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# Pond Dynamics/Aquaculture Collaborative Research Support Program

## Eighteenth Annual Administrative Report

1 August 1999 to 31 July 2000

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# INTRODUCTION

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The Pond Dynamics/Aquaculture Collaborative Research Support Program (PD/A CRSP) conducts research that contributes significantly to the removal of major constraints to aquacultural development, thereby promoting economic growth and enhancing food security. This report describes the activities and accomplishments of the PD/A CRSP during the period 1 August 1999 to 31 July 2000.

The PD/A CRSP is funded by the United States Agency for International Development (USAID), under authority of the International Development and Food Assistance Act of 1975 (PL 94-161), and by the universities and institutions that participate in the CRSP. This cohesive program of research is carried out in selected developing countries and the United States by teams of US and host country scientists. Now operating under its fourth USAID grant since 1982, the CRSP is guided by the concepts and direction set down in the *Continuation Plan 1996–2001*, which was awarded funding under USAID Grant No. LAG-G-00-96-90015-00. This grant authorizes program activities from 1 August 1996 to 31 July 2001. An overview of CRSP history and how the program has evolved since its inception is provided in Appendix 1.

The activities of this multi-national, multi-institutional, and multidisciplinary program are administered by Oregon State University (OSU), which functions as Management Entity (ME) and has technical, programmatic, and fiscal responsibility for the performance of grant provisions. ME activities at OSU are carried out through a Program Management Office (PMO), which is supported in the task of program administration by three advisory bodies: the Board of Directors (BOD), the Technical Committee (TC), and the External Evaluation Panel (EEP). PMO staff as well as advisory group membership during the reporting period appears in Appendix 2.

## ANNUAL HIGHLIGHTS

- In the reporting period, the CRSP welcomed three new members to the Board of Directors (BOD) and two new members to the External Evaluation Panel (EEP). A complete listing of advisory panel members appears in Appendix 2.
- The BOD met during the reporting period via a conference call in October and in person in New Orleans in January 2000. Principal topics included how to disperse funds left in the FY00 allocation due to declined Ninth Work Plan awards, advice on a proposal to change the Philippines Project lead US institution to Florida International University, and a discussion of strategies for requesting a cost-extension from USAID.
- The PD/A CRSP Annual Meeting was held in New Orleans, Louisiana, 31 January to 2 February 2000, providing a forum for meetings among a number of program components: program researchers and administrators, the Technical Committee (TC), and the BOD.
- The 2000 TC membership election took place at the Annual Meeting. Newly elected to the TC were CRSP principal investigators Freddy Arias, Amrit Bart, Wilfrido Contreras-Sánchez, James Diana, Carole Engle, and external at-large member Damon Seawright; a complete listing of TC and Subcommittee members appears in Appendix 2.
- The Scope of Work for the in-depth 5-year EEP review was developed with input from the BOD, TC Co-chairs, and USAID and was approved by USAID in June 2000.
- Official meetings with the EEP took place by conference call in February and in person in Washington, DC, in March 2000.
- In June 2000 two members of the EEP, Kevan Main and David Cummins, participated in the first of three planned visits to CRSP research sites. PD/A CRSP Director Hillary Egna and USAID Project Officer Harry Rea accompanied the two EEP members to Thailand. While there the team met with CRSP researchers, students, farmers, and government officials at the Asian Institute of Technology and in Udorn Thani.
- As an add-on to the Thailand EEP visit, Egna and Rea visited several development groups, nongovernmental organizations, and fisheries agencies in Bangladesh to explore its potential as a PD/A CRSP regional site.
- New subcontracts with University of Georgia, lead US institution for the Honduras Project, and with collaborating US institution Auburn University were formalized in the reporting period. The CRSP also welcomed a new US institutional partner, Florida International University. Florida International University is the new lead US institution for the Philippines Project.
- In September 1999, a Memorandum of Understanding between Escuela Agrícola Panamericana El Zamorano, Honduras, and University of Georgia was executed. Also, a new Memorandum of Understanding for collaborative work on the Philippines Project between Central Luzon State University, Philippines, and Florida International University was near completion by the end of the reporting period. A complete listing

of active memoranda of understanding appears on page 75.

- The CRSP produced an updated edition of the *Eighth Work Plan Project Profiles* and the first edition of the *Ninth Work Plan Project Profiles*. These publications contain administrative summaries of CRSP projects organized by work plan and present information on personnel, funding, proposal review statistics, work plan changes, and deliverables.
- Egna, Cormac Craven, and Deborah Burke co-authored a poster entitled “The Pond Dynamics/Aquaculture CRSP–Developed Technologies: Domestic Rewards and Returns,” which was presented by Craven at Aquaculture America 2000, the annual meeting of the US chapter of the World Aquaculture Society, in New Orleans, Louisiana, in February 2000. The PD/A CRSP also donated a copy of *Dynamics of Pond Aquaculture*, edited by Egna and Claude Boyd, for an auction conducted by the National Aquaculture Association (part of Aquaculture America 2000) in New Orleans.
- The PD/A CRSP was featured in the third annual exhibition and reception on Capitol Hill, sponsored by the National Association of State Universities and Land-Grant Colleges (NASULGC), in March 2000. The event was entitled “Agricultural Research and Education Serving the Nation: A University Exhibition and Reception on Capitol Hill.”
- The Director participated in teleconference and in-person CRSP Council Steering Committee meetings throughout the reporting period. In addition, Egna attended a Board for International Food and Agricultural Development meeting and USAID Partners Conference, both in March 2000, in Washington, DC; and the June 2000 meeting of the Association for International Agriculture and Rural Development, also in Washington, DC. The Director also attended a July 2000 “Impact Assessment Workshop” in Washington, DC, at the invitation of the United States Department of Agriculture.
- As part of a joint CRSP Council Steering Committee activity, Egna co-authored a poster entitled “Collaborative Research Support Programs: A Vital Link between US Universities and Developing Countries,” an abstract of which was submitted in March 2000 for a session entitled “Global Research and Education” as part of the Annual Meetings of the American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America. The meetings, with a theme of Agronomy, Crop and Soil Sciences: Stars of the 20th Century—Beacons for the 21st, will be held in Minneapolis, Minnesota, in November 2000.
- A paper co-authored by Egna, Matt Niles, and Claude Boyd, entitled “Research Priorities and Highlights: An Overview of the Pond Dynamics/Aquaculture CRSP,” was presented by Boyd at the Western Regional Aquaculture Conference, held in Desert Hot Springs, California, in April 2000.
- The PD/A CRSP was a co-sponsor of IIFET 2000, the July 2000 conference of the International Institute of Fisheries Economics and Trade, held at Oregon State University. The CRSP participated by making it possible for four international scholars from CRSP host countries—Mexico, Kenya, Thailand, and the Philippines—to travel to and present papers at the meeting. In addition, Egna chaired five sessions at the meeting.
- The PD/A CRSP participated in planning for co-sponsorship of ISTA 5, the Fifth International Symposium on Tilapia Aquaculture, to be held in September in Rio de Janeiro, Brazil. The co-sponsorship included travel support to ISTA 5 for three international scholars, from Malawi, the Philippines, and Thailand, and support for publishing the conference proceedings.
- Throughout the reporting period, Egna worked closely with USAID on a number of different issues, including a request for a cost-extension for the current grant; a proposal for—and subsequent awarding of—\$200,000 for impact assessment and evaluation; a report on PD/A CRSP funding to Historically Black Colleges and Universities; input into a revision of the Strategic Framework and a review of the Office of Agriculture and Food Security Portfolio and R4 Report; and follow-up discussions related to Egna’s proposal, “Improving Nutritional Status of Children under Five through Enhanced Micronutrient Availability, Access and Utilization,” which had been submitted in the previous reporting period to the Center for Economic Growth and Agricultural Development, Office of Agriculture and Food Security, Global Bureau.
- Other professional activities undertaken by Egna in the reporting period included authoring a paper for the Handbook of Global Environmental Policy and Administration, Marcel Dekker, Inc., and serving as a reviewer for articles in the Journal of the International Water Resources Association and the Journal of Communications in Soil Science and Plant Analysis.

### RESEARCH AND RESEARCH SUPPORT AGENDA

Research conducted by the PD/A CRSP since 1982 has helped to remove some of the constraints facing aquaculture development. Still, aquaculture continues to be hampered in several important areas. In developing the *Continuation Plan 1996–2001*, the CRSP undertook an in-depth constraints analysis. That analysis led to the identification of a number of major constraints that limit the development of extensive to semi-intensive sustainable aquaculture systems. Chief among these were:

- Inefficient and inconsistent aquacultural productivity
- Negative environmental effects resulting from aquaculture operations
- A poor understanding of social and economic factors
- Insufficient human capacity development
- Poor or outdated information management
- Limited networking capacities

The *Continuation Plan 1996–2001* responds to the first three of these factors by setting a research agenda that addresses constraints to aquacultural productivity, environmental effects, and social and economic aspects of aquaculture. The second three constraints are addressed by a research support agenda committed to improving human capacity development, information management, and networking. To carry out that agenda, the program includes a Research Support component comprising three efforts:

- A project that manages the CRSP Central Database, the largest repository of standardized data related to aquaculture; and
- An Information Management project for reporting and disseminating project and program outputs via publications and a central website.
- Numerous human capacity development activities carried out by existing research projects.

The PD/A CRSPs multidisciplinary team of researchers and advisors represents a wide range of US and international aquacultural experience. During the reporting period, participating US institutions included:

- Auburn University
- Florida International University
- The Ohio State University
- Oregon State University
- Southern Illinois University at Carbondale
- University of Arizona
- University of Arkansas at Pine Bluff
- University of Georgia
- University of Hawaii
- The University of Michigan
- University of Oklahoma

Research activities were conducted at host country sites in Mexico, Honduras, Peru, Kenya, the Philippines, and Thailand, at the participating US institutions, and with collaborators in Colombia, Nicaragua, and Malawi. Memoranda of Understanding, representing formal ties between US and host country institutions, which were in place during the reporting period include those between:

- Oregon State University and the Universidad Juárez Autónoma de Tabasco, Mexico
- Oregon State University and the Department of Fisheries, Kenya
- University of Hawaii at Manoa and Freshwater Aquaculture Center, Central Luzon State University
- Florida International University and Freshwater Aquaculture Center, Central Luzon State University
- Southern Illinois University at Carbondale and the Instituto de Investigaciones de la Amazonia Peruana and the Universidad Nacional de la Amazonia Peruana
- The University of Michigan and the Asian Institute of Technology, Thailand
- University of Georgia and Escuela Agrícola Panamericana, Zamorano, Honduras

## RESEARCH PROGRAM FRAMEWORK

The *Continuation Plan 1996–2001* program framework, and the foundation for the current portfolio of PD/A CRSP research projects, consists of two building blocks: research in sustainable production systems and research support activities.

The sustainable production systems research framework is organized into the areas of production optimization, environmental effects, and social and economic aspects. Each area is further subdivided into specific research themes, which are the thematic areas of research needed to remove constraints to the development of more sustainable aquaculture. The results framework for research areas as presented in the *Continuation Plan 1996–2001* is summarized in Table 1, and the results framework for research themes is provided in Tables 2 through 4. Research areas and their respective themes are listed here:

Research Area: **Production Optimization**

Research Themes: Pond Dynamics  
Feeds and Fertilizers  
Reproduction Control  
Aquaculture Systems Modeling  
New Aquaculture Systems/New Species

Research Area: **Environmental Effects**

Research Themes: Effluents and Pollution  
Appropriate Technology  
Responsible Science Policy  
Geographic Information Systems:  
Planning, Policy, and Global Data  
Analysis

Research Area: **Social and Economic Aspects**

Research Themes: Marketing and Economic Analysis  
Adoption/Diffusion  
Food Security  
Regional Analysis: Human-Environment  
Interactions  
Decision Support Systems  
Product Diversification

## NINTH WORK PLAN

The Ninth Work Plan of the Pond Dynamics/Aquaculture CRSP was developed by the CRSP Technical Committee and describes activities to be conducted by the CRSP from 1 August 1998 through 30 April 2001. CRSP work plans have typically covered two-year periods. This holds true under the Ninth Work Plan for individual investigations, but while the overall time frame is greater than two years, no one investigation extends beyond a two-year period.

Increasing the time period of the overall work plan was necessitated by the CRSPs substantially reduced USAID annual budget allocation for years 3 through 5 of the *Continuation Plan*—thus the start dates of Ninth Work Plan investigations were staged over a nine-month period to allow for funding of as much of the original research portfolio as possible.

Despite the staged funding approach, the budget cut also necessitated major revisions to the portfolio to ensure adequate coverage of the critical areas within the newly imposed financial constraints, such as the elimination of the Global Experiment (see below) and other studies and curtailment of several research support activities. Ninth Work Plan research is underway in Mexico, Honduras, Peru, Kenya, the Philippines, and Thailand, as well as in the US.

Earlier PD/A CRSP work plans—the first through the third—specified identical experiments (called Global Experiments) at all CRSP sites to provide a baseline for comparisons among sites. This approach was changed starting with the Fourth Work Plan when different but related experiments were also conducted at the various sites. The particular topics studied at each site were based on the research and information needs in each country, as identified by the Technical Committee.

The body of investigations funded under the Eighth and Ninth Work Plans reflects the broadening of research as was proposed in the *Continuation Plan 1996-2001* as well as increased integration among sites. In addition to prime site activities, CRSP research now underway includes a cross-cutting, thematic approach for investigations that may be conducted at one or more PD/A CRSP sites and whose results may have wider application than results from prime and companion site investigations. All Eighth Work Plan research was concluded in the reporting period and is described, together with research funded under the Ninth Work Plan, in this report.

The Program Management Office tracks work plan schedule and methods changes to assure continuing accountability for program awards. Reflecting methods and schedule changes to the funded research under the Eighth Work Plan, work plan addenda were printed in Spring 1998 and Spring 1999. Additional changes to Eighth Work Plan research as well as changes to Ninth Work Plan research will be documented in a forthcoming work plan addendum document.

### PROGRAM IMPACTS 1999–2000

- Eight Best Management Practices (BMPs) for two nongovernmental organizations were developed using soils data from CRSP pond dynamics research.
- On-farm trials in the Philippines verified the value of waiting an additional month to begin feeding tilapia in ponds. This practice resulted in a 17% increase in the net value of the crop with no loss of fish yield; farmers in the region immediately adopted the practice.
- CRSP researchers investigated several new aquaculture systems and species in this reporting period. Researchers in Thailand found that growing tilapia in ponds planted with lotus reduces nutrient levels in pond muds. Preliminary results suggest that polyculture of tilapia and predatory snakehead controls reproduction, allowing pond resources to be more optimally utilized by stocked fish. Researchers in Peru working with two fish species indigenous to the Amazon Basin demonstrated the species' economic suitability for pond culture and identified nutrition requirements for broodstock and optimal stocking densities for culture populations.
- Continued research in Mexico and the US on the persistence of the masculinizing hormone 17 $\alpha$ -methyltestosterone suggests that caution should be exercised by those handling the hormone. Research on an alternative hormone, trenbolone acetate, indicates that this hormone may reduce environmental hazards while still masculinizing tilapia effectively.
- Researchers in Thailand showed that adding Nile tilapia to intensive hybrid catfish ponds resulted in a drop of 40% in nitrogen and 60% in phosphorus in the effluent. No additional cost was associated with the addition of tilapia.
- Economic analyses of integrated pond systems in Thailand identified practices that are most appropriate given the amount of supplies and funding available. Organic fertilization with chicken manure is the most economically efficient practice for farmers with funding limitations; use of high-input green water technology is optimal when fingerling supply is limited.
- A survey of 146 farmers in Peru suggests that fish farmers view fish culture in a positive light, plan to build more ponds, and want more visits from extension workers.
- The CRSP assisted 35 US and 36 international students with funding, training, and research opportunities. Workshops to disseminate CRSP results were held in five countries and benefited more than 100 host country agency employees and 120 farmers. Researchers and students gave 39 presentations at scientific conferences in 10 countries.
- The CRSP-developed POND<sup>®</sup> software remains popular; 1,140 users from all six major continents have downloaded the software from the project's website in this reporting period. Additions to the software include a user-friendly interface and the capability to assess population growth and fish biomass. Researchers also released AquaFarm<sup>®</sup>, a tool for simulating a full range of processes in both semi-intensive and intensive systems.
- The CRSP website experienced a 50% increase in use over the previous year, with 450 visitors per week from over 60 countries. New publications were added to the website, with a total of 187 publications now available for downloading. Use of the Central Database website doubled in the past year to 1,700 visits, bringing the total number of visitors to 4,680.



Table 1. Results Framework for Research Areas within the Production Systems PD / A CRSP Building Block.

PRODUCTION SYSTEMS				
PD / A CRSP RESEARCH AREA	OBJECTIVE	CAUSAL ASSUMPTIONS	MEASURE	TARGET
Production Optimization	<ul style="list-style-type: none"> <li>* To increase the overall sustainability of aquacultural production systems through production optimization.</li> </ul>	<ul style="list-style-type: none"> <li>* Productivity and sustainability can be increased with better management of pond inputs, waste reduction, use of underutilized resources, and the conservation of non-renewable resources.</li> </ul>	<ul style="list-style-type: none"> <li>* More sustainable, efficient production systems appropriate for the biophysical environment.</li> </ul>	<ul style="list-style-type: none"> <li>* Improved scientific understanding of pond processes.</li> <li>* Improved pond management strategies.</li> <li>* Significant advances in reproduction technology.</li> <li>* Development of alternative aquacultural systems.</li> </ul>
Environmental Effects	<ul style="list-style-type: none"> <li>* To minimize the detrimental environmental impacts of aquaculture operations through improved pond management.</li> </ul>	<ul style="list-style-type: none"> <li>* Sustainable aquaculture is possible only in a healthy environment.</li> <li>* Detrimental effects of aquaculture operations can be reduced or eliminated through changed management development.</li> </ul>	<ul style="list-style-type: none"> <li>* Reduced detrimental environmental impact of aquaculture operations.</li> </ul>	<ul style="list-style-type: none"> <li>* Development of methodologies to assess and reduce negative environmental impacts of aquaculture operations.</li> </ul>
Social and Economic Aspects	<ul style="list-style-type: none"> <li>* To increase our understanding of the social and economic implications of aquaculture development.</li> </ul>	<ul style="list-style-type: none"> <li>* Successful aquaculture development is contingent upon the social and economic constraints of each location.</li> </ul>	<ul style="list-style-type: none"> <li>* Improved viability of subsistence and commercial aquaculture farms at various sites.</li> </ul>	<ul style="list-style-type: none"> <li>* Positive net returns to capital investment.</li> <li>* Positive financial and nutritional impact on participating household communities.</li> </ul>

Table 2. Results Framework for Research Themes within the Production Optimization PD/A CRSP Research Area.

<b>PRODUCTION OPTIMIZATION</b>				
RESEARCH THEME	OBJECTIVE	CAUSAL ASSUMPTIONS	MEASURE	TARGET
Pond Dynamics	* To further our understanding of the influence of pond processes on pond productivity.	* Knowledge of pond processes and organisms is necessary to improve productivity and fine-tune existing pond management guidelines as well as to reduce production losses and waste as aquaculture systems become more intensified.	* Improved predictability of pond processes and pond productivity.	* Illumination of the role of heterotrophy on pond production. * Development of pond bottom management techniques through a better understanding of pond soil-water interactions.
Feeds and Fertilizers	* To optimize use of pond inputs.	* Optimal fish growth can be achieved if the culture species' nutritional needs are addressed.	* Improved capabilities for prescribing optimal feed/fertilizer inputs to meet economic and environmental criteria.	* Reduce inputs of fertilizers and/or feeds to produce one unit of fish.
Reproduction Control	* To develop short- and long-term solutions to reproduction technology problems.	* Guaranteed seed supply and reliable broodstock is essential for the undertaking and maintenance of fish farming. Gender manipulations add management options which increase economic viability in intensified systems.	* Improved efficiency, efficacy, and safety of steroid use. * Successful production of sufficient amounts of YY-males. * Successful use of piscivorous fish to control excess tilapia offspring.	* Development of procedures that guarantee the safety of animals and farmers during steroid use. * Demonstration of the functional nature of YY-males for producing all male tilapia offspring. * Demonstration of the effects of piscivorous fish on tilapia production.
Aquaculture Systems Modeling	* To analyze and synthesize research results into models which better describe system processes.	* Models demonstrate the state of our current understanding of systems and system processes and provide direction for further inquiries.	* Improved representation of systems processes.	* Simulations which adequately describe biophysical processes in ponds.
New Aquaculture Systems/New Species	* To develop alternative aquaculture systems through the use of new or under-utilized resources or through resource partitioning. * To develop culture systems for local and native species.	* Production can be tailored to local conditions through diversification of aquaculture systems.	* Development of production procedures for new species, combinations of species and/or the establishment of new aquaculture systems.	* Foundation for the use of other species and/or new species combinations in pond aquaculture.

Table 3. Results Framework for Research Themes within the Environmental Effects PD/A CRSP Research Area.

<b>ENVIRONMENTAL EFFECTS</b>				
RESEARCH THEME	OBJECTIVE	CAUSAL ASSUMPTIONS	MEASURE	TARGET
Effluents	* To improve effluent water quality and water use efficiency.	* Reduction of excess nutrient loads will lessen environmental impact.	* Reduced nutrient loading.	* Demonstration of the effectiveness of CRSP guidelines to reduce effluent load.
Appropriate Technology	* To develop socially acceptable and environmentally friendly aquaculture technologies.	* Modification of current practices, tools, and facilities will lessen environmental impact.	* Reduced resource use in socially acceptable ways.	* Development of innovative approaches which result in a reduction of pond inputs, energy and/or excessively intensive management practices.
Responsible Science Policy	* To develop policies and guidelines that will govern the CRSPs work with exotic species, pharmaceuticals, and biotechnology.	* Communication and cooperation between potential host countries and the CRSP will be facilitated by a codified set of guidelines.	* Improved interaction with host country researchers and government officials in the area of exotics/drugs.	* Faster processing of necessary paperwork by host country officials.
GIS: Planning, Policy, Global Data Analysis	* To analyze and synthesize existing information at local, national, and regional scales.	* Integrating tools are required to assess potential and impact of aquaculture operations at scales above individual ponds.	* Analysis tools to determine environmental effects of proposed aquaculture locations.	* Assembly of datasets containing relevant summaries of CRSP research and data.

Table 4. Results Framework for Research Themes within the Social and Economic Aspects PD/A CRSP Research Area.

<b>SOCIAL AND ECONOMIC ASPECTS</b>				
RESEARCH THEME	OBJECTIVE	CAUSAL ASSUMPTIONS	MEASURE	TARGET
Marketing and Economic Analysis	* To develop marketing strategies for aquacultural products based on analysis of markets.	* Financial success is dependent upon meeting market demands.	* Improved pricing of aquaculture products. * Improved sales of products. * Reduced risk of adopting CRSP pond management technologies.	* Provision of information which (when applied) will allow the targeted aquaculture industry to access new markets and increase the volume of sold goods.
Adoption/Diffusion	* To identify barriers to the acceptance of new aquaculture technologies.	* Aquaculture technology will be adopted if the social, economic, and technological requirements of the local community are addressed. In order to create a successful aquaculture development, these requirements must be known by decision-makers.	* Successfully identified barriers to adoption of CRSP practices.	* Provision of guidance to extension workers to further increase acceptance of CRSP technologies in host countries.
Food Security	* To improve understanding of food security issues and their relationship to aquacultural practices.	* Extensive fish farming can successfully provide a source of necessary animal protein for the rural poor.	* Assessment of food security needs of the rural poor, and the impact of aquaculture on dietary intake of animal protein.	* Provision of information on nutritional status and needs of rural poor. * Assessment of technology transfer impact on rural poor.
Regional Analysis: Human-Environment Interactions	* To develop an information base of the effects of socioeconomic conditions on the development of a local, national or regional aquaculture industry.	* Aquacultural development is often seriously constrained by the regulatory, social, and economic environment. These large-scale constraints must be known in order to implement a successful aquaculture development strategy.	* Improved understanding of the socioeconomic conditions that constrain aquaculture development.	* Development of recommendations that enable host countries to establish a successful aquaculture development strategy.
Decision Support Systems	* To refine computer applications to assist planners and managers in the development of economically efficient production technologies.	* Profitability can be improved through computer exploration of the effects of different management strategies on pond production potential and economic performance.	* Increased use of DSS by target clientele.	* Delivery of completed DSS to CRSP researchers, in-country personnel, development agencies, US producers, and extension agents. * Positive feedback from DSS users.
Product Diversification	* To develop a range of aquaculture products.	* Consumption of aquaculture products will increase if consumers are given a variety of product options.	* Availability of new aquaculture products in local markets.	* Development of processes and guidelines for the production of new aquacultural products.



# RESEARCH SUPPORT

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Preparation of the *Continuation Plan 1996-2001* entailed a review of current aquaculture literature and discussions with many aquaculturists to determine research needs and constraints to aquaculture development. In addition to limited knowledge of various aspects of production systems, lack of access to training and to information were found to restrict aquaculture development. In response to these needs, the program created research support as a separate building block of its proposed research activities. Research support activities build capacity through technology transfer, information management, and networking.

Central Database and Information Management and Networking are the two branches of the CRSP's research support activities in this period. Annual activity reports for these two projects make up this chapter. During the Eighth Work Plan, a third research support component, Education Development, worked toward strengthening human capacity in participating CRSP countries. The program's human capacity development activities in the reporting period have been carried out in part by the Information Management and Networking Component and in part under specific research projects (see Effluents and Pollution Research, p. 35).

## CENTRAL DATABASE MANAGEMENT

MOU No. RD009G

### Staff

*Oregon State University, Corvallis, Oregon*

John Bolte

US Principal Investigator

Doug Ernst

Database Manager (Research Associate)

### Networking

CRSP Database staff John Bolte and Doug Ernst are developing a collaborative effort with research scientist L.G. Obaldo from The Oceanic Institute in Waimanalo, Hawaii, concerning shrimp culture, empirical datasets, and the development of component and system models. They are also collaborating with Kevin Hopkins, an aquaculture professor at the University of Hawaii, on statistical work and the production of overview-level journal articles regarding the database.

Ernst continues to serve as an online aquaculture extension agent, and he fields aquaculture-related questions from the general public and high schools. He receives one to two information requests per week.

### Publication

Ernst, D., 2000. AquaFarm<sup>®</sup>: Simulation and decision-support software for aquaculture facility design and management planning. Ph.D. dissertation, Oregon State University, Corvallis, Oregon, 400 pp.

### Award

Doug Ernst was asked to serve on an editorial committee of the journal *Aquacultural Engineering*.

## REPORT: PD/A CRSP CENTRAL DATABASE MANAGEMENT AND DEVELOPMENT

*Ninth Work Plan, Database Management 2 (9DM2)*

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### INTRODUCTION

The PD/A CRSP Central Database is a centralized storage and retrieval system for aquaculture research data and related information (Hopkins et al., 1987; Batterson et al., 1991; Ernst et al., 1997; Bolte et al., 1998; Ernst and Bolte, 1999; Ernst and Bolte, 2000). The Database currently contains datasets from CRSP-sponsored research, but it is open to other aquaculture research with compatible objectives and compliance with standardized methodology. Access to the

Database is available cost-free and is of interest to researchers, educators and students, outreach and extension agents, and producers in pond-based aquaculture. Datasets may be searched and retrieved based on specified location (research site), calendar year, fish species, fish culture methods, and desired type of data. An interface to the data and related information contained in the Database is provided at the Database website, located at <biosys.bre.orst.edu/crspDB/>. For intensive users of the Database, the contents are also available on electronic media (CD or Zip Disk).

The Database currently contains 108 aquaculture production studies and represents the world's largest inventory of standardized aquaculture data. The majority of studies in the Database are for production of Nile tilapia (*Oreochromis niloticus*) in sub-tropical and tropical solar algae ponds receiving inputs of plant materials, inorganic/organic fertilizers, and/or prepared feeds. Studies of other pond fishes and penaeid shrimp, under monoculture and polyculture management, are also available. Countries with research and research-support projects that have contributed to the Database include Egypt, Honduras, Indonesia, Kenya, Panama, Peru, Philippines, Rwanda, Thailand, and the US.

The Database project was started by the CRSP in 1985. The original purpose of the Database was oriented towards aquaculture science and engineering. Objectives were to:

- 1) Provide a mechanism for analysis of variance and multivariate analyses among geographically dispersed aquaculture research sites (in addition to analyses within single ponds and among ponds at a single location); and
- 2) Support development of predictive models for aquaculture pond processes and software for aquaculture design and management.

Since the placement of the Database on the Internet in January 1997, the purpose and functionality of the Database have expanded to address needs of aquaculture educators, planners, and producers. While continuing to serve as a centralized repository for aquaculture research data, the Database website also provides data search and extraction procedures, data graphing functionality, and contextual information specific to extracted datasets. (Additional statistical and regression tools for extracted datasets are under development.) Users can retrieve results of fish culture studies for a variety of geographical regions and production strategies, along with related information such as analytical methods, research site descriptions, publications, and author contact information. In this capacity, the Database serves as a major outreach mechanism of the PD/A CRSP.

### WORK PLAN TASKS AND ACCOMPLISHMENTS

Objectives of the work to be completed under the Ninth Work Plan address the needs of both data suppliers and users. For data suppliers, objectives are to support the ongoing entry of new datasets into the Database, including continued improvements in administrative and technical support. For data users, objectives include continued improvements in Database query procedures, linkage support to related information resources for extracted datasets, statistical processing and data reduction, and provision of automated regression procedures to calibrate fish growth models that can be used as predictive tools for aquaculture planning and management.

Objectives of this report are to describe accomplishments to date and ongoing work for each of the tasks to be completed under the Ninth Work Plan for the reporting period 1 August 1999 to 31 July 2000. Database architecture, programming, and Internet software tools used in this work are described to a large degree in Ernst et al. (1997).

### Database Hardware and Software

The hardware and software of the Database website server were upgraded to improve Internet security and website performance. Hardware upgrades included expanded storage, faster processing, and a write drive for compact disks. The latter provides a mechanism to provide large datasets to intensive users of the Database, as a supplement to Internet access. Current copies of the Database are also maintained on two additional computers, one of which has an automated daily backup system. Software upgrades included a new operating system (Windows 2000<sup>®</sup>; Microsoft<sup>®</sup>) and the latest versions of ColdFusion<sup>®</sup> (version 4.5; Allaire<sup>®</sup>) and Access<sup>®</sup> (version 2000; Microsoft<sup>®</sup>). In the course of this upgrade, the existing protocol used to communicate with the Database (ODBC) was changed to OLEDB, as recommended by Microsoft<sup>®</sup>. Unfortunately, the use of OLEDB caused unanticipated problems for both data retrieval and entry at the Database website due to high-level program bugs in the software products of Allaire<sup>®</sup> and/or Microsoft<sup>®</sup>. At the time of this report, some of these problems remain unresolved. If solutions cannot be found soon, alternative programming strategies will be required.

Independent of the OLEDB problem, alternative user interface programming mechanisms for the Database website were explored. While these alternative mechanisms are generally transparent to the user, the graphical interface options, data processing speed, and complexity of website programming vary with the methods used. Ongoing objectives are to provide the best possible performance for users while minimizing the complexity of website programming. Work accomplished in this area consisted of the development and assessment of a "client-based" approach (using Java<sup>®</sup>; Sun Microsystems<sup>®</sup>), as opposed to the "server-based" approach currently employed (Cold Fusion<sup>®</sup>; Allaire<sup>®</sup>). Given the considerably different program architectures required by these two approaches, staff compared the two approaches to determine which was most appropriate for the Database website. Results of these exercises showed that the client-based approach was excessively complex and required software products that were not sufficiently developed. The server-based approach in use was determined to be the best available technology. We will continue to periodically assess the methods used at the Database website relative to new developments in Internet technology.

### Data Submission Templates—Economic Data

The data templates and specific data types used in the Database are described in the Data Submission Manual, available at the Database website. An updated version of this manual was published in June 2000, including changes to the Project Specification Form, added data types, and added data templates. The data templates and types of the Database have been relatively stable for some time, but continued progress was made in the area of economics. A data template was added to the Database for "full enterprise budgets," which complements the simpler templates for "partial enterprise budgets" added in the prior year. Economic data would be useful to supplement the wealth of physical, chemical, biological, and management data already available.

Partial enterprise budgets support comparative economic analyses of production trials (experimental treatments) in comparison to a base production scenario (control treatment). Partial budgets do not require comprehensive itemization and accounting of all cost and revenue items, given that their purpose is to compare the relative economics of alternative production practices. For example, in a pond production study comparing fertilization only to fertilization plus supplemental feeding, partial budgets could be limited to applied materials, fish produced, and labor, given that all other cost items are comparable. Partial budgets may be performed for on-farm production trials as well as research experiments. Given their simplicity, the Database Manager asks that all aquaculture production studies submitted to the Database include at least partial budget data.

The new data template for full enterprise budgets consists of:

- 1) Itemizations of the resources consumed and produced, including quantities and unit costs;
- 2) Additional cost items such as maintenance, depreciation, and interest; and
- 3) Derived values such as total costs, gross receipts, net gain/loss, and break-even prices and yields (kg ha<sup>-1</sup> yr<sup>-1</sup>) for produced fish.

All quantities and costs are unitized to a per area (hectare) basis. Any number of cost and revenue items may be lumped together under "miscellaneous" cost and revenue quantities, respectively, at the discretion of the research project submitting the data. For full enterprise budgets to be most useful, however, they must contain all significant cost and revenue items itemized to a meaningful degree. The

Database template used for full budgets supports complete flexibility in itemization, regarding both the extent of itemization and the specific items listed. Similar to the contextual information that is available for physical, chemical, and biological datasets from fish production trials, economic datasets are fully supported with contextual information such as farm description, production area, and technology used.

**Data Submission Progress**

Data submissions to the Database from CRSP research projects can be broken into two major periods: 1) First through Seventh and Interim Work Plans, or through 31 July 1996, and 2) Eighth and Ninth Work Plans, or from 1 August 1996. For the earlier period, data submissions for CRSP projects were not contractually required. Efforts to collect past-due data submissions for this period are ongoing and ultimately depend on the goodwill of CRSP researchers. From the Eighth Work Plan onward, data submissions from CRSP projects are contractual requirements.

Past-due datasets are welcome from the First through Fourth Work Plans (1982 to 1989) but are not being actively pursued. It is felt that too much time has elapsed to expect dataset submissions from this period. It is not known how many past-due datasets from this period would be appropriate for use in the Database.

An inventory was completed of the CRSP studies performed from 1989 to 1996 (Fifth through Interim Work Plans) and the associated datasets potentially due to the Database (Table 1).

Table 1. Total studies (datasets) available in the PD/A CRSP Central Database as of 31 July 2000, shown in conjunction with the number of datasets possibly due to the Database. Grayed areas denote periods of inactivity for the listed site regarding CRSP aquaculture research.

Site Code	Site Name	Datasets Received and Due for First through Eighth Work Plans																Total Rcvd	Total Due								
		1		2		3		4		5		6		7		Interim				8							
		Rcvd	Due	Rcvd	Due	Rcvd	Due	Rcvd	Due	Rcvd	Due	Rcvd	Due	Rcvd	Due	Rcvd	Due	Rcvd	Due								
A	Aguadulce, Panama	2	2	2	2	2	2	[Grayed]												6	6						
B	Gualaca, Panama	2	2	0	0	2	2	[Grayed]												4	4						
C	Ayutthaya, Thailand	1	1	2	2	2	2	3	3	4	5	5	5	1	1	1	1	0	0	19	20						
D	Nong Sua, Thailand	1	1	[Grayed]																1	1						
E	Bogor, Indonesia	2	2	1	1	2	2	[Grayed]												5	5						
F	Comayagua, Honduras	2	2	2	2	2	2	2	2	4	6	2	6	0	3	0	0	2	2	16	25						
G	Iloilo, Philippines	2	2	2	2	2	2	[Grayed]												6	6						
H	Rwasave, Rwanda	2	2	0	0	2	2	4	4	3	6	0	5	0	4	[Grayed]				11	23						
I	AIT, Thailand	[Grayed]						3	3	3	6	3	5	4	4	0	1	7	7	20	26						
J	Choluteca, Honduras	[Grayed]												0	4	1	6	4	4	5	14						
K	Abbassa, Egypt	[Grayed]												2	5	[Grayed]				2	5						
L	U. of Oklahoma, USA	[Grayed]																0	0	0	0						
N	Auburn U., USA	[Grayed]																0	0	0	0	1	1	1	1		
O	Oregon State U., USA	[Grayed]																0	0	0	0	2	2	2	2		
P	FAC, Philippines	[Grayed]										2	2	3	3	0	3	0	2	5	10						
Q	U. Arkansas @ PB, USA	[Grayed]												0	0	1	1	1	1	1	1						
R	UNAP, Peru	[Grayed]																1	1	1	1						
S	Sagana, Kenya	[Grayed]																2	2	2	2						
U	Huay Luang, Thailand	[Grayed]								0	1	0	1	1	3	0	1	[Grayed]				1	6				
V	U. of Calif. Davis, USA	[Grayed]																0	0	0	0	0	0	0	0	0	0
Total		14	14	9	9	14	14	12	12	14	24	12	24	11	27	2	12	20	22	108	158						

Results showed that 39 out of 87 datasets have been submitted for this period. The remaining 48 of 87 (55%) studies not submitted represent a worst-case scenario, since of these datasets it is not yet known which are appropriate for the Database. Most of these past-due studies are somewhat ancillary to the major research thrust of the CRSP for this period. Efforts to determine the usefulness and availability of these datasets are currently underway and consist of correspondence with the specific project leaders who carried out the research. A final, concentrated effort to gain these past-due datasets will continue through the end of 2000.

Dataset submissions associated with the Eighth and Ninth Work Plans (1996 to present) are current relative to project schedules, or—where not—active correspondence with project leaders is in progress. Correspondence among the Database Manager, the CRSP Program Management Office, and project leaders has documented exceptions that exist and intended submission schedules. We are pleased to report that we have received our first economic datasets for entry into the Database.

### Work Plan and Project Summary Tables

As used here, the term “work plan” conforms to that typically used by the CRSP and the term “project” collectively refers to the individual studies and experiments performed within these work plans. The purpose and content of the work plan and project summary tables maintained in the Database were described in an earlier report (Ernst and Bolte, 2000). These tables contain specifications and related information for experiments and studies completed over the lifetime of the CRSP (1982 to present). In summary, they facilitate administrative and communication tasks of the Database Manager and provide contextual information for extracted datasets.

Beginning with the Eighth Work Plan, experiment-treatment specifications have been submitted by researchers in conjunction with project datasets (see Data Submission Manual). This has been working very well and has supported the development of both textual and codified experiment-treatment descriptions. Textual descriptions provide short narratives for review by Database users, and codified descriptions support data searches based on experiment methods and materials. Experiment-treatment specifications list and describe the experiment-treatment protocols used in fish production studies. This information essentially consists of the fish culture methods employed and is required to take full advantage of data search and extraction procedures at the Database website.

Prior to the Eighth Work Plan, materials and methods information was not provided with submitted datasets. To the extent possible, experiment-treatment specifications for past projects have been developed by reviewing project reports and compiling management data in the Database. Results, questions, and incomplete information identified by this work were reviewed in a prior Database report (Ernst and Bolte, 1999). To verify and augment this information, forms have been made available to researchers at the

Database website for adding, editing, and reviewing the experiment-treatment specifications used in individual projects. CRSP researchers are being asked to access these forms for projects under their responsibility and make additions and corrections as necessary. This effort is ongoing and progress has been slow.

### Dataset Searching, Processing, and Linkage

Database search and linkage procedures available at the Database web site feature 1) completely user-directed search criteria and 2) facilitated, context-specific linkage to related resources. These website facilities have been described in previous reports (e.g., Ernst and Bolte, 1999; Ernst and Bolte, 2000). Data search criteria include fish production site, dates, production methods and species, and desired data types. As discussed earlier, use of search criteria based on fish production methods is only as good as the available experiment-treatment specifications. While significant progress for past work plans has been made in gaining these specifications, continued effort is required.

