I. INTRODUCTION

This Eighth Annual Progress Report of the Southern Regional Aquaculture Center (SRAC) covers the period from September 1, 1994, to August 31, 1995. Section IV includes Progress Reports on the five multi-year research and extension projects supported by SRAC during this reporting period.

Progress Reports are included in Section IV for the following on-going research and extension projects:

Food Safety and Sanitation for Aquacultural Products: Microbial

Aquaculture Food Safety: Residues

Improving Production Efficiency of Warmwater Aquaculture Species Through Nutrition

Delineation and Evaluation of Catfish and Baitfish Pond Culture Practices

Publications, Videos and Computer Software

Work has also begun on development of three additional projects:

Management of Environment-Derived Off-Flavors in Warmwater Fish Ponds

Verification of Recommended Management Practices for Major Aquatic Species

Optimizing Nutrient Utilization and Waste Control Through Diet Composition and Feeding Strategies

These projects will be initiated after final approval of the SRAC Board of Directors and USDA/CSREES has been granted.

The objectives of the project **Management of Environment-Derived Off-Flavors in Warmwater Fish Ponds** are:

1. Evaluate the feasibility of decreasing the incidence of fish off-flavors by reducing the amount of phosphorus available to support phytoplankton growth.

2. Evaluate the feasibility of reducing the incidence of fish off-flavors by manipulating pond phytoplankton community biomass and taxonomic composition.

3. Determine the feasibility of managing fish off-flavors by reducing rates of MIB uptake by fish and/or enhancing rates of MIB elimination from fish.

4. Develop statistical models describing the within-pond variation in the degree of off-flavor in fish populations under various conditions.

5. Develop publications to educate producers and processors on the ecology of environment-derived off-flavors, off-flavor management procedures, and the results of this project.

The Administrative Advisor and Steering Committee for this project are as follows:

Administrative Advisor:

Dr. Don Richardson, Dean
University of Tennessee
Tennessee Agricultural Experiment Station
Knoxville, TN

Steering Committee -- Research/Extension:

Tom Hill, Chair, TN
David Rouse, AL
Delbert Gatlin, TX
Billy Griffin, AR
John Jensen, AL
Ken Roberts, LA

Craig Tucker, MS
Larry Wilson, TN

Steering Committee -- Producer/Industry:

Walter Landry, LA
David Pearce, AL
Jerry Williamson, AR
Billy George Janous, MS

The objectives of the project **Verification of Recommended Management Practices for Major Aquatic Species** include:

1. Develop and implement verification programs of recommended management practices for catfish, baitfish, trout and crawfish production systems in participating states.

2. Publish guidelines for intrastructure development, program implementation and assessing results/benefits of aquaculture management verification.

3. Publish recommended management plans and results of Objective 1.

The Administrative Advisor and Steering Committee for this project are:

Administrative Advisor:

Dr. Billy G. Hicks, Dean
Tennessee Agricultural Extension Service
University of Tennessee
Knoxville, TN

Steering Committee -- Research/Extension:

Carole Engle, Chair, AR
Jack Whetstone, SC
R. M. Durborow, KY
Chris Hyde, AL
G. W. Lewis, GA
M. W. Brunson, MS
Andy Lazur, FL
J. L. Avery, LA

Steering Committee -- Producer/Industry:

Jerry Williamson, AR
Walter Landry, LA

The objectives of the project **Optimizing Nutrient Utilization and Waste Control Through Diet Composition and Feeding Strategies** include:

1. Determine the effects of manipulating diet composition on fish production, nutrient utilization, and consequently production of organic and nitrogenous wastes.

2. Assess the effects of various feeding strategies and techniques on fish production, nutrient utilization, and waste production.

3. Develop publications to effectively extend information derived from this project to feed manufacturers and fish producers.

The Administrative Advisor and Steering Committee for this project are:

Administrative Advisor:

Dr. W. H. Brown, Associate Director
Louisiana Agricultural Experiment Station
Louisiana State University
Baton Rouge, LA

Steering Committee -- Research/Extension:

Ken Davis, Chair, TN
Ray McClain, LA
R. C. Reigh, LA
T. A. McCaskey, AL
Rebecca Lochmann, AR
E. H. Robinson, MS
Y. W. Huang, GA
J. M. Hinshaw, NC
Delbert Gatlin, TX

Steering Committee -- Producer/Industry:

Lester Myers, MS
W. T. Kyser, AL

II. 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 FY's, 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.

A. 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 status and progress of projects, preparing and executing Letters of Agreement, tracking administrative and project expenditures, reviewing progress reports and assisting Principal Investigators 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 under Section III of this report.

B. 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 Council of Administrative Heads of Agriculture.

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 CAHA administrator from the host institution

Members of the Board are:

Harold R. Benson, Kentucky State University
William H. Brown, Louisiana State University
L. B. Daniels, University of Arkansas
R. Rodney Foil, Mississippi State University (Chairman)
David E. Foster, Arkansas Cooperative Extension Service
B. G. Hicks, Tennessee Cooperative Extension Service
Hiram Palmertree, Mississippi Cooperative Extension Service
Mazo Price, University of Arkansas at Pine Bluff
David H. Teem, Auburn University

Ex-officio Board members are:

Lester Myers, Chairman, Industry Advisory Council
James T. Davis, Co-chairman, Technical Committee
J. Larry Wilson, Co-chairman, Technical Committee
Charles G. Shepherd, Director, SRAC

The Board is responsible for (1) overall administration and management of the regional center program; (2) establishment of overall regional aquaculture research and extension goals and allocations of fiscal resources to ensure that the center develops strong programs in both research and extension; (3) establishment of priorities for regional aquaculture research and extension education activities based on inputs from the 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.

C. 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 on-going plans for SRAC. The chairman is elected by IAC members.

Members of the IAC are:

J. Neal Anderson, Producer, AR
L. H. Barner, III, Financial Institution, MS
James A. Battle, Jr., Producer, SC
Randy Deshotel, Producer, LA
Bill Galbraith, Producer, TN
Lane Gregory, Producer, NC
Walter Landry, Other, LA
Lester Myers, Feed Mill/Service, MS (Chairman)
Rick Perry, Commissioner of Agriculture, TX
Kenneth Semmens, Producer, GA
Jerry Williamson, Processing/Marketing, AR

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

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.

D. 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 for extension. Co-chairmen serve for two years and are elected by TC members.

Members of the TC for research are:

Dallas Alston, PR
Gary Burtle, GA
Frank Chapman, FL
J. A. Collier, SC
Harry Daniels, NC
Carole Engle, AR
Delbert Gatlin, TX
Leonard Lovshin, AL
Douglas Marshall, MS
Ray McClain, LA
Stephen Smith, VA
Craig S. Tucker, MS
J. L. Wilson, TN (Co-chair)

Members of the TC for Extension are:

Jimmy Avery, LA
Martin W. Brunson, MS
Charles "Bo" Collins, AR
James T. Davis, TX (Co-chair)
Robert Durborow, KY
G. J. Flick, Jr., VA
Tom Hill, TN
Conrad Kleinholz, OK
Andy Lazur, FL
G. W. Lewis, GA
Tom Losordo, NC
Jack Whetstone, SC
Greg Whitis, AL

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.

E. PROJECT 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;
- can be organized and conducted on a regional level, assuring coordinated and complementary contributions by all participants.

F. PROJECT DEVELOPMENT PROCEDURES

Research and extension priorities and statements of problems defining priority areas are jointly developed and recommended to the Board by the IAC and TC. 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 By Participant" 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.

III. 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 including:

-- Center Director serves as an ex-officio member of the Board, TC, and IAC.

-- Monitor research and extension activities sponsored by SRAC.

-- Provide documentation for, attend and assist with meetings of the Board, TC and IAC; prepare minutes of meetings of the Board.

-- Attend and participate in meetings of producers, industry representatives, scientists, and others involved in the aquaculture industry in the Southern Region and nationally.

-- Solicit and receive nominations for memberships on the Technical Committee and the Industry Advisory Council.

-- Coordinate and participate in testimony before the House Agriculture, Rural Development, and Related Agencies Subcommittee on Appropriations regarding RAC support.

-- Work with members of the House and Senate Appropriations Committees, as well as other members of Congress from the Southern Region, in support of the RAC's.

-- 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; Coordinator of Aquaculture, Principal Aquaculture Scientist, and National Aquaculture Program Leader, USDA/CSREES; Coordinator of National Agricultural Library Aquaculture Information Center; and National Program Leader for Animal Nutrition/ Aquaculture for USDA/ARS/NPS.

-- Prepare and submit the Grant Application entering into funding agreement with USDA/ CSREES for each fiscal year.

-- Prepare and submit 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 distribute funds as approved under the grants and as set forth in the Letters of Agreement.

-- Approve and process invoices received from participating institutions for reimbursement of expenditures.

-- Track status of reimbursement of expenditures to each participating institution for all funded projects.

-- Monitor budgetary status and progress of participating institutions for all funded projects.

-- 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 personnel from participating institutions in establishing procedures for invoicing for expenditures and obtaining reimbursements.

-- Assist Steering Committees and Work Groups with preparation and revision of proposals for technical and scientific merit, feasibility and applicability to priority problem areas.

-- Assist Administrative Advisors and Work Group chairmen as needed.

-- Solicit and coordinate national reviews of project proposals.

-- Review project progress reports, publications and videos.

-- Distribute extension fact sheets, research publications and videos to research and extension contacts throughout the Southern Region, other RAC's, 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. Approximately 400 copies of this report are distributed by the Administrative Center each year.

-- Produce and distribute "SRAC Publications and Videos" which lists extension publications and videos developed through SRAC projects, and the "SRAC Summary of Projects". This involves editing, designing and, using desktop publishing, producing camera-ready copy. Numerous requests are received for these reports each year, and they are widely distributed throughout the Region.

-- Maintain mailing lists for solicitation of proposals and announcements of *Ad Hoc* Work Group meetings and distribution of fact sheets and other SRAC publications.

-- Prepare and distribute Work Group announcements and Requests for Proposals to research and extension directors and other interested parties throughout the Southern Region.

-- Prepare and distribute interim reports on SRAC activities to provide information regarding on-going projects.

-- 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.

IV. PROGRESS REPORTS

A. FOOD SAFETY AND SANITATION OF AQUACULTURAL PRODUCTS: MICROBIAL

Progress Report
For the Period
April 1, 1992 to August 31, 1995

FUNDING LEVEL:

Year 1 ..... $ 85,000
Year 2 ..... $225,000
Year 3 ..... $260,000
Total $570,000

PARTICIPANTS:

University of Tennessee (Lead Institution) - J. L. Wilson, F. Ann Draughon

Auburn University - T. Lovell, T. McCaskey, Brian Perkins

University of Florida - Steve Otwell, Gary Roderick, Mark Tamplin

University of Georgia - Yao-Wen Huang, Romeo Toledo, Mark Harrison

Louisiana State University - Wendell Lorio

Mississippi State University - Juan Silva, Chinling Wang, Charles White, Douglas Marshall (previously at LSU)

Texas A & M University - Gary Acuff, Delbert Gatlin

Texas Agricultural Extension Service - Katheleen Ladewig

Virginia Polytechnic Institute and State University - Joe W. Boling, George J. Flick, Geoffrey M. Knobl, and C. Fernandes

ADMINISTRATIVE ADVISOR:

Graham Purchase, Director of Research
College of Veterinary Medicine
Mississippi State University
Mississippi State, Mississippi

PROJECT OBJECTIVES:

1.a. Collect data that are available to define aquacultured food safety problems and to design a control program.

b. Conduct a forum to assess all relevant data on food safety of aquacultured foods. This event will assemble all knowledgeable individuals that can bring their expertise to bear on this subject.

c. Prepare and distribute a bibliography of the available publications, mimeographs, fact sheets, and videos relative to food safety and sanitation in the aquaculture industry.

d. Evaluate data on microbiological quality in catfish, crawfish, and rainbow trout processing and distribution operations. Determine if there are critical control points which need attention.

e. Do supplemental laboratory work to clarify areas of concern. This is designed to fill gaps in the database, not to conduct an industry-wide survey.

