

# AQUACULTURE COLLABORATIVE RESEARCH SUPPORT PROGRAM

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TWENTY-FOURTH ANNUAL ADMINISTRATIVE REPORT  
1 August 2005 to 31 July 2006



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## Acknowledgments

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**AQUACULTURE COLLABORATIVE RESEARCH SUPPORT PROGRAM**  
Twenty-Fourth Annual Administrative Report

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# INTRODUCTION:



KHALID SALIE

The Aquaculture Collaborative Research Support Program's (ACRSP) mission is to enrich livelihoods and promote health by cultivating international multidisciplinary partnerships that advance science, research, education, and outreach in aquatic resources.

This report describes the activities and accomplishments of the ACRSP from 1 August 2005 to 31 July 2006. The United States Agency for International Development (USAID) funds the ACRSP under authority of the Foreign Assistance Act of 1961 (PL 87-195), as amended. Funding is also provided by the participating universities. The ACRSP 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 ACRSP's cohesive program of research is carried out in selected developing countries and in the United States by teams of US and host country researchers, faculty, and students. Now operating under its fourth USAID grant since 1982, the ACRSP is guided by the concepts and direction set down in the Continuation Plan 1996, which is funded 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 appear in Appendix 1.



## PROGRAM HIGHLIGHTS

This reporting year was marked by great uncertainty. The Aquaculture CRSP was slated to end on 31 July 2006. Most activities were completed by mid-2006, but many students were in the middle of their degree programs. Critical research underway in ACRSP host countries offered promising results in the near-term. In response, Oregon State University, Management Entity of the ACRSP, submitted a continuation proposal to USAID in April 2006. On the termination date of 31 July 2006, USAID finally signed official paperwork allowing the ACRSP an 11-month funded extension. The final year will be devoted to outreach and capacity building, with the expectation of accelerated outputs through June 2007.

The context for much of this uncertainty was USAID's desire to end old CRSPs and initiate new ones. USAID wanted to realign the dated CRSP portfolio to better meet changing world needs and at the same time attract new talent and greater value to its research portfolio. CRSPs remain the primary vehicle through which USAID can accomplish research and capacity building in agriculture. Within this context, USAID decided to end the Aquaculture CRSP. In its place came the idea for a new CRSP – called Aquaculture & Fisheries – and an RFA (Request for Assistance) seeking proposals for a new Management Entity. Oregon State University competed against a number of other fine universities to win the award for the new CRSP. Because the ACRSP had just received an extension, both the Aquaculture CRSP and the new Aquaculture & Fisheries CRSP will operate concurrently through 2007. Both will be managed by Oregon State University, although only the ACRSP is the subject of this Annual Administrative Report.

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During this reporting period, Oregon State University managed a portfolio of 19 subcontracts and an additional 7 extended sub-contracts with 19 US institutions in 23 countries. The overall annual funding for the program was US\$2.15M from USAID with about another US\$2M provided by leveraged funding and university matching.

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The Aquaculture CRSP has a long and successful track record in capacity building. More than 630 students have earned university degrees—more than 400 attained advanced graduate degrees—in disciplines related to business, ecology, health, agriculture, and natural resources. Additionally, the ACRSP has offered short-term trainings and topical workshops to over 3,500 people in developing countries.

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Two jointly funded projects engaged new communities in the ACRSP enterprise:

ACRSP and the Indigenous Environmental Network, through funding from Heifer International, Inc., initiated an innovative project to involve Native Americans from the North (US and Canada) and Native Americans from the South (Mexico and Peru) in consultations about the governance of natural resources; linkages between aquaculture, health, and income generation; and aquatic resources management. The ACRSP Management Entity at OSU secured funding for this concept, and after much background work, the project held the first of two exchanges in Peru in April 2006. Reports, photos,

and participant feedback on the Peru workshop are available from the ACRSP website. Planning is underway for the Mexico exchange, which will take place in 2007.

A jointly funded project with the US Department of Commerce's NOAA Sea Grant has the objective of bringing US aquaculture extension expertise to bear on problems host countries are facing in aquaculture and aquatic resources management. With NOAA's leveraging funds, ACRSP is able to make the leap into extension as a way to bring the positive benefits of ACRSP research to more people. In a competitive process for the joint ACRSP-NOAA funding, Cornell University partnered with a number of other universities to win the award in March 2005 and has since been engaged in outreach and capacity building in Mexico. NOAA Sea Grant is jointly funding a related initiative with ACRSP to provide technical assistance by US extension agents to ACRSP host countries. Areas of need identified by host countries include HACCP and seafood safety, which became the focus of the first assistance training in Bangladesh, undertaken by Paul Olin of University of California at Davis. These projects with Sea Grant facilitate better access to aquaculture technologies developed in host countries, establishment of worldwide networks, and dialog on trade and marketing issues in the aquaculture sector.

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Why have certain ACRSP technologies worked in one location but not another? What are some of the most successful ACRSP methods that have benefited



producers? These questions form the foundation for a lessons learned evaluation of tilapia and native cichlid production in five countries. Connecting ACRSP host country scientists through the exchange of tilapia technologies was an idea generated by host country scientists themselves. The initial work plan was completed this year, with the ME assisting in project implementation for researchers in Honduras, Kenya, Mexico, the Philippines, and Thailand.

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The ACRSP continued developing its ambassador program as a means to foster closer ties with USAID field missions. The Management Entity established the ACRSP Ambassador Program to engage USAID Missions in advanced understanding of the ACRSP and the aquatic resources sector, provide qualified, on-the-ground professionals to act as resources to the Missions, and help link Mission needs with ACRSP capabilities. The first two ambassadors — Nancy Gitonga, ACRSP Kenya Ambassador, and Amrit Bart, ACRSP Thailand and South Asia Ambassador — connected with various USAID efforts and ushered in new projects during this reporting period. USAID-Kenya Business Development Service is initiating a new aquaculture project with ACRSP researchers at Moi University. ACRSP researcher Kevin Fitzsimmons and Amrit Bart engaged in post-tsunami outreach by partnering with another USAID project (SUCCESS) and the private sector.

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The Management Entity sponsored four professional meetings, including

- World Aquaculture Society (WAS) held in Italy in May 2006
- Cage Culture in Asia (CAA2) held in China in July 2006
- International Symposium on Tilapia in Aquaculture (ISTA) held in Mexico just after this reporting period in September 2006,
- International Institute of Fisheries, Economics, and Trade (IIFET) held in England in July 2006.

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The ME organized and chaired the annual program meeting which was held in conjunction with WAS in Italy. The Director worked closely with TC co-chairs to organize the annual technical meeting, also held in Italy. External evaluators from the UN Food and Agriculture Organization and World Wildlife Fund assessed project outputs and focus. Their complete findings are available on the ACRSP website. They report on promising research, the excellent integration of research and training, and a relevant research portfolio.

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The ME published Research Reports (Notices of Publication), the Twelfth Work Plan, Aquanews, EdOp Net and a number of other reports that can be accessed through the ACRSP website. The ME created posters for presentation at the following scientific conferences during this reporting cycle: WAS Florence; ISTA VII, Mexico; American Water Resources Association (Seattle, November 2005). ME staff participated in broader aquaculture discourse through journal and proposal reviews. ACRSP Director Hillary Egna continued her service to the US National Science Foundation and served as a reviewer for USDA, NOAA, and Catholic Relief Services.

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The ME's Library Donation Project continues to be appreciated by host country participants and their institutions. After receiving library donations from OSU faculty and the OSU Valley Library, the ME identifies suitable host country libraries and sends collections to them. ACRSP plans to continue the library donation project through the final year of the program, as almost all host country libraries need scientific journals and books to enhance their collections.

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The ME organized and hosted the CRSP Council meeting in Portland, Oregon in August 2005. USAID and CRSP participants met to discuss the overall CRSP portfolio and new approaches for managing research programs. Other CRSP Council activities in which the ME participated included periodic conference calls, and a steering committee meeting and joint Council-USAID meeting held in June 2006 in Punta Cana, Dominican Republic.

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Program website renovation began this year, with advances in providing greater access and search functions for the many ACRSP publications. Although the ACRSP grant is slated to end in 2007, a fully functional website will provide a useful archive for future researchers, students, and administrators. The ME at OSU has agreed to maintain the website beyond the ACRSP period of performance as a way to encourage creativity and usefulness of the vast amounts of information collected and generated by the ACRSP. The site will be available indefinitely at this address: <http://pdacrsp.oregonstate.edu/>

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## RESEARCH HIGHLIGHTS



ACRSP research in Mexico demonstrated that the masculinizing hormone methyltestosterone (MT) can be eliminated from aquaculture effluents by exposure to solar irradiation or UV sterilizers. Solar irradiation of MT-treated water for a period of two days resulted in approximately 50% elimination of the compound. Intense treatment of the water with a UV sterilizer resulted in 100% elimination of MT over a two-day period.

An ACRSP selective breeding program with Nile tilapia has resulted in a source of broodstock that has increased reproductive fitness. Supply of high quality fingerlings remains a major constraint to successful fish farming.

Universidad Juárez Autónoma de Tabasco (UJAT) and OSU researchers determined the reproductive capacity and nutrient requirements of *Petenia splendida* as a first step towards incorporation of this native species into aquaculture systems.

ACRSP participants have conducted three workshops on masculinization techniques and safe handling of steroids. These workshops were presented to fish farmers, extension agents, and students in Central America.

In Thailand, Auburn University and the Royal Thai Department of Fisheries collaborated to analyze research results and produce Best Management Practices (BMPs) for pond soils. These BMPs have been listed with additional notes for successful implementation. This material has been translated into Thai for use by fish farmers in Thailand.

In South Africa and Brazil, workshops were conducted through a partnership between Auburn University, Stellenbosch University (South Africa), Universidade Estadual Paulista (Brazil), and Embrapa Environment (Brazil) to train local stakeholders in appropriate methods to develop BMPs that are suitable for the local aquaculture industry and environment. A comprehensive manual on Best Management Practices for responsible aquaculture has been field-tested and will be published by ACRSP.

ACRSP participants taught fish farmers in Ghana and Kenya techniques to improve pond record keeping and business enterprise bookkeeping. An assessment of smallholder, medium-scale, and community-based ventures is helping potential NGOs maximize benefits of development interventions in these countries.

In collaboration with oyster farmers, a project in Mexico has been monitoring water quality in the Boca de Camichin oyster production grounds. Outreach has been conducted with farmers and government agencies responsible for shellfish sanitation to increase awareness of the production and post-harvest processing requirements for safety, and the need for ongoing water quality monitoring and classification of shellfish growing grounds.

In Kenya, the short courses presented focused on simple, low-cost techniques for spawning, hatching, and rearing juvenile catfish. Moi University graduate students have discovered new techniques for increasing survival of catfish fry to the fingerling stage. Hatchery-raised catfish larvae exhibit better growth and survival when reared in darkened aquaria and fed live feeds such as rotifers for only the first 10 days. Cost savings result from not overfeeding. The highest survival was exhibited by larvae reared in the hatchery for five days.

The Kenya Watersheds Project identified 73 macroinvertebrate taxa representing 13 orders and 51 families in the Nzoia River. The main taxonomic groups encountered were Diptera, Ephemeroptera, Coleoptera, Oligochaeta, Trichoptera, Gastropoda, and Odonata. The Plecoptera were poorly represented in this river and the low EPT Index of 32% indicates that the system is experiencing some stress. This is more likely the case in the lower sections of the river where fewer EPT taxa were collected. However, the high number of taxa collected in the entire river and the high abundance indicate good overall water quality. ACRSP researchers came closer to improving the reproductive performance of Amazonian native species (*Piaractus brachipomus*) through experimental trials at La Terraza Aquaculture Research Facility

of the Universidad Nacional de Colombia in Meta. They did this by simulating the three most common Amazonian ecosystems where *Piaractus* naturally occur to evaluate water quality as a fish reproduction-conditioning factor. Survival was 100% for the two higher pH and low tannic acid treatments, while it was 42.8% for the lowest pH and high tannic acid treatment. Broodstock from the lowest pH, high tannic acid, and high conductivity treatment were the only ones to successfully spawn.

## PROGRAM AREAS & THEMES

### FOR THE TWELFTH WORK PLAN

**A**CRSP projects concentrate on institutional strengthening and outreach while fostering a vision of economic growth, food security, and the wise use of natural resources.

Current ACRSP projects focus on one of three program areas:

**Production Technology**

**Watershed Management**

**Human Welfare, Health, and Nutrition**

Within these program areas, researchers can focus their investigations on any of the following research themes:

#### **ENVIRONMENTAL IMPACTS ANALYSIS**

With the rapid growth in aquaculture production, environmental externalities are of increasing concern. Determining the scope and mitigating or eliminating the negative environmental impacts of aquaculture — such as poor management practices and the effects of industrial aquaculture — is a primary goal of the ACRSP.

#### **SUSTAINABLE DEVELOPMENT AND FOOD SECURITY**

Aquaculture is increasing in importance as a means for poverty alleviation and food security in developing regions of the world. A focal area of the program is to support efforts related to sustainable aquatic farming systems that can demonstrably ensure a reliable, future food supply.

#### **PRODUCTION SYSTEM DESIGN AND INTEGRATION**

Aquaculture is an agricultural sector with specific input demands. Systems must be designed to improve efficiency and/or integrate aquaculture inputs and outputs with other agricultural and non-agricultural production systems.

#### **INDIGENOUS SPECIES DEVELOPMENT**

Domestication of new and indigenous species may contribute positively to the development of local communities as well as protect ecosystems. At the same time, the development of new species for aquaculture

must be approached in a responsible manner that diminishes the chance for negative environmental, technical, and social impacts. Efforts that investigate relevant policies and practices are encouraged while exotic species development is not encouraged.

#### **WATER QUALITY AND AVAILABILITY**

Aquaculture development that fosters the wise use of natural resources is at the core of ACRSP. Gaining a better understanding of water and aquaculture is a matter of great interest to ACRSP. The range of possibilities is broad—from investigations that quantify such things as availability and quality to those that look into the social context of water and aquaculture, including water rights, national and regional policies (or the lack of them), traditional versus industrial uses, and the like.

#### **ECONOMIC / RISK ASSESSMENT AND SOCIAL ANALYSIS**

Aquaculture is a rapidly growing industry; its risks and impacts on society need to be assessed. Significant issues in this area include cost, price, and risk relationships; domestic market and distribution needs and trends; working relationships with women and other underrepresented groups; and availability of financial resources for small farmers.

**APPLIED TECHNOLOGY AND EXTENSION  
METHODOLOGIES**

Developing appropriate technology and transferring technology-related information to end-users are high priorities. The program encourages efforts leading to a better understanding of factors and practices that set the stage for near-term technology implementation and that contribute to the development of successful extension tools and methods.

**SEEDSTOCK DEVELOPMENT AND  
AVAILABILITY**

Procuring reliable supplies of high quality seed for stocking local and remote sites is critical to continued development of the industry. A better understanding of the factors that can contribute to stable seedstock quality and quantity for aquaculture enterprises is essential.

**DISEASE, PREDATION, PREVENTION, AND  
FOOD SAFETY**

Protecting aquatic animals from diseases and predators and ensuring high-quality, safe, and nutritious aquaculture products for local consumers and the competitive international marketplace are primary goals. Consumers and producers alike will benefit from efforts that contribute to the development of standards and practices that protect aquaculture products from spoilage, adulteration, mishandling, and off-flavors.

**FISH NUTRITION AND FEED TECHNOLOGY**

Increasing the range of available ingredients and improving technologies for manufacturing and delivering feeds is an important theme. Better information on fish nutrition can lead to the development of less expensive and more efficient feeds. Efforts that investigate successful adoption and extension strategies for the nutritional needs of fish are also encouraged.

**AQUACULTURE AND HUMAN HEALTH  
IMPACTS**

Aquaculture products can provide a critical source of proteins and micronutrients for improved human health, growth, and development. Conversely, human health can be negatively affected by aquaculture if it serves as a vector for human diseases. There is also interest in better understanding the interconnectedness between human health crises such as AIDS/HIV and aquaculture production.



## COLLABORATING INSTITUTIONS

### US AND HOST COUNTRY PARTNERS

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

#### Lead US Institutions

Auburn University, Alabama  
 Cornell University, New York (NY Sea Grant)  
 Florida International University  
 Institute of Agriculture and Trade Policy,  
 Minnesota  
 Oregon State University  
 Purdue University, Indiana  
 Southern Illinois University at Carbondale  
 The Ohio State University  
 The University of Michigan  
 University of Arizona  
 University of Arkansas at Pine Bluff  
 University of Georgia  
 University of Hawaii at Hilo

#### Subcontracting US Institutions

Alaska State University  
 Louisiana State University  
 Michigan State University  
 North Carolina State University  
 Texas Tech University  
 University of Alaska, Fairbanks  
 University of Rhode Island  
 University of the Virgin Islands

#### Collaborating Institutions

Brooklyn College, New York  
 New York Sea Grant  
 Puerto Rico Sea Grant  
 Texas Sea Grant

#### Joint Project Participants

Aquaculture without Frontiers  
 Bemidji State University, Minnesota  
 Heifer International, Arkansas

International Institute of Fisheries Economics and  
 Trade

David and Lucile Packard Foundation  
 National Sea Grant College Program  
 World Aquaculture Society Tsunami Relief Fund  
 YSI Inc.

Work undertaken in the reporting period comprised the Twelfth Work Plan and continuing investigations from the Eleventh Work Plan. Activities involved investigations in 23 countries:

Bangladesh  
 Bolivia  
 Brazil  
 China  
 Colombia  
 Cambodia  
 Dominican Republic  
 Ecuador  
 Ghana  
 Guatemala  
 Honduras  
 Indonesia  
 Kenya  
 Mexico  
 Nepal  
 Nicaragua  
 Peru  
 Philippines  
 South Africa  
 Tanzania  
 Thailand  
 USA  
 Vietnam

The following international institutions were involved in Aquaculture CRSP activities in the reporting period:

Acuarios Leticia, Colombia  
 Asian Institute of Technology, Thailand  
 Bangladesh Agricultural University, Bangladesh  
 Can Tho University, Vietnam  
 Caritas, Bangladesh  
 Central Luzon State University, Philippines



Comunidad Indígena Sarayuku, Ecuador  
 Department of Environmental Studies, Kenya  
 Department of Fisheries, Ministry of Livestock  
 and Fisheries Development, Kenya  
 Ecocostas, Ecuador  
 Ecuador–USAID, Arcoiris  
 Egerton University, Kenya  
 Embrapa Environment, Brazil  
 Embrapa Meio Ambiente, Brazil  
 Empresa Brasileira de Pesquisa, Brazil  
 Escuela Agrícola Panamericana, Zamorano,  
 Honduras  
 Fisheries and Aquaculture Development Division,  
 Tanzania  
 Fisheries Department, Ministry of Food and  
 Agriculture, Ghana  
 Fondo Nacional de Desarrollo Pesquero, Peru  
 Foundation Chile, Chile  
 Fundación Arcoiris, Ecuador  
 FYD International Farm, Philippines  
 Hainan University, China  
 Huazhong Agricultural University, China  
 Institute of Agriculture and Animal Science, Nepal  
 Institute for Research and Food Development,  
 Mexico  
 Instituto Amazónico de Investigaciones Científicas  
 SINCHI, Colombia  
 Instituto Colombiano de Desarrollo Rural  
 INCODER, Colombia  
 Instituto de Investigaciones IMANI, Colombia  
 Instituto de Investigaciones de la Amazonia  
 Peruana, Peru  
 Instituto Nacional de Pesquisas da Amazonia,  
 Brazil  
 Instituto Tecnológico Saleciano, Ecuador  
 Instituto Tecnológico del Mar, Veracruz, Mexico  
 Kasetsart University, Thailand  
 Kellogg Foundation, Dominican Republic  
 La Fundacion Chile  
 Ministry of Education, Dominican Republic  
 Moi University, Kenya  
 National Center for Genetic Engineering and  
 Biotechnology (BIOTEC), Thailand  
 National Freshwater Fisheries Technology Center,  
 Philippines  
 Nepal Agriculture Research Center  
 Nong Nam University, Vietnam  
 Peace Corps, Ecuador  
 Quisqueya University, Haiti  
 Regional Center of Education and Qualification for  
 Sustainable Development CREDES, Mexico  
 Research Institute for Aquaculture No. 1, Vietnam  
 Royal University of Agriculture, Nepal  
 Sao Paulo State University, Brazil  
 Sinaloa State Committee for Aquaculture  
 Sanitation, Mexico  
 Sokoine University of Agriculture, Tanzania  
 Southwest University, China  
 Stellenbosch University, South Africa  
 Thailand Department of Fisheries  
 Ujong Batee Aquaculture Research and Education  
 Center, Indonesia  
 Universidad Autónoma de Sinaloa, Mexico  
 Universidad Estadual Paulista, Brazil  
 Universidade Federal do Amazonas, Brazil  
 Universidad Juárez Autónoma de Tabasco, Mexico  
 Universidad Mayor de San Simón, Bolivia  
 Universidad Nacional de la Amazonia Peruana,  
 Peru  
 Universidad Nacional de Colombia  
 Universidad Nacional Mayor de San Marcos, Peru  
 University of Agriculture and Forestry, Vietnam  
 University of Puerto Rico, Puerto Rico  
 University of San Carlos, Guatemala  
 University of Science and Technology, Ghana  
 Vincent Foundation, Haiti  
 Wetlands Conservation Program, Mexico  
 Wuhan University, China  
 Xiamen University, China  
 Zamorano Alumni Association, Dominican  
 Republic  
 Zhejiang University, China

## TRAINING HIGHLIGHTS

One of the ACRSP's driving missions is to create a sustainable system that allows anyone with the appropriate resources to conduct aquaculture responsibly. It is fitting, then, to note that the staff and researchers — the faces behind this effort — are also part of a sustainable framework that engages dedicated students, hones their knowledge and develops their skills, and ultimately folds them into a global scientific network in which they can continue conducting their own research.

