Pond Dynamics/Aquaculture Collaborative Research Support Program

Nineteenth Annual Administrative Report

1 August 2000 to 31 July 2001

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Edited by Danielle Clair, Jeff Burright, Kris McElwee, Mary Nidiffer, Steve Sempier, and Hillary Egna. Assistance provided by Kristen Lewis, Cormac Craven, and Pamela Buitrago.

Pond Dynamics/Aquaculture CRSP Management Office
Oregon State University
418 Snell Hall
Corvallis, Oregon 97331-1643 USA

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INTRODUCTION

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 2000 to 31 July 2001. A companion volume to this report, The Nineteenth Annual Technical Report, comprises the collected technical accomplishments of CRSP-funded research in the period.

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*, which was awarded funding under USAID Grant No. LAG-G-00-96-90015-00. This grant authorized program activities from 1 August 1996 to 31 July 2001. The grant was extended in the reporting period, changing the formal completion date of the program to 31 July 2003. An overview of CRSP history and how the program has evolved since its inception is provided in Appendix 1.

The activities of this multinational, 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

- The PD/A CRSP Program Management Office (PMO) prepared and submitted a successful two-year extension proposal to USAID. The completion date for the current grant was extended from 31 July 2001 to 2003. In response to a directive from Congress on biotechnology, USAID allocated additional funding to several CRSPs, among them the PD/A CRSP for a biotechnology proposal submitted by the PMO.

- In the CRSPs two-year extension period, the program will undertake a new work plan of research investigations, the Tenth Work Plan, as well as plan a new continuation proposal. The Tenth Work Plan reflects a body of research that fills needed *Continuation Plan 1996* gaps that resulted from earlier annual budget cuts to the program. The Management Entity (ME) issued a restricted Request for Proposals (RFP) for the Tenth Work Plan in February 2001 with an April deadline for proposal submission. Developed with assistance from CRSP advisory bodies, the RFP solicited proposals for regional and cross-cutting research. Twenty-three proposals were submitted, and proposals were reviewed by experts outside of the program and by CRSP researchers. The Work Plan and Budget Subcommittee of the Technical Committee then evaluated the reviews and made recommendations to the ME. Proposals were selected for funding primarily based on their technical merit, gaps in the current CRSP research portfolio, and geographic regions. Tenth Work Plan funding decisions were announced in July 2001.

- The reporting period included the completion of a five-year program review by the External Evaluation Panel (EEP) that involved site visits, review of written materials, and meetings with researchers from sites not visited and those engaged in non-site-specific research. CRSP staff coordinated all travel logistics for and information collection on behalf of the EEP.

- In September 2000, EEP members Kevan Main and David Cummins, CRSP Director Hillary Egna, and USAID Cognizant Technical Officer Harry Rea visited Peru in the second of three visits to CRSP research sites. (The first site visit to Thailand took place in the previous reporting period.) The group met with CRSP researchers, students, farmers, and officials at the Instituto de Investigaciones de la Amazonia Peruana, the Universidad Nacional de la Amazonia Peruana, and the IIAP Quistococha research station. In addition they met with representatives of Terra Nuova, an Italian nongovernmental organization that works with farmers.

- In November 2000, EEP members Cummins and Christine Crawford and Director Egna visited Kenya in the third of three visits to CRSP research sites. In Kenya the group met with CRSP researchers, students, farmers, and government officials at the Sagana Fish Farm, Moi University, and the Kenya Department of Fisheries. Egna presented an overview of the CRSP at a CRSP Kenya Project workshop for new farm trainees at Moi University.

- In January 2001 in Orlando, Florida, EEP members Main, Cummins, Crawford, and Edna McBreen met

variously with Director Egna, individual CRSP project participants, and among themselves.

- Upon submission by the EEP of a draft review report in March 2001, the PMO distributed the EEPs draft review report to program researchers for review and comment. The EEP report and CRSP response was submitted to USAID in May.

- The Board of Directors met during the reporting period via conference calls in October and December 2000, in person in Orlando, Florida, in January 2001, and via email in June 2001. Major topics were an update on the External Evaluation Panel (EEP) review; discussion of strategy for the next CRSP Continuation Plan proposal; and discussion of the Request for Proposals and review process for the Tenth Work Plan.

- Oregon State University Board of Directors member L.J. (Kelvin) Koong stepped down and was replaced by Stephanie Sanford, Program Coordinator for the Center for Water and Environmental Sustainability (CWESt) at OSU. A listing of the Board members appears in Appendix 2.

- The PD/A CRSP co-sponsored ISTA 5, the Fifth International Symposium on Tilapia Aquaculture, held in Rio de Janeiro, Brazil, in September 2000. The co-sponsorship included travel support to the symposium for Host Country CRSP researchers Daniel Jamu from Malawi, Remedios Bolivar from the Philippines, and Yang Yi from Thailand, as well as support for the production of the conference proceedings. Director Egna presented an overview of the PD/A CRSPs ongoing research in tilapia aquaculture during the plenary session.

- In November 2000 Director Egna presented a poster at the USAID Bureau for Africa Workshop on Agriculture, Environment, Private Sector and Food for Peace Officers in Nairobi, Kenya.

- In November 2000 a poster "Collaborative Research Support Program: Vital Links" co-authored by Egna was presented by the CRSP Council in the session on Global Research and Education as part of the Annual Meeting of the American Society of Agronomy, Soil Science Society of America, and Crop Science Society of America.

- The PMO organized the PD/A CRSP Annual Meeting held in Orlando, Florida, on 25 and 26 January 2001, in conjunction with Aquaculture America 2001. The 2001 gathering featured a Technical Committee Meeting and separate meetings between program investigators and EEP members. Newly elected to the TC were CRSP principal investigators Kevin Fitzsimmons, Yang Yi, Jim Bowman, and Wilfrido Contreras-Sánchez. The complete listing of TC and Subcommittee members appears in Appendix 2.

- The PMO sponsored CRSP host country researchers to attend Aquaculture America 2001, the annual meeting of the US chapter of the World Aquaculture Society, in Orlando, Florida, in January 2001.

- The PD/A CRSP sponsored a special session at Aquaculture America 2001 that was chaired by CRSP researcher Claude Boyd. Entitled "Best Management Practices (BMPs) for Pond Aquaculture," the session comprised 12 presentations, including three by CRSP participants. The PD/A CRSP also donated a copy of the book *Dynamics of Pond Aquaculture*, edited by Egna and Boyd, for an auction conducted by the National Aquaculture Association as part of Aquaculture America 2001.

- Director Egna and Assistant Director Cormac Craven co-authored a poster entitled "The Pond Dynamics/ Aquaculture CRSP: Strengthening linkages and developing technologies for sustainable aquaculture in the United States and worldwide" that was presented at Aquaculture America 2001.

- The PD/A CRSP participated in the Fourth Annual Food and Agricultural Science Exhibition and Reception on Capitol Hill sponsored by the National Association of State Universities and Land–Grant Colleges (NASULGC), in March 2001. The display by the nine CRSPs was entitled "CRSPs–Food and Health Promotion by US Universities and Developing Countries."

- The PMO and IMNC submitted information on the PD/A CRSP for a USAID/CRSP Council publication entitled "Global Research for Agricultural Development and Sustainable Resource Management in Developing Economies," which serves to showcase CRSP strengths and impacts.

- Director Egna served as chair of the CRSP Impact Assessment Strategy Committee (CIASC), a joint CRSP Council/USAID committee, which met by phone and in person in May, June, and July 2001. A position paper articulating CRSP Council support for the USAID/AFS Impact Assessment Initiative and outlining a course for developing a CRSP-wide impact assessment (IA) strategy that fulfills the needs of the CRSPs and USAID/AFS was sent to USAID in June 2001.

- The Director participated in teleconference calls and in-person CRSP Council Committee meetings in September, October, and December 2000, and in February, March, May, and June 2001.

- Egna attended Board for International Food and Agricultural Development (BIFAD) meetings in Washington, DC, held 6 and 7 October 2000 and 29 and 30 March 2001. For CRSP Day 2001, the PD/A CRSP wrote and participated in presentations on biotechnology and natural resource management that took place as part of the 29 March BIFAD meeting in Washington, DC.

- The PMO inaugurated a program-wide library donation initiative to provide host country researchers with

textbooks, academic journals, and other reference materials.

- The PMO convened the Proposal Planning Executive Committee (PPEC) to coordinate and lead the planning effort for the CRSP 2003–2008 continuation proposal for submission to USAID in early 2003. Stakeholder meetings are planned for three world regions: Central America, South America, and the Caribbean; Africa; and Asia. Each stakeholder meeting will be followed by a meeting of an expert panel of CRSP researchers and others selected by the PPEC, which will use current information, professional expertise, and findings from the regional meetings to identify a set of global constraints to aquaculture development.

- The CRSP produced Spanish translations of the current constraints and four white papers for distribution to attendees of the first of the planned regional stakeholder meetings. The white papers, written by CRSP researchers, on biotechnology, best management practices, indigenous species, and seed production were prepared to assist the CRSP move forward on the new continuation proposal.

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*, 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* 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 and Networking project for reporting and disseminating project and program outputs via publications and a central website and for fostering new exchanges and linkages within the global aquaculture community.
- 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
- Oregon State University
- Southern Illinois University at Carbondale
- The Ohio State University
- The University of Michigan
- University of Arizona
- University of Arkansas at Pine Bluff
- University of Georgia
- University of Hawaii
- University of Oklahoma

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

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

Research Program Framework

The *Continuation Plan 1996* 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* 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

RESEARCH WORK PLANS

The portfolio of research reported upon in the current period is summarized in Appendix 4, pp. 78–79. With a few exceptions, Ninth Work Plan research was concluded in the reporting period and is described in this report. The Ninth Work Plan was developed by the CRSP Technical Committee and reflects activities to be conducted by the CRSP from 1 August 1998 through the end of this reporting period. CRSP work plans have typically covered two-year periods. This held true under the Ninth Work Plan for individual investigations, but while the overall time frame was greater than two years, no one investigation extended beyond a two-year period. Increasing the time period of the overall work plan came about because of the CRSPs substantially reduced USAID annual budget allocation beginning in the third year of the *Continuation Plan*.

Ninth Work Plan research took place in Mexico, Honduras, Peru, Kenya, Malawi, the Philippines, and Thailand, as well as in the US. The CRSPs two-year extension, though 31 July 2003, will allow the program to fulfill the objectives set out in the *Continuation Plan 1996*, completion of which was not possible in the originally-envisioned 5-year plan owing to the annual cuts mentioned above. The Tenth Work Plan, comprising investigations slated to begin, for the most part, in mid-2001, reflects a body of research that fills needed *Continuation Plan 1996* gaps and rounds out the portfolio of work identified in the current grant. In those few instances where delays set Ninth Work Plan research schedules back, the commencement of new research under the Tenth Work Plan has been deferred until completion of prior obligations.

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, Ninth, and Tenth Work Plans reflects the broadening of research as was proposed in the *Continuation Plan 1996* 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.

The CRSPs Information Management and Networking Component (IMNC) solicits research progress reports on a quarterly basis. Adherence to work plan schedules and methods and fulfillment of work plan objectives is also tracked by IMNC 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, Spring 1999, and Fall 2000. Changes to Ninth Work Plan research are documented in an addendum that was printed in Fall 2000.

PROGRAM IMPACTS 2000–2001

- A pond soil classification system that will integrate into the existing system of Soil Taxonomy was developed with data from five years of CRSP pond soils research at 12 sites. The result of a study in Pond Dynamics research, this system establishes a uniform method of describing ponds soils from different areas and will be useful in predicting the limitations of pond soils in developing countries and in pond aquaculture in general.

- An activity in Appropriate Technology research yielded a spreadsheet model that is easy to use and distributed via the Honduran CRSP-sponsored website <acuacultura-ca .org.hn> allows prospective fish farmers to make decisions on pond design. A user with information about soil type, hillslope, location, and water availability can use the model to determine an appropriate pond size. By balancing seepage and evaporation against water input from a stream, spring, well, or rainfall, the model allows farmers to determine how much water exchange is possible at their pond site.

- CRSP research in New Aquaculture Systems/New Species led to the development of diet recommendations for captive gamitana and paco, two Amazonian

fish species troubled by inconsistent spawning due to inadequate nutrition. The guidelines suggest feeding the fish less protein and supplementing Vitamins C and E, imitating their natural diets, which are rich in fruit. Making these changes should not only increase spawning success and the quality of resulting fry but should also be more economical for farmers in the Amazon region.

- Nine tilapia farmers on Luzon Island in the Philippines participated in PD/A CRSP on-farm trials. This Adoption/ Diffusion research activity demonstrated that reducing feed rations by one-third can effectively lower tilapia grow-out costs without compromising growth or yield.

- In a test of sex-reversal technologies, CRSP researchers in Thailand focusing on Effluents and Pollution research used ultrasound to increase the transport of three synthetic hormones from water into tilapia. This immersion technique resulted in a more consistent and higher rate (98 to 100%) of masculinization of tilapia fry, and it also decreased the amount of time needed for successful sex reversal (two hours). Using ultrasound has the potential to replace the costly, inefficient, and risky technique of feeding synthetic testosterone for sex reversal of tilapia. Ultrasound also lowers the amount of hormones needed, which benefits both hatchery workers and the environment.

- CRSP researchers in Mexico and at Oregon State University have recently identified over 100 genes not previously identified in tilapia. They also announced a research breakthrough, showing induction of an Mx gene, which is important to tilapia immune system functions. This Reproduction Control research result represents the first time this gene product has been found in tilapia and may be useful for investigating the health of this important aquaculture species. Also, cDNA libraries have been established, and the researchers identified other important biomolecules involved in sex differentiation.

- Results of Pond Dynamics research in Thailand showed that snakehead were able to completely control Nile tilapia recruitment at all tested stocking ratios, and the best ratio of snakehead to tilapia was 1:80. Unwanted reproduction is a major constraint for tilapia producers. In areas where all-male fingerlings are unavailable, farmers can add to their ponds predatory fish that eat the offspring of stocked tilapia.

- CRSP scientists looking at New Aquaculture/New Species research found that lotus co-cultured with tilapia or cultured alone in ponds in Thailand was able to effectively take up nutrients from old pond mud and resulted in the reduction of nutrients in mud by about 2.4 tonnes of nitrogen and 1 tonne of phosphorus per hectare per year. Lotus contributed the largest portion of net income in lotus-tilapia co-culture. This CRSP research demonstrated the effectiveness of nutrient removal from old pond mud by lotus and the feasibility of rotation and co-culture of lotus and Nile tilapia both technically and economically. Both culture systems, lotus alone and co-culture with tilapia, recycle nutrients effectively within ponds and are environmentally friendly.

- CRSP researchers investigated several options for using abandoned shrimp farms for tilapia culture. New Aquaculture/New Species research in Thailand showed that growing tilapia can be a cost-effective and low-risk use of underutilized or abandoned shrimp ponds. Brackishwater ponds fertilized at rates of 14 kg N and 7 kg P ha^{-1} wk^{-1} at 10‰ salinity showed the highest net returns. Supplemental feeding of tilapia is recommended with 50% satiation being the most efficient rate.

- A CRSP stocking density study in New Aquaculture/ New Species research suggests the economic feasibility of rearing two native species in the Peruvian Amazon. The production of these native species at densities of at least 2,500 fish ha^{-1} will be more profitable (by a factor of over four for gamitana and two and one-half for paco) than the production of pineapple (US$1,008 ha^{-1}), which is currently the highest market value agriculture cash crop produced in the region studied.

- An Adoption/Diffusion research survey of 128 Honduran farmers (including 64 tilapia producers) identified the following characteristics of farmers who are more likely to integrate tilapia into their production systems: they are younger, their principal occupation is farming, they use their land more intensively, and they culture basic grains. Lack of access to financing was identified by 80% of respondents as the biggest barrier to farm investments and to intensifying tilapia production.

- As aquaculture production increases in Central America, developing domestic markets for tilapia is important to keep prices, and hence profitability, from dropping due to oversupply. CRSP research in Marketing and Economic Analysis is the first to conduct surveys in three potential tilapia markets (restaurants, supermarkets, and fish markets) in Honduras and Nicaragua. The most promising Honduran market appears to be larger chain supermarkets, where marketing strategies could focus on selling whole-dressed tilapia in specialized fish sections of the stores. To develop a domestic market for farmed tilapia in Nicaragua, consumer fears of contaminated fish from Lake Managua must be addressed by education and labeling efforts to distinguish farmed from wild tilapia.

- Studies conducted by the Philippines Project in Feeds and Fertilizers research indicated that a number of methods are available by which farmers can minimize the cost of feeding tilapia grown in ponds without compromising yields. The researchers created several extension brochures based on these results and distributed them to farmers. In addressing the human capacity development objective of current work, the Philippines Project provided partial support for the doctoral studies of a graduate student at Central Luzon

State University (CLSU), Philippines. The student's research, including descriptive and experimental components, investigated the interactions of growth, survival, and social behavior of genetically manipulated tilapia.

- The CRSP assisted 19 international graduate and 29 undergraduate students, as well as 7 graduate and 12 undergraduate students from the US with funding, training, and research opportunities. At various scientific conferences and workshops, researchers and students gave 32 presentations in 9 countries to disseminate CRSP results to over 130 host country agencies, researchers, farmers, and students. Two fingerling production technical workshops were presented to 35 Honduran fingerling producers and NGO representatives to discuss current and potential production techniques and to analyze conditions and fingerling demands. A series of five highly successful short courses was conducted for the Kenya Fisheries Department personnel.

- In collaboration with Honduran NGOs and the Red de Desarrollo Sostenible-Honduras (RDS-HN), CRSP scientists working in Decision Support Systems research developed and launched a user-friendly website <acuacultura-ca.org.hn> designed to give extension workers and farmers access to easy-to-use information on fish culture and connect them with NGOs and decision-makers. In its first five months of operation, the website received 6,800 hits, and more than 300 people registered to receive information. The site features over 100 documents, an Excel-based pond design model, a chat room, and a page from which users can send questions to aquaculture experts.

- Adoption/Diffusion research yielded four technical manuals and several training modules to address lack of informational and technical training materials. Based on previous CRSP studies, the Thailand Project developed a manual that provides simple guidelines on fertilization, supplemental feeding, and pond management, as well as basic extension and training materials. The Peru Project produced a Spanish-language manual that includes topics such as broodstock preparation and selection, ovulation and spawning, and hormonal treatment for inducing reproduction in two Amazonian fish species. The Honduras Project developed a 37-page Spanish-language booklet that describes methods of tilapia production on Central American farms using low-cost inputs. The Mexico Project produced a manual that describes masculinization of Nile tilapia fry while emphasizing safe handling procedures. Meanwhile, CRSP researchers on the Kenya Project developed modules for training Kenya Fisheries Department extension officers and undergraduates in the Moi University Department of Fisheries in response to the lack of necessary training materials.

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	* To increase the overall sustainability of aquacultural production systems through production optimization.	* 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.	* More sustainable, efficient production systems appropriate for the biophysical environment.	* Improved scientific understanding of pond processes. * Improved pond management strategies. * Significant advances in reproduction technology. *Development of alternative aquacultural systems.
Environmental Effects	* To minimize the detrimental environmental impacts of aquaculture operations through improved pond management.	* Sustainable aquaculture is possible only in a healthy environment. * Detrimental effects of aquaculture operations can be reduced or eliminated through changed management development.	* Reduced detrimental environmental impact of aquaculture operations.	* Development of methodologies to assess and reduce negative environmental impacts of aquaculture operations.
Social and Economic Aspects	* To increase our understanding of the social and economic implications of aquaculture development.	* Successful aquaculture development is contingent upon the social and economic constraints of each location.	* Improved viability of subsistence and commercial aquaculture farms at various sites.	* Positive net returns to capital investment. * Positive financial and nutritional impact on participating household communities.

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

PRODUCTION OPTIMIZATION				
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.

ENVIRONMENTAL EFFECTS				
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.

SOCIAL AND ECONOMIC ASPECTS				
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 socio-economic 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

Preparation of the *Continuation Plan 1996* 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 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.

The Central Database and the Information Management and Networking Component are two branches of the CRSPs research support activities in this period. Annual activity reports for these two projects make up the first sections of 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 this reporting period have been assumed in part by the Information Management and Networking Component and in part under specific research projects such as the Effluents and Pollution Research project 9ER4 (see p. 33), the Kenya Project 9FFR6 (see p. 55), and the Philippines Project 9FFR5 (formerly 9HCD4, see p. 62).

CENTRAL DATABASE MANAGEMENT

MOU No. RD009G

Staff

Oregon State University, Corvallis, Oregon

John Bolte	US Principal Investigator
Doug Ernst	Database Manager (Research Associate)

Networking

Bolte established contacts with participants in aquaculture education at the community-college and university levels in order to promote the availability and uses of the Database in conjunction with aquaculture coursework.

CRSP collaborative work with Leonard Obaldo from the Oceanic Institute (OI) in Waimanalo, Hawaii, continues to progress. Obaldo attended the CRSP annual meeting in January 2001, and CRSP researchers met with him and discussed proposed work involving modeling (simulation) for zero-exchange shrimp culture systems and the addition of OI shrimp culture data to the CRSP Database. The latter involves the use of standard analytical methods, data collection protocols (data types and frequency of recording), and data formatting by OI. The Database received a first dataset for shrimp feeding and growth from OI, which will be used for calibration of a shrimp production model and for possible inclusion in the Database.

Ernst was asked by the Aquacultural Engineering Society to serve as their committee chair for standard research methods.

Conference

PD/A CRSP Annual Meeting at Orlando, Florida, 26 January 2001. (Bolte, Ernst)

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

Ninth Work Plan, Database Management 2 (9DM2)

Douglas H. Ernst and John P. Bolte
Department of Bioengineering
Oregon State University
Corvallis, Oregon, USA

INTRODUCTION

The PD/A CRSP Central Database is a centralized storage and retrieval system for aquaculture research data and related documentation (Hopkins et al., 1987; Batterson et al., 1991; Bolte et al., 1998; Ernst et al., 1997; Ernst and Bolte, 1999; Ernst and Bolte, 2000; Ernst and Bolte, 2001). Started by the CRSP in 1985, the Database currently contains 116 datasets from aquaculture studies performed under the CRSP. The majority of datasets derive from studies on the production of Nile tilapia in subtropical and tropical, solar algae ponds receiving inputs of plant materials, inorganic and organic fertilizers, or prepared feeds. Datasets from studies of other pond fishes and penaeid shrimp, under monoculture and polyculture management, are also available. Datasets in the Database represent CRSP studies that have been carried out in Egypt, Honduras, Indonesia, Kenya,

Mexico, Panama, Peru, the Philippines, Rwanda, Thailand, and the US.

Specific data types supported by the Database include site weather, pond soils, pond application materials and rates, water flow and volume management, water quality and primary productivity, fish productivity, and enterprise economics. In conjunction with these data, the Database contains or links supporting information to assist users in the interpretation and application of extracted datasets. This supporting information includes project descriptions, author contact information, analytical methods, research site descriptions, and related publications. Together, all research datasets and supporting information are available at the Database website, located at <biosys.bre.orst.edu/crspDB/>. Datasets may be searched and retrieved based on geographical location, fish species, fish culture methods, and desired types of data. As described at the Database website, user applications of the Database include aquaculture science and engineering, education and outreach, and pond-based commercial aquaculture.

TASKS AND ACCOMPLISHMENTS

This report is organized by task areas. Technical methods and Internet and software tools used in this work are described in Ernst et al. (1997). The server on which the Database resides and the operating system, database, and website software used were all upgraded over the last year. All software components are currently performing to their full specifications. All security and performance issues of the Database website have been addressed. The current software and hardware configurations of the Database and its website should be sufficient for a number of years.

ENTRY OF CRSP DATASETS AND SUPPORTING INFORMATION

The current data content of the Database is summarized in Table 1. At the time of this report, six datasets remained due for the Eighth and Ninth Work Plans. For a current listing of data requirements and submission status, see the CRSP Projects section at the Database website. Until the Eighth Work Plan, which formally began on 1 August 1996, data

Table 1. Listing of datasets in the CRSP Database as of August 2001. (Grayed areas denote periods of site inactivity. See menu item CRSP Projects at the database website for up-to-date information and a comprehensive listing of all CRSP projects.)

Site Name	Datasets Available for First through Ninth Work Plans (1983–2001)										
	1 83–84	*2 84–85*	*3 85–87*	*4 87–89*	*5 89–91*	*6 91–93*	*7 93–95*	*7/8 95–96*	*8 96–98*	*9 98–01*	*Total Datasets*
UJAT, Mexico									n/a	n/a	-
Comayagua, Honduras	2	2	2	2	4*	2*	0	n/a	2†		16
Choluteca, Honduras							0	1*†	4		5
Zamorano, Honduras										n/a	-
Aguadulce, Panama	2	2	2								6
Gualaca, Panama	2		2								4
IIAP, Peru									1†	0†	1
Iloilo, Philippines	2	2	2								6
FAC, Philippines						2	3†	0†	1*†‡	2†‡	8
Nong Sua, Thailand	1										1
Huay Luang, Thailand					0	0	1*†	0			1
Ayutthaya, Thailand	1	2	2	3	4*	5	1	1			19
AIT, Thailand				3	3*	3*	4	0†	7†	5†‡	25
Bogor, Indonesia	2	1	2								5
Abbassa, Egypt							2*†				2
Rwasave, Rwanda	2		2	4	3*†	0†	0†				11
Sagana, Kenya									4†	0†	4
Global/Regional Studies (Includes US Universities)					0†	0†	0†	0†	1†	1*†	2
Total Datasets	14	9	14	12	14	12	11	2	20	8	116

* Additional dataset(s) not submitted.
† Additional dataset(s) not included in Database.
‡ Dataset(s) submitted but not yet available.

submission to the Database was not contractually enforced. A total of 50 datasets from that earlier period that are appropriate for submission have not been submitted. Efforts over the last few years resulted in the collection of 16 datasets from the earlier period, but additional contributions are unlikely. Overall, a total of 292 projects are contained in the First through Ninth Work Plans. Of these, 40% are not appropriate for data submission, 40% are appropriate for data submission and datasets have been submitted, and 20% are appropriate for data submission but datasets have not been submitted.

With considerable assistance from the CRSP Information Management and Networking Component office, the CRSP Projects and Publications tables contained in the Database are up to date and contain 292 and 543 records, respectively. These tables can be accessed at the website main menu and searched according to user criteria (described below). The Projects table contains descriptions and specifications for all CRSP projects to date. In conjunction, experiment treatment specifications for all CRSP projects are codified, tabularized, and available for use in data searches.

WEBSITE DEVELOPMENT

A major upgrade to the navigation and functionality of the Database website has been accomplished. Overall, user support and context-specific connectivity between the different website sections has been improved. Specific accomplishments are detailed below. This is organized according to the main menu of the Database website.

Database Home: The homepage was redesigned to provide a geographically organized overview and linkage of CRSP study sites.

CRSP Projects: Studies, experiments, and activities (projects) can be searched and listed. Search criteria include research site, year span, and keywords for project title, description, and leader. Experiment treatment specifications (fish culture methods) pertaining to specific datasets can be viewed here as quantitative descriptions. These same specifications are summarized in a look-up tabular format for use in data searches.

CRSP Publications: Publications can be searched and listed. Search criteria include publication type and language, geographical location, year span of publication date, and subject and author keywords. Listings include complete citations and links to abstracts.

Standard Methods: This section provides 1) enterprise budget procedures for aquaculture, 2) the CRSP Handbook of Analytical Methods, and 3) supporting references. The budget document describes the terminology and formatting of full and partial enterprise budgets. The Handbook provides methods for physical, chemical, and biological measurements. Variables described in the Handbook are linked to the Data Submission Manual through variable (data) names. Supporting references include feed and fertilizer analysis, water quality analysis, soil analysis, and water body measurements.

References and Resources: This section provides related Internet links and publication references.

Data Submission: The Data Submission Manual was last updated June 2001. The most current version is always available at the Database website for on-screen review or downloading. The manual contains submission procedures and a comprehensive listing of data types collected by the CRSP (data names, definitions, units, and analytical reference).

Data Search: Empirical datasets are available to users for a wide range of physical, chemical, and biological variables. Datasets can be searched and retrieved for tabular and graphical display or for downloading. Search criteria include project site, year span of project starting dates, fish culture methods, and types of data desired. These criteria are now established successively and interactively, such that dead-end searches have been eliminated. Linkage to supporting information has been improved, including project descriptions, investigator contact information, experiment treatment specifications, and publications. Summary statistics for selected variables is now available, including fish growth, water temperature, and dissolved oxygen data. Statistics for additional variables will be completed by November 2001, including alkalinity, pH, total ammonia nitrogen, dissolved inorganic nitrogen, dissolved inorganic phosphorous, and primary productivity.

How to Use the Database: This new section of the Database website shows the relationships of the different data and information components of the Database and provides procedures and examples for their application. Possible applications of the Database are illustrated, including aquaculture science and engineering, education, and commercial production. Procedures and links for statistical analyses of datasets are provided. Applications of datasets to the calibration and use of fish feeding and growth models are described.

DATABASE USE

The total visitor count to the Database website as of August 2001 was 6,350 (Figure 1). The rate of increase in total visitors over the 4.5-year lifetime of the website (started January 1997) has been fairly constant, at about 1,400 visitors per year. This visitor count does not include any that originated from Oregon State University. It is not known in detail how these users utilized the Database, but section counters at the website (publicly viewable) show distributed interests. To whatever extent these visitor counts are interpreted, they compare well to the 30 documented cases of Database use from 1983 (inception) through the end of 1996. However, it is also apparent that more should be done to promote the Database to new users.

Historically, the Database has been mainly used for the calibration and validation of aquaculture models (e.g., Piedrahita et al., 1997) and the development of aquaculture simulation and decision support systems (e.g., Bolte et al., 2000; Ernst et al., 2001). However, a much larger number of potential users works in areas of aquaculture education and

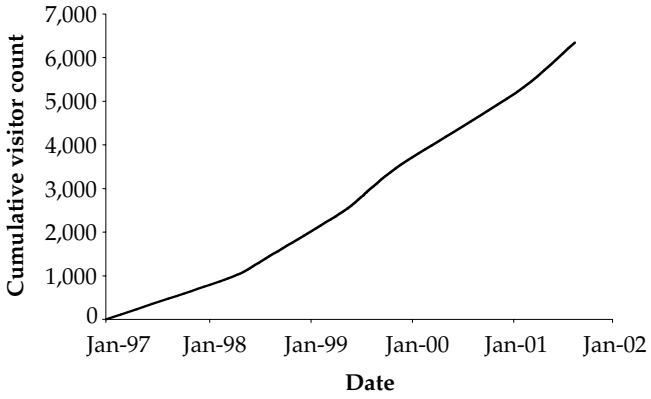

Figure 1. Visitor count for the CRSP Database website home page.

production. For aquaculture educators and students, the Database can provide a virtual experimental lab, where experiment treatments can be selected and recombined, raw empirical datasets obtained, and experimental hypotheses tested through analysis of variance. For pond-based aquaculture producers, the Database provides an objective resource for aquaculture production results under documented culture conditions. Datasets can also be used in the development of planning and management tools (see website).