2. Investigate various methods to reduce and detect significant pathogenic and spoilage micro-organisms on processed catfish, rainbow trout, and crawfish. Coordinate findings with publications work group if necessary.

3. Conduct a food safety HACCP audit to determine if this approach would be cost-effective and result in increased product safety.

4. Produce new publications to complement

existing publications on food safety and sanitation. These would be completed during the second and third years of the project.

OBJECTIVE 1A: COLLECT DATA THAT ARE AVAILABLE TO DEFINE AQUACULTURED FOOD SAFETY PROBLEMS AND TO DESIGN A CONTROL PROGRAM.

PROGRESS:

Efforts to assess the food safety of southern aquacultured products based on reported illnesses, literature reviews, and liaison with numerous related government programs still reveal that cultured fish represent the safest source of muscle protein and related nutrients among all muscle foods produced in the United States. Cultured molluscan shellfish, which in the southern region are primarily hard clams, are more suspect for potential microbial foodborne illnesses, yet actual reported illnesses do not reflect any significant reporting of occurrences from cultured molluscan products. Likewise, shrimp and crawfish, as cooked ready-to-eat items, are suspect, but not evidenced as problems. These conclusions are based on updated literature reviews per the previously identified sources through 1995 and supplements from pertinent agencies in regional State and Federal programs.

The few reported illnesses associated with consumption of clams, *Mercenaria campechensis,* harvested in Florida involved encounters with the potential pathogen bacteria, *Vibrio vulnificus.* These limited illnesses typically involve 'at-risk' consumers in that they have health conditions that compromise their immunity to infections introduced by consumption. These pathogens are indigenous to southern coastal waters approved for shellfish production, particularly during warmer months (April - October). In order to help reduce the levels of *Vibrio vulnificus* on oysters and related shellfish, the Interstate Shellfish Sanitation Conference (ISSC) introduced (August 1995) a new time-temperature harvesting scheme to retard growth of the bacteria on harvested products. The new harvesting guidelines, linked to growing water temperatures, are referenced in the Total Quality Assurance (TQA) and Hazard Analysis and Critical Control Point Manuals generated, in part, by this SRAC project (Otwell and Garrido, 1995).

Agency liaison through this project has matured into a number of collaborative projects to implement respective control measures for aquatic food product safety during processing. Meetings with the pertinent regional State agencies and their professional association, AFDOSS (Association of Food & Drug Officials of Southern States), have led to a formal partnership called the "Seafood HACCP Alliance for Education and Training". This partnership, formalized in June 1994 with support from the National Sea Grant Office, has developed a network of Cooperative Extension Services and related Sea Grant Advisory Programs working with representatives from the FDA Office of Seafoods, USDA, National Marine Fisheries Service, and all respective regional AFDO (Association of Food & Drug Officials) affiliates to design and deliver a uniform HACCP education and training program for all aquatic food processors. Aquatic foods include all seafoods (harvested, cultured or imported).

SRAC's Objective 1a provided the initial opportunity for the project personnel to draft and advance the "Alliance" concept in conjunction with the AFDOSS (AFDO of Southern States) organization. This educational "Alliance" will offer continuing controls for aquacultured product safety through the joint development of 'core HACCP curriculum', establishment of a cadre of HACCP instructors, pilot-testing in processing firms, and maintenance of a 'compendium' of approved processing methods and recommendations for HACCP monitoring and record keeping. To date the investigators have assisted in preparation of HACCP training modules for processing of molluscan shellfish and crawfish, which can include cultured products. This involvement assures a role for SRAC in providing essential HACCP training for aquacultured production and processing in southern states.

Concurrent with the aforelisted activity, this project has helped foster regional collaboration in a joint USDA Extension Service project, "Implementation of TQA and HACCP Concepts for Processing Aquacultured Products". This project has been completed with the development and in-plant testing of HACCP programs for cultured molluscan shellfish (University of Florida - Steve Otwell with Louisiana State University - Mike Moody) and catfish (Mississippi State University - Anna Hood with Virginia Tech - George Flick). The second year of work will continue with cultured crawfish (LSU - Mike Moody with University of Florida - Steve Otwell) and trout (Virginia Tech - George Flick with MSU - Anna Hood). The SRAC project initiated this collaboration. Likewise, as a consequence of this work the SRAC investigator has been asked to serve as the Chairman of the Interstate Shellfish Sanitation Conference's HACCP Committee to investigate the integration of proposed HACCP concepts and regulations within the existing Federal manuals which govern the production and processing of all cultured and natural harvested bivalves.

Two HACCP manuals (Otwell and Garrido, 1995) for cultured shellfish have been generated by this work in conjunction with SRAC.

WORK PLANNED:

All project work has been completed. A final "Train-In-Place (T.I.P.)" training program to assist TQA & HACCP implementation in aquaculture production and processing will be included in the SRAC project termination report.

IMPACTS:

Reviews of previous and current literature and data sources further substantiate the food safety status for southern aquacultured products. Project activity helped found a national "Seafood HACCP Alliance for Education and Training" which will lead to more uniform implementation of control measures for aquacultured product safety. Project activity also fostered cooperative projects funded by USDA to implement HACCP programs in actual aquaculture process settings for cultured bivalves, catfish, crawfish and trout.

Manuals for commercial guidance in implementation of TQA & HACCP programs are now available for cultured oysters and clams.

OBJECTIVE 1B: CONDUCT A FORUM TO ASSESS ALL RELEVANT DATA ON FOOD SAFETY OF AQUACULTURED FOODS. THIS EVENT WILL ASSEMBLE ALL KNOWLEDGEABLE INDIVIDUALS THAT CAN BRING THEIR EXPERTISE TO BEAR ON THIS SUBJECT.

PROGRESS AND PRINCIPAL ACCOMPLISHMENTS:

An *Aquaculture Safety Forum* was held February 2-4, 1993, at the Auburn University Hotel and Conference Center. The two-and-a-half-day *Forum* brought approximately 45 industry, academic, and government agency representatives from 11 southeastern states together to assess all the relevant data available on the safety of aquacultured foods. The plenary sessions provided opportunities for aquaculture researchers and Extension workers to update the group on recent research findings and other current topics. The breakout sessions afforded an opportunity for *Forum* participants to develop "White Papers" about the present status and future needs of the chemical and microbial aspects of aquacultured foods in the southeastern United States. All *Forum* participants received an evaluation form on which their perceptions of various aspects of the *Forum* could be rated on a scale of 1 (=Poor) to 5 (=Very Good). Forty percent of the evaluations were completed and returned. The following ratings are presented as means +/- standard deviations: the overall format of the *Forum* received a very favorable rating of 4.72 +/- 0.45. The attendees were also favorably impressed with the strength of the agenda (4.67 +/- 0.47) and the quality of the speakers (4.61 +/- 0.49). Evaluation respondents indicated that the degree to which the *Forum* addressed the

issue of aquaculture products safety merited a rating of 4.56 +/- 0.60.

A 157-page *Proceedings of the Aquaculture Products Safety Forum* was produced. The *Proceedings* included transcripts of 20 formal presentations made during the plenary sessions, plus recommendations made by working groups regarding microbial and chemical safety of aquacultured food products. Nearly 275 copies of the *Forum Proceedings* were distributed to extension workers, researchers, and government agency representatives in 33 states plus Puerto Rico and the Virgin Islands. While no formalized method was established to evaluate the Proceedings, informal comments were positive with regard to content, utility, layout, and design of the Proceedings.

A 60-minute live, interactive *Aquaculture Products Safety* satellite videoconference was produced which highlighted the objectives and recommendations developed during the *Forum*. Among the issues discussed were: Hazard Analysis of Critical Control Points (HACCP) method of fishery product inspection, microbial aspects of aquaculture safety, and chemical residues and their relation to aquaculture safety. Another portion of the videoconference presented videotaped excerpts of interviews (conducted during the forum) in which the interviewees discussed what they perceived as the greatest needs related to aquaculture safety, and what would be the most appropriate ways to address those needs. A final segment of the program was devoted to questions and answers, some of them phoned in from interested viewers.

Videoconference Evaluation Forms were sent to each Alabama Cooperative Extension Service County Office. Although relatively few of the forms were returned, those who did respond felt the videoconference was worthwhile. Ratings of the panelists' presentations ranged from "useful" to "very useful". The interactive segment of the program was deemed beneficial, with viewers feeling "somewhat involved". The technical quality of the production received ratings that ranged from good to excellent.

IMPACTS:

Participant and viewer evaluation results were mentioned previously and demonstrate the very positive impacts that Objective 1b had on three distinct audiences. Since the conclusion of the "Forum Project", many researchers, Extension workers, and government agency personnel have commented as to the "focusing" effect produced by the *Forum*. Many believe that the *Aquaculture Products Safety Forum* helped to reduce the amount of overlap and increase the complementary nature of subsequent aqaucultured products research and Extension efforts in the Southeast.

OBJECTIVE 1C: PREPARE AND DISTRIBUTE A BIBLIOGRAPHY OF THE AVAILABLE PUBLICATIONS, MIMEOGRAPHS, FACT SHEETS, AND VIDEOS RELATIVE TO FOOD SAFETY AND SANITATION IN THE AQUACULTURE INDUSTRY.

ANTICIPATED BENEFITS:

The bibliography on available information on food safety and sanitation as related to the freshwater aquaculture industry will provide a vital resource to those interested in these topics. The information will be available both in the printed form and on computer discs.

PROGRESS AND PRINCIPAL ACCOMPLISHMENTS:

Academic institutions, governmental agencies and companies involved in processing aquacultured products were contacted. Requests were made to notify the researchers of any documentation within their groups that pertained to food safety and sanitation as related to the aquaculture industry. Information to be included in the bibliography has been compiled and final corrections are being made. Copies of the bibliography will be made and distributed to those involved in freshwater aquaculture.

WORK PLANNED:

Objective completed.

OBJECTIVE 1D: EVALUATE DATA ON MICROBIOLOGICAL QUALITY IN CATFISH, CRAWFISH, AND RAINBOW TROUT PROCESSING AND DISTRIBUTION OPERATIONS. DETERMINE IF THERE ARE CRITICAL CONTROL POINTS WHICH NEED ATTENTION.

ANTICIPATED BENEFITS:

The aquaculture industry will benefit directly from technical information generated in this project. Methods were developed and tested to identify control points during processing that result in increased microbial loads and to design alternatives to the process to enhance the overall microbial quality of processed aquaculture products. Methods were also developed to inhibit the proliferation of the human pathogen *Listeria monocytogenes* on ready-to-eat crawfish tail meat, including modified atmosphere packaging, heat pasteurization, and a combination of physical and chemical treatments. Vacuum skin packaging, an advanced packaging system, was shown to improve shelf life and product appearance of rainbow trout by inhibiting the production of *Clostridium botulinum* type E toxin. These results will help the industry in distribution and retailing and in developing standard procedures and methods for the examination of processed products to monitor and maintain microbial quality and safety.

PROGRESS AND PRINCIPAL ACCOMPLISHMENTS:

Evaluation of microbial data (aerobic plate counts, total coliforms, and *E. coli*) representing 5 replicate samples from each stage of processing collected on 5 separate occasions over a one and one half year period has revealed a critical control point. The magnitude of the increase observed at the critical control point in processing is not significantly different between seasons. Process modifications evaluated to date have not significantly reduced the impact of the critical control point on the overall microbial load. Additional process modifications, such as chlorine sprays, are currently being evaluated by the processor as a means of reducing microbial loads after the critical point in processing.

