AQUACULTURE COLLABORATIVE RESEARCH SUPPORT PROGRAM

TWENTY-SECOND ANNUAL ADMINISTRATIVE REPORT

1 August 2003 to 31 July 2004

Aquaculture CRSP Management Office
Oregon State University
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Acknowledgments
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INTRODUCTION

The Aquaculture Collaborative Research Support Program's (CRSP) mission is to enrich livelihoods and promote health by cultivating international mutidisciplinary partnerships that advance science, research, education, and outreach aquatic resources. This report describes the activities and accomplishments of the Aquaculture CRSP from 1 August 2003 to 31 July 2004.

The United States Agency for International Development (USAID) funds the Aquaculture CRSP under authority of the Foreign Assistance Act of 1961 (PL 87-195), as amended; funding is also provided by the universities and institutions that participate in the CRSP. The Aquaculture CRSP is a partner of USAID's Economic Growth, Agriculture, and Trade (EGAT) Bureau's Office of Natural Resources Management and USAID's Water Team.

The CRSP's cohesive program of research is carried out in selected developing countries and the United States by teams of US and host country researchers, faculty, and students. 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 authorizes program activities from 1 August 1996 to 31 July 2006.

The activities of this multinational, multi-institutional, and multidisciplinary program are administered by Oregon State University (OSU), which functions as the 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 advisory bodies. PMO staff as well as advisory group membership during the reporting period appears in Appendix 1.

RESEARCH HIGHLIGHTS

- Low supply of high quality tilapia fingerlings has hindered growth of the tilapia aquaculture sectors throughout Central America. Auburn University researchers collaborated with researchers at Escuela Agrícola Panamericana Zamorano to assess fingerling production in Honduras. Socioeconomic data were collected from fingerling producers and fingerlings obtained for grow-out trials to compare quality. Improvements to fingerling quality will greatly benefit tilapia production in Honduras.

- Two Aquaculture CRSP projects are developing methods to culture indigenous fish species in the Peruvian Amazon Basin. Surubim (*Pseudoplatystoma* sp.) broodstock development and larval feeding experiments are being conducted by researchers from The Ohio State University and Universidad Nacional Mayor de San Marcos. Concurrently, researchers at Southern Illinois University Carbondale and University of Arkansas at Pine Bluff are collaborating with colleagues at the Instituto de Investigaciones de la Amazonía Peruana to determine the feasibility of using wild fruits and plant products as feed components to culture two native fish species, *Piaractus brachypomus* and *Colossoma macropomum*.

- Researchers from University of Hawaii, University of Rhode Island, and Universidad Autónoma de Sinaloa are collaborating to address cross-sectoral issues that affect aquaculture. Extension efforts are directed at implementing best management practices for established aquaculture sectors while diversifying local aquaculture production through production of other freshwater finfish and native bivalve species. Inclusion of previously neglected stakeholder groups such as women, youth, and the physically disadvantaged is also a priority.

- During the Aquaculture CRSP Ninth and Tenth Work Plans, Oregon State University, the Kenya Fisheries Department, and Moi University conducted training sessions for Kenyan Fisheries Officers. These workshops were considered so valuable that in 2004 additional short courses were provided to 36 Fisheries Department Fisheries Assistants—who work most directly with fish farmers in Kenya—through funds provided by the Aquaculture CRSP and leveraged with host country funds from the Kenya Fisheries Department. The workshops focused on pond construction, fish handling, and pond and fish stock management. Training materials have been organized into a training manual that can be used for future references as well as additional training sessions throughout the region.

- Normal procedures of pond soil management (e.g., drying bottoms between crops, liming, and periodic sediment removal) were confirmed to be effective in maintaining good sediment quality in freshwater aquaculture ponds over a period of at least 30 years through Aquaculture CRSP research conducted in Thailand by researchers from Auburn University and the Thailand Department of Fisheries. This information will be useful to pond culturists in Thailand, and the information should be applicable to pond culture both abroad and in the US.

- Numerous Aquaculture CRSP studies were conducted by researchers at The University of Michigan and the Asian Institute of Technology to determine the feasibility of various integrated polyculture methods in countries throughout Southeast Asia. Specific examples include co-culture of lotus plants and hybrid catfish in Thailand, cage-cum-pond culture with carp and catfish in Bangladesh, cage-cum-pond culture with tilapia and perch in Vietnam, and cage-cum-cove culture in Vietnam. Anticipated benefits to farmers include reduced environmental impacts from farming practices and increased economic opportunities through product diversification.

Administrative Highlights

During this period the PMO assisted in facilitating several new initiatives:

- A new collaboration between US partners University of Hawaii and University of Rhode Island and host country partners Universidad Autónoma de Sinaloa, Mexico and Ecocostas, Ecuador, is entitled Human Health Impacts and Aquaculture: Intenational Extension Exchange and Health Impact Studies.

- A new project entitled "Sustainable Development of Aquaculture in Africa" links the University of Arkansas at Pine Bluff with: Sokoine University of Agriculture, Tanzania; Fisheries and Aquaculture Development Division, Government of Tanzania; University of Science and Technology, Ghana; and the Ministry of Food and Agriculture, Ghana; and Moi University, Kenya.

- The PMO has sponsored the initiation of a Host Country Tilapia and Native Cichlids Project, the first of its kind, which brings together CRSP researchers from Mexico, Honduras, Thailand, the Philippines, and Kenya to exchange information about CRSP-funded technologies directly among host country participants.

- The PMO sponsored a New Principal Investigator Workshop in June in Portland, Oregon. The purpose of this meeting was to introduce new participants to CRSP policies, procedures, and philosophies.

- The PMO pursued new funding for a joint project with Heifer International and the Indigenous Environmental Network. The project's goal is to bring the knowledge of Native Americans in the North and South to bear on pressing aquatic resources management issues.

- The PMO assisted in the conceptual development of two new studies that will look into the status and future of offshore aquaculture.

- The ACRSP is sponsoring an initiative that brings prominent researchers in aquaculture, aquatic sciences, and international development to Washington, DC, to present up-to-date information on water-related issues to the USAID community, including the Water Team within USAID's Office of Natural Resources Management. Among the presenters so far have been:
  - –Barry Costa-Pierce, Director of Rhode Island Sea Grant as well as USAID subsector review panelist, presented "Aquaculture Status and Trends" in late January;
  - –Hillary Egna, Aquaculture CRSP Director, presented "Overview of International Aquaculture Priorities" in March; and
  - –Kevin Fitzsimmons, Professor at the University of Arizona, Aquaculture CRSP Principal Investigator, Vice President of the American Tilapia Association, and President of the World Aquaculture Society presented "Markets for African Tilapia Products and Impacts on Local Supplies" in April.

Electronic copies of these PowerPoint® presentations are available at the CRSP website <http://pdacrsp.oregonstate.edu/miscellaneous/WTpresentations/WTpresentations.html>.

- The director participated in CRSP Council conference calls meetings on 4, 11, and 24 September 2003 and on 5 and 11 March and 24 May 2004. In addition, the CRSP was represented at a USAID/CRSP retreat in Shepherdstown, West Virginia on 3–5 December 2003. The Aquaculture CRSP also contributed to comments submitted by the CRSP Council on the Rubin–Miller report "Making Good Programs More Effective." A refinement of the advisory structure was made in response to suggestions in this report and by new trends emerging in the CRSP Council. The Board of Advisors and the External Evaluation Panel were merged into an External Advisory Panel. The structural change will be staged to allow for current BOD and EEP members to retain positions until they are scheduled to cycle off the panel and new positions offered to external advisors.

- The Aquaculture CRSP was represented at Oregon State University's Earth Day celebration and "University Days" event in September 2003 and April 2004, respectively.

- The Aquaculture CRSP PMO presented the poster "Sustainable International Aquaculture Research: A focus on low food chain species," authored by Stephen H. Sempier, Katy R. Lloyd, Roger J. Harris, and Hillary S. Egna, at the January 2004 meeting of the National Council for Science and the Environment Water for a Sustainable and Secure Future in Washington, DC.

- Aquaculture CRSP researcher Joseph Molnar from Auburn University organized a symposium on aquaculture at the February 2004 meeting of the American Association for the Advancement of Science in Seattle, Washington. A number of CRSP researchers presented papers at this session, including: Chhorn Lim (New Direction in Fish Feeds and Feeding: Long Term Implications); Claude E. Boyd (Environmental Barriers to Aquacultural Development); and Nguyen Thanh Phuong (Shrimp Farming in Vietnam: An Overview). The PMO was also represented at the AAAS meeting, presenting the poster, "Sustainable International Aquaculture Research: A Focus on Low Food Chain Species."

- At the CRSP Technical Committee meeting, held in conjunction with the World Aquaculture Society meeting in March in Honolulu, HI, the PMO took the opportunity to organize and hold three Regional Networking Opportunity Meetings for all of the participants from the Asia, Africa, Latin America, and Caribbean regions.

- The Aquaculture CRSP also sponsored a series of awards in conjunction with the 2004 World Aquaculture Society meeting. These included: six student pre-conference awards, two professional pre-conference awards, one first place and two second place Student Poster Awards, and one Aquaculture CRSP Lifetime Achievement Award.

- Two Aquaculture CRSP collaborators, Kevin Fitzsimmons of the University of Arizona and Wilfrido Contreras-Sánchez of the Unversidad Juárez Autónoma de Tabasco, were awardees of a Training, Internships, Exchanges, and Scholarships (TIES) grant. The US-Mexico Training, Internships, Exchanges, and Scholarships Partnership Initiative is a program initiated by the State Department as an adjunct to the North American Free Trade Agreement (NAFTA). It covers all fields of education with the goal of increasing academic interactions between US and Mexican institutions of higher education. The intention is that TIES will address a variety of issues including job creation, environmental stewardship, food security, and education.

- The Aquaculture CRSP produced a DVD that showcases the projects and people of the program. "Ponds for Life" combines factual information and interviews with CRSP researchers in a framework that explains the challenges of small-scale aquaculture and some of our successes that have made it easier and safer.

- The "Solution Finder" website was developed by the Aquaculture CRSP PMO to present the depth and breadth of Aquaculture CRSP capabilities available to USAID Missions and to assist Aquaculture CRSP Ambassadors as they interact with USAID Mission officials. Using the "Solution Finder," visitors can access the developmental goals for each of the countries under USAID's strategic objectives umbrella. The site also features a menu of services that the CRSP can offer to solve specific problems in areas such as natural resource management, food security, health, and economic development, with links to relevant CRSP research.

- The PMO launched the ACRSP Ambassador Program. As CRSP Ambassadors to USAID Missions, host country partners are serving as country and regional resource persons on aquaculture and related water issues.

- The Aquaculture CRSP provided comments on "Linkages Between Development Assistance and Invasive Alien Species in Freshwater Systems in Southeast Asia," a report to USAID by Alexis T. Gutiérrez and Jamie K. Reaser on behalf of the Global Invasive Species Programme.

US and Host Country Partners

The Aquaculture CRSP's multidisciplinary team of researchers and advisors represent a wide range of US and international aquacultural experience. During the reporting period, participating US institutions included:

- Auburn University
- Florida International University
- Heifer International, Arkansas
- Louisiana State University
- Michigan State University
- North Carolina State University
- Oregon State University
- Purdue University, Indiana
- Southern Illinois University at Carbondale
- Texas Tech University
- The Ohio State University
- The University of Michigan
- University of Arizona
- University of Arkansas at Pine Bluff
- University of Georgia
- University of Hawaii, Hilo
- University of Rhode Island
- University of the Virgin Islands

Work undertaken in the reporting period comprised the Eleventh Work Plan and involved activities at sites in Bangladesh, Bolivia, Brazil, Cambodia, Colombia, Ecuador, El Salvador, Ghana, Guatemala, Honduras, Kenya, Laos, Mexico, Nepal, Nicaragua, Panama, Peru, South Africa, Tanzania, Thailand, the Philippines, and Vietnam.

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
- Auburn University and Stellenbosch University, South Africa
- Florida International University and the Freshwater Aquaculture Center, Central Luzon State University, the Philippines
- Oregon State University and Moi University, Kenya
- Oregon State University and the Department of Fisheries, Ministry of Livestock and Fisheries 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
- The University of Hawaii at Manoa and the Freshwater Aquaculture Center, Central Luzon State University, the Philippines

In addition, the following international institutions were involved in CRSP activities in the reporting period:

- Bangladesh Agricultural University, Bangladesh
- Can Tho University, Vietnam
- Centro de Aquicultura, Jaboticabal, SP, Brazil
- Centro de Investigación en Alimentación y Desarrollo, Mexico
- Centro Internacional de Agricultura Tropical (CIAT), Colombia
- Comunidad Indígena Sarayuku, Ecuador
- Corporación Regional del Amazonas, Colombia
- Department of Fisheries, Thailand
- Ecocostas, Ecuador
- EMBRAPA, Brazil
- Fisheries and Aquaculture Development Division, Tanzania
- Fondo Nacional del Desarrollo Pesquero, Peru
- Fundación Arcoiris, Ecuador
- Institute of Agriculture and Animal Science, Nepal
- Instituto Amazónico de Investigaciones Científicas, Colombia
- Instituto de Investigaciones, Colombia
- Instituto Nacional de Pesquisas da Amazonia, Brasil
- Instituto Tecnológico Saleciano, Ecuador
- Kasetsart University, Thailand
- KMFR Sangora Aquaculture Station, Ondito Kisumu, Kenya
- Ministry of Agriculture, Tanzania
- Ministry of Agriculture and Rural Development, Kenya
- Ministry of Food and Agriculture, Ghana
- Nong Nam University, Ho Chi Minh City, Vietnam
- Peace Corps, Ecuador
- Research Institute for Aquaculture No. 1, Vietnam
- Sao Paulo State University, Jaboticabal, Brazil
- Sokoine University of Agriculture, Tanzania
- Universidad Autónoma de Sinaloa, Mexico
- Universidad Federal do Amazonia, Brasil
- Universidad Mayor de San Simón, Bolivia
- Universidad Nacional Mayor de San Marcos, Peru
- Universidade Estadual Paulista, Brasil
- University of Agriculture & Forestry, Vietnam
- University of Science and Technology, Ghana

Continuation Plan Framework

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; and
- Limited networking capacities.

The sustainable production systems research framework, which guided research under the Eighth, Ninth, and Tenth Work Plans, 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. 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

Eleventh Work Plan

In anticipation of the program's submittal of a new five-year grant proposal to USAID in 2003, the Aquaculture CRSP issued the Eleventh Work Plan RFP in Summer 2002. The RFP incorporated constraints to aquaculture development as identified by stakeholders and experts that attended Aquaculture CRSP regional meetings throughout the world in 2001 and 2002.

Proposals for two-year projects focused on one of three program areas—Production Technology, Watershed Management, or Human Welfare, Health, and Nutrition. Within these program areas, researchers focused their investigations on any of the following research themes:

- Environmental Impacts Analysis
- Sustainable Development and Food Security
- Production System Design and Integration
- Indigenous Species Development
- Water Quality and Availability
- Economic/Risk Assessment and Social Analysis
- Applied Technology and Extension Methodologies
- Seedstock Development and Availability
- Disease, Predation Prevention, and Food Safety
- Fish Nutrition and Feed Technology
- Aquaculture and Human Health Impacts

In late fall of 2002, USAID notified the CRSP that the program would be given a one-year extension on the current grant—through 31 July 2004—rather than the two years that would have been needed for completing a full Work Plan cycle. High ranking proposals were shortened to reflect the timeline of the now one-year Eleventh Work Plan. As the CRSP was subsequently awarded another extension through 31 July 2006, Eleventh Work Plan proposals will be able to be completed as originally envisioned.

Work Plan Reporting and Monitoring

Projects' adherence to Work Plan schedules and methods and their fulfillment of Work Plan objectives is tracked to assure continuing accountability for program awards. These types of changes are collected and published in Work Plan addenda as needed. The PMO collects research progress reports on a quarterly basis.

SOUTHEAST ASIA PROJECT

Subcontract No. RD010E-04

Participants

The University of Michigan

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Work Plan Research

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

- Co-Culture of Lotus and Hybrid Catfish to Recycle Wastes from Intensive Feeding/11EIAR1. The report submitted for this investigation was a final report.
- Controlled Reproduction of an Important Indigenous Species, *Spinibarbus denticulatus*, in Southeast Asia/11ISDR2. The report submitted for this investigation was a final report.
- New Paradigm in Farming of Freshwater Prawn (*Macrobrachium rosenbergii*) with Closed and Recycle Systems/11PSDR2. The report submitted for this investigation was a final report.
- Integrated Cage-Cum-Pond Culture Systems with High-Valued Fish Species in Cages and Low-Valued Species in Open Ponds/11PSDR3. The report submitted for this investigation was a final report.
- Mitigating Environmental Impact of Cage Culture through Integrated Cage-Cum-Cove Culture System in Tri An Reservoir of Vietnam/11PSDR4. The report submitted for this investigation was a final report.
- Optimization of Nitrogen Fertilization Regime in Fertilized Nile Tilapia Ponds With Supplemental Feed/11PSDR5. The report submitted for this investigation was a final report.
- Workshop on Fertilization Strategies for Pond Culture in Bangladesh/11PSDR6. The report submitted for this investigation was a final report.
- Tilapia (*Oreochromis niloticus*) Production Constraints in Bangladesh/11SDFR2. The report submitted for this investigation was a final report.
- Growth and Reproductive Performance of Improved Tilapia, *Oreochromis niloticus*/11SDFR3B. The report submitted for this investigation was a final report.
- Mitigating the Effects of High Temperature and Turbidity on Seed Production of Nile Tilapia from Hapa-in-Pond Systems/11SDAR1. The report submitted for this investigation was a final report.

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Co-Culture of Lotus and Hybrid Catfish to Recycle Waste From Intensive Feeding

Eleventh Work Plan, Environmental Impacts Analysis Research 1 (11EIAR1)
Final Report

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Abstract

An experiment was conducted in nine 200-m^2 earthen ponds at the Asian Institute of Technology (AIT), Thailand from 17 July 2003 to 3 March 2004 (230 days). The objectives of the study were to assess the feasibility of co-culture of lotus and hybrid catfish in intensively fed ponds, to assess nutrient recovery from feed waste by lotus plants, to assess pond mud characteristics after lotus-fish co-culture, and to compare catfish growth with and without lotus integration. There were three treatments in triplicate: (1) catfish at 25 fish m^{-2}; (2) lotus at 50 seedlings $pond^{-1}$; and (3) lotus-catfish co-culture (lotus 50 seedlings $pond^{-1}$ and catfish at 25 fish m^{-2}). Lotus plants, root intact, were transplanted to ponds of treatments with lotus at a density 50 plants $pond^{-1}$. Hybrid catfish were stocked at a density 25 fish m^{-2} in treatments with catfish. Experimental catfish were fed with commercial floating pelleted feed. Feeding rate was adjusted for each pond separately based on the monthly fish growth measurement and estimated average catfish survival. There were no nutrient inputs in lotus ponds. Catfish growth performance was not significantly different ($P > 0.05$) between catfish and co-culture treatments. However, catfish survival was unpredictably low. There were no significant differences in lotus growth performance between lotus and co-culture treatments; however, total harvested lotus biomass was lower in comparison with previous production records in similar ponds. Lotus co-culture with catfish or lotus culture in ponds resulted in reduced pond mud nutrient concentrations. Nutrient loss from mud in a 1-ha pond was 0.32 tonnes N, and 0.44 tonnes P, out of which 44 kg N and 9.3 kg P were incorporated into the harvested lotus biomass. Most of the water quality parameters remained in the safe range for catfish growth and thus, integration of lotus and catfish could be a potential strategy to recover nutrient from intensive catfish feeding systems.

Controlled Reproduction of an Important Indigenous Species, *Spinibarbus denticulatus*, in Southeast Asia

Eleventh Work Plan, Indigenous Species Development Research 2 (11ISDR2)
Final Report

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Abstract

Preliminary studies were conducted to understand some basic reproductive parameters of the indigenous carp *Spinibarbus denticulatus* as a prelude to more specific research studies and subsequent development of hatchery technology. The study objectives were to: 1) Understand the seasonal pattern of gonad development, sexual maturation, and various reproductive parameters; 2) Induce this species to spawn in captivity using natural and artificial methods; and 3) Assess larval growth and survival using available low-cost food items. The first two objectives have been achieved, and the final experiments are underway.

The study was carried out on sub-adult and adult fish. Gonad and egg development was assessed over a 12-month period. Observation of the annuli rings on fish scales was found to be a reliable measure of age. In a population of males and females of similar age, males were generally smaller (2.54 ± 0.34 kg) than females (3.46 ± 0.45 kg). The age at sexual maturation of a natural stock was earlier for males (4 years) than females (5 or older). The gonadosomic index revealed two peaks, April and October. Further examination of the ovaries and eggs during January, February, and March suggested that eggs were developing at various stages. During January, the eggs in the ovary of mature females were uniformly small (0.7 ± 0.1mm diameter.). Two distinct egg groups (0.7 ± 0.1mm, 36% and 1.0 ± 0.2mm, 54%) were observed in February. Three distinct size groups were observed during March (1.1 ± 0.03mm, 1.6 ± 0.01mm and 2.1 ± 0.03mm). The proportion of large eggs (55%) was higher compared to mid (26%) and small eggs (19%) during the near-peak spawning month. The average number of eggs in the ovary of a female (3.1 ± 0.4 kg) was 31,041 (12,632–45,359). Males synchronized milt production with egg maturation and ovulation under pond conditions. Milt flowed out readily during the spawning season. Sperm characteristics were similar to those of most teleosts. The mean sperm concentration was 8.42 ± 0.36 million cells per ml with only a small amount (3.3 ± 0.2ml) of total expressible milt per male. However, when induced with LH-RHa (10μg kg^{-1}) the milt production increased to 6.2 ± 0.5 ml without an increase in the total number of sperm cells. While this new species for aquaculture shows potential for mass production of seed, low fecundity and late puberty could present obstacles.

A second series of experiments indicated that natural induction methods (rain simulation, decreased/increased water depth and flow) did not induce mature females to spawn in ponds. A series of injection using locally available hormones (e.g., HCG, LH- RHa+Dom, PG) were used to induce females to ovulate. Although all inducing agents resulted in ovulation, the combination of LH-RH and Domperidone resulted in the most consistent results.

New Paradigm in Farming of Freshwater Prawn (*Macrobrachium rosenbergii*) With Closed and Recycle Systems

Eleventh Work Plan, Production System Design and Integration Research 2 (11PSDR2)
Final Report

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Abstract

An experiment was conducted in 15 cement tanks (2 x 2.5 x 1m) at the Asian Institute of Technology, Thailand, during 5 January–12 May 2004, to develop closed and recycle systems for culture of giant freshwater prawn (*Macrobrachium rosenbergii*). Juvenile prawns were cultured in three systems as three treatments, each in triplicate: (A) open system with water exchange, (B) closed system with aeration, and (C) recycle system, in which water from a prawn tank was circulated through a Nile tilapia (*Oreochromis niloticus*) tank to a water mimosa (*Neptunia oleracea*) tank and back to the prawn tank. Prawn juveniles of 2.8 g were stocked in all prawn tanks at an average density of 19 prawns m^{-2}, sex-reversed Nile tilapia of 10.6 g were stocked in tilapia tanks at 2 fish m^{-2}, and water mimosa seedlings at 0.4 kg m^{-2} were planted in mimosa tanks. Prawns were fed *ad libitum* two times daily.