Given that the Database is dominated by tilapia production studies, it is most relevant to tilapia producers. Reflecting the research emphasis of the CRSP, much of the tilapia production data in the Database is for extensive aquaculture practices, at stocking densities of one to two fish m^{-2}, with no or low use of prepared feeds. A need to better represent commercial tilapia producers using semi-intensive and intensive practices is evident, through CRSP-directed research and the inclusion of datasets from commercial tilapia farms.

LITERATURE CITED

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Bolte, J.P., D.H. Ernst, and D. Lowes, 1998. Central Database Management. In: D. Clair, B. Goetze, D. Burke, J. Baker, and H. Egna (Editors), Fifteenth Annual Administrative Report. Pond Dynamics/ Aquaculture CRSP, Oregon State University, Corvallis, Oregon, pp. 36–45.

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Ernst, D.H. and J.P. Bolte, 2001. PD/A CRSP Central Database management and development. In: D. Clair, K. McElwee, A. Gupta, D. Burke, and H. Egna (Editors), Eighteenth Annual Administrative Report. Pond Dynamics/Aquaculture CRSP, Oregon State University, Corvallis, Oregon, pp. 9–13.

Ernst, D.H., J.P. Bolte, and D. Lowes, 1997. PD/A CRSP Central Database: A Standardized Information Resource for Pond Aquaculture. In: K. Fitzsimmons (Editor), Tilapia Aquaculture, Proceedings from the Fourth International Symposium on Tilapia in Aquaculture (ISTA), November 1997. NRAES-106, Vol. 2. Northeast Regional Agricultural Engineering Service, Ithaca, New York, pp. 683–700.

Ernst, D.H., J.P. Bolte, and S.S. Nath, 2000. AquaFarm: simulation and decision support for aquaculture facility design and management planning. Aquacultural Engineering, 23(1–3):121–179.

Hopkins, K.D., J.E. Lannan, and J.R. Bowman, 1987. A Database Management System for Research in Pond Dynamics. CRSP Research Reports 87-1. Pond Dynamics/ Aquaculture CRSP, Oregon State University, Corvallis, Oregon, 4 pp.

Piedrahita, R.H., S.S. Nath, J. Bolte, S.D. Culberson, P. Giovannini, and D.H. Ernst, 1997. Computer applications in pond aquaculture—modeling and decision support systems. In: H.S. Egna and C.E. Boyd (Editors), Dynamics of Pond Aquaculture. CRC Press, New York, 480 pp.

INFORMATION MANAGEMENT AND NETWORKING

MOU No. RD009D

Staff

Oregon State University, Corvallis, Oregon

Danielle Clair	Director of Information Management
Kris McElwee	Assistant Information Manager; System Administrator
Pamela Buitrago	Faculty Research Assistant (from October 2001)
Deborah Burke	Faculty Research Assistant (through September 2000)
Anu Gupta	Faculty Research Assistant (through November 2000)
Xena Cummings	Graduate Research Assistant (USA; through June 2001; CRSP funded)
Stephen Sempier	Graduate Research Assistant (USA; from September 2000; CRSP funded)
Jeff Burright	Undergraduate Student Worker
Kenny Duong	Undergraduate Student Worker (January through June 2001)
Heidi Furtado	Undergraduate Student Worker (through February 2001)
Kristen Lewis	Undergraduate Student Worker (from September 2000)
Mary Nidiffer	Undergraduate Student Worker (from February 2001)

Conferences

PD/A CRSP Annual Meeting at Orlando, Florida, 26 January 2001. (Clair, McElwee)

Work Plan Activities

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

REPORT: ANNUAL ACTIVITIES OF THE INFORMATION MANAGEMENT AND NETWORKING COMPONENT

Ninth Work Plan, Information Management and Networking 3 (9IMNC3)

Danielle Clair, Jeff Burright, and Kris McElwee
Oregon State University
Corvallis, Oregon, USA

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 CRSPs 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 1,221 entries from 93 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.

Eighteenth Annual Administrative Report
Clair, D., K. McElwee, A. Gupta, D. Burke, and H. Egna (Editors), 2001. PD/A CRSP, Oregon State University, Corvallis, Oregon, 118 pp.

Eighteenth Annual Technical Report
Gupta, A., K. McElwee, D. Burke, J. Burright, X. Cummings, and H. Egna (Editors), 2001. PD/A CRSP, Oregon State University, Corvallis, Oregon, 163 pp.

Addendum to the Ninth Work Plan
Printed Fall 2000, 41 pp.

Third Addendum to the Eighth Work Plan
Printed Fall 2000, 5 pp.

Aquanews, quarterly newsletter (distributed by hard copy and available on the CRSP website): Vol. 14, No. 4 and Vol. 15, 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. 5, Nos. 8, 9, 10, 11, and 12; Vol. 6, Nos. 1, 2, 3, 4, 5, 6, and 7.

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

00-150 Effects of shrimp farming on the hydrography and water quality of El Pedregal and San Bernardo estuaries, Gulf of Fonseca, Honduras. (10/00)
00-151 Chemical and physical properties of shrimp pond bottom soils in Ecuador. (10/00)
00-152 Vertical gradients of organic matter concentration and respiration rate in pond bottom soils. (10/00)
00-153 Development of decision support tools for aquaculture: The POND experience. (10/00)
00-154 AquaFarm: Simulation and decision support for aquaculture facility design and management planning. (10/00)
00-155 Application of geographical information systems (GIS) for spatial decision support in aquaculture. (10/00)
00-156 Response to selection for body weight on Nile tilapia (*Oreochromis niloticus*) in different culture environments. (10/00)
00-157 Criteria for selecting Nile tilapia and red tilapia for culture. (10/00)
00-158 Timing of the onset of supplemental feeding of Nile tilapia (*Oreochromis niloticus*) in ponds. (10/00)
00-159 Analysis of various inputs for pond culture of Nile tilapia (*Oreochromis niloticus*): Profitability and potential environmental impacts. (10/00)
00-160 Concurrent design of hillside ponds for tilapia production. (10/00)
00-161 Microbiological hazards of tilapia culture systems. (10/00)
00-162 Bio-energetic modeling of growth and waste production of Nile tilapia (*Oreochromis niloticus*) in recirculation systems. (1/01)
00-163 A pilot study on the spatial and temporal soil moisture and distribution in integrated crop-fish-wetland and crop-wetland agroecosystems in Zomba-East, Malawi. (1/01)
00-164 Evaluation of tilapia culture by resource limited farmers in Panama and Guatemala. (1/01)
01-165 Masculinization of Nile tilapia with steroids: Alternate treatments and environmental effects. (1/01)
01-166 Managing the accumulation of organic matter deposited on the bottom of shrimp ponds… Do chemical and biological probiotics really work? (1/01)
01-167 Environment, aquaculture, and food policy nexus: Case study of two USAID aquaculture projects in Rwanda. (1/01)
01-168 Effects of biomass of caged Nile tilapia (*Oreochromis niloticus*) and aeration on the growth and yields in an integrated cage-cum-pond system. (4/01)
01-169 Pond soil pH measurement. (7/01)
01-170 Nonparametric estimation of returns to investment in Honduras shrimp research. (7/01)
01-171 Risk analysis of shrimp farming in Honduras. (7/01)

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

- *Sixteenth Annual Administrative Report*
- *Sixteenth Annual Technical Report*
- *Eighteenth Annual Administrative Report*
- *Eighteenth Annual Technical Report*
- *First Addendum to the Ninth Work Plan*
- *Third Addendum to the Eighth Work Plan*
- *Research Report 98-124*
- *Research Report 98-124A*
- *Research Report 99-129*
- *Research Report 00-150*
- *Site Descriptions*

WORLD WIDE WEB

Online 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:

- *Aquanews*—PD/A CRSP quarterly newsletter (4 issues)
- *Eighteenth Annual Technical Report*
- *Eighteenth Annual Administrative Report*
- Full-text version of the PD/A CRSP *Research Report 95-91*
- Full-text version of the PD/A CRSP *Research Report 00-150*

Documents that 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:

- *First Addendum to the Ninth Work Plan*
- *Third Addendum to the Eighth Work Plan*
- *Aquanews*—PD/A CRSP quarterly newsletter (4 issues)
- *Sixteenth Annual Technical Report*
- *Seventeenth Annual Technical Report*
- *Eighteenth Annual Administrative Report*
- *Eighteenth Annual Technical Report*

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 511 subscribers. The printed version is mailed to 50 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, 14 formal programs (seven masters, one Ph.D., and six bachelors degrees) were completed by CRSP-sponsored students. The following theses were completed this year with assistance from CRSP researchers:

Athauda, A.R.S.B., 2000. Ultra-sound immersion techniques to improve the efficiency of sex inversion of male tilapia population. M.S. thesis, Asian Institute of Technology, Bangkok, Thailand.

Contreras-Sánchez, W., 2001. Sex determination in Nile tilapia, *Oreochromis niloticus*: Gene expression, masculinization methods, and environmental effects. Ph.D. dissertation, Oregon State University, Corvallis, Oregon.

Hayes, J., 2001. The safe handling of 17α-methyltestosterone in tilapia aquaculture. M.S. project report, Oregon State University, Corvallis, Oregon.

Lanuza, J.A.D., 2000. Effect of stocking sizes on the growth and survival performance of Nile tilapia (*Oreochromis niloticus*) in ponds. Undergraduate thesis, Central Luzon State University, Muñoz, Nueva Ecija, Philippines.

Martínez, J.A., 2000. Socioeconomic characterization of farmers with and without a system of tilapia production in Honduras. B.S. thesis, Escuela Agrícola Panamericana El Zamorano, Honduras. (in Spanish)

McElwee, K.R., 2001. An analysis of water resource management in the Senegal River Valley. M.S. internship report, Oregon State University, Corvallis, Oregon.

Mejía, G.M., 2000. Study of the production costs for culture of tilapia on small and medium farms in five departments of Honduras. B.S. thesis, Escuela Agrícola Panamericana El Zamorano, Honduras. (in Spanish)

Molina, J.C., 2000. Study of the actual and potential demand for tilapia in five secondary cities in Honduras. B.S. thesis, Escuela Agrícola Panamericana El Zamorano, Honduras. (in Spanish)

Mwau, P., 2000. Nutrient dynamics with special reference to nitrogen and phosphorus in tilapia (*Oreochromis niloticus*)/catfish (*Clarias gariepinus*) polyculture ponds at Sagana Fish Farm, Central Kenya. M.S. thesis, University of Nairobi, Nairobi, Kenya.

Quan, V., 2000. Evaluation of the reproduction of tilapia (*Oreochromis niloticus*) in plastic and concrete lined and earthen ponds. B.S. thesis, Escuela Agrícola Panamericana El Zamorano, Honduras. (in Spanish)

Quispe, F., 2000. Evaluation of the production costs for tilapia fingerlings in Honduras. B.S. thesis, Escuela Agrícola Panamericana El Zamorano, Honduras. (in Spanish)

Thunjai, T., 2001. Pond soil pH measurement. M.S. thesis, Auburn University, Alabama.

Zelaya, O., 2001. Effects of water recycling on water quality and bottom soils in shrimp ponds. M.S. thesis, Auburn University, Alabama.

PROGRAM PROMOTION AND NETWORKING

The IMNC participated in University Day, a campus-wide event at Oregon State University designed to familiarize faculty and staff with programs on campus, and 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. An additional campus-wide event was held during International Week, in November 2000. The IMNC hosted a booth at this event also. Visitors were primarily faculty and students with an interest in international affairs.

Graduate Assistant Steve Sempier contacted eight organizations and educational institutions that have been included in *EdOp Net* to solicit their opinions regarding optimization

of *EdOp Net*'s listings of educational and job opportunities. This year, 188 new subscribers were added to *EdOp Net*'s email list, and 9 to the postal mail list.

Over the course of the reporting period, IMNC staff responded to more than 50 email requests for information received from countries around the globe, including: Mexico, Nicaragua, Panama, Jamaica, Haiti, Brazil, Chile, Gabon, Nigeria, Rwanda, South Africa, Pakistan, Philippines, Malaysia, Indonesia, Armenia, Canada, and the US.

Following are a sample of representative inquiries:

- A doctoral student in earth and environmental science was interested in aquaculture development for the mitigation of rural poverty in Latin America. She was pointed to CRSP publications of interest on the web as well as the FAO/CRSP report on the use of GIS to evaluate aquaculture potential in Latin America.

- A request came from a person in South Africa who was interested in using biosuccession to treat organic effluents and supply fish protein to a poor community. He was directed to several CRSP and non-CRSP researchers with experience in biological treatment of wastes, as well as several online and printed references.

- A group that makes periodical visits to Haiti to help a local pastor build schools and develop other community projects contacted IMNC regarding the possibility and feasibility of establishing a fishery as a source for food production. They were directed to past FAO reports that assessed the potential for fish farming in Central America and the Caribbean, as well as the PD/A CRSP website's publication section.

- A university professor in Chile wrote IMNC with a request for materials pertaining to sustainable aquaculture, general introductory information for beginning aquaculturists, and websites that cover related topics in sustainability and development. He was provided with an ample list of aquaculture-related websites, including general aquaculture sources and sites with aquaculture links, publications and videos, teaching resources, and information about sustainable development. He was also sent several PD/A CRSP publications, a publications catalog, and current issues of *Aquanews* and *EdOp Net*.

The PD/A electronic mailing list was migrated to a new, more robust server in February 2001. The list, renamed pdacrsp, 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.

Research Summary

Research Area: Production Optimization
Research Theme: Pond Dynamics Research
9PDR2/Pond soil characteristics and dynamics of soil organic matter and nutrients/Boyd [Final report]

For years aquaculturists have largely ignored bottom soils, but as levels of production have increased, it is apparent that bottom soils are an important factor in pond dynamics. During the Eighth and Ninth Work Plans, soil cores were obtained from ponds at PD/A CRSP sites in Thailand, Honduras, Kenya, Peru, and the Philippines and non-CRSP sites in Brazil and Ecuador. The data obtained on the composition of pond sediment were used to develop a system for classifying pond soils; this report mainly describes this system. The proposed system allows pond sediment to be classified using four primary and five secondary properties, as well as two optional tertiary properties. The primary properties used were pH, texture, sediment thickness, and organic matter status (mineral or organic in nature). The secondary properties used were organic carbon, carbon:nitrogen ratio, acidity, carbonates, and sodium adsorption ratio. The two tertiary properties used were the thickness of the F horizon and the oxidation status of the sediment surface; these may be used for classification when desired. Results from the pond soil studies also revealed information such as: reactions between pond soil and pond water occur primarily in the upper 2 to 10 cm layer; low pH, high acidity, and elevated organic matter concentration in surface sediment appear to be the most common chemical problem with pond soils; and accumulation of soft sediment in ponds is the most common physical problem with pond soils. These observations suggest that pond bottoms should be dried between crops and that ponds should be limed in order to reduce acidity and increase pH levels. It is anticipated that these findings will greatly improve pond soil management practices.

Research Area: Production Optimization
Research Theme: Feeds and Fertilizer Research
9FFR2/Growth performance and economic benefits of *Oreochromis niloticus*/*Clarias gariepinus* polyculture fed on three supplementary feeds in fertilized tropical ponds/Bowman [Final report; report title different than study title in *Ninth Work Plan*]

High-quality, nutritionally complete supplemental feeds produce high fish yields; however, this strategy is often impossible or inappropriate in countries where high quality feedstuffs are limited. In Africa, nutritionally complete diets for tilapia are very expensive, and poultry and bran diets are often substituted, both of which are nutritionally unbalanced. This experiment examined appropriate feed/fertilizer combinations for tilapia in order to increase natural food organisms in ponds and ultimately improve production. Three low-cost supplemental feeds were tested: rice bran, a commercially available pig finisher pellet, and a formulated, test-diet pellet. Fertilizer regimes were the same for all three diets, consisting of application of diammonium phosphate and urea. Results showed the locally available pig finisher pellets was the most profitable.

Research Area: Production Optimization
Research Theme: Feeds and Fertilizers Research
9FFR2A/Fish yields and economic benefits of tilapia/*Clarias* polyculture in fertilized ponds receiving commercial feeds or pelleted agricultural by-products/Lochmann [Final report]

Stable isotope ratios have been used to trace the assimilation of materials ingested by fish and hence estimate the relative contribution of different feedstuffs to fish growth. In this component of a related Kenya Project feeding investigation (9FFR2), stable isotope ratios of carbon and nitrogen in three test diets, plankton, and Nile tilapia were analyzed. In the feeding study, caged tilapia had access only to plankton, while free-swimming fish consumed plankton and one of three test diets. It was anticipated that as fish assimilated food with a distinctive stable isotope signature, it would be possible to estimate the contribution of each food to growth. The free-swimming tilapia (those that ate both plankton and a test diet) showed isotopic evidence of a varied diet. However, growth during the experimental period (50% of final body weight) was not high enough to distinguish the influence of assimilation of different foods.

Research Area: Production Optimization
Research Theme: Feeds and Fertilizers Research
9FFR3/Reduction of feed rations below satiation levels in tilapia pond production/Brown [Final report; report title different than study title in *Ninth Work Plan*]

An important goal of CRSP feeds and fertilizers research is to optimize the economic benefits of all pond inputs. The use of supplementary feed in addition to fertilization has improved tilapia yields economically, but while using commercial feeds ensures rapid growth of fish, feed costs often demand 60 to 70% of total production costs. Good feeding procedures are important in order to minimize feed wastage and deterioration of water quality. The goal of this study was to evaluate growth, yield, and survival for tilapia fed daily at 100 and 67% of experimentally determined satiation. Two ponds stocked with sex-reversed Nile tilapia at each of the nine participating farm sites were assigned one of each of the two treatments. All ponds were fertilized weekly with urea and ammonium phosphate at a rate of 28 kg N ha^{-1} wk^{-1} and 5.6 kg P ha^{-1} wk^{-1}, and water quality parameters were monitored monthly using standard methods. A sample of 50 fish was obtained from each pond every month to measure average weights of the fish. After 120 days, the ponds were harvested and the total number of fish were counted and bulk-weighed. Results at harvest showed that there were no significant differences found in mean weights, daily weight gains, fish yields, extrapolated

gross yields, and survival between the two satiation levels tested. Fish fed at the reduced satiation level displayed a better feed conversion ratio than those fed at full satiation, and the reduction in the amount of feed used amounted to about US$400 savings in terms of feed costs. The results of this study may be readily accepted by tilapia farmers who seek to reduce production costs without compromising yields or quality.

RESEARCH AREA: PRODUCTION OPTIMIZATION
RESEARCH THEME: FEEDS AND FERTILIZERS RESEARCH
9FFR5/Educational development activities in support of tilapia aquaculture in the Philippines/Brown [Final report; report title different than study title in *Ninth Work Plan*]

The objective of this activity was to further the formal education and training of a graduate student in the Aquaculture masters or doctoral program at the Freshwater Aquaculture Center of Central Luzon State University (CLSU) and to improve the capabilities of aquaculture teaching laboratories at this facility. During the time of this activity, graduate student Eddie Lopez was supported during the concluding stages of his doctoral studies. The student's research, including descriptive and experimental components, investigated the interactions of growth, survival, and social behavior of genetically manipulated tilapia. In addition, improvements of facilities at CLSU were made, including the construction of 15 concrete tanks for student and faculty research. A Fisheries Information and Learning Center is also being set up to catalog and maintain various aquaculture and fisheries references. The improvements should benefit all students and faculty at the Freshwater Aquaculture Center at CLSU.

RESEARCH AREA: PRODUCTION OPTIMIZATION
RESEARCH THEME: FEEDS AND FERTILIZERS RESEARCH
9FFR6/Development of training modules for aquaculture extension workers and university students in Kenya/Bowman [Final report]

Lack of technical training is a major reason for the low output of fish ponds in Kenya. The objective of this activity was to increase the capability of the Department of Fisheries at Moi University (MU) in order to improve aquacultural practices in the region. This activity provided funds and mentoring to allow one faculty member from the MU Department of Fisheries to travel to Auburn University (AU) to learn technical skills needed in order to prepare training modules for use in training courses in Kenya. Charles Ngugi of MU spent about eight weeks in the US developing three complete training modules including: Introduction to Aquaculture–An Overview, Pond Construction–Site Selection, and Pond Management and Maintenance. Ngugi also began work on a number of other modules, which will be adaptations of existing modules for the Kenya region. The activity has also provided MU faculty with improved computer and course preparation skills, which will lead to the development of better training materials and the more thorough dissemination of information to extension workers and university students in the region.

RESEARCH AREA: PRODUCTION OPTIMIZATION
RESEARCH THEME: REPRODUCTION CONTROL RESEARCH
9RCR5C/Masculinization of tilapia by immersion in trenbolone acetate: Detection of trenbolone acetate in water after treatment/Schreck [Final report]

Masculinizing Nile tilapia fry by immersion can be a good alternative to feeding the fry with food containing hormones, posing fewer risks to hatchery workers and the environment. Previous experiments have found that two 3-hour immersions in trenbolone acetate (TA) can successfully masculinize Nile tilapia fry. This experiment investigated the change in concentration of TA in the immersion water before and after treatment to determine the amount of hormone to use and to estimate the potential to reuse the treatment water. Nile tilapia were immersed twice for three hours in the steroid, then collected and sent to a laboratory for examination. Results showed that TA concentrations were highly variable at all times, indicating that a target dose for TA immersion is rarely achieved. The low concentrations of TA found in the treatment water before the fish immersion may explain the lack of masculinization that happened during this experiment. Results also showed that the steroid was present in the water even after the fish had been immersed, which suggests that reuse of the treatment water for consecutive treatments may be an improvement on this technique.

RESEARCH AREA: PRODUCTION OPTIMIZATION
RESEARCH THEME: REPRODUCTIVE CONTROL RESEARCH
9RCR5D/Masculinization of Nile tilapia fry by immersion in trenbolone acetate: Reuse of hormone solution and effects of temperature/Schreck [Final report]

If a technique were developed that could consistently masculinize tilapia fry using short-term treatments while presenting little or no risk to the environment, it could potentially replace the current method of administering hormones to fish through the diet, in which uneaten steroids accumulate in the pond sediment and eventually contaminate the water. Preliminary studies have shown that short immersions in the synthetic androgen trenbolone acetate (TA) may be a good way to masculinize Nile tilapia fry. TA is a synthetic steroid that is widely used in the cattle industry to enhance growth and is considered to be a very potent masculinizing agent. The objectives of this study were to 1) determine if masculinization of Nile tilapia fry by immersion in synthetic steroids is efficient in large-scale systems, 2) evaluate if the interaction of immersions with elevated temperatures improves masculinization rates, and 3) evaluate the potential for reuse of steroid solutions used in immersions. Fry were immersed twice for three hours each in the TA. Results showed that there were significantly more males in the groups treated with TA (55.9 and 61.6%) than in the control groups, but the amount of males was still far below the percentage of males recommended for aquacultural purposes. When the TA was reused, the treatments did not produce a significant number of males. Results also showed that elevating temperatures in combination with TA treatments did not result in a greater number of males. More research is needed to investigate immersion protocol and hormone treatments for masculinization.

RESEARCH AREA: PRODUCTION OPTIMIZATION
RESEARCH THEME: REPRODUCTIVE CONTROL RESEARCH
9RCR6A/Monosex tilapia production through androgenesis: Selection of individuals for sex inheritance characteristics for use in monosex production/Phelps [Final report]

One of the goals of CRSP reproduction control research is to develop short- and long-term solutions to reproduction technology problems. If tilapia reproduction is not controlled during the culture period, there will be few or no marketable fish after six months. All-male populations are preferred and can be created using hormone sex-reversal, but some consumers have concerns about eating hormone-treated fish. Inter- and intraspecific breeding programs can also result in populations high in males but give inconsistent results. Sex inheritance in Nile tilapia does not conform to a 1:1 ratio of females to males, as would be expected from a simple Mendelian XX:XY sex determination process. This study used cross-breeding among and within nine families of Nile tilapia to determine a true-breeding tilapia strain. Results from the 88 spawns collected showed that sex ratios did not appear to be passed on from one generation to another. The offspring from sibling mating within each family had a wide range of sex ratios from 19 to 86% male, and no family with skewed sex ratios produced offspring with similarly skewed ratios. This lack of consistent sex ratios in the offspring provided evidence that a YY breeding program to produce all-male offspring in Nile tilapia is not likely to succeed.

RESEARCH AREA: PRODUCTION OPTIMIZATION
RESEARCH THEME: REPRODUCTIVE CONTROL RESEARCH
9RCR7/Monosex tilapia production through androgenesis/ Shelton [Final Report]

As part of a five-year effort to produce all-male tilapia populations without the use of steroids, this investigation was designed to examine the mechanism of sex determination in Nile tilapia and to develop a chromosome manipulation protocol for the production of progeny with only a paternal genome. However, the severe temperature and UV shocks necessary to accomplish ploidy manipulation resulted in very high mortality, and none of the androgenotes survived to maturity. The lack of survival of androgenotes, combined with ongoing uncertainty as to the mechanism of sex determination in tilapia, indicated a likelihood of continued failure. Thus, the study was terminated.

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

This investigation sought to increase the efficacy and efficiency of masculinizing hormones in producing all-male populations of tilapia. In efforts to control unwanted reproduction of tilapia and because males are preferred since they grow faster than females, the practice of masculinizing tilapia has been developed using various types of hormones. Current methods of masculinizing tilapia populations include adding hormones into feed; however, hormones are unevenly distributed to the fish and potentially unsafe because the hormone-containing feed dissolves in water over time. Immersion of fish in hormone-containing solution has also been practiced to masculinize tilapia. This study explored the use of ultrasound to improve the effectiveness of immersion. Three experiments were carried out to evaluate variation in hormone type and dosage, duration of exposure, and influence of cavitation-level ultrasound. The first experiment used treatments in one- and two-hour durations to assess the effects of two hormones at concentrations of 100 and 500 mg l^{-1}. Results indicated that two-hour immersion combined with ultrasound produced consistently larger percentages of males than one-hour treatments. The second experiment repeated the procedures of the first experiment, except that it used three replicates per treatment, used a lower MT dose of 50 mg l^{-1}, and tested the hormones MDHT and TBA at 100 and 250 mg l^{-1}. The experiment illustrated that all three hormones are potent masculinizers of tilapia, but results were clouded by high mortality due to a bacterial infection in the pond. In order to verify the results from the second experiment, a third experiment was carried out using only MDHT and TBA at two concentrations (100 and 250 mg l^{-1}), and with or without ultrasound treatments. Results showed that TBA at 250 mg l^{-1} with ultrasound was the most effective hormone in consistently producing a large percentage (98 to 100%) of male tilapia.

RESEARCH AREA: PRODUCTION OPTIMIZATION
RESEARCH THEME: NEW AQUACULTURE SYSTEMS/NEW SPECIES RESEARCH
9NS1/Lotus-fish culture in ponds: Recycling of pond mud nutrients/Diana [Final report]

Regular feeding and fertilization in fish ponds encourages the accumulation of nutrients, especially phosphorus, in pond mud. Pond muds have been used to fertilize land crops; however, removing pond mud is labor intensive, and its practicability is questionable. Aqueous macrophytes, like lotus, may be better able to utilize the phosphorus found in the pond soil. This experiment examined whether the alternative practice of lotus-fish culture can better recover these deposited nutrients. Ponds were cultivated with fish alone, lotus alone, and fish and lotus together. Fish were stocked at 2 fish m^{-2}, and lotus plants were stocked at 20 plants per 200-m^2 pond. Treatment ponds stocked with tilapia were fertilized weekly at rates of 28 kg N and 7 kg P ha^{-1} wk^{-1}; no fertilizer was applied in ponds with lotus alone. Results showed that lotus co-cultured with tilapia or alone in ponds effectively took up nutrients in old pond mud by about 2.4 t N and 1 t P ha^{-1} yr^{-1}. Nile tilapia cultured alone grew significantly better than those co-cultured with lotus, while there was no significant difference in lotus growth between treatments. Since dead lotus leaves were not removed from the ponds, the shading effect of the leaves could have caused the slow growth and higher morality of tilapia in the lotus-tilapia co-culture system in this experiment. The experiment showed an effective way to remove nutrients from old pond mud using lotus plants and to feasibly rotate or co-culture lotus and Nile tilapia; however, more research is needed to refine the system and make it more profitable.

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

9NS2/Culture of mixed-sex Nile tilapia with predatory snakehead/Diana [Final report]

Intensive culture of Nile tilapia often leads to overpopulation in ponds, resulting in a shortage of food for the fish, which stunts their growth. In areas where all-male tilapia populations cannot be produced, predation of tilapia offspring may prove an effective means of controlling reproduction. Predators such as snakehead (*Channa striata*) have been reported as effective in reducing population numbers. This experiment examined the efficiency of snakehead in controlling tilapia reproduction and their effect on tilapia growth and production. The experiment included six treatments: monoculture of sex-reversed all-male tilapia, monoculture of mixed-sex tilapia, and polyculture of snakehead and mixed-sex tilapia at stocking ratios of 1:10, 1:20, 1:40, and 1:80. Results showed that snakehead were able to completely control overpopulation of Nile tilapia at the low predator:stocked-prey ratio of 1:80; however, considering all growth parameters, the best predator: stocked-prey ratio was 1:20. All of the predator treatments were profitable, and the mixed-sex culture produced significantly higher net return than the sex-reversed culture. Polyculture at the lowest ratio of 1:80 showed the highest net return, followed by the 1:20 ratio. Results also showed that while adding snakehead into Nile tilapia ponds did not result in significantly greater tilapia growth, it did lower total net and gross yields of tilapia recruited (but only compared to mixed-sex fish).

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

9NS3 and 6/Development of sustainable pond aquaculture practices for *Colossoma macropomum* and *Piaractus brachypomus* in the Peruvian Amazon [Final report; report title different than investigation title in *Ninth Work Plan*]

The culture of two species native to the Peruvian Amazon, *Colossoma macropomum* (gamitana) and *Piaractus brachypomus* (paco), form the basis of Peru Project research. Previous investigations into stocking density were continued, with paco tested at 4,000, 6,000, and 8,000 fish ha^{-1}; all three densities were shown to be economically viable, and the highest stocking density was the most profitable. Gamitana, with similar culture costs and market value 50% higher than that of paco, is even more profitable, although either species cultured at any density tested showed more profit potential per hectare than pineapple, the next most profitable agricultural product in the region. A second component of the study examined reproduction of the two species. A hormone, LHRHa, was identified as successful in inducing spawning of paco. Gamitana was not successfully induced to spawn. Additional components involved training technicians in laboratory and pond practices, producing a Spanish-language manual on reproduction of paco and gamitana, and conducting outreach activities to regionalize the results of CRSP Peru Project research.

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

9NS3A/Spawning and grow-out of *Colossoma macropomum* and/or *Piaractus brachypomus*/Lochmann [Final report]

Colossomid broodstock cultures in Iquitos, Peru, are limited by the inability to spawn consistently, which may be caused by inadequate nutrition. This study analyzed broodstock feedstuffs and diet in order to make recommendations for nutrition to maximize spawning. Results showed that the energy:protein ratio is too low in the broodstock diet, causing the fish to metabolize for basic maintenance requirements protein needed for gamete production. These results also revealed that there is an apparent lack of lipids in fertilized colossomid eggs. Both of these problems can be solved by supplementing the diet with additional lipids. Studies have found that a 1:1 ratio of n-3 to n-6 fatty acids is optimal for most fish functions, including reproduction; however, colossomid eggs in this study appeared to have twice as many n-3 fatty acids as n-6 fatty acids. This condition could impair spawning and lower gamete and larval quality, as it has been known to do in other fish species. Since the main source of these fatty acids in the current broodstock diet is fish meal, it is recommended that a combination of fish meal and soybean meal be used to meet the fish's amino acid requirements. Fish should be fed diets containing eight to ten times the level of vitamin C required for optimal growth to increase the quality of their eggs. Both vitamins C and E should be supplemented in stabilized forms to prevent deterioration under conditions of high heat and humidity found in Iquitos. This study also examined carotenoids, but further research is necessary to identify an inexpensive source that could be used in Iquitos.