Sampling of processing plants during different seasons demonstrated that aerobic plate, total coliform and *E. coli* counts are affected by season. During warmer months of spring and summer, all parameters measured increased 10- to 100-fold. The increase was associated with higher surface microbial loads of catfish entering the processing plant. Although pond water was not analyzed, a change in water quality during the warmer months is probably the origin of the increase, because the level of microorganisms on fish is usually a function of the microbial content of the water. Methods of controlling waste production, excess nutrients and other parameters within the catfish ponds during this critical time period should be evaluated to determine if initial surface microbial loads of catfish can be reduced prior to entering the processing plant.

A pathogen survey of fully processed catfish fillets was conducted in conjunction with Virginia Polytechnic Institute and State University and Mississippi State University. Twenty fully processed fillets from each of 3 processing plants were collected on a quarterly basis for one year. Investigators from Auburn University were assigned analyses for the following three pathogens: *Edwardsiella, Salmonella*, and *Shigella*. *Edwardsiella*, which is primarily a pathogen of fish, was isolated from 12.3% of 220 fillets sampled. *Salmonella* and *Shigella* were less common and were isolated from 2.3% and 1.8% of fillets sampled, respectively. A slight seasonal increase in the number of fillets harboring *Edwardsiella* was observed, with 63% of the positives occurring in the spring and summer. A similar trend was not observed for *Salmonella* and *Shigella*, which were isolated on rare occasions throughout the year. The incidence of *Salmonella* and *Shigella* on catfish is lower than reported incidences for most other raw meats.

Glycerol monolaurate (monolaurin) inhibition of *L. monocytogenes* was affected by pH and testing medium; monolaurin activity increased as pH decreased. Monolaurin interacted additively with citric acid and synergistically with acetic acid, benzoic acid and lactic acid to inhibit *L. monocytogenes*. For growth prevention or destruction of *L. monocytogenes* in crawfish tail meat, 224 or 336 mM lactic acid was required, respectively. Destruction of the bacterium could be achieved with 224 mM lactic acid when 0.72 mM monolaurin was added.

Citric acid or potassium sorbate sprays applied to crawfish tail meat to a final concentration of 0.03 g/kg did not prevent growth of *L. monocytogenes* at 4°C. Potassium sorbate did, however, extend lag phase of the bacterium by 2 days. Thus, these treatments were not effective to control the bacterium.

Modified atmosphere packaging (MAP; 74.8% CO_2, 10.4% O_2, and 14.8% N_2) inhibited growth of *L. monocytogenes* in crawfish tail meat treated with 0 and 1% lactic acid (LA) and stored at 4°C when compared to air and vacuum packaging. No differences in effectiveness of the packaging atmospheres were observed with 2% LA. Addition of 200 µg/g glycerol monolaurate (ML) with 1% LA inactivated *L. monocytogenes* for 20 d at 4°C in each packaging atmosphere. This treatment reduced pH from 7.4 to 5.4.

Lactic acid addition to crawfish tail meat could increase the resistance of *L. monocytogenes* pasteurization temperatures. D_{60} values of *L. monocytogenes* in tail meat treated with 0, 0.5, 0.75, and 1% lactic acid were 4.68, 4.41, 3.46, and 2.49 minutes, respectively. Atmosphere surrounding the tail meat, whether air, O_2, CO_2, or N_2, had no apparent effect on heat resistance of the bacterium. *L. monocytogenes*, at levels naturally occurring, can be eliminated from crawfish tail meat by treatment with heat alone (60°C for 15 minutes) or heat (60°C for 8 minutes) combined with 1% lactic acid. Crawfish tail meat dipped in 1% lactic acid were brighter in color (enhanced redness and whiteness), had reduced fishy odor, and were firmer than untreated controls. These character changes were not disliked by taste panelists.

The effects of monolaurin and lactic acid, singly or combined, on *L. monocytogenes* attached to catfish fillets revealed that monolaurin up to 400 µg/ml had no influence on counts. Conversely, lactic acid-treated fillets had reduced counts compared to controls. Dipping in 0.85, 1.70, or 2.55% lactic acid for 30 minutes reduced counts by 0.9, 1.4, or 1.3 logs, respectively. Extending dipping time to 60 minutes resulted in little additional decrease in counts. Combining monolaurin with lactic acid yielded results similar to lactic acid alone. Hence, population reduction ability of the two compounds resides with lactic acid and not monolaurin.

Planktonic and adherent cells of *L. monocytogenes* were subjected to heat, monolaurin and acetic acid to evaluate biofilm removal from stainless steel. Planktonic cells were more sensitive than attached cells to the physical and chemical treatments. Effectiveness of 100 µg/ml monolaurin on destruction of biofilm cells was increased when combined with heat (60°C) or acetic acid (1%). Old biofilm cells (7 days) were more resistant than young biofilm cells (1 day) to the treatments. Cells in a rich nutrient environment were more resistant than those in a depleted nutrient environment. Results suggest that eradication of cells in biofilms is more easily accomplished when biofilms are young. Processors of aquacultured products should have frequent, routine cleaning and sanitation programs to minimize biofilm problems.

The growth and toxin production of *C. botulinum* type E in rainbow trout fillets held in vacuum skin packaging indicated no toxin was produced by *C. botulinum* type E in fillets stored at <3°C. This advanced packaging method improved the shelf life and product appearance. The use of modified atmospheres at 10°C had little practical usefulness. Carbonic acid dips

caused a slight reduction in microflora of trout (approximately a ½ log reduction); however, the effect was negated by the additional handling and cost involved in preparation of the dip. No *Salmonella* or *Listeria* were detected in any sample of rainbow trout during the study using FDA and USDA isolation and confirmation protocols.

Higher concentrations of CO_2 (60% and 100%) in modified atmospheres with no addition of O_2 extended shelf life of trout fillets at least 7 days longer than trout packaged in atmospheres containing O_2 at 3°C. The presence of O_2 in atmospheres encouraged growth of aerobic bacteria, psychrotrophic bacteria, yeasts, aerobic sporeformers, coliforms, proteolytic and lipolytic bacteria. The odor and appearance of fillets packaged in atmospheres containing O_2 were significantly less acceptable ($p<0.05$). Proteolytic and lipolytic bacteria were extremely sensitive to high CO_2 atmospheres resulting in a 4 to 6 log difference after 10-15 days of storage. The more rapid spoilage in trout packaged in O_2 containing atmospheres was probably due to breakdown of amino acids, fatty acid and-non protein nitrogenous compounds by lipolytic and proteolytic bacteria.

WORK PLANNED:

Investigations are in progress to evaluate the use of edible films to improve microbial quality of smoked rainbow trout. Growth and toxin production of *C. botulinum* type E on modified atmosphere packaged rainbow trout and catfish are being studied; the application of time and temperature indicators on packaged aquaculture products is being evaluated. The investigators will continue to communicate data and ideas to producers and processors to further improve the quality and safety of catfish from the farm to the consumer.

IMPACTS:

Processing steps have been identified where microbial counts increase faster than at other processing sites, which makes these sites targets to control microbial proliferation, thereby improving quality and microbial safety of the processed product. The project has focused directly on conditions which promote quality and safety of marketed aquaculture products. The training of processing plant personnel during the collection of base line data and the feedback of data to the industry will have a major impact on successful implementation of the HACCP concept and on the safety of aquaculture products.

Methods have been tested for the prevention of growth or destruction of the human pathogen *L. monocytogenes* on precooked ready-to-eat crawfish tail meat and the inhibition of *C. botulinum* toxin in rainbow trout fillets. These methods can prevent costly foodborne outbreaks associated with these bacteria.

It has been demonstrated that the shelf life of rainbow trout can be extended by one week at 3°C by packaging with 60% CO_2 and 40% N_2. Also, packaging of trout under 60% CO_2/40% N_2 did not significantly increase anaerobic spore counts during the 21-day storage period at 3°C.

OBJECTIVE 1E: DO SUPPLEMENTAL LABORATORY WORK TO CLARIFY AREAS OF CONCERN. THIS IS DESIGNED TO FILL GAPS IN THE DATABASE, NOT TO CONDUCT AN INDUSTRY-WIDE SURVEY.

ANTICIPATED BENEFITS:

The project will provide the aquaculture industry with the necessary database and expertise to improve the microbial quality and safety of aquaculture products and to aid in the implementation of industry obtainable standards and effective HACCP programs.

PROGRESS AND PRINCIPAL ACCOMPLISHMENTS:

Data collected from each stage of processing from whole fish to finished product reveal that

the overall microbial load on catfish increases by 100- to 1000-fold during processing. Three conditions are chiefly responsible for the increase: (1) contamination of flesh from equipment surfaces after the skin is removed, (2) growth of contaminating organisms during processing and holding, and (3) cross contamination of fillets during specific stages of processing. Analysis of farm raised catfish fillets from several retail markets indicated an additional 100-fold increase in the microbial load during distribution and final marketing. Although differences in aerobic, total coliform, and *E. coli* counts were evident among retail markets, it is not possible from these data to determine the cause of the higher microbial loads. The incidence of three pathogens, *L. monocytogenes*, *E. coli* O157:H7, and *Salmonella* species on retail catfish fillets was also determined. *L. monocytogenes* was isolated from 5 fillets (5.4%), no *E. coli* O157:H7 was detected and a *Salmonella* species was isolated from one fillet (1.1%). Contrary to expected trends, no correlation existed between retail markets with high aerobic, total coliform and *E. coli* counts and the incidence of the three pathogens. Data collected from these studies continues to build a database essential in determining the stages of processing, distribution and marketing which significantly impact the microbial quality of farm raised catfish and can be used to develop alternative processing and handling procedures to further improve the microbial quality and safety of catfish products.

IMPACTS:

Substantial resources in terms of expertise and manpower have been provided to build a microbial database for processed catfish, which were previously not available to the aquaculture industry.

OBJECTIVE 2. INVESTIGATE VARIOUS METHODS TO REDUCE AND DETECT SIGNIFICANT PATHOGENIC AND SPOILAGE MICRO-ORGANISMS ON PROCESSED CATFISH, RAINBOW TROUT, AND CRAWFISH. COORDINATE FINDINGS WITH THE EDUCATIONAL PUBLICATIONS WORK GROUP IF NECESSARY.

ANTICIPATED BENEFITS:

Catfish processors have continued to express an interest to initiate a total quality assurance program to meet present and future market demands for increased quality assurance of fresh and processed products. To assist the processors in this effort, a microbiological based quality evaluation was performed on finished products. The microbiological based quality evaluation program included a routine microbial evaluation of the processed products for selective indicative bacteria (aerobic, fecal coliform and *E. coli* counts). Currently there are no standards in the United States for dressed fresh/frozen catfish products using indicative microbes as the criterion. However, there are general standards for fresh fish products developed by The International Commission on Microbiological Specifications for Foods. Wholesale distributors in the United States and Canada are stipulating purchase specifications for catfish products that processors must meet in order to prevent their rejection. These specifications are particularly directed toward *E. coli* counts even though all *E. coli* are not pathogenic. Unfortunately, the buyer's specifications that reflect high standards may not be consistently achieved during processing. The indicative microbiological quality control program could define the development of realistic and achievable standards. Processors could use these standards to market their products while assuring both product quality and safety.

To illustrate the benefit, if a buyer specifies a product count less than x cfu/g and the cfu/g are lower than the specifications by 10 fold, the processor may be able to request a premium price for the higher quality. Domestic consumers, however, are less quality conscious than the Canadian, European, and Japanese consumers. The European and Japanese consumers will pay premium prices for product quality. Processors have expressed a desire to expand their markets

to Europe and Japan where, generally, the standards are higher. Also, these markets are desirable since they have the potential for greater profits. Thus, an indicative microbiological quality control program could be beneficial for the processor.