Members of this cycle include:

**Wilfrido Contreras-Sánchez** — a former graduate student, who became a leader in the Mexico project studying the fate of steroids in tilapia sex alteration and its potential impact on the environment and farmer safety.

**Yang Yi** — beginning as a Ph.D. student, he is now one of the ACRSP's longest involved collaborators, who studies fertilization and alternative feeds at the Asian Institute of Technology in Thailand.

Below are brief profiles of the next generation of up and coming students and researchers. Each student brings a much needed local perspective on aquaculture benefits and barriers in his or her home country. This shared knowledge allows the program as a whole to better help aquaculture's growth.

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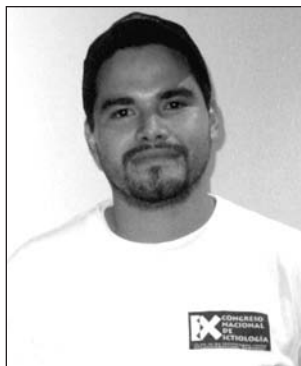
### Rafael Martínez García

Rafael Martínez García has been a student of aquaculture at UJAT, Mexico for the past four years. He has been working with other researchers to study the endemic garfish in the belief that this fish will diversify the market and strengthen aquaculture's ability to improve the lives of the rural poor. Rafael began his studies at UJAT in biology, but after his second year he was drawn to aquaculture. "I began with cleaning the tanks, but the more I studied, the more I got involved in the research."

Gar nets almost three times the profit of tilapia in Mexico because it fills a niche in a marketplace saturated with tilapia. Native species research can face challenges in its early stages, however, as the dedication of a new, regionally specific culture species entails years of research on limited global support in order to grow efficiently in a pond setting. Rafael and others at UJAT strive to make gar accessible in a small-scale farm setting.

Rafael's senior project focused on antibodies and reproduction in the female gar. With most species, hatchery workers determine fish maturity through a biopsy of the eggs, which in turn lets them know when to induce spawning. Gar, however, possess a uniquely sticky egg that is nearly impossible to biopsy and presents a barrier to reproduction. Rafael's research developed a system to measure proteins in reproductive antibodies and determine gar maturity. This is the first indirect sign of spawn readiness for this new culture species, and it provides technicians with

a new tool to save time and increase production levels. In addition to his student research, Rafael plays a large role in UJAT's efforts to extend aquaculture to the surrounding population. This work allows the students to present tilapia to members of rural communities, introducing fish farming as a means of providing food and income. If a party is interested, they develop a detailed farm plan with the help of Rafael and other students and staff in order to petition government social programs to assist with the startup capital. Once a plan has been approved, the students participate in on-site visits to supervise construction, fertilization and feeding, and the harvest. "You make an agreement, man to man. You can't just give them fry and say 'good luck.' You have to stay and make sure they make it." These visits occur once per month at each of the six current projects and will continue through the first successful harvests. Rafael and the other UJAT representatives then advise the farm cooperatives on the best way to reinvest their profits for further growth with their next crop.



In January Rafael will begin his Master's degree at the University of Arizona with ACRSP researcher Kevin Fitzsimmons studying shrimp-tilapia polyculture. Afterward, he plans to earn a Ph.D. and ultimately return to Tabasco and continue his work with gar research and aquaculture extension to new farmers. "There's so much to do. Production and extension is hard, but we need it, and the harvest for the poor is the prize at the end."

## Victoria Boit

Victoria Boit has been working on her Master's degree in the Moi University Department of Fisheries (and Aquatic Sciences), Eldoret, Kenya, since September 2004. She was drawn to aquaculture because of its potential for production of high-quality, high-protein food for the people of Kenya and its potential as a source of income for Kenyan farmers. These potential benefits are especially important in the area around Victoria's home town of Kericho.



Victoria's research is part of a CRSP-sponsored series of experiments designed to identify factors and eliminate problems currently causing poor survival of catfish larvae during the nursery phase (rearing to fingerling size). Her thesis, entitled "Effect of sequential feeding under two light regimes on growth and survival of African catfish (*Clarias gariepinus*, Burchell, 1822) fry," will help shed light on the best management practices for catfish ponds both in Kenya and abroad.

Victoria conducted an experiment comparing three feeding regimes for rearing catfish larvae at the Moi University hatchery (Chepkoilel Campus, Eldoret) in the summer of 2005. In all treatments she offered live rotifers to the larvae for the first four days of feeding. In one treatment she kept the fry on rotifers for an additional ten days and then switched them to a commercial diet (chick mash). In a second treatment, she substituted *Artemia nauplii* for ten days, after which she switched to chick mash. In the third treatment, the fry were switched to the chick mash immediately after the first four days on rotifers. The overall duration of the experiment was 30 days. Preliminary results suggest that the best feeding regime was the one in which the fry were fed rotifers for the first 14 days and chick mash for the remaining 16 days.

After completion of her Master's degree, Victoria hopes to work at Moi University teaching fisheries and aquaculture and conducting further research. She would also enjoy participating in extension work, for example conducting seminars geared towards promoting aquaculture in the region, and collaborating with organizations like the CRSP, where there might be opportunities to conduct additional studies. She also plans to continue her education by working towards a Ph.D. at some point in the future.

Victoria enjoys fishing, reading, and swimming. She also enjoys conducting interviews, a passion that she adopted after working in a radio station in Eldoret, Kenya from 2001–2002.

## Idsariya Wudtisn

"Thailand has numerous resources and the landscape allows us to be fruitful in agriculture," Idsariya Wudtisn said of her home country and its capacity to develop aquaculture.

Wudtisn has been working on an ACRSP sponsored project under the supervision of Claude Boyd (USPI), since moving to Auburn in the spring of 2003. She credits Boyd for her decision to attend Auburn University to pursue a Ph.D. "I have known him since I was in Thailand – not personally, but I used his book for my class and for my research. Then I had a chance to come to Auburn and work under his supervision," she said.

Wudtisn presented some of her findings at the Aquaculture America 2005 conference in New Orleans during a special ACRSP Research session. Her presentation, entitled "Bottom soil quality in ponds for culture of catfish, freshwater prawn, and carp in Thailand" and co-authored with Boyd, demonstrated that pond age (1 to 30 years in use) was not a factor influencing the physical and chemical composition of pond soils. Their conclusion was 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."

When asked to describe her future research plans to complete her Ph.D. in 2006 Wudtisn initially responded with "talking about aspects of my research, it depends on how much time you have!" Her overall research plan is focused upon bottom soil quality of catfish, prawn, and carp ponds in Thailand. The premise for her dissertation is that bottom soil quality should be controlled in order to maintain and improve upon present production levels. For example, Wudtisn explains that while use of antibiotics (such as tetracycline) might be beneficial in the short-term, these chemicals may accumulate in pond bottom soil and affect pond productivity over longer periods of time.

While Wudtisn feels that Thailand has numerous resources, there is also a general lack of financing that has limited aquaculture growth in her home country. In addition, from



her perspective, "one of the major obstacles is the use of suitable technology. Most farmers in Thailand lack the correct knowledge in aquaculture, which leads to the improper use of technology to solve the problems." As to her future endeavors, this native of Rayong Province in eastern Thailand says she "enjoys conducting research since I have an opportunity to apply what I learn

in the classroom into reality, which I find very interesting and challenging." Wudtisin plans to "expand [her] horizon, gain more experience in research, and prepare myself for the

practical problems in aquaculture." We wish Idsariya Wudtisin all the best with her dissertation research and many future endeavors.

### Vu Cam Luong

Dr. Vu Cam Luong became a lecturer at the Fisheries Department of the University of Agriculture and Forestry in Ho Chi Minh City of Vietnam in May 1997 after he received his Bachelor's degree from the same university that April. He joined the Asian Institute of Technology (AIT) as a Masters student in January 1999 with a DANIDA Master Research Abroad Fellowship, and received his M.Sc. degree in December 2000. He conducted the research entitled

"Trophic model and technical-economic aspects of cove aquaculture in Tri An Reservoir of Vietnam" under the supervision of ACRSP Host Country PI, Professor C. Kwei Lin.

He was selected as an exchange student to be trained for Ecopath modeling and research methodology from January–April 2000 at center, Aarhus and Copenhagen University in Denmark, and in September 2001 he started his doctoral study at AIT, with support

from the Vietnamese Government Ph.D. Research Abroad Fellowship. The ACRSP sponsored his dissertation research entitled "Management strategies of natural food webs for marble goby-carp polyculture in coves based on natural food webs in Tri An Reservoir, Vietnam." His project linked with an ACRSP project in Vietnam under HCPI Yang Yi's supervision. He successfully obtained his doctoral degree in December 2004, and returned to his home institution where his research interests are limnology, aquaculture, food web interaction and trophic modeling.



### Md. Asaduzzaman

Md. Asaduzzaman, a Bangladeshi student, has been working on ACRSP sponsored projects under the supervision of Md. Abdul Wahab (Bangladesh Agricultural University) and Yang Yi (Asian Institute of Technology) since completion of his Bachelor's degree in June 2004. He worked as a research fellow in a number of ACRSP funded research projects, such as "New paradigm in farming of freshwater prawn (*Macrobrachium rosenbergii*) with closed and recycle systems," "Integrated cage-cum-pond culture systems with high valued climbing perch (*Anabas testudineus*) in cages suspended in carp polyculture ponds" and "Use of rice straw as a resource for freshwater pond culture."

Asaduzzaman completed a B.Sc. Fisheries (Honors) from the Faculty of Fisheries, BAU. He received the "Prime Minister Gold Medal Award" in recognition for excellent results during his B.Sc. After completing his Bachelor's degree, he was inspired by ACRSP Host Country Principal Investigator Wahab to obtain his Master's degree in Fisheries Management. This led him to the ACRSP-supported work, "The potentials of organic farming of freshwater prawn in Bangladesh." He successfully defended his thesis in December 2005 and earned recognition as best M.Sc. student in the department.

In the future, Asaduzzaman wants to implement his knowledge of aquaculture from the classroom into practice for sustainable aquaculture development in Bangladesh. To make this a reality, he plans to study for a Ph.D. in crustacean aquaculture with a focus on farming systems management and monosex culture strategies. Although he was involved in a number of finfish research projects with ACRSP, his interests focus on freshwater





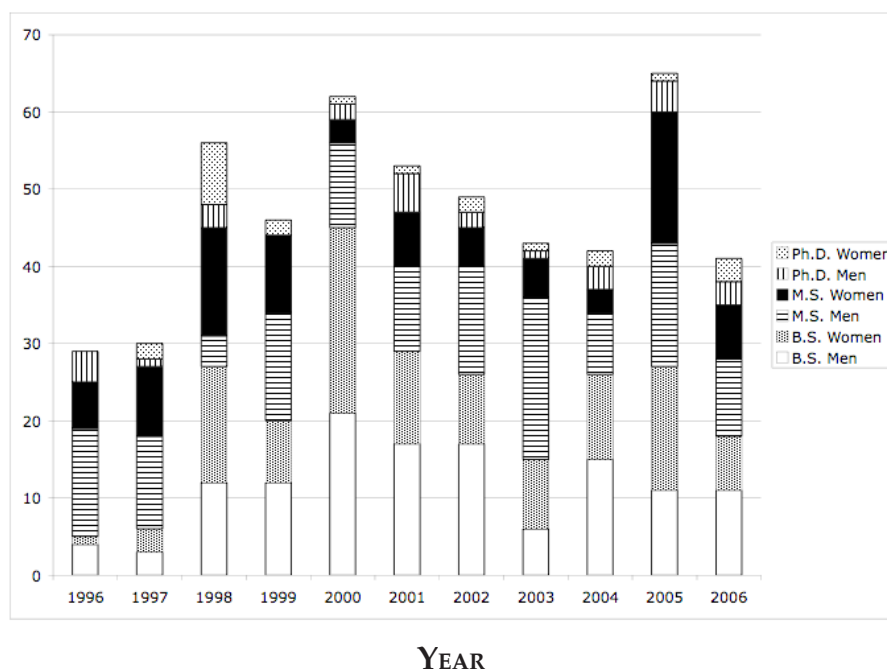
prawn farming systems. Some of his findings on freshwater prawns were presented by Wahab at the WAS AQUA 2006 conference in Florence, Italy in the crustacean aquaculture session. His presentation was entitled "Farming systems of giant freshwater prawn *Macrobrachium rosenbergii* in Bangladesh: A combination of tradition and technology." The study demonstrated that there were both traditional and improved extensive (combination of traditional and new techniques) freshwater prawn farming systems in terms of management practices. The study revealed that farmers faced problems with limited access to credit, insufficient supply and high priced quality post-larvae, high priced quality feed, transport and marketing problems, natural disasters, lack of institutional and administrative support, and inadequate infrastructure and extension services. Asaduzzaman's present aim is to raise freshwater prawn productivity without the massive investment common to many intensive systems by combining and upgrading two approaches. The first one is based on microbial control of water quality and recycling of protein through the adjustment of the carbon/nitrogen ratio in the pond. The second one is based on the application of vertical substrates and development of periphyton in extensive ponds, increasing productivity by 70–250%. This new technology is referred to as "C/N controlled periphyton based pond (C/

N-CPP) systems." The expected outcome of this technology will benefit both Bangladesh and exporting countries. Dr. Marc Verdegem from the Wageningen University has been assisting as an external expert.

To meet Bangladesh's challenges, it is urgently necessary to increase average pond productivity. Raising aquaculture production through pond expansion would demand large additional quantities of water and land area, which are both very scarce resources in Bangladesh. In consequence, the only practical and sustainable way to raise pond aquaculture production is by increasing pond productivity per unit of land area and water. With the present state of knowledge, higher pond yields can be obtained by applying energy, capital and technology but these inputs are out of reach for the majority of people in Bangladesh. Therefore, the challenge is to develop a simple technology that raises pond productivity in a sustainable way while minimizing the inputs of energy and capital. When describing the future prospects for aquaculture development in Bangladesh, Asaduzzaman said there is huge potential for "aquaculture development in Bangladesh through the culture of suitable species into unutilized water bodies, improvement of current culture practices, development of suitable low-cost technology and the motivation of the farmers."

### ACRSP Long Term Training As of April 2006

NUMBER OF  
STUDENTS



The following reports are printed  
as submitted with minimal editing.





# Southeast Asia Project: Production Technology

Thailand, Bangladesh, Nepal, Vietnam, Cambodia, China  
Subcontract No. RD010A-04 (UM)



JAMES BOWMAN

The ACRSP has been active in Thailand from the program's inception in 1982. The lead US institution, The University of Michigan, has collaborated with the Asian Institute of Technology (AIT) since 1987 through a formal Memorandum of Understanding. AIT is an important regional training center, providing not only excellent research facilities but also regional networking opportunities for outreach activities. Research and outreach partnerships were fostered throughout the region in Bangladesh, China, Nepal, and Vietnam during the reporting period. Ongoing investigations include integrated cage-cum-pond evaluations, indigenous species development, recirculating aquaculture system development for freshwater prawn, optimization of aquaculture production, reclaiming of nutrients from shrimp culture, and environmental impacts research. Additional research cooperation involves the University of the Virgin Islands, Bangladesh Agricultural University, Can Tho University (Vietnam), Research Institute for Aquaculture No. 1 (Vietnam), the Institute of Agriculture and Animal Science (Nepal), Hainan University (China), Huazhong Agricultural University (China), Southwest University.

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**Staff***The University of Michigan, Ann Arbor, Michigan (Lead US Institution)*

James S. Diana	Lead US Principal Investigator
C. Kwei Lin	US Co-Principal Investigator
Vicki Schwantes	M.S. Student (US)
Barbara A. Diana	Research Assistant (US)
Lauren Theodore	Graduate Student (US)

*Asian Institute of Technology, Pathumthani, Thailand (Lead Host Country Institution)*

Amrit N. Bart	Lead Host Country Principal Investigator
Yang Yi	Host Country Principal Investigator
Thakur Dharendra Prasad	Postdoctoral Research Fellow (India)
Aye Aye Mon	Research Assistant (Myanmar)
Derun Yuan Ph.D. Student (China)	
Rai Sunila	Ph.D. Student (Nepal)
Sultanul Arifin Shameem Ahmad	Ph.D. Student (Bangladesh)
Moe Thidar Oo	Graduate Assistant (Myanmar)
A.M. Shahabuddin	Graduate Assistant (Bangladesh)

*University of the Virgin Islands, St. Thomas, USVI*

James E. Rakocy	US Co-Principal Investigator
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Ash Kumar Rai	Host Country Co-Principal Investigator
Narayan P. Pandit	Research Assistant (Nepal)
Meena Malla	Research Assistant (Nepal)
Hare Ram Devkota	Graduate Assistant (Nepal)

*Research Institute of Aquaculture No. 1, Dinh Bang, Tu Son, Bac Ninh, Vietnam*

Dinh Van Trung	Ph.D. Student (Vietnam)
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Nguyen Thanh Phoung	Host Country Co-Principal Investigator
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Tran Van Bui	Graduate Assistant (Vietnam)

*Bangladesh Agricultural University, Mymensingh, Bangladesh*

Md. Abdul Wahab	Host Country Co-Principal Investigator
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Mostaque Ahmed	Graduate Assistant (Bangladesh)
Md. Shah Alam	Graduate Assistant (Bangladesh)
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Qiu Yunhao	Undergraduate Assistant (China)
Sun Jie	Undergraduate Assistant (China)
Wang Huangxin	Undergraduate Assistant (China)
You Zhengyong	Undergraduate Assistant (China)
Zhang Yifei	Undergraduate Assistant (China)
Zhou Ling	Undergraduate Assistant (China)

*Huazhong Agricultural University, Wuhan, China*

Wang Weimin	Host Country Co-Principal Investigator
Cao Ling	Graduate Assistant (China)
Yao Rongrong	Graduate Assistant (China)
Wang Youji	Graduate Assistant (China)

*Southwest University, Chongqing, China*

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 Yu Xiaodong Graduate assistant (China)

*Wuhan University, Wuhan, China*

Song Biyu Host Country Co-Principal Investigator  
 Song Yan Graduate Assistant (China)  
 Ou Yanghui Graduate Assistant (China)  
 Wan Hong Graduate Assistant (China)

*Xiamen University, Xiamen, China*

Prof. Su Yongquan Host Country Co-Principal Investigator  
 Cai A Yuan Graduate student (China)  
 Huang Ding Yong Undergraduate (China)  
 Pan Ying Undergraduate (China)  
 Hong Jing Ni Undergraduate (China)

*Zhejiang University, Hangzhou, China*

Shao Qingjun Host Country Co-Principal Investigator

**Work Plan Research**

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

- Integrated cage-cum-pond culture systems with high-valued climbing perch (*Anabas testudineus*) in cages suspended in carp polyculture: Bangladesh/ 12ATE1a. A progress abstract was submitted for this investigation.
- Integrated cage-cum-pond culture systems with high-valued African catfish (*Clarias gariepinus*) in cages suspended in carp polyculture ponds: Nepal / 12ATE1b. A progress abstract was submitted for this investigation.
- Integrated cage-cum-pond culture systems with high-valued climbing perch (*Anabas Testudineus*) in cages suspended in Nile tilapia (*Oreochromis niloticus*) ponds: Vietnam/ 12ATE1c. A progress abstract was submitted for this investigation.
- Impact of Nile tilapia (*Oreochromis niloticus*) introduction on the indigenous species of Bangladesh and Nepal/ 12EIA3. A progress abstract was submitted for this investigation.
- Assessment of coastal and marine aquaculture development for low trophic level species/ 12ERA1. A progress abstract was submitted for this investigation.
- New paradigm in farming of freshwater prawn (*Macrobrachium rosenbergii*) with closed and recycle systems: Thailand/ 12PSD1a. A progress abstract was submitted for this investigation.
- New paradigm in farming of freshwater prawn (*Macrobrachium rosenbergii*) with closed and recycle systems: Vietnam/ 12PSD1b. A progress abstract was submitted for this investigation.
- New paradigm in farming of freshwater prawn (*Macrobrachium rosenbergii*) with closed and recycle systems: Bangladesh/ 12PSD1c. A progress abstract was submitted for this investigation.
- Optimization of fertilization regimes in fertilized Nile tilapia (*Oreochromis niloticus*) ponds with supplemental feed/ 12PSD2. A progress abstract was submitted for this investigation.
- Use of rice straw as a resource for freshwater pond culture/ 12PSD3. A progress abstract was submitted for this investigation.
- Reproductive performance and growth of improved tilapia (*Oreochromis niloticus*)/ 12ATE2. A progress abstract was submitted for this investigation.

**Publications**

- Kwantong, S., and A. N. Bart, 2006. Cryopreservation of black ear catfish, *Pangasius larnaudii*, (Bocourt) sperm. *Aquaculture Research*, 37: 955-957.
- Lin, C.K., 2006. Integrated aquaculture-aquaculture systems. *Aquaculture Compendium* — CAB International.
- Lin, C.K., 2006. Coastal shrimp culture in Thailand. *Aquaculture Compendium* — CAB International.
- Lin, C.K., 2006. Inland shrimp farming in Thailand. *Aquaculture Compendium* — CAB International.
- Yi, Y., 2006. Water quality parameters. *Aquaculture Compendium* — CAB International.
- Yuan, D.R., Y. Yi and J.S. Diana, 2006. Walking Catfish Production in Thailand – Hybrid Species Helped Fuel Culture Boom. *Global Aquaculture Advocate*, 9: 59-61.
- Wu, Z.W. and Y. Yi., 2006. Rice-crab culture in China. *Aquaculture Compendium* — CAB International.
- Wu, Z.W. and Y. Yi., 2006. Rice-fish culture in China. *Aquaculture Compendium* — CAB International.