Survival of prawns, ranging from 40.64% to 88.72%, was highest in the closed system, intermediate in the recycle system, and lowest in the open system ($P < 0.05$). There were also mass mortalities in one open and one recycle tank. Growth of prawns was not significantly different among all three systems ($P > 0.05$), while gross and net yields of prawn were significantly lower in the open system than in closed and recycle systems ($P < 0.05$). Feed conversion ratio (FCR) in the open system was 2.81, which was significantly higher than in the closed (1.67) and recycle (1.78) systems (P <

0.05). Prawn recovered 12.02% N and 7.01% P from feed and fertilizer in the open system, and 25.26% N and 13.67% P in the closed system. Prawn, tilapia, and water mimosa together recovered 39.55% N and 25.53% P in the recycle system. Economic analyses showed that there were no significant differences in net returns among the three systems.

The present study demonstrated that the closed and recycle systems are more environmentally friendly and have good profit potential compared to the open system. Further study is needed to determine appropriate ratio of culture area for prawn, tilapia, and mimosa to minimize environmental pollution, optimize production and maximize profits in the recycle system.

Integrated Cage-Cum-Pond Culture Systems With High-Valued Stinging Catfish (*Heteropneustes fossilis*) in Cages and Low–Valued Carps in Open Ponds

Eleventh Work Plan, Production System Design and Integration Research 3A (11PSDR3A)
Final Report

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Abstract

An experiment was conducted over 237 days at Bangladesh Agricultural University to adapt an integrated cage-cum-pond system to local conditions in Bangladesh, to determine appropriate stocking density of fish in cages, to assess growth and production of fishes in both cages and open ponds, and to assess the economic and environmental benefits of this integrated system.

Stinging catfish and carp were stocked in cages and open water of ponds to give caged to open-pond fish ratios of 0.5:1, 1:1, 1.5:1, and 2:1 as four treatments with three replicates each. Stinging catfish fingerlings with a mean weight of 12.6 g were stocked at 50, 100, 150, and 200 fish per 0.85-m^3 cage, while fingerlings of silver carp (*Hypophthalmichthys molitrix*), catla (*Catla catla*), rohu (*Labeo rohita*) and common carp (*Cyprinus carpio*) were stocked at 100 fish per pond with a species ratio of 2:2:3:3 in open water of all ponds. Commercial pelleted feed (30% crude protein) was given to caged fish twice daily at a rate of 10% body weight per day. No feed or fertilizer was added into open water of the ponds. Survival of caged catfish was low, ranging from 39.33% to 60.67% with the highest survival in the 1:1 treatment. Caged catfish in all treatments grew slowly, giving daily weight gains of about 0.06 g $fish^{-1}$. Net yields in the 0.5:1 and 1:1 treatments were 0.10 and 0.18 kg m^{-3} $crop^{-1}$, respectively, while the other two treatments gave negative net yields. FCRs were extremely high in the 0.5:1 and 1:1 treatments (131 and 148, respectively), while FCRs were negative in the 1.5:1 and 2:1 treatments (-66 and -311, respectively). Survival of open-pond carps was high, ranging from 71.67% to 100% without significant differences for each carp species among all treatments. All carp species grew steadily throughout the experimental period, with daily weight gains of 0.76 to 1.62 g $fish^{-1}$. Net and gross yields of all carps were significantly higher in the 1:1, 1.5:1 and 2:1 treatments than in the 0.5:1 treatment. Overall FCRs were best in the 2:1 treatment (0.42), intermediate in the 1:1 and 1.5:1 treatments (0.76 and 0.59, respectively), and poorest in the 0.5:1 treatment (0.86). Net revenues were positive but low in all treatments. This experiment demonstrated the potential of the cage-cum-pond integrated culture system, but more research is needed.

Integrated Cage-Cum-Pond Culture Systems With High-Valued Sahar (*Tor putitora*) In Cages Suspended In Carp Polyculture Ponds

Eleventh Work Plan, Production System Design and Integration Research 3B (11PSDR3B)
Final Report

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Abstract

This experiment was conducted for 150 days in 15 earthen ponds, 100 m^2 in surface area and 1.2 m in depth, at the Institute of Agriculture and Animal science (IAAS), Rampur, Chitwan, Nepal. One cage (1.5 x 1.5 x 1 m and water volume of 2-m^3) covered with 1-cm mesh net was suspended in each of the treatment ponds. There were one control and four treatments with three replicates each: carps at 1 fish m^{-2} in open ponds without cages (control); Sahar at 5 fish m^{-3} in cages and carps at 1 fish m^{-2} in open ponds (5 fish m^{-3}); (3) Sahar at 25 fish m^{-3} in cages and carps at 1 fish m^{-2} in open ponds (25 fish m^{-3}); Sahar at 50 fish m^{-3} in cages and carps at 1 fish m^{-2} in open ponds (50 fish m^{-3}); Sahar at 100 fish m^{-3} in cages and carps at 1 fish m^{-2} in open ponds (100 fish m^{-3}), giving ratios of caged to open-pond fish of 0:1, 0.1:1,

0.5:1, 1:1, and 2:1. Caged Sahar were fed with a locally made pelleted feed (28% crude protein), while no feed or fertilizer was added into open water of treatment ponds. The control ponds were fertilized weekly using DAP and urea at rates of 4 kg N and 2 kg P ha^{-1} d^{-1}.

Survival of Sahar was high without significant differences among treatments. Daily weight gains of Sahar, ranging from 0.11 to 0.25 g $fish^{-1}$, were significantly higher at low stocking densities of Sahar. Feed conversion ratio (FCR) of Sahar ranged from 2.2 to 2.8, and was not significantly different among treatments. The total net and gross yields of all carps were significantly higher in the control than in treatments. The total net and gross yields of carps in the control were significantly higher than the combined net and gross yields of Sahar and carps in all treatments. The overall FCRs in the treatments were 0.15–0.95, and were significantly better in the lower Sahar density treatments. The control and all treatments produced positive net returns, and the highest net returns were produced by the control, followed by treatments with high to low stocking density of Sahar.

This study demonstrated that high-valued Sahar has potential to be cultured in an integrated cage-cum-pond system, but it is necessary to fine-tune stocking ratios of Sahar to carps. This can be accomplished by adjusting stocking density of Sahar in cages, cage size, or cage number. Growth could also be improved by providing higher quality feed.

Integrated Cage-Cum-Pond Culture Systems With High-Valued Climbing Perch (*Anabas testudineus*) In Cages Suspended in Nile Tilapia (*Oreochromis niloticus*) Ponds

Eleventh Work Plan, Production System Design and Integration Research 3C (11PSDR3C)
Final Report

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Abstract

An experiment was conducted over a period of 150 days at Can Tho, Vietnam to adapt integrated cage-cum-pond systems to local conditions in Vietnam, to determine appropriate stocking density of selected fish species in cages, to assess growth and production of fishes in both cages and open ponds, and to assess the economic and environmental benefits of this integrated system.

Nile tilapia (*Oreochromis niloticus*) fingerlings (10.1 g) were stocked at 2 fish m^{-2} in all ponds of 100-m^2 area, while climbing perch (*Anabas testudineus*) fingerlings (9.0 g size) were stocked in a 4-m^3 cage suspended in each pond. Stocking density of *Anabas* was the treatment variable and was 50, 100, 150, and 200 fish m^{-3}, giving caged climbing perch to open-pond Nile tilapia ratios of 1:1, 2:1, 3:1, and 4:1. There were also control ponds without a cage (0:1), and control ponds were fertilized weekly with urea and diammonium phosphate (DAP) at 28 kg N and 7 kg P ha^{-1} $week^{-1}$. Pelleted feed (26–28% crude protein) was given to caged fish twice daily at a rate of 5–2% body weight per day. No fertilizer was added into treatment ponds.

Survival of climbing perch in cages ranged from 97.1% to 99.6%, without significant difference among treatments. Mean weight of climbing perch at harvest was not significantly different among treatments, indicating that stocking density of climbing perch in cages did not affect growth. Net and gross yields were significantly higher in the treatments at higher stocking ratios. FCRs were very high in all treatments, ranging from 4.97 to 6.07. Survival and growth of Nile tilapia did not differ significantly among treatments. Combined net and gross yields ranged from 3.0 to 6.6 and 4.0 to 8.7 t ha^{-1} $year^{-1}$, respectively, in the treatments. Overall FCRs ranged from 0.98 to 1.58, which, however, did not differ among treatments. The highly valued climbing perch has

potential to be cultured in a cage-cum-pond culture system, but it is necessary to fine-tune stocking ratios, provide high quality feed, and improve growth of *Anabas*.

Mitigating Environmental Impact of Cage Culture Through Integrated Cage-Cum-Cove Culture System in Tri An Reservoir of Vietnam

Eleventh Work Plan, Production System Design and Integration Research 4 (11PSDR4)
Final Report

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Abstract

A study was conducted at Truong Dang Cove of Tri An Reservoir during June 2003–June 2004 to assess the feasibility of an integrated cage-cum-cove system, to assess effects of cages on water quality and plankton abundance in both the cove and the main reservoir, to assess effects of cages on fish production in coves, and to assess effects of accumulated wastes on terrestrial vegetation.

Five 16-m^3 net-cages were set up at the middle of the cove for the culture of red tilapia (*Oreochromis niloticus* x *O. mossambicus*) and stocked at 50, 75, 100, 125, and 150 fish m^{-3} during 19 August 2003–17 January 2004. Water samples were collected at 20 sampling stations grouped into 6 locations at different distances from the cage sites for water quality analyses. Ten plots (1 x 1 m quadrat) were selected for sampling sediment and terrestrial vegetation, with five plots at the cage culture sites and five at random sites, for sampling soil and terrestrial vegetation before and after cage culture to determine vegetation biomass as well as nitrogen, phosphorus, and organic matter content of sediments.

Red tilapia grew well in cages, and cage wastes may have enhanced the growth performance of open-water fish in the cove. Nutrients released from cages to the cove did not significantly affect water quality in the main reservoir, and there were no significant accumulations of cage wastes on the cove bottom. Fish in the cove and terrestrial vegetation during the dry season may efficiently utilize the surplus nutrients derived from the cage culture.

The integrated cage-cum-cove culture system can enhance fish production in coves through cage-cultured fish and increased production of open-water fish by using wastes from cage culture. The integrated cage-cum-cove system can stock appropriate species composition in open water to more efficiently use cage wastes, manage the terrestrial vegetation to use the cage wastes at the cove bottom, and also allow the dry period of the cove to decompose organic cage wastes. However, cage culture in a cove is a new practice and needs more research to develop an environmentally sound integrated cage-cum-cove culture system.

Optimization of Nitrogen Fertilization Regime in Fertilized Nile Tilapia Ponds with Supplemental Feed

Eleventh Work Plan, Production System Design and Integration Research 5 (11PSDR5)
Final Report

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Abstract

An experiment was conducted in fifteen 200-m^2 earthen ponds at the Asian Institute of Technology, Thailand during October 2003 to June 2004. The objectives of the study were to assess effects of different nitrogen fertilization regimes on tilapia production, to assess effects of different fertilization regimes on pond water quality, to quantify nutrient budgets, and to analyze the cost and return for fish with different fertilization regimes and supplemental feed. Ponds were stocked with sex-reversed male Nile tilapia (*Oreochromis niloticus*) of 10–12 g in size at a density of 3 fish m^{-2}. Urea and triple super phosphate were applied to all ponds at rates of 28 kg N and 7 kg P $ha^{-1}{\cdot}wk^{-1}$ until fish reached 100 g in size. Supplemental feeding was then provided at 50% satiation level, and nitrogen fertilization was adjusted for different treatments while phosphorus fertilization was kept unchanged for all ponds. Five nitrogen fertilization rates were used as treatments with three replicates each: 0%, 25%, 50%, 75%, and 100% (control) of 28 kg $N{\cdot}ha^{-1}$ wk^{-1}, giving 0, 7, 14, 21, and 28 kg $N{\cdot}ha^{-1}$ wk^{-1}, respectively.

Average survival of Nile tilapia ranged from 79.2% to 85.7%, without significant differences among treatments. Mean weight, mean weight gain, daily weight gain, and net yield were significantly higher in the 75% N treatment than in the 0% N treatment, while no significant differences were observed among the other treatments. There was considerable natural reproduction in all ponds and a variable biomass of recruits produced. There were no significant differences in

gross and net yield of combined adult and recruited tilapias among treatments. Estimated nutrient inputs showed that fertilizer was the major source of nitrogen and phosphorus, accounting for 63.63–75.23% of N and 65.64–71.84% of P in different treatments. Nutrients from pelleted feed represented 24.77–36.37% N and 28.16–34.36% P. Harvested tilapia incorporated 16.40–22.02% N and 12.11–16.27% P of the total inputs from both fertilizer and feed, without significant differences among all treatments. All treatments resulted in negative revenue due to poor tilapia growth. However, there were indications that reduced fertilization rates improved culture conditions. Further research should be conducted using better tilapia seed to fine-tune the nitrogen fertilization rate.

Workshop on Fertilization Strategies For Pond Culture in Bangladesh

Eleventh Work Plan, Production System Design and Integration Research 6 (11PSDR6)
Final Report

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Abstract

A one-day workshop was held on 26 June 2003 at BRAC Center in Dhaka, Bangladesh, and was organized by Aquaculture CRSP, the Asian Institute of Technology, and Bangladesh Agricultural University in cooperation with the three nongovernmental organization (NGO) partners, namely, BRAC, CARITAS, and PROSHIKA. The objectives of this workshop were to disseminate information of Aquaculture CRSP fertilization technologies, to transfer appropriate fertilization strategies developed by Aquaculture CRSP to aquaculture extension agencies in Bangladesh, and to enhance cooperation between Aquaculture CRSP with academic institutions, government agencies, NGOs, and international organizations in Bangladesh.

Forty-seven participants, including government fisheries officers, researchers, university teachers and students, NGO extension workers, and international organization/project staff attended the workshop. During the workshop, speakers briefed Aquaculture CRSP activities and achievements in the past two decades, overviewed the current status of pond aquaculture in Bangladesh, introduced pond fertilization practices of NGOs, BAU, BFRI, and DOF in Bangladesh, summarized the results of Aquaculture CRSP on-station and on-farm trials of different fertilization regimes used in Bangladesh, presented fertilization strategies for tilapia culture developed by the Aquaculture CRSP, and discussed environmental impacts of the intensification of pond culture. This workshop has increased impacts of the Aquaculture CRSP in Bangladesh and will help aquaculture development in Bangladesh.

Tilapia Production Constraints in Bangladesh: a) Socio-Economic Perspective

Eleventh Work Plan, Sustainable Development and Food Security Research 2A (11SDFR2A)
Final Report

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Abstract

The purpose of this study was to identify underlying socioeconomic constraints to the adoption of tilapia culture and to formulate appropriate policy guidelines to promote this species in existing aquaculture systems. The overall goal was to promote and sustain tilapia production in Bangladesh and other South Asian countries. The specific objectives included identifying sets of constraints impeding tilapia production, formulating appropriate policy guidelines, and suggesting research priorities to promote tilapia in Bangladesh.

Farm households from five major tilapia growing areas (Mymensingh, Dhaka, Chittagong, Jessore, and Patuakhali) were evaluated by observational tours and in-depth discussion with relevant actors. A total of 30 households were selected from each study location. The interpretation of qualitative data was conducted by content analysis.

Tilapia producers' responses on tilapia adoption trends (TAT) were analyzed through correlation (Spearman's rho), which identified 17 major constraining factors. These were grouped into five major categories, including physical resources, technology, support services, market and financial, and environmental constraints. About 80 percent of variation in the negative trend for tilapia adoption was explained by limited availability of technical information, high seed price, poor seed quality, and difficult technology. All important variables from the regression fell within the upper 7 of the 17 ranked variables.

Limited availability of technical information was one of the major significant constraining factors of TAT. To address this problem, a public-private partnership is needed in extension activities. Strategically important private sectors, such as hatcheries, should become involved not only in improved seed supply but also in technology generation and dissemination.

Tilapia Production Constraints In Bangladesh: b) Technological Constraints

Eleventh Work Plan, Sustainable Development and Food Security Research 2B (11SDFR2B)
Final Report

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Abstract

Tilapia was introduced to Bangladesh in 1954. Culture of this species is still in infancy compared to neighboring countries, including Indonesia, Philippines, Thailand, and Vietnam. Despite many positive culture attributes of tilapia, culture in Bangladesh may be constrained by different technical, socio-economic and institutional factors. Some attempts have been made by the Department of Fisheries, Bangladesh Fisheries Research Institute, and Bangladesh Agricultural University over last decades to develop production technology and disseminate this through their own channels. However, production levels failed to increase despite reasonably high prices for tilapia. In order to better understand the causes of this problem, we reviewed published literature on tilapia in Bangladesh and conducted a nation-wide survey of farmers. The survey was designed to identify factors that constrained adoption of this species. Results indicated several technological and socioeconomic constraints impeding adoption of tilapia culture in this country. Among the technological constraints, the perceptions were that this is difficult technology, there is not appropriate technical information and technical support, there is poor quality of seed, seed is limited in availability and high price, and that feed is also limited in availability.

Tilapia Production Constraints in Bangladesh: c) Workshop and Expert Panel Meetng on Tilapia Culture in Bangladesh

Eleventh Work Plan, Sustainable Development and Food Security Research 2C (11SDFR2C)
Final Report

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Abstract

A one-day workshop was held on 4 April 2004 at BRAC Center in Dhaka of Bangladesh organized by Aquaculture CRSP, the Asian Institute of Technology, and Bangladesh Agricultural University. The objectives of this workshop were to bring together all stakeholders to an open discussion on the present status as well as future potentials and directions for tilapia production in Bangladesh, and to enhance cooperation among the stakeholders in order to set proper strategies to promote tilapia culture in Bangladesh.

Seventy-four participants, including government fishery officers, researchers, university teachers and students, NGO extension workers, and international project staff attended the workshop. During the workshop, speakers explained Aquaculture CRSP activities and achievements in the past two decades, overviewed the status of tilapia culture in Bangladesh, Nepal, Thailand, The Philippines, and Vietnam, and also presented strategies for Nile tilapia culture.

An expert panel meeting was held on 5 April 2004 at BRAC Center in Dhaka of Bangladesh to identify constraints to developing tilapia culture in Bangladesh, and to develop a list of researchable topics for development of tilapia culture. A total of 33 experts attended the meeting, which included CRSP experts, experts from neighboring countries facing problems similar to Bangladesh in promoting tilapia culture, experts from countries successful in adopting tilapia culture, and national experts working for universities, fisheries departments and also from NGOs working in Bangladesh. The expert panel members discussed local conditions that impact development of tilapia culture and identified the most important constraints to development of tilapia culture in Bangladesh. Then they moved to discuss researchable priorities arising from constraints and worked out a list of prioritized researchable topics for promotion of tilapia culture in Bangladesh.

Reproductive Performance and Growth of Improved Tilapia, *Oreochromis niloticus*

Eleventh Work Plan, Sustained Development and Food Security Research 3 (11SDFR3)
Final Report

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Abstract

Currently, there are four lines (GIFT, IDRC, Fishgen, and Chitralada) of established and productive stocks of Nile tilapia in Asia, and three of them have been selected for improved growth. Although the selected lines are thought to have higher growth rates under extensive culture systems, there may have been a number of correlated responses to selection that could impact other traits such as reproduction. Such traits have not been subjected to comparative evaluation. Therefore, this study examined reproduction as well as growth, under an intensive culture system, for these four strains of tilapia.

The study has two components with the following objectives:

1) Compare reproductive performance (fecundity, spawning frequency, fertilization, hatch and larval survival) of three improved (GIFT, IDRC, Fishgen) and the Thai Chitralada strain of Nile tilapia; and
2) Compare growth, as well as age and size at sexual maturation, of the four strains in earthen ponds and in an intensive recirculation system.

Significant progress has been made on the first of these objectives, but experiments relating to the second objective are in progress.

Our study compared growth, survival, sexual maturation, and various reproductive parameters in four tilapia strains, three of which have been improved through various selective breeding approaches (GIFT, IDRC, and Fishgen-selected), and a local stock (Chitralada) was included as a non-improved control. The four strains were originally reared in extensive culture systems with fertilization only. Growth (weight and length) and reproductive parameters (gonadosomatic index, hepatosomatic index, and stages of sexual maturation) were measured on fish sampled every 21 days. Based on staging of gonad development, GIFT were found to become sexually mature somewhat later than the other two strains. At nine months, broodstock from each strain were stocked in 5-m^2 breeding hapas, with 5 males and 15 females per hapa and four replicate hapas per strain. Broodstock were sampled for eggs every week, and data on fecundity and inter-spawning interval for the four strains were assessed. Seasonal and environmental variances appear to be major determinants of egg/fry production, with the only strain difference observed being a lower relative fecundity in GIFT. Across all strains, fecundity per female increased over time, while fecundity per unit weight of female remained constant. Spawning frequency and interval of spawning fluctuated widely between individual fish. Spawning interval was highly variable within individual females making it difficult to identify trends. Many females spawned very infrequently, and the means to identify fecund females could have huge impacts upon hatchery efficiency.

Mitigating The Effects of High Temperature and Turbidity on Seed Production of Nile Tilapia From Hapa-In-Pond Systems

Eleventh Work Plan, Seedstock Development and Availability Research 1 (11SDAR1)
Final Report

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Abstract

A study, consisting of two experiments, was conducted at the Asian Institute of Technology (AIT), Thailand, for 95 days for Experiment A and 113 days for Experiment B during May 2003–March 2004 to investigate effects of high temperature and turbidity on seed production of Nile tilapia. Experiment A was conducted using a randomized complete block design in a 300-m^2 earthen pond of 1.6 m deep, and had three treatments with three replicates each: (A) 70-cm water depth in hapas (control); (B) 100-cm water depth in hapas; and (C) 140-cm water depth in hapas. Experiment B was conducted using a complete randomized design in six 200-m^2 earthen ponds of 1.2 m deep, and had two treatments with three replicates each: (A) without underwater walkways (control); (B) with underwater walkways.

Egg production was increased by about 72% and 96% in the 100- and 140-cm treatments, compared to the control. There was no significant difference in mean individual egg weight among all three treatments ($P > 0.05$). Fertilization rates in the two deeper treatments (37.49% and 42.05% in the 100- and 140-cm deep treatments, respectively) were significantly higher than that (21.06%) in the control ($P < 0.05$), however, hatching rates were not significantly different among all three treatments ($P > 0.05$). Lowering water temperature by using deep ponds is an effective way to increase reproductive performance of Nile tilapia during the hot season.

The turbidity at the end of the experiment and its change throughout the experiment was significantly lower in the treatment with walkways than in the treatment without walkways ($P < 0.05$), however, there was no significant difference in egg production, fertilization rate and hatching rates between the two treatments ($P > 0.05$). Lowering turbidity and fouling caused by egg collection through underwater walkways may not be effective in improving reproductive performance. However, further research is needed on the effects of fouling on reproductive performance of Nile tilapia.

