the females ovulating. There was no difference in ovulation rate for females that did not ovulate in 2017, 86.8% and those that did ovulate in 2017, 92.7%. An additional 23 females were evaluated that were injected in 2016 and 2018, but not in 2017. Their ovulation rate in 2018 was 78.3%. Leaving females fallow for a year did not enhance ovulation rate.

Several strains/lines were mixed for this study. Kansas random strain had higher ovulation percentage than Lake Marepas, 103KS, KxTH, Kmix select and Mix in 2017 (Table 4). However, genetic differences in ovulation rate were minor the following year.

Females that did not ovulate in 2017 had a higher (Table 3, P=0.0001) survival rate (post-spawning 2017 until spawning season 2018) than females that ovulated in 2017 (30.7%). Strain affected survival and ranged from 0% for a commercial strain (limited sample) to 58% for 103KS (Table 3).

For females that ovulated in both 2017 and 2018, repeatability of performance was essentially zero. The correlation between 2017 and 2018 for egg quality, relative fecundity, and female gravidness was near zero for each trait. Strain effects were minimal for these traits, however, there appeared to be a trend that the poorest ranking strains in 2017 became the best ranking strains in 2018, but this requires further analysis.

Outreach Overview: Results were presented at the annual December research meeting for farmers in Demopolis, Alabama. The results were also presented at the Catfish Session at Aquaculture America in New Orleans.

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

Outputs: Several graduate students have been trained. Within the reporting period for this project, two oral presentations have been delivered at conferences and professional meetings.

Outcomes/Impacts:

- Based on ovulation rate only, surviving females are good for hybrid embryo production for at least 2 years.
- Letting a female “rest” for 2 years had no benefit.

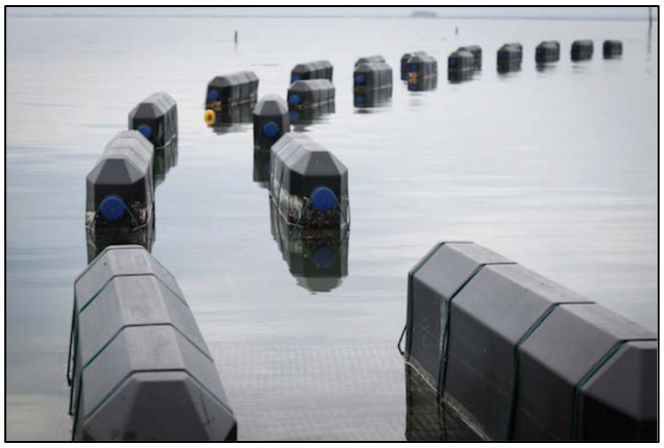
- Strain affected ovulation in bad spawning years and post-spawning survival.
- Ovulating one year does not affect the probability of ovulating a second year.
- Degree of female readiness, fecundity and egg quality were not repeatable over a 2-year period.
- Hand-stripping increases the probability of death prior to the next spawning season.
- Brood stock handling procedures at research institutions and possibly farms need improvement if brood females are to be used multiple years.
- Farm research is needed to determine if brood stock survival problems also exist on farm, and to determine if there are factors at research institutions and farms that affect brood stock survival
- Management of brood stock densities is problematic because of potential high mortality that is not detected (we observed no fish “floating up” after death, giving unexpectedly low numbers of fish to inject at harvest for spawning). Inventories or careful monitoring of feed intake may be required to ensure brood stock densities are appropriate.

Partnerships Developed: None.

Techniques to Improve Production of Off-bottom Cultured Oysters

Reporting Period: September 1, 2018 - October 31, 2019
Length of Project: 2 years
Current Project Year: 2
Total Funds Committed: $168,576
Principal Investigators: Susan Lovelace, *South Carolina Sea Grant Consortium*; Thomas Bliss, Robert Bringolf, *University of Georgia*; Leslie Sturmer, *University of Florida*; John Supan, Robert Twilley, *Louisiana State University Agricultural Center*; William Walton, *Auburn University*; Charles Weirich, *North Carolina State University*

Relevance: The benefits associated with fine tuning methods to control biofouling when using the OysterGro™ system to grow high value single oysters include: reduced labor costs, improved product quality, improved yield, and shorter grow-out time. The methods used commercially today by the emerging oyster aquaculture industry in the Southern U.S. are effective, however, reducing or increasing the frequency of aerial drying and/or applying a fouling release coating could improve the profit margin of the business without impacting or improving product quality. These benefits will allow growers within the Southern U.S. to grow their businesses quicker and take advantage of strong and expanding markets for high value single oysters.



Response: The objectives of this project are to:

1) Determine the impacts of cage manipulation to decrease biofouling, and evaluate the effects on time to harvest, survival, and morphometric factors, such as meat weight and shell shape (height, length, depth).
2) Determine the impacts of antifouling agents to decrease biofouling, and evaluate the effects on time to harvest, survival, and morphometric factors, such as meat weight and shell shape (height, length, depth).
3) Determine the economic impact of each methodology on production costs.

Results: The field component of the project on Gulf Coast was terminated in June 2018 with harvesting of the product and final sampling. On the Atlantic Coast, by June 2018, 70% or more of the oysters in the bi-weekly flipping treatment had reached harvest size in North Carolina and South Carolina within the reporting period. In Georgia, however, the oysters were smaller. As of June 2018, the gear in each Atlantic state had not been exposed to what would be considered a heavy fouling season (i.e. summer). The decision was made to treat the June sampling trip as a 'harvest' sampling for NC and SC. At that time the densities were reduced in each bag as outlined in our proposal and the experimental treatments continued to be applied until the one-year post-deployment time. Sample processing for the Gulf States commenced during the reporting period and carried on into 2019, as did sample processing for the Atlantic States.

In October 2018, in the South Atlantic, all remaining bags were emptied and weighed immediately using a fish scale to determine the overall wet weight of bag fouling and bag sides were photographed. Fouling on oysters appeared to be unaffected by both drying regimes and bag coatings. This was unexpected, as tidal aerial exposure has been shown to decrease fouling coverage on oysters (Bishop and Peterson, 2006). Increased fouling on cultured shellfish within bags coated with fouling-release agents has also been observed, as organisms settle on the next hard uncoated substrate they encounter (Sievers et al., 2017; Tettelbach et al., 2014). While there were small but significant differences among drying treatments in hard fouling ratios for SC and NC oysters in June, there were no differences among any treatments for total or soft fouling ratios among any states in June or October.

Biofouling accumulation trends varied among sampling seasons. Overall, there seemed to be a negative relationship between drying frequency and fouling accumulation in December. Triweekly drying treatments had the highest fouling percent coverage in SC and weekly drying bags had significantly lower percent fouling coverage for GA, NC, and combined data. In contrast, biweekly drying in GA had higher fouling coverage compared to weekly and triweekly bags. However, fouling coverage in all drying treatments in December was low (<20%) and oysters were not yet at harvest size. The negative trend between drying frequency was not as evident in March. While SC and combined data showed that triweekly bags had higher percent coverage, GA and NC showed no difference.