**Theses**

- Chamsai, S., 2006. Stress response of goldfish (*Carassius auratus*, Linnaeus 1758) cultured with suckermouth catfish (*Hypostomus* spp.). M.Sc. Thesis. AIT.
- Mya, A. Y., 2006. The effect of chitosan and hydroxycytic acid on the body lipid content of striped catfish (*Pangasius hypophthalmus*). M.Sc. Thesis. AIT.
- Oo, M.T., 2006. Phosphorus fertilization requirement of supplemental feed-fed Nile tilapia (*Oreochromis niloticus*) ponds. M.Sc. Thesis. AIT.
- Shahabuddin, A.M., 2006. Use of rice straw as a substrate for periphyton-based aquaculture system. M.Sc. Thesis. AIT.
- Singappuli, M.S., 2006. Effects of pure oxygen injection on water quality and growth performance of shrimp

(*Litopenaeus vannamei*) in intensive culture system. M.Sc. Thesis. AIT.

Sokhannaro, H., 2006. Assessment of perceptions and attitude changes of a post-tsunami community on the use of aquatic resources. M.Sc. Thesis. AIT.

Viet, T.V., 2006. An evaluation of management of semi-intensive and intensive culture of black tiger shrimp (*Penaeus monodon*) in Soc Trang Province, Mekong Delta, Vietnam. AIT.

#### Presentations/Conferences:

Bart, Amrit, 2006. Rearing of Early Stage Humpback Grouper Larvae *Cromileptes altivelis* with SS-Thai Strain Rotifers Enriched with DHA-EPA, Vitamin C and Astaxanthin. AQUA 2006, Annual Meeting of the World Aquaculture Society, Florence, Italy, 9-13 May 2006.

Diana, James, 2005. Efficient Fertilization, Feeding, and Culture Systems for Nile Tilapia in Southeast Asia. Annual meeting – American Fisheries Society, Madison, Wisconsin, August 2005.

Diana, James, 2006. Comparison of Giant Freshwater Prawn, *Macrobrachium rosenbergii*, Culture in Open Water Exchange System, Closed Aeration System and Integrated Recycling System. AQUA 2006, Annual Meeting of the World Aquaculture Society, Florence, Italy, 9-13 May 2006.

Diana, James, 2006. Aquaculture and Biodiversity Conservation. Biodiversity Symposium, Punta Cana, Dominican Republic. 1 June 2006.

Diana, James, 2006. Integrated Cage-Cum-Pond Aquaculture Systems: a Conceptual Model (J.S. Diana, Y. Yi and C.K. Lin). Second International Symposium on Cage Aquaculture in Asia, Hangzhou, China, 5 July 2006.

Lin, C. Kwei, 2005. Status and business opportunities of inland fisheries in Southeast Asia. Workshop for Asian Productivity Organization (APO), New Delhi, India, September 2005.

Lin, C. Kwei, 2005. Backyard hatcheries for finfish and shellfish: the Asian phenomenon. Symposium Larvi05, University of Ghent, Ghent, Belgium, September 2005.

Lin, C. Kwei, 2006. Tsunami impact and relief effort in Thailand. Second International Symposium on Cage Aquaculture in Asia, Hangzhou, China, 5 July 2006.

Lin, C. Kwei, 2006. Cage culture of catfish in the Mekong Delta, Vietnam (N.T. Phuong, C. K. Lin and Y. Yi). Second International Symposium on Cage Aquaculture in Asia, Hangzhou, China, 5 July 2006.

Shrestha, Madhav K., 2006. Integrated cage-cum-pond culture system with *Clarias gariepinus* in cages and carps in open ponds (M. K. Shrestha, N. P. Pandit, Y. Yi, C.K. Lin and J.S. Diana). Second International Symposium on Cage Aquaculture in Asia, Hangzhou, China, 5 July 2006.

Yi, Yang, 2005. Minimizing environmental impacts of shrimp culture. China Ocean Forum 2005, Xiangshan, Zhejiang Province, China, September 2005.

Yi, Yang, 2005. Overview of tilapia aquaculture. 7th Indian Fisheries Forum, Bangalore, India. November 2005.

#### Achievements/Kudos:

Yi, Yang. Elected Asian Fisheries Society President from November 2007 to October 2010. Election took place during the 30th council meeting in Bangalore, India on 7-9 Nov 2005.

Yi, Yang. Appointed Vice Chair of Organizing Committee, Chair of Scientific Committee, and one of three editors-in-chief for the Second International Symposium on Cage Aquaculture in Asia in Hangzhou, China, 3-8 July 2006.

Diana, James. Named Outstanding Undergraduate Instructor at the University of Michigan, November 2005.

Diana, James. Appointed member of the Scientific Technical Committee, North Central Regional Aquaculture Center, and attended the annual meeting in Lansing, 4-5 February 2006.

Diana, James. Presented with the Justin Leonard Award of Excellence by the Michigan Chapter, American Fisheries Society, 7 March 2006.

#### Workshops/Seminars/Educational Outreach:

Bart, Amrit, 2005. Comparison of Reproductive Parameters among improved strains of Nile Tilapia *Oreochromis niloticus* L. Mexico (HCPI), October 2005.

Bart, Amrit, 2005. Study of an indigenous, herbivorous species, *Spinibarbus denticulatus*, for low input aquaculture. Honduras (HCPI), October 2005.

Lin, C. K., 2005. Pen and cage culture. AIT, Pathumthani, Thailand, 10 Oct 2005.

Lin, C. K., 2005. Inland marine shrimp / freshwater prawn culture. AIT, Pathumthani, Thailand, 17 Oct 2005.

Lin, C. K., 2006. Water quality management for aquaculture. University of Fisheries, Nhatrang, Vietnam. February 2006.

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#### INTEGRATED CAGE-CUM-POND CULTURE SYSTEMS WITH HIGH-VALUED CLIMBING PERCH (*ANABAS TESTUDINEUS*) IN CAGES SUSPENDED IN CARP POLYCULTURE PONDS: BANGLADESH

Twelfth Work Plan, Applied Technology and Extension Methodologies 1a (12ATE1a)  
Abstract

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#### ABSTRACT

An on-farm trial was conducted to evaluate the growth performance of caged climbing perch (*Anabas testudineus*) with six carp species (*Catla catla*, *Hypophthalmichthys molitrix*, *Labeo rohita*, *Cirrhinus cirrhosus*, *Barbodes gonionotus*, and *Cyprinus carpio*) stocked in the open water of 18 rural ponds for 150 days in the Mymensingh region of Bangladesh. One 1-m<sup>3</sup> cage per 200 m<sup>2</sup> pond area was suspended in each of 12 earthen ponds and the remaining six ponds served as controls without cages. Climbing perch fingerlings of 2–3 g in size were stocked at 200 and 400 fish m<sup>-3</sup> in cages, while carp fingerlings of 8–15 g size were stocked at 1 fish m<sup>-2</sup> in all 18 ponds, giving caged climbing perch to open-pond carp ratios of 1:1 and 2:1, respectively. Caged climbing perch were fed on Saudi Bangla commercial pelleted feed (32.38% crude protein) for the first 90 days and grower feed (38.06% crude protein) for the rest. Feeds were supplied at 100% body weight per day for the first month and at 5% body weight per day for the rest of the culture period. No additional supplemental feeds were supplied for carp production in control or treatment ponds.

Survival of climbing perch was 40.4% in the 1:1 treatment and 29.5% in the 2:1 treatment; these values were not significantly different ( $P>0.05$ ). There was no significant ( $P>0.05$ ) difference in survival of carp either, ranging from 41% to 93%. Final mean weights of both climbing perch and carp were not significantly different ( $P>0.05$ ) among all treatments, ranging from 15.1 to 20.1 g and from 235.3 to 341.1 g, respectively. Total harvest weight of climbing perch was not significantly different ( $P>0.05$ ) between treatments ( $3.04 \pm 1.28$  and  $2.49 \pm 2.24$  kg per pond in the 1:1 and 2:1 ratio treatments, respectively). Production performance of carp was not significantly different among treatments. The combined total weights of both climbing perch and carp were not significantly different between treatments. Net revenues were positive but comparatively low in all treatments. The results indicated that the caged climbing perch to open-pond carp ratio 1:1 was better, but stocking size of climbing perch fry should be larger. More on-farm trials in different ecosystems are necessary to develop the technology for further dissemination among the rural farmers.

#### INTEGRATED CAGE-CUM-POND CULTURE SYSTEMS WITH HIGH-VALUED AFRICAN CATFISH (*CLARIAS GARIEPINUS*) IN CAGES SUSPENDED IN CARP POLYCULTURE PONDS: NEPAL

*Twelfth Work Plan, Applied Technology and Extension  
Methodologies 1b (12ATE1b)*  
Abstract

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#### ABSTRACT

This on-farm trial was carried out for 164 days in 18 earthen ponds of 85–130 m<sup>2</sup> in surface area in three sites of Nepal to adapt integrated cage-cum-pond systems to local conditions in Nepal and to verify best results of the on-station trial. One cage (1.5 x 1.5 x 1.0 m), with water volume of 2 m<sup>3</sup> and covered with 1-cm mesh net, was suspended in each of the treatment ponds. There were two treatments: 1) carp at 1 fish m<sup>-2</sup> in open ponds without cages (control); and 2) African catfish (*Clarias gariepinus*) at 100 fish m<sup>-3</sup> in cages and carp at 1 fish m<sup>-2</sup> in open ponds (caged treatment). Each trial site had three replicates for both the control and treatment. African catfish fingerlings of 12.8–13.2 g in size were stocked in cages, while fingerlings of silver carp (*Hypophthalmichthys molitrix*), bighead carp (*Aristichthys nobilis*), common carp (*Cyprinus carpio*), rohu (*Labeo rohita*), and mrigal (*Cirrhinus mrigala*), with average weights of 4.6, 2.2, 4.2, 0.5, and 0.7 g, respectively, were stocked in the open water of all ponds. The stocking ratio of silver carp, bighead carp, common carp, rohu, and mrigal was 4:2:2:1:1, respectively, in each pond. Caged catfish were fed twice daily with a locally made pellet feed (28% crude protein), while no feed or fertilizer was added into open water. In the control, ponds were fertilized weekly with diammonium phosphate (DAP) and urea at rates of 2 kg N and 1 kg P ha<sup>-1</sup> d<sup>-1</sup> throughout the experimental period.

Survival of African catfish, ranging from 53.3% to 56.8%, was not significantly different among all sites. Daily weight gains (1.2 to 1.4 g fish<sup>-1</sup> d<sup>-1</sup>), gross fish yield (19.0 to 25.4 kg cage<sup>-1</sup> crop<sup>-1</sup>), net fish yield (16.6 to 22.9 kg cage<sup>-1</sup> crop<sup>-1</sup>), and feed conversion ratio (2.6 to 3.3) of African catfish were not significantly different among all sites. Most growth and production parameters of carps were not significantly different between the control and treatment ( $P>0.05$ ). Both the caged treatment and control ponds produced positive net returns (NRs) with 1860 NRs/100-m<sup>2</sup> pond in the caged treatment ponds, and 1400 NRs/100-m<sup>2</sup> pond in the control ponds in one culture cycle.

African catfish has the potential to be cultured in an integrated cage-cum-pond culture system, but it is necessary to fine-tune stocking ratios of catfish to carp and escape the winter season for culture.

**INTEGRATED CAGE-CUM-POND CULTURE SYSTEMS WITH HIGH-VALUED CLIMBING PERCH (*ANABAS TESTUDINEUS*) IN CAGES SUSPENDED IN NILE TILAPIA (*OREOCHROMIS NILOTICUS*) PONDS: VIETNAM**

*Twelfth Work Plan, Applied Technology and Extension Methodologies 1c (12ATE1c)*  
Abstract

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**ABSTRACT**

This on-farm trial was carried out in three districts of Vietnam (Tam Binh district of Vinh Long province, Thot Not district of Can Tho city, and Vi Thuy district of Hau Giang province) to adapt integrated cage-cum-pond systems to local conditions. Five earthen ponds of 100 m<sup>2</sup> in surface area were selected in each of the three sites for the on-farm trial.

Nile tilapia (*Oreochromis niloticus*) fingerlings (8–10 g size) were stocked at two fish m<sup>2</sup> in all ponds, while climbing perch (*Anabas testudineus*) fingerlings (8–10 g size) were stocked in a 4-m<sup>3</sup> cage suspended in each treatment pond. Stocking density of climbing perch was the treatment variable and was 50, 100, 150, and 200 fish m<sup>-3</sup>, 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), which were fertilized weekly with urea and diammonium phosphate (DAP) at 28 kg N and 7 kg P ha<sup>-1</sup> week<sup>-1</sup>. No fertilizer was added into treatment ponds. Pelleted feeds containing 32%, 26–28%, and 22% crude protein were given twice daily to caged climbing perch during the first, second and remaining months at rates of 5%, 3%, and 2% body weight per day, respectively.

Survival of climbing perch, ranging from 85.5% to 91.1%, was not significantly different among sites and treatments. Daily weight gain (0.28 g fish<sup>-1</sup> day<sup>-1</sup>) of climbing perch was significantly higher in the 1:1 ratio treatment than those (0.16–0.17 g fish<sup>-1</sup> day<sup>-1</sup>) in other treatments ( $P < 0.05$ ), among which there were no significant differences ( $P > 0.05$ ). Total harvested climbing perch biomass, ranging from

8.77 to 23.7 kg cage<sup>-1</sup>, increased with increasing stocking ratio of climbing perch to Nile tilapia ( $P < 0.05$ ). Feed conversion ratio (FCR) was lowest in the 4:1 ratio treatment, intermediate in the 1:1 and 3:1 ratio treatments and highest in the 2:1 ratio treatment ( $P < 0.05$ ). Survival of Nile tilapia was highest (93%) in the 3:1 ratio treatment, intermediate (86.8%–89.3%) in the 0:1, 1:1, and 2:1 ratio treatments, and lowest (84%) in the 4:1 ratio treatment ( $P < 0.05$ ). Growth of Nile tilapia, ranging from 1.17 to 1.78 g fish<sup>-1</sup> day<sup>-1</sup>, was not significantly different among treatments ( $P > 0.05$ ), while total harvested tilapia biomass was highest in the 3:1 ratio treatment, intermediate in the 1:1, 2:1, and 4:1 treatments, and lowest in the 0:1 ratio treatment (control) ( $P < 0.05$ ). Treatments with higher ratios (3:1 and 4:1) gave higher net revenues (0.374 and 0.361 million VND per 100 m<sup>2</sup> pond).

The on-farm trial has demonstrated that the high-valued climbing perch may provide potential for the integrated cage-cum-pond culture system, but it is necessary to improve FCR of climbing perch in order to increase the profitability of the system.

**IMPACT OF NILE TILAPIA (*OREOCHROMIS NILOTICUS*) INTRODUCTION ON THE INDIGENOUS FISH SPECIES OF BANGLADESH AND NEPAL**

*Twelfth Work Plan, Environmental Impacts Analysis 3 (12EIA3)*  
Abstract

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**ABSTRACT**

The objective of this study is to assess the impact of the introduction of mixed-sex and male mono-sex Nile tilapia on three important indigenous fish species of Bangladesh and Nepal. The study is being conducted in small ponds where changes in population structure and recruitment are being assessed over time. This study consists of three experiments, two of which are being conducted in Bangladesh and the other in Nepal.



**Experiment 1:** This experiment is being conducted in nine 100 m<sup>2</sup> earthen ponds at the Bangladesh Agricultural University, Mymensingh, Bangladesh to assess the impact of mixed-sex and male mono-sex Nile tilapia (*Oreochromis niloticus*) on mola (*Amblypharyngodon mola*), chela (*Chela cachius*), and punti (*Puntius sophore*). Fish population structure and recruitment rates are being assessed over time, and the dietary overlap between tilapia and these indigenous species will be evaluated. The experiment commenced on 8 December 2004, and will continue for 20 months. A completely randomized design with three treatments and three replicates per treatment is being used. The treatments are (i) mixed-sex tilapia with the three indigenous fish species (T1), (ii) mono-sex male tilapia with the indigenous species (T2), and (iii) the indigenous species without tilapia (T3-control). Before stocking, all ponds were drained completely to ensure that no other fish were present. The ponds were then limed (250 kg ha<sup>-1</sup> of CaCO<sub>3</sub>) and manured (1000 kg ha<sup>-1</sup> of cow dung). After that, the ponds were filled with water and fertilized at 100 kg ha<sup>-1</sup> of urea and 50 kg ha<sup>-1</sup> of TSP one week prior to stocking. Each species was apportioned equally (25%) with a total stocking rate of 0.56 fish m<sup>-2</sup> for the two tilapia treatments (T1 and T2). Each indigenous species was apportioned equally (33%) with a total stocking rate of 0.42 fish m<sup>-2</sup> for the control (T3). The male-to-female ratio of indigenous species was 1:1. Nile tilapia were stocked 74 days after the indigenous species were stocked. There was no additional nutrient input to the ponds after the indigenous species were stocked. Individual lengths and weights of a sample of fish were determined during stocking. The initial average weight of mola, chela, punti, and tilapia were 0.68, 0.73, 4.54, and 5.12 g, respectively.

Monthly fish sampling was done to observe fish population structure. Recruitment (offspring resulting from spawning) of each species is being enumerated during monthly sampling to estimate total recruitment of each species. Batch weights of newly recruited fish are being measured. The length and weight of individual fish are being measured and recorded from a sample of each fish generation. Water quality analyses are being conducted weekly for water temperature, dissolved oxygen, pH, transparency; and monthly for total ammonia-nitrogen, nitrite-nitrogen, nitrate-nitrogen, total suspended solids, alkalinity, chlorophyll-*a*, and plankton. At the end of experiment, gut analyses will be performed on each species to determine the Electivity Index and Dietary Overlap.

Results to date indicate that mola spawned two times a year in all treatments during the period of June to September 2005 and one time during May to June 2006. Chela spawned only one time in all treatments during June to October 2005 and one time during April to July 2006. Punti spawned two times during April to October 2005 and one time during May to June 2006. Nile tilapia spawned five times during the period of May to November 2005 and four times during the period of March to July 2006 in the mixed sex tilapia treatment (T1). Nile tilapia did not spawn during December 2005 to February 2006. The results of the physical and chemical parameters of water varied little among treatments and no trends were discernible in the three treatments. The experiment was terminated in August 2006 after 20 months.

**Experiment 2:** This experiment is being conducted at the Bangladesh Agricultural University to assess the impact of mixed-sex Nile tilapia on mola (*Amblypharyngodon mola*), chela (*Chela cachius*), and punti (*Puntius sophore*) in simulated open-water environments. A large pond (about 24 m x 83.5 m) was drained completely and partitioned by bamboo split mat (covered by fine meshed nylon net) into two big ponds of 1000 m<sup>2</sup> each. The objectives and procedures are the same as in experiment 1 with the following exceptions. The experiment commenced on 21 March 2006 and will continue for 12 months. Two treatments and one replicate per treatment are being used. The treatments are (i) mixed-sex tilapia with the three indigenous fish species (T1), and (ii) the indigenous species without tilapia (T2-control). Each species was apportioned equally (25%) with a total stocking rate of 1 fish m<sup>-2</sup> for the tilapia treatment (T1). Each indigenous species was apportioned equally (33%) with a total stocking rate of 0.75 fish m<sup>-2</sup> for the control (T2). Nile tilapia were stocked 30 days after the indigenous species were stocked. Individual lengths and weights of a sample of fish were determined during stocking. The initial average weight of mola, chela, punti, and tilapia were 1.58, 0.77, 4.47, and 5.93 g, respectively.

Results to date indicate that mola, chela, and punti spawned only one time in both two treatments (T1 and T2) during May to July 2006. Spawning has occurred in the treatment of Nile tilapia (T1). The experiment will be terminated in March 2007 after 12 months duration.

**Experiment 3:** This experimental design was similar to experiment 1 but at a different location. This experiment was conducted in Nepal where the water temperature even in the south declines to 15°C for over two to three weeks a year. This temperature variation places tilapia in a disadvantaged position. This study also provides information on tilapia competitiveness in a different type of environmental conditions than in Bangladesh. The experiment was completed recently; gut content and other data are being analyzed.

## ASSESSMENT OF COASTAL AND MARINE AQUACULTURE DEVELOPMENT FOR LOW TROPHIC LEVEL SPECIES

*Twelfth Work Plan, Economic/Risk Assessment and Social Analysis 1 (12ERA1)*  
Abstract

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### ABSTRACT

The primary aim of this report is to provide the ACRSP an overview of the literature to-date regarding use of low trophic level species in near shore aquaculture development around the world. Additionally, the study will provide a detailed analysis of the literature and make specific

recommendations regarding the prioritization of research needs as they relate to culture of low trophic level species in the near shore. This project was initiated 1 January 2005.

We focus our definition and research of low trophic level, near-shore aquaculture on aquaculture systems that we refer to as Low-Trophic Ecological Aquaculture in the Near shore, or LEAN. The principles defining LEAN were adopted from Costa-Pierce's philosophy of "ecological aquaculture" and applied to the near shore. LEAN systems 1) include any method of cultivating plant or animal species that requires minimal to no outside energy or food inputs to foster adequate growth; 2) occur in coastal estuaries, beaches, bays, inlets, or lagoons that can be easily managed for human benefit with little invested capital or equipment; 3) have minimal effects on the environment; and 4) can be integrated within local socio-economic and cultural structures.