MEXICO PROJECT

MOU No. RD009C
Subcontract No. RD010E-A

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Work Plan Research

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

- Training Local Farmers on Safe Handling of Steroids and Masculinization Techniques in Central America/11ATER1. The report submitted for this investigation was a final report.
- Continuation of a Selective Breeding Program for Nile Tilapia to Provide Quality Broodstock for Central America/11SDAR3. The report submitted for this investigation was a final report.
- Development of Aquaculture Techniques for the Indigenous Species of Southern Mexico, *Centropomus undecimalis*: Sex Determination and Differentiation and Effects of Temperature/11ISDR3. The report submitted for this investigation was a final report.
- Elimination of Methyltestosterone from Intensive Masculinization Systems: Use of Ultraviolet Irradiation of Water/11WQAR1. The report submitted for this investigation was a final report.
- Use of Phytochemicals as an Environmentally-Friendly Method to Sex-Reverse Nile Tilapia/11FNFR3. The report submitted for this investigation was a final report.
- Diversification Into Sustainable Tilapia-Shrimp Polyculture and Small-Scale Tilapia Cage Culture in Mexico/11PSDR1. The report submitted for this investigation was a final report.

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Training Local Farmers on Safe Handling of Steroids and Masculinization Techniques in Central America

Eleventh Work Plan, Applied Technology and Extension Methodologies Research 1 (11ATER1)
Final Report

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Abstract

The need to deliver recently generated information and technological packages to the immediate users (students, extension agents, and farmers) is fundamental for aquaculture development. Training workshops are one way to achieve these goals. Through workshops, researchers can obtain feedback information from farmers and identify problems that may compromise advances in the field of interest. Developing new techniques, such as methods for sex reversal or production of clean effluents, would be futile unless the information that is generated is transferred to people conducting aquacultural activities. This is especially difficult in Mexico and Central America because information is not readily accessible. Workshops conducted in Mexico under CRSP support have already impacted tilapia culture in Tabasco and Chiapas and most farmers are growing sex-reversed tilapias—this activity was not conducted until only a few years ago. To complement research for the production of clean sex-inversion techniques, we implemented three regional workshops and one local workshop on safe handling of steroids and masculinization techniques in Mexico. We have also generated printed and electronic materials for safe handling of steroids and masculinization techniques.

Continuation of a Selective Breeding Program for Nile Tilapia to Provide Quality Broodstock for Central America

Eleventh Work Plan, Seedstock Development and Availability Research 3 (11SDAR3)
Final Report

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Abstract

Since 1964, Mexico has imported five species of tilapia for aquaculture purposes. Despite the establishment and long use of tilapia culture as a major economic activity and as a high-quality source of food, the emergence of this activity from a technical standpoint has been minimal. Some of the most important factors for the development of tilapia culture in Mexico are access to genetically improved species for better growth, characterization of species and lines present in Mexico, and the development of dependable methods for the production of monosex populations of males. The use of improved tilapia with high mass production has contributed to increasing its popularity among producers. We have been conducting a selective breeding program for three years which has produced an F3 generation of broodstock that performs better than the line traditionally used by local farms. We have been using selection on three lines of tilapia the line that the hatchery has traditionally used (Teapa), a wild line from the Usumacinta river basin (San Pedro), and a line obtained from Egypt by the State government (DS1). Three selections were performed. The first was conducted at 70 days of age, the second at 160 days and the last at 11 months. Initially, 10% of the population was measured and tables of frequency distributions were constructed. The mean, median, and standard deviations were estimated and the fish were divided into three groups, based on the median of the total length (TL). During the first selection (all fish, no sex separation), the mid-sized fish were grown-out until the next selection. For the second selection, fish were separated by sex, and then selected in the same manner as the first selection. For the third selection, 60% of the females with the largest size (TL) were selected, and from these fish, 50% of the individuals with the highest condition factor were selected

as breeders. Thirty percent of the males with the largest size (TL) were also selected, and from these fish, 35% of the individuals with the highest condition factor were selected as sires. Fry obtained from spawnings of the three lines were analyzed for growth performance. Fry from the DS1 line had consistently higher growth rates than the other two lines. This study was conducted as a collaborative effort between UJAT, the National Council for Science and Technology (SIGOLFO-CONACyT), and the office for Agriculture and Fisheries Development (SEDAFOP) in Tabasco.

Development of Aquaculture Techniques for the Indigenous Species of Southern Mexico, *Centropomus undecimalis*: Sex Determination and Differentiation and Effects of Temperature

Eleventh Work Plan, Indigenous Species Development
Research 3 (11ISDR3)
Final Report

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Abstract

Species of "robalo," or snook, are an important indigenous food fish in southern Mexico. Over fishing has resulted in diminishing catch volumes of the common snook (*Centropomus undecimalis*). This has led to concerns for the health of the regional fisheries and to calls for improved management practices. An important step in reducing pressure on native populations, while ensuring a reliable food source, would be incorporation of the species into aquaculture systems. An understanding of the reproductive biology of a fish species is necessary in order to begin an aquaculture program, yet little is known regarding these processes in snook. As an important first step, we conducted a workshop on the biolgy and culture of snook which brought together specialists from North and Central American and the Carribean. The workshop was conducted for four days at the División Académica de Ciencias Biológicas, Universidad Juárez Autónoma de Tabasco in Villahermosa and was attended by 51 people from 23 institutions. The workshop covered general snook biology, people's experiences with the culture of snook, and culminated with a visit to a grow-out farm in Tabasco. Knowledge gained from this workshop will aid us during our next phase of research, which will examine the timing and morphological pattern of gonadal sex differentiation in common snook, and also determine the effect of early treatment with low or high water temperature or sex steroids on sex ratios and growth rate.

Elimination of Methyltestosterone from Intensive Masculinization Systems: Use of Ultraviolet Irradiation of Water

Eleventh Work Plan, Water Quality and Availability
Research 1 (11WQAR1)
Final Report

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Abstract

This study tested the hypothesis that 17α-methyltestosterone (MT) could be eliminated from the water used in intensive sex-inversion systems using sunlight and UV sterilizers. Different concentrations of MT diluted in water were exposed to UV or sunlight and measured through time for 48 hours. Water samples were collected from aquaria at the onset of treatments and at 2, 4, 8, 24, and 48 hours. All samples were extracted using ether and the concentration of MT was determined by radioimmunoassay. We also evaluated the elimination of MT in masculinization systems and the masculinizing effects of effluents produced in these systems on tilapia. MT was partially eliminated when water was exposed to direct sunlight; however, MT was completely eliminated from water following exposure to UV. At the end of the treatments, sunlight exposure eliminated between 48 and 62% of the MT detected at the beginning of the trials. When water with MT was exposed to UV light, MT was not detectable after 48 h of treatment. When intensive masculinization systems were used, MT was only detected in 7.1% of the water samples. Five of the detections were from tanks that received MT that had no UV sterilizers and six samples were from tanks with UV sterilizers. Significant

masculinization was obtained when MT was administered through the food and the results indicate that UV treatment allowed for higher masculinization rates. Our results also indicate that effluents from masculinization systems can masculinize fish that are not the target of the treatment. This may be due to the sterilizers degrading MT slowly over time or perhaps that the UV degradation products resulted in compounds that increased masculinization. More research is needed regarding treatment methods for masculinization effluents to eliminate the risks of unintended exposure to humans and other non-target organisms.

Use of Phytochemicals as an Environmentally Friendly Method to Sex-Reverse Nile Tilapia

Eleventh Work Plan, Fish Nutrition and Feed Technology
Research 3 (11FNFR3)
Final Report

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Abstract

This study evaluated the use of daidzein, chrysin, and caffeic acid as potential sex reversal agents in Nile tilapia by dietary administration or immersion treatments. Three feeding experiments were conducted at two locations: Aquaculture Laboratory at the Ohio State University (Experiment 1 and 2) and the Aquaculture laboratory at the Universidad Juarez Autonoma de Tabasco UJAT-Mexico (Experiment 3). An immersion treatment experiment took place at the Aquaculture Laboratory of The Ohio State University (Experiment 4). The dietary administration experiments were as follows: for Experiments 1 and 3, diets control, chrysin (500 mg/kg), daidzein (500 mg/kg) and caffeic acid (500 mg/kg) along with the steroidal compounds spironolactone (500 mg/kg), 1,4,6-androstratiene-3-17-dione ATD (150 mg/kg) and 17α-methyltestosterone (MT) (60 mg/kg) were fed for 8 weeks. For Experiment 3, the diets were control, chrysin (500 mg/kg), daidzein (500 mg/kg) and caffeic acid (500 mg/kg) along with the steroidal compounds spironolactone (500 mg/kg) were offered for 6 weeks. In all cases, semi-purified casein gelatin diets were used to avoid contamination with external sources of either phytochemicals or steroid-like compounds. For the immersion experiment (Experiment 4), four immersion trials were carried out at 10, 17, 21, and 28 day post-hatching on the following chemicals and concentrations, vehicle DMSO (1 ml/l), daidzein 400 (mg/l), chrysin (20 mg/l), caffeic acid (40 mg/l), spironolactone (5 mg/l), ATD (1.2 mg/l) and MT (400 μg/l). In all experiments, final sex ratio was determined by gonad squash; in feeding trials, the final individual body weight and survival were evaluated. Results of experiments conducted at The Ohio State University indicate that the presence of the tested phytochemicals in food or in immersion baths has no effect on the final sex ratio of tilapia or growth performance. In Experiment 1, ATD and MT had a significant effect on final sex ratio (50% and 100% masculinization, respectively); in Experiment 3 (UJAT-Mexico) MT and ATD along with SPIRO affected the male ratio significantly. No effects were observed in Experiment 2 (97±3% males) or Experiment 4 (60-40% male:female ratio) across experimental groups.

Economics of a Hypothetical Tilapia-Shrimp Polyculture Farm in Sinaloa, Mexico

Eleventh Work Plan, Production System Design and Integration
Research 1 (11PSDR1)
Final Report

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Abstract

An economic model was developed to consider and test the potential advantages of incorporating tilapia polyculture into existing shrimp farms in Northeastern Mexico. The model is developed from a "standard" farm representative of farms operating in 2003. The standard model could eventually be adapted and tested in other regions of the world where shrimp farming has been impacted by disease and over-supply. The result of the analyses conducted using the Mexican model found that there was not a significant increase in profitability by incorporating tilapia production into an existing shrimp farm. A sensitivity analysis was conducted to determine if tilapia polyculture could maintain profitability in the face of further declines in shrimp prices or in the event of lower shrimp production due to disease. In both cases, profits decreased and the net present value of the farm became negative. Further analyses considering higher tilapia prices, or increases in shrimp survival commonly reported from tilapia-shrimp polycultures, will be conducted in the future.

Amazon Basin Project

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Work Plan Research

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

- Amazon Aquaculture Outreach/11SDFR1. The report submitted for this investigation was a final report.
- Nutrition and Nutrient Utilization in Native Peruvian Fishes/11FNFR1. The report submitted for this investigation was a final report.
- Broodstock Development and Larval Feeding of Amazonian Fishes/11ISDR1. The report submitted for this investigation was a final report.

Publications

Alcantara, F.B., C.V. Chávez, L.C. Rodríguez, W.N. Camargo, C. Kohler, M. Colace, and S. Tello. Gamitana (*Colossoma macropomum*) and Pacu (*Piaractus brachypomus*) Culture in Floating Cages in the Peruvian Amazon. World Aqua., 34(4):22-24.

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Camargo, W.N., C. Kohler, S. Kohler, M. Rebaza, C. Rebaza, S. Deza, E. Villafana, and C. Alvarez. Fish Culture at the Pucallpa Navy Base in the Peruvian Amazon. Aquanews, 18(4):7-8.

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Silva, M., 2004. Reproductive Strategies for the Cichlasoma Amazonarum (bujurqui). B.S. thesis, Universidad Nacional de la Amazonia Peruana, Peru.
Tello, S. Aquaculture in the Peruvian Amazon: A Case Study of Microenterprise. Aquanews, 18(4):5.

Presentations

Camargo, W.N. I Curso de Internacional Nutrición de Peces Tropicales. Seminar presented to public audience in Pucallpa, Peru, 2003.
Camargo, W.N. III Curso de Internacional Acuacultura con Especies Promisorias de la Amazonia. Seminar presented to public audience in Pucallpa, Peru, 2003.
Camargo, W.N. Sustainable Small-Scale Aquaculture in the Amazon Region. Seminar presented to public audience in Carbondale, Illinois, March, 2004.
Dabrowski, K. Peptide Utilization in Larval Fish Diet Formulation: Basic and Applied Aspects. Presented at the World Aquaculture Society Meeting, Honolulu, Hawaii. 1-5 March, 2004 (Oral presentation).
Dabrowski, K., K. Ware, and M. Tesser. Larval and juvenile rearing of pacu *Piaractus mesopotamicus* using live food and formulated diets (Poster presentation).
Lochmann, R. Broodstock Diet Development for Tropical Amazonia Fishes. Presented at III Curso de Internacional Acuacultura con Especies Promisorias de la Amazonia and I Curso de Internacional Nutrición de Peces Tropicales in Pucallpa, Peru, 2003.
Lochmann, R. Clues to Characid Broodstock Diet Development. Presented at World Aquaculture Society Annual Conference. Honolulu, Hawaii, March, 2004.
Ostaszewska, T., K. Dabrowski, M. Wegiel, and M.E. Palacios. Growth and Morphological Changes in the Digestive Tract of Rainbow Trout and Paku Due to Casein Protein Replacement With Soybean Protein. Presented at the World Aquaculture Society Meeting, Honolulu, Hawaii. 1-5 March, 2004. (Oral Presentation).
Palacios, M.E., K. Dabrowski, and C.C. Kohler. Growth and Diet Utilization in Pacu (*Piaractus mesopotamicus*) Using Soybean Replacement of Casein Gelatin as a Protein Source. Presented at the World Aquaculture Society Meeting, Honolulu, Hawaii. 1-5 March, 2004 (Oral Presentation).
Tesser, M., K. Dabrowski, B. Terjesen, J.M. Pizauro, and M.C. Portella. Free- and peptide-based arginine supplementation into arginine-deficient diets for South American fish *Piaractus mesopotamicus*. (Poster Presentation).
Tesser, M., M.C. Portella, and K. Dabrowski. Growth and survival of pacu *Piaractus mesopotamicus* larvae fed formulated diets and live *Artemia* (Oral Presentation).

Conferences

I Curso de Internacional Nutrición de Peces Tropicales in Pucallpa, Peru, 2003. (Lochmann)
III Curso de Internacional Acuacultura con Especies Promisorias de la Amazonia in Pucallpa, Peru, 2003. (Lochmann)
World Aquaculture Society Annual Conference. Honolulu, Hawaii, March, 2004. (Camargo, Chu, C. Kohler. S. Kohler, Lochmann, and Tello)

Amazon Aquaculture Outreach

Eleventh Work Plan, Sustainable Development and Food Security Research 1 (11SDFR1)
Final Report

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Abstract

Outreach activities significantly benefited over 150 producers and their families (346 ponds, 110 ha.) in the Peruvian Amazon. The certification of six master aquaculturists and on-farm research activities helped provide technical assistance in aquaculture techniques to local and prospective fish farmers. The on-farm research activites, conducted with four local fish farmers, was part of an undergraduate thesis project on species diversification. Several aquarium fish species (*Osteoglossum bicirrhosum*, *Astronotus ocellatus, and Cichla monoculus*), also consumed in some local markets, were found to be suitable for culture. The two CRSP-funded extensionists provided aquaculture training to 777 vocational, high school, and university students in the Amazon Basin (Brazil, Colombia, Ecuador, and Peru). Sixty-two individuals representing Ecuador, Bolivia, Brazil, Colombia, Venezuela, and Peru participated in aquaculture short courses. The Amazonian aquaculture website, developed during the Tenth Work Plan, was expanded. This website is an important tool to communicate the work done by research institutions in the US, many Amazon nations, and elsewhere (over 6,000 hits from 1 May 2003 through 31 May 2004).

Nutrition and Nutrient Utilization in Native Peruvian Fishes

Eleventh Work Plan, Fish Nutrition and Feed Technology Research 1 (11FNFR1)
Final Report

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Abstract

Numerous wild fruits and plant products are reportedly utilized as fish feed in the Amazon region. To assess the feasibility of utilizing these and other plant products for small-scale sustainable aquaculture production of *Piaractus brachypomus* and *Colossoma macropomum*, samples of several fruits and plant products were collected in Iquitos Peru in the Tenth Work Plan. Proximate analysis was performed in the Eleventh Work Plan on fruit samples available during the summer or through the year. Proteins, lipids, calories and fiber content were analyzed using standard techniques (Kjeldahl, Folch, spectrophotometry, and chromatography). In addition, data on the seasonal availability of the plants/plant products were collected. Digestibility trials with *P. brachypomus* were conducted on three native feedstuffs (plantain, *Musa paradisiacal;* yucca, *Manihot sculenta;* and pijuayo, *Bactris gasipaes)* in 110-L tanks in a flow-through system at Southern Illinois University at Carbondale (SIUC). Digestible energy, protein, lipid and dry matter digestibility coefficients were determined for each feedstuff. The reference diet was similar in composition to those used currently for Characid fishes at Instituto de Investigaciones de la Amazonia Peruana (IIAP), Peru. Digestibility coefficients were determined by using an indirect method, involving chromic oxide (Cr_2O_3) as a non-digestible marker. The digestibility of crude proteins (85.6%), crude fat (90.4%), and energy (70.3%) of pijuayo in *P. brachypomus* was far superior to that of yucca and plantain. The digestibility of plantain and yucca by *P. brachypomus* were very similar to each other for crude proteins (57.5 vs. 53.0%), crude fat (54.9 vs. 64.8%), and energy (29.0 vs. 21.0%). Pijuayo appears to be an excellent ingredient to be employed in formulated diets for *P. brachypomus.* Additionally, the abundance of pijuayo in the Amazon Basin makes this fruit economically viable to the small-scale farmers to reduce feed manufacturing cost.

Broodstock Development and Larval Feeding of Amazonian Fishes

Eleventh Work Plan, Indigenous Species Development Research 1A (11ISDR1A)
Final Report

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Abstract

Larvae of *C. macropomum* and *P. brachypomus* were obtained from fish induced to spawn by hormonal injections. The feeding experiment was initiated 19 February 2004, and was conducted in a flow-through system consisting of 18 70-L aquaria (3 aquaria/dietary treatment; 9 aquaria per species) supplied with aeration. Water quality was monitored throughout the larval rearing process. Temperature was maintained between 26–28°C and dissolved oxygen ranged from 5–6 mg/L. Larvae were randomly distributed at a density of 500 larvae/aquarium and conditioned for 10 days using plankton as feed; thereafter larvae were fed their respective experimental diets at a restricted ration up to 8% their body weight (8 times per day) for 2 weeks. Larvae were fed three diets: 1) freshly hatched *Artemia* nauplii; 2) decapsulated *Artemia* cysts; and 3) local plankton (*Moina sp*.) produced in raceways with anchovy fishmeal. Larval samples (n=5) were taken every week from each tank (45 larvae total per species) and fixed in buffered formalin for biometric measurements (total length, standard length, mouth opening). At the end of the experiment, growth performance was evaluated in terms of final individual body weight, specific growth rate (SGR, %), weight gain (%), condition factor (*k*) and survival (%). Larvae of *C. macropomum* and *P. brachypomus* fed decapsulated *Artemia* cysts and *Moina sp*. performed better than those fed freshly hatched *Artemia* nauplii. However, the survival of *C. macropomum* larvae did not differ significantly in any of the treatments (decapsulated *Artemia* cysts 34%, *Artemia* nauplii 26%, and *Moina sp*. 46%). In contrast, survival of *P. brachypomus* larvae was significantly different between treatments; larvae fed *Moina sp.* had higher mean survival (44.3%) compared to those fed nauplii (39.6%) or decapsulated *Artemia* cysts (36.5%). Though *Artemia* are a more readily available and reliable larval food source, *Moina sp.* appear to be a cost-effective substitute for use in the in the Amazon Basin.

Broodstock Development and Larval Feeding of Amazonian Fishes

Eleventh Work Plan, Indigenous Species Development Research 1B (11ISDR1B)
Final Report

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Abstract

Growth and plasma sex steroid hormone (including, estradiol-17α, testosterone, and 11-ketotestosterone) levels were investigated in surubim *Pseudoplatystoma* sp. over a 1-year period. Growth of surubim in laboratory conditions was high. The gonadosomatic index (<1%) and the histological analysis (presence of only perinucleolar oocytes in female and spermatogonia in males) of the gonads indicated that the fish would not reach sexual maturity for at least a year. All three steroids measured (estradiol, testosterone, and 11-ketotestorone) did not show any significant variation throughout the year. Moreover, the concentrations were low in comparison to those reported in other catfish species and confirmed the results of the histological and morphological analysis. As a result, we postponed the induction of ovulation or spermiation until spring 2005.

Africa Project
MOU No. RD009A

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Judith Amadiva	Host Country Principal Investigator

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Charles Ngugi	Host Country Principal Investigator
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John Rauni	Graduate Student (through May 2004, thesis submitted)
Julius Nzeve	Graduate Student (through May 2004, thesis submitted)
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Work Plan Research

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

- Aquaculture Training for Kenyan Fisheries Assistants/11ATER4. The report submitted for this investigation was a final report.
- Evaluation of Aquaculture Training Provided to Fisheries Officers and Fisheries Assistants of the Kenya Fisheries Department/11ATER5. The report submitted for this investigation was a final report.
- Development of an Aquaculture Handbook for Extension Workers and Trainers of Extension Workers in Sub-Saharan Africa/11ATER6. The report submitted for this investigation was a final report.

Publications

Ngugi, C.C., J. Amadiva, K. Veverica, J. Bowman, S. Imende, B. Nyandatt, and G. Matolla. On Farm Trials in Kenya Change Attitudes of Fish Farmers and Extensionists. Samaki News, Vol. 2 July 2003.

Presentations

Ngugi, C.C. Development of a National Fisheries Policy. Seminar presented to government officials in Nairobi, Kenya, 2003.

Ngugi, C.C, J. Nzeve, and J.R. Bowman. Growth and survival of African catfish *Clarias gariepinus* larve fed *Artemia* nauplii, freshwater rotifers, and whole, freeze-dried *Cyclops* in indoor tanks. Aquaculture 2004, March 1-5, 2004. Honolulu, Hawaii.

Conferences

Third International Conference of Panafrican Fish and Fisheries in Cotonou, Benin, West Africa, November, 2003. (Omolo)

Aquaculture Training for Kenyan Fisheries Assistants

Eleventh Work Plan, Applied Technology and Extension Methodologies Research 4 (11ATER4)
Final Report

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Abstract

Increasing aquaculture production in a sustainable way requires trained manpower, but for several decades up until 1998, opportunities for aquaculture training in Kenya had been limited. Sustained funding and well-thought-out training strategies were lacking. In response to this deficiency, as part of its Ninth and Tenth Work Plans, the Aquaculture Collaborative Research Support Program (ACRSP) provided technical and monetary support for a series of twelve two- and three-week short courses for officers of the Kenya Fisheries Department (FD), who are the officials responsible for carrying out aquaculture extension activities.

Feedback from the training sessions conducted under the Ninth and Tenth Work Plans indicated that they had been extremely valuable to the participants, giving them the ability to construct fish ponds properly and to give sound pond management advice to farmers. The FD was so satisfied with the results of those training sessions that they sought and secured their own funding for additional training sessions. This report describes two short courses funded by matching contributions from the FD and the ACRSP under the ACRSP's Eleventh Work Plan. These two additional courses were targeted specifically towards the FD's Fisheries Assistants, the Department's officers who work most directly with fish farmers in Kenya.