Continued progress has been made in the ability to direct Database users to context-specific, Internet, or locally accessible information that is relevant to extracted datasets. The basic structure and operation of this information network remains essentially the same as that described in earlier reports. Entry of new information is ongoing. Major areas of information include:

- 1) Research site and facility descriptions;
- 2) Analytical methods used in production experiments;
- 3) Explicit definitions of all available data types, with links to analytical methods where appropriate;
- 4) Experiment-treatment specifications, available as concise narratives;
- 5) References to electronic and printed publications; and
- 6) Author citations and contact information.

These navigational linkages consist of automated active links and manual reference links. The end objective is to make all links active. These linkages take advantage of project information and literature maintained at the PMO website as well as new components of the Database developed for this purpose. The availability of these related information resources enhances the ability of Database users to interpret and apply extracted datasets.

Progress has been made in the development of statistical and regression tools for extracted datasets, but these tasks have not been fully completed and implemented at the Database website. Completion of these tasks has been hampered by unanticipated technical challenges encountered in the combining and processing of raw, replicate data into treatment summary statistics and regression parameters. This area of work is currently the top priority of the Database Manager and considered vital to the continued development of the Database. While aquaculture scientists and engineers may prefer raw data, they are of limited use to those working in aquaculture education, extension, and production and to collaborators operating related aquaculture databases. These users will be best supported by summary statistics and design and management tools generated from extracted datasets.



To address these needs, four tasks remain in progress. These consist of the development of automated procedures to generate:

- 1) Experiment-treatment summary statistics (range, mean, and variance statistics and support for analysis of variance);
- 2) Derived values useful to fish culturists (fish growth and feeding rates, feed conversion efficiency, and biomass density and productivity);
- 3) Calibrated models for describing and predicting fish feeding and growth rates based on specific datasets; and
- 4) Summary tables of the specifications and results of multiple treatments from multiple experiments.

Areas of these tasks that have been completed include:

- 1) Mechanisms to define and group experimental treatments;
- 2) Mechanisms to group replicates (ponds) into their original experimental treatments;
- 3) Mechanisms to coordinate time-series replicate data within a given treatment;
- 4) Development of models for fish growth based on fish size, water temperature, and availability of prepared (exogenous) and natural (endogenous) foods; and
- 5) Development of models for estimating natural foods based on primary productivity, whole pond respiration rates, and "critical standing crop" and "carrying capacity" fish biomass densities.

### Database Use and Promotion

Since its inception in January 1997, the Database website has received a total of 4,680 visitors as of 31 July 2000. Over 1,700 of these visits occurred in the last year, and the usage rate of the Database website continues to accelerate. Improved tracking of Database users has been implemented, consisting of hit counters distributed throughout the Database website to monitor the relative use of the seven major areas of the site. Methods to automatically log country of origin and other general characteristics of website visitors are under development. The use of optional user profile forms (e.g., type of aquaculture work and specific interests) is under consideration. Objectives are to better understand user needs.

Promotion of the Database to potential users is ongoing. Critical issues are awareness of the Database availability, content, and applications. To date, the Database has been promoted through aquaculture conferences, publications, and linkages to related websites and databases. Direct promotion to specific user groups remains to be accomplished, following completion of the statistical data summary and reduction tools discussed earlier and a supporting Database Users Manual. Data submission from outside the CRSP has been limited, but the potential for this type of collaboration will increase as the analytical capacity

available at the Database website is further developed and made known.

Collaboration with related databases has been established for some time. Collaborators include the International Center for Living Aquatic Resource Management (ICLARM), Network of Aquaculture Centres in Asia-Pacific (NACA), and Consortium of International Earth Science Information Networks (CIESIN). Data content and format requirements have been established for these potential indexing links and access points to the Database, but completion of the intended scope of these collaborations will follow completion of the statistical data summary and reduction tools discussed earlier. Simple site-to-site web linkages with major fishery, aquaculture, and agriculture professional societies, research groups, universities, and information providers continue to be developed.

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## INFORMATION MANAGEMENT AND NETWORKING

MOU No. RD009D

### Staff

*Oregon State University, Corvallis, Oregon*

Danielle Clair	Information Manager
Ingvar Elle	Systems Administrator and Webmaster (through September 1999)
Kris McElwee	Assistant Information Manager; System Administrator (from October 1999)
Deborah Burke	Graduate Research Assistant (CRSP funded; through September 1999); Research Assistant (from May 2000)
Anu Gupta	Graduate Research Assistant (CRSP funded; from April 2000)
Matt Niles	Graduate Research Assistant (CRSP funded; through June 2000)
Jeff Burrigh	Undergraduate Student Worker (from June 2000)
Heidi Furtado	Undergraduate Student Worker

### Conferences

Central American Symposium on Aquaculture V at San Pedro Sula, Honduras, 18–20 August 1999. (Clair)

PD/A CRSP Annual Meeting at New Orleans, Louisiana, 31 January–2 February 2000. (Clair, McElwee)

Western Regional Aquaculture Expo at Desert Hot Springs, California, 27 February–1 March 2000. (Niles)

Website Development and Design at Eugene, Oregon, 1 June 2000. (McElwee)

### Work Plan Activities

The following report describes Information Management and Networking Component activities in the second year of the Ninth Work Plan.

#### REPORT: ANNUAL ACTIVITIES OF THE INFORMATION MANAGEMENT AND NETWORKING COMPONENT

*Ninth Work Plan, Information Management and Networking 2 (9IMNC2)*

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### BACKGROUND

The mission of the Information Management and Networking Component (IMNC) is to increase awareness and visibility of the PD/A CRSP by publishing and providing accessible technical and programmatic information, to monitor and report CRSP impacts, and to foster networking among persons involved in aquaculture.

Of the CRSP's research support components, IMNC works in closest concert with the Program Management Office (PMO) in disseminating technical and programmatic information in accordance with grant reporting requirements and in collecting and analyzing program impact information.

Component objectives are to:

- Identify target audiences for publications;
- Disseminate technical and programmatic information generated by the CRSP by providing appropriate materials and avenues;
- Track outputs of CRSP investigations; and
- Promote networking of CRSP participants with aquaculturists around the world.

In the reporting period IMNC activities have encompassed publication production and distribution, Internet activities, impact monitoring, and program promotion and networking.

### CRSP PUBLICATIONS

#### Data and Resource Management

An ongoing IMNC activity is managing the program's mailing database, which increases by about 10% per year. The database currently numbers 1,095 entries from 85 countries. IMNC staff also maintain a detailed inventory of PD/A CRSP publications and track publication circulation.

#### Production

IMNC has produced and distributed a variety of publications and informational materials during the reporting period, listed below.

##### *Seventeenth Annual Administrative Report*

Clair, D., K. McElwee, D. Burke, M. Niles, and H. Egna (Editors), 2000. PD/A CRSP, Oregon State University, Corvallis, Oregon, 124 pp.

##### *Seventeenth Annual Technical Report*

McElwee, K., D. Burke, M. Niles, X. Cummings, and H. Egna (Editors), 2000. PD/A CRSP, Oregon State University, Corvallis, Oregon, 178 pp.

##### *Ninth Work Plan Project Profiles*

Published in conjunction with the PMO, May 2000, 68 pp.

Bookmark to promote the new look of the PD/A CRSP website; April 2000.

*Aquanews*, quarterly newsletter (distributed by hard copy and available on the CRSP website): Vol. 13, No. 4 and Vol. 14, Nos. 1, 2, and 3.

*EdOp Net*, monthly newsletter of aquaculture-related education and employment opportunities (distributed by hard copy and electronic mail and available on the CRSP website): Vol. 4, Nos. 8, 9, 10, 11, and 12; Vol. 5, Nos. 1, 2, 3, 4, 5, 6, and 7.

*CRSP Research Reports*, an in-house publication series which includes *Notices of Publication*:

- 99-133 Masculinization of Nile tilapia (*Oreochromis niloticus*) by immersion in androgens (10/99)
- 99-134 Risks associated with the use of chemicals in pond aquaculture (10/99)
- 99-135 Generation of daily and hourly solar radiation values for modeling water quality in aquaculture ponds (10/99)
- 99-136 Good management practices (GMPs) to reduce environmental impacts and improve efficiency of shrimp aquaculture in Latin America (1/00)
- 99-137 Estimation of carrying capacity for shrimp aquaculture in the eastern estuaries of the Gulf of Fonseca (1/00)
- 99-138 Non-parametric estimation of returns to investment in Honduras shrimp research (1/00)
- 99-139 Risk analysis of shrimp farming in Honduras (1/00)
- 99-140 Masculinization of Nile tilapia (*Oreochromis niloticus*) by immersion in synthetic androgens: Timing and efficacy (1/00)
- 99-141 Fate of the masculinization agent methyltestosterone in the pond environment (1/00)
- 99-142 Sistemas de producción de tilapia en Honduras (Tilapia production systems in Honduras) (1/00)
- 99-143 Evaluation of integrated tilapia culture by resource limited farmers in Panama and Guatemala (1/00)
- 99-144 Efecto del recambio de agua en la producción semi-intensiva de *Penaues vannamei* (Effect of water exchange on semi-intensive production of *Penaues vannamei*) (1/00)
- 99-145 Modeling growth of Nile tilapia (*Oreochromis niloticus*) in a cage-cum-pond integrated culture system (1/00)
- 00-146 Effects of feeding pelleted versus non-pelleted defatted rice bran on Nile tilapia *Oreochromis niloticus* production and water quality in ponds (4/00)
- 00-147 Sound policies for food security: The role of culture and social organization (4/00)
- 00-148 Integrated cage culture in ponds: Concepts, practice and perspectives (4/00)
- 00-149 An overview of freshwater cage culture in Thailand (4/00)

*PD/A CRSP Publications Catalog*  
Published June 2000, 24 pp.

*CRSP Participant Directory*  
Published October 1999 and March 2000, 21 pp.

The following publications were submitted electronically to and are available to download as PDF files from the USAID Development Experience Clearinghouse:

- *Fourteenth Annual Technical Report*
- *Fifteenth Annual Administrative Report*
- *Fifteenth Annual Technical Report*
- *Seventeenth Annual Administrative Report*
- *Seventeenth Annual Technical Report*
- *Ninth Work Plan*
- *Pond Fertilization: Ecological Approach and Practical Applications*

## WORLD WIDE WEB

### PD/A CRSP Website Developments

IMNC is responsible for the development and maintenance of the PD/A CRSP website <pdacrsp.orst.edu>, which was brought online in 1995. The IMNC tracks usage of the website. The site averaged over 456 external hits each week (Figure 1). The EdOp Net page, a database of educational and employment opportunities in aquaculture and related fields was the most visited, averaging 288 hits per week (Figure 2). The Publications page was also popular, with an average of 136 hits per week (Figure 3). Other pages feature programmatic information, links to aquaculture-related websites, and links to the PD/A CRSP Database and other data tools. Web-related activities in the current reporting period have included:

- Adopting a virtual domain name <pdacrsp.orst.edu> to replace the unwieldy <www.orst.edu/dept/crsp/homepage.html>;
- Redesigning the site and posting the new home, Data Tools, and EdOp Net pages;
- Modifying images and page design to allow better access to people with limited vision;
- Upgrading the EdOp Net database program to allow Web access to an unlimited number of users and to facilitate the addition of a search feature;
- Adding new documents to the publications section;
- Developing an online HTML version of *Aquanews*;

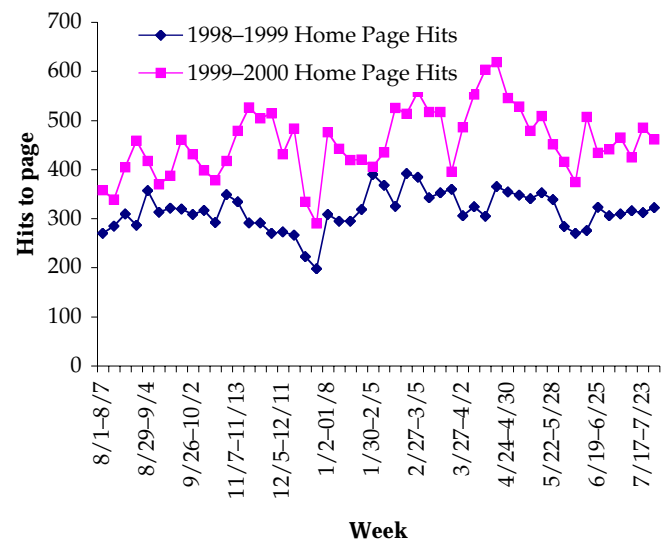


Figure 1. Weekly hits to the PD/A CRSP website home page, August 1999 to July 2000.

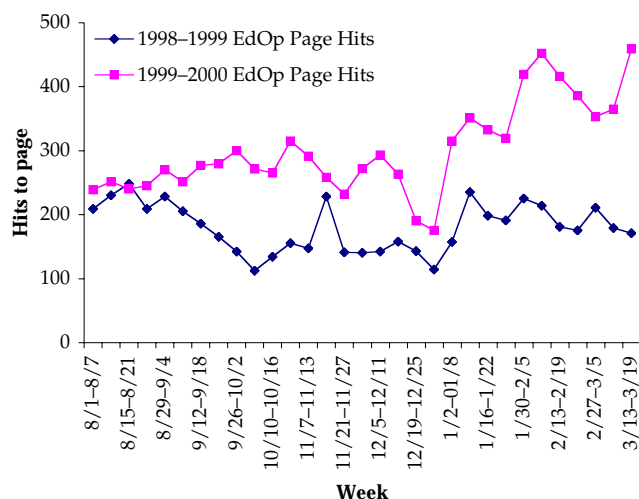


Figure 2. Weekly hits to the EdOp Net page measured between August 1999 and March 2000.

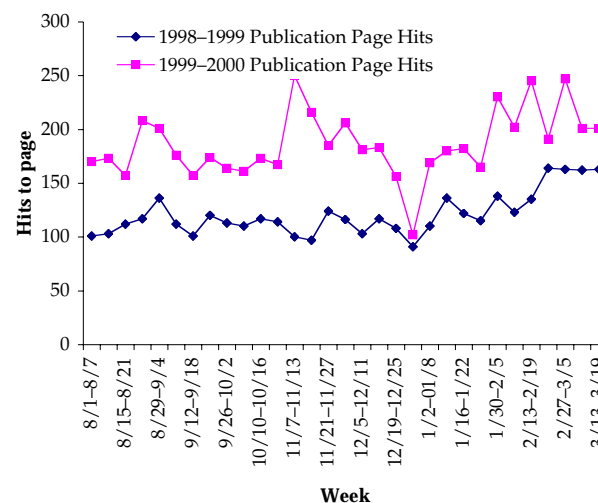


Figure 3. Weekly hits to the PD/A CRSP website publications page measured between August 1999 and March 2000.

- Joining the Sustainable Development Networks database of the European Foundation, available at <susdev.eurofound.ie/>; and
- Adding the PD/A CRSP to the International Higher Education Linkages Project (IHELP) Database, available at <www.aascu.org/alo/ihelp>.

### Publications and Their Formats

The Publications page of the PD/A CRSP website is an important source of programmatic and research material. Documents are placed on the site in one of two formats: PDF and HTML. Documents containing many complex graphics and a detailed layout are generally placed on the site in PDF format. These documents can be read with Adobe Acrobat Reader. Documents added in this format to the Publications page in the last year include:

- *Site Descriptions*—as a single document and as separate country files
- *Aquanews*—PD/A CRSP quarterly newsletter (4 issues)
- *Seventeenth Annual Technical Report*
- *Seventeenth Annual Administrative Report*
- Full-text version of the *PD/A CRSP Research Report 99-129*

Documents that contain few graphics and can be divided into relatively short sections are placed on the web in HTML format. Publications added in the last year in this format include:

- *Second Addendum to the Eighth Work Plan*
- *Ninth Work Plan*
- *Aquanews*—beginning with Winter 2000 issue (3 issues)
- *PD/A CRSP Notices of Publication*
- Complete list of PD/A CRSP publications

Tables of contents of most publications are placed on the web in HTML format to allow rapid browsing of publication contents.

### Employment and Educational Opportunities Online

*EdOp Net* is a perennially popular source of aquaculture-related employment and education opportunities made

available from the PD/A CRSP website, via monthly email, and in a mailed, printed format. *EdOp Net* is delivered from the CRSP website via a searchable relational database and its web-enabling plug-in. The email version is sent out monthly to 323 subscribers. The printed version is mailed to 41 international and 23 domestic subscribers.

### IMPACT MONITORING

The CRSP uses impact indicators to monitor the effects of its research on stakeholders, beneficiaries, extension services, the research community, and the field of aquaculture. The IMNC is responsible for annually soliciting and collecting researchers' quantifications of their impacts.

In addition to these formal impact indicators, IMNC staff collect project-specific impact information designed to capture CRSP participants' activities that were sponsored by the CRSP or came about as a result of CRSP work. These forms are requested on a quarterly basis and allow the IMNC to monitor, track, and report progress in the areas of outreach, public service, and professional development. The types of information collected include:

- Research progress
- Institution building (contacts with host country scientists, government officials, extension agents, farmer organizations, farmers, nongovernmental organizations)
- New host country involvement
- Physical support for host country institutions (e.g., pond renovation)
- Linkage development (technical or professional communications with USAID missions, host country institutions, nongovernmental organizations, and regional institutions)
- Conferences attended
- Students advised
- Lectures, seminars, presentations, and workshops given
- Outreach activities (community or school extension activities) undertaken
- Electronic linkages made

- Publications, including technical papers and book chapters, authored
- Theses published
- Awards or commissions received
- Informational material developed

Following the discontinuation of the Education Development Component, IMNC now collects information related to student activities supported by CRSP researchers. Support typically includes providing graduate research assistantships, hiring undergraduate student workers, providing research materials, and advising student workers' research papers. During this reporting period, five formal programs (two Masters and three Ph.D. degrees) were completed by CRSP-sponsored students. The following theses were completed this year with assistance from CRSP researchers:

- Ernst, D., 2000. AquaFarm<sup>®</sup>: Simulation and decision-support software for aquaculture facility design and management planning. Ph.D. dissertation, Oregon State University, Corvallis, Oregon.
- Gichuri, W.M., 1999. Relative contribution of rice bran and inorganic fertilisers in semi-intensive tilapia (*Oreochromis niloticus*) and catfish (*Clarias gariepinus*) polyculture in Kenya. M.Sc. thesis, University of Nairobi, Kenya.
- Lockhart, M., 1999. Farmer perceptions of constraints on aquaculture development in Central Kenya: Market, household, and resource considerations. M.S. thesis, Auburn University, Alabama.
- Mon, A.A., 2000. Use of lotus (*Nelumbo nucifera*) for nutrient retrieval from pond mud. M.S. Thesis, Asian Institute of Technology, Bangkok, Thailand.
- Valderrama, D., 2000. Economic analysis of shrimp farming in Honduras. M.S. thesis, University of Arkansas at Pine Bluff, Arkansas.
- Warrington, R.L., 1999. Sex ratio variation and sex determining mechanisms in *Oreochromis niloticus*. M.S. thesis, Auburn University, Alabama.

In addition to maintaining records of students trained under CRSP support and direction, the IMNC prepared a CRSP Training Inventory for use by the External Evaluation Panel (EEP) during its visits to CRSP sites. The report included a list of students, their national and university affiliation, degree granted or sought, degree topic, funding status, and advisor. The IMNC also prepared statistics on student gender, type of degree, funding status, current occupation, and non-CRSP training.

### PROGRAM PROMOTION AND NETWORKING

IMNC sought to increase the visibility of the PD/A CRSP both in Oregon and throughout the world. The PD/A CRSP co-sponsored two conferences, the Fifth Central American Symposium on Aquaculture (V CASA), held in August 1999 in Honduras, and the Tenth Biennial Conference of the International Institute of Fisheries Economics and Trade (IIFET 2000). The IMNC assisted the PMO by promoting the events through the PD/A CRSP website and through publication in *Aquanews*. The IMNC also participated in University Day, a campus-wide event at Oregon State University designed to familiarize faculty and staff with

programs on campus. The CRSP booth received over 100 visitors. IMNC staff answered questions about the program and distributed informational materials such as program brochures, annual reports, *EdOp Net*, and *Aquanews*. In addition to the distribution of informational materials, IMNC increased program visibility through the creation of a jovial atmosphere with games and food.

IMNC also established new connections both domestically and internationally and provided information worldwide via CRSPMail, an electronic mail address for website visitors. During this reporting period, CRSPMail received over 50 queries from individuals representing 24 countries: Bangladesh, Brazil, Colombia, Egypt, India, Indonesia, Jamaica, Lebanon, Malaysia, Mexico, Nicaragua, Nigeria, Pakistan, Panama, Peru, Philippines, Senegal, Singapore, South Africa, Tanzania, United Arab Emirates, the US, Vietnam, and Zambia. Many of the queries originated in countries with no previous or formal linkage with the CRSP. Answering queries provided a valuable forum to introduce aquaculture enthusiasts to CRSP researchers and to encourage the use of CRSP-developed sustainable practices. Many individuals interested in establishing fish farms wrote asking for advice on materials, species, funding, and practices. The IMNC endeavored to answer each query using country-specific details. Querying individuals were also directed to publications and researchers whose topics and interests matched their own. Many queries were about topics beyond the scope of regular CRSP research. For instance, a Nigerian fish farmer wrote to ask about leech infestation, an Illinois high school student inquired about the effects of acid rain on pond organisms, and a Peruvian wrote about establishing a high altitude trout aquaculture operation. The IMNC responded to these requests by searching library databases and Internet pages to find publications, agency names, and researchers that could provide information. A second type of query concerned employment. People from all around the world wrote the IMNC to offer their services or to inquire about graduate opportunities and scholarships. The IMNC responded by offering them a free subscription to *EdOp Net*, and in many cases, by suggesting the names of local organizations or agencies that might offer positions. The IMNC was rewarded in many circumstances when it heard back from people who found that the publications, technical information, contacts, conference dates, or job notices offered were valuable.

PD/A CRSP researchers were also responsive to CRSPMail inquiries and offered assistance and resources.

- An individual in Zambia hoping to set up a tilapia production facility to satisfy local demand wrote requesting information on reproduction control, supplementary feeding, oxygen enrichment, and sourcing materials. The questions were sent out to CRSP researchers; responses were pooled then forwarded to the correspondent. The man in Zambia wrote back to say that he was grateful for the assistance and would utilize the information.
- An individual in Malaysia wrote for advice on designing an experiment growing tilapia. Remedios Bolivar, CRSP Philippines Project Host Country Principal Investigator, responded with details of experiments

conducted at the Freshwater Aquaculture Center at Central Luzon State University, Philippines. She offered guidance on stocking rates, culture period, water circulation rates, and anticipated yields.

- Bolivar also assisted a man from San Diego who had contacted the IMNC for help in starting a shrimp farm in the Philippines. He had been given Bolivar's name, as well as information on sustainable shrimp farming practices, researchers, consulting companies, and publications. When the IMNC wrote to Bolivar to notify her that she would be receiving a request, she wrote to say that the man had contacted her immediately, and that they were already looking into his options.
- An aquaculturist in Mexico hoping to import tilapia to the US was pointed to the Dirección General de Acuicultura in Mexico City for a list of tilapia exporters. This information was provided by CRSP researcher Wilfrido Contreras-Sánchez.

An electronic mailing list, PDA-CRSP-L, continues to complement other means of communication within the PD/A CRSP community. The mailing list, which includes approximately 65 members, allows any subscriber to distribute a message to the entire group quickly and at no cost. Typical postings include administrative information of

general interest, availability of new publications, requests for training materials, announcements of opportunities in the field of aquaculture, and relevant travel advisories.

In addition to these activities, IMNC worked closely with the PMO in creating materials for the following events:

- A poster entitled "Global Partnerships and Research: Highlights from the Pond Dynamics/Aquaculture Collaborative Research Support Program" was presented at the World Aquaculture Society Meeting in New Orleans, Louisiana.
- "CRSPs—A Vital Link between US Universities and Developing Countries" highlighted domestic benefits of the CRSPs at the Third Annual Food and Agricultural Science Exhibition and Reception on Capitol Hill. The event was held 7 March 2000 in Washington, DC, and was sponsored by the National Association of State Universities and Land-Grant Colleges (NASULGC).
- A plaque that was presented to outgoing Bean/Cowpea CRSP Director Pat Barnes-McConnell during a meeting of the CRSP Council Steering Committee. The Steering Committee meeting coincided with a NASULGC meeting, which was attended by both Barnes-McConnell and PD/A CRSP Director Hillary Egna. Both meetings were held in Otter Rock, Oregon.



# RESEARCH SUMMARY

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Research conducted under the Eighth and Ninth Work Plans includes nine of the fifteen themes outlined in the *Continuation Plan 1996–2001* (see also Tables 1 through 4 on pp. 5–8 of the present report). In the reporting period (1 August 1999 through 31 July 2000), CRSP scientists conducted research in the following areas: pond dynamics, feeds and fertilizers, reproduction control, new aquaculture systems/new species, effluents and pollution, appropriate technology, marketing and economic analysis, adoption/diffusion, and decision support systems.

A summary of each study report received during the reporting period is presented below. Reports are identified by research area, research theme and code, project leader, and report title. In addition, information about the status (i.e., final vs. progress) of each report is also provided. For example, a final report was owed if the completion date for a study fell within the reporting period; similarly, if a study was not scheduled to be completed until after the close of the reporting period, a progress report was owed on 31 July. Please see Appendix 5 for a tabular overview of reports received, themes addressed, and study completion dates (where these differ from completion dates listed in the *Eighth* or *Ninth Work Plan*, it is owing to schedule changes requested and approved in the reporting period).

**RESEARCH AREA: PRODUCTION OPTIMIZATION**

**RESEARCH THEME: POND DYNAMICS**

9PDR2/Pond soil characteristics and dynamics of soil organic matter and nutrients/Boyd [Progress report]

Historically, little work has been conducted on the role of bottom soils in pond aquaculture. As levels of production have increased, it has become apparent that bottom soils are an important factor in pond dynamics. This study is a continuation of Eighth Work Plan studies to characterize pond soils. Three ponds from a freshwater site at the Ayutthaya Fisheries Station and three ponds from a brackishwater shrimp farm at Banggachi, Thailand, were cored in September 1999. Moisture content, pH, organic carbon, nitrogen, and phosphorus decreased with depth; sulfur also increased with depth. Calcium, magnesium, potassium, and sodium were unexpectedly high at the freshwater site. Concentrations of minerals and nutrients were greater at the brackishwater site than at the freshwater site; this was due to intensive farming practices involving high inputs of nutrients and organic matter and to the naturally occurring concentrations of minerals in salt water at the brackishwater site. Young and old ponds developed profiles with distinct horizons. Horizon development is highly influenced by external input of soils, followed by internal input of organic matter, internal resuspension and resedimentation, and changes in soil properties resulting from nutrient and lime inputs. This study suggests that the simplest and most reliable method of pH measurement, direct insertion of a standard pH probe into a 1:1 mixture of dry soil (dried at 40°C and pulverized to pass through a 2.36-mm screen) and distilled water, should be adopted as a standard procedure. Cores were selected from the CRSP site in the Philippines and from an additional site in Brazil and will be analyzed in the following months. Results from all sampled CRSP sites will then be used to develop a concept of pond soil development and a system of pond classification.

**RESEARCH AREA: PRODUCTION OPTIMIZATION**

**RESEARCH THEME: FEEDS AND FERTILIZERS**

8FFR1K/Global Experiment: Optimization of nitrogen fertilization rate in freshwater tilapia production ponds/Bowman [Final report]

Prior PD/A CRSP research has addressed primary production in tilapia ponds through the addition of inorganic and organic fertilizers. While increased fertilization generally increases primary productivity (and thus tilapia yield) in aquaculture ponds, experiments to determine optimal levels of inorganic fertilization rates are lacking. Researchers at all PD/A CRSP sites undertook the Eighth Work Plan Global Experiment to accomplish the following objectives: 1) determine the optimal rate of nitrogen fertilization (in the presence of adequate phosphorus and carbon) to obtain optimal primary productivity and yields of Nile tilapia in freshwater production ponds; 2) determine the most profitable nitrogen fertilization rate; and 3) develop a full-cost enterprise budget for the most profitable nitrogen fertilization rate identified. This study summarizes results from cool- and warm-season experiments conducted at the Sagana Fish Farm, Kenya. In the cool-season experiment, ponds were stocked with sex-reversed Nile tilapia, *Oreochromis niloticus*, averaging 16.9 g at a rate of 1,000 kg ha<sup>-1</sup> and with *Clarias gariepinus* fingerlings at a rate of 37 kg ha<sup>-1</sup>. In the warm season experiment, all ponds were stocked with sex-reversed *O. niloticus* at 1000 kg ha<sup>-1</sup> and with *C. gariepinus* juveniles at 125 kg ha<sup>-1</sup>. Treatments for this experiment consisted of nitrogen (diammonium phosphate and urea) applied at 0, 10, 20, and 30 kg ha<sup>-1</sup> wk<sup>-1</sup>. Phosphorous was applied at a rate of 8 kg ha<sup>-1</sup> wk<sup>-1</sup> to the three treatments receiving quantifiable urea. In both season trials there was a significant quadratic relationship between gross fish yield and nitrogen input. However, increasing nitrogen input beyond 20 kg ha<sup>-1</sup> wk<sup>-1</sup> did not result in increased tilapia yields. A partial budget



analysis indicated that calculated rates of 19.9 and 16.0 kg N ha<sup>-1</sup> wk<sup>-1</sup> yielded the highest marginal returns for the cool- and warm-season experiments, respectively. These results are in the range of those reported from other CRSP sites. *Clarias* did not affect tilapia production and was not negatively impacted by high nitrogen levels. The results of this study, advocating a low-intensity approach to aquaculture, may be readily accepted by local farmers who are willing to adopt low-cost aquaculture methods over increasingly intensified approaches that drive up production costs.

**RESEARCH AREA: PRODUCTION OPTIMIZATION**

**RESEARCH THEME: FEEDS AND FERTILIZERS**

8FFR1Ph/Global Experiment: Optimization of nitrogen fertilization rate in freshwater tilapia production ponds (Cool season trial)/Brown [Final report]

Prior PD/A CRSP research has addressed primary production in tilapia ponds through the addition of inorganic and organic fertilizers. While increased fertilization generally increases primary productivity (and thus tilapia yield) in aquaculture ponds, experiments to determine optimal levels of inorganic fertilization rates are lacking. Researchers at all PD/A CRSP sites undertook the Eighth Work Plan Global Experiment to accomplish the following objectives: 1) determine the optimal rate of nitrogen fertilization (in the presence of adequate phosphorus and carbon) to obtain optimal primary productivity and yields of Nile tilapia in freshwater production ponds; 2) determine the most profitable nitrogen fertilization rate; and 3) develop a full-cost enterprise budget for the most profitable nitrogen fertilization rate identified. This study summarizes results from a cool-season experiment conducted at the Freshwater Aquaculture Center of Central Luzon State University, Philippines. Ponds were stocked with sex-reversed male *Oreochromis niloticus* at an initial density of 1,000 kg ha<sup>-1</sup>. Treatments for this experiment consisted of nitrogen (urea and ammonium phosphate) applied at 0, 10, 20, and 30 kg ha<sup>-1</sup> wk<sup>-1</sup>. Phosphorous was applied at a rate of 8 kg ha<sup>-1</sup> wk<sup>-1</sup> to the three treatments receiving quantifiable urea. Extrapolated gross fish yield was highest in the treatment receiving 30 kg N ha<sup>-1</sup> wk<sup>-1</sup> (2,671 kg ha<sup>-1</sup>), followed by the treatments receiving 10, 20, and 0 kg N ha<sup>-1</sup> wk<sup>-1</sup>, in that order. These results are in the range of those reported from other sites. However, the variation in return was not statistically significant, indicating that while some fertilization is better than no fertilization for increasing yield, doubling or tripling the amount of fertilizer does little to increase yield. A partial budget analysis indicated that the 10 kg N ha<sup>-1</sup> wk<sup>-1</sup> treatment gave slightly higher profit than the treatments with higher fertilization. A net return of US\$57 can be obtained from the culture of Nile tilapia in a 0.05-ha pond for 90 days. The results of this study, advocating a low-intensity approach to aquaculture, may be readily accepted by local farmers who are willing to adopt low-cost aquaculture methods over increasingly intensified approaches that drive up production costs.

**RESEARCH AREA: PRODUCTION OPTIMIZATION**

**RESEARCH THEME: FEEDS AND FERTILIZERS**

9FFR2/Fish yields and economic benefits of tilapia/*Clarias* polyculture in fertilized ponds receiving commercial feeds or pelleted agricultural by-products/Bowman [Progress report]

High-quality, nutritionally complete supplemental feeds produce high fish yields; however, in many developing countries such feeds are limited. In Kenya, high-quality feeds are expensive, and poultry and bran diets are often substituted. However, poultry rations contain more energy per unit of protein than recommended, and brans are nutritionally deficient. This experiment examines appropriate feed/fertilizer combinations for tilapia that will increase natural food organisms in ponds, thus improving production. Three low-cost supplemental feeds were tested: rice bran, a commercially available pig finisher pellet, and a formulated, test-diet pellet. Fertilization regimes were the same for all three diets, consisting of application of diammonium phosphate and urea. Measurements of fish size, fish growth, and water quality parameters were taken throughout the experiment. Preliminary results indicate that average fish yield is greatest in ponds receiving pig finisher pellets, followed by the formulated, test-diet pellets, and finally by rice bran. Economic analyses also indicate that pig finisher pellets yield the greatest profit given the investment. Further analyses of collected data are currently being conducted.

**RESEARCH AREA: PRODUCTION OPTIMIZATION**

**RESEARCH THEME: FEEDS AND FERTILIZERS**

9FFR2A/Stable carbon and nitrogen isotope analysis of tilapia and *Clarias* fed commercial feeds or agricultural by-products /Lochmann [Abstract; report title different than experiment title in *Ninth Work Plan*]

High-quality, nutritionally complete feeds produce high fish yields; however, in many developing countries such feeds are limited. In Kenya, high-quality feeds are expensive, and poultry and bran diets are often substituted. Feeds that consist of small particles are often unconsumed, and pelleting appears to increase efficiency of use. This experiment examines a variety of diets with the goal of developing a feed/fertilizer combination that is appropriate for fish farming in Kenya. Tilapia were cultured at the Sagana Fish Farm using three treatments: 1) a rice bran diet, 2) a pelleted poultry feed, and 3) a high-quality, nutritionally formulated pelleted feed. All treatments received identical chemical fertilization. Measurements of fish growth rate, fish yield, water quality, and reproduction were taken. Samples of feeds, fertilizers, fish, mud, and plankton are currently being prepared for isotopic analysis.

**RESEARCH AREA: PRODUCTION OPTIMIZATION**

**RESEARCH THEME: FEEDS AND FERTILIZERS**

9FFR4/Timing of the onset of supplemental feeding of Nile tilapia (*Oreochromis niloticus*) in ponds/Brown [Final report]

Tilapia producers in the Philippines commonly provide supplemental feeds to fertilized ponds. Supplemental feeding, in addition to fertilization, is often done during the first 40 days of the grow-out period. CRSP research in



Thailand, however, has shown that a delay in feeding onset of 80 days, rather than 38 days, after stocking results in no loss of productivity. On-farm trials to test the application of these results were conducted in Nueva Ecija, Philippines. Seven farmers each raised fish in two ponds: one with a 45-day delay in feeding and one with a 75-day delay. Ponds were stocked with Nile tilapia of the GIFT strain and fertilized with urea and ammonium phosphate at a rate of 28 kg N ha<sup>-1</sup> wk<sup>-1</sup> and 5.6 kg P ha<sup>-1</sup> wk<sup>-1</sup>. Fish were given feeds consisting of 67% rice bran and 33% fish meal. There were no significant differences in final mean weight, daily weight gain, fish yield, or survival rate between the two treatments. A significant difference was found in the amount of feed used and its associated costs. A simple cost/benefit analysis showed that by delaying the onset of feeding, the net value of the crop was improved.

**RESEARCH AREA: PRODUCTION OPTIMIZATION**

**RESEARCH THEME: REPRODUCTION CONTROL**

8RCR1C/Methods for the contribution from the male and female genome to sex inheritance/Phelps [Final report]

Sex inheritance in Nile tilapia does not conform to a 1:1 ratio of females to males, as expected from a simple Mendelian XX:XY sex determination process. All-male populations are desirable, but the widely noted variation and general unpredictability of tilapia sex ratios makes the selection of true-breeding YY fish difficult. This study is part of a three-phase Eighth Work Plan research program to characterize sex determination. Specifically, this study examined the role of autosomes. The experimental design used three strains of highly inbred tilapia from the Ivory Coast, Egypt, and Ghana. The design also used three variations in breeding: 1) single males with multiple partners, 2) single females with multiple partners, and 3) repeat spawns of the same pair. Results from all designs yielded mean average male populations of greater than 50%, with considerable ranges. For the entire population, the mean percent male was 54.1% with a range of sex ratios from single spawns of 16 to 100% male; this is a statistically significant variation from the expected 1:1 inheritance pattern. Results of this study did not clearly indicate that sex determination in tilapia is sex linked. Sex determination appears to be a product of individual parent contribution, making a true-breeding YY program difficult.

**RESEARCH AREA: PRODUCTION OPTIMIZATION**

**RESEARCH THEME: REPRODUCTION CONTROL**

9RCR5B/Masculinization of tilapia by immersion in trenbolone acetate: Growth performance of trenbolone acetate-immersed tilapia/Fitzpatrick [Final report]

All-male populations of tilapia are desirable to prevent unwanted reproduction and because males grow more quickly than females. Past research has identified a diet with 17 $\alpha$ -methyltestosterone (MT)-treated food as an effective masculinizing agent. This experiment, one component of a three-part Ninth Work Plan examination of trenbolone acetate (TA), examines short-term immersion in TA as an alternative to treated food. TA has been used previously in the cattle industry and is considered a more potent masculinizing agent than MT. The effects of

TA immersion were compared to the effects of MT treatment; these were both compared to results from a feeding control and an immersion control. Results showed that TA immersion led to significant masculinization of tilapia fry, but with a lower efficiency than the MT treatment. Neither treatment led to increases in fish growth; however, immersion in TA may remove some of the environmental risks of treatment with MT, which has been found to remain in pond sediments.

**RESEARCH AREA: PRODUCTION OPTIMIZATION**

**RESEARCH THEME: REPRODUCTION CONTROL**

9RCR5C/Masculinization of tilapia by immersion in trenbolone acetate: Detection of trenbolone acetate after treatment/Fitzpatrick [Progress report]

Previous studies have shown that immersion in trenbolone acetate (TA) can be an alternative to the use of 17 $\alpha$ -methyltestosterone (MT)-treated food to achieve all-male tilapia populations. However, the concentration of TA in solution is greater than that of MT in treated food, and the costs of immersion are greater than that of food treatment. This study examines the fate of TA in solution and the potential for reuse of immersion water. Tilapia fry were immersed in water containing either TA or an ethanol control. An additional control consisted of hormone-treated water that did not receive fry. Before, during, and after immersion and fry removal, water samples were tested to detect remaining levels of TA. Initial results have shown that TA concentrations are highly variable, with some treatments showing an increase in TA after introduction and removal of fish. In addition, these results show that masculinization rates were low and mortality was high in TA-immersed fry. Thus, initial findings indicate that a target dose for TA immersion is difficult to achieve, perhaps due to TA precipitation in water. Additional trials are being conducted, both to validate existing results and to remove confounding variables.

