SOUTHERN
REGIONAL
AQUACULTURE
CENTER

FIFTEENTH ANNUAL PROGRESS REPORT

For the Period Through August 31, 2002

December, 2002

Southern Regional Aquaculture Center
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In cooperation with the U.S. Department of Agriculture,
Cooperative State Research, Education, & Extension Service

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FIFTEENTH ANNUAL PROGRESS REPORT

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PREFACE

In 1980, Congress recognized the opportunity for making significant progress in aquacultural development, and included in Title XIV of the Agriculture and Food Act of 1981 and later, in the Food Security Act of 1985, the authority to establish aquacultural research, development, and demonstration centers in the United States (Subtitle L, Sec. 1475[d]) to enhance viable and profitable aquaculture production for the benefit of consumers, producers, service industries, and the American economy. It was envisioned that the centers would be used in a national program of cooperative research and extension activities in association with colleges and universities, state Departments of Agriculture, federal facilities, and nonprofit private institutions with demonstrated expertise in aquaculture research and development. Eventually, five such centers were established, one each in the northeastern, southern, north-central, western, and tropical Pacific regions of the country. The 1990 Farm Bill (Food, Agriculture Conservation, and Trade Act of 1990; P.L. 101-624) reauthorized funding for the Regional Aquaculture Center program.

Projects that are developed and funded by the Regional Centers are based on industry needs and are designed to directly impact commercial aquaculture development in all states and territories. The Centers are organized to take advantage of the best aquaculture science, education skills, and facilities in the United States. Center programs insure effective coordination and a region-wide, team approach to projects jointly conducted by research, extension, government, and industry personnel. Inter-agency collaboration and shared funding are strongly encouraged.

ACKNOWLEDGMENTS

The Southern Regional Aquaculture Center (SRAC) would like to acknowledge the contributions of the Project Leaders and Participating Scientists involved in the projects reported in this Fifteenth Annual Progress Report. Members of the SRAC Board of Directors, Industry Advisory Council, and Technical Committee have provided valuable inputs to the successful operation of SRAC during the past year. We particularly appreciate the assistance of the chairs of our Board, IAC and TC, and those serving as Administrative Advisors.

We also thank the scientists and aquaculturists from across the country who contributed their expertise and valuable time to review SRAC project proposals and publications. Without their help, it would be impossible to maintain the high quality of this program.

INTRODUCTION

The farm-gate value of United States aquaculture in 2002 exceeded $1 billion dollars, with nearly 70% of the total production occurring in the southeastern states. Aquaculture has become one of the stars of southeastern agriculture, and its importance to the region reaches far beyond the farm gate. Many of the support functions for the industry—such as feed manufacture and equipment fabrication—also take place in the region, so the total economic impact of aquaculture is many times the value of production alone. Further, if the overall economic value of aquaculture is viewed against a generally depressed agricultural economy, it is clear that aquaculture is a critical factor in the economy of the southeastern United States.

Oddly, the success of aquaculture development in the southeast has come with relatively little private sector support for research and development. Larger, more developed agricultural sectors—such as poultry, cotton and soybeans—are supported by a vast infrastructure of agribusinesses conducting most of the research needed to sustain commodity growth. Aquaculture, on the other hand, receives little private-sector R&D support, relying instead almost entirely on public sector funds for technology development. Although government agencies, particularly the United States Department of Agriculture, have provided significant support for aquaculture research and development, much of that funding is earmarked for specific uses by specific institutions. The USDA-CSREES Regional Aquaculture Center program is the only funding mechanism 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.

One measure of the productivity of the Regional Aquaculture Center program is the hundreds of high-quality, peer-reviewed scientific articles, graduate theses, and technical papers that have been generated since program inception in 1987. We are particularly proud of the work conducted by scientists in the southern region, as exemplified by the work summarized in this Annual Report. Work on two of our projects—“Blue-Green Algae” and “Effluents”—has been reported in 58 presentations at scientific meetings and 63 scientific papers, with 28 more papers in preparation. This is a remarkable record, particularly considering that more work is to be conducted on both projects.

A more important measure of the impact of projects funded by the Southern Regional Aquaculture Center is the extent to which the results have influenced or improved domestic aquaculture. For example, although the project is only at its mid-way point, two products of the “Harvesting” project have already been adopted by the industry. A new seine developed at Mississippi State University allows catfish ponds to be harvested faster and with greater capture efficiency than traditional seine designs. Seines based on the new design are already available from commercial netmakers. The second success is the floating platform grader developed at the University of Arkansas at Pine Bluff. The mechanical grader is so superior to conventional technologies at grading fish from mixed-sized populations that it may revolutionize catfish harvest technology, particularly for fingerling producers.

Research to address the impact of aquaculture on the environment—including work in the “Effluents” project reported here—has been critical in recent regulatory activities. In September 2002, the United States Environmental Protection Agency published proposed regulations for aquaculture effluents. The proposal excludes pond culture systems from regulation, which means that most aquaculture producers in the south will not be saddled with costly or ineffective regulations. This good news is, in large part, the result of EPA's analysis of data derived from projects organized and supported by the Southern Regional Aquaculture Center. The scientists and farmers who developed the Center's aquacultural effluents projects in 1991, 1996, and 1999 showed remarkable foresight by anticipating the need for credible scientific information to support reasonable decisions on environmental regulation.

Beginning with the first projects funded by the Southern Regional Aquaculture Center, interest among aquaculture research and extension scientists in Center activities has been excellent. We are pleased with the participation by our research and extension scientists in the Southern Region in ad hoc Work Group meetings and Steering Committees, and their willingness to serve as Project Leaders and Principal Investigators for the projects. We believe this broad-based representation has resulted in strong, cooperative research that will be of long-lasting benefit to aquaculture producers and consumers, and to the growth of the aquaculture industry in the Southern United States.

This Fifteenth Annual Progress Report of the Southern Regional Aquaculture Center covers the activities of the Administrative Center during the past year. Progress reports on the four multi-year research and extension projects supported by Southern Regional Aquaculture Center during this reporting period cover the life of the projects from their initiation date through August 31, 2002.

ORGANIZATIONAL STRUCTURE

The Agriculture Acts of 1980 and 1985 authorized the 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.

The Board of Directors, the policy-making body for SRAC, utilizes recommendations from an Industry Advisory Council (IAC) and a Technical Committee (TC) to determine priorities for new and continuing aquaculture research and extension projects for the Southern Region. IAC membership represents different segments of the aquaculture industry throughout the region and provides valuable inputs for identifying priorities from an industry perspective. The TC is composed of research and extension scientists from essentially all states within the region and identifies priorities from a technical perspective. These groups provide valuable inputs into the SRAC program by identifying and developing priority research and extension needs in aquaculture. Using recommendations from these two groups, the SRAC Board of Directors selects priority categories for project development and funding.

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 of Directors, Industry Advisory Council, Technical Committee, Steering Committees and project Work Groups are provided by the Administrative Center. This includes monitoring the 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 Office personnel as needed.

Operation and funding of the Center are approved by the Board of Directors for inclusion in the Grant Application submitted annually by the Administrative Center to USDA/CSREES. The Center staff also prepares and submits to USDA/CSREES for approval an Annual Plan of Work covering Center activities and projects to be funded. Following final approval, Letters of Agreement are prepared and executed by the Center with all participating institutions. The Center acts as fiscal agent to disburse and track all funds in accordance with the provisions of the grants. Additional Administrative Center responsibilities are detailed in the "Administrative Activities" section of this report.

BOARD OF DIRECTORS

The Board of Directors is the policy-making body for SRAC. Membership of the Board provides an appropriate balance among representatives from State Agricultural Experiment Stations, Cooperative Extension Services, 1890 Institutions, and the Administrative Heads of Agriculture Section (AHS) of the Board of Agriculture of the National Association of State Universities and Land Grant Colleges.

The structure of the Board is as follows:

Three members of the 1862 Southern Extension Service Directors Association
Three members of the 1862 Southern Experiment Station Directors Association
One member of the 1890 Association of Research Administrators
One member of the 1890 Association of Extension Administrators
One AHS administrator from the host institution

Members of the Board are:

Harold R. Benson, Kentucky State University
W. S. Clarke, Virginia State University
Paul Coreil, Louisiana State University
Ivory Lyles, Arkansas Cooperative Extension Service
David Morrison, Louisiana State University
Daniel Smith, Clemson University Cooperative Extension Service
Vance Watson, Mississippi State University, Chairman
Greg Weidemann, University of Arkansas

Ex-officio Board members are:

Chairman, Industry Advisory Council
Co-chairman for Extension, Technical Committee
Co-chairman for Research, Technical Committee
Director, SRAC

The Board is responsible for (1) overall administration and management of the regional center program; (2) establishment of overall regional aquaculture research and extension goals and allocation 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 Technical Committee and Industry Advisory Council and guidance from the National Aquaculture Development Plan; (4) review and approval of annual plans of work and accomplishment reports; and (5) final selection of proposals for funding by SRAC.

INDUSTRY ADVISORY COUNCIL

The IAC, which meets at least annually, is composed of representatives of state and regional aquaculture associations, federal, territorial and state agencies, aquaculture producers, aquaculture marketing and processing firms, financial institutions, and other interests or organizations as deemed appropriate by the Board of Directors.

The IAC provides an open forum wherein maximum input from private and public sectors can be gained and incorporated into annual and ongoing plans for SRAC. The chairman serves for two years and is elected by IAC members.

Members of the IAC are:

Steve Abernathy, LA
J. Neal Anderson, AR
James Bardsley, GA
Richard Eager, SC
James P. Ekstrom, TX
J. B. Hanks, LA
R. C. Hunt, NC
Austin Jones, MS
Joey Lowery, AR
Robert Mayo, NC
Bryan P. Plemmons, VA
Steve Price, KY
Marty Tanner, FL
Rafe Taylor, AL

IAC members serve up to three-year appointments having staggered terms with options for re-appointment.

The IAC (1) recommends to the Board research and extension needs and priorities from an industry perspective; (2) reviews project proposals and accomplishment and termination reports; and (3) recommends to the Board, jointly with the Technical Committee, actions regarding new and continuing proposals, proposal modifications and terminations.

TECHNICAL COMMITTEE

The TC is composed of representatives from participating research institutions and state extension services, other state or territorial public agencies as appropriate, and non-profit private institutions. Membership of the TC includes research and extension scientists representing essentially all states in the region. The TC meets as needed, but at least annually, and has a co-chairman for research and a co-chairman for extension. Co-chairmen serve for two years and are elected by TC members.

Members of the TC for research are:

David Brune, SC
Gary Burtle, GA
Frank Chapman, FL
Harry Daniels, NC
Allen Davis, AL
Delbert Gatlin, TX
Andrew Goodwin, AR
John Hargreaves, MS
Rebecca Lochmann, AR
Ray McClain, LA
Steve Mims, KY
Jim Tidwell, KY
J. L. Wilson, TN

Members of the TC for Extension are:

Jimmy Avery, MS
Jerry Crews, AL
Dennis DeLong, NC
David Heikes, AR
Tom Hill, TN
Jeff Hinshaw, NC
Greg Lutz, LA
Michael Masser, TX
Brian Nerrie, VA
Nathan Stone, AR
Craig Watson, FL
Jack Whetstone, SC
Forrest Wynne, KY

Technical Committee members serve up to three-year appointments having staggered terms with options for reappointment.

The TC (1) recommends to the Board research and extension needs and priorities from a scientific perspective; (2) develops problem statements for research and extension areas under consideration; (3) plans, develops, and implements regional proposals; (4) reviews proposals and accomplishment and termination reports; and (5) recommends to the Board, jointly with the IAC, actions regarding new and continuing proposals, proposal modifications and terminations.

PROJECT CRITERIA

Projects developed within SRAC should meet the following criteria:

- Involves participation by two or more states in the Southern Region.
- Requires more scientific manpower, equipment, and facilities than generally available at one location.
- Approach is adaptable and particularly suitable for inter-institutional cooperation, resulting in better use of limited resources and a saving of funds.
- Will complement and enhance ongoing extension and research activities by participants, as well as offer potential for expanding these programs.
- Is likely to attract additional support for the work which is not likely to occur through other programs and mechanisms.
- Is sufficiently specific to promise significant accomplishments in a reasonable period of time (usually up to 3 years).
- Can provide the solution to a problem of fundamental importance or fill an information gap.

PROJECT DEVELOPMENT PROCEDURES

Research and extension priorities and statements of problems defining priority areas are jointly developed and recommended to the Board by the Industry Advisory Council and the Technical Committee. Using their recommendations as guidelines, the Board selects specific problem areas to be funded and appoints a Steering Committee (comprised of research, extension and industry representatives from the IAC, TC and other agencies) and an Administrative Advisor. The Steering Committee has full responsibility for developing a definitive research and extension Problem Statement, recommending levels of funding for each year of the proposed work, and preparation of the subsequent project proposal.

An Administrative Advisor is appointed by the Board for each active project area, and serves as the coordinator for activities related to the project, providing continuous linkage between the Work Group, Steering Committee and SRAC. Responsibilities of Administrative Advisors are outlined in the SRAC Operations Manual.

Following review of the Problem Statement by the IAC and TC, and review and approval by the Board, announcements to convene an *ad hoc* Work Group are made regionally to (1) institutions and individuals identified by the Steering Committee; (2) extension and research directors of 1862 and 1890 Land Grant Universities within the Southern Region; and (3) other institutions, agencies and organizations within the Southern Region having demonstrated capabilities in the area under consideration.

All *ad hoc* Work Group participants desiring to participate in a proposed research and extension activity must submit a "Commitment to Participate" form. Participants will also have an opportunity to make appropriate comments and suggestions relative to the development of the proposal and their interest and capability in participating. This information is used by the Steering Committee to draft a proposal, recommending the best qualified participants, as well as tentative funding allocations, to address objectives outlined in the Problem Statement.

Project proposals are reviewed by the Steering Committee, IAC, TC, all proposed participants and designated peer reviewers from within the region and from outside the region. The SRAC Director submits the project proposal and peer reviews to the Board of Directors for review and approval. Proposals not approved by the Board are returned for revision or eliminated from consideration.

Final selection of projects and levels of funding are determined by the Board. Most projects have an expected duration of three years. Following final approval by the Board of Directors and CSREES, work described in the research and extension project is implemented. Participating scientists, along with the Steering Committee, comprise the permanent Work Group for the research and extension effort and are responsible for implementation and conduct of the proposed work.

Separate allocations are made for research and extension to ensure strong programs in each of these areas. All funds allocated for extension activities are administered through the respective State Cooperative Extension Services.

ADMINISTRATIVE ACTIVITIES

The SRAC administrative staff consists of the Center Director and Administrative Assistant. A wide variety of support functions for the various SRAC components, including the Board, TC, IAC, Steering Committees and project Work Groups are provided:

- Center Director serves as an ex-officio member of the Board, TC, and IAC.
- Monitor research and extension activities sponsored by SRAC.
- Solicit and receive nominations for memberships on the TC and IAC.
- Coordinate submission of written testimony to the House Agriculture, Rural Development, and Related Agencies Subcommittee on Appropriations regarding RAC support.
- The Director of SRAC serves as a member of the National Coordinating Council for Aquaculture which consists of the Directors of the five Regional Centers and appropriate USDA/CSREES National Program staff.
- Prepare and submit the Grant Application entering into funding agreement with USDA/CSREES for each fiscal year, and Annual Plans of Work and Amendments to USDA/CSREES.
- Develop and execute appropriate Letters of Agreement with participating institutions in each funded proposal for the purpose of transferring funds and coordinating and implementing projects approved under each of the grants.
- Serve as fiscal agent to review and approve invoices and distribute funds to participating institutions as approved under the grants and as set forth in the Letters of Agreement.
- Prepare budgets for the Administrative Center, track administrative expenditures, and obtain USDA/CSREES approval for project and budget revisions.
- Prepare budget reports for the Board of Directors, tracking expenditures and status of funded projects and the Administrative Center.
- Assist Steering Committees and Work Groups with preparation and revision of proposals for technical and scientific merit, feasibility and applicability to priority problem areas.
- Solicit and coordinate national reviews of project proposals.
- Distribute extension fact sheets, research publications and videos to research and extension contacts throughout the Southern Region, other RACs, USDA personnel, and the Aquaculture Information Center.
- Produce and distribute the "SRAC Annual Progress Report," which includes editing and proofreading the project reports, designing and, using desktop publishing, producing camera-ready copy.
- Produce and maintain the web site for SRAC which provides downloadable copies of all SRAC fact sheets, the Operations Manual and Annual Reports, as well as lists of other research publications and extension contacts in the Southern Region.
- Prepare and distribute Work Group announcements and Requests for Proposals to research and extension directors and other interested parties throughout the Southern Region.
- Respond to numerous requests from aquaculture producers, the public, and research and extension personnel for copies of fact sheets, research publications and videos produced by SRAC and the other Centers, as well as requests for general aquaculture-related information.

PROGRESS REPORTS

The following cumulative reports detail the progress of research and extension work accomplished for the duration of the respective projects through August 31 of the current year. These reports are prepared by the Project Leaders in conjunction with the institutional Principal Investigators.

PUBLICATIONS, VIDEOS AND COMPUTER SOFTWARE

Reporting Period
April 1, 1995 - August 31, 2002

Funding Level	Year 1	$50,000
	Year 2	60,948
	Year 3	45,900
	Year 4	60,500
	Year 5	67,000
	Year 6	80,546
	Year 7	83,850
	Total	$448,744

Participants Texas A&M University System serves as Lead Institution, with Dr. Michael Masser as Project Leader. Participants in this project include authors and co-authors from all states in the region as shown in the listing of publications at the end of this report.

Administrative Advisor Dr. Daniel Smith, Director
South Carolina Cooperative Extension Service
Clemson University
Clemson, South Carolina

PROJECT OBJECTIVES

1. Review and revise, as necessary, all SRAC Extension printed and video publications.

2. Establish an ongoing project location to develop and distribute new SRAC educational publications and videos for Southern Region aquaculture industries. This project will be responsible for preparation, peer review, editing, reproduction, and distribution of all Extension and popular-type publications for all SRAC projects.

3. Place current, revised, and new publications in electronic format (e.g., Internet or compact disk) for more efficient use, duplication, and distribution.

ANTICIPATED BENEFITS

The most direct benefit from this project to the aquaculture industry is the widespread and ready availability of detailed information on production and marketing of aquacultural products.

SRAC fact sheets, videos, and other publications are distributed worldwide to a diverse clientele.

Extension Specialists. When this project was initiated, fewer than half the states had educational materials covering the major aquacultural species in their state. The concept of using the SRAC program to produce timely, high-quality educational materials is based upon the benefit of utilizing a region-wide pool of expertise to develop materials for distribution through the nationwide network of Extension Specialists and County Agents. This process makes efficient use of personnel at the State level, and results in high-quality educational materials that are readily available to scientists, educators, producers, and the general public.

Educators. Several colleges and universities in the United States use SRAC technical fact sheets as reference material in aquaculture and fisheries courses. Educational institutions at the elementary and secondary level use SRAC extension materials in the classroom to make students aware of aquaculture production and associated trades as a possible vocation.

Results at a glance...

- ☆ *121 authors from across the United States have contributed to SRAC's publication projects.*

Consumers. Information is readily available for consumers who are seeking background information on aquaculture.

Results at a glance...

Titles of some recent SRAC publications:

- ☆ *Measuring Dissolved Oxygen in Aquaculture Ponds*
- ☆ *Grass Carp for Aquatic Weed Control*
- ☆ *Toxicity of Agricultural Pesticides to Selected Aquatic Organisms*
- ☆ *Cultivation of Eastern Oyster*
- ☆ *Opportunities and Constraints in Marine Shrimp Farming*

Producers. Information on the use of therapeutants, pesticides, methods of calculating treatment rates, and possible alternative crops and marketing strategies is in constant demand by aquaculturists. Videos that demonstrate such techniques are a ready source of "how-to" information.

Potential investors. Detailed information on production and marketing constraints and ways to alleviate or manage those constraints is particularly helpful to people making decisions about entering the aquaculture business. Economic information is used by lending agencies and potential investors, as well as established producers who use the information to help make day-to-day decisions on farm management.

Internet access. Availability of SRAC publications via the Internet and compact disk makes access faster and easier, facilitates searching for needed information, and reduces storage space requirements for printed documents.

PROGRESS AND PRINCIPAL ACCOMPLISHMENTS

During this project year, six new fact sheets were written and five were revised. All have been distributed throughout the Southern Region and to interested Extension Specialists in other regions. Approximately fifteen fact sheets, a video, and a compilation CD are currently in some stage of writing, production, or revision.

All SRAC publications are based on research conducted within the region or in surrounding areas. Research funding from universities within the region, as well as funding from private sources, has been used to support the work on which the fact sheets are based. Copies of all fact sheets are available at **http://www.msstate.edu/dept/srac** on the Internet.

WORK PLANNED

During the next project year, two fact sheets will be revised and thirteen new fact sheets, including one species profile, will be produced. The new fact sheets will address 1) mud minnow production, 2) channel catfish virus, 3) aquaponics, 4) intensive culture of crawfish, 5) channel catfish hatcheries, 6) channel catfish fingerling production, 7) crawfish marketing, 8) inland marine shrimp, 9) fish anesthetics, 10) koi and goldfish production, 11) liming ponds, 12) HACCP regulations, and 13) a yellow perch species profile.

Two fact sheets will be revised on the following topics: 1) hybrid striped bass: pond production, and 2) clam culture.

IMPACTS

This is a highly productive project with significant regional and national impact. Fact sheets and videos are requested and used by clientele in all 50 states on a regular basis. Within the Southern Region, more than 80 fact sheets and six videos are distributed on request daily. Fact sheets generated within the Southern Region are also widely distributed by RACs and extension personnel in other regions. An average of 5 to 20 SRAC fact sheets and 3 videos are distributed daily from each of the other four regions. This means that about 20,000 fact sheets and 3,200 videos per year are used by interested producers or consumers. In addition to direct requests for printed material, fact sheets and other informational materials are accessed daily from the SRAC web site by people searching for technical information. Since the fact sheets are also accessible through numerous other university research and extension web sites, the total usage and impact is undoubtedly several times greater.

Results at a glance...

- ✰ *Eleven fact sheets were completed this year with 15 more in progress.*
- ✰ *Twenty-one scientists from across the Southern Region contributed to publications produced by SRAC this year.*
- ✰ *SRAC has now published 154 fact sheets, 16 research publications, and 19 videos.*
- ✰ *Educators in schools and colleges use SRAC publications in classrooms throughout the U.S. and the world.*

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

Results at a glance...

✰ All fact sheets completed by this project to date are available on the Internet at http://www.msstate.edu/dept/srac

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

The impact on consumers of aquaculture products is also likely significant, although it has not been quantified. Consumers are primarily interested in a wholesome, safe, and inexpensive product, and it has been reported that the consumer-oriented fact sheets and videos developed within SRAC have generated more interest than the producer-directed materials. The fact sheets are in demand in both the English and Spanish versions and, as more information becomes available, extension materials on food safety will be in increased demand by health conscious consumers.

PUBLICATIONS, MANUSCRIPTS OR PAPERS PRESENTED

Fact Sheets Completed (7/1/01 - 8/31/2002)

Dunning, Rebecca and Harry Daniels. Hybrid Striped Bass Production in Ponds—Enterprise Budget. SRAC Fact Sheet 3000.

Hargreaves, John A. and Craig S. Tucker. Measuring Dissolved Oxygen Concentration in Aquaculture. SRAC Fact Sheet 4601.

Lochmann, Rebecca, Nathan Stone and Eric Park. Baitfish: Feeds and Feeding Practices. SRAC Fact Sheet 121 (Revision).

Masser, Michael P. Grass Carp for Aquatic Weed Control. SRAC Fact Sheet 3600.

Masser, Michael P. Aquatic Weed Management Herbicides. SRAC Fact Sheet 361.

Morgan, E. Ruth and Martin W. Brunson. Toxicity of Agricultural Pesticides to Selected Aquatic Organisms. SRAC Fact Sheet 4600.

Steeby, Jim and Jimmy Avery. Construction of Levee Ponds for Commercial Catfish Production. SRAC Fact Sheet 101 (Revision).

Supan, John. Extensive Culture of *Crassostrea virginica* in the Gulf of Mexico Region. SRAC Fact Sheet 4300.

Wallace, Rick and Leslie Sturmer. Cultivation of Eastern Oyster. SRAC Fact Sheet 432.

Whetstone, Jack, Granvil Treece and Craig Browdy. Opportunities and Constraints in Marine Shrimp Farming. SRAC Fact Sheet 2600.

Whitis, Greg and Jeff Allred. Watershed Fish Production Ponds—Site Selection and Construction. SRAC Fact Sheet 102 (Revision).