While our findings suggest that aerial drying frequency and bag coating treatments provide little difference among fouling coverage, ratios, and occurrences, there are many factors that could have altered our findings. Differences in October bag coverage trends and the lack of difference among bag weights in GA and SC may be explained by the overall success of the flipping regimes. With SC having reduced stocks, drying regimes continued without any issue while GA oysters grew heavier than the cages could handle, causing them to flip back over before the full 24-hour drying time was complete, thus decreasing the efficacy of the drying regimes. While fouling ratios may have showed little to no treatment effects, the length of time between sampling season may have resulted in us overlooking differences. By the October sampling period, GA oysters were so significantly fouled that stocked bags were full, and oysters needed to be broken apart in the bags prior to harvest. Freezing oysters prior to fouling analysis may have also affected our results. Ascidians either fell off the oysters as they were removed or lost water while traveling back to the freezers, decreasing both their mass and occurrence. If fouling was assessed biweekly or monthly and with live organisms, differing trends may have been easier to identify.

Data were organized using Excel®2016. Bags within cages represented our experimental units as these bags were the lowest level of randomly assigned treatment and each oyster sampled was considered a subsample. Therefore, mean oyster measurements, growth rates, weights, and CI were calculated per bag. Comparisons were made within states with data analyzed quarterly to determine seasonal effects of treatments. No comparisons were made among states because of site variation.

In the South Atlantic States (GA, SC, NC) the experiment started in early October with oysters in SC and NC reaching harvest size by June. Oysters in Georgia reached harvest size by August. Our endpoint for the experiment was set at when the majority of oysters in the ‘every other week’ flipping treatment reached 76 mm (3 inches). Across all states, the oysters flipped less than that (every three weeks) were larger and those flipped more frequently (weekly) were smaller. Reasonably, the oysters not flipped as often have more time to feed and are not jostled around by the flipping action thereby maintaining their fragile growing edge longer. The oysters contained in cages that were flipped on a weekly basis needed

a bit longer to reach market size (4 weeks) but they were slightly 'cuppier' than the other treatments, which is a desirable market characteristic.

The most profitable scenario in SC and NC was to flip every three weeks, however, the oysters reached market size in June prior to the peak of heavy fouling season. In SC, a sample of oysters was maintained in each cage and flipping treatments applied until September. By September, the oysters in cages flipped every other week and every three weeks were more fouled than those flipped every week. In Georgia, the degree of fouling was higher likely due to site selection in a high energy area prone to barnacle settlement. The degree of fouling in GA was such that the oysters would have required some cleaning prior to being sent to market. In SC, had the oysters been held through the summer, those flipped on a non-weekly basis would have required cleaning prior to harvest as well. Based on the results of the study, we recommend employing a more frequent flipping routine when larval settlement (and therefore fouling) is at its peak in your area, which is usually during the warmer months of the year.

We recommend an approach that increases the frequency of flipping in the warmer months because even though fouling can be cleaned off of the oyster it is: 1) more difficult and time consuming to clean the cage and bags and can impact life span of the gear; 2) the appearance of the oyster is marred by cleaning fouling and you may not achieve the price point you desire, and; 3) when fouling becomes heavy it will impact meat quality.

Oysters in Louisiana and Florida reached market size quicker than those in Mississippi and Alabama. In FL and LA, oysters were ready for harvest after 24-30 weeks while in MS and AL they required 32-38 weeks of grow out time. Florida experienced the highest degree of fouling which impacted profit. Although flipping every three weeks is most profitable it is important to consider product quality, impact of fouling on the longevity of the cage and associated rigging, and the fact that meat quality was poorer in those oysters which were in cages flipped only every three weeks. In Alabama, mortality was higher than in other states and did not correlate with air drying frequency but was the biggest factor impacting profit. The shortened grow-out time in FL and LA could lead to higher profits overall and help off-set the cost of a more frequent flipping routine because the crop can be turned over more frequently.

It is important to keep in mind that these models represent an experiment conducted at one site in each state. Each state and indeed each waterbody can have its own characteristics and differences in fouling. The information presented here is a reflection of our experience with this experiment and it should not be assumed the experience will be the same at every site. It does, however, aid the thought process on factors to consider when employing an air drying routine to control biofouling in the Southern United States

Outreach Overview: As this project reached its conclusion the team focused on sharing products and information with growers throughout the project area. This included presentations at scientific and trade meetings, posting on information websites, video production, presentations and thesis generation by the two student involved in the project.

Targeted Audiences: Oyster producers in the Gulf and Atlantic States.

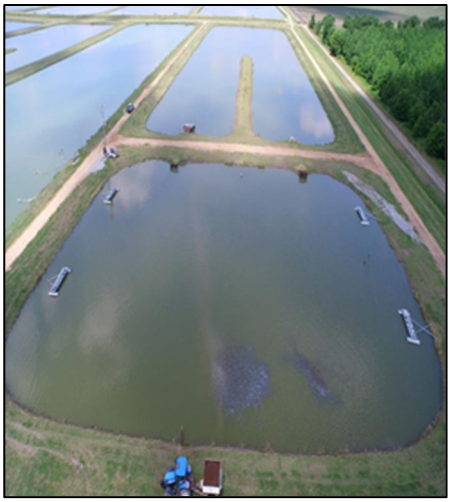
Outputs: Economic Model, a Microsoft Excel spreadsheet model which will assist a grower in determining the effect of employing either a weekly, every other week, or every three weeks, air drying

routine. A separate model has been developed for each state based on the biological results of the study.

Outcomes/Impacts: During the reporting period, there are no impacts as the project had yet to be deployed. In the South Atlantic, however, the project realized one significant accomplishment in that as a result of this project, the state of Georgia allowed import of oyster seed with no detectable level of disease into the state. This project also represents the first-time floating oyster cages have been permitted for deployment in Georgia and Mississippi.

Partnerships Developed: None to date.

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



Reporting Period: September 1, 2018- December 31, 2019
Length of Project: 2 years
Current Project Year: 2
Total Funds Committed: $116,179
Principal Investigators: Ganesh Kumar, *Mississippi State University*; Jonathan van Senten, *Virginia Polytechnic Institute and State University*; Terry Hanson and Luke Roy, *Auburn University*; Carol Engle, *Engle-Stone Aquatic$, 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: A comprehensive survey of catfish farms and associated backward- and forward-linked sectors (i.e., hatcheries, feed mills, processors) was designed and launched to collect detailed firm-level data to estimate the economic impact of the catfish industry. Surveys were well underway by early 2019, but COVID-19 and the ensuing economic shutdowns resulted in the suspension of survey efforts. Surveys have resumed recently and are expected to be completed by the end of 2020.

Results: The survey field data collection was suspended due to COVID-19 and the ensuing economic shutdowns and only recently have resumed. There are no results to date.