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

9NS4/Semi-intensive culture of red tilapia in brackishwater ponds/Diana [Final report; report title different than investigation title in *Addendum to the Ninth Work Plan*]

Many tilapia species, including Thai red tilapia, are capable of tolerating a wide range of salinities and can successfully grow in brackish water after proper acclimation. However, information on semi-intensive tilapia culture in saline ponds is almost nonexistent. In Thailand, shrimp culture is commonly reduced to one crop per year, leaving the ponds empty for large portions of the year, or in some cases the ponds have been abandoned due to failure of shrimp farming. The objectives of this experiment were to 1) determine appropriate fertilization regimes in brackishwater ponds, 2) investigate nutritional value and digestibility of marine phytoplankton, and 3) exploit underutilized or abandoned shrimp ponds for tilapia production. This experiment tested two fertilization regimes (28 kg N and 7 kg P ha^{-1} wk^{-1}, N:P = 4:1, and 14 kg N and 7 kg P ha^{-1} wk^{-1}, N:P = 2:1) and three salinity levels (10, 20, and 30‰). Results showed that Thai red tilapia grew better in brackishwater ponds than in freshwater ponds in semi-intensive fertilization culture systems, with the best growth performance and highest net return from ponds fertilized with the N:P

ratio of 2:1 at 10‰ salinity. These data provide farmers of the coastal zones of Southeast Asia with a low-risk use of their shrimp ponds.

RESEARCH AREA: PRODUCTION OPTIMIZATION
RESEARCH THEME: NEW AQUACULTURE SYSTEMS/NEW SPECIES RESEARCH
9NS5/Supplemental feeding for semi-intensive culture of red tilapia in brackishwater ponds/Diana [Final report]

Developing alternative aquaculture systems to aid in the use of underutilized resources is an important goal of new aquaculture systems research. A large number of shrimp ponds in Southeast Asia and Central and South America are left underutilized or abandoned due to failure of shrimp farming or the farmer's desire to diversify shrimp culture. The purpose of this experiment was to determine appropriate levels of supplemental feeding in fertilized brackishwater ponds for maximum growth of red tilapia and to provide farmers with a cost-effective alternative to leaving their shrimp ponds empty. Five different supplemental feeding regimes consisting of 0, 25, 50, 75, and 100% of satiation were tested. Red tilapia fingerlings were stocked in 15 net cages suspended in an earthen pond and cultured for 90 days. The pond was maintained at 10‰ salinity and fertilized weekly at rates of 4 kg N and 1 kg P ha^{-1} d^{-1}. Results showed that growth and yield of the tilapia increased significantly with increased feeding rates from 0 to 75% satiation, while there were no significant differences between 75 and 100% of satiation. The feed conversion ratio was significantly better with lower percentages of satiation feeding, and total weight gain of the tilapia was linearly and positively correlated with total feed input to cages. Partial budget analysis indicated that supplemental feeding at 25 to 75% satiation was profitable for red tilapia, but 50% satiation feeding was the most efficient rate.

RESEARCH AREA: ENVIRONMENTAL EFFECTS
RESEARCH THEME: EFFLUENTS AND POLLUTION RESEARCH
9ER2D/Fate of methyltestosterone in the pond environment: Use of MT in earthen ponds with no record of hormone usage/Schreck [Final report]

This is the fourth phase of an investigation examining the fate of 17α-methyltestosterone (MT) used to masculinize Nile tilapia fry in the pond environment. The first two phases found that MT persists in soil for up to eight weeks after treatment termination in model and actual ponds. The third phase found that MT in soils in model ponds had little masculinizing effect on fish. This final phase examined the buildup and persistence of MT in soils in a pond in Mexico used for masculinizing fry. MT was not detectable in water at any point in the trial and was detected in soils only after 10 days of administering MT-treated feed to fry. MT concentration did not correlate with proximity to feeding location nor did it gradually increase over time. Bacterial degradation of the steroid and patchiness due to uneven food deposition or mixing may have contributed to the variable MT levels. Another component of this investigation was the production of a Spanish-language manual on safe and effective use of MT to masculinize fry.

RESEARCH AREA: ENVIRONMENTAL EFFECTS
RESEARCH THEME: EFFLUENTS AND POLLUTION RESEARCH
9ER4/Effects of water recycling on water quality and bottom soils in shrimp ponds/Boyd [Final report; report title different than investigation title in *Addendum to the Ninth Work Plan*]

Shrimp aquaculture pond water can become overly rich in mineral and organic nutrients when excessive amounts of fertilizer and feed are used to produce shrimp, and water quality can be compromised. A conventional practice to replace degraded water in shrimp ponds is to exchange the old water with cleaner water, but the effluents can have negative impacts on receiving waters. An alternative to water exchange may be to recycle pond water in an oxidation pond. This study evaluated changes in chemical characteristics of pond water, soils, and shrimp yields in response to water recycling. Results showed no differences in water quality between ponds with recycled water and ponds without it. Also, no differences among treatments were observed for soil pH; concentrations of carbon, sulfur, and nitrogen; soil respiration; and phosphorus absorption capacity. It was concluded that recycling water from a production pond through an oxidation pond of equal volume had minimal to no effect on water quality or shrimp yields.

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

On-farm testing in 52 ponds, with 30 participating farmers, was conducted in Kenya's Central Province to determine whether research-based technologies are directly transferable to the farm, as well as to help farmers and extension agents understand stocking strategies and pond management options. A three-fold increase in production was obtained, and farmers were able to evaluate technologies and make informed decisions about increasing fish production in their own ponds under local conditions. The trials also allowed project personnel to train fisheries extension agents, thereby complementing the training they will receive through other Kenya Project activities.

RESEARCH AREA: ENVIRONMENTAL EFFECTS
RESEARCH THEME: APPROPRIATE TECHNOLOGY RESEARCH
9ATR2/Linkages of aquaculture within watersheds and concurrent design of hillside ponds/Verma [Final report]

The hillsides of Central America and the Andean region cover about 1 million km^2 and provide livelihood for some 20 million people, half of whom are small-scale farmers living in marginalized, rural communities. Introducing tilapia production to the hillside regions of Central America could improve nutrition and provide additional income for farm families and local communities. A levee pond design model was developed for extension personnel to use as they assist local producers in building hillside ponds. The levee pond model is an Excel® spreadsheet that computes a volume balance on a levee pond. The model can compute the inflow

of water needed to balance net seepage and evaporation and can determine the pump-in and pump-out rates needed to reach a target volume change per month. A spillway design is also provided based on an empirical spillway design approach. The model is currently in verification and testing and is expected to benefit locations previously determined to have market potential.

RESEARCH AREA: SOCIAL AND ECONOMIC ASPECTS
RESEARCH THEME: MARKETING AND ECONOMIC ANALYSIS RESEARCH

9MEAR3/Development of Central American markets for tilapia produced in the region/Engle [Final report]

Virtually no research has been done on the potential to develop domestic markets for tilapia in Central America. If markets are not expanded and developed, increased production of tilapia will result in declining prices, having a negative impact on Central America's tilapia industry. The objective of this activity was to conduct an analysis of potential Central American markets for tilapia and to develop marketing strategies for tilapia produced in the region. Surveys of supermarkets, fish markets, and restaurants were conducted between 1999 and 2000 in both Honduras and Nicaragua in order to characterize each outlet in terms of business, clientele, and types of fish sold. Questions specifically about tilapia included volumes, prices, suppliers, product forms, supply problems, and market channels used. Results from the Honduras surveys showed that tilapia is a well-known product and that tilapia sales have increased in recent years. Reasons for not selling tilapia included availability problems, lack of demand, and freshness problems. Negative ratings of tilapia by some respondents may have to do with the poor quality of wild-caught tilapia also sold in the markets. Strategies to improve domestic markets in Honduras should include offering catch-of-the-day promotions in restaurants, sampling and in-store demonstrations in supermarkets, and informing consumers about the differences between wild-caught and farm-grown tilapia. Results from the surveys conducted in Nicaragua showed that open-air markets were selling less tilapia than in prior years, but supermarket surveys indicated that their tilapia sales had increased. Reasons vendors did not sell tilapia included an inconsistent supply, odor problems, and consumer fear that the fish came from Lake Managua, which is contaminated. Strategies for improving tilapia marketability in Nicaragua include developing markets in upscale restaurants and educating consumers to alleviate contamination fears.

RESEARCH AREA: SOCIAL AND ECONOMIC ASPECTS
RESEARCH THEME: MARKETING AND ECONOMIC ANALYSIS RESEARCH

9MEAR4/Economic and social returns to technology and investment in Thailand/Engle [Final report]

The farm-level economic impacts of three aquaculture production technologies in Thailand were compared with the fertilization technology developed by the PD/A CRSP. Assuming adequate resources exist on the farm, the combination of intensive fertilization practices and monoculture of sex-reversed tilapia developed by the PD/A CRSP produced the most profitable technology. However, given the limited resources generally available on farms in northeastern Thailand, the optimal model would be that four out of five ponds be stocked in the extensive polyculture system and only one pond stocked in tilapia monoculture. Thus, despite the expected strong impact of PD/A CRSP technologies, the lack of operating capital common throughout the country will sharply constrain the adoption, implementation, and impact of these technologies.

RESEARCH AREA: SOCIAL AND ECONOMIC ASPECTS
RESEARCH THEME: MARKETING AND ECONOMIC ANALYSIS RESEARCH

9MEAR5/Rapid economic evaluation tools/Hatch [Final report]

The adoption of pond aquaculture depends in part on its expected net returns. This investigation aimed to provide research and extension workers with a user-friendly rapid evaluation tool with which to assess the potential economic risks of a given technology. In the second year of this study, researchers tested the rapid decision economic tool by testing two case studies; using the tool, the economic risks were evaluated for an independent, small-scale tilapia producer in Honduras and for three production practices for small-scale production, also in Honduras. With the @Risk add-in to the Excel® program, the user can enter data on the minimum, most-likely, and maximum values to determine their percentage of risk. The current version of the tool provides an easy and flexible way to evaluate the risks of small-scale tilapia production systems.

RESEARCH AREA: SOCIAL AND ECONOMIC ASPECTS
RESEARCH THEME: ADOPTION/DIFFUSION RESEARCH

9ADR3/Aquaculture training for Kenyan fisheries officers and university students/Bowman [Progress report]

A major reason for the low output of fish ponds in Kenya is a lack of technical training on all levels of production. This activity sought to produce a number of trainers with extensive practical fish production experience. In the current reporting period the Kenya Project continued scholarship support for two M.S. students, one at Moi University in Eldoret, Kenya, and one at Auburn University in Alabama. Also, the series of short courses for personnel of the Kenyan Fisheries Department (FD) was concluded during this reporting period; more than 80 FD staff received two weeks of training in pond construction and pond management techniques. An additional 26 people received three weeks of advanced training in pond construction, pond management, and business planning. Additional field days for about 50 farmers are planned for later in 2001.

RESEARCH AREA: SOCIAL AND ECONOMIC ASPECTS
RESEARCH THEME: ADOPTION/DIFFUSION RESEARCH

9ADR4/Establishment of companion sites in the Africa region/Bowman [Final report]

Research at an African site has been a major component of the PD/A CRSP since its beginning in 1982, and has mostly centered around the Rwasave Fish Culture Station in Rwanda and the Sagana Fish Farm in Kenya. During this

reporting period the Kenya Project proposed to establish at least one companion site in the Africa region and to design and implement investigations at that site in accordance with the goals of the CRSP and the companion site. The sites selected were the ICLARM-Malawi National Aquaculture Center in Zomba, Malawi, and Bunda College near Lilongwe, Malawi. The results of the investigations conducted during this time are detailed in the reports 9ADR4A and 9ADR4B.

RESEARCH AREA: SOCIAL AND ECONOMIC ASPECTS
RESEARCH THEME: ADOPTION/DIFFUSION RESEARCH
9ADR4A/Effect of stocking size and nutrient inputs on productivity of *Oreochromis shiranus* in ponds/Bowman [Final report]

Malawian small-scale farmers widely practice extensive tilapia culture using the indigenous *Oreochromis shiranus*; however, stocking sizes and inputs vary greatly in these systems due to the lack of information available on the optimal fingerling size for increased efficiency of fish production. During the production cycle, stock manipulation is complicated and may be difficult to implement on small-scale farms. This study was designed to evaluate the production and profitability of tilapia in experimental ponds using three different fingerlings stocking sizes and two isonitrogenous pond input regimes and to recommend a fingerling stocking size and input regime that will result in improved production and profitability. During this study, inputs were applied to ponds stocked with fish at three stocking sizes so that each input regime supplied 20 kg N ha^{-1} wk^{-1}, and fish were stocked at a rate of 2 fish m^{-2}. Results showed that there were no significant differences in water quality between treatments, and all water quality parameters except water temperature were within acceptable limits. Results also showed that stocking fish at 5 g resulted in higher fish production and gross margin compared to stocking larger fish. Under certain conditions where inorganic fertilization is used, substituting napier grass for maize bran increases profitability without affecting overall fish yield. This study will provide extension workers with stocking strategies to profitably grow tilapia in fertilized ponds in Malawi.

RESEARCH AREA: SOCIAL AND ECONOMIC ASPECTS
RESEARCH THEME: ADOPTION/DIFFUSION RESEARCH
9ADR4B/Studies on potential use of salinity to increase growth of tilapia in aquaculture in Malawi/Bowman [Final report]

In agriculture, soils may be too saline to support profitable crop husbandry; such soils may be used alternatively for productive aquaculture if a salinity-tolerant fish species is used. In landlocked Malawi, there is only freshwater aquaculture at small-scale and semi-commercial levels with little knowledge about the environmental requirements of and best management practices for many of the currently cultured species. A classification of cultured tilapias based on differences in their metabolic rates in seawater and fresh water in Malawi was totally unknown before this study, which was conducted to determine which tilapia species could be best cultured in Malawi. Five taxonomic groups of tilapia were observed in waters of three salinity levels (0, 10, and 20‰). *Tilapia rendalli* and *Oreochromis shiranus shiranus* demonstrated the best growth in fresh water, so the range of these species would be effectively limited by salinity in the natural waters of Malawi and surrounding southern African countries. Also, this study found that *O. shiranus chilwae* (both Bunda College and Lake Chilwa stains) and *O. karongae* are potential candidates for brackishwater aquaculture in Malawi. These findings suggest that Malawi's marginal lands could contribute significantly to increased food production, improved human health, improved income generation, and increased total national fish production from aquaculture.

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

An important goal of CRSP adoption/diffusion research is to provide guidance to extension workers in order to further increase acceptance of CRSP technologies in host countries. One of the challenges of developing aquaculture in Africa is disseminating the information developed as a result of CRSP research. The goal of this activity was to promote contact and communication among aquaculture researchers and extension agents through participation in and organization of regional meetings. The current reporting period's activity allowed researchers from the Kenya Project to attend and present at the World Aquaculture Society and PD/A CRSP annual meetings. These meetings provided opportunities for CRSP researchers to share their findings, learn from others' experiences, and establish linkages with other aquaculture researchers.

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

One goal of adoption/diffusion research is to assist extension workers to increase the adoption of CRSP-developed technologies in host countries. A number of methods developed as a result of CRSP research are available to farmers to minimize the cost of feeding tilapia grown in ponds in the Philippines. Currently this information is being spread by word of mouth, workshops, and newsletters. Through this activity extension materials were created and disseminated among tilapia farmers in the Central Luzon region of the Philippines. Extension brochures included information realized from over two years of CRSP Ninth Work Plan Philippines Project research on reducing costs in the initial phase of grow-out, the use of subsatiation feeding levels, and the cost benefit of using only light application of fertilizers. Since farmers in the Central Luzon region are generally receptive to the adoption of new technologies, it appears likely that a significant portion of the hundreds of farmers reached will implement what they learned from the brochures on their own farms.

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

The Honduras Project focuses on strengthening local capabilities to extend findings of CRSP research. The initial meetings showed that a large network of nongovernmental organizations (NGOs) in Honduras operates at the village level; improving the linkages among these NGOs could increase the effectiveness of their work. The objective of this activity was to create an environment for developing linkages in order to reach out to NGOs, extension agents, and farmers via a website, focus groups, training meetings, and printed documents. The Red de Desarrollo Sostenible-Honduras (RDS-HN) is a local network established to provide information about forest and natural resource systems. RDS-HN, in collaboration with Honduras Project investigators, was engaged in developing a Web-based Information Delivery System for Tilapia (WIDeST). WIDeST provides information on tilapia production and related topics, natural resources of Honduras, contact information for NGOs, chat-room facilities, and an email facility that allows users to ask questions and get answers from an expert. From its inception in March 2001 the website, <www.acuacultura-ca.org.hn>, had more than 6,800 visitors in just five months.

RESEARCH AREA: SOCIAL AND ECONOMIC ASPECTS
RESEARCH THEME: ADOPTION/DIFFUSION RESEARCH
9ADR8/Production strategies characterizing small- and medium-scale tilapia farms/Verma [Final report; report title different than investigation title in *Addendum to the Ninth Work Plan*]

This study examined Honduran farmers who do not currently grow tilapia and compared them to farmers in their region who have adopted tilapia farming. To obtain information, 128 farmers were selected at random and interviews were conducted. This sample constituted a representative portion of the population of small-scale farmers in Honduras. The analysis profiled basic differences between the two categories of farms, their operators, and their households in areas such as age, gender, marital status, and income. Results showed that younger farmers were more likely to become involved with tilapia farming, married farmers were more likely to grow tilapia, and those who grow tilapia reported having higher average incomes than non-tilapia growers. The results of this study will provide additional guidance to the technology development and outreach efforts of the PD/A CRSP in Honduras.

RESEARCH AREA: SOCIAL AND ECONOMIC ASPECTS
RESEARCH THEME: ADOPTION/DIFFUSION RESEARCH
9ADR9 and 10/Technical assistance for fingerling production serving small- and medium-scale tilapia producers & Training and technical assistance for Honduras institutions working with small- and medium-scale tilapia producers/Verma [Final report]

Two critical issues facing smaller-scale tilapia farmers in Honduras are an inconsistent and often insufficient supply of fingerlings, especially for those in remote areas, and the lack of availability of technical assistance. Farmers find that transport of the fingerlings is difficult, costly, and hard to organize. A number of nongovernmental organizations (NGOs) have been active in rural development, but the amount of technical information available is insufficient for productive pond management. The first objective of this activity was to provide information required to develop and strengthen small- and medium-scale producers of tilapia fingerlings. The second objective was to identify the NGOs and agencies interested in incorporating small-scale fish farming into their development programs and then provide technical assistance and training to their field staff. During this reporting period a two-day technical workshop was held for actual and prospective fingerling producers, and more than 30 publications on fingerling production and pond management practices were incorporated into a web-based information system developed in cooperation with a local NGO. Also, 20 NGOs expressed their willingness to incorporate aquacultural development into their programs.

RESEARCH AREA: SOCIAL AND ECONOMIC ASPECTS
RESEARCH THEME: ADOPTION/DIFFUSION RESEARCH
9ADR11/A manual of fertilization and supplemental feeding strategies for small-scale Nile tilapia culture in ponds/Diana [Final report]

The PD/A CRSP has been working to improve aquaculture in Thailand continuously since 1982. This activity was conducted to summarize the PD/A CRSP work on Nile tilapia pond culture in Thailand. A manual was developed aiming to provide simple guidelines of fertilization, supplemental feeding, and pond management for small-scale Nile tilapia pond culture and to provide simple extension and training materials to extension workers, trainers, and well-educated farmers. Small-scale fish farmers in Asian countries should benefit from the use of this manual through effective use of organic and inorganic fertilizers and feeds to increase fish production, achieve higher economic returns, and reduce environmental impacts.

RESEARCH AREA: SOCIAL AND ECONOMIC ASPECTS
RESEARCH THEME: REGIONALIZATION ACTIVITIES
9RA1/Establishment of new collaboration in Bangladesh/Diana [Final report]

The PD/A CRSP has not yet expanded to Southern Asia, where a large part of the population might benefit from improved aquaculture, especially in countries like Bangladesh. Fisheries and aquaculture are particularly important to Bangladesh's economy in terms of nutrition, income, and employment, but population growth is rapidly degrading natural habitat and drastically reducing the availability of fish to Bangladesh's people. Indian major carps have been the dominant cultured species, but tilapia is now playing an increasing role in solving problems of malnutrition and alleviating poverty in Bangladesh. Activities were conducted by researchers at the Asian Institute of Technology in order to establish a new link to a Bangladesh institution and to identify a potential PD/A CRSP site in Bangladesh. Contact

was made with Bangladesh Agricultural University (BAU), the sole trainer of fisheries and aquaculture graduates in Bangladesh, where interest was expressed in the potential development of collaborative research activities between the PD/A CRSP and BAU. Several nongovernmental organizations also expressed interest in collaborating to maximize fish production, maintain good water quality, reduce environmental degradation, and maximize economic returns in Bangladesh.

RESEARCH AREA: SOCIAL AND ECONOMIC ASPECTS
RESEARCH THEME: DECISION SUPPORT SYSTEMS RESEARCH
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 in order to continually supply fish to markets or processors. The distribution of fish sizes over time can be modeled mathematically in order to estimate growth and harvest parameters. This study focused on developing software tools that could analyze the fish population size distributions in commercial catfish operations in the southeastern US and also be adaptable to other types of operations and locations. During this reporting period, progress was made in two primary areas: continued development of models of size distributions and their dynamics through time related to biological and management factors; and software development for the decision tool deliverable from this study.

RESEARCH AREA: SOCIAL AND ECONOMIC ASPECTS
RESEARCH THEME: DECISION SUPPORT SYSTEMS RESEARCH
9DSSR3/Enhancing the POND decision support system for economics, education, and extension/Bolte [Progress report]

This investigation enhances and refines the POND© software to better manage commercial production facilities, primarily by applying the core models of facility processes to applied management. Efforts include creating tutorials for easier use in educational and extension environments, updating the user's manual, and incorporating a shrimp growth and development model into POND©. With these additions, POND© has become a powerful decision support tool of the PD/A CRSP available to end users worldwide via the Internet.

RESEARCH PROJECTS

POND DYNAMICS RESEARCH

Subcontract No. RD010A-07

Staff

Auburn University, Alabama

Claude E. Boyd	US Principal Investigator
C. Wesley Wood	US Principal Investigator
Brenda Wood	Technician
Taworn Thunjai	Graduate Assistant (Thailand; CRSP funded)
Oscar Zelaya	Graduate Assistant (Honduras; CRSP funded)
Kom Silapajarn	Graduate Assistant (Thailand; from May 2001; partially CRSP funded)
Orawan Silapajarn	Graduate Assistant (Thailand; from May 2001; partially CRSP funded)
Francisco Gomes	Graduate Assistant (Portugal; from June 2001; partially CRSP funded)

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 five PD/A CRSP research sites (Honduras, Peru, Kenya, the Philippines, and Thailand) as well as at non-CRSP sites in Ecuador and Brazil 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:

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

Note: The schedule for 9PDR2 was modified. The revised schedule appears in the *Addendum to the Ninth Work Plan*.

Networking

Members of the CRSP Pond Dynamics project visited several countries to collect soil samples for their research. Boyd, Wood, and Thunjai visited the University of the North, South Africa. Together they collected pond soil cores at three sites and discussed possible future collaboration with Koos Prinsloo, Johan Theron, and Andrew Scholtz of the Aquaculture Program at the University of the North. Boyd and Thunjai also visited Centro Nacional de Acuicultura e Investigaciones Marinas (CENAIM/ESPOL) in Ecuador on a separate trip where they collected pond soil cores from three ponds at one site. Boyd traveled to Thailand 13 to 25 June 2001 and visited an aquaculture site to observe bottom soil management techniques. He also visited inland ponds with low-salinity shrimp culture to observe environmental conditions in the ponds' vicinity and discuss with Mali Boonyaratpalin of Kasetsart University and Sidthi Boonyaratpalin of the Thailand Department of Fisheries. Finally, Greg Whitis traveled to Brazil 8 to 15 July 2001 where, with the assistance of Julio Queiroz of EMBRAPA, he collected pond soil samples from three ponds on a fish farm. Queiroz reciprocated by visiting Auburn University for four weeks and helping with analyses of soil samples collected in Brazil in June 2000.

Boyd presented data from the CRSP project (Water Quality Monitoring in Honduras) at workshops in Choluteca, Honduras, and Managua, Nicaragua. The workshops were funded with USDA Hurricane Mitch Recovery Funds, but nearly all of the data discussed were collected by CRSP researchers in Honduras. The workshops were held on 5 to 12 February in Honduras and 26 February to 6 March 2001 in Nicaragua.

During the year, a total of fourteen commercial aquaculture concerns contacted Boyd about soil information from CRSP research. This group consisted of six companies from Ecuador, two companies from Guatemala, one each from Colombia, India, Saudi Arabia, and Thailand, and five US companies.

Educational Outreach

Boyd presented a lecture on 1 August 2000 to the Ministry of the Environment at Muscat, Oman, on best management practices in aquaculture. He later presented a lecture on water and soil quality to faculty and students at Centro Nacional de Acuicultura e Investigaciones Marinas (CENAIM), San Pedro, Ecuador, on 24 May 2001.

Boyd used material from CRSP-related research in teaching the course "Water and Sediment Quality Management in Aquaculture" at Auburn University during fall of 2000. Two lectures were devoted to findings from the CRSP.

Boyd presented a workshop on inland shrimp farming to an estimated 250 farmers in Guayaquil, Ecuador, on 28 and 29

May 2001. PD/A CRSP soil data were an important aspect of the presentation.

Publications

Sonnenholzner, S. and C.E. Boyd, 2000. Managing the accumulation of organic matter deposited on the bottom of shrimp ponds… Do chemical and biological probiotics really work? World Aquaculture, 31(3):24–28.

Thunjai, T., 2001. Pond soil pH measurement. M.S. thesis, Auburn University, Alabama.

Thunjai, T., C.E. Boyd, and K. Dube, 2001. Pond soil pH measurement. Journal of the World Aquaculture Society, 32(2):141–152.

Presentations

Boyd, C.E. BMPs in aquaculture. Presented to AquaMexico at Culiacan, Mexico, 5–7 October 2000.

Boyd, C.E. BMPs in aquaculture. Presented to the Fourth Latin American Aquaculture Congress and Exhibition at Panama City, Panama, 25–28 October 2000.

Boyd, C.E. Best management practices (BMPs) for pond aquaculture. Presented to Aquaculture America 2001 at Orlando, Florida, 21–25 January 2001.

Boyd, C.E., J. Clay, and J. Hargreaves. Codes of conduct for improving environmental and social performance in shrimp farming. Presented to Aquaculture America 2001 at Orlando, Florida, 21–25 January 2001.

Sonnenholzner, S. and C.E. Boyd. Chemical and physical properties of shrimp pond bottom soils in Ecuador. Presented to Aquaculture America 2001 at Orlando, Florida, 21–25 January 2001.

Thunjai, T., C.E. Boyd, and W. Wood. Vertical profiles of bulk density, total carbon, total nitrogen, and total phosphorus in pond soil cores. Presented to Aquaculture America 2001 at Orlando, Florida, 21–25 January 2001.

Wood, W. Perspectives on use of best management practices in agriculture. Presented to Aquaculture America 2001 at Orlando, Florida, 21–25 January 2001.

Conferences

AquaMexico at Culiacan, Mexico, 5–7 October 2000. (Boyd)

International Aquaculture Conference at Panama City, Panama, 25–28 October 2000. (Boyd)

Aquaculture America 2001 at Orlando, Florida, 21–25 January 2001. (Boyd, Wood)

PD/A CRSP Annual Meeting at Orlando, Florida 26 January 2001. (Boyd, Wood)

Award

C.E. Boyd was selected as the Butler/Cunningham Eminent Scholar in Agriculture and the Environment at Auburn University.

POND SOIL CHARACTERISTICS AND DYNAMICS OF SOIL ORGANIC MATTER AND NUTRIENTS

Ninth Work Plan, Pond Dynamics Research 2 (9PDR2)
Final 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
Department of Fisheries and Allied Aquacultures
Auburn University, Alabama, USA

ABSTRACT

Soil cores were taken from ponds in Thailand, Honduras, Kenya, Peru, Brazil, and the Philippines. All cores could be delineated into F, S, M, T, and P horizons without difficulty. The major similarities among cores involved an increase in dry bulk density and a decrease in concentrations of total carbon, total nitrogen, and total sulfur with increasing depth into the sediment. There was wide variation in acidity, phosphorus, major cation and micronutrient concentrations, pH, texture, and color in samples from different sites, but differences in these variables with sediment depth did not follow clear trends. The S horizon, the main sediment layer that interacts with pond water quality, varied in thickness from 2 to 10 cm. Pond management should focus on neutralizing acidity and enhancing organic matter decomposition within the S horizon through liming and drying of pond bottoms between crops. Sediment accumulates in deeper parts of ponds over time, and soft sediment should be removed periodically.

Results of sediment analyses were used in formulating a pond soil classification system based on levels of primary and secondary sediment properties. The primary properties are pH, texture, sediment thickness, and organic matter status (mineral or organic in nature). The secondary properties are organic carbon, carbon:nitrogen ratio, acidity (exchangeable acidity and acidity from sulfide oxidation), carbonates, and sodium adsorption ratio. Two optional, tertiary properties, thickness of F horizon and oxidation status of the sediment surface, may be used in the classification system if desired. The classification system is described in this report.

REPRODUCTION CONTROL RESEARCH

Subcontract No. RD010A-02

Staff

University of Oklahoma, Norman, Oklahoma

William Shelton	US Principal Investigator
William Baker	Graduate Student (USA; through August 2000; 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*. 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. Ninth Work Plan research sought 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

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

- Monosex tilapia production through androgenesis/ 9RCR7. The report submitted for this investigation was a final report.

Note: 9RCR7 was terminated. The decision to terminate 9RCR7 is documented in the *Addendum to the Ninth Work Plan*.

Conference

PD/A CRSP Annual Meeting at Orlando, Florida, 26 January 2001. (Shelton)

MONOSEX TILAPIA PRODUCTION THROUGH ANDROGENESIS

Ninth Work Plan, Reproduction Control Research 7 (9RCR7) Final Report

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

ABSTRACT

Control of reproduction is vital to aquaculture and includes artificial propagation as well as management of unwanted recruitment. Developments in manipulation of the reproductive system provide options to enhance production. Nile tilapia, *Oreochromis niloticus*, spawning was managed by photoperiod and temperature manipulation. A controlled light cycle of 20L:4D and water temperature of 26 ± 2°C directed spawning to a predictable time frame. A developmental rate (τ_0) relationship was described and applied to chromosome manipulation. Blond Nile tilapia are homozygous recessive for a color mutation that was used as a phenotypic marker in the development of protocol for androgenetic induction, while the color pigmentation for red Nile tilapia is dominant over the wild type color pattern. Androgenotes were produced by neutralizing the female genome of normal color Nile tilapia or that of Red tilapia (600 J m^{-2} UV dose), eggs were activated with sperm from blond males or Ghana males, respectively, and then the eggs were diploidized with cold shock (11 ± 0.5°C for 60 min) applied at various times after incubation at 28 ± 0.2°C. Shock applied at 69 min post-activation produced greater numbers of androgenotes than shocks applied at 59 or 79 min post-activation; the shock application time of 69 min was used for induction with red tilapia stocks. Production of viable diploid androgenotes for crosses involving either red or blond and Ghana stocks was very low, and no progeny survived to maturity. Thus, neither verification of sex determination in androgenotes nor testing of monosex breeding was accomplished.