Manuscripts in review

Avery, Jimmy. Aquatic Weed Management—Herbicide Technology and Application Techniques.
Engle, Carole and Nathan Stone. Cost Economics of Small-scale Catfish Production.
Kelly, Anita M. Channel Catfish Broodfish Management.
Mims, Steven and Andy Lazur. Species Profile: Sturgeon.
Santerre, Charles R. and George W. Lewis. Aquaculture Food Safety—Residues. SRAC Final Project Report.
Terhune, Jeffery S., David J. Wise, Jimmy L. Avery and Lester H. Khoo. *Bolbophorus confusus* Trematode Infections in Channel Catfish.

Manuscripts in preparation

Brune, David. Partitioned Aquaculture Systems.
Durborow, Robert and David Wise. Common Parasites.
Durborow, Robert and David Wise. Winter Kill Syndrome.
Hargreaves, John and Craig Tucker. Copper Use in Aquaculture.
Hargreaves, John. Pond Mixing and Circulation.
Hargreaves, John. Ammonia in Fish Ponds (Revision).
Romaire, Robert and Ray McClain. Crawfish Production (Revision).
Rosati, Ronald. Building Simple Recirculating Systems for the Classroom.
Tucker, Craig S. Pond Aeration (Revision).

CD in preparation

Masser, Michael P. CD of all SRAC Fact Sheets and Species Profiles.

Videos in preparation

Durborow, Robert and Jim Tidwell. Culture of Freshwater Shrimp.

On-going project

Development of web site on aquatic weed management. Michael Masser.

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CONTROL OF BLUE-GREEN ALGAE IN AQUACULTURE PONDS

Reporting Period
January 1, 1999 - August 31, 2002

Funding Level	Year 1	$307,574
	Year 2	275,970
	Year 3	252,703
	Total	$836,247

Participants	University of Tennessee (Lead Institution)	J. Larry Wilson
	University of Arkansas at Pine Bluff	Nathan M. Stone
	Auburn University	David Bayne, Thomas J. Popma, Claude Boyd
	Clemson University	David A. Brune, John A. Collier, T.E. Schwedler
	University of Georgia	Gary J. Burtle, George W. Lewis, Eloise L. Styer
	Louisiana State University	Robert R. Romaire
	Mississippi State University	John A. Hargreaves, Susan K. Kingsbury, Edwin H. Robinson
	University of Mississippi	Dale G. Nagle
	North Carolina State University	Harry V. Daniels, Ronald G. Hodson
	USDA, ARS, NPURU	Kevin K. Shrader
	USDA, ARS, SRRC	Paul V. Zimba, Casey C. Grimm

Administrative Advisor Dr. Greg Weidemann, Associate Director
Arkansas Agricultural Experiment Station
University of Arkansas
Fayetteville, Arkansas

PROJECT OBJECTIVES

1. Develop chemical control methodologies to prevent the establishment of noxious blue-green algal communities.

    a. Evaluate novel selective blue-green algicides identified through laboratory screening.

    b. Isolate, identify, and test allelopathic chemicals produced by competing blue-green algae and other micro-organisms found in local aquatic communities.

2. Evaluate nutrient manipulation to promote desirable phytoplankton community structure.

    a. Increase nitrogen-to-phosphorus ratios in the water.

    b. Reduce the availability of phosphorus from pond bottom muds.

    c. Enhance the availability of inorganic carbon.

    d. Manipulate trace metal availability.

    e. Increase potassium levels in the water.

    f. Increase salinity levels in the water.

3. Evaluate water circulation as a means of altering the environment to promote desirable phytoplankton community structure.

4. Evaluate the use of plankton-feeding fish to alter the environment to promote desirable phytoplankton community structure.

5. Evaluate the development of phytoplankton communities in the Partitioned Aquaculture System.

ANTICIPATED BENEFITS

The overall goal of this project is to identify methods of controlling or eliminating blue-green algae from aquaculture ponds. The ability to control algal communities in ponds could benefit farmers in several ways. Excessive abundance of blue-green algae, especially when combined with their habit of growing in surface scums, can cause low dissolved oxygen concentrations and other water quality aberrations that affect fish growth and health. Therefore, the ability to control the composition of blooms could result in better fish growth and lower costs for aeration and other water quality management procedures.

The largest and fastest growing segment of aquaculture in the United States is farm-raised channel catfish. Catfish that are off-flavor are unmarketable, and farmers are forced to hold those fish in inventory until composition of the pond microbial community changes and flavor improves. Holding market-sized fish in inventory imposes an economic burden on farmers, and off-flavor is estimated to cost the industry well over $20 million a year.

Baitfish mortalities associated with blue-green algae are common in the early summer. Historical use of high rates of granular fertilizers may be a factor in these excessive algae blooms, especially in baitfish ponds that have been in production for years and have accumulated sediments. Phosphorus in the groundwater in Lonoke County, Arkansas, also contributes to nutrient loading. In addition, golden shiners may stimulate phytoplankton production by foraging on larger species of zooplankton that would otherwise feed on the phytoplankton. Goldfish may indirectly contribute to phytoplankton production through phosphorus release due to their bottom feeding activities. Evaluation of methods with the potential to reduce excessive blooms (pond renovation, sodium nitrate application) will provide farmers with information to make informed decisions when weighing possible benefits against the costs.

Most of the treatments and management practices considered in this project have been promoted for controlling blue-green algae, but their effectiveness has not been documented. It is anticipated that this research will reveal which, if any, of these treatments are beneficial. Any practice demonstrated to be effective in controlling blue-green algae has considerable potential for improving aquaculture management and enhancing profits.

PROGRESS AND PRINCIPAL ACCOMPLISHMENTS

Objective 1. *Develop chemical control methodologies to prevent the establishment of noxious blue-green algal communities.*

University of Mississippi. More than 4,000 plant and algae extracts have been prepared from several thousand collections of plants, cyanobacteria (blue-green algae) and algae. These collections now include more than 300 collections of tropical cyanobacteria and marine algae, and 450 collections of aquatic and wetland plants, cyanobacteria (collections and cultures), algae, and thousands of collections of higher plants. These extracts were evaluated for selective blue-green algicidal activity in a rapid bioasay using 96-well microtiter plates.

Initial extract evaluations were conducted using *Oscillatoria agardii* as the cyanobacterial test organism, and *Selenastrum capricornutum* as a chlorophyte control for nonspecific algicidal activity. These organisms were grown in continuous flow culture and provide uniform algal material for biological evaluation. Lipid extracts of 33 tropical marine cyanobacteria and algae were evaluated in these assays at an initial concentration 100 ppm. Two related species of marine green algae and one species of marine brown algae were found to contain substances that were selectively algicidal against *O. agardii.* While these results are promising, the cyanobacterium *O. agardii* is not known to produce odorous compounds that cause off-flavor problems in aquaculture. We have since established cultures of the *O. perornata*, a filamentous blue-green alga that produces 2-methylisoborneol (MIB), the major tainting substance in catfish grown in northwest Mississippi. These cultures are suitable for high-throughput extract evaluation.

In the first phase of the project, 356 extracts from collections of aquatic and marine cyanobacteria, plants and algae have subsequently been evaluated in replicate bioassays using *O. perornata*. Forty-three extracts (12%) were found to be strongly active and cyanobacterial-selective at the concentration of 100 ppm, used for initial screening. Dose response data was obtained for these extracts at half-log concentrations. Twelve extracts were found to be effective at 30 ppm or lower. The two most potent extracts were confirmed to be two of the related marine green algae species first identified in the initial bioassays that used *O. agardii* rather than *O. perornata*.

Bioassay-guided fractionation of several extracts has resulted in the purification of unusual cyanobacterial-selective natural products that are effective against both *Oscillatoria* strains at concentrations in the parts-per-billion range. The chemical structures of several of these metabolites have been solved and are undergoing additional toxicological and antimicrobial evaluation.

The second phase of the program focused on the evaluation of plants found in tropical rainforests and temperate regions throughout the world for cyanobacterial-selective algicidal activity. Initial evaluations of plant extracts at 100 ppm picked up some activity associated with less selective antimicrobial substances such as tannins. In order to reduce the incidence of "false-positive" hits and to select for only those plants that contain potent and potentially more selective compounds, the primary phase of the high-throughput screening program evaluated plant extracts at 20 ppm. Extract plates were evaluated in duplicate. Plant extracts that showed cyanobacterial-selective activity at 20 ppm were reconfirmed by secondary evaluations at 20, 10 and 2.0 ppm. A bio-genetically diverse repository of plant extracts from over 170 plant families collected was examined. These plants were obtained from Peru, New Guinea, and the United States. This repository contained chemically distinct crude lipophilic extracts of separate plant parts (roots, leaves and stems, flowers, etc.) of each species collected. Over 2,300 crude extracts of more than 1,050 species of higher plant extracts were evaluated in this high-throughput screening system.

Over 70 plant species showed some level of selective activity against *O. perornata*. Since the major goal of this project was to identify cyanobacteria-specific agents, a process of "deselection" was undertaken to exclude compounds with broad activity against other microorganisms (blue-green algae are gram-negative bacteria). Thus, the active extracts that showed broad antimicrobial activity against a panel of biomedically important microorganisms (bacteria and fungi) were used to deselect extracts from further study. The microorganisms used to dereplicate antibiotic-containing extracts were *Staphylococcus aureus*, methicillin-resistant *Staphylococcus aureus*, *Pseudomonas aeruginosa*, and *Trichophyton mentarophytes*. In addition, all active extracts that showed mammalian toxicity in the monkey kidney Vero cell cytotoxicity assay were also deselected for further examination.

The most potent cyanobacteria-selective extracts (that were not significantly antibacterial and were non-toxic) were those obtained from the roots and stems of a Peruvian collection of *Dulacia candida* (family = Olacaceae). *Dulacia candida* is a widely distributed tropical Amazonian shrub. The crude *D. candida* extracts showed extremely potent anti-cyanobacterial activity, approaching the parts per billion range. The components of the extract were separated and the bioactivity was confined to several moderately non-polar chromatographic fractions. However, the substance (or substances) responsible for the potent anti-cyanobacterial have not yet been identified.

In addition, more than one hundred pure biologically active compounds from marine invertebrates and algae have been examined for anti-cyanobacterial activity. Some of these substances inhibited algae growth, but were either cytotoxic or not selectively toxic to nuisance blue-green algae.

USDA-ARS. Proprietary analogs of a promising natural product found in certain plants were tested in ponds for selective activity against blue-green algae. Efficacy testing yielded promising results, and one of the best proprietary compounds (as determined by laboratory screening studies) significantly reduced the MIB-producing cyanobacterium *Oscillatoria perornata* and the cyanobacterium *Raphidiopsis* *brookii* at application levels of 125 ppb. The abundance of green algae and diatoms increased dramatically two days after application of 125 ppb of this proprietary compound. Based upon the results, this proprietary compound is promising as a selective algicide to help prevent the growth of *O. perornata* and *R. brookii* in catfish aquaculture ponds, but it is not a broad-spectrum blue-green algicide. The half-life of the proprietary compound in pond water has been determined to be 19 hours, much less than the synthetic herbicide diuron. Efficacy testing of the proprietary compound using 0.25-acre catfish ponds stocked with channel catfish is currently being performed 1) to confirm effective application rates for obtaining acceptable flavored catfish; 2) to determine if the proprietary compound accumulates in catfish flesh; and 3) to observe for any negative effects on the catfish crop from application of the proprietary compound.

Results at a glance...

- ✩ *A derivative of a natural compound found in certain plants is undergoing patent application for use as a selective algicide to help prevent musty off-flavor in farm-raised catfish.*

Additional testing of several of the most promising proprietary compounds has determined that they are neither carcinogenic, antifungal, antibiotic, nor anti-protozoal. Analogs were also evaluated in the laboratory for acute toxicity and histopathology using channel catfish fingerlings. Acute toxicity was determined through measurement of mortality following 96 hours of aqueous exposure. The 96-hour LC50 for the analogs tested ranged from approximately 2-6 ppm. Histological analysis revealed abnormalities in the gills of treated fish. It was determined that the lethality of the analogs is related to histological changes in the gills of the catfish. Additional screening of pure natural compounds and crude plant extracts has identified several other leads for blue-green algicides.

Objective 2. *Evaluate nutrient manipulation to promote desirable phytoplankton community structure.*

Mississippi State University. In experiments repeated over two years, eight 1,450-gallon enclosures (limnocorrals) were placed in a small research pond or a commercial earthen fish pond in which a dense phytoplankton community dominated by *Oscillatoria agardhii* was present. The N:P ratio of four enclosures was adjusted by addition of KNO_3 to provide a N:P ratio of about 30 and chelated iron was added to provide 1 ppm iron. Four enclosures did not receive nutrient additions. All enclosures were supplied with diffused aeration to produce gentle turbulence. Water samples collected every 2 to 3 days were analyzed for nutrients, solids, and indices related to phytoplankton biomass and community composition. After 2 weeks, the combination nutrient addition did not result in a shift of the phytoplankton community from dominance

Results at a glance...

- ✩ *Studies in Mississippi and Alabama indicate that various manipulations of waterborne plant nutrients have little promise for controlling phytoplankton community composition in catfish ponds with high feeding rates.*

by *O. agardhii*. Nitrite concentrations increased and soluble phosphorus concentrations declined in nitrate-treated enclosures. Algal biomass in untreated enclosures declined, suggesting that continued nutrient supply is necessary to sustain high algal biomass. Nutrient manipulation does not appear to hold promise as a technique to effect phytoplankton community structure in hypereutrophic aquaculture ponds.

Auburn University. An initial laboratory study considered the effectiveness of the chelating agents ethylenediamine tetra-acetic acid (EDTA), lignin sulfonate, and citric acid for maintaining iron in solution. EDTA was the most promising of the chelating agents, because iron remained at concentrations above 0.5 ppm for 30 days in soil-water systems treated with 1 ppm iron from iron-EDTA. Thus, it was decided to use EDTA chelated metals for pond research.

Pond studies in 1999 had three treatments: (1) chelated iron (0.5 ppm) plus chopped legume hay (40 kg/ha per week); (2) chelated iron, chopped legume hay, plus a trace element mix (1 kg/ha per week); (3) control. The hay applications resulted in low dissolved oxygen concentrations, and no benefits related to blue-green algae control were observed.

Results at a glance...

✰ *Phosphorus-only fertilization was as effective as nitrogen plus phosphorus fertilization in bait minnow ponds. Phosphorus-only fertilization is less expensive, it conserves nitrogen, and it lessens the possibility for nitrogen pollution of natural waters by pond effluents. Removal of soft sediment from old (25 + years) bait minnow ponds should improve bottom soil quality.*

In 1999, potassium chloride treatments of 0, 30, 90, and 120 ppm did not result in significant differences in blue-green algal abundance. A sodium nitrate based fertilizer containing 8% N, 24% P_2O_5, and 15% K_2O was as effective as a standard, 10-34-0 liquid fertilizer in promoting sunfish production.

In 2000, two treatments (legume hay at 20 kg/ha per week and legume hay plus 0.5 ppm chelated iron and 1 kg/ha per week of trace element mix) were compared to the control. No benefits of treatments on water quality or blue-green algae control were observed.

Studies conducted in bait minnow ponds failed to show a need for nitrogen fertilizer. Phosphate-only fertilization was as effective as nitrogen plus phosphorus fertilization. However, sodium nitrate was shown to be a more "environmentally-friendly" source of nitrogen than ammonium sulfate.

In 2001, additional experiments were conducted on nitrogen fertilization in sunfish ponds that were also fertilized with phosphorus. These findings suggest that fertilization with nitrogen may be more important in older ponds than in younger ones, because earlier studies in the same ponds in 1971, 1978, and 1987 had not revealed a benefit to fish production of nitrogen applications in ponds fertilized with phosphorus. No effects of nitrogen and phosphorus fertilization ratios on blue-green algae abundance were observed.

Work on the pond soil cores from bait minnow ponds in Arkansas showed that the major effect of pond aging on sediment quality was the accumulation of soft sediment of high phosphorus concentration over time. There was a drastic decline in sediment quality in 30- to 35-year-old ponds as compared to 7- to 25-year-old ponds. Laboratory experiments indicated that sodium nitrate treatment would not improve sediment quality in older ponds. The problem of impaired sediment quality in old ponds can probably be best resolved by removing soft sediment from ponds to provide firmer bottoms.

University of Arkansas at Pine Bluff. A laboratory study was conducted to evaluate the effects of incorporating sodium nitrate into pond bottom soils. Two common soils (Perry-Portland, known locally as gumbo, and Calloway-Calhoun-Loring, or crawfish) were collected from the bottoms of 20- to 45-year-old commercial baitfish ponds. A layer (4.5 L) of gumbo or crawfish soil was added to each of 24 microcosms (13-L buckets) and sodium nitrate was soil-incorporated at rates of 0, 25, 50 or 75 g N/m^2. Buckets were filled with pond water, and sodium acetate was added throughout the study as a source of organic matter, to create anoxic conditions and simulate pond bottom waters.

Results at a glance...

☆ *No benefit was found from using sodium nitrate to suppress phosphorus release from pond sediments.*

Results showed that incorporating sodium nitrate suppressed phosphorus release in both soils for 11-19 days. However, elevated nitrite concentrations were also found during this period. Nitrite levels as high as 180-250 ppm were measured in the high rate treatment. The higher the rate of sodium nitrate, the longer was the duration of phosphorus suppression, but the additional time was not proportional to the dose.

A second laboratory study was conducted to evaluate the effects of adding different forms of sodium nitrate through the water column on pond bottom soil. A layer of gumbo soil collected from a 45-year-old commercial baitfish pond was added to each of 25 microcosms (13-L buckets), buckets were filled with pond water, and sodium acetate was added as a source of organic matter to create anoxic conditions and simulate pond bottom waters. Sodium nitrate was added to the buckets at a rate of 50 g N/m^2 in the form of a powder, prill, or two types of coated prills (short-term and long-term). Coated prills were suggested as a mechanism to permit application of sodium nitrate through the water column in established ponds. The short-term coating was designed to release 20% the first day and to finish release by day 10 to 15, while the long-term coating was intended to slowly release sodium nitrate over a 2- to 3-month period. Results showed that compared to controls, adding sodium nitrate suppressed phosphorus release regardless of product form, with the long-term coated prill treatment lasting 10 days. Elevated nitrite levels were found in all buckets treated with sodium nitrate, however, nitrite concentrations were lowest in the long-term release prill treatment (highest concentration for this product form was 13 ppm NO_2). Nitrite levels as high as 180-250 ppm were measured in containers with the other three product forms.

A field study was conducted in eight 4.7-m^2 fiberglass limnocorrals within a 0.04-ha goldfish pond located at the University of Arkansas at Pine Bluff Aquaculture Research Station. Coated sodium nitrate prills (time-release coating was 6% total weight) were sprinkled uniformly over the water surface in four corrals at a rate of 50 g N/m^2. A low-pressure blower was used to direct an air current over the surface of each corral to provide mixing without aeration. Soluble reactive phosphorus, nitrite, and Secchi disk visibility were measured at intervals before and after application of sodium nitrate. Oxidation-reduction potential (silver/silver chloride) was measured weekly in the upper 0.5 cm of soil cores extracted from three locations within each corral. Although oxidation-reduction potential results indicated less reduced soil conditions in treated corrals for a 3-week period, there were no significant water quality benefits. Nitrite levels in treated corrals did not exceed 3 ppm throughout the experiment. Sodium nitrate additions do not appear to be a practical treatment for baitfish pond soils.

Water quality and plankton community data were collected from 12 commercial golden shiner ponds at monthly intervals. Study ponds ranged in size from 7 to 25 acres (3 to 10 ha) and represented two soil types and two ages (20-25 years and 40-45 years). Using a column sampler, water samples were collected from a single location in each pond. Results showed that for parameters linked to phytoplankton abundance (i.e., chlorophyll *a*, COD, TP, TN), seasonal water quality changes in golden shiner ponds were similar to those reported for channel catfish culture. Dissimilar results were found for dissolved inorganic nitrogen, which was highest in the fall rather than in the winter, as has been reported for catfish. This may reflect the relatively low feeding rates used for baitfish. In addition, relatively higher SRP concentrations were found in the summer months, perhaps a result of powdered feed used for young fish.

Pond renovation was evaluated as a technique to reduce problematic blue-green algae blooms and associated water quality problems. Monthly water quality and plankton community data were collected from 12 commercial goldfish ponds for a year. Six of the 12 ponds were renovated during the winter (1999-2000) and returned to production in late spring. Results indicated little difference in water quality in renovated ponds as compared to controls. Soluble reactive phosphorus was significantly higher in renovated ponds for the first two months after ponds were returned to production, reflecting pond management practices for rearing new crops of fish. Pre- and post-renovation soil testing showed no overall significant difference in sediment phosphorus concentrations. This may reflect the fact that sediment from inside ponds is used to re-build ponds levees. However, pond renovation significantly reduced the phosphorus level in the upper 2 cm of sediment. Sulfate-sulfur concentrations in pond bottom sediments averaged 98 ppm, and ranged from 3 to 417 ppm. Compared to typical levels in terrestrial soils in the study area, these concentrations are very high. Sulfate sulfur results from the decomposition of organic matter and typically is higher in clayey soils.

Results at a glance...

- ✰ *Pond renovation had little effect on subsequent levels of soluble reactive phosphorus in baitfish pond waters or on average concentrations of phosphorus in bottom sediments. A possible explanation for these results is that pond bottom soils are used to rebuild levees during renovation and not removed from ponds. Bottom soils are mixed in the pond reconstruction process, and renovation decreased the average soil phosphorus concentration in the upper 2-cm of sediment.*

Louisiana State University. Concentrations of 2-methylisoborneol and geosmin were determined from March 1999 through February 2000 in fifteen 0.2-acre channel catfish experimental catfish ponds located at the Aquaculture Research Station, Louisiana State University Agricultural Center, in Baton Rouge. Ponds were assigned randomly to three mineralization (salinity) levels): 0.0 parts per thousand (ppt) - control, 1.5 ppt, and 3.0 ppt.

Nominal mineral concentrations were established and maintained with periodic additions of salt (NaCl). Water samples were collected twice a week and analyzed by solid phase micro-extraction gas chromatography mass spectrometry for MIB and geosmin concentrations. All ponds contained little or no MIB until late May. All ponds experienced off-flavor episodes at one time or another. Only trace levels of geosmin were observed throughout the year. Three major increases in the concentration levels of MIB were observed; one in early June, a second in early August, and a third in late September. Increases were not observed in all ponds. In several cases, concentrations of MIB increased rapidly from barely quantifiable levels (<0.1 ppb) to very high levels (>30 ppb) over a 3-4 day period. A slight reduction in the concentrations of MIB was observed in the ponds with 3.0 ppt NaCl. Ponds with 1.5 ppt salinity routinely contained higher levels of MIB than the control (0 ppt NaCl); but there was insufficient data to determine the impact on the mitigation of off-flavor episodes by using low levels of NaCl.

A simplified method for analyzing for the muddy, musty off-flavor in catfish was developed that uses the liver of the fish rather than the muscle tissue. Slurried liver tissue permits partitioning of the analytes directly from the sample, thus eliminating the need for the microwave distillation step. Sample preparation takes less than five minutes per sample and GC/MS analysis takes 15 minutes from start to finish, for a total analysis time of 20 minutes. A comparison of the concentrations of MIB and geosmin from fish fillet tissue and the liver was made by dosing fish (previously depurated for 96 hours) with MIB and geosmin at a final concentration of 3 ppb. Fish were sampled at 0, 2, 24, 48, and 72 hours after dosing to assess uptake of off-flavor compounds. The amount of 2-MIB and geosmin recovered directly from the liver was near 5%, while the recovery from muscle tissue employing microwave distillation approaches 60%. Fish were off-flavor after only one hour of exposure. The concentrations determined from the analysis of the livers are consistent with those determined from the fillets.

An instrumental method for determining the presence of the earthy, muddy or blue-green off-flavor in catfish was compared with four professional flavor checkers. The odor threshold for a theoretical average flavor checker was between 0.1 and 0.2 ppb for 2-methylisoborneol. The lower end of the range (0.1 ppb) was selected as the instrumental cut-off for determining off-flavor fish. Results from the instrumental method were highly correlated to flavor checker results.

North Carolina State University. In 1999, a study was conducted at the Tidewater Research Station to determine the effect of applications of trace metals and organic matter on water quality and phytoplankton population dynamics in hybrid striped bass ponds. Twelve 0.25-acre hybrid striped bass (*Morone chrysops* × *M. saxatilis*) ponds were stocked (4,000/acre) in the spring and managed according to standard commercial hybrid striped bass culture procedures. Chelated iron, a mineral mix, and alfalfa pellets were periodically applied to six of the ponds during an entire growing season. Ponds were harvested in late fall. Water samples were taken weekly and analyzed for nutrients and phytoplankton composition, and soil samples taken at the beginning and end of the study were analyzed for total nitrogen, total carbon, organic matter, pH and metals. Blue-green algae began to appear in samples during the second week of September 1999 and dominated phytoplankton composition in all treatments during the month of October 1999. Application of iron, minerals, and organic matter did not result in any differences in phytoplankton species composition, fish production, soil quality or water quality when compared to control ponds.