Listeria monocytogenes contamination of foods remains the focus of vigorous efforts by government and industry concerned with food safety, especially that related to ready-to-eat products. In a highly competitive market, as in the catfish industry, processes that could reduce initial numbers of bacteria on fillets or extend shelf life and improve product safety would result in a more stable economic environment for the catfish processor. Due to the decline of red meat consumption and steady increase in aquaculture fish consumption, this information may be vital to the industry by providing direction for future quality control programs.

PROGRESS AND PRINCIPAL ACCOMPLISHMENTS:

Both indicative and pathogenic microbial flora of fresh aquacultured channel catfish fillets were sampled to evaluate the microbiological quality. Three catfish processors participated and were selected with consent to represent small through large processors. Products were screened during four different seasons (e.g., summer, fall, winter and spring); there were significant differences in the microbiological quality of fillets due to processing conditions and to production seasons. All of the processors produced products that were acceptable from a microbiological safety and a quality perspective. However, there was a problem with *E. coli* counts obtained from some of the products; *E. coli* counts in products were high during the summer season and decreased with relatively cooler weather. Some processors have purchase specifications based on *E. coli* counts for their products and meeting the specification could be difficult at times. It should be realized that not all *E. coli* cells are pathogenic.

Fresh catfish fillets were also screened for common and new and emerging pathogens. Products were obtained from the same processors and were analyzed at four different times of the year. In all, 120 samples were examined for each of the 11 pathogens, including *Campylobacter jejuni / coli, Escherichia coli* O157:H7, *Klebsiella pneumoniae* subsp. *pneumoniae*, *Plesiomonas shigelloides* and *Vibrio cholerae*. *P. shigelloides*, an emerging pathogen, and *V. cholerae* were isolated from the fresh catfish fillets. Frequency of isolation of *P. shigelloides* was very low and the pathogen was isolated only when the weather was warm; the isolation rate for *V. cholerae* was higher but was also isolated only during the warmer weather. Since these products are raw and are not consumed without cooking, the need for proper product handling after processing through the distribution system should be emphasized. Aquacultured products have a history of product safety and the combination of proper handling and cooking will prevent foodborne illness from these pathogens.

Fresh aquacultured catfish fillets were also surveyed for their antibiotic resistant bacteria during the various seasons. There was a significant difference in the number of antibiotic resistant bacteria which was attributed to the production source.

To improve the quality of the fresh catfish products, several mechanical and chemical processes were evaluated. High pressure spray washing has been evaluated using water at low temperature. Chemical agents (lactic, propionic and acetic acids) were added to water to increase shelf life of the products. Propionic acid was the best acidulant in reducing bacterial counts in broth cultures. However, during washing tests, all acids exhibited similar results by reducing bacterial counts by 1.0 log cycle.

L. monocytogenes does not appear to be very prevalent in aquaculture ponds or on whole catfish; contamination of fillets appears to occur post-harvest, and can be present on more than

30% of fillets.

Catfish fillets, prepared by harvesting and processing in an industrial setting at L & R Aqua catfish farms in Damon, TX, were treated by tumbling with 0.5, 1.0, 2.0, and 3.0% lactic acid for 1 or 3 min, followed by draining through placement of the fillet in a stainless steel perforated tub for 1 minute. Each group of treated fillets was placed in individual 100-L plastic bags and held in refrigerated storage at 4°C with ice surrounding the bags.

In general, lactic acid treatments extended the shelf life of catfish fillets 2-3 days compared to the control. Higher concentration lactic acid treatments imparted a discoloration to the fillets, but no detectable off-odors were noted. Total volatile nitrogen values remained constant at around 22-24 mg/100 g for all treatments. Trimethylamine values similarly remained unchanged during the shelf life study.

A procedure was developed and evaluated for a non-destructive method of sampling channel catfish for bacteriological analysis. The procedure is applicable for sampling of processed fish, fillets, frozen and breaded products. Benefits of the procedure include improved sensitivity of microbial detection, reduced time and cost of sample preparation for microbial analysis, and is non-destructive and easily accomplished. The procedure has been standardized to maximize the detection of microbes on processed catfish, and data are being prepared to seek approval of the procedure as an official method of microbial sampling of processed catfish. During the past year the procedure was evaluated for the detection of bacterial pathogens. Studies have demonstrated that the rinse technique can consistently recover as few as 5 viable *E. coli* O157:H7, 3 viable *S. typhimurium*, and 4 viable *L. monocytogenes* inoculated per catfish fillet. Because the procedure involves sampling the entire surface of the processed fish and includes two pathogen enrichment steps, it can detect low numbers of pathogens on the surface of catfish.

A commercially available one-day rapid *E. coli* enumeration test (EC Petrifilm 3M Company) was evaluated and compared to a standardized FDA procedure. Data revealed that the rapid test provides accurate counts in one-eighth the amount of time as compared to the FDA procedure. The rapid test will allow processors to ensure the microbial quality of their product prior to shipment to the public.

WORK PLANNED:

Objective completed.

IMPACTS:

Significant reductions in microbial populations could be obtained at processing facilities with alternative unit processing operations, such as the application of irradiation energy, the use of microbicidal chemicals in chilling waters, or temperature adjustments from harvest through product storage. The project has indicated that catfish products have pathogenic microbial profiles to prevent food borne illness in normal individuals. Also, pathogenic microbial profiles should permit international sales in most foreign countries.

The non-destructive procedure for sampling catfish is presently being used at the Fish Farming Center (Alabama Cooperative Extension Service) to evaluate catfish products from processing plants in Alabama. The rapid *E. coli* enumeration test will allow processors to ensure the microbial quality of their product prior to shipment to the general public and to demonstrate compliance with specific microbial specifications established by individual buyers in domestic and foreign markets.

Anti-listerial processing aids, such as Alta 2341, dehydroacetic acid, and nisin, can markedly lower levels of *L. monocytogenes* on catfish fillets. Ice impregnated with these antimicrobials reduces *L. monocytogenes* on catfish fillets and would incorporate easily into current retail practices.

Some improvement in shelf life of catfish fillets can be obtained through lactic acid treatment at processing. However, the benefit of increase in shelf life (2-3 days) would have to be weighed against increased processing costs to determine probable positive impacts of the treatment.

OBJECTIVE 3. CONDUCT A FOOD SAFETY HACCP AUDIT TO DETERMINE IF THIS APPROACH WOULD BE COST-EFFECTIVE AND RESULT IN INCREASED PRODUCT SAFETY.

ANTICIPATED BENEFITS:

The HACCP audit effort should provide the basis for the implementation of HACCP audits in individual plants. The audit form developed can be adopted or modified to fit individual needs.

PROGRESS AND PRINCIPAL ACCOMPLISHMENTS:

A HACCP audit sheet was developed and evaluated by a commercial processor in Mississippi. The audit sheet will be available to those who are interested.

IMPACTS:

The HACCP audit will become a quality assurance tool for the aquaculture processing industry and result in increased economic benefits in the future.

WORK PLANNED:

Objective completed.

OBJECTIVE 4. PRODUCE NEW PUBLICATIONS TO COMPLEMENT EXISTING PUBLICATIONS ON FOOD SAFETY AND SANITATION. THESE WOULD BE COMPLETED DURING THE SECOND AND THIRD YEARS OF THE PROJECT.

ANTICIPATED BENEFITS:

Information gathered for this project will be a valuable tool for improving the microbiological safety of aquaculture products. This information will be given to state cooperative extension services to relay to the aquaculture industry because their knowledge of target industries and individuals within their state makes this method of education very effective. No other means are presently available to adequately relay this information than by state cooperative extension services.

PROGRESS AND PRINCIPAL ACCOMPLISHMENTS:

Reports and relevant information from research scientists as well as a literature review dealing with the food safety/microbial study issues have been obtained. Representatives of both processor and consumer groups were interviewed; both groups agreed that negative media coverage has resulted in consumers perceiving that numerous fishery products are unsafe, and that there is a need for written materials to bolster consumers' confidence in aquacultured products.

Approximately 70 published articles, fact sheets, videos, and oral presentations at technical and consumer meetings have been produced during the course of the project. Information on foodborne illnesses due to microbiological contamination has been included in fact sheets and brochures. Valuable information including the purchasing, storage, handling, preparation, temperature control, spoilage and processing of aquacultured products has been produced. Publications have been written on pesticides, residues, risks, chemicals and regulators and their role in microbial food safety. All the information collected has produced substantial amounts of educational materials for the aquaculture industry and the general public.

WORK PLANNED:

Publications are planned for the research work which is to be completed during Year 3;

data from these studies will be given to the Extension publications project for development into fact sheets, brochures, and videos.

APPENDIX

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Anthony, B.K., F.A. Draughon, M.E. Denton, and W. Tan. 1993. Comparison of methods for isolation of *Listeria* from rainbow trout (*Oncorhynchus mykiss*). Proceedings, Annual Meeting International Association Milk Food and Environmental Sanitation, Abstract #143, Atlanta, GA.

Bolton, L.F., Huang, Y.W., and Harrison, M.A. 1993. Effects of sodium lactate on microbiological changes and Torrymeter readings of prepackaged rainbow trout during refrigerated storage. Institute of Food Technologists Annual Meeting, July 10-14, Chicago, IL.

Huang, C.Y., Zheng, M., and Huang, Y.W. 1993. Psychrotrophic plate count, nucleotide degradation products and color changes of sodium lactate treated rainbow trout fillets as affected by packaging method at 4°C. Institute of Food Technologists Annual Meeting, July 10-14, Chicago, IL.

Huang, Y.W., Bolton, L.F., Harrison, M.K., and Toledo, R.T. 1993. Effects of trisodium phosphate and lactic acid on microbiological and physical quality of packaged rainbow trout. International Association Food, Milk and Environmental Sanitation Annual Meeting, July 31-August 3, San Antonio, TX.

Huang, Y.W., Huang, C.Y., and Burtle, G. 1994. *Aeromonas hydrophila* and psychrotrops population of cage- and pond-raised channel catfish. Institute of Food Technologists Annual Meeting, June 25-29. Atlanta, GA.

He, L.P., and Huang, Y.W. 1994. Use of time temperature indicator to monitor the shelf life of packaged fresh catfish. International Association Food, Milk and Environmental Sanitation Annual Meeting,

July 31-August 3, San Antonio, TX.

Huang, C.Y., and Huang, Y.W. 1994. Effects of packaging system on lactate treated tilapia fillet stored at 4°C. International Association Food, Milk and Environmental Sanitation Annual Meeting, July 31-August 3, San Antonio, TX.

Garren, D.M., Harrison, M.A., and Y.W. Huang. 1993. *Clostridium botulinum* type E outgrowth and toxin production in vacuum-skin packaged rainbow trout. Abstract, Institute of Food Technologists, July 10-14, Chicago, IL.

Huang, Y.W. 1993. Uses of sodium lactate on packaged rainbow trout. Aquaculture Products Safety Forum Proceedings, February 2-4, Auburn University, AL.

Huang, Y.W. 1993. Use of vacuum-skin packaging to improve product quality of fresh fish treated with sodium lactate and propyl gallate. Abstract, Food Preservation 2000: Integrating Processing, Packaging and Consumer Research, October 19-21, Natick, MA.

Flick, G.J. 1994. Developing a total quality assurance program. Presented paper at the annual catfish processors meeting in Greenwood, MS. Sept. 1994.