REPRODUCTION CONTROL RESEARCH

Subcontract No. RD010A-09

Staff

Auburn University, Alabama

Ronald P. Phelps	US Principal Investigator
Robert Carpenter	Graduate Research Assistant (USA; 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*. 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.

Work Plan Research

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

- Monosex tilapia production through androgenesis: Selection of individuals for sex inheritance characteristics for use in monosex production/9RCR6A. The report submitted for this investigation was a final report.

Note: Owing to delays, the scope of 9RCR6 was limited to 9RCR6A, Selection of individuals for sex inheritance characteristics for use in monosex production. Details of this change are documented in the *Addendum to the Ninth Work Plan*.

Conferences

Aquaculture America 2001 at Orlando, Florida, 21–25 January 2001. (Phelps)

PD/A CRSP Annual Meeting at Orlando, Florida, 26 January 2001. (Phelps)

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) Final Report

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

ABSTRACT

Intraspecific breeding programs have been developed to exploit the sex inheritance mechanism in the tilapia *Oreochromis niloticus* to produce male populations. These programs are built on the premise that the mechanism of sex inheritance must conform closely to a monofactorial sex determination with a heterogametic male. Sex inheritance in tilapia, however, appears to be more complicated. The sex ratio of an individual spawn often does not conform to the expected 1:1 ratio. A better understanding of sex inheritance in tilapia and the identification of tilapia populations with a minimum variation in progeny sex ratios from individual spawns is needed for a successful intraspecific breeding program to produce male tilapia.

Nine families of *O. niloticus*, each from individual pair spawns, were selected based on the sex ratio in the family. Two families were highly skewed to male (100% male), three were near 50% male, and four were skewed to female. Fish within the same family were mated, and the sex ratios of the progeny were determined. In the two families that were all males, the males were mated to females from a family with a sex ratio near 1:1. Ten sets of progeny per family were sexed with the exception of one family, from which only eight sets were available.

Sex ratios did not appear to be passed on from one generation to another in the fish used in our study. A realized heritability for sex ratio of –0.09 was calculated. No family with skewed sex ratios produced progeny from sibling matings with similarly skewed sex ratios. Family VIII, which had a 1:1 male:female ratio, had a range of 43 to 68% male in its sets of progeny. Family V, which was 22% male, gave 10 sets of progeny, of which five sets were > 70% male. Families II and VII, which were 100% male, when crossed with females from Family III gave sets of progeny ranging from 23 to 79% male. When the percentage of males in the female parent family (III, 40% male) was considered in matings with Families II and VII, 40 and 50% of the spawns, respectively, differed in sex ratios from the female parent family.

EFFLUENTS AND POLLUTION RESEARCH

Subcontract No. RD010A-19

Staff

Auburn University, Alabama

Claude E. Boyd	US Principal Investigator
Oscar Zelaya	Graduate Assistant (Honduras; CRSP funded)

Cooperators

Auburn University, Alabama
Bartholomew Green
David Teichert-Coddington

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 CRSPs Education Development Component. Responsibility for overseeing this activity was then 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*. 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

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

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

Note: 9ER4 was funded after publication of the *Ninth Work Plan*. The 9ER4 work plan appears in the *Addendum to the Ninth Work Plan*. The deliverable under this project was a thesis; however, for reporting purposes, a modification of the thesis was submitted.

Publication

Zelaya, O., 2001. Effects of water recycling on water quality and bottom soils in shrimp ponds. M.S. thesis, Auburn University, Alabama.

Presentation

Zelaya, O., C.E. Boyd, D. R. Teichert-Coddington, and D.B. Rouse. Effects of water circulation on water quality and bottom soil in shrimp ponds. Presented to Aquaculture America 2001 at Orlando, Florida, 21–25 January 2001.

EFFECTS OF WATER RECYCLING ON WATER QUALITY AND BOTTOM SOILS IN SHRIMP PONDS

Ninth Work Plan, Effluents and Pollution Research 4 (9ER4)
Final 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

This study evaluated changes in chemical characteristics of production pond water, soils, and shrimp yields in response to water recycling through an oxidation pond. Nine 0.1-ha ponds were stocked with *Litopenaeus vannamei* post-larvae. Three ponds were stocked with a high density of shrimp (50 m^{-2}), three were stocked with a low density of shrimp (25 m^{-2}), and three others were stocked with a high density of shrimp while pond water was recycled through an adjacent pond of equal volume not stocked with shrimp. The density of shrimp in low-density and high-density-with-recycling treatments was equal when based on the total water area of production and recycling ponds. Mean shrimp yields for low-density (LD), high-density (HD), and high-density-recycling ponds (HDR) were 1,706 kg ha^{-1}, 4,648 kg ha^{-1}, and 4,534 kg ha^{-1}, respectively. There was no significant difference ($P > 0.05$) in yields between HD and HDR treatments or between LD and HDR treatments when based on total water surface area. Mean harvest weights of individual shrimp ranged from 22 to 25 g and were not different ($P > 0.05$) among treatments. Recycling water from HDR ponds through an oxidation pond resulted in significant reductions in the mean mass weight of total nitrogen (TN) and total ammonia nitrogen (TAN) compared with HD ponds because HDR ponds used twice the water volume. The sum of the mean mass weight (kg) for water quality variables found in HDR ponds and oxidation ponds was significantly greater than the mean mass weight in HD ponds, except for nitrate-nitrogen (NO_3-N), nitrite-nitrogen (NO_2-N), and TAN. No differences were noted for water quality in HDR and LD ponds. No differences were observed among treatments for soil pH; concentrations of carbon, sulfur, and nitrogen; soil respiration; and phosphorus absorption capacity. We concluded that recycling water from a production pond through an oxidation pond of equal volume had minimum to no effect on water quality and shrimp yields. The major operational disadvantages of recycling water were that pond space was put into nonproductive use as oxidation ponds, and 3.3 times more energy was used for aeration and water circulation. It would be better to stock two ponds at half the rate instead of doubling the volume of water per pond by recycling through an oxidation pond.

MARKETING AND ECONOMIC ANALYSIS RESEARCH

Subcontract No. RD010A-01

Staff

University of Arkansas at Pine Bluff, Arkansas

Carole Engle	US Principal Investigator
Siddhartha Dasgupta	US Principal Investigator (through December 2001)
Ivano Neira	Graduate Research Assistant (Peru; CRSP funded)
Diony Monestime	Undergraduate Student (Haiti; from July 2000)
Nelson Omar Funez Flores	Undergraduate Student (Honduras; from September 2000)

Asian Institute of Technology, Pathumthani, Thailand

Harvey Demaine	Host Country Principal Investigator

Escuela Agrícola Panamericana El Zamorano, Honduras

Daniel Meyer	Host Country Principal Investigator

Background

The *Continuation Plan 1996* 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 was one goal of Ninth Work Plan research. Reaching a better understanding of risk and farmers' perception of risk is valuable in order to develop and encourage the adoption of technologies was 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 and Nicaragua was 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 final report.
- Economic and social returns to technology and investment in Thailand/9MEAR4. The report submitted for this investigation was a final report.

Note: The schedules for 9MEAR3 and 9MEAR4 were modified. The revised schedules will appear in the *Second Addendum to the Ninth Work Plan*.

Networking

Engle has been corresponding electronically with Harvey Demaine of AIT in Thailand throughout the period; they have been collecting data and are awaiting additional input from the field.

As a result of her CRSP work, Engle was invited to participate in a proposal that is being submitted to the National Research Initiative on evaluating impacts of 1890 research in the US. 1890 extension programs and research, which are based at historically black colleges and universities, carry scientific knowledge of agriculture, resource management, human development, and technology to farmers and urban residents.

CRSP researchers conducted surveys in Nicaragua in August and September 2000. During this period, they had contact with Agnes Saborio, David Hughes, Aldo Gutierrez, and several farmers to obtain background information and implement the survey. These contacts have continued via email since the trip to Nicaragua.

Engle received several email requests for information on tilapia markets in Central America and a number of information requests during the trip for a USDA training program regarding research conducted under the CRSP.

The CRSP researchers were invited to write a series of six articles for the *Global Aquaculture Advocate* regarding the six Nicaragua and Honduras surveys conducted under the CRSP project. They also submitted two articles to *Panorama Acuícola* about the marketing survey results.

Educational Outreach

Engle and Valderrama were invited by USDA to participate in training programs in Honduras and Nicaragua. They visited with USDA personnel at the USAID mission and met other mission personnel. The training programs included host country scientists, government officials, extension agents, and shrimp-farming cooperatives. Engle and Valderrama co-authored a training manual based on CRSP-funded project results that is being published by the USDA training project. The manual, titled "Shrimp Farm Business Management and Economics: A Training Manual," is being published in English and in Spanish.

Engle used her Honduras shrimp industry work as the basis for a case study in a UAPB class on aquaculture economics and marketing, as well as CRSP-related shrimp budgets, risk analysis, and a mathematical programming model in a course module on analytical techniques.

Publications

Dasgupta, S. and C.R. Engle, 2000. Non-parametric estimation of returns to investment in Honduras shrimp research. Aquaculture Economics and Marketing, 4(3–4):141–156.

Fúnez, O., I. Neira, and C. Engle, 2001. Honduras survey: 50% of supermarkets to sell tilapia. Global Aquaculture Advocate, 4(2):89.

Neira, I., O. Fúnez, and C. Engle, 2001. Honduras survey shows potential for tilapia. Global Aquaculture Advocate, 4(1):86.

Valderrama, D. and C. Engle. 2001. Risk analysis of shrimp farming in Honduras. Aquaculture Economics and Marketing, 5(1–2):49–48.
Valderrama, D. and C.R. Engle, 2001. Efectos en la rentabilidad y las estrategias de manejo de las fincas en Honduras, por las tasa de sobrevivencia del camarón blanco. Panorama Acuícola, 6(4):40–41.
Valderrama, D. and C.R. Engle. The effect of survival rates of white shrimp *Litopenaeus vannamei* on net farm income and optimal management strategies of Honduras shrimp farms. Aquaculture. (submitted)

Presentations

Neira, I. and C. Engle. The Honduran market for tilapia: Restaurant and supermarket surveys. Presented to Aquaculture America 2001 at Orlando, Florida, 21–25 January 2001.
Valderrama, D. and C.R. Engle. The effect of survival rates of white shrimp *Litopenaeus vannamei* on net farm income and optimal management strategies of Honduran shrimp farms. Presented to Aquaculture America 2001 at Orlando, Florida, 21–25 January 2001.

Conferences

Aquaculture America 2001 at Orlando, Florida, 21–25 January 2001. (Engle, Neira, Valderrama)
PD/A CRSP Annual Meeting at Orlando, Florida, 26 January 2001. (Engle, Neira, Valderrama)

Development of Central American Markets for Tilapia Produced in the Region

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

Carole R. Engle, Ivano Neira, Nelson Omar Fúnez, and Diony Monestime
Department of Aquaculture and Fisheries
University of Arkansas at Pine Bluff
Pine Bluff, Arkansas, USA

Abstract

Domestic markets for farm-raised tilapia could reduce market risk by providing alternative market outlets. Surveys of restaurants, supermarkets, and fish markets were conducted in Honduras and in Nicaragua between 1999 and 2000. Tilapia was well known in both countries. Wild-caught tilapia was sold by a majority of fish market vendors in both countries. Market penetration of tilapia products was greater in Honduras than in Nicaragua. In Honduras 40% of supermarkets and 30% of restaurants sold tilapia compared to 21% of restaurants and 26% of supermarkets that sold tilapia in Nicaragua. Both restaurants and supermarkets in both countries indicated that tilapia sales had increased over the previous year. Half of respondents who were not selling tilapia indicated that they were likely to begin selling tilapia the next year. In Honduras the primary reasons for not selling tilapia were availability problems, lack of demand, and freshness. In Nicaragua, however, the fear on the part of consumers that freshwater fish may be from Lake Managua and may be contaminated was a major constraint to tilapia sales. Marketing strategies in Honduras could focus on sales of whole-dressed tilapia to larger chain supermarkets with specialized fish sections and to international and middle-high income clients. In-store demonstrations, samples, and point-of-purchase information should be used to increase demand. Restaurant sales in both countries could likely be enhanced through catch-of-the-day promotions in upscale restaurants that feature product information supplied by tilapia growers. Fish markets in both countries and supermarkets in Nicaragua do not appear to be viable market outlets because wholesale tilapia prices appear to be too low for farm-raised products.

Economic and Social Returns to Technology and Investment in Thailand

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

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

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

Siddhartha Dasgupta
Aquaculture Research Center
Kentucky State University
Frankfort, Kentucky, USA

Abstract

Thailand has a long and rich history of aquaculture production. The Pond Dynamics/Aquaculture Collaborative Research Support Program (PD/A CRSP) has been involved in fish production research in Thailand since 1983. The economic impact of new technologies will depend upon farm-level benefits of the new technologies. However, if the new technologies require resources at a level not readily available to farmers, then the overall adoption rates and economic impacts will be lower. This study compares three aquaculture production technologies in Thailand with a fertilization technology developed by the PD/A CRSP to evaluate the farm-level economic impacts. Enterprise budgets were developed for each production technology. Price and cost data used in the analysis were pre-1998 data. These were used to formulate a whole-farm mathematical programming model. Farm resource levels specified in the model were based on survey data of small-scale fish farmers in northeastern Thailand. The production technologies evaluated included an extensive polyculture system that included tilapia, a more intensive polyculture of herbivorous fish including tilapia, monoculture of sex-reversed tilapia, and production of hybrid catfish. The enterprise budget analysis indicated that profits were highest for the tilapia monoculture system, second highest for the hybrid catfish

production system, third highest for the more intensive polyculture system, and lowest for the extensive polyculture system. However, total annual costs were highest for hybrid catfish production, followed in descending order by tilapia monoculture and more intensive polyculture, and were lowest for the extensive polyculture system. The majority of the costs of catfish production were for the feed, whereas feed, fry, and fertilizer costs were the most important cost categories for tilapia monoculture production. Urea and triple superphosphate (TSP) costs were most important for the more intensive polyculture system, whereas manure was the greatest cost for extensive polyculture production. Results of the whole-farm mathematical programming analysis showed that if adequate resources exist on the farm, the optimal production mix is to stock all ponds in tilapia monoculture in order to maximize profits. However, when the model was constrained to the level of resources typically available on farms in northeastern Thailand, four of five ponds would be stocked in the extensive polyculture system with only one pond stocked in tilapia monoculture. Parametric analyses indicated that operating capital was the key limiting factor and constraint. Net returns increased dramatically as operating capital levels increased and the mix of production technologies moved more towards the more profitable tilapia monoculture production. The technologies were not labor intensive and the availability of labor did not change the mix of production activities, even at very low levels of labor. Yield of monosex tilapia production was also a key factor. The analysis indicated that a yield of 4,000 kg ha^{-1} constituted a threshold below which the production mix excluded tilapia monoculture and substituted the more intensive polyculture system. The price analysis showed that, if tilapia prices fell to Baht 27 kg^{-1}, the production mix would switch to the more intensive polyculture from tilapia monoculture. Feed and fertilizer prices, even at four times the level identified from the survey, did not affect the choice of production technology. Hybrid catfish production would only enter the mix if extremely high levels of operating capital were available and if the price of catfish were at least Baht 29 kg^{-1}.

MARKETING AND ECONOMIC ANALYSIS RESEARCH

Subcontract No. RD010A-18

Staff

Auburn University, Alabama

Upton Hatch	US Principal Investigator
Jose Falck-Zepeda	Postdoctoral Research Associate (through March 2001)

Cooperator

Auburn University, Alabama
Tom Popma

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,* 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

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

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

Note: The schedule for 9MEAR5 was modified. The revised schedule appears in the *Addendum to the Ninth Work Plan*.

Networking

Hatch attended the course "El Cultivo Exitoso de la Tilapia" 2 to 6 October 2000 at the Escuela Agrícola Panamericana (Zamorano), Honduras. There he interacted with small producers, NGO representatives, and government officials in charge of abatement measures in electrical company dams. Two Peace Corps volunteers were also present. While there, Hatch established contacts with 13 Honduran people representing Zamorano, the Empresa Nacional de Energia Electrica, Grupo Granjas Marinas, Aquacorporacion, independent producers, and numerous nongovernmental organizations, including Honduras Outreach, Ayuda en Acción, Centro de Adiestamiento de la Agricultura Sostenible (CEASO), PRODEHCO, and Aldea Global.

Postdoctoral research associate José Falck-Zepeda joined the International Service for National Agricultural Research (ISNAR) in March 2001. This organization assists developing countries in improving the performance of their national agricultural research systems and organizations.

Educational Outreach

Hatch developed teaching materials based on the evaluation tool to be used by Tom Popma at a workshop held at Zamorano in March 2001.

Presentation

Hatch, U. Rapid economic evaluation tool. Presented to Aquaculture America 2001 at Orlando, Florida, 21–25 January 2001.

Conference

Aquaculture America 2001 at Orlando, Florida, 21–25 January 2001. (Hatch)

RAPID ECONOMIC EVALUATION TOOLS

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

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

Tom Popma
Department of Fisheries and Allied Aquacultures
Auburn University, Alabama, USA

ABSTRACT

The main objective of the project was to provide a user-friendly rapid economic evaluation tool which allows research and extension personnel to quantify possible outcomes of new tilapia production techniques and assess potential economic risk consequences of these techniques. We developed such a tool, having produced a first version for release. The quantitative tool allows the examination of not only mean response of tilapia production systems as reflected in economic budgets but also the risk associated with them. We present results from using the evaluation tool in the text. These results are based on available literature, a case study from an independent producer in Honduras, and results from the identification of three basic tilapia production technologies in Honduras. These results are not meant to be a diagnostic of the risk situation facing Honduras producers, rather to illustrate the potential uses of the evaluation tool by end users.

DECISION SUPPORT SYSTEMS RESEARCH

MOU No. RD009B

Staff

Oregon State University, Corvallis, Oregon

John Bolte	US Principal Investigator
Doug Ernst	Research Associate
Charles Hillyer	Graduate Assistant (USA; CRSP funded)
Trina Seibert	Graduate 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©) that allows simulation modeling and economic analyses of entire pond facilities. POND© 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.

Ninth Work Plan research in Decision Support Systems focused on improving the utility and interface of POND© software for education and extension purposes; including budget and cost capabilities; and improving POND©s ability to address scheduling and other applied pond management issues. One other aspect of this research aimed to improve the models contained within POND©, particularly as they relate to modeling population size distribution. These enhancements will likely 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 investigations continued into the current reporting period:

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

Note: The schedules for 9DSSR2 and 9DSSR3 were modified. The revised schedules appear in the *Addendum to the Ninth Work Plan*. The study 9DSSR2, "Decision support systems for fish population management and scheduling in commercial pond aquaculture operations," was a collaborative project between University of Arkansas at Pine Bluff (as a subproject administered through Subcontract No. RD010A-01) and Oregon State University.

Networking

Bolte received approximately twenty inquiries from various developing countries, requesting suggestions, strategies, and contacts for aquaculture facility planning and economic analysis of the potential for new facility development. Many of the questions were from people familiar with POND© software.

Bolte has developed contacts with Wageningen University in the Netherlands regarding development of aquaculture production models applicable to facility planning in developing countries.

Educational Outreach

Bolte uses POND© software in a class he teaches on the development and use of pond models.

Conference

PD/A CRSP Annual Meeting at Orlando, Florida, 26 January 2001. (Bolte, Ernst)

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, Associate Professor
Charles Hillyer, Graduate Research Assistant
Bioengineering Department
Oregon State University
Corvallis, OR

Printed as Submitted

ABSTRACT

We report on the development of a new software tool for the analysis of fish population size distributions, focusing initially 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) continued development of models of 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. Software development has focused on developing entity descriptions and resulting implementations for describing populations and population dynamics in the model. Further, interoperability with datasets used by other catfish production software, (Fish98) was developed. The resulting Catfish Inventory Management (CIM) software allows users to represent populations of catfish in any number of ponds, and simulate the population dynamics and associated variability in response to differential growth rates and harvest practices of these ponds.

ENHANCING THE POND DECISION SUPPORT SYSTEM FOR ECONOMICS, EDUCATION, AND EXTENSION

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

John Bolte, Associate Professor
Doug Ernst, Research Associate, Bioengineering
Charles Hillyer, Graduate Research Assistant
Trina Seibert, Graduate Research Assistant
Bioengineering Department
Oregon State University
Corvallis, OR

Printed as Submitted

ABSTRACT

This study deals with development of decision support tools for warmwater pond aquaculture. Efforts are directed at refining the POND software. Refinements to POND discussed here include development of tutorials and user interaction enhancements to facilitate the use of POND in educational and extension environments, and the development of a shrimp growth and development model incorporated into the POND framework. A POND tutorial has been developed, addressing problems relating to fertilization and liming calculations and to simulation setup. A new set of tutorial databases have been developed to facility the use of POND in these environments. In the interest of familiarizing the user with POND, discussions of how to create new ponds, fishlots, and other database objects have been expanded. The development of a marine shrimp model in POND is complete. It was developed using the BIOE bioenergetic model built into POND, and calibrated using the results from twenty six datasets related to shrimp production in the CRSP database.

MEXICO PROJECT

MOU No. RD009C

Staff

Oregon State University, Corvallis, Oregon

Carl B. Schreck	US Principal Investigator, US Regional Coordinator
Wilfrido M. Contreras-Sánchez	Graduate Research Assistant (Mexico; through January 2001; CRSP funded)
Carisska Anthony	Undergraduate Student (through January 2001)
Janine Gonzalez	Undergraduate Student (through January 2001)
Damien Wycoff	Undergraduate Student (through January 2001)

Universidad Juárez Autónoma de Tabasco, Villahermosa, Mexico

Wilfrido M. Contreras-Sánchez	Host Country Principal Investigator
Gabriel Márquez Couturier	Host Country Principal Investigator
Alfredo Ramos Montero	Technician (from February 2001)
Heleodoro Reyes Reyes	Technician (from January 2001)
Alejandro MacDonald Vera	Technician Student (through June 2001; CRSP funded)
Guadalupe Morales Lara	Technician Student (partially CRSP funded)
Maria de Jesús Contreras Garcia	Undergraduate Student (from January 2001)
Luis Arturo Dorantes Lopez	Undergraduate Student
Thelma R. González Márquez	Undergraduate Student
Albaro Hernández Hernández	Undergraduate Student (from January 2001)
Sofia Carolina Santiago Ruiz	Undergraduate Student

Cooperator

Oregon State University, Corvallis, Oregon
Martin Fitzpatrick

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 2000, research conducted in Mexico was reported as either Reproduction Control Research or Effluents and Pollution Research. Beginning with last year's report, because of 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 investigation continued into the current reporting period:

- 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 final report.

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

- Masculinization of Nile tilapia fry by immersion in trenbolone acetate: Reuse of hormone solution and effects of temperature/9RCR5D. The report submitted for this investigation was a final report.
- Fate of methyltestosterone in the pond environment: Use of MT in earthen ponds with no record of hormone usage/9ER2D. The report submitted for this investigation was a final report.

Note: The schedule for 9RCR5C was modified. The revised schedule appears in the *Addendum to the Ninth Work Plan*. 9RCR5D and 9ER2D were approved after the publication of the *Addendum to the Ninth Work Plan.* The work plans for these investigations will appear in the *Second Addendum to the Ninth Work Plan*.

Networking

Contreras-Sánchez met with Oceanol representative Silvia Wizar, director of development for the municipality of Centro, Tabasco, to initiate talks regarding collaboration between UJAT and the municipality on a proposal for the production of sex-reversed tilapia using clean technologies.

Formal collaboration between UJAT and the University of San Carlos, Guatemala, will take place in the form of a project that involves the use of activated charcoal filters for the elimination of MT from intensive fry production systems. UJAT also initiated contacts with the Office for Development in the municipality of Centro, which may participate in experiments with UJAT related to the study.

Allyse Ferrara (Clemson University), Reynaldo Patiño, and Kevin Pope (both of Texas Tech University) contacted the CRSP researchers to plan a visit to UJAT to develop collaborative agreements to work with the native gar *Atractosteus tropicus*. Since the alligator gar has been listed as a species at risk in Texas, both Patiño and Pope are interested in understanding how gar spawning and larval rearing are performed at UJAT.

The laboratory of aquaculture at UJAT will provide 3,000 control fish (50% males) and 3,000 masculinized fish (95%

males) to a group of tilapia producers from the Sánchez Magallanes, Cardenas. The farmers will conduct a short experiment in hapas where they will grow the fish and compare growth rates.

Márquez Couturier met with a producer at the Ejido Rio Playa, Comalcalco, Tabasco, which has recently built facilities for aquacultural purposes. UJAT will provide sex-reversed tilapia and training for initiating tilapia aquaculture.

Contreras was contacted by the nongovernmental organization Santo Tomás, a group that is interested in writing a proposal to work in collaboration with UJAT for developing the culture in hapas of masculinized mojarra castarrica (*Cichlasoma urophthalmus*), a native cichlid.

A group of producers from Huimanguillo requested information regarding the use of masculinized tilapia fry. UJAT will provide fry to start small production systems depending upon the producers' ability to form effective working groups.

The researchers received a request from Aqua Technics of Carlsborg, Washington, to analyze fish food for methyltestosterone, and the assays were conducted.

Educational Outreach

The UJAT laboratory is currently involved in training workshops for tilapia culture organized by Fideicomisos Instituidos en Relación con la Agricultura (FIRA). Candelario Bautista, a volunteer at UJATs laboratory, has already participated in two workshops, one of which was conducted in Sánchez Magallanes. The researchers are emphasizing the use of masculinized tilapia, and the laboratory is providing information for the workshop.

Publication

Contreras-Sánchez, W., 2001. Sex determination in Nile tilapia, *Oreochromis niloticus*: Gene expression, masculinization methods, and environmental effects. Ph.D. dissertation, Oregon State University, Corvallis, Oregon.

Conference

PD/A CRSP Annual Meeting at Orlando, Florida, 26 January 2001. (Contreras-Sánchez)

Award

Schreck received the Excellence in Fisheries Education Award from the American Fisheries Society.

Masculinization of Tilapia by Immersion in Trenbolone Acetate: Detection of Trenbolone Acetate in Water after Treatment

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

Wilfrido M. Contreras-Sánchez
Laboratorio de Acuacultura
Universidad Juárez Autónoma de Tabasco
Villahermosa, Tabasco, Mexico

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 a previous experiment in which Nile tilapia fry were successfully masculinized, we investigated how the concentration of trenbolone acetate (TA) in the immersion water changed before and after treatment. The results from that experiment indicated that the concentration of TA before and after treatment of Nile tilapia fry was highly variable and below the expected levels. Therefore, we decided to corroborate those results by running two experiments in which fry were not present and by testing different water sources. These new experiments confirmed our previous findings, indicating that independently of the source of water, the concentration of TA is highly variable and below the expected levels.

MASCULINIZATION OF NILE TILAPIA FRY BY IMMERSION IN TRENBOLONE ACETATE: REUSE OF HORMONE SOLUTION AND EFFECTS OF TEMPERATURE

Ninth Work Plan, Reproduction Control Research 5D (9RCR5D)
Final Report

Wilfrido M. Contreras-Sánchez, Gabriel Márquez-Couturier,
Thelma Ruth González Márquez, and
Luis Arturo Dorantes Lopez
Laboratorio de Acuacultura
Universidad Juárez Autónoma de Tabasco
Villahermosa, Tabasco, Mexico

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 short immersions in the synthetic androgen trenbolone acetate (TA) constitute a good option for masculinizing Nile tilapia fry produced by a single female. This technique offers the potential to replace MT feeding for 28 days and avoid steroid accumulation in pond sediments. We investigated the effects of TA treatment on fry collected from a tank containing batches produced in multiple spawnings. Our results suggest that masculinization involving short-term immersions in TA results in significantly more males in the treated groups (55.9 and 61.6%) than in the controls (44.5 and 38.9%). However, the percentage of males produced is far below that recommended for aquacultural purposes. We further investigated the potential enhancing effects of elevated temperatures in combination with TA treatment during immersion time and found no significant effects of temperature on the proportion of males obtained.

FATE OF METHYLTESTOSTERONE IN THE POND ENVIRONMENT: USE OF MT IN EARTHEN PONDS WITH NO RECORD OF HORMONE USAGE

Ninth Work Plan, Effluents and Pollution Research 2D (9ER2D)
Final Report

Wilfrido M. Contreras-Sánchez and
Gabriel Márquez Couturier
Laboratorio de Acuacultura
Universidad Juárez Autónoma de Tabasco
Villahermosa, Tabasco, Mexico

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 17α-methyltestosterone (MT) in the environment after its use for masculinizing Nile tilapia in nursery ponds located in the Universidad Juárez Autónoma de Tabasco, Mexico. Fry harvested from spawning ponds were treated with a masculinizing dose of MT (60 mg kg^{-1}) for four weeks. Concentrations of MT were determined by radioimmunoassay. MT was not detectable in the water at any time. In the sediments, MT was not detectable during the first 10 days of treatment. Afterwards MT was detectable in all sampling points (mean = 146.7 pg g^{-1}; SE = 21.3). MT values varied from not detectable to 368.9 pg g^{-1}. Masculinizing efficiency was low in the first trial (87.4% males) but increased significantly afterwards, reaching 92.6% males in the second trial and 98.7% in the third trial.

Another outcome of this investigation is a manual on tilapia masculinization using synthetic steroids. This manual is intended to reach fry producers, extension agents and technicians; it contains a general description of the biology of the tilapias, traditional culture practices, masculinization methods, and a detailed section on safe handling of steroids.

HONDURAS PROJECT

Subcontract No. RD010A-16 (UG)
Subcontract No. RD010A-17 (AU)

Staff

University of Georgia, Athens, Georgia

Brahm P. Verma	US Principal Investigator, US Regional Coordinator
E. William Tollner	US Principal Investigator
Steven Arnold	Undergraduate Student (February through June 2001)

Auburn University, Alabama

Joseph J. Molnar	US Principal Investigator
Thomas Popma	US Principal Investigator
Julian Montoya	Undergraduate Student (Colombia; from February 2001)
Abel Carrias	Undergraduate Student (Belize; from January 2001)

Escuela Agrícola Panamericana El Zamorano, Honduras

Daniel Meyer	Host Country Principal Investigator
Freddy Arias	Host Country Principal Investigator
Suyapa Triminio de Meyer	Research Assistant (from November 2000)
Hector Lagos	Research Assistant
Juan Carlos Molina	Undergraduate Student (through December 2000)
Jose Antonio Martinez Ayala	Undergraduate Student (El Salvador; through December 2000)
Gloria Margarita Mejía	Undergraduate Student (El Salvador; through December 2000)
Vivian Quan	Undergraduate Student (through December 2000)
Flor Quispe	Undergraduate Student (Ecuador; through December 2000)

Cooperators

Escuela Agrícola Panamericana El Zamorano, Honduras
José A. Martínez Ayala

Auburn University, Alabama
Robert Nelson

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. Ninth Work Plan research in Honduras was 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 has built 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 in Honduras is successful in the long term. These efforts are addressed by strengthening institutional support for aquaculture in Honduras through a multidisciplinary approach.