Outreach Overview: None to date, due to the suspension of field data collection due to COVID-19.

Targeted Audiences: Targeted audience are primarily catfish farmers, policymakers, researchers, industry organizations, congressional members and staffs, and the general public

Outputs: None to date, due to the suspension of field data collection due to COVID-19.

Outcomes/Impacts: None to date, due to suspension of field data collection due to COVID-19. The ultimate impact of this collective study cannot be estimated at this moment as the study is ongoing.

Partnerships Developed: Dr. Jimmy Avery, Mississippi State University, Extension Professor and Director, 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: September 1, 2018 – December 31, 2019
Length of Project: 2 years
Current Project Year: 2
Total Funds Committed: $186,635
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 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 percent 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. Trial two began during this reporting period.

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. Data collection and analysis for Trial two will be completed in the next reporting period.

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: We are working with one partner that is not being paid by SRAC

Evaluation of Probiotics in Finfish Hatcheries to Improve Larval Production

Reporting Period: September 1, 2018- December 31, 2019
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 development and enhancement of marine fish aquaculture in the United States. Due to numerous common challenges in hatchery operation, conditions such as overcrowding, poor water quality and inconsistent feeding, may result in unexpected mortalities. To improve early rearing survival, as well as enhance subsequent fish growth and immunity, investigations into early exposure to both probiotics and prebiotics are being pursed in this project with red drum, domesticated striped bass and southern flounder. It is anticipated that administration of probiotics and prebiotics during the larval stages of culture will improve the efficiency of hatchery production of these species.

Response: This project has the following objectives

1) Conduct *in-vitro* clinical trials to determine effectiveness of two selected commercially available probiotics and two commercially available prebiotics (Aquaculture Blend from Bio-Cat and BioPower PA (*Pediococcus acidilactici*) from Lalleman; and GroBiotic®-A from International Ingredient Corporation and SiLO Health® from BASF, Germany, respectively) at inhibiting important bacterial fish pathogens. The respective pathogens identified as being problematic for successful production of the species being evaluated are as follows: southern flounder; *Vibrio* sp., *Edwardsiella tarda*; red drum; *Vibrio* sp., *Aeromonas hydrophila*; and striped bass; *Vibrio* sp., *Streptococcus iniae, Mycobacterium marinum* and *Edwardsiella tarda.*
2) Evaluate the above mentioned two commercially available probiotics and two commercially available prebiotics under *in-vivo* conditions that adhere to commercial hatchery production. These approaches will include assessment of possible beneficial effects on production characteristics such as growth in length, weight gain, survival, and other responses as deemed appropriate and insightful such as improved gut morphology (microvilli length), and evidence of probiotic colonization to support beneficially competitive exclusion against pathogenic bacteria.
3) After metamorphosis to juveniles, conduct an *in-vivo* challenge of each fish species with problematic bacterial pathogens to determine their ability to resist disease using methods that simulate natural routes of infection.
4) Evaluate the economy of the additives based on observed improvements in fish production and disease resistance relative to costs associated with including the additives.

Results: North Carolina State University - To conduct the in-vitro evaluation, we were relying on the pathogenic materials used for the in-vivo trial (Objective 2, above) during 2019. As we were setting up the in-vivo test, our lab was closed due to COVID-19. To date, the lab has opened, however only with

limited access to which strict prohibitions remain for multiple persons working in close proximity. This trial will begin once our facility reopens to the extent we can adequately perform our activities.

We began our investigation with domesticated striped bass (DSB) in two stages, first in 2018, then 2019. Note that in 2018, we had received notice of our award just prior to the spring DSB spawning season and began a trial before funds were allocated or facilities completed. We did this to gain additional experience with the culture system as it had not been previously used for DSB.

1) In 2018, we begin feeding *Artemia* in our clear-tank zebrafish system and found the fry soon starving as they could not see the *Artemia* to eat. The system was then modified by covering the exterior of each tank black with epoxy paint. A second trial began using similar DSB fry which were now able to see and consume *Artemia.* The protocol called for a transition from the *Artemia* to the inert feeds midway in the culture cycle. Administering the probiotics to the feed using a vaporizer failed due to the oil carrier causing the microdiet particles to clump and the feed that was unsuitable for larval fish. We then obtained fry from a subsequent hatch and stocked the tanks, feeding *Artemia*, alone. In this case, the fish were fed daily, every 3-4 hours. By day 12, we noticed that all fry became hypersensitive to physical stimulation, "dropping out" (falling to the tank bottom) and dying if they missed a feeding by more than 2 hours. On each of two days during the middle of a cycle, two early feedings were extended by 2 hours. All fry became stressed and died within an 8-hour period. A third hatch of fish was obtained and fed through to metamorphosis, however, these fish arrived from the hatchery at 4 dph and were found to have 99% without swimbladder inflation. Deformities, mainly lordosis, became severe as fish grew. The fish were eventually judged to be of such poor condition they were considered improper for use in the investigation.
2) In 2019, we began with a strategy to ensure fry were chosen that successfully completed swim bladder inflation (SBI). The first batch of fry were used in an experiment to test four methods to support SBI. Fish from the treatment providing the highest %SBI were chosen for use in the feeding trials.

Our goal with the feeding trial was to use a microdiet throughout the study; thus avoiding the need of feeding live *Artemia*. The daily production of *Artemia* is labor intensive. The ability to feed inert diets would resolve labor challenges and encourage greater precision feeding the test additives. With the assistance of Dr. Lou D'Abramo, we had feeds manufactured specially for us in the fish nutrition lab of Dr. Steve Watts at the Univ. of Alabama, Birmingham. Feeds were created using a successful marine larval diet that was formulated to meet the complete needs of DSB. Feeds were manufactured with the pre and probiotics included to ensure their uniform consumption at prescribed rates. Unfortunately, while the fry were attracted to the feeds, none was consumed by any fry and all starved. We then obtained fry from another hatch and returned to the 2018 protocol of feeding enriched *Artemia* throughout the complete larval cycle. By the end of the metamorphosis, fry samples were collected for analysis and the disease challenge.

Samples for SEM and TEM are currently being processed. However, the SEM lab has been closed since March 2019 and while it is now open for the faculty operators, they both have chosen to retire and it is not clear if the samples will need to be moved to another lab for processing and analysis.
We are just finishing processing gut samples for microbiome genomics. Again, our lab had closed, but is now open and processing will begin again shortly (October 2020).

We have not yet been able to conduct the disease challenge due principally to the closure of our labs to multiple users required to perform the work.

Texas A&M University - A series of experiments were conducted to expose rotifers (*Brachionus plicatilus*) and (*Brachionus manjavacus*) to the various prebiotic and probiotic supplements in large-scale production. Several modifications to the rotifer culture system and refinements in administration of the supplements were required but resulted in consistent alteration of the microbial composition of the rotifers as determined by denaturing gradient gel electrophoresis.