Objective 3. *Evaluate water circulation as a means of altering the environment to promote desirable phytoplankton community structure.*

Louisiana State University. Twelve 0.1-acre ponds were stocked with multiple cohorts of channel catfish at a nominal stocking density of 10,000/acre. In eight ponds, fish were restricted to approximately one-quarter of the pond area by a barrier placed across the pond width. In these ponds, a continuously-operating, horizontally-mounted pump mixed water between the area containing fish with the open area of the pond. In four of the mixed ponds, threadfin shad were stocked at 200/acre in the open area of the pond. Although the experiment is on-going, there are no differences in water quality, phytoplankton community composition, or feeding rate among the three treatments.

Three water management practices were evaluated, each at two levels (presence or absence), alone, and in combination, to determine their effects on blue-green algal community composition and water quality in experimental mesocosms managed to simulate commercial catfish production practices. In one treatment, aluminum sulfate (alum) was applied weekly at 3 ppm to reduce phosphorus (chemical control). In a second treatment, the water column was destratified by continuous vertical mixing in contrast to conventional surface aeration (physical control). In the third treatment, planktivorous gizzard and threadfin shad (*Dorosoma* sp.) were stocked at 25,000 juveniles/acre with channel catfish to evaluate their ability to control blue-green algae (biological control).

The eight treatment combinations, arranged in a 2^3 factorial design, were randomly assigned to twenty-four 3,000-gallon fiberglass tanks with soil bottoms (mesocosms) with three replicates per treatment combination. Catfish juveniles (mean = 52 g) were stocked in May at 10,000/acre, fed a 32% crude protein commercial feed daily at rates ranging from 40 to 150 pounds/acre, and harvested in November. Water samples were collected biweekly for nutrient and phytoplankton analysis.

Mean catfish survival was 88.5% and yield averaged 7,133 pounds/acre, with no observed differences related to water management practices. Shad biomass averaged 625 pounds/acre at harvest. The alum reduced soluble reactive phosphorus in October, but had no effect on phytoplankton density or community composition. Suspension of sediments in the water column from vertical mixing increased total nitrogen, total phosphorus, nitrate, and pH but had no discernible effect on the phytoplankton community. The presence of shad significantly reduced total algal biomass as evidenced by reductions in total nitrogen, total phosphorus, chemical oxygen demand, and chlorophyll *a*. Although the percentage of blue-green algae in the phytoplankton community was not significantly reduced compared to mesocosms without shad, odorous species of blue-green algae (*Oscillatoria perornata* and *Anabaena* spp.), known to cause off-flavor in catfish, were nearly eliminated by the presence of shad. Mesocosms with shad never had odorous species of blue-green algae that accounted for more than about 3% of the blue-green algal community, while odorous blue-green algae in mesocosms without shad accounted for as much as 20% of the community. Shad had no impact on catfish production.

North Carolina State University. Twelve ponds at the Tidewater Research Station were stocked in spring of 2000 with hybrid striped bass at 4,000/acre to evaluate the effectiveness of water circulation for controlling blue-green algae abundance in hybrid striped bass ponds. Ponds were managed according to standard procedures and harvested late fall. In six of the ponds, circulators were placed to produce whole-pond horizontal water circulation. Effectiveness of the water circulators in creating currents that circulated throughout the pond was evaluated with gypsum blocks. However, the water circulators used were very unreliable, and repeated mechanical problems throughout the duration of the study resulted in both decreased water circulation and the loss of several replicates in the treatment receiving circulation. Although water quality and phytoplankton population analysis revealed no differences among treatments, frequent breakdowns of circulators resulted in inconsistent water circulation and prevented a meaningful evaluation of the circulation treatment. Consequently, a second evaluation of water circulation in hybrid striped bass ponds was planned for the 2001 production season.

Results at a glance...

☆ *Artificial daytime water circulation of hybrid striped bass ponds had no effect on the incidence of blue-green algae in the phytoplankton community and did not measurably improve water quality.*

In May 2001, hybrid striped bass were stocked at 4,000/acre into twelve 0.25-acre ponds at the Tidewater Research Station. In six of the ponds, water was circulated during daylight hours (from 0900 to 1600) with a 0.5-hp pump (70 gallons/minute) placed on the pond bank. The pumps drew water from near the pond bottom and discharged at the surface approximately a third of the way down the length of the pond. Water samples were analyzed weekly or biweekly for concentrations of total and soluble reactive phosphorus, ammonia, nitrite, nitrate, total suspended solids, chemical oxygen demand, biochemical oxygen demand, pH, and chlorophyll *a*. In addition, phytoplankton abundance and composition were measured biweekly. Ponds were harvested in November 2001. There were no differences among treatments in fish production or in any of the measured water quality parameters. Uncirculated ponds had higher numbers of diatoms, but there were no differences among treatments in incidence of blue-green algae or overall phytoplankton abundance. This study showed no benefits resulting from water circulation in hybrid striped bass ponds.

Mississippi State University. In three experiments, twelve 0.1-acre ponds were stocked with multiple cohorts of channel catfish at a nominal stocking density of 10,000/acre. In the first experiment, fish in eight ponds were restricted to approximately one-quarter of the pond area by a barrier placed across the pond width. In these ponds, a continuously-operating, horizontally-mounted ½-hp pump mixed water between the area containing fish with the open area of the pond. In four of the mixed ponds, threadfin shad were stocked at 200/acre in the open area of the pond. In the second and third experiments, a baffle oriented along the long axis of the pond was placed in eight ponds. One ½-hp pump mixer was placed in each of four baffled ponds and two mixers were placed in each of the other four baffled ponds. Four ponds did not have a baffle and were not mixed. Results were similar in the three experiments: there were no differences in water quality, phytoplankton community composition, or feeding rate among the three treatments. Ponds with two mixers were more turbid than ponds in the other treatments. Turbidity in ponds with two mixers was dominated by suspended mineral matter.

Objective 4. *Evaluate the use of plankton-feeding fish to alter the environment to promote desirable phytoplankton community structure.*

Auburn University. Ten 0.1-acre earthen ponds were stocked with 9-g channel catfish at a density equivalent to 6,000/acre with 0.3-pound grass carp at 20/acre. Five randomly selected ponds were stocked with 8-g threadfin shad at 800/acre. Each pond was fed once daily to apparent satiation with a commercial floating feed (32% crude protein). All ponds were harvested 8 November 1999 and fish were identified, sorted and weighed. One channel catfish was randomly selected from each pond for flavor analysis.

Total threadfin shad mortality occurred in one of the shad ponds (9 September 1999). One of the no-shad treatment ponds experienced a catfish kill during the final two weeks of September when they had attained an average weight of 0.7 pounds. Observed mortality during this period was 31% of the original stock and only 48% of the original stock was recovered at harvest. Following the shad mortality, that pond was eliminated for further consideration of water quality and phytoplankton analysis for the shad treatment.

The presence of shad had no effect on temperature, dissolved oxygen concentrations, pH, or total alkalinity of pond waters. Total organic carbon concentrations ranged from 6.3 ppm in April to 30.5 ppm in October in the shad treatment and from 4.7 ppm in April to 34.1 ppm in September in the no-shad treatment. Total organic carbon levels increased in both treatments during the growing season and were higher in the shad treatment on 27 April and 25 May and higher in the no-shad treatment on 19 August.

Total ammonia-nitrogen (TAN) concentrations increased in both treatments throughout the growing season, but reached higher levels in the no-shad treatment. In the shad treatment, TAN concentrations ranged from 0.03 ppm in April to 1.92 ppm in October. In the no-shad treatment, TAN ranged from 0.03 ppm in June to 3.88 ppm in September. TAN concentrations in the no-shad treatment were significantly higher than concentrations measured in the shad treatment for the period 1 September through the end of the study. Nitrite-nitrogen concentrations in both treatments remained below 2.0 ppb until July and then began to increase, reaching a maximum of 37.2 ppb in the shad treatment in September and 94.5 ppb in the no-shad treatment in October. For the period 1 September through 25 October, nitrite-nitrogen levels were significantly higher in the no-shad ponds.

Phytoplankton abundance (as indicated by chlorophyll *a* levels) were low initially and increased progressively throughout the study to highs of 263 ppb chlorophyll *a* in the shad treatment in September and 285 ppb in the no-shad treatment in August. Chlorophyll *a* levels were significantly higher in the no-shad treatment on only one sampling date. There were no differences overall in phytoplankton abundance when data for chlorophyll *a* levels for all

Results at a glance...

- ☆ *In both Alabama and Georgia, stocking threadfin shad with channel catfish resulted in lower ammonia and nitrite levels late in the growing season. The improved environmental conditions apparently resulted in significantly better survival of catfish in the presence of shad in the Alabama study.*

sampling dates in September and October were combined.

Ponds with shad had significantly higher abundance (36.6 organisms/mL) of phytoplankton than ponds without shad (22.2 organisms/mL), as well as significantly higher number of taxa present (ponds with shad = 17.2 taxa; ponds without shad = 15.6 taxa). However, there was no significant difference in diversity indices between treatments (ponds with shad = 2.02; ponds without shad = 1.97).

When at least 60% of the phytoplankton present in a sample were measured for the period August through October, phytoplankton in ponds without shad were larger (average greatest axial linear diameter, GALD = 63 μm) than in ponds with shad (average GALD = 39 μm). The percentage of green algae and blue-green algae in the phytoplankton community did not differ between treatments. The percentage of other algae, which included diatoms, euglenophytes, and dinoflagellates, was significantly lower in phytoplankton communities of ponds with shad compared to ponds without shad.

Survival of channel catfish in ponds with threadfin shad was 92%, which was higher than the 77% survival in ponds without shad. Catfish production was also higher in ponds with shad (4,651 pounds/acre) than in ponds without shad (3,980 pounds/acre). However, average weight at harvest was similar in both treatments (overall mean = 0.80 pounds). Feed conversion was marginally better in ponds with shad (1.30) than in ponds without shad (1.40).

Off-flavor analysis was performed on one catfish from each pond. The catfish were filleted with the skin-on, microwaved, and served to a panel of three taste testers. Slight off-flavor was detected by two of the three panelists in both treatments, but no significant differences were found.

In 2000, eight commercial channel catfish ponds were selected for analysis on three catfish farms in West Alabama. Four ponds with catfish and established threadfin shad populations were selected along with four similar ponds stocked only with channel catfish. All ponds were managed with common commercial practices. Nightly aeration was used in all ponds to prevent fish loss caused by low dissolved oxygen concentrations. Copper sulfate was added periodically to six of the eight ponds for algal management. Partial harvests of catfish were carried out in ponds throughout the study. Water samples were collected twice a month from May through October 2000.

Results at a glance...

- ☆ *Polyculture of threadfin shad with channel catfish in relatively small experimental ponds resulted in improved water quality conditions and enhanced catfish survival. The stocking of threadfin shad, in four commercial channel catfish ponds in West Alabama, did not result in improved water quality when compared to four similar ponds with catfish, but no threadfin shad.*

Mean total organic carbon (TOC) increased gradually through the entire growing season in both treatments. The TOC concentrations in the shad treatment (mean = 34.26 ppm; range = 22.1 to 56.5 ppm) were significantly higher than TOC concentrations in the no-shad treatment (mean = 27.57 ppm; range = 20.8 to 38.4 ppm).

Mean total ammonia-nitrogen concentrations also were higher in the shad treatment (mean = 1.6 ppm; range = 2.3 ppm in June to 0.3 ppm in September) than in the no-shad treatment (mean = 0.7 ppm; range = 0.3 ppm in October to 1.2 ppm in September). Nitrite nitrogen (NO_2-N) concentrations did not differ significantly between treatments, remaining below 0.1 ppm throughout most of the growing season.

Mean chlorophyll *a* concentrations (corrected for phaeophytin) varied throughout the growing season in both treatments, but the mean concentration for the entire growing season was significantly higher in the shad treatment (mean = 299 ppb; range =153 ppb to 407 ppb) than in the no-shad treatment (mean = 155 ppb; range = 66 ppb and 308 ppb). Phytoplankton community structure and size distribution are currently being examined.

This study did not reveal an improvement in water quality of commercial channel catfish ponds containing threadfin shad. In fact, concentrations of TOC, total ammonia, and chlorophyll *a* were significantly higher in the shad treatment than in the no-shad treatment. These ponds were stocked, harvested, fed, aerated, and chemically treated (with copper sulfate) independently by three different farm managers. As such, water quality differences measured between treatments were likely not solely caused by the presence or absence of threadfin shad.

University of Georgia. Threadfin shad or fathead minnows were stocked with catfish in 0.25-acre earthen ponds at Tifton, Georgia, and compared to ponds with only channel catfish. At Cohutta, Georgia, two treatments were started comparing threadfin shad and channel catfish to channel catfish alone in 0.1-acre earthen ponds. Three replicate ponds were used for each treatment for a total of nine ponds at Tifton and six at Cohutta. Channel catfish were stocked as fingerlings in multiple sizes at 44,500/acre. Threadfin shad were stocked at about 2,500/acre and were 1.7 to 4 inches long. Fathead minnows were stocked at about 10 pounds/acre (8,900 to 10,000/acre) and were 1.4 to 2 inches long.

Threadfin shad stocking was difficult due to the fragility of this species during handling, hauling, and transfer into receiving waters. Five attempts were made to stock threadfin shad at both locations. The most successful method of threadfin shad stocking was to obtain 1.5 to 2 inch shad from local ponds in the months of January to April. Even under the best conditions, it was difficult to determine the survival of the threadfin shad after stocking. Stocking threadfin shad into holding ponds and seining after one or two weeks indicated that 30-90% of the threadfin shad could die a short time after stocking due to loss of scales during handling, temperature shock, alkalinity shock, salinity shock, or other stress due to handling or transfer. Sorting threadfin shad from gizzard shad, which often is found together with the threadfin in lakes, rivers, and aquaculture ponds, causes an increase in threadfin shad losses. Cast nets or seines can be utilized for capturing threadfin shad. However, each method of capture has disadvantages. Casting nets near paddlewheel aerators appear to be successful for monospecific harvests of threadfin shad. Hauling aids should be utilized during transport and may include an anesthetic, sodium chloride, calcium chloride, anti-foaming agents, or a buffer of pH 8.0 to 7.0. Tempering should be extended to two hours of gradual exchange of hauling water with receiving water, even when similar water temperatures are found in the two water sources.

Over 50 algal species have been identified from Georgia ponds during the growing season. Blue-green algal blooms are denser at the Tifton location than at the Cohutta location. Water temperatures are cooler at Cohutta and the water source is a spring from limestone caverns. The water source at Tifton is the Floridan aquifer. No differences among treatments were observed in 1999. All ponds had blue-green algae in abundant populations. Establishment of threadfin shad populations was variable and appeared to affect the observed phytoplankton population densities. Off-flavors were not detected in channel catfish harvested from the study in 1999 or 2000. Off-flavors were detected in fish from control ponds at Tifton in 2001.

In 1999, total ammonia concentrations were lower in the shad and minnow treatments than in the ponds with only channel catfish. Also, nitrite concentrations were lower in the minnow treatment than in the other two fish combinations. Soluble reactive phosphorus was similar in all ponds.

In 2000 at Tifton, blue-green algae became abundant in ponds with channel catfish only as early as April, in May with fathead minnows and catfish, and in June with threadfin shad and catfish. Blue-green populations reached 100 million cells/mL in ponds with channel catfish only, 80 million cells/mL with fathead minnows and catfish, and 35 million cells/mL with threadfin shad and catfish. At the Cohutta location, blue-green algae did not become abundant until August. It was apparent that blue-green algae were less abundant in the ponds with threadfin shad; however, all ponds had blue-green algae blooms by late summer.

In 2001 at Tifton, the presence of threadfin shad reduced the number of blue-green algae colonies versus the control or fathead minnow treatment. Blue-green algal numbers were higher in fathead minnow ponds from March through August than in control ponds. At Cohutta, the blue-green algae, *Microcystis aeruginosa*, became abundant later than at the Tifton location. Few blue-green algal species were observed in ponds containing threadfin shad by August. The number of hours of aeration was reduced in ponds containing threadfin shad.

Although threadfin shad were successfully maintained at Tifton in catfish ponds, the final harvest at Cohutta showed that green sunfish had displaced the threadfin shad over the course of the three year project. It is apparent that channel catfish eat many of the threadfin shad and may completely eliminate the population. It is also apparent that threadfin shad do not necessarily spawn in channel catfish ponds, and may need added spawning substrate.

Results at a glance...

- ✰ *Blue-green algae numbers were reduced by threadfin shad over a three-year period in intensively-managed catfish ponds.*

Louisiana State University. Eighteen 0.1-acre earthen ponds at the ARS-LAES were stocked with channel catfish fingerlings in May 2000 at 10,000 fish/acre to study the efficacy of threadfin shad for control of blue-green algae. Juvenile and adult threadfin shad were captured from a local lake for stocking in the experimental ponds, but physiological stress associated with high water temperatures resulted in >90% mortality in the shad. Surviving shad were held in ponds and were to be stocked into catfish ponds in November-early December 2000. However, the study was irreversibly compromised when a flock of 300 white pelicans entered the research facility in December and dramatically reduced catfish and shad populations, thereby requiring repetition of the experiment.

The 18 ponds were re-stocked with catfish fingerlings in April 2001 at 10,000/acre, and six 1-acre ponds were stocked with mixed size classes of channel catfish and channel x blue catfish hybrids at densities of 7,000 fish/acre in summer. Threadfin shad were stocked in half the replicate ponds (0.1 and 1-acre) in November/December 2001 when temperatures were sufficiently cool to safety transport and stock the fish. Heavy monofilament with reflectors was placed over all experimental ponds to minimize depredation by avian predators.

A ¾-acre demonstration-size partitioned aquaculture system (PAS) was stocked with channel catfish, blue catfish, and channel x blue catfish hybrid fingerlings into individual raceways (~5,000 fish/raceway) in June and July 2001, at a collective stocking density of 19,600 fish/acre. Nearly 1,400 Nile tilapia (*Oreochromis nilotica*) weighing 860 pounds (average weight = 0.6 pounds) were stocked for algal control in late May. The presence of tilapia as biological filter-feeders in the open area of the PAS stabilized oxygen concentrations, and odorous species of blue-green algae were rarely observed. Tilapia were not re-stocked into the PAS in 2002, and incidences of low dissolved oxygen episodes and odorous communities of blue-green algal populations occurred with regularity. The absence of the filter-feeding fish appeared to be a major contributing factor to algal community and dissolved oxygen instability.

Three 1-acre ponds at the Aquaculture Research Station were stocked with 7,000 catfish fingerlings in March 2002. One of the 1-acre ponds will be managed with catfish only, one with a combination of catfish and filter-and bottom-feeding fishes (golden shiners, goldfish and freshwater drum and buffalofish), and the third with catfish, filter- and bottom-feeding fishes, and one or more floating aquatic macrophytes for nutrient removal. A combination of golden shiners and goldfish, and freshwater drum and buffalofishes will be stocked in winter when the catfish standing crop exceeds 5,000 pounds/acre and feeding rates exceed 100 pound/acre per day. A process control water quality monitoring system was built to measure oxygen, temperature, pH, nitrite, and ammonia on a continuous basis in the 1-acre ponds. Water samples are being collected from each pond monthly and analyzed for algal species composition, algal density, and off-flavor in catfish. Nutrients, organic matter, and bottom organisms (benthos) will be determined from standardized sampling protocols. Geosmin and MIB in water and fish will be analyzed by the USDA Southern Regional Research Center in New Orleans.

Objective 5. *Evaluate the development of phytoplankton communities in the Partitioned Aquaculture System.*

Clemson University

Results from the1999 Season

The 2-acre commercial scale PAS unit was brought into production in the spring of 1999 (Figure 1).

The unit was stocked with 33,000 catfish fingerlings in May. Stocked fingerlings averaged 15, 31, 48, 61 and 80 g. The catfish were stocked in two raceways consisting of four sections each. In addition, 1,320 pounds of tilapia (15,000 fish at 40 g each) were stocked into the 2-acre system. An additional 216 breeding tilapia (250-300 g) were stocked into the algal basin. The 2-acre unit successfully produced 14,500 pounds/acre of catfish at a carrying capacity of 17,000 pounds/acre. Feed applications reached 260 pounds/acre-day (Table 1). The 2-acre unit was dominated by green algal populations throughout the season and off-flavor in 1999 ranged from 1.0 to 1.5 (out of 5) at the time of harvest. This mild off-flavor was described as being “grassy”.

Figure 1. Overview of 2-acre (above) and six-1/3 acre PAS units at Clemson University.

Table 1. Summary of 1/3 acre PAS performance for growing seasons 1995-2000.

Year	Avg. max. catfish carrying capacity lb/acre	Avg. seasonal catfish yield lbs/acre	Avg. feed application lbs/acre	Avg. max. feed application lbs/acre	Tilapia co-production lbs/acre	Catfish feed conversion ratio
1995	3,258	3,078	20	60	0	1.34
1996	8,811	8,151	60	150	0/805[a]	1.53
1997	14,054	12,965	94	200	1,826	1.41
1998	16,694	14,952	113	210	2,266	1.40
1999	10,479	11,474	100	260	3,843	1.60
2000	14,108	17,232	115	260	5,407	1.50

[a/] In 1996, three of the units contained tilapia (0 lbs/acre production) and three of the units contained tilapia (805 lbs/acre production).

Six 0.33-acre PAS units were stocked with both adult tilapia alone (breeding pairs) and with tilapia fingerlings and adults to see if successful algal species control could be sustained with reducing stocking requirement through the use of breeding pairs. By mid-season, four of the six 0.33-acre PAS units shifted from early blue-green dominance back to populations of more desirable green algae as the tilapia breeding pairs expanded in numbers and weight. In two of the 0.33-acre PAS units, late season algal populations shifted to predominantly blue-green populations suggesting that use of tilapia breeding pairs alone at these feed application rates is close to, or slightly beyond, the limit of blue-green population control.

Stocking density experiments were conducted showing that raceway catfish stocking could be increased from 4-5 pounds/cubic foot to 8-10 pounds/cubic foot with no adverse effect on growth. These results demonstrated that overall system costs can be reduced by using a single high-density raceway and fewer raceway paddlewheels. A preliminary economic analysis projects that 40 acres of PAS units would produce catfish at a 5 to15¢/pound lower cost than conventional pond culture (Table 2). However, this analysis is based on the assumption the net production would exceed 22,000 pounds/acre. Because of loss of winter fish carryover as a result of spring proliferative gill disease (PGD), this potential yield has yet to be realized.

Flow experiments were conducted in 1999 to determine the uniformity of the water velocity field that can be sustained with different combinations of paddles and paddle speeds. The results suggest that sufficient mixing and flow velocity in the algal channel can be maintained with 50% of algal channel width coverage by paddlewheels (Figure 2).

Table 2. Estimated PAS Annual Ownership Costs, Operating Costs, and Unit Costs Comparison Summary (1999).