Fernandes, C.F. and G.J. Flick. 1995. Evaluation of riboflavin-methionine superoxide system for improving the quality of aquacultured catfish fillets during the chilling process. Poster presented at the 56th annual meeting of the Institute of Food Technologists, Anaheim, CA. June 16-19.

Silva, J.L., C.F. Fernandes, G.J. Flick, T.A. McCaskey, E. Marroquin, C. Handumrongkul and A. F. Hood. 1995. Effect of cleaning on microbial loads in a catfish filleting operation. Poster presented at the 56th annual meeting of the Institute of Food Technologists, Anaheim, CA. June 16-19.

Fernandes, C.F., G.J. Flick, J.L. Silva, T.A. McCaskey and A.F. Hood. 1995. Evaluation of microbial swabs for releasing HCMC and their viability on ice using 3M Petrifilm. Poster presented at the 82nd annual meeting of the International Association of Milk, Food and Environmental Sanitarians, Pittsburgh, PA. Jul. 30 - Aug. 1.

Fernandes, C.F., G.J. Flick, J.L. Silva, T.A. McCaskey and A.F. Hood. 1995. Effect of processing protocols on quality of aquacultured fresh catfish fillets. Poster presented at the 82nd annual meeting of the International Association of Milk, Food and Environmental Sanitarians, Pittsburgh, PA. Jul. 30 - Aug. 1.

McCaskey, T.A. 1993. Bacterial evaluation of catfish products. Proceedings of the Aquaculture Products Safety Forum, Auburn University, Alabama. February 2-4, 1993.

Hannah, T.C., and T.A. McCaskey. 1995. Evaluation of the microbial quality and safety of retail channel catfish fillets. Proceedings of the 92nd Annual Meeting Southern Regional Sections of Institute of Food Technologists, New Orleans, LA. January 28 - February 2, 1995.

Mu, D.M. and Huang, Y.W. 1995. Effect of trisodium phosphate on *Listeria monocytogenes* attached to rainbow trout. Intnatl. Assocn. Food Milk and Environ. Sanitation Annual Meeting, July 30-August 2, Pittsburgh, PA.

Zhuang, R.Y., Huang, Y.W., and Beuchat, L.R. 1995. Quality changes in pre-packaged shrimp and catfish treated with sodium acetate, sodium lactate and propyl gallate during refrigerated storage, June 3-7, Anaheim, CA.

SUPPORT:

YEAR	SRAC FUNDING	OTHER SUPPORT					TOTAL SRAC+ OTHER SUPPORT
		UNIVERSITY	INDUSTRY	OTHER FEDERAL	OTHER	TOTAL OTHERSUPPORT	
1	85,000	77,623				77,623	162,623
2	225,000	139,740	2,500	2,000	15,000	158,240	383,240
3	260,000	141,760	200	1,800		143,760	403,760
Total	570,000	359,123	2,700	3,800	15,000	379,623	949,623

B. AQUACULTURE FOOD SAFETY: RESIDUES

Progress Report
For the Period
September 11, 1992 to August 31, 1995

FUNDING LEVEL:

Year 1 ..... $100,000
Year 2 ..... $155,000
Year 3 ..... $101,000
Total $356,000

PARTICIPANTS:

University of Georgia (Lead Institution) - George Lewis, James Shelton, P. Bush, C. R. Santerre (formerly at University of Georgia now at Silliker Laboratories, Inc.)

University of Florida - Cheng-I Wei

Texas A & M University - Delbert Gatlin, James T. Davis

Mississippi State University - Earl G. Alley, L. G. Lane

Auburn University - W. Rodgers, Dehai Xu

Louisiana State University - Robert M. Grodner, Wendell Lorio

ADMINISTRATIVE ADVISOR:

Neal Thompson, Professor
University of Florida
Gainesville, Florida

PROJECT OBJECTIVES:

Objective 1: Information on residues is available for many food products and some is available for specific aquaculture products. Various state and federal agencies and private companies have collected data on chemical residues in channel catfish. The quality and quantity of this data is unknown. For instance, distinctions between farm-raised channel catfish and 'wild' channel catfish are often overlooked. The exposure of 'wild' channel catfish to hazardous compounds is often greater due to point source environmental contamination and data collected from 'wild' catfish may not be representative of aquaculture products. In the development of an appropriate data base, related publications and educational programs, distinctions will be made between farm-raised channel catfish and 'wild' channelcatfish.

Survey and review of databases for pesticide, PCB and metal residues in farm-raised catfish, crawfish and rainbow trout.

Objective 2: Protocols and guidelines are to be developed and disseminated for a residue monitoring program.

Objective 3: All research scientists participating in the study are to be contacted and requested to send reports and/or any information that they have that could be used in the development of Extension-type fact sheets or brochures. The information received will be catalogued as reference sources so that outlines and eventually fact sheets can be written with this new data. Also, a library search will be conducted for additional information that may be applicable in writing the products mentioned above.

Objective 4: The University of Georgia is actively developing a chemical application record system for producers. This information will be completed in the near future.

Objective 5: The steady growth in per capita consumption of fish and seafood products has caused increased attention to product safety. There is always a potential for problems due to contamination of foods by pesticides, heavy metals, and pharmaceutical compounds either from direct or indirect sources. These potential

problems can occur on the farm, during processing, or at the wholesale/retail levels. There is a need to minimize potential problems during and following production by determining the influence of processing on residues.

The aim of this study is to determine the fate of residues from the farm to the processing plant and finally to a product which would be prepared by the consumer.

Objective 6: The aim of this project is to attempt to improve the available information on residues in farm-raised channel catfish, crawfish and rainbow trout so that consumers can more realistically assess issues related to consumer safety from scientific data.

ANTICIPATED BENEFITS:

Objective 1: The aquaculture industry will have scientifically-generated residue data to support its contention that aquaculture products are safe for consumption.

Objective 2: Residues will be monitored by producers to increase consumer confidence in the safety of aquaculture products.

Objective 3: Educational programs are invaluable to preventing residue problems in the industry in the future.

Objective 4: Proper record-keeping will also help to ensure that pesticides and animal drugs have been used in a safe manner.

Objective 5: The benefits of food processing and preparation for reducing residue levels in edible tissue will be determined.

Objective 6: Pesticide and heavy metal residue data will be made available for selected aquaculture products. Preliminary indications are that the fish sampled in this study are free from residues or have much lower residues than wild fishes.

PROGRESS AND PRINCIPAL ACCOMPLISHMENTS:

Objective 1: Data included in this report on fish and seafood products were retrieved from FOODCONTAM, a national database consisting of state generated information on pesticide and other toxic chemical residues in human foods. Data are generated by state agriculture, food, and health protection agencies responsible for assuring the quality and safety of foods grown or imported into their states. The data are presented in four separate computer generated packets for FY 1986-1989, FY 1990-1992, FY 1993, FY 1994 and First Quarter FY 1995.

Objective 2: Protocols and guidelines were developed and disseminated for a residue monitoring program. We are currently using these protocols in collecting and analyzing residue data.

Objective 3: Educational materials are being developed as the project data become available.

Objective 4: A chemical application record system will be developed in the third year of the project.

Objective 5: Work is concluding to determine the fate of residues during the processing of fish. Analytical methods for pharmaceutical compounds have been developed at the University of Florida. Dosing of fish with antibiotics or pesticides and collection of fillets has been completed at Auburn University. Processing of the dosed fish was done at the University of Georgia. Fish samples were analyzed at Florida and Auburn University for antibiotic residue analysis on raw and processed fillets. The University of Florida is completing analysis of lipid and moisture concentration on samples. Two of six pesticides were analyzed at the University of Georgia and the remaining samples will be analyzed at Mississippi State University within the next six months. Production studies involving residues

from antibiotics applied during production have been completed at Texas A & M University.

Objective 6: Progress for the first three years included: development of standard operating procedures for sample collection, sample preparation, pesticide analysis, metal analysis, and quality assurance; producers' and processors' samples were submitted to the University of Georgia for sample preparation; analysis of samples should be completed within the next six months at the University of Georgia and Mississippi State University. Residue data will be provided to cooperators in the eight states.

WORK PLANNED:

The following provides information concerning the sequence of research activities which have been completed:

CATFISH PROCESSING

After appropriate dosing of pesticides and pharmaceuticals, channel catfish were processed by researchers at the University of Georgia into four consumer-ready products in order to determine the effects of different processing conditions on the residues. Catfish were stunned, beheaded, eviscerated, skinned, filleted and washed. Both fillets from each fish were frozen for subsequent residue analyses either before or after cooking. One of the frozen complimentary fillets was thawed then either: (1) breaded and fried in vegetable oil at 190°C; (2) breaded and baked at 190°C in a conventional oven; (3) injected with a mixture of polyphosphates and citric acid, then frozen for four weeks, thawed, breaded and fried in vegetable oil at 190°C; or (4) brined and smoked in a temperature- and humidity-controlled smoke house to achieve an internal temperature of 71°C for 30 min. Raw and cooked fillets were homogenized following processing into a table-ready item and stored at -80°C until analyses.

PESTICIDE AND PHARMACEUTICAL RESIDUE ANALYSES

Pesticide residues are being determined in fillets from duplicate fish for each treatment using standard procedures (FDA, PAM-1 Methods, AOAC Methods, etc.).

Development of methods to determine residues of pharmaceuticals in catfish were conducted at the University of Florida from dosed catfish raised at Auburn and Texas A&M Universities. Processed catfish samples which were generated during this study have been analyzed at the University of Florida and Auburn University. Before and after processing, pharmaceutical residues were quantified in fillets from three replicate fish per treatment by high performance liquid chromatography (Weiss et al., 1987) or other appropriate methods. Finally, moisture and fat content will be measured in raw and prepared samples.

LONG-TERM PHARMACEUTICAL FEEDING

There is some concern that pharmaceuticals are being used in commercial aquaculture for prophylaxis. Since these practices may significantly influence residue levels in the fish and thus product safety, additional experiments were conducted to determine the effects of long-term exposure to pharmaceuticals on residue levels and depletion rates.

Two separate feeding trials were conducted at Texas A&M University in which experimental diets containing graded levels of oxytetracycline and Romet-30 (sulfadimethoxine and ormetoprim) (0, 1x, 2x, and 4x recommended dose) of each antibiotic alone or in combination were fed to replicate groups of fingerling channel catfish in flow-through aquaria under controlled conditions (Gatlin et al., 1986) for two months. All fish were then fed a control diet without antibiotic supplementation for one additional month. Growth and feed efficiency of fish fed the various diets was determined weekly. At monthly intervals,

muscle samples were obtained from one fish per tank (three fish per treatment) and analyzed at the University of Florida for oxytetracycline and Romet-30 residuals using a modified procedure from Weiss et at. (1987). Catfish samples from this experiment were also used in the methods development phase to determine the appropriate steps necessary when performing sampling, sample extraction, clean-up, concentration, and analyses.

Farm-raised channel catfish, rainbow trout and red swamp crawfish were collected from commercial ponds and processing sites at intervals for the two-year period. Locations for sample collection are as follows:

Location	Catfish Processors	Catfish Pond Sites	Rainbow Trout Pond Sites	Crawfish Production Sites
Mississippi	3	4	--	--
Alabama	2	3	--	--
Georgia	--	4	2	--
Louisiana	2	3	--	3
Tennessee	--	3	3	--
Florida	2	4	--	--
Texas	2	4	--	2
N. Carolina	--	--	20 *	--
TOTAL	11	25	25	5

*Samples were only submitted following a single collection from this location.