The larval feeding trials conducted to date have not provided an adequate number of juvenile fish from each treatment to be subjected to disease challenges. Economic analysis of the various prebiotic and probiotic supplements is pending completion of all the larval rearing trials with the various species to provide the most comprehensive evaluation of the various products.

Specific impacts of this project have been limited to quantify to date because of the restrictive number of larval trials conducted with the three different targeted fish species. The limited number of trials has been due to extremely restrictive availability of larval stages to specific times of the year. In particular, domesticated striped bass larvae are only available in the spring of the year and southern flounder are available only in the late fall, early spring as these are the times broodstock of each species are available to be induced to spawn.

Impacts related to DSB have actually been productive. We have shown the following:

1) Fry cannot see any feeds, including *Artemia*, when cultured in clear plexiglass Zebrafish tanks. When sides and bottoms are painted with black epoxy, fry readily find both *Artemia* and microdiets.
2) Regardless of attraction to feed, fry have not been found to ingest any commercial or laboratory diets of similar size to *Artemia* that are readily consumed.
3) DSB fry at 4 dph that are placed into 10-L plexiglass aquaria with modest water flow and gentle aeration do not develop inflated swim bladders. Fry placed in 530-L tanks with upwelling and strong surface agitation show >75% SBI.
4) Oil-mist application of probiotics failed as unwanted particle clumping results
5) Fry are sensitive to physical stimulation from 12-18 dph.
6) Fry digest feed approximately every 3-4 hours at 20C and become weakened when feeding occurs more than 2 hours past clearing the gut of feed.

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: 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 conduced.

Outputs: No outputs besides publications have been generated to data.

Outcome/Impacts: Outcomes/impacts have not been achieved to date.

Partnerships: Texas Parks and Wildlife Department provided larval red drum and southern flounder for the research. Pamlico Aquaculture Field Laboratory provided larval domesticated striped bass.

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

Reporting Period: Oct. 1, 2018 – Dec. 31, 2019
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:

1. *Compare the channel catfish and zebrafish strains of* E. ictaluri *at: a) the molecular level and b) the biological/ serological level*: 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.
2. *Molecular characterization of* E. ictaluri *isolates from catfish and zebrafish*. Genome survey and plasmid profiling.
3. *Biological/Serological profiling of* E. ictaluri *isolates from catfish and zebrafish*. Antimicrobial susceptibility profiles and serological profiling.
4. *Evaluate effectiveness of disease management strategies including the following: a) optimization of vaccine design and administration, b) antibiotic effectiveness, c) antibiotic dosing (pharmacokinetics), d) potential use of commercial probiotics, and e) naturally occurring bacteriocins*. 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 contacted for product testing and delivery.
5. *Optimization of vaccine design and administration.* Two vaccines developed; initial studies run but unsuccessful and will be repeated.
6. *Antibiotic effectiveness.* Antibiotics ordered to incorporate into medicated feeds.
7. *Antibiotic dosing (pharmacokinetics)*. Pharmacokinetics run for oral and bath dosing of enrofloxacin. Pharmacokinetics run for oral dosing of florfenicol.
8. *Potential use of commercial probiotics.* Probiotics successful in laboratory trials sent to UF-TAL for field studies.
9. *Naturally occurring bacteriocins*. Five different gram-negative bacteria isolated for evaluation of bacteriocins.

Results:

1. *Molecular characterization of E. ictaluri isolates from catfish and zebrafish*. Rep-PCR analysis: A total of 50 catfish derived and 42 ornamental derived bacterial isolates were analyzed. Genetic analysis of E. ictaluri isolates identified different profiles for isolates from catfish compared to those from ornamental fish. Disease-causing genes from catfish were also different from ornamentals. In

general, isolates from catfish were very similar to each other, and isolates from ornamental fish were similar to each other, but the two groups differed.

2. *Genome survey*: Complete genomes were obtained for 19 catfish derived and 18 ornamental derived isolates analyzed by rep-PCR. Genetic analysis revealed two different branches, one for catfish and one for ornamental derived isolates. Genome and plasmid sequence data were analyzed and showed multidrug resistant plasmids among selected antibiotic resistant catfish derived E. ictaluri isolates. No plasmid mediated antibiotic resistance was identified for any ornamental fish derived isolates.
3. *Biological/Serological profiling of* E. ictaluri *isolates from catfish and zebrafish*. Phenotypic analysis: Basic growth, movement, biochemical and enzyme profiles of *E. ictaluri* isolates from catfish and ornamental fish species were similar, although in at least one test, they differed. Susceptibility of *E. ictaluri* isolates against approved antibiotics (Aquaflor®, Terramycin®, and Romet®) in catfish aquaculture differed in sensitivity because some strains had drug resistance genes. Ornamental fish derived isolates were susceptible to all three antibiotics indicating a lack of resistance genes. When another panel of 18 antibiotics were tested, antibiotic resistant, catfish derived isolates were resistant to multiple compounds, related to presence of resistance genes. Protein profiles were mostly similar. Serological analysis identifying shared and unique antigens among catfish and ornamental derived strains is ongoing.
4. *Optimization of vaccine design and administration.* 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. A second population of zebrafish was ordered.
5. *Antibiotic effectiveness*. Antibiotic effectiveness trials will be conducted concurrently with the vaccine trials. Antibiotics have been ordered to incorporate into medicated feeds.

Outreach Overview: Nothing to report; after completion of studies, outreach will occur by industry seminars, professional presentations, extension publications, and one-on-one farm contacts.

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. Use of the closely related zebrafish proxy, the giant danio for pharmacokinetic studies provide a much more scientifically based regimen for antibiotic dosing of florfenicol and enrofloxacin in infected zebrafish.

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

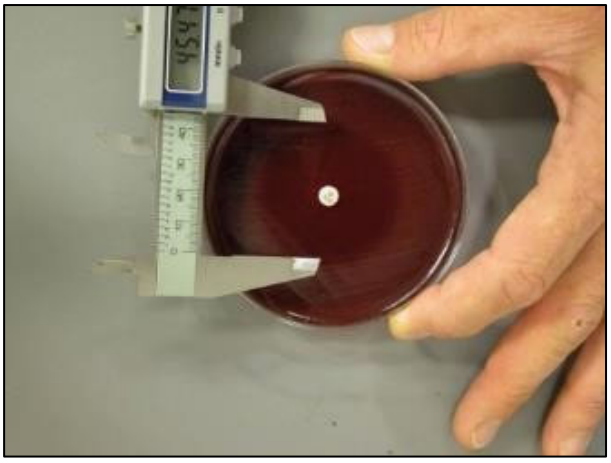
Reporting Period: October 1, 2019 – December 31, 2019
Length of Project: 1 year
Current Project Year: 1
Total Funds Committed: $124,474
Principal Investigators: Jeffrey E. Hill and Quenton Tuckett, *IFAS – University of Florida*; Christopher Green, *Louisiana State University*; Jonathan van Senten, *Virginia Tech University;* Carol Engle, *Engle-Stone Aquatic$, LLC*

Relevance: Scientists at the University of Florida (UF), Louisiana State University (LSU), University of Tennessee (UT), and Virginia Polytechnic Institute and State University (VT) 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: At the time this report was requested, work has only just begun on this project, so no report was requested from the Principal Investigators.