**RESEARCH AREA: PRODUCTION OPTIMIZATION**

**RESEARCH THEME: REPRODUCTION CONTROL**

9RCR6A/Monosex tilapia production through androgenesis: Selection of individuals for sex inheritance characteristics for use in monosex production/Phelps [Abstract; report title different than study title in *Ninth Work Plan*]

Sex inheritance in Nile tilapia does not conform to a 1:1 ratio of females to males, as expected from a simple Mendelian XX:XY sex determination process. All-male populations are desirable, but the wide variation and unpredictability of tilapia sex ratios makes the selection of true-breeding YY fish difficult. This study uses cross-breeding among and within nine families to determine a true-breeding tilapia strain. A total of 80 within-family and 65 cross-family spawns have been obtained from the nine families, with the goal of determining the heritability of sex and factors influencing it. In addition, the study is culturing progeny in aquaria at either 28°C or 36°C during the period of gonadal differentiation to determine the effect of temperature on sex ratios. Sex ratios will be determined and analyzed for frequency within families.

**RESEARCH AREA:** PRODUCTION OPTIMIZATION  
**RESEARCH THEME:** REPRODUCTION CONTROL  
 9RCR7/Monosex tilapia production through androgenesis/  
 Shelton [Abstract]

Sex inheritance in Nile tilapia does not conform to a 1:1 ratio of females to males, as expected from a simple Mendelian XX:XY sex determination process. All-male populations are desirable to prevent unwanted reproduction and because males grow more quickly than females. Goals of this experiment are to produce a protocol for the production of androgenotes carrying only the paternal genome and to examine the mechanism of sex determination. In order to test for the succession of the paternal genome, a phenotypic marker must be developed. This experiment is currently examining color mutation as a phenotypic marker by crossing red tilapia with Ghana tilapia. Once the phenotypic marker is established, construction of the protocol will commence.

**RESEARCH AREA:** PRODUCTION OPTIMIZATION  
**RESEARCH THEME:** REPRODUCTION CONTROL  
 9RCR8/The application of ultrasound to produce all-male tilapia using immersion protocol/Diana [Abstract]

Masculinization of tilapia continues to be an important tool for aquaculturists to prevent unwanted reproduction and because males grow more quickly than females. Past and concurrent research has identified the hormones 17 $\alpha$ -methyltestosterone (MT) and androstenedione as effective masculinizing agents. One of the objectives of this investigation is to examine the efficacy of using ultrasound technology to enhance the delivery of hormones using immersion protocol. MT and androstenedione were tested during one- or two-hour treatments with concentrations of 100 and 500  $\mu\text{g l}^{-1}$ . Fish were treated on days 10 and 13 post-fertilization. In this test, the use of ultrasound showed a significantly higher rate of masculinization than that seen in a control. Further tests will examine two more potent hormones using the same immersion protocol.

**RESEARCH AREA:** PRODUCTION OPTIMIZATION  
**RESEARCH THEME:** NEW AQUACULTURE SYSTEMS/  
 NEW SPECIES  
 9NS1/Lotus-fish culture in ponds: Recycling of pond mud nutrients/Diana [Abstract; report title different than experiment title in *Ninth Work Plan*]

Nutrient enrichment of pond waters is an essential management practice in aquaculture, particularly in semi-intensive and intensive culture systems. Nutrients, and in particular phosphorus, accumulate in pond muds, which serve as a sink. Pond muds have been used to fertilize land crops, whereby phosphorus is extracted and used. However, removing pond mud is labor intensive. This experiment examines whether the alternative practice of lotus-fish culture can utilize these reserved nutrients. Ponds will be cultivated with fish alone, lotus alone, and fish and lotus together. Fish were stocked at 2 fish  $\text{m}^{-2}$  and lotus plants were stocked at 20 plants per 200- $\text{m}^2$  pond. Treatment ponds stocked with tilapia were fertilized weekly with urea and triple superphosphate (TSP) at rates of 28 kg N and

7 kg P  $\text{ha}^{-1} \text{wk}^{-1}$ ; no fertilizer was applied in ponds with lotus alone. After fish harvest, nutrient recovery rates, fish growth rates, and mud characteristics will be analyzed. Cost analyses will also be performed.

**RESEARCH AREA:** PRODUCTION OPTIMIZATION  
**RESEARCH THEME:** NEW AQUACULTURE SYSTEMS/  
 NEW SPECIES  
 9NS2/Culture of mixed-sex Nile tilapia with predatory snakehead/Diana [Abstract]

Intensive culture of Nile tilapia can reap profits. However, intensive culture can also lead to overpopulation of tilapia ponds, which leads to a loss of efficiency, as growth is stunted by a shortage of food. Predators such as snakehead (*Channa striata*) have been reported as effective in reducing population numbers, but the most effective densities of snakehead are unknown. This experiment examined the efficiency of snakehead in controlling tilapia reproduction and its effect on tilapia growth and production. Six treatments were monoculture of sex-reversed tilapia, monoculture of mixed-sex tilapia, and polyculture of mixed-sex tilapia with snakehead at stocking ratios of 10:1, 20:1, 30:1, 40:1, and 80:1. Initial results from trials in 1999 showed that snakehead can control overpopulation of mixed-sex Nile tilapia. However, the snakehead burrowed through pond walls and moved freely among ponds, confounding results and necessitating duplication of the experiment.

**RESEARCH AREA:** PRODUCTION OPTIMIZATION  
**RESEARCH THEME:** NEW AQUACULTURE SYSTEMS/  
 NEW SPECIES  
 9NS3/Development of sustainable pond aquaculture practices for *Colossoma macropomum* in the Peruvian Amazon/Kohler [Progress report; report title different than investigation title in *Ninth Work Plan*]

Evaluating the aquaculture potential of local and native species remains a need in Peru, as few production technologies for species in the Amazon basin have been developed. In addition, the nutrition requirements and optimal stocking densities of local species such as *Colossoma* spp. and *Piaractus* spp. are poorly understood. This investigation addresses these topics for *Colossoma macropomum*. *C. macropomum* was cultured at densities of 2,500, 3,250, and 4,000 fish  $\text{ha}^{-1}$  and fed a locally prepared diet. The mean weight decreased with increasing density, but feed conversion efficiency increased proportionately with increasing density. There was no significant change in survival. The study also examined financial aspects of *Colossoma* culture and found it to be economically feasible.

**RESEARCH AREA:** PRODUCTION OPTIMIZATION  
**RESEARCH THEME:** NEW AQUACULTURE SYSTEMS/  
 NEW SPECIES  
 9NS3A/Practical diet development for broodstock of *Colossoma macropomum* and *Piaractus brachypomus*/Lochmann [Progress report; report title different than study title in *Ninth Work Plan*]

Colossomid broodstock cultures in Peru suffer from inconsistent spawning. Inadequate nutrition of the brood-

stock may contribute to the spawning problem; however, little is known about broodstock nutrition. This investigation examines broodstock feedstuffs and diets with the goal of formulating diet and spawning procedures that will maximize broodstock spawning. Feed nutrients were analyzed using standard techniques. Results show that current Colossomid diets have an energy:protein ratio of 8.7, which is lower than the reported range of efficient values and indicate that the diets are neither cost-effective nor efficient, as broodstock may metabolize protein for the purposes of growth and at the expense of reproduction. Lipids are naturally in the diet; however, there are not enough data to determine if the amount in the diet is sufficient for reproduction. Results also show that vitamin C must be added in a stable form. This investigation also examined vitamin E, carotenoids, and amino acids. Trials are being conducted to ascertain specific vitamin C and E requirements.

**RESEARCH AREA:** PRODUCTION OPTIMIZATION  
**RESEARCH THEME:** NEW AQUACULTURE SYSTEMS/  
 NEW SPECIES

9NS4/Semi-intensive culture of tilapia in brackishwater ponds/Diana [Abstract]

Many tilapia species, including Thai red tilapia, can grow successfully in euryhaline water after proper acclimation. However, information on semi-intensive tilapia culture in saline ponds is almost nonexistent. The objectives of this experiment are to 1) determine appropriate fertilization regimes, 2) investigate nutritional value and digestibility of specific marine phytoplankton, and 3) determine the utility of underutilized or abandoned shrimp ponds for tilapia production. This experiment is examining the impacts of two fertilization regimes (28 kg N and 7 kg P ha<sup>-1</sup> wk<sup>-1</sup> and 28 kg N and 14 kg P ha<sup>-1</sup> wk<sup>-1</sup>) and three levels of salinity (10, 20, and 30‰). This experiment will also examine budgets of brackishwater ponds to estimate the cost of inputs versus the value of the fish crop.

**RESEARCH AREA:** ENVIRONMENTAL EFFECTS  
**RESEARCH THEME:** EFFLUENTS AND POLLUTION  
 9ER1/Use of pond effluent for irrigation in an integrated crop/aquaculture system/Wood [Final report]

Aquaculture in Kenya is practiced in water retention reservoirs and fish ponds. In addition, 80% of Kenya's land falls in arid and semi-arid zones, where rains are unpredictable. Effluents from aquaculture operations can be used as irrigation waters, thereby aiding farmers' needs; however, the interaction between effluent nutrients, applied fertilizers, and crops is unknown. This investigation consisted of two experiments. The first experiment sought to determine the effects of pond effluent when used as irrigation water for fertilized and unfertilized crops of French beans and kale. To do so, a factorial design was constructed consisting of six treatments in the first growing season and twelve treatments in the second growing season, with varying rates and types of irrigation and fertilization. Fresh and dry matter yields were recorded at harvest, and samples were collected for determination of tissue nutrient content. After the second season, the highest yield for French beans was found in

crops that had been irrigated with pond water and then fertilized. However, the highest yield for kale was found in crops that had been irrigated and fertilized using traditional sources. The second experiment examined the effectiveness of two types of soil (a black clay vertisol and a red clay cambisol) in removing nutrient effluents. Results from a laboratory experiment involving packed columns of soil showed that land soils can remove substantial amounts of phosphorus and nitrogen from pond effluents, potentially aiding in pollution reduction.

**RESEARCH AREA:** ENVIRONMENTAL EFFECTS  
**RESEARCH THEME:** EFFLUENTS AND POLLUTION  
 9ER2B/Fate of methyltestosterone in the pond environment: Detection of MT in pond soil from a CRSP site/Fitzpatrick [Final report]

This is the second phase of an investigation examining the fate of 17 $\alpha$ -methyltestosterone (MT) in the pond environment. The first phase found that in the laboratory, MT persists in the soil for up to eight weeks. Persistent MT may lead to unintended exposure of humans and animals. The second phase examined the persistence of MT in semi-closed pond systems at CRSP sites with previous MT use (Kenya) and with no history of MT use (Mexico). Soil samples were collected after administration of either an MT or a control diet to fry. Concentrations of MT in the water, soil, and water-soil interface were ascertained using radioimmunoassay techniques. Results showed that levels of MT at the Kenya site exhibited levels higher than laboratory background, perhaps due to a gradual accumulation of MT over its history of use. In Mexico, levels returned to near background levels on the last day of the experiment. Levels of MT in the water and gradually accumulating levels in soils may lead to unintended exposure of humans and fish and may cause intersex characteristics in exposed fish.

**RESEARCH AREA:** ENVIRONMENTAL EFFECTS  
**RESEARCH THEME:** EFFLUENTS AND POLLUTION  
 9ER2C/Fate of methyltestosterone in the pond environment: Impact of MT-contaminated soil on tilapia sex differentiation/Fitzpatrick [Final report]

This is the third phase of an investigation examining the fate of 17 $\alpha$ -methyltestosterone (MT) in the pond environment. The first two phases found that MT persists in soil for up to eight weeks after treatment termination, adding to concerns about unintentional MT exposure. This phase examined whether the persistence of MT in soils influenced sex differentiation of tilapia. In the experiment, one set of fry was fed MT-impregnated food. When the cycle of MT-treatment was over, the fry were then fed a control diet. Simultaneously, another set of fry were fed a control diet only. After treatment, sex ratios were determined. Rates of masculinization were lower in control groups. Fish fed MT-impregnated food and then fed a control diet while being maintained in the MT-treatment tanks showed no difference in sex ratio from fish that were fed a control diet throughout the experiment. However, several individuals in the MT-treatment tanks had intersex gonads, suggesting some impact on development.

**RESEARCH AREA:** ENVIRONMENTAL EFFECTS  
**RESEARCH THEME:** EFFLUENTS AND POLLUTION  
 9ER3/Integrated recycle system for catfish and tilapia culture/Diana [Final report]

Clarid catfish have been one of the most popular freshwater fish cultured in Southeast Asia. Catfish can be grown at extremely high density and are fed mainly trashfish, chicken offal, or pelleted feed, which cause poor water quality and phytoplankton blooms. Past studies have shown that tilapia can feed on phytoplankton from catfish culture systems, improving water quality and producing an extra crop. This experiment examined the relationship between catfish and tilapia culture and water quality through the use of three treatments: 1) catfish alone, 2) catfish and tilapia without artificial water circulation, and 3) catfish and tilapia with artificial circulation. Growth rate, water quality, and soil analyses were conducted throughout the experiment. Results showed no significant differences in catfish and tilapia growth rates and survival rates among all treatments; however, high mortality of tilapia was observed in the artificial recirculation treatment, perhaps due to heavy loading of wastes. Nutrient budgets showed that total nitrogen and total phosphorus contents in pond effluents in treatments with catfish-tilapia polyculture were significantly lower than those with catfish alone. The results of this experiment indicate that Nile tilapia can effectively recover nutrients contained in wastewater of intensive catfish culture. They further suggest that natural water circulation between catfish and tilapia compartments can cost-effectively reduce nutrient contents in pond effluents.

**RESEARCH AREA:** ENVIRONMENTAL EFFECTS  
**RESEARCH THEME:** EFFLUENTS AND POLLUTION  
 9ER4/Effects of water recirculation on water quality and bottom soil in aquaculture ponds/Boyd [Progress report]

Nutrient enrichment of pond waters is an essential management practice in aquaculture, particularly in semi-intensive and intensive culture systems. However, the discharge of pond effluents may result in deterioration of the receiving waters due to high organic carbon, nitrogen, and phosphorus concentrations. Growing concern about the release of nutrient-enriched effluents has created a need for more environmentally responsible techniques for managing pond waters. This study examined the effectiveness of a water-recirculating system in removing organic carbon and nutrients from pond waters and soils. Shrimp ponds were subjected to one of three treatments: 1) high-density stocking with water recirculation into another pond of equal volume without shrimp, 2) high-density stocking without water recirculation, and 3) low-density stocking without water recirculation. Recirculation of water had no effect on shrimp yields. Recirculation effectively reduced the amount of total ammonia nitrogen, but the concentrations of all other variables were either significantly greater or no different than the ponds without recirculation. Soil samples are currently being analyzed.

**RESEARCH AREA:** ENVIRONMENTAL EFFECTS  
**RESEARCH THEME:** APPROPRIATE TECHNOLOGY  
 9ATR1/On-farm trials: Evaluation of alternative aquaculture technologies by local farmers in Kenya/Bowman [Progress report]

On-farm trials are valuable for two reasons: they offer an opportunity to test, in a real-world setting, the effectiveness of technologies developed in controlled laboratory settings, and they allow for communication of management alternatives to both farmers and extension agents associated with the trials. Farmers participating in these trials elected to practice either a "no cash expenditure" type of management, which relied on inputs such as manure found on their farm, or a "purchased feed/fertilizer" management scheme. Four treatments were applied, using monosex or mixed-sex tilapia in one of the two management schemes. Extension agents visit farmers regularly. Ponds have been stocked, and weekly or as-needed data on inputs, water addition, mortality, expenses, weight, and length are recorded. Fish harvests will take place in late 2000.

**RESEARCH AREA:** ENVIRONMENTAL EFFECTS  
**RESEARCH THEME:** APPROPRIATE TECHNOLOGY  
 9ATR2/Linkage of aquaculture within watersheds and concurrent design of hillside ponds/Verma [Abstract]

The promotion of tilapia culture in Honduras can result in improved nutrition and economic status of local farmers. The majority of farmers who might benefit from the addition of aquaculture to their production systems own or farm land located on hillslopes (generally land with a slope of 2 to 15%). Poor management of hillslopes for agricultural use has resulted in deterioration of natural resources and environments. In addition, fish ponds are rare on hillsides due to engineering constraints. Hillside aquaculture operations must be sited carefully, taking into consideration environmental and stakeholder needs. This investigation examines the design of hillside ponds. Two types of ponds are being examined: watershed ponds in which water is supplied by rainfall and spring-fed ponds. Additional testing variables include pond size, hillside slope, ground cover, and soil. Design modules have been constructed for nine combinations of tested variables. The designs are intended not only to meet engineering requirements, but also to meet stakeholder concerns, such as investment constraints and land availability. Researchers will include spatial data analysis tools in their development of designs. Farmers will then be encouraged to adopt the designs for testing.

**RESEARCH AREA:** SOCIAL AND ECONOMIC ASPECTS  
**RESEARCH THEME:** MARKETING AND ECONOMIC ANALYSIS  
 9MEAR3/Development of Central American markets for tilapia produced in the region: Potential markets for farm-raised tilapia in Honduras/Engle [Progress report; report title different than activity title in *Ninth Work Plan*]

Much of CRSP research focuses on increasing tilapia production yields. This activity builds on past research efforts by identifying potential markets for tilapia in Honduras. Currently, most Honduran-produced tilapia is

exported. In 1999, a survey was distributed to restaurants and supermarkets along the major north-south route in Honduras. The survey examined seafood and tilapia sales, consumer reactions to tilapia, and tilapia supply. Additional survey questions examined store and restaurant sizes and histories, as well as clientele characteristics and preferences. Raw scores of this survey are presented in the report; analysis of scores will be conducted by late 2000.

**RESEARCH AREA:** SOCIAL AND ECONOMIC ASPECTS  
**RESEARCH THEME:** MARKETING AND ECONOMIC ANALYSIS  
 9MEAR4/Economic and social returns to technology and investment in Thailand/Engle [Progress report]

This two-phase study was designed to develop and refine a model of economic tradeoffs associated with adopting CRSP-developed technologies. In the first phase, researchers assessed the choices a small-scale tilapia farmer in Thailand would make based on the availability of four CRSP-developed technologies: 1) low-intensity inorganic fertilization, 2) organic fertilization with collected chicken manure, 3) organic fertilization in layered pond-chicken coop systems, and 4) high-input green water use. Existing secondary data were used to examine gross and net expenditures and revenues, supply availability and price, and financing amount and availability as they affect the choice of technology. A mixed-integer programming model used 11 scenarios to determine efficient choices. The study found that the layered systems provided the greatest returns but required heavy operating costs. Low-intensity inorganic fertilization required the least investment but always resulted in the lowest net returns. When loan amounts are restricted, the model indicated organic fertilization with collected chicken manure to be the optimal choice. High-input green water technology is optimal only when fingerling availability is restricted. The second phase of this study will involve primary data collection by survey to determine actual rates of adoption of CRSP-developed technologies and provide estimates of the social and economic returns generated by CRSP research in Thailand.

**RESEARCH AREA:** SOCIAL AND ECONOMIC ASPECTS  
**RESEARCH THEME:** MARKETING AND ECONOMIC ANALYSIS  
 9MEAR5/Rapid economic evaluation tools/Hatch [Progress report]

Among the factors influencing the adoption of tilapia production technologies are the associated costs, risks, and incentives. This study involves development of a tool to quickly estimate the economic consequences of a given technology. Such a tool would enable researchers to consider economic as well as physical and biological considerations in designing research to develop effective and efficient tilapia production technologies. In the first year of this study, researchers tested a prototype of a rapid decision economic tool by evaluating two technologies developed under an earlier CRSP research project in Honduras: 1) chemical fertilization and 2) fertilization followed by supplemental feeding. The decision tool is being developed using the software programs Excel and @Risk. Use of SIMTool and integration with the CRSP-developed POND<sup>®</sup> simulation software are being considered. The first run of the prototype

tool showed that the fertilization-followed-by-supplemental-feed technology provides a higher net income and a lower risk of losing money in the short run than the chemical-fertilization technology. This tool, when fully developed, should help aquaculture researchers judge economic incentives and risks of various technologies.

**RESEARCH AREA:** SOCIAL AND ECONOMIC ASPECTS  
**RESEARCH THEME:** ADOPTION/DIFFUSION  
 8ADR1-2/Sources of technical assistance for fish farmers in the Peruvian Amazon/Molnar [Final report; report title different than study title in *Eighth Work Plan*]

Adoption of PD/A CRSP technologies and research findings by local farmers can be facilitated with knowledge of local pond environments and cultural practices. In particular, attitudes toward extension agents providing technical assistance are particularly important, as it is through extension agents that CRSP-developed findings are translated and diffused to hatcheries, fish farmers, and other agencies and organizations involved in aquaculture development. This study examined prior experience with and attitudes toward extension agents in the Napo, Tamishiyacu, and Tahuayo river system areas north and south of Iquitos, Peru. A survey developed for use in other CRSP countries was modified and distributed to 146 fish farmers in those regions. The survey asked participants about species raised, land holding patterns, and their experience with and expectations of those providing technical assistance. Results of the survey show that attitudes toward extension did not vary greatly based on the species cultured; however, attitudes varied based on land holdings. Those holding more parcels of land reported less contact with extension than those holding more hectares of land. Nearly all farmers surveyed wanted extension contact in the future.

**RESEARCH AREA:** SOCIAL AND ECONOMIC ASPECTS  
**RESEARCH THEME:** ADOPTION/DIFFUSION  
 8ADR1-3/Identifying goals and priorities of fish farmers in the Peruvian Amazon/Molnar [Final report; report title different than study title in *Eighth Work Plan*]

Fisheries in the Amazon basin play a vital role in the economic and nutritive health of local populations. Interest in aquaculture has been growing, in large part due to support and training from government agencies, nongovernmental organizations, and missionaries. Aquaculture is also one way of combating the cyclical nature of Amazon fisheries, in which fishing is more difficult during high-water periods. This study surveyed 143 fish farmers in the region. Results show that the majority of farmers grow more than two species of fish, with tuacanare and bujurqui being the most frequently grown combination. The fish most frequently grown in monoculture were boquichico and gamitana, local fish with abundant fingerlings in the rivers and simple diets. In general, respondents had favorable attitudes towards fish farming and found that it did not affect their ability to care for their families or other crops. The largest problem associated with fish farming was loss due to human and animal predation. The majority of respondents felt optimistic about aquaculture growth in the future.

**RESEARCH AREA:** SOCIAL AND ECONOMIC ASPECTS  
**RESEARCH THEME:** ADOPTION/DIFFUSION  
 9ADR3/Aquaculture training for Kenyan fisheries officers and university students/Bowman [Progress report]

Aquaculture productivity in Kenya is low, in part due to a lack of adequate technical skills among fisheries officers and university personnel involved with the field. The objectives of this activity are to increase the pond management skills of fisheries and extension personnel and to enhance the research and extension opportunities of Kenyan university students likely to seek employment in the aquaculture sector. To fulfill these objectives the CRSP project in Kenya has begun scholarship support for two graduate students and offers stipends for undergraduate and graduate level research at Sagana Fish Farm. In addition, the project has offered a series of four short courses, lasting two weeks each, which were attended by over 80 Kenya Fisheries Department personnel. Farmer field days, with an anticipated total attendance of 50 farmers, have been planned for late 2000.

**RESEARCH AREA:** SOCIAL AND ECONOMIC ASPECTS  
**RESEARCH THEME:** ADOPTION/DIFFUSION  
 9ADR4/Establishment of companion sites in the Africa region/Bowman [Progress report]

CRSP research in Africa has centered around the Rwasave Fish Culture Station in Rwanda (1983 to 1994) and the Sagana Fish Farm in Kenya (1997 to present). In the current period, the Kenya Project received funding to regionalize CRSP efforts and thus extend the validity and benefits of CRSP research. This activity commenced by identifying companion sites and beginning preliminary research investigations at those sites. Selected companion sites are the ICLARM-Malawi National Aquaculture Center in Zomba, Malawi, and Bunda College near Lilongwe, Malawi. Research at the National Aquaculture Center is currently underway to examine the effect of stocking size and nutrient inputs on productivity of *Oreochromis shiranus*. Work is being conducted by students from the National Aquaculture Center and Bunda College. Research on the use of salinity to increase growth of tilapia is scheduled to begin at Bunda College in the fall of 2000.

**RESEARCH AREA:** SOCIAL AND ECONOMIC ASPECTS  
**RESEARCH THEME:** ADOPTION/DIFFUSION  
 9ADR5/Regional outreach in Africa/Bowman [Progress report]

One of the challenges facing the development of aquaculture in Africa is the dissemination of research information to local users. Extension services are best suited to do this; however, currently there is a lack of adequate communication and cooperation between researchers and extension agents in Kenya and surrounding areas. The goal of this activity is to promote communication between aquaculture researchers and extension agents through participation in and organization of regional meetings. In this reporting period, researchers at Sagana Fish Farm orchestrated a workshop on pond aquaculture, attended and made presentations at conferences in the US and Africa, and established numerous linkages.

**RESEARCH AREA:** SOCIAL AND ECONOMIC ASPECTS  
**RESEARCH THEME:** ADOPTION/DIFFUSION  
 9ADR6A/Workshop on the timing of the onset of supplemental feeding of Nile tilapia (*Oreochromis niloticus*) in ponds/Brown [Final report; report title different than activity title in *Ninth Work Plan*]

Socioeconomic studies carried out by CRSP researchers have shown that farmers in Central Luzon, Philippines, are receptive to the adoption of new technologies. Feeds and Fertilizers Research performed with seven on-farm trials has shown that delayed feeding (75 days rather than the usual 45 days) does not reduce pond productivity but does reduce investment costs. The objective of this activity was to disseminate these results to other area farmers through a workshop at the Freshwater Aquaculture Center, Central Luzon State University (CLSU). Attendees of the workshop included the farmers of the previous trials, two additional farmers, and CLSU students, faculty, and administrators. Farmers who attended were impressed by the results and indicated that they would immediately adopt the practice. Other farmers in the region have also learned of the research through word-of-mouth and have adopted the delayed feeding practice. This workshop will be complemented by another activity (9ADR6B), the development and dissemination of printed materials.

**RESEARCH AREA:** SOCIAL AND ECONOMIC ASPECTS  
**RESEARCH THEME:** ADOPTION/DIFFUSION  
 9ADR6B/Production of improved extension materials/Brown [Abstract]

Socioeconomic studies carried out by CRSP researchers have shown that farmers in Central Luzon, Philippines, are receptive to the adoption of new technologies. Feeds and Fertilizers Research performed with seven on-farm trials has shown that delayed feeding (75 days rather than the usual 45 days) does not reduce pond productivity, but does reduce investment costs. As farmers are receptive to this change in practice, extension materials will be created and distributed to complement a workshop that was held at Central Luzon State University (9ADR6A). Development of extension materials is underway; materials may include technical bulletins and fact sheets.

**RESEARCH AREA:** SOCIAL AND ECONOMIC ASPECTS  
**RESEARCH THEME:** ADOPTION/DIFFUSION  
 9ADR7/Decision support for policy development: Planning conferences for collaborating researchers, public agencies, and nongovernmental organizations working in aquaculture/Verma [Abstract]

The "Red Nacional de Acuicultura" (National Aquaculture Network) was created by the United Nations Food and Agriculture Organization (FAO) in 1992 with the purpose of integrating international institutions with the private and public sectors in Honduras. CRSP researchers at the Escuela Agrícola Panamericana El Zamorano (referred to as Zamorano) in Honduras are working to strengthen this network as a hub for information exchange, research activity, and policy leadership. Using Zamorano as a base, this activity will foster linkages among national and regional

organizations and disseminate tilapia production information. Initial meetings have shown that communication among organizations and between organizations and farmers is lacking. To address this and other needs, a series of three meetings are being held for various stakeholders. One of the primary topics will be a Web-based Information Delivery System for Tilapia (WIDeST). WIDeST makes knowledge of tilapia production available to farmers, nongovernmental organizations, policy makers, businesses, and consumers. WIDeST is expected to aid in the process of information dissemination and institution linkage.

**RESEARCH AREA: SOCIAL AND ECONOMIC ASPECTS**

**RESEARCH THEME: ADOPTION/DIFFUSION**

9ADR8/Production strategies characterizing small- and medium-scale tilapia farms: Approaches, barriers, and needs/Verma [Abstract]

Rural farmers in Honduras face numerous production and distribution challenges, making adoption of PD/A CRSP aquaculture technologies and research findings difficult. To understand these challenges and thereby facilitate use of aquaculture techniques, the current study is being undertaken. A survey instrument that has been used in research in other CRSP countries was modified and will be used to survey rural farmers. A 1996 evaluation of CRSP technologies in Honduras showed that rural farmers relied heavily on middlemen, sold their product largely to Honduran restaurants, and used word of mouth as a means of marketing. The current study will provide data on the changes since then in production practices and distribution strategies to verify and extend the previous research findings.

**RESEARCH AREA: SOCIAL AND ECONOMIC ASPECTS**

**RESEARCH THEME: ADOPTION/DIFFUSION**

9ADR9/Technical assistance for fingerling production serving small- and medium-scale tilapia producers/Verma [Abstract]

An inconsistent and often insufficient supply of fingerlings is one of the central challenges facing Honduran tilapia aquaculture. The Comayagua research station does not produce a reliable supply, and private suppliers are more often geared toward large-scale commercial operations. Smaller-scale farmers must expend large amounts of energy locating and transporting fingerlings, when they are available. The objective of this activity is to address this constraint by providing technical assistance and training to current and potential fingerling suppliers to small- and medium-scale tilapia producers. Surveys have been conducted of farmers and restaurants to assess production and marketing needs of fingerling suppliers. A workshop will be provided for current and prospective fingerling producers.

**RESEARCH AREA: SOCIAL AND ECONOMIC ASPECTS**

**RESEARCH THEME: ADOPTION/DIFFUSION**

9ADR10/Training and technical assistance for Honduras institutions working with small- and medium-scale tilapia producers/Verma [Abstract]

The Honduran national extension program in aquaculture is present in many regions, but it is fragmented and

underfunded. In particular, activity with small- and medium-scale farms, which are mostly rural, has been largely ignored. Nongovernmental organizations (NGOs) are present in many of these rural regions but often lack the expertise to advise on issues related to tilapia aquaculture. This activity's objectives include identifying NGOs that are interested in incorporating aquaculture extension into their activities and then providing the technical assistance and training to allow them to do so. A meeting held in 1999 between collaborating institutions has identified potential NGOs, and training workshops are scheduled for Fall 2000.

**RESEARCH AREA: SOCIAL AND ECONOMIC ASPECTS**

**RESEARCH THEME: DECISION SUPPORT SYSTEMS**

9DSSR2/Decision support systems for fish population management and scheduling in commercial pond aquaculture operations/Bolte [Progress report]

Commercial large-scale aquaculture producers commonly stock multiple fish lots at a time. The distribution of fish sizes through time can be modeled mathematically, allowing for estimation of growth and harvest parameters. As such, this study endeavored to modify existing POND<sup>®</sup> software and other models to develop new software that can be used to simulate population growth and fish biomass and to inventory fish stocks. A set of mass balance equations was used to describe fish size distribution as it relates to individual fish growth. The software provides two views: a facility-level view, showing a schematic of the entire farm, and a pond-level view, showing pond inventory, feed rate history, and a spreadsheet containing feeding, stocking, and harvest data. Using the summary data provided by these views, a user can quickly and easily view a pond's readiness for harvest. A final part of this study will be the development of training materials for a workshop on the use of the software.

**RESEARCH AREA: SOCIAL AND ECONOMIC ASPECTS**

**RESEARCH THEME: DECISION SUPPORT SYSTEMS**

9DSSR3/Enhancing the POND<sup>®</sup> decision support system for economics, education, and extension/Bolte [Progress report]

POND<sup>®</sup> software is a decision support tool developed by the PD/A CRSP for analyzing and projecting fish-culture and economic aspects of warmwater aquaculture production systems. This study is focused on enhancing the economic capability of the program by supporting partial budgeting and the inclusion of time-based costs. Efforts to create a task-oriented user interface have led to the formulation of "wizards," which automate key simulation tasks. In addition to enhancement of POND<sup>®</sup>, the researchers are releasing an additional decision support tool, AquaFarm<sup>®</sup>, which provides simulation of physical, chemical, and biological unit processes, facilities, and management systems for a broad class of aquaculture systems, including semi-intensive and intensive systems. AquaFarm<sup>®</sup> complements and expands many of the functionalities contained within POND<sup>®</sup>.







# RESEARCH PROJECTS

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## POND DYNAMICS RESEARCH

Subcontract No. RD010A-07

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### Background

The interactions among nutrients, primary and heterotrophic productivity, and fish yield are known as pond dynamics. Water quality imbalances that have their origins in interactions between pond soil and water are not fully understood. Current PD/A CRSP research in pond dynamics focuses on the influence of pond bottom soils on water quality and productivity. The two primary goals of pond dynamics research are characterizing the soils at each of the PD/A CRSP research sites (Honduras, Peru, Kenya, the Philippines, and Thailand) and examining the changes in organic matter and nutrient concentrations and availability over time. The results will be used to develop a pond soil classification system similar to that used in terrestrial soils. The information on changes in nutrient availability over time and site soil characteristics will be especially relevant to pond fertilization studies and practices.

### Work Plan Research

The following Ninth Work Plan investigation continued into the current reporting period (see Effluents and Pollution Research (p. 35) for information on another funded investigation under this subcontract):

- Pond soil characteristics and dynamics of soil organic matter and nutrients/9PDR2. The report submitted for this investigation was a progress report.

**Note:** The schedule for 9PDR2 has been modified. Please see Appendix 5, "Completion Dates for Work Plan Studies," for schedule information.

### Networking

In September 1999, CRSP researchers Claude Boyd and Wes Wood visited former CRSP ponds at the Ayutthaya Freshwater Fisheries Station in Thailand to collect soil samples. They also sampled soil from commercial aquaculture ponds near Chantaburi. The researchers held meetings with Mali Boonyaratpalin of Thailand's Department of Fisheries regarding CRSP pond soil research.

Boyd has worked with Jason Clay of the World Wildlife Fund and Michael Phillips of the Network of Aquaculture Centres in Asia-Pacific (NACA) in regard to best management practices (BMPs) for soils.

During a trip to South America, Boyd met with Julio Queiroz of the Embrapa (Empresa Brasileira de Pesquisa Agropecuária) Environmental Laboratory in Campinas, Brazil. Queiroz assisted with the collection of soil samples in Brazil and later visited Auburn University for three weeks to discuss CRSP research with Boyd. Boyd also met with scientists from Epagri (Empresa de Pesquisa Agropecuária e Extensão Rural de Santa Catarina) to discuss the use of BMPs in aquaculture.

Boyd has been collaborating with several groups and using PD/A CRSP data to prepare an upcoming Codes of Conduct in Aquaculture publication. Six BMPs have been created with data from CRSP soils research for use by the Global Aquaculture Alliance. Boyd also recommended BMPs to the Alabama Catfish Producers Association; two of the BMPs used CRSP soil data.

CRSP Philippines Project researcher Remedios Bolivar coordinated Wood's and graduate student Martha Rowan's visit to the Philippines and aided in the collection of core samples. Wood also visited with several university administrators, including University President Rodolfo Undan and Ruben C. Sevilleja, Vice President of Academic Affairs and Director of the Freshwater Aquaculture Center at Central Luzon State University.

Boyd received fifteen telephone requests (twelve US, three international), sixteen emails (three US, thirteen international), and one international letter from individuals requesting information on pond soil management.

### Educational Outreach

Boyd made presentations on aquaculture-related topics to several governmental and nongovernmental organizations, private-sector businesses, and public groups. Boyd's lecture themes included water quality, aquaculture codes of conduct, environmental issues, soil management, and various shrimp-related topics, and he presented them to the National Prawn Company in Al Lith, Saudi Arabia; Centro Nacional de Acuicultura e Investigaciones Marinas (CENAIM) in Ecuador; Walailak University in Thailand; the Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis (IBAMA) Fisheries Station in São Paulo, Brazil;

and groups of shrimp farmers and workers in Colombia and Madagascar.

### Publications

- Boyd, C.E., 2000. *Water Quality, An Introduction*. Kluwer Academic Publishers, Boston, MA, 330 pp.
- Boyd, C.E. and M.C. Haws, 1999. Good management practices (GMPs) to reduce environmental impacts and improve efficiency of shrimp aquaculture in Latin America. In: B.W. Green, H.C. Clifford, M. McNamara, and G.M. Montaña (Editors), *V Central American Symposium on Aquaculture*. San Pedro Sula, Honduras, pp. 9–33.
- Boyd, C.E. and L. Massaut, 1999. Risks associated with the use of chemicals in pond aquaculture. *Aquacult. Eng.*, 20(1999):113–132.
- Sonnenholzner, S. and C.E. Boyd, 2000. Chemical and physical properties of shrimp pond bottom soils in Ecuador. *J. World Aquacult. Soc.*, 31:358–375.
- Sonnenholzner, S. and C.E. Boyd, 2000. Vertical gradients of organic matter concentration and respiration rate in pond bottom soils. *J. World Aquacult. Soc.*, 31:376–380.
- Sonnenholzner, S. and C.E. Boyd. Managing the accumulation of organic matter deposited on the bottom of shrimp ponds: Do chemical and biological probiotics really work? *World Aquacult.* 31(3). (in press)
- Thunjai, T., C.E. Boyd and K. Dube. Pond soil pH measurement. *J. World Aquacult. Soc.* (submitted)

### Presentations

- Boyd, C.E. Environmental issues in shrimp farming. Plenary address presented to the V Central American Symposium on Aquaculture at San Pedro Sula, Honduras, 18–20 August 1999.
- Boyd, C.E. Codes of conduct and better management practices in shrimp farming. Presented to the Fifth Ecuadorian Aquaculture Conference at Guayaquil, Ecuador, 28–30 October 1999.
- Boyd, C.E. Pond water and soil management procedures to minimize the effects of disease epidemics in shrimp farming. Presented to the Fifth Ecuadorian Aquaculture Conference at Guayaquil, Ecuador, 28–30 October 1999.
- Boyd, C.E. Pond soil management and shrimp aquaculture. Presented to the First National Symposium on Aquaculture at Penang, Malaysia, 22–24 November 1999.
- Boyd, C.E. Water quality characteristics of overflow from aquaculture ponds. Presented to Aquaculture America 2000 at New Orleans, Louisiana, 2–5 February 2000.

- Boyd, C.E. Use of BMPs in a systems approach to aquaculture. Presented at Conference on Aquaculture in the Third Millennium at Bangkok, Thailand, 20–25 February 2000.
- Boyd, C.E. An overview of the Pond Dynamics/Aquaculture CRSP. Presented at the Western Regional Aquaculture Expo 2000 at Desert Hot Springs, California, 27 February–1 March 2000.
- Boyd, C.E. Aquaculture and the environment. Plenary address, presented at the Western Regional Aquaculture Expo 2000 at Desert Hot Springs, California, 27 February–1 March 2000.
- Boyd, C.E. Substance exchange between pond sediments and water. Presented at the Western Regional Aquaculture Expo 2000 at Desert Hot Springs, California, 27 February–1 March 2000.
- Boyd, C.E. Reduction in environmental impact of pond aquaculture through proper site selection, design, and construction. Presented to World Aquaculture 2000 at Nice, France, 2–6 May 2000.
- Boyd, C.E. and M.C. Haws. Good management practices (GMPs) to reduce environmental impacts and improve efficiency of shrimp aquaculture in Latin America. Presented to the V Central American Symposium on Aquaculture at San Pedro Sula, Honduras, 18–20 August 1999.

### Conferences

- V Central American Symposium on Aquaculture at San Pedro Sula, Honduras, 18–20 August 1999. (Boyd)
- Fifth Ecuadorian Aquaculture Conference at Guayaquil, Ecuador, 28–30 October 1999. (Boyd)
- First National Symposium on Aquaculture at Penang, Malaysia, 22–24 November 1999. (Boyd)
- PD/A CRSP Annual Meeting at New Orleans, Louisiana, 31 January–2 February 2000. (Boyd, Thunjai, Zelaya)
- Aquaculture America 2000 at New Orleans, Louisiana, 2–5 February 2000. (Boyd, Thunjai, Zelaya)
- Conference on Aquaculture in the Third Millennium at Bangkok, Thailand, 21–26 February 2000. (Boyd)
- Western Regional Aquaculture Expo 2000 at Desert Hot Springs, California, 27 February–1 March 2000. (Boyd)
- World Aquaculture 2000 at Nice, France, 2–6 May 2000. (Boyd)

### Award

- C.E. Boyd received Honorary Life Membership in the World Aquaculture Society.