The first section of this report will define and describe LEAN for the purposes of this study; the second section will provide an overview on the current status of LEAN in the near shore; the third section will detail the methodology used to search the literature; and the fourth section will detail the specific ecological, economic, social, political, and cultural issues relevant to LEAN development in the near shore region. In the fifth section of the report, the material presented in earlier sections will be synthesized and applied in the analysis of three case studies, each of which involves the use of LEAN for three distinct purposes: 1) as effluent treatment for high-intensity production systems, 2) for small-scale production of food and income, and 3) for enhancement of wild-capture fisheries.

The possibilities for LEAN systems are innumerable and routinely site-specific. The literature relating to this topic is immense and extremely diverse. LEAN systems occur worldwide with a myriad of species and in a multitude of forms that include monoculture, polyculture, and integrated culture. The literature on LEAN-related topics reflects its variability and ubiquity.

We conclude by presenting a conceptual model of the ideal LEAN project based upon the literature and case studies examined, and make four recommendations in which the ACRSP could pursue productive research on LEAN and promote effective LEAN project development. These four recommendations are to: 1) identify already existing practices that could be developed into more formalized LEAN systems in each ACRSP country; 2) perform in-depth case studies of established LEAN practices with a goal to better understand their failures and successes; 3) establish local educational and training programs that can instruct local peoples on LEAN development; and 4) financially support LEAN projects currently underway and establish long-term research projects at selected sites focusing on the interactions between LEAN systems and near-shore ecosystems.

## NEW PARADIGM IN FARMING OF FRESHWATER PRAWN (*MACROBRACHIUM ROSENBERGII*) WITH CLOSED AND RECYCLE SYSTEMS: THAILAND

*Twelfth Work Plan, Production System Design and Integration Research 1a (12PSD1a)*

*Abstract*

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### ABSTRACT

This study included two parts: an experiment on a water recycling system for giant freshwater prawn (*Macrobrachium rosenbergii*) and a survey of prawn farming systems in Thailand.

The experiment was conducted in 15 cement tanks (2 x 2.5 x 1 m) at the Asian Institute of Technology, Thailand, during 5 January to 12 May 2004, to develop closed and recycle systems for culture of giant freshwater prawn. 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.

Survival of prawns, ranging from 40.6% to 88.7%, was highest in the closed system, intermediate in the recycle system, and lowest in the open system ( $P < 0.05$ ). 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 socioeconomic and technical survey of 100 prawn farmers was conducted during 1 May–31 July 2005 in Thailand. Survey results showed that the majority of respondents were male (70%) and ranged in age from 19–72 years, average age 46. Most farmers (77%) had completed an elementary level of schooling (4 years), 16% had completed high school (12 years), 6% had vocational/university education, and 1% had no formal education. Experience or length of time working on the farm as owner, manager, or

both ranged from 8 to 25 years, averaging approximately 10 years. Formal training was received by 19% of respondents and most (92.9%) obtained information about prawn culture from their neighbors.

The majority of farms were under 5 ha in both total and water area. Monoculture was the dominant system (96%) while remaining farmers utilized polyculture systems consisting of prawns and white shrimp (*Metapenaeus vannamei*). The most common management strategy (66%) included nursing post larvae (PL) and harvesting with the combined method where farmers cull only marketable sized prawns after five months and allow those stunted by dominants to grow and be harvested on a 30–45 day basis. After several harvests, ponds are drained and all prawns are harvested. Other strategies included stocking PL or juveniles directly into grow-out ponds and using the batch method, where all individuals are harvested after reaching a medium market size.

Semi-intensive culture was predominant. Most farmers stocked at densities below 20 pcs m<sup>-2</sup>, average  $11 \pm 1$  pcs m<sup>-2</sup> (72%,  $n = 75$ ). Transfer survival values (from the nursing pond) were transformed to the natural log to correct for normality and this variable was significantly correlated to stocking density (slope = 0.012,  $P < 0.05$ ,  $R^2 = 0.599$ ). Average production was  $2155 \pm 146$  kg ha<sup>-1</sup> yr<sup>-1</sup> and ranged from 438 to 6381 kg ha<sup>-1</sup> yr<sup>-1</sup> ( $n = 72$ ). Major problems identified were diseased or poor quality seed supply (67%), disease outbreak within the crop (64%), and external pollution (37%). External pollution was severe for 16% of respondents, moderate for 46%, and not an issue for 38%. A linear regression model is being developed to establish which variables are most important in driving production and net economic profits.

#### **NEW PARADIGM IN FARMING OF FRESHWATER PRAWN (*MACROBRACHIUM ROSENBERGII*) WITH CLOSED AND RECYCLE SYSTEMS: VIETNAM**

*Twelfth Work Plan, Production System Design and Integration Research 1b (12PSD1b)*  
Abstract

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#### **ABSTRACT**

Two surveys on giant freshwater prawn (*Macrobrachium rosenbergii*) farming were conducted in the Mekong Delta, Vietnam. The first survey was carried out during March–April 2005 and the second during May–June 2006. These two surveys were conducted in the same locations. Forty-seven prawn farmers were randomly selected during the first survey, among whom 15 farmers were from Co Do district of Can Tho city, 15 farmers from Vinh Thanh district of Can Tho city, and 17 farmers from Thoai Son district of An Giang province. For the second survey, 20 farmers were selected from Co Do district, 16 from Vinh Thanh district, and 20 from Thoai Son district. The selected farmers were interviewed using a structured checklist and open-ended type of questionnaire. The surveys focused on prawn farming in rice paddies to assess the changes of giant freshwater prawn farming including development trends and technical, socio-economic, and environmental aspects.

The results showed that prawn farming in rice paddies in the Mekong delta is continuing to expand. There were improvements of culture techniques between two surveys in terms of rice paddy design and construction, stocking density, feeds and feeding, water quality management, productivity, profitability, and so on. Detailed data analyses are ongoing and detailed results will be included in the final report.

#### **NEW PARADIGM IN FARMING OF FRESHWATER PRAWN (*MACROBRACHIUM ROSENBERGII*) WITH CLOSED AND RECYCLE SYSTEMS: BANGLADESH**

*Twelfth Work Plan, Production System Design and Integration Research 1c (12PSD1c)*  
Abstract

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#### **ABSTRACT**

The study was conducted to understand the status and practices of freshwater prawn production systems in four different zones of Bangladesh during January to July 2005. A total of 100 farmers were interviewed with a semi-structured questionnaire and participatory rural appraisal tools on prawn post-larvae (PL) nursing and grow-out rearing in ponds or ghers.<sup>1</sup>



In nursing systems, the farmers reared post larvae in small ponds or in the trench of ghers with water area ranging from 5 to 30 decimals (average 8.29 decimals). About 49% of farmers stocked hatchery PLs due to shortage of supply and high price of wild PLs. Almost all farmers dried and limed their nursery ponds or pocket ghers, repaired their dikes, and removed aquatic weeds in the dry season. Farmers used urea, TSP, and cow dung. The stocking density of PLs was 400 to 1500 individuals decimal<sup>-1</sup>. The mean quantity of supplied feeds was 36.97 g per 1000 PLs day<sup>-1</sup> for the first 15 days, 72.11 g per 1000 PLs day<sup>-1</sup> for the second 15 days, 125.59 g per 1000 PLs day<sup>-1</sup> for the third 15 days, and 205.15 g per 1000 PLs day<sup>-1</sup> up to the juvenile stage. The PL mean survival rate was 67.5%.

In the grow-out farming system, farmers reared juvenile prawns either in ponds and/or ghers. Farm size and individual pond/gher size ranged from 0.08 to 31.5 ha and 0.08 to 3.94 ha, respectively. The gher/pond design provides good opportunities for diversification with primary dependence on prawns, fish, and rice. Thirty percent of farmers did not practice integrated culture, 40% practice integrated prawn with paddy culture, 10% integrated prawn farming with only dike crops, and 20% integrated farming with paddy and dike crops. In all study areas, the peak season of prawn farming was from May to January. Prawn farmers used three different types of supplementary feed (processed feed, homemade feed, and snail meat). Almost all farmers applied feeds at an average rate of 4.5% body weight basis. The peak season of partial harvesting was from October to January and small prawns were reared up to next season and were harvested in the following year from August to September. The average annual yield of prawns, fish, and shrimp was estimated at 390.2 kg ha<sup>-1</sup>, 658.5 kg ha<sup>-1</sup>, and 123.9 kg ha<sup>-1</sup>, respectively. Farmers also cultivated small numbers of silver carp, rohu, catla, and silver barb with prawns mainly used for their own consumption.

Major problems of prawn farming were lack of capital, lack of education, shortage of PLs, high price of quality feed, poor technical knowledge, marketing problems, poor water quality, excessive and late rain, natural disasters (flood and drought), poisoning, water exchange problems, traditional technology, and disease problems. For long-term sustainability of prawn farming in the study area, adequate bank credits at very low interest, sufficient and quality seed production, and improved management skills are needed. Moreover, good transportation, a favorable marketing system, and a positive attitude towards prawn farming should be developed. Training, extension services, and institutional and policy support should be provided to the prawn farmers for sustainable prawn farming in Bangladesh.

<sup>1</sup> The Bangla term "gher" is an enclosure made for prawn cultivation by modifying rice fields by building higher dikes around the field and excavating a canal several feet deep inside the periphery of the dikes to retain water during the dry season.

## OPTIMIZATION OF FERTILIZATION REGIMES IN FERTILIZED NILE TILAPIA (*Oreochromis niloticus*) PONDS WITH SUPPLEMENTAL FEED

*Twelfth Work Plan, Production System Design and Integration 2 (12PSD2)*

*Abstract*

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### ABSTRACT

An experiment was conducted in 15 200-m<sup>2</sup> earthen ponds at the Asian Institute of Technology, Thailand from September 2005 to January 2006. The objectives of this experiment were to determine effects of different rates of phosphorus fertilizer application on Nile tilapia (*Oreochromis niloticus*) production, pond water quality parameters, and nutrient utilization efficiency under supplemental feeding and to evaluate the cost and return of Nile tilapia production. Five phosphorus fertilization rates were used as treatments in a randomized complete block design: 100%, 75%, 50%, 25%, and 0% of 7 kg P ha<sup>-1</sup> wk<sup>-1</sup>. Nitrogen fertilization rate was fixed at 28 kg N ha<sup>-1</sup> wk<sup>-1</sup> for all the treatments throughout the experiment. Sex-reversed, all-male Nile tilapia of about 100 g size were stocked at 3 fish m<sup>-2</sup> and fed at 50% satiation feeding rate during the culture period.

Mean weight, mean weight gain, daily weight gain, and net fish yield were not significantly different among treatments ( $P > 0.05$ ). Water quality parameters were not significantly different among treatments, except total Kjeldahl nitrogen, total phosphorus, and soluble reactive phosphorus. Nutrient budget showed that higher rates of phosphorus fertilizer input resulted in higher phosphorus accumulation in the sediments. Economic analysis showed that all treatments with phosphorus fertilization resulted in positive net returns. Gross income was not affected by different phosphorus fertilization rates. Treatment with 25% phosphorus fertilization might be used as an alternative strategy for Nile tilapia pond culture in terms of good economic return and reduced nutrient loss in sediment.

## USE OF RICE STRAW AS A RESOURCE FOR FRESHWATER POND CULTURE

*Twelfth Work Plan, Production System Design and Integration 3 (12PSD3)*

*Abstract*

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### ABSTRACT

Rice straw is a low-cost material and widely available in farms from South and Southeast Asia. Rice straw can enhance fish production if used as a substrate in aquaculture ponds because it allows periphyton colonization and also increases benthic organisms on decomposition. The objectives of this study were to investigate the role of rice straw in fish ponds and to develop a low-cost aquaculture system using rice straw to enhance fish production through reduced turbidity, enhanced biofilm, and increased periphyton development. This study was comprised of four experiments that were conducted in Thailand and Bangladesh.

**Experiment 1** was conducted in 21 outdoor cement tanks of 5-m<sup>2</sup> in surface area at the Asian Institute of Technology, Thailand (AIT), for 35 days to assess effects of straw decomposition at various loading levels on physical, chemical, and biological water quality parameters. The treatments were seven loading levels of rice straw mats: 0, 625, 1,250, 2,500, 5,000, 10,000, and 20,000 kg ha<sup>-1</sup> (dry matter basis). Tanks were fertilized weekly with urea and TSP at 28 kg N and 7 kg P ha<sup>-1</sup> week<sup>-1</sup>, respectively. Diel temperature, dissolved oxygen (DO), and pH were monitored every day, while Secchi disk visibility was measured daily at 0900 h. Water column samples were taken weekly at 0900-1000 h for the analyses of total alkalinity, total ammonia nitrogen (TAN), nitrite-N, nitrate-N, total Kjeldahl nitrogen (TKN), total phosphorus (TP), soluble reactive phosphorus (SRP), total suspended solids (TSS), total volatile solids (TVS), chlorophyll *a*, and tannin. Rice straw samples were taken from each tank at the beginning and the end of the experiment to quantify periphyton using Sedgwick-Rafter cells and bacteria number (cfu/g) using total plate counts.

High straw loading rates caused deteriorating water quality. Increased loading rates decreased DO, pH, and transparency ( $P < 0.05$ ), while total alkalinity, nitrite-N, TP, SRP, TKN, TSS,

TVS, and chlorophyll *a* increased with increasing loading rates ( $P < 0.05$ ). Periphyton biomass (chlorophyll *a* content, dry matter, ash- and ash-free dry matter), was found to be higher in lower straw-loading treatments ( $P < 0.05$ ). However, plankton (cell/L) and bacteria number (cfu/g) did not differ significantly among treatments ( $P > 0.05$ ). The loading rate of 625 kg ha<sup>-1</sup> was found to be best among treatments.

**Experiment 2** was conducted with different rice straw loading rates in fertilized earthen ponds of 200 m<sup>2</sup> at AIT to assess effects of straw mats on growth performance of Nile tilapia (*Oreochromis niloticus*), pond water quality, periphyton, plankton, bacterial biofilm, and benthos. There were six treatments with three replicates: 1) control (without rice straw mats); 2) rice straw mats of 5 x 0.5 m covering dikes; 3) one rice straw mat of 5 x 1 m in water column; 4) two rice straw mats of 5 x 1 m in water column; 5) three rice straw mats of 5 x 1 m in water column; and 6) four rice straw mats of 5 x 1 m in water column. All ponds were fertilized weekly with urea and TSP at 28 kg N and 7 kg P ha<sup>-1</sup> week<sup>-1</sup>. Sex-reversed, all-male Nile tilapia with a mean weight of  $24.7 \pm 3.0$  g were stocked 39 days after placing rice straw mats in the pond at 2 fish m<sup>-2</sup>.

Growth performance of Nile tilapia was not significantly different ( $P > 0.05$ ) between treatments with straw mats and the control, except the treatment with two straw mats, which had a significantly lower mean weight gain and mean yield than the control ( $P < 0.05$ ). There was no significant difference ( $P > 0.05$ ) in mean survival and yield among the treatments with different straw loading rates. Rice straw loading had no significant affect on the major water quality parameters, plankton density, bacterial biofilm, or benthos. Periphyton samples were collected only during the first month of the experimental period as the rice straw fell off the supporting structure, and thus, it was not possible to collect substrate samples to determine periphyton biomass. A sharp decline in DO was observed in the rice straw treatments after placing rice straw mats in the ponds (pre-stocking period). Eighty-seven genera of phytoplankton were identified with dominant species in the following orders: Bacillariophyceae, Chlorophyceae, Cyanophyceae, and Euglenophyceae. *Cyclotella*, *Microcystis*, and *Euglena* were the dominant genera. Twenty genera of zooplankton were identified; among those, Rotifera and Crustacea were the most dominant groups, whereas *Brachionus* and *Nauplius* were the dominant genera. Total plate count of bacteria in water did not significantly differ among treatments, but total counts declined towards the end of the experiment. Total benthos count was also not significantly different ( $P > 0.05$ ) among treatments, and Oligochaete was the dominant group. Rice straw loading did not enhance growth and yield of Nile tilapia and had no apparent affect on major water quality parameters, plankton community, bacterial growth, or benthos. However, rice straw mat structure collapsed during the early experimental period (15 days after fish stocking), and therefore the full potential of rice straw as a substrate for periphyton attachment could not be evaluated in this study. Further research is required to assess the effect of rice straw loading in fertilized Nile tilapia ponds with a durable rice straw mat structure.

**Experiment 3** was carried out in 18 40-m<sup>2</sup> earthen ponds in a completely randomized design at the Bangladesh Agricultural University (BAU) for 90 days to optimize the loading number of rice straw mats in carp polyculture ponds. The treatments with three replicates are: 1) control (without rice straw mats); 2) rice straw mats covering the slope of dikes; 3) one rice straw mat in the water column; 4) two rice straw mats; 5) three rice straw mats; and 6) four rice straw mats. Ponds were drained, dried, and limed using CaCO<sub>3</sub> at a rate of 250 kg ha<sup>-1</sup>, then rice straw mats (2 x 1 m) were placed into the treatment ponds according to the design. Urea, TSP, and cow dung were applied on the following day at rates of 31 kg ha<sup>-1</sup>, 16 kg ha<sup>-1</sup>, and 1,250 kg ha<sup>-1</sup>, respectively, and continued throughout the experiment on a biweekly basis. After placing rice straw mats, DO was monitored daily at 0600 h. Fingerlings of rohu (*Labeo rohita*), mrigal (*Cirrhinus mrigala*), catla (*Catla catla*), common carp (*Cyprinus carpio*), and silver carp (*Hypophthalmichthys molitrix*) with mean weights of 25.5 ± 0.31, 26.2 ± 0.93, 24.0 ± 0.87, 23.5 ± 0.85 g, and 25.9 ± 0.48, respectively, were stocked at one fish m<sup>-2</sup> one month later after DO recovery at a ration of 3:2:2:2:1. Diel temperature, DO, pH, and Secchi disk visibility were measured weekly, while total alkalinity, TAN, nitrite-N, nitrate-N, TN, SRP, TP, chlorophyll *a*, TSS, and TVS were analyzed biweekly. Periphyton and plankton were quantified following the method in Experiment 1.

Preliminary analyses showed that all measured water quality parameters were found within the desirable range for fish culture. Net fish yield was highest in the treatment with three mats (1.76 tons ha<sup>-1</sup> year<sup>-1</sup>) and lowest in the control (0.9 tons ha<sup>-1</sup> year<sup>-1</sup>;  $P < 0.05$ ).

**Experiment 4** is being conducted in nine 40 m<sup>2</sup> ponds at BAU for three months to compare rice straw and kanchi as periphyton substrates to enhance fish production. There were three treatments in triplicate: A) without substrate (control); B) rice straw mats as substrate (three mats per pond, 3 x 625 kg ha<sup>-1</sup>); and C) kanchi as substrate (390 bamboo side shoots per pond). Prior to placing the substrates, ponds were drained and dried, the top layer of sediment was removed and limed using CaCO<sub>3</sub> at a rate of 250 kg ha<sup>-1</sup>. Urea, TSP, and cow dung were applied on the following day at rates of 31 kg ha<sup>-1</sup>, 16 kg ha<sup>-1</sup>, and 1,250 kg ha<sup>-1</sup>, respectively, and continued throughout the experiment on a biweekly basis. Then, 390 kanchi and three straw mats per pond were fixed in the respective treatment ponds. DO in ponds with rice straw mats was monitored for two weeks until it recovered to a normal level. Fingerlings of rohu (24.5 ± 0.5 g), mrigal (25.1 ± 0.6 g), catla (25.8 ± 0.5 g), silver (30.4 ± 0.9 g) and common carp (27.6 ± 0.6 g) were stocked at 1 fish m<sup>-2</sup> with the species ratio of 3:2:2:2:1. Diel temperature, DO and pH were measured weekly, while total alkalinity, TAN, nitrite-N, nitrate-N, TN, SRP, TP, chlorophyll *a*, TSS, and TVS are analyzed biweekly. Qualitative and quantitative analysis of periphyton, plankton, and bacteria is performed monthly. The experiment continues is ongoing.

#### REPRODUCTIVE PERFORMANCE AND GROWTH OF IMPROVED TILAPIA, *OREOCHROMIS NILOTICUS*

*Twelfth Work Plan, Applied Technology and Extension (12ATE2 and 11SDFR3)*

*Previously printed in the 23rd Annual Administrative Report*

#### CONTROLLED REPRODUCTION OF AN IMPORTANT INDIGENOUS SPECIES, *SPINIBARBUS DENTICULATUS*, IN SOUTHEAST ASIA

*Twelfth Work Plan, Indigenous Species Development (12ISD1 and 11ISDR2)*

*Previously printed in the 23rd Annual Administrative Report*





# Philippines Project: Production Technology

Philippines

Subcontract No. RD010A-20 (FIU)



JAMES BOWMAN

The Aquaculture CRSP has been active in the Philippines from the program's inception in 1982, with a hiatus from 1987 to 1992. From 1992–1998, research in the Philippines was reported as part of the Thailand Project since the Philippines functioned as a companion site to Aquaculture CRSP sites in Thailand. In July 1998, the University of Hawaii (UH) was selected as lead US institution for a new Philippines Project, and in August 1998 a Memorandum of Understanding was executed between UH and the Freshwater Aquaculture Center at Central Luzon State University (CLSU). In June 2000, UH ended its role as the Philippines Project lead institution, and Florida International University (FIU) assumed the lead institution role. FIU now holds a Memorandum of Understanding with CLSU.

Aquaculture CRSP Philippines Project research emphasized development of tilapia grow-out technologies to produce larger fish for the international fillet export market in this reporting period. A second investigation explored the usefulness of measuring the abundance of insulin like growth factor-I gene expression as an instantaneous growth indicator in Nile tilapia. Developed methodology will allow estimation of tilapia growth response without requiring costly and time-consuming grow-out experiments. Researchers at North Carolina State University are also involved in this aspect of the Philippines Project research.