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

Reporting Period: October 1, 2019- December 31, 2019
Length of Project: 3
Current Project Year: 1
Total Funds Committed: $358,232
Principal Investigators: Suja Aarattuthodiyil, Matt Griffin, Ganesh Kumar, Terry Greenway, Lester Khoo, and David Wise, *Mississippi State University*; Alvin Camus, *University of Georgia*; Jonathan van Senten, *Virginia Polytechnic Institute and State University*; Carol Engle, Engle-Stone Aquatic$, LLC; 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: At the time this report was requested, work has only just begun on this project, so no report was requested from the Principal Investigators.

Products Developed and Students Supported

Journal Articles and Abstracts

Chapman, E., Davis, J., Rider, J., Sturmer, L., Walton, W., & Supan, J. 2019. Comparing Off-Bottom Techniques of Oyster Aquaculture Crassostrea virginica on Biofouling in the Northern Gulf of Mexico. Program and Abstracts of the 2019 Triennial Aquaculture Meeting of the World Aquaculture Society, National Shellfisheries Association, Fish Culture Section of the American Fisheries Society, and the National Aquaculture Association: 217. ABSTRACT.

Christie, T. W., B. Davis, B. S. Dorr, K. C. Hanson-Dorr, L. A. Roy, A. M. Kelly, and C. R. Engle. 2020. Food Habits of Wintering Double-crested Cormorants in the Mississippi Delta. Food Webs, under review.

Christie, T. W., B. Davis, B. S. Dorr, K. C. Hanson-Dorr, L. A. Roy, A. M. Kelly, C. R. Engle. 2017. Predation Risk of Double-crested Cormorants (*Phalacrocorax auritus*) on Commercial Catfish Production in the Mississippi Delta. Abstract. Mississippi Academy of Science Summer Student Science Symposium. Starkville, Mississippi. July 26.

Christie, T. W., B. Davis, B. S. Dorr, K. C. Hanson-Dorr, L. A. Roy, A. M. Kelly, C. R. Engle. 2018. Predation Risk of Double-crested Cormorants (*Phalacrocorax auritus*) on Commercial Catfish Production in the Mississippi Delta. Abstract. Alabama and Mississippi TWS Joint Conference, Meridian, Mississippi.

Christie, T. W., B. Davis, B. S. Dorr, K. C. Hanson-Dorr, L. A. Roy, A. M. Kelly, C. R. Engle. 2018. Predation Risk of Double-crested Cormorants (*Phalacrocorax auritus*) on Commercial Catfish Production in the Mississippi Delta. Abstract. Mississippi TWS Conference, Biloxi, Mississippi.

Christie, T. W., B. Davis, B. S. Dorr, K. C. Hanson-Dorr, L. A. Roy, A. M. Kelly, C. R. Engle. 2018. Predation Risk of Double-crested Cormorants (*Phalacrocorax auritus*) on Commercial Catfish Production in the Mississippi Delta. Abstract. The Wildlife Society National Conference, Cleveland, Ohio.

Christie, T. W., B. Davis, B. S. Dorr, K. C. Hanson-Dorr, L. A. Roy, A. M. Kelly, C. R. Engle. 2018. Predation Risk of Double-crested Cormorants (*Phalacrocorax auritus*) on Commercial Catfish Production in the Mississippi Delta. Abstract. Southeastern Association of Fish and Wildlife Agencies Conference, Mobile, Alabama.

Christie, T. W., B. Davis, B. S. Dorr, K. C. Hanson-Dorr, L. A. Roy, A. M. Kelly, C. R. Engle. 2019. Depredation Impact of Double-crested Cormorants (*Phalacrocorax auritus*) on Commercial Catfish Production in the Mississippi Delta. Abstract. World Aquaculture Society Conference, New Orleans, Louisiana.

Christie, T. W., B. Davis, B. S. Dorr, K. C. Hanson-Dorr, L. A. Roy, A. M. Kelly, C. R. Engle. 2019. Depredation Impact of Double-crested Cormorants (*Phalacrocorax auritus*) on Commercial Catfish Production in the Mississippi Delta. Abstract. Wildlife Damage Management Conference, Starkville, Mississippi.

Clark, G. 2020. Evaluating the effect of prebiotics and probiotics on rotifer and juvenile red drum (*Sciaenops ocellatus*) production. Texas A&M University, M.S. Thesis, 41 pp.

Clements, S. A., B. Davis, B. S. Dorr, K. C. Hanson-Dorr, L. A. Roy, A. M. Kelly, C. R. Engle. 2017. Foraging habits of lesser scaup (*Aythya affinis*) and greater scaup (*Aythya marila*) on commercial baitfish and sportfish farms in eastern Arkansas. Abstract. Alabama and Mississippi TWS Joint Conference, Meridian, Mississippi.

Clements, S. A., B. Davis, B. S. Dorr, K. C. Hanson-Dorr, L. A. Roy, A. M. Kelly, C. R. Engle. 2018. Foraging habits of lesser scaup (*Aythya affinis*) and greater scaup (*Aythya marila*) on commercial baitfish and sportfish farms in eastern Arkansas**.** Abstract. 2018 Annual Meeting of the Arkansas Bait and Ornamental Fish Growers Association, Lonoke, Arkansas.

Clements, S. A., B. S. Dorr, J. B. Davis, L. A. Roy, C. R. Engle, K. C. Hanson-Dorr, and A. M. Kelly. 2020. Diets of scaup occupying baitfish and sportfish farms in eastern Arkansas. Food Webs, e00141. https://doi.org/10.1016/j.fooweb.2020.e00141

Clements, S. A., B. S. Dorr, J. B. Davis, L. A. Roy, C. R. Engle, K. C. Hanson-Dorr, and A. M. Kelly. Distribution and abundance of scaup using baitfish and sportfish farms in eastern Arkansas. Journal of the World Aquaculture Society, in press.

Clements, S. A., B. S. Dorr, J. B. Davis, L. A. Roy, C. R. Engle, K. C. Hanson-Dorr, and A. M. Kelly. Scaup depredation on Arkansas baitfish and sportfish aquaculture. The Wildlife Society Bulletin, under review.

Engle, C.R., L. Roy, B. Dorr, B. Davis, A. Kelly, S. Clements, and T. Christie. 2018. Baitfish farm costs of scaring birds. Abstract. 2018 Annual Meeting of the Arkansas Bait and Ornamental Fish Growers Association, Lonoke, Arkansas.

Engle, C.R., S. Clements, B. Dorr, B. Davis, L. Roy, and A. Kelly. In review. Economic effects of predation by scaup on baitfish/sportfish farms. Journal of the World Aquaculture Society, under review.