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**POND SOIL CHARACTERISTICS AND DYNAMICS OF SOIL  
ORGANIC MATTER AND NUTRIENTS**

*Ninth Work Plan, Pond Dynamics Research 2 (9PDR2)  
Progress Report*

Claude E. Boyd  
Department of Fisheries and Allied Aquacultures  
Auburn University, Alabama, USA

C. Wesley Wood  
Department of Agronomy and Soils  
Auburn University, Alabama, USA

Taworn Thunjai and Martha Rowan  
Department of Fisheries and Allied Aquacultures  
Auburn University, Alabama, USA

Karen Dube  
Central Institute of Fisheries Education  
Verosa, Mumbai, India

**ABSTRACT**

Pond soil cores were obtained from six ponds in Thailand. Cores were segmented into 2-cm-long segments which were analyzed for texture, bulk density, pH, organic carbon, and major and minor nutrients. The resulting information increases the data base for use in presenting a concept of pond soil development and for preparation of a pond soil classification system. The six ponds in Thailand had profiles with discernible layers (horizons). Bulk density tended to increase with depth in the profile. Concentrations of carbon, nitrogen, and phosphorus decreased with depth, but sulfur concentration increased with depth. Concentrations of mineral nutrients were within the ranges of values found at other sites sampled during this project. There was considerable variation in bottom soil pH estimates made by the several methods used in aquaculture. The simplest and most reliable method, direct insertion of a standard pH probe into a 1:1 mixture of dry soil (dried at 40°C and pulverized to pass through a 2.36-mm screen) and distilled water, should be adopted as a standard procedure.

## REPRODUCTION CONTROL RESEARCH

Subcontract No. RD010A-02

### Staff

*University of Oklahoma, Norman, Oklahoma*

William Shelton	US Principal Investigator, Project Leader
William Baker	Research Assistant (June through August 2000)
Robert Raymond	Research Assistant

### Background

Limited knowledge of the reproductive physiology and breeding of culture species was identified as one of the key constraints to aquaculture in the *Continuation Plan 1996–2001*. Specifically, effective and practical control of reproduction is the major constraint in tilapia culture. Inter- and intraspecific breeding programs can result in populations with highly skewed sex ratios but often give inconsistent results. Interspecific crosses have not proven to be practical due to difficulties in maintaining the parent species integrity.

Intraspecific breeding programs have been developed to exploit the sex inheritance mechanism in Nile tilapia, *Oreochromis niloticus*. The androgenetic approach to developing YY males simplifies the identification of YY males as all males produced should be of the YY genotype. Proposed Ninth Work Plan research will search for a phenotypic marker to further simplify identification of YY males and continues efforts to develop androgenesis techniques for Nile tilapia of the Egyptian and Ghanaian strains.

### Work Plan Research

This subcontract was awarded funding to conduct the following Ninth Work Plan investigation:

- Monosex tilapia production through androgenesis/9RCR7. An abstract was submitted for this investigation.

**Note:** The schedule and methods for 9RCR7 have been modified. Please see Appendix 5, "Completion dates for Work Plan Studies," for revised schedule information. The revised methods will appear in the *Addendum to the Ninth Work Plan*.

### Conferences

PD/A CRSP Annual Meeting at New Orleans, Louisiana,  
31 January–2 February 2000. (Shelton)  
Aquaculture America 2000 at New Orleans, Louisiana,  
2–5 February 2000. (Shelton)

## MONOSEX TILAPIA PRODUCTION THROUGH ANDROGENESIS

*Ninth Work Plan, Reproduction Control Research 7 (9RCR7)*  
*Abstract*

William L. Shelton  
University of Oklahoma  
Norman, Oklahoma, USA

### ABSTRACT

A phenotypic marker in chromosome manipulation investigations is vital to interpreting induction results. During earlier studies on androgenesis in tilapias, males of the homozygous recessive color mutation (blond) in Nile tilapia (*Oreochromis niloticus*; Egyptian strain, Lake Manzala) were used as an induction control to verify that progeny carried only the paternal genome. Control crosses between blond males and normal colored females (Ghana strain) produced viable progeny, but survival of androgenotes (paternal, blond) was extremely low. Severity of the induction treatment and inbreeding of the blond mutant were considered possible factors. An alternative approach is being tested which involves another color mutation as the phenotypic marker. Red tilapia also originated from the same population (Egyptian strain, Lake Manzala), but the color mutation is a dominant trait. Thus, red females and Ghana males are being used, since the relatively unselected paternal genome of the Ghana strain might be hardier. However, the inheritance of the color and the pigment development pattern must be verified through progeny testing. The color pattern of red × red and red × Ghana is now being examined. Broodstock of these phenotypes and in these combinations have been pair spawned during the latter part of this reporting period.

## REPRODUCTION CONTROL RESEARCH

Subcontract No. RD010A-09

### Staff

*Auburn University, Alabama*

Ronald P. Phelps

US Principal Investigator, Project Leader

Ron Carpenter

Graduate Research Assistant (USA; from January 2000; CRSP funded)

Ryan Peasley

Graduate Research Assistant (USA; October 1999 through January 2000; CRSP funded)

Lee Warrington

Graduate Research Assistant (USA; through October 1999; CRSP funded)

### Background

Limited knowledge of the reproductive physiology and breeding of culture species was identified as one of the key constraints to aquaculture in the *Continuation Plan 1996–2001*. Specifically, effective and practical control of reproduction is a major constraint in tilapia culture. Inter- and intraspecific breeding programs can result in populations with highly skewed sex ratios but often give inconsistent results. Interspecific crosses have not proven to be practical due to difficulties in maintaining the parent species integrity. Intraspecific breeding programs have been developed to exploit the sex inheritance mechanism in Nile tilapia, *Oreochromis niloticus*. The androgenetic approach to developing YY males simplifies the identification of YY males as all males produced should be of the YY genotype.

Broodstock and seed supply was also identified as a major constraint in the *Continuation Plan 1996–2001*, resulting in reproduction control becoming one of the CRSP research priorities. Another priority of the plan is identification of alternatives to dietary hormone treatment, the standard masculinization method. Much of the CRSP research effort has focused on tilapia, for which management of unwanted reproduction is an essential part of most culture systems. The objectives identified in the Eighth Work Plan include a series of studies which address this issue by determining whether there is an autosomal influence on the sex ratio of Nile tilapia and developing a pure YY line of male Nile tilapia. A Ninth Work Plan study examines the use of within- and cross-family breeding as an alternative method of developing YY tilapia and examines the effect of temperature on gonadal differentiation.

### Work Plan Research

The following Eighth Work Plan investigation continued into the current reporting period:

- Methods for contribution from the male and female genome to sex inheritance/8RCR1C. The report submitted for this investigation was a final report.

This subcontract was awarded funding to conduct the following Ninth Work Plan investigations:

- Monosex tilapia production through androgenesis: Selection of individuals for sex inheritance characteristics for use in monosex production/9RCR6A. An abstract was submitted for this investigation.
- Monosex tilapia production through androgenesis: Verification of androgenically produced males, their viability, and the influence of the female on progeny sex ratios/9RCR6B. This investigation was cancelled.

- Monosex tilapia production through androgenesis: Growth of genetically derived males in production settings/9RCR6C. This investigation was cancelled.

**Note:** The methods for 8RCR1C have been modified. The revised methods will appear in the *Third Addendum to the Eighth Work Plan*. The decision to terminate 8RCR1D will be documented in the same addendum. Owing to delays, the scope of 9RCR6 was limited to 9RCR6A, Selection of individuals for sex inheritance characteristics for use in monosex production. The decision to terminate 9RCR6B and 9RCR6C will be documented in the *Addendum to the Ninth Work Plan*.

### Publications

Phelps, R.P. and T.J. Popma, 2000. Sex reversal of tilapia. In: B.A. Costa Pierce and J.E. Rakocy (Editors), *Tilapia Aquaculture in the Americas, Volume Two*. The World Aquaculture Society, Baton Rouge, Louisiana, pp. 34–59.

Warrington, L., 2000. Sex ratio variation and sex determining mechanisms in *Oreochromis niloticus*. M.S. thesis, Auburn University, Alabama.

### METHODS FOR THE CONTRIBUTION FROM THE MALE AND FEMALE GENOME TO SEX INHERITANCE

*Eighth Work Plan, Reproduction Control Research 1C (8RCR1C) Final Report*

Ronald P. Phelps and Richard Lee Warrington  
Department of Fisheries and Allied Aquacultures  
Auburn University, Alabama, USA

### ABSTRACT

The variability in the factors affecting the sex ratios of Nile tilapia (*Oreochromis niloticus*) was studied using pair spawns from the Egypt, Ghana, and Ivory Coast strains. Sex ratios from 129 progeny groups were determined by microscopic inspection of the gonads. Of the 12,450 progeny sexed, 54.14% were males; this differed significantly from a 1:1 sex ratio ( $P < 0.001$ ). Sex ratios from the 129 progeny groups produced a normal distribution ( $P > 0.45$ ) but did not reflect a binomial distribution ( $P < 0.01$ ) as would be expected from a simple monofactorial sex determination process. Therefore, other factors must account for the variation observed in sex ratios. Single spawn sex ratios ranged widely from 16 to 100% male. Chi-square tests revealed weak correlations between strain and progeny gender, individual parent and progeny gender, and male-female parent combinations and progeny gender. Sixty-five percent (11 of 17) of the repeat spawns by the same pairings produced sex ratios that

extended beyond a range of 10%. The continuous range of sex ratios within the normal distribution suggests the presence of several minor sex-modifying factors in *O. niloticus* and raises questions as to whether sex inheritance in tilapia is predictable enough for a YY breeding program to be practical.

**MONOSEX TILAPIA PRODUCTION THROUGH ANDROGENESIS: SELECTION OF INDIVIDUALS FOR SEX INHERITANCE CHARACTERISTICS FOR USE IN MONOSEX PRODUCTION**

*Ninth Work Plan, Reproduction Control Research 6A (9RCR6A)*  
*Abstract*

Ronald P. Phelps  
Department of Fisheries and Allied Aquacultures  
Auburn University, Alabama, USA

**ABSTRACT**

There is evidence that in domestic stocks of Nile tilapia (*Oreochromis niloticus*) sex ratios of individual pairs may vary from 50:50. Several authors have found wide variation in sex ratios from one single pair mating to another. The grand mean for the population might average 50:50, but individual pairs would produce sets of progeny where the male

frequency may range from 5 to 100%. This variability in sex ratios is a challenge to the development of YY breeding programs, where sex determination is assumed to be controlled by the "Y" chromosome with no other factors involved. For YY production of males to be successful, variability in the percent males produced must be reduced and parent lines that conform to a simple Mendelian inheritance must be established.

Nine families of Nile tilapia based on single pair matings have been selected, each with a sex ratio that was either highly skewed to male or female, or that conformed closely to a 50:50 sex ratio. Matings within the families as well as across families are being conducted to determine the heritability of sex and the factors influencing it. Progeny from representative matings are being cultured in 45-l aquaria at temperatures of 27–28°C and 36°C during the period of gonadal differentiation to determine the effect of temperature on altering sex ratios and how that response may vary by family. A total of 80 within-family and 65 cross-family spawns have been obtained from the nine families. Additional pair spawns were made through 30 July 2000. The sets of progeny obtained to date are being grown to a sexable size to determine the frequency of each sex. Sex ratios from each set will be compared to those of other sibling matings and the frequency from the parent family.

## EFFLUENTS AND POLLUTION RESEARCH

Subcontract No. RD010A-07

**Note:** Additional project information on Staff, Networking, Educational Outreach, Publications, Presentations, Conferences, and Awards appears in the Pond Dynamics Research Section, p. 29.

### Staff

*Auburn University, Alabama*

Claude E. Boyd

Oscar Zelaya

US Principal Investigator, Project Leader

Graduate Assistant (Honduras; CRSP funded)

### Background

Oscar Zelaya, a student from Honduras, was selected to receive CRSP funding for graduate studies under 8HCD1B, an Eighth Work Plan activity originally overseen by the CRSP's Education Development Component. Responsibility for overseeing this activity has since been transferred to Claude Boyd, Zelaya's major professor. Zelaya's thesis research is described in work plan study 9ER4, "Effects of water recirculation on bottom soils and water quality in aquaculture ponds."

Development of alternative production and harvest technologies to reduce the environmental impact of nutrient loading in receiving waters by aquacultural effluents was identified as a key objective in the *Continuation Plan 1996–2001*. A series of research projects examining the impacts of shrimp culture effluents in Honduras identified the presence of nutrients and dissolved oxygen beyond the carrying capacity of the local estuarine system. Current research examines the use of recirculating water systems as an alternative to effluent release and examines the effect of varying stocking densities and recirculation rates on pond production.

### Work Plan Research

This subcontract was awarded funding to conduct the following Ninth Work Plan investigation (see Pond Dynamics Research (p. 29) for information on another funded investigation under this subcontract):

- Effects of water recirculation on water quality and bottom soil in aquaculture/9ER4. The report submitted for this investigation was a progress report.

**Note:** 9ER4 was funded after publication of the *Ninth Work Plan*. The 9ER4 work plan will appear in the *Addendum to the Ninth Work Plan*.

### EFFECTS OF WATER RECIRCULATION ON WATER QUALITY AND BOTTOM SOIL IN AQUACULTURE PONDS

*Ninth Work Plan, Effluents and Pollution Research 4 (9ER4)  
Progress Report*

Oscar Zelaya, Claude E. Boyd,  
David R. Teichert-Coddington, and Bartholomew W. Green  
Department of Fisheries and Allied Aquacultures  
Auburn University, Alabama, USA

### ABSTRACT

There is considerable interest in reducing negative environmental impacts of shrimp and fish farming. One of the most promising methods for reducing the environmental effects of pond aquaculture is to use water-recirculating systems to minimize effluents. However, few studies have been performed to evaluate the effect of recirculation upon soil and water quality in ponds. This study evaluates changes in physical and chemical characteristics of pond water and soils in response to varying density of production and in the presence or absence of water recirculation. Ponds were stocked with *Litopenaeus vannamei* and arranged in three treatments: 1) high-density stocking (50 post-larvae m<sup>-2</sup>) (HDR) with water recirculation into another pond of equal volume without shrimp (R); 2) high-density stocking (50 post-larvae m<sup>-2</sup>) without recirculation (HD); and 3) low-density stocking (25 post-larvae m<sup>-2</sup>) without water recirculation (LD). Water quality variables determined weekly included soluble reactive phosphorus, total phosphorus, total nitrogen, nitrites, nitrates, and total suspended solids. Every two weeks determinations were done for 5-d biochemical oxygen demand, and chlorophyll *a*. Soil variables determined at the beginning and end of the study included total nitrogen, soil respiration, pH, carbon, and sulfur. Analysis of variance techniques were used to determine if significant differences existed among treatments with respect to soil and water quality variables.

## MARKETING AND ECONOMIC ANALYSIS RESEARCH

Subcontract No. RD010A-01

### Staff

#### *University of Arkansas at Pine Bluff, Arkansas*

Carole Engle	US Co-Principal Investigator, Project Leader
Siddhartha Dasgupta	US Co-Principal Investigator
Ivano Neira	Graduate Research Assistant (Peru; from January 2000; CRSP funded)
Diego Valderrama	Graduate Research Assistant (Colombia; through June 2000; CRSP funded)

#### *Asian Institute of Technology, Pathumthani, Thailand*

Harvey Demaine	Host Country Principal Investigator
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#### *Escuela Agrícola Panamericana El Zamorano, Honduras*

Dan Meyer	Host Country Principal Investigator
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### Background

The *Continuation Plan 1996–2001* envisioned a broader involvement of social scientists in the PD/A CRSP. The intended impact of CRSP research is greater economic and social returns to farmers who adopt CRSP-developed technologies. Quantifying those returns is one goal of Ninth Work Plan research. Reaching a better understanding of risk and farmers' perception of risk is valuable in developing and encouraging the adoption of technologies and is the focus of one Ninth Work Plan investigation. As production increases as a result of CRSP research, markets must be developed to keep pace with increasing supply. The development of domestic markets for tilapia in Honduras is the focus of another investigation.

### Work Plan Research

The following Ninth Work Plan investigations continued into the current reporting period:

- Development of Central American markets for tilapia produced in the region/9MEAR3. The report submitted for this investigation was a progress report.
- Economic and social returns to technology and investment in Thailand/9MEAR4. The report submitted for this investigation was a progress report.

### Networking

In August, CRSP researcher Carole Engle traveled to Honduras, where she consulted with Dan Meyer from the Escuela Agrícola Panamericana El Zamorano (Zamorano), about the design of a marketing study and about recruiting a graduate student to assist with the project. She also met with Carlos Leyva of Aqua Corporacion to discuss the marketing study. Engle has already received two requests from Honduras for copies of the marketing report. She has also networked with Agnes Saborio and Julio Castaneda, who are assisting with the design and implementation of surveys in Nicaragua.

Engle has maintained correspondence with Nelson Omar Funes Fuentes, the individual who was contracted to complete the marketing surveys in Honduras. Fuentes hopes to attend graduate school at the University of Arkansas at Pine Bluff (UAPB). To help him attain the required proficiency in English, Engle arranged for him to attend an intensive English training program in the US in October.

Engle continues to provide assistance to shrimp farmers in Honduras on a variety of economic issues. This is an outgrowth of shrimp economics work conducted under the Eighth Work Plan. The researchers continue to field email requests for information. They are commonly queried about information on markets for tilapia.

### Educational Outreach

Graduate student Diego Valderrama presented several lectures on economics and risk analysis of shrimp farming in Honduras. The lectures were for both undergraduate and graduate students taking aquaculture economics and marketing classes at UAPB. He used data and analyses from his own thesis to illustrate points in the lectures.

### Publications

- Dasgupta, S. and C.R. Engle, 1999. Non-parametric estimation of returns to investment in Honduras Shrimp Research. In: B.W. Green, H.C. Clifford, M. McNamara, and G.M. Montaña (Editors), *V Central American Symposium on Aquaculture*. San Pedro Sula, Honduras, pp. 201–203.
- Valderrama, D., 2000. Economic analysis of shrimp farming in Honduras. M.S. thesis, University of Arkansas, Pine Bluff, Arkansas.
- Valderrama, D. and C.R. Engle, 1999. Risk analysis of shrimp farming in Honduras. In: B.W. Green, H.C. Clifford, M. McNamara, and G.M. Montaña (Editors), *V Central American Symposium on Aquaculture*. San Pedro Sula, Honduras, pp. 236–239.
- Valderrama, D. and C.R. Engle. Risk analysis of shrimp farming in Honduras. *Aquacult. Econ. and Manage.* (in press)

### Presentations

- Dasgupta, S. and C.R. Engle. Non-parametric estimation of returns to investment in Honduras Shrimp Research. Presented to the *V Central American Symposium on Aquaculture* at San Pedro Sula, Honduras, 17–20 August 1999.
- Valderrama, D. A risk programming model for shrimp farming in Honduras. Presented to the *Tenth Biennial Conference of the International Institute of Fisheries Economics and Trade (IIFET 2000)* at Corvallis, Oregon, 10–13 July 2000.
- Valderrama, D. and C.R. Engle. Risk analysis of shrimp farming in Honduras. Presented to the *V Central*



American Symposium on Aquaculture at San Pedro Sula, Honduras, 17–20 August 1999.

Valderrama, D. and C.R. Engle. Risk analysis of shrimp farming in Honduras. Presented to Aquaculture America 2000 at New Orleans, Louisiana, 2–5 February 2000.

### Conferences

V Central American Symposium on Aquaculture at San Pedro Sula, Honduras, 17–20 August 1999. (Engle)  
 PD/A CRSP Annual Meeting at New Orleans, Louisiana, 31 January–2 February 2000. (Engle, Valderrama)  
 Aquaculture America 2000 at New Orleans, Louisiana, 2–5 February 2000. (Engle, Valderrama)  
 Tenth Biennial Conference of the International Institute of Fisheries Economics and Trade (IIFET 2000) at Corvallis, Oregon, 10–13 July 2000. (Valderrama)

### Awards

Diego Valderrama received a plaque and check for one of the best student abstracts submitted to Aquaculture 2000 by the US Aquaculture Society for his paper "Risk Analysis of Shrimp Farming in Honduras."

Valderrama won Best Graduate Student Paper in the School of Agriculture, Fisheries, and Human Sciences at the March 2000 UAPB Research Forum for the paper entitled "A Risk Programming Model for Shrimp Farming in Honduras."

Valderrama also received an honorable mention for his paper "A risk programming model for shrimp farming in Honduras" in the Best Student Paper award competition at the IIFET 2000 conference.

### DEVELOPMENT OF CENTRAL AMERICAN MARKETS FOR TILAPIA PRODUCED IN THE REGION: POTENTIAL MARKETS FOR FARM-RAISED TILAPIA IN HONDURAS

*Ninth Work Plan, Marketing and Economic Analysis Research 3 (9MEAR3)  
 Progress Report*

Carole Engle, Ivano Neira, and Diego Valderrama  
 Department of Aquaculture and Fisheries  
 University of Arkansas at Pine Bluff  
 Pine Bluff, Arkansas, USA

### ABSTRACT

Three surveys were conducted in Honduras from September through December 1999. A random sample of restaurants and a census of supermarkets and fish markets were conducted in the major urban areas and in selected small rural towns. Descriptive analyses of the restaurant and supermarket surveys are attached; the descriptive analysis of the fish market vendor survey is nearly complete. Quantitative analyses of the survey data have been initiated. Similar surveys are scheduled to be conducted in Nicaragua from August through October 2000. Descriptive and quantitative analyses will also be conducted with the Nicaraguan survey data.

### ECONOMIC AND SOCIAL RETURNS TO TECHNOLOGY AND INVESTMENT IN THAILAND

*Ninth Work Plan, Marketing and Economic Analysis Research 4 (9MEAR4)  
 Progress Report*

Siddhartha Dasgupta and Carole R. Engle  
 Department of Aquaculture and Fisheries  
 University of Arkansas at Pine Bluff  
 Pine Bluff, Arkansas, USA

### ABSTRACT

The first phase of this study was to conduct an analysis of the economic tradeoffs associated with PD/A CRSP–developed technologies in Thailand using secondary data. This paper outlines conditions under which a small-scale tilapia producer in Thailand chooses among four PD/A CRSP–developed technologies: low-intensity inorganic fertilization (inorganic technology), organic fertilization with collected chicken manure (organic technology), organic fertilization in layer-fish integrated ponds (integrated technology), and high-input green water (HIGW) technology using intensive inorganic fertilization treatments. A mixed-integer programming (MIP) model of annual operations of a small-scale Thai tilapia farm was developed and used to attribute technologies to the production ponds based on maximization of net income. Eleven scenarios were developed that were based on the advantages of each of the four technologies. Results of this first-phase analysis will provide important insights into the key relationships to be explored in the survey data collection phase. The following progress report presents the results of the analysis conducted in Phase I and a draft of the survey instrument to be used in data collection in the second phase (a draft of this survey may be obtained from the PD/A CRSP).

## MARKETING AND ECONOMIC ANALYSIS RESEARCH

Subcontract No. RD010A-18

### Staff

*Auburn University, Alabama*

Upton Hatch

Jose Falck

US Principal Investigator, Project Leader

Postdoctoral Research Associate

### Background

Research under this subcontract will determine profitability and risk indicators for various aquaculture systems developed by the CRSP in Honduras, which will be used to make a rapid determination of whether a particular tilapia production strategy is likely to be profitable, easy to implement, and associated with acceptable levels of risk. In doing so, this study addresses several socioeconomic constraints to the development of more sustainable aquacultural systems identified in the *Continuation Plan 1996–2001*, specifically, inadequate attention to economic analysis of production; poor understanding of investment, markets, and risk reduction; lack of attention to efficient resource utilization; and barriers to assimilation of technological innovations through extension and training.

### Work Plan Research

This subcontract was awarded funding to conduct the following Ninth Work Plan investigation:

- Rapid economic evaluation tools/9MEAR5. The report submitted for this investigation was a progress report.

**Note:** The schedule for 9MEAR5 has been modified. Please see Appendix 5, "Completion Dates for Work Plan Studies," for revised schedule information.

### RAPID ECONOMIC EVALUATION TOOLS

*Ninth Work Plan, Marketing and Economic Analysis Research 5  
(9MEAR5)  
Progress Report*

Upton Hatch and Jose Falck  
Department of Agricultural Economics and Rural Sociology  
Auburn University, Alabama, USA

### ABSTRACT

A demonstration of the first prototype of a rapid decision economic evaluation tool is presented. We performed an economic evaluation of two tilapia production technologies in Honduras: 1) chemical fertilization (CF) and 2) fertilization followed by supplemental feed (FSF), published by CRSP researchers in Honduras. The demonstration's initial results agree with the Honduran results in that the FSF treatment has a higher net income than the CF treatment. In addition, results from our prototype program indicate that the FSF treatment is associated with a lower risk of losing money in the short run.

## ADOPTION/DIFFUSION RESEARCH

Subcontract No. RD010A-10

### Staff

#### *Auburn University, Alabama*

Joseph J. Molnar	US Principal Investigator, Project Leader
Malkia Lockhart	Graduate Research Assistant (Bahamas; through December 1999; CRSP funded)
Steve Miklouchich	Graduate Research Aide (US; from May 2000)

#### *Sagana Fish Farm, Sagana, Kenya*

Judith Amadiva	Social Development Officer
Bethuel Omolo	Head of Station (through December 1999)

#### *Instituto de Investigaciones de la Amazonia Peruana, Iquitos, Peru*

Fernando Alcántara	Host Country Co-Principal Investigator
Salvador Tello	Host Country Co-Principal Investigator

### Background

Adoption/Diffusion Research investigates the barriers to assimilation of technological innovations through extension and training. Advances in basic understanding of the pond environment and cultural practices must eventually be translated and diffused to hatcheries, fish farmers, and other agencies and organizations involved in aquaculture development. Documenting the central mechanisms of transaction between fish farmers and the knowledge system in aquaculture is a fundamental objective of this work. Current activities build upon earlier Adoption/Diffusion Research, with a survey instrument that was used in Honduras, Thailand, Philippines, and Kenya being employed in Peru. This research completed Eighth Work Plan objectives of identifying farmer perceptions towards aquaculture, technology, and extension.

### Work Plan Research

The following Eighth Work Plan investigations continued into the current reporting period:

- Sources of technical assistance for fish farmers in the Peruvian Amazon/8ADR1-2. The report submitted for this investigation was a final report.
- Identifying goals and priorities of fish farmers in the Peruvian Amazon/8ADR1-3. The report submitted for this investigation was a final report.

### Networking

CRSP researchers involved in Adoption/Diffusion research are collaborating with CARE/Peru and Terra Nuova, an Italian nongovernmental organization (NGO). The NGOs are using the study results to shape their community-level training and outreach programs to include aquaculture as an option for farmers and communities in Peru. CRSP researcher Fernando Alcántara, located at the Institute de Investigaciones de la Amazonia Peruana (IIAP), continues

making presentations to CARE/Peru, local NGOs, and other groups in the Iquitos area.

### Educational Outreach

Molnar has used his research and experiences with the PD/A CRSP as an aid in two graduate classes he teaches at Auburn, one on rural sociology and another on extension programs and methods.

### Publications

- Lockhart, M., 1999. Farmer perceptions of constraints on aquaculture development in Central Kenya: Market, household, and resource considerations. M.S. thesis, Auburn University, Alabama.
- Molnar, J.J., 2000. Sound policies for food security: The role of culture and social organization. *Rev. Agric. Econ.*, 21(2):489-498.

### Presentations

- Molnar, J.J., F. Alcántara, and S. Tello. Sustaining livelihoods, ecologies, and rural communities. Presented to the American Association for the Advancement of Science 2000 AAAS Annual Meeting and Science Innovation Exposition at Washington, DC, 17-22 February 2000.
- Molnar, J.J., F. Alcántara, and S. Tello. Sustaining small-scale aquaculture in the Peruvian Amazon: Producer perceptions of constraints and opportunities. Presented to World Aquaculture 2000 at Nice, France, 2-6 May 2000.

### Conferences

- 2000 AAAS Annual Meeting and Science Innovation Exposition at Washington, DC, 17-22 February 2000. (Molnar)
- World Aquaculture 2000 at Nice, France, 2-6 May 2000. (Molnar)

**SOURCES OF TECHNICAL ASSISTANCE FOR FISH FARMERS IN THE PERUVIAN AMAZON**

*Eighth Work Plan, Adoption/Diffusion Research 1-2 (8ADR1-2)  
Final Report*

Joseph J. Molnar  
Department of Agricultural Economics and Rural Sociology  
International Center for Aquaculture  
and Aquatic Environments  
Auburn University, Alabama, USA

Fernando Alcántara Bocanegra and Salvador Tello  
Instituto de Investigaciones de la Amazonia Peruana  
Iquitos, Peru

**ABSTRACT**

Data were collected from a sample of 146 practicing fish farmers in the Napo, Tamishiyacu, and Tahuayo river systems areas north and south of Iquitos, Peru, as well as in the Iquitos-Nauta Road area directly south of the city. Fish farmers were identified in selected communities that were provided technical assistance in aquaculture by CARE/Peru and several other nongovernmental organizations. The data suggest few differences in extension experience and perceptions by species cultured, but there is a notable pattern of differences across three measures of farm size. Larger operators tended to have more contact with extension and were slightly more likely to want extension contact in the future. There was little difference by farm size regarding contact with university technicians working in aquaculture or contact with government fish stations. Nearly all farmers wanted extension contact in the future.

**IDENTIFYING GOALS AND PRIORITIES OF FISH FARMERS IN THE PERUVIAN AMAZON**

*Eighth Work Plan, Adoption/Diffusion Research 1-3 (8ADR1-3)  
Final Report*

Joseph J. Molnar  
Department of Agricultural Economics and Rural Sociology  
International Center for Aquaculture  
and Aquatic Environments  
Auburn University, Alabama, USA

Fernando Alcántara Bocanegra and Salvador Tello  
Instituto de Investigaciones de la Amazonia Peruana  
Iquitos, Peru

**ABSTRACT**

The Peruvian Amazon is in an advantageous situation for fish culture. Survey data from 146 practicing fish farmers show that they culture a variety of species, but regardless of the kind of fish they grow, farmers view fish culture in a positive light. While gamitana (*Colossoma macropomum*) is not the only Amazon fish to deserve special attention, it is the first species about which enough is known to both manage wild stocks and develop aquaculture. PD/A CRSP research at the Quistococha Station near Iquitos, Peru, focuses on this species. Most respondents grew a number of different species, planned to build more ponds, were content with growing fish, and felt the pond was the best use of the land it occupies. In addition, most felt that the pond was worth the work put into it. One of the most problematic aspects of owning a fish pond is the loss of inventory due to human or animal predation. The data show 58% of respondents indicating problems with people stealing fish; 75% of the tucanare (*Cichla ocellaris*) growers had this problem.

## DECISION SUPPORT SYSTEMS RESEARCH

MOU No. RD009B

### Staff

*Oregon State University, Corvallis, Oregon*

John Bolte	US Principal Investigator, Project Leader
Doug Ernst	Research Associate
Charles Hillyer	Graduate Research Assistant (USA; CRSP funded)
Trina Seibert	Graduate Research Assistant (USA; CRSP funded)

### Background

Aquaculture planners and managers must make increasingly complex decisions regarding routine operations of culture facilities, effects of such operations on the surrounding environment, and the role of aquaculture production facilities within larger farming systems. Analytical tools for decision support systems integrate knowledge—as mathematical models, expert systems, and databases—into software systems.

CRSP research in Decision Support Systems has developed a Windows-based software package (POND<sup>®</sup>) that allows simulation modeling and economic analyses of entire pond facilities. POND<sup>®</sup> facilitates the assessment of economic and ecological impacts of alternative decisions on production and allows an increased understanding of the interrelationships that can affect production dynamics. By capturing the fundamental principles affecting pond production, coupling these with appropriate economic analyses, and presenting results in a readily understandable form, these decision support tools can improve the design, management, and analysis of production facilities.

The current research in Decision Support Systems focuses on improving the utility and interface of POND<sup>®</sup> software for education and extension purposes; including budget and cost capabilities; and improving POND<sup>®</sup>'s ability to address scheduling and other applied pond management issues. One other aspect of this research is improving the models contained within POND<sup>®</sup>, particularly as they relate to modeling population size distribution. These enhancements should improve the usefulness of the software in addressing the needs of both educators and pond managers and allow improved decision-making in areas related to fertilization, feeding, stocking, water use and effluent discharge, and economic optimization.

### Work Plan Research

The following Ninth Work Plan investigation continued into the current reporting period:

- Enhancing the POND<sup>®</sup> decision support system for economics, education, and extension/9DSSR3. The report submitted for this investigation was a progress report.

This MOU was also awarded funding to conduct the following Ninth Work Plan investigation:

- Decision support systems for fish population management and scheduling in commercial pond aquaculture operations/9DSSR2. The report submitted for this investigation was a progress report.

**Note:** The schedule for 9DSSR3 has been modified. Please see Appendix 5, "Completion Dates for Work Plan Studies," for revised schedule information. The study 9DSSR2, "Decision

support systems for fish population management and scheduling in commercial pond aquaculture operations," is a collaborative project between University of Arkansas at Pine Bluff (as a sub-project administered through Subcontract No. RD010A-01) and Oregon State University.

### Networking

In March, CRSP researcher John Bolte traveled to Wageningen University in the Netherlands to meet with a number of scientists regarding simulation frameworks. Bolte's research group from Oregon State University (OSU) was invited primarily based upon the framework it developed in support of the POND<sup>®</sup> model effort. Scientists in the Netherlands wanted to develop a common framework for agriculture/aquaculture/ecological modeling to allow for an interchange between model components; after reviewing several other existing frameworks, they chose POND<sup>®</sup> as the framework for future standardization. Bolte also established a listserve to facilitate collaboration among the scientists engaged in this project.

The researchers have received approximately twenty requests from individual producers around the world for assistance in planning aquaculture facilities.

### Educational Outreach

Bolte uses examples from the POND<sup>®</sup> software in a Bio-systems Modeling Techniques class he teaches at OSU.

### Publications

- Bolte, J., S. Nath, and D. Ernst, 2000. Development of decision support tools for aquaculture: The POND<sup>®</sup> experience. *Aquacult. Eng.*, 23:103–119.
- \*Ernst, D., 2000. AquaFarm<sup>®</sup>: Simulation and decision-support software for aquaculture facility design and management planning. Ph.D. dissertation, Oregon State University, Corvallis, Oregon, 400 pp.
- Ernst, D.H., J.P. Bolte, and S. Nath, 2000. AquaFarm<sup>®</sup>: Simulation and decision-support software for aquaculture facility design and management planning. *Aquacult. Eng.*, 23:121–179.
- Nath, S., J.P. Bolte, L.G. Ross, and J. Aguilar-Manjarrez, 2000. Applications of geographic information systems (GIS) for spatial decision support in aquaculture. *Aquacult. Eng.*, 23:233–278.

\* This publication appears under the entry for the Central Database Research Support Project as well. The author is employed by and involved with both projects.

### Conference

PD/A CRSP Annual Meeting at New Orleans, Louisiana, 31 January–2 February 2000. (Bolte)

**DECISION SUPPORT SYSTEMS FOR FISH POPULATION  
MANAGEMENT AND SCHEDULING IN COMMERCIAL  
POND AQUACULTURE OPERATIONS**

*Ninth Work Plan, Decision Support Systems Research 2  
(9DSSR2)  
Progress Report*

John Bolte and Charles Hillyer  
Department of Bioresource Engineering  
Oregon State University  
Corvallis, Oregon, USA

**ABSTRACT**

This study is focused on developing software tools for the analysis of fish population size distributions, focusing initially on commercial catfish operations in the southeastern United States, but generalizable to other types of operations and locations. Progress has been made in two primary areas: 1) modeling size distributions and their dynamics through time related to biological and management factors, and 2) software development for the decision tool deliverable from this study. The current status of both is described in this progress report.

**ENHANCING THE POND<sup>®</sup> DECISION SUPPORT SYSTEM  
FOR ECONOMICS, EDUCATION, AND EXTENSION**

*Ninth Work Plan, Decision Support Systems Research 3  
(9DSSR3)  
Progress Report*

John Bolte  
Department of Bioresource Engineering  
Oregon State University  
Corvallis, Oregon, USA

**ABSTRACT**

This study deals with development of decision support tools for warmwater pond aquaculture. Efforts are directed at refining the POND<sup>®</sup> software and developing a new farm-level decision support tool. Refinements to POND<sup>®</sup> focus on general issues related to program maintenance, enhancements to the enterprise budgeting tool within POND<sup>®</sup>, and a task-oriented interface for assisting users in accomplishing specific activities within the tool related to educational and extension application. A brief summary of AquaFarm<sup>®</sup>, a new aquaculture decision support tool developed in part with PD/A CRSP support, is presented.

## MEXICO PROJECT

MOU No. RD009C

### Staff

#### *Oregon State University, Corvallis, Oregon*

Martin S. Fitzpatrick	US Co-Principal Investigator, US Regional Coordinator (through April 2000)
Carl B. Schreck	US Co-Principal Investigator
Wilfrido M. Contreras-Sánchez	Graduate Research Assistant (Mexico; CRSP funded)
John Hayes	Graduate Research Assistant (Uruguay/USA; from July 2000; CRSP funded)
Carisska Anthony	Undergraduate Student Worker (USA; from April 2000)
Kelly Callison	Undergraduate Student Worker (USA; through September 1999)
Jesse Chastain	Undergraduate Student Worker (USA; from October 1999)
Janine Gonzalez	Undergraduate Student Worker (USA; from August 1999)
Nancy Savage	Undergraduate Student Worker (USA; through January 2000)

#### *Universidad Juárez Autónoma de Tabasco, Villahermosa, Mexico*

Gabriel Márquez-Couturier	Host Country Co-Principal Investigator
Wilfrido M. Contreras-Sánchez	Host Country Co-Principal Investigator
Mario Fernandez	Professor
Ulises Hernandez Vidal	Technician
Alejandro MacDonald Vera	Technician
Guadalupe Morales Lara	Technician
Luis Arturo Dorantes Lopez	Undergraduate Student
Sofia Carolina Santiago Ruiz	Undergraduate Student

### Site Background

The PD/A CRSP has been active in Mexico since 1997. A Memorandum of Understanding (MOU) was signed between Oregon State University (OSU) and the Universidad Juárez Autónoma de Tabasco (UJAT) in June 1999. Until now, research conducted in Mexico has been reported as either Reproduction Control Research or Effluents and Pollution Research. In 2000, due to exclusive collaboration between OSU and UJAT, research conducted under the differing research themes was consolidated to form the Mexico Project. CRSP research in Mexico emphasizes reproduction control through the use of hormone immersion and examines the fate of masculinizing agents in effluents.

### Work Plan Research

The following Ninth Work Plan investigations continued into the current reporting period:

- Masculinization of tilapia by immersion in trenbolone acetate: Growth performance of trenbolone acetate-immersed tilapia/9RCR5B. The report submitted for this investigation was a final report.
- Fate of methyltestosterone in the pond environment: Detection of MT in pond soil from a CRSP site/9ER2B. The report submitted for this investigation was a final report.

This MOU was also awarded funding to conduct the following Ninth Work Plan investigations:

- Masculinization of tilapia by immersion in trenbolone acetate: Detection of trenbolone acetate in water after treatment/9RCR5C. The report submitted for this investigation was a progress report.
- Fate of methyltestosterone in the pond environment: Impact of MT-contaminated soil on tilapia sex differentiation/9ER2C. The report submitted for this investigation was a final report.