Evaluation of Aquaculture Training Provided to Fisheries Officers and Fisheries

Eleventh Work Plan, Applied Technology and Extension Methodologies Research 5 (11ATER5)
Final Report

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Abstract

Following a series of twelve short courses in pond construction, pond management, and farm management planning sponsored by the Aquaculture CRSP and conducted in Kenya by the CRSP, the Moi University Department of Fisheries, and the Kenya Fisheries Department between 2000 and 2003, a study was undertaken to evaluate the effectiveness of these training courses. The evaluation focused on the content and quality of the courses as well as on their usefulness to the trainees, as perceived by the trainees themselves.

The study used a mail-out questionnaire to ask for input from all but the most recent participants in the courses. Questions related to the participants' perceptions about course content and presentation as well as to ways they had been able to apply what they had learned in the field after completion of their respective sessions. Included in the latter category was an attempt to quantify changes in numbers and areas of ponds, pond productivity, and income earned from fish farming in the participants' areas of responsibility.

The questionnaire used is shown, along with summaries of the major findings of the survey and a summary table of pond data from before and after the training courses. Significant findings and possible areas for improvement of future training courses are discussed.

In addition to the report on the survey and its results, direct and indirect results from CRSP-sponsored training efforts are reported on through four case studies. Two of the case studies focus on Kenyan fish farmers whose farm operations have been positively influenced by CRSP training efforts and two are about individuals who received training under CRSP programs and have subsequently gone on to make valuable contributions to the development of aquaculture in Kenya.

Development of an Aquaculture Handbook for Extension Workers and Trainers of Extension Workers and Sub-Saharan Africa

Eleventh Work Plan, Applied Technology and Extension Methodologies Research 6 (11ATER6)
Final Report

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Abstract

Between 2000 and 2003, a series of twelve short courses focusing on pond construction, pond management, and the economics of fish farming were offered to Fisheries Officers (FOs) and Fisheries Assistants (FAs) of the Kenya Fisheries Department as part of the research and training efforts of the Aquaculture Collaborative Research Support Program (ACRSP). The training materials used in these courses were developed by the collaborating principal investigators to meet the specific needs of these two groups of trainees, drawing on past experience in Kenya (CRSP-sponsored research at Sagana Fish Farm and in On-Farm Trials), information from CRSP research sites in other countries, and published aquaculture literature, and recognizing that most of the intended audience (FOs and FAs) had never previously received any kind of training in aquaculture. Insofar as possible, training materials were organized into PowerPoint® "modules" for use in the classroom setting and supplemented with a large amount of practical work in the field.

Following completion of the twelfth training session it was deemed desirable to organize the PowerPoint® module material into a handbook that could be used not only for future short courses but also as a reference manual for workers involved in aquacultural extension activities in Kenya. This report describes the development of the draft of that manual and a companion document, an "Instructor's Guide" containing supplemental material for instructors in future training sessions.

AFRICA PROJECT
Subcontract No. RD010E-D

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Work Plan Research

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

- Preliminary Work on Site Description, Evaluation, and Development Planning: Tanzania, Ghana, and Kenya/11ERAR1. The report submitted for this investigation was an abstract.
- Cost Evaluation and Benefit Assessment of Fish Farming in Selected African Nations/11ERAR2. The report submitted for this investigation was an abstract.
- An Economic Assessment of Aquaculture in Rural Africa: The Case of Tanzania, Kenya, and Ghana/11ERAR3. The report submitted for this investigation was an abstract.
- A Cross-National Analysis of the Potential Economic Impact of Aquaculture in Africa/11ERAR4. The report submitted for this investigation was an abstract.

Preliminary Work On Site Description, Evaluation And Development Planning: Tanzania, Ghana and Kenya

Eleventh Work Plan, Economic/Risk Assessment and Social Analysis 1 (11ERAR1)
Final Abstract

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Abstract

Requests for proposals under the Eleventh Work Plan encouraged the inclusion of new host countries and new researchers in Aquaculture CRSP activities. Ghana and Tanzania were proposed as potential new host countries in Africa, and as such, some preliminary work on site descriptions and updates were required. The activity verified the existence of basic institutional research capacities needed to make collaborative research viable. It also studied government policies to ascertain support for aquaculture, research, and extension. In Tanzania, a number of aquaculture projects funded by other non-governmental organizations including the FAO have been going on. A government aquaculture policy was obtained, which indicated a commitment to developing aquaculture. Two universities are engaged in aquaculture and fisheries research, University of Dar-es-Salaam and Sokoine University of Agriculture. In Ghana, the Kwame Nkrumah University of Science and Technology offers a degree program in aquaculture and has aquaculture research facilities. The government has a research center that is involved in aquaculture research called the Aquaculture Research and Development Center. The center is adequately staffed with aquaculture professionals and is well equipped. International agencies that are currently active in aquaculture development in Ghana include FAO, Danish International Development Agency, German International Development Agency, and the World Fish Center. Both Tanzania and Ghana are recommended to be included as new sites for Aquaculture CRSP research in Africa.

Cost Evaluation and Benefit Assessment of Fish Farming in Selected African Nations

Eleventh Work Plan, Economic/Risk Assessment and Social Analysis Research 2 (11ERAR2)
Final Abstract

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Abstract

This activity required identification of socio-economists in the respective countries who will assist in the development of teaching modules for farmers. The following have now been identified; K. A. Osei Fosu, Kwame Nkrumah University of Science and Technology, Ghana, Ephraim M. M. Senkondo, Sekione University of Agriculture, Tanzania, and John Mackambo, Moi University, Kenya. These individuals have started developing teaching materials to be used in teaching farmers simple methods for assessing and evaluating costs and benefits as well as principles of record keeping.

An Economic Assessment of Aquaculture in Rural Africa: The Case of Tanzania, Kenya, and Ghana

Eleventh Work Plan, Economic/Risk Assessment and Social Analysis Research 3 (11ERAR3)
Final Abstract

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Pine Bluff, Arkansas

Abstract

The study involves a comprehensive questionnaire for households involved in fish farming or other aquaculture ventures. A draft questionnaire has been developed with inputs from the host country Principal Investigators. The questionnaire has been pre-tested in Tanzania and is currently being pre-tested in Kenya and Ghana.

A Cross-National Analysis of the Potential Economic Impact of Aquaculture in Africa

Eleventh Work Plan, Economic/Risk Assessment and Social Analysis Research 4 (11ERAR4)
Final Abstract

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Pine Bluff, Arkansas

Abstract

The study involves an estimation of the potential economic impact of small- and medium-scale aquaculture developments on community development. A draft questionnaire required for collecting data has been developed and pre-tested in Tanzania. The questionnaire is currently being pre-tested in Kenya and Ghana. Some secondary data has been collected from Tanzania and some preliminary analysis is underway.

Philippines Project

Subcontract No. RD010E-20

Participants

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Emmanuel Angeles	Administrative Assistant
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Ronaldo Bernardino	Undergraduate Student (through April 2004)
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North Carolina State University, Raleigh, North Carolina

Russell Borski	US Principal Investigator

Work Plan Research

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

- Evaluation of Tilapia Aquaculture Best Practices in Central Luzon, the Philippines/11FNFR2. The report submitted for this investigation was a final report.
- Insulin-like Growth Factor-I as a Growth Indicator in Tilapia/11FNFR4 The report submitted for this investigation was a final report.

Publications

Bolivar, R..B Meet a Tilapia Farming Husband and Wife Team. Aquanews, 18(4):5.

Bolivar, R.B. On-Farm Trial Participants Share Successes. Aquanews, 18(4):3–6.

Bolivar, R.B. The CLSU-Aquaculture CRSP Project Funds Four Undergraduate Students. Aquanews, 18(4):8.

Bolivar, R.B, E.B.T. Jimenez, and C.L. Brown. Large-scale application of an alternate-day feeding strategy for tilapia growout in the Philippines (submitted by invitation). North American Journal of Aquaculture (NAJA)

Bolivar, R.B., E.B.T. Jimenez, J.R. Sugue, and C.L. Brown. Effect of stocking size on the yield and survival of Nile tilapia (Oreochromis niloticus L.) on-grown in ponds. Submitted, International Society for Tilapia Aquaculture (ISTA) for inclusion in proceedings.

Brown, C.L., R.B. Bolivar, and E.B. Jimenez. Feeding Moderation in Tilapia, An Overview of Economic and Environmental Implications. Global Aquaculture Advocate. (in press)

Jimenez, E.B., R.B. Bolivar, and C.L. Brown. 2004. Cost Containment Options in Semi-Intensive Tilapia Culture: Evaluation of Alternate-Day Feeding Strategy (abstract). World Aquaculture Society Book of Abstracts, page 291.

Vera Cruz, E., C.L. Brown, J.A. Luckenbach, M.E. Picha, R.J. Borski, and R.B. Bolivar. PCR-cloning of Nile tilapia, Oreochromis niloticus L., insulin-like growth factor-I and its possible use as an instantaneous growth indicator. Submitted to Aquaculture.

Presentations

Brown, B. Cost Containment Options in Semi-Intensive Tilapia Culture: Evaluation of Alternate-Day Feeding Strategy. Presented at the World Aquaculture Society Annual Conference. Honolulu, Hawaii, March, 2004.

Brown, B. Tilapia Culture in Bangladesh: Constraints and Potential. Presented at Tilapia Culture in Bangladesh: Constraints and Potential. Dhaka, Bangladesh, April, 2004.

Conferences

Philippine Society for Microbiology Annual Meeting. Manila, Philippines, April, 2004. (Babas)

Shrimp Congress 2004. Cebu Grand Convention Center, Cebu City, March, 2004. (Bolivar, Jimenez, Sugue, Angeles)

Tilapia Culture in Bangladesh: Constraints and Potential. Dhaka, Bangladesh, April, 2004. (Bolivar)

World Aquaculture Society Annual Conference. Honolulu, Hawaii, March, 2004. (Brown, Bolivar)

Evaluation of Tilapia Aquaculture Best Practices in Central Luzon, the Philippines

Eleventh Work Plan, Fish Nutrition and Feed Technology
Research 2 (11FNFR2)
Final Report

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Abstract

Work under this investigation included farm survey, extension, and research components using both the CLSU research station and demonstration farms. An experiment was conducted for the determination of optimal stocking sizes, considering the growth and survival performance of various sizes of fingerlings along with economic factors.

Size #22 sex-reversed nursery phase fingerlings of Nile tilapia (*Oreochromis niloticus*) of the Genomar Supreme Tilapia or GST strain were grown in fifteen (15) 2 x 2 x 1m hapas in pond at a stocking density of 200 fish m^{-3} to attain size #10. After two weeks, another batch of size #22 sex-reversed fingerlings were grown in 15 nursery hapas at 200 fish m^{-3} to attain size #14.

In the grow-out phase, twelve (12) 500m^2 ponds were used in the study to determine the growth, yield and survival of Nile tilapia (*Oreochromis niloticus* L.) in ponds. The treatments consisted of the following: I- direct stocking at size #22; II- stocking at size #14; and III- stocking at size #10. The various treatments and replicates were assigned randomly in the ponds following a completely randomized design.

Treatment III gave the highest extrapolated fish yield (3,799 $kgha^{-1}$), followed by Treatment II (3,065 $kgha^{-1}$) then Treatment I (2,738 $kgha^{-1}$). Analysis of variance on fish yield showed significant difference between Treatments I and III ($P < 0.05$). Specific growth rate likewise significantly differed among treatments ($P < 0.01$). Survival rate of Nile tilapia was also significantly affected by stocking size of fingerlings. Higher survival rate was obtained with larger size of fingerlings at stocking for grow-out production

In addition, a farm survey was conducted, in which 70 participating farmers were queried on a range of practical issues. This has established a database of farm practices (see appendix 1) which is being expanded upon by additional survey work, and which will be useful for a variety of applications.

Insulin-like Growth Factor-I as a Growth Indicator in Tilapia

Eleventh Work Plan, Fish Nutrition and Feed Technology
Research 4 (11FNFR4)
Final Report

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Abstract

A set of studies was carried out on the expression of the IGFI gene in juvenile tilapia, using fish approximately of the initial size that is stocked for growout in commercial aquaculture in the Philippines (~1–1.5 g). IGF-I is a mitogenic polypeptide that is an important regulator of growth in fish. The potential of IGF-I mRNA abundance as an instantaneous growth indicator in juvenile Nile tilapia, *Oreochromis niloticus*, was evaluated. Hepatic IGF-I cDNA was isolated and cloned and partially cloned. The partial sequence having 539 bp was found to code for the signal peptide (44 amino acids), mature protein (68 aa) and a portion of the E domain (19 aa). The deduced 68 aa sequence for mature IGF-I showed 84–90% and 77–79% sequence identity with fish and mammalian counterparts, respectively, confirming the highly conserved sequence homology among species. The B and A domains were even more highly conserved with respect to the deduced amino acid sequence (90–96%). Based on the mature IGF-I peptide, a sensitive TaqMan real time qRT-PCR assay for *O. niloticus* was developed for measures of hepatic IGF-I mRNA levels. Hepatic IGF-I mRNA levels were found to be significantly correlated with growth rate of individual juvenile fish reared under different feeding regimes and temperature conditions. Higher feed consumption and water temperature produced faster growing fish and increased hepatic IGF-I mRNA expression. These findings suggest that hepatic IGF-I plays a key role in controlling growth in *O. niloticus* and indicates IGF-I mRNA measures could prove useful to assess current growth rate in this species.

Global Projects

Honduras, Thailand, Vietnam, Philippines
Subcontract No. RD010E-11

Participants

University of Arizona

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Wanwisa Saelee	Graduate Student

Central Luzon State University, Philippines

Remedios Bolivar	Host Country Principal Investigator
Bong Bolivar	Host Country Principal Investigator
JunRey Sugue	Research Assistant
Cecelia Villamo	Research Assistant

Private Sector Collaborators

John Clarke	Schering-Plough, Philippines
Fu-Sung Frank Chiang	President, Taiwan Tilapia Farmers
Calvin Burgess	Private tilapia farm owner, Kenya

Work Plan Research

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

- Aquaculture CRSP Sponsorship of the Sixth International Symposium on Tilapia in Aquaculture/11ATER2. The report submitted for this investigation was a final report.
- Aquaculture CRSP—Global Contributions to Sustainable Aquaculture: A Special Session at the 2004 World Aquaculture Conference/11ATER3. The report submitted for this investigation was a final report.

Presentations

Fitzsimmons, K. Aquaculture CRSP Contributions to Sustainable Aquaculture. Presented to farmers and government officials in Honolulu, Hawaii, March, 2004.

Fitzsimmons, K. Tilapia Aquaculture in Africa. Presented to government officials and visitors from World Fish Center at AID Headquarters in Washington D.C., April, 2004

Aquaculture CRSP Sponsorship of the Sixth International Symposium on Tilapia in Aquaculture

Eleventh Work Plan, Applied Technology and Extension Methodologies Research 2 (11ATER2)
Final Report

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Science City of Muñoz, Nueva Ecija, Philippines

Abstract

This project supported the planning and conduct of the Sixth International Symposium on Tilapia in Aquaculture. The ISTA 6 conference held 12–16 Sept 2004 in Manila, Philippines, was widely hailed as the most successful symposium yet held on tilapia aquaculture. Total attendance at the conference was almost 700 people, with 80 oral presentations and a dozen posters presented. ISTA 6 included a heavily attended trade show and field trips to tilapia production and processing centers at Lake Taal and Pampanga Province; research and development sites at the Science City of Muñoz; and supporting industries including feed mills, hatcheries, and other government institutions in the provinces of Laguna and Nueva Ecija.

Aquaculture CRSP—Global Contributions to Sustainable Aquaculture: A Special Session at the 2004 World Aquaculture Conference

Eleventh Work Plan, Applied Technology and Extension Methodologies Research 3 (11ATER3)
Final Report

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Tucson, Arizona

Abstract

Aquaculture CRSP sponsored several events, awards, and a special session at the Triennial World Aquaculture Society meetings in Hawaii in March 2004. The triennial meeting of the WAS is the premier aquaculture technical and trade show held globally. Every third year WAS meets in conjunction with the American Fisheries Society and National Shellfish Association, as well as over 20 smaller aquaculture organizations.

The sponsorship included organizing the session, providing the chair, the speakers, and collecting all of the Powerpoint and audio files for posting on the Internet for additional viewing. Travel funds were provided for eleven scientists and students to attend the WAS conference and present their research findings. The special session titled: Aquaculture CRSP—Global Contributions to Sustainable Aquaculture, was well attended by CRSP and non-CRSP scientists. At the end of the presentations, two panel discussions were conducted.

Panel Discussion 1: Tilapia Production: Subsistence Culture to International Markets; and

Panel Discussion 2: Indigenous Fish for Aquaculture.

In addition to funding travel and registrations, the grant purchased subscriptions to the online presentations at the WAS website for the session presenters and students. This allowed them to view Web-based streaming video and audio of WAS conference presentations from meetings in Kentucky, Brazil, Hawaii, and Australia. It also included a CD-ROM version of the Kentucky and Brazil meetings. More importantly the subscription number allowed them (or their students and colleagues) to log on from anywhere and view the presentations. The CD-ROM version accommodates computers without internet connections and allows for easy use in the classroom.

Another aspect of the grant was to organize and present a Lifetime Achievement Award. The Award was to recognize a career dedicated to developing sustainable aquaculture systems in CRSP host countries. C. Kwei Lin, who recently retired from the Asian Institute of Technology, was selected as the recipient. The award included a lifetime membership in the World Aquaculture Society. The project also included cash awards for Best Student Posters at the conference. A team of judges evaluated student posters that dealt specifically with aquaculture research that was directed toward sustainable aquaculture systems in or for developing countries. A first place award of $400 and two runner up awards of $200 were presented at a WAS student function.

Global Projects

South Africa, Thailand, Brazil
Subcontract No. RD010E-07

Participants

Auburn University

Claude E. Boyd	US Principal Investigator
Chhorn Lim	US Principal Investigator
Taworn Thunjai	Ph.D. Student (Thailand)
Kom Silapajarn	Ph.D. Student (Thailand; through Spring 2004)
Orawan Silapajarn	Ph.D. Student (Thailand)
Idsariya Wudtisin	Ph.D. Student (Thailand)
Wararat Wudtisin	Ph.D. Student (Thailand)

University of Stellenbosch, South Africa

Danie Brink	Host Country Principal Investigator
Lourens de Wet	Host Country Principal Investigator
Khalid Salie	Research Assistant

Kasetsart University, Bangkok, Thailand

Mali Boonyaratpalin	Host Country Principal Investigator

Embrapa Meio Ambiente, Brazil

Julio Queiroz	Host Country Principal Investigator

Centro de Aqüicultura, Universidade Estadual Paulista, Jaboticabal, São Paulo, Brazil

Lúcia Sipaúba-Tavares	Host Country Principal Investigator

Work Plan Research

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

- Use of a Wetland to Treat Effluent from a Flow-Through Aquaculture System/11WQAR2. The report submitted for this investigation was a final report.
- Influence of Daily Feed Allowance on Pond Water and Effluent Quality/11WQAR4. The report submitted for this investigation was a final report.
- Further Studies on Soil Quality in Aquaculture Ponds in Thailand/11EIAR2. The report submitted for this investigation was a final report.

Publications

Salie, K. Small-Scale Aquaculture Enterprises for the People. Aquanews, 18(4):4–5.

Silapajarn, K, C.E. Boyd, and O. Silapajarn. An Improved Method for Determining the Fineness Value of Agricultural Limestone for Aquaculture. North American Journal of Aquaculture 66:113-118.

Thunjai T., C.E. Boyd, and M. Boonyaratapalin. Bottom Soil Quality in Tilapia Ponds of Different Age in Thailand. Aquaculture Research 35:698-705.

Thunjai T., C.E. Boyd, and M. Boonyaratapalin. Quality of Liming Materials Used in Aquaculture in Thailand. Aquaculture International 12:161-168.

Presentations

Boyd, C.E. Aquaculture and the Environment. Seminar presented AAAS meeting in Seattle, Washington, February, 2004.

Boyd, C.E. Aquaculture and the Environment. Seminar presented to upper level undergraduate students at Rumkhumhaeng University in Bangkok, Thailand, December, 2003.

Boyd, C.E. Overcoming Environmental Barriers to Aquaculture Development. Presented at the World Aquaculture Society Annual Conference. Honolulu, Hawaii, March, 2004.

Boyd, C.E. Quality of Liming Materials Used in Shrimp Farming in Thailand. Presented at the World Aquaculture Society Annual Conference. Honolulu, Hawaii, March, 2004.

Silapajarn, K. Particle Size and Reaction of Agricultural Limestone. Presented at the World Aquaculture Society Annual Conference. Honolulu, Hawaii, March, 2004.

Silapajarn, O. Nitrogen and Phosphorus Concentration and Loads in a Stream Receiving Catfish Farm Effluents. Presented at the World Aquaculture Society Annual Conference. Honolulu, Hawaii, March, 2004.

Conferences

AAAS Annual Meeting. Seattle, Washington , February, 2004. (Boyd)

World Aquaculture Society Annual Conference. Honolulu, Hawaii, February, 2004. (O. Silapajarn, K. Silapajarn)

World Aquaculture Society Annual Conference. Honolulu, Hawaii, March, 2004. (Boyd)

Use of a Wetland to Treat Effluent From a Flow-Through Aquaculture System

Eleventh Work Plan, Water Quality and Availability
Research 2 (11WQAR2)
Final Report

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Abstract

A study was conducted at Jaboticabal, São Paulo, Brazil to evaluate the effectiveness of a wetland consisting of a 90 m long by 2 m wide ditch as a treatment system for effluent from a 3-ha aquaculture research station. The wetland (vegetated ditch) contained four major species of aquatic macrophytes as follows: *Ludwigia elegans*, *L. sericia*, *Alternanthera philoxeroides*, and *Myriophyllum aquaticum*. The biofilter action of the wetland caused an annual reduction in five day biochemical oxygen demand of 48.1% and a 26.4% reduction in total suspended solids. Although nutrient concentrations were not reduced in water passing through the wetland, the chlorophyll *a* concentration was about 14% less in the discharge of the wetland than in the incoming aquaculture effluent. Results of this study suggest that a wetland biofilter consisting of a vegetated ditch could cause modest improvements in the quality of aquaculture effluents.

Influence of Daily Feed Allowance on Pond Water and Effluent Quality

Eleventh Work Plan, Water Quality and Availability
Research 4 (11WQAR4)
Final Report

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Abstract

A feeding trial was conducted towards optimization of feeding regimes for semi-intensive culture of Mozambique tilapia in earthen ponds in order to improve pond and effluent water quality, and reduce feeding cost. Fifty Mozambique tilapia fingerlings with an average weight of 17.8 ± 1.6 g were stocked in each of the 40 hapas. The experimental layout consisted of five feeding treatments of 20, 40, 60, 80, and 100% of apparent satiation with 8 replicates each. Fish were fed three times a day for 111 days. Specific growth rate (SGR) and feed conversion ratio (FCR) were used to measure the response to the various feeding regimes. Results were analyzed at three separate periods: at days 27, 55, and 111. At 27 and 55 days no significant improvement in FCR and SGR were observed at feeding levels above levels 60 and 80%, respectively. At 111 days, no significant difference in SGR was observed at feeding levels of 60% and above. This is an indication that 60% is the optimum feeding management regime. Natural food intakes calculated based on SGR and FCR were 0.34, 0.29, and 0.20% of body weight per day at 27, 55, and 111 days, respectively. Results from water quality analyses sampled fortnightly indicated no significant difference between the ponds. Analyses for correlations between production performance parameters and water quality parameters provided a regression equation to predict the natural food intake at specific water quality parameters, viz. Natural food intake (expressed as percentage of bodyweight per day) = 27.2 – 0.0962 morning measured oxygen – 0.0328 conductivity – 0.911 pH + 13.0 ammonia-nitrogen – 2.52 nitrate + 41.2 nitrite – 7.72 phosphate + 0.337 TSS (R2 = 80.9, P = 0.000). These results may provide useful data to quantify the utilization of natural pond productivity in the feeding management of Mozambique tilapia.