	160-Acre Conventional Ponds	20, 2-Acre PAS Unit Farm
Annual ownership cost	$ 95,301	$114,181
Annual operating cost	418,325	418,617
Total Annual Cost	513,626	532,798
Total Annual Cost/Acre	3,669	13,319
Annual pounds harvested	700,000	909,840
Ownership cost/pound	0.136	0.125
Operating cost/pound	0.598	0.460
Total Cost/Pound	0.734	0.585
TOTAL REVENUE	$525,000	$681,630

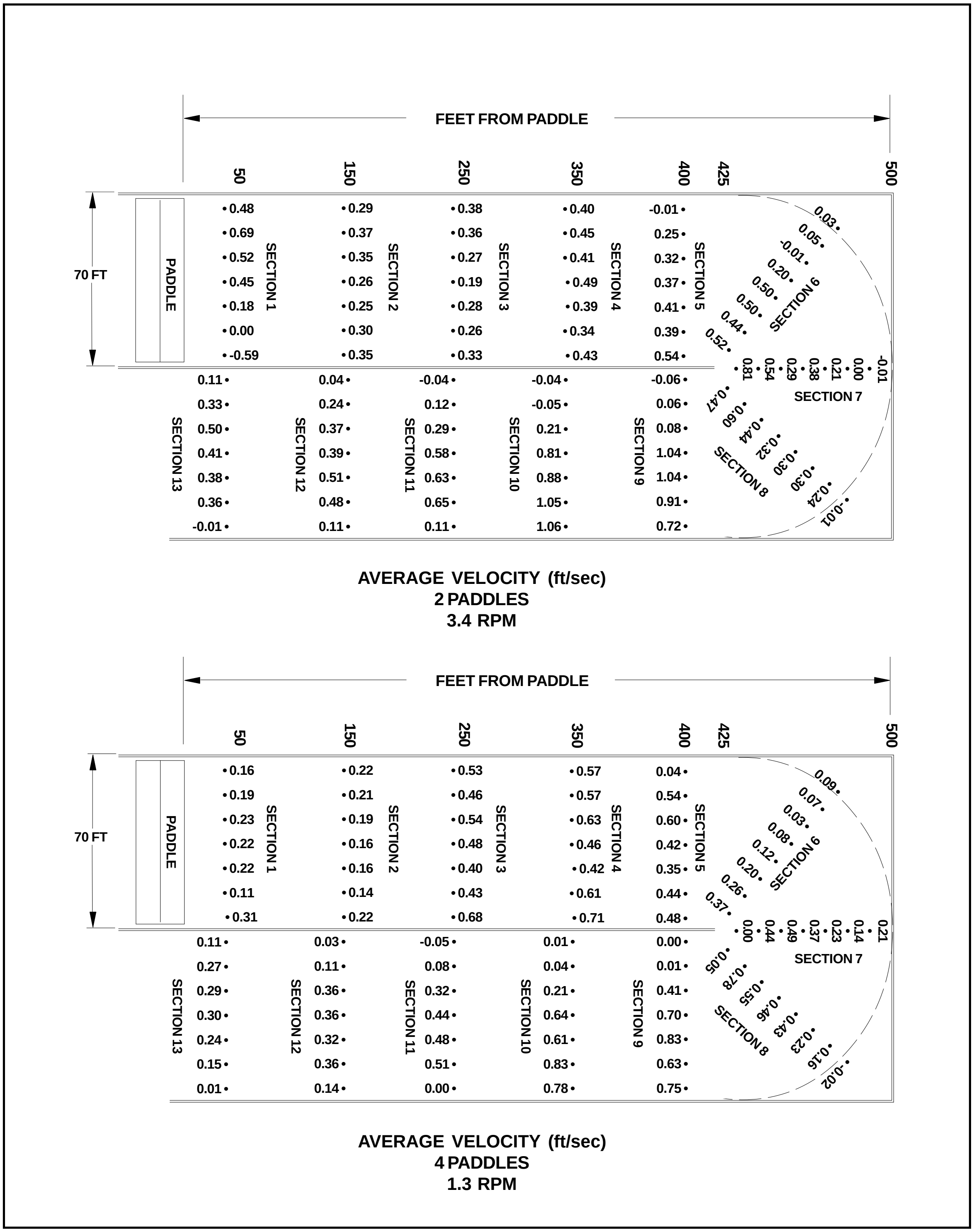

Figure 2. Velocity profiles in 2-acre PAS with 2 paddles and with 4 paddles.

<u>Results from the 2000 Season</u>
In May, the 2-acre PAS unit was stocked with 33,419 catfish fingerlings (2,050 pounds/acre) in size classes of 20, 65, and 88 g. In addition, 110 pounds/acre of tilapia breeding pairs were stocked at large in the algal basin (150 - 250 g males and 200 - 250 g females). The 1999 carryover fish (250 g each) were lost in spring 2000 in the 2-acre unit due to proliferative gill disease (PGD). Treatment of pond sediment with hydrated lime was observed to be effective in reducing the occurrence of PGD, although treatment was initiated too late to be effective.

The use of “breeding pairs” of tilapia alone in the 2-acre PAS produced marginal water quality results. By the third week of August, the phytoplankton community was completely dominated by blue-green algae. However, at the end of August, communities were undergoing a shift to green algal populations, an apparent result of increased filter-feeding activity of the expanding tilapia population.

In contrast, four 1/36-acre PAS units operating in August of 2,000 at 12,000 pounds/acre catfish carrying capacity, with 1,600 pounds/acre of native mussel in two units and 2,300 pounds/acre of silver carp in two units, exhibited a dominance of green algal populations. However, the mussels were not as effective as silver carp or tilapia at controlling blue-green algal populations and, as a result, the visual color difference between the mussel and silver carp unit was obvious (Figure 3). In August 2000 the 0.33-acre units shifted to green algal populations using tilapia breeding pairs.

Figure 3. Visual algal differences between mussel PAS unit (right) and silver carp PAS unit (left).

In Spring 2000, the net production for this season reached a 6-year average high in the six 0.33-acre units of 17,232 pounds/acre of catfish with 5,407 pounds/acre of tilapia. Average feeding rates reached 115 pounds/acre per day, with a maximum feed application of 260 pound/acre per day (Table 1). Because of excessive over-winter losses, the 2-acre prototype only produced 12,480 pounds/acre of catfish at the end of 2000.

Results from 2001 Season

In Spring 2001, the six 0.33-acre PAS units were stocked with an average of 2,931 carryover catfish (mean weight = 394 g), 3,484 large catfish fingerlings (mean weight = 71 g), and 2,092 small catfish fingerlings (mean weight = 26 g). The six 0.33-acre units were also stocked with 25 male tilapia (160 g) and 50 female tilapia (76 g). The 2-acre prototype PAS unit was stocked with 10,500 carryover catfish (318 g) along with 8,734 (132 g), 9,872 (114 g), and 11,159 (21 g) catfish fingerlings. The 2.0-acre system was also stocked with 450 breeding pairs of tilapia. Prophylactic treatments for control of early spring PGD in the winter carryover fish were conducted in winter/spring of 2000. The incidence of PGD was significantly reduced in the carryover fish in 2001. By the end of July of 2001, the 2-acre prototype system shifted to predominantly green algal population (Figure 4). Seasonal average net catfish production for 2001 averaged 16,735 pounds/acre with 2,375 pounds/acre of tilapia co-production at maximum feed application rates of 240 pounds/acre.

Summary of 3 Years of PAS Studies

Three years of catfish/tilapia co-culture in a single commercial scale 2-acre PAS unit and six 1/3-acre PAS units have demonstrated the capacity of the PAS technique for reduction of blue-green algal dominance within the culture systems.

From 1999 to 2001 annual catfish production ranged from 11,474 pounds/acre to 17,232 pounds/acre with a tilapia co-production ranging from 2,375 to 5,407 pounds/acre (Figure 5). Maximum feed application rates exceeded 250 pounds/acre per day with average application rates of 100-130 pounds/acre per day.

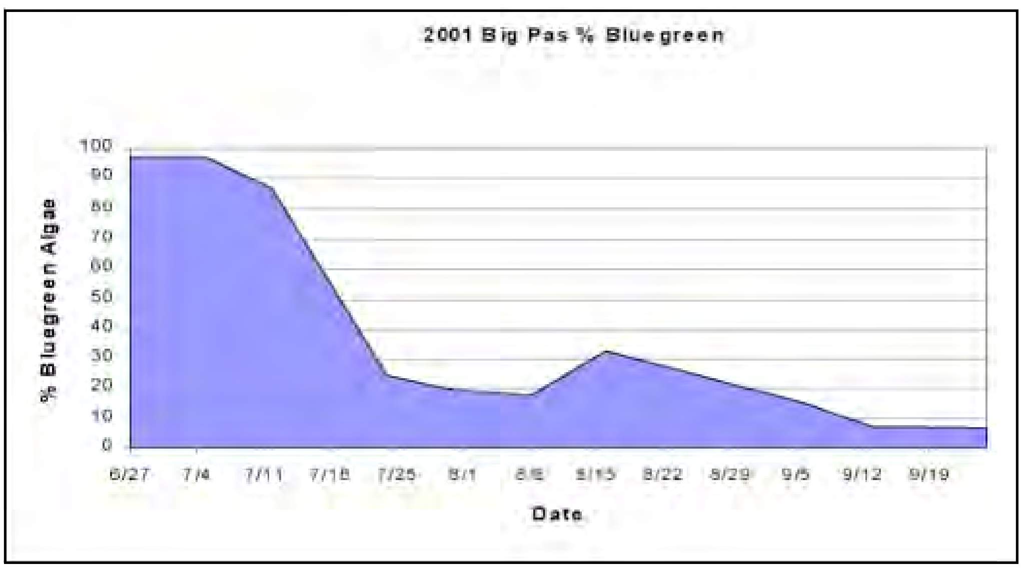

Figure 4. Blue-green algae occurrence in 2-acre PAS prototype in 2001.

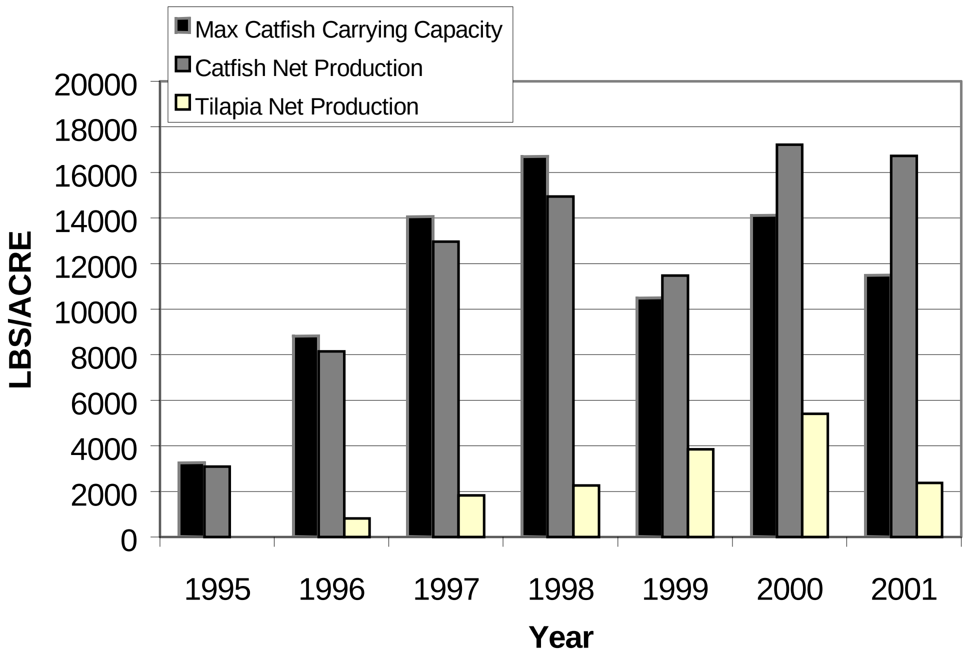

Figure 5. Six 1/3-acre PAS catfish production and maximum carrying capacities and tilapia production from 1995 to 2001.

Previous experimental trials (in 1997) had shown blue-green algal dominance could be eliminated from the PAS water column throughout the growing season by stocking the unit with large numbers of tilapia early in the season. However it was felt that this requirement may not be practical for most fish farmers. For this reason, all experimental PAS trials since 1998 have employed the technique of stocking with tilapia "breeding pairs" early in the season (typically, 150 adult females and 75 adult males/acre).The major advantage of this technique lies in the small number of tilapia needed in early spring. The disadvantage of this technique is in the overall reduction in system water quality control, particularly during mid-season. In 1997, full tilapia stocking resulted in system total ammonia-nitrogen (TAN) levels of 1-4 ppm at maximum feed application rates of 200 pounds/acre per day. As feed application rates were progressively increased (using the tilapia breeding pair stocking technique), system TAN ranged from 0.3-8 ppm (1998) to 1-12 ppm by 2001 season. Blue-green dominance is typically reduced to less than 30% of total algal population by the end of the season (with a reduction in associated off flavor). Fortunately, a harvest window of reduced blue-green occurrence is typically observed in July (at the time of the carryover fish harvest, Figure 6). This is the result of lower water temperatures and lower feed application rates at this time. As the season progresses, increased feed applications and increased water temperatures lead to a dominance by blue-green algae by the end of July to early August. As tilapia numbers and biomass expand at the end of August, blue-green numbers are again seen to decline (Figure 6).

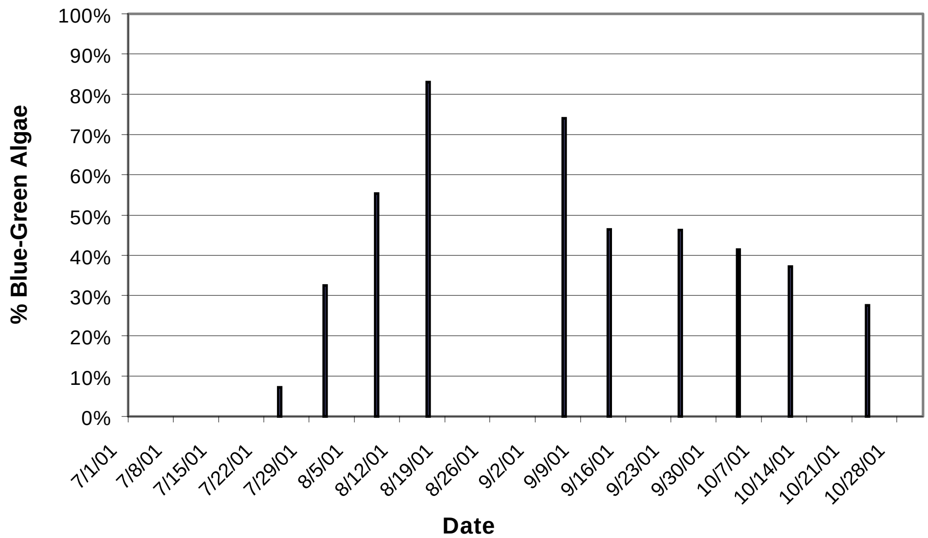

Figure 6. Typical blue-green algae abundance (as % of total) in PAS population in 2001 using tilapia "breeding pairs".

As of September 2002, the performance of the PAS units is typical of that observed in the previous three years; catfish carrying capacity has passed 10,000 pounds/acre and feed application rates exceed 250 pounds/acre per day. System pH has declined from a high of 10 early in May to typical values of 7.0-7.8 by September 10 as increased organic carbon addition and respiration rates increase CO_2 supply to the PAS water columns. The increase in tilapia numbers impacts the water quality of the system dramatically. From late July to early September 2002, system TAN levels drop from 5-8 ppm to 4-6 ppm (with very low free NH_3 at pH of 7.0-7.8). The driving force for the reduction in TAN is the much improved reduction in algal standing crop reflected by the increase in Secchi disk transparency from 6-8 cm to 12-16 cm being driven by the expanding tilapia numbers and biomass. In June 2002, seasonal blue-green algal dominance in the six 1/3-acre units peaked at 82% of total algal population; however, by September blue-green population were less than 1% of total. As of mid-September, the 2-acre unit still consisted of 41% blue-green (of total algal population).The 2-acre unit was typically observed to "lag" behind the 1/3-acre units in Secchi disk transparency and algal species control, suggesting that the larger PAS units may need more tilapia breeding pairs per acre than the small units to ensure adequate tilapia numbers to control

Results at a glance...

- *Early spring stocking of only 150-200 tilapia "breeding pairs" per acre into PAS units allows for a minimum cost control of late season blue-green algal dominance allowing for catfish harvest during a "window" of reduced fish off-flavor. This technique promotes acceptable PAS water quality limits supporting observed net catfish productions in 1999-2001 of 11,500 to 17,200 pounds /acre with a tilapia co-production of 2,400 to 5,400 pounds/ acre.*

WORK PLANNED

Much of the proposed research is completed; the remaining work as noted below is proceeding on schedule and no major changes in the work plan have occurred.

Auburn University. All pond and laboratory studies have been completed, but we still are analyzing data collected during the project and will prepare two additional manuscripts.

University of Georgia. Planktivorous fish have not yet been examined for digestive tract contents. Further publications will be developed when those data are collected. A follow-up study was begun to compare threadfin shad stocked together with fathead minnows in catfish ponds with copper sulfate application for control of blue-green algae.

Mississippi State University/USDA-ARS. A request for biopesticide classification/ registration of the proprietary compound currently undergoing patent application for use as a selective algicide in catfish aquaculture will be made to the U.S. Environmental Protection Agency.

North Carolina State University. Additional studies of pond water circulation using gypsum blocks are planned as described in the proposed project objectives. A comprehensive analysis of the phytoplankton composition and nutrient concentrations of the ponds in the current study will be finished by the end of this year.

IMPACTS

Selected plant and algae extracts have shown strong anti-cyanobacterial activity. The findings indicate that natural products (small biologically active organic compounds) produced by organisms that live and compete in cyanobacteria-rich environments are a valuable source of new cyanobacterium-selective algicides and may be of use in the control of blue-green algae in aquaculture ponds. The occurrence of both noxious and toxic blue-green algal blooms in fish aquaculture is a worldwide problem. The idea that chemicals in trees (and marine algae) may have the ability to control blue-green algal blooms is intriguing, especially in extremely poor regions (such as developing countries) where one could envision harvesting these natural materials for use in aquaculture ponds. A rather unexpected outcome of this research is the discovery of several new substances with herbicidal activity. As a result of natural products screening efforts, extracts from several plants and marine organisms were found to be selectively toxic only to the green alga control (*S. capricornutum*) and to specific types of higher plants. Some of the chemical constituents of these anti-algal/herbicidal extracts may hold promise as new natural product-based means of agricultural weed control.

A proprietary natural-based compound derived from certain plants is undergoing patent application for use as a selective algicide in catfish aquaculture. This proprietary compound may eventually be used as an alternative to the synthetic algicidal compounds (e.g., diuron and copper sulfate) that catfish producers are currently using to help prevent musty off-flavor in farm-raised catfish.

Results of studies of baitfish ponds have increased our understanding of water quality and pond bottom sediments in this important sector of aquaculture in the southeast. Despite a history of long-term use of granular fertilizer in study ponds, sediment-bound phosphorus did not appear to exert a discernible effect on water quality under conditions of commercial production. Discovery of high soil sulfate sulfur levels in pond bottom samples contributed to affected baitfish farmers changing pond management practices to reduce chances of hydrogen sulfide problems.

Research at Auburn University showed that EDTA is an excellent chelating agent for iron (and presumably other metals) for use in pond aquaculture. Application of potassium chloride, legume hay, and iron and other trace elements to ponds do not appear to be useful for controlling blue-green algae in ponds. Sodium nitrate is a good nitrogen fertilizer for ponds; it has been shown to be environmentally superior to ammonium-based nitrogen fertilizers for use in aquaculture and sportfish ponds. Nitrate is not acid-forming, does not exert an oxygen demand, and its presence in effluents is less objectionable than ammonia. Pond fertilization work also revealed that nitrogen fertilization was not needed in bait minnow ponds at Auburn University, but older (25 years or more) sunfish ponds may benefit from nitrogen fertilization. All ponds needed phosphorus fertilization. Sediment removal seems to be the only feasible way of improving soil quality in old bait minnow ponds.

Research at Mississippi State University showed that nutrient manipulation techniques consisting of simultaneous adjustment of N:P ratios and addition of chelated iron do not affect phytoplankton community structure. Results from mixing studies suggest that some threshold level of turbulent mixing is necessary to overcome light limitation of phytoplankton production and to cause a shift of phytoplankton community composition from dominance by cyanobacteria. Application of turbulent mixing should attempt to develop a uniform flow field to avoid areas of concentrated turbulence that can suspend pond soils.

Research conducted at NCSU demonstrated no benefit from enhanced water circulation in hybrid striped bass ponds. Water circulation provided no improvement in water quality or fish production and did not affect the phytoplankton composition of the pond. Manipulation of micro-nutrient and carbon availability (through additions to the pond water of chelated iron, mineral premix, and organic matter) did not reduce blue-green algae abundance or change the phytoplankton community composition in hybrid striped bass ponds.

Shad stocking is being considered by catfish farmers in Georgia who had off-flavor catfish and who could not utilize herbicides for control of blue-green algae. Shad stocking started in the winter of 2000 and spring of 2001 in Georgia. Shad stocking is limited by the availability of threadfin shad. Information from this study has helped with the fathead minnow/channel catfish stocking program for proliferative gill disease control. Behavior of fathead minnows in channel catfish ponds indicated a need to encourage spawning by adding spawning substrate or to restock the fathead minnows at regular intervals in order to maintain at least 1,500 minnows/acre.

The Partitioned Aquaculture System (PAS) design and associated fish culture and management techniques provide a method to quadruple current fish production from a system which can eliminate blue-green algal dominance sufficiently to provide a “window of time” for fish harvest during a period of reduced fish off-flavor occurrence. The PAS also permits the elimination of nitrogen and phosphorus discharges from aquaculture production systems, which currently pose a potential eutrophication threat to surface and groundwater supplies. Economic projections suggest that PAS catfish production costs are 15 to 17 cents/pounds lower than conventional pond production costs providing strong motivation for widespread adaptation of PAS fish culture as a better management practice for the aquaculture industry.

PUBLICATIONS, MANUSCRIPTS, OR PAPERS PRESENTED

Publications in Print

Bett, K. L., D. A. Ingram, C. C. Grimm, B. T. Vinyard, and C. P. Dionigi. 2000. Alteration of the human sensory perception of the muddy/earthy odorant 2-methylisoborneol in channel catfish *(Ictalurus punctatus*) fillet tissues by addition of seasonings. Journal of Sensory Studies 15:459-472.

Brune, D. E., J. A. Collier, and T. E. Schwedler. 2001. Partitioned Aquaculture System. United States Patent No. 6,192,833.

Brune, D. E., S. Reed, G. Schwartz, J. A. Collier, A. G. Eversole, and T. E. Schwedler. 2001. High Rate Algal Systems for Aquaculture. Proceedings of the Aquacultural Engineering Society Issues Forum, Shepardstown, WV.

Burtle, G. J., E. L. Styer, and G. W. Lewis. 2000. Control of blue-green algae with planktivorous fish. University of Georgia, College of Agriculture and Environmental Science, Department of Animal and Dairy Science. Annual Report, pp. 7-9.

Burtle, G. J., G.W. Lewis, M. Fowler, and T. Cummings. 2001. Establishing a catfish off-flavor control program in Georgia. Journal of Animal Science 79 (Suppl. 1):219.

Drapcho, C. M. and D. E. Brune. 2000. Modeling of oxygen dynamics in the partitioned aquaculture system. Aquacultural Engineering 21:151-162.

Goode, T. R. 2002. The Partitioned Aquaculture System: A comparative economic analysis with traditional catfish technology and risk analysis for investment and adoption of technology. Ph.D. dissertation, Clemson University, 150 pp.

Grimm C., S. Lloyd, P. Zimba, and M. Palmer. 1999. Microwave desorption - solid phase microextraction gas chromatographic analysis of geosmin and 2-methylisoborneol in catfish. American Laboratory 32(3): 40-48.

Grimm, C., S. Lloyd, R. Batista, and P. Zimba. 2000. Using MD/SPME/GC/MS for analyzing fish tissue. Journal of Chromatographic Science 38:289-295.

Grimm, C., S. W. Lloyd, and P. Zimba. 2000. Instrumental determination of off-flavors in farm-raised catfish. Proceedings of the Catfish Processors Workshop, Starkville, MS.

Gross, A., C. E. Boyd, and C. W. Wood. 2000. Nitrogen transformations and balance in channel catfish ponds. Aquacultural Engineering 24:1-14.

Miller, B. 1999. Effects of three water management practices on water quality and algal populations in channel catfish production mesocosms. Master's thesis, Louisiana State University.

Mueller, C. R. 2001. Effects of filter feeders on the phytoplankton community of the Partitioned Aquaculture System. Master's thesis, Clemson University.

Nagle, D. G. and V. J. Paul. 1999. Production of secondary metabolites by filamentous tropical marine cyanobacteria: Ecological functions of the compounds. Journal of Phycology 35:1412-1421.

Phillips, M. J., C. E. Boyd, and P. Edwards. 2001. Systems approach to aquaculture management, pp. 239-247. In: R. P. Subasinghe, P. Bueno, M. J. Phillips, C. Hough, S. E. McGladdery and J. R. Arthur (editors), Aquaculture in the Third Millennium. Technical Proceedings of the Conference on Aquaculture in the Third Millennium, Bangkok, Thailand, 20-25 February 2000. NACA, Bangkok, Thailand and FAO, Rome, Italy.

Reed, S. M. 2001. Development of a methodology to determine algal growth kinetics and total water column photosynthesis in the Partitioned Aquaculture System. MS Thesis, Clemson University, 91 pp.

Schrader, K. K., F. E. Dayan, S N. Allen, M. Q. de Regt, C. S. Tucker, and R.N. Paul, Jr. 2000. 9,10-anthraquinone reduces the photosynthetic efficiency of *Oscillatoria perornata* and modifies cellular inclusions. International Journal of Plant Sciences 161:265-270.