**Note:** The schedule for 9RCR5C has been modified. The methods and schedules for 9RCR5B and 9ER2B have been modified. Please see Appendix 5, "Completion Dates for Work Plan Studies," for revised schedule information. The revised methods will appear in the *Addendum to the Ninth Work Plan*.

### Networking

Throughout the course of this year, OSU researchers have been in contact with Amrit Bart, CRSP researcher on the Thailand Project, regarding collaboration on an investigation of masculinization of tilapia. OSU researchers sent information to Bart regarding the purchase of steroids in the US and Thailand, as well as their experimental design for masculinizing Nile tilapia by immersion in trenbolone acetate. A graduate student will be using this technique in Bart's laboratory.

After presenting two papers at the V Central American Symposium on Aquaculture and the Aquaculture America 2000 meeting, Wilfrido Contreras-Sánchez received several requests for the group's published information regarding tilapia masculinization protocols with the use of steroids and information for determining the fate of MT in the pond environment. The researchers sent descriptions of their methods and results to scientists and farmers in Mexico, Costa Rica, Honduras, Nicaragua, Brazil, Ecuador, Venezuela, Thailand, and the US.

Contreras shared information on PD/A CRSP masculinization techniques with Javier Romero, a student at the Universidad Técnica de Machala, Ecuador. Contreras reviewed Romero's bachelor's degree thesis, entitled "Evaluation of bio-enriched *Daphnia* sp. for sex inversion of red tilapia fry."

Contreras is a participant in an online discussion group on tilapia culture in which he interacts with tilapia growers from sites around the world. As a result of these conversations, the researchers have sent copies of the group's methods and published results to growers in Mexico, Brazil, Ecuador, Venezuela, Thailand, and the US.

Martin Fitzpatrick and Contreras made an agreement with two professors from the Universidad Autónoma Metropolitana and the Instituto Politecnico Nacional, both in Mexico City, regarding a research project that was submitted to the National Council for Science and Technology (Mexico) for funding. If approved, the researchers will collaborate on the construction of experimental design; training of students, technicians, and researchers on safe handling of steroids; sex inversion by immersion trials; sex identification using histological methods; and data analysis.

Gabriel Márquez-Couturier has initiated collaborative research with Mario Fernández from the aquaculture school at UJAT. Their proposed studies involve masculinization of Nile tilapia fry through large-scale immersions and additional comparison trials to MT-fed groups. Márquez-Couturier additionally trained 12 students and a professor on the safe handling of synthetic steroids and masculinizing techniques. He has also been working closely with farmers from Rio Playa in Tabasco on a project involving the use of native species (*Atractosteus tropicus*, *Cichlasoma urophthalmus*, and *Petenia splendida*) and Nile tilapia in aquaculture. Márquez-Couturier has also started a number of small projects involving tilapia culture in hapas and earthen ponds using sex-inverted tilapia from CRSP project technology.

CRSP researchers at OSU provided juvenile Nile tilapia to a beginning aquaculturist who is experimenting with the feasibility of hydroponics using water from a tilapia system as the primary nutrient source. The aquaculturist plans to grow basil plants in his recirculating system and has obtained the necessary permits to grow and distribute tilapia. He hopes to become a tilapia fry distributor for Oregon.

### Educational Outreach

CRSP researchers at OSU provided tilapia fry to Mike Tyler, a teacher at Arcadia Elementary School in Toledo, Oregon. Tyler's students grew the tilapia to learn about aquaculture, and they sold the adult fish in the local market when they were finished. The researchers also provided fry to Doug Ernst, PD/A CRSP Database Manager and Research Associate on Decision Support Systems Research, for use at Corvallis High School.

Fitzpatrick used examples from his PD/A CRSP-sponsored research in an OSU Fish Physiology course.

Contreras advised students in OSU's Department of Fisheries and Wildlife who were taking a problem-solving class. The students proposed and developed a project to evaluate the growth of Nile tilapia juveniles under different density conditions. Contreras provided them information on the principles for setting experimental designs, tilapia culture, and data analysis, and he provided juvenile tilapia for use in the project.

### Publications

- Contreras-Sánchez, W., M.S. Fitzpatrick, G. Márquez-Couturier, and C.B. Schreck, 1999. Masculinization of the Nile tilapia (*Oreochromis niloticus*) by immersion in synthetic androgens: Timing and efficacy. In: B.W. Green, H.C. Clifford, M. McNamara, and G.M. Montaña (Editors), V Central American Symposium on Aquaculture. San Pedro Sula, Honduras, pp. 246–248.
- Contreras-Sánchez, W.S., M. Fitzpatrick, R.H. Milston, and C.B. Schreck, 2000. Masculinization of Nile tilapia: Alternate treatments and environmental effects. In: B. Norberg, O.S. Kjesbu, G.L. Taranger, E. Andersson, and S.O. Stefansson (Editors), Proceedings of the Sixth International Symposium on the Reproductive Physiology of Fish. Institute of Marine Research and University of Bergen, Bergen, Norway, pp. 250–252.
- Fitzpatrick, M., W. Contreras-Sánchez, R.H. Milston, and C.B. Schreck, 1999. Fate of masculinizing agent methyltestosterone in the pond environment. In: B.W. Green, H.C. Clifford, M. McNamara, and G.M. Montaña (Editors), V Central American Symposium on Aquaculture. San Pedro Sula, Honduras, pp. 249–250.
- Gale, W.L., M. Fitzpatrick, M. Lucero, W.M. Contreras-Sánchez, and C.B. Schreck, 1999. Masculinization of Nile tilapia (*Oreochromis niloticus*) by immersion in androgens. *Aquaculture*, 178(1999):349–357.

### Presentations

- Contreras-Sánchez, W.M., M.S. Fitzpatrick, and C.B. Schreck. Masculinization of Nile tilapia (*Oreochromis niloticus*) by immersion in trenbolone acetate. Presented to Aquaculture America 2000 at New Orleans, Louisiana, 2–5 February 2000.
- Contreras-Sánchez, W.M., M.S. Fitzpatrick, R.H. Milston, and C.B. Schreck. Masculinization of Nile tilapia with steroids: Alternate treatments and environmental effects. Presented to the Gilbert Ichthyological Society Meeting at Newport, Oregon, 18 October 1999.
- Contreras-Sánchez, W.M., M.S. Fitzpatrick, M. Alonso, C.B. Schreck, and J.C. Leong. Identification of unique genes expressed during sex inversion of Nile tilapia (*Oreochromis niloticus*) induced by short immersions in the synthetic steroid trenbolone acetate. Presented to Fourth International Symposium on Fish Endocrinology at Seattle, Washington, 31 July–3 August 2000.
- Contreras-Sánchez, W.M., M.S. Fitzpatrick, M. Alonso, C.B. Schreck, and J.C. Leong. Identification of unique genes induced by trenbolone acetate during sex inversion of Nile tilapia (*Oreochromis niloticus*). Presented to the Eleventh Western Regional Conference on Comparative Endocrinology at Corvallis, Oregon, 24–25 March 2000.
- Fitzpatrick, M.S., W.M. Contreras-Sánchez, and C.B. Schreck. Methyltestosterone persists in the environment after use for masculinizing Nile tilapia. Presented to Aquaculture America 2000 at New Orleans, Louisiana, 2–5 February 2000.

### Conferences

- V Central American Symposium on Aquaculture at San Pedro Sula, Honduras, 18–20 August 1999. (Contreras, Márquez-Couturier)



The Gilbert Ichthyological Society Meeting at Newport, Oregon, 18 October 1999. (Contreras).  
 PD/A CRSP Annual Meeting at New Orleans, Louisiana, 31 January–2 February 2000. (Fitzpatrick, Contreras, Márquez-Couturier)  
 Aquaculture America 2000 at New Orleans, Louisiana, 2–5 February 2000. (Fitzpatrick, Contreras, Márquez-Couturier)  
 Eleventh Western Regional Conference on Comparative Endocrinology at Corvallis, Oregon, 24–25 March 2000. (Fitzpatrick, Contreras)  
 Fourth International Symposium on Fish Endocrinology at Seattle, Washington, 31 July–3 August 2000. (Contreras)

#### Award

Wilfrido Contreras-Sánchez was awarded the Savery Outstanding Graduate Student Award, given by the College of Agricultural Sciences, Oregon State University, at a ceremony on 18 May 2000.

#### MASCULINIZATION OF TILAPIA BY IMMERSION IN TRENBOLONE ACETATE: GROWTH PERFORMANCE OF TRENBOLONE ACETATE-IMMERSED TILAPIA

*Ninth Work Plan, Reproduction Control Research 5B (9RCR5B) Final Report*

Wilfrido M. Contreras-Sánchez and Martin S. Fitzpatrick  
 Department of Fisheries and Wildlife  
 Oregon State University  
 Corvallis, Oregon, USA

Carl B. Schreck  
 Oregon Cooperative Fishery Research Unit  
 Biological Resources Division—US Geological Survey  
 Department of Fisheries and Wildlife  
 Oregon State University  
 Corvallis, Oregon, USA

#### ABSTRACT

Preliminary studies in our laboratory showed that the synthetic androgen trenbolone acetate (TA) is a good candidate for masculinizing Nile tilapia (*Oreochromis niloticus*) fry using short immersions. In this study, we investigated the effects of TA treatment on the growth performance of Nile tilapia. We tested the potential anabolic effects of two treatments by growing treated and control fish for 81 and 114 days. Our results suggest that masculinizing treatments involving short-term immersions in TA and 4-week feeding with 17 $\alpha$ -methyltestosterone (MT) do not result in significant increases in fish growth. Despite significant masculinization (65 to 70% with TA and 100% with MT) in both treatments, we found no differences in final weight between treatments.

#### MASCULINIZATION OF TILAPIA BY IMMERSION IN TRENBOLONE ACETATE: DETECTION OF TRENBOLONE ACETATE AFTER TREATMENT

*Ninth Work Plan, Reproduction Control Research 5C (9RCR5C) Progress Report*

Wilfrido M. Contreras-Sánchez and Martin S. Fitzpatrick  
 Department of Fisheries and Wildlife  
 Oregon State University  
 Corvallis, Oregon, USA

Carl B. Schreck  
 Oregon Cooperative Fishery Research Unit  
 Biological Resources Division—US Geological Survey  
 Department of Fisheries and Wildlife  
 Oregon State University  
 Corvallis, Oregon, USA

#### ABSTRACT

In previous experiments we have found that two 3-hour immersions in trenbolone acetate (TA) can successfully masculinize Nile tilapia fry. In this study we are investigating how the concentration of TA in the immersion water changes before and after treatment to determine the amount of hormone uptake and estimate the potential for reuse of the treatment water. Nile tilapia fry were subjected to two 3-hour immersions at 11 and 13 days post-fertilization (dpf) in water containing 500 ml of TA. Surprisingly, we have found that the concentration of TA before and after treatment is highly variable and below the expected levels. We are currently assessing whether TA comes out of solution and forms precipitates or binds to the jar glass.

**FATE OF METHYLTESTOSTERONE IN THE POND ENVIRONMENT: DETECTION OF MT IN POND SOIL FROM A CRSP SITE**

*Ninth Work Plan, Effluents and Pollution Research (9ER2B)  
Final Report*

Wilfrido M. Contreras-Sánchez and Martin S. Fitzpatrick  
Department of Fisheries and Wildlife  
Oregon State University  
Corvallis, Oregon, USA

Carl B. Schreck  
Oregon Cooperative Fishery Research Unit  
Biological Resources Division—US Geological Survey  
Department of Fisheries and Wildlife  
Oregon State University  
Corvallis, Oregon, USA

**ABSTRACT**

The following study examined the persistence of 17 $\alpha$ -methyltestosterone (MT) in the environment after its use for masculinizing Nile tilapia in nursery ponds located at two CRSP sites: Sagana Fish Farm, Kenya, and the Universidad Juárez Autónoma de Tabasco (UJAT), Mexico. Fry were treated with a masculinizing dose of MT (60 mg kg<sup>-1</sup>) for four weeks beginning at the initiation of feeding. Concentrations of MT were determined by radioimmunoassay, which revealed that the levels of MT in the sediments from the Sagana Fish Farm had a mean value of 4,567 pg g<sup>-1</sup>. The concentration of MT slightly decreased near the drain of the pond. Concentration of MT in water and sediments from UJAT showed background levels after first-time use of MT in the pond. These results suggest that accumulation of MT may take place after masculinization of a significant number of fish.

**FATE OF METHYLTESTOSTERONE IN THE POND ENVIRONMENT: IMPACT OF MT-CONTAMINATED SOIL ON TILAPIA SEX DIFFERENTIATION**

*Ninth Work Plan, Effluents and Pollution Research 2C (9ER2C)  
Final Report*

Wilfrido M. Contreras-Sánchez and Martin S. Fitzpatrick  
Department of Fisheries and Wildlife  
Oregon State University  
Corvallis, Oregon, USA

Carl B. Schreck  
Oregon Cooperative Fishery Research Unit  
Biological Resources Division—US Geological Survey  
Department of Fisheries and Wildlife  
Oregon State University  
Corvallis, Oregon, USA

**ABSTRACT**

The following study examined the effect of environmentally persistent 17 $\alpha$ -methyltestosterone (MT) on sex differentiation of Nile tilapia (*Oreochromis niloticus*). Three different broods of fry were treated one after the other with a masculinizing dose of MT (60 mg kg<sup>-1</sup>) for four weeks beginning at the initiation of feeding in model ponds which consisted of 60-l tanks that contained 5 kg of soil. Four weeks after the last MT treatment, two different broods of tilapia fry were fed control feed while being maintained in the tanks that had contained the MT-treatment groups. Water and soil samples were taken before the onset of treatment and on the last day of treatment during each treatment cycle. Concentrations of MT were determined by radioimmunoassay, which showed that the levels of MT in the water were elevated between about 200 and 1,250 pg ml<sup>-1</sup> during the three cycles of MT, and then returned to background levels during the remaining cycles of control diet feeding. Analysis of water samples taken shortly after adding the MT-impregnated food to the tanks revealed that MT leaks into the water within a minute of treatment. The levels of MT in the soil were elevated to about 2,000 pg g<sup>-1</sup> after one feeding cycle and remained elevated between 1,400 and 3,300 pg g<sup>-1</sup> through three months after the conclusion of the last MT feeding cycle, including the time during which the control-fed fry were raised in these tanks. The sex ratios of the groups fed control food while being maintained in the tanks that had contained the MT-treatment groups were not different from control fish; however, several individuals in the former groups had intersexual gonads, suggesting some impact on development.

## HONDURAS PROJECT

Subcontract No. RD010A-16 (UG)

Subcontract No. RD010A-17 (AU)

### Staff

*University of Georgia, Athens, Georgia*

Brahm Verma US Co-Principal Investigator, US Regional Coordinator

E. William Tollner US Co-Principal Investigator

*Auburn University, Alabama*

Joseph J. Molnar US Co-Principal Investigator

Thomas Popma US Co-Principal Investigator

*Escuela Agrícola Panamericana El Zamorano, Honduras*

Daniel Meyer Host Country Co-Principal Investigator

Freddy Arias Host Country Co-Principal Investigator

### Cooperators

*Auburn University, Alabama*

Robert Nelson

*Centro Internacional de Agricultura Tropical, Cali, Colombia*

E. Bronson Knapp

### Site Background

Honduras has been a PD/A CRSP host country since the program's inception in 1983 (excluding a brief interruption from 1987 to 1988). In 1999, PD/A CRSP research in Honduras moved to a new site at the Escuela Agrícola Panamericana El Zamorano (Zamorano). A Memorandum of Understanding was signed between Zamorano and the University of Georgia (UG) in October 1999; Auburn University (AU) is a collaborating US institution. New research in Honduras is largely focused on enhancing the existing aquaculture network.

Earlier CRSP research in Honduras established a network of relationships with aquaculture producers in the country. The current Honduras project is building on this experience, making use of the pool of trained individuals—many of them with previous CRSP involvement—now present there. In doing so, the Honduras project seeks to help Honduran tilapia farmers take better advantage of the strong potential for aquaculture in Honduras and to help ensure that small- and medium-scale aquaculture production will remain viable in Honduras when the CRSP is no longer active there. These efforts are addressed by strengthening institutional support for aquaculture in Honduras through a multi-disciplinary approach.

Research under the Ninth Work Plan largely focuses on Adoption/Diffusion Research. Several topics address the needs of small- and medium-scale farmers, who are faced with inadequate land, fingerling supply, and extension contact. Research will identify needs and approaches to working with small- and medium-scale farmers. Research will also focus on the collaborative process undertaken by those assisting farmers; this will involve planning of several conferences. Additional research will examine placement of hillside ponds as they relate to the hillslope and watershed characteristics; hillside pond practices are most often practiced by marginalized populations such as small family farmers.

### Work Plan Research

These subcontracts were awarded funding to conduct the following Ninth Work Plan investigations:

- Linkages of aquaculture within watersheds and concurrent design of hillside ponds/9ATR2. An abstract was submitted for this investigation.
- Decision support for policy development: Planning conferences for collaborating researchers, public agencies, and nongovernmental organizations working in aquaculture/9ADR7. An abstract was submitted for this investigation.
- Production strategies characterizing small- and medium- scale tilapia farms: Approaches, barrier, and needs/9ADR8. An abstract was submitted for this investigation.
- Technical assistance for fingerling production serving small- and medium-scale tilapia producers/9ADR9. An abstract was submitted for this investigation.
- Training and technical assistance for Honduras institutions working with small- and medium-scale tilapia producers/9ADR10. An abstract was submitted for this investigation.

**Note:** 9ATR2, 9ADR7, 9ADR8, 9ADR9, and 9ADR10 were approved after publication of the *Ninth Work Plan*. The work plans for these investigations will appear in the *Addendum to the Ninth Work Plan*. Please see Appendix 5, "Completion Dates for Work Plan Studies," for schedule information. The investigations listed above are collaborative projects between UG and AU.

### Networking

Brahm Verma and research associates are forming stronger ties with Red de Desarrollo Sostenible Honduras (RDS-HN; Network for Sustainable Agriculture) associates. The researchers have made excellent networking advances and have connected with several nongovernmental organizations—Global Village, World Neighbors, CARE/Honduras,

and the UN Food and Agriculture Organization—as well as local ministry officers and farmers.

### Conference

PD/A CRSP Annual Meeting at New Orleans, Louisiana, 31 January–2 February 2000. (Meyer, Tollner, Verma)

### LINKAGE OF AQUACULTURE WITHIN WATERSHEDS AND CONCURRENT DESIGN OF HILLSIDE PONDS

*Ninth Work Plan, Appropriate Technology Research 2 (9ATR2) Abstract*

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#### ABSTRACT

Hillsides in Latin America cover about one million square kilometers and provide livelihood for some 200 million people. Farming on the hillside has resulted in progressive deterioration of natural resources due to a combination of overgrazing, poor farming practices, deforestation, and poor water management. The introduction of tilapia production could improve the nutrition of farm families and local communities and provide a means of additional earning for improving economic status. However, improper pond designs and construction and maintenance methods can result in failed attempts to introduce tilapia. An important aspect for designing and successfully introducing tilapia in Honduras and the adjoining regions is to have all stakeholders identify needs that include technical requirements as well as social and environmental issues important in the design of ponds and the production of tilapia.

The fundamental method of pond design is based on the principles of concurrent engineering design methodology. Our stakeholder list included Honduran farmers, extension agents, government agencies, nongovernmental organizations, builders, and design engineers. To insure that pond design meets the identified needs, specific measurable requirements for each need were listed and quantitative targets set.

The hillside pond was defined as a pond that is built on land slopes ranging from 2 to 15%. Two types of hillside ponds were considered in this study: 1) a watershed pond in which water availability is entirely dependent on rainfall in the

watershed catchment area, and 2) a spring-fed pond in which water supply is entirely dependent on springs. Critical analysis of water balance considering water source, availability, distribution over time, and losses is important in the design of ponds. Thus, water balance models are being constructed for both pond types. For the watershed pond both runoff and evapotranspiration were modeled, whereas for spring-fed ponds only the evapotranspiration and rate of water exchange were used for modeling.

Climate plays an important role in estimating water balance. Based on monthly average temperature and monthly rainfall, we selected six geographic locations distributed across Honduras. Selection was also based on number of years of available records for the candidate locations and on the results of in-depth analysis of rainfall to estimate water availability for watershed ponds. These locations are Comayagua, Choluteca, Santa Rosa, Catacamas, La Ceiba, and Sico. Rainfall data from these locations were used to estimate 90% probability distribution.

Thus, conditions for pond design are as follows:

- a) Two pond types: watershed and spring-fed ponds.
- b) Three pond sizes: small = 0.05 ha, medium = 0.05 to 0.5 ha, and large = 0.5 ha.  
The three sizes of pond were selected based on current farm sizes in Honduras and on meeting the needs at the following three levels: tilapia production for meeting needs of the farm family only, the farm family plus the immediate neighbors, and the farm family and the local market on a consistent basis.
- c) Three slopes: low = 2 to 5%, medium = 5 to 10%, and high = 10 to 15%.
- d) Three ground covers: forest, pasture, and mix of forest and pasture.
- e) Selection of regions in Honduras based on adequate rainfall, appropriate slopes, and soil with greater than 20% clay content (to seal the pond).

To address diverse design needs of various communities we have decided to identify modules in the design of ponds and develop concepts that will likely meet a range of anticipated conditions in Honduras. This approach will enable users to receive design information for a customized pond based on their own constraints and needs.

At this time we have selected nine conditions to provide the design for. They include a combination of three sizes of pond (small, medium, and large) and three levels of land slope (low, medium, and high), giving the nine alternatives. The following structural features will be included in the design recommendations: shape of pond, dimensions of pond, outlet pipe, spillway, diversion ditch, pond sealing, drainage outlet, construction methods, materials, cost, labor requirements, and maintenance.

In summary, we are using a design approach that concurrently considers the needs of all individuals and entities that can impact the construction, operation, and maintenance of a pond. Market considerations relevant to the pond design are also being considered. Furthermore, we are developing models for estimating the water balance to make a more

informed decision while selecting pond size and type. Although many specifics of pond dimensions and design features have been reported earlier, this approach provides a means for the user to interactively input his/her needs and select a design for the conditions unique to his/her environment and constraints. Finally, concurrently considering needs of all "customers" in the design and selection of construction methods provides a powerful method to have users educated and invested in the design. This approach presents an increased possibility of introducing acceptable pond design and tilapia production as an economic enterprise in Honduras and Central America.

**DECISION SUPPORT FOR POLICY DEVELOPMENT:  
PLANNING CONFERENCES FOR COLLABORATING  
RESEARCHERS, PUBLIC AGENCIES, AND  
NONGOVERNMENTAL ORGANIZATIONS WORKING IN  
AQUACULTURE**

*Ninth Work Plan, Adoption/Diffusion Research 7 (9ADR7)  
Abstract*

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**ABSTRACT**

This work relates to fostering linkages among national and regional organizations to pursue capacity building and institutional strengthening for aquaculture. All Co-Principal Investigators met in Honduras for one week in October/November 1999. The meeting was devoted to understanding the local conditions that will impact the effectiveness of envisioned linkages for development. The investigators:

- 1) Toured facilities of Escuela Agrícola Panamericana El Zamorano (Zamorano) and met key university faculty and administrators;
- 2) Met 12 national and international nongovernmental organizations (NGOs), extension agents, government officials, and policy makers;
- 3) Visited several small, medium, and large tilapia farms;

- 4) Visited sites of earlier work developed with PD/A CRSP support; and
- 5) Developed plans for identifying individuals and groups who should be included in training workshops on tilapia production, pond design, and decision-making approaches in which tilapia is an alternative for economic development.

Some of the observations made during this meeting were:

- There is a large network of NGOs operating at the village level that need to be linked.
- Many NGOs are currently offering assistance to small farms and are interested in adding technical assistance capabilities in tilapia culture.
- NGOs and government policy makers are interested in water, water harvesting, and hillside stabilization.
- The Comayagua research station in El Carao can be an appropriate site for providing training to NGO technicians and extension personnel.
- There is a need to expand the number and geographical distribution of fingerling producers and to improve fingerling quality in Honduras.
- Women and children often bear primary responsibilities for managing small-scale aquaculture ponds.
- Home consumption, pond-bank sales, and local markets are important outlets and can be the primary marketing opportunities for small- and medium-scale producers.
- Innovative methods of delivering information on tilapia culture and markets as a source of economic development should be considered. The project should provide for stakeholders to give input for developing these methods.
- There is a need for a method and a manual describing pond siting (that includes source of water and quality of watershed), construction, and management of ponds.

Based on these observations, much work is in progress.

A one-day meeting with select stakeholders has been organized to present objectives of this research and receive inputs. This will contribute to the development of innovative methods for delivering information and training of individuals and groups that can affect introduction of tilapia culture as an alternative in sustainable economic development. This meeting is scheduled at Zamorano and a follow-up questionnaire is planned to identify NGOs and policy makers for a three-day training session on tilapia biology and culture, pond design, and water harvesting. The three-day workshop is scheduled for September 2000. The group will be introduced to an envisioned *Web-based Information Delivery System for Tilapia (WIDeST)*. The work on development of (WIDeST) is in progress. WIDeST has three important ingredients, namely:

- 1) Sources of data and information for successful production and marketing of tilapia;
- 2) The knowledge of decision-making methodology for sustainable economic development; and
- 3) The knowledge and experience of developing electronic information networks and Web-based online information exchange.

Its goal is to develop a system of information delivery by using the Web-based technology for making available the knowledge on tilapia production and management to farmers, NGOs, policy makers, businesses, consumers, and other stakeholders. WIDeST will contribute to successful introduction of tilapia production and marketing as an alternative in the economic development of Honduras and

other parts of Latin America. A key cooperater in this work is the Red de Desarrollo Sostenible-Honduras (RDS-HN). RDS-HN was created with the initial grant from the United Nations Development Programme in response to the 1992 Earth Summit, which mandated assistance to "developing" countries for establishing in-country Sustainable Development Networks (SDNs). These networks were envisioned to provide infrastructural support for rapid communication through electronic information technology. RDS-HN is a very successful organization, and in partnership with Zamorano we planned the three components for the envisioned WIDeST:

- 1) A website accessible via the Internet;
- 2) A newsletter published and distributed periodically giving updates; and
- 3) Presentations and training through meetings and conferences.

Work on the website has begun, and materials for presentations and training are planned for upcoming events in September, November/December, and March/April. The newsletter is not planned at this time due to lack of firm funding. We feel that WIDeST will be a strong contribution from the PD/A CRSP that will initiate an innovative method to foster linkages and communication among all stakeholders. This will be an outstanding legacy of the PD/A CRSP. Of course, considerable development beyond the duration of this project will be needed to complete WIDeST and to increase its effectiveness in sustainable economic development and decision making. This level of development is beyond the scope of this project.

**PRODUCTION STRATEGIES CHARACTERIZING  
SMALL- AND MEDIUM-SCALE TILAPIA FARMS:  
APPROACHES, BARRIERS, AND NEEDS**

*Ninth Work Plan, Adoption/Diffusion Research 8 (9ADR8)  
Abstract*

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**ABSTRACT**

This study portrays Honduran tilapia producer perceptions of production processes, limitations, constraints, and possibilities through on-farm interviews with a selected sample of growers. Wholesalers, distributors, and urban restaurant buyers typically rely on connections to large-scale producers who can provide a regular supply of uniform product. Small- and medium-scale farmers rely largely on a diverse set of local strategies for realizing cash from their tilapia crops. One significant commercial distribution

channel for small-scale and limited-resource farmers often is the intermediary or "coyote." Such persons generally do not live in the community, but instead travel from community to community buying and selling farm products. Rural producers in Honduras face particular difficulties due to the difficult terrain, poor road system, and fragmentation in the rural sector. Students from the Escuela Agrícola Panamericana El Zamorano are currently conducting interviews with approximately 20 tilapia farmers at each of five regionally representative fingerling supplier sites throughout Honduras. As many women producers as possible will be interviewed so that the study results can identify their special problems and needs. An interview instrument was collaboratively developed by the researchers, who are extending the instrument used in a previous study, adapting it to focus on experiences and perceptions of the distribution process. At least 20 interviews have been completed. Previous research showed that almost half the Honduran farmers report that middlemen purchase some or all of their fish. A higher proportion of farmers sold tilapia to restaurants in Honduras than in the other PD/A country samples. Honduran farmers were the most confident about being able to sell their tilapia at some price, even if it was not what they originally asked. The most common distribution method for farmers is pond bank sales to neighbors and to others coming to the ponds at harvest. Word-of-mouth knowledge about prospective harvests or the willingness to partial-harvest for immediate sale was a primary means for marketing tilapia for most small- and medium-scale farmers. Data collection continues from a new sample of tilapia producers that will provide longitudinal data on production practices and distribution strategies to verify and extend the previous research findings.

**TECHNICAL ASSISTANCE FOR FINGERLING PRODUCTION  
SERVING SMALL- AND MEDIUM-SCALE  
TILAPIA PRODUCERS**

*Ninth Work Plan, Adoption/Diffusion Research 9 (9ADR9)  
Abstract*

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**ABSTRACT**

A central issue for aquacultural development in Honduras is fingerling supply. Previous PD/A CRSP research reported that farmers in remote places found that fingerlings were difficult to obtain but did not consider this sufficient reason for withdrawing from fish farming. Prior researchers reported that the Comayagua research station, El Carao, is not a reliable supplier of fingerlings for area producers. This observation was recently confirmed by the Escuela Agrícola Panamericana El Zamorano (Zamorano) Principal Investigator (PI) and technician in this project. Private fingerling producers are few and generally geared to supply large-scale commercial operations. The overriding objective of this Adoption/Diffusion activity is to provide technical assistance and training to current and potential fingerling suppliers to small- and medium-scale tilapia producers in Honduras. During the project team visit to Zamorano in November 1999, a strategy and timetable were developed for implementing technical assistance and training of fingerling suppliers. Since then, at least 33 small- and medium-scale tilapia producers (each with 150 to 12,000 m<sup>2</sup> of water surface) and 26 restaurants were interviewed by the Zamorano PI and technical team to assess the production and marketing demands for tilapia in Honduras. The Zamorano team continues to identify and provide technical assistance to regional fingerling producers. During September 2000, a fingerling production technical workshop will be provided by Zamorano and Auburn PIs for actual and prospective fingerling producers.

**TRAINING AND TECHNICAL ASSISTANCE FOR  
HONDURAS INSTITUTIONS WORKING WITH SMALL-  
AND MEDIUM-SCALE TILAPIA PRODUCERS**

*Ninth Work Plan, Adoption/Diffusion Research 10 (9ADR10)  
Abstract*

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**ABSTRACT**

The Peace Corps program of technical support to fish farmers was possibly the most focused on-farm assistance to small-scale fish farmers in Honduras, but this program ended in 1995. The national extension program in aquaculture has a presence in many regions, but the effort is fragmented and underfunded. A number of nongovernmental organizations (NGOs) have been active in rural development, including several active fish farming projects, but expertise in this activity is often insufficient to provide critical technical information required for productive pond management. The objective of this PD/A CRSP activity is to identify the NGOs and agencies interested in incorporating small-scale fish farming in their development programs and then to provide technical assistance and training to their field staff. The training is a collaborative effort between Auburn University and the Escuela Agrícola Panamericana El Zamorano (Zamorano).

In November 1999, the Principal Investigators from Zamorano, the University of Georgia, and Auburn University visited directors and representatives from eleven educational and national and international governmental, nongovernmental, and private agencies involved in tilapia culture in Honduras. During this visit, a strategy and timetable were developed for implementing technical assistance and training of NGO technicians.

As a result of the Ninth Work Plan activity entitled "Decision support for policy development—Planning conferences for collaborating researchers, public agencies, and nongovernmental organizations working in aquaculture," (9ADR7), NGOs involved in rural development and with interest in evaluating tilapia culture as a component in the programs were identified. Meyer and F. Arias of Zamorano will offer a one-day workshop in August 2000 on the technical and economic aspects of tilapia culture, with emphasis on its potential value in rural and community development programs. The resulting clearer understanding of the benefits and constraints of tilapia culture will help NGOs make more knowledgeable decisions about the appropriateness of tilapia culture in their overall rural development program. In September 2000 technical staff of interested NGOs will attend a three-day workshop on technical aspects of fingerling production and grow-out of tilapia.

## PERU PROJECT

Subcontract No. RD010A-12

### Staff

#### *Southern Illinois University at Carbondale, Illinois*

Christopher C. Kohler	US Co-Principal Investigator, US Regional Coordinator
Susan T. Kohler	US Co-Principal Investigator
Marcos J. De Jesus	Research Associate

#### *The Ohio State University, Columbus, Ohio*

Konrad Dabrowski	US Co-Principal Investigator
Jacques Rinchar	Postdoctoral Research Associate

#### *Instituto de Investigaciones de la Amazonia Peruana, Iquitos, Peru*

Salvador Tello	Host Country Co-Principal Investigator, Host Country Project Leader
Fernando Alcántara	Host Country Co-Principal Investigator
Palmira Padilla Perez	Aquaculturist
Lamberto Arevalo	Technician
Cesar A. Flores	Technician
Arturo Flores Huang	Technician

#### *Universidad Nacional de la Amazonia Peruana, Iquitos, Peru*

Enrique Rios Isern	Host Country Co-Principal Investigator
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### Site Background

The Peru Project has been active since 1996 and is located at Iquitos, in the heart of the Peruvian Amazon (Loreto Region). The lead US institution, Southern Illinois University at Carbondale (SIUC), collaborates with the Instituto de Investigaciones de la Amazonia Peruana (IIAP) and the Universidad Nacional de la Amazonia Peruana (UNAP). In the past ten years IIAP and UNAP, along with the Peruvian government, have produced thousands of fry and have developed various aquacultural techniques. *Colossoma* and *Piaractus* are considered by local aquaculturists as the best fish for commercialization in the tropical part of Peru. (Tilapia have been introduced to all six USAID-presence countries in South America. However, they are illegal in the Peruvian Amazon basin.) Current research examines practical diets and densities for pond culture, examines gamete quality and spawning requirements, and conducts yield trials and cost analyses of various stocking densities.

### Work Plan Research

This subcontract was awarded funding to conduct the following Ninth Work Plan investigation:

- Spawning and grow-out of *Colossoma macropomum* and/or *Piaractus brachypomus*/9NS3. The report submitted for this investigation was a progress report.

**Note:** The studies grouped under the research study code 9NS3, "Spawning and grow-out of *Colossoma macropomum* and/or *Piaractus brachypomus*," are collaborative efforts among the University of Arkansas at Pine Bluff (UAPB; under Subcontract No. RD010A-13), The Ohio State University (as a sub-project administered by Subcontract No. RD010A-12), and SIUC. The following report addresses rearing and reproduction objectives; the objective regarding local feeds is addressed in the 9NS3A report submitted by UAPB (see p. 55).

### Networking

CRSP researchers Marcos De Jesus, Christopher Kohler, and Konrad Dabrowski visited Peru in October and November and met with several host country representatives. In Lima, they visited the Universidad Nacional Agraria La Molina, where they received a tour of the host facilities, exchanged ideas about their feed production projects, and discussed other fisheries research conducted in Lima.

Project researchers Fernando Alcántara, Palmira Padilla Pérez, Kohler, Dabrowski, and others worked in Iquitos to engage in the production of *Piaractus brachypomus*. They were able to produce 850,000 healthy larvae, insuring a promising crop for future research and extension provision for neighboring farmers.

Kohler, Alcántara, and Salvador Tello met to organize an extension project planning committee. Participants included Marco Colace (Terra Nuova), Julio Tapia (Peruvian Ministry of Fisheries), and Juan Guerrero (CARE/Peru).

Researchers also met with Jessie Vargas and Fernando Galecio of the Universidad Nacional Agraria (UNA), La Molina, Peru. UNA is in the process of remodeling and expanding its campus research facilities and has several operational fisheries stations in Peru, some of which lie within the Amazonian flood plain. Vargas and Galecio have been concentrating on marine aquaculture but would like to change their focus to Amazonian fisheries and aquaculture research. De Jesus then traveled to Honduras, where he met with representatives from local universities, private farms, and the Chinese Mission.

In December, De Jesus traveled to Peru, where he attended and participated in a small, specialized conference focused on the development of aquaculture in the Amazon Basin. There he met with several colleagues, farmers, and aqua-



culture businesspeople from the host country. Among those he met with were Julio Fasanando Del Aguila and Maria H. Cuadros Dulante of the Peruvian Ministry of Fisheries. The two are interested in collaborating on the development of an environmental conservation project in the area of San Martin, Peru, an area that is negatively affected by intensive tilapia farming. De Jesus also met with Angel Pérez Duque of the Institute for the Regional Ecodevelopment of the Amazon, Ecuador, who is interested in developing Ecuadorian Amazon aquaculture.

Throughout the reporting period, Alcántara and Marina Del Aguila of UNAP offered weekend workshops in collaboration with nongovernmental organization (NGO) representatives in a Peruvian extension program. Alcántara also traveled the Iquitos-Nauta road offering free technical advice and support to beginning fish farmers. Tello and Alcántara frequently receive requests for information and assistance from the public.

Word is spreading in the region about the aquaculture industry and the support IIAP is offering to all those who wish to get involved with fish production. Landowners continually visit the IIAP facilities to request technical support or to ask about workshops. Many have taken advantage of the opportunity offered by IIAP and the NGOs and have initiated small farm operations on their land.

#### Educational Outreach

Dabrowski presented two seminars while visiting Peru in August 1999. The first seminar was presented at UNA and was entitled "Effects of vitamin C in prepared trout diets." The second seminar was held at IIAP, and was entitled "Global perspectives of aquaculture." The audiences each consisted of 30 to 40 scientists, faculty, and students.

In December 1999, Alcántara and De Jesus gave several presentations to audiences composed of scientists, professors, producers, farmers, government officials, NGO representatives, and students. Presentations were held in Iquitos, Peru.

Palmira Padilla Perez has continually offered general aquaculture courses to high school students in Iquitos to introduce them to the field and hopefully foster the students' interest in aquaculture. Padilla also participates in weekend workshops with Alcántara which benefit regional farmers involved in local extension projects and high school students.

#### Publication

De Jesus, M.J. and C.C. Kohler. The commercial fishery of the Peruvian amazon: Is it sustainable? Fisheries. (in revision)

#### Presentations

- Alcántara, F. Status of aquaculture in the Peruvian Amazon. Presented to Development of Aquaculture in the Amazon at Instituto de Investigaciones de la Amazonia Peruana, Iquitos, Peru, 30 November–4 December 1999.
- Alcántara, F. Performance of *Piaractus brachypomus* and *Colossoma macropomum* stocked in ponds at different densities in Iquitos, Peru. Presented to Development of Aquaculture in the Amazon at Instituto de Investigaciones de la Amazonia Peruana, Iquitos, Peru, 30 November–4 December 1999.
- Dabrowski, K., J. Rinchar, F. Alcántara, P. Padilla, A. Ciereszko, and M. De Jesus. Preliminary assessment of gamete quality of *Piaractus brachypomus* cultured in ponds in Iquitos, Peru. Presented to Development of Aquaculture in the Amazon at Instituto de Investigaciones de la Amazonia Peruana, Iquitos, Peru, 30 November–4 December 1999.
- Kohler, C.C., S.T. Kohler, M.J. De Jesus, and F. Alcántara. Use of *Colossoma macropomum* and *Piaractus brachypomus* for sustainable aquaculture in the Peruvian Amazon. Presented to World Aquaculture 2000 at Nice, France, 2–6 May 2000.
- Molnar, J., F. Alcántara, C.C. Kohler, S. Tello, and M.J. De Jesus. Aquaculture in the Amazon: Sustaining livelihoods, food security, and species in a complex ecological context. Presented to the V Central American Symposium on Aquaculture at San Pedro Sula, Honduras, 18–20 August 1999.