Further Studies on Soil Quality in Aquaculture Ponds in Thailand

Eleventh Work Plan, Environmental Impacts Analysis
Reseaarch 2 (11EIAR2)
Final Report

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Abstract

Bottom soil samples were collected from 42 catfish (*Clarius* hybrid) ponds, 40 freshwater prawn (*Macrobrachium rosenbergii*) ponds, and 18 carp (*Puntius* spp.) ponds in Thailand. The ponds ranged from 1 to 30 years in age. Regression analysis revealed that pond age was not a factor influencing the physical and chemical composition of pond soils.

Sediment depth, S horizon thickness, and bulk density of S horizon were greater for carp ponds than for catfish and prawn ponds. This resulted because sediment was removed from catfish and prawn ponds more frequently than from carp ponds. Total, organic, and inorganic carbon and total nitrogen concentrations were higher in carp ponds than prawn and catfish ponds. However, few ponds had sediment organic carbon concentrations above 3%, and carbon:nitrogen ratios did not differ among the three cultured species.

The results of this study confirm that normal procedures of pond soil management e.g., drying bottoms between crops, liming, and periodic sediment removal, were effective in maintaining good sediment quality in freshwater, aquaculture ponds over a period of at least 30 years.

Global Project
Subcontract No. RD010E-E

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Emilio Ochoa Moreno	Host Country Principal Investigator (from February 2004)

Regional Center of Education and Qualification for Sustainable Development (CREDES), Mazatlan, Mexico

Ana Luisa Toscano	Director of CREDES and Gender specialist (from February 2004)

Wetlands Conservation Program, Mazatlan, Mexico

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

- Cross-Sectoral and International Extension Exchange and Learning/11AHHR1. The report submitted for this investigation was an abstract.
- Connectivity of Water Resource Status, Environment Quality, Aquaculture, and Human Health/11AHHR2. The report submitted for this investigation was an abstract.
- Analysis of Critical Points in Aquaculture Production Affecting Participation and Level of Benefits to Women, Youth, and Disadvantaged Stakeholders/11AHHR3. The report submitted for this investigation was an abstract.
- Food Safety and Handling: Increasing Local Consumption and Aquaculture Products and Improving Quality/11DPPR1. The report submitted for this investigation was an abstract.

Cross-Sectoral and International Extension Exchange and Learning

Eleventh Work Plan, Aquaculture and Human Health Research 1 (11AHHR1)
Final Abstract

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Abstract

Extension is a recognized vehicle to raise awareness, modify behavior and transfer technology, but it also represents one of the principal obstacles to developing and improving aquaculture in many part of the world. Long-term efforts have been made in Sinaloa, Mexico to establish a corps of extension agents to support the aquaculture sector and to work with other specialist to tackle cross-sectoral problems that affect aquaculture. Extension efforts are directed at implementing best management practices for the major form of aquaculture in the region (shrimp culture) and diversifying the industry through increasing production of freshwater finfish and native species of bivalves. Inclusion of neglected stakeholder groups such as women, youth, and the physically disadvantaged is also a goal. The CRSP Cross-Sectoral and International Extension Exchange and Learning Workshop builds on these efforts and extends them into new areas of learning to include sharing of experiences from other sectors such as public health, agriculture, gender equity efforts, and work with the physically challenged. A three day workshop was held in Mazatlan, Mexico on 14-16 June during which training was provided and sharing of experience occurred. Participants included aquaculture extension agents and NGO representatives from Mexico, representatives from other CRSP initiatives (Mexico, Peru, and Honduras) and project personnel from other innovative aquaculture extension efforts (UCA/Nicaragua and Ecocostas/Ecuador). An additional two days were spent reviewing the research and progress of the three case studies associated with this project. Course materials from the workshop are being compiled and will be distributed widely for the benefit of extension workers elsewhere.

Connectivity of Water Resource Status, Environmental Quality

Eleventh Work Plan, Aquaculture and Human Health Research 2 (11AHHR2)
Final Abstract

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Abstract

The goal of this investigation is to characterize the relationships between water resources and aquaculture and aquaculture development in relation to human health. Sinaloa, Mexico is an ideal study site to elucidate the inter-connectivity of water resources, aquaculture production, environmental quality and human health being a state rich in both agriculture and industrial activities with rapid urbanization, like many developing regions of the world. Pressures on water resources are rapidly increasing in terms of quality and available volume at the precise moment that aquaculture development is accelerating. Previous work suggested that the status of water resources and aquaculture development affect and are affected by human health parameters. This study is focused on watersheds within Sinaloa where aquaculture (shrimp, bivalves, and freshwater finfish) development is growing and health-related effects have been observed. To date, extensive literature research, field investigations, interviews, site observations, and studies have been conducted. Multidisciplinary teams including specialists from the University of Sinaloa, University of Rhode Island, University of Hawaii Hilo, NGOs such as Conservation International, and government agencies are responsible for this research. Four workshops have been held to plan the work, define research methodologies, present preliminary results and analyze findings have been held. A draft of the case study has been produced and is now under review. It is expected that work will be completed by March 2005.

Analysis of Critical Points in Aquaculture Production Affecting Participation and Level of Benefits to Women, Youth, and Disadvantaged Stakeholders

Eleventh Work Plan, Aquaculture and Human Health
Research 3 (11AHHR3)
Final Abstract

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Abstract

Preliminary work with the predominant form of aquaculture in Sinaloa, Mexico (shrimp culture) to improve management practices and increase direct benefits to local communities indicated that women and other marginalized stakeholders play a key role in this industry and must be included in participatory, community-based efforts to implement Best Management Practices. Other efforts to increase aquaculture production, particularly in the case of freshwater fish and local species of bivalves, suggested that women would be primary target groups for these efforts given their roles as producers, fishers, and vendors. Additionally, Sinaloa like many other regions in the world is dealing with issues associated with urbanization, globalization, and impacts of the growing drug trade. There are large numbers of young, unemployed youth and a high level of physically challenged individuals due to locally high rates of birth defects, HIV/AIDS, cancer, vehicular accidents, and drug-related violence. It is clear that many stakeholders from these groups already participate in aquaculture in aquaculture or wish to do so, but confront challenges to entering or increasing their participation in this activity. This work is designed to better understand key obstacles (technical, social, and economic) to increased participation and develop simple and immediately applicable strategies to encourage more aquaculture production among these groups. For example, a key deliverable will be a feasibility study and plan to guide the physically disabled in establishing tilapia culture. Research is being carried out with women's oyster cultivating cooperatives, women working with impoundment tilapia culture, seafood vendors, women fishers, and two groups of physically challenged, rural adults who are currently engaged in manufacturing occupations who now wish to cultivate tilapia. The latter operate an NGO called PROJIMO that engages in community-based work to address the needs of the rural handicapped. To date, extensive literature research, field investigations, interviews, site observations and studies have been conducted. Multidisciplinary teams including specialists from the University of Sinaloa, University of Rhode Island, University of Hawaii Hilo, NGOs such as Conservation International, CIAD, and government agencies are responsible for this research. Four workshops have been held to plan the work, define research methodologies, present preliminary results and analyze findings have been held. A draft of the case study has been produced and is now under review. It is expected that work will be completed by March 2005. The women's groups and PROJIMO have also participated in the Cross-sectoral and International Extension Exchange and Learning (11AHHR1) to share their experience working with extension to their respective stakeholder groups and to learn from the aquaculture extension agents.

Food Safety and Handling: Increasing Local Consumption of Aquaculture Products and Improving Quality

Eleventh Work Plan, Aquaculture and Human Health
Research 1 (11DPPR1)
Final Abstract

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Abstract

Food safety and handling have become major issues for aquaculture in much of the world, including Sinaloa, Mexico, where efforts are underway to sustainably manage and improve benefits from aquaculture. Shrimp culture is the predominant form of aquaculture in the region, and preliminary work has shown that there is a need for small producers, processor employees, and seafood vendors to improve their ability to safely harvest, handle, store, and market shrimp and shrimp products. Many of these workers are women and the rural poor. Additionally, other forms of aquaculture have had their development slowed through the general lack of capacity in this area. Tilapia

and other freshwater fish are major aquaculture products, but their full potential cannot be exploited unless means are found to process and transport under safe conditions beyond the immediate local market. A major effort is being made to diversify aquaculture away from shrimp to local species of bivalves in coastal areas. Constraints exist for both local and international marketing of bivalves as water quality deteriorates and standards become more rigorous. Thus, addressing bivalve sanitation issues is a focal point not only for aquaculture development, but for environmental management and public health. As the multi-sectoral working group proceeds in its investigations, new, previously unrecognized risks are being uncovered. High level of gnathosome infection in most bodies of freshwater, which coupled with the customary and growing habit of eating raw fish products is poised to become a greater health issue as this parasite can cause severe illness and death. Contaminant levels appear to be increasing in aquatic products as urban, agricultural, and industrial pollution increases unchecked. Previously undetected levels of gastrointestinal illness associated with consumption of fish and shellfish is beginning to be documented and rates appear to be high and increasing. Public perception of the safety of aquatic products appears to be diminishing. Given that much of the work focuses on sectors of society most at risk for food-borne illnesses, including the physically disabled, the challenge of finding practical means of ensuring food safety is critical to maintaining aquaculture as a source of healthy and quality food. Research is being carried out with women's oyster cultivating cooperatives, women working with impoundment tilapia culture, seafood vendors, women fishers and two groups of physically challenged, rural adults who are currently engaged in manufacturing occupations who wish to cultivate tilapia. To date, extensive literature research, field investigations, interviews, site observations, and studies have been conducted. Multidisciplinary teams including specialists from the University of Sinaloa, University of Rhode Island, University of Hawaii Hilo, NGOs such as Conservation International, CIAD, and government agencies are responsible for this research. Four workshops have been held to plan the work, define research methodologies, present preliminary results and analyze findings have been held. A draft of the case study has been produced and is now under review. It is expected that work will be completed by March 2005.

Central America Project

Subcontract No. RD010E-16 (AU)
Subcontract No. RD010E-17 (UG)

Participants

Auburn University, Auburn, Alabama

Joseph Molnar	US Principal Investigator
Elizabeth Trejos Castillo	Graduate Student
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Julian Montoya	Undergraduate Student
Abel Carias	Undergraduate Student

University of Georgia, Athens, Georgia

Brahm P. Verma	US Principal Investigator
E. William Tollner	US Principal Investigator
Jennifer Maldonado	Collaborator (through 2003)
Tom Popma	US Technical Support (retired in 2003)

Escuela Agrícola Panamericana, El Zamorano, Honduras

Daniel Meyer	Host Country Principal Investigator
Freddy Arias	Collaborator
George Pilz	Collaborator
Suyapa Triminio de Meyer	Research Assistant
Hector Lagos	Research Assistant (through 2003)
Franklin Martinez	Research Associate

Work Plan Research

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

- Evaluation and Improvement of Tilapia Fingerling Production and Availability in Honduras/11SDAR2. The report submitted for this investigation was a final report.
- Pond Design and Watershed Analyses Training/ 11WQAR3. The report submitted for this investigation was a final report.

Publications

Martinez, P.R., J. Molnar, E. Trejos, S. Meyer, D. Meyer, and E.W. Tollner. Cluster Membership As a Competitive Advantage in Aquacultural Development: Case Study of Tilapia Producers in Olancho, Honduras. Journal of Aquaculture and Management. (submitted)

Martinez-Mejia, P. Case Study of Commercial Tilapia Production in Olancho, Honduras. M.S. thesis, Auburn University, Alabama, USA.

Trejos-Castillo, E. Income, Food Security, and Poverty Reduction: Case Studies of Small-Scale Aquaculture Producers in Santa Barbary, Honduras. M.S. thesis, Auburn University, Alabama, USA.

Trejos-Castillo, E., J. Molnar, S. Meyer, and D. Meyer. Income, Food Security, and Poverty Reduction: Case Studies of Small-Scale Aquaculture Producers in Santa Barbary, Honduras. Community Development Journal. (submitted)

Presentations

Molnar, J. Fingerling Production and Distribution. Presented to farmers and NGO agents in Zamorano, Honduras, December, 2003.

Molnar, J. Symposium: Aquaculture: Recent Advances in Fish Culture, Breeding, and the Mitigation of Environmental Impact. Presented at the American Association for the Advancement of Science. Seattle, Washington, February, 2004.

Trejos-Castillo, E., J. Molnar, P. Martinez, E.W. Tollner, B. Verma, G. Pilz, and S. Meyer. Income, Food Security and Poverty Reduction: Case Studies of Small-Scale Aquaculture Producers in Santa Barbara, Honduras. Presented at the World Aquaculture Society Annual Conference. Honolulu, Hawaii, March, 2004.

Triminio-Meyer, S. and C. Ponciano. Programa de Enseñanza y Proyección Acuícola en Zamorano, Honduras. Presented in The Workshop International Exchange on Aquaculture Extension. Mazatlan, Mexico, June 2004

Triminio-Meyer, S., D.E. Meyer and J. Molnar. Productores de Alevines de Tilapia en Honduras, Características, Prácticas y Necesidades de Apoyo. Presented in the First Latin American workshop for the Tilapia Sector. Puerto Vallarta, Mexico, June 2004.

Triminio-Meyer, S., D.E. Meyer, and J. Molnar. Tilapia Fingerling Producers in Honduras: Characteristics, Practices and Needs. Presented at the World Aquaculture Society Annual Conference. Honolulu, Hawaii, March, 2004.

Triminio-Meyer, S., J. Molnar and D.E. Meyer. Opciones de Mercadeo para productores de Tilapia de Mediana y Pequeña escala en Honduras. Presented in the V Symposium of Aquaculture of Guatemala, October 2003.

Conferences

American Association for the Advancement of Science. Seattle, Washington, February, 2004. (Molnar)

World Aquaculture Society Annual Conference. Honolulu, Hawaii, March, 2004. (Meyer, Trejos, Molnar, Triminio, Tollner)

Evaluation and Improvement of Tilapia Fingerling Production and Availability in Honduras

Eleventh Work Plan, Seedstock Development and Availability Research 2 (11SDAR2)
Final Report

Suyapa Triminio Meyer and Daniel Meyer
Agricultural Production and Science
Escuela Agrícola Panamericana El Zamorano
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International Center for Aquaculture and Aquatic Environments
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Abstract

One important factor limiting tilapia culture development in Honduras as well as in the rest of the Central America is the lack of supply of fingerlings in sufficient quantity and quality. To assess the situation, we endeavored to obtain information and purchase fingerlings from every seed producer in Honduras. Sixteen tilapia fingerling producers were visited and interviewed during September of 2003 to April 2004. They provided information about their production facilities and techniques, the quality and quantity of fingerlings produced, their socio-economic situation, and their technical needs. Fingerlings were obtained from 12 farms, and then transported to the Zamorano campus for grow-out and comparison. Most samples (70%) contained more than 10% females. Only three of the 10 samples of sex-reversed tilapia fingerlings had less than 3% females. There was a high degree of variability in the sizes of the fingerlings in each sample. Two of the 16 fingerling producers do not use MT sex-reversal. Seven fingerling farms are family-owned, four are private companies, one is a cooperative, and the remaining four are operated by non-profit organizations (NGOs), universities, and government agencies). In aggregate, they produce approximately 15.3 million fingerlings a year. Most (75%) of the fingerling producers interviewed also raise tilapia, produce other aquaculture species, and have other farm enterprises.

Pond Design and Watershed Analyses Training

Eleventh Work Plan, Water Quality and Availability Research 3 (11WQAR3)
Final Report

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Joseph Molnar
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Dan Meyer and Suyapa Triminio-Meyer
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Zamorano, Honduras

Abstract

Variable rainfall distribution and terrain make surface water harvesting and storage a challenge in many developing countries. The overall goal of this study is to collect and develop information required to equip extension, nongovernmental organization (NGO) agents, contractors, and engineers for surface water development and aquaculture enterprise development in Honduras and Latin America. A pond water balance for the levee production pond enabling determination of water flow required to balance seepage, evaporation, and direct rainfall was developed in English and Spanish on the Microsoft Excel® platform. The pump-in flow rate can also be determined for reaching a volume change per month target. A second model was formulated for evaluating surface water capture by watershed and/or hillside ponds for meeting the levee pond demand. Using hillside ponds that fill by impounding a fraction of total runoff (e.g., diverting water upstream) from streams appears to have promise for meeting water needs. A systematic approach using both models to reach a sustainable water supply target emerged from this work. Both the levee pond model and the water harvest model are based on balancing inputs and outputs given monthly rainfall patterns. A simple approach to mechanical spillways preliminary design was developed. The models are adaptable to any location if key input data is available, particularly average monthly rainfall and storm frequency-duration data. The models do not address water quality issues. The software is intended for watershed sizes not larger than 500 ha and storage ponds of less than 5 ha surface area and 4 m depth due to relationship limitations and safety concerns. Coupling with other cooperative development concerns such as marketing associations provides a platform for helping groups of people in a watershed to realize further the potential of enlightened self-interest in developing common solutions to water problems.

Tenth Work Plans

New Aquaculture Systems/New Species Research

Mexico
Subcontract No. RD010E-11

Participants

University of Arizona

Kevin Fitzsimmons	US Principal Investigator
Huruy Zerzghi	Graduate Student (Eritrea)

Universidad Juárez Autónoma de Tabasco, Mexico

Wilfrido Contreras-Sanchez	Host Country Principal Investigator
Alejandro McDonal Vera	Graduate Student

Work Plan Research

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

- Stocking densities for tilapia-shrimp polyculture in Mexico/10NSR3D. The report submitted for this investigation was a final report.

Effect of Stocking Density of Red Hybrid Tilapia on Growth And Survival of Juvenile Tilapia And Shrimp in Polyculture

Tenth Work Plan, New Species Research 3D (10NSR3D)
Final Report

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Neil J. Duncan
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Kevin Fitzsimmons
University of Arizona
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Abstract

A single earth pond (3/4 hectare) was prepared and divided into nine (7 x 30 m) enclosures that were considered to be three blocks of three enclosures. During water exchange, the water passed first through block A (first use water), then block B (second use) and finally block C (third use). Each block was randomly stocked with shrimp (*Litopenaeus vannamei*) and three different densities of red tilapia hybrids (with an *Oreochromis mossambicus* genetic component) to give three different treatments: T0: zero tilapia per m^2 and 30 shrimp m^2; T25: 0.25 tilapia per m^2 and 30 shrimp m^2; T50: 0.50 tilapia per m^2 and 30 shrimp m^2. Tilapia and shrimp populations in each enclosure were sampled and growth was estimated approximately every two weeks. During the two month experiment temperature ranged from 16.2 to 25.6 °C and salinity from 28 to 35ppt. Growth rates of the tilapia and shrimp across the different treatments were similar and no significant differences were observed in mean sample weights for any sample date. Growth of the tilapia was also similar across the experimental blocks and no significant differences were observed. The tilapia grew from 4.6 ± 0.9g to mean final weights from the replicates that ranged from 32.8 ± 8.1g to 38.8 ± 10.0g.

However, the experimental blocks had a significant ($P < 0.05$) affect on mean sample weight of shrimp and when the experiment finished shrimp in blocks B and C were significantly ($P < 0.05$) bigger than shrimp from block A. The shrimp grew from 0.004 g to mean weights from the replicates that ranged from 1.82 ± 0.40 g to 2.07 ± 0.45 g in block A and from 2.08 ± 0.48 g to 2.29 ± 0.47 g in blocks B and C. There was no significant difference in survival of tilapia among the different treatments and blocks, survivals ranged from 86 to 92%. A larger variation was observed in the survival of the shrimp, the replicates exhibited a range from 46.6 to 73.9%. Survivals from block C that ranged from 66.4 to 73.9% were significantly ($P < 0.05$) higher than in blocks A and B that exhibited survivals that ranged from 46.6 to 57.0%. The three stocking densities of tilapia (0, 0.25, and 0.50 tilapia per m^2) did not affect survival or growth of the tilapia or shrimp. Shrimp survival and growth was affected by position of the enclosure in the pond, survival and growth was significantly higher with water that had previously passed through other enclosures.

New Aquaculture Systems/New Species Project

Subcontract No. RD010E-C

Participants

Auburn University

Ronald P. Phelps	US Principal Investigator
Karen Veverica	US Principal Investigator
George Osure	Graduate Student (Kenya) (through fall 2003)

Fisheries Department, Nairobi, Kenya

Bethuel Omolo	HC Research Associate/Head of Station, Sagana Fish Farm

Moi University

David Liti	Host Country Principal Investigator
Mucai Muchiri	Host Country Principal Investigator
James Barasa	Graduate Student

KMFRI Sangoro Aquaculture Station, Onditi Kisumu, Kenya

Jonathan Munguti	Host Country Principal Investigator

Work Plan Research

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

- Evaluation of growth and reproductive performance in three strains of Nile tilapia *Oreochromis niloticus* found in Kenya for use in Aquaculture/10NSR4A. The report submitted for this investigation was a final report.

Publications

Osure, G. Evaluation of Growth and Reproductive Performance and Microsatellite Variability of Four Strains of Nile Tilapia, *Oreochromis niloticus*. M.S. thesis, Auburn University.

Presentations

Osure, G. Evaluation of Growth and Reproductive Performance and Microsatellite Variability of Four Strains of Nile Tilapia, *Oreochromis niloticus*. Seminar presented at Auburn University and Wageningen University.

Evaluation of Growth and Reproduction Capacity of Three Strains of Nile Tilapia, *Oreochromis niloticus*, Found Locally in Kenya for Use in Aquaculture

Tenth Work Plan, New Aquaculture Systems/New Species Research 4 A (10NSR4A)
Final Report

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Eldoret, Kenya

Jonathan Munguti
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Abstract

In a series of experiments, the performance of three strains of Nile Tilapia, *Oreochromis niloticus,* was evaluated in 0.015 ha earthen ponds at Sagana Fish Farm. The strains were acquired from Lake Victoria, Lake Turkana, and Sagana fish farm. The first experiments were conducted from June 2002 to May 2003 and the other from October 2003 to April 2004. Nine ponds were limed at 3.3 tons/ha and treated weekly with urea and di-ammonium phosphate (DAP) at rates of 20 kg N/ha and 8 kg P/ha. The brood stock was conditioned in the ponds, and the F1 generation for each strain was produced. The experimental ponds were stocked with fry from the broodstock strains at 70,000 fry/ha, and raised from 0.5g to between 6-7g for a period of 66 days; their growth performance and survival were evaluated. The 6g frys were harvested and restocked at 50,000 fish/ha and further raised

to 22g fingerlings. Later the 22g fingerlings were hand-sexed and the male *O. niloticus* post fingerlings from each strain were stocked at 20,000/ha. Their growth performance was then compared under two different feeding regimes. Relative ficundity was evaluated by counting fry from the bucal cavity of females from a broodstock that was placed in cages. Victoria strain had the highest growth performance, survival and relative fecundity while Turkana and Sagana strains had lower but similar performance. Sagana strain recorded the lowest survival and relative fecundity. The sex ration of the Sagana strain was highly skewed towards females while the wild strains had sex ratios close to 1:1. The results of the present study revealed that the Victoria strain was the fastest grower and survivor while the Sagana strain was a inbred strain.