Pond sites for channel catfish, rainbow trout and red swamp crawfish were selected to obtain the most diverse and representative sampling sites from each state. Catfish and rainbow trout were harvested from ponds within each state; fillets, including bellyflap, were collected and frozen. Crawfish were harvested; raw tail flesh was obtained and frozen. In addition, catfish, rainbow trout and crawfish feed were collected for analyses when fish with elevated residues are found. Catfish fillets obtained from commercial processing facilities were collected and frozen. Frozen samples were shipped to the University of Georgia where a composite sample will be coded, homogenized, frozen and distributed to analytical facilities. Samples are being maintained below 0°C for five years for future retesting or additional residue analyses. The following residues will be determined:

<u>Organochlorines</u>

PCB's (1242, 1248, 1254, 1260)
Chlordane's
BHC's (Lindane, etc.)
Heptachlor
Heptachlor Epoxide
Dieldrin
Endosulfan I & II
Endosulfan sulfate
Endrin
o,p'- and p,p'-DDD, DDE, DDT
Methoxychlor
Toxaphene
Hexachlorobenzene
Mirex

<u>Organophosphates</u>

Chlorpyrifos
Diazinon
Malathion
methyl-Parathion
ethyl-Parathion

<u>Pyrethroids</u>

Cypermethrin
Fenvalerate

<u>Metals</u>

Copper
Cadmium
Lead
Mercury
Arsenic
Selenium
Chromium
Barium
Silver

Since pharmaceutical compounds are approved for use during production, samples of catfish are being maintained below 0°C until such time as the methods have been satisfactorily developed and additional funds become available. Multiples of all samples collected during this study will be maintained below 0°C for five years from collection date for subsequent residue determinations which may be of interest to the industry.

Quality assurance is being conducted by the University of Georgia in a facility which is independent of sample analyses. Standard Operating Procedures (SOP) have been developed to ensure the validity of the data generated during this study.

IMPACTS:

Objective 5: Regulatory agencies are currently evaluating animal drugs for use in aquaculture systems. A major impact of this study will be to determine the fate of antibiotics from production through processing. It is not known whether prophylactic treatment with antibiotics will increase the residues in harvested catfish which have or haven't been held for adequate withdrawal times before harvest.

One of the important educational aspects which will result from this study will be a better understanding of the fate of antibiotics used in production. The information generated during this study will be communicated to production and processing segments of the industry to help avoid problems which may occur involving resistant organisms and residues in the processed fish.

Objective 6: The results generated during this objective are likely to have a major impact on the aquaculture industry. The data are expected to follow trends from other limited sampling experiments which demonstrate much lower residues in farm-raised products than in wild caught fish. The results from this study will be used to find potential problems relating to elevated residues and solve these problems with the help of the producer or processor. Furthermore, this study will serve as a pilot study for the industry to develop a quality assurance program to routinely monitor for residues in aquaculture products.

Educational opportunities are also expected as a result of this project. First, producers and processors will be made more aware of the importance in reducing residues in aquaculture products. Second, there will be many analytical methods developed from this study which will be useful for people to conduct future testing. Third, undergraduate and graduate students as well as faculty participants will become more aware of aquacultural products and practices and be better able to serve the industry.

PUBLICATIONS, MANUSCRIPTS, OR PAPERS PRESENTED:

Campbell, J., N. Khanna, T.K. Park, C.R. Santerre, R. Reinert, V. Blazer and R. Barrows. 1994. Absorption of dieldrin in feed by striped bass. Bulletin of Environmental Contamination and Toxicology (submitted).

Khanna, N., C.R. Santerre, Dehai Xi and Y.W. Huang. 1995. Influence of Processing on Residues of Dieldrin and p,p'-DDE in Channel Catfish. Journal of Food Protection (in preparation).

Wei, C. et al. 1995. Determination of Oxytetracycline, Sulfadimethoxine and Ormetoprim Residues in Catfish Using HPLC. (in preparation)

Wei, C. et al. 1995. Processing Affects on Oxytetracycline, Sulfadimethoxine and Ormetoprim Residues in Catfish (in preparation).

SUPPORT:

Additional support ($95,048 over two years) has been received by the University of Georgia from the National Biological Survey under a project entitled, "Use of Immune Factors in Fish as Indicators of Environmental Contamination" with R. Reinert as the PI and C. Santerre as CoPI and V. Blazer as the agency coordinator. Results from this research are demonstrating the relationship between residue levels of pesticides in fish and exposure through the diet.

YEAR	SRAC FUNDING	OTHER SUPPORT					TOTAL SRAC+ OTHER SUPPORT
		UNIVERSITY	INDUSTRY	OTHER FEDERAL	OTHER	TOTAL OTHER SUPPORT	
1	100,000	29,978				29,978	129,978
2	155,000	60,785		95,048		155,833	310,833
3	101,000	48,651				48,651	149,651
Total	356,000	139,414		95,048		234,462	590,462

C. IMPROVING PRODUCTION EFFICIENCY OF WARMWATER AQUACULTURE SPECIES THROUGH NUTRITION

Progress Report
for the period
January 1, 1994 to August 31, 1995

FUNDING LEVEL:

Year 1 ..... $280,310
Year 2 ..... $249,485
Year 3 (projected) $234,705
Total $764,500

PARTICIPANTS:

Texas A&M University - Delbert M. Gatlin (Institutional leader), William H. Neill, James T. Davis, L.V. DiMichele, J.B. Cotner

Mississippi State University -E.H. Robinson (Institutional leader), H.R. Robinette, R.P. Wilson

Auburn University - R.T. Lovell (Institutional leader), Upton Hatch

University of Arkansas at Pine Bluff - Rebecca T. Lochmann

Louisiana State University -R.C. Reigh

Kentucky State University - C.D. Webster (Institutional leader), J.H. Tidwell

East Carolina University - Margie L. Gallagher

University of Georgia - Gary J. Burtle (Institutional leader), G. L. Newton

University of Memphis - Kenneth B. Davis (Institutional leader), Bill A. Simco

ADMINISTRATIVE ADVISOR:

Dr. L. B. Daniels, Associate Director
Arkansas Agricultural Experiment Station
University of Arkansas
Fayetteville, Arkansas

PROJECT OBJECTIVES:

1. Determine minimum effective levels of vitamin and protein/amino acid supplementation to maximize feed efficiency in commercial-scale channel catfish production.

2. Evaluate feeding strategies and their effects on commercial-scale channel catfish production. Of particular concern will be the effects of feeding time, frequency, and rate (satiation or restricted) on production efficiency. Feeding regimes to achieve maintenance of body weight and compensatory growth also will be addressed.

3. Investigate nutritional aspects that are most limiting production of baitfish and hybrid striped bass. This will include determining digestible energy and availability of amino acids in practical feedstuffs for hybrid striped bass and the relative contribution of natural foods and prepared feeds to growth of baitfish under conditions of commercial production.

ANTICIPATED BENEFITS:

It is anticipated that results from part of this project will provide more cost-effective diet formulations and improved feeding strategies to be used in the commercial rearing of channel catfish. Advancements in these areas will significantly improve production efficiency by reducing diet costs and increasing feed utilization. The benefits obtained from these advancements will be substantial because over one-half of the variable production costs associated with channel catfish aquaculture relates to diets and feeding. The efficiency and profitability of baitfish production also should be improved by obtaining

specific information on the nutritional requirements of these fish and how to meet those requirements most economically. Additional information concerning nutritional requirements of hybrid striped bass and their utilization of feedstuffs also will facilitate the development of optimized formulations that will reduce diet costs and improve production efficiency of this emerging sector of aquaculture.

PROGRESS AND PRINCIPAL ACCOMPLISHMENTS:

Several feeding trials have been completed and others initiated in laboratories and experimental ponds to investigate vitamin and protein/amino acid supplementation of practical diets for channel catfish. At the Mississippi State University Delta Research and Extension Center, a study was conducted in ponds to examine the need to supplement typical commercial catfish diets with vitamin C, riboflavin, and niacin. The control diet contained about 9 mg riboflavin/kg, 150 mg niacin/kg, and 100 mg vitamin C/kg from a combination of endogenous vitamins in the feed ingredients and supplemental vitamins. Diets were also fed that contained either no supplemental vitamin C, no supplemental riboflavin, or no supplemental niacin. In addition, diets were supplemented with either vitamin C at approximately 15 and 50 mg/kg, riboflavin at 7 mg/kg, or niacin at 40 mg/kg diet. All diets were fed to fish in 0.04-ha earthen ponds under commercial conditions beginning in May of 1994 through the spring of 1995 until the fish were market size. Weight gain, feed conversion, and feed consumption data indicated that supplemental riboflavin and niacin may not be needed in commercial catfish feeds as there were no differences in fish performance regardless of diet. Data from fish fed the vitamin C test diets also indicated that the requirement is much less than previously reported. There were no gross signs of vitamin C deficiency in any fish regardless of diet. Tissue levels of the three vitamins are currently being determined. Colleagues at the University of Memphis subjected representative fish fed the various diets to confinement at least twice during this study to evaluate stress responses. Plasma chloride and osmotic pressure were stable during all of the stress tests and did not change markedly due to confinement. Plasma cortisol concentration responded to the confinement stress during each test period. The response by the control fish at each time was characterized by an initial low level with a significant elevation by 1 hour which was maintained during the 6 hours of confinement. Cortisol concentrations had recovered to the initial levels 12 hours after release from confinement. The pattern of cortisol response in the experimental groups did not indicate any consistent difference due to reduced vitamin levels in the feeds.

At this time it appears that supplemental niacin is not needed in typical commercial catfish feeds used for growout. There is enough endogenous niacin in a commercial catfish feed to more than meet the requirement and the vitamin is stable during feed manufacture (losses of both niacin and riboflavin during extrusion were extremely low (< 4%). Supplemental riboflavin does not appear to be needed, but yet the level in a typical commercial catfish feed does not appear to be adequate to meet the requirement reported for small fish grown under laboratory conditions. Perhaps the riboflavin requirement is lower for larger fish, that natural foods are contributing to the requirement, or that the requirement is met by a combination of these factors. The vitamin C requirement appears to be less than 15 mg/kg. All three of these vitamins are abundant in plankton. Further conclusions or recommendations may follow after tissue data are available.

A similar investigation concerning vitamin E supplementation of diets for channel catfish was conducted in ponds at Texas A&M University. A typical commercial diet formulation (with approximately 10 mg vitamin E/kg provided endogenously) was supplemented with vitamin E acetate at either 0, 30, 60 or 240 mg/kg diet. No

differences in growth, feed efficiency and survival were observed over the 1-year trial; however, plasma tocopherol was directly correlated with tocopherol supplementation in the diet. Based on the lack of overt or histological signs of vitamin E deficiency, it appears that vitamin E supplementation of practical diets for growout of channel catfish can be reduced considerably. Further conclusions or recommendations may follow after analysis of vitamin E in liver is completed.

In the Department of Biochemistry at Mississippi State University, the dietary riboflavin requirement of channel catfish has been reevaluated and determined to be 6 mg/kg diet which is lower than previously reported. Preliminary evidence also suggests that the niacin requirement also may be much lower than previously reported although additional experiments are underway for confirmation. It also has been confirmed that tryptophan does not serve as an important precursor of niacin in channel catfish. These requirement studies also are providing the response criteria for determining bioavailability of vitamins from practical feedstuffs.