Research under the Ninth Work Plan largely focuses on adoption and diffusion of aquaculture technologies. Several topics addressed the needs of small- and medium-scale farmers, who are faced with inadequate land, fingerling supply, and extension contact. Research helped identify needs and approaches to working with small- and medium-scale farmers. Research also focused on the collaborative process undertaken by those assisting farmers. The use of the Internet as a means of providing information to aid in decision-making was the focus of another investigation. Additional research will examine placement of hillside ponds as they relate to the hillslope and watershed characteristics; hillside pond systems are most often employed by marginalized populations such as small-scale, family farmers.

Work Plan Research

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

- Linkages of aquaculture within watersheds and concurrent design of hillside ponds/9ATR2. The report submitted for this investigation was a final report.
- Decision support for policy development: Planning conferences for collaborating researchers, public agencies, and nongovernmental organizations working in aquaculture/9ADR7. The report submitted for this investigation was a final report.
- Production strategies characterizing small- and medium-scale tilapia farms: Approaches, barriers, and needs/ 9ADR8. The report submitted for this investigation was a final report.

- Technical assistance for fingerling production serving small- and medium-scale tilapia producers/9ADR9. The report submitted for this investigation was a final report.
- Training and technical assistance for Honduras institutions working with small- and medium-scale tilapia producers/9ADR10. The report submitted for this investigation was a final report.

Note: 9ATR2, 9ADR7, 9ADR8, 9ADR9, and 9ADR10 were approved after publication of the *Ninth Work Plan*. The work plans for these investigations appear in the *Addendum to the Ninth Work Plan*. The investigations listed above are collaborative projects between UG and AU. The results of 9ADR9 and 9ADR10 have been combined into one report.

Networking

CRSP activities provided opportunities for researchers from Escuela Agrícola Panamericana (Zamorano) to visit government facilities, such as the El Carao Fish Culture Station in Comayagua, and interact with government technicians.

Meyer and Arias established a collaborative relationship with George Pilz, Department of Soils, Zamorano, who will cooperate in an evaluation of water resources in Honduras.

The Honduras CRSP Project was represented at the three-day exhibition and fair held by Red para Comercialización Comunitaria Alternativa (Red-COMAL) in Tegucigalpa in November 2000. An estimated 1,000 people visited the display and exhibition of live fish and documents from the CRSP and other sources.

José Falck-Zepeda, a postdoctoral student working with CRSP researcher Upton Hatch from Auburn University, traveled to Honduras. There he met with CRSP researchers Tollner and Molnar, providing translation and guidance for their work as well as conducting some analysis for Hatch's CRSP-funded economics project.

Zamorano staff members have contacted Taiwanese and other international technicians working in aquaculture in Honduras.

The researchers received a request from an aquaculturist in Brazil regarding pond design.

Joe Molnar traveled to both Santa Barbara and the Danli area of Honduras, where he visited such organizations as Project Globale, Red de Desarrollo Sostenible–Honduras (RDS-HN), and a number of other nongovernmental organizations (NGOs).

Researchers published 500 copies of a newsletter reporting on Zamorano aquaculture activities, *Acua-Noticias Zamorano*, in February 2001.

Honduras Project participants were involved in the planning and organization of the 6th Central American Symposium on Aquaculture to be held on 22 to 24 August 2001. Meyer traveled to the University of Georgia in March 2001 to help complete organization plans for the sessions. A special session was planned to highlight CRSP contributions to extension and development, with the project inviting and sponsoring several invited speakers to present topics of interest at the event. They also collaborated on the planning of the editing and publishing of the tilapia session proceedings.

Educational Outreach

The CRSP Honduras team developed and published the 37-page booklet "Producción de tilapia en fincas integradas utilizando insumos de bajo costo" (Production of tilapia on integrated farms using low-cost inputs) by Dan Meyer and Suyapa Meyer. The content of the booklet was evaluated in June 2001 by a group of eight local farmers with experience in tilapia culture, two extension agents, and several Zamorano staff members prior to publication, and the researchers are distributing copies of the pamphlet to NGOs and other interested parties. In July 2001, 750 copies of the publication were produced for distribution.

Meyer and Lagos used information derived from CRSP research to train a group of 20 private tilapia farmers at the El Cajón dam in Northern Honduras. The week-long training session included field visits to farms and cage culture projects in Honduras.

The CRSP researchers have planned a training program for Project Globale in Santa Barbara, Honduras.

Tom Popma incorporated CRSP findings into a one-week course on principles of aquaculture and water quality management at Can Tho University in Vietnam.

Meyer gave a graduate seminar on aquaculture in Central America at the University of Georgia. Meyer has also used a great amount of information and experimental results from CRSP activities in his academic course on aquaculture (4 credits), which is offered as an elective course to the 115 third-year students enrolled in the class at Zamorano.

Publications

Martínez, J.A., 2000. Socioeconomic characterization of farmers with and without a system of tilapia production in Honduras. B.S. thesis, Escuela Agrícola Panamericana El Zamorano, Honduras. (in Spanish)

Mejía, G.M., 2000. Study of the production costs for culture of tilapia on small and medium farms in five departments of Honduras. B.S. thesis, Escuela Agrícola Panamericana El Zamorano, Honduras. (in Spanish)

Molina, J.C., 2000. Study of the actual and potential demand for tilapia in five secondary cities in Honduras. B.S. thesis, Escuela Agrícola Panamericana El Zamorano, Honduras. (in Spanish)

Quan, Vivian, 2000. Evaluation of the reproduction of tilapia (Oreochromis niloticus) in plastic and concrete lined and earthen ponds. B.S. thesis, Escuela Agrícola Panamericana El Zamorano, Honduras. (in Spanish)

Quispe, F., 2000. Evaluation of the production costs for tilapia fingerlings in Honduras. B.S. thesis, Escuela Agrícola Panamericana El Zamorano, Honduras. (in Spanish)

Verma, B., J. Renew, E.W. Tollner, T. Popma, J.L. Molnar, and D. Meyer, 2000. Concurrent design of hillside ponds for tilapia production. In: K. Fitzsimmons and J. Carvalho Filho (Editors), Proceedings of the Fifth International Symposium on Tilapia Aquaculture. Rio de Janeiro, Brazil, pp. 311–315.

Conferences

Fifth International Symposium on Tilapia Aquaculture at Rio de Janeiro, Brazil, 2–7 September 2000. (Meyer, Verma)

Aquaculture America 2001 at Orlando, Florida, 21–25 January 2001. (Meyer, Molnar, Popma)

PD/A CRSP Annual Meeting at Orlando, Florida, 26 January 2001. (Meyer, Molnar, Popma, Tollner, Verma)

LINKAGES OF AQUACULTURE WITHIN WATERSHEDS AND CONCURRENT DESIGN OF HILLSIDE PONDS

Ninth Work Plan, Appropriate Technology Research 2 (9ATR2)
Final Report

Ernest W. Tollner and Brahm P. Verma
Department of Biological and Agricultural Engineering
University of Georgia
Athens, Georgia, USA

Joseph Molnar
Department of Agricultural Economics and Rural Sociology
Auburn University, Alabama, USA

Tom Popma
Department of Fisheries and Allied Aquacultures
Auburn University, Alabama, USA

ABSTRACT

The hillsides in Latin America cover about one million square kilometers and provide livelihood for some 200 million people. Nearly one-half of this population is classified as "poor." There is a possibility of introducing tilapia production to the hillside regions in Latin America for improving nutrition of farm families and local communities and for providing a means of additional income. The objective of this paper is to present a levee pond design model for NGO personnel to use as they assist local producers. The model resides on the Excel® platform. The model is based on a monthly volume balance. The model enables iterative computation of the inflow needed to balance seepage and net evaporation. One can also determine the pump-in and pump-out rates needed to reach a target volume change rate per month. The model also includes an empirical spillway design.

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)
Final Report

Brahm P. Verma
Department of Biological and Agricultural Engineering
University of Georgia
Athens, Georgia, USA

Daniel Meyer
Department of Biology
Escuela Agrícola Panamericana El Zamorano
Zamorano, Honduras

Tom Popma
Department of Fisheries and Allied Aquaculture
Auburn University, Alabama, USA

Joseph J. Molnar
Department of Agricultural Economics and Rural Sociology
Auburn University, Alabama, USA

E. William Tollner
Department of Biological and Agricultural Engineering
University of Georgia
Athens, Georgia, USA

ABSTRACT

The project focused on identifying and developing methods to create an enabling environment for sustainable development of aquaculture in Honduras. Honduras has a large network of nongovernmental organizations (NGOs) operating at the village level, an exceptional educational institution in Zamorano with commitment to extend training and knowledge in aquaculture, and an established in-country sustainable-development electronic network operated by Red de Desarrollo Sostenible–Honduras (RDS-HN). We developed the concept of training the trainers (NGOs working with farmers at the village level) by bringing together Zamorano and RDS-HN and developing a Web-based Information Delivery System for Tilapia (WIDeST). In this approach WIDeST captures the already-developed electronic information technology network and capacity of RDS-HN while providing easy-to-use information developed by Zamorano. Furthermore, it provides a way to connect local NGOs, farmers, and decision-makers so they can exchange information and make informed decisions. The WIDeST provides information on tilapia production and related topics, natural resources of Honduras, contact information for NGOs, and chat-room facilities for conducting virtual forums and discussions. The email facility enables the user to ask questions and get answers from an expert. Since its inauguration session in March 2001, the website has had more than 6,800 hits, and more than 300 individuals have formally registered to receive information. The participants at training and workshop sessions have

found this to be an easy and useful approach, and they have provided strong encouragement for adding new information. The number of individuals already reached, as evidenced from the numbers of visits to the website, strongly indicates that this may be a way to build the capacity of local institutions to develop an environment that enables farmers to adopt aquaculture as an alternative on their farms.

PRODUCTION STRATEGIES CHARACTERIZING SMALL- AND MEDIUM-SCALE TILAPIA FARMS

Ninth Work Plan, Adoption/Diffusion Research 8 (9ADR8)
Final Report

José A. Martínez Ayala
Department of Agribusiness
Escuela Agrícola Panamericana
Zamorano, Honduras

Joseph J. Molnar
Department of Agricultural Economics and Rural Sociology
Auburn University, Alabama, USA

Freddy Arias
Department of Agribusiness
Escuela Agrícola Panamericana
Zamorano, Honduras

Tom Popma
Department of Fisheries and Allied Aquacultures
Auburn University, Alabama, USA

ABSTRACT

This report examines samples of farms from Honduras departments that have and do not have tilapia ponds as part of their farming systems. Data were obtained through personal interviews with 128 farmers, including 64 tilapia producers, in five departments: Olancho, Intibuca, El Paraíso, Francisco Morazán, and Santa Bárbara.

To obtain information about farms without tilapia, farmers were selected at random from within the same community as the identified tilapia producers. Interviews were conducted in communities where the small-scale farmers with production of tilapia were located. The data are intended to constitute a representative sample of the population of the Honduran small-scale aquaculture farmers in these departments. The analysis presents basic comparisons of landholding, farm, and personal characteristics of tilapia producers with the mirror sample of the farmers without tilapia. The analysis profiles basic differences between the two categories of farms, the operators, and their households. Younger farmers were more likely to become involved with tilapia farming. Those farmers more dedicated to their work inside their farm from which they obtain all their income, and whose principal occupation is farming, were more inclined to adopt farming of tilapia. Farmers who use their land more intensively and who dedicate themselves more to the farming of basic grains were more likely to adopt the farming of tilapia. Since Honduran small-scale farmers tend to be a depressed segment economically, they tend to satisfy first their subsistence necessities by maximizing the use of their resources. The financing for both tilapia growers and nongrowers tends to be a limiting factor because more than 80% of the population work without financing, a clear barrier to farm investments. Tilapia growers participated more in development projects.

TECHNICAL ASSISTANCE FOR FINGERLING PRODUCTION SERVING SMALL- AND MEDIUM-SCALE TILAPIA PRODUCERS AND TRAINING AND TECHNICAL ASSISTANCE FOR HONDURAS INSTITUTIONS WORKING WITH SMALL- AND MEDIUM-SCALE TILAPIA PRODUCERS

Ninth Work Plan, Adoption/Diffusion Research 9 and 10
(9ADR9 and 10)
Final Report

Thomas J. Popma
Department of Fisheries and Allied Aquacultures
Auburn University, Alabama, USA

Daniel E. Meyer
Department of Biology
Escuela Agrícola Panamericana El Zamorano
Zamorano, Honduras

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. The Zamorano principal investigator and his technician in this project confirmed that the Comayagua research station El Carao was not a reliable supplier of fingerlings for area producers. Private fingerling producers are few and generally geared to supply large-scale commercial operations. The overriding objective of activity 9ADR9 was to provide technical assistance and training to current and potential fingerling suppliers to small- and medium-scale tilapia producers in Honduras.

A 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.

In November 1999 we consulted with 13 representatives of national and international, government and nongovernmental organizations (NGOs). From these consultations a strategy and timetable were developed for implementing technical assistance and training for fingerling suppliers and technicians working with NGOs currently or potentially involved in small- and medium-scale fish culture develop-

ment. At least 33 small- and medium-scale tilapia producers (each with 150 to 12,000 m^2 of water surface) and 26 restaurants were subsequently interviewed to assess the production and marketing demands for tilapia in Honduras. With the collaboration of a local NGO, representatives of NGOs with actual or potential interest in aquaculture development were invited to a one-day seminar to describe opportunities and constraints for family-scale fish culture in Honduras. The Zamorano team continues to identify and provide technical assistance to regional fingerling producers and organizations involved in aquaculture extension. During the life of this activity, three technical workshops were provided for actual and prospective fingerling producers and extensionists. More than 30 publications on fingerling production and pond management practices have been incorporated in a web-based information system developed by a local NGO, primarily in response to the needs of local NGOs.

PERU PROJECT

Subcontract No. RD010A-12

Staff

Southern Illinois University at Carbondale, Illinois

Christopher C. Kohler	US Principal Investigator, US Regional Coordinator
Susan T. Kohler	US Principal Investigator
Marcos J. De Jesus	Research Associate (through February 2001)
William Camargo	Research Associate (from March 2001)

The Ohio State University, Columbus, Ohio

Konrad Dabrowski	US Principal Investigator
Jacques Rinchard	Postdoctoral Research Associate

Instituto de Investigaciones de la Amazonia Peruana, Iquitos, Peru

Salvador Tello	Host Country Principal Investigator
Fernando Alcántara	Host Country Principal Investigator
Palmira Padilla Perez	Aquaculturist (through January 2001)
Rosa Ismiño	Aquaculturist (from February 2001)
Lamberto Arevalo	Technician
Cesar A. Flores	Technician
Arturo Flores Huang	Technician

Universidad Nacional de la Amazonia Peruana, Iquitos, Peru

Marina del Aguila	Host Country Principal Investigator

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

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

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

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

- Sustainable aquaculture in the Peruvian Amazon/9NS6. The report submitted for this investigation was combined with the report for 9NS3, and it was a final report.

Note: The schedule for 9NS3 has been modified. The revised schedule appears in the *Addendum to the Ninth Work Plan*.

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. 51). The results of 9NS3 and 9NS6 have been combined into one report.

Networking

In conjunction with the September 2000 External Evaluation Panel Peru Project site visit, CRSP researchers discussed the impact of the project in the region and in the host country institutions with President of INAP Dennis Del Castillo, President of Consejo Nacional del Ambiente (CONAM) Luis Campos Baca, and IIAP Fisheries Biologist Vitor Montreuil. They also met with collaborating biologists Padilla and Ismiño.

The Peru Project participants also met with President of UNAP Jose Torres Vasquez, mayor of the Province of Maynas Ivan Vasquez Valera, Regional Director of the Ministry of Fisheries Julio Tapia, and Assistant Director Carlos Cabrera to discuss the respective roles of their organizations in the CRSP project and future involvement in aquaculture activities in the region. They additionally interviewed some of the families producing fish on the Napo–Mazan Road.

The researchers met with Marco Colace Bucchi of the Italian nongovernmental organization (NGO) Terra Nuova and

Director of the Food Security Program (PROSEAL in its Spanish-language acronym). Colace, Terra Nuova Sociologist Elizabeth Lozano, and two extensionists discussed the extension work taking place on the Iquitos–Nauta Road. The group then traveled the road to visit several beneficiaries of the program and met with Baldomero Sanchez, Reogildo Panaifo, and Romero Palla, who were very pleased with their fish production and grateful for the continuous support they receive from the extension program. Technical assistance was provided to fish producers along the Iquitos–Nauta Road regardless of their affiliation with PROSEAL.

Camargo traveled to Iquitos to familiarize himself with the host country research facilities. He gave two presentations on the importance of live food production to IIAP administrative personnel and another presentation to extensionists, UNAP students, and tropical fish exporters. Finally, he made recommendations for the construction of the new fish hatchery and prepared future experimental materials.

Fingerlings produced at IIAP Quistococha are being distributed among PROSEAL members with additional support from Terra Nuova and other local organizations.

Educational Outreach

Alcántara enrolled six students from three Peruvian universities to conduct their undergraduate practical training in Iquitos. These students came from the Universidad Nacional Mayor de San Marcos in Lima, Universidad Nacional Federico Villareal in Lima, and UNAP.

Alcántara and Padilla participate routinely in weekend workshops for high school students and regional farmers involved in local extension projects. Padilla also teaches aquaculture mini-courses to high school students in the Iquitos region.

Alcántara provides technical support to future and existing fish farmers involved with the local extension project. His expertise has guided farmers to generate successful fish crops.

Thirty producers were trained in *Colossoma* and *Piaractus* culture in Nauta, Peru, in a one-week workshop presented by PROSEAL extension agents and Alcántara with PD/A CRSP support.

The manual "Reproduccion Inducida de Gamitana y Paco" was printed with CRSP support and is currently being used as an extension manual by IIAP collaborators.

Landowners visit IIAP facilities to request technical support or to inquire about workshops that are offered. Many have benefited from the opportunity offered by IIAP and the NGOs to initiate small farm operations on their lands.

Presentations

Kohler, C., M. De Jesús, S. Kohler, L.B. Campos, and F. Alcántara. Culture of *Colossoma macropomum* in South America. Presented to Aquaculture America 2001 at Orlando, Florida, 21–25 January 2001.

Molnar, J.J., Fernando Alcántara, and S. Tello. Small-scale aquaculture in the Peruvian Amazon: Marketing practices and strategies. Presented to Aquaculture America 2001 at Orlando, Florida, 21–25 January 2001.

Conferences

Aquaculture America 2001 at Orlando, Florida, 21–25 January 2001. (Alcántara, C. Kohler, Tello)

PD/A CRSP Annual Meeting at Orlando, Florida, 26 January 2001. (Alcántara, Dabrowski, De Jesus, C. Kohler, S. Kohler, Tello)

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

Ninth Work Plan, New Aquaculture Systems/New Species Research 3 and 6 (9NS3 and 6)
Final Report

Christopher C. Kohler
Fisheries and Illinois Aquaculture Center
Southern Illinois University at Carbondale
Carbondale, Illinois, USA

Susan T. Kohler
Economic and Regional Development Office
Southern Illinois University at Carbondale
Carbondale, Illinois, USA

Konrad Dabrowski and Jacques Rinchard
School of Natural Resources
The Ohio State University
Columbus, Ohio, USA

William M. Camargo and Marcos J. De Jesus
Fisheries and Illinois Aquaculture Center
Southern Illinois University at Carbondale
Carbondale, Illinois, USA

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

ABSTRACT

Studies on the sustainable aquaculture production of gamitana (*Colossoma macropomum*) and paco (*Piaractus brachypomus*) in the Peruvian Amazon were conducted at the Instituto de Investigaciones de la Amazonia Peruana (IIAP) Quistococha Aquaculture Station in Iquitos, Peru. Growth performance of paco stocked at 4,000, 6,000, and 8,000 fish ha^{-1} in an experiment was not significantly different among stocking densities. Fish were harvested after six and one-half months for the 4,000, 6,000, and 8,000 fish ha^{-1} study; mean weights of 418.2, 447.5, and 474.9 g, respectively, were attained. Specific growth rates (% d^{-1}) were 1.8, 1.8, 1.7; feed conversion efficiencies were 72.9, 76.2, and 74.7; and condition factors were 2.7, 2.7, and 2.8 at the low to high densities, respectively. Survival for the paco experiment was > 80%. Paco fingerlings were fed a locally prepared diet (26.7% crude protein, 9.0% crude lipid). Water quality

parameters (dissolved oxygen, temperature, total ammonia nitrogen, and pH) remained within acceptable levels for tropical aquaculture. The stocking density study suggests the economic feasibility of rearing paco in the Peruvian Amazon. The cost of production analysis in this and an earlier study indicated that gamitana production is economically more feasible than paco production because of its higher market value (US$3.00 vs. US$2.10 kg^{-1} fresh weight) and equal production costs (US$0.6 to US$0.9 kg^{-1} fresh weight). Production of gamitana and paco at densities of 2,500 fish ha^{-1} and higher will be more profitable than pineapple production, which is the highest market value agriculture cash crop produced in the Loreto region at the present time.

In another experiment, plasma concentrations of sex steroids—testosterone (T), 11-ketotestosterone (11-kT), estradiol-17β (E2) and 17,20β-dihydroxy-4-pregnen-3-one (17,20βP)—were measured by radioimmunoassay following ethyl-ether extraction to monitor and understand the dynamics of gonadal steroidogenesis during maturation of paco and gamitana. In paco, prior to hormonal treatments with luteinizing hormone-releasing hormone analog (LHRHa), the concentrations of 11-kT in males and E2 in females as well as the ones of their precursor T were significantly ($P < 0.01$) higher in fish maintained under normoxic conditions than in fish exposed to hypoxia. After ovulation and spermiation, the concentrations of T and 17,20βP significantly ($P < 0.05$) increased in both sexes in both experiments. However, the levels of plasma sex steroids reached under normoxic conditions were higher than the ones recorded under hypoxia, except the ones of 17,20βP in males. Additionally, the effect of oxygen concentration on human chorionic gonadotropin (hCG) was evaluated during final stages of induced maturation on blood steroid profiles in an attempt to correlate these data with gamete viability. In 8 to 11 November 2000, the second attempt at artificial spawning of paco and the first of gamitana were performed. Six pairs of paco were selected and transferred to indoor concrete tanks. Treatments involved injection of three pairs with LHRHa and three pairs with hCG (Sigma, at St. Louis, Missouri) at 500 IU kg^{-1} (females) or 100 IU kg^{-1} (males). Fish were observed during the following 48 h and spawning attempted. Fish were weighed, tags identified, and blood samples taken prior to injection, at the time of ovulation, or 48 h after injection. In the case of gamitana, four pairs were formed after preliminary selection (robustness or sperm presence). All fish were injected with LHRHa at the same dose as paco. Conditions in ponds and indoor tanks were monitored during spawning procedures. LHRHa proved to be the only sex hormone effective for inducing spawning in both males and females.

PERU PROJECT

Subcontract No. RD010A-13

Staff

University of Arkansas at Pine Bluff, Arkansas

Rebecca Lochmann	US Principal Investigator
Felicia Bearden	Assistant
Jason Brown	Undergraduate Student Assistant

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. Research on broodstock nutrition of *Colossoma* and *Piaractus* via proximate analysis of locally available feeds addresses objectives in the *Continuation Plan 1996* regarding sustainable culture of new species.

Work Plan Research

The following Ninth Work Plan investigation continued into the current reporting period (see the Kenya Project (p. 59) for information on another funded investigation under this subcontract):

- Spawning and grow-out of *Colossoma macropomum* and/or *Piaractus brachypomus*/9NS3A. The report submitted for this investigation was a final report.

Note: The methods and schedule for 9NS3A were modified. The revised methods and schedule 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. 49).

Networking

Lochmann had regular email contact with Alcántara regarding spawning schedules for *Colossoma* and *Piaractus*, and they discussed details of culture of gamitana, plans for the continuation of broodstock nutrition studies, and the formulation of broodstock diets.

Joaõ B. Kochenborger of São Paulo, Brazil, is at UAPB to complete collaborative research with Lochmann on pacu nutrition (nutrient digestibility trials). This arrangement is an effect of Lochmann's involvement with colossomids because of the Peru Project. Kochenborger's project is funded by the Brazilian government.

People have contacted Lochmann to express interest in colossomids as ornamentals. Fish farmers in Arkansas occasionally inquired about culturing them commercially.

Educational Outreach

Lochmann includes material from her CRSP project in fish nutrition lectures. While conducting two feeding studies with *Piaractus,* she used the studies for experiential learning in the lab. Her students also had an opportunity to work with the tambaquí from Peru that she keeps in her lab.

Lochmann has slides and transparencies (in English) that she presents to groups of visitors who visit the Fisheries Department at UAPB.

Lochmann presented a seminar at UAPB on 7 November 2000 regarding colossomid broodstock nutrition and fishes of Peru. Her audience was an undergraduate class of five students and two faculty members.

Conference

Aquaculture America 2001 at Orlando, Florida, 21–25 January 2001. (Lochmann)

SPAWNING AND GROW-OUT OF *COLOSSOMA MACROPOMUM* AND/OR *PIARACTUS BRACHYPOMUS*

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

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

ABSTRACT

Proximate analysis of broodstock and grow-out feeds for gamitana (*Colossoma macropomum)* and paco (*Piaractus brachypomus*) and their constituent feedstuffs was conducted. Literature values for specific nutrients known to affect fish reproduction were calculated from published sources for the broodstock diet. Fatty acid and amino acid profiles of broodstock eggs were obtained. Analytical information on the feedstuffs and diets currently being used in Iquitos, Peru, together with the egg data and published information on the natural diets of colossomids and broodstock nutrition in other species, was combined to formulate preliminary recommendations for the nutrition and feeding of gamitana and paco broodstock.

KENYA PROJECT

MOU No. RD009A (OSU)
Subcontract No. RD010A-08 (AU)

Staff

Oregon State University, Corvallis, Oregon

Jim Bowman	US Principal Investigator, US Regional Coordinator
Christopher Langdon	US Principal Investigator

Auburn University, Alabama

Tom Popma	US Principal Investigator
Karen Veverica	US Principal Investigator
Bethuel Omolo	Graduate Research Assistant (Kenya; CRSP funded)

Fisheries Department, Nairobi, Kenya

Nancy Gitonga	Host Country Principal Investigator
John Kinyanjui	Host Country Research Associate and Head of Station, Sagana Fish Farm (from September 2000)
Japhet Ngatuni	Host Country Research Associate and Head of Station, Sagana Fish Farm (through August 2000)

Moi University, Eldoret, Kenya

David Liti	Host Country Principal Investigator
Mucai Muchiri	Host Country Principal Investigator
Charles Ngugi	Host Country Principal Investigator
Robinson Mugo	Graduate Research Assistant (partially CRSP funded)
Enos Mac'Were	Graduate Student (partially CRSP funded)
Robert Olendi	Graduate Student (partially CRSP funded)
Victoria Boit	Undergraduate Student (August 2000 through March 2001)
Maria Fungomeli	Undergraduate Student (August 2000 through March 2001)
Karen Lerimoi	Undergraduate Student (from December 2000)
Bernard Maundu	Undergraduate Student (August 2000 through March 2001)
Jedidah Atieno Nyongayo	Undergraduate Student
Barua Tsuma	Undergraduate Student (from December 2000)

Bunda College, Lilongwe, Malawi

Jeremy Likongwe	Host Country Principal Investigator
Lucius Chimwala	Undergraduate Student (through December 2000)
Kenneth Chaula	Undergraduate Student (through December 2000)

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

Daniel Jamu	Host Country Principal Investigator

University of Nairobi, Nairobi, Kenya

Patricia Mwau	Graduate Student (through January 2001; partially CRSP funded)
Hellen Njeri	Undergraduate Student (from September 2000)

Kenyatta University, Nairobi, Kenya

Paul Wamwea Wabitah	Undergraduate Student (through January 2001)

Nyanchwa College of Science and Technology, Kisii, Kenya

Lucy Wambui	Undergraduate Student (from September 2000)

Cooperators

Auburn University, Alabama
Leonard Lovshin

Sagana Fish Farm, Sagana, Kenya
Judith Amadiva

Site Background

Kenya Project research is conducted at 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 Agriculture and Rural Development. In the last two years, additional MOUs have been established with Moi University and with companion site institutions in Malawi.

Research activities in this reporting period addressed aquaculture development constraints and research priorities identified in the *Continuation Plan 1996*. These included optimization of production/management strategies through more efficient use of supplemental feeds, 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 Ninth Work Plan investigations continued into the current reporting period:

- 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 final 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.
- 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 final report.
- Regional outreach in Africa/9ADR5. The report submitted for this investigation was a final report.

This MOU and subcontract were also awarded funding to conduct the following Ninth Work Plan investigation:

- Development of training modules for aquaculture extension workers and university students in Kenya/9FFR6. The report submitted for this investigation was a final report.

Note: The schedule for 9ATR1 has been modified. The schedule and methods for 9FFR2 were modified. The methods for 9ADR3 were modified. Revised schedules and methods appear in the *Addendum to the Ninth Work Plan*. The investigations listed above were 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," was 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. 59). 9FFR6 was approved after the publication of the *Addendum to the Ninth Work Plan.* The work plan for this investigation will appear in the *Second Addendum to the Ninth Work Plan*.

Networking

Among their regional outreach activities, the Kenya Project researchers had contact with the director of the Uganda Wetlands and Resource Conservation Association (UWRCA) to discuss the possibilities for training for Ugandans in aquaculture at Sagana. They also met with George Onyango, the Task Coordinator of the Lake Victoria Environmental Management Programme (LVEMP), to discuss issues concerning the strengthening of extension services.

Bowman and other Kenya Project participants made new contacts at the Forum for Organic Resource Management (FORMAT) when they presented a paper titled "The Use of Organic Resources in Research and Development Activities." They also established a relationship with the German Development Service (which supports the Sagana Jua Kali Association) when they provided information on integration of fish farming with other agricultural activities.

The Sagana researchers have developed a linkage with the University of Nairobi's Department of Hydrobiology for doctoral studies on *Labeo* by staff member Dorothy Ogony.

CRSP researchers communicated with the Museums of Kenya regarding a student who was studying killifishes through Luc de Vos. The researchers also utilized Moi University's departments of Agriculture and Chemistry when giving student demonstrations of some analyses for which the Sagana laboratory is not equipped.

Liti and Fisheries Officer Raphael Mbaluka visited several reservoirs in Kitui District, Eastern Province, to assess the awareness of the community regarding fish farming. Following the visit they received requests to have some of the reservoirs stocked. CRSP researchers stocked Karia Reservoir, which is run by the local community, with fingerlings and gave an on-site seminar on the role of fish in protein supplementation.

The researchers have also presented demonstrations on the processing and preparation of fish, e.g., gutting and cooking, for the Ruthagati community in Nyeri District.