Marketing and Economic Analysis and Product Diversification Research

Honduras, Kenya, Mexico, Nicaragua, and Peru
Subcontract No. RD010E-01

Participants

University of Arkansas at Pine Bluff
Carole Engle — US Principal Investigator
Ivano Neira — Research Associate
Carlos Leyva Carias — Graduate Student
Yong-Suhk Wui — Collaborator

Instituto de Investigaciones de la Amazonia Peruana, Iquitos, Peru
Fernando Alcántara Bocanegra — Host Country Principal Investigator

Universidad Juárez Autónoma de Tabasco, Villahermosa, Mexico
Wilfrido Contreras-Sánchez — Host Country Principal Investigator
Raymundo Sury — Undergraduate Student

Universidad Centroamericana, Nicaragua
Agnes Saborio — Host Country Principal Investigator

Moi University, Eldoret, Kenya
Mucai Muchiri — Host Country Principal Investigator
Charles Ngugi — Host Country Principal Investigator

Escuela Agrícola Panamericana, El Zamorano, Honduras
Daniel Meyer — Host Country Principal Investigator
Freddy Arias — Host Country Principal Investigator

Work Plan Research

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

- Optimal (profit-maximizing) target markets for small and medium-scale tilapia farmers in Honduras and Nicaragua/10MEAR1. The report submitted for this investigation was a final report.
- Development and evaluation of a simple market feasibility assessment methodology/10MEAR2. The report submitted for this investigation was a final report.
- Regional enterprise budget and business plan development/10MEAR3. The report submitted for this investigation was a final report.
- Economic and risk analysis of tilapia production in Kenya/10MEAR4. The report submitted for this investigation was a final report.

Publications

Neira, I. and C. Engle. Domestic Marketing Strategies for Small-Scale Farmers in Nicaragua. Aquanews, 19(1):3–6.

A Mixed-Integer Transshipment Model for Tilapia (*Oreochromis sp.*) Marketing in Honduras

Tenth Work Plan, Marketing and Economic Analysis Research 1A (MEAR1A)
Final Report

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Abstract

Tilapia production in Honduras has increased in recent years. However, a lack of thorough understanding of domestic markets and coordinated production efforts has hampered the development of a domestic market. This study quantified domestic Honduran marketing costs for tilapia and developed a mixed-integer transshipment mathematical programming model to identify the most profitable marketing alternatives for small- and medium-scale farmers. Of the total marketing costs of $0.07-$0.41/kg, 40-73% were for transportation and 13-30% for packaging, depending upon farm size, location, and specific market targeted. Model results suggested restaurants as primary targets with supplemental production delivered to supermarkets

in relative proximity to the selected restaurants. The model selected cities with sufficient restaurant demand to absorb the farm's total production. Farms with high production levels can take advantage of the reduced transport cost of larger trucks and sell excess product to alternative outlets, whereas small-scale farm volumes were too low to supply markets on a weekly basis. Farms located in the East and South regions had a marketing advantage over farms in other regions due to proximity to the most profitable Distrito Central outlets. To successfully compete for Honduran markets other than the low-priced local open-air markets will require farm sizes greater than 6 ha for a minimum weekly production of 900 kg.

A Mixed-Integer Transshipment Model for Optimizing Tilapia (*Oreochromis sp.*) Marketing Strategies in Nicaragua

Tenth Work Plan, Marketing and Economic Analysis
Research 1B (10MEAR1B)
Final Report

Carlos M. Leyva and Carole R. Engle
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University of Arkansas at Pine Bluff, Pine Bluff, Arkansas

Abstract

Tilapia production in the Central American region has increased in recent years. Yet in Nicaragua, a country with great potential for aquaculture, commercial tilapia aquaculture has not developed on the scale that it has in other neighboring countries. Although demand for tilapia products exists, the lack of a thorough understanding of domestic markets and coordinated production and marketing efforts has hampered the development of a domestic market. The objectives of this study were to quantify domestic marketing costs for tilapia produced in Nicaragua and develop a mixed-integer transshipment mathematical programming model that represents the Nicaraguan tilapia market to identify the most profitable marketing alternatives for tilapia farmers. Results from the model suggested targeting primarily outlets with higher sales prices, such as restaurants, with supplemental production delivered to local supermarkets. The model chooses cities with restaurant demand capable of absorbing the farm's production. Excess product is sold to alternative outlets. The pattern of satisfying restaurant demand first and delivering to less profitable markets later in order to coordinate production with sales is common to all the scenarios considered in the model. Currently, farm-raised tilapia production in most regions of the country is insufficient, resulting in problems associated with dependable and regular deliveries required by higher-paying outlets (restaurants and supermarkets). Significant efforts will be required to overcome these obstacles in addition to quality issues such as freshness and off-flavor.

Development and Assessment of a Simple Market Feasibility Assessment Methodology

Tenth Work Plan, Marketing and Economic Analysis
Research 2 (10MEAR2)
Final Report

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University of Arkansas at Pine Bluff, Pine Bluff, Arkansas

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Abstract

Market surveys require extensive time and funding on the part of skilled researchers to develop useful answers on the market feasibility of aquaculture species. Comprehensive surveys were done in Peru and in Mexico to test a simplified market feasibility assessment methodology. A followup of the methodology was conducted in Kenya. Three interview guides have been developed based on the most important variables from the previous surveys conducted in Honduras and Nicaragua and the surveys in Peru and Mexico conducted as part of this project. The interview guides solicit information on competing, preferred products, such as freshwater versus marine species and the preferred product forms, sizes, current supply quantities, and prices of the four most preferred species. Availability of the proposed aquaculture species product is assessed at each market level. Attitudes are evaluated through simple scaled questions on the consistency of supply, consumer preferences, quality, flavor, price, and size. The interview guides end with sociodemographic and store size characteristics. Interview guides were developed for restaurants, supermarkets, and wholesalers. Open-air markets were not included because, in many areas, prices paid by vendors in open-air markets are too low to cover costs of producing farm-raised aquaculture products. These interview guides can be used to rapidly assess market potential for new aquaculture products.

Regional Enterprise Budget and Business Plan Development

Tenth Work Plan, Marketing and Economic Analysis
Research 3 (10MEAR3)
Final Report

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Mucai Muchiri
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Moi University
Eldoret, Kenya

Abstract

The objective of this activity was to develop pro forma financial statements for use as components of business plans. These materials were deemed important to provide a basis for encouraging lending to the incipient commercial tilapia industry in Kenya. The primary deliverable of this activity was a training manual that presents the pro forma financial statements accompanied by instructions for tailoring these statements to specific farm situations. The manual includes a disk with the spreadsheets, instructions, exercises, and an answer guide to the exercises. This manual can be used as a self-guided tutorial to build feasible business plans.

Economic and Risk Analysis of Tilapia Production in Kenya

Tenth Work Plan, Marketing and Economic Analysis
Research 4 (10MEAR4)
Final Report

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Charles Ngugi
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Moi University
Eldoret, Kenya

Abstract

Fish farming in Kenya has potential to further develop commercial production of tilapia. Further growth and development of the tilapia industry in Kenya will depend upon its profitability and the effect of associated risks. Data from pond experiments, on-farm trials, and farm surveys were used to develop enterprise budgets and a risk analysis for two mixed-sex tilapia monoculture production scenarios: 1) stocking tilapia at 2 m^{-2} fed with rice bran; and 2) stocking tilapia at 3 m^{-2} fed with a pelleted diet. Net returns/ha were highest for the farms feeding pellets while lower net returns/ha were obtained by the rice-bran fed alternative. Profitability was affected by feed cost, survival, and farm size. The lower yields from the rice-bran feed scenario resulted in its greater sensitivity to fluctuating survival and costs.

Feeds and Fertilizers Project

Kenya
Subcontract No. RD010E-08

Participants

Auburn University
Chhorn Lim — US Principal Investigator
Karen Veverica — US Principal Investigator

Moi University
David M. Liti — Host Country Principal Investigator
Mucai Muchiri — Host Country Principal Investigator
Leah Cherop — Graduate Student
James Baraza Echessa — Graduate Student

Kenya Fisheries Department
Nancy Gitonga — Host Country Principal Investigator

Work Plan Research

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

- Development of economically feasible feeds for semi-intensive culture of tilapia, *Oreochromis niloticus*, using locally available agricultural by-products/ 10FFR4B. The report submitted for this investigation was a final report.
- Effect of feeding duration of sodium chloride diets on some osmoregulatory parameters of nile tilapia (*Oreochromic niloticus*) after transfer from fresh water to saline water/10FFR4A. The report submitted for this investigation was a final report.

Development and Evaluation of The Nutritive and Economic Potential of Formulated Fish Feeds and Comparison With Locally Available Feeds For Semi-Intensive Production of Nile Tilapia *(Oreochromis niloticus)*.

Tenth Work Plan, Feeds and Fertilizers Research 4A (10FFR4A)
Final Report

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Jonathan Munguti
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Onditi Kisumu, Kenya

ABSTRACT

An experiment was conducted at Sagana Fish farm, Kenya, to evaluate the nutritional value and the economic potential of four feeds for semi-intensive production of Nile tilapia (Oreochromis niloticus) in 0.08 ha earthen ponds. Two isonitrogenous (24%) diets were formulated from three ingredients at the following inclusion levels: shrimp meal 12%, cottonseed meal 24%, and wheat bran 64%. One of the formulated diets was supplemented with locally available vitamins and mineral premix at 0.5% inclusion level; wheat bran was included at 63.5% to make allowance for the vitamins and minerals premix. Commercial pig pellets and wheat bran were also used in the trials. The four diets were assigned to four replicate ponds, which were stocked with sex-reversed O. niloticus (average weight 21 g) and Clarias gariepinus fingerlings (average weight 2.4 g) at stocking densities of 20,000 and 1,000 fish ha-1, respectively. C. gariepinus was included to control the recruitment of O. niloticus. The fish were fed twice a day at 2% body weight for 258 days. The ponds were limed once at a rate of 2.5 ton ha-1 and fertilized weekly at rates of 20 kg N ha-1 and 8 kg P ha-1 with urea and Dap respectively. Samples of fish and water were taken on a monthly basis to monitor fish growth, water quality variables, and adjust the feed ration. Enterprise budgets were used to evaluate the economic performance of the dietary treatments. There were significant ($P < 0.05$) differences in mean fish weight, growth rate, net and gross yields, feed conversion ratio, fingerling recruitment, and percent survival among treatments. However, there were no significant differences ($P > 0.05$) in these variables between the two formulated feeds and also between pig pellets and wheat bran. Performance indicator variables of fish fed on formulated diets were higher than those of fish fed on either wheat bran or commercial pig pellets. However, in terms of

economic performance, wheat bran was the best followed by the formulation without vitamins and mineral premix while pig pellets had the least economic performance. Based on the present results, it can be concluded that formulated diets were more effective in the production of O. niloticus than pig pellet or wheat bran but wheat bran was economically the best. Results from the present study also revealed that vitamins and minerals supplementation could be omitted in simple formulations for semi-intensive production of O. niloticus in heavily fertilized ponds without significant loss in fish growth. These results suggest that the nutrient deficiency in feed supplements could adequately be met by the natural food items.

Effect of Feeding Duration of Sodium Chloride Diets on Some Osmoregulatory Parameters of Nile Tilapia (*Oreochromis niloticus*) After Transfer from Fresh Water to Saline Water

Tenth Work Plan, Feeds and Fertilizers Research 4B (10FFR4B)
Final Report

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Abstract

Two feeding studies were conducted to evaluate the effect of feeding duration of dietary salt (NaCl) on hematocrit, blood glucose, and serum osmolarity and cortisol of Nile tilapia acclimated for various time periods to salt water of different salinities (three-factor experiment). Quadruplicate groups of fish averaging 5.52 ± 0.13 g (Study I) and 10.04 ± 0.19 g (Study II) were fed to apparent satiation twice daily with a basal diet without NaCl for 6 weeks, and the basal diet supplemented with 6% NaCl for 2 (4 week basal diet + 2 week NaCl diet), 4 (2 weeks basal diet + 4 weeks NaCl diet) and 6 weeks (6 weeks NaCl diet). Fish from each replicate aquarium in study I were transferred to salt water at 0, 15, and 30 ppt whereas those from Study II were transferred to salt water at 0, 10 and 20 ppt. Hematocrit (Study II only), blood glucose, and serum osmolarity and cortisol were determined at 48 and 96 h, and 0, 6, 12, 24, and 48 h for Studies I and II, respectively, after transfer to salt water. In both studies, weight gain after 6 weeks of feeding did not differ ($P > 0.05$) among treatments, although all fish fed various durations of the NaCl-containing diet had consistently higher weight gain than those fed the basal diet. Dry matter feed intake and survival were similar in both studies. Feed efficiency was significantly lower in fish fed the basal diet in Study I, but in Study II, the value of this parameter did not differ among treatments. All fish transferred to 30 ppt salinity died within 8 h. No mortality occurred in fish transferred to 0, 10, 15 or 20 ppt salinity. Feeding dietary salt had no effect on blood glucose and hematocrit levels in either study. Serum osmolarity of fish in Study I decreased in fish fed dietary salt, but the differences were not always significant. This value was similar among fish fed dietary salt in Study II. In both studies, blood glucose and serum osmolarity significantly increased, whereas hematocrit decreased with increasing water salinity. Duration of exposure to salt water also significantly increased blood glucose levels but decreased hematocrit values. Duration of salt water exposure had no effect on serum osmolarity. The interaction between duration of feeding dietary salt and water salinity, water salinity and exposure time, and exposure time and duration of feeding dietary salt had no effect on hematological values in both studies except blood glucose and serum osmolarity in Study II were significantly affected by water salinity and exposure time. The interaction between the three main factors had no effect on measured hematological parameters. Serum samples for cortisol assays are stored at -80°C pending the installation and demonstration of the equipment by Perkin Elmer'specialist.

Decision Support System Project

Thailand
Subcontract No. RD010E-04

Participants

The University of Michigan
James S. Diana — US Principal Investigator

Asian Institute of Technology
Yang Yi — Host Country Principal Investigator
Sahdev Singh — Host Country Principal Investigator

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

- PD/A CRSP Aquaculture Database/10DSSR1. The report submitted for this investigation was a final report.

Aquaculture CRSP Database: Finalization, Management, and Distribution

Tenth Work Plan, Decision Support System Research 1 (10DSSR1)
Final Report

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Abstract

The Asian Institute of Technology (AIT) recently established a mirror site (http://www.aqua-information.ait.ac.th) to make available experimental data generated by the Aquaculture Collaborative Research Support Program (CRSP). The experimental data cover a variety of culture environments and practices from a number of countries across the world and span a period of about 20 years. The Aquaculture CRSP Database is a unique global aquaculture research resource and invaluable for researchers, educators and extension staff in aquaculture research/outreach worldwide. Wider and easier availability of the Database is of global importance to aquaculture planning, management and development, and also results in larger impacts of the Aquaculture CRSP. By providing the web-based Database, establishing an additional manned outlet (mirror website at AIT), expanding web linkages, distributing the Database in the forms of CD and Zip disk, the Aquaculture CRSP Database can be accessed by a wider international audience. It also ensures continuous availability of the Database in the event of any temporary shutdown of the main Aquaculture CRSP Database website, which is maintained at Oregon State University.

This mirror site not only enhances worldwide availability of the Aquaculture CRSP Database, but also helps reduce the Database download time for users in Asian countries and to some extent in African countries. The same is true in terms of service time for user queries about the Database as well as requests for CD-based copies. The database is being promoted through flyers, technical workshops and paper presentations in aquaculture related conferences and meetings. Technical workshops and papers have been presented at the recent Joint Conference of the "Asian Federation for Information Technology in Agriculture (AFITA)" and the "World Congress on Computers in Agriculture (WCCA)" demonstrating various example applications of the database, including creation and download of datasets based on a number of user preferences.

APPENDIX 1. STAFF SUMMARY

PROGRAM MANAGEMENT OFFICE STAFF

Oregon State University, Corvallis, Oregon

Hillary Egna	Director
Danielle Clair	Assistant Director of Operations
Steve Sempier	Assistant Director of Research (through 5/04)
Joan Westfall	Office/Financial Manager
Gwyn Newcombe	Accounting Technician (through 11/03)

UNITED STATES AGENCY FOR INTERNATIONAL DEVELOPMENT

Washington, DC

Harry Rea	Cognizant Technical Officer

ADVISORY BODIES

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T.H. Lee Williams	University of Oklahoma
Anthony Young, Chair	Southern Illinois University at Carbondale
Ronald Jones	Florida International University
Edna McBreen	University of Connecticut
Dave Cummins	University of Georgia, Athens (retired)
Colin Kaltenbach	University of Arizona
Stephanie Sanford	Oregon State University institutional representative

Ex-Officio Members

Harry Rea	USAID
Hillary Egna	Oregon State University

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Co-Chairs	
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Chris Brown	FIU

Material and Methods Subcommittee		*Research Area of Expertise*
Yang Yi	AIT	Environmental Effects
Claude Boyd	AU	Production Optimization
Suyapa Meyer	Zamorano	Social and Economic Aspects

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Joe Molnar	AU	Social and Economic Aspects
Bill Tollner	UG	Environmental Effects

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Dan Meyer	Zamorano	Production Optimization
Nancy Gitonga	Kenya DOF	Social and Economic Aspects

External At-Large Members

Damon Seawright	US tilapia producer

Ex-Officio Members

Harry Rea	USAID
Hillary Egna	OSU
Steve Sempier	OSU

* Membership as of 2003 Technical Committee election; see *Twenty-First Annual Administrative Report* for the previous roster.

Appendix 2. 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 2003 to 31 July 2004. 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

1 August 2003–31 July 2004

Subcontract Number	Project Leader	Institution	USAID[1] 8/03-7/04	USAID[1] Since 8/96	Cost Share[2] 8/03-7/04	Cost Share[2] Since 8/96	Total US Funds	Host Country Contributions[3] 8/03-7/04	Host Country Contributions[3] Since 8/96
Research									
RD009A-01	Bowman	Kenya: OSU		894,098		79,096	973,194		135,512
RD009B-01	Bolte	Global: OSU		313,524		85,835	399,359		
	Heikes [4]	*Global: UAPB*		7,900		4,148	12,048		
RD009C-01	Schreck	Mexico: OSU		710,312		147,310	857,622		45,670
	Patino [4]	*Mexico: Texas Tech*		28,107		9,273	37,380		
RD009L-01	Clair	Global: OSU		404,636		98,052	502,688		
RD010E-01	Engle	Global: UAPB		436,910		105,869	542,779		42,000
RD010E-02	Shelton	Global: UO		117,280		31,194	148,474		
RD010E-03	Piedrahita	Global: UCD		78,101		26,611	104,712		
RD010E-04	Diana	Southeast Asia: UM		1,418,909		183,749	1,602,658		146,000
	Rakocy [4]	*Southeast Asia : UVI*		9,889		0	9,889		
RD010E-05	Ward	Honduras: UT		19,767		4,066	23,833		
RD010E-06	Green	Honduras: AU		502,056		78,435	580,491		140,484
RD010E-07	Boyd	Global: AU		402,273		109,937	512,210		31,000
RD010E-08	Lim	Kenya: AU		520,679		120,018	640,697		
RD010E-09/C	Phelps	Global/Kenya: AU		175,352		42,171	217,523		
RD010E-10	Molnar	Global: AU		68,293		14,489	82,782		
RD010E-11	Fitzsimmons	Global: UA		207,205		76,673	283,878		7,050
RD010E-12	Kohler	Peru: SIUC		712,019		233,071	945,090		175,607
	Dabrowski [4]	*Peru: OhSu*		13,000		11,963	24,963		
RD010E-13	Lochmann	Peru/Kenya: UAPB		122,305		37,622	159,927		
RD010E-14	Lovshin	Guatemala: AU		67,168		16,792	83,960		
RD010E-15	Brown	Philippines: UH		100,061		25,015	125,076		
RD010E-16 [6]	Tollner	Kenya/Honduras: UGA		476,268		86,065	562,333		29,225
RD010E-17	Molnar	Honduras: AU		231,263		48,203	279,466		
RD010E-18	Hatch	Honduras: AU		55,266		13,816	69,082		
RD010E-19	Boyd	Honduras: AU		45,947		11,487	57,434		
RD010E-20	Brown	Philippines: FIU		367,527		137,481	505,008		21,000
	Borski [4]	*Philippines: NCSU*		8,737		2,929	11,666		
RD010E-A	Dabrowski	Mexico/Peru: OhSU		157,173		93,416	250,589		
RD010E-B	Batterson	Thailand: MSU		57,020		14,274	71,294		
RD010E-D [6]	Haws	Mexico/LAC: UH		100,000		16,500	116,500		
International Extension Exchange	TBA	Global: TBA		250,000		0	250,000		
Special Activities									
ISTA 5 Sponsorhip	Fitzsimmons	Global: UA		12,500		5,000	17,500		15,000
IIFET Conference Sponsorhip	Shriver	Global: OSU		10,000		2,500	12,500		
Côte d'Ivoire Report	Kaplan	Côte d'Ivoire: Hofstra University		4,000		0	4,000		
Impact Assessment Report	TBA	Global: TBA		128,676		32,199	160,875		
Research Support									
RD009G-01 Central Database Management		Global: OSU		279,714		73,083	352,797		
RD009E-01 Education Development		Global: OSU		244,970		61,242	306,212		
RD009K-01 Information Management & Networking		Global: OSU		2,225,283		556,321	2,781,604		
Subcontract Administration		Indirect on Subs up to 25,000		154,640		0	154,640		
Research Subtotal			0	12,138,828	0	2,695,905	14,834,733	0	788,548
MANAGEMENT									
Program Management									
Operations and Administration [5]		OSU Management		3,284,685	n/a	n/a	3,284,685		
Advisory Groups		OSU Advisory		499,710	0	124,928	624,638		
Program Management Subtotal				3,784,395			3,909,323		
Total				15,923,223	0 [6]	2,695,905	18,744,056	0	788,548