#### Conferences

- V Central American Symposium on Aquaculture at San Pedro Sula, Honduras, 18–20 August 1999. (De Jesus)
- Development of Aquaculture in the Amazon at Instituto de Investigaciones de la Amazonia Peruana, Iquitos, Peru, 30 November–4 December 1999. (De Jesus, Alcántara)
- PD/A CRSP Annual Meeting at New Orleans, Louisiana, 31 January–2 February 2000. (C. Kohler, S. Kohler, De Jesus, Dabrowski)
- Aquaculture America 2000 at New Orleans, Louisiana, 2–5 February 2000. (C. Kohler, S. Kohler, De Jesus, Dabrowski)
- World Aquaculture 2000 at Nice, France, 2–6 May 2000. (C. Kohler, S. Kohler)

**DEVELOPMENT OF SUSTAINABLE POND AQUACULTURE  
PRACTICES FOR *COLOSSOMA MACROPOMUM* IN THE  
PERUVIAN AMAZON**

*Ninth Work Plan, New Aquaculture Systems/  
New Species Research 3 (9NS3)  
Progress Report*

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*Printed as submitted*

**ABSTRACT**

*Colossoma macropomum* growth performance did not significantly differ in trials conducted in ponds at 2,500, 3,250, and 4,000 fish ha<sup>-1</sup> in Iquitos, Peru. Fish initially weighing 3.4 g were fed a locally prepared diet (26.7% crude protein; 9.0% crude lipid) in rations ranging from 3 to 5% body weight per day. Fish were harvested after 168 days and had mean weights of 374.7, 307.7, and 287.0 g for the 2,500, 3,250, and 4,000 fish ha<sup>-1</sup> stocking rates, respectively. Survival ranged from 67 to 96%, though all but two of nine ponds exceeded 80% survival. Feed conversion efficiency was 40.4, 43.4, and 61.3%, respectively, for the 2,500, 3,250, and 4,000 fish ha<sup>-1</sup> treatments. Fish in two of the ponds were reared for an additional five months and attained a mean weight of 1 kg. Water quality parameters remained within acceptable ranges for tropical aquaculture. As with *Piaractus brachipomus* in a previous study, this study suggests the economic feasibility of rearing *Colossoma* in the Peruvian Amazon. Generally, the combined cost of fingerlings (US\$0.14 each; corrected for 90% survival) and feed (US\$1.02 kg<sup>-1</sup> to produce 1 kg fresh fish) is under half the price (US\$3.00 to \$4.00 kg<sup>-1</sup>) for which the fish are sold in the Iquitos market during flood periods.

## PERU PROJECT

Subcontract No. RD010A-13

### Staff

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US Principal Investigator, Project Leader

### Background

*Colossoma* and *Piaractus* are important food fishes in the Amazon basin, but little production technology regarding these species has been developed. Spawning and broodstock maintenance have been difficult to achieve, in part due to a lack of understanding of dietary needs of these species. A component of the Peru Project's Ninth Work Plan research (9NS3) involves the design of feeds using locally available ingredients for use in broodstock maintenance. Information on the nutrition of *Piaractus brachypomus* will be obtained through bracketing of vitamin requirements. Research on broodstock nutrition of *Colossoma* using locally available feeds addresses objectives in the *Continuation Plan 1996–2001* regarding sustainable culture of new species.

### Work Plan Research

This subcontract was awarded funding to conduct the following Ninth Work Plan investigation (see the Kenya Project (p. 62) for information on another funded investigation under this subcontract):

- Practical diet development for broodstock of *Colossoma macropomum* and *Piaractus brachypomus*/9NS3A. The report submitted for this investigation was a progress report.

**Note:** The methods for 9NS3 have been modified. The revised methods will appear in the *Addendum to the Ninth Work Plan*. The study 9NS3, "Spawning and grow-out of *Colossoma macropomum* and/or *Piaractus brachypomus*," is a collaborative project among Southern Illinois University at Carbondale (SIUC; under Subcontract No. RD010A-12), The Ohio State University (as a sub-project administered by Subcontract No. RD010A-12), and the University of Arkansas at Pine Bluff. The following report addresses objectives related to local feeds; the remaining objectives are addressed in the 9NS3 report submitted by SIUC (see p. 54).

### Educational Outreach

Lochmann teaches an undergraduate- and graduate-level aquatic animal nutrition course at the University of Arkansas at Pine Bluff, in which she includes discussions about CRSP research. She also made presentations about CRSP research in connection with geography lessons at local elementary schools. Lochmann uses a set of overheads describing her research in Peru and Kenya when making

presentations to students and visitors who are interested in aquaculture and fisheries.

In April, Lochmann made a presentation entitled "Development of Broodstock Diets for *Colossoma* in Peru" to a group of elementary school students at the Edgewood Elementary School in Pine Bluff, Arkansas.

Lochmann continually fields questions from the public about her research, and she has received several questions and comments on pacu as ornamental fish in the US.

### Publication

Perschbacher, P. and R. Lochmann, 1999. Effects of feeding pelleted versus non-pelleted defatted rice bran on Nile tilapia *Oreochromis niloticus* production and water quality in ponds. *Asian Fish. Sci.*, 12(1999):49–55.

### PRACTICAL DIET DEVELOPMENT FOR BROODSTOCK OF *COLOSSOMA MACROPOMUM* AND *PIARACTUS BRACHYPOMUS*

*Ninth Work Plan, New Aquaculture Systems/  
New Species Research 3A (9NS3A)  
Progress Report*

Rebecca Lochmann  
Department of Aquaculture and Fisheries  
University of Arkansas at Pine Bluff  
Pine Bluff, Arkansas, USA

### ABSTRACT

Proximate analyses of broodstock and grow-out feeds for gamitana (*Colossoma macropomum*) and paco (*Piaractus brachypomus*) and their constituent feedstuffs were conducted. Literature values for specific nutrients known to affect fish reproduction were calculated from published sources for the broodstock diet. Broodstock eggs have not yet been obtained for proximate analysis. However, similar analyses conducted previously on eggs of similar species in Brazil have been described. Analytical information on the feedstuffs and diets currently being used in Iquitos, Peru, together with published information on the natural diets of colossomids and broodstock nutrition of other species were combined to formulate preliminary recommendations for the nutrition and feeding of gamitana and paco broodstock.

## KENYA PROJECT

MOU No. RD009A (OSU)

Subcontract No. RD 010A-08 (AU)

### Staff

#### *Oregon State University, Corvallis, Oregon*

James Bowman US Co-Principal Investigator, US Regional Coordinator

Christopher Langdon US Co-Principal Investigator

#### *Auburn University, Alabama*

Thomas Popma US Co-Principal Investigator

Karen Veverica US Co-Principal Investigator

Bethuel Omolo Graduate Research Assistant (Kenya; from January 2000; CRSP funded)

#### *Fisheries Department, Nairobi, Kenya*

Nancy Gitonga Host Country Principal Investigator (from January 2000)

Fred Pertet Host Country Principal Investigator (through August 1999)

#### *Moi University, Eldoret, Kenya*

David Liti Host Country Co-Principal Investigator (from January 2000)

Mucaï Muchiri Host Country Co-Principal Investigator (from March 2000)

Charles Nguni Host Country Co-Principal Investigator (from December 1999)

Robertson Mugo Graduate Research Assistant (from October 1999; CRSP funded)

#### *Sagana Fish Farm, Sagana, Kenya*

Japhet Ngatuni Host Country Research Associate and Head of Station (from January 2000)

Bethuel Omolo Host Country Research Associate and Head of Station (through December 1999)

Patricia Mwau Graduate Student, University of Nairobi (partially CRSP funded)

Daniel Oenga Nyanchiri Graduate Student, Moi University (through October 1999; partially CRSP funded)

Robert Olendi Graduate Student, Moi University (partially CRSP funded)

Enos Were Graduate Student, Moi University (partially CRSP funded)

David Mirera Undergraduate Student, Moi University (through December 1999)

Cosmos Mungo Undergraduate Student, Moi University (through December 1999)

Daniel Ndegwa Nderitu Undergraduate Student, Mombasa Polytechnic (through August 1999)

William Nyaga Undergraduate Student, Moi University (through December 1999)

Paul Wamwea Undergraduate Student, Kenyatta University (through May 2000)

#### *International Center for Living Aquatic Resources Management (ICLARM), Zomba, Malawi*

Daniel Jamu Host Country Co-Principal Investigator

#### *Bunda College, Lilongwe, Malawi*

Jeremy Likongwe Host Country Co-Principal Investigator

### Site Background

The Kenya Project operates out of Sagana Fish Farm, in Central Province, in collaboration with the Kenya Fisheries Department under a Memorandum of Understanding between Oregon State University (OSU) and the Fisheries Department of Kenya's Ministry of Tourism and Wildlife. (In 1999, the Fisheries Department moved to the Ministry of Agriculture and Rural Development.)

Research activities in this reporting period addressed aquaculture development constraints and research priorities identified in the *Continuation Plan 1996–2001*. These include optimization of production/management strategies through more efficient use of fertilizers and feeds, use of supplemental feeds, increasing control over tilapia reproduction and fingerling production, conducting training activities in basic pond management practices, regionalizing the benefits of the CRSP research program through outreach activities, and establishing a companion site.

### Work Plan Research

The following Eighth Work Plan investigation continued into the current reporting period:

- Global Experiment: Optimization of nitrogen fertilization rate in freshwater tilapia production ponds/8FFR1K. The report submitted for this study was a final report.

The following Ninth Work Plan investigations continued into the current reporting period:

- Aquaculture training for Kenyan fisheries officers and university students/9ADR3. The report submitted for this investigation was a progress report.
- Establishment of companion sites in the Africa region/9ADR4. The report submitted for this investigation was a progress report.
- Regional outreach in Africa/9ADR5. The report submitted for this investigation was a progress report.

These subcontracts were also awarded funding to conduct the following Ninth Work Plan investigations:

- Fish yields and economic benefits of tilapia/ *Clarias* polyculture in fertilized ponds receiving commercial feeds or pelleted agricultural by-products/9FFR2. The report submitted for this investigation was a progress report.
- On-farm trials: Evaluations of alternative aquaculture technologies by local farmers in Kenya/9ATR1. The report submitted for this investigation was a progress report.

**Note:** The schedule for 9ATR1 has been modified. The schedule and methods for 9FFR2 have been modified. The methods for 9ADR3 have been modified. Please see Appendix 5, "Completion Dates for Work Plan Studies," for revised schedule information. Revised methods will appear in the *Addendum to the Ninth Work Plan*. The investigations listed above are collaborative projects between OSU and Auburn University (AU). The study 9FFR2, "Fish yields and economic benefits of tilapia/ *Clarias* polyculture in fertilized ponds receiving commercial feeds or pelleted agricultural by-products," is a collaborative project among OSU, AU, and the University of Arkansas at Pine Bluff (UAPB; under Subcontract No. RD010A-13). The following report submitted by OSU and AU addresses objective 1, locally available and lower-cost feeds. The 9FFR2A report submitted by UAPB addresses objective 2, the relative contribution of natural food (see p. 62). The study 9ER1, "Use of pond effluents for irrigation in an integrated crop/aquaculture system" (AU; under Subcontract No. RD010A-07) is another collaborative project (see p. 63).

### Networking

During CRSP researcher James Bowman's Kenya visit in January, he and Karen Veverica met several times with the department head and professors from the Moi University Department of Fisheries (DOF) regarding collaboration on training and research, as well as on formalization of the collaboration between the two groups for the remainder of Ninth Work Plan activities. One outcome was a set of short training courses for DOF personnel. DOF faculty and Host Country Principal Investigators Charles Ngugi and Mucai Muchiri were instrumental in planning and implementation of the new courses. During the past year, the Kenya Project also helped the Moi University DOF library acquire current textbooks and references on aquaculture and fisheries.

Veverica and Bowman also met twice with then-Interim Director of the Kenya Fisheries Department (KFD), Nancy Gitonga, who pledged KFD support in seeing the successful completion of all CRSP-supported activities. Veverica remains in weekly contact with Gitonga.

Sagana Fish Farm and the KFD contributed to a display for the Ministry of Natural Resources at the Agriculture Society of Kenya's annual Nairobi Show held at the end of September. Attendance reached 100,000 visitors a day for the event. CRSP researchers and students arranged a 10-foot aquarium to showcase aquaculture species such as tilapia, *Clarias*, and carp; Sagana also donated *Clarias* fillets to be served at the Ministry of Agriculture's display.

Researchers at Sagana Fish Farm met with the Provisional Commissioner for Central Province when he visited the farm in October. The researchers continue to meet with extension agents from seven districts to discuss and organize on-farm trials.

Researchers from the Kenya Project have assisted board members of the Mt. Kenya Fish Farmers Association in writing a proposal for a small grant to purchase harvesting gear and marketing equipment as well as in marketing and group organization. Francis Ndonga, chairman of the Mt. Kenya Fish Farmers Association and a participant in CRSP on-farm trials, has begun to teach and hold seminars on fish farming by using information gained from farmers workshops.

An owner of fish ponds in Kiambu and Laikipia asked for advice on the possibility of starting a fish feed manufacturing plant. In addition, Alpha Aquaculture in Kitengela was provided a supply of fry to start grow-out ponds and advice on water chemistry and aeration. CRSP researchers also evaluated the water supply and chemistry for a prospective fish farmer in Makueno and worked with a group of rice growers to develop rice-fish farming techniques. The Sagana farm receives at least one visit a week from farmers, teachers, or students interested in aquaculture.

CRSP researchers have worked with the owner of a large dam near Nairobi who is building 12 cages for holding fish to supply his restaurant. They are also currently advising five other commercial ventures in Western Kenya and Rift Valley. The researchers provided information on air blower specifications and an enterprise budget to the owner of Anicare, the largest pet store in Kenya and exporter of ornamental fish.

The Kenya Project researchers have begun a relationship with the Lake Victoria Environmental Management Programme. This has been a prolonged development, and conversations have taken place in person, by phone, and via email.

Milton Egesa, the Program Coordinator and Director of the Uganda Wetlands and Resource Conservation Association (UWRCA), expressed his interest in training programs for farmers and visited Sagana for a month to work on a proposal for funding such programs.

Sagana Women's Group received funding to expand its fish/pig/bee-rearing business. Amadiva and Veverica advise the group, and they visit the group every two weeks.

### Educational Outreach

CRSP researcher David Liti taught an aquaculture course at Moi University for graduate students. The course was held at Sagana Fish Farm, and Fisheries Officers were also able to attend. Veverica also gave two lectures on hatchery design and on pond construction and management. Additional courses on these topics were held in May, in which 20 Fisheries Officers and 3 private contractor crews participated.

Fish farmers continue to visit Sagana Fish Farm on a regular basis for advice on pond construction, stocking, or management, or to pick up aquaculture Fact Sheets. School children of all ages also continue to make regular field trips to Sagana.

### Publications

- Gichuri, W.M., 1999. Relative contribution of rice bran and inorganic fertilizers in semi-intensive tilapia (*Oreochromis niloticus*) and catfish (*Clarias gariepinus*) polyculture in Kenya. M.S. thesis, University of Nairobi, Nairobi, Kenya.
- Veverica, K.L. and B. Omolo. Commercial tilapia production recommendations and enterprise budgets for East Africa in the absence of formulated feeds. Naga. (in press)

### Presentations

- Muchiri, M. Break-even price and investment costs under different loan schemes for small-scale fish farmers in Kenya. Presented to the Tenth Biennial Conference of the International Institute of Fisheries Economics and Trade (IIFET 2000) at Corvallis, Oregon, 10–13 July 2000.
- Veverica, K.L. Commercial tilapia production recommendations and enterprise budgets of East Africa in the absence of formulated feeds. Presented to Lake Victoria 2000 at Jinja, Uganda, 14–19 May 2000.
- Veverica, K.L., B.W. Green, J. Bowman, D.R. Teichert-Coddington, and C.E. Boyd. Optimization of nitrogen fertilization rate in freshwater tilapia production ponds in Honduras and Kenya. Presented to World Aquaculture 2000 at Nice, France, 2–6 May 2000.

### Conferences

- PD/A CRSP Annual Meeting at New Orleans, Louisiana, 31 January–2 February 2000. (Omolo, Popma, Bowman)
- Aquaculture America 2000 at New Orleans, Louisiana, 2–5 February 2000. (Bowman, Popma)
- Lake Victoria 2000 at Jinja, Uganda, 14–19 May 2000. (Veverica, Ngatuni, Kahareri, Mbaluka, Were)
- Tenth Biennial Conference of the International Institute of Fisheries Economics and Trade (IIFET 2000) at Corvallis, Oregon, 10–14 July 2000. (Muchiri)

## GLOBAL EXPERIMENT: OPTIMIZATION OF NITROGEN FERTILIZATION RATE IN FRESHWATER TILAPIA PRODUCTION PONDS

*Eighth Work Plan, Feeds and Fertilizers Research 1 (8FFR1K)  
Final Report*

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*Printed as Submitted*

### ABSTRACT

Two experiments to determine the optimum nitrogen fertilization rates for freshwater tilapia production ponds at Sagana Fish Farm, Sagana, Kenya, were conducted during 1998 and 1999. Twelve 800m<sup>2</sup> earthen research ponds managed by the PD/A CRSP at Sagana were used for the experiments. Diammonium phosphate and urea were used to apply nitrogen to the ponds at rates of 0, 10, 20, and 30 kg N ha<sup>-1</sup> wk<sup>-1</sup>. Triple superphosphate or diammonium phosphate and sodium carbonate were applied to ponds to assure that phosphorus and carbon were not limiting. A completely randomized design was used, with three replicates for each of the four treatments. The experiment was conducted once during the 1998 cool season (May to October) and again during the warm season of 1998-1999 (November to March). In the cool-season experiment, ponds were stocked with sex reversed Nile tilapia, *Oreochromis niloticus*, averaging 16.9 grams at a rate of 1,000 kg ha<sup>-1</sup> and with *Clarias gariepinus* fingerlings averaging 37 g at a rate of 37 kg ha<sup>-1</sup>. In the warm season experiment, all ponds were stocked with sex reversed *O. niloticus* averaging 90 g at 1000 kg ha<sup>-1</sup> and with *C. gariepinus* juveniles averaging 166 g at 125 kg ha<sup>-1</sup>. Pond assignments were re-randomized prior to the second experiment. Ponds were drained when fish growth appeared to have stopped in all treatments. In both experiments, a highly significant ( $p < 0.01$ ) quadratic relationship best described gross fish yield (as well as net) as related to weekly nitrogen input. Presence of *Clarias* had little impact on the relationship but it appeared the high nitrogen input rates had no negative effect on *Clarias* production. Increasing nitrogen input beyond 20 kg N ha<sup>-1</sup> wk<sup>-1</sup> did not result in increased tilapia yields. Total nitrogen and all mineral forms of nitrogen increased with increasing nitrogen input, as did chlorophyll *a*. Partial budget analysis indicated that greatest marginal returns were at the calculated rates of 19.9 and 16.0 kg N ha<sup>-1</sup> wk<sup>-1</sup> for the cool- and warm-season experiments, respectively. A carryover effect from the first experiment is suggested. Results from this experiment are

similar to those obtained at the CRSP site at El Carao, Honduras.

**FISH YIELDS AND ECONOMIC BENEFITS OF TILAPIA/  
CLARIAS POLY CULTURE IN FERTILIZED PONDS  
RECEIVING COMMERCIAL FEEDS OR PELLETTED  
AGRICULTURAL BY-PRODUCTS**

*Ninth Work Plan, Feeds and Fertilizers Research 2 (9FFR2)  
Progress Report*

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Jim Bowman  
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**ABSTRACT**

There is a clear need to develop feed/fertilizer combinations that are appropriate for fish farming in Kenya and other parts of Africa. The strategy of using high-quality nutritionally complete feeds to produce high fish yields, frequently employed in developed countries, is often impossible or inappropriate in countries where high-quality feed ingredients are in short supply or are very expensive. However, the use of lower-quality pelleted feeds formulated specifically for tilapia, combined with fertilization regimes to increase the availability of natural food organisms, may be an economically appropriate approach for intensification of tilapia culture in Africa. This experiment is the second in a series designed to compare fish performance and economic benefits under different fertilization/feeding regimes—using low-cost, locally available materials—in earthen ponds. Water quality and fish growth sampling data were collected throughout the experiment, but data have not yet been analyzed. This report includes preliminary observations regarding the experiment. The experiment was conducted in twelve 800-m<sup>2</sup> earthen research ponds at Sagana Fish Farm, Kenya, between November 1999 and May 2000. Four replicates of each of three combinations of feed and fertilizer were tested. The treatments were Rice Bran (RB), Pig Finisher Pellets (PFP), and Test Diet Pellet (TDP). The experiment was concluded when fish reached market size, which occurred after 180 days. Water quality parameters were not significantly different ( $P > 0.05$ ) among the three treatments except for total alkalinity, for which PFP ponds had a significantly higher ( $P < 0.05$ ) mean value. Phytoplankton communities exhibited a strong seasonal succes-

sion, being dominated by green algae in the beginning and by blue-greens later in the cycle. Gross primary productivity ranged from 0.1 to 11.9 g C m<sup>-2</sup> d<sup>-1</sup> for all treatments. It took almost two months to develop phytoplankton blooms in the ponds, and fish growth was relatively slow at first. Fish receiving RB grew much slower than in similar treatments in previous trials. This was probably due to the lower than normal protein content of the bran. Average fish yield was greatest in ponds receiving PFP, followed by TDP, and finally by RB. Less than 50% of the fish in the RB treatment attained market size (300 g), whereas over 80% of the fish from the other two treatments were over 300 g. *Clarias* in all treatments attained market size of 600 g. If price varies by fish size, using PFP for supplemental feeding would be the best choice. Rice bran had significantly lower fish growth rate, net fish yield, and annual production compared to PFP and TDP ( $P < 0.05$ ). However, there were no significant differences in survival rate and relative condition factor among the treatments. Relative profitability analysis using partial and enterprise budgets revealed that the PFP treatment was the best, followed by the RB treatment. Net returns were positive for all treatment regimes. However, RB had the lowest break-even price and the least investment cost.

**ON-FARM TRIALS: EVALUATION OF ALTERNATIVE  
AQUACULTURE TECHNOLOGIES  
BY LOCAL FARMERS IN KENYA**

*Ninth Work Plan, Appropriate Technology Research 1 (9ATR1)  
Progress Report*

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**ABSTRACT**

Research conducted by the PD/A CRSP at Sagana Fish Farm has begun to identify alternative management practices and technologies that may be suitable in the region, but it should not be assumed that results obtained under controlled experimental conditions at Sagana are directly transferable to farms in the area. On-farm testing is therefore a logical step in transferring research-based technologies to the farm. On-farm testing of various alternatives allows farmers to assess their costs and benefits under local conditions as well as to receive instruction and training in basic pond management skills. The conduct of such trials also allows project personnel to work with and train the fisheries extension officers who are involved in the trials at the various locations, thus complementing the training they receive through "regular" training activities.

Thirty farmers were selected to participate in on-farm trials in five districts of Central Province, Kenya, in 1999–2000. A pre-trial workshop including farmers, extension agents, Kenyan and US CRSP personnel, and students working on research projects at Sagana was held in December 1999 to discuss and select management schemes for testing, to agree on how the trials would be conducted, and to plan for proper record keeping during the trial period. Fifty-two ponds were stocked with monosex male tilapia (*Oreochromis niloticus*), mixed-sex tilapia, and/or catfish (*Clarias gariepinus*) between January and March 2000. Stocking densities were 2 fish m<sup>-2</sup> for tilapia, 0.2 fish m<sup>-2</sup> for catfish stocked with tilapia, and 1 fish m<sup>-2</sup> for catfish stocked alone. Management schemes being tested include a “no cash expenditure” type of management, which relied on inputs such as manures and leaves found on farms, and a “purchased feed/fertilizer” management scheme, which featured chemical fertilizer and a feed such as bran or maize germ. Ponds are sampled for fish growth at four- to six-week intervals, and farmers keep records of input type and weight, input costs, pond water additions, fish mortality, and fish weight and length. The trials are underway, but harvests were not expected to begin until at least September 2000. A post-trial workshop will be held to summarize and evaluate the results of the trials. A similar set of trials is planned for western Kenya.

## AQUACULTURE TRAINING FOR KENYAN FISHERIES OFFICERS AND UNIVERSITY STUDENTS

### *Ninth Work Plan, Adoption/Diffusion Research 3 (9ADR3) Progress Report*

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Moi University

Charles C. Ngugi  
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*Printed as Submitted*

### ABSTRACT

Lack of technical training has been cited as a major reason for the low output of fish ponds in Kenya. The lack was observed at all levels, from the lowest level extension agent through university levels. The training program undertaken by the Africa Project in Kenya seeks to improve training and to provide a cadre of trainers who have extensive practical fish production experience.

This year the Africa Project has begun scholarship support for two MS students, one at Moi University's Chepkoilel Campus, Eldoret, Kenya, and the other at Auburn University, Auburn, Alabama. Small stipends for student research conducted at Sagana Fish Farm have allowed undergraduate as well as graduate-level university students to remain longer to complete projects and gain valuable field experience. A small research projects program for station staff has allowed them to further their professional development and carry out their own research, which can have a positive impact on station management.

The program of farmer education days developed during the first half of 1999 (Veverica et al, 2000) was followed this year by a series of four short courses for personnel of the Kenya Fisheries Department (KFD). In this series of courses, more than 80 FD staff received two weeks of training in pond construction methods and pond management techniques. Additional farmer field days for approximately 50 farmers are also planned for later in 2000.



### ESTABLISHMENT OF COMPANION SITES IN THE AFRICA REGION

#### *Ninth Work Plan, Adoption/Diffusion Research 4 (9ADR4) Progress Report*

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#### ABSTRACT

The establishment of one or more companion sites in the Africa Region was proposed as a way of expanding regional efforts of the CRSP by assisting with the conduct of needed research at other sites in the region and of verifying the results of CRSP research at its prime site. The objectives specifically listed for this effort in the Ninth Work Plan are 1) to identify and establish one or more companion sites for the Africa Region (year 1) and 2) to define and implement investigations at the companion site in support of PD/A CRSP and companion site goals (year 2). During the first year of the Ninth Work Plan (December 1998 to November 1999), CRSP Kenya Project personnel continued discussions with possible collaborators in Malawi, leading to a proposal to collaborate with the International Center for Living Aquatic Resources Management (ICLARM) at the National Aquaculture Center, Zomba, and with Bunda College, near Lilongwe. During year 2 an agreement was reached whereby two studies supported by the CRSP Kenya Project will be conducted in Malawi under the oversight of Dr. Daniel Jamu. One will be conducted at the National Aquaculture Center, and the second will be conducted at Bunda College. Work on the Zomba study began in May 2000.

### REGIONAL OUTREACH IN AFRICA

#### *Ninth Work Plan, Adoption/Diffusion Research 5 (9ADR5) Progress Report*

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James R. Bowman  
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#### ABSTRACT

The intent of the Kenya Project's regional outreach activity is to promote contact and communication among aquaculture research and extension personnel and organizations throughout the region. This is to be achieved mainly through participation at regional meetings, not only by presenting papers but also through participation in planning and organizing the meetings. It is hoped that such participation will help promote the dissemination of information emanating from PD/A CRSP research, help conference participants learn about fish culture practices and research priorities and activities in Kenya and in neighboring countries, and encourage the establishment of regional linkages among research and extension programs in the region. During the current reporting year Sagana Fish Farm and the CRSP hosted a meeting of the Aquaculture Committee of the Lake Victoria Environmental Management Programme. The Kenya Project sponsored travel to several workshops and conferences, including a two-week study tour on agro-aquaculture in Malawi for then Sagana Head of Station B. Omolo; attendance at the LV2000 conference in Jinja, Uganda, for K. Veverica, J. Ngatuni (current Head of Station at Sagana), K. Kahareri, R. Mbaluka, and E. Were; and attendance at the IIFET 2000 conference "Microbehavior and Macroresults" by M. Muchiri, Head of the Department of Fisheries at Moi University, Eldoret, Kenya, and a collaborator on several CRSP Kenya Project activities. Graduate student B. Meso presented information on the first season of the study "Use of Pond Effluents for Irrigation in an Integrated Crop/Aquaculture System" at the 25<sup>th</sup> Conference and Silver Jubilee of the Soil Science Society of East Africa, in Kampala, Uganda, and was awarded the prize for academic excellence and diversity in soil science at the university post-graduate level for his presentation. As it has for several years, the CRSP supported the participation of the Kenya Fisheries Department and Sagana Fish Farm in the Agriculture Society of Kenya's annual "Nairobi Show." Although the Fisheries Society of Africa (FISA) did not hold any conferences this year, Veverica continues to maintain contact with officers of that organization, which is headquartered in Nairobi.

## KENYA PROJECT

Subcontract No. RD010A-13

**Note:** Additional project information on Educational Outreach and Publications appears in the Peru Project section, p. 55.

### Staff

*University of Arkansas at Pine Bluff, Arkansas*

Rebecca Lochmann US Principal Investigator, Project Leader

Felicia Bearden Assistant

### Background

The *Continuation Plan 1996–2001* addressed the use of feed and fertilization combinations as a way of intensifying production systems. The plan also identified research objectives geared as optimizing resource utilization based on factors at each site and development of practical guidelines for improving management of ponds. Ninth Work Plan research in this component of the Kenya Project examines tilapia utilization of different locally available feeds and feedstuffs by analyzing carbon and nitrogen isotope ratios.

### Work Plan Research

This subcontract was awarded funding to conduct the following Ninth Work Plan investigation (see the Peru Project (p. 55) for information on another funded investigation under this subcontract):

- Stable carbon and nitrogen isotope analysis of tilapia and *Clarias* fed commercial feeds of agricultural by-products/ 9FFR2A. An abstract was submitted for this investigation.

**Note:** The schedule and methods for 9FFR2 have been modified. Please see Appendix 5, "Completion Dates for Work Plan Studies," for revised schedule information. Revised methods will appear in the *Addendum to the Ninth Work Plan*. This investigation is a collaborative project among University of Arkansas at Pine Bluff (UAPB), Oregon State University (OSU; under MOU No. RD009A), and Auburn University (AU; under Subcontract No. RD010A-08). The following report submitted by UAPB addresses

objective 2, the relative contribution of natural food. The 9FFR2 report submitted by OSU and AU addresses objective 1, locally available and lower-cost feeds (see p. 59).

### STABLE CARBON AND NITROGEN ISOTOPE ANALYSIS OF TILAPIA AND CLARIAS FED COMMERCIAL FEEDS OR AGRICULTURAL BY-PRODUCTS

*Ninth Work Plan, Feeds and Fertilizers Research 2A (9FFR2A)*

*Abstract*

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#### ABSTRACT

Samples of feeds, fertilizers, fish, mud, and plankton from the final feeding study in Kenya were received in Pine Bluff, Arkansas, in late June 2000. These samples are being freeze-dried and ground. In addition, mud must be treated to remove carbonates. All prepared samples will be submitted to a laboratory for isotope analysis, which will begin in two to three months. Final results should be available by 31 December 2000. Since all samples were received only after the feeding trial was completed, there are no preliminary isotope data to report. Several sets of feeds and feedstuffs have been subjected to proximate analysis at University of Arkansas at Pine Bluff to verify results of analysis conducted in Kenya.

## KENYA PROJECT

Subcontract No. RD010A-07

### Staff

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Wesley Wood

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*Sagana Fish Farm, Sagana, Kenya*

Bernard Meso

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*University of Nairobi, Kenya*

Nancy Karanja

Host Country Co-Principal Investigator

S.M. Kinyali

Host Country Co-Principal Investigator (through January 2000)

### Background

Integration of aquaculture and agriculture systems can result in higher productivity of each component. In Kenya fish are grown in both irrigation reservoirs and fish ponds. Farmers may be reluctant to fertilize irrigation water due to a lack of information on the effects of fertilization on irrigated crops. On the other hand, water from fish ponds may be used to irrigate agricultural crops. One goal of the Government of Kenya is to encourage multiple uses of irrigation waters. This investigation was designed to assess the effects of fertilizing irrigation water and of using fishpond effluent to water crops.

### Work Plan Research

The following Ninth Work Plan investigation continued into the current reporting period:

- Use of pond effluent for irrigation in an integrated crop/aquaculture system/9ER1. The report submitted for this investigation was a final report.

**Note:** The methods for 9ER1 have been modified. The revised methods will appear in the *Addendum to the Ninth Work Plan*. This study is a collaboration among Auburn University (AU), Oregon State University (under MOU No. RD009A), and AU (under Subcontract No. RD010A-08).

### Networking

CRSP Effluents and Pollution researchers have hosted over 100 visitors to the Sagana site, including representatives from the Kenyan government's Arid and Semi-Arid Lands (ASAL) project in Laikipia, Kenya. Visitors representing the Ministry of Agriculture have also requested that the

researchers continue their drip irrigation work as a demonstration plot for local farmers.

### Educational Outreach

Wood is now an adjunct graduate faculty member at the University of Nairobi, Kenya.

### Presentations

Meso, B. Application of fish pond effluent to French beans through drip irrigation at Sagana, Kenya. Presented to the Soil Science Society of East Africa (SSSEA) Silver Jubilee (25<sup>th</sup> Annual) Conference at Kampala, Uganda, 6–10 September 1999.

Wood, C.W. and C.E. Boyd. Carbon and nitrogen in pond bottom soils. Presented to World Aquaculture 2000 at Nice, France, 2–6 May 2000.

### Conferences

The Soil Science Society of East Africa (SSSEA) Silver Jubilee (25<sup>th</sup> Annual) Conference at Kampala, Uganda, 6–10 September 1999. (Meso)

World Aquaculture 2000 at Nice, France, 2–6 May 2000. (Wood)

### Awards

Bernard Meso was awarded the prize for academic excellence and diversity in soil science at university post-graduate level from the Soil Science Society of East Africa (SSSEA) Silver Jubilee (25<sup>th</sup> Annual) Conference at Kampala, Uganda, 6–10 September 1999.

Wood was named a Fellow of the Soil Science Society of America.

## USE OF POND EFFLUENT FOR IRRIGATION IN AN INTEGRATED CROP/AQUACULTURE SYSTEM

*Ninth Work Plan, Effluents and Pollution Research (9ER1)  
Final Report*

C. Wesley Wood  
Department of Agronomy and Soils  
Auburn University, Alabama, USA

M. Bernard Meso  
Sagana Fish Farm  
Sagana, Kenya

Karen L. Veverica  
Department of Fisheries and Allied Aquacultures  
Auburn University, Alabama, USA

Nancy Karanja  
Department of Soil Science  
University of Nairobi  
Nairobi, Kenya

### ABSTRACT

When fish are recovered from ponds, the effluent is often drained, presenting both an environmental challenge and an agricultural opportunity. The effects of irrigation with pond effluent and its interaction with applied fertilizer were assessed in a field experiment using French bean (*Phaseolus vulgaris*) and kale (*Brassica oleracea*) over two growing seasons near Sagana, Kenya. Fresh and dry matter yields of the crops were recorded at harvest, and samples were collected for determination of tissue nutrient concentration. In the first season, French bean fresh pod yield differed significantly ( $P = 0.05$ ) among treatments. Plots receiving

canal water and fertilizer at recommended rates had the highest yield (9.1 t fresh pod ha<sup>-1</sup>), while those receiving no fertilizer or irrigation had the lowest yield (1.3 t fresh pod ha<sup>-1</sup>). In the second season, significant differences ( $P = 0.05$ ) were observed among treatments in fresh bean pod and fresh kale leaf yields. The highest (4.4 t ha<sup>-1</sup>) fresh pod yield was observed in pond-effluent-irrigated and fertilized plots, while the lowest (1.3 t ha<sup>-1</sup>) was observed in non-irrigated/unfertilized plots. The highest fresh kale leaf yield (11.5 t ha<sup>-1</sup>) was obtained with irrigation with canal water combined with fertilizer application, while the lowest (4.2 t ha<sup>-1</sup>) was observed in non-irrigated/unfertilized plots. Low nutrient status in the pond water together with inadequate water supplied to some crops due to emitter clogging was responsible for low yields in treatments where pond water was substituted for canal water. Pond water from the Sagana Fish Farm supplied low amounts of nitrogen (N) and phosphorus (P) for crops, indicating that recommended rates of mineral fertilizers should be used when pond water is used for irrigation. In the second experiment, the effectiveness of two types of soil occurring at Sagana, Kenya—a vertisol (black clay soil) and a cambisol (red clay soil)—in retaining nutrients from pond effluent was investigated. A laboratory experiment was conducted with soil columns containing red or black clay soil. Pond effluent application intensities of 31, 81, and 161 mm d<sup>-1</sup> were tested on both soils. Both soils retained over 60% of total P from pond effluents, with red clay soil retaining 27% more P than black clay soil. At the high effluent loading rate, low % N removal was observed in both soils. Total N removal efficiency declined with time after 21 days at the high rate, and after that time no N removal was observed where red clay soil was used. Black clay soil was more enriched by N than red clay soil, while P enrichment was higher in red clay soil than in black clay soil. It appears that land application can remove substantial amounts of P and N from pond effluent.

## PHILIPPINES PROJECT

Subcontract No. RD010A-15 (UH)

Subcontract No. RD010A-20 (FIU)

### Staff

*Florida International University, Miami, Florida*

Christopher L. Brown US Co-Principal Investigator, US Regional Coordinator (from June 2000)

*University of Hawaii, Manoa, Hawaii*

Christopher L. Brown US Co-Principal Investigator, US Regional Coordinator (through May 2000)

James Szyper US Co-Principal Investigator

Robert Howerton Associate Investigator

Claudia Farfan Graduate Student (Mexico; CRSP funded; through January 2000)

*Central Luzon State University, Muñoz, Nueva Ecija, Philippines*

Remedios B. Bolivar Host Country Principal Investigator

Eddie Boy T. Jimenez Research Assistant

### Site Background

The PD/A CRSP has been active in the Philippines from the program's inception in 1982. Until 1998, research in the Philippines was reported as part of the Thailand Project, as the Philippines functioned as a companion site to CRSP sites in Thailand. In July 1998, the University of Hawaii (UH) was selected as lead US institution for the Philippines Project, and in August 1998 a Memorandum of Understanding was executed between UH and the Freshwater Aquaculture Center (FAC) at Central Luzon State University (CLSU). In June 2000 the lead institution for the Philippines Project was changed to Florida International University (FIU) and a new subcontract awarded.

Early researchers in the Philippines concluded that the Central Luzon region was receptive to the adoption of CRSP technologies. CRSP Philippines Project research in this reporting period emphasized development of feed and fertilizer strategies. Research on optimum nitrogen fertilization rates addressed the *Continuation Plan 1996-2001* goal of determining optimum fertilization rates at different sites. Another objective is to enhance fertilizer and feed efficiency and improve resource utilization, which was addressed by an investigation on the timing of supplemental feeding. Another aspect of Philippines research is the dissemination of the CRSP research results through extension activities such as workshops and development of written materials.

### Work Plan Research

The following Eighth Work Plan investigation continued into the current reporting period:

- Global Experiment: Optimization of nitrogen fertilization rate in freshwater tilapia production ponds (cool-season trial)/8FFR1Ph. The report submitted for the investigation was a final report.

The following Ninth Work Plan investigation continued into the current reporting period:

- Timing of the onset of supplemental feeding of Nile tilapia (*Oreochromis niloticus*) in ponds/9FFR4. The report submitted for this investigation was a final report.

These subcontracts were also awarded funding to conduct the following Ninth Work Plan investigations:

- Reduction of rations below satiation levels/9FFR3. This study has not yet begun.
- Workshop on the timing of the onset of supplemental feeding of Nile tilapia (*Oreochromis niloticus*) in ponds/9ADR6A. The report submitted for this investigation was a final report.
- Production of improved extension materials/9ADR6B. An abstract was submitted for this investigation.

**Note:** The schedules for 8FFR1Ph, 9FFR3, 9FFR4, and 9ADR6B have been modified. Please see Appendix 5, "Completion Dates for Work Plan Studies," for revised schedule information. In addition, the methods for 9FFR4 have been modified. The revised methods will appear in the *Addendum to the Ninth Work Plan*.