Schrader, K. K., M. D. Harries, M. Q. de Regt, P. R. Tidwell, C. S. Tucker, and S. O. Duke. 2000. Natural compounds discovered to be selectively toxic towards the musty-odor cyanobacterium *Oscillatoria perornata*. Proceedings of Pre-Congress Internet Conference of the 11th World Congress of Food Science and Technology, pp. 399-401.

Schrader, K. K., and M. D. Harries. 2001. Compounds with selective toxicity towards the noxious, musty-odor cyanobacterium *Oscillatoria perornata*. Bulletin of Environmental Contamination and Toxicology 66:801-807.

Schrader, K. K., C. S. Tucker, M. Q. de Regt, and S. K. Kingsbury. 2000. Evaluation of limnocorrals for studying the effects of phytotoxic compounds on plankton and water chemistry in aquaculture ponds. Journal of the World Aquaculture Society 31:403-415.

Schrader, K. K., D. G. Nagle, and D. E. Wedge. 2002. Algal and cyanobacterial metabolites as agents for pest management. *In* R. K. Upadhyay, editor. Advances in Microbial Toxin Research. Kluwer Academic/ Plenum Press, London, pp. 171-195.

Schwedler, T. E., J. A. Collier, D. E. Brune, A. G. Eversole, and M. Hammig. 1999. The Partitioned Aquaculture System. *In* Technology for the Twenty-First Century, College of Agriculture, Forestry, and Life Sciences, Clemson University.

Starkey, R. W., A. G. Eversole, and D. E. Brune. 2000. Growth and survival of juvenile and adult freshwater mussels in the Partitioned Aquaculture System. Proceedings of the Conservation, Captive Care, and Propagation of Freshwater Mussel Symposium, pp.109-114.

Stuart, K. R. 2000. Algal filtration by the freshwater mussel, *Elliptio complanata*. Master's Thesis, Clemson University, Clemson, SC.

Stuart, K. R., A. G. Eversole, and D. E. Brune. 2000a. Effect of flow rate and temperature on algal uptake by freshwater mussels. Freshwater Mollusk Conservation Society Proceedings, pp. 219-224.

Stuart, K. R., A. G. Eversole, and D. E. Brune. 2000b. Filtration of green and cyanobacteria algae by freshwater mussels in the Partitioned Aquaculture System. Journal of the World Aquaculture Society 32:105-111.

Tepe, Y. and C. E. Boyd. 2001. A sodium nitrate-based, water-soluble, granular fertilizer for sportfish ponds. North American Journal of Aquaculture 63:328-332.

Thunjai, T. and C. E. Boyd. 2001. Pond soil pH measurement. Journal of the World Aquaculture Society 32:141-152.

Turker, H., A. G. Eversole, and D. E. Brune. 2002. Partitioned Aquaculture Systems: Tilapia filter green algae and cyanobacteria. Advocate 5(1): 68-69.

Turker, H. 2002. Filtration kinetics of Nile tilapia, *Oreochromis niloticus*, in the Partitioned Aquaculture System. Ph.D. dissertation, Clemson University, 72pp.

Zimba, P., M. A. Chatham, C. S. Tucker, E. L. Torrans, and C. C. Grimm. 2000. Field assessment of diuron use in catfish production systems. Delta Business Journal 2(12):63.

Zimba, P., C. C. Grimm, C. P. Dionigi, and C. Weirich. 2001. Phytoplankton community structure and off-flavor levels in Louisiana catfish ponds. Journal of the World Aquaculture Society 32(1):96-104.

Manuscripts

Boyd, C. E. In press. Off-flavor in pond-cultured marine shrimp. In: A. M. Rimando and K. K. Schrader (editors). Off-Flavors in Aquaculture, American Chemical Society, Washington, D.C.

Brune, D. E., G. Schwartz, J. A. Collier, A. G. Eversole, and T. E. Schwedler. In press. Partitioned Aquaculture Systems, Chapter 20 in: Biology and Culture of Channel Catfish, C. Tucker and J. Hargreaves, editors.

Goode, T., M. Hammig, and D. E. Brune. In press. Profitability comparison of the Partitioned Aquaculture System with a traditional catfish farm. Aquaculture Economics and Management.

Grimm, C., S.W. Lloyd, M.A. Godshall, and T. J. Braggins. In press. Screening for sensory quality in foods using solid phase micro-extraction tandem mass spectrometry. ACS Symposium Series, Fereidoon Shahidi, Editor. ACS Publications, Washington, D.C.

Grimm, C., P. Zimba. 2002. Applications of an instrumental method for the analysis of off-flavors in fresh water aquaculture. For publication in ACS Symposium series, Off-flavors in Acquaculture, Rimando, A., Schrader, K. (Eds.), Accepted July 2002.

Hargreaves, J. A. In press. Eco-physiology of cyanobacteria: implications for off-flavor management in pond aquaculture. In: Off-flavors in Aquaculture. American Chemical Society.

Lo Giudice, G.M. In preparation. Threadfin shad effects on water quality, phytoplankton, and fish production in channel catfish ponds. Master's thesis. Auburn University, Auburn, AL.

Nagle, D. G. and V. J. Paul. In preparation. Production of secondary metabolites by filamentous tropical marine cyanobacteria: ecological functions of the compounds.

Schrader, K.K., N.P.D. Nanayakkara, A.M. Rimando, M. Ganzera, B.T. Schaneberg, and C.S. Tucker. In preparation. Novel quinone derivatives are selective algicides against the musty-odor cyanobacterium *Oscillatoria perornata*.

Tepe, Y. and C. E. Boyd. In press. Nitrogen fertilization of golden shiner ponds. North American Journal of Aquaculture 64.

Tepe, Y. and C. E. Boyd. In press. Sediment quality in Arkansas bait minnow ponds. Journal of the World Aquaculture Society 32.

Tucker, C. S. and J. A. Hargreaves. In press. Copper sulfate to manage cyanobacterial off-flavors in pond-raised channel catfish. In: Off-flavors in Aquaculture. American Chemical Society.

Turker, H., A. G. Eversole, and D. E. Brune. In press. Filtration of green and cyanobacteria by Nile tilapia, *Orechromis niloticus*, in the Partitioned Aquaculture System. Aquaculture.

Turker, H., A. G. Eversole, and D. E. Brune. In press. Effects of temperature and phytoplankton concentration on Nile tilapia, *Orechromis niloticus*, filtration rate. Aquaculture Research.

Turker, H., A.G. Eversole, and D. E. Brune. In press. Comparative Nile tilapia and silver carp filtration rates of Partitioned Aquaculture System phytoplankton. Aquaculture.

Zimba, P., M. A. Chatham, C. C. Grimm. 2002. A synoptic survey of musty/muddy odor metabolites and microcystin toxin occurrence and concentration in southeastern USA channel catfish. Accepted by Aquaculture, July, 2002.

Presentations

Bodary, M. and N. Stone. 2000. Effects of soil-incorporated sodium nitrate on phosphorus release from baitfish pond soils. (Poster presentation). Aquaculture Field Day, University of Arkansas at Pine Bluff, Pine Bluff, AR.

Bodary, M. and N. Stone. 2001. Effects of soil-incorporated sodium nitrate on phosphorus release from baitfish pond bottom soils. Annual Research Forum 2001, University of Arkansas at Pine Bluff, Pine Bluff, AR.

Bodary, M. and N. Stone, 2002. Effects of soil-incorporated sodium nitrate on phosphorus release from baitfish pond soils. Arkansas Aquaculture 2002, Little Rock, AR, 22-23 March. (Poster presentation).

Brune, D. E., J. A. Collier, T. E. Schwedler, A. G. Eversole, and M.D. Hammig. 1999. Water reuse technology in freshwater ponds: Partitioned aquaculture. World Aquaculture Society Annual Meeting, Sydney, Australia.

Brune, D. E., J. A. Collier, T. E. Schwedler, and A. G. Eversole. 1999. Designed ecosystems for aquaculture: The Clemson Partitioned Aquaculture System. ASAE 1999 Annual Meeting, Toronto, Ontario.

Brune, D. E. 1999. Partitioned Aquaculture Systems. Aquaculture Engineering Society Issues Forum, Raleigh, NC.

Brune, D. E., J. A. Collier, T. E. Schwedler, J. L. Meade, G. Schwartz, S. Davis, A. G. Eversole, and M. D. Hammig. 1999. Partitioning ponds to increase fish yield. North Carolina Aquaculture Association Meeting, New Bern, NC.
Brune, D. E., J. A. Collier, T. E. Schwedler, and A. G. Eversole. 1999. Water reuse systems. Workshop presented at the North Carolina Aquaculture Development Conference, New Bern, NC.
Brune, D. E., G. Schwartz, J. A. Collier, T. E. Schwedler, A. G. Eversole, and T. Goode. 2000. Designing a commercial scale partitioned aquaculture system. Catfish Farmers of American Research Symposium. Albuquerque, NM.
Brune, D. E., G. Schwartz, J. A. Collier, A. G. Eversole, and T. E. Schwedler. 2000. Designing Partitioned Aquaculture Systems for marine shrimp culture. World Aquaculture Society Annual Meeting, Nice, France.
Brune, D. E., S. Reed, G. Schwartz, J. A. Collier, A. G. Eversole, and T. E. Schwedler. 2002. High rate algal systems for aquaculture. Algal biotechnology: Ninth International Congress on Applied Algology, Almeria, Spain.
Brune, D. E., S. Reed, and G. Schwartz. 2002. Bacterial and algal processes in aquaculture. Presentation at Aquaculture America, San Diego, CA.
Burtle, G. J. 2000. Off-flavor. The University of Georgia Cooperative Extension Service. Extension presentation. Louisville, GA.
Burtle, G.J., E.L. Styer, G.W. Lewis, T. Ingram, and D. Blakey. 2000. Effects of threadfin shad and fathead minnows on blue green algae in channel catfish ponds. Southern Division, American Fisheries Society Mid-Year Meeting. Savannah, GA.
Grimm, C. and S. Lloyd. 2000. Determination of off-flavors in farm-raised catfish. Aquaculture America 2000, New Orleans, LA.
Grimm, C., R. Batista, M.A. Chatham, C.P. Dionigi, S. Brashear, and P.V. Zimba. 2001. Determining off-flavor in catfish by analysis of the liver. World Aquaculture Society, Orlando, FL.
Grimm, C., S. Lloyd, and P. Zimba. 2000. Instrumental determination of off-flavors in farm raised catfish. Proceedings of the Catfish Processors Workshop, Starkville, MS.
Grimm, C., S. Lloyd, and P. Zimba. 2001. A one-time survey of off-flavor in catfish ponds in MS, LA, AR, and AL. Proceedings of the Catfish Processors Workshop. Starkville, MS.
Grimm, C., S. Lloyd, and P. Zimba. 2001. Instrumental analysis of off-flavors in farm raised catfish, Proceedings of the Catfish Processors Workshop. Starkville, MS.
Grimm, C., S. Lloyd, and P. Zimba. 2002. Instrumental analysis of off-flavors in aquaculture. Book of Abstracts paper # 76. The 223rd ACS National Meeting and Exposition. Orlando, FL.
Holmes, B.D., C.M. Foran, D. Schlenk, K. Schrader, and D. Nanayakkara. 2000. Toxicological evaluation of a cyanobacteria-specific biocide. Society of Environmental Toxicology and Chemistry, 21st Annual Meeting, Nashville, TN.
Lo Giudice, G.M., D.R. Bayne, and T.J. Popma. 2000. Threadfin shad effects on water quality, phytoplankton, and fish production in channel catfish ponds. Mid-South Aquatic Plant Management Society Annual Meeting.
Lo Giudice, G.M., T.J. Popma, and D.R. Bayne. 2000.Threadfin shad effects on water quality, phytoplankton, and fish production in channel catfish ponds. Alabama Fisheries Association Annual Meeting.
Massingill, M., and D. E. Brune. 2002. Partitioned Aquaculture Systems. Presentation at Aquaculture America, San Diego, CA.
McNulty, E., and N. Stone. 2000. Seasonal water quality in golden shiner production ponds. (Poster presentation). Aquaculture Field Day, University of Arkansas at Pine Bluff, Pine Bluff, AR.
McNulty, E., and N. Stone. 2001. Seasonal variation in water quality in commercial golden shiner *Notemigonus crysoleucas* ponds. (Poster presentation). World Aquaculture Society Annual Meeting, Orlando, FL.
Mueller, C.M., A. G. Eversole, and D. E. Brune. 2001. The effects of filter feeders on the algal community in the PAS. Presented at the World Aquaculture Society.

Nagle, D. G., D. E. Wedge, K. K. Schrader, I. Rajbhandari, and C.J.G. Duncan. 1999. Algae and aquatic plants as sources of new agrochemicals. American Society of Pharmacognosy Interim Meeting, Tunica, MS.

Nagle, D.G., D. E. Wedge, K. K. Schrader, and I. Rajbhandari. 1999. Algae and aquatic plants as sources of new agrochemicals. First Asia-Pacific Conference on Chemical Ecology, Shanghai, China.

Rajbhandari, I., and D.G. Nagle. 2000. Aquatic and wetland plants as sources of new agrochemicals. The University of Mississippi Field Station Conference on Sustainability of Wetlands and Water Resources, Oxford, MS.

Reed, S. M., D. E. Brune, J. A. Collier, G. Schwartz, and T. E. Schwedler. 2002. Development of a technique for *in-situ* determination of algal growth kinetics in the Partitioned Aquaculture System. Presentation at Aquaculture America, San Diego, CA.

Schrader, K. K., C. S. Tucker, M. Q. de Regt, and S. K. Kingsbury. 2000. Evaluation of limnocorrals for studying the effects of phytotoxic compounds on plankton and water chemistry in aquaculture ponds. Aquaculture America 2000, New Orleans, LA.

Schrader, K. K., C. S. Tucker, M. Q. de Regt, and S. K. Kingsbury. 2000. Limnocorrals as an alternative to full-scale pond studies to monitor the effects of phytotoxic compounds on plankton and water quality in catfish aquaculture ponds. 2000 Catfish Farmers of America Research Symposium, Albuquerque, NM.

Schrader, K. K. 2001. Natural compounds as selective algicides in aquaculture. British Mycological Society International Symposium, University of Wales, Swansea, United Kingdom.

Schrader, K. K., A.M. Rimando, N.P.D. Nanayakkara, and C. S. Tucker. 2001. A new selective algicide with potential use in catfish aquaculture. Annual Meeting of the American Society for Microbiology, Orlando, FL.

Schrader, K. K., A. M. Rimando, N. P. D. Nanayakkara, and C. S. Tucker. 2001. A new selective algicide with potential use in catfish aquaculture. Mississippi Catfish Processor's Conference, Mississippi State University, MS.

Schrader, K. K. Natural algicides for the control of cyanobacteria-related off-flavors in catfish aquaculture. 2002. American Chemical Society 223rd National Meeting, Orlando, FL.

Seo, J., and C. E. Boyd. 2001. Water quality improvement with physical and chemical management practices in channel catfish ponds. World Aquaculture Society Annual Meeting, Orlando, FL.

Slattery, M., and D. G. Nagle. 2000. Chemical ecology and natural products from wetlands: Emerging perspectives. The University of Mississippi Field Station Conference on Sustainability of Wetlands and Water Resources, Oxford, MS.

Starkey, R. W., A. G. Eversole, D. E. Brune, and K. R. Stuart. 2000. Channel catfish *Ictalurus punctatus* production in the PAS. Aquaculture America 2000, New Orleans, LA.

Starkey, R. W., A. G. Eversole, and D. E. Brune. 2000. Uptake of green and blue-green algae by freshwater mussels. Aquaculture America 2000, New Orleans, LA.

Stuart, K. R., A. G. Eversole, and D. E. Brune. 2000. Algal uptake rate of freshwater mussels. Aquaculture America 2000, New Orleans, LA.

Turker, H., A. G. Eversole, and D. E. Brune. 2000. Effect of flow rate and temperature on the algal uptake by Nile tilapia *Oreochromis niloticus*. Aquaculture America 2000, New Orleans, LA.

Turker, H., A. G. Eversole, and D. E. Brune. 2001. Algal uptake rates of Nile tilapia in green and blue-green algal dominated PAS water. Presented at the World Aquaculture Society.

Turker, H., A. G. Eversole, and D. E. Brune. 2002. Effect of tilapia size on the phytoplankton filtration rate in the Partitioned Aquaculture System. Presented at the World Aquaculture Society, San Diego, CA.

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MANAGEMENT OF AQUACULTURAL EFFLUENTS FROM PONDS

Reporting Period
April 1, 1999 to August 31, 2002

Funding Level	Year 1	$227,597
	Year 2	222,289
	Year 3	150,740
	Total	$600,626

Participants	Mississippi State University (Lead Institution)	John Hargreaves, Thomas Cathcart
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PROJECT OBJECTIVES

1. Develop additional information to characterize the components of aquaculture effluents that represent the greatest potential risk of deleterious environmental impact (e.g. suspended solids, total phosphorus).

2. Evaluate the impact of aquaculture pond effluent discharge on receiving stream water quality.

3. Evaluate a range of water management techniques appropriate for ponds as a means of reducing the quantity and improving the quality of discharged water.

4. Develop and evaluate models for predicting risks to the environment and the costs and benefits of implementing Best Management Practices (BMPs).

5. Based upon existing information, supplemented by project findings, develop a comprehensive

set of BMPs that can be implemented to reduce the environmental impacts of pond aquaculture in general. Develop supplemental BMPs particular to the various pond cultured species in the region that will complement the generic, pond-system BMPs. These BMPs would include best culture practices, waste handling and management, and water quality management and reuse.

6. Convene a series of workshops to educate and inform producers and regulators on the characteristics and management of aquaculture effluents from ponds, including BMPs, based on the best available information and that minimize environmental impact and satisfy regulatory compliance requirements.

ANTICIPATED BENEFITS

Results of this project will provide simple management alternatives to reduce the volume and improve the quality of effluents, possibilities for water reuse, and inexpensive treatment methods based on sedimentation. This project will provide beneficial effluent management practices to producers of channel catfish, striped bass, baitfish, crawfish, and marine shrimp. Development of practical, environmentally sound management practices that minimize the effect of pond effluents on receiving streams will reduce the environmental impact and contribute to the sustainability of the regional aquaculture industry. Information generated by this project can be used by regulators and permit writers to provide effective and coherent regulation of aquaculture effluents.

PROGRESS AND PRINCIPAL ACCOMPLISHMENTS

Objective 1. *Develop additional information to characterize the components of aquaculture effluents that represent the greatest potential risk of deleterious environmental impact (e.g. suspended solids, total phosphorus).*

Auburn University. Studies indicated that about 53% of total suspended solids, total phosphorus, total nitrogen, and biochemical oxygen demand were associated with particles less than 5 micrometers in diameter. Studies suggest that a water retention time in settling basins of 8 hours will improve effluent quality significantly and a settling time of 2 to 4 hours is sufficient to reduce total suspended solids in effluents to 75 to 90% of original concentrations. Solids removal is associated with declines in the mineral fraction with little change in organic solids concentrations in effluents. Application of aluminum sulfate at 25 to 50 ppm did not improve the efficiency of solids removal in initial trials.

Estimates of runoff from watersheds suggest that settling basins to treat storm runoff from watershed-type catfish ponds require volumes of 30 to 40% of pond volume in order to provide a retention time of 8 hours. Thus, because of the large volume required, settling basins do not appear to be feasible for treating storm runoff. Settling basins for treating intentional discharge from partial drawdown or complete draining would need to be only 10 to 20% of the volume of the largest pond on the farm because the quality of catfish pond effluents is relatively high except for the final 20 to 25% of water released when ponds are drained completely.

Most existing catfish farms in Alabama extend to property lines or streams, and there seldom is space for installing settling basins. However, settling basins could be considered an essential component in the design of new farms. On farms without settling basins, it is possible to use the pond being harvested as its own settling basin. Water levels should be lowered to 20% to 25% of full volume, drains should be closed and fish harvested by seining. Once fish have been removed, the water should be allowed to stand until most of the suspended solids have settled. This will normally take only 2 or 3 days. The water should then be released slowly to prevent resuspension of solids. It is recommended that the valve only be opened to 25% of its maximum capacity during final draining. The valve should be closed at the beginning of rainfall and not reopened until water has cleared.

Results at a glance...

- ✰ *Treatment of the final 20% of water discharged when ponds are drained can be accomplished with sedimentation basins designed with a hydraulic retention time of 8 hours. However, a settling time of 2 to 4 hours is sufficient to reduce total suspended solids in effluents to 75 to 90% of original concentrations.*

Louisiana State University. Water budgets were calculated over three production seasons in experimental crawfish ponds. The average annual water requirement was 7.5 feet. More than 71% of intentional water inflow over the three production seasons replaced losses from evaporation, evapotranspiration by rice planted as crawfish forage, and seepage, with intentional and unintentional effluent release accounting for the remainder. Precipitation was a significant water inflow in these shallow-water ecosystems, contributing nearly 40% of the total over the three production seasons. Intentional water discharge during summer drawdown, an established management practice, was consistent over the three seasons, averaging 10.8 inches. Unintentional discharge was highly correlated with the magnitude of precipitation events. Precipitation from October to June in year one (25.1 inches) and year three (27.2 inches) resulted in very low unscheduled water release (3.6 and 2.5 inches, respectively). Unintentional water release in the second production season, representative of normal precipitation patterns in southern Louisiana (53.6 inches) was 17.7 inches (24% of annual water budget). Eighty-nine percent of TSS released from 29 experimental crawfish ponds during summer drawdown occurred with the first 5% and last 20% of water released. Levels of TSS in effluent released from the experimental ponds were reduced by 50 to 80% after passing through highly vegetated drainage canals (filter strips) over a distance of about 900 feet.

A water budget model was developed to determine seasonal effluent quantity and mass loading for solids and nutrients representative of crawfish production systems in south-central and southwest Louisiana. Precipitation, evaporation, evapotranspiration, and infiltration data for southern Louisiana was obtained from the National Climatic Data Center and published research. Model output closely agreed with annual water budgets calculated from the experimental crawfish ponds, with an average deviation of 14% (range: 4 to 25%). Unintentional and intentional effluent discharge and seasonal mass loading for TSS, TP, TN, and $CBOD_5$ are being determined under various simulation scenarios which include type of crawfish production system (permanent, rice-crawfish double-cropping, and rice-crawfish rotational system), annual precipitation (average, wet, and dry years), added pond storage capacity (0, 2, 4 and 6 inches), and intentional flushing to improve water quality (1, 2, 3 exchanges per year). Most water additions from pumping is to replace losses from evaporation, evapotranspiration, and seepage (usually 60% or higher). Unintentional discharge, largely from precipitation, usually ranges from 13% in an average year to as much as 30% in a high rainfall year, with most of the discharge occurring in winter. Over 70% of TSS mass loading occurs during scheduled summer drawdown in average precipitation years. Seasonal mass loading for TP, TN, and BOD_5 are being calculated.

Mississippi State University. In commercial channel catfish ponds dominated by a dense bloom of the blue-green alga *Oscillatoria agardhii*, about 51% of total suspended solids had a diameter of less than 5 micrometers. Similar results were obtained from fractionation of solids in water collected from ponds dominated by inorganic turbidity (55% of the total suspended solids were less than 5 micrometers). Treatment of water collected from a pond dominated by a dense bloom of *O. agardhii* with alum between 0 and 50 ppm resulted in a solids reduction rate of 1.11 grams of solids per gram of alum. Size fractionation of pond water following alum treatment indicated that the proportional removal of solids less than 5 micrometers was greatest, although the greatest absolute solids reduction rate occurred in whole (not fractionated) pond water. The proportion of solids in the smallest size fractions increased with alum dose, suggesting that larger solids were selectively settled by alum treatment.

North Carolina State University. Fractionation of solids in overflow water from hybrid striped bass ponds shows that approximately 95% of total solids and 65% of total suspended solids are less than 5 micrometers in diameter. More than 80% of biochemical oxygen demand, total phosphorus and total nitrogen in pond water is associated with particles less than 5 micrometers. More than 90% of the solids in the pond water overflow are dissolved and about 25% of total solids are volatile. Suspended solids, which account for 10% of total solids, are approximately 63% volatile, with solids in the smaller particle fractions more volatile than in the larger fractions. The amount of settleable solids in hybrid striped bass pond water overflow is negligible, suggesting that sedimentation alone, without the use of chemical amendments to coagulate and precipitate solids, would not be an effective treatment of this fraction of pond water.