PRODUCTION TECHNOLOGY				
Research Theme	**Reporting PI**	**Report Title**	**Researh Theme Code**	**Report Received**
Sustainable Development and Food Security	Kohler	Amazon Aquaculture Outreach	11SDFR1	Final
	Diana	Tilapia (*Oreochromis niloticus*) Production Constraints In Bangladesh: A Socio-Economic Perspective	11SDFR2A	Final
	Diana	Tilapia (*Oreochromis niloticus*) Production Constraints In Bangladesh: Technological Constraints	11SDFR2B	Final
	Diana	Tilapia (*Oreochromis niloticus*) Production Constraints In Bangladesh: Workshop and Expert Panel Meetng on Tilapia Culture in Bangladesh	11SDFR2C	Final
	Diana	Reproductive Performance and Growth of Improved Tilapia, *Oreochromis niloticus*	11SDFR3	Final
Production System Design and Integration	Diana	New Paradigm in Farming of Freshwater Prawn (*Macrobrachium rosenbergii*) with Closed and Recycle Systems	11PSDR2	Final
	Diana	Integrated Cage-Cum-Pond Culture Systems with High-Valued Stinging Catfish (*Heteropneustes fossilis*)) in Cages and Low-Valued Species in Open Ponds	11PSDR3A	Final
	Diana	Integrated Cage-Cum-Pond Culture Systems with High-Valued Sahar (*Tor putitora*) In Cages Suspended In Carp Polyculture Ponds	11PSDR3B	Final
	Diana	Integrated Cage-Cum-Pond Culture Systems with High-Valued Climbing Perch (*Anabas testudineus*) In Cages Suspended in Nile Tilapia (*Oreochromis niloticus*) Ponds	11PSDR3C	Final
	Diana	Mitigating Environmental Impact of Cage Culture through Integrated Cage-Cum-Cove Culture System in Tri An Reservoir of Vietnam	11PSDR4	Final
	Diana	Optimization of Nitrogen Fertilization Regime in Fertilized Nile Tilapia Ponds With Supplemental Feed	11PSDR5	Final
	Diana	Workshop on Fertilization Strategies for Pond Culture in Bangladesh	11PSDR6	Final
Indigenous Species Development	Kohler	Broodstock Development and Larval Feeding of Amazonian Fishes	11ISDR1A	Final
	Dabrowski	Broodstock Development and Larval Feeding of Amazonian Fishes	11ISDR1B	Final
	Diana	Controlled Reproduction of an Important Indigenous Species, *Spinibarbus denticulatus*, in Southeast Asia	11ISDR2	Final
Economic/Risk Assessment and Social Analysis	Quagrainie	Preliminary Work on Site Description, Evaluation, and Development Planning: Tanzania, Ghana, and Kenya	11ERAR1	Abstract
	Quagrainie	Cost Evaluation and Benefit Assessment of Fish Farming in Selected African Nations	11ERAR2	Abstract
	Quagrainie	An Economic Assessment of Aquaculture in Rural Africa: The Case of Tanzania, Kenya, and Ghana	11ERAR3	Abstract
	Quagrainie	A Cross-National Analysis of the Potential Economic Impact in Africa	11ERAR4	Abstract
Fish Nutrition and Feed Technology	Kohler	Nutrition and Nutrient Utilization in Native Peruvian Fishes	11FNFR1	Final
	Brown	Evaluation of Tilapia Aquaculture Best Practices in Central Luzon, the Philippines	11FNFR2	Final
	Dabrowski	Reproductive Performance and Growth of Improved Tilapia, *Oreochromis niloticus* †	11FNFR3	Final
	Brown	Insulin-like Growth Factor-I as a Growth Indicator in Tilapia	11FNFR4	Final

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

PRODUCTION TECHNOLOGY (CONTINUED)

Research Theme	Reporting PI	Report Title	Research Theme Code	Report Received
Water Quality and Availability	Tollner	Pond Design and Watershed Analyses Training	11WQAR3	Final
Seedstock Development and Availability	Diana	Mitigating the Effects of High Temperature and Turbidity on Seed Production of Nile Tilapia from Hapa-in-Pond Systems	11SDAR1	Final
	Molnar	Evaluation and Improvement of Tilapia Fingerling Production and Availability in Honduras	11SDAR2	Final
Applied Technology and Extension Methodologies	Fitzsimmons	Aquaculture CRSP Sponsorship of the Sixth International Symposium on Tilapia in Aquaculture	11ATER2	Final
	Fitzsimmons	Global Contributions to Sustainable Aquaculture: A Special Session at the 2004 World Aquaculture Conference	11ATER3	Final
	Bowman	Aquaculture Training for Kenyan Fisheries Assistants	11ATER4	Final
	Bowman	Evaluation of Aquaculture Training Provided to Fisheries Officers and Fisheries Assistants of the Kenya Fisheries Department	11ATER5	Final
	Bowman	Development of an Aquaculture Handbook for Extension Workers and Trainers of Extension Workers in Sub-Saharan Africa	11ATER6	Final
Environmental Impacts Analysis	Diana	Co-Culture of Lotus and Hybrid Catfish to Recycle Wastes from Intensive Feeding †	11EIAR1	Final

WATERSHED MANAGEMENT

Research Theme	Reporting PI	Report Title	Research Theme Code	Report Received
Environmental Impacts Analysis	Boyd	Further Studies on Soil Quality in Aquaculture Ponds in Thailand	11EIAR2	Final
Production System Design and Integration	Fitzsimmons	Diversification Into Sustainable Tilapia-Shrimp Polyculture and Small-Scale Tilapia Cage Culture in Mexico	11PSDR1	Final
Indigenous Species Development	Schreck	Development of Aquaculture Techniques for the Indigenous Species of Southern Mexico, Centropomus undecimalis: Sex Determination and Differentiation and Effects of Temperature	11ISDR3	Final
Water Quality and Availability	Schreck	Elimination of Methyltestosterone from Intensive Masculinization Systems: Use of Ultraviolet Irradiation of Water	11WQAR1	Final
	Boyd	Use of a Wetland to Treat Effluent from a Flow-Through Aquaculture System †	11WQAR2	Final
	Boyd	Influence of Daily Feed Allowance on Pond Water and Effluent Quality	11WQAR4	Final
Applied Technology and Extension Methodologies	Schreck	Training Local Farmers on Safe Handling of Steroids and Masculinization Techniques in Central America	11ATER1	Final
Seedstock Development and Availability	Schreck	Continuation of a Selective Breeding Program for Nile Tilapia to Provide Quality Broodstock for Central America	11SDAR3	Final

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

HUMAN WELFARE, HEALTH, AND NUTRITION

Research Theme	Reporting PI	Report Title	Research Theme Code	Report Received
Aquaculture and Human Impacts	Haws	Cross-Sectional and International Extension Exchange and Learning	11AHHR1	Abstract
	Haws	Connectivity of Water Resource Status, Environmental Quality, Aquaculture, and Human Health	11AHHR2	Abstract
	Haws	Analysis of Critical Points in Aquaculture Production Affecting Participation and Level of Benefits to Women, Youth, and Disadvantaged Stakeholders	11AHHR3	Abstract
Disease, Predation Prevention, and Food Safety	Haws	Food Safety and Handling: Increasing Local Consumption of Aquaculture Products and Improving Quality	11DPPR1	Abstract

TENTH WORK PLAN REPORTS

Research Theme	Reporting PI	Report Title	Research Theme Code	Report Received
New Aquaculture Systems/New Species	Fitzsimmons	Effect of Stocking Density of Red Hybrid Tilapia (*Oreochromis* sp.) on Growth And Survival of Juvenile Tilapia And Shrimp (*Litopenaeus Vannamei*) in Polyculture	10NSR3D	Final
	Phelps	Evaluation of Growth and Reproductive Performance of Three Strains of Nile Tilapia *Oreochromis niloticus* Found in Kenya for Use in Aquaculture	10NSR4A	Final
Marketing and Economic Analysis	Engle	A Mixed-Integer Transshipment Model for Tilapia (*Oreochromis* sp.) Marketing in Honduras †	10MEAR1A	Final
	Engle	A Mixed-Integer Transshipment Model for Optimizing Tilapia (*Oreochromis* sp.) Marketing Strategies in Nicaragua	10MEAR1B	Final
	Engle	Development and Assessment of a Simple Market Feasibility Assessment Methodology	10MEAR2	Final
	Engle	Regional Enterprise Budget and Business Plan Development	10MEAR3	Final
	Engle	Economic and Risk Analysis of Tilapia Production in Kenya	10MEAR4	Final
Feeds and Fertilizers	Lim	Effect of Feeding Duration of Sodium Chloride Diets on Some Osmoregulatory Parameters of Nile Tilapia (*Oreochromis niloticus*) After Transfer from Fresh Water to Saline Water †	10FFR4A	Final
	Liti	Development of Economically Feasible Feeds for Semi-Intensive Culture of Tilapia, *Oreochromis niloticus*, Using Locally Available Agricultural By-Products †	10FFR4B	Final
Decision Support System	Diana	Aquaculture CRSP Database: Finalization, Management, and Distribution	10DSSR1	Final

† Title of report is different than investigation title listed in the respective work plan.

APPENDIX 4. 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

Theses

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

Martinez-Mejia, P. Case Study of Commercial Tilapia Production in Olancho, Honduras. M.S. thesis, Auburn University, Alabama, USA.

Trejos-Castillo, E. Fish Culture as a Sustainable Rural Livelihood: Case study of the functioning clusters of successful small-scale tilapia producers in Santa Barbara, Honduras. Agricultural Workers Conference, Tuskegee University, Alabama, December 2002.

Trejos-Castillo, E. Income, Food Security, and Poverty Reduction: Case Studies of Small-Scale Aquaculture Producers in Santa Barbary, Honduras. M.S. thesis, Auburn University, Alabama, USA.

Publications and Reports

Alvarenga, H.R. and B.W. Green, 1985. Production of hybrid tilapia (*Tilapia nilotica* x *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* x *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* x *Tilapia honorum*) 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.), 2pp. (in Spanish)

Alvarenga, H.R., B.W. Green, and M.I. Rodriguez, 1987. Production of hybrid tilapia (*Tilapia nilotica* x *Tilapia honorum*) in ponds using corn gluten as a supplemental feed. CRSP Technical Report (unpubl.), 13 pp. (in Spanish)

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.

Berrios, J.M., 1986. Growth and survival of hybrid tilapia (*Tilapia nilotica* x *Tilapia honorum*) fingerlings during the nursery phase in ponds. CRSP Technical Report (unpubl.), 16 pp. (in Spanish)

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., D.Teichert-Coddington, and T.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., D.Teichert-Coddington, M. Micheletti, and C.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 Oct 1997. CENAIM, ESPOL, Camera Nacional de Acuicultura, Guayaquil, Ecuador. CD-ROM.

Green, B.W. and C.R. Engle, 2002. Commercial tilapia aquaculture in Honduras. In: B.A. Costa-Pierce and J.E. Rakocy (Editors), Tilapia Aquaculture in the Americas, Volume 2. World Aquaculture Society, Baton Rouge, Louisiana, pp. 151–170.

Green, B.W. and D.R. Teichert-Coddington, 1990. Comparison of two sampler designs for use with automated data acquisition systems in whole-pond community metabolism studies. Proceedings of FAO-EIFAC Symposium on Production Enhancement in Still-Water Pond Culture at Prague: Research Institute of Fish Culture and Hydrobiology, Vodnany, Czechoslovakia.

Green, B.W. and D.R. Teichert-Coddington, 1991. Comparison of two samplers used with an automated data acquisition system in whole-pond community metabolism studies. The Progressive Fish-Culturist, 53(4):236–242.

Green, B.W. and D.R. Teichert-Coddington, 1993. Production of *Oreochromis niloticus* fry for hormonal sex reversal in relation to water temperature. Journal of Applied Ichthyology, 9:230–236.

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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 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)

Green, B.W. D.R. Teichert-Coddington, C.E. Boyd, J. Wigglesworth, H. Corrales, D. Martinez, and E. Ramirez, 1999. Efecto del recambio de agua 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)

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.

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Green, B.W., R.P. Phelps, and H.R. Alvarenga, 1989. The effect of manures and chemical fertilizers on the production of *Oreochromis niloticus* in earthen ponds. Aquaculture, 76:37–42.

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Rodriguez, R., G. Nuñez, and D. Teichert-Coddington, 1993. Evaluación de dos dietas alimenticias con diferente porcentaje de proteina, bajo dos densidades de siembra epoca de invierno en Granjas Marinas San Bernardo. II Simposio Centralamericano Sobre Camarón Cultivado, Tegucigalpa, Honduras. Federación de Productores y Exportadores (FPX), San Pedro Sula, Honduras, 267 pp.

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Teichert-Coddington, D.R. and B.W. Green, 1997. Experimental and commercial culture of tilapia in Honduras. In: B.A. Costa-Pierce and J.E. Rakocy (Editors), Tilapia Aquaculture in the Americas, Vol. I. World Aquaculture Society, Baton Rouge, Louisiana, pp. 142–162.

Teichert-Coddington, D.R. and R. Rodriguez, 1994. Relationship of pen-aeid shrimp yields to diet protein level, stocking density and season: a field test on commercial farms of southern Honduras. Abstracts of World Aquaculture '94, New Orleans, Louisiana. World Aquaculture Society, Louisiana State University, Baton Rouge, Louisiana.

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Nicaragua

University of Arkansas at Pine Bluff

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Panama ~ Aguadulce

Auburn University

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Panama ~ Gualaca

Auburn University

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Peru

Auburn University

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Instituto de Investigaciones de la Amazonia Peruana

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The Ohio State University

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Universidad Nacional de la Amazonia Peruana

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Universidad Nacional Mayor de San Marcos

Publication

Palacios, M.E., 2003. Local Peruvian cooperatives recognize use of maca in fish nutrition. Envision (online), http://envision.osu.edu/news.asp?ID=384, 10 August 2003.

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Boyd, C.E. Workshop on soil management in shrimp ponds (4 days), Guayaquil, Ecuador, (32 participants) Aug 1997.
Boyd, C.E. Workshop on water and soil quality in shrimp farming (2 days), Mazatlan, Mexico (41 participants) Jan 1998.
Boyd, C.E. Workshop on water quality (1/2 day), Pietersburg, South Africa (25 participants) Mar 1998.
Boyd, C.E. Workshop on water quality and pond bottom soils (1/2 day), China, four locations (total of 385 participants) Aug 1997.
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Aquaculture CRSP Publications

Notices of Publication and Research Reports

87-1 Hopkins, K.D., J.E. Lannan, and J.R. Bowman. A data base management system for research in pond dynamics.
87-2 Nash, G., S. Chinabut, and C. Limsuwan. Idiopathic muscle necrosis in the freshwater prawn, *Macrobrachium rosenbergii* de Man, cultured in Thailand.
87-3 Tavarutmaneegul, P. and C.K. Lin. Breeding and rearing of sand goby (*Oxyeleotris marmoratus*, Blk.) fry.
88-4 Lin, C.K. Acidification and reclamation of acid sulfate soil fishponds in Thailand.
88-5 Ver, L.M.B. and Y.N. Chiu. The effect of paddlewheel aerators on ammonia and carbon dioxide removal in intensive pond culture.
88-6 Carpenter, K.E., A.W. Fast, V.L. Corre, J.W. Woessner, and R.L. Janeo. The effects of water depth and circulation on the water quality and production of Penaeus monodon in earthen ponds.
88-7 Sanares, R.C., S.A. Katase, A.W. Fast, and K.E. Carpenter. Water quality dynamics in brackish water shrimp ponds with artificial aeration and circulation.
88-8 Batterson, T.R., C.D. McNabb, C.F. Knud-Hansen, H.M. Eidman, and K. Sumatadinata. Effect of chicken manure additions on fish production in ponds in West Java, Indonesia.
88-9 Teichert-Coddington, D.R., N. Stone, and R.P. Phelps. Hydrology of fish culture ponds in Gualaca, Panama.
88-10 Sikoki, F.D., R.A. Tubb, and L.R. Curtis. Elevation of sex steroids and inhibition of UDP-glucuronyltransferase are out of phase during gonadal maturation in the common carp.
88-11 Minsalan, C.L.O. and Y.N. Chiu. Effects of teaseed cake on selective elimination of finfish in shrimp ponds.
88-12 Fortes, R.D., V.L. Corre, Jr., and E. Pudadera. Effects of fertilizers and feeds as nutrient sources on *Oreochromis niloticus* production in Philippine brackish water ponds.
89-13 Fast, A.W., K.E. Carpenter, V.J. Estilo, and H.J. Gonzales. Effects of water depth and artificial mixing on dynamics of Philippines brackish water shrimp ponds.
89-14 Chang, W.Y.B. and H. Ouyang. Dynamics of dissolved oxygen and vertical circulation in fish ponds.
89-15 Green, B.W., R.P. Phelps, and H.R. Alvarenga. The effect of manures and chemical fertilizers on the production of *Oreochromis niloticus* in earthen ponds.
89-16 Lin, C.K. and M. Boonyaratpalin. An analysis of biological characteristics of *Macrobrachium rosenbergii* (de Man) in relation to pond production and marketing in Thailand.
89-17 Chang, W.Y.B. Estimates of hypolimnetic oxygen deficits in ponds.
89-18 Diana, J.S. and A.W. Fast. The effects of water exchange rate and density on yield of the walking catfish, Clarias fuscus.
89-19 Diana, J.S., P.J. Schneeberger, and C.K. Lin. Relationships between primary production and yield of tilapia in ponds.
89-20 Lin, C.K., V. Tansakul, and C. Apinhapath. Biological nitrogen fixation as a source of nitrogen input in fishponds.
89-21 Teichert-Coddington, David R. and Ronald P. Phelps. Effects of seepage on water quality and productivity of inorganically fertilized tropical ponds.
90-22 Chang, W.Y.B. Integrated lake farming for fish and environmental management in large shallow Chinese lakes: A review.
90-23 Hopkins, K.D., M.L. Hopkins, and D. Pauley. A multivariate model of tilapia growth, applied to seawater tilapia culture in Kuwait.
90-24 Hopkins, K.D. Reporting fishpond yields to farmers.
90-25 Peralta, M. and D. Teichert-Coddington. Comparative production of Colossoma macropomum and Tilapia nilotica in Panama.
90-26 Teichert-Coddington, D.R., B.W. Green, N. Matamoros, and R. Rodriguez. The substitution of chicken litter for feed in the commercial production of penaeid shrimp in Honduras.
90-27 Green, B.W. and L.A. Lopez. Implementing the large-scale production of young males of *Tilapia nilotica* using hormonal sex inversion in Honduras.
90-28 Hanson, B.J., J.F. Moehl, Jr., K.L. Veverica, F. Rwangano, and M. Van Speybroek. Pond culture of tilapia in Rwanda, a high altitude equatorial African country.
90-29 Knud-Hansen, C.F., T.R. Batterson, and C.D. McNabb. Hatchery techniques for egg and fry production of *Clarias batrachus* (L.).
91-30 Green, B.W., D.R. Teichert-Coddington, and R.P. Phelps. Response of tilapia yield and economics to varying rates of organic fertilization and season in two Central American countries.
91-31 Szyper, J.P. and C.K. Lin. Techniques for assessment of stratification and effects of mechanical mixing in tropical fish ponds.
91-32 Knud-Hansen, C.F., T.R. Batterson, C.D. McNabb, I.S. Harahat, K. Sumantadinata, and H.M. Eidman. Nitrogen input, primary productivity and fish yield in fertilized freshwater ponds in Indonesia.
91-33 Piedrahita, R.H. Calibration and validation of TAP, an aquaculture pond water quality model.
91-34 Piedrahita, R.H. Modeling water quality in aquaculture ecosystems.
91-35 Piedrahita, R.H. Engineering aspects of warmwater hatchery design.
91-36 Piedrahita, R.H. and P. Giovannini. Fertilized non-fed pond systems.
91-37 McNabb, C.D., T.R. Batterson, B.J. Premo, C.F. Knud-Hansen, H.M. Eidman, C.K. Lin, K. Jaiyen, J.E. Hanson, and R. Chuenpagdee. Managing fertilizers for fish yield in tropical ponds in Asia.

91-38 Green, B.W. and H.R. Alvarenga. The effect of different application rates of chicken litter on tilapia production.
91-39 Alvarenga, H.R. and B.W. Green. Production and economic aspects of tilapia cultivation in ponds fertilized with chicken litter.
92-40 Szyper, J.P., K.D. Hopkins, and C.K. Lin. Production of *Oreochromis niloticus* (L.) and ecosystem dynamics in manured ponds of three depths.
92-41 Piedrahita, R.H. Simulation of short-term management actions to prevent oxygen depletion in ponds.
92-42 Teichert-Coddington, D.R., B.W. Green, and R.W. Parkman. Substitution of chicken litter for feed in production of penaeid shrimp in Honduras.
92-43 Knud-Hansen, C.F., C.D. McNabb, and T.R. Batterson. Application of limnology for efficient nutrient utilization in tropical pond aquaculture.
92-44 Hopkins, K. and A. Yakupitiyage. Bias in seine sampling of tilapia.
92-45 Engle, C.R. and M. Skladany. The economic benefit of chicken manure utilization in fish production in Thailand.
92-46 Green, B.W. Substitution of organic manure for pelleted feed in tilapia production.
92-47 Green, B.W., and D.R. Teichert-Coddington. Comparison of two samplers used with an automated data acquisition system in whole-pond, community metabolism studies.
92-48 Liu, K.M. and W.Y.B. Chang. Bioenergetic modeling of effects of fertilization, stocking density, and spawning on growth of the Nile tilapia, *Oreochromis niloticus* (L.).
93-49 Teichert-Coddington, D.R., B.W. Green, and R.P. Phelps. Influence of site and season on water quality and tilapia production in Panama and Honduras.
93-50 Suresh, A.V. and C.K. Lin. Tilapia culture in saline waters: A review.
93-51 Knud-Hansen, C.F. Analyzing standard curves in the chemistry of waters used for aquaculture.
93-52 Szyper, J.P., J.Z. Rosenfeld, R.H. Piedrahita, and P. Giovannini. Diel cycles of planktonic respiration rates in briefly incubated water samples from a fertile earthen pond.
93-53 This report is a duplicate of an earlier number.
93-54 Lin, C.K., K. Jaiyen, and W. Muthuwana. Integration of intensive and semi-intensive aquaculture: Concept and example.
93-55 Szyper, J.P. and J.M. Ebeling. Photosynthesis and community respiration at three depths during a period of stable phytoplankton stock in a eutrophic brackish water culture pond.
93-56 Knud-Hansen, C.F., T.R. Batterson, and C.D. McNabb. The role of chicken manure in the production of Nile tilapia, *Oreochromis niloticus* (L.).
93-57 Boyd, C.E. and D. Teichert-Coddington. Relationship between wind speed and reaeration in small aquaculture ponds.
93-58 Teichert-Coddington, D.R. and B.W. Green. Influence of daylight and incubation interval on water column respiration in tropical fish ponds.
93-59 Knud-Hansen, C.F. and A.K. Pautong. On the role of urea in pond fertilization.
94-60 Shrestha, M.K. and C.F. Knud-Hansen. Increasing attached microorganism biomass as a management strategy for Nile tilapia (*Oreochromis niloticus*) production.
94-61 Springborn, R.R., A.L. Jensen, W.Y.B. Chang, and C. Engle. Optimum harvest time in aquaculture: An application of economic principles to a Nile tilapia, *Oreochromis niloticus* (L.), growth model.
94-62 Hopkins, K.D. and D. Pauly. Instantaneous mortalities and multiva-riate models: Applications to tilapia culture in saline water.
94-63 Green, B.W. and D.R. Teichert-Coddington. Production of *Oreochromis niloticus* fry for hormonal sex reversal in relation to water temperature.
94-64 Engle, C.R., M. Brewster, and F. Hitayezu. An economic analysis of fish production in a subsistence agricultural economy: The case of Rwanda.
94-65 Knud-Hansen, C.F. and T.R. Batterson. Effect of fertilization frequency on the production of Nile tilapia (*Oreochromis niloticus*).
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94-67 Springborn, R.R., A.L. Jensen, and W.Y.B. Chang. A variable growth rate modification of von Bertalanffy's equation for aquaculture.
94-68 Diana, J.S., D.J. Dettweiler, and C.K. Lin. Effect of Nile tilapia (*Oreochromis niloticus*) on the ecosystem of aquaculture ponds, and its significance to the trophic cascade hypothesis.
94-69 Ayub, M., C.E. Boyd, and D. Teichert-Coddington. Effects of urea application, aeration, and drying on total carbon concentrations in pond bottom soils.
94-70 Boyd, C.E. and D. Teichert-Coddington. Pond bottom soil respiration during fallow and culture periods in heavily-fertilized tropical fish ponds.
94-71 Hopkins, K.D. Reporting fish growth: A review of the basics.
94-72 Hopkins, K.D. and J.D. Bowman. A research methodology for integrated agriculture-aquaculture farming systems.
94-73 Diana, J.S. and K. Jaiyen. Supplemental feeding of tilapia in fertilized ponds.
94-74 Knud-Hansen, C.F. Pond history as a source of error in fish culture experiments: A quantitative assessment using covariate analysis.
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94-76 Teichert-Coddington, D. and B. Green. Comparison of two techniques for determining community respiration in tropical fish ponds.
94-77 Teichert-Coddington, D. and B. Green. Tilapia yield improvement through maintenance of minimal oxygen concentrations in experimental growout ponds in Honduras.
94-78 Teichert-Coddington, D., M. Peralta, and R.P. Phelps. Seepage reduction in tropical fish ponds using chicken litter.
95-79 Giovannini, P. and R.H. Piedrahita. Modeling photosynthetic production optimization for aquaculture ponds.
95-80 Culberson, S.D. and R.H. Piedrahita. Model for predicting dissolved oxygen levels in stratified ponds using reduced data inputs.
95-81 Culberson, S.D. and R.H. Piedrahita. Modification of stratified temperature model to accommodate reduced data inputs: Identifying critical requirements.
95-82 Teichert-Coddington, D. Development of production technologies for semi-intensive fish farming during the past decade in Central America.
95-83 Teichert-Coddington, D. Effects of protein diet and sowing density on the production of Penaeus vannamei in land tanks.
95-84 Szyper, J.P., C.K. Lin, D. Little, S. Setboonsarng, A. Yakupitiyage, P. Edwards, and H. Demaine. Techniques for efficient and sustainable mass production of tilapia in Thailand.
95-85 Egna, H.S. Psychological distress as a factor in environmental impact assessment: Some methods and ideas for quantifying this intangible intangible.
95-86 Bowman, J.R. and J.E. Lannan. Evaluation of soil pH-percent base saturation relationships for use in estimating the lime requirements of earthen aquaculture ponds.
96-87 Green, B.W. and C.E. Boyd. Water budgets for fish ponds in the dry tropics.
96-88 Green, B.W. and C.E. Boyd. Chemical budgets for organically fertilized fish ponds in the dry tropics.
96-89 Teichert-Coddington, D.R. and R. Rodriguez. Semi-intensive commercial grow-out of Penaeus vannamei feed diets containing differing levels of crude protein during wet and dry seasons in Honduras.
96-90 Boyd, C.E. and D. Teichert-Coddington. Dry matter, ash, and elemental composition of pond-cultured *Penaeus vannamei* and *P. stylirostris*.
95-91 Green, B.W., Z.E. Nagdy, H. Hebicha, I. Shaker, D.A.R. Kenawy, and A.R.E. Gamal. Evaluation of Nile tilapia production systems in Egypt.