### Networking

CRSP researcher Christopher Brown visited the CLSU/FAC to assist with the completion of experiments and to meet with the university's administration, including University President Rodolfo Undan. Undan and Ruben Sevilleja, Director of the CLSU/FAC and Vice President of Academic Affairs, then traveled to Hawaii to meet with UH President Kenneth Mortimer.

Brown has remained in contact with the Philippine Bureau of Fisheries and Aquatic Resources. He also established new contacts with two large tilapia farms designated as registered producers of Genetically Improved Farm Tilapia (GIFT). He also continues collaborating with the non-profit, research-oriented GIFT Foundation.

Brown replied to a request via email from Andrew Kikeros in Perth, Western Australia, regarding marine net-pen cultures and a technical assistance request from a tilapia farmer in New Zealand. Additionally, Brown has provided information about fish diets and genetically enhanced tilapia to several people, including A.M. D'Silva from the University of Arizona. D'Silva wishes to make GIFT fish available to farmers in Arizona and Brazil. He maintains ties with both the Philippines and Thailand projects. Brown also helped J.C. Brown from

Frankford, Delaware, who is planning a tilapia culture venture and asked for advice on diets and genetic strains.

In January, Brown met with the president of the Shrimp Improvement Company, located in the Florida Keys, regarding the possibility of beginning an internship program for graduate students and trainees. The internships would focus on the technical aspects of genetic management techniques in practical aquaculture situations.

Project staff in the Philippines have traveled to four farms (not including those involved with the project's on-farm trials) to assist farmers who had requested help establishing tilapia farms.

The Whitney Laboratory at the University of Florida asked researchers at UH to send specimens of a pure strain of tilapia and the red hybrid *Oreochromis mossambicus*. While they could not send specimens due to shipping restrictions, they did provide an alternate source.

The researchers have fielded several email requests for information about tilapia culture, specifically fish stocking, fertilization, and feeding questions. They responded to seven inquiries and have maintained contact with the senders, most of whom initially checked the CRSP website. They have also helped six people who paid direct visits to the center.

### Educational Outreach

Brown presented a guest lecture to a senior-level fisheries course at UH. His lecture discussed the status of world aquaculture.

In November 1999, Brown hosted a field trip from the Sunshine Preschool (Kailua, Hawaii) to the Hawaii Institute of Marine Biology. He guided twelve area children through a tour of the aquaculture facilities, gave them a brief introduction to fish breeding, and showed them baby fish and *Artemia* through a projection microscope.

In March 2000, Brown presented at a seminar at The Oceanic Institute in Waimanalo, Hawaii. The seminar discussed gastrointestinal system development and function and used current results from the CRSP Philippines Project.

Researchers at CLSU hosted a workshop in December 1999 for local area tilapia farmers. The group represented twelve farms, five of whom are already participating in on-farm trials. They discussed the year's experimentation results concerning experimental feeding strategies and the use of rapidly growing genetically modified tilapia (GIFT).

Project team members have been lecturers and laboratory instructors for six training programs that were held in the Philippines and covered topics related to tilapia pond culture and management.

### Conference

PD/A CRSP Annual Meeting at New Orleans, Louisiana, 31 January–2 February 2000. (Brown)

### Award

Remedios Bolivar received an award from CLSU for Best Doctoral Dissertation.

### GLOBAL EXPERIMENT: OPTIMIZATION OF NITROGEN FERTILIZATION RATE IN FRESHWATER TILAPIA PRODUCTION PONDS (COOL-SEASON TRIAL)

*Eighth Work Plan, Feeds and Fertilizers Research 1Ph (8FFR1Ph)  
Final Report*

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Eddie Boy T. Jimenez  
Freshwater Aquaculture Center  
Central Luzon State University  
Nueva Ecija, Philippines

James P. Szyper  
Sea Grant College Program  
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Hilo, Hawaii, USA

### ABSTRACT

An experiment was conducted, following a standardized experimental design, to determine optimum inputs of nitrogen to be used in pond cultivation of tilapia. Twelve 0.05-ha earthen research ponds were used at the Freshwater Aquaculture Center of the Central Luzon State University, Nueva Ecija, Philippines, from 14 December 1999 to 14 March 2000. A completely randomized design was employed, involving the use of three replicates per treatment of the following nitrogen fertilization rates: 0, 10, 20, and 30 kg N ha<sup>-1</sup> wk<sup>-1</sup> (termed Treatments 1, 2, 3, and 4, respectively). Productivity, water chemistry, and cost parameters were analyzed statistically. A trend in mean body weights favoring the ponds receiving supplemental nitrogen was detected, favoring higher mean body weights in Treatments 4, 2, 3, and 1 in that order, although the apparent difference was not statistically significant due in part to inherent variance in growth and also to the competition of unwanted tilapia recruits into the experimental ponds. Yields were improved in the fertilized ponds (Treatments 2, 3, and 4) relative to those receiving no nitrogen (Treatment 1), although only the presence or absence of fertilizer had a significant effect, and not the concentration that was applied. Some water chemistry differences were noted, specifically higher Secchi disk readings, alkalinity, and dissolved oxygen levels in ponds receiving less added nitrogen. The most cost-effective treatment was the addition of the lowest tested concentration of nitrogen (Treatment 2).

### **TIMING OF THE ONSET OF SUPPLEMENTAL FEEDING OF NILE TILAPIA (*OREOCHROMIS NILOTICUS*) IN PONDS**

#### *Ninth Work Plan, Feeds and Fertilizers Research 4 (9FFR4) Final Report*

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#### **ABSTRACT**

An on-farm trial was conducted in seven farms in Nueva Ecija, Philippines, to investigate the effect of two onsets of feeding on the growth, yield, and survival of Nile tilapia. There were no significant differences in the performance data (final mean weight, daily weight gain, extrapolated gross fish yield, and survival rate) that were recorded in this study. The only statistically significant difference observed was in the total feed used in the trial. The 45-day onset in feeding produced more gross value of the crop (P205,617 ha<sup>-1</sup>) compared with the 75-day delay (P197,063 ha<sup>-1</sup>), but by delaying the start of feeding, the costs were reduced such that the net value of the crop was improved (P124,242 ha<sup>-1</sup> in 75-day versus P106,026 ha<sup>-1</sup> in 45-day delay).

### **WORKSHOP ON THE TIMING OF THE ONSET OF SUPPLEMENTAL FEEDING OF NILE TILAPIA (*OREOCHROMIS NILOTICUS*) IN PONDS**

#### *Ninth Work Plan, Adoption/Diffusion Research 6A (9ADR6A) Final Report*

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Central Luzon State University  
Nueva Ecija, Philippines

#### **ABSTRACT**

Ninth Work Plan Feeds and Fertilizers research (9FFR4) has determined that delaying the onset of feeding in tilapia grow-out ponds reduces farmer investment while maintaining production levels. The application of these research

results is encouraged, and a workshop was held at the Freshwater Aquaculture Center, Central Luzon State University, Nueva Ecija, Philippines, to extend the results to area farmers. Eight farmers participated in the workshop, which included both presentation of results and group discussion of impacts. Farmers who attended stated that they would immediately adopt the delayed feeding strategy. Since the workshop, farmers who heard of delayed feeding through word-of-mouth have already adopted the practice.

### **PRODUCTION OF IMPROVED EXTENSION MATERIALS**

#### *Ninth Work Plan, Adoption/Diffusion Research 6B (9ADR6B) Abstract*

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Freshwater Aquaculture Center  
Central Luzon State University  
Nueva Ecija, Philippines

James P. Szyper  
Sea Grant College Program  
University of Hawaii at Manoa  
Hilo, Hawaii, USA

#### **ABSTRACT**

In our first year of work on the Ninth Work Plan Philippines Project, we have generated meaningful results in two areas: the reduction of feeds used in the initial phase of grow-out ("Timing of the onset of supplemental feeding of Nile tilapia (*Oreochromis niloticus*) in ponds," 9FFR4) and the cost-benefit of using only light application of fertilizers ("Global Experiment: Optimization of nitrogen fertilization rate in freshwater tilapia production ponds," 8FFR1Ph). Both of these lines of work lend themselves to extension effort. The results of the studies have been accepted by farmers near Central Luzon State University, suggesting that broader dissemination will have broader impact. We anticipate that a broad base of the fish farming industry in the Philippines will adopt methods shown convincingly to have the potential to improve their profits while reducing the amount of labor required. Thus far, we have presented results of the first of these two series of feeds experiments in a workshop ("Workshop on the timing of the onset of supplemental feeding of Nile tilapia (*Oreochromis niloticus*) in ponds," 9ADR6A) at an annual CRSP meeting and at an international meeting and have drafted a manuscript. We are presently working on conceptual design for extension materials for dissemination and have collected similar extension materials (tech bulletins, fact sheets, etc.) from the US to use as models.

## THAILAND PROJECT

Subcontract No. RD010A-04

### Staff

#### *The University of Michigan, Ann Arbor, Michigan*

James S. Diana	US Co-Principal Investigator, US Regional Coordinator
C. Kwei Lin	US Co-Principal Investigator (stationed in Pathumthani, Thailand)
Yang Yi	Postdoctoral Researcher (stationed in Pathumthani, Thailand)
Barbara Diana	Research Assistant

#### *Asian Institute of Technology, Pathumthani, Thailand*

Amrit Bart	Host Country Principal Investigator
Dao Huy Giap	Research Associate (through April 2000)
Chumpol Srithong	Research Associate
A.R.S.B. Athauda	Graduate Student (Sri Lanka; partially CRSP funded)
Ma Aye Aye Mon	Graduate Student (Burma; partially CRSP funded)
Potjane Nadtrom	Graduate Student (Thailand; CRSP funded)
Ngo Van Hai	Graduate Student (Vietnam; partially CRSP funded)
A. Weerasooriya	Graduate Student (Sri Lanka; partially CRSP funded)

### Site Background

The PD/A CRSP has been active in Thailand from the program's inception in 1982. The CRSP, through lead US institution The University of Michigan, has collaborated with the Asian Institute of Technology (AIT) since 1987. AIT is an important regional training center, providing not only excellent research facilities but also regional networking opportunities for outreach activities.

Studies conducted in the reporting period have concentrated on two areas of emphasis: environmental impacts of aquaculture and production optimization. CRSP research on semi-intensive culture of tilapia continues to examine new species and systems, including polyculture of tilapia with predatory snakehead, cultivation of tilapia in ponds planted with lotus for excess nutrient uptake, and tilapia culture in brackishwater ponds. An investigation of polyculture of tilapia and catfish addresses effluent release and pollution concerns. A new Reproduction Control investigation examines the use of ultrasound to induce sex reversal.

### Work Plan Research

The following Ninth Work Plan investigation continued into the current reporting period:

- Culture of mixed-sex Nile tilapia with predatory snakehead/9NS2. An abstract was submitted for this investigation.

This subcontract was also awarded funding to conduct the following Ninth Work Plan investigations:

- The application of ultrasound to produce all-male tilapia using immersion protocol/9RCR8. An abstract was submitted for this investigation.
- Lotus-fish culture in ponds: Recycling of pond mud nutrients/9NS1. An abstract was submitted for this investigation.
- Semi-intensive culture of tilapia in brackishwater ponds/9NS4. An abstract was submitted for this investigation.
- Integrated recycle system for catfish and tilapia culture/9ER3. The report submitted for this investigation was a final report.

**Note:** The schedule for 9NS2 has been modified. Please see Appendix 5, "Completion Dates for Work Plan Studies," for revised schedule information. The methods for 9NS1 and 9ER3 have been modified. 9RCR8 and 9NS4 were approved after publication of the *Ninth Work Plan*. The revised methods for 9NS1 and 9ER3 and the 9RCR8 and 9NS4 work plans will appear in the *Addendum to the Ninth Work Plan*.

### Networking

CRSP researcher Yang Yi met with David M. Sims from the Sarasawathi Foundation, a Thai nongovernmental organization (NGO), to provide technical advice on integrated cage-cum-pond and fish-livestock farming for a project at the Ban Kai school of Chaiyapoom Province. The Foundation project is intended to provide poor students with a free source of protein through fish farming. Yi also sent information on semi-intensive low-cost tilapia culture to Robert Hartnell, who will use the data in his own low-cost tilapia culture experiment in South Africa under the United Kingdom's Department for International Development Genetics Program.

CRSP researchers at AIT have maintained contacts in Vietnam, including the Research Institute for Aquaculture No. 1, the Socio-Economic Development Center (SEDEC), and the University of Aquaculture and Forestry. Kwei Lin cooperated with SEDEC on coastal zone development and management in the Binh Thuan Province of Vietnam. He then discussed further cooperation with the director of SCALE (SAO (Southeast Asian Outreach) Cambodia Aquaculture at Low Expenditure), and later visited the USAID office in Cambodia.

Lin made a site visit to the Crescent Syndicate Fish Farm in Pakistan to provide technical advice, and he has continued correspondence with the farm via email and telephone.

Researchers at AIT hosted A.M. D'Silva from the University of Arizona and conducted discussions on the technical aspects of tilapia culture. AIT researchers later provided him with technical information on reservoir culture via email. D'Silva also maintains ties with the Philippines Project.



### Educational Outreach

Yi taught a short course on water quality and soil analyses to visiting research staff from the Vietnamese Research Institute for Aquaculture No. 1 in March. Lin taught a water quality management class for visiting Vietnamese masters program students in April. Later in the year, Lin also taught an aquatic ecosystems and water quality management class for masters and doctoral students, and Amrit Bart taught a short-course focusing on hatchery management of finfish. These courses were all held at AIT. Additionally, Lin presented a workshop on pond dynamics to fisheries officers in a workshop hosted by the Japan International Cooperation Agency (JICA) at the Thai Department of Fisheries.

### Publications

- Edwards, P., C.K. Lin, and A. Yakupitiyage. Semi-intensive pond aquaculture. In: M. Beveridge and B. McAndrews (Editors), *Tilapia Culture and Exploitation*. Chapman and Hall, London. (in press)
- Liao, I.C. and C.K. Lin (Editors), 2000. Proceedings of the First International Symposium on Cage Aquaculture in Asia. Asian Fisheries Society, Manila, the Philippines. 312 pp.
- Lin, C.K. and K. Kaewpaitoon, 2000. An overview of freshwater cage culture in Thailand. In: I.C. Liao and C.K. Lin (Editors), *Proceedings of the First International Symposium on Cage Aquaculture in Asia*. Asian Fisheries Society, Manila, the Philippines, pp. 237–242.
- Lin, C.K. and Y. Yi. Development of integrated aquaculture in Southeast Asia. In: *Proceedings of the SEAFDEC Workshop*. (in press)
- Lin, C.K., J.S. Diana, and Y. Yi. Stocking densities and fertilization regimes for Nile tilapia (*Oreochromis niloticus*) production in ponds with supplemental feeding. *J. World Aquacult. Soc.* (in review)
- Mon, A.A., 2000. Use of lotus (*Nelumbo nucifera*) for nutrient retrieval from pond mud. M.S. Thesis, Asian Institute of Technology, Bangkok, Thailand.
- Yi, Y., 1999. Modeling growth of Nile tilapia (*Oreochromis niloticus*) in a cage-cum-pond integrated culture system. *Aquacult. Eng.*, 21:113–133.
- Yi, Y. and C.K. Lin, 2000. Integrated cage culture in ponds: Concepts, practice and perspectives. In: I.C. Liao and C.K. Lin (Editors), *Proceedings of the First International Symposium on Cage Aquaculture in Asia*. Asian Fisheries Society, Manila, the Philippines, pp. 217–224.
- Yi, Y. and C.K. Lin. Analyses for various inputs for pond culture of Nile tilapia (*Oreochromis niloticus*): Profitability and possible environmental impacts. *Aquacult. Econ. Manage.* (accepted)
- Yi, Y. and C.K. Lin. Effects of biomass of caged Nile tilapia (*Oreochromis niloticus*) and aeration on the growth and yields in a cage-cum-pond integrated culture system. *Aquaculture*. (revised)

### Presentations

- Lin, C.K. and K. Kaewpaitoon. An overview of freshwater cage culture in Thailand. Presented to the First International Symposium on Cage Aquaculture in Asia at Tungkang, Taiwan, 2–6 November 1999.
- Lin, C.K. and Y. Yi. Development of integrated aquaculture in Southeast Asia. Presented to the Workshop on

Responsible Aquaculture Development in Southeast Asia at the Southeast Asian Fisheries Development Center (SEAFDEC), Iloilo, Philippines, 11–15 October 1999.

- Wu, Z.W., J.W. Guo, and Y. Yi. Current status and sustainability of cage culture in reservoirs: A case study in China. Presented to the First International Symposium on Cage Aquaculture in Asia at Tungkang, Taiwan, 2–6 November 1999.
- Yi, Y. and C.K. Lin. Integrated cage culture in ponds: concepts, practice and perspectives. Presented to the First International Symposium on Cage Aquaculture in Asia at Tungkang, Taiwan, 2–6 November 1999.

### Conferences

- Workshop on Responsible Aquaculture Development in Southeast Asia at the Southeast Asian Fisheries Development Center (SEAFDEC), Iloilo, Philippines, 11–15 October 1999. (Lin)
- First International Symposium on Cage Aquaculture in Asia at Tungkang, Taiwan, 2–6 November 1999. (Lin, Yi)
- PD/A CRSP Annual Meeting at New Orleans, Louisiana, 31 January–2 February 2000. (Bart, Diana)
- Aquaculture America 2000 at New Orleans, Louisiana, 2–5 February 2000. (Diana)
- International Conference on Aquaculture in the Third Millennium at Bangkok, Thailand, 20–25 February 2000. (Lin, Yi)

### THE APPLICATION OF ULTRASOUND TO PRODUCE ALL-MALE TILAPIA USING IMMERSION PROTOCOL

#### *Ninth Work Plan, Reproduction Control Research 8 (9RCR8) Abstract*

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Asian Institute of Technology  
Pathumthani, Thailand

James S. Diana  
School of Natural Resources and Environment  
The University of Michigan  
Ann Arbor, Michigan, USA

#### ABSTRACT

This study was initiated in February of 2000 and is expected to be completed by December 2000. The experiment is designed to reveal the application of cavitation-level ultrasound to enhance delivery of androgens using immersion protocol. This experiment is in two parts: 1) a preliminary study to detect the effect of ultrasound on sex reversal using two commonly available androgens in Asia (17 $\alpha$ -methyltestosterone and andostrenedione); and 2) an examination of the effects of two novel and more potent hormones using a protocol established by CRSP researchers. In the preliminary experiment, the variables tested were androgens (17 $\alpha$ -methyltestosterone and andostrenedione), duration of treatment (1 or 2 h), and hormone concentrations (100 or 500  $\mu\text{g l}^{-1}$ ). Fish were treated on days 10 and 13 post-hatch. This study has been completed, and

the results clearly indicate an effect of ultrasound. Although the rate of sex reversal was less than 100% in all cases, significant differences were observed between those treated with and without ultrasound in two-hour treatments, irrespective of the hormone concentration used. The highest number of males (88 to 94%) was obtained from the two-hour ultrasound-treated group, while the lowest number of males (44 to 75%) was observed from the same group without application of ultrasound. The second experiment is underway to examine the hormones trenbolone acetate (TA) and 17 $\alpha$ -methyl-dihydrotestosterone (MDHT) at different concentrations (250 or 500  $\mu\text{g l}^{-1}$ ) and duration of treatment (1 or 2 h). We expect a higher and more consistent rate of sex reversal between treatments by varying these parameters.

### LOTUS-FISH CULTURE IN PONDS: RECYCLING OF POND MUD NUTRIENTS

*Ninth Work Plan, New Aquaculture Systems/  
New Species Research 1 (9NS1)*  
Abstract

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The University of Michigan  
Ann Arbor, Michigan, USA

#### ABSTRACT

This experiment started in February 2000 and will be terminated in September 2000. The purposes of the experiment were to: 1) assess the pond mud nutrient recovery by lotus plants (*Nelumbo nucifera*); 2) assess pond mud characteristics after lotus-fish culture; and 3) compare fish growth in ponds with and without lotus integration. There were three treatments: A) lotus-fish integrated culture; B) fish alone; and C) lotus alone. Lotus plants were transplanted at 20 plants per pond in treatments A and C. Sex-reversed all-male Nile tilapia (*Oreochromis niloticus*) fingerlings were stocked at 2 fish  $\text{m}^{-2}$  in ponds of treatments A and B. Treatment ponds stocked with tilapia (treatments A and B) were fertilized weekly with urea and triple superphosphate (TSP) at rates of 28 kg N and 7 kg P  $\text{ha}^{-1} \text{wk}^{-1}$ . No fertilizer was applied in treatment ponds with lotus alone (treatment C). Fish growth and survival will be assessed only at the end of the experiment due to sampling difficulties. Fish and lotus plants will be harvested by draining. Nutrient budgets will be determined for all ponds. Partial budgets will be estimated for cost of inputs and value of fish and lotus.

### CULTURE OF MIXED-SEX NILE TILAPIA WITH PREDATORY SNAKEHEAD

*Ninth Work Plan, New Aquaculture Systems/New Species  
Research 2 (9NS2)*  
Abstract

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Ann Arbor, Michigan, USA

#### ABSTRACT

An experiment was conducted in eighteen 200- $\text{m}^2$  earthen ponds at the Asian Institute of Technology, Thailand, during May through October 1999. The purposes of the experiment were to: 1) assess the efficiency of snakehead (*Channa striata*) in controlling overpopulation of mixed-sex Nile tilapia (*Oreochromis niloticus*) in ponds and 2) assess growth and production characteristics of Nile tilapia in monoculture and polyculture with snakehead. The six treatments were: A) monoculture of sex-reversed tilapia; B) monoculture of mixed-sex tilapia; C) polyculture of mixed-sex tilapia and snakehead at 10:1 ratio; D) polyculture of mixed-sex tilapia and snakehead at 20:1 ratio; E) polyculture of mixed-sex tilapia and snakehead at 40:1 ratio; and F) polyculture of mixed-sex tilapia and snakehead at 80:1 ratio. All ponds were fertilized weekly with urea and triple superphosphate (TSP) at rates of 28 kg N and 7 kg P  $\text{ha}^{-1} \text{wk}^{-1}$ . Sex-reversed all-male and mixed-sex Nile tilapia were stocked at 2 fish  $\text{m}^{-2}$  at sizes of  $42.3 \pm 1.0$  g and  $31.0 \pm 0.5$  g, respectively. Snakehead dug holes in the pond dikes and moved freely between ponds and the canal. The experiment showed that snakehead can control overpopulation of mixed-sex Nile tilapia. This experiment is currently being repeated, starting in March 2000 and terminating in September 2000.

## SEMI-INTENSIVE CULTURE OF TILAPIA IN BRACKISHWATER PONDS

*Ninth Work Plan, New Aquaculture Systems/  
New Species Research 4 (9NS4)  
Abstract*

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Aquaculture and Aquatic Resources Management Program  
Asian Institute of Technology  
Pathumthani, Thailand

James S. Diana  
School of Natural Resources and Environment  
The University of Michigan  
Ann Arbor, Michigan, USA

### ABSTRACT

This experiment was started in June and will be terminated in November 2000. The purposes of the experiment were to: 1) determine appropriate fertilization regimes in brackish-water ponds; 2) investigate nutritional value and digestibility of specific marine phytoplankton as food organisms to tilapia; and 3) exploit underutilized or abandoned shrimp ponds for tilapia production. Two fertilization regimes (28 kg N and 7 kg P ha<sup>-1</sup> wk<sup>-1</sup> and 28 kg N and 14 kg P ha<sup>-1</sup> wk<sup>-1</sup>) and three levels of salinity (10, 20, and 30‰) were tested by a 2 × 3 factorial design. Eighteen cement ponds (6 m<sup>2</sup>) were filled with 15 cm of soil and then flooded with water of differing salinities by diluting hypersaline water to the appropriate concentrations. Thai red tilapia fingerlings were stocked at 2 fish m<sup>-2</sup>. All ponds were fertilized weekly at the two rates using urea and triple superphosphate (TSP). Water levels will be maintained at 0.8 m depth, and salinity levels will be checked and adjusted weekly. Plankton composition will be assessed biweekly. Partial budgets will be calculated to estimate cost of inputs and value of fish crop.

## INTEGRATED RECYCLE SYSTEM FOR CATFISH AND TILAPIA CULTURE

*Ninth Work Plan, Effluents and Pollution Research (9ER3)  
Final Report*

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### ABSTRACT

An experiment was conducted to test using effluents from intensive hybrid catfish (*Clarias macrocephalus* × *C. gariepinus*)

ponds as nutrient inputs for Nile tilapia (*Oreochromis niloticus*) culture, which would reduce effluent effects from catfish culture, gain extra fish production at low cost, and possibly make aquaculture more profitable to farmers. Three treatments were done with three replicates each in seven 200-m<sup>2</sup> earthen ponds at the Asian Institute of Technology (AIT), Thailand, for 87 days. The treatments were A) catfish alone (control); B) catfish and tilapia without artificial water circulation; and C) catfish and tilapia with artificial water circulation. The pond used for control treatments was partitioned by 1.0-cm mesh plastic net into three equal compartments with 67 m<sup>2</sup> each for the replicates. The six other ponds were partitioned into two compartments: 1/3 for catfish and 2/3 for tilapia. Sex-reversed all-male Nile tilapia were stocked at 2 fish m<sup>-2</sup>, and catfish at 25 fish m<sup>-2</sup>. Catfish were fed twice daily with commercial pelleted feed at rates of 3 to 10% body weight per day. During the first month, tilapia compartments were fertilized weekly using urea and triple superphosphate (TSP) at rates of 28 kg N and 7 kg P ha<sup>-1</sup> wk<sup>-1</sup>. In the artificial water circulation treatment, the water in the catfish compartment was continuously circulated by a submersed pump to the tilapia compartment at a rate of one exchange per week, starting the second month.

There were no significant differences in growth performance of catfish among all treatments. Mean catfish weight at harvest ranged from 237.8 to 249.0 g, giving extrapolated net yields of more than 200 t ha<sup>-1</sup> yr<sup>-1</sup>. Final mean tilapia weight was 114.9 g in treatment B and 115.0 g in treatment C without significant differences. Although there was no significant difference in survival rates between treatments B (92%) and C (70%), high mortality of tilapia was observed in two replicates of treatment C due to heavy waste loading in the tilapia compartment by artificial water circulation. Extrapolated net tilapia yields (7.2 ± 1.3 t ha<sup>-1</sup> yr<sup>-1</sup> in treatment B and 4.9 ± 0.3 t ha<sup>-1</sup> yr<sup>-1</sup> in treatment C) obtained by using catfish wastes in this study were comparable to those achieved in organically and inorganically fertilized tilapia ponds. Nutrient budgets showed that total nitrogen and total phosphorus contents in pond effluents in treatments B and C were significantly lower than those in treatment A. Nile tilapia recovered 3.30 and 2.12% of total nitrogen and 1.29 and 0.84% of total phosphorus from feed wastes and fertilizer inputs in treatments B and C, respectively. Concentrations of total Kjeldahl nitrogen (TKN), total phosphorus (TP), and soluble reactive phosphorus (SRP) were also significantly lower in treatments B and C than in treatment A. This experiment indicates that Nile tilapia can effectively recover nutrients contained in wastewater of intensive catfish culture and suggests that natural water circulation between catfish and tilapia compartments can reduce nutrient contents in pond effluents and is cost-effective.





# APPENDIX 1. PD/A CRSP HISTORY

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The PD/A CRSP was initiated formally on 1 September 1982 as a Title XII program under the International Development and Food Assistance Act of 1975. The Consortium for International Fisheries and Aquaculture Development (CIFAD), Auburn University (AU), and the University of California, Davis (UCD) were chosen to participate in a tripartite management of the PD/A CRSP, and CIFAD was designated as the lead group in the management of the program, with Oregon State University (OSU) serving as lead institution. CIFAD, no longer a functional entity, consisted of the University of Arkansas at Pine Bluff (UAPB), the University of Hawaii (UH), the University of Michigan (UM), Michigan State University (MSU), and OSU. Most of the CIFAD institutions continue to participate in the PD/A CRSP. However, beginning with this Grant and the dissolution of CIFAD, a new advisory structure allows greater equity among participating institutions and provides an effective mechanism for new institutions to be represented on the Board of Directors.

## HISTORICAL OVERVIEW OF PROGRAM OBJECTIVES

In 1980, the First PD/A CRSP Preliminary Design Proposal was approved by the Joint Committee on Agricultural Research and Development (JCARD). The approach for designing the PD/A CRSP included a review and synthesis of the state of the art of pond aquaculture, overseas site visits to determine research needs in host countries, and negotiation of provisional administrative agreements with collaborating institutions. Findings from the literature and field surveys were translated into planning guidelines. The most important needs identified for improving the efficiency of pond culture systems were 1) the need for technological advances to improve the reliability of pond production and 2) the need for economic optimization based on local conditions. The common link was to improve the understanding of pond dynamics.

The 1980 Preliminary Proposal identified four systems which were considered to have the greatest potential for contributing to the supply of low-cost animal protein. These systems, listed in priority sequence according to the proportion of rural poor they would expect to serve, are:

- small, low-intensity tropical pond systems characterized by limited external inputs of feed or fertilizers;
- cooler-water (15 to 25°C) tropical ponds at medium to high elevations;
- brackishwater and hypersaline ponds, including those in tropical mangrove zones; and
- higher-intensity tropical pond systems, characterized by high external inputs of feed and fertilizers.

The main research objectives for the first five years of the PD/A CRSP (1982–1987 PD/A CRSP Grant) were:

- to compile a quantitative baseline of chemical, physical, and biological parameters for each work location, and to correlate responses of these parameters to various levels of organic and inorganic fertilizer applications to pond culture systems (referred to as the “Global Experiment”);
- to compile a baseline of information on hydrology, locally available nutrient inputs, geography, and water quality in each participating country, utilizing available host country resources;
- to observe and document technical constraints limiting fry availability in each participating host country, and to

test alternative fry production methods where appropriate;

- to develop models describing the principles of pond culture systems.

These objectives were modified in 1986 because of technical, geopolitical, and financial considerations. A data analysis and synthesis component was added in 1987 with the following objectives:

- to statistically analyze data from the field experiments to describe global and site-specific variations in pond culture systems;
- to synthesize data from the Global Experiment and develop descriptive models of the physical, chemical, and biological processes that regulate the productivity of pond culture systems;
- to develop conceptual frameworks for one or more pond management models and develop operating instructions consistent with each conceptual framework;
- to compile a manual of operating instructions describing pond management procedures for optimizing yields, increasing the reliability, and improving the efficiency of pond culture systems.

The *1987–1990 Continuation Plan* addressed the most important objectives of the original plan, with the goal of synthesizing the results of the first three work plans as a staged progression into a conceptual model of pond aquaculture systems. This model was used to identify research needs which were prioritized and translated into objectives for field research projects specific for each host country.

The programmatic and operational objectives in the *1990–1995 Continuation Plan* were:

- to continue to develop technology, through research, to overcome major problems and constraints affecting the efficiency of pond aquaculture in developing countries;
- to maintain or improve environmental quality through proper management of aquacultural systems;
- to stimulate and facilitate the processing and flow of new technologies and related information to researchers, to extension workers, and ultimately, to fish farmers in developing countries;
- to promote activities that encourage faculty and researchers to build and maintain linkages;

- to create opportunities for greater multidisciplinary research in aquaculture and to enhance the socio-economic and ecological aspects of the PD/A CRSP;
- to encourage informational and data exchange among international agricultural research centers, universities, the non-government research community, and United States Agency for International Development centrally funded and mission-funded projects;
- to expand results derived from the site-specific research to regional recommendations through a global analysis of the data; and
- to use an ecosystem approach to arrange the research agenda and integrate technologies.

While many program objectives have been met over the past decade of PD/A CRSP research, the original program goal, that advances in pond aquaculture are based on greater understanding of pond dynamics, continues to be relevant. It serves as an effective organizing principle for new research that aims at resolving constraints faced by farmers and commercial aquaculturists in the US and host countries.

1 August 1996 marked the beginning of the PD/A CRSP's first year of operations under its fourth 5-year USAID grant (the *Continuation Plan 1996–2001*).

#### **HISTORICAL OVERVIEW OF THE PD/A CRSP— AGREEMENTS WITH HOST COUNTRIES, 1982 TO 1995**

With the initiation of the 1987 CRSP Grant, host country and US institutions renewed their Memoranda of Understanding (MOU). These MOUs reflected the structural changes that had occurred since 1982. While several US universities collaborated at each country site, only one represented the US in each MOU. This structure provided for a more equitable arrangement with the host country institutions.

For example, UM, a CIFAD member, had separate MOUs with the Thai Department of Fisheries and the Asian Institute of Technology. UM and the Thai Department of Fisheries acted as the lead US university and host country institution, respectively, in Thailand. This provided a focal point for the other institutions that worked on the CRSP project in Thailand. UM in turn had informal subagreements with MSU and UH.

Likewise, the Université Nationale du Rwanda held a MOU with OSU, the lead US university on the Rwanda Project. As lead, OSU was the main contact for the Rwandan researchers and was responsible for overall coordination of US CRSP research activities in Rwanda. AU and UAPB collaborated with OSU in Rwanda.

In Honduras, AU held a MOU with the Secretaría de Recursos Naturales (since renamed the Secretaría de Agricultura y Ganadería). In Egypt—a bilaterally funded project under USAID/Cairo—OSU held the MOU with the Egyptian National Agricultural Research Project.

This hierarchical structure differed from the contractual arrangements among US universities and the Management Entity (ME). While all participating institutions had access to

the services of the ME, past contractual agreements were made directly with AU, UCD, and CIFAD. CIFAD in turn had formal contracts with its member universities: UM, MSU, OSU, UH, and UAPB. When CIFAD was dissolved, all institutions were elevated to the same contractual status. The hierarchical arrangement arrived at through the designation of lead US universities was seen to promote a greater degree of cooperation among US universities and greater involvement of the host institutions at the highest level. Certain programmatic and fiscal responsibilities were delegated to participating US institutions through subagreements from the ME. For the Egypt Project, the ME had formal contracts with each participating university.

#### **CRSP MEMORANDA OF UNDERSTANDING, 1996 TO 2000**

Since the initiation of the current grant, the *Continuation Plan 1996–2001*, new lead projects have been established in Mexico, Peru, Kenya, and the Philippines, and institutional relationships were restructured for the Honduras Project.

Southern Illinois University at Carbondale (SIUC) was awarded funding as the lead US institution for research in Peru. By 1997, MOUs were in place between SIUC and the Instituto de Investigaciones de la Amazonia Peruana and the Universidad Nacional de la Amazonia Peruana, Peru. In Kenya, CRSP research was underway in 1997, under a new MOU between OSU and the Kenya Department of Fisheries, Ministry of Wildlife and Tourism (the Department moved in 1998 to the Ministry of Natural Resources and again in 2000 to the Ministry of Agriculture and Rural Development). OSU is the lead US institution for the Kenya Project, sharing responsibility with AU for a joint research work plan. Under previous grants, the Philippines served as a companion site to the lead Southeast Asia site at the Asian Institute of Technology in Thailand; however, the *Continuation Plan 1996–2001* identified the Philippines as a potential lead site. In October 1997, the Management Entity issued a restricted Request for Proposals (RFP) for lead US and host country institutions for a new Philippines Project. Upon completion of internal and external peer reviews and evaluations of proposals, UH was awarded funding to serve as lead institution of the Philippines Project. A new subcontract with UH was established in July 1998; the host country collaborating institution is Central Luzon State University (CLSU). In 2000, the US Regional Coordinator moved to Florida International University (FIU). A new subcontract with FIU was established in June 2000, and a new MOU between FIU and CLSU is in the process of being formalized.

In January 1999 the extant Honduras Project, led by AU, declined an award offer for Ninth Work Plan research and dissolved its MOU with the Secretaría de Agricultura y Ganadería in Honduras in April 1999. To identify new lead US and host country institutions for a new Honduras Project, the ME issued a restricted RFP in March 1999. The University of Georgia (UG) was selected as the new Honduras lead US institution with Escuela Agrícola Panamericana El Zamorano as the host country institution and AU as a collaborating US institution. Under subcontracts with OSU, UG and AU commenced work on the Honduras Project in May 1999.

At the close of the present reporting period, Memoranda of Understanding are in place among the following CRSP partner institutions:

- Oregon State University and the Universidad Juárez Autónoma de Tabasco, Mexico;
- University of Georgia and the Escuela Agrícola Panamericana El Zamorano, Honduras;
- Southern Illinois University at Carbondale and the Instituto de Investigaciones de la Amazonia Peruana and the Universidad Nacional de la Amazonia Peruana, Peru;
- Oregon State University and the Department of Fisheries, Ministry of Wildlife and Tourism, Kenya (the Department moved in 2000 to the Ministry of Agriculture and Rural Development);
- Florida International University and Central Luzon State University, Philippines;

- University of Hawaii and Central Luzon State University, Philippines; and
- The University of Michigan and the Asian Institute of Technology, Thailand.

The PD/A CRSP also has formal agreements with the following organizations:

- West Africa InterCRSP
- CRSP Council

Many other informal agreements exist with nongovernmental organizations, private voluntary organizations, private industry, government agencies, universities, and other groups and organizations. A small sample of these linkages appears in Appendix 6.







## APPENDIX 2. PROGRAM PARTICIPANTS

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The Pond Dynamics/Aquaculture CRSP represents the joint efforts of more than 75 professional and support personnel from US universities. It also represents the collaborative efforts of over 45 scientists, technicians, and students from project sites in six host countries—Mexico, Honduras, Peru, Kenya, the Philippines, and Thailand. The expertise of host country and US personnel is broad-based and encompasses the major fields of specialization included in this CRSP: limnology and water quality; fisheries and aquaculture; soil science; engineering; information systems; data management, analysis, and modeling; endocrinology; genetics; environmental hazard management; sociology; agricultural economics; policy development; adult education; and research administration.

The program's US-based participants are drawn from the CRSP partner institutions—Auburn University (AU), Florida International University, The Ohio State University, Oregon State University (OSU), Southern Illinois University at Carbondale (SIUC), the University of Arkansas at Pine Bluff (UAPB), the University of Arizona (UA), the University of Georgia, the University of Hawaii, The University of Michigan (UM), and the University of Oklahoma (UO).

Host country staff participate in the CRSP through their involvement with:

Universidad Juárez Autónoma de Tabasco, Villahermosa, Mexico  
Escuela Agrícola Panamericana El Zamorano (Zamorano), Honduras  
Instituto de Investigaciones de la Amazonia Peruana, Iquitos, Peru  
Universidad Nacional de la Amazonia Peruana, Iquitos, Peru  
Fisheries Department, Nairobi, Kenya  
Moi University, Eldoret, Kenya  
Sagana Fish Farm, Sagana, Kenya  
University of Nairobi, Kenya  
Bunda College, Lilongwe, Malawi  
International Center for Living Aquatic Resources Management (ICLARM), Zomba, Malawi  
Central Luzon State University, Muñoz, Nueva Ecija, Philippines  
Asian Institute of Technology (AIT), Pathumthani, Thailand

Cooperating institutions include:

Centro Internacional de Agricultura Tropical, Cali, Colombia

Researchers and research project staff are named within each research project report in the body of this report. Following are listings for staff of the Program Management Office as well as members of the program's three advisory groups—Board of Directors, External Evaluation Panel, and Technical Committee.