Effluents from the initial and final stages of pond draining were collected and characterized during pond harvest. Total suspended solids were 40% higher in the final 10% of water drained from the ponds compared to the first 10%. This increase in total suspended solids was primarily from small particles of the mineral fraction of the pond sediment. Where almost all of the suspended solids in the first 10% of water drained were volatile, only 60% of the suspended solids in the final water were volatile. Because total suspended solids account for only approximately 10% of total solids in these waters, the concentration of total solids was only slightly higher (less than 8%) in effluent from the final stages of pond draining than in the initial stage. Concentrations of total phosphorus and total nitrogen in the effluent did not increase significantly from the beginning of pond draining to the end.

University of Arkansas at Pine Bluff. A field study characterized suspended solids and 5-day biochemical oxygen demand (BOD_5) in baitfish pond effluents by serial fractionation, and evaluated exiting drainage ditches as possible solids settling systems. Effluents from a total of ten ponds on five farms were sampled between

9 December 2000 and 3 June 2001. Total suspended solids (TSS) concentration at the point of discharge averaged 36 ppm during the draining of the first 10% of pond volume and increased by approximately 70% during the last 10% of the effluent volume. Volatile suspended solids (VSS) were more variable but averaged about 50% of TSS. BOD_5 averaged 9.0 ppm and did not increase significantly in the last 10% of effluent volume. Screening through a 10-micrometer mesh removed more mineral than organic solids and reductions in TSS, although small, were statistically significant. Volatile suspended solids and BOD_5 generally did not change with reductions in TSS, except small but significant reductions in the first 10% of effluent after screening through a 41-micrometer mesh. Based on averages, 75-82% of suspended particles were less than 5 micrometers, with smaller particles being more organic. The last 10% of effluent was characterized by smaller particles than the first 10% of effluent volume. VSS in the last 10% of effluent had a stronger correlation ($r = 0.91$) with BOD_5 than the first 10% ($r = 0.71$). TSS had a weaker correlation with BOD_5 ($r = 0.55$ in first 10% of effluent and 0.71 in last 10%).

Waddell Mariculture Center. Water quality effects of settling the last 20 to 30% of shrimp pond drainage were examined during the harvest of four commercial ponds during 2001, and compared to results from one commercial and four research ponds examined in the previous years. Sedimentation often, but not always, reduced total nitrogen and total phosphorus. These reductions were sometimes as great as 80% of initial levels, and were typically only significant during the first hour of sedimentation. Proportional reductions in total nitrogen and total phosphorus were not as great as proportional reductions in suspended solids, turbidity, and BOD_5.

Reductions in turbidity and suspended solids were similar. Reductions in suspended solids in the first hour of settling were greater than reductions that occurred during the subsequent 19 hours of settling. In higher density ponds (i.e., stocked with 100 PL/m^2), turbidity was reduced by 45 to 92% during the first 30 minutes of settling. In lower density ponds (i.e., stocked with 10 to 50 PL/m^2) turbidity was reduced by 5 to 49% after 30 minutes of settling. Planktonic algae appeared to be a primary component of turbidity in drainage water and was only modestly changed with sedimentation.

Although there was a tendency for the higher density ponds to have greater initial levels of suspended solids, turbidity, and BOD_5, and greater reductions (both in magnitude and proportion) in these parameters during relatively short sedimentation periods, there was substantial overlap between these groups. The findings preclude firm statements regarding the benefit of sedimentation based solely upon shrimp stocking density. Both initial levels and the effect of sedimentation on suspended solids, turbidity, and BOD_5 varied greatly between ponds, regardless of whether the ponds were at the same facility or at similar stocking densities. Factors that contributed to this high variability include those that affect sediment resuspension during harvest, in particular, sludge pile size and location with respect to drainage flow, slope of the pond, operation of aerators during harvest, and shrimp activity. When pond harvest strategies that encourage the flushing of sludge are employed, sedimentation prior to water release may be particularly beneficial.

Finally, pond drainage after passage through a discharge canal was examined during two harvests. In both cases, suspended solids, turbidity, and BOD_5 at the farm discharge were at levels similar to pond effluent after 20 hours of sedimentation, suggesting there can be significant water quality improvements during passage through the drainage canal from the pond to the facility outfall.

Objective 2. *Evaluate the impact of aquaculture pond effluent discharge on receiving stream water quality.*

Mississippi State University. Seventeen stream sample locations were selected and geo-referenced within four sub-watersheds with variable development of the landscape to aquaculture ponds. Stream sampling occurred during base flow conditions and during the only significant runoff event that occurred during spring 2000. Despite elevated stream flow during this event, few ponds were observed to be discharging water. No changes in stream water quality could be attributed to aquaculture ponds. In some stream reaches, the magnitude of in-stream variation in water quality over short distances was large.

A study was conducted to evaluate the duration and settling characteristics of initial pond effluent from levee ponds. Settling characteristics of effluent samples collected at the discharge point were determined. In addition, spatial and temporal variation of water quality in channels receiving the effluent was measured. When draining was initiated, shear forces generated by water moving into the drain pipe caused scouring in a zone around the entrance to the drain pipe. The initial flush of discharged water consisted of pond water and a slurry of sediment that had accumulated over the screen inside the pond. The initial discharge was very high in total suspended solids (43,860 ppm), volatile suspended solids (3,770 ppm), BOD_5 (118 ppm), and nutrients. Within 2.5 minutes of the initial discharge, total suspended solids decreased to 1,790 ppm, volatile suspended solids to 205 ppm, and BOD_5 to 29 ppm. By 30 minutes, the poorly consolidated sediment from around the drain structure inside the pond had been discharged, and the effluent quality was identical to the bulk pond water for the remainder of the draining period (approximately 5 days). For the effluent, 15.2% of the total solids were discharged with the first 1.7% of the total volume discharged. The initial solids concentration was 900 times higher than the solids concentration in the bulk pond water. In contrast, the BOD_5 of the initial flush of water discharged was only about 9 times higher than the BOD_5 of the bulk pond water and concentrations decreased more rapidly than total suspended solids. Therefore, cumulative discharge of BOD_5 as a function of water volume discharged did not have an initial spike of similar magnitude as for total suspended solids; rather, cumulative discharge of BOD_5 was roughly proportional to the volume of water discharged. These results suggest that the ratio of mineral solids to organic matter of the initial flush of water was relatively higher than that of subsequently discharged water.

The median settling velocity decreased from 0.3 cm/second in the initial effluent to 0.06 cm/second after 30 minutes. Total suspended solids in a ditch 100 m from a catfish pond outfall increased to a maximum 30 minutes following the initiation of pond discharge, but then decreased to concentrations that were less than or equal to initial ditch concentrations. The duration of poor water quality of initial effluent from catfish ponds with internal drains is brief (less than 30 minutes) and discharged solids settle rapidly within receiving ditches.

University of Arkansas at Pine Bluff. A field study evaluated exiting drainage ditches for solids settling. Surveyed ditches ranged from 1,050 to 2,300 feet in length and from 12 and 39 feet in width. Study ditches included vegetated and non-vegetated types. Volatile suspended solids (VSS) decreased by 14.1% over the first 100 meters (110 yards) of ditch. Total suspended solids (TSS) remained unchanged because of increases in fixed suspended solids (FSS). Current velocity in the ditch explained up to 65% of the variability in change in solids. There was a net increase in TSS when average velocity exceeded 2 feet/second. Theoretical settling rates of particles suggest that more VSS were removed in ditches than would have been possible based on particle distribution results obtained from fractionation. Fractionation may have affected the character of organic particles by breaking large particles into fine particles. The study suggests that ditches would be economical, effective solids settling systems if erosion in the ditch is prevented through vegetation, especially at the point of discharge, and ditches are engineered to minimize current velocity.

Additional work was conducted to characterize nutrient concentrations in baitfish pond effluents and receiving streams. Ten baitfish ponds were sampled and characterized from December 2000 through June 2001 in the central Arkansas Delta ecoregion. Effluent samples taken during the first and last 10% of pond drainage volume were analyzed for total nitrogen, total phosphorus, BOD, and TSS as well as general physical characteristics. Pond drainage ditch lengths were sampled to determine overall reduction of TSS, and ditch water quality was sampled and analyzed prior to stream discharge. Upstream samples were taken concurrently with pond and ditch samples and were analyzed for similar nutrient concentration and physical characteristics. There were no significant differences in effluent quality between the first 10% and the last 10% of effluent volume, except the last 10% had significantly higher TSS concentrations than the first 10%. There was no significant difference in nutrient concentrations in effluents sampled at the standpipe and effluents sampled at the end of drainage ditches. There was also no significant difference in standpipe effluent concentrations versus those found upstream of the discharge point. In general, concentrations of measured parameters in commercial baitfish pond effluents were lower than or similar to those reported for commercial catfish ponds during the same seasons.

Data on nutrient concentration by sediment particle size resulting from serial fractionation of effluent samples are currently being analyzed, as are changes in sediment and nutrients in receiving ditches during the first and last 10% of discharge. Nutrients and solids composition data were collected in an intermittent receiving stream at regular intervals for a 6-month period. Changes in chemical composition of stream water from the headwaters, past an urban area, downstream of a water treatment facility, and upstream and downstream of a large baitfish farm are being analyzed.

Objective 3. *Evaluate a range of water management techniques appropriate for ponds as means of reducing the quantity and improving the quality of discharged water.*

Mississippi State University. A study was conducted over 3 years to evaluate the accuracy of a mathematical model used to predict performance of a management strategy to reduce pond effluent volume and groundwater use requirements. The strategy consisted of increasing the water storage capacity (depth) of one pond by 1 foot in an interconnected 2-pond or 4-pond module. Tested pond system configurations included 3 conventional production ponds linked to 1 production/storage pond; 1 conventional production pond linked to 1 production/storage pond; and 1 conventional (control) pond. During the study, effluent release, groundwater use, rain, evaporation, and infiltration were monitored to

Results at a glance...

- *Effluent volume can be reduced by increasing pond depth to increase rainwater storage capacity and linking the combined storage/ production pond to one or three adjacent conventional ponds. Effluent volume was reduced by more than 50% and groundwater consumption was reduced by more than 40% compared to conventionally managed ponds. Linking ponds and reusing stored water has not affected fish growth, occurrence of diseases, or water quality.*

validate the model. Additionally, ponds were stocked at commercial rates and water quality (dissolved oxygen, temperature, total ammonia, nitrate, chlorophyll *a*, conductivity, alkalinity, and hardness) and occurrences of disease (proliferative gill disease, enteric septicemia of catfish) were monitored to determine whether the management strategy had unintended consequences.

The process of comparing actual system performance to model predictions has not yet been completed. Initial inspection of a portion of the data suggests that predicted and actual performance will agree well over extended time scales (i.e., seasonally). There are, however, incidents of disagreement over shorter (i.e., single storm event) time scales that have not yet been explained. Work continues in this area.

Although only three years of validation data have been collected (testing only 3 specific combinations of meteorological data) the study period encompassed years that were both drier and wetter than normal. The range of conditions encountered suggests good agreement between the model and actual pond performance and provides some degree of optimism about the utility of the model for other precipitation/ evaporation regimes. At the moment, significant reductions in effluent release and groundwater use can be achieved using this approach. Additional measurements (harvest size, water quality, and occurrence of disease) appear to show no negative consequences of linking ponds.

North Carolina State University. Data on water discharge quantity and quality is being collected from an 80-acre commercial hybrid striped bass farm. During selected pond drawdown events, water samples were collected from the farm drainage ditch and at 3 sites downstream and solids and nutrient concentrations were measured. Data on rainfall, runoff, and water use have been collected since fall of 2000, and a water budget for this farm is currently under development.

A study comparing water quality in annually drained hybrid striped bass ponds to ponds managed for zero discharge was run for 3 years. Twelve, 0.25-acre ponds were managed according to common commercial practices for foodfish production. After the third year fish production was not significantly different between the two treatments, although the mean concentration of total suspended solids was higher in the undrained ponds. There were no other differences in water quality between the two water management regimes.

Two fixed-film filters (vertical brushes and a block honeycomb medium) are being evaluated for suspended solids and nutrient removal from hybrid striped bass pond water. Rectangular fiberglass tanks were fitted with baffles to contain the filter material, and pond water was pumped into the tanks at one end, flowed over/through the filter media, and drained from the other end. A control was also used, which consisted of a tank with no baffles and no filter media. Water quality was measured at the inflow and outflow of each tank approximately every three days, and trials lasted between 15 and 22 days. Four different hydraulic loading rates have been evaluated, with flow rates between 1.4 to 16.6 gallons per minute corresponding to retention times between 2.5 and 0.2 hours. Water quality analyses reveal little difference in tanks with either of the filter media between inflowing and outflowing water in concentrations of total nitrogen, total phosphorus, total suspended solids and chlorophyll *a*. Although solids removal was not measurable on a daily basis, by the end of the trials significantly more solids were removed by the media than in the controls. At lower flow rates the block honeycomb medium removed approximately 3 times more solids than was removed by the brushes and 10 times more solids than removed by the control. At the highest flow rate used, the brush medium removed approximately 3 times the amount of solids removed by the honeycomb medium and 15 times the amount removed by the control. Solids removed by both filters and control are approximately 15% organic material. Further evaluation of the media at high flow rates is planned for late 2002.

A study is being conducted during 2002 to evaluate the effect of different pond bottom management practices on production and water quality in hybrid striped bass ponds. Preliminary results indicate much higher concentrations of turbidity and total suspended solids in pond water and lower feed consumption and mean weight of fish in ponds that were not dried in between crops compared to ponds that were dried and received soil or water amendments. The relative effectiveness of the different amendments is still being evaluated, although bench scale tests show applications of anionic polyacrylamide to be more effective in reducing turbidity and improving water quality than alum or gypsum when applied to pond water in soil-water mesocosms.

University of Arkansas at Pine Bluff. As a water conservation technique in response to declining aquifer levels, re-use of pond water is growing popular in the Arkansas baitfish industry. Predation of fry by cyclopoid copepods present in re-used water is the greatest challenge to widespread adoption of this practice. A study was conducted to evaluate treatments affecting zooplankton populations so that water can be re-used and the volume of effluent reduced. The aim of this study was to evaluate methods of restarting the zooplankton bloom in pond water held from previous production operations. The abundance and evolution of rotifer and copepod populations in ponds containing old water, old water treated with 0.25 ppm Dylox, and mechanically filtered old water were compared to ponds filled with ground water. Zooplankton were sampled and water quality was monitored daily for 6 weeks. Rotifer abundance increased in ponds in all treatments during the first 8 days. Average rotifer density over 8 days did not differ between treatments. However, average copepod abundance was affected by treatments. New water had significantly fewer copepods than Dylox-treated or old water, but did not have fewer copepods than mechanically filtered water. Mechanical filtration compared more favorably to ponds filled with ground water than to ponds treated with Dylox or not treated. Filtration minimized adult copepods, while maintaining sufficient rotifer density for baitfish culture. Mechanically filtered old water has good potential of providing sufficient food (rotifers and nauplii) for newly stocked fry while minimizing the risk of copepod predation on fry.

Cyclopoid copepod predation has been established as an important factor causing low and variable survival rates during sunshine bass fingerling production. A concentration of 500 copepods/L can result in 0% survival of 5-day-old fry stocked at 20 fry/L during a 24-h period. Concentrations of 50 copepods/L and below resulted in survival rates not significantly different from controls with no copepods. Farmers will encounter cyclopoid copepod concentrations between 50 and 500 copepods/L in pond water fertilized to enhance rotifer blooms or in water held from previous operations. This study investigated the effect of cyclopoid copepod concentration on survival rates of sunshine bass, golden shiner, fathead minnow, and goldfish fry. Survival of golden shiner, fathead minnow, and goldfish was 95-100% at all copepod concentrations (0, 100, 200, 300, 400, and 500/L). Survival rates of sunshine bass (75.0-93.1%) were not significantly different among copepod concentrations ranging from 0 to 300/L. Sunshine bass fry survival at 400 copepods/L (62.5%) was significantly higher than at 500 copepods/L (39.4%), and significantly lower than at 0 and 100 copepods/L. On the basis of these results, stocking sunshine bass fry into ponds with fewer than 300 cyclopoid copepods/L probably represents a low risk of predation. Concentrations of cyclopoids between 300 and 500/L represent a higher risk of predation. Concentrations of cyclopoids exceeding 500/L will probably result in extremely low survival and poor yields. Five-day-old golden shiner, fathead minnow, and goldfish stocked in old pond water with 500 cyclopoid copepods/L or less could have acceptable survival rates.

Objective 4. *Develop and evaluate models for predicting risks to the environment and the costs and benefits of implementing Best Management Practices (BMPs).*

University of Arkansas at Pine Bluff. Partial enterprise budgets are being developed for the various effluent management strategies evaluated in this project. Budget analyses were completed for sedimentation basin management options for commercial catfish ponds. In all, 108 different scenarios were analyzed for sedimentation basins on catfish farms. Budgeting work on the water-storage/production pond strategies for catfish ponds was also completed. Seventy-two different scenarios were analyzed for production/storage ponds. Preliminary cost data have been collected on the fixed-film filter options under study in this project.

<u>Sedimentation Basins</u>. Costs associated with settling basins are dependent on the size and number of basins, and whether sufficient land is available for basin construction or if existing production ponds must be retrofitted and taken out of production. Sizing of settling basins is controlled by factors such as the type of effluent to be treated (draining or storm overflow), layout of ponds, size of the largest foodfish pond, the number of drainage canals, and the scope of regulations governing the release of aquacultural effluents. The number of settling basins is affected by the hydraulic residence time (HRT) which is calculated from Stoke's Law. The HRT, in turn, is affected by the size of particles in suspension.

The number of settling basins is also affected by the number of drainage outlets on a farm. Some farms may drain in four to five different directions. Furthermore, farms that have ponds that are not contiguous would need a greater number of basins. Three farm size scenarios were considered in an analysis of settling basin costs: a 160-acre farm with approximately 140 acres of water, a 320-acre farm with 280 acres of water and a 640-acre farm with 560 acres of water. Average sizes of foodfish ponds in this analysis were assumed to be 10 and 15 acres, while fingerling ponds were 5 acres each.

Larger farm sizes will result in higher and more variable costs. Investment costs included excavation of settling basins and the installation of stationary re-lift pumps to drain effluents from excavated basins. Annual operating costs consisted of copper sulfate applications (to promote sedimentation of phytoplankton cells), the annual cost of pumping, and levee mowing and maintenance; whereas annual fixed costs refer to depreciation of basins and pumps, interest on investment, and the opportunity costs associated with land taken out of production for the settling basin. Estimates of lost revenue due to production foregone from retrofitted production ponds were $300, $346, and $480/acre for the 160-, 320-, and 640-acre farms, respectively. Larger farm sizes will result in higher and more variable costs. Investment costs included excavation of settling basins and the installation of stationary re-lift pumps to drain effluents from excavated basins.

Large investments are needed for the construction of settling basins. This investment cost depends heavily on the drainage layout of the farm and the scope of regulations governing the release of effluents. For instance, investment costs in a 160-acre catfish farm may range from $28,648 to over $375,000. For the 640-acre farm, investment costs under certain scenarios exceeded $750,000.

Utilization of existing foodfish ponds to settling basins represents a more economical approach for the treatment of harvest/draining effluents than construction of settling basins. This is particularly true for those scenarios in which all effluent volume must be treated. This difference was a consequence of the extremely high cost associated with excavating a sedimentation basin sufficiently deep to collect all farm effluents by gravity flow. Finally, compliance costs for the treatment of overflow effluents were moderate to high and strongly influenced by farm size.

<u>Production/Storage Ponds</u>. Two configurations (1:1 and 1:3), based on the number of production ponds served by each production/storage pond, were assumed. Increased depth of the combined production/storage pond increases the storage capacity of the system but incurs higher earthmoving costs. Three additional depths were considered: 12, 24, and 36 cm and seepage values of 0.0 and 1.0 mm/d were assumed. Cost estimates were developed for farms with average foodfish pond sizes of 10 and 15 acres. Fingerling ponds were not linked.

In total, 24 scenarios were defined for each farm size for a total of 72 scenarios. Depth of storage pond and pond configuration were the two most important factors affecting implementation costs of this technology. For instance, estimated total investment costs for a 160-acre farm with 10-acre foodfish ponds, 1:1 configuration, and 0-mm/d infiltration rate, ranged from $76,123 to $215,088 as the additional depth of storage ponds was increased from 12 to 36 cm. However, if the configuration is 3:1, investment costs decreased (ranging from $44,782 to $115,947).

<u>Fixed-film Filtering Systems</u>. Investment and operating costs were estimated for the fixed-film honeycomb and brush filtering systems. Based on the assumptions used and on the experimental data available, costs of this filtering system ranged from $0.03-$0.07/kg of fish produced with this treatment option.

<u>Farm-Level Economic Effects of Imposing Effluent Treatments on Hybrid Striped Bass Farms</u>. A Mixed-Integer Programming (MIP)

model was developed to evaluate the farm-level effect of imposing effluent treatment options on hybrid striped bass farms. Results indicted that the use of settling basins, either newly constructed settling basins or basins converted from existing ponds, constructed wetlands, and fixed-film filtering systems would not be economically feasible alternatives for hybrid striped bass farmers.

Objective 5. *Based upon existing information, supplemented by project findings, develop a comprehensive set of BMPs that can be implemented to reduce the environmental impacts of pond aquaculture in general. Develop supplemental BMPs particular to the various pond cultured species in the region that will complement the generic, pond-system BMPs. These BMPs would include best culture practices, waste handling and management, and water quality management and reuse.*

Auburn University. An environmental audit form for assessing the status of environmental management on catfish farms is under development. This instrument will be used to identify potential problems that can possibly be solved with BMPs. The audit form will be used by project participants to conduct environmental audits of aquaculture production facilities. A document containing best management practices to reduce the volume and improve the quality of channel catfish farm effluents has been prepared. A cooperative effort has been established between Auburn University, Alabama Catfish Producers Association, Natural Resources Conservation Service (NRCS), and the Alabama Department of Environmental Management to develop a set of best management practices (BMPs) for Alabama catfish farming. These BMPs will be reviewed by all agencies involved and they will be presented to the farmers for comment. Moreover, farmer meetings will be held to assure that farmers are aware of the BMPs and have opportunity for input. Environmental groups also will be asked to comment on the BMPs. When formalized, the BMPs will be maintained by NRCS in the form of Guide Sheets and made available to farmers. Draft guide sheets have been developed for:

- Reducing Storm Runoff into Ponds
- Managing Ponds to Reduce Effluent Volume
- Erosion Control on Watersheds and Embankments
- Pond Management to Minimize Erosion
- Control of Erosion by Effluents
- Settling Basins and Wetlands
- Feed Management
- Fertilization of Catfish Ponds
- Water Quality Protection to Improve Effluents
- Water Quality Enhancers
- Therapeutic Agents
- Fish Carcasses

The principal investigator formed a cooperative effort with the Alabama Catfish Producers, Natural Resources Conservation Service, Alabama Department of Environmental Management, and the Alabama Fish Farming Center to develop BMPs for catfish farming in Alabama. The effort utilized data collected in this SRAC project, earlier SRAC projects, and on projects funded by the Alabama Catfish Producers in a series of activities through which the BMPs were formulated, reviewed and revised, and finalized. The BMPs are posted on the Alabama Natural Resources Conservation Service website at http://www.al.nrcs.usda.gov/SOsections/Engineering/BMPindex.html.

These BMPs will be referred to in the Alabama Department of Environmental Management regulations that will be made for aquaculture effluents.

Louisiana State University. Current NRCS Conservation Practices were reviewed to assess their applicability to development of a set of BMP effluent and watershed management guidelines for the crawfish aquaculture industry. Specific attributes evaluated for each conservation practice included applicability, need for clarification or modification, economic feasibility, environmental effectiveness, need for additional research, and need for educational programs for users. A draft set of BMPs for aquaculture production in Louisiana has been completed and reviewed by various commodity, state, and federal agencies. The revised document – "Aquaculture Best Management Practices" – was completed and is currently in press. The document will be electronically accessible, and includes individual reviews of BMPs for crawfish pond production, catfish pond production and recirculating system production (for alligators, finfish, or shedding crustaceans). Crawfish pond production BMPs focus on reducing pumping costs, improving flushing efficiency and minimizing sediment loading during draining.

Objective 6. *Convene a series of workshops to educate and inform producers and regulators on the characteristics and management of aquaculture effluents from ponds, including BMPs, based on the best available information and that minimize environmental impact and satisfy regulatory compliance requirements.*

The first workshop convened on 6-7 November 2000 in Roanoke, VA. The objectives of the workshop were to (1) develop a prioritized list of practices that will minimize environmental impacts of aquaculture and be economically acceptable to producers; and (2) familiarize state regulators and consultants with the aquaculture effluents issue and provide the information necessary to develop effective and reasonable regulations.