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R. Moncarz	Collaborator

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**Work Plan Research**

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

- Insulin-Like Growth Factor-1 Gene Expression as a Growth Indicator in Nile Tilapia/ 12PSD5. A progress abstract was submitted for this investigation.
- Development of Nile Tilapia Fillets as an Export Product for the Philippines/ 12PSD6. A final report was submitted for this investigation.

**Publications**

Danting, J.L. Cuanan and C.L. Brown. 2006. Comparison on the Use of Cast Net and Seine Net in Fish Sampling in Ponds. pp. 323-330. In: W. Contreras-Sánchez and K. Fitzsimmons (eds). *Proceedings of the Seventh International Symposium on Tilapia Aquaculture*. Boca del Rio, Veracruz, Mexico. *Panorama Acuicola Magazine* and American Tilapia Association, Charles Town, West Virginia, USA. 389 pp.

Madriaga, L. and Bolivar, R.B. 2006. Sugarcane Bagasse as Periphyton Substrate in the Culture of Nile Tilapia (*Oreochromis niloticus*) in Fertilized Ponds. pp. 124-140. In: W. Contreras-Sánchez and K. Fitzsimmons (eds). Proceedings of the Seventh International Symposium on Tilapia Aquaculture. Boca del Rio, Veracruz, Mexico. Panorama Acuicola Magazine and American Tilapia Association, Charles Town, West Virginia, USA. 389 pp.

#### Presentations/Conferences

- Directo, Marilou, 2006. Status of Cage and Pen Culture in Laguna de Bay, Philippines. 2<sup>nd</sup> International Symposium on Cage Aquaculture in Asia, Hangzhou, Shejiang Province, China, 3-8 July 2006.
- Bolivar, Remedios B., 2006. Tilapia feeding strategies to optimize production in semi-intensive pond culture & CRSP at CLSU. Training information exchange on Cichlid culture and the adoption of ACRSP technologies in ACRSP Host Countries, Nairobi, Kenya, January 21-27, 2006.
- Bolivar, Remedios B., 2005. Tilapia feeding strategies to optimize production in semi-intensive pond culture & CRSP at CLSU. Training information exchange on Cichlid culture and the adoption of ACRSP technologies in ACRSP Host Countries. Panamerican Agricultural School (Zamorano), Honduras, 8-13 October 2005.
- Bolivar, Remedios B., 2005. Tilapia feeding strategies to optimize production in semi-intensive pond culture & CRSP at CLSU. Training information exchange on Cichlid culture and the adoption of ACRSP technologies in ACRSP Host Countries. UJAT, Villahermosa, Mexico, 1-7 October 2005.

#### Workshops/Seminars/Educational Outreach

- Bolivar, Remedios B., 2005. Design and lay-out of fishpond; principles of pond fertilization, feeding strategies. Victoria, Ilanera, Nueva Ecija, Philippines, 18 December 2005.
- Bolivar, Remedios B., 2006. Principles of pond fertilization, feeding strategies. Sto. Nino Ist, San Jose City Nueva Ecija, Philippines, 7 January 2006.
- Bolivar, Remedios B., 2006. Principles of pond fertilization, feeding strategies. Lupao, Nueva Ecija, Philippines, 8 January 2006.
- Bolivar, Remedios B., 2006. Tilapia feeding strategies. CLSU College of Fisheries Science City of Munoz, Nueva Ecija, Philippines, 23 January 2006.
- Bolivar, Remedios B., 2005. Delayed Feeding Strategy (Lecture and Farm Visitation). Sto. Cristo, Gapan, Nueva Ecija, Philippines, 17 September 2005.
- Bolivar, Remedios B., 2005. Delayed and Alternate Day Feeding Strategy (Lecture and Farm Visitation). Soledad, Cabanatuan City, Nueva Ecija, Philippines, 18 September 2005.
- Bolivar, Remedios B., 2005. Sub-satiation and Alternate Day Feeding Strategy (Lecture and Farm Visitation). Malimba, Gapan, Nueva Ecija, Philippines, 8 October 2005.
- Bolivar, Remedios B., 2005. Principles of Pond Fertilization, Feeding Strategies (Lecture). College of Fisheries, CLSU, Muñoz, Nueva Ecija, Philippine, 5-9 September 2005.
- Bolivar, Remedios B., 2005. Feeding Strategies (Lecture). Institute of Graduate Studies, CLSU, Muñoz, Nueva Ecija, Philippine, June from October 2005.

Bolivar, Remedios B., 2005. Tilapia feeding strategies. CLSU College of Fisheries, Science City of Munoz, Nueva Ecija, Philippines, 6 December 2005.

#### INSULIN-LIKE GROWTH FACTOR-1 GENE EXPRESSION AS A GROWTH INDICATOR IN NILE TILAPIA

*Twelfth Work Plan, Production System Design and Integration 5 (12PSD5)*

##### Abstract

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##### ABSTRACT

IGF-I, a mitogenic polypeptide, is an important regulator of growth in fish. The potential of IGF-I mRNA abundance as a rapid growth indicator in Nile tilapia (*Oreochromis niloticus*) was evaluated. Hepatic IGF-I cDNA was isolated and partially cloned. The partial 539-base sequence encodes for the signal peptide, mature protein, and a portion of the E domain. The deduced 68 amino acid sequence for mature IGF-I showed 84–90% and 77–79% sequence identity with fish and mammalian counterparts, respectively. The deduced amino acid sequence for domains B and A was most conserved (93–97%) relative to other fishes. A sensitive TaqMan real time qRT-PCR assay for *O. niloticus* was developed based on the mature IGF-I peptide for measures of hepatic IGF-I mRNA levels. Hepatic IGF-I mRNA levels were found to be significantly correlated with growth rate of 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-derived IGF-I plays a key role in controlling growth in *O. niloticus* and indicates that IGF-I mRNA quantification could prove useful for the rapid assessment of growth rate in this species.

Additional studies undertaken by our group have shown that IGF-1, and consequently growth, are influenced by temperature, social status, and photoperiod. The growth rate of fish reared in warmer temperatures was significantly increased in a time dependent manner ( $r = 0.93$ ). Mean hepatic IGF-I mRNA levels in fish reared at warm temperature for two, five, and seven days were elevated 1.6-fold, 2.5-fold, and 3.6-fold, respectively, compared to that of fish reared at cold temperature.

A fish's relative position in the social hierarchy consistently influenced levels of IGF-I mRNA in the liver and eye color pattern. Lower social status correlated with depressed hepatic IGF-I levels while dominant status stimulated hepatic IGF-I production.

## DEVELOPMENT OF NILE TILAPIA FILLETS AS AN EXPORT PRODUCT FOR THE PHILIPPINES

*Twelfth Work Plan, Production System Design and Integration 6 (12PSD6)*

*Abstract*

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### ABSTRACT

The experiment was undertaken to determine the culture period for Nile tilapia (*Oreochromis niloticus*) to reach an average weight of 600 g at a stocking size of 50–120 g. This is the approximate size required for the production of fillets to serve export markets. The grow-out study was conducted in six 500 m<sup>2</sup> earthen ponds. GET-ExCEL Nile tilapias were stocked at a density of 1 pc m<sup>-2</sup> (Treatment I) and 2 pcs m<sup>-2</sup> (Treatment II).

Analysis of variance revealed no significant differences in the initial weights of the fish between treatments ( $P>0.05$ ). After a culture period of four months, harvested fish in Treatment I had a mean weight of 590.17 g while in Treatment II, they had a mean weight of 512.99 g. Similarly, there was no significant difference for the mean final weights of fish between treatments. There were also no significant differences in the mean final length, mean survival rates, daily weight gains, specific growth rates, feed conversion ratios, or feed conversion efficiencies of the fish stocks in the two treatments ( $P>0.05$ ). Significant differences ( $P<0.05$ ) were observed between the extrapolated fish yield in Treatment I ( $5,250.93 \pm 313.05$  kg ha<sup>-1</sup>) and Treatment II ( $8,256.43 \pm 423.16$  kg ha<sup>-1</sup>) and on fish biomass in Treatment I ( $219.84 \pm 15.93$  kg) and Treatment II ( $327.77 \pm 21.91$  kg).

The percent fillet recovery was highest in fish sizes ranging from 601–700 g which had a mean value of 36% while fish size ranging from 701–800 g and 501–600 g had 34.99% and 34.03% fillet recovery, respectively. Our economic analysis showed that Treatment I had better cost-benefit ratio compared with Treatment II. This suggests that rearing of Nile tilapia at a density of 1 pc m<sup>-1</sup> was more profitable for the production of tilapia for fillet production.

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# Philippines-Thailand Project: Production Technology

Philippines, Thailand  
Subcontract No. RD010A-11 (UA)



During the Tenth Work Plan, the Aquaculture CRSP funded a survey identifying tilapia-shrimp polyculture production operations in Honduras, Mexico, the Philippines, Thailand, and Vietnam. Results from these surveys indicated that many shrimp ponds have been abandoned due to disease, poor management, and environmental degradation. Raising tilapia with low densities of shrimp in abandoned shrimp ponds could help support local fish farmers that did not benefit from the earlier shrimp farming boom. To this end, the Aquaculture CRSP funded on-farm research trials to study the production of tilapia and shrimp in polyculture. During this reporting period, two studies are ongoing to evaluate and compare tilapia-shrimp polyculture in Mexico and the Philippines. The Mexico component is reported in the Mexico Project: Watershed Management section of this report. The Philippines component is reported here. This research involves collaborators from the University of Arizona, Central Luzon State University (the Philippines), and the Asian Institute of Technology (Thailand).

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## Work Plan Research

- Tilapia-Shrimp Polyculture in Negros Occidental, Philippines/ 12PSD7. A progress abstract was submitted for this investigation.

## Publications

- Fitzsimmons, K., 2006. Tilapia Markets 2006. 3rd International Technical Seminar and Trade Meeting on Tilapia. Xiamen, CHINA, pp. 1–5.
- Watanabe, W., K. Fitzsimmons, and Yang Yi., 2006. Salt water culture of tilapia. In: Webster, C. and Lim, C., eds. Tilapia Culture, Nutrition, and Feeding. Hawthorn Press, pp. 51–70, 347–427, 607–619.
- Fitzsimmons, K. 2005. ISTA 6 in Manila. Aquaculture Asia-Pacific 1:8.

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- Cruz, Phillip, 2006. Advances in shrimp farming on Negros Island, Philippines. AQUA 2006, Annual Meeting of the World Aquaculture Society, Florence, Italy, 9–13 May 2006.
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## TILAPIA-SHRIMP POLYCULTURE IN NEGROS OCCIDENTAL, PHILIPPINES

*Twelfth Work Plan, Production System Design and Integration 7 (12PSD7)*  
Abstract

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## ABSTRACT

The tilapia-shrimp polyculture project on Negros Island in the Philippines started quickly, but was then slowed considerably when our industry partner (FYD International) left the project. Students who had begun research were delayed until another farm location was identified with a new industry partner. Our new partner, Cruz Aquaculture, has been a good collaborator and we are back on track and expect to have the research and reporting completed within the period of the extension.

Specifically we will be comparing three different polyculture styles, a sequential method having tilapia in one pond and passing the same water to a shrimp pond, and two simultaneous methods — the first having tilapia in cages in shrimp ponds and the second having tilapia loose in shrimp ponds. We will focus on production results (fish and shrimp yields and survival, feed conversion ratios, and cost and benefits), water quality parameters (dissolved oxygen, secchi disk measurements, total chlorophyll, and temperature), and microbiology (algae counts and bacterial populations).

Tilapia-shrimp polyculture has been adopted and adapted in many of the shrimp farming regions of the world and we hope to better define the methodologies and provide guidance as to which practices seem to be most beneficial.



# Amazon Basin Project: Production Technology

Peru, Bolivia, Colombia, Brazil, Ecuador  
Subcontract No. RD010A-12 (SIUC)  
Subcontract No. RD010A-13 (UAPB)  
Subcontract No. RD010E-A (OhSU)



The Peru Project has been active since 1996 under the lead of Southern Illinois University at Carbondale (SIUC). SIUC collaborates with the Universidad Nacional de Colombia (UNAL-Colombia), Universidad Federale do Amazonas (UFAM-Brazil), Fundacion Arcoiris (Ecuador), Instituto de Investigaciones de la Amazonia Peruana (IIAP), and the Peace Corps Ecuador through a shared Memorandum of Understanding. Additional separate subcontract relationships exist within the Amazon Basin Project between The Ohio State University and Universidad Nacional Mayor de San Marcos, with IIAP and the University of Arkansas at Pine Bluff, and with IIAP. Beginning in the Eleventh Work Plan, the Amazon Basin Project expanded its scope to address broader issues throughout the Amazon region. As a result, numerous additional partnerships have been fostered with Fondo Nacional del Desarrollo Pesquero (Peru), Universidad Mayor de San Simón (Bolivia), Instituto Nacional de Pesquisas da Amazonia (INPA-Brazil), EMBRAPA (Brazil), Instituto Amazónico de Investigaciones Científicas SINCHI (Colombia), and Comunidad Indígena Sarayaku (Ecuador). Research during the reporting period focused on the development of broodstock and appropriate diet formulations for indigenous Amazonian fishes. Outreach activities include a series of workshops designed to promote sustainable aquaculture development throughout the region.

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Susan T. Kohler	US Co-Principal Investigator
William N. Camargo	Research Associate

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Edgar Guillen Collaborator

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Thomaz Jordão de Sousa Ayres Graduate Student (Brazil)

Thiago Mendes Freitas Undergraduate Student (Brazil)

César Victorino de Melo Undergraduate Student (Brazil)

### Work Plan Research

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

- Nutrition and nutrient utilization in native Peruvian fishes/ 12FNF2. A final abstract was submitted for this investigation.
- Broodstock development of Amazonian fishes/ 12ISD2. A final abstract was submitted for this investigation.
- Amazon aquaculture outreach/ 12SDF1. A final abstract was submitted for this investigation.
- Amazon aquaculture outreach: Fifth International Aquaculture Extension Course in the Amazon region and first meeting for the Amazon region aquaculturists/ 12SDF5. A final abstract was submitted for this investigation.
- Effects of native Peruvian feedstuffs on growth and health of *Colossoma* and *Piaractus*/ 12FNF1. A progress abstract was submitted for this investigation.
- Broodstock development and larval feeding of Amazonian fishes/ 12ISD4. A progress abstract was submitted for this investigation.

### Publications

Camargo, W.N., C.C. Kohler, S.T. Kohler, F.B. Alcántara, C.A. Sias, and M.P. Silva, 2005. Live diets for pacu larvae tested in Peru. *Aquaculture Advocate*. (Magazine Article). Dec. 2005. 8:78–80.

Campos-Baca, L. and C.C. Kohler. Aquaculture of *Colossoma macropomum* and Related Species in Latin America. *American Fisheries Society Symposium*. 46: 451–561.

### CD-ROM

SIUC, CRSP-USAID, Fundación Arcoiris, USAID Ecuador, CARE, PSUR, Plan Binacional, Instituto Tecnológico Salesiano de Sevilla Don Bosco, Global Water for Sustainability (GLOWS) Program, Municipio de

Huamboya, Peace Corps Ecuador, COMAGA, FUNDACYT, OPIP, Consejos Provinciales de Morona Santiago, Sucumbios y Napo, Alcaldía de Macas, Gobernación, Museo Ecuatoriano de Ciencias Naturales (MECN), Organizaciones de Productores Rurales y Asociaciones/ Colegios Profesionales. V Curso Internacional de Extensión en Acuicultura en la Amazonía y I Encuentro de Acuicultores de la Región Amazónica. Fundación Arcoiris, Macas, Ecuador. 11–15 April 2006

### Theses

Palacios, Maria Esther, 2006. Nutritional optimization of pacu *Piaractus brachypomus* Cuvier using atypical plant ingredients. Degree: Master in Aquatic Resources with mention in Aquaculture. Biological Sciences Faculty, Universidad Nacional Mayor de San Marcos, Peru. 01 August 2006.

### Presentations

Camargo, W.N., F.W. Chu-Koo, C.C. Kohler, and C. Kasper, 2006. Evaluation of Three Plant Feedstuffs on Growth Characteristics of Amazonian Black-Finned Pacu (*Colossoma macropomum*). Las Vegas, USA. 13–16 Feb. 2006.

Chu-Koo, F.W., W.N. Camargo, C. Kasper, M. Alvan and C.C. Kohler, 2006. Feasibility of Using Barium Carbonate as Alternative Marker for Digestibility Studies in Black-Finned Pacu *Colossoma macropomum* and Red-Belly Pacu *Piaractus brachypomus*. WAS Aquaculture 2006, Florence, Italy, 9–13 May 2006.

Dabrowski, Konrad, 2006. Regulating dietary intake of nutrients-balancing act between control of appetite and metabolism. *Aqua Ciência* 2006, Bento Gonçalves, Brazil. 14–17 August 2006.

Dabrowski, Konrad, 2006. Perspectivas para o desenvolvimento de dietas artificiais adequadas para a alimentação de larvas e juvenis de pexes [Perspectives



for the development of adjusted artificial diets for the feeding of juvenile larval fish]. Workshop: Larvicultura de Peixes Neotropicais. Center of the Sao Paulo State University in Jaboticabal, Brazil. 12 August 2006.

Dabrowski, Konrad, 2006. *Experiencia de cultivo de Pseudoplatystoma spp* nos estados [Experience of *Pseudoplatystoma spp* culture in the United States]. Aquaculture Center of the Sao Paulo State University in Jaboticabal, Brazil. 12 August 2006.

### Workshops/Education and Outreach

Several education and workshop outreach activities occurred during the 2005-2006 annual reporting year. These include: lecture series, which colleague Konrad Dabrowski presented to graduate students at Bento Gonçalves, Brazil, on 14 August 2006; a workshop entitled 1er Curso Basico en Aspectos Economicos de la Piscicultura, attended by nine farmers in Iquitos, Peru on 28-29 October 2005; a workshop entitled Alimentación y Cultivo de Peces en Jualas, given to 11 members of the Indigenous community of Cahuide at Alto Itaya River, Peru on 28-29 January 2006. In addition, 124 participants — 65 from the Indigenous community and small scale producers (9 female, 56 males) and 59 students and professionals (11 females, 48 males) — attended the 5th International Aquaculture Extension Course in the Amazon Region and the 1st Aquaculturist Meeting from the Amazon Region at Salas de Conferencias de La Voz del Upano in Macas, Ecuador on 11-15 April 2006. On 12-14 April 2006, the II International Fish Culture Fair (Brazil, Colombia and Peru) was held for farmers and the general public at Parque Da Suframa in Tabatinga, Brazil.

Extensionists — aside from offering the extension service (site visits, construction assistance or upgrading of fish culture ponds, monitoring water quality) to more than 110 producers — continue to offer training courses to students and teachers (both natives and settlers) from high schools and vocational schools in Iquitos, Peru, and Leticia Colombia. The extensionist in Leticia, in collaboration with the National Learning Service (SENA, Colombia), informed the communities on fish culture as well as offering information on how to diversify crops through the use of apiculture (using local stingless honey producing bees), and transformation of some of their products, like fish into fish meal, to expand the efficiency and productivity of their livelihood. Our extensionist, Gabriel Barreto, in Leticia, Colombia is collaborating with government officials and NGOs to create a basic fisheries and aquaculture ordinance for the Amazon Department (Colombia). The extensionist in Colombia is assisting government officials in assessing the fish landing at the Leticia fish market in order to determine the number of species captured, seasonal prices, sizes, volume, and origin (Brazil, Peru, or Colombia) to determine when to commercialize cultured fish and at which size.

In April 2006, colleague William Camargo travelled to Colombia, Peru, and Ecuador to meet HC personnel (country scientists, government officials, extension agents, farmer organizations, farmers, and NGOs) and to inspect collaborative work performed. He also travelled to the 5th International Aquaculture Extension Course in the Amazon Region and the

1st Meeting for the Amazon Region Aquaculturists in the city of Macas, Ecuador, from 11-15 April 2006.

Camargo and Edgar Guillen (USAID Ecuador) contacted Michael McClain (Associate professor, Department of Environmental Studies at Florida International University) who is in charge of the Global Water Sustainability Program (GLOWS, funded by USAID). The contact was made to join efforts in the organization of two events that were held in the city of Macas, Ecuador this past April. GLOWS donated over \$5,000 USD in international airplane tickets to sponsor the presenters of these events from Brazil, Peru and Colombia. Peace Corps Ecuador (USAID funded) also participated in the organization of these events. Through our Colombian extensionist (at the National University of Colombia), we are working with the Dutch University of Larestein (Netherlands) and the National Educational Service (SENA) to develop participative productive programs for the local community. The Dutch University of Larestein has committed 1 million Euros to strengthened aquaculture education programs in the Colombian Amazon region.