CRSP researchers helped Sagana Women's Group in the construction and management of fish ponds, and they have provided them with information on feeding practices.

At the World Aquaculture Society (WAS) Annual Conference in Orlando, Florida, Gitonga established contact with Peter Edwards of the Asian Institute of Technology (AIT), Thailand, and discussed possibilities for future training of Kenyan Fisheries Department personnel at AIT. She and Ngugi also met with CRSP researcher Kevin Fitzsimmons (University of Arizona) during the WAS conference to discuss possible future collaboration on training for Eritrean students. Such training could include components at Sagana Fish Farm as well as the University of Arizona.

Mugo, Mac'Were, Veverica, and Fisheries Officer George Owiti visited Western Kenya in December 2000 to view fingerling production sites for a CRSP investigation and a pond construction site of one of the trainees. During the trip, the group collected endemic killifishes (*Notobranchius* spp.) along the roadside. The fish were taken to Moi University for identification and follow-up work, as well as to Sagana where Mugo made observations on spawning and egg hatching.

Sagana received visits from various officials, academics and others, including:

- B. Ayugu, Deputy Director of Fisheries, regarding training for Fisheries Officers;
- John Maina, an officer from the Embu Agricultural and Livestock office, on issues related to integrated fish farming;
- Ms. Mehlhom, an officer from the German Development Service, and Joseph Lokaale, a member of the Sagana Jua Kali Association, toured the facility;
- Chemiati Wasike, Fisheries Officer, to collect fingerlings;
- D. M. Mutemi, DC Kirinyaga, to tour development projects in the district;
- Paul Onjoro of Egerton University;
- Richard Rugandya, Makerere University, while conducting masters research on carp impacts on the environment;
- Senior Officers of the Department of Fisheries from Eastern and Central provinces, to attend a hosted meeting;
- Munguti Jonathan, a masters student from Austria on data collection for his project;
- Paul Wanjala of Moi University, to examine fish for parasites;
- Students from 26 primary schools, 11 secondary schools, and 2 universities;
- A medium-scale commercial fish farmer, to receive training in fish transportation techniques; and
- Representatives from two local companies seeking information on water control systems, hatchery design and management, pond management, tilapia culture, the economics and viability of tilapia culture, conservation issues, and management of aquaculture effluents.

Educational Outreach

Liti presented lectures to students from the University of Nairobi and Moi University at Sagana during August and October 2000. He discussed phytoplankton dynamics in Sagana fish ponds and their role in fish nutrition and water quality management, methods available for managing the prolific breeding of *O. niloticus* (e.g., production of monosex population through hand-sexing and sex reversal), and the role of fertilizer and supplementary feeds in fish production.

Amadiva and Fulanda made a presentation in a workshop organized by the Forum for Organic Resource Management and Agricultural Technologies (FORMAT) held 19 to 21 September 2000 in Village Market, Nairobi.

Liti and Gichuri arranged a seminar at Sagana for Moi University students from 31 September to 2 October 2000. The discussions centered around common diseases and parasites in warmwater fish, fertilization and supplemental feeding as strategies for increasing fish production, and different methods used in seed production of *Clarias gariepinus* and *O. niloticus* at Sagana.

Fulanda presented a seminar at Sagana met with agriculture/aquaculture extension agents from Embu District, Kenya (Eastern Province), on 3 November 2000 to provide them with information on general aspects of fish farming.

Sagana provided local schools with information pertinent to their National Examinations. The researchers hosted institutions ranging from primary schools to universities, and visited the site between August and November 2000. The average attendance for a visit was 30 students and teachers.

Two Austrian students from the University of Technology, Vienna, and the University of Agriculture, Vienna, conducted research related to masters degrees at Sagana between May and August 2001. They worked under the supervision of Liti and their Austrian advisors, who visited Kenya briefly between May and July 2001.

Publication

Mwau, P., 2000. Nutrient dynamics with special reference to nitrogen and phosphorus in tilapia (*Oreochromis niloticus*)/catfish (*Clarias gariepinus*) polyculture ponds at Sagana Fish Farm, Central Kenya. M.S. thesis, University of Nairobi, Nairobi, Kenya.

Presentations

Liti, D., E. MacWere, and K. Veverica. Growth performance and economic benefits of *Oreochromis niloticus* and *Clarias gariepinus* polyculture in fertilized tropical ponds. Poster presented to the Aquaculture America 2001 at Orlando, Florida, 21–25 January 2001.

Veverica, K., D. Mirera, and G. Matolla. Optimization of phosphorus fertilization rate in freshwater tilapia production ponds in Kenya. Presented to Aquaculture America 2001 at Orlando, Florida, 21–25 January 2001.

Conferences

Aquaculture America 2001 at Orlando, Florida, 21–25 January 2001. (Bowman, Gitonga, Liti, Ngugi, Veverica)

PD/A CRSP Annual Meeting at Orlando, Florida, 26 January 2001. (Bowman, Gitonga, Liti, Ngugi, Omolo, Veverica)

GROWTH PERFORMANCE AND ECONOMIC BENEFITS OF *OREOCHROMIS NILOTICUS*/*CLARIAS GARIEPINUS* POLYCULTURE FED ON THREE SUPPLEMENTARY FEEDS IN FERTILIZED TROPICAL PONDS

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

David M. Liti
Zoology Department
Moi University
Eldoret, Kenya

O.E. Mac'Were
Fisheries Department
Moi University
Eldoret, Kenya

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

ABSTRACT

An experiment was conducted for 180 days at Sagana Fish Farm, Kenya, to evaluate the performance of two formulated pellet feeds and a locally available rice bran. A polyculture of *Oreochromis niloticus* and *Clarias gariepinus* in fertilized tropical ponds was used. Twelve 800-m^2 ponds were used, and each pond was limed at a rate of 20,000 kg ha^{-1} and stocked at a rate of 19,375 ha^{-1} with sex-reversed male *O. niloticus* and 625 ha^{-1} with *C. gariepinus*. The fish were fed daily at a rate of 2% body weight. Two formulated diets were compared with rice bran in three treatments that were replicated four times. The composition of the diets was as follows: Pig finisher pellet (PFP): crude protein 12.5%, lipids 10.9%, crude fiber 15.1%; Rice bran (RB): crude protein 6.5%, lipid 10%, crude fiber 37.9%; Test diet pellet (TDP): crude protein 12.5%, lipid 13.1%, crude fiber 14.1%. Diammonium phosphate (DAP) and urea were used at rates of 8 kg P ha^{-1} wk^{-1} and 20 kg N ha^{-1} wk^{-1}, respectively. After one month urea input was reduced from 2.7 to 2.2 kg $pond^{-1}$ to allow for the nitrogen contributions from the feed and to maintain the inputs at 35 kg N ha^{-1} wk^{-1} in the ponds. Water quality analyses showed no significant differences ($P > 0.05$) among treatments in the parameters measured. Exceptions were alkalinity, pH, and dissolved oxygen (DO), which were significantly ($P < 0.05$) different among treatments. The lowest dawn DO level (0.9 mg l^{-1}) was recorded in the PFP treatment, while the highest afternoon value (9.9 mg l^{-1}) was recorded in the RB treatment. The lowest pH value of 7.9 was recorded in PFP, while the highest value (8.3) was recorded in the RB treatment. The overall range of monthly mean total alkalinity was 98.0 to 118.8 mg $CaCO_3$ l^{-1}, and the lowest value was observed in the RB treatment. The phytoplankton community was dominated by green algae in the beginning of the culture period but later by the blue-greens towards the end of the experiment. The overall mean diversity index of phytoplankton was 0.7, and values were not significantly different ($P > 0.05$) among treatments. Gross primary production ranged from 0.1 to 11.5 g C m^{-2} d^{-1}. However, the values were also not significantly different ($P > 0.05$) among treatments. The RB treatment gave significantly ($P < 0.05$) lower values in fish growth rate and annualized net fish yield (0.69 g d^{-1} and 5,000 kg ha^{-1}, respectively) than both PFP (1.17 g d^{-1} and 9,298 kg $ha^{-1,}$ respectively) and TDP (1.15 g d^{-1} and 8,828 kg ha^{-1}, respectively). The feed conversion ratio was highest in the RB treatment. There were no significant differences ($P > 0.05$) in survival rates and relative condition factors among the treatments. Profitability analysis by using partial and enterprise budgets revealed that locally available pig finisher pellets were the most profitable followed by rice bran at the local market price of US$1.17 kg^{-1} fish. At a higher price of US$1.56, PFP would still be the best choice, followed by TDP, while RB would be the least profitable. The net returns were positive for all the treatments. However, RB had the lowest break-even price and the least investment cost.

DEVELOPMENT OF TRAINING MODULES FOR AQUACULTURE EXTENSION WORKERS AND UNIVERSITY STUDENTS IN KENYA

Ninth Work Plan, Feeds and Fertilizers Research 6 (9FFR6)
Final Report

Charles C. Ngugi
Department of Fisheries
Moi University
Eldoret, Kenya

Len Lovshin, Karen Veverica, and Tom Popma
Department of Fisheries and Allied Aquacultures
Auburn University, Alabama, USA

James Bowman
Department of Fisheries and Wildlife
Oregon State University
Corvallis, Oregon, USA

ABSTRACT

A series of five highly successful short courses was conducted by the Kenya Project of the PD/A CRSP for Kenya Fisheries Department personnel during the period of the Ninth Work Plan. Activity leaders responsible for planning and carrying out these short courses felt constrained by a lack of training materials relevant to the aquaculture situation in Kenya. Although they were able to develop some materials and to borrow others for use in these courses, they did not have teaching modules specifically suited to Kenya on topics such as pond construction, composting, pond production of mixed-sex tilapia, fish nutrition, or production by species, all of which are key for the type of training currently needed in Kenya.

This activity was proposed to begin work on the development of such training modules. A faculty member from the Moi University Department of Fisheries spent eight weeks at Auburn University, Alabama, while beginning to develop training modules for use in future training sessions in Kenya. Three complete modules were developed, and work on nine others was begun. A digital camera and a new computer, to be used for continued work on module

development back in Kenya, were provided. Over 1,800 slides and photographs suitable for use in training courses were digitized and saved to disk for further work in Kenya. While in the US, the participant was also able to attend and participate in the annual conference of the World Aquaculture Society (Aquaculture America 2001) and the Annual Meeting of the PD/A CRSP, as well as to visit commercial fish-farming operations in western Alabama. This activity was conducted between 16 January and 15 March 2001.

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

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

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

Charles Ngugi
Department of Fisheries
Moi University
Eldoret, Kenya

Judith Amadiva
Social Development Officer
Sagana Fish Farm
Sagana, Kenya

James R. Bowman
Department of Fisheries and Wildlife
Oregon State University
Corvallis, Oregon, USA

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. Such trials also allow 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 four districts in Central Province and one in Eastern Province, Kenya, in 1999 and 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^{-2} for tilapia, 0.2 fish m^{-2} for catfish stocked with tilapia, and 1 fish m^{-2} for catfish stocked alone. Management schemes tested included high, medium, and low management levels. Ponds were sampled for fish growth at four- to six-week intervals, and farmers kept records of input type and weight, input costs, pond water additions, fish mortality, and fish sampling data. A post-trial workshop was held in March 2001 to summarize and evaluate the results of the trials. As a result of their participation in these trials, farmers learned that improved management can indeed lead to increased production, something that they were not convinced of prior to the trials. The average increase in fish harvested during these trials was 330% (3.5 T ha^{-1}, as compared with an estimate of just over 1 T ha^{-1} prior to the trials). Almost two-thirds of the ponds gave net revenues exceeding 250,000 KSh ha^{-1} yr^{-1}; the average being 310,832 KSh ha^{-1} yr^{-1}. Farmers also concluded that increasing the sizes of their ponds would further contribute to increases in production.

Phase two of the trials—in the western region of Kenya—began with a visit to the six districts' headquarters in December 2000. In May 2001 a pre-trial farmers workshop was held at the Bungoma Farmers Training Center to discuss and select management options suitable to the farmers. Ponds for the western region trials were stocked in May and June, and the first sampling visits were conducted in August. The trials are ongoing as of this report. As in Central and Eastern provinces, a post-trial workshop will be held to evaluate the results of these trials.

AQUACULTURE TRAINING FOR KENYAN FISHERIES OFFICERS AND UNIVERSITY STUDENTS

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

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

Charles C. Ngugi
Department of Fisheries
Moi University
Eldoret, Kenya

Judith Amadiva
Sagana Fish Farm
Sagana, Kenya

Mucai Muchiri
Department of Fisheries
Moi University
Eldoret, Kenya

James R. Bowman
Department of Fisheries and Wildlife
Oregon State University
Corvallis, Oregon, USA

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 Kenya Project in Kenya seeks to improve training and to provide a cadre of trainers who have extensive practical fish-production experience.

This year the Kenya Project continued scholarship support for two M.S. students, one at Moi University's Chepkoilel Campus, Eldoret, Kenya, and the other at Auburn University, 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.

The series of short courses for personnel of the Kenya Fisheries Department (FD), begun in 1999 and 2000, was concluded this year with the fifth and final course planned under this activity. In this series of courses, more than 80 FD staff received two weeks of training in pond construction methods and pond management techniques, and an additional 26 persons (24 Fisheries Officers and 2 outside-funded participants) received three weeks of advanced training in pond construction, pond management, and business planning. Additional farmer field days for approximately 50 farmers are also planned for later in 2001.

ESTABLISHMENT OF COMPANION SITES IN THE AFRICA REGION

Ninth Work Plan, Adoption/Diffusion Research 4 (9ADR4)
Final Report

James R. Bowman
Department of Fisheries and Wildlife
Oregon State University
Corvallis, Oregon, USA

Daniel Jamu
ICLARM/Malawi
National Aquaculture Center
Zomba, Malawi

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

ABSTRACT

The establishment of companion sites was proposed as a way of expanding CRSP efforts in each region by assisting with needed research at sites other than CRSP host country sites and verifying the results of CRSP research at its host country sites. For the Ninth Work Plan the Kenya Project set out to identify and establish at least one companion site in the Africa region and to design and implement investigations at that site in support of the goals and needs of both the PD/A CRSP and the companion site. Discussions in 1999 between CRSP Kenya Project personnel and ICLARM-Malawi (Zomba, Malawi) and Bunda College of Agriculture (near Lilongwe) led to an agreement to collaborate. With oversight from Daniel Jamu, Director of ICLARM-Malawi, two studies were conducted between May 2000 and January 2001, one at the National Aquaculture Center near Zomba, and the second at Bunda College, Lilongwe. Reports on these two studies, are included in this volume (See 9ADR4A, "Effect of Stocking Size and Nutrient Inputs on Productivity of *Oreochromis shiranus* in Ponds," and 9ADR4B, "Studies on Potential Use of Salinity to Increase Growth of Tilapia in Aquaculture in Malawi." An additional spin-off study conducted by a Bunda College student, "*Tilapia rendalli* Fry Production under a *Tilapia rendalli*/*Oreochromis shiranus* Polyculture: The Role of Competition and Predation," may be requested from the Program Management Office.

EFFECT OF STOCKING SIZE AND NUTRIENT INPUTS ON PRODUCTIVITY OF *OREOCHROMIS SHIRANUS* IN PONDS

Ninth Work Plan, Adoption/Diffusion Research 4A (9ADR4A)
Final Report

Kenneth Chaula
Aquaculture and Fisheries Science Department
Bunda College of Agriculture
University of Malawi
Lilongwe, Malawi

Daniel Jamu
ICLARM/Malawi
National Aquaculture Center
Zomba, Malawi

James R. Bowman
Department of Fisheries and Wildlife
Oregon State University
Corvallis, Oregon, USA

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

ABSTRACT

A study to investigate the effects of three different stocking sizes (5, 10, 20 g) and two isonitrogenous input regimes (maize bran × urea and napier grass × urea) on the production of *Oreochromis shiranus* was conducted between June and November 2000 at the Malawi National Aquaculture Center. Six treatments (three stocking sizes × two input regimes), each in triplicate, were used in the study. Inputs were applied to ponds stocked with fish at the three stocking sizes such that each input regime supplied 20 kg N ha^{-1} wk^{-1}. Fish were stocked at 2 fish m^{-2} and sampling (mean weight of 100 fish) was conducted biweekly. Water quality parameters (dissolved oxygen, pH, electrical conductivity, and Secchi disk visibility) were measured weekly, and total ammonia nitrogen and chlorophyll *a* were measured biweekly. The experiment was conducted over a period of 150 days.

The two isonitrogenous input regimes did not significantly affect fish net yield and growth rate. There were significant

differences ($P < 0.05$) in fish growth rate and net yield between treatments. The highest fish growth rates and production (net yield) were achieved in ponds when fish were stocked at 5 g and either input regime was used, while ponds stocked with 20-g fingerlings and supplied with either napier grass × urea or maize bran × urea had the lowest net mean yield. There were significant differences ($P < 0.05$) in gross margins between treatments, with treatments where fish were stocked at 5 g and napier grass × urea were applied giving higher gross margins than the rest of the treatments. Mean fish survival rate was not significantly different between treatments. Results from this study suggest that stocking *Oreochromis shiranus* at 5 g results in higher fish production and gross margins compared to stocking larger fish. The results further show that under conditions where inorganic fertilization is used, substituting napier grass for maize bran increases profitability without affecting overall fish yield.

STUDIES ON POTENTIAL USE OF SALINITY TO INCREASE GROWTH OF TILAPIA IN AQUACULTURE IN MALAWI

Ninth Work Plan, Adoption/Diffusion Research 4B (9ADR4B)
Final Report

Jeremy S. Likongwe
Aquaculture and Fisheries Science Department
Bunda College of Agriculture
University of Malawi
Lilongwe, Malawi

ABSTRACT

In a series of studies conducted in Malawi to determine the effects of different salinity concentrations on survival, growth, feed conversion, reproduction, and whole-body composition of five taxonomic groups of tilapia—*Oreochromis shiranus chilwae* (Lake Chilwa strain), *O. shiranus chilwae* (Bunda College strain), *O. karongae*, *O. shiranus shiranus*, and *Tilapia rendalli*—it was observed that the first three species grew faster in 10‰ salinity and would be recommended as potential candidates for brackishwater aquaculture in Malawi. *T. rendalli* and *O. shiranus shiranus* grew faster in fresh water (0‰ salinity) and are unsuitable for brackishwater aquaculture. With the exception of *O. shiranus chilwae* (Lake Chilwa strain) and *O. shiranus chilwae* (Bunda College strain), all species had lost carcass protein at the end of the study, suggesting that they used tissue protein as an additional energy source for osmoregulation and homeostasis. Salinity tolerance varied ontogenetically in almost all the above taxonomic groups, with younger individuals tolerating salinity longer than larger individuals. This study has also shown that the range of *T. rendalli* and *O. shiranus shiranus* would effectively be limited by salinity. The interactive effect of salinity and water temperature was not investigated in this study since all experiments were conducted at room temperature and ambient photoperiod. Temperature, however, has an influence on salinity tolerance, and in that light, we strongly recommend further investigations on the combined influence of the two abiotic factors (salinity and temperature) since they fluctuate together in nature, and their fluctuations may positively or negatively influence growth and reproductive performance of the above cichlids.

REGIONAL OUTREACH IN AFRICA

Ninth Work Plan, Adoption/Diffusion Research 5 (9ADR5)
Final Report

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

James R. Bowman
Department of Fisheries and Wildlife
Oregon State University
Corvallis, Oregon, USA

Bethuel Omolo
Kenya Fisheries Department
Sagana, Kenya

ABSTRACT

The goal of the Kenya Project's regional outreach activity has been to promote contact and communication among aquaculture research and extension personnel and organizations throughout the region. This was originally intended to be achieved mainly through participation at regional meetings and conferences, not only by presenting papers but also through participation in planning and organizing the meetings. It was hoped that such participation would 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. Several CRSP participants attended the Annual Conference of the World Aquaculture Society and the Annual Meeting of the PD/A CRSP in Orlando, Florida, in January 2001. This was followed by visits to research facilities at Auburn University and commercial operations in West Alabama.

KENYA PROJECT

Subcontract No. RD010A-13

Note: Additional project information on Networking, Educational Outreach, and Conferences appears in the Peru Project section, p. 51.

Staff

University of Arkansas at Pine Bluff, Arkansas

Rebecca Lochmann	US Principal Investigator
Felicia Bearden	Assistant
Jason Brown	Undergraduate Student Assistant

Background

The *Continuation Plan 1996* addressed the use of feed and fertilization combinations as a way of intensifying production systems. The plan also identified research objectives geared at 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

The following Ninth Work Plan investigation continued into the current reporting period (see the Peru Project (p. 51) for information on another funded investigation under this subcontract):

- Fish yields and economic benefits of tilapia/*Clarias* polyculture in fertilized ponds receiving commercial feeds or pelleted agricultural by-products /9FFR2A. The report submitted for this investigation was a final report.

Note: The schedule for 9FFR2A was modified. The revised schedule appears in the *Addendum to the Ninth Work Plan*. This investigation was 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. 55).

Networking

Lochmann met with David Liti from Moi University in Kenya at the World Aquaculture Society meeting in Orlando, Florida, on 21 January 2001. They discussed the use of stable isotopes to trace food sources in aquaculture ponds.

Educational Outreach

Lochmann includes material from the CRSP project in her fish nutrition lectures, and students and faculty are interested in the use of stable isotopes as tracers in pond studies.

Lochmann has developed a set of overheads describing Sagana Fish Farm and how her research benefits the overall Kenya Project. She presents it to students in classes and to visitors who are specifically interested in aquaculture and fisheries. Colleagues also borrow them to display in group presentations, showcasing the departmental research by faculty at UAPB.

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

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

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

ABSTRACT

Stable carbon and nitrogen isotopes were used to obtain estimates of the contribution of natural and supplemental feeds to the nutrition of *Oreochromis niloticus* in ponds (free-swimming or caged) receiving different inputs in Sagana, Kenya. Three dietary treatments were employed in the pond study: 1) the test diet; 2) a pig finisher diet; and 3) a rice bran diet. Feeding rates and fertilization regimes are detailed in the report for 9FFR2. For isotope analysis, samples of *Oreochromis* (free-swimming and caged) and plankton were taken from ponds in Sagana three times (January, March, and May) during the study. The carbon and nitrogen isotope ratios of the diets were analyzed once. Modest fish growth during the study on all dietary treatments (the fish acquired ≤ 50% of their final weight between January and May) limited the application of the stable isotope technique for determining the relative assimilation of plankton and the different diets. The patterns of change in the $\delta^{13}C$ and $\delta^{15}N$ of free-swimming and caged *Oreochromis* and plankton over time and their possible interpretation were described within and between treatments.

PHILIPPINES PROJECT

Subcontract No. RD010A-15 (UH)
Subcontract No. RD010A-20 (FIU)

Staff

Florida International University, Miami, Florida

Christopher L. Brown	US Principal Investigator, US Regional Coordinator

University of Hawaii, Manoa, Hawaii

Robert Howerton	Associate Investigator
James Szyper	Associate Investigator

Central Luzon State University, Muñoz, Nueva Ecija, Philippines

Remedios B. Bolivar	Host Country Principal Investigator
Joan T. Bulacso	Research Aide (May through June 2001)
Jason Bulaong	Graduate Student (March through April 2001; CRSP funded)
Eddie Boy T. Jimenez	Graduate Student (through March 2001; CRSP funded)
Julie Anne Lanuza	Undergraduate Student (through October 2000)

Site Background

The PD/A CRSP has been active in the Philippines from the program's inception in 1982, with a hiatus from 1987 to 1992. 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 Florida International University (FIU) became the lead institution for the Philippines Project. FIU now holds an MOU with CLSU.

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* goal of determining optimum fertilization rates at different sites. Another objective was to enhance fertilizer and feed efficiency and improve resource utilization and was addressed by an investigation on the timing of supplemental feeding. Another aspect of Philippines research was the dissemination of CRSP research results through extension activities such as workshops and development of written materials. Human capacity development through student support and facilities improvements rounds out the current reporting period's activities.

Work Plan Research

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

- Reduction of rations below satiation levels/9FFR3. The report submitted for this investigation was a final report.
- Production of improved extension materials/9ADR6B. The report submitted for this investigation was a final report.

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

- Educational development activities in support of tilapia aquaculture in the Philippines/9FFR5. The report submitted for this investigation was a final report.

Note: The schedule and methods for 9FFR3 were modified. The methods for 9ADR6B were modified. Revised schedule and methods appear in the *Addendum to the Ninth Work Plan*. 9FFR5 was approved after the publication of the *Ninth Work Plan*. The work plan for this investigation appears in the *Addendum to the Ninth Work Plan* coded as 9HCD4.

Networking

A collaboration between Central Luzon State University (CLSU) and the Genetically Improved Farmed Tilapia (GIFT) Foundation International is being formalized through a new memorandum of understanding. The organizations will work together on training aquaculture farmers in the use of PD/A CRSP feeding and fertilization strategies and the determination of standard curves for the growth of *Oreochromis niloticus*. The University of Arizona and the American Tilapia Association will also be involved in this effort.

Email contacts over the reporting period have included inquiries about tilapia farming, pond design, the types of tilapia strains and feed to use, and the economics of culture from places as far away as Ontario, Canada, and California. Most of the email contacts are from Filipinos living abroad who wish to establish tilapia businesses in the Philippines. The researchers commonly respond via email, and some replies are supplemented with written materials such as brochures and leaflets.

Two people visited Bolivar at CLSU to seek assistance on tilapia pond and tank culture, and technical assistance was provided to four individuals who made an inquiry on tilapia culture.

Domingo Guiwo, living in New Jersey, visited FAC after an initial contact had been made via email. Jim Mixon, an

American working in Riyadh, Saudi Arabia, who has maintained contact with Philippines Project personnel via email since 1999, visited FAC in April 2001.

Bolivar gave a lecture on "Pond fertilization and feeding strategies: The PD/A CRSP experience" for a symposium on pond management that was held in conjunction with a celebration of the 25th anniversary of the founding of the CLSU College of Fisheries. An estimated 140 participants attended, consisting of farmers (13 females; 47 males), fisheries students (24 females; 20 males), and faculty members and staff (22 females; 14 males).

Bolivar and Jimenez also presented a paper on "Supplemental feeding of Nile tilapia (*Oreochromis niloticus*) below satiation level in fertilized ponds" in the Fisheries session of an Agency In-House Review of On-going and Completed Research held at CLSU on 30 May 2001. An estimated 20 people attended the session, including three evaluators, fisheries students, faculty members of the College of Fisheries, and researchers from FAC and the Bureau of Fisheries and Aquaculture Research.

Educational Outreach

Jimenez was involved in the training of 20 farmers in Quirino, Isabela, in the northern Philippines on the subject of tilapia cage culture.

Bolivar gave a presentation on the PD/A CRSP Philippines Project to 84 students of Brown's Introductory Marine Biology course at FIU on 27 January 2001.

Bolivar and Jimenez served as resource persons on a training for tilapia production and hatchery management at FAC from 17 to 19 April 2001. The subject of the presentation was "Tilapia Production in Ponds," and the training was attended by six participants (two females and four males) from the private sector.

From 13 November to 4 December 2000, Bolivar provided training on pond aquaculture to Irima Alinafe Gondwe, a student from Malawi. Gondwe also conducted her research under the supervision of Bolivar on the comparison of two feeding strategies: ration below satiation levels and ration based on fish biomass percentage.

Bolivar also lectured in four courses: Hatchery and Pond Management; Advanced Aquaculture; Management of Hatcheries and Related Facilities; and Hatchery Management, which has one Ph.D. student. She integrated methods and results of the feeding strategies and pond fertilization experiments obtained from the PD/A CRSP research into her teachings.

Brown twice visited North Miami Beach High School, which has a magnet program in science. He is currently establishing undergraduate internships for two research students, at least one of whom will study tilapia issues of direct relevance to the ongoing PD/A CRSP project.

Brown also presented a lecture at the South Broward High School Marine Magnet program, including a section on PD/A CRSP research and educational activities, on 29 March 2001.

Jimenez and CLSU faculty member Vera Cruz visited FIU for technical training sessions lasting 10 and 8 days, respectively. They received technical training in confocal microscopy, specimen preparation, measurement of protein by the Lowry method, spectrophotometry, and morphometric analysis of larval and juvenile fish.

Publications

Bolivar, R.B. and G.F. Newkirk, 2000. Response to selection for body weight of Nile tilapia (*Oreochromis niloticus*) in different culture environments. In: K. Fitzsimmons and J. Carvalho Filho (Editors), Proceedings of the Fifth International Symposium on Tilapia Aquaculture. Rio de Janeiro, Brazil, pp. 12–23.

Bolivar, R.B., EB.T. Jimenez, and C.L. Brown, 2000. Tilapia feeding strategy to optimize production in ponds. Fisheries and Aquatic Resources Gazette, 2(2):2–3.

Brown, C.L., R. Bolivar, EB. T. Jimenez, and J. Szyper, 2000. Timing of the onset of supplemental feeding of Nile tilapia (*Oreochromis niloticus*) in ponds. In: K. Fitzsimmons and J. Carvalho Filho (Editors), Proceedings of the Fifth International Symposium on Tilapia Aquaculture. Rio de Janeiro, Brazil, pp. 237–240.

Lanuza, J.A.D., 2000. Effect of stocking sizes on the growth and survival performance of Nile tilapia (*Oreochromis niloticus*) in ponds. Undergraduate thesis, Central Luzon State University, Muñoz, Nueva Ecija, Philippines.

Conferences

Fifth International Symposium on Tilapia in Aquaculture at Rio de Janeiro, Brazil, September 3-7, 2000. (Bolivar)

Aquaculture America 2001 at Orlando, Florida, 21–25 January 2001. (Bolivar, Brown)

PD/A CRSP Annual Meeting at Orlando, Florida, 26 January 2001. (Bolivar, Brown)

USAID Biotechnology in Africa Roundtable at Washington, DC, 24 April 2001. (Brown)

REDUCTION OF FEED RATIONS BELOW SATIATION LEVELS IN TILAPIA POND PRODUCTION

Ninth Work Plan, Feeds and Fertilizers Research 3 (9FFR3)
Final Report

Christopher L. Brown
Marine Biology Program
Florida International University
North Miami, Florida, USA

Remedios B. Bolivar and Eddie Boy T. Jimenez
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

The goal of this study was to evaluate feeding strategies that could be used to reduce tilapia grow-out costs. Growth, yield, and survival of tilapia fed daily were compared at 100 and 67% of experimentally determined satiation. Analysis of growth performance parameters demonstrated that the reduction of rations to 67% of satiation had no effect on growth or yield suggesting that this approach may be useful to farmers wishing to reduce costs without compromising sales.

EDUCATIONAL DEVELOPMENT ACTIVITIES IN SUPPORT OF TILAPIA AQUACULTURE IN THE PHILIPPINES

Ninth Work Plan, Feeds and Fertilizers Research 5 (9FFR5)
Final Report

Christopher L. Brown
Marine Biology Program
Florida International University
North Miami, Florida, USA

Remedios B. Bolivar and Eddie Boy T. Jimenez
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

This host-country institutional capacity-building objective has been met and in fact exceeded, in part because of a small budget supplement that was made available late in the project. Three visitors from Central Luzon State University, Philippines, traveled to Florida International University as part of this objective, including two who received technical training. An additional graduate student at Central Luzon State University was supported in the course of his doctoral studies.