In Arkansas, information on effluents and BMPs for pond aquaculture has been extended to producers. Two Extension newsletter articles were published. Results of the water re-use zooplankton study were presented to baitfish producers at the UAPB Aquaculture Field Day (attendance was approximately 300 people). A poster presentation on effluents and BMPs was exhibited at the Aquaculture Field Day and a presentation was made on the same topic at the annual convention of catfish and baitfish producers (150 people). Extension faculty assisted the Arkansas Bait and Ornamental Fish Growers Association in adapting proposed BMPs for catfish production to baitfish, and in developing the association's BMP document.

Most scientists in this SRAC project are active participants in activities coordinated by the Joint Subcommittee on Aquaculture's Aquaculture Effluent Task Force, including the various subgroups representing the species and areas of specialization of project scientists.

WORK PLANNED

The original work plan will be followed. The effort to formulate BMPs will continue.

IMPACTS

The technical guidelines for several straightforward options for effluent treatment or volume reduction have been evaluated and are now available for consideration and implementation by producers of fish in ponds. Project personnel have been involved with the development and dissemination of information on best management practices to fish producers and to federal regulatory authorities considering regulation of aquaculture pond effluents. The comprehensive cost estimates and the best management practices developed in this study could potentially provide valuable information for both the Environmental Protection Agency (EPA) and the aquaculture industry as EPA proceeds with their rule-making effort to develop Effluent Limitation Guidelines.

Generalized results of the comprehensive cost estimates related to sedimentation basins have been discussed by members of the Economics Subgroup of the JSA Aquaculture Effluents Task Force with officials of the Environmental Protection Agency and the aquaculture industry. It is likely that the results of these studies will play a role in decisions made as EPA proceeds with their rule-making effort to develop Effluent Limitation Guidelines.

The Arkansas Bait and Ornamental Fish Growers Association used SRAC information in developing a set of Best Management Practices for bait and ornamental fish farms. Association members have committed to following these recommended practices in order to minimize any possible environmental impacts from their farms.

PUBLICATIONS, MANUSCRIPTS, OR PAPERS PRESENTED

Publications in Print

Bodary, M. 2001. Characterization of baitfish pond effluents and receiving stream water quality in central Arkansas. M.S. Thesis, University of Arkansas at Pine Bluff, Pine Bluff, AR.

Boyd, C. E. 2001. Inland shrimp farming and the environment. World Aquaculture 32(1):10-12.

Boyd, C. E. 2001. Inland shrimp farming and the environment. Global Aquaculture Advocate 4(4):88-89.

Boyd, C. E. 2001. Nitrogen, phosphorus loads vary by system, USEPA should consider system variables in setting new effluent rules. Global Aquaculture Advocate 4(6):84-86.

Boyd, C. E. 2001. Site selection, design, and construction for environmentally-responsible aquaculture. Eurofish 1/2001:96-98.

Boyd, C. E. 2001. Water quality standards: total suspended solids. Global Aquaculture Advocate 4(2):70-71.

Boyd, C. E. 2001. Water quality standards: total phosphorus. Global Aquaculture Advocate 4(3):70-71.

Boyd, C. E. 2001. Water quality standards: total ammonia nitrogen. Global Aquaculture Advocate 4(4):84-85.

Boyd, C. E. 2001. Water quality standards: biological oxygen demand. Global Aquaculture Advocate 4(5):71-72.

Boyd, C. E. 2001. Water quality standards: dissolved oxygen. Global Aquaculture Advocate 4(6):70-72.

Boyd, C. E. 2001. Aquaculture and water pollution. Pages 153-157 in: D. F. Hayes and M. McKee (eds.), Decision Support Systems for Water Resources Management, American Water Resources Association, Middleburg, Virginia.

Boyd, C. E., and A. Gross. 1999. Biochemical oxygen demand in channel catfish *Ictalurus punctatus* pond water. Journal of the World Aquaculture Society 30:349-356.

Boyd, C. E., and A. Gross. 2000. Water use and conservation in inland aquaculture ponds. Fisheries Management and Ecology 7:55-63.

Boyd, C. E., and C. Jackson. 2001. Effluent water quality report. Global Aquaculture Advocate 4(4):52-53.

Boyd, C. E., and J. Queiroz. 2001. Feasibility of retention structures, settling basins, and best management practices in effluent regulation for Alabama channel catfish farming. Reviews in Fisheries Science 9:43-67.

Boyd, C. E., J. Queiroz, J. Lee, M. Rowan, G. N. Whitis, and A. Gross. 2000. Environmental assessment of channel catfish farming in Alabama. Journal of the World Aquaculture Society 31:511-544.

Boyd, C. E., J. Queiroz, G. N. Whitis, R. Hulcher, P. Oakes, J. Carlisle, D. Odom, Jr., M. M. Nelson, and W. G. Hemstreet. 2002. Best management practices for Alabama catfish farming. Alabama Agricultural Experiment Station, Auburn University, Alabama, Research and Development Series: in press.

Browdy, C. L., D. Bratvold, J. S. Hopkins, A. D. Stokes, and P. Sandifer. 2001. Emerging technologies for mitigation of environmental impacts associated with shrimp aquaculture pond effluents. Asian Fisheries Science 14:255-267.

Cathcart, T. P., J. W. Pote, and D. W. Rutherford. 1999. Reduction of effluent discharge and groundwater use in catfish ponds. Aquacultural Engineering 20:163-174.

Engle, C.R. and D. Valderrama. 2002. The economics of environmental impacts in the United States. In: J. R. Tomasso (ed.) The Environmental Impact of Aquaculture in the United States. United States Aquaculture Society, Baton Rouge, LA.

Frimpong, E. A. 2001. Analysis of baitfish pond effluents, drainage ditch use, and effects of pond and ditch characteristics on solids. M.S. Thesis, University of Arkansas at Pine Bluff, Pine Bluff, AR.

Hargreaves, J. A., C. E. Boyd, and C. S. Tucker. 2002. Water budgets for aquaculture production. In: J. R. Tomasso (ed.) The Environmental Impact of Aquaculture in the United States. United States Aquaculture Society, Baton Rouge, LA.

Hargreaves, J. A., D. W. Rutherford, T. P. Cathcart and C. S. Tucker. 2001. Drop-fill water management schemes for catfish ponds. The Catfish Journal 15(10):8-9.

McClain, W. R., R. P. Romaire, and J. J. Sonnier. 2002. Determination of water budgets in experimental crawfish ponds. Ann. Res. Rpt., Rice Res. Stn., La. Agri. Exp. Stn., LSU Agricultural Center, 94:277-279.

McClain, W. R., R. P. Romaire, J. J. Sonnier, and S. J. Gravot. 2000. Determination of water budgets in experimental crawfish ponds. Ann. Res. Rpt., Rice Res. Stn., La. Agri. Exp. Stn., LSU Agricultural Center, 92:317-319.

McClain, W. R., R. P. Romaire, J. J. Sonnier, and S. J. Gravot. 2001. Determination of water budgets in experimental crawfish ponds. Ann. Res. Rpt., Rice Res. Stn., La. Agri. Exp. Stn., LSU Agricultural Center, 93:272-299.

Romaire, R. 1999. Management of water quality and effluents from aquacultural systems. Louisiana Agriculture 42(4):6.

Stone, N. 2000. Effluent regulations due by 2004. Arkansas Aquafarming 17(2):6.

Stone, N. 2001. Best management practices for pond aquaculture. On the Bayou (Bayou Bartholomew Water Quality Project newsletter), University of Arkansas Cooperative Extension Service. Winter, pg. 3.

Tucker, C. S., J. A. Hargreaves, and C. E. Boyd. 2001. Management of effluents from catfish ponds. Pages 27-50 in S. T. Summerfelt, B. J. Watten, and M. B. Timmons, editors. 2001 AES Issues Forum. Aquacultural Engineering Society, c/o The Freshwater Institute, Shepherdstown, WV.

Tucker, C. S., C. E. Boyd, J. A. Hargreaves. 2002. Characterization and management of effluents from warmwater aquaculture ponds. In: J. R. Tomasso (ed.) The Environmental Impact of Aquaculture in the United States. United States Aquaculture Society, Baton Rouge, LA.

Waddell Mariculture Center. 2002. Analysis of the effect of sedimentation on shrimp harvest discharge. Unpublished report prepared for the Technical Subgroup for Shrimp Production, Joint Subcommittee on Aquaculture - Effluents Task Force, 16 pp.

Manuscripts

Avnimelech, Y., D. Bratvold, and C. L. Browdy. Analysis of the effect of sedimentation on shrimp harvest discharge. Aquaculture.

Boyd, C. E. 2002. Aquaculture effluent management at the farm-level. Aquaculture.

Boyd, C. E. 2002. The status of codes of practice in pond aquaculture. World Aquaculture.

Engle, C. R. and D. Valderrama. Farm-level costs of settling basins for treatment of effluents from catfish ponds. Aquacultural Engineering.

Frimpong, E. A., S. E. Lochmann, and N. Stone. A methodology for ditch and water reuse assessment applied to baitfish farms. North American Journal of Aquaculture.

Frimpong, E. A., S. E. Lochmann, and N. Stone. Baitfish pond effluents and ditch treatment. Journal of the World Aquaculture Society.

Hargreaves, J. A. and C. S. Tucker. Characteristics of effluent discharged from levee ponds with internal drainage structures. Aquacultural Engineering.

Ozbay, G. and C. E. Boyd. 2002. Particle size fractions in pond effluents. World Aquaculture.

Sanders, F., R. Hendrick, G. Lutz, and R. Romaire. In press. Aquaculture production: Best management practices. Louisiana State University Agricultural Center, Baton Rouge, LA.

Tavares, L. H. S. and C. E. Boyd. 2002. Possible effects of sodium chloride treatment on quality of effluents from Alabama channel catfish ponds. Journal of the World Aquaculture Society.

Tucker, C. S., C. E. Boyd, J. A. Hargreaves, N. Stone, and R. P. Romaire. 2000. Effluents from channel catfish aquaculture ponds. Unpublished report prepared by the Technical Subgroup for Catfish Production in Ponds, Joint Subcommittee on Aquaculture - Effluents Task Force, 56 pp.

Tucker, C. S. and J. A. Hargreaves. Submitted. Management of effluents from channel catfish *(Ictalurus punctatus)* embankment ponds in the southeastern United States. Aquaculture.

Papers Presented

Bodary, M., and N. Stone. 2001. Characterization of baitfish pond effluents and receiving stream water quality in central Arkansas. American Fisheries Society Annual Meeting, Phoenix, AZ, 12 – 16 August.

Bodary, M., and N. Stone. 2002. Characterization of baitfish pond effluents and receiving stream water quality in central Arkansas. Southern Division American Fisheries Society Meeting, Little Rock, AR, 21-24 February.

Boyd, C. E. 2001. Aquaculture and water pollution. American Water Resources Association, Summer Specialty Conference, Snowbird, UT.

Boyd, C. E. 2001. Best waste management practices for the shrimp and catfish industries. Aquaculture Waste Management Symposium, Virginia Polytechnic Institute and State University, Roanoke, VA.

Boyd, C. E. 2001. Role of BMPs in environmental management of aquaculture. Aquaculture 2001, World Aquaculture Society, Orlando, FL.

Cathcart, T. P., D. W. Rutherford, and J. A. Hargreaves. 2000. Field study for evaluating effluent and groundwater use reduction in catfish ponds. Water Resources Research Institute Conference Proceedings, Jackson, MS, April.

Engle, C. R. 2001. Efficient management of catfish farms and best management practices. Presentation and abstract. North American Association of Fisheries Economists, New Orleans, LA.

Frimpong, E. A., and S. E. Lochmann. 2000. An evaluation of treatments affecting zooplankton populations for water re-use and effluent reduction. Aquaculture Field Day, University of Arkansas at Pine Bluff.

Frimpong, E. A., and S. E. Lochmann. 2001. Managing the impact of pond aquaculture on water resources of Arkansas, United States. Second Annual Students' Conference on Conservation Science, University of Cambridge, UK, 27-30 March.

Frimpong, E. A., and S. E. Lochmann. 2001. An evaluation of treatments affecting zooplankton populations for water re-use and effluent reduction. UAPB Student-Faculty Research Forum, Pine Bluff, AR, 14-15 March.

Frimpong, E. A., and S. E. Lochmann. 2001. An evaluation of treatments affecting zooplankton populations for water re-use and effluent reduction. Joint annual meeting of the American Fisheries Society and the

Wildlife Society, Arkansas Chapter, Heber Springs, AR, 6-8 February.
Frimpong, E. A., and S. E. Lochmann. 2001. An evaluation of treatments affecting zooplankton populations for water re-use and effluent reduction. Aquaculture 2001, World Aquaculture Society, Orlando, FL.
Hargreaves, J. A. 2001. Research needs to evaluate best management practices for pond aquaculture. Aquaculture 2001, World Aquaculture Society, Orlando, FL.
Hargreaves, J. A., C. S. Tucker, E. R. Thornton, and S. Kingsbury. 2002. Settling characteristics of effluent from levee ponds with internal drainage structures. Aquaculture America 2002, San Diego, CA.
Lutz, G. 2001. Best waste management practices for the alligator, crawfish, and turtle industries. Aquaculture Waste Management Symposium, Roanoke, VA, July 22-24, 2001.
Stone, N. 2001. Best management practices for aquaculture. Arkansas Aquaculture 2001, Hot Springs, AR, 9 February.
Stone, N., G. Ludwig, S. Lochmann and E. Park. 2002. New vs. old water in fry ponds. Arkansas Aquaculture 2002, Little Rock, 15 February.
Stone, N., H. Thomforde and S. Lochmann. 2000. Best management practices and pond effluents. Poster presentation. Aquaculture Field Day, University of Arkansas at Pine Bluff.
Tucker, C. S., J. A. Hargreaves, and C. E. Boyd. 2002. Characterization and management of effluents from channel catfish ponds. Book of Abstracts – Aquaculture 2002, January 27-30, San Diego, CA.
Valderrama, D., and C. R. Engle. 2001. Estimating settling basin size for treating effluents from aquaculture. Presentation and abstract. North American Association of Fisheries Economists, New Orleans, LA.
Valderrama, D., and C. R. Engle. 2001. Estimating settling basin size for treating effluents from aquaculture Presentation and abstract. Annual Meeting Arkansas Chapter AFS, Heber Springs, AR.
Valderrama, D., and C. R. Engle. 2001. Preliminary analysis of costs associated with settling basins and production/storage ponds to reduce effluents discharged from ponds. Presentation and abstract. UAPB Student/Faculty Research Forum 2001, UAPB, Pine Bluff, AR.

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DEVELOPMENT OF IMPROVED HARVESTING, GRADING AND TRANSPORT TECHNOLOGY FOR FINFISH AQUACULTURE

Reporting Period
January 1, 2001 - August 31, 2002

Funding Level	Year 1	$287,053
	Year 2 (Projected)	$272,391
	Year 3 (Projected)	$190,556
	Total	$750,000

Participants	Mississippi State University (Lead Institution)	Edwin H. Robinson, Jason E. Yarbrough, Terry R. Hanson
	University of Tennessee	Richard J. Strange
	North Carolina State University	Harry V. Daniels, Thomas Losordo
	University of Memphis	Bill A. Simco, Ken Davis (now at the Harry Dupree Stuttgart National Aquaculture Research Center)
	University of Florida	Craig A. Watson, Roy P.E. Yanong
	University of Arkansas at Pine Bluff	David Heikes, Carole R. Engle, Hugh W. Thomforde

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PROJECT OBJECTIVES

1. Develop and evaluate new gear and methods or modify existing methods to improve harvest (seining and trapping) efficiency and fish grading selectivity and reduce stress during these activities.

2. Evaluate methods relative to loading and transport of fish to reduce fish mortalities and the negative effects of stress on product quality.

3. Conduct comparative analyses of new technology and current technology for harvesting, grading, and loading fish.

ANTICIPATED BENEFITS

The primary benefit of this project will be to significantly improve profitability of the finfish aquaculture industry by improving harvesting efficiency, grading selectivity, and methods for loading and hauling fish, and by reducing the stress associated with these practices.

PROGRESS AND PRINCIPAL ACCOMPLISHMENTS

Objective 1. *Develop and evaluate new gear and methods or modify existing methods to improve harvest (seining and trapping) efficiency and fish grading selectivity and reduce stress during these activities.*

Channel Catfish

Mississippi State University. Studies have shown that braided polyethylene (BPE) mesh is the choice for constructing seines and socks for harvest of catfish. Mesh sizes recommended for grading food sized catfish have been determined. Several prototype seines have been constructed and tested on commercial catfish farms. A prototype seine was used during the harvest of the USDA 103 strain of catfish at the National Warmwater Aquaculture Center (NWAC). Ten ponds (4 or 10 acre) were harvested with an average efficiency of catch of 93.5% in a single seine haul.

Full-sized commercial socks were built of BPE having a mesh size of 1-9/16 inch, 1-5/8 inch, and 1-11/16 inch. These socks were used to harvest commercial catfish ponds. The average population distribution for five size classes of fish is summarized in Table 1. We will continue with data collection in the upcoming year to verify our recommendations. Collection of

> ## *Results at a glance...*
>
> ☆ *A prototype seine constructed from braided polyethylene mesh netting and consisting of a large funnel, mudrollers, and a zipper for attaching the sock has been commercialized. The seine is currently being used by some catfish producers and commercial seine crews in Mississippi, Arkansas, and North Carolina.*

Table 1. Average Percentage of Catfish Grading From Socks of Different Mesh Size After 6 Hours

Mesh size (inches)	Size Classes (pounds)				
	<¾	¾-1	1-1 ¼	1¼ -1½	1½+
1-9/16	6	23	15	11	45
1-5/8	1	4	19	24	53
1-11/16	0	0	3	6	91

grading data using the prototype seines is also continuing on commercial farms.

In addition, some catfish producers and commercial seining crews in Mississippi, Arkansas, and North Carolina have purchased a prototype seine and socks constructed using BPE. Anecdotal reports indicate that harvest efficiency has been increased using the new type seines. These reports agree with data collected from research studies.

University of Arkansas at Pine Bluff. Two projects are currently underway to develop in-pond fish grading technology for both market-size channel catfish and channel catfish fingerlings. Two horizontal floating platform graders with adjustable spacing have been designed and fabricated. An eductor-style fish pump mechanism has also been designed and fabricated. Design specifications for the fingerling grader were finalized and a demonstration grading system has been built. Public demonstrations were conducted in Arkansas, Louisiana and Mississippi. Preliminary field trials indicate that the prototype food-fish grading system can be effectively integrated into current harvesting procedures and has led to several design modifications and improvements. A working prototype food-fish grader is operational, but slight design and process improvements are continuing. A controlled research study was initiated in August, 2002, to compare the in-pond grader to conventional live cars.

University of Memphis. Preliminary data have been obtained on the stress response of channel catfish harvested by Mississippi State University personnel utilizing seines with different mesh and materials. Blood samples have been obtained from fish harvested on three different occasions. Preliminary analyses from one sampling period indicate that stress hormones of fish sampled prior to seining are relatively low, similar to those observed previously in unstressed fish. However, stress hormones increased significantly by the time fish were crowded into a live car. These stress hormone concentrations were at an apparently maximum concentration and remained relatively constant until the fish were removed from the live car. The rate of secretion of stress hormones was such that this maximum concentration was maintained for at least one hour. Stress appeared to be more severe in fish harvested with the traditional type of seine than those collected with the prototype seine being evaluated. Stress hormones of fish analyzed from one sampling period were seemingly maintained at a maximum concentration during harvest and preliminary evaluation of data did not initially provide a basis to distinguish any differential stress associated with the types of seines evaluated.

University of Tennessee. One study has been conducted and another is underway to evaluate the effect of confinement stress on infection with a virulent strain of *Edwardsiella ictaluri*, the bacterium responsible for enteric septicemia of catfish. Juvenile channel catfish were exposed to three levels of confinement stress and then challenged with the bacterium. The degree of stress as measured by plasma cortisol was highly correlated with subsequent mortality to the disease challenge. This provides evidence of a serious consequence of sublethal stress such as might be encountered during harvest of catfish.

Striped Bass

North Carolina State University. An in-pond portable grader has been designed and constructed for use on hybrid striped bass farms. The grader was modified from the original design that was developed for channel catfish. On-farm demonstrations/trials have been conducted on commercial hybrid striped bass farms. Based on these trials, the transfer box has been modified to improve the passage of fish from the holding net onto the grader panels. Significant changes to the intake end of the portable in-pond grader have been made. The initial design was not successful in transferring the hybrid striped bass from the holding net to the floating grader. The current design has been modified after numerous field tests but is still causing unacceptable levels of scale loss and lesions that lead to mortality of the fish. The floating grader portion of the design can effectively grade a large number of different sized fish. To date, we still do not have a good working design to proceed with larger-scale grading trials. Modifications and testing of the grader will continue.

University of Tennessee. Progress toward evaluation of stress in striped bass during grading includes the establishment and characterization of the cortisol, glucose and chloride assays that will be employed and the training of the graduate student responsible for the work. Blood samples will be taken from striped bass used in harvest technology projects by researchers at North Carolina State University to evaluate stress indicators.

Ornamental Fish

University of Florida. A survey was distributed to all the tropical fish farms in the state of Florida seeking information on existing technologies and practices, and suggestions for new technologies and/or practices they would recommend investigating. Results of year one observations and direct farm input to questionnaires and site visits have been analyzed and evaluated in regards to year one objectives. A manuscript, including statistical analysis of existing harvesting, grading and transportation practices in the ornamental fish industry is in its final stages of editing. An extension program to summarize these findings is being developed for industry participants. Collaboration with other project participants at Memphis State University has been initiated to develop a base-line for measuring stress in selected ornamental fish, using blood cortisol levels. Use of new sedatives and stress reduction compounds (Metomodate, Aqua Vitae) are being tested for impact on fish stress and condition during and after harvesting, grading, and transportation.

Objective 2. *Evaluate methods relative to loading and transport of fish to reduce fish mortalities and the negative effects of stress on product quality.*

Baitfish

University of Arkansas at Pine Bluff. Studies were conducted to determine the effect of simulated fish-hauling conditions on ammonia excretion rates of the golden shiner, *Notemegonus crysoleucas*. Studies were conducted at 15, 20 and 25°C in three recirculating systems for 24 hours using freshly harvested fish that were fasted and acclimated for 2 days. Each recirculating system consisted of a reservoir, three stocking tanks, air pump, floating bead filters and 1-micron bag filter. Total ammonia nitrogen, pH, temperature and DO were measured at the beginning of the experiment by stopping water flow. After 30 minutes, water flow was restarted to flush for three and a half hours. The procedures were repeated 6 times in 24 hours. The experiment was repeated four times using different batches of shiners. Average hourly ammonia excretion rates under three temperatures were obtained (Table 2). Maximum average daily ammonia excretion rates at three temperatures were applied to calculate the size of floating biological filters (FBFs) and zeolite (clinoptilolite) for one vat (378.5 L water,

Table 2. Hourly ammonia excretion (mg NH3-N/kg fish per hour) by golden shiners

Exp. No.	Unit fish size (g)	Hourly Ammonia Excretion Rates (mg NH_3-N/kg per hour) Treatment I 25°C	Treatment II 20°C	Treatment III 15°C
1	2.7	13.8 ± 4.0	10.1 ± 2.2	4.8 ± 1.2
2	2.7	15.0 ± 6.1	11.2 ± 3.1	7.4 ± 2.4
3	3.6	6.2 ± 2.7	5.8 ± 2.4	4.1 ± 2.1
4	3.6	11.1 ± 2.9	5.2 ± 1.7	2.9 ± 1.6

63.5 kg fish) in hauling trucks. Considering the limitations of temperature, salinity and the operational feasibility, zeolite filters are more promising than FBFs for live fish transport.

The University of Memphis. Facilities have been constructed for use in this project to evaluate the effect of handling on the stress response of fish. An analytical laboratory has been developed that will enable us to monitor changes in water conditions when fish are subjected to various stressors associated with the transportation of fish. Small fish, larvae and eggs are often shipped in plastic bags filled with a small amount of water and an oxygen atmosphere. Preliminary comparisons have been made of traditional plastic bags with "breathing" bags made of a material that permit exchange of oxygen between the environment and the water in the bag. Initial observations indicate that the traditional bags provide a suitable amount of dissolved oxygen for a longer period of time than the "breathing" bags. The slow rates of diffusion of oxygen from the surface of the breathing bag to the central water mass limits the volume of water that can be used. Oxygen quickly limits survival in breathing bags that contain a large volume of water that requires oxygen to diffuse for a considerable distance. However, small "breathing" bags that contained a small amount of water and no oxygen atmosphere supported individual fish for several days. Ammonia and carbon dioxide typically increased and pH decreased with increased transport time. Controlling of these variables could increase the time fish can be shipped in bags.