### NUTRITION AND NUTRIENT UTILIZATION IN NATIVE PERUVIAN FISHES

*Twelfth Work Plan, Fish Nutrition and Feed Technology 2 (12FNF2)*

*Final Report*

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### ABSTRACT

Black-finned pacu, *Colossoma macropomum* (Characiformes: Characidae), is the second-largest scaled, freshwater fish in South America. It is native to the Amazon Basin and possess many characteristics suitable for aquaculture. Black-finned pacu is in high demand and attains a high price at the marketplace. However, no formulated diets are available specifically for *C. macropomum* culture. Consequently, a wide range of ingredients for locally manufactured formulated diets is used in countries where this fish is cultured. These diets have variable crude protein (CP) ranging from 18 to 43% and the supplied ration ranges from 1 to 5% of the fish wet body weight. Commonly wheat, corn, or rice serve as one of the main energy sources in these formulated diets. As wheat is not traditionally cultured in the Amazonian region, it has to be imported from distant regions, thus limiting its use for direct human consumption. A growth experiment was conducted to determine the effect of substituting three alternative ingredients for wheat middlings on growth performance and conversion efficiency of *C. macropomum*. Fish ( $86.9 \pm 6.4$  g) were fed four practical diets: 1) control (31.8% CP), 2) cassava (27% CP), 3) plantain (27.5% CP), and



4) palm peach (28.1%) for a 24-wk period and their weight (g), length (cm), specific growth rates (SGR), feed conversion ratio (FCR), and protein efficiency ratio (PER) were determined and compared. Fish were fed 3% of body weight/day divided in two daily rations. Weight and length were measured every two weeks to adjust their feed allotments. Final mean weights for *C. macropomum* fed the control, cassava, plantain, and palm peach diets were 538.8, 559.0, 552.7, and 527.4 g, respectively, and were not significantly different ( $P < 0.05$ ); final mean weight gained in each treatment were 458.2, 476.2, 465.8, and 437.8 g, respectively, and were also not significantly different ( $P > 0.05$ ). SGR and FCR did not significantly influence dietary treatments ( $P > 0.05$ ); however, PER was significantly affected ( $P < 0.05$ ). Based on the findings, we conclude any of the tested ingredients (cassava, plantain, or palm peach meal) might serve as carbohydrate sources in formulated diets for *C. macropomum* without negatively influencing the fish growth performance.

In a second experiment, the digestible energy and apparent nutrient digestibility coefficients of three plant-source ingredients common to the Amazon Basin, pijuayo (*Bactris gasipaes*), plátano (*Musa paradisiaca*), and yuca (*Manihot sculenta*), were determined for black-finned pacu (61.05 ± 16.96 g). Fish were fed pelleted practical diets to apparent satiation and the feces were collected in specially designed chambers. The digestibility value for each ingredient was determined by comparison to the digestibility of the test diet to a reference diet (27.6% crude protein and 1% chromic oxide). The digestible energy values of pijuayo (PI), plátano (PL), and yuca (YU) were 4,518, 4,386, and 4,355 kcal/kg, respectively, while the apparent dry matter digestibility coefficients were 91.7, 87.6, and 65.8%, respectively. The apparent crude protein digestibility coefficients were 81, 32.9 and 30.1% for PI, PL, and YU, respectively, and the apparent lipid digestibility coefficients were 89.0, 77.9, and 41.2%, respectively. These results suggest that of the three plant sources tested, only pijuayo can likely be utilized as an ingredient in commercial pelleted diets for black-finned pacu without compromising the assimilation of dietary intake of protein, lipids, or dry matter.

#### BROODSTOCK DEVELOPMENT OF AMAZONIAN FISHES

*Twelfth Work Plan, Indigenous Species Development 2 (12ISD2) Final Report*

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#### ABSTRACT

Forty-two *Piaractus brachipomus* broodstock between 4.0 and 5.0 kg for males and 4.1 and 5.9 kg for females were stocked in three earthen ponds at the La Terraza Aquaculture Research Facility of the Universidad Nacional de Colombia (Meta, Colombia). Selection factors for male and female broodstock, respectively, were semen release with a slight pressure on abdomen, or the presence of an enlarged flaccid abdomen, enlarged-reddish genital papillae, and egg nucleus migration for eggs sampled by catheter. Broodstock were pit-tagged and randomly distributed in three 250-m<sup>2</sup> ponds (14 per pond: even sex distribution). Water quality was modified to simulate the three most common Amazon ecosystems where these fish naturally inhabit to evaluate water quality as a fish reproduction-conditioning factor. The three treatments were: T<sub>1</sub>: pH = 6, high tannic acid (1.20 mg/L), and conductivity (197 µs/cm); T<sub>2</sub>: pH = 7, low tannic acid (0.42 mg/L), and conductivity (157 µs/cm); and T<sub>3</sub>: pH = 8, low tannic acid (0.14 mg/L), and conductivity (131 µs/cm). All treatments were characterized by having low alkalinities (<34 mg/L) and hardness (<62 mg/L). Temperature, DO, pH, and conductivity were monitored three times per day (07:00; 12:00, and 17:00), CO<sub>2</sub> and ammonia were monitored once daily (07:00), and hardness, alkalinity, tannic acid, ammonium, nitrite, nitrate, sulphate, phosphate, and sulphite were monitored once weekly. After 33 days, fish were induced to spawn by hormonal injections (carp pituitary extract), and eggs from each female per treatment were fertilized with sperm from a separate male from the same treatment. Egg volume was calculated and eggs were incubated separately for each treatment to evaluate fertilization and hatching percentage. Blood samples were taken prior to, and at the time of, hormonal injection from at least four fish of each sex per treatment. Blood samples were collected for hematocrit evaluation, and remaining blood was immediately frozen for later hemoglobin and steroid hormone (testosterone and estradiol) analysis. Two males and two females per treatment were anesthetized with MS-222 and euthanized to verify gonadal development macroscopically and to determine gonadosomatic index (GSI). Additionally, gonad portions were fixed in 6% buffered formalin for histological analysis. Spawning success was considered as the final indicators of treatment effect. Survival was 100% for the two higher pH and low tannic acid treatments, while it was 42.8% for the lowest pH and high tannic acid treatment (3 males and 3 females died of hypoxia). Female individuals from the T<sub>1</sub> (lowest pH, high tannic acid, and high conductivity) treatment presented the best macroscopic gonad maturation characteristics; all males (n=4) from the same treatment released sperm upon a slight abdominal pressure. Similarly, fertilization rates were 74.3% for the same treatment, and GSI values were relatively high for T<sub>1</sub> males (0.29–0.41) and very high for the T<sub>1</sub> females (13.8–20.6). No fertilization rates were calculated for the other two treatments (T<sub>2</sub> and T<sub>3</sub>) since no gamete products were concurrently available from both genders; further, GSI values were low for both T<sub>2</sub> males (0.09–0.10) and T<sub>3</sub> males (0.10–0.11) and relatively high for T<sub>2</sub> females (4.56–9.16) and T<sub>3</sub> females (6.37–8.62). The results will be confirmed and conclusions will be presented after performing statistical analysis on all the collected data.

**AMAZON AQUACULTURE OUTREACH**

*Twelfth Work Plan, Sustainable Development and Food Security 1 (12SDF1)*

*Final Report*

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**ABSTRACT**

Outreach activities have significantly benefited over 129 producers and their families (256 ponds having 90 ha) in the Peruvian Amazon (Iquitos-Nauta) and 78 producers (23 females, 37 males, and 18 teenagers) and their families in the Colombian Amazon (Leticia), the latter group being in its first year of extension activities. Additionally, the two ACRSP-funded extensionists have provided aquaculture training to 68 vocational high school students and Aquaculture Cooperative members (25 females and 43 males) in the Amazon Basin (Brazil, Colombia, Ecuador, and Peru). One of our extensionists (Pedro Ramirez) from Peru was in an exchange program, initiated in WP11, in the Ecuadorian Amazon for one month, training a total of 69 (12 females and 57 males) producers in two basic aquaculture training courses held in El Puyo and Macas. The training courses helped provide technical assistance in aquaculture techniques to local and prospective fish farmers. Fifty-seven individuals representing Ecuador, Brazil, Colombia, Venezuela, and Peru participated in the “4<sup>th</sup> International Training Course of Prominent Amazonian Aquaculture Species for Students and Professionals”, which was held in the National University, Leticia Campus, Colombia, from 21–24 July 2004. Twenty producers and farmers representing Brazil, Colombia, and Peru participated in the “4<sup>th</sup> International Training Course of Prominent Amazonian Aquaculture Species for Producers” that was held in Leticia, Colombia, from 22–24 July 2004. Eighteen participants representing Brazil and Colombia attended the “1<sup>st</sup> International Training Course of Ornamental Amazonian Fish Species” that was held in Leticia, Colombia from 25–27 July 2004. The Amazonian aquaculture website, developed in WP10, is being maintained. This site is an important tool to communicate the work done by research institutions in the US, many Amazon basin nations, and elsewhere (over 16,000 hits from 1 August 2004 through 31 July 2006).

**AMAZON AQUACULTURE OUTREACH: 5<sup>TH</sup> INTERNATIONAL  
AQUACULTURE EXTENSION COURSE IN THE AMAZON  
REGION AND 1<sup>ST</sup> MEETING FOR THE AMAZON REGION  
AQUACULTURISTS**

*Twelfth Work Plan, Sustainable Development and Food Security 5 (12SDF5)*

*Final Report*

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#### ABSTRACT

The 5th International Aquaculture Extension Course in the Amazon Region and the 1st Meeting for the Amazon Region Aquaculturists are part of a series of events in the Amazon region since 2002 that have been successfully organized by Southern Illinois University at Carbondale (SIUC). The outreach activities have been implemented with the collaboration of several Amazon institutions and funded partially by the United States Agency for International Development and the ACRSP. Two intensive training courses (one for producers/indigenous communities and another for professionals/students) were presented to a large group (124 participants: 20 females and 104 males; 65 indigenous community and small-scale producers; and 59 students and professionals) of governmental and non-governmental personnel conducting aquaculture research and/or extension activities in Bolivia, Brazil, Colombia, Ecuador, Peru, or Surinam. Both events were held from 11 to 15 April 2006 in the Macas Salesian Institute and the Voz del Upano conference auditorium in the city of Macas, Ecuador. For each course, 10 qualified candidates from Ecuador's neighboring Amazon countries were invited to participate, as well as a similar number from Ecuador. The main objectives of these courses were to: 1) train participants on the use of technological tools (pond construction, broodstock selection and handling, spawning techniques, incubation, larviculture, grow out, and disease prevention and treatment); and 2) facilitate the exchange of strategies, experiences, and learned lessons on rural aquaculture extension for the management and reproduction of native Amazon species (i.e., *Colossoma* sp., *Piaractus* sp., *Arapaima gigas*, *Prochilodus* sp., *Brycon* sp., and *Ampularia* sp.). A CD-ROM displaying all the course material for the Amazon aquaculture training course was also produced.

#### EFFECTS OF NATIVE PERUVIAN FEEDSTUFFS ON GROWTH AND HEALTH OF *COLOSSOMA* AND *PIARACTUS*

*Twelfth Work Plan, Fish Nutrition and Feed Technology 1 (12FNF1)*

*Abstract*

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#### ABSTRACT

A feeding trial with juvenile (22.5 g) *Colossoma macropomum* was conducted at the University of Arkansas at Pine Bluff to determine the effects of cooked or uncooked plant feedstuffs (plantain, pijuayo, and yucca) on fish growth, survival, and health. These high-carbohydrate feedstuffs are readily available in Peru and have the potential to replace more expensive or less available ingredients in Characid diets. The control diet was similar to a commercial formulation for channel catfish (containing fish meal, soybean meal, wheat, corn, rice bran, soybean oil, and supplemental vitamins and minerals). The experimental feedstuffs replaced wheat in the control diet. Starch was the primary carbohydrate in wheat and all of the test feedstuffs. The available energy from cooked starch is reportedly higher than that from uncooked starch in some fish species, so we tested both versions of each feedstuff within the same trial. Diets were similar in total protein (33–34%) and other ingredients except for the experimental feedstuffs (inclusion rate: 30%). Growth rates were high, and three fish were removed from each tank six weeks into the study to allow the remaining fish to resume rapid growth. Liver glycogen of the fish that were removed from the study did not differ due to dietary treatment. After 12 weeks, there were no differences in growth or survival of fish due to diet. Lysozyme activity was not detected, but it is possible that the pH used in our standard protocol is not appropriate for this species. Additional work is needed to determine the optimal pH for lysozyme assays for *C. macropomum* (and for *P. brachypomus*, which also had no detectable lysozyme activity in a previous trial). Based on growth, survival, and liver glycogen, these feedstuffs are all suitable, practical carbohydrate sources for *C. macropomum*. Furthermore, there was no indication that cooking increased the available energy of plantain, pijuayo, or yucca for this species.

## BROODSTOCK DEVELOPMENT OF LARVAL FEEDING OF AMAZONIAN FISHES

*Twelfth Work Plan, Indigenous Species Development 4 (12ISD4) Abstract*

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### ABSTRACT

We reproduced South American catfish (surubim, *Pseudoplatystoma* sp.) successfully in our facility. On 6 February, 2006, fish were checked for signs of maturity (release of sperm by gentle pressure of the abdomen in males and oocyte biopsy using a catheter in females). Sperm was collected from two males weighing 3,599 (male 1) and 3,521 (male 2) g, respectively. Sperm concentrations reached  $24 \times 10^9$  and  $15.5 \times 10^9$  spz/ml in male 1 and male 2, respectively. Oocytes were collected from six females varied from 1,936 to 4,605 g in mass and were fixed in Bouin's solution. Oocytes were measured for each female and their diameter varied from  $0.30 \pm 0.08$  to  $0.74 \pm 0.06$  mm. These females as well as males which produced sperm on 6 February, and two other potential males, were then injected with carp pituitary extract (0.5 mg/kg).

On 13 February 2006, the females which were injected before were injected again with two doses of carp pituitary extract (0.5 and 5 mg/kg) at 11-h interval. Then these fish were observed regularly after treatment in accordance with the description given for propagation of *Pseudoplatystoma fasciatum*.

On 14 February 2006, 9 h after the second injection, 47.9 g of eggs ( $\sim 114,500$  eggs,  $0.62 \pm 0.09$  mm in diameter) were produced by a female weighing 2,064 g. Sperm samples were collected from males 1 and 2. Sperm from each individual male was used to fertilize eggs (2 g). The remaining eggs were inseminated with a mixture of sperm. Temperature was  $25^\circ\text{C}$  at fertilization and ranged from  $25$  to  $27^\circ\text{C}$  during the incubation period. Embryo survival 9 h after fertilization was 44 and 23% for male 1 and male 2, respectively. Embryos hatched at 11 p.m., 15 h after fertilization. Larvae were  $3.53 \pm 0.09$  mm in length at hatching.

On 17 February, following the yolk sac absorption, larvae were transferred and distributed into 12 aquaria with a semi-recirculated system at approximately 120–150 larvae per tank. Larval size was  $5.15 \pm 0.42$  mm at that time. Temperature was adjusted to  $28^\circ\text{C}$ . Salinity was adjusted at 2 ppt by adding Instant Ocean (Aquarium Systems Inc., Mentor, Ohio, US) salt to the system. Three groups of larvae were fed blood worms and nine groups were fed newly hatched *Artemia nauplii* after stocking. Blood worm (*Chironomus*) was a homogenate of frozen worms (Fish King Inc., Chicago, IL, USA) with water (1:1). *Artemia* was accepted right away. Fish were kept in constant dark. On February 24, larvae were provided with a formulated, commercial food (Aglo Norse, 500–710  $\mu\text{m}$ ) and transition was successful.

On 30 March, juvenile surubim were distributed in 24 aquaria in a semi-recirculated system at the density of 18 fish per tank. Nine casein-gelatin based diets with different protein/lipid levels were formulated. Protein levels were 40, 45, and 50%, and lipid levels were 12, 16, and 20%. Six weeks after the first feeding, survival averaged  $57.8 \pm 10.0\%$  among the treatments with no significant differences. Final individual weight did not differ between the dietary treatments and the average weight gain was  $2,124.2 \pm 295.7\%$ .





# Central America Project: Production Technology

Honduras, Guatemala, Nicaragua, Dominican Republic  
Subcontract No. RD010A-16 (UG)  
Subcontract No. RD010A-17 (UA)



ADONIS GALLINDO

Honduras has been an ACRSP host country since the program's inception in 1982, excluding a brief interruption from 1987 to 1988 during the crisis created by Hurricane Mitch in late 1998. During the interruption, ACRSP research in Honduras moved from Comayagua to the Escuela Agrícola Panamericana El Zamorano (Zamorano). A Memorandum of Understanding was signed between Zamorano and the University of Georgia (UG) in October 1999, which served as lead institution until 2003. Auburn University (AU) is now the lead US institution. While Honduras serves as the focal point, research and outreach for the Central America Project occur in Nicaragua, Dominican Republic, and Guatemala as well. Ongoing Aquaculture CRSP research in Central America is focused on economics and marketing assessment, subsistence aquaculture for indigenous people, evaluating tilapia seed supply, training on production technologies, marketing, pond design and watershed analyses, and production of training materials and website information ([www.acuacultura.org](http://www.acuacultura.org)). Our more recent activities include work and training in Honduras, Nicaragua, El Salvador, Guatemala, the Dominican Republic and Chile.

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## Work Plan Research

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

- Evaluation and improvement of tilapia fingerling production and availability in Honduras/ 12SDA1. A final abstract was submitted for this investigation.
- Understanding the knowledge system for aquaculture development Nicaragua: economics, markets, and institutions/ 12SDF2. A final abstract was submitted for this investigation.
- Assessing the potential for aquacultural development to promote food security among indigenous people in Guatemala/ 12SDF3. A final abstract was submitted for this investigation.
- Pond design and watershed analyses training/ 12WQA1. A final abstract was submitted for this investigation.

In addition, the following Eleventh Work Plan investigations are ongoing during the reporting period:

- Spreadsheet tool for computing pond costs in developing countries/ 11WQAR3. A final abstract was submitted for this investigation.

## Theses

Meyer, Suyapa Triminio, 2005. Tilapia fingerlings production in Honduras. Auburn University. M.Sc. Thesis. 8 August 2005.

## Presentations/Conferences

Meyer, Suyapa Triminio, 2005. Evaluation and improvement of tilapia fingerling production and availability in Honduras. Rural Sociological Society Annual Meeting, Tampa, Florida, 8–12 August 2005.

## Workshops/ Educational Outreach

A workshop, Pond Design Techniques, was held in Santiago, in the Dominican Republic on 10 April 2006.

The workshop was hands on, with each of the 28 participants working through computer exercises. The workshop was organized by the Zamorano Alumni Association, with Pilar Martinez being the local host and interpreter. All handouts

and models were translated to Spanish prior to the workshop. The participants were left with a CD of all materials.

A Spanish-language manual designed for fingerling producers was developed to provide a technical outline of best management of tilapia broodstock. It has an estimated audience size of 5,000 Central American tilapia fingerling producers.

## EVALUATION AND IMPROVEMENT OF TILAPIA FINGERLING PRODUCTION AND AVAILABILITY IN HONDURAS

*Twelfth Work Plan, Seedstock Development and Availability 1 (12SDA1)*

### Abstract

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## ABSTRACT

The lack of an adequate supply of all-male tilapia fingerlings has been identified by fish farmers as a principal constraint to small- and medium-scale fish culture development in Honduras. A survey of tilapia fingerling producers was conducted to evaluate fingerling production and examine

the factors that influence the way farmers produce and distribute them. Sixteen farmers were identified and interviewed during the period from September 2003 to July 2004. Seed production is concentrated in valley areas of Olancho, Comayagua, and Cortez. Fingerling sex reversal with hormone-treated feed was practiced by 14 of the 16 farmers. Seven fingerling farms are family-owned, four are private companies, one is a cooperative, one is operated by a non-profit organization, another is run by a university, and two are government stations. From each of the farms and in the manner that would be used by a typical producer, a minimum of 1,000 fingerlings were purchased and transported to the aquaculture station at Zamorano for evaluation (count, uniformity of size, and uniformity of color). A sub-sample of 250 fingerlings purchased from each farm was reared to a size when sex identification was possible. The sex of each adult fish was determined by visual examination of the genital papilla to ascertain the percent of males in each sub-sample. In aggregate, the sample produces 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. Fingerling farmers have at least four to six years of formal education and fingerling production experience on average of 6.7 years with a range 0 to 25. This study considered three indicators of fingerling quality (uniformity of color, size and male gender). The results show that there is higher variability for color and gender than for size among the fingerling batches evaluated. This variability suggests that the quality of fingerlings delivered to tilapia farmers is not consistent. Most of the fingerling batches evaluated fall under the 90% level of uniformity of size, color, and gender. Only two independent variables had a significant relationship with fingerling quality. Farmer experience growing tilapia is positively related to fingerling quality production, but production training in itself was not related to fingerling quality as producing seed is a specialized and skilled activity. High variability in sex-reversal occurs in part because most farmers do not use standard methods of grading their fry and fingerlings by size, thus introducing inconsistency in hormone dosage and length of treatment. This is an area where training can accomplish improvement in the outcomes on the sex reversal practices as well the size uniformity of fingerlings sold. Feeding methods could be one source of low quality. Producers often do not count fry in the sex reversal process, thus feed they provide is often not well-gauged to the number of fish. Some reported that when the demand is high, they sometimes sell fingerlings before the recommended treatment period (28 to 30 days) is completed. Even though most farmers used the recommended protocol for the preparation of the hormone-treated feed (60 mg MT/kg of feed), some economize by lowering the dosage or using cheaper alcohol of a different type. Some use outdated hormone (more than four years old). One approach that has proven effective for some fingerling producers is to purchase prepared hormone feed from other farmers or institutions with more experience and access to the hormone source. Improving the level of practice among fingerling producers is a key step to improving quality and productivity in the industry.