Engle, C.R., T. Christie, B. Dorr, G. Kumar, B. Davis, L. Roy, and A. Kelly. Principal economic effects of cormorant predation on catfish farms. Journal of the World Aquaculture Society, in press. DOI:10.1111/jwas.12728.

Fetterman, J.A., and C. Green. 2020. Morphological and gonadal assessments from historical collections of Bluenose Shiners *Pteronotropis welaka*. Journal of Applied Ichthyology. 36(1):95-104.

Fetterman, J.A., and C. Green. 2020. Weight Dependent Intraspecific Variation in Reproductive Parameters of Female Golden Topminnows *Fundulus chrysotus*. North American Journal of Aquaculture. 82(3): 359-367.

Lipscomb, T., Q. Tuckett, A. Wood, J. Patterson, S. Ramee, C. Watson, and M.A. DiMaggio. 2019. Culture protocols for the Gulf Coast pygmy sunfish *Elassoma gilberti*. Journal of the World Aquaculture Society 1-11. DOI:10.1111/jwas.12646.

Simon, N., Sturmer, L., & Markham, R. 2019. Gear Type Comparison for Off-Bottom Oyster Aquaculture in Florida, USA. Program and Abstracts of the 2019 Triennial Aquaculture Meeting of the World Aquaculture Society, National Shellfisheries Association, Fish Culture Section of the American Fisheries Society, and the National Aquaculture Association: 1013. ABSTRACT.

Extension/Outreach Publications

Alabama and Mississippi results concerning the Oyster Project were distributed via the "On the Lid" newsletter to 169 readers in May 2020.

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

Christie, T., B. Dorr, L. Roy, A.M. Kelly, C. Engle, P. Burr, B. Davis, and J. van Senten. 2020. Cormorant predation of commercial catfish aquaculture in the Mississippi Delta. Fact Sheet, Virginia Cooperative Extension AAEC 231NP, Virginia Tech University. Available at https://www.pubs.ext.vt.edu/AAEC/AAEC-231/AAEC-231.html.

Clements, S. A., B. Davis, B. S. Dorr, K. C. Hanson-Dorr, L. A. Roy, A. M. Kelly, and C. R. Engle 2017. Collaborative research on foraging habits and the economic impact of scaup on commercial baitfish and sportfish farms in Arkansas. *The Wildlife Society Southeastern Section 59*(3):13.

Clements, S. A., B. Davis, B. S. Dorr, L. A. Roy, A. M. Kelly, and C. R. Engle. 2016. New study underway to estimate the impact of lesser scaup on Arkansas' baitfish industry. *Arkansas Aquafarming 33*(3):2.

Clements, S., B. Dorr, C. Engle, L. Roy, A. Kelly, J. van Senten, and B. Davis. 2019. The Problems of Avian Predators on Fish Farms: Scaup on Baitfish (Golden Shiner) Farms. Virginia Cooperative Extension AAEC 191NP, Virginia Tech University, Virginia. Available at https://www.pubs.ext.vt.edu/AAEC/AAEC-191/AAEC-191.html

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

Engle, C. R., G. Kumar, T. Christie, B. Dorr, B. Davis, L. Roy, and A. Kelly. 2020. Economics of cormorant predation on catfish farms. National Warmwater Aquaculture Center Fall Newsletter, Stoneville, Mississippi.

Floating Gear Comparison for Off-bottom Oyster Culture. UF/IFAS Extension, *Online Resource Guide for Shellfish Aquaculture*. http://shellfish.ifas.ufl.edu/oyster-culture-other-projects/comparison-of-stocking-densities-for-floating-bag-oyster-culture/. WEBSITE PAGE 3,488,915 valid hits in 2019.

Florida results concerning Oyster Project were summarized in the following article: https://shellfish.ifas.ufl.edu/oyster-culture-other-projects/biofouling-control/.

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.

Management Strategies for Culturing Oysters in Floating Cages. UF/IFAS Extension, *Online Resource Guide for Shellfish Aquaculture*. http://shellfish.ifas.ufl.edu/oyster-culture-other-projects/floating-gear-comparison-for-off-bottom-oyster-culture/. WEBSITE PAGE, 3,488,915 valid hits in 2019.

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

Chapman, E., Davis, J., Rider, J., Sturmer, L., Walton, W., & Supan, J. 2019. Comparing Off-Bottom Techniques of Oyster Aquaculture *Crassostrea virginica* on Biofouling in the Northern Gulf of Mexico. Presented at Aquaculture 2019, New Orleans, Louisiana, 7-11 March.

Christie, T. W., B. Davis, B. S. Dorr, K. C. Hanson-Dorr, L. A. Roy, A. M. Kelly, C. R. Engle. 2018. Predation Risk of Double-crested Cormorants (*Phalacrocorax auritus*) on Commercial Catfish Production in the Mississippi Delta. Oral Presentation. Mississippi TWS Conference, Biloxi, Mississippi.

Christie, T. W., B. Davis, B. S. Dorr, K. C. Hanson-Dorr, L. A. Roy, A. M. Kelly, C. R. Engle. 2018. Predation Risk of Double-crested Cormorants (*Phalacrocorax auritus*) on Commercial Catfish Production in the Mississippi Delta. Oral Presentation. The Wildlife Society National Conference, Cleveland, Ohio.

Christie, T. W., B. Davis, B. S. Dorr, K. C. Hanson-Dorr, L. A. Roy, A. M. Kelly, C. R. Engle. 2018. Predation Risk of Double-crested Cormorants (*Phalacrocorax auritus*) on Commercial Catfish Production in the Mississippi Delta. Oral Presentation. Southeastern Association of Fish and Wildlife Agencies Conference, Mobile, Alabama.

Christie, T. W., B. Davis, B. S. Dorr, K. C. Hanson-Dorr, L. A. Roy, A. M. Kelly, C. R. Engle. 2019. Depredation Impact of Double-crested Cormorants (*Phalacrocorax auritus*) on Commercial Catfish Production in the Mississippi Delta. Oral Presentation. World Aquaculture Society Conference, New Orleans, Louisiana.

Christie, T. W., B. Davis, B. S. Dorr, K. C. Hanson-Dorr, L. A. Roy, A. M. Kelly, C. R. Engle. 2019. Depredation Impact of Double-crested Cormorants (*Phalacrocorax auritus*) on Commercial Catfish Production in the Mississippi Delta. Oral Presentation. Wildlife Damage Management Conference, Starkville, Mississippi.

Christie, T. W., B. Davis, B. S. Dorr, K. C. Hanson-Dorr, L. A. Roy, A. M. Kelly, C. R. Engle. 2019. Depredation Impact of Double-crested Cormorants (*Phalacrocorax auritus*) on Commercial Catfish Production in the Mississippi Delta. Oral Presentation. American Fisheries Society and The Wildlife Society Joint National Conference, Reno, Nevada.