An investigation to optimize dietary protein/amino acid supplementation of channel catfish diets is underway at Louisiana State University. Fish of multiple sizes were stocked in April and June of 1994 in 16, 0.08-ha (0.2-acre) ponds. Feeding of custom-formulated experimental diets, one with animal protein and one without, began in July and will continue through the fall of 1996. Each diet is being fed at two maximum feeding rates -- satiation (maximum of 134.5 kg/ha/day; 120 lbs/acre/day) or restriction (78.45 kg/ha/day; 70 lbs/acre/day) to fish in four replicate ponds. Feed allotments are being adjusted daily to provide as much feed as the fish will eat. This will continue until the maximum feeding rate for the pond has been achieved, at which point there will be no further increase. The first top-harvest occurred in late April-early May 1995 and will continue at 4-month intervals. No significant differences in total weight of fish harvested and average fish weight were apparent due to the two diets; however, fish fed the diet without animal protein tended to have lower visceral fat content and dressing percentage. Fingerling fish (10 cm; 4 in) were restocked one week after the top-harvest to maintain a density of 24,710 fish/ha (10,000 fish/acre) for the duration of the 3-year growth trial. The maximum "restricted" feeding rate has been attained in some ponds but not the "satiation" rate. Top-harvesting and restocking will continue until the termination of the growth trial in the fall of 1996. At the University of Georgia, a study also is underway to evaluate ethanol-extracted soybean meal in diets of channel catfish.

Several studies to investigate various feeding strategies in channel catfish production also are currently in progress. Laboratory experiments have been completed at Texas A&M University to investigate how different degrees of feed restriction and dissolved oxygen concentration influence growth of channel catfish. Fish maintained at two levels of dissolved oxygen (60 and 92% of air saturation) were either starved or fed at 1.5 or 3% of body weight per day for one month after which they were all fed to satiation for another month. Weight gain and feed efficiency of fish subjected to low dissolved oxygen were significantly reduced compared to those of fish maintained at the higher dissolved oxygen concentration. At Auburn University, channel catfish of two sizes, year-1 (43 g; 0.09 lb.) and year-2 (660 g; 1.5 lb.), were stocked separately in 0.04-ha (0.1-acre) ponds in mid-November of 1994 and subjected to three overwinter management regimes: no feed, restricted feeding and continuous feeding. Fish were challenged with *Edwardsiella ictaluri* the following spring. Among year-1 fish, those not fed during the 5-month overwintering period showed significantly higher mortality from *E. ictaluri* than fish fed continuously or restricted (not fed during December, January and February). However, among year-2 fish, those not fed showed significantly lower mortality than fish fed

continuously or restricted. Several subclinical immune responses and tissue assays are being conducted to try to discern the mechanism of the influence of feeding on immune responses of channel catfish.

In the Department of Wildlife and Fisheries at Mississippi State University, a study of the effects of size-class distribution and dietary protein level on protein utilization and feed conversion of channel catfish was conducted. Fish averaging either 24.1 g (0.05 lb.) or 392.1 g (0.86 lb.) were stocked in earthen ponds as separate size classes and in a 50:50 ratio in June 1994, and fed either a 28 or 32% protein diet daily to satiation. There were no significant differences in average harvest weight, average weight gain, survival, feed conversion, or proximate composition of whole body or filets for fish fed either diet or stocked with only the same size versus mixed sizes.

However, there were significant differences in dressout characteristics between fish stocked with only the same size versus mixed sizes. Large fish stocked with small fish had higher percentage filet, carcass and fat dressout (32.2, 51.5, and 2.3, respectively) than large fish stocked alone (29.7, 48.3, and 1.6, respectively). Small fish stocked alone had higher percentage carcass dressout (50.3) than small fish stocked with large fish (47.6). Additionally, small fish stocked in mixed-size ponds displayed significantly less average weight gain (147.5 g; 0.32 lb.) than small fish stocked alone (264.3 g; 0.58 lb.).

Several other studies have been completed and are in progress with baitfish and hybrid striped bass to investigate various aspects of their nutrition and feeding. Investigators at the University of Arkansas at Pine Bluff (UAPB) have completed the following: (1) The dietary protein requirement of golden shiners and goldfish in aquaria was established; (2) A series of stable-carbon-isotope-ratio studies has been completed with golden shiners. Isotope analysis of fish and plankton indicated that fish obtained approximately 40-83% of their nourishment from the plankton, and the remainder from prepared feeds. The percentage of plankton consumed by golden shiners was inversely related to the assimilation of the diets which varied with diet composition; (3) Aquarium studies of the dietary lipid requirement of golden shiners were completed. Golden shiners performed well when fed diets containing a wide range of lipid (7-19%), but performance showed a peak when the diet contained around 12% lipid; (4) Aquarium studies showed that the range of dietary energy:protein ratio that promoted best performance of golden shiners was 9.7-12.0 kcal digestible energy/g protein; (5) An additional pond feeding trial performed jointly at UAPB and Texas A&M University (TAMU) was recently completed. Stable carbon isotope analysis will be used to study the effect of different stocking densities (750,000 fish/ha; 300,000 fish/acre at UAPB vs. 375,000 fish/ha; 150,000 fish/acre at TAMU) on the dependence of golden shiners on natural vs. prepared feeds. Isotopic analysis is currently in progress.

At East Carolina University, feeding trials have been completed to determine the digestibility of simple and complex carbohydrates by both large (>300 g; >0.66 lb.) and small (<60 g; <0.13 lb.) original cross hybrid striped bass. The apparent organic matter digestibility coefficients for large fish were 100% for both dextrin and molasses. Wheat starch and wheat flour were also highly digestible with organic matter digestibility coefficients of $94.1 \pm 6.9\%$ and $89.2 \pm 4.4\%$, respectively. Potato starch and wheat middlings had organic matter digestibility coefficients of $69.0 \pm 4.7\%$ and $69.1 \pm 5.9\%$. The digestibility coefficient for corn starch varied widely between experiments and is being reevaluated. These data indicate that carbohydrate sources, especially simple sugars, are well utilized by large hybrid striped bass. Diet analyses have been completed for smaller fish, and fecal sample analyses are underway.

Digestibility determinations also have been conducted at Texas A&M University with reciprocal cross hybrid striped bass (sunshine bass). Apparent protein and organic matter digestibility coefficients have been determined for menhaden fishmeal, anchovy meal, meat and bone meal, poultry byproduct meal, soybean meal and cottonseed meal.

At Kentucky State University, a study has been completed in which optimal protein and lipid (energy) levels were determined for juvenile sunshine bass. Sunshine bass required a diet containing at least 41% protein and a protein to energy ratio greater than 99 mg protein/kcal. The storage stability of frozen filets from fish in the feeding trial was determined by measuring lipid oxidation and changes in shear stress and tensile strength of the muscle during storage. Results indicate that physical and chemical characteristics of sunshine bass muscle after 6 months of frozen storage were minimally influenced by dietary protein level.

WORK PLANNED:

All project activities are proceeding as planned.

IMPACTS:

Considerable benefits to the aquaculture industry already have emerged relatively early in this project. Based on research to date, it appears that dietary supplementation of some vitamins may be reduced substantially, resulting in a reduction in feed costs which represents a considerable savings to the industry. Research concerning various feeding strategies also has identified means of improving health and increasing production efficiency of channel catfish. Significant advancements also have been made in obtaining specific information on the nutritional requirements of baitfish and hybrid striped bass, and how to meet those requirements most economically. Additional benefits to the aquaculture industry are anticipated as the project continues.

PUBLICATIONS, MANUSCRIPTS, OR PAPERS PRESENTED:

PUBLICATIONS IN PRINT

Keembiyehetty, C.N. 1995. Amino acid nutrition of sunshine bass (*Morone chrysops* x *M. saxatilis*). Ph.D. Dissertation, Texas A&M University, College Station, TX, 84 pp.

Lochmann, R. T. and H. Phillips. 1994. Dietary protein requirement of juvenile golden shiners (*Notemigonus crysoleucas*) and goldfish (*Carassius auratus*) in aquaria. Aquaculture, 128:277-285.

Serrini, G., Z. Zhang and R. P. Wilson. In press. Dietary riboflavin requirement of fingerling channel catfish (*Ictalurus punctatus*). Aquaculture.

Webster, C. D., L. G. Tiu, J. H. Tidwell, P. Van Wyk, and R. D. Howerton. 1995. Effects of dietary protein and lipid levels on growth and body composition of sunshine bass (*Morone chrysops* X *M. saxatilis*) reared in cages. Aquaculture 131:291-301.

Xiong, Y. L., E. A. Decker, S. P. Blanchard, A. D. Crum, N. C. Shantha, C. D. Webster, L. G. Tiu and J. H. Tidwell. In press. Dietary protein level has minimal effect on flesh quality of frozen stored sunshine bass, *Morone chrysops* X *M. saxatilis*. Journal of Applied Aquaculture.

MANUSCRIPTS

Gallagher, M. L. In preparation. Digestibility of carbohydrates in diets for hybrid striped bass.

Lochmann, R. T. and H. Phillips In review. Stable isotopic evaluation of the relative assimilation of natural and artificial foods by

golden shiners (*Notemigonus crysoleucas*) in ponds. Journal of the World Aquaculture Society.

Lochmann, R. T. and H. Phillips. In review. Dietary lipid requirement of juvenile golden shiners (*Notemigonus crysoleucas*) fed diets differing in protein level in aquaria. Aquaculture.

Rawles, S. D., T. G. Gaylord and D. M. Gatlin III. In preparation. Vitamin E supplementation of practical diets for channel catfish. Aquaculture.

PAPERS PRESENTED

Stahl, C. J., W. H. Neill and D. M. Gatlin III. Influence of feeding time and dissolved oxygen on the growth performance of fingerling channel catfish. Aquaculture America, February 1996 (abstract).

Unprasert, P. and H. R. Robinette. Influence of channel catfish, *Ictalurus punctatus*, size-class distribution on protein utilization and feed conversion. Aquaculture America, February 1996 (abstract).

SUPPORT:

YEAR	SRAC FUNDING	OTHER SUPPORT					TOTAL SRAC+ OTHER SUPPORT
		UNIVERSITY	INDUSTRY	OTHER FEDERAL	OTHER	TOTAL OTHER SUPPORT	
1	280,310	290,009	19,000			309,009	589,319
2	249,485	251,522				251,522	501,007
3	234,705	221,510				221,510	456,215
Total	764,500	763,041	19,000			782,041	1,546,541

D. DELINEATION AND EVALUATION OF CATFISH AND BAITFISH POND CULTURE PRACTICES

Progress Report
for the period
April 1, 1994 to August 31, 1995

FUNDING LEVEL:

Year 1 ..... $147,500
Year 2 ..... $152,000
Year 3 (projected) $150,500
Total $450,000

PARTICIPANTS:

Auburn University -Jerry Crews, Leonard Lovshin, John Jensen, Michael Masser, Chris Hyde, Greg Whitis

LSU Agricultural Center (Cooperative Extension Service) - C. Greg Lutz

Mississippi State University (Delta Research and Extension Center) - David Wise

Texas A & M University (Texas Agricultural Extension Service) - Greg Clary, Joe Lock

University of Arkansas at Pine Bluff -Carole Engle, Nathan Stone, David Heikes, Larry Dorman, Steve Killian

University of Georgia -Ronnie Gilbert

ADMINISTRATIVE ADVISOR:

Dr. David Foster, Associate Vice President for Agriculture-Extension
University of Arkansas
Little Rock, Arkansas

PROJECT OBJECTIVES:

1. Develop catfish and baitfish standardized production and financial performance analysis (SPFPA-CC and SPFPA-BF) guidelines which include measures for evaluating the performance of commercial catfish and baitfish production systems.

2. Delineate and evaluate current commercial catfish and baitfish production practices (i.e., stocking, feeding, aeration, water exchange, pond size and configuration, harvesting, etc.) utilizing SPFPA-CC and SPFPA-BF guidelines.

3. Identify relationships between production and measures of production and financial performance as calculated according to SPFPA-CC and SPFPA-BF guidelines.

4. Develop management tools to assist commercial catfish and baitfish producers, lenders, aquaculture specialists and others in determining the efficacy of selected production practices.