## UNDERSTANDING THE KNOWLEDGE SYSTEM FOR AQUACULTURE DEVELOPMENT NICARAGUA: ECONOMICS, INSTITUTIONS AND MARKETS

*Twelfth Work Plan, Sustainable Development and Food Security 2 (12SDF2)*

*Abstract*

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### ABSTRACT

Tilapia culture has been practiced in Nicaragua for more than 25 years. In recent years, it has expanded rapidly in Nicaragua as in other Caribbean Basin Economic Recovery Act (CBERA) nations primarily to supply US markets for fresh and frozen fillets. This study assesses the export opportunities of Nicaragua in the fresh and frozen fillet markets in the US. It applies the approach suggested by Cuyvers et al. (1995) based on a combination of market growth rate and market share. Market shares are estimated applying a Linear Approximation of the Almost Ideal Demand System (LA/AIDS) model to the levels and differences of the variable imports from Andean nations, CBERA nations, and Asian nations. Since the world market share of Nicaragua is very small, imports from Nicaragua were included in those of CBERA nations; thus, Nicaragua's growth rate and market share behavior are inferred from CBERA estimates. The results indicate that the market for fresh and frozen fillets has a positive growth rate of 0.03 percent. However, the market share of Andean and CBERA nations are decreasing at a monthly rate of 0.032 and 0.036 %, respectively; whereas the Asian nations' share is increasing at a rate of 0.098 %.

In Nicaragua, production systems included mixed-sex culture and use of animal manure or inorganic fertilizer. Now producers are implementing more intensive approaches in ponds and cages to meet the demand of the export-oriented market. The new methods require a more complex farm management plan that should reflect the economic evaluation of production alternatives. In aquaculture, enterprise budget analysis has been the tool of choice to assess the financial viability of farm activities. Fingerling production, tilapia pond culture, and cage culture budgets were analyzed to estimate their profitability. The results indicate that fingerling production generates an estimated profitability of 11%; three-phase grow-out had a profit rate of 22%; and a subsidized project generated an economic loss of approximately 10%. However, with subsidy, producers get a profitability of 59%. One actual producer had a profitability of 6%, and farms using cage culture generated a profitability rate of nearly 15%.

The flow of information between researchers, extension agents, education institutions, and farmers involved in tilapia culture should produce technologies that better suit the needs of producers. Understanding the aquaculture knowledge system requires the identification of stakeholders and their interactions. Furthermore, it requires the documentation of producers' knowledge. In Nicaragua, the analysis of the Aquaculture Knowledge and Information System (AKIS) for small- and medium-scale tilapia culture revealed that the system is not well developed. Tilapia culture is a highly subsidized activity undertaken by only a small number of producers, mainly in Northern Nicaragua. The level of producer knowledge is low and other stakeholders do not take this into consideration. Researchers, extension agents, and education institutions do not often share or discuss their experiences with tilapia culture; each institution works largely in isolation. This analysis also shows that small- and medium-scale tilapia culture has not developed due to a pattern of government support that favors shrimp production over fish culture. Other obstacles include lack of domestic supply of good quality commercial feed and fingerlings as well as environmental controversy over large-scale tilapia culture in Lake Nicaragua. The future of small- and medium-scale tilapia culture depends on the successful development of export oriented tilapia culture that could attract other business such as input suppliers. The domestic market would develop with a high quality product meeting international standards.

#### **ASSESSING THE POTENTIAL FOR AQUACULTURAL DEVELOPMENT TO PROMOTE FOOD SECURITY AMONG INDIGENOUS PEOPLE IN GUATEMALA**

*Twelfth Work Plan, Sustainable Development and Food Security 3 (12SDF3)*

##### *Abstract*

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##### **ABSTRACT**

Guatemala is a multi-ethnic, multilingual, and highly stratified society in which 55% of its 14.7 million people are indigenous Maya, Xinca, and Garifuna peoples. The people of non-European origin are much poorer and reside in more remote and difficult to access locations than the wealthier Ladino minority. Freshwater pond area totals

about 100 ha, an area less than 10% of the total surface dedicated to shrimp production. Some additional 26 ha produce freshwater prawns for domestic consumption. In 1989, FAO reported that five tilapia species (*O. mossambicus*, *T. rendalli*, *O. niloticus*, *O. aureus*, and *S. hornorum*) have been introduced into the region and stocked in ponds, in large water bodies, or released in open watersheds. The Peace Corps and governmental technical assistance constructed nearly 600 small ponds in recent decades. Most ponds are managed on subsistence and semi-commercial levels, but the coffee crisis and growing market potential have increased interest in tilapia production. Fish are harvested for home consumption and surpluses are sold in local markets. Women often are responsible for the daily management and feeding of ponds while the men are primarily responsible for pond construction and harvest. Two case study areas were chosen where several indigenous communities have sustained involvement in tilapia culture over extended periods. Each set of communities is located at moderate altitudes in Central Guatemala in coffee-growing areas. Although the ponds are small, communal interest in tilapia production is sustained by the absence of alternative sources of fish. The study examines prospects for small- and medium-scale tilapia culture in Chimaltenango and Quetzaltenango — locales where the need is great, market access is often limited, and conditions are often less than optimal for production. The guiding questions are centered on understanding the motivating interests, barriers, and appropriate intervention points for aquacultural development in indigenous communities. Communities that practice fish culture seem to take pride in the communal accomplishment of developing the pond site and rearing repeated crops of fish. Although economic returns were not estimated by this study, they are unlikely to be competitive with capital costs. The amount of fish produced, even if all are sold at prevailing prices would not produce a return sufficiently motivating for most producers. Nonetheless, the enthusiasm and pride that residents expressed about their fish ponds reflect the community development achievements represented by aquaculture. The community achievement represented by a functioning pond that periodically yields quantities of fish was sufficiently motivating for the La Bendicion community to build an additional pond. Despite the pond's poor construction, lack of gravity flow water, and the disappointment stemming from the ill-functioning pump, participants seemed eager to find another way to build additional ponds in more appropriate locations. While lauding the enthusiasm exhibited in these communities, nongovernmental organizations and others advising indigenous rural communities in Guatemala should carefully address site selection and the community context for tilapia culture. Pumping costs are not typically part of an economically sustainable approach to tilapia culture in cool water areas. Water supplies should be sufficiently malleable and reliable to enable producers to fill and replenish ponds whenever water is needed. Thus, local spring, stream, and irrigation schemes represent possible sources for this foundational ingredient for pond aquaculture.

## POND DESIGN AND WATERSHED ANALYSES TRAINING

*Twelfth Work Plan, Water Quality and Availability 1 (12WQA1)*  
*Abstract*

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### ABSTRACT

In many parts of the world, including Central America, rainfall is highly variable throughout the year. This extreme variation in rainfall from month to month frustrates efforts to develop surface water as a viable alternative for water supply for aquaculture, irrigation, or other uses. Developing impoundments in regions with highly variable rainfall may lead to several times the volume of the pond effectively passing through the pond location and thus causing premature failure due to siltation. High runoff rates increase the risk of failure due to difficulties in achieving adequate spillway capacity.

The strategy advanced to address the variable rainfall-runoff while achieving useful water storage in ponds is to manage pond inflow by diverting most runoff into the pond during dry times and diverting most runoff away from the pond during wet months.

A simple rainfall-runoff catchment analysis model has been developed that can simulate monthly rainfall-runoff in small watersheds. The model runs on the Excel platform and can easily be implemented on any PC running Microsoft® Office. Twenty three inputs describe the catchment characteristics, pond area and depth, proposed pond spillway materials, and regional climatic variables. The user may also input a diversion factor for each month to simulation of diversion management strategies to assess impact on the pond feasibility. Using this information, the model computes runoff volume, pond volume, and spillway sizes. A scoring system may then be used to evaluate the suitability of the diversion management strategy. A scoring system ranging from 1 (unsustainable pond) to 5 (sustainable pond) was developed following trends in cumulative overflows and underflows. The model, with versions in English and Spanish, is available for public use.

A presentation series has been developed which consists of powerpoint presentations and a software CD. These presentations have been delivered in Nicaragua, Honduras, and the Dominican Republic in the past year.







# Mexico Project: Watershed Management

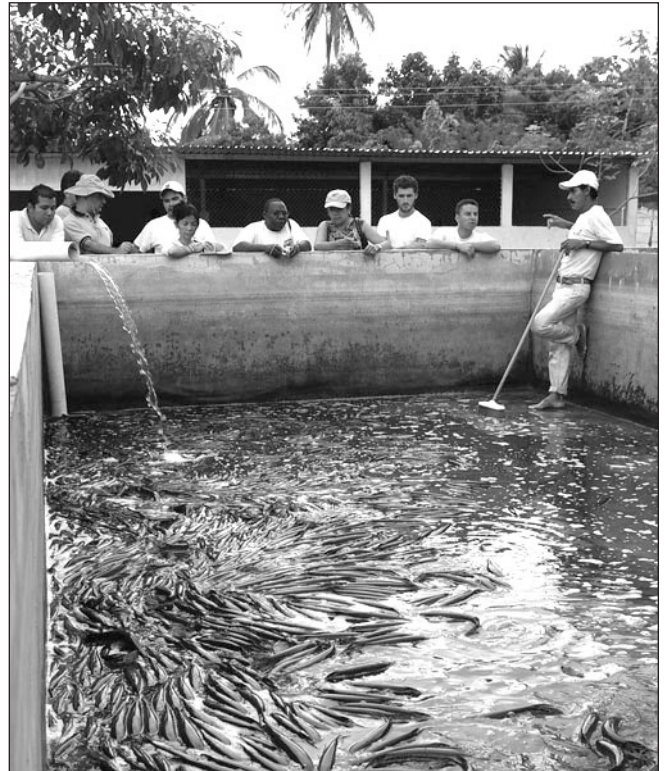
Mexico

Subcontract No. RD009C-01 (OSU)

Subcontract No. RD009E-A (OhSU)

Subcontract No. RD010A-11 (UA)

The ACRSP has been active in Mexico since 1997. A Memorandum of Understanding was signed between Oregon State University (OSU) and the Universidad Juárez Autónoma de Tabasco (UJAT) in June 1999. Following a recommendation from the Administrative Management Review in 2002, several ACRSP-funded Mexico projects at UJAT — involving Texas Tech University, The Ohio State University, and the University of Arizona — were consolidated to form a single umbrella Mexico Project with OSU serving as the lead. Present research within the Mexico Project emphasizes alternative methods of tilapia sex control, the incorporation of indigenous species into aquaculture practices, safe handling methods for masculinizing compounds, evaluation of tilapia-shrimp polyculture, selective breeding programs to enhance fitness of tilapia brood stock, and outreach work to disseminate our research findings to growers, extension agents, and educators.



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Rodriguez Graduate student  
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 Graduate Student (Mexico) (from July 2006)  
 Graduate Student (Mexico) (from July 2006)

### Work Plan Research

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

- Training local farmers on safe handling of steroids and masculinization techniques in Central America / 12ATE4. A final abstract was submitted for this investigation.
- Incorporation of the native cichlid *Petenia splendida* into sustainable aquaculture: Reproduction systems, nutrient requirements and feeding strategies / 12ISD3. A progress abstract was submitted for this investigation.
- Continuation of a selective breeding program for Nile tilapia to provide quality broodstock for Central America / 12SDA3. A progress abstract was submitted for this investigation.
- Elimination of methyltestosterone from intensive masculinization systems: Use of ultraviolet irradiation of water / 12WQA2. A progress abstract was submitted for this investigation.
- Elimination of methyltestosterone from intensive masculinization systems: Use of solar and bacterial degradation / 12WQA3. A progress abstract was submitted for this investigation.
- Testing three styles of tilapia-shrimp polyculture in Tabasco, Mexico / 12PSD8. A progress abstract was submitted for this investigation.
- Development of aquaculture techniques for indigenous species of southern Mexico, *Centropomus undecimalis*: Sex determination and differentiation and effects of temperature / 12SDA4. A progress abstract was submitted for this investigation.
- Use of phytochemicals as a new method to sex-reverse Nile tilapia and tropical garfish / 12FNF3. A progress abstract was submitted for this investigation.

### Presentations/Conferences

Alvarez-González, Carlos Alfonso, Arkady Uscanga-Martínez, Wilfrido M. Contreras-Sánchez, Roberto Civera-Cerecedo and Ernesto Goytortúa-Bores, 2006. Evaluation of dietary protein requirement on growth and survival of masculinized and non masculinized juvenile tenhuayaca *Petenia splendida*. Aquaculture America 2006. Las Vegas, Nevada, USA, February, 2006. Alvarez-Gonzalez, Carlos Alfonso, Wilfrido M. Contreras-Sánchez and Juan Manuel Vidal-López, 2006. Masculinization of the native cichlid tenhuayaca *Petenia splendida* using steroid-enriched *artemia nauplii*. Aquaculture America 2006. Las Vegas, Nevada, USA. February, 2006.

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Contreras-Sanchez, Wilfrido M., Grant W. Feist and Carl B. Schreck, 2006. Elimination of MT from intensive masculinization systems. Aqua 2006, Florence, Italy, May 2006.

Dabrowski, Konrad, 2006. Gonadal differentiation in longnose gar *Lepiosteus osseus*. Red Internacional para la Investigación de Lepisosteidos, Villahermosa, Tabasco, Mexico, 7-9 August 2006.

Jaroszewska, Marta, 2006. Morphological features of digestive tract development in the longnose gar *Lepiosteus osseus*. Red Internacional para la Investigación de Lepisosteidos, Villahermosa, Tabasco, Mexico, 7-9 August 2006.

### Theses

Pascual-Valencia, Luis E., 2005. Eliminación de la Hormona 17- $\alpha$  Metiltestosterona en sistemas de masculinización intensiva: Uso de radiación ultravioleta en el agua. UJAT. B.Sc. Thesis. September 2005.

Pérez-Pérez, Rosa, 2006. Técnica Alternativa para la masculinización de Tenhuayaca (*Petenia splendida*; Gunter 1862): Alimento vivo y alimento hormonado con el esteroide 17  $\alpha$ -Metiltetosterona. B.Sc. Thesis. March 2006.

### Workshops/Seminars/Educational Outreach

Thanks to workshops in Honduras, Guatemala and Costa Rica, UJAT has increased collaboration ties with scientists from Central America. One workshop conducted by the ACRSP staff travelled to many places this year. "Masculinization of Nile tilapia fry and safe handling of steroids in aquaculture," aimed at reaching an audience of farmers, researchers, students, and extension agents, was held in San Pedro Sula, Honduras in October 2005, in Ciudad de Guatemala, Guatemala in December 2005, and in Ciudad Heredia, Costa Rica in June 2006. Farmers attending events held at the Tilapia Farm Kab-já in Villahermosa, Tabasco participated in the following workshops: "Biology of tilapias (5 May 2006)," "Fish Reproduction (5 May 2006)," "Sex Inversion (12 May 2006)," "Tilapia Grow-out (13 May 2006)," "Water quality (19 May 2006)," "Aquatic Health (20 May 2006)," and "Harvest and Post-Harvest of Tilapias (26 May 2006)."



**Interactions:** In Tabasco, we have had meetings with government officials to let them know about the different projects and results from our ACRSP investigators.

**Public Interactions:** At UJAT at least three people are attended every day. People generally request information about tilapia and native fish culture.

**Outreach Activities:** The laboratory of aquaculture at UJAT has an outreach program that involves training and visits to farms in several municipalities of the state. At least eight visits are conducted every month.

#### TRAINING LOCAL FARMERS ON SAFE HANDLING OF STEROIDS AND MASCULINIZATION TECHNIQUES IN CENTRAL AMERICA

*Twelfth Work Plan, Applied Technology and Extension Methodologies 4 (12ATE4)  
Final Report*

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#### ABSTRACT

The need to deliver recently generated information and technological packages to the immediate users 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 for 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 ACRSP support have already impacted tilapia culture in Tabasco and Chiapas, and most farmers are growing sex-reversed tilapias — this was not practiced until a few years ago. To complement research for the production of clean sex-inversion techniques, we implemented three workshops on safe handling of steroids and masculinization techniques in Central America.

#### INCORPORATION OF THE NATIVE CICHLID (*PETENIA SPLENDIDA*) INTO SUSTAINABLE AQUACULTURE: REPRODUCTION SYSTEMS, NUTRIENT REQUIREMENTS, AND FEEDING STRATEGIES

*Twelfth Work Plan, Indigenous Species Development 3 (12ISD3)  
Abstract*

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#### ABSTRACT

The first steps for a successful aquaculture program are to obtain spawnings systematically and produce high-quality eggs and healthy fry. To reach this point, it is necessary to obtain a high-quality batch of adults and to select for the most desirable traits to be expressed in subsequent generations. All of this is required to develop aquaculture programs capable of supporting medium-to-large-scale facilities. For many native cichlids, these aspects have not been evaluated, and because of the introduction of non-native species (i.e., tilapia) that have high reproduction, growth rates, and survival, their potential has been ignored. In southeastern Mexico, a growing number of fish producers are requesting the development of alternative culture techniques that involve native species. Since the early 1970s, the only species that has been available in this region is the Nile tilapia and little effort has been devoted to developing any alternatives. The culture of native species of fish is important from an economic and conservation standpoint at a time when the local and foreign demand has imposed great pressures on their natural populations. In this study, we have conducted experiments to evaluate the reproductive potential and growth capacity of *Petenia splendida* under diets that contain vegetable meals instead of fish meals. Three experiments were conducted to determine reproductive performance and fry survival. In Experiment 1, parental sex ratios were evaluated. Our results indicate that the 2:1 female:male ratio resulted in the highest production of eggs and larvae. In Experiment 2, fecundity and hatching success were evaluated. Our data indicate that fecundity in all spawnings was 100%. Hatching rate was higher than 95% in all cases. In Experiment 3, we evaluated the effect of stocking density on growth and survival of *P. splendida* fry. Results

have shown that a density of 10 fry/L resulted in similar growth and survival compared to densities of 0.5, 1, and 5 fry/L, but higher than at a density of 20 fry/L. However, fry survival decreased as density increased. Survival for the densities of 0.5, 1, and 5 fry/L were 100, 98, and 96%, respectively, while densities of 10 and 20 fry/L had 89 and 68% survival. Three more experiments were conducted to evaluate the substitution of vegetable meal for fish meal at different life stages of *P. splendida*. In Experiment 4, we found that the best growth and survival was obtained when fry were fed with diets that had 25 and 50% of fish meal replaced with wheat gluten, compared with the other experimental diets (0, 75, and 100% wheat gluten). In Experiment 5, we observed the same results with juveniles, indicating that 25 and 50% replacement of fish meal with wheat gluten is feasible. Similar results were obtained in Experiment 6, where 25 and 50% replacement of fish meal with vegetable meal resulted in the highest growth and survival.

#### CONTINUATION OF A SELECTIVE BREEDING PROGRAM FOR NILE TILAPIA TO PROVIDE QUALITY BROODSTOCK FOR CENTRAL AMERICA

*Twelfth Work Plan Seedstock Development and Availability 3 (12SDA3)*

*Abstract*

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#### ABSTRACT

The establishment of good quality broodstock treatments, their distribution to local hatcheries, and the implementation of intensive masculinization programs are basic steps for sustainable aquaculture. The selective breeding program supported by the ACRSP from 2001 to 2003 was initiated using 220 females and 110 males obtained from a batch of fish purchased from Egypt by the state government. A second line is currently being selected from a wild population. We have identified a stock of wild Nile tilapia in the Usumacinta River that shows several advantageous phenotypic traits (small head, small tail, large body, and uniform color). For the first year of work, we were able to combine the efforts of the ACRSP project and another

project supported by the National Council for Science and Technology (CONACyT-Mexico). This allowed us to work at the Mariano Matamoros Hatchery using 200, 1,000, and 2,000 m<sup>2</sup> ponds and to use fish first selected by Mario Fernández in 2000. To date, we have selected organisms from the third generation (F3) based on a combination of length and condition factor and we are currently raising a fourth generation. In this study we evaluated six tilapia lines (three more than originally proposed) in terms of growth, condition factor, fillet production, and feed conversion factor. The lines evaluated were: Tabasco-1, Control, Teapa, Wild-1, Wild-2, and Stirling. Fish were stocked in 2 m<sup>3</sup> hapas at a density of 25 fish/m<sup>3</sup>. All hapas were placed in a single earthen pond. Average initial weight was 50 g. Best values obtained for weight corresponded to the line Tabasco-1 averaging 446.2 g at the end of the grow-out trial. This line had a 1.77 g/day growth rate. Followed by the Stirling line with an average final weight of 439.47 g (1.74 g/day). The lowest value was obtained from fish of the Teapa line (original broodstock of the state hatchery) with an average final weight of 343.86 g (1.30 g/day). Fillet yield was higher for the Tabasco-1 line (31.44% of body weight) and an average fillet weight of 130.1g, followed by the Stirling line (31.30% and 125.3 g). Once again, the lowest value corresponded to the Teapa line (28.70% and 99.6 g). From the first generation, the Tabasco-1 line has demonstrated the productive potential that is available to farmers, allowing high yields at harvest.

#### ELIMINATION OF METHYLTESTOSTERONE FROM INTENSIVE MASCULINIZATION SYSTEMS: USE OF ULTRAVIOLET IRRADIATION OF WATER

*Twelfth Work Plan, Water Quality and Availability 2 (12WQA2)*  
*Abstract*

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#### ABSTRACT

Methyltestosterone (MT) is a light-sensitive hormone which is subject to photodegradation. The type of light most likely responsible for photodegradation is UV-B (wavelengths of 280–315 nm). Methyltestosterone absorbs UV light strongly at a wavelength of 254 nm, which is in the UV-C part of the spectrum (100–280 nm), and absorbs UV weakly in the UV-B

area of the spectrum. Unlike UV-B, UV-C is quickly absorbed in the atmosphere and does not reach the earth's surface. Since MT does not absorb UV-B very effectively, treatment with irradiation at 254 nm should be much more effective than exposure to sunlight or UV-B. Little is known about the amount of exposure to UV needed to remove MT or of possible metabolites produced during photodegradation. Commercial ultraviolet water sterilizers are currently being used by some growers in Central America to destroy pathogens. These sterilizers emit UV light at a wavelength of 254 nm. We propose the use of intensive systems for masculinizing tilapia fry using MT-impregnated food at a large scale where excess MT is eliminated from the water by means of continuous filtration through UV sterilizers. Removal of MT should both increase masculinization rates and reduce the amount entering substrates which could affect other aquatic organisms. This method may allow for the production of large numbers of all-male populations of tilapia fry using a reliable technique compatible with the proposed Best Management Practices (BMPs) for aquacultural systems. Ultraviolet sterilizers are relatively cheap, available in many sizes for different volumes of water in aquaculture systems, and can be readily obtained in southern Mexico. This study tested the hypothesis that MT could be eliminated from the water for intensive sex-inversion systems using UV sterilizers emitting a wavelength of 254 nm. Water samples were collected daily after hormonal treatment of tilapia fry at different times. MT was extracted by filtering 20 ml of water with Sep-Pak cartridges and MT content is currently being determined by radioimmunoassay at Oregon State University.