Clements, S. A., B. Davis, B. S. Dorr, K. C. Hanson-Dorr, L. A. Roy, A. M. Kelly, C. R. Engle, S. C. Barras. 2018. Foraging Ecology and Depredation Impact of Scaup on Commercial Baitfish and Sportfish Farms in

Eastern Arkansas. Mississippi Academy of Sciences, Summer Student Science Symposium 2018, July 26, 2018, Bost Conference Center, Mississippi State University, Starkville, Mississippi.

Clements, S. A., B. Davis, B. S. Dorr, K. C. Hanson-Dorr, L. A. Roy, A. M. Kelly, C. R. Engle. 2018. Foraging Ecology and the Resulting Economic Impact of Lesser and Greater Scaup on Commercial Baitfish and Sportfish Farms in Arkansas. Aquaculture Workshop and Arkansas Bait and Ornamental Fish Growers Association Annual Meeting. February 8th, 2018 Lonoke, Arkansas.

Clements, S. A., B. Davis, B. S. Dorr, K. C. Hanson-Dorr, L. A. Roy, A. M. Kelly, and C. R. Engle, S. C. Barras. 2018. Foraging ecology and depredation impact of scaup on commercial baitfish and sportfish farms in eastern Arkansas. Oral presentation. Southeastern Association of Fish and Wildlife Agencies 72nd Annual Conference, Mobile, Alabama.

Clements, S. A., B. Davis, B. S. Dorr, K. C. Hanson-Dorr, L. A. Roy, A. M. Kelly, and C. R. Engle, S. C. Barras. 2018. Foraging ecology and depredation impact of scaup on commercial baitfish and sportfish farms in eastern Arkansas**.** Oral presentation. The Wildlife Society's 25th Annual Conference, Cleveland, Ohio.

Clements, S. A., B. Davis, B. S. Dorr, K. C. Hanson-Dorr, L. A. Roy, A. M. Kelly, and C. R. Engle, S. C. Barras. 2019. Foraging ecology and distribution of scaup *Aythya* spp. on Arkansas commercial baitfish and sportfish farms. 2019 Wildlife Damage Management Conference, Mississippi State, Mississippi.

Clements, S. A., B. Davis, B. S. Dorr, K. C. Hanson-Dorr, L. A. Roy, A. M. Kelly, and C. R. Engle, S. C. Barras. 2019. Foraging ecology and distribution of scaup *Aythya* spp. on Arkansas commercial baitfish and sportfish farms. Aquaculture 2019, New Orleans, Louisiana.

Clements, S. A., B. Davis, B. S. Dorr, K. C. Hanson-Dorr, L. A. Roy, A. M. Kelly, and C. R. Engle, S. C. Barras. 2019. Foraging ecology and depredation impact of scaup on commercial baitfish and sportfish farms in eastern Arkansas. 2019 Annual Meeting of the Arkansas Bait and Ornamental Fish Growers Association, Lonoke, Arkansas.

Clements, S. A., B. Davis, B. S. Dorr, K. C. Hanson-Dorr, L. A. Roy, A. M. Kelly, C. R. Engle. 2017. Foraging Habits of Lesser Scaup (*Aythya affinis*) and Greater Scaup (*Aythya marila*) on Commercial Baitfish and Sportfish Farms in eastern Arkansas. The Wildlife Society, Mississippi Chapter Annual Meeting, Meridian, Mississippi. September 7-8.

Clements, S. A., B. Davis, B. S. Dorr, K. C. Hanson-Dorr, L. A. Roy, A. M. Kelly, and C. R. Engle. 2018. Foraging habits of lesser scaup (*Aythya affinis*) and greater scaup (*Aythya marila*) on commercial baitfish and sportfish farms in eastern Arkansas**.** Oral presentation. 2018 Annual Meeting of the Arkansas Bait and Ornamental Fish Growers Association, Lonoke, Arkansas.

Clements, S. A., B. Davis, B. S. Dorr, L. A. Roy, A. M. Kelly, and C. R. Engle. 2017 Foraging ecology and the resulting economic impact of lesser and greater scaup on commercial baitfish and sportfish farms in Arkansas. Oral presentation. 2017 Annual Meeting of the Arkansas Bait and Ornamental Fish Growers Association, Lonoke, Arkansas.

DiMaggio, M., T. Lipscomb, A. Wood, Q. Tuckett, S. Ramee, J. Patterson, and C. Watson. 2020. Development of aquaculture protocols for blackbanded sunfish *Enneacanthus chaetodon* and flagfin shiner *Pteronotropis signipinnis*, two Florida native ornamental species. World Aquaculture Society - Aquaculture America 2020. Honolulu, HI.

DiMaggio, M., T. Lipscomb, Q. Tuckett, A. Wood, S. Ramee, J. Patterson, and C. Watson. 2019. Evaluation of Culture Protocols for two Florida Native Ornamental Species: *Elassoma Gilberti* and *Pteronotropis metallicus*. 39th Annual Meeting of the Florida Chapter of the American Fisheries Society. Haynes City, Florida.

Dunham, R. 2018. Catfish Genetics Update (sub-part: R. A. Dunham, N. Chatakondi, B. Bosworth and P. Allen. Repeatability of Incidence and Time of Ovulation, Fecundity and Fertility in Channel Catfish Females Induced to Ovulate for Production of Hybrid Catfish Fry). Catfish Update Meeting. Demopolis, Alabama.

Engle, C.R., L. Roy, B. Dorr, B. Davis, A. Kelly, S. Clements, and T. Christie. 2018. Farm costs of scaring birds. Oral presentation, 2018 Catfish Farmers of Arkansas Annual Convention, Hot Springs, Arkansas.

Engle, C.R., L. Roy, B. Dorr, B. Davis, A. Kelly, S. Clements, and T. Christie. 2018. Baitfish farm costs of scaring birds. Oral presentation, 2018 annual meeting of the Arkansas Bait and Ornamental Fish Growers Association, Lonoke, Arkansas.

Fetterman, J. A. and C. C. Green. 2019. Use of historical collections to aid in reproductive assessments of the Bluenose Shiner. North American Native Fishes Association Annual Meeting. May 31, 2019, Jackson, MS.

Fetterman, J. A., Murr, C. E., and C. C. Green. 2018. Mophology, gonadosomatic index, and gonad histology assessment of the Bluenose Shiner (*Pteronotropis welaka*). Louisiana Chapter of the American Fisheries Society, Annual meeting, May 24-25, 2018, Baton Rouge, LA.

Fetterman, J. A., Murr, C. E., and C. C. Green. 2019. Bluenose Shiner (*Pteronotropis welaka*) Spawning Trials and Suggested Culture Methods. Louisiana Chapter of the American Fisheries Society, Annual meeting, May 23-24, 2019, Thibodaux, LA.

Fetterman, J. A., Murr, C. E., and C. C. Green. 2019. Weight dependent intraspecific variation in female Golden Topminnow *Fundulus chrysotus* reproduction. World Aquaculture 2019, New Orleans.