Physical improvements within the Freshwater Aquaculture Center were completed in the process of meeting the capacity-building objective; these improvements included the replacement of two obsolete computers, the renovation of teaching laboratories, and the construction of a set of poured-concrete fish-culture tanks on campus.

PRODUCTION OF IMPROVED EXTENSION MATERIALS

Ninth Work Plan, Adoption/Diffusion Research 6B (9ADR6B)
Final Report

Christopher L. Brown
Marine Biology Program
Florida International University
North Miami, Florida, USA

Remedios B. Bolivar and Eddie Boy T. Jimenez
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

Experimental results accumulated over two years of study indicate that a number of methods are available by which farmers can minimize the cost of feeding tilapia grown in ponds in the Philippines, with no adverse effects. Farmers have been clearly impressed with these results and the graphic demonstration of the potential to expand profit margins without adversely affecting fish health or uniformity. The distribution of extension brochures will allow the spread of this information more widely than is currently occurring (that is, by word of mouth, workshops, and newsletters). The inclusion of data and the contact information for project personnel will ensure the diffusion of useful technical details to tilapia farmers in and potentially beyond the Central Luzon region.

THAILAND PROJECT

Subcontract No. RD010A-04

Staff

The University of Michigan, Ann Arbor, Michigan

James S. Diana	US Principal Investigator, US Regional Coordinator
C. Kwei Lin	US Principal Investigator (stationed in Pathumthani, Thailand)

Asian Institute of Technology, Pathumthani, Thailand

Amrit Bart	Host Country Principal Investigator
Yang Yi	Host Country Principal Investigator
Chumpol Srithong	Research Associate (through November 2000)
Htin Aung Kyaw	Research Associate (through January 2001)
Vu Cam Luong	Research Associate (May and June 2001)
A.R.S.B. Athauda	Graduate Student (Sri Lanka; partially CRSP funded)
Ma Aye Aye Mon	Graduate Student (Burma; partially CRSP funded)
Potjanee Nadtirom	Graduate Student (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 concentrated on two areas of emphasis: environmental impacts of aquaculture and production optimization. CRSP research on semi-intensive culture of tilapia continued 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 addressed effluent release and pollution concerns. An additional investigation examined the use of ultrasound to enhance hormone-induced sex reversal.

Work Plan Research

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

- The application of ultrasound to produce all-male tilapia using immersion protocol/9RCR8. The report submitted for this investigation was a final report.
- Lotus-fish culture in ponds: Recycling of pond mud nutrients/9NS1. The report submitted for this investigation was a final report.
- Culture of mixed-sex Nile tilapia with predatory snakehead/9NS2. The report submitted for this investigation was a final report.
- Semi-intensive culture of tilapia in brackishwater ponds/9NS4. The report submitted for this investigation was a final report.

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

- Supplemental feeding for semi-intensive culture of red tilapia in brackishwater ponds/9NS5. The report submitted for this investigation was a final report.
- A manual of fertilization strategies and supplemental feeding for small-scale Nile tilapia culture in ponds/9ADR11. The report submitted for this investigation was a final report in the form of an abstract.
- Establishment of new collaboration in Bangladesh/9RA1. The report submitted for this investigation was a final report.

Note: The schedule for 9NS2 was modified. The schedule and methods for 9NS1 were modified. 9NS4 was approved after publication of the *Ninth Work Plan*. The revised schedule and methods for 9NS1 and 9NS2 and the 9NS4 work plan appear in the *Addendum to the Ninth Work Plan*. 9NS5, 9ADR11, and 9RA1 were approved after the publication of the *Addendum to the Ninth Work Plan.* The work plans for these investigations will appear in the *Second Addendum to the Ninth Work Plan*.

Networking

Bart visited Nepal (Kathmandu, Bitatnagar-Tarahara, Rampur, and Pokhara) to determine a research location suitable for a CRSP companion site and met there with Bhola Pradhan, Director of the Nepal Agricultural Research Council, and A.K. Rai, the Fisheries Station Chief for the Council. Bart also visited with three graduates from the AIT aquaculture program at the Institute of Agriculture and Animal Science in Rampur, where all three teach. The Asian Development Bank–supported site in Tarahara was selected as the companion site.

Yi traveled to Bangladesh where he discussed potential CRSP collaborations with Abdul Wahab of Bangladesh Agricultural University, John Grover of the International Center for Living Aquatic Resources Management (ICLARM) Office in Bangladesh, and Anwara Begum Shelly of the Caritas Fisheries Program in Bangladesh. Yi also corresponded via email with Bitu D'Costa, Executive Director of Caritas; Thomas Costa, Development Director of Caritas; Mokarrom Hossain, Senior Regional Manager (Fisheries) of the Bangladesh Rural Advancement Committee (BRAC); Greg Chapman, Rice-Fish Project Coordinator, CARE-Bangladesh; and Mr. Marahman of the NGO PROSHIKA, regarding potential collaboration between Caritas and the CRSP.

Lin traveled to Vietnam to visit Can Tho University and the University of Agriculture and Forestry in Ho Chi Minh City to engage in research collaboration.

James Rakocy, University of the Virgin Islands, visited AIT and discussed with Lin, Bart, and Yi the potential for future collaboration. Additionally, Syed Mannan, Director of United Aqua Farms (Bangladesh), visited AIT and discussed possibilities for future collaboration in tilapia culture with Lin and Yi.

Marc Verdegem and Anne van Dam of Wageningen University similarly visited AIT in April to discuss the possibilities of future collaboration with Lin and Yi.

Yi provided technical information on supplemental feeding of tilapia to Randall Reid Bevis, a member of a Christian NGO tilapia project in Chiang Mai, Thailand. Yi also provided technical information on tilapia culture to the Chiang Mai Rehabilitation Center in Thailand.

Lin, Yi, and Bart discussed aquaculture development with Mr. Rabindra and his colleague, both representatives of the Department of Aquaculture, Nepal.

Bjørn Myrseth, President of Marine Farms ASA, Norway, visited AIT. Yi briefed him on the PD/A CRSP and provided information on tilapia brackishwater culture.

Muhammad Mustafizur Rahman, a research assistant from Bangladesh Agricultural University, was invited to visit AIT and several fish farms in Thailand 6 to 14 June 2001. CRSP researchers at AIT briefed him on the history and current activities of the PD/A CRSP and trained him in analysis of water quality parameters using PD/A CRSP standard methods in data collection, data management, and data analysis.

Educational Outreach

Bart presented a lecture series to the Faculty of Aquatic Sciences, Burapa University, Chonburi, Thailand, on the sexual differentiation of teleost fish using tilapia as one of the model species.

Bart also worked with University faculty to improve aquaculture curriculum and teacher training in Bangladesh for the Support for University Fisheries Education and Research Project funded by the UKs Department for International Development (DFID).

Lin taught a water quality analysis course at the Research Institute for Aquaculture No. 1, Vietnam, in December 2000. Additionally, Lin gave a seminar on the status of aquaculture and fisheries management in the Mekong Delta in Jakarta, Indonesia, on 5 April 2001.

Yi presented a day-long lecture on Small-Scale/Rural Aquaculture Development for Rural Livelihood and Poverty Alleviation to 30 senior fisheries staff from Asia, Africa, South America, and Australia. The lecture was organized by the Asia-Pacific Regional Research and Training Center for Integrated Fish Farming at Wuxi, China, on 30 October 2000.

Yi also gave a half-day lecture on tilapia production to a group of five Indian senior fisheries staff in a training course organized by the Network of Aquaculture Centres in Asia-Pacific (NACA) on 16 December 2000.

Publications

Athauda, A.R.S.B., 2000. Ultra-sound immersion techniques to improve the efficiency of sex inversion of male tilapia population. M.S. thesis, Asian Institute of Technology, Pathumthani, Thailand.

Lin, C.K., M.K. Shrestha, Y. Yi, and J.S. Diana, 2001. Management to minimize the environmental impacts of pond effluent: Harvest draining techniques and effluent quality. Aquacultural Engineering, 25(2):125-135.

Yakupitiyage, A. and Y. Yi. Feeds in small-scale aquaculture. In: Utilizing Different Aquatic Environments for Small-Scale Aquaculture. (in press)

Yi, Y. and C.K. Lin, 2000. Analyses for various inputs for pond culture of Nile tilapia (*Oreochromis niloticus*): Profitability and possible environmental impacts. In: K. Fitzsimmons and J. Carvalho Filho (Editors), Proceedings of the Fifth International Symposium on Tilapia Aquaculture. Rio de Janeiro, Brazil, pp. 247–257.

Yi, Y. and C.K. Lin, 2001. 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, 195:253-267.

Yi, Y. and C.K. Lin. Role of low-cost fertilization in inland pond aquaculture. In: Utilizing Different Aquatic Environments for Small-Scale Aquaculture. (in press)

Yi, Y., C.K. Lin, and J.S. Diana. Comparison of economic returns for various strategies of Nile tilapia (*Oreochromis niloticus*) pond culture. Asian Fisheries Science. (in review)

Yi, Y., C.K. Lin, and J.S. Diana. Hybrid catfish (*Clarias macrocephalus* × *C. gariepinus*) and Nile tilapia (*Oreochromis niloticus*) culture in an integrated pen-cum-pond system: Growth performance and nutrient budgets. Aquaculture. (in review)

Yi, Y., C.K. Lin, and J.S. Diana. Recycling feeding wastes through integration of intensive and semi-intensive culture. In: Utilizing Different Aquatic Environments for Small-Scale Aquaculture. (in press)

Yi, Y., C.K. Lin, and J.S. Diana. Waste recycling in fish pond culture through integrated cage-cum-pond and pen-cum-pond culture systems. In: Proceedings of the Third World Fisheries Congress. (in review)

Presentations

Bart, A.N. Seed production of farmed fish: Critical issues for Asia. Presented to the Ag-Asia 2000 Conference at Bangkok, Thailand, 9–12 November 2000.

Bart, A.N. The use of ultrasound in mass marking of fish population, drug delivery, DNA transfer and cryopreservation of fish embryos. Presented to the International Conference on Advanced Technologies in Fisheries and Marine Sciences at Nagercoli, India, 2–6 February 2001.

Lin, C.K. Status of aquaculture and fisheries management in Mekong Delta. Presented to the International Symposium on Mahakum Delta at Jakarta, Indonesia, 4 April 2001.

Yi, Y., C.K. Lin, and J.S. Diana. Comparison of economic return, nutrient utilization efficiency and environmental impact among different culture systems of Nile tilapia *Oreochromis niloticus*. Presented to Aquaculture America 2001 at Orlando, Florida, 21–25 January 2001.

Conferences

Fifth International Symposium on Tilapia Aquaculture at Rio de Janeiro, Brazil, 2–7 September 2000. (Yi)
Third World Fisheries Congress at Beijing, China, 30 October–3 November 2000. (Yi)
Ag-Asia 2000 Conference at Bangkok, Thailand, 9–12 November 2000. (Bart)
Aquaculture America 2001 at Orlando, Florida, 21–25 January 2001. (Bart, Yi)
PD/A CRSP Annual Meeting at Orlando, Florida, 26 January 2001. (Bart, Diana, Yi)
International Conference on Advanced Technologies in Fisheries and Marine Sciences at Tamil Nadu, India, 2–6 February 2001. (Bart)
International Symposium on Mahakum Delta at Jakarta, Indonesia, 4 April 2001. (Lin)

The Application of Ultrasound to Produce All-Male Tilapia Using Immersion Protocol

Ninth Work Plan, Reproduction Control Research 8 (9RCR8)
Final Report

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

Abstract

Immersion protocols have been unsuccessful in consistently producing all-male tilapia at a high enough ratio for them to be commercially viable. This study explored ultrasound to improve on the results of previous immersion studies. Experiments were carried out to evaluate immersion with ultrasound as a sex-reversal procedure by 1) assessing duration of treatment (one vs. two hours) on the efficacy of hormone to sex reverse female tilapia and 2) examining the efficacy of various androgens. Due to low survival in experiment 2, experiment 3 was conducted with fewer treatments that included only two hormones (trenbolone acetate–TBA and 17a-methyldihydrotestosterone–MDHT) at two concentrations (100 and 250 mg l^{-1}) and with ultrasound (cavitation level).

Two-hour treatments with ultrasound resulted in a significantly higher percentage of males (92%) than one-hour (73%) treatments. Ultrasound treatment resulted in significantly higher percentages of males (94%) compared to treatments without ultrasound (89%). Two of the three replicates of the TBA-250 mg l^{-1} treatment in the third experiment resulted in 100% males and also in the highest percentage of males (98%). Variability within and between treatments with ultrasound was significantly lower (91 to 98%) than treatments with no ultrasound (83 to 94%). While there was no concentration effect, treatment of fry in TBA-250 mg l^{-1} and ultrasound resulted in significantly higher percentages of males (98.5%) than treatment with MDHT and ultrasound (90.5%). This study thus demonstrated the potential of a short-term immersion protocol using ultrasound to more predictably produce all-male tilapia seed.

Lotus-Fish Culture in Ponds: Recycling of Pond Mud Nutrients

Ninth Work Plan, New Aquaculture Systems/New Species Research 1 (9NS1)
Final Report

Yang Yi and C. Kwei Lin
Aquaculture and Aquatic Resources Management
Agricultural & Aquatic Systems and Engineering Program
Asian Institute of Technology
Pathumthani, Thailand

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

Abstract

An experiment was conducted in nine 200-m^2 fertilized earthen ponds at the Asian Institute of Technology, Thailand, from January to September 2000. This experiment was designed to assess the recovery of pond mud nutrient by lotus (*Nelumbo nucifera*), to assess pond mud characteristics after lotus-fish co-culture, and to compare fish growth with and without lotus integration. There were three treatments in triplicate: A) lotus-tilapia together; B) tilapia alone; and C) lotus alone. Seedlings (0.39 ± 0.09 kg) of Thai lotus variety were transplanted to ponds of treatments A and C at a density of 25 seedlings $pond^{-1}$, while sex-reversed all-male Nile tilapia (*Oreochromis niloticus*) fingerlings (8.6 to 10.3 g) were stocked at 2 fish m^{-2} in ponds of treatments A and B when the water depth had been increased to 50 cm due to increasing lotus height. Ponds stocked with tilapia (treatments A and B) were fertilized weekly with urea and triple superphosphate (TSP) at a rate of 28 kg nitrogen and 7 kg phosphorus ha^{-1} wk^{-1} after tilapia stocking. There was no fertilization in ponds of treatment C.

Lotus co-cultured with tilapia or cultured alone in ponds was able to effectively take up nutrients from old pond mud (about 300 kg N and 43 kg P ha^{-1} yr^{-1}) and resulted in the reduction of nutrients in mud by about 2.4 t N and 1 t P ha^{-1} yr^{-1}. There were no significant differences in lotus growth performance between treatments A and C, while Nile tilapia cultured alone grew significantly better than when co-cultured with lotus. The partially budget analysis indicates that lotus cultured alone generated the highest net return, and lotus contributed the largest portion of net income in lotus-tilapia co-culture. The present experiment has demonstrated the effectiveness of nutrient removal from old pond mud by lotus and the feasibility of rotation and co-culture of lotus and Nile tilapia technically and economically. Both systems can recycle nutrients effectively within ponds and are environmentally friendly culture systems.

CULTURE OF MIXED-SEX NILE TILAPIA WITH PREDATORY SNAKEHEAD

Ninth Work Plan, New Aquaculture Systems/New Species
Research 2 (9NS2)
Final Report

Yang Yi and C. Kwei Lin
Aquaculture and Aquatic Resources Management
Agricultural & Aquatic Systems and Engineering Program
Asian Institute of Technology
Pathumthani, Thailand

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

ABSTRACT

An experiment was conducted in eighteen 200-m^2 fertilized earthen ponds at the Asian Institute of Technology, Thailand, from March through October 2000. This experiment was designed to assess the efficiency of snakehead (*Channa striata*) in controlling recruitment of mixed-sex Nile tilapia (*Oreochromis niloticus*) in ponds and to assess growth and production characteristics of Nile tilapia in monoculture and polyculture with snakehead. There were six treatments: A) monoculture of sex-reversed all-male tilapia; B) monoculture of mixed-sex tilapia; C) polyculture of snakehead and mixed-sex tilapia at 1:80 ratio; D) polyculture of snakehead and mixed-sex tilapia at 1:40 ratio; E) polyculture of snakehead and mixed-sex tilapia at 1:20 ratio; F) polyculture of snakehead and mixed-sex tilapia at 1:10 ratio. Sex-reversed and mixed-sex Nile tilapia were stocked at 2 fish m^{-2} at sizes of 10.5 to 11.6 g and 7.2 to 8.1 g, respectively.

Results show that snakehead were able to completely control Nile tilapia recruitment at all tested predator:stocked-prey ratios, and the best predator:stocked-prey ratio was 1:80. The addition of snakehead into Nile tilapia ponds did not result in significantly greater tilapia growth, but it significantly lowered total net and gross yields of adult plus recruited tilapia. Snakehead growth was density-dependent, decreasing significantly with increasing stocking densities. While snakehead biomass gain was not significantly different at stocking densities from 0.025 to 0.1 fish m^{-2}, the gain was significantly lower at a stocking density of 0.2 fish m^{-2}. The present experiment demonstrates that snakehead are able to control Nile tilapia recruitment completely and provide an alternative technique for Nile tilapia culture.

SEMI-INTENSIVE CULTURE OF RED TILAPIA IN BRACKISHWATER PONDS

Ninth Work Plan, New Aquaculture Systems/New Species
Research 4 (9NS4)
Final Report

Yang Yi and C. Kwei Lin
Aquaculture and Aquatic Resources Management
Agricultural & Aquatic Systems and Engineering Program
Asian Institute of Technology
Pathumthani, Thailand

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

ABSTRACT

An experiment was conducted at the Asian Institute of Technology, Thailand, to investigate effects of fertilization rates and salinity levels on the growth of sex-reversed, Thai red tilapia (*Oreochromis* sp.). The experiment was designed to test two fertilization rates (28 kg nitrogen and 7 kg phosphorus ha^{-1} wk^{-1}, N:P = 4:1; and 14 kg N and 7 kg P ha^{-1} wk^{-1}, N:P = 2:1) and three salinity levels (10, 20, and 30‰). An additional treatment using optimized fertilization rates (28 kg N and 7 kg P ha^{-1} wk^{-1}, N:P = 4:1) in freshwater ponds served as a control. Red tilapia fingerlings (20.2 to 23.7 g size) were stocked at 2.4 fish m^{-2} in 5-m^2 cement tanks with soil bottoms. They were cultured for 160 days.

Growth performance of red tilapia was better in brackish water than in fresh water. Growth of red tilapia in brackish water was inversely related to the salinity levels (r = –0.63, $P < 0.05$), decreasing significantly with increasing salinity. Best growth performance was achieved in the treatment with N:P ratio of 4:1 at 10‰ salinity. The highest net economic return was achieved in the treatment with N:P ratio of 2:1 at 10‰ salinity, and all treatments had positive returns.

Preliminary trials using a single species of marine phytoplankton showed that growth of red tilapia fed with *Chaetoceros* sp. and *Thalassiosira* sp. was significantly better than those fed with *Tetraselmis* sp. and *Chlorella* sp., and the former two resulted in a significantly higher protein utilization efficiency than the latter two. The prey ingestion rate of red tilapia for *Chaetoceros* sp. and *Thalassiosira* sp. was significantly higher than that for *Tetraselmis* sp. and *Chlorella* sp.

SUPPLEMENTAL FEEDING FOR SEMI-INTENSIVE CULTURE OF RED TILAPIA IN BRACKISHWATER PONDS

Ninth Work Plan, New Aquaculture Systems/New Species Research 5 (9NS5)
Final Report

Yang Yi and C. Kwei Lin
Aquaculture and Aquatic Resources Management
Agricultural & Aquatic Systems and Engineering Program
Asian Institute of Technology
Pathumthani, Thailand

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

ABSTRACT

An experiment was conducted at the Asian Institute of Technology, Thailand, to investigate effects of feeding regimes on growth of sex-reversed Thai red tilapia (*Oreochromis* sp.). There were five different supplemental feeding regimes: 0, 25, 50, 75, and 100% of satiation. Red tilapia fingerlings (33.2 to 33.4 g size) were stocked at 62.5 fish m^{-3} in fifteen 0.8-m^3 net cages suspended in a 200-m^2 earthen pond and cultured for 90 days. The pond was maintained at 10‰ salinity and fertilized weekly at rates of 4 kg N and 1 kg P ha^{-1} d^{-1}. Growth performance of red tilapia was significantly better in the feeding treatments than in the non-feeding treatment. Red tilapia growth and average feeding rate increased, but the Feed Conversion Ratio (FCR) and net economic return decreased with increasing percentages of satiation feeding levels from 25 to 100%. Considering low FCR, good growth and yield performance, high economic return, and potential for growing to greater size, 50% satiation feeding was the most efficient feeding rate.

A MANUAL OF FERTILIZATION AND SUPPLEMENTAL FEEDING STRATEGIES FOR SMALL-SCALE NILE TILAPIA CULTURE IN PONDS

Ninth Work Plan, Adoption/Diffusion Research 11 (9ADR11)
Final Report

Yang Yi and C. Kwei Lin
Aquaculture and Aquatic Resources Management
Agricultural & Aquatic Systems and Engineering Program
School of Environment, Resources and Development
Asian Institute of Technology
Pathumthani, Thailand

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

ABSTRACT

This study was conducted at the Asian Institute of Technology from January to June 2001 to summarize the PD/A CRSP work on Nile tilapia (*Oreochromis niloticus*) pond culture in Thailand and thus to develop a manual of fertilization and supplemental feeding strategies for small-scale Nile tilapia culture in ponds. The manual consists of eight sections. Section 1 gives a brief introduction to PD/A CRSP work and Nile tilapia culture; section 2 introduces pond preparation; section 3 examines different sources of pond inputs and quality; sections 4 and 5 focus on fertilization and supplemental feeding strategies, respectively; section 6 presents methods to control overpopulation of Nile tilapia; section 7 introduces pond management; and section 8 gives a simple economic analysis to select the suitable strategy. The aims of the manual are to provide simple guidelines of fertilization, supplemental feeding, and pond management for small-scale Nile tilapia pond culture and to provide simple extension and training materials to extension workers, trainers, and well-educated farmers. We expect that small-scale fish farmers in Asian countries, especially in Southeast and South Asia, will benefit from this manual to produce Nile tilapia through effectively using organic and inorganic fertilizers and feeds to increase fish production, achieve higher economic returns, and reduce environmental impacts.

ESTABLISHMENT OF NEW COLLABORATION IN BANGLADESH

Ninth Work Plan, Regional Analysis: Human-Environment Interactions 1 (9RA1)
Final Report

Yang Yi and C. Kwei Lin
Aquaculture and Aquatic Resources Management
Agricultural & Aquatic Systems and Engineering Program
School of Environment, Resources and Development
Asian Institute of Technology
Pathumthani, Thailand

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

ABSTRACT

This activity was conducted from January to June 2001. Through this activity, a new link between the PD/A CRSP and a Bangladesh institution has been established. The potential PD/A CRSP collaborators in Bangladesh were identified, including an academic institution, Bangladesh Agricultural University, and three nongovernmental organizations (NGOs), namely Bangladesh Rural Advancement Committee (BRAC), Caritas and PROSHIKA. The needs in aquaculture research in Bangladesh were also identified with a priority to optimize the fertilization regimes in pond culture. This report describes the potential site, current status of aquaculture development in Bangladesh, and the potential role of the PD/A CRSP. The establishment of collaboration with academic institutions and NGOs in Bangladesh will provide great opportunities for extending research and impacts of the PD/A CRSP to Bangladesh and South Asia, which is a potential site of the project in the future. Bangladesh researchers, NGO and government extension staff, and fish farmers will benefit from the experiences, research results, and approaches of the PD/A CRSP through the collaboration.

APPENDIX 1. PD/A CRSP HISTORY

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. Oregon State University is the Management Entity for the PD/A CRSP. Under the CRSPs current grant, the program is authorized through 31 July 2003.

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; and
- 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; and
- 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 research-

ers, 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 CRSPs first year of operations under its fourth 5-year USAID grant. A two-year grant extension by USAID authorizes the program through 31 July 2003.

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 an 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 2001

Since the initiation of the current grant, the *Continuation Plan 1996*, new lead projects have been established in Mexico, Peru, Kenya, and the Philippines and institutional relationships were restructured for the Honduras Project. CRSP research in Southeast Asia has been headed up by the Thailand Project since the inception of the program.

In 1996 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* identified the Philippines as a potential lead site. In 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 has also since been formalized.

In early 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. 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:

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

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 5, pp. 80–82.

APPENDIX 2. PROGRAM PARTICIPANTS

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, 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.

Host country staff participate in the CRSP though 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
Kenyatta University, Nairobi, Kenya
Moi University, Eldoret, Kenya
Nyanchwa College of Science and Technology, Kisii, 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

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
Danielle Clair	Assistant Director of Operations
Cormac Craven	Assistant Director of Research
Joan Westfall	Office Manager
Pamela Buitrago	Faculty Research Assistant (from March 2001)
John Hayes	Graduate Research Assistant (Uruguay/USA; through June 2001; CRSP funded)
Heidi Furtado	Undergraduate Student Worker (from March 2001)
Kelli Lewis	Undergraduate Student Worker (October 2000 through June 2001)
Katy Lloyd	Undergraduate Student Worker (from June 2001)

United States Agency for International Development (USAID), Washington, DC

Harry Rea	Cognizant Technical Officer

ADVISORY BODIES

Board of Directors

Dennis Balogu, Chair	University of Arkansas at Pine Bluff
L.J. (Kelvin) Koong	Oregon State University (through December 2000)
Stephanie Sanford	Oregon State University (from February 2001)
T.H. Lee Williams	University of Oklahoma
Anthony Young	Southern Illinois University at Carbondale

Ex-Officio Board Members

Harry Rea	USAID
Hillary Egna	Oregon State University

External Evaluation Panel

Christine Crawford	University of Tasmania, Australia
Dave Cummins	University of Georgia
Kevan Main, Chair	Mote Marine Laboratory, Sarasota, Florida
Edna McBreen	University of Connecticut, Tarrington

Technical Committee*

Technical Committee*	Institution	
Co-Chairs		
Jim Diana	UM	
Kevin Fitzsimmons	UA	
Material and Methods Subcommittee		*Research Area of Expertise*
Claude Boyd	AU	Production optimization
Freddy Arias	Zamorano	Social and economic aspects
Yang Yi	AIT	Environmental effects
Technical Progress Subcommittee		
Joe Molnar	AU	Social and economic aspects
Amrit Bart	AIT	Environmental effects
Jim Bowman	OSU	Production optimization
Work Plan and Budget Subcommittee		
Tom Popma	AU	Production optimization
Carole Engle	UAPB	Social and economic aspects
Wilfrido Contreras-Sánchez	OSU	Environmental effects
External At-Large Members		
Damon Seawright	US tilapia producer	
Ex-Officio Members		
Harry Rea	USAID	
Hillary Egna	OSU	
Cormac Craven	OSU	

* Membership as of 2001 Technical Committee election; see *Eighteenth Annual Administrative Report* for previous roster. Subcommittee members are listed in order of seniority.

APPENDIX 3. FINANCIAL SUMMARY

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 2000 to 31 July 2001. Official financial reports are submitted to USAID via the Management Entity's Research Accounting Office.