### PROGRAM MANAGEMENT OFFICE

#### Staff

*Oregon State University, Corvallis, Oregon*

Hillary Egna	Director
Cormac Craven	Assistant Director
Danielle Clair	Program Associate
Viji Sreenivasan	Financial Manager (through February 2000)
Kevin Bokay	Management Assistant (August 1999 through May 2000)
Joan Westfall	Administrative Program Assistant (from April 2000)
Xena Cummings	Graduate Research Assistant (USA; CRSP funded)
John Hayes	Graduate Research Assistant (Uruguay/USA; September 1999 through June 2000; CRSP funded)
Josh Moentenich	Undergraduate Student Worker (USA)

**ADVISORY BODIES****Board of Directors**

Dennis Balogu, Chair  
L.J. (Kelvin) Koong  
T.H. Lee Williams  
Anthony Young

**Institution**

UAPB  
OSU  
UO  
SIUC

*Ex-Officio Board Members*

Harry Rea  
Hillary Egna

USAID  
OSU

**External Evaluation Panel**

Kevan Main  
Edna McBreen  
David Cummins  
Christine Crawford

**Affiliation**

Harbor Branch Oceanographic Institute, Sarasota, Florida  
University of Nebraska, Lincoln  
Peanut CRSP (retired)  
University of Tasmania, Australia

**Technical Committee\****Co-Chairs*

John Bolte  
Jim Diana

**Institution**

OSU  
UM

*Material and Methods Subcommittee*

Doug Ernst  
Claude Boyd  
Freddy Arias

OSU  
AU  
Zamorano

*Research Area of Expertise*

Environmental effects  
Production optimization  
Social and economic aspects

*Technical Progress Subcommittee*

Joe Molnar  
Wilfrido Contreras-Sánchez  
Amrit Bart

AU  
OSU  
AIT

Social and economic aspects  
Production optimization  
Environmental effects

*Work Plan and Budget Subcommittee*

Kevin Fitzsimmons  
Tom Popma  
Carole Engle

UA  
AU  
UAPB

Environmental effects  
Production optimization  
Social and economic aspects

*External At-Large Members*

Marc Verdegem  
Damon Seawright

Wageningen Agricultural University, The Netherlands  
US tilapia producer

*Ex-Officio Members*

Harry Rea  
Hillary Egna  
Cormac Craven

USAID  
OSU  
OSU

\* Membership as of 2000 Technical Committee election; see *Seventeenth Annual Administrative Report* for previous roster. Subcommittee members are listed in order of seniority.



## APPENDIX 3. FINANCIAL SUMMARY

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This section summarizes the expenditures of USAID, non-federal, and host country funds for CRSP research activities and program management. This unaudited information is intended to provide an overview of CRSP program budgets and matching support for the period 1 August 1999 to 31 July 2000. Official financial reports are submitted to USAID via the Management Entity's Research Accounting Office.

Emphasis, as indicated by funding commitments, was placed upon both global research and research support.

Cost sharing contributions from the US institutions and contributions from host countries are presented in the table on the following page. Not all sites reported host country contributions, and those that did may not have fully accounted for in-kind contributions, typically including water, electricity, fish stock, labor, and supplies.

**Financial Summary under Continuation Plan 1996-2001**

August 1, 1999 - July 31, 2000

Research Project	Project Leader	Institution	USAID <sup>1</sup>		Cost Share <sup>2</sup>		Total US Funds	Host Country Contribution 8/99-7/00	Since 8/96
			8/99-7/00	Since 8/96	8/99-7/00	Since 8/96			
<b>RESEARCH</b>									
<b>Global Research</b>									
Pond Dynamics	Boyd	Auburn University	8,704	148,797	2,354	39,724	188,521		
Reproduction Control	Shelton	University of Oklahoma	48,481	165,761	12,120	40,133	205,894		
Reproduction Control	Phelps	Auburn University	16,436	0	4,109	0	115,520		
Reproduction Control	Fitzpatrick	Oregon State University	0	127,934	0	31,983	159,917		
Aquaculture Systems Modeling	Piedrahita	University of California, Davis	0	78,101	0	26,611	104,712		
Effluents & Pollution	Boyd	Auburn University	45,947	45,947	11,487	11,487	292,473		
Marketing & Economic Analysis	Engle	University of Arkansas at Pine Bluff	57,802	232,614	15,029	59,859	69,082		
Marketing & Economic Analysis	Hatch	Auburn University	27,633	55,266	6,908	13,816	91,459		
Adoption/Diffusion	Molnar	Auburn University	0	68,293	0	23,166	83,960		
Adoption/Diffusion	Lovshin	Auburn University	0	67,168	0	16,792	398,701		
Decision Support Systems	Bolte	Oregon State University	54,238	313,524	13,559	85,177	12,048		
Decision Support Systems sub-project	Heikes	University of Arkansas at Pine Bluff	0	7,900	0	4,148			
<b>Regional Research</b>									
Central America									
Mexico	Fitzpatrick	Oregon State University	104,967	293,545	10,051	63,185	356,730	15,000	15,000
Honduras	Ward	University of Texas at Austin	0	19,767	0	4,066	23,833		
Honduras	Green	Auburn University	0	502,056	0	78,435	580,491	0	140,484
Honduras	Verna	University of Georgia	102,592	180,000	19,415	37,906	217,906	7,000	7,000
Honduras	Molnar	Auburn University	35,116	65,001	8,779	25,029	90,030		
Africa									
Kenya	Bowman	Oregon State University	145,740	742,057	6,442	56,857	798,914	28,000	82,000
Kenya	Popma	Auburn University	59,286	448,978	14,821	102,093	551,071		
Kenya	Lochmann	University of Arkansas at Pine Bluff	0	29,251	0	7,228	36,479		
Kenya	Wood	Auburn University	0	30,449	0	8,254	38,703		
South America									
Peru	Kohler	Southern Illinois University	67,286	316,041	10,000	85,596	401,637	45,118	144,593
Peru sub-project	Dabrowski	Ohio State University	0	13,000	0	11,963	24,963		
Peru	Lochmann	University of Arkansas at Pine Bluff	0	20,065	0	8,576	28,641		
Asia									
Philippines	Fitzsimmons	University of Arizona	0	69,833	0	20,908	90,741	0	7,050
Philippines	Brown	University of Hawaii	0	209,912	0	52,477	262,389		
Philippines	Brown	Florida International University	147,850	147,850	39,369	39,369	187,219	8,000	8,000
Thailand	Diana	University of Michigan	87,162	544,853	7,415	84,073	628,926	26,000	104,000
<b>Special Activities</b>									
ISTA 5 Sponsorship	Fitzsimmons	University of Arizona	12,500	12,500	5,000	5,000	17,500	15,000	15,000
IFFET Conference Sponsorship	Striver	Oregon State University	14,300	14,300	3,600	3,600	17,900		
Côte d'Ivoire Report	Kaplan	Hofstra University	4,000	4,000	1,000	1,000	5,000		
Impact Assessment Report	TBA	TBA	30,000	30,000	7,500	7,500	37,500		
<b>Research Support</b>									
Central Database Management		Oregon State University	63,458	279,214	16,065	73,083	352,297		
Education Development		Oregon State University	0	241,845	0	95,512	337,357		
Information Management & Networking		Oregon State University	313,501	1,298,281	78,375	324,646	1,622,927		
Subcontract Administration		Indirect on Subs up to 25,000	8,634	118,832	2,159	29,708	148,540		
<b>Research Subtotal</b>			1,455,633	7,032,938	295,557	1,604,477	8,579,981	144,118	523,127
<b>MANAGEMENT</b>									
<b>Program Management<sup>3</sup></b>									
Operations and Administration		OSU Management	390,000	1,981,000			1,981,000		
Advisory Groups		OSU Advisory	154,708	424,710			424,710		
<b>Program Management Subtotal</b>			544,708	2,405,710			2,405,710		
<b>Total</b>			2,000,341	9,438,648	295,557	1,604,477	10,985,691	144,118	523,127

Notes:

1. Reflects funding received under five USAID allocations and obligations made to research projects by thematic and geographic emphases.
2. Cost share includes commitments made in association with the allocated funds in addition to cost share already accumulated.
3. Cost sharing is not required for management operations.



## APPENDIX 4. STAGED START DATES

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Fiscal year 1999 was the first year of reduced annual program budgets under the current grant. Those unexpected cutbacks resulted in the need to stagger the start dates (see below) of Ninth Work Plan research so that all the meretricious research plans that were originally proposed could still be undertaken, though over a three- rather than a two-year schedule. While this approach satisfactorily allowed the realization of the Ninth Work Plan, it should be noted that it also necessarily foreshortened the program's ability to complete all grant objectives. Currently in progress are experiments and activities in environmental management and socioeconomic aspects of fish culture systems in Kenya, Thailand, Mexico, Peru, Honduras, and the Philippines. Also underway are regional research and development plans for East Africa, Southeast Asia, Central America, and South America. Extending the current grant would enable the program to fulfill *Continuation Plan 1996-2001* objectives in full.

Start Date	Research Project	Project Leader	Institution
8/98	Mexico	Fitzpatrick	Oregon State University
8/98	Decision Support Systems	Bolte	Oregon State University
8/98	Peru	Kohler	Southern Illinois University at Carbondale
11/98	Pond Dynamics	Boyd	Auburn University
12/98	Kenya	Popma	Auburn University
12/98	Kenya	Bowman	Oregon State University
12/98	Kenya	Wood	Auburn University
1/99	Marketing & Economic Analysis	Engle	University of Arkansas at Pine Bluff
1/99	Kenya	Lochmann	University of Arkansas at Pine Bluff
1/99	Peru	Lochmann	University of Arkansas at Pine Bluff
1/99	Philippines	Brown	University of Hawaii
1/99	Thailand	Diana	University of Michigan
5/99	Reproduction Control	Shelton	University of Oklahoma
5/99	Reproduction Control	Phelps	Auburn University
5/99	Marketing & Economic Analysis	Hatch	Auburn University
5/99	Honduras	Verma	University of Georgia, Athens
5/99	Honduras	Molnar	Auburn University
12/99	Effluents and Pollution	Boyd	Auburn University

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# APPENDIX 5. COMPLETION DATES

RESEARCH AREA: PRODUCTION OPTIMIZATION					
Research Theme	Project Leader	Report Title	Research Theme Code	Study End Date	Report Received
Dynamics	Boyd	Pond Soil Characteristics and Dynamics of Soil Organic Matter and Nutrients	9PDR2	04/01	Progress
Feeds and Fertilizers	Bowman	Global Experiment: Optimization of Nitrogen Fertilization Rate in Freshwater Tilapia Production Ponds	8FFR1K	08/99	Final
	Brown	Global Experiment: Optimization of Nitrogen Fertilization Rate in Freshwater Tilapia Production Ponds (Cool-Season Trial)	8FFR1Ph	03/00	Final
	Bowman	Fish Yields and Economic Benefits of Tilapia/Clarias Polyculture in Fertilized Ponds Receiving Commercial Feeds or Pelleted Agricultural By-Products	9FFR2	12/00	Progress
	Lochmann	Stable Carbon and Nitrogen Isotope Analysis of Tilapia and Clarias Fed Commercial Feeds or Agricultural By-Products <sup>†</sup>	9FFR2A	04/01	Abstract
	Brown	Reduction of Rations below Satiation Levels	9FFR3	04/01	None expected
	Brown	Timing of the Onset of Supplemental Feeding of Nile Tilapia ( <i>Oreochromis niloticus</i> ) in Ponds	9FFR4	12/99	Final
Reproduction Control	Phelps	Methods for the Contribution from the Male and Female Genome to Sex Inheritance	8RCR1C	08/99	Final
	Fitzpatrick	Masculinization of Tilapia by Immersion in Trenbolone Acetate: Growth Performance of Trenbolone Acetate-Immersioned Tilapia	9RCR5B	07/00	Final
	Fitzpatrick	Masculinization of Tilapia by Immersion in Trenbolone Acetate: Detection of Trenbolone Acetate after Treatment	9RCR5C	11/00	Progress
	Phelps	Monosex Tilapia Production through Androgenesis: Selection of Individuals for Sex Inheritance Characteristics for Use in Monosex Production <sup>†</sup>	9RCR6A	04/01	Abstract
	Shelton	Monosex Tilapia Production through Androgenesis	9RCR7	04/01	Abstract
	Diana	The Application of Ultrasound to Produce All-Male Tilapia using Immersion Protocol	9RCR8	10/00	Abstract
New Aquaculture Systems/ New Species	Diana	Lotus-Fish Culture in Ponds: Recycling of Pond Mud Nutrients <sup>†</sup>	9NS1	11/00	Abstract
	Diana	Culture of Mixed-Sex Nile Tilapia with Predatory Snakehead	9NS2	09/00	Abstract
	Kohler	Development of Sustainable Pond Aquaculture Practices for <i>Colossoma macropomum</i> in the Peruvian Amazon <sup>†</sup>	9NS3	11/00	Progress
	Lochmann	Practical Diet Development for Broodstock of <i>Colossoma macropomum</i> and <i>Piaractus brachypomus</i> <sup>†</sup>	9NS3A	04/01	Progress
	Diana	Semi-Intensive Culture of Tilapia in Brackishwater Ponds	9NS4	11/00	Abstract

<sup>†</sup>Title of report is different than study title listed in the Ninth Work Plan.

**RESEARCH AREA: ENVIRONMENTAL EFFECTS**

<b>Research Theme</b>	<b>Project Leader</b>	<b>Report Title</b>	<b>Research Theme Code</b>	<b>Study End Date</b>	<b>Report Received</b>
Effluents and Pollution	Wood	Use of Pond Effluent for Irrigation in an Integrated Crop / Aquaculture System	9ER1	02/00	Final
	Fitzpatrick	Fate of Methyltestosterone in the Pond Environment: Detection of MT in Pond Soil from a CRSP Site	9ER2B	07/00	Final
	Fitzpatrick	Fate of Methyltestosterone in the Pond Environment: Impact of MT-Contaminated Soil on Tilapia Sex Differentiation	9ER2C	07/00	Final
	Diana	Integrated Recycle System for Catfish and Tilapia Culture	9ER3	03/00	Final
	Boyd	Effects of Water Recirculation on Water Quality and Bottom Soil in Aquaculture Ponds	9ER4	03/01	Progress
Appropriate Technology	Bowman	On-Farm Trials: Evaluation of Alternative Aquaculture Technologies by Local Farmers in Kenya	9ATR1	04/01	Progress
	Verma	Linkage of Aquaculture within Watersheds and Concurrent Design of Hillside Ponds	9ATR2	04/01	Abstract

**RESEARCH AREA: SOCIAL AND ECONOMIC ASPECTS**

<b>Research Theme</b>	<b>Project Leader</b>	<b>Report Title</b>	<b>Research Theme Code</b>	<b>Study End Date</b>	<b>Report Received</b>
Marketing and Economic Analysis	Engle	Development of Central American Markets for Tilapia Produced in the Region: Potential Markets for Farm-Raised Tilapia in Honduras <sup>†</sup>	9MEAR3	01/01	Progress
	Engle	Economic and Social Returns to Technology and Investment in Thailand	9MEAR4	04/01	Progress
	Hatch	Rapid Economic Evaluation Tools	9MEAR5	04/01	Progress
Adoption/ Diffusion	Molnar	Sources of Technical Assistance for Fish Farmers in the Peruvian Amazon <sup>†</sup>	8ADR1-2	10/99	Final
	Molnar	Identifying Goals and Priorities of Fish Farmers in the Peruvian Amazon <sup>†</sup>	8ADR1-3	03/00	Final
	Bowman	Aquaculture Training for Kenyan Fisheries Officers and University Students	9ADR3	03/01	Progress
	Bowman	Establishment of Companion Sites in the Africa Region	9ADR4	03/01	Progress
	Bowman	Regional Outreach in Africa	9ADR5	03/01	Progress
	Brown	Workshop on the Timing of the Onset of Supplemental Feeding of Nile Tilapia ( <i>Oreochromis niloticus</i> ) in Ponds <sup>†</sup>	9ADR6A	07/00	Final
	Brown	Production of Improved Extension Materials	9ADR6B	04/01	Abstract
	Verma	Decision Support for Policy Development: Planning Conferences for Collaborating Researchers, Public Agencies, and Nongovernmental Organizations Working in Aquaculture	9ADR7	04/01	Abstract
	Verma	Production Strategies Characterizing Small- and Medium-Scale Tilapia Farms: Approaches, Barriers, and Needs	9ADR8	04/01	Abstract
	Verma	Technical Assistance for Fingerling Production Serving Small- and Medium-Scale Tilapia Producers	9ADR9	04/01	Abstract
	Verma	Training and Technical Assistance for Honduras Institutions Working with Small- and Medium-Scale Tilapia Producers	9ADR10	04/01	Abstract
Decision Support Systems	Bolte	Decision Support Systems for Fish Population Management and Scheduling in Commercial Pond Aquaculture Operations	9DSSR2	04/01	Progress
	Bolte	Enhancing the POND <sup>®</sup> Decision Support System for Economics, Education, and Extension	9DSSR3	04/01	Progress

<sup>†</sup>Title of report is different than study title listed in the Second Addendum to the Eighth Work Plan or the Ninth Work Plan.



## APPENDIX 6. LINKAGES

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Developing and maintaining links among collaborating universities and government ministries, departments of agriculture, and private sector aquaculturists around the world forms a significant ancillary contribution to the CRSPs research effort and to the goal of expanding the role of aquaculture in the developing world. The following list includes informal linkages and connections made by CRSP researchers in the field and reported to the Program Management Office as well as those maintained by the Program Management Office. (Please see p. 75 for a listing of institutions with formal linkages to the CRSP.)

Alabama Catfish Producers Association, Montgomery, Alabama  
American Association for the Advancement of Science (AAAS), Washington, DC  
American Association of State Colleges and Universities  
    International Higher Education Linkages Project (IHELP), Washington, DC  
American Fisheries Society, Bethesda, Maryland  
American Tilapia Association, Arlington, Virginia  
Arid and Semi-Arid Lands (ASAL) Project, Government of Kenya, Laikipia, Kenya  
Asociación Nacional de Acuicultores de Honduras (ANDAH), Tegucigalpa, Honduras  
Association for International Agriculture and Rural Development (AIARD), Washington, DC  
Bean/Cowpea CRSP, East Lansing, Michigan  
Board for International Food and Agricultural Development (BIFAD) Washington, DC  
Brackish Water Shrimp Culture Station, Ranot, Thailand  
Broadening Access and Strengthening Input Market Systems (BASIS) CRSP, Madison, Wisconsin  
Bunda College of Agriculture, University of Malawi, Lilongwe, Malawi  
Bureau of Fisheries and Aquatic Resources (BFAR), Manila, Philippines  
Canadian International Development Agency (CIDA), Hull, Quebec, Canada  
Cáritas del Perú, Iquitos, Peru  
Central Laboratory for Aquaculture Research (CLAR), Abbassa, Egypt  
Chulalongkorn University, Bangkok, Thailand  
Clackamas County Extension Office, Oregon City, Oregon  
Coastal Resources Center, Narragansett, Rhode Island  
Comite para la Defensa y Desarrollo de la Flora y Fauna del Golfo de Fonseca (CODDEFFAGOLF), Tegucigalpa, Honduras  
Consejo Nacional del Ambiente (CONAM), Lima, Peru  
Consortium for International Earth Science Information Network (CIESIN), Washington, DC  
Consultative Group on International Agricultural Research (CGIAR), Washington, DC  
    Centro Internacional de Agricultura Tropical (CIAT), Cali, Colombia  
    International Center for Living Aquatic Resources Management (ICLARM), Penang, Malaysia  
    International Center for Research in Agroforestry (ICRAF), Nairobi, Kenya  
    West African Rice Development Association (WARDA), Bouaké, Côte d'Ivoire  
Cooperative for Relief and Assistance Everywhere (CARE), Bangladesh, Peru, and Atlanta, Georgia  
Danish International Development Agency (DANIDA), Copenhagen, Denmark  
Department for International Development (DFID) Fish Genetics Research Programme, Swansea, Wales, United Kingdom  
Department of Fisheries, Udorn Thani, Thailand  
Egerton University, Njoro, Kenya  
Empresa Brasileira de Pesquisa Agropecuária (Embrapa) Environmental Laboratory, Campinas, Brazil  
Empresa de Pesquisa Agropecuária e Extensão Rural de Santa Catarina (Epagri), Brazil  
Escuela de Agricultura de la Region Tropical Humeda (EARTH), San José, Costa Rica  
Escuela Superior Politécnica del Litoral (ESPOL)/Centro Nacional de Acuicultura e Investigaciones Marinas (CENAIM),  
    Guayaquil, Ecuador  
European Foundation for the Improvement of Living and Working Conditions, Dublin, Ireland  
Farm-Level Applied Research Methods for East and Southern Africa (FARMESA), Swedish International Development  
    Cooperation Agency (SIDA), Stockholm, Sweden  
Fe y Alegria, Lima, Peru  
Federación de Agroexportadores de Honduras (FPX), San Pedro Sula, Honduras  
Fisheries Society of Africa (FISA), Nairobi, Kenya  
Fondo Nacional de Desarrollo Pesquero (FONDEPES), Lima, Peru  
Food and Agriculture Organization of the United Nations (FAO), Rome, Italy  
    Aquaculture for Local Community Development Programme (ALCOM), Harare, Zimbabwe  
    European Inland Fisheries Advisory Commission (EIFAC), Rome, Italy  
    Inland Water Resources and Aquaculture Service (FIRI), Rome, Italy



Genetically Improved Farmed Tilapia Program (GIFT), Muñoz, Nueva Ecija, Philippines  
Global Aquaculture Alliance, St. Louis, Missouri  
Global Livestock CRSP, Davis, California  
Global Village, Honduras  
Hofstra University, Hempstead, New York  
Institut Pertanian Bogor (IPB), Bogor, Indonesia  
Institute for the Regional Ecodevelopment of the Amazon, Ecuador  
Institute of Agricultural and Food Information, Prague, Czech Republic  
Instituto del Mar del Perú (IMARPE), Callao, Peru  
Instituto Politécnico Nacional, Mexico City, Mexico  
Integrated Pest Management CRSP, Blacksburg, Virginia  
International Development Research Centre (IDRC), Ottawa, Canada  
International Sorghum and Millet (INTSORMIL) CRSP, Lincoln, Nebraska  
Japan International Cooperation Agency (JICA), Japan  
Katholieke Universiteit Leuven (KUL), Belgium  
Kenya Medical Research Institute (KEMRI), Nairobi, Kenya  
Kenyatta University, Nairobi, Kenya  
Lake Victoria Environmental Management Programme, Kenya  
Land Tenure Center, Madison, Wisconsin  
Mekong River Commission, Phnom Penh, Cambodia  
Microcredit Summit Campaign, Washington, DC  
Ministry of Agricultural Development, Panama  
Ministry of Agriculture, Animal Husbandry, and Fisheries, Entebbe, Uganda  
Ministry of Environment and Natural Resources, Tegucigalpa, Honduras  
Ministry of Fisheries, Iquitos, Peru  
Ministry of Tourism, Natural Resources, and Environment, Fisheries Division, Dar es Salaam, Tanzania  
Mount Kenya Fish Farmers Association, Central Province, Kenya  
National Agricultural Library, Washington, DC  
National Aquaculture Centre, Zomba, Malawi  
National Council for Science and Technology, Mexico  
National Inland Fisheries Institute (NIFI), Bangkok, Thailand  
National Shrimp Culture Advisory Group, Tegucigalpa, Honduras  
National Technical Information Services (NTIS), Springfield, Virginia  
Network of Aquaculture Centres in Asia-Pacific (NACA), Bangkok, Thailand  
North Central Regional Aquaculture Center (NCRAC), East Lansing, Michigan  
Nuestros Pequeños Hermanos (NPH), Honduras  
Oceanic Institute, Waimanalo, Hawaii  
Oregon Sea Grant, Corvallis, Oregon  
Organization of African Unity, Addis Ababa, Ethiopia  
    Inter-African Committee on Oceanography, Sea and Inland Fisheries  
Patani Fisheries College, Patani, Thailand  
Peanut CRSP, Griffin, Georgia  
Programa Regional de Apoyo al Desarrollo de la Pesca en el Istmo Centroamericano (PRADEPESCA), Panama  
Red de Desarrollo Sostenible Honduras (RDS-HN), Honduras  
Research Institute for Aquaculture No. 1, Hanoi, Vietnam  
Roche Aquaculture Research Centre Asia Pacific, Bangkok, Thailand  
Sarasawathi Foundation, Thailand  
Sichuan Provincial Fisheries Association, Ziyang, Sichuan Province, People's Republic of China  
Socio-Economic Development Centre (SEDEC), Binh Thuan Province, Vietnam  
Soil Management CRSP, Honolulu, Hawaii  
Southeast Asian Fisheries Development Center (SEAFDEC), Iloilo, Philippines  
Southeast Asian Outreach (SAO) Cambodia Aquaculture at Low Expenditure (SCALE) Project, Cambodia  
Southern African Development Community (SADC), Harare, Zimbabwe  
Special Program for African Agricultural Research (SPAAR), Washington, DC  
Sustainable Agricultural Centre for Research and Development in Africa (SACRED-Africa), Bungoma, Kenya  
Sustainable Agriculture and Natural Resources Management (SANREM) CRSP, Watkinsville, Georgia  
Terra Nuova, Lima, Peru  
Texas A&M University, College Station, Texas  
Uganda Wetlands and Resource Conservation Association (UWRCA), Uganda  
United States Department of Agriculture (USDA), Washington, DC  
United States Fish and Wildlife Service (USFWS), Washington, DC  
United States Food and Drug Administration (FDA), Washington, DC

Universidad Autónoma Metropolitana, Mexico City, Mexico  
Universidad Nacional Agraria La Molina, Lima, Peru  
Universidad Técnica de Machala, Machala, Ecuador  
Universidade de São Paulo, Brazil  
Universität Hohenheim, Stuttgart, Germany  
Université Nationale du Rwanda, Butare, Rwanda  
University of Agriculture and Forestry, Ho Chi Minh City, Vietnam  
University of Cantho, Vietnam  
University of Fisheries, Nhatrang, Vietnam  
University of the Philippines in the Visayas, Iloilo, Philippines  
University of Wales, Swansea, UK  
    Population and Fish Genetics Group  
University of Washington, Seattle, Washington  
Virginia Polytechnic Institute, Blacksburg, Virginia  
Wageningen University, Holland  
Western Regional Aquaculture Consortium (WRAC), Seattle, Washington  
Winrock International, Lima, Peru  
World Aquaculture Society (WAS), Baton Rouge, Louisiana  
World Bank, Washington, DC  
World Conservation Union (IUCN), Nairobi, Kenya  
World Neighbors, Honduras  
World Wildlife Fund, Washington, DC



# APPENDIX 7. PUBLICATIONS

## Regional Research

### CENTRAL AMERICA

#### Honduras

#### ASIAN INSTITUTE OF TECHNOLOGY

#### Publication

Munsiri, P. and B.F. Hajek, 1996. Texture and chemical composition of soils from shrimp ponds near Choluteca, Honduras. *Aquaculture International*, 4:154-168.

#### AUBURN UNIVERSITY

#### Thesis

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#### Publications and Reports

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- Boyd, C.E. Workshop on soil management in shrimp ponds (4 days), Guayaquil, Ecuador, (32 participants) August 1997.
- Boyd, C.E. Workshop on water quality and pond bottom soils (½ day), China, four locations (total of 385 participants) August 1997.
- Boyd, C.E. Workshop on water quality in shrimp ponds (3 days), Guayaquil, Ecuador (22 participants) November 1997.
- Boyd, C.E. Farm level indicators and criteria for sustainable shrimp farming. FAO Ad-Hoc Expert Meeting on Indicators and Criteria for Sustainable Shrimp Farming, Rome, Italy, 1998.
- Boyd, C.E. Workshop on water and soil quality in shrimp farming (2 days), Mazatlan, Mexico (41 participants) January 1998.
- Boyd, C.E. Workshop on water quality (1/2 day), Pietersburg, South Africa (25 participants) March 1998.
- Boyd, C.E. Workshop on shrimp pond water quality (2 hr), Chantaburi and Surat Thani, Thailand (total 73 participants) May 1998.
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# APPENDIX 8. ACRONYMS

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AAAS	American Association for the Advancement of Science	EDC	Education Development Component
ADR	Adoption/Diffusion Research	EdOp Net	Educational Opportunities Network
AIARD	Association of International Agriculture and Rural Development	EEP	External Evaluation Panel
AIT	Asian Institute of Technology	EIFAC	European Inland Fisheries Advisory Commission
ALCOM	Aquaculture for Local Community Development Programme	Embrapa	Empresa Brasileira de Pesquisa Agropecuária (Brazilian Agricultural Research Corporation)
ANDAH	Asociación Nacional de Acuicultores de Honduras (Honduran National Association of Aquaculturists)	Epagri	Empresa de Pesquisa Agropecuária e Extensão Rural de Santa Catarina (Rural Extension and Agricultural Research Institute of Santa Catarina)
ASAL	Arid and Semi-Arid Lands	ER	Effluents and Pollution Research
ATR	Appropriate Technology Research	ESPOL	Escuela Superior Politécnica del Litoral (Superior Polytechnical School of the Coast)
AU	Auburn University	FAC	Freshwater Aquaculture Center
BASIS CRSP	Broadening Access and Strengthening Input Market Systems CRSP	FAO	Food and Agriculture Organization of the United Nations
BFAR	Bureau of Fisheries and Aquaculture Research	FARMESA	Farm-Level Applied Research Methods for East and Southern Africa
BIFAD	Board for International Food and Agricultural Development	FDA	United States Food and Drug Administration
BMP	Best Management Practice	FFR	Feeds and Fertilizers Research
BOD	Board of Directors	FIRI	Inland Water Resources and Aquaculture Service of the FAO
CARE	Cooperative for Assistance and Relief Everywhere	FISA	Fisheries Society of Africa
CASA	Central American Symposium on Aquaculture	FIU	Florida International University
CENAIM	Centro Nacional de Acuicultura e Investigaciones Marinas (National Center for Aquaculture and Marine Research)	FONDEPES	Fondo Nacional de Desarrollo Pesquero (National Fund for Fishing Development)
CF	Commercial Fertilization	FPX	Federación de Agroexportadores de Honduras (Federation of Export Producers of Honduras)
CGIAR	Consultative Group on International Agricultural Research	FSF	Fertilization Followed by Supplemental Feeding
CIAT	Centro Internacional de Agricultura Tropical (International Center of Tropical Agriculture)	GIFT	Genetically Improved Farmed Tilapia
CIDA	Canadian International Development Agency	GIS	Geographic Information System
CIESIN	Consortium of International Earth Science Information Networks	GMP	Good Management Practices
CIFAD	Consortium for International Fisheries and Aquaculture Development	HD	High-Density Stocking without Water Recirculation
CLAR	Central Laboratory for Aquaculture Research	HDR	High-Density Stocking with Water Recirculation
CLSU	Central Luzon State University	HIGW	High-Input Green Water
CODDEFFAGOLF	Comite para la Defensa y Desarrollo de la Flora y Fauna del Golfo de Fonseca (Committee for the Protection and Development of the Flora and Fauna of the Gulf of Fonseca)	HTML	Hypertext Markup Language
CONAM	Consejo Nacional del Ambiente (National Council for the Environment)	IBAMA	Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis (Brazilian Institute for the Environment and for Renewable Natural Resources)
CRSP	Collaborative Research Support Program	ICLARM	International Center for Living Aquatic Resources Management
DANIDA	Danish International Development Agency	ICRAF	International Center for Research in Agroforestry
DFID	Department for International Development	IDRC	International Development Research Centre
DOF	Department of Fisheries, Moi University	IHEL	International Higher Education Linkages Project
DSSR	Decision Support System Research	IIAP	Instituto de Investigaciones de la Amazonia Peruana (Research Institute of the Peruvian Amazon)
EARTH	Escuela de Agricultura de la Region Tropical Humeda (Agriculture School of the Tropical Humid Region)		

IIFET	International Institute of Fisheries Economics and Trade	RDS–HN	Red de Desarrollo Sostenible–Honduras (Network for Sustainable Agriculture–Honduras)
IMARPE	Instituto del Mar del Perú (Marine Institute of Peru)	RFP	Request for Proposals
IMNC	Information Management and Networking Component	SACRED	Sustainable Agricultural Centre for Research and Development
INTSORMIL CRSP	International Sorghum and Millet CRSP	SADC	Southern African Development Community
IPB	Institut Pertanian Bogor (Agricultural Institute of Bogor)	SANREM CRSP	Sustainable Agriculture and Natural Resources Management CRSP
ISTA	International Symposium on Tilapia Aquaculture	SAO	Southeast Asian Outreach
IUCN	World Conservation Union	SCALE	SAO Cambodia Aquaculture at Low Expenditure Project
JCARD	Joint Committee on Agricultural Research and Development	SDN	Sustainable Development Network
JICA	Japan International Cooperation Agency	SEAFDEC	Southeast Asian Fisheries Development Center
KEMRI	Kenya Medical Research Institute	SEDEC	Socio-Economic Development Centre
KFD	Kenya Fisheries Department	SIDA	Swedish International Development Cooperation Agency
KUL	Katholieke Universiteit Leuven (Catholic University of Leuven)	SIUC	Southern Illinois University at Carbondale
LD	Low-Density Stocking without Water Recirculation	SPAAR	Special Program for African Agricultural Research
LV	Lake Victoria	SRP	Soluble Reactive Phosphorus
MDHT	17 $\alpha$ -methyl dihydrotestosterone	SSSEA	Soil Science Society of East Africa
ME	Management Entity	TA	Trenbolone Acetate
MEAR	Marketing and Economic Analysis Research	TC	Technical Committee
MIP	Mixed-Integer Programming	TDP	Test-Diet Pellet
MOU	Memorandum of Understanding	TKN	Total Kjeldahl Nitrogen
MSU	Michigan State University	TP	Total Phosphorus
MT	17 $\alpha$ -methyltestosterone	TSP	Triple Superphosphate
NACA	Network of Aquaculture Centres in Asia-Pacific	UA	University of Arizona
NASULGC	National Association of State Universities and Land-Grant Colleges	UAPB	University of Arkansas at Pine Bluff
NCRAC	North Central Regional Aquaculture Center	UCD	University of California, Davis
NGO	Nongovernmental Organization	UG	University of Georgia
NIFI	National Inland Fisheries Institute	UH	University of Hawaii
NPH	Nuestros Pequeños Hermanos (Our Little Brothers)	UJAT	Universidad Juárez Autónoma de Tabasco (University of Tabasco)
NS	New Aquaculture Systems/New Species Research	UM	The University of Michigan
NTIS	National Technical Information Services	UNA	Universidad Nacional Agraria (National Agricultural University)
ODBC	Open Database Connectivity	UNAP	Universidad Nacional de la Amazonia Peruana (National University of the Peruvian Amazon)
OLEDB	Object Linking and Embedding Database	UO	University of Oklahoma
OSU	Oregon State University	US	United States
PD/A CRSP	Pond Dynamics/Aquaculture CRSP	USA	United States of America
PDF	Portable Document Format	USAID	United States Agency for International Development
PDR	Pond Dynamics Research	USDA	United States Department of Agriculture
PFP	Pig Finisher Pellets	USFWS	United States Fish and Wildlife Service
PI	Principal Investigator	UWRCA	Uganda Wetlands and Resource Conservation Association
PMO	Program Management Office	WARDA	West African Rice Development Association
PRADEPESCA	Programa Regional de Apoyo al Desarrollo de la Pesca en el Istmo Centroamericano (Regional Development Support Program for Fisheries in the Central American Isthmus)	WAS	World Aquaculture Society
RB	Rice Bran	WIDeST	Web-Based Information Delivery System for Tilapia
RCR	Reproduction Control Research	WRAC	Western Regional Aquaculture Consortium





# APPENDIX 9. EIGHTEENTH ANNUAL TECHNICAL REPORT CONTENTS

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## I. PRODUCTION OPTIMIZATION

### Pond Dynamics Research

Pond Soil Characteristics and Dynamics of Soil Organic Matter and Nutrients (9PDR2)

### Feeds and Fertilizers Research

Global Experiment: Optimization of Nitrogen Fertilization Rate in Freshwater Tilapia Production Ponds (8FFR1K)

Global Experiment: Optimization of Nitrogen Fertilization Rate in Freshwater Tilapia Production Ponds (Cool-Season Trial) (8FFR1Ph)

Fish Yields and Economic Benefits of Tilapia/*Clarias* Polyculture in Fertilized Ponds Receiving Commercial Feeds or Pelleted Agricultural By-Products (9FFR2)

Stable Carbon and Nitrogen Isotope Analysis of Tilapia and *Clarias* Fed Commercial Feeds or Agricultural By-Products (9FFR2A)

Timing of the Onset of Supplemental Feeding of Nile Tilapia (*Oreochromis niloticus*) in Ponds (9FFR4)

### Reproduction Control Research

Methods for the Contribution from the Male and Female Genome to Sex Inheritance (8RCR1C)

Masculinization of Tilapia by Immersion in Trenbolone Acetate: Growth Performance of Trenbolone Acetate-Immersed Tilapia (9RCR5B)

Masculinization of Tilapia by Immersion in Trenbolone Acetate: Detection of Trenbolone Acetate after Treatment (9RCR5C)

Monosex Tilapia Production through Androgenesis: Selection of Individuals for Sex Inheritance Characteristics for Use in Monosex Production (9RCR6A)

Monosex Tilapia Production through Androgenesis (9RCR7)

The Application of Ultrasound to Produce All-Male Tilapia Using Immersion Protocol (9RCR8)

### New Aquaculture Systems/New Species Research

Lotus-Fish Culture in Ponds: Recycling of Pond Mud Nutrients (9NS1)

Culture of Mixed-Sex Nile Tilapia with Predatory Snakehead (9NS2)

Development of Sustainable Pond Aquaculture Practices for *Colossoma macropomum* in the Peruvian Amazon (9NS3)

Practical Diet Development for Broodstock of *Colossoma macropomum* and *Piaractus brachypomus* (9NS3A)

Semi-Intensive Culture of Tilapia in Brackishwater Ponds (9NS4)

## II. ENVIRONMENTAL EFFECTS

### Effluents and Pollution Research

Use of Pond Effluent for Irrigation in an Integrated Crop/Aquaculture System (9ER1)

Fate of Methyltestosterone in the Pond Environment: Detection of MT in Pond Soil from a CRSP Site (9ER2B)

Fate of Methyltestosterone in the Pond Environment: Impact of MT-Contaminated Soil on Tilapia Sex Differentiation (9ER2C)

Integrated Recycle System for Catfish and Tilapia Culture (9ER3)

Effects of Water Recirculation on Water Quality and Bottom Soil in Aquaculture Ponds (9ER4)

### Appropriate Technology Research

On-Farm Trials: Evaluation of Alternative Aquaculture Technologies by Local Farmers in Kenya (9ATR1)

Linkage of Aquaculture within Watersheds and Concurrent Design of Hillside Ponds (9ATR2)

## III. SOCIAL AND ECONOMIC ASPECTS

### Marketing and Economic Analysis Research

Development of Central American Markets for Tilapia Produced in the Region: Potential Markets for Farm-Raised Tilapia in Honduras (9MEAR3)

Economic and Social Returns to Technology and Investment in Thailand (9MEAR4)

Rapid Economic Evaluation Tools (9MEAR5)

**Adoption/Diffusion Research**

- Sources of Technical Assistance for Fish Farmers in the Peruvian Amazon (8ADR1-2)
- Identifying Goals and Priorities of Fish Farmers in the Peruvian Amazon (8ADR1-3)
- Aquaculture Training for Kenyan Fisheries Officers and University Students (9ADR3)
- Establishment of Companion Sites in the Africa Region (9ADR4)
- Regional Outreach in Africa (9ADR5)
- Workshop on the Timing of the Onset of Supplemental Feeding of Nile Tilapia (*Oreochromis niloticus*) in Ponds (9ADR6A)
- Production of Improved Extension Materials (9ADR6B)
- Decision Support for Policy Development: Planning Conferences for Collaborating Researchers, Public Agencies, and Nongovernmental Organizations Working in Aquaculture (9ADR7)
- Production Strategies Characterizing Small- and Medium-Scale Tilapia Farms: Approaches, Barriers, and Needs (9ADR8)
- Technical Assistance for Fingerling Production Serving Small- and Medium-Scale Tilapia Producers (9ADR9)
- Training and Technical Assistance for Honduras Institutions Working with Small- and Medium-Scale Tilapia Producers (9ADR10)

**Decision Support Systems Research**

- Decision Support Systems for Fish Population Management and Scheduling in Commercial Pond Aquaculture Operations (9DSSR2)
- Enhancing the POND® Decision Support System for Economics, Education, and Extension (9DSSR3)