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.

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. 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.

Lipscomb, T., Q. Tuckett, A. Wood, S. Ramee, J. Patterson, C. Watson, and M. DiMaggio. 2019. Development of aquaculture techniques for two Florida native ornamental fishes: *Elassoma gilberti* and *Pteronotropis metallicus*. Aquaculture 2019. New Orleans, Louisiana.

R. A. Dunham, N. Chatakondi, B. Bosworth, I. Butts, N. El Husseini, A. Salah, Z. Taylor, M. Coogan, J. Gurbatow and P. Allen. 2019. Repeatability of Incidence and Time of Ovulation, Fecundity and Fertility in Channel Catfish Females Induced to Ovulate for Production of Hybrid Catfish Fry. Aquaculture America 2019. New Orleans.

Schwarz, M.H. 2017. VSAREC Program. Fish Propagation Workshop. Carteret Community College, Morehead City, NC. July 27.

Schwarz, M.H. 2019. VSAREC New Programming and Infrastructure. APAVa Conference Working Water Fronts Mobile Tour. Hampton, VA. July 22.

Schwarz, M.H. 2019. VSAREC Program Overview/Tour. VAAEA Site visit. Hampton, VA. July 23.

Schwarz, M.H. J. van Senten, R. Ovissipour, and D. Kuhn. 2019. Virginia Tech Research and Extension Updates. Virginia Aquaculture Conference 2019. Newport News, VA. November 15 – 16.

Schwarz, M.H., 2018. Virginia Tech - Seafood AREC: Programming and Technical Assistance to Industry. Virginia Sea Grant Site Review: panel Presentation. Gloucester, VA. October 24.

Schwarz, M.H., J. Bosmans, C. Clayton, and S. Urick. 2018. Larval Feeds for High-Value Foodfish and Ornamental/Conservation Aquaculture: Research Needs to Increase Live Feeds Quality, Safety, Biosecurity, and Optimization of Larval Production Protocols. AQUA 2018. Montpellier, France. August 25 – 29. Abstract published.

Simon, NA., Sturmer, L., & Markham, R. 2019. Gear Type Comparison for Off-Bottom Oyster Aquaculture in Florida, USA. 24 slides. Presented at Aquaculture 2019, New Orleans, Louisiana, 7-11 March.

Poster Presentations

Christie, T. W., B. Davis, B. S. Dorr, K. C. Hanson-Dorr, L. A. Roy, A. M. Kelly, C. R. Engle. 2017. Predation Risk of Double-crested Cormorants (*Phalacrocorax auritus*) on Commercial Catfish Production in the Mississippi Delta. Poster presentation. Alabama and Mississippi Chapters of The Wildlife Society Joint Conference, Meridian, Mississippi.

Christie, T. W., B. Davis, B. S. Dorr, K. C. Hanson-Dorr, L. A. Roy, A. M. Kelly, C. R. Engle. 2018. Predation Risk of Double-crested Cormorants (*Phalacrocorax auritus*) on Commercial Catfish Production in the Mississippi Delta. Poster presentation. Mississippi Academy of Science Summer Student Science Symposium. Starkville, Mississippi. July 26. (Placed second in the Graduate Student Division).

Clements, S. A., B. Davis, B. S. Dorr, K. C. Hanson-Dorr, L. A. Roy, A. M. Kelly, C. R. Engle. 2017. Foraging habits of lesser scaup (*Aythya affinis*) and greater scaup (*Aythya marila*) on commercial baitfish and sportfish farms in eastern Arkansas. Poster presentation. Alabama and Mississippi Chapters of The Wildlife Society Joint Conference, Meridian, Mississippi.

Murr, C. E., Fetterman, J. A., and C. C. Green. 2018. Application of hormones as a potential spawning aid for a species of conservation concern. Louisiana State University Discover Day, April 10, 2018, Baton Rouge, LA.

Murr, C. E., Fetterman, J. A., and C. C. Green. 2018. Application of hormones as a potential spawning aid for a species of conservation concern. Louisiana Chapter of the American Fisheries Society, Annual meeting, May 24-25, 2018, Baton Rouge, LA.

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/

Popoff Enterprises worked with growers and extension agents in South Carolina, Florida and Alabama to produce two videos. Growers and prospective growers are the target audience for the video entitled *Oyster Farming in the Southern United States Using the OysterGro System* (10 minute duration) which is hosted on the OysterSouth YouTube channel, https://www.youtube.com/channel/UCJxNbOcCLXdNxKqz3GC5SAg/videos and to date has 1000 views since posting in February 2020. Hosted on the same channel is *Oyster farming in the South* which is a five-minute long video aimed at a consumer audience. This video has been viewed 956 times in the past five months since posting in February 2020. Additionally, the South Carolina Sea Grant Consortium had both videos captioned and can provide that option.

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.*

Jacob A. Fetterman, Louisiana State University, Master of Science, Graduated Summer 2019. Thesis title: *Reproductive Parameters and Methodologies for the Culture of Golden Topminnows (Fundulus chrysotus) and Bluenose Shiners (Pteronotropis welaka).* LSU Master's Thesis. 4941. https://digitalcommons.lsu.edu/gradschool_theses/4941

Courtney Murr, Louisiana State University, Master of Science, Anticipated date of graduation – Spring 2021.

Angel Cosillo, Louisiana State University, Undergraduate Student, Graduated December 2019.

Taylor Lipscomb, University of Florida, PhD Student, Graduated – May 2020, Dissertation title: *Evaluation of Digestive System Ontogeny in Selected Freshwater Ornamental Species to Guide Larval Nutrition Protocols*.

Shane Ramee, University of Florida, PhD Student, Graduated August 2019, Dissertation title: *Potential Influences of Environmental Factors on Sex Differentiation in two Freshwater Ornamental Species, Rosy Barb and Dwarf Gourami*.

Stephen Clements, Mississippi State University, M.S. degree track, Degree completed May 2019. Thesis title: *Foraging Ecology and Depredation Impact of Scaup on Commercial Baitfish and Sportfish Farms in Eastern Arkansas*

Terrel Christie, Mississippi State University, M.S. degree track, Degree completed May 2019, Thesis title: *Predation Risk of Double-crested Cormorants (Phalacrocorax auritus) on Commercial Catfish Production in the Mississippi Delta*.

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. M.S. Thesis, 41 pp.

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

Alex Geddy, 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.

Shannon Kirk, University of Georgia, Master's student, Graduated Summer 2019, Thesis Title: *Efficacy of Biofouling Mitigation Methods for Floating Cage Production of Southeastern Triploid Eastern Oysters*.

Ellis Chapman, Louisiana State University, Master's student, Graduate Summer 2019, Thesis Title: *Comparing Off-Bottom Oyster Aquaculture Techniques in the Northern Gulf of Mexico on Biofouling*.

Appendix 1. List of Completed SRAC Projects to Date

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: $126,619
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