Objective 3. *Conduct comparative analyses of new technology and current technology for harvesting, grading, and loading fish.*

Channel Catfish

Mississippi State University. Studies to compare harvest efficiency of two types of seines have been initiated at the National Warmwater Aquaculture Center (NWAC), Stoneville, Mississippi. A conventional twisted polyethylene mesh seine (CTPE) with a standard frame and CTPE sock

Results at a glance...

☆ *Tests indicate that a new seine design improved catch efficiency by about 20% and reduced seining time by 45%.*

and a braided polyethylene seine with mudrollers, large funnel, and zipper attached BPE sock have been tested. Testing is continuing, but preliminary results are shown in Table 3. Economic analysis of the data will be conducted once all the data are collected.

University of Arkansas at Pine Bluff. Formal testing began in Year 2 to test the modifications made to the grader and to gather data for economic analysis. Tests are currently underway.

Three, 0.1-acre earthen ponds were stocked with 2500 pounds of channel catfish at one of three ratios: 75% harvestable (>1.25 pound): 25% sub-harvestable (0.4-0.6 pound); 50% harvestable: 50% sub-harvestable; and 25% harvestable: 75% sub-harvestable. Two replicate grading trials were completed during hot weather conditions (>27°C) for each of the three harvestable: sub-harvestable size proportions. (The third replicate is scheduled for the week of Aug. 26-30, 2002). For each trial, fish were seined and moved into live cars and then graded using the UAPB prototype grader.

The UAPB grader took from 2-6 minutes to grade 10,000 pounds of catfish. There was no

Table 3. Preliminary Harvest Efficiency Data

Seine type	CTPE	BPE
Parameters		
Mean Seining Time (min.)	90	60
Mean Stock Attachment Time (min.)	11	5
Labor to Attach Sock	2	1
Mean Efficiency (%)	69	83

difference due to size proportions of catfish. Dissolved oxygen levels were not significantly different in the control live car after 14 hours of grading than in the pond. Little direct mortality was observed due to either grading technology, but all the mortality found (7 fish in all) was in the control live car.

Results at a glance...

☆ *The UAPB prototype mechanical grader graded 5 - 11% more weight (based on the total pre-grade weight) of sub-harvestable size fish than the control live car technology in a significantly shorter time at the high temperatures of the main production season. This resulted in a 12.5% increase in average weight of the fish available for transport to a processing plant.*

Both the UAPB and control live car grading technologies significantly reduced the number and weight of sub-harvestable fish. However, the UAPB grader retained only 27-47 pounds of sub-harvestable fish while the control live car retained approximately 3-4 times the weight of sub-harvestable fish (69-159 pounds; Figs. 1 and 2). Overall the UAPB grader graded out from 46-112 pounds (5 - 11% of the total weight graded) more sub-harvestable size fish than the control live car. This resulted in a 12.5% increase in average weight of fish available for transport to a processing plant. Both these differences were statistically significant. There was no difference in weight of harvestable-size fish retained by the graders.

Spreadsheet templates have been developed for the partial budget analysis to be conducted as the first step in the economic analysis.

Baitfish

University of Arkansas at Pine Bluff--*Economic evaluation of new transport technology*. Existing enterprise budgets for baitfish are over 5 years old. These budgets have been updated to reflect current costs of production. Data acquisition forms have been developed to evaluate the current costs of transporting baitfish. These forms were developed with input from industry cooperators and are currently on review by others. These will be used to develop a database of cost information related to fish transportation. This database will serve as the basis of comparison for comparing and evaluating the new technologies to be developed.

Figure 1. Mean percentage (by number) of remaining sub-harvestable fish after grading

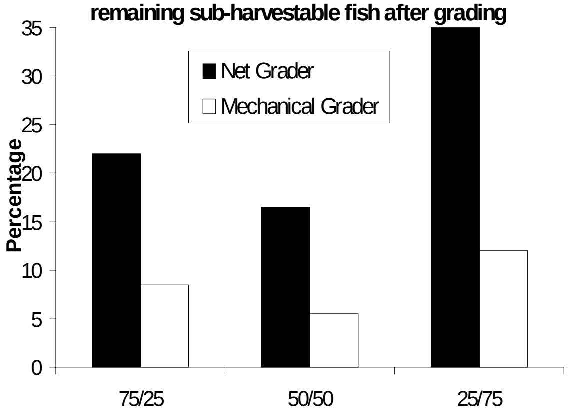
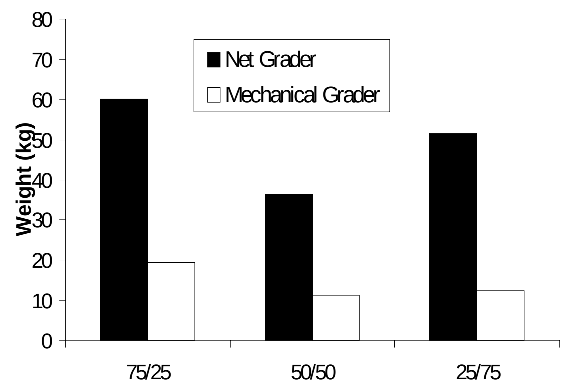


Figure 2. Mean weight of remaining sub-harvestable fish after grading



WORK PLANNED

Year 3

Objective 1. *Develop and evaluate new gear and methods or modify existing methods to improve harvest (seining and trapping) efficiency and fish grading selectivity and reduce stress during these activities.*

Channel Catfish

Mississippi State University. Work will continue on evaluating prototype seines on commercial catfish farms as well as by controlled studies in NWAC ponds. Trials will be conducted under warm and cool water temperatures to account for seasonal variation in fish behavior.

University of Arkansas at Pine Bluff. Grader performance data will continue to be collected through this next year to ensure performance data is collected throughout the entire temperature range. Food-fish grading demonstrations will also be conducted.

University of Memphis. Stress responses by fish will continue to be evaluated in association with research being conducted by Mississippi State University, who will harvest fish from commercial sized ponds utilizing different types of seines. Blood samples will be taken at different times of the year, at different times of day and under different water conditions. Blood will subsequently be evaluated to determine the stress imposed on fish under these varying conditions. This information will be compared with observations taken by Mississippi State University scientists on the health and survival of fish harvested with each type of seine. This information will be helpful to determine which methods and materials enable handling of fish with the least adverse effects.

University of Tennessee. Work will continue on challenge experiments with various size catfish and different stressors to measure the potential effects of sublethal stressors.

Striped Bass

University of North Carolina. We anticipate having a functional grader ready for the winter grading season in the early fall. As soon as the grader is found to satisfactorily grade fish without causing external damage, we will be able to conduct trials on a weekly basis to collect the data as we had originally proposed.

University of Tennessee. Work planned includes assaying striped bass blood after different harvesting and grading procedures in order to evaluate relative stress of the different methods.

Ornamental Fish

University of Florida. Working at the Tropical Aquaculture Laboratory and with a select group of farm collaborators, we will be collecting data on existing practices and technologies, emphasizing analysis of cost of materials, labor, and impact of practices on fish health and condition. New practices such as water treatments, aeration, in-pond grading, and non-baited traps will be evaluated in the same manner.

Objective 2. *Evaluate methods relative to loading and transport of fish to reduce fish mortalities and the negative effects of stress on product quality.*

Baitfish

University of Arkansas at Pine Bluff. Work will begin on the evaluation of varying loading rates and using various commercial water quality stabilizers on closed system long-hauls on fish survival and profitability of baitfish aquaculture.

University of Memphis. Stress responses will be evaluated in fish subjected to different shipping methods. Variables to be investigated include: fish density, water volume, temperature, time, shipping container, and water additives to regulate the accumulation of fish waste products. This information will be helpful to increase the efficiency of transporting fish for a maximum distance with maximum survival and reduced stress.

Objective 3. *Conduct comparative analyses of new technology and current technology for harvesting, grading, and loading fish.*

Channel Catfish

Mississippi State University. Studies will continue under controlled conditions at the NWAC to compare new seining technology to conventional seining technology. Benefits and costs for the harvest technologies developed for catfish will be estimated at the farm, processor, and consumer levels using various economic models. Economics of new technologies will be compared to current technologies.

University of Arkansas at Pine Bluff. Three replicate grading trials will be conducted with each size proportion ratio at two other water temperatures: intermediate (14-26°C) and cold (< 10°C). Three trials will also be conducted on commercial farms at each of the three temperature ranges. Farmer cooperators have been selected for the commercial farm trials. These datasets will form the basis for the economic analyses to be conducted this coming year also.

Baitfish

University of Arkansas at Pine Bluff. Economic evaluation of new transport technologies will be collected and summarized. Data on mortalities associated with the new technologies will also be collected. The additional costs and benefits associated with the new transport technologies will be compared to existing technologies within a partial budget framework. This analysis will then be extended to evaluate the effect on farm profits of adoption of the new technologies.

IMPACTS

Channel Catfish

Braided polyethylene (BPE) mesh is recommended for construction of catfish seines and socks based on performance characteristics determined in research and commercial catfish ponds. Even though work is continuing on prototype seines, the seines have been commercialized. The development of new seine technology should increase profits because the new technology improves the efficiency of catch and grading and reduces seining time.

The fish grading work could potentially impact both producers and processors of channel catfish food fish. The adjustable nature of the fish grader allows more control over the size of fish retained. This could lead to more harvesting flexibility and more marketing options for producers. Another advantage is that fish can be graded immediately after seining, allowing more accurate inventory estimates to be relayed to the plant. Preliminary data suggest the in-pond mechanical grader removes more sub-marketable fish as compared to conventional socks. If shown to be economically feasible, this might allow food fish producers to retain more sub-marketable fish in the production pond while improving efficiency at the processing plant. Fingerling producers marketing graded channel catfish fingerlings could benefit greatly from in-pond grading as it can eliminate the need for costly vat grading facilities, drastically reduce the time and labor requirement of other grading methods and can eliminate costly haul-backs. To date, six catfish fingerling facilities, two commercial catfish food-fish facilities and one hybrid striped bass facility, have adopted this technology.

Improved grading technologies have the potential to improve farm profits theoretically by as much as 5-10%.

Striped Bass

In-pond graders have the potential to significantly reduce the labor and costs associated with harvesting and minimize mortality caused by excessive handling.

Ornamental Fish

Initial surveys and analysis of existing practices provided producers with accurate information of the economic cost and impact of their existing practices, which can be used successfully as a management tool. In addition, this base-line information provided a means to evaluate new practices and technologies planned for year two and three.

While evaluations of treatment impacts have not been completed, initial observations are extremely promising. It is anticipated that addition of stress relieving compounds to water during handling of ornamental fish will greatly increase their general condition and health, and increase the efficiency of all steps in the process (i.e. harvesting, grading, and transportation) .

Baitfish

Studies on ammonia excretion rates of golden shiners provide a basis for calculating the type of filter that is best for transporting live fish. Based on the data collected thus far, it appears that zeolite filters are more promising than floating-bead filters for live fish transport.

PUBLICATIONS, MANUSCRIPTS, OR PAPERS PRESENTED

Hoskinson, J. and B. A. Simco. 2001. Evaluation of Kordon Breathing Bags for the Transportation of Fish. Tennessee Academy of Science, Collegiate Division, Memphis, TN.

Trimpey, J. and C. Engle. 2002. Grading technologies for catfish. Abstract. UAPB Research Forum, University of Arkansas at Pine Bluff, Pine Bluff, AR.

Yarbrough, J. E. 2000. Harvest Technology: A glimpse of the past, a look at the future. Delta Business Journal. July 2000.

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SUPPORT OF CURRENT PROJECTS

Title	Yr	SRAC Funding	Other Support: University	Industry	Other Federal	Other	Total Other Support	Total SRAC+ Other Support
Publications, Videos and Computer Software	1	50,000	43,950	-0-	-0-	-0-	43,950	93,950
	2	60,948	30,737	-0-	-0-	-0-	30,737	91,685
	3	45,900	35,710	-0-	1,000	-0-	36,710	82,610
	4	60,500	41,000	-0-	-0-	-0-	41,000	101,500
	5	67,000	47,000	-0-	-0-	-0-	47,000	114,000
	6	80,546	52,975	-0-	-0-	-0-	52,975	133,525
	7	83,850	43,000	-0-	-0-	-0-	43,000	126,850
Total		**448,744**	**294,372**	-0-	**1,000**	-0-	**295,372**	**744,120**
Control of Blue-green Algae in Aquaculture Ponds	1	307,574	171,746	27,000	172,500	-0-	371,246	678,820
	2	275,970	161,882	35,000	98,380	-0-	295,262	575,901
	3	252,703	149,662	16,000	120,983	-0-	286,645	539,971
Total		**836,247**	**483,290**	**78,000**	**391,863**	-0-	**953,153**	**1,794,692**
Management of Aquacultural Effluents fromPonds	1	227,597	105,319	-0-	-0-	-0-	105,319	332,922
	2	222,289	117,051	-0-	-0-	-0-	117,051	353,970
	3	150,740	109,516	-0-	-0-	-0-	109,516	260,256
Total		**600,626**	**331,886**	-0-	-0-	-0-	**331,886**	**947,148**
Development of Improved Harvesting, Grading and Transport Technology for Finfish Aquaculture	1	287,053	218,353	-0-	-0-	-0-	218,353	505,406
	2	272,391	227,188	-0-	-0-	-0-	227,188	499,579
	3	190,556	232,823	-0-	-0-	-0-	232,823	423,379
Total		750,000	**678,364**	-0-	-0-	-0-	**678,364**	**1,428,364**

SRAC RESEARCH AND EXTENSION PROJECTS

Project	Duration	Funding	Grant No.
*Analysis of Regional and National Markets for Aquacultural Products Produced for Food in the Southern Region. Dr. J. G. Dillard, Mississippi State University, Principal Investigator	04/01/88-06/30/90		
	Project Total	**$346,038**	87-CRSR-2-3218
*Preparation of Southern Regional Aquaculture Publications. Dr. J. T. Davis, Texas A&M University, Principal Investigator	01/01/88-12/31/90		
	Project Total	**$150,000**	87-CRSR-2-3218
*Performance of Aeration Systems for Channel Catfish, Crawfish, and Rainbow Trout Production. Dr. C. E. Boyd, Auburn University, Principal Investigator	03/01/88-10/31/90		
	Project Total	**$124,990**	87-CRSR-2-3218
*Develop a Statistical Data Collection System for Farm-Raised Catfish and Other Aquaculture Products in the Southern Region. Dr. J. E. Waldrop, Mississippi State University, Principal Investigator	06/01/89-11/30/90		
	Project Total	**$13,771**	88-38500-4028
*Immunization of Channel Catfish. Dr. J. A. Plumb, Auburn University, Principal Investigator	Yr. 1-05/02/89-04/30/90	$50,000	88-38500-4028
	Yr. 2-05/01/90-04/30/91	49,789	89-38500-4516
	Project Total	**$99,789**	
*Enhancement of the Immune Response to *Edwardsiella ictaluri* in Channel Catfish. Dr. J. R. Tomasso, Clemson University, Principal Investigator	Yr. 1-05/02/89-04/30/90	$46,559	88-38500-4028
	Yr. 2-05/01/90-10/31/91	51,804	89-38500-4516
	Project Total	**$98,363**	
*Effect of Nutrition on Body Composition and Subsequent Storage Quality of Farm-Raised Channel Catfish. Dr. R. T. Lovell, Auburn University, Principal Investigator	Yr. 1-05/02/89-04/30/90	$274,651	88-38500-4028
	Yr. 2-05/01/90-04/30/91	274,720	89-38500-4516
	Yr. 3-05/01/91-12/31/92	273,472	90-38500-5099
	Project Total	**$822,843**	
*Project Completed			

Project	Duration	Funding	Grant No.
*Harvesting, Loading and Grading Systems for Cultured Freshwater Finfishes and Crustaceans. Dr. R. P. Romaire, Louisiana State University, Principal Investigator	Yr. 1-05/02/89-04/30/90	$124,201	88-38500-4028
	Yr. 2-05/01/90-04/30/91	124,976	89-38500-4516
	Yr. 3-05/01/91-04/30/93	124,775	90-38500-5099
	Project Total	**$373,952**	
*Preparation of Extension Publications on Avian Predator Control in Aquaculture Facilities. Dr. James T. Davis, Texas A&M University, Principal Investigator	05/01/90-12/31/92		
	Project Total	**$15,000**	89-38500-4516
*National Extension Aquaculture Workshop. Dr. Carole Engle, University of Arkansas at Pine Bluff, Principal Investigator	10/01/91-09/30/92		
	Project Total	**$3,005**	89-38500-4516
*Educational Materials for Aquaculturists and Consumers. Dr. J. T. Davis, Texas A&M University, Principal Investigator	Yr. 1-05/01/91-04/30/92	$3,971	87-CRSR-2-3218
		35,671	88-38500-4028
	Total Yr. 1	$39,642	
	Yr. 2-06/01/92-05/31/93	$59,000	91-38500-5909
	Yr. 3-06/01/93-12/31/94	34,500	92-38500-7110
	Project Total	**$133,142**	
*Characterization of Finfish and Shellfish Aquacultural Effluents. Dr. J. V. Shireman, University of Florida, Principal Investigator	Yr. 1-05/01/91-04/30/92	$13,081	88-38500-4028
		82,747	89-38500-4516
		49,172	90-38500-5099
	Total Yr. 1	$145,000	
	Yr. 2-06/01/92-05/31/93	$168,105	91-38500-5909
	Yr. 3-06/01/93-12/31/94	$128,936	92-38500-7110
	Project Total	**$442,041**	
*Food Safety and Sanitation for Aquacultural Products: Microbial. Dr. J. L. Wilson, University of Tennessee, Principal Investigator	Yr. 1-04/01/92-03/30/93	$12,649	89-38500-4516
		71,608	90-38500-5099
	Total Yr. 1	$84,257	
	Yr. 2-06/01/93-05/31/94	$213,106	92-38500-7110
	Yr. 3-06/01/94-05/31/95	$237,975	93-38500-8393
	Project Total	**$535,338**	
*Project Completed			

Project	Duration	Funding	Grant No.
*Aquaculture Food Safety: Residues.	Yr. 1-09/11/92-09/30/93	$99,393	91-38500-5909
Dr. George Lewis, University of	Yr. 2-10/01/93-09/30/94	$44,631	90-38500-5099
Georgia, Principal Investigator		107,050	91-38500-5909
	Total Yr. 2	$151,681	
	Yr. 3-10/01/94-09/30/95	$89,463	93-38500-8393
	Yr. 4-10/01/95-09/30/96	$11,392	93-38500-8393
	Project Total	**$351,929**	
*National Coordination for Aquaculture Investigational New Animal Drug (INAD) Applications. (In cooperation with other Regional Aquaculture	Yr. 1-09/01/93-08/31/94		
Centers and USDA)	**Project Total**	**$2,000**	90-38500-5099
*Improving Production Efficiency of	Yr. 1-01/01/94-12/31/94	$28,148	90-38500-5099
Warmwater Aquaculture Species		123,705	91-38500-5909
Through Nutrition. Dr. Delbert		128,444	92-38500-7110
Gatlin, Texas A&M University,	Total Yr. 1	$280,297	
Principal Investigator	Yr. 2-01/01/95-12/31/95	$38,059	92-38500-7110
		175,450	93-38500-8393
		32,397	94-38500-0045
	Total Yr. 2	$245,906	
	Yr. 3-01/01/96-12/31/96	$23,907	93-38500-8393
		210,356	94-38500-0045
	Total Yr. 3	$234,263	
	Project Total	**$760,466**	
*Delineation and Evaluation of	Yr. 1-04/01/94-03/31/95	$75,530	92-38500-7110
Catfish and Baitfish Pond Culture		43,259	93-38500-8393
Practices. Dr. Michael Masser,	Total Yr. 1	$118,789	
Auburn University, Principal	Yr. 2-04/01/95-03/31/96	$113,406	94-38500-0045
Investigator	Yr. 3-04/01/96-03/31/97	$28,517	93-38500-8393
		72,281	94-38500-0045
	Total Yr. 3	$100,798	
	Project Total	**$332,993**	
*Optimizing Nutrient Utilization			
and Waste Control through Diet	Yr. 1-12/01/96-11/30/97	$241,476	95-38500-1411
Composition and Feeding Strategies.	Yr. 2-12/01/97-11/30/98	$47,105	95-38500-1411
Dr. Kenneth Davis, University of		210,047	96-38500-2630
Memphis, Principal Investigator	Total Yr. 2	$257,152	
	Yr. 3-12/1/98-11/30/99	$34,365	96-38500-2630
		199,811	97-38500-4124
	Total Yr. 3	$234,176	
	Project Total	**$732,804**	

*Project Completed

Project	Duration	Funding	Grant No.
*Management of Environmentally-Derived Off-Flavors in Warmwater Fish Ponds. Dr. Tom Hill, University of Tennessee, Principal Investigator	Yr.1-06/01/96-05/31/97	$29,349	93-38500-8393
		34,918	94-38500-0045
		186,560	95-38500-1411
	Total Yr. 1	$250,827	
	Yr. 2-06/01/97-05/31/98	$68,718	94-38500-0045
		97,393	95-38500-1411
		84,031	96-38500-2630
	Total Yr. 2	$250,142	
	Yr. 3-06/1/98-05/31/99	$154,621	96-38500-2630
		74,645	97-38500-4124
	Total Yr. 3	$229,266	
	Yr. 4-06/01/99-05/31/00	$80,900	98-38500-5865
	Yr. 5-06/01/00-05/31/01	$55,146	99-38500-7375
	Project Total	**$866,281**	
*National Aquaculture Extension Conference (In cooperation with other Regional Aquaculture Centers)	01/01/97-12/31/97	$3,392	93-38500-8393
		308	95-38500-1411
	Project Total	**$3,700**	
*Verification of Recommended Management Practices for Major Aquatic Species. Dr. Carole Engle, University of Arkansas at Pine Bluff, Principal Investigator	Yr. 1-01/01/97-12/31/97	$31,410	95-38500-1411
	Yr. 2-01/01/98-12/31/99	$7,186	95-38500-1411
		58,928	96-38500-2630
	Total Yr. 2	$66,114	
	Yr. 3-01/01/99-12/31/00	$62,781	
	Project Total	**$160,305**	
Publications, Videos and Computer Software. Dr. Michael Masser, Texas A&M University, Principal Investigator (Continuing project)	Yr. 1-04/01/95-03/31/96	$50,000	94-38500-0045
	Yr. 2-04/01/96-03/31/97	$13,405	93-38500-8393
		47,543	94-38500-0045
	Total Yr. 2	$60,948	
	Yr. 3-04/01/97-03/31/98	$45,900	96-38500-2630
	Yr. 4-04/01/98-03/31/99	$60,500	97-38500-4124
	Yr. 5-04/01/99-03/31/00	$67,000	98-38500-5865
	Yr. 6-07/01/00-06/30/01	$80,546	00-38500-8992
	Yr. 7-07/01/01-06/30/02	$83,850	2001-38500-10307
	Project Total	**$448,744**	
*Project Completed			

Project	Duration	Funding	Grant No.
Control of Blue-green Algae in Aquaculture Ponds. Dr. Larry Wilson, University of Tennessee, Principal Investigator	Yr. 1-01/01/99-12/31/99	$25,147	96-38500-2630
		105,167	97-38500-4124
		177,260	98-38500-5865
	Total Yr. 1	$307,574	
	Yr. 2-01/01/00-12/31/00	$975	96-38500-2630
		17,394	97-38500-4124
		158,608	98-38500-5865
		98,993	99-38500-7375
	Total Yr. 2	$275,970	
	Yr. 3-01/01/01-12/31/01	$26,186	97-38500-4124
		7,202	98-38500-5865
		191,186	99-38500-7375
		28,129	00-38500-8992
	Total Yr. 3	$252,703	
	Project Total	**$836,247**	
Management of Aquacultural Effluents from Ponds. Dr. John Hargreaves, Mississippi State University, Principal Investigator	Yr. 1-04/01/99-03/31/00	$100,000	97-38500-4124
		127,597	98-38500-5865
	Total Yr. 1	$227,597	
	Yr. 2-04/01/00-03/31/01	$222,289	99-38500-7375
	Yr. 3-04/01/01-03/31/02	$150,740	
	Project Total	**$600,626**	
Development of Improved Harvesting, Grading and Transport Technology for Finfish Aquaculture. Dr. Ed Robinson, Mississippi State University, Principal Investigator	Yr. 1-01/01/01-12/31/01	$287,053	00-38500-8992
	Yr. 2-01/01/02-12/31/02	$14,259	98-38500-5865
		151	99-38500-5865
		14,757	00-38500-8992
		243,224	01-38500-10307
	Total Yr. 2	$272,391	
	Yr. 3-01/01/03-12/31/03	$34,088	99-38500-5865
		15,000	00-38500-8992
		141,468	01-38500-10307
	Total Yr. 3	$190,556	
	Project Total	**$750,000**	