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, Continuation Plan 1996

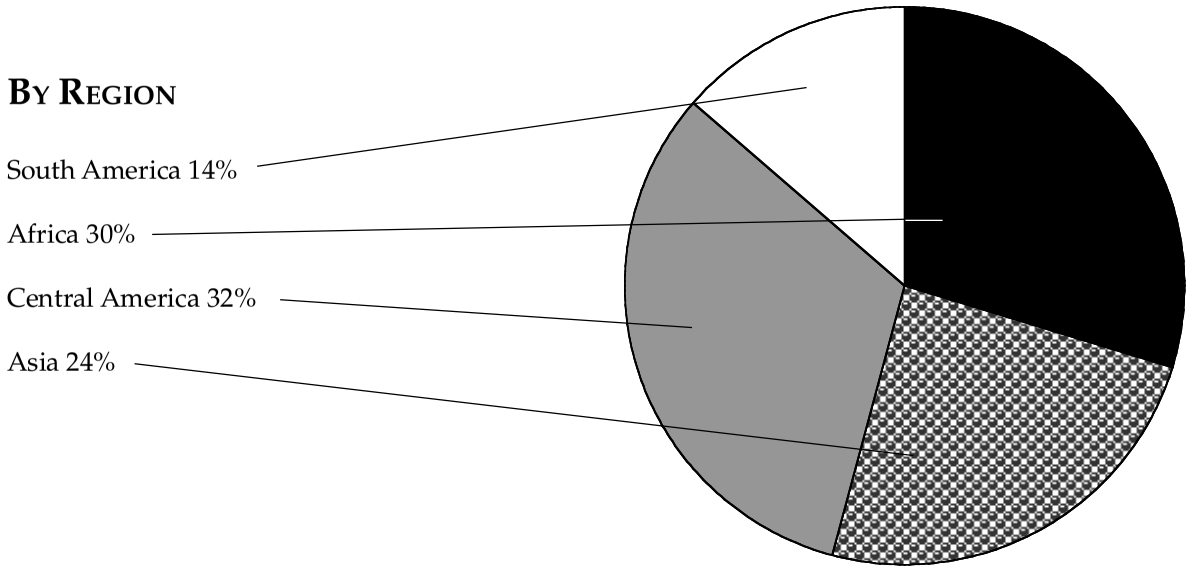
August 1, 2000–July 31, 2001

Subcontract Number	Project Leader	Institution	USAID[1] 8/00-7/01	USAID[1] Since 8/96	Cost Share[2] 8/00-7/01	Cost Share[2] Since 8/96	Total US Funds	Host Country Contributions[3] 8/00-7/01	Host Country Contributions[3] Since 8/96
Research									
RD009A-01	Bowman	Oregon State University	0	708,058	0	65,663	773,721	40,512	122,512
RD009B-01	Bolte	Oregon State University	0	313,524	0	85,835	399,359		
RD009B-01	*Heikes*	*University of Arkansas at Pine Bluff*	0	7,900	0	4,148	12,048		
RD009C-01	Schreck	Oregon State University	110,683	479,500	26,391	103,928	583,428	13,850	28,850
RD009L-01	Clair	Oregon State University	188,022	188,022	34,114	34,114	222,136		
RD010E-01[4]	Engle	University of Arkansas at Pine Bluff	101,815	326,529	38,449	94,159	420,688		
RD010E-02	Shelton	University of Oklahoma	0	117,280	0	31,194	148,474		
RD010E-03	Piedrahita	University of California, Davis	0	78,101	0	26,611	104,712		
RD010E-04	Diana	University of Michigan	246,318	791,171	41,452	128,249	919,420	21,000	125,000
RD010E-05	Ward	University of Texas at Austin	0	19,767	0	4,066	23,833		
RD010E-06	Green	Auburn University	0	502,056	0	78,435	580,491	0	140,484
RD010E-07	Boyd	Auburn University	58,562	207,359	15,284	55,008	262,367		
RD010E-07	Wood	Auburn University	64,721	95,170	16,180	24,434	119,604		
RD010E-08	Lim	Auburn University	68,680	517,658	17,925	120,018	637,676		
RD010E-09	Phelps	Auburn University	47,230	137,233	12,401	33,234	170,467		
RD010E-10	Molnar	Auburn University	0	68,293	0	14,489	82,782		
RD010E-11	Fitzsimmons	University of Arizona	41,755	124,088	14,368	40,276	164,364	0	7,050
RD010E-12	Kohler	Southern Illinois University	142,158	430,199	48,336	151,419	581,618	43,218	128,607
RD010E-12	*Dabrowski*	*Ohio State University*	0	13,000	0	11,963	24,963		
RD010E-13	Lochmann	University of Arkansas at Pine Bluff	29,868	79,184	8,750	24,554	103,738		
RD010E-14	Lovshin	Auburn University	0	67,168	0	16,792	83,960		
RD010E-15	Brown	University of Hawaii	0	100,061	0	25,015	125,076		
RD010E-16	Verma	University of Georgia	65,433	220,433	9,532	54,233	274,666	11,200	18,200
RD010E-17	Molnar	Auburn University	44,319	109,320	11,080	27,330	136,650		
RD010E-18	Hatch	Auburn University	0	55,266	0	13,816	69,082		
RD010E-19	Boyd	Auburn University	0	45,947	0	11,487	57,434		
RD010E-20	Brown	Florida International University	91,593	218,287	45,153	84,522	302,809	6,500	14,500
RD010E-21	Dabrowski	The Ohio State University	67,224	67,224	24,600	24,600	91,824		
RD010E-22	Batterson	Michigan State University	57,020	57,020	14,274	14,274	71,294		
Special Activities							0		
ISTA 5 Sponsorhip	Fitzsimmons	University of Arizona	0	12,500	0	5,000	17,500	15,000	15,000
IFFET Conference Sponsorhip	Shriver	Oregon State University	0	10,000	0	2,500	12,500		
Côte d'Ivoire Report	Kaplan	Hofstra University	0	4,000	0	0	4,000		
Impact Assessment Report	TBA	TBA	0	30,000	0	7,500	37,500		
Database Transition	TBA	TBA	30,000	30,000	7,500	7,500	37,500		
Research Support							0		
RD009G-01 Central Database Management		Oregon State University	0	279,214	0	73,083	352,297		
RD009E-01 Education Development		Oregon State University	0	244,970	0	61,242	306,212		
RD009K-01 Information Management & Networking		Oregon State University	313,501	1,611,782	79,300	402,946	2,014,728		
Subcontract Administration		Indirect on Subs up to 25,000	13,000	141,640	0	0	141,640		
Research Subtotal			1,781,902	8,508,924	465,089	1,963,637	10,472,561	151,280	600,203
MANAGEMENT									
Program Management									
Operations and Administration[5]		OSU Management	430,000	2,411,000			2,411,000		
Advisory Groups		OSU Advisory	35,000	459,710			459,710		
Program Management Subtotal			465,000	2,870,710			2,870,710		
Total			2,246,902	11,379,634	465,089	1,963,637	13,343,271	151,280	600,203

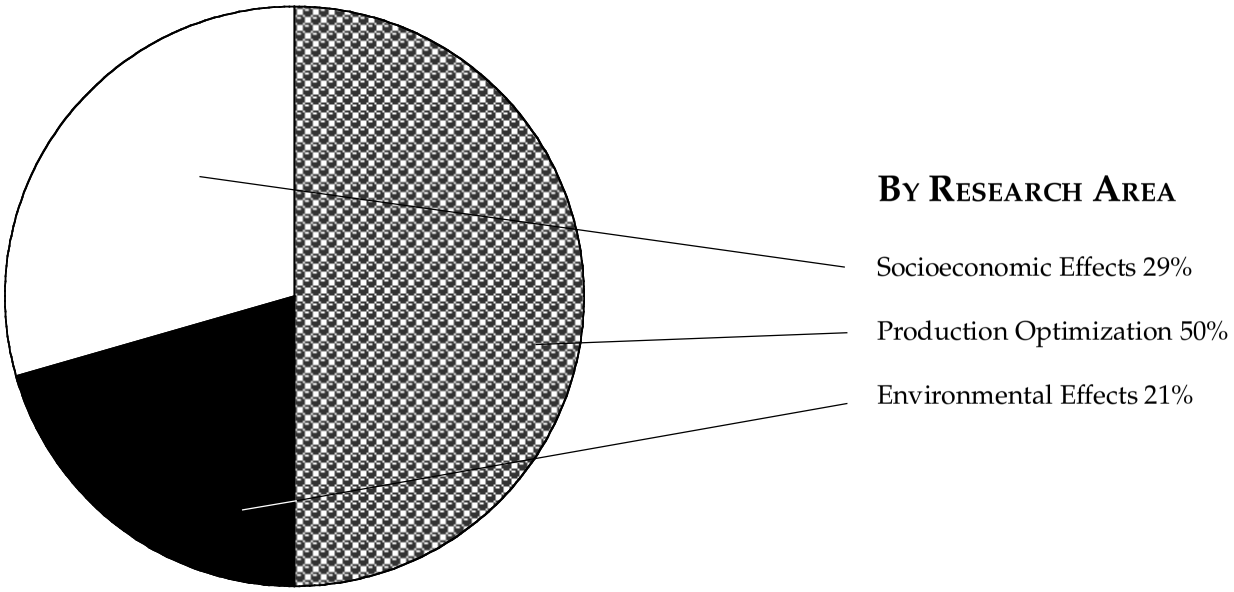
Notes: 1. Reflects funding received and committed under six USAID allocations; 2. Cost share figures reflect subcontract commitments; 3. Host country contributions are voluntary; 4. Current year allocation is an estimate; 5. Cost sharing is not required for management operations.

Research Expenditures for the Period 1 August 1996 through 31 July 2001

BY REGION



BY RESEARCH AREA



RESEARCH AREA: PRODUCTION OPTIMIZATION				
Research Theme	**Reporting PI**	**Report Title**	**Research Theme Code**	**Report Received**
Pond Dynamics	Boyd	Pond Soil Characteristics and Dynamics of Soil Organic Matter and Nutrients	9PDR2	Final
Feeds and Fertilizers	Bowman	Growth Performance and Economic Benefits of *Oreochromis niloticus/Clarias gariepinus* Polyculture Fed on Three Supplementary Feeds in Fertilized Tropical Ponds †	9FFR2	Final
	Lochmann	Fish Yields and Economic Benefits of Tilapia/*Clarias* Polyculture in Fertilized Ponds Receiving Commercial Feeds or Pelleted Agricultural By-Products	9FFR2A	Final
	Brown	Reduction of Feed Rations below Satiation Levels in Tilapia Pond Production †	9FFR3	Final
	Brown	Educational Development Activities in Support of Tilapia Aquaculture in the Philippines	9FFR5	Final
	Bowman	Development of Training Modules for Aquaculture Extension Workers and University Students in Kenya	9FFR6	Final
Reproduction Control	Schreck	Masculinization of Tilapia by Immersion in Trenbolone Acetate: Detection of Trenbolone Acetate in Water after Treatment	9RCR5C	Final
	Schreck	Masculinization of Nile Tilapia Fry by Immersion in Trenbolone Acetate: Reuse of Hormone Solution and Effects of Temperature	9RCR5D	Final
	Phelps	Monosex Tilapia Production through Androgenesis: Selection of Individuals for Sex Inheritance Characteristics for Use in Monosex Production	9RCR6A	Final
	Shelton	Monosex Tilapia Production through Androgenesis	9RCR7	Final
	Diana	The Application of Ultrasound to Produce All-Male Tilapia Using Immersion Protocol	9RCR8	Final
New Aquaculture Systems/ New Species	Diana	Lotus-Fish Culture in Ponds: Recycling of Pond Mud Nutrients	9NS1	Final
	Diana	Culture of Mixed-Sex Nile Tilapia with Predatory Snakehead	9NS2	Final
	Kohler	Development of Sustainable Pond Aquaculture Practices for *Colossoma macropomum* and *Piaractus brachypomus* in the Peruvian Amazon †	9NS3 and 6	Final
	Lochmann	Spawning and Grow-Out of *Colossoma macropomum* and/or *Piaractus brachypomus*	9NS3A	Final
	Diana	Semi-Intensive Culture of Red Tilapia in Brackishwater Ponds †	9NS4	Final
	Diana	Supplemental Feeding for Semi-Intensive Culture of Red Tilapia in Brackishwater Ponds	9NS5	Final

† Title of report is different than investigation title listed in the Ninth Work Plan.

RESEARCH AREA: ENVIRONMENTAL EFFECTS				
Research Theme	**Reporting PI**	**Report Title**	**Research Theme Code**	**Report Received**
Effluents and Pollution	Schreck	Fate of Methyltestosterone in the Pond Environment: Use of MT in Earthen Ponds with No Record of Hormone Usage	9ER2D	Final
	Boyd	Effects of Water Recycling on Water Quality and Bottom Soils in Shrimp Ponds †	9ER4	Final
Appropriate Technology	Bowman	On-Farm Trials: Evaluation of Alternative Aquaculture Technologies by Local Farmers in Kenya	9ATR1	Progress
	Verma	Linkages of Aquaculture within Watersheds and Concurrent Design of Hillside Ponds	9ATR2	Final

RESEARCH AREA: SOCIAL AND ECONOMIC ASPECTS				
Research Theme	**Reporting PI**	**Report Title**	**Research Theme Code**	**Report Received**
Marketing & Economic Analysis	Engle	Development of Central American Markets for Tilapia Produced in the Region	9MEAR3	Final
	Engle	Economic and Social Returns to Technology and Investment in Thailand	9MEAR4	Final
	Hatch	Rapid Economic Evaluation Tools	9MEAR5	Final
Adoption/ Diffusion	Bowman	Aquaculture Training for Kenyan Fisheries Officers and University Students	9ADR3	Progress
	Bowman	Establishment of Companion Sites in the Africa Region	9ADR4	Final
	Bowman	Effect of Stocking Size and Nutrient Inputs on Productivity of *Oreochromis shiranus* in Ponds	9ADR4A	Final
	Bowman	Studies on Potential Use of Salinity to Increase Growth of Tilapia in Aquaculture in Malawi	9ADR4B	Final
	Bowman	Regional Outreach in Africa	9ADR5	Final
	Brown	Production of Improved Extension Materials	9ADR6B	Final
	Verma	Decision Support for Policy Development: Planning Conferences for Collaborating Researchers, Public Agencies, and Nongovernmental Organizations Working in Aquaculture	9ADR7	Final
	Verma	Production Strategies Characterizing Small- and Medium-Scale Tilapia Farms †	9ADR8	Final
	Verma	Technical Assistance for Fingerling Production Serving Small- and Medium-Scale Tilapia Producers & Training and Technical Assistance for Honduras Institutions Working with Small- and Medium-Scale Tilapia Producers	9ADR9 and 10	Final
	Diana	A Manual of Fertilization and Supplemental Feeding Strategies for Small-Scale Nile Tilapia Culture in Ponds	9ADR11	Final
Regional Analysis	Diana	Establishment of New Collaboration in Bangladesh	9RA1	Final
Decision Support Systems	Bolte	Decision Support Systems for Fish Population Management and Scheduling in Commercial Pond Aquaculture Operations	9DSSR2	Progress
	Bolte	Enhancing the POND© Decision Support System for Economics, Education, and Extension	9DSSR3	Progress

† Title of report is different than investigation title listed in the Ninth Work Plan.

APPENDIX 5. LINKAGES

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. 71 for a listing of institutions with formal linkages to the CRSP.)

Alabama Catfish Producers Association, Montgomery, Alabama
Alpha Aquaculture, Kenya
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
Aquacorporacion, International, Honduras
Aqua Technics, Carlsborg, Washington
Arid and Semi-Arid Lands (ASAL) Project, Government of Kenya, Laikipia, Kenya
Asian Development Bank, Tarahara, Nepal
Asociación Nacional de Acuicultores de Honduras (ANDAH), Tegucigalpa, Honduras
Association for International Agriculture and Rural Development (AIARD), Washington, DC
Bangladesh Agricultural University, Bangladesh
Bangladesh Rural Advancement Committee (BRAC), Bangladesh
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
Brunell Engineering Works, Kenya
Bunda College of Agriculture, University of Malawi, Lilongwe, Malawi
Bureau of Fisheries and Aquatic Resources (BFAR), Manila, Philippines
Can Tho University, Vietnam
Canadian International Development Agency (CIDA), Hull, Quebec, Canada
Caritas, Bangladesh and Iquitos, Peru
Central Laboratory for Aquaculture Research (CLAR), Abbassa, Egypt
Centro de Adiestamiento de la Agricultura Sostenible (CEASO), Honduras
Chiang Mai Rehabilitation Center, Thailand
Chulalongkorn University, Bangkok, Thailand
Clackamas County Extension Office, Oregon City, Oregon
Clemson University, Clemson, South Carolina
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, Honduras, Peru, and Atlanta, Georgia
Danish International Development Agency (DANIDA), Copenhagen, Denmark
Department of Agriculture, Yunnan Province, China
Department of Aquaculture, Nepal
Department for International Development (DFID) Fish Genetics Research Programme, Swansea, Wales, United Kingdom
Department of Fisheries, Udorn Thani, Thailand
Derby Holding Company, Kenya
Egerton University, Njoro, Kenya
Ejido Rio Playa, Comalcalco, Tabasco, Mexico
El Carao Fish Culture Station, Comayagua, Honduras

Empresa Brasileira de Pesquisa Agropecuária (Embrapa) Environmental Laboratory, Campinas, Brazil
Empresa Nacional de Energia Electrica, Tegucigalpa, Honduras
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
Fideicomisos Institutos en Relación con la Agricultura (FIRA), Morelia, Michoacán, Mexico
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
Forum for Organic Resource Management (FORMAT), Nairobi, Kenya
Genetically Improved Farmed Tilapia Program (GIFT), Muñoz, Nueva Ecija, Philippines
German Development Service, Kenya
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 Service for National Agricultural Research (ISNAR), Honduras
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
Magarini Aquafarmers, Malindi, Kenya
Marine Farms ASA, Norway
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 Agricultural Research Council, Nepal
National Council for Science and Technology, Mexico
National Inland Fisheries Institute (NIFI), Bangkok, Thailand
National Museums of Kenya, Nairobi, Kenya
National Research Initiative, 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
Noorul Islam College of Engineering, Tamil Nadu, India

Nuestros Pequeños Hermanos (NPH), Honduras
Oceanic Institute, Waimanalo, Hawaii
Oceanol, Centro, Tabasco, Mexico
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 Cooperativo de Investigacion y Transferencia de Tecnologia Agropecuaria para los Tropicos (PROCITROPICS), Peru
Programa Regional de Apoyo al Desarrollo de la Pesca en el Istmo Centroamericano (PRADEPESCA), Panama
Project Globale, Honduras
PROSEAL, Iquitos, Peru
PROSHIKA, Bangladesh
Red de Desarrollo Sostenible Honduras (RDS-HN), Honduras
Research Institute for Aquaculture No. 1, Hanoi, Vietnam
Roche Aquaculture Research Centre Asia Pacific, Bangkok, Thailand
Sagana Women's Group, Sagana, Kenya
Santo Tomás, Mexico
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
Texas Tech University, Lubbock, Texas
Uganda Wetlands and Resource Conservation Association (UWRCA), Uganda
United Aqua Farms, Bangladesh
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 Nacional Federico Villareal, Lima, Peru
Universidad Nacional Mayor de San Marcos, 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 Fisheries, Nhatrang, Vietnam
University of the North, Pietersburg, South Africa
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 6. 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

Green, B., 1992. Water and chemistry budgets for organically fertilized fish ponds in the dry tropics. Ph.D. dissertation, Auburn University, Alabama.

Publications and Reports

Alvarenga, H.R. and B.W. Green, 1985. Production of hybrid tilapia (*Tilapia nilotica* × *Tilapia honorum*) fingerlings. CRSP Technical Report (unpubl.), 12 pp. (in Spanish)

Alvarenga, H.R. and B.W. Green, 1986. Growth and production of all male *Tilapia nilotica* and all male hybrid tilapia (*Tilapia nilotica* × *Tilapia honorum*) in ponds. Rev. Latinoamericana de Acuicultura, 29:6–10. (in Spanish)

Alvarenga, H.R. and B.W. Green, 1989. Production and economic aspects of tilapia culture in ponds fertilized with chicken litter. Rev. Latinoamericana de Acuicultura, 40:35–39. (in Spanish)

Alvarenga, H.R., B.W. Green, and M.I. Rodriguez, 1984. A system for producing hybrid tilapia (*Tilapia nilotica* ×) fingerlings at the El Carao Aquaculture Experiment Station, Comayagua, Honduras. CRSP Technical Report (unpubl.), 9 pp. (in Spanish)

Alvarenga, H.R., B.W. Green, and M.I. Rodriguez, 1985. Pelleted fish feed vs. corn gluten as feed for tilapia and Chinese carp polyculture in ponds. CRSP Technical Report (unpubl.). (in Spanish)

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Ayub, M., C.E. Boyd, and D.R. Teichert-Coddington, 1993. Effects of urea application, aeration, and drying on total carbon concentrations in pond bottom soils. The Progressive Fish-Culturist, 55:210–213.

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Boyd, C.E. and B. Green, 1998. Dry matter, ash, and elemental composition of pond-cultured tilapia (*Oreochromis aureus* and *O. niloticus*). Journal of the World Aquaculture Society, 29:125–128.

Boyd, C.E. and D.R. Teichert-Coddington, 1992. Relationship between wind speed and reaeration in small aquaculture ponds. Aquacultural Engineering, 11:121–131.

Boyd, C.E. and D.R. Teichert-Coddington, 1994. Pond bottom soil respiration during fallow and culture periods in heavily-fertilized tropical fish ponds. Journal of the World Aquaculture Society, 25(3):210–213.

Boyd, C.E. and D.R. Teichert-Coddington, 1995. Dry matter, ash, and elemental composition of pond-cultured *Penaeus vannamei* and *P. stylirostris*. Journal of the World Aquaculture Society, 26(1):88–92.

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. Montaño (Editors), V Central American Symposium on Aquaculture. San Pedro Sula, Honduras, pp. 9–33.

Green, B.W., 1985. Report on the induced spawning of the silver and grass carps. CRSP Technical Report (unpubl.), 8 pp. (in Spanish)

Green, B.W., 1992. Substitution of organic manure for pelleted feed in tilapia production. Aquaculture, 101:213–222.

Green, B.W., 1995. Polyculture of tilapia with marine shrimp. Actas del Primer Simposio Centroamericano sobre cultivo de tilapia, pp. 117–125.

Green, B.W., 1997. Inclusion of tilapia as a diversification strategy for penaeid shrimp culture. In: D.E. Alston, B.W. Green, and H.C. Clifford (Editors), IV Symposium on Aquaculture in Central America: Focusing on Shrimp and Tilapia, 22–24 April 1997, at Tegucigalpa, Honduras. Asociación Nacional de Acuicultores de Honduras and the Latin American Chapter of the World Aquaculture Society, pp. 84–93.

Green, B.W., 1999. Sistemas de producción de tilapia en Honduras (Tilapia production systems in Honduras). In: B.W. Green, H.C. Clifford, M. McNamara, and G.M. Montaño (Editors), V Central American Symposium on Aquaculture, 18–20 August 1999 at San Pedro Sula, Honduras, pp. 254–257. (in Spanish)

Green, B.W. and H.R. Alvarenga, 1985. Tilapia and carp polyculture in ponds receiving organic fertilization and supplemental feed. CRSP Technical Report (unpubl.), 10 pp. (in Spanish)

Green, B.W. and H.R. Alvarenga, 1989. The effect of different application rates of chicken litter on tilapia production. Rev. Latinoamericana de Acuicultura, 40:31–34. (in Spanish)

Green, B.W. and C.R. Engle. Commercial tilapia aquaculture in Honduras. In: B. Costa-Pierce and J. Rakocy (Editors), Tilapia Aquaculture in the Americas, Volume 2. World Aquaculture Society, Baton Rouge, Louisiana. (in press)

Green, B.W. and L.A. López, 1990. Implementing the large-scale production of young males of *Tilapia nilotica* using hormonal sex inversion in Honduras. Agronomía Mesoamericana, 1:21–25. (in Spanish)

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Green, B.W. and D.R. Teichert-Coddington, 1994. Growth of control and androgen-treated Nile tilapia during treatment, nursery and growout phases in tropical fish ponds. Aquaculture and Fisheries Management, 25:613–621.

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Green, B.W., D.R. Teichert-Coddington, and T.R. Hanson, 1994. Development of semi-intensive aquaculture technologies in Honduras: Summary of freshwater aquacultural research conducted from 1983 to 1992. International Center for Aquaculture and Aquatic Environments Research and Development Series No. 39, Auburn University, Alabama, 48 pp.

Green, B.W., D.R. Teichert-Coddington, and R.P. Phelps, 1990. Response of tilapia yield and economics to varying rates of organic fertilization and season in two Central American countries. Aquaculture, 90:279–290.

Green, B.W., D.R. Teichert-Coddington, M.P. Micheletti, and C.A. Lara, 1997. A collaborative project to monitor water quality of estuaries in the shrimp producing regions of Honduras. Proceedings of the IV Ecuadorian Aquaculture Symposium, 22–27 October 1997. CENAIM, ESPOL, Camera Nacional de Acuicultura, Guayaquil, Ecuador. CD-ROM.

Green, B.W. D.R. Teichert-Coddington, C.E. Boyd, J. Wigglesworth, H. Corrales, D. Martinez, and E. Ramirez, Efecto del recambio de aqua en la producción semi-intensiva de *Penaeus vannamei* (Boone, 1831) (Crustacea Penaidae) en una granja pilota. In: B.W. Green, H.C. Clifford, M. McNamara, and G.M. Montaño (Editors), V Central American Symposium on Aquaculture. San Pedro Sula, Honduras, pp. 209–212. (in Spanish)

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Sherman, C., 1986. Growth of all-female *Tilapia nilotica* in earthen ponds fertilized with chicken litter. CRSP Technical Report (unpubl.), 14 pp. (in Spanish)

Teichert-Coddington, D.R., 1988. Effects of protein diet and sowing density on the production of *Penaeus vannamei* in land tanks. Rev. Latinoamericana de Acuicultura, 35:29–44.

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Panama ~ Aguadulce

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Panama ~ Gualaca

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APPENDIX 7. ACRONYMS

AAAS	American Association for the Advancement of Science
ADR	Adoption/Diffusion Research
AIARD	Association of International Agriculture and Rural Development
AIT	Asian Institute of Technology
ALCOM	Aquaculture for Local Community Development Programme
ANDAH	Asociación Nacional de Acuicultores de Honduras (Honduran National Association of Aquaculturists)
ASAL	Arid and Semi-Arid Lands
ATR	Appropriate Technology Research
AU	Auburn University
BASIS CRSP	Broadening Access and Strengthening Input Market Systems CRSP
BAU	Bangladesh Agricultural University
BFAR	Bureau of Fisheries and Aquaculture Research
BIFAD	Board for International Food and Agricultural Development
BMP	Best Management Practice
BOD	Board of Directors
BRAC	Bangladesh Rural Advancement Committee, Bangladesh
CARE	Cooperative for Assistance and Relief Everywhere
CASA	Central American Symposium on Aquaculture
CEASO	Centro de Adiestamiento de la Agricultura Sostenible
CENAIM	Centro Nacional de Acuicultura e Investigaciones Marinas (National Center for Aquaculture and Marine Research)
CGIAR	Consultative Group on International Agricultural Research
CIASC	CRSP Impact Assessment Strategy Committee
CIAT	Centro Internacional de Agricultura Tropical (International Center of Tropical Agriculture)
CIDA	Canadian International Development Agency
CIESIN	Consortium of International Earth Science Information Networks
CIFAD	Consortium for International Fisheries and Aquaculture Development
CIM	Catfish Inventory Management
CLAR	Central Laboratory for Aquaculture Research
CLSU	Central Luzon State University
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)
CONAM	Consejo Nacional del Ambiente (National Council for the Environment)
CRSP	Collaborative Research Support Program
CWESt	Center for Water and Environmental Sustainability
DANIDA	Danish International Development Agency
DFID	Department for International Development
DFID	Department of International Development
DM	Database Management
DSSR	Decision Support System Research
EAEN	East African Environmental Network
EARTH	Escuela de Agricultura de la Region Tropical Humeda (Agriculture School of the Tropical Humid Region)
EdOp Net	Educational Opportunities Network
EEP	External Evaluation Panel
EIFAC	European Inland Fisheries Advisory Commission
Embrapa	Empresa Brasileria de Pesquisa Agropecuária (Brazilian Agricultural Research Corporation)
Epagri	Empresa de Pesquisa Agropecuária e Extensão Rural de Santa Catarina (Rural Extension and Agricultural Research Institute of Santa Catarina)
ER	Effluents and Pollution Research
ESPOL	Escuela Superior Politécnica del Litoral (Superior Polytechnical School of the Coast)
FAC	Freshwater Aquaculture Center
FAO	Food and Agriculture Organization of the United Nations
FARMESA	Farm-Level Applied Research Methods for East and Southern Africa
FCR	Feed Conversion Ratio
FD	Fisheries Department
FDA	United States Food and Drug Administration
FFR	Feeds and Fertilizers Research
FIRA	Fideicomisos Institutos en Relación con la Agricultura, Morelia, Michoacán, Mexico
FIRI	Inland Water Resources and Aquaculture Service of the FAO
FISA	Fisheries Society of Africa
FIU	Florida International University
FONDEPES	Fondo Nacional de Desarrollo Pesquero (National Fund for Fishing Development)
FORMAT	Forum for Organic Resource Management, Nairobi, Kenya
FPX	Federación de Agroexportadores de Honduras (Federation of Export Producers of Honduras)
GIFT	Genetically Improved Farmed Tilapia
GIS	Geographic Information System
HBCU	Historically Black Colleges and Universities
HC	Host country
HCD	Human Capacity Development
hCG	Human chorionic gonadotropin
HD	High-Density Stocking without Water Recirculation
HDR	High-Density Stocking with Water Recirculation
HTML	Hypertext Markup Language
IA	Impact Assessment
ICLARM	International Center for Living Aquatic Resources Management
ICRAF	International Center for Research in Agroforestry
IDRC	International Development Research Centre
IHELP	International Higher Education Linkages Project

IIAP	Instituto de Investigaciones de la Amazonia Peruana (Research Institute of the Peruvian Amazon)
IIFET	International Institute of Fisheries Economics and Trade
IMARPE	Instituto del Mar del Perú (Marine Institute of Peru)
IMNC	Information Management and Networking Component
INTSORMIL CRSP	International Sorghum and Millet CRSP
IPB	Institut Pertanian Bogor (Agricultural Institute of Bogor)
ISNAR	International Service for National Agricultural Research, Honduras
ISTA	International Symposium on Tilapia Aquaculture
IUCN	World Conservation Union
JCARD	Joint Committee on Agricultural Research and Development
JICA	Japan International Cooperation Agency
KEMRI	Kenya Medical Research Institute
KUL	Katholieke Universiteit Leuven (Catholic University of Leuven)
LD	Low-Density Stocking without Water Recirculation
LHRHa	Luteinizing hormone-releasing hormone analog
LVEMP	Lake Victoria Environmental Management Programme
MDHT	17α-methyldihydrotestosterone
ME	Management Entity
MEAR	Marketing and Economic Analysis Research
MOU	Memorandum of Understanding
MSU	Michigan State University
MT	17α-methyltestosterone
NACA	Network of Aquaculture Centres in Asia-Pacific
NASULGC	National Association of State Universities and Land-Grant Colleges
NCRAC	North Central Regional Aquaculture Center
NGO	Nongovernmental Organization
NIFI	National Inland Fisheries Institute
NPH	Nuestros Pequeños Hermanos (Our Little Brothers)
NS	New Aquaculture Systems/New Species Research
NTIS	National Technical Information Services
ODBC	Open Database Connectivity
OLEDB	Object Linking and Embedding Database
OSU	Oregon State University
PD/A CRSP	Pond Dynamics/Aquaculture CRSP
PDF	Portable Document Format
PDR	Pond Dynamics Research
PI	Principal Investigator
PMO	Program Management Office
PPEC	Proposal Planning Executive Committee
PRADEPESCA	Programa Regional de Apoyo al Desarollo de la Pesca en el Istmo Centroamericano (Regional Development Support Program for Fisheries in the Central American Isthmus)
PROCITROPICS	Programa Cooperativo de Investigacion y Transferencia de Tecnologia Agropecuaria para los Tropicos, Peru
PROSEAL	Programa de Seguridad Alimentaria (Food Security Program)
PVO	Private volunteer organization
RA	Regional Analysis
RCR	Reproduction Control Research
RDS–HN	Red de Desarrollo Sostenible–Honduras (Network for Sustainable Agriculture–Honduras)
Red-COMAL	Red para Comercialización Comunitaria Alternativa (Alternative Community Marketing Network)
RFP	Request for Proposals
SACRED	Sustainable Agricultural Centre for Research and Development
SADC	Southern African Development Community
SANREM CRSP	Sustainable Agriculture and Natural Resources Management CRSP
SAO	Southeast Asian Outreach
SAS	Statistical Analysis System
SCALE	SAO Cambodia Aquaculture at Low Expenditure Project
SEAFDEC	Southeast Asian Fisheries Development Center
SEDEC	Socio-Economic Development Centre
SIDA	Swedish International Development Cooperation Agency
SIUC	Southern Illinois University at Carbondale
SPAAR	Special Program for African Agricultural Research
T	Testosterone
TA	Trenbolone Acetate
TAN	Total Ammonia Nitrogen
TBA	Trenbolone Acetate
TC	Technical Committee
TN	Total Nitrogen
TSP	Triple Superphosphate
UA	University of Arizona
UAPB	University of Arkansas at Pine Bluff
UCD	University of California, Davis
UG	University of Georgia
UH	University of Hawaii
UJAT	Universidad Juárez Autónoma de Tabasco (University of Tabasco)
UM	The University of Michigan
UNAP	Universidad Nacional de la Amazonia Peruana (National University of the Peruvian Amazon)
US	United States
USA	United States of America
USAID	United States Agency for International Development
USD	United States Dollar
USDA	United States Department of Agriculture
USFWS	United States Fish and Wildlife Service
UWRCA	Uganda Wetlands and Resource Conservation Association
V CASA	Fifth Central American Symposium on Aquaculture
WARDA	West African Rice Development Association
WAS	World Aquaculture Society
WIDeST	Web-based Information Delivery System for Tilapia
WRAC	Western Regional Aquaculture Consortium

Appendix 8. Nineteenth Annual Technical Report Contents

Studies on Potential Use of Salinity to Increase Growth of Tilapia in Aquaculture in Malawi (9ADR4B)
Regional Outreach in Africa (9ADR5)
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 (9ADR8)
Technical Assistance for Fingerling Production Serving Small- and Medium-Scale Tilapia Producers & Training and Technical Assistance for Honduras Institutions Working with Small- and Medium-Scale Tilapia Producers (9ADR9 and 10)
A Manual of Fertilization and Supplemental Feeding Strategies for Small-Scale Nile Tilapia Culture in Ponds (9ADR11)

Regional Analysis: Human-Environment Interactions Research

Establishment of New Collaboration in Bangladesh (9RA1)

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)