ANTICIPATED BENEFITS:

Narrow margins between production costs and revenues result in challenges for managers of commercial catfish and baitfish production systems. Decisions must be made regarding resource allocation, optimal production alternatives, reinvestment, marketing strategies, use of credit and many other issues. A standardized system to measure production and financial performance is necessary to monitor the impact that decisions have on the productivity, financial performance of entire farms, and more specifically on commercial catfish and baitfish enterprises. Standardization lends itself to comparing performance of farms with different locations, management levels, production strategies, sizes and other characteristics.

This project proposes to delineate and evaluate current commercial practices by developing a standardized system of production and financial performance measures for catfish and baitfish operations independent of size, production methods, or marketing strategies. This

standardized system will then be used to make an integrated evaluation of biological and financial risk, and the consequences of management decisions on productivity and profitability with a group of cooperating producers in six southeastern states. The results will only be indicative of the cooperators and not necessarily the entire industry but should begin to elucidate best management practices. At the conclusion of the project the standardized system that has been developed will be available for producers to utilize throughout the nation.

PROGRESS AND PRINCIPAL ACCOMPLISHMENTS:

CATFISH

Objective 1: A final draft of the Performance Evaluation Standards for Commercial Catfish Operations (PESCAT) is complete and ready for distribution. These guidelines establish standards for production and financial performance analysis of commercial catfish production systems. Producers have been heavily involved with the development of these guidelines. The guidelines are divided into two publications: one for fingerling production enterprises and one for food fish production enterprises. Workbooks will be made available to producers and other interested individuals through project participants in the respective states.

Objective 2: Guidelines will be implemented shortly by project participants and producers so that data will be available to complete this objective. PESCAT includes descriptive items that will allow for comparison of production and financial performance measures which ultimately should provide information to assist producers in improving their operational efficiency.

Objective 3: Work on this objective is subject to data collection, so no progress is noted in this report.

Objective 4: PESCAT workbooks contain instructional materials to assist in data collection and calculation of performance measures. Software to facilitate this process is in development. Data collection forms are provided for use or adaptation by producers. Example reports are provided, both on data sheets and in electronic spread sheets, to suggest a format which will enhance collection, analysis, and interpretation of results.

BAITFISH

Standard Production and Financial Performance Analysis (SPFPA) guidelines and data forms have been developed, reviewed, and finalized for the four principal species of baitfish: golden shiner, goldfish, fathead minnows, and rosy red minnows. A codebook, database structure and analysis worksheets have been developed and reviewed for data entry and analysis. The SPFPA-Golden Shiner guidelines, data forms, database structure, and worksheet analysis formulae were pilot tested with a cooperating farmer and modifications made accordingly. Additional golden shiner cooperators were identified and interviewed to explain expectations and benefits of participation in the project. Project data are currently being collected periodically on five golden shiner farms. Preliminary drafts of enterprise budgets have been developed.

WORK PLANNED - 1994-95:

CATFISH

Objective 1: This objective is essentially complete with the final adoption of PESCAT guidelines. Some minor changes may be necessary as guidelines are put into use by producers. Modifications will be studied and implemented as deemed appropriate by project participants.

Objective 2: Data collection will begin in September 1995 and continue until the project ends. Producers with a variety of different production practices have been identified and many have agreed to participate in implementing

PESCAT guidelines into their management information systems.

Objective 3: Work on this objective is subject to data collection, therefore, very little progress is expected during this year. However, as data become available, preliminary results will be studied in order to decide on proper methods of analysis and project reporting.

Objective 4: PESCAT workbooks will be distributed more widely throughout the six state study area as project participants identify other producers interested in this type of analysis. Data collection instruments, report formats, and software will be refined as suggestions from users are incorporated. Training sessions for project participants are scheduled and will continue throughout this year.

BAITFISH

Data collection on golden shiners will be expanded to a total of 10 cooperators. The goldfish and fathead minnow guidelines and data forms will be pilot tested and data collection on five producers each of goldfish and fathead minnows will be initiated over the Fall-Winter. In 1996, collection will begin on a full production year of data on all species (second year of data on golden shiners). Baitfish enterprise budgets will be finalized.

IMPACTS:

This project is moving from the development phase, where there has been little direct impact, to the implementation phase which should directly impact participants. Incorporating PESCAT and SPFPA guideline measures into the management information systems of producers will result in more useful information, in improved analytical skills for all participants, and in increased efficiency through more informed decision making.

PUBLICATIONS, MANUSCRIPTS, OR PAPERS PRESENTED:

Performance Evaluation Standards for Commercial Catfish Operations (PESCAT) Workbooks, Part 1 - The Fingerling Enterprise, and Part 2 - The Food Fish Enterprise, published by project participants, TAMU, August 1995.

Standardized Production and Financial Performance Analysis - Golden Shiners (SPFPA-GS), published by project participants, UAPB, February 1995.

Standardized Production and Financial Performance Analysis - Fathead Minnows (SPFPA-FM), published by project participants, UAPB, February 1995.

Standardized Production and Financial Performance Analysis - Goldfish (SPFPA-GF), published by project participants, UAPB, February 1995.

Standardized Production and Financial Performance Analysis - Rosy Red Minnows (SPFPA-RR), published by project participants, UAPB, February 1995.

SUPPORT:

The Alabama Cooperative Extension Service (ACES) at Auburn University has provided an additional $7,000 to support this project. No other additional support is noted at this time other than in-kind support from each participating institution.

YEAR	SRAC FUNDING	OTHER SUPPORT					TOTAL SRAC+ OTHER SUPPORT
		UNIVERSITY	INDUSTRY	OTHER FEDERAL	OTHER	TOTAL OTHER SUPPORT	
1	147,500	178,024				178,024	325,524
2	152,000	176,746				176,746	328,746
3	150,500	180,605				180,605	331,105
Total	450,000	535,375				535,375	985,375

E. PUBLICATIONS, VIDEOS AND COMPUTER SOFTWARE

Progress Report
for the period
April 1, 1995 to August 31, 1995

FUNDING LEVEL:

Year 1 ..... $50,000
Year 2 (Projected)..... $61,000
Total $111,000

PARTICIPANTS:

Mississippi Cooperative Extension Service - Martin Brunson

Mississippi State University - Louis R. D'Abramo

Georgia Cooperative Extension Service - George Lewis

University of Georgia - Ronnie Gilbert

Kentucky Cooperative Extension Service - Robert Durborow

Arkansas Cooperative Extension Service - Nathan Stone, Eric Park, Debbie Archer

Louisiana State University - J. D. Bankston

Louisiana Cooperative Extension Service - Sandra Malone, Wendell Lorio, Fred Eugene Baker

Florida Cooperative Extension Service - Charles Cichra

Alabama Cooperative Extension System - Michael Masser

Texas Agricultural Extension Service - Katheleen F. Ladewig, Michelle Morat, Russell Miget, James T. Davis

ADMINISTRATIVE ADVISOR:

Dr. Hiram Palmertree, Director
Mississippi Cooperative Extension Service
Mississippi State University
Mississippi State, Mississippi

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 disc) for more efficient use, duplication and distribution.

ANTICIPATED BENEFITS:

The most direct benefit from this project to the aquaculture industry is making information available on production and marketing constraints and possible ways to remove these constraints. Most of the information is of assistance to those making decisions about beginning an aquaculture business. In addition, economics information is used by lending agencies and individuals. The placing of the information on the Internet and/or CD-ROM will make access easier, facilitate searching for needed information, and reduce the need for storage space for printed documents.

Producers will benefit indirectly from the materials intended for use by consumers as well as those which furnish background information on aquaculture. Such information

helps in decision making when citizens are involved in regulations on the industry. This is particularly important, with the increased emphasis on possible environmental contamination, to show the relatively minor detrimental impact from aquaculture on the surrounding areas.

PROGRESS AND PRINCIPAL ACCOMPLISHMENTS:

Writing of the new and revised fact sheets is progressing well and should be completed within the year. The shooting script for the baitfish video has been prepared and is out for review at this time.

The publications completed to date are the result of work conducted under other projects. Most of these projects have been completed and the Extension type publications are now being prepared. Funding for preparation of the fact sheets and videos was borne by other projects. Only editing, printing and distribution costs were charged to this project.

Work on placing all fact sheets into electronic format is progressing steadily. Problems with computer software and hardware have been overcome and at least 15 publications have been forwarded to AquaNIC to be placed on the World Wide Web.

WORK PLANNED:

The freshwater shrimp fact sheets are ready to begin peer review and the saltwater shrimp fact sheets are in the writing stage. Revisions of the three fact sheets projected for this year are proceeding well and should be in the editing cycle within in 60 days. At least two publications based on other projects are scheduled for completion during the year.

IMPACTS:

It is too early to measure the impacts from this project but potential impacts based on earlier similar projects are many and varied. All 50 states and United States owned islands utilize these fact sheets and videos on a regular basis. Within the Southern Region it has been estimated that more than 60 fact sheets and four videos are sent to interested persons daily. In other regions the numbers have been reported to be from five to 20 per day for the fact sheets and three videos per day on the average for each of the other four regions. This would mean about 20,000 fact sheets and 3200 videos per year are used by interested producers and/or consumers. Though there has been no attempt to quantify the impact financially, at least one Extension agent has estimated that the savings from potential producers not going into the aquaculture business exceeds $100,000 per contact researching beginning production. For producers in the business the savings are probably more in the order of $5,000 per producer using the service per year. For those producers looking for new methods and procedures, no profit margin has been measured or estimated at this time.

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 the publications 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 more enlightened regulations being developed.

The impact on consumers utilizing aquaculture products has not been measured. Nonetheless it has been estimated that the consumer oriented fact sheets and videos have an even wider utilization than the producer directed materials. Because the consumer is primarily interested in a wholesome, safe and inexpensive product, the fact sheets are in demand in both the English and Spanish versions. As more information becomes available, consumer items of literature will be even more in demand by health conscious homemakers and those dining out.

PUBLICATIONS, MANUSCRIPTS OR PAPERS PRESENTED:

PUBLICATIONS IN PRINT

Bankston, J. David, Jr. and Fred Eugene Baker. SRAC #372. Selecting the Proper Pump

Bankston, J. David, Jr. and Fred Eugene Baker. SRAC #373. Piping Systems.

Bankston, J. David, Jr. and Fred Eugene Baker. SRAC #374. Open Channel Flow in Aquaculture.

Bankston, J. David, Jr. and Fred Eugene Baker. SRAC #375. Powering Aquaculture Equipment.

Cichra, Charles E., Michael P. Masser and Ronnie J. Gilbert. SRAC #479 Fee Fishing, An Introduction

Cichra, Charles E., Michael P. Masser and Ronnie J. Gilbert. SRAC #482. Fee Fishing, Location, Site Development and Other Considerations.

Ladewig, Katheleen F. and Michelle Morat. SRAC #224. Rainbow Trout.

Lorio, Wendell J. and Sandra Malone. SRAC #432. The Cultivation of American Oyster *Crassostrea virginica*.

Lorio, Wendell J. and Sandra Malone. SRAC #433 Biology and Culture of the Northern Quahog Clam.

VIDEOS COMPLETED

Ladewig, Katheleen F. Get Hooked on Rainbow Trout.

Miget, Russell J. Shrimp Farming.

MANUSCRIPTS

Baitfish production - Video - shooting script completed.

PAPERS PRESENTED

Davis, James T. and Kim Jefferson, Using Adobe Capture for Electronic Formatting of Publications, Texas Chapter of the American Fisheries Society, September 1995.

SUPPORT:

YEAR	SRAC FUNDING	OTHER SUPPORT					TOTAL SRAC+ OTHER SUPPORT
		UNIVERSITY	INDUSTRY	OTHER FEDERAL	OTHER	TOTAL OTHER SUPPORT	
1	50,000	43,950				43,950	93,950