96-92 Egna, H.S. Monitoring water quality for tropical freshwater fisheries and aquaculture: A review of aircraft and satellite imagery applications.
96-93 Lin, C.K. and J.S. Diana. Co-culture of catfish (*Clarias macrocephalus* x *C. gariepinus*) and tilapia (*Oreochromis niloticus*) in ponds.
96-94 Lin, C.K. Clarias and tilapia interaction in polyculture.
96-95 Abdalla, A.A.F. and C.D. McNabb. Ammonia dynamics in fertilized fish ponds stocked with Nile tilapia.
96-96 Boyd, C.E. and P. Munsiri. Phosphorus adsorption capacity and availability of added phosphorus in soils from aquaculture areas in Thailand.
96-97 Teichert-Coddington, D.R. Effect of stocking ratio on semi-intensive polyculture of Colossoma macropomum and *Oreochromis niloticus* in Honduras, Central America.
96-98 Munsiri, P. and B.F. Hajek. Texture and chemical composition of soils from shrimp ponds near Choluteca, Honduras.
97-99 Moehl, J.F. and J.J. Molnar. Institutional requirements for aquacultural development in Africa: Lessons from Rwanda.
97-100 Hishamunda, N., C.M. Jolly, and C.R. Engle. Estimating *Oreochromis niloticus* production function for small-scale fish culture in Rwanda.
97-101 Shrestha, M.K. and C.K Lin. Phosphorus fertilization strategy in fish ponds based on sediment phosphorus saturation level.
97-102 Green, B.W. Polyculture of tilapia with marine shrimp.
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97-104 Engle, C.R. Optimal resource allocation by fish farmers in Rwanda.
97-105 Szyper, J.P. Observations and model predictions of daily areal primary production in a eutrophic brackish water culture pond.
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97-108 Teichert-Coddington, D., J. Harvin, and D. Martinez. Semi-intensive shrimp pond management and quality of effluents.
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97-115 Yi, Y., C.K. Lin, and J.S. Diana. Influence of Nile tilapia (*Oreochromis niloticus*) stocking density in cages on their growth and yield in cages and in ponds containing the cages.
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97-117 Ward, G.H. Water effluent and quality, with special emphasis on finfish and shrimp aquaculture.
97-118 Green, B.W., M.P. Micheletti, and C.A. Lara. A collaborative project to monitor the water quality of estuaries in the shrimp producing regions of Honduras.
98-119 Ernst, D.H., J.P. Bolte, D. Lowes, and S.S. Nath. PD/A CRSP Central Database: A standardized information resource for pond aquaculture.
98-120 Jamu, D.M., Z. Lu, and R. Piedrahita. Secchi disk visibility and chlorophyll a relationship in aquaculture ponds.
98-121 Contreras-Sánchez, W., M.S. Fitzpatrick, R.H. Milston, and C.B. Schreck. Masculinization of Nile tilapia (*Oreochromis niloticus*) by single immersion in 17a-methyldihydrotestosterone and trenbolone acetate.
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98-124a Hishamunda, N., M. Thomas, D. Brown, C. Engle, and C. Jolly. Small-scale fish farming in Rwanda: Data report.
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98-128 Yi, Y. A bioenergetics growth model for Nile tilapia (*Oreochromis niloticus*) based on limiting nutrients and fish standing crop in fertilized ponds.
99-129 Veverica, K.L., N. Hishamunda, and P. Nyirahabimana. Aquaculture extension in Rwanda.
99-130 Boyd, C.E. and B.W. Green. Dry matter, ash, and elemental composition of pond-cultured tilapia (*Oreochromis aureus* and *O. niloticus*).
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99-132 Jamu, D.M., Z. Lu, and R.H. Piedrahita. Relationship between Secchi disk visibility and chlorophyll a in aquaculture ponds.
99-133 Gale, W.L., M.S. Fitzpatrick, M. Lucero, W.M. Contreras-Sánchez, and C.B. Schreck. Masculinization of Nile tilapia (*Oreochromis niloticus*) by immersion in androgens.
99-134 Boyd, C.E. and L. Massaut. Risks associated with the use of chemicals in pond aquaculture.
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99-137 Ward, G.W., B.W. Green, and D.R. Teichert-Coddington. Estimation of carrying capacity for shrimp aquaculture in the eastern estuaries of the Gulf of Fonseca.
99-138 Dasgupta, S. and C.R. Engle. Non-parametric estimation of returns to investment in Honduras shrimp research.
99-139 Valderrama, D. and C.R. Engle. Risk analysis of shrimp farming in Honduras.
99-140 Contreras-Sánchez, W.M., M.S. Fitzpatrick, G. Márquez-Couturier, and C.B. Schreck. Masculinization of Nile tilapia (*Oreochromis niloticus*) by immersion in synthetic androgens: Timing and efficacy.
99-141 Fitzpatrick, M., W.M. Contreras-Sánchez, R.H. Milston, C.B. Schreck. Fate of the masculinizing agent methyltestosterone in the pond environment.
99-142 Green, B.W. Sistemas de produccíon de tilapia en Honduras (Tilapia production systems in Honduras).
99-143 Lovshin, L.L. and N.B. Schwartz. Evaluation of integrated tilapia culture by resource limited farmers in Panama and Guatemala.
99-144 Green, B.W., D.R. Teichert-Coddington, C.E. Boyd, J.M. Wigglesworth, H. Corrales, D. Martínez, and E. Ramírez. Efecto del recambio de agua en la producción semi-intensiva de *Penaeus vannamei* (Effect of water exchange on semi-intensive production of *Penaeus vannamei*).
99-145 Yi, Y. Modeling growth of Nile tilapia (*Oreochromis niloticus*) in a cage-cum-pond integrated culture system.
00-146 Perschbacher, P. and R. Lochmann. Effects of feeding pelleted versus non-pelleted defatted rice bran on Nile tilapia *Oreochromis niloticus* production and water quality in ponds.
00-147 Molnar, J.J. Sound policies for food security: The role of culture and social organization.
00-148 Yi, Y. and C.K. Lin. Integrated cage culture in ponds: Concepts, practice and perspectives.
00-149 Lin, C.K. and K. Kaewpaitoon. An overview of freshwater cage culture in Thailand.

00-150 Ward, Jr., G.H. Effects of shrimp farming on the hydrography and water quality of El Pedregal and San Bernardo estuaries, Gulf of Fonseca, Honduras.
00-151 Sonnenholzner, S. and C.E. Boyd. Chemical and physical properties of shrimp pond bottom soils in Ecuador.
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00-153 Bolte, J., S. Nath, and D. Ernst. Development of decision support tools for aquaculture: The POND© experience.
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00-155 Nath, S.S., J.P. Bolte, L.G. Ross, and J. Aguilar-Manjarrez. Application of geographical information systems (GIS) for spatial decision support in aquaculture.
00-156 Bolivar, R.B. and G.F. Newkirk. Response to selection for body weight on Nile tilapia (*Oreochromis niloticus*) in different culture environments.
00-157 Lovshin, L.L. Criteria for selecting Nile tilapia and red tilapia for culture.
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00-160 Verma, B., E.W. Tollner, J. Renew, T. Popma, J.L. Molnar, and D. Meyer. Concurrent design of hillside ponds for tilapia production.
00-161 McKeon, C., E. Glenn, C.P. Gerba, and K. Fitzsimmons. Microbiological hazards of tilapia culture systems.
00-162 Verdegem, M.C.J., A.A. van Dam, A.A. Cabarcas-Nuñez, and L. Oprea. Bio-energetic modeling of growth and waste production of Nile tilapia (*Oreochromis niloticus* L.) in recirculation systems.
00-163 Jamu, D. 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.
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01-165 Contreras-Sánchez, W.M., M.S. Fitzpatrick, R.H. Milston, and C.B. Schreck. Masculinization of Nile tilapia with steroids: Alternate treatments and environmental effects.
01-166 Sonnenholzner, S. and C.E. Boyd. Managing the accumulation of organic matter deposited on the bottom of shrimp ponds… Do chemical and biological probiotics really work?
01-167 Egna, H. Environment, aquaculture, and food policy nexus: Case study of two USAID aquaculture projects in Rwanda.
01-168 Yi, Y. and C.K. Lin. Effects of biomass of caged Nile tilapia (*Oreochromis niloticus*) and aeration on the growth and yields in an integrated cage-cum-pond system.
01-169 Thunjai, T., C.E. Boyd, and K. Dube. Pond soil pH measurement.
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01-172 Lin, C.K., M.K. Shrestha, and Y. Yi. Management to minimize the environmental impacts of pond effluent: Harvest draining techniques and effluent quality.
01-173 Lin, C.K. and Y. Yi. Developments in integrated aquaculture in Southeast Asia.
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01-175 Meyer, D.E. Nutrition and feeding of tilapia.
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Fitzsimmons, K. High school students and aquaculture projects. Presented to Aquaculture America '99 at Tampa, Florida, 27–30 Jan 1999.

Lin, C.K. and C. Limsuwan. Management strategies and approaches for water quality improvement in shrimp farming. Presented to the American Association for the Advancement of Science at Philadelphia, Pennsylvania, 12–17 Feb 1998.

Lin, C.K. Inland marine shrimp culture and its legislative, environmental and socio-economic implications in Thailand. Presented to Aquaculture '99, World Aquaculture Society Annual Meeting at Sydney, Australia, 26 Apr–2 May 1999.

Lin, C.K., J.B. Hambrey, and J. Szyper. Environmental impact assessment for a shrimp farm project in Tanzania: A case study. Presented to Aquaculture '98, World Aquaculture Society Annual Meeting at Las Vegas, Nevada, 15–19 Feb 1998.

Lin, C.K., W. Ruttanagosrigit, D. Thakur, and P. Wanuchsoontorn. Organic matter and nutrients in sludge of closed ponds for intensive shrimp culture. Presented to Aquaculture '98, World Aquaculture Society Annual Meeting at Las Vegas, Nevada, 15–19 Feb 1998.

Muthuwan, V. and C.K. Lin. Green water recirculating system for intensive culture of marine shrimp (*Penaeus monodon).* Presented to the Fifth Asian Fisheries Forum at Chiang Mai, Thailand, 10–14 Nov 1998.

Phelps, R.P., K.L. Veverica, R.S. Weyers, and J.J. Duffy. Induced spawning of the red snapper, *Lutjanus campechanus*, using three different hormone treatments. Poster presented to the World Aquaculture Society Meeting at Bangkok, Thailand, Jan 1996.

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 as well as those maintained by the Program Management Office.

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
Aqua Technics, Carlsborg, Washington
Aquacorporacion, International, Honduras
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
Australian Center for International Agricultural Research (ACIAR), Nelson Bay, Australia
Bangladesh Agricultural University (BAU), Mymensingh, 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
Brooklyn College, New York
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 de Ciencia y Technologia (CONACYT), Mexico
Commonwealth Agricultural Bureau International,
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 Research in Agroforestry (ICRAF), Nairobi, Kenya
West African Rice Development Association (WARDA), Bouaké, Côte d'Ivoire
World Fish Center (ICLARM), Penang, Malaysia
Cooperative for Relief and Assistance Everywhere (CARE), Bangladesh, Honduras, Peru, and Atlanta, Georgia
CP Group, Thailand
CSIRO Livestock Industries Chiswick Pastoral Research Laboratory, Armidale, Australia
Danish International Development Agency (DANIDA), Copenhagen, Denmark
Dar es Saalam University, Dar es Saalam, Tanzania
Department for International Development (DFID) Fish Genetics Research Programme, Swansea, Wales, United Kingdom
Department of Agriculture, Yunnan Province, China
Department of Aquaculture, Nepal
Department of Fisheries, Phnom Penh, Cambodia
Department of Fisheries, Udorn Thani, Thailand
Department of Livestock and Fisheries, Savannakhet, Laos
Derby Holding Company, Kenya
Development for the Municipality of Centro, Tabasco, Mexico
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 de Pesquisa Agropecuária e Extensão Rural de Santa Catarina (Epagri), Brazil
Empresa Nacional de Energia Electrica, Tegucigalpa, Honduras
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
General Directorate of Fisheries and Aquaculture (DIGEPESCA), Tegucigalpa and San Pedro Sula, Honduras
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
Henry Spira/GRACE Project on Industrial Production, School of Hygiene and Public Health, Johns Hopkins University
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
Institute of Agriculture and Animal Science (IAAS), Tribhuvan University, Rampur Campus, Chitwan, Nepal
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
Kasetsart University, Thailand
Katholieke Universiteit Leuven (KUL), Belgium
Kenya Fisheries Department, Kenya
Kenya Marine and Fisheries Research Institute
Kenya Medical Research Institute (KEMRI), Nairobi, Kenya
Kenyatta University, Nairobi, Kenya
Lake Basin Development Authority, Kenya
Lake Victoria Environmental Management Programme, Kenya
Land Tenure Center, Madison, Wisconsin
Louisiana State University, Baton Rouge, Louisiana
Magarini Aquafarmers, Malindi, Kenya
Malawi National Aquaculture Center, Malawi
Marine Farms ASA, Norway
Mekong River Commission, Phnom Penh, Cambodia
Mesta de Bombon Maca Producers Association, Peru
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 Agricultural Research Council, Nepal
National Agriculture University (NAU), La Molina, Peru
National Aquaculture Centre, Zomba, Malawi
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
Nepal Agricultural Research Council, Lalitpur, Nepal
Network of Aquaculture Centres in Asia-Pacific (NACA), Bangkok, Thailand
Noorul Islam College of Engineering, Tamil Nadu, India
North Central Regional Aquaculture Center (NCRAC), East Lansing, Michigan
Nuestros Pequeños Hermanos (NPH), Honduras
Oceanic Institute, Waimanalo, Hawaii
Oceanol, Centro, Tabasco, Mexico
Ohio State University Research Foundation (OSURF), Columbus, Ohio
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
Peace Corps, Ecuador
Peanut CRSP, Griffin, Georgia
Population and Fish Genetics Group
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
Project Rural Reconstruction, Santa Barbara, Honduras
PROMIPAC, Nicaragua and El Salvador
PROSEAL, Iquitos, Peru
PROSHIKA, Dhaka, Bangladesh
Red de Desarrollo Sostenible Honduras (RDS-HN), Honduras
Research Institute for Aquaculture No. 1, Dinh Bang, Tu Son, Bac Ninh, Vietnam
Roche Aquaculture Research Centre Asia Pacific, Bangkok, Thailand
Royal Institute of Technology, Stockholm, Sweden
Rural Reconstruction Program (PRR), Santa Barbara, Honduras
Sagana Women's Group, Sagana, Kenya
Santo Tomás, Mexico
Sarasawathi Foundation, Thailand
Science and Math Investigative Learning Experiences Program (SMILE), Oregon State University
Secretaria de Agricultura e Abastecimento do Estado de Sao Paolo, Brazil
Secretaría de Agricultura y Ganadería, Honduras
Sichuan Provincial Fisheries Association, Ziyang, Sichuan Province, People's Republic of China
Sisaket College of Agriculture and Technology, Thailand
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
Taiwanese Mission, Honduras
Technical Integration Asia Network, Yangon, Myanmar
Terra Nuova, Lima, Peru
Texas A&M University, College Station, Texas
Texas Tech University, Lubbock, Texas
Thai Lux, Thailand
Training and Occupation for Disabled Association, Poi Pet, Cambodia
Uganda Wetlands and Resource Conservation Association (UWRCA), Uganda
United Aqua Farms, Bangladesh
United States Department of Agriculture (USDA), Washington, DC
Foreign Agricultural Service, Research and Scientific Exchange Division
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
Universidad de Santiago de Compostela, Santiago, Spain
Universidade de São Paulo, Brazil
Universidade Federal de Minas Gerais, Belo Horizonte, Minas Gerais, Brazil
Universität Hohenheim, Stuttgart, Germany
Université Nationale du Rwanda, Butare, Rwanda
University of Agriculture and Forestry, Ho Chi Minh City, Vietnam
University of California, Davis
University of Cantho, Vietnam
University of Delaware
University of Fisheries, Nhatrang, Vietnam
University of Nairobi, Kenya
University of Oklahoma
University of Stirling, United Kingdom
University of Texas at Austin
University of the North, Pietersburg, South Africa
University of the Philippines in the Visayas, Iloilo, Philippines
University of Wales, Swansea, UK
University of Washington, Seattle, Washington
University of Wisconsin-Madison, Madison, Wisconsin
Virginia Polytechnic Institute, Blacksburg, Virginia
Wageningen University, The Netherlands
Western Regional Aquaculture Consortium (WRAC), Seattle, Washington
Winrock International, Lima, Peru
WorldFish (ICLARM)
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. ACRONYMS

ACIAR	Australian Center for International Agricultural Research
ADR	Adoption/Diffusion Research
AIT	Asian Institute of Technology
AMR	Administrative Management Review
ANDAH	Asociación Nacional de Acuicultores de Honduras
ASF	Animal source foods
ASMR	Aquaculture Systems Modeling Research
ATR	Appropriate Technology Research
AU	Auburn University
BAU	Bangladesh Aqucultural University
BOD	Biochemical oxygen demand
BOD	Board of Directors
BRAC	Bangladesh Rural Advancement Committee
CF	Condition factor
CFS	China Society of Fisheries
CIAT	Centro Internacional de Agricultura Tropical
CIFAD	Consortium for International Fisheries and Aquaculture Development
CLSU	Central Luzon State University
CONACYT	Consejo Nacional de Ciencia y Tecnología (National Council for Science and Technology)
CRSP	Collaborative Research Support Program
DBT	Database Task Force
DIGEPESCA	General Directorate of Fisheries and Aquaculture
DO	Dissolved oxygen
E2	Estradiol
EdOp Net	Educational Opportunities Network
EEP	External Evaluation Panel
ER	Effluents and Pollution Research
FFR	Feeds and Fertilizers Research
FIU	Florida International University
FONDEPES	Fondo Nacional de Desarrollo Pesquero (National Fund for Fishing Development)
FSR	Food Security Research
GAFY	Gross annualized fish yield
GIFT	Genetically Improved Farmed Tilapia
GIS	Geographic Information System
GISR	GIS: Planning, Policy, and Global Data Analysis Research
HSI	Hepatosomatic index
HTML	Hypertext Markup Language
IAAS	Institute of Agriculture and Animal Science
ICLARM	International Center for Living Aquatic Resources Management
IIAP	Instituto de Investigaciones de la Amazonia Peruana (Research Institute of the Peruvian Amazon)
IIFET	International Institute of Fisheries Economics and Trade
IGF-1	Insulin-like growth factor 1
IMNC	Information Management and Networking Component
INPA	Instituto Nacional de Pesquisas da Amazonia
JCARD	Joint Committee on Agricultural Research and Development
LHRHa	Luteinizing hormone-releasing hormone analog
LIFD	Low-income food-deficit
ME	Management Entity
MEAR	Marketing and Economic Analysis Research
MOU	Memorandum of Understanding
MRC	Mekong River Commission
MSU	Michigan State University
MT	17α-methyltestosterone
NAR	Net annualized revenue
NASULGC	National Association of State Universities and Land-Grant Colleges
NAU	National Agriculture University
NGO	Nongovernmental organization
NSR	New Aquaculture Systems/New Species Research
OhSU	The Ohio State University
OSU	Oregon State University
OSURF	Ohio State University Research Foundation
ACRSP	Aquaculture CRSP
PDF	Portable Document Format
PDR	Pond Dynamics Research
PDVR	Product Diversification Research
PMO	Program Management Office
PPEC	Proposal Planning Executive Committee
PRR	Rural Reconstruction Program
RCR	Reproduction Control Research
RFP	Request for Proposals
SIUC	Southern Illinois University at Carbondale
SMILE	Science and Math Investigative Learning Experiences Program
SRP	Soluble reactive phosphorus
TA	Trenbolone acetate
TAN	Total ammonia nitrogen
TC	Technical Committee
TIPS	Tilapia Integration to Prawn Culture System
TN	Total nitrogen
TP	Total phosphorus
TS	Total solids
TSP	Triple superphosphate
TSS	Total suspended solids
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
UM	The University of Michigan
UO	University of Oklahoma
US	United States
USAID	United States Agency for International Development
UT	University of Texas
UV	Ultraviolet
VSS	Volatile suspended solids
WAS	World Aquaculture Society
WIDeST	Web-Based Information Delivery System for Tilapia