#### **ELIMINATION OF METHYLTESTOSTERONE FROM INTENSIVE MASCULINIZATION SYSTEMS: USE OF SOLAR IRRADIATION AND BACTERIAL DEGRADATION**

*Twelfth Work Plan, Water Quality and Availability 3 (12WQA3) Abstract*

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#### **ABSTRACT**

Methyltestosterone (MT) is a light-sensitive hormone which is subject to photodegradation. Speculation among farmers based on this characteristic has led to a general belief that MT can be degraded by exposing the water with the steroid to sunlight. In a previous study we developed a Recirculating Aquaculture System (RAS) to eliminate MT from aquaculture effluents in an intensive system for masculinizing tilapia fry at a large scale. In this system, the excess MT was eliminated from the water and the substrate by means of continuous filtration through activated charcoal filters. The RAS is economical, easily constructed, and is composed of a submersible pump, sediment trap, charcoal filter section, mechanical filter section, and a biological filter section. After the water leaves the RAS it returns to the tank through a perforated section of PVC pipe resulting in a "water curtain" which both aerates the water and exposes it to sunlight. Results from the study showed that although MT was eliminated from the water and accumulated in the charcoal of the RAS, water from control treatments (MT-treated water, but with no charcoal filters when passed through the RAS) also did not have detectable levels of MT. In another investigation, we demonstrated that exposure of MT-treated water to sunlight resulted in reduced levels of the compound but it was not completely eliminated. It is also known that some bacteria are capable of degrading steroids. From this information and results from the previous two investigations, we hypothesized that MT was being eliminated from control water by solar irradiation and/or bacterial degradation within the RAS. This study tested the hypothesis that MT could be eliminated from the water used in intensive sex-inversion systems using biological filtration and/or sunlight exposure. Two experiments were conducted and water samples were collected daily at different times after either simulating a feeding regime or adding a large dose of MT to the water. No fish were present in both experiments. MT was extracted by filtering 20 ml of water with Sep-Pak cartridges and MT content will be determined by radioimmunoassay at Oregon State University.

#### **TESTING THREE STYLES OF TILAPIA-SHRIMP POLYCULTURE IN TABASCO, MEXICO**

*Twelfth Work Plan, Production System Design and Integration 8 (12PSD8) Abstract*

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#### **ABSTRACT**

The tilapia-shrimp polyculture project in Tabasco has been slowed by extensive renovations to the facility operated by the Universidad Juárez Autónoma de Tabasco. Arrangements were made for stocking the ponds more than a year ago, but plumbing and pond dike repairs were hindered by equipment malfunctions and problems with sub-contractors operating heavy equipment. Students



designed the exact experimental protocols and were trained at the school in operating procedures.

Specifically our plan is to compare three different polyculture styles, sequential (with tilapia in one pond, then water passing to shrimp pond), simultaneous (tilapia in cages in shrimp ponds), and simultaneous with tilapia loose in shrimp ponds. We will focus on production results (fish and shrimp yields and survivals, Feed Conversion Ratios, and cost benefits), water quality parameters (dissolved oxygen, secchi disk measurements, total chlorophyll, and temperatures), and microbiology (algae counts and bacterial populations).

We expect to compare our results with findings from similar trials conducted in the Philippines and an earlier trial from the west coast of Mexico. Tilapia–shrimp polyculture has been adopted and adapted in many of the shrimp-farming regions of the world and we hope to better define the methodologies and provide guidance as to which practices seem to be most beneficial.

**DEVELOPMENT OF AQUACULTURE TECHNIQUES FOR THE INDIGENOUS SPECIES OF SOUTHERN MEXICO, *CENTROPOMUS UNDECIMALIS*: SEX DETERMINATION AND DIFFERENTIATION AND EFFECTS OF TEMPERATURE**

*Twelfth Work Plan, Seedstock Development and Availability 4 (12SDA4)*

*Abstract*

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**ABSTRACT**

Species of “robalo,” or snook, constitute one of the most important commercial fisheries in Mexico’s gulf coast. The common snook has perhaps received the most attention and fishing pressure. On the southwestern side of the Gulf of Mexico, spawning grounds for common snook have been reported as far north as southern Texas. The Texas snook

population once supported a commercial and recreational fishery, but it is now only able to support a strictly regulated recreational fishery. In Mexico, there is a trend for diminishing catch volumes for common snook, a situation that has led to concerns for the regional snook fisheries and to calls for improved management practices. Thus, the development of culture techniques for common snook would benefit a common resource in the US and Mexico by providing relief from fishing pressure on wild snook stocks.

Female common snook are larger than males of the same age class, especially in younger fish. Thus, female snook may have an intrinsically faster growth rate than males. The present study focuses on an evaluation of rearing techniques to skew sex ratios toward females and lead to enhanced growth rates for farmed common snook. In order to accomplish this objective, it is first necessary to establish the pattern and timing of gonadal sex differentiation. Although it has been reported that common snook are protandric — they first develop as males before changing sex into females — basic information about gonadal sex differentiation is not available for this species. This information is needed to determine the time at which treatment can be applied to feminize snook fry and bypass the male phase.

In Mexico, 256 juvenile snook were collected. Otoliths from 228 fish were extracted and processed. Results indicate that age can be determined up to day 100. After this point, the daily marks get too close to be used accurately. The histological analyses of gonads indicate that testicular differentiation initiates between 91 and 123 days of age (fork length ranging between 11 and 21.1 cm). At this stage, spermatogonia are clearly identified and efferent ducts are present. All fish analyzed differentiated as males and no indication of female development was observed. This information suggests that treatment for sex inversion needs to begin between 60 and 70 days of age (3–6 cm). During June–July 2006, 30 adult snook were captured alive in Tabasco (400–6000 g; 30–95 cm) to produce fry for experimentation; however, only six have survived (2 females and 4 males). More captures are scheduled to ensure enough fish to induce spawning. In addition, a recirculating system containing 21 70 L fiberglass tanks for fry rearing has been built and tested. Our feminization experiments will be conducted between August and December 2006.

In Texas, the lower portion of the Rio Grande is believed to be important nursery habitat for juvenile snook. However, little knowledge is available about the riverine habitat requirements for juvenile snook and its early reproductive development. The objectives of the US component of the study are to examine the pattern and timing of the early gonadal development of Texas snook populations and to compare with observations for common snook in Mexico (Tabasco). Snook were sampled from January through March 2006 along the lower 51.5 km of the river. We captured 225 common snook, all above river kilometer 12.9. All fish <13.4 cm contained indifferent gonads and are believed to be young-of-the-year individuals; larger fish, up to 67.4 cm, were males (including juveniles and adults) except for one female (61.4 cm). Fish age will be confirmed by counting annuli on otoliths. The results of this study will provide



useful information to understand the reproductive biology of the snook populations inhabiting the Texas-Mexico gulf coast. In addition, these results are expected to assist in efforts to manage the Texas snook population. The US component of the study also aims to characterize habitat requirements for juvenile snook and is being supplemented by funds or in-kind support from the US Geological Survey, Texas Tech University, and Texas Parks and Wildlife.

#### USE OF PHYTOCHEMICALS AS A NEW METHOD TO SEX-REVERSE NILE TILAPIA AND TROPICAL GARFISH

*Twelfth Work Plan, Fish Nutrition and Feed Technology 3 (12FNF3)*

##### Abstract

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##### ABSTRACT

Many studies have focused on the use of chemicals produced by plants (phytochemicals) that can be characterized as sexual steroid-endocrine regulators. Such studies anticipate that phytochemicals will act as endocrine modulators by changing endogenous hormone profiles. These effects could be related to their aromatase-activity or inhibitory capacity among other unidentified mechanisms. If such activity is precisely expressed by these chemicals, they could provide a novel (alternative to synthetic inhibitors) mode of action to induce changes in the phenotypical process of sex differentiation in fish gonads, especially in tilapia. Natural chemicals with expected safer utilization and handling issues, and possibly lower toxicity for both fish and the surrounding environment, are a very attractive alternative.

We have conducted a series of feeding trials on first feeding all-female Nile tilapia (>80% females). Phytochemicals have been obtained as aqueous extracts from *Hibiscus micranthus*, mate (*Ilex* sp.), and maca (*Lepidium meyenii*) by suspension of dry plant material in distilled water for 12 hours, and filtered using paper filters. The resulting suspended solutions were freeze-dried to obtain dry powder extracts. These extracts were added to casein-gelatin based diets and fed to fish at different concentrations. Also, diets free from phytochemicals and diets supplemented with two different synthetic substances, 17 $\alpha$ -methyltestosterone (MT) and

spironolactone (SPIRO), were used as controls in the second feeding experiment. Preliminary results indicate that the sex ratio is not affected by the inclusion of the tested plant extracts; however MT- and SPIRO-supplemented diets exhibited significant change in sex ratio, 100% and 75% males, respectively. In addition, no significant differences were observed in the final individual body weight, specific growth rate, or Food Conversion Ratio among dietary groups in all experiments.

For longnose gar (*Lepisosteus osseus*) used as a surrogate species, our studies have been focused on the early gonad development as well as the alimentary tract. Results are preliminary, and the digestive system and "yolk-liver-intestine" connections during the larval stages were characterized. We have focused on the description of the ontogenetical development of gonads, in order to determine the relationship between fish size (age) and the gender. Histological appearances of the gonads were characterized by early signs of morphological structure of primordial germ cells and presumptive seminiferous tubules in fish of 107 mm total length. We have concluded that garfish larvae/juveniles can be effectively adapted to consume dry formulated diets at early stages, after an initial feeding using live food. We recommend that diets supplemented with 17 $\alpha$ -methyltestosterone should be used from 14 days after hatching; therefore, the hormonal treatment could be included within the first 3–6 weeks of exogenous feeding.



### Mexico Project: Human Welfare, Health and Nutrition



JIM BOWMAN

Mexico, Ecuador  
Subcontract No. RD010E-D (UH)

The Mexico Project: Human Welfare, Health and Nutrition was developed during the Eleventh Work Plan. Aquaculture can affect human health through a wide variety of direct and indirect causal pathways, including: a general positive relationship between aquaculture productivity and environmental quality; increasing consumption of safe, high protein food products; rising household revenue to improve quality of life; and involvement of women, youth and marginalized groups. Three case-study investigations were initiated, involving collaborators from the University of Hawaii at Hilo (lead US institution), University of Rhode Island, Universidad Autónoma de Sinaloa (Mexico) and Ecocostas (Ecuador). Additional investigations with Louisiana State University focus on classifying bivalve production and export to international markets and associated outreach for ensuring appropriate sanitation during the harvest and processing of bivalve products.

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Luis Miguel Aguilar                                      Collaborator

**Work Plan Research**

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

- Diversifying and strengthening aquaculture extension capacity to develop a regional extension service model/12ATE6. A final abstract was submitted for this investigation.
- Water quality monitoring and identification of pollution sources leading towards classification of bivalve growing waters/12AHH1. A progress abstract was submitted for this investigation.
- Outreach and planning for implementation of bivalve growing areas classification and related sanitation action items/12AHH2. A progress abstract was submitted for this investigation.
- Bivalve market study in Pacific Mexico/ 12ERA6. A progress abstract was submitted for this investigation.

In addition, the following Eleventh Work Plan investigations are ongoing during the reporting period:

- Cross-sectoral and international extension exchange and learning/11AAHR1. A final abstract was submitted for this investigation.

- Connectivity of water resource status, environmental quality, aquaculture, and human health/11AHHR2. A progress abstract was submitted for this investigation.
- Analysis of critical points in aquaculture production affecting participation and level of benefits to women, youth, and disadvantaged stakeholders/11AHHR3. A progress abstract was submitted for this investigation.
- Food safety and handling: Increasing local consumption of aquaculture products and improving quality/11DPPR1. A progress abstract was submitted for this investigation.

**Publications**

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Jiddawe, N., A. Mmochi, 2005. Rural Women's Groups Conduct integrated shellfish and seaweed culture in Zanzibar. *Aquanews*, 20(3):3,9.

Dominguez, Guillermo Rodriguez, Eladio Gaxiola, María del Carmen Velázquez Cuadras, Maria C. Haws, and John

Supan, 2006. Classification of shellfish growing waters and oyster depuration in Boca de Camichín, Nayarit, Mexico (Poster). Presented at AQUA 2006, Annual Meeting of the World Aquaculture Society, Florence, Italy, 9-13 May 2006.

#### **DIVERSIFYING AND STRENGTHENING AQUACULTURE EXTENSION CAPACITY TO DEVELOP A REGIONAL EXTENSION SERVICE MODEL**

*Twelfth Work Plan, Appropriate Technologies and Extension Methodologies 6 (12ATE6)*

*Abstract*

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#### **ABSTRACT**

Building individual and institutional capacity for extension and community outreach is key to achieving aquaculture development and natural resources management goals. Capacity building for professionals working in extension or community development was the overall objective of this work. The first ACRSP Cross-Sectoral and International Extension Exchange and Learning Workshop, held in June 2004, built on past and current extension efforts and extended them into new areas of learning. This included sharing experiences from other sectors such as public health, agriculture, gender equity efforts, and work with the physically challenged. As a part of the continuation of efforts to develop a strong, multi-institutional extension delivery service, a five-day workshop was held in Mazatlán, Mexico,

from 25–29 July 2005 during which training in advanced extension methodologies, tools, and approaches was provided in a Training-of-Trainers mode. Presentations and updates were given by 30 participants representing 20 institutions in five states in Pacific Mexico. Fifty to 75 participants attended each day. Participants included aquaculture extension agents and NGO representatives from Mexico and representatives from Ecuador and the US. An additional two days were spent planning and reviewing the progress of the research associated with three case studies linked to the extension effort and for two additional Aquaculture CRSP investigations.

Training in key topics related to the Aquaculture CRSP investigations 12AHH1 (Water Quality Monitoring and Identification of Pollution Sources Leading towards Classification of Bivalve Growing Waters) and 12AHH2 (Outreach and Planning for Implementation of Bivalve Growing Areas Classification and Related Sanitation Action Items) was provided by: John Supan, Louisiana State University Sea Grant Program; Roberto Quintana, LSU Sea Grant Program; and Maria Haws, University of Hawaii at Hilo and UH Sea Grant College Program.

Extension visits to Boca Camichin, Nayarit, a primary site for oyster culture and one of the ACRSP investigation sites was made by the team to begin planning for the investigations and to provide some experiential training in extension methods. An extension visit was also made to the oyster farm of Jorge Guevarra where culture of the native oyster is being revived.

Course materials from the workshop were compiled and distributed widely for the benefit of extension workers elsewhere. Further work required to build extension capacity was also scoped out and an agenda developed for future efforts.

#### **WATER QUALITY MONITORING AND IDENTIFICATION OF POLLUTION SOURCES LEADING TOWARDS CLASSIFICATION OF BIVALVE GROWING WATERS**

*Twelfth Work Plan, Aquaculture and Human Health Impacts 1 (12AHH1)*

*Abstract*

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## ABSTRACT

Two major bay systems in Mexico, which are the focus of collaborative efforts for international integrated coastal zone management efforts, Bahia Santa Maria (BSM) in Sinaloa and Marismas Nacionales in Nayarit are home to growing oyster industries. Oyster farming in Nayarit has a 30-year history while women's producer groups in BSM are just beginning. In Nayarit, farming has been demonstrated to be a viable alternative to fishing for coastal communities, particularly because women have a high level of participation, both in production and processing. Two oyster species are commonly cultivated along the Pacific coastline. *Crassostrea gigas* seed is imported from the US and used for remote setting in Mexico, mainly along the northern extent of the coast. A native species, *Crassostrea corteziensis*, has sufficiently high levels of localized spat set to support a limited industry, mostly confined to Nayarit and two newer farms in Sinaloa. There is also growing interest in other native bivalve species, so it is hoped that the outcomes of this effort to improve shellfish sanitation will have wider benefits.

Among the obstacles to progress is the questionable water quality in bivalve growing areas. Increasing populations and pollution in coastal areas threaten the safety and economic viability of the growing oyster culture industry. Opportunities also exist as many areas are still relatively pristine and produce a high quality and safe product. Previous work found that the ability to assure product safety, transport, and market in other areas and to produce value-added products could greatly increase the direct socio-economic benefits this industry provides to coastal communities. There is also a possibility that shellfish could be exported to the US, as two Mexican farms are already doing, if water quality and the regulatory framework is such that growing areas could be classified according to US standards.

Because both the existing Mexican and US protocols and standards would require at least one year of intensive water quality monitoring to classify a growing area and because these areas are extensive, attempting to classify them is not a trivial task and resources do not exist to undertake large-scale monitoring efforts. The first, more feasible option is to conduct rapid assessments that include shoreline surveys and preliminary water quality monitoring to eliminate any areas which could be conclusively barred from consideration and to identify the areas most likely to be able to meet standards in the future. Once these areas are identified, intensive monitoring efforts could then be conducted in a more cost-effective manner in narrowly targeted geographic areas of the two bays. Participants in this work include Universidad Autónoma de Sinaloa, Pacific Aquaculture and Coastal Resources Center / University of Hawaii at Hilo, University of Hawaii Sea Grant College Program, Ecocostas, Coastal Resources Center / University of Rhode Island, Louisiana State University Sea Grant College Program, CESASIN, CREDES, Autonomous University of Nayarit, oyster farming cooperatives of Nayarit, and women's groups of BSM. Investigation 12AHH2, "Outreach and Planning for Implementation of Bivalve Growing Areas Classification and Related Sanitation Action Items," is complementary to this investigation and constitutes a planning, regulatory, and outreach component.

Working closely with local stakeholders, progress to date includes identification of the oyster growing sites and water quality monitoring sampling stations. Two workshops have also been held with the full range of stakeholders concerned with this work including aquaculturists, federal and state government representatives, researchers, students, and oyster vendors to present the objectives of the work, preliminary results, and to build constituency for development of an integrated management plan for the estuary. First steps have been taken towards drafting of a management plan with full involvement of the stakeholders.

## OUTREACH AND PLANNING FOR IMPLEMENTATION OF BIVALVE GROWING AREAS CLASSIFICATION AND RELATED SANITATION ACTION ITEMS

*Twelfth Work Plan, Aquaculture and Human Health Impacts 2 (12AHH2)*

*Abstract*

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## ABSTRACT

Culture of oysters and other bivalve species is a growing opportunity for aquaculture along the Pacific Mexican coast. Bivalve culture, and the need for sanitation protocols to assure the safety and quality of the shellfish products are relatively new topics for the Pacific Mexico region. As efforts to diversify aquaculture through strengthening of shellfish culture are underway and as consumer awareness of the potential dangers of consuming aquatic products increases, measures to assure the production of safe shellfish and other aquaculture products are needed. This activity is linked to Investigation 12AHH1 "Water Quality Monitoring and Identification of Pollution Sources Leading towards Classification of Bivalve Growing Waters," and will be aimed at disseminating the findings of that study and raising awareness of the issues associated with shellfish sanitation and other aquaculture products. Researchers, extension agents, and government officials will then work together to identify strategies and resources to implement recommendations stemming in part from Investigation 12AHH1 as well as the outcomes of the Year 10 work. A wide range of environmental, community,

and product sanitation issues were identified during study of finfish, shellfish, and shrimp operations.

Particular attention will be paid to monitoring and classification of shellfish growing waters and actions targeted towards mitigating major sources of pollution that are affecting aquaculture as a whole. Previous work in Bahía Santa María (BSM) by the members of the Sinaloa working group has already developed tools and strategies that have led to positive improvements in community sanitation and water quality. Expansion of these efforts within the BSM system and replication in Nayarit would contribute to an increased probability that shellfish growing areas could be classified as approved and that other aquaculture sanitation problems could be addressed.

Specifically, this work will raise awareness among key institutional and community stakeholders about the major issues associated with aquaculture sanitation. Stakeholders will be educated about the technical and legal requirements for safe production of bivalves. Findings, outcomes, lessons learned, and strategies will be disseminated to the authorities and key stakeholders so that joint development of strategies and resources to implement programs for classification of shellfish growing waters and other strategies related to community sanitation and water quality can take place. An implementation plan for the above mentioned topics will also be developed. Participants in this work include Universidad Autónoma de Sinaloa, Pacific Aquaculture and Coastal Resources Center/University of Hawaii at Hilo, University of Hawaii Sea Grant College Program, Ecocostas, Coastal Resources Center/University of Rhode Island, Louisiana State University Sea Grant College Program, CESASIN, CREDES, Autonomous University of Nayarit, oyster farming cooperatives of Nayarit, and women's groups of BSM.

Two workshops have also been held with the full range of stakeholders concerned with this work including aquaculturists, federal and state government representatives, researchers, students, and oyster vendors to present the objectives of the work, preliminary results, and to build a constituency for development of an integrated management plan for the estuary. First steps have been taken towards drafting a management plan with full involvement of the stakeholders. Awareness has also been raised among the oyster farmers and government representatives as to the need for a shellfish sanitation plans and the requirements of such a plan to assure product quality within the Mexican regulatory framework and secondarily, within that of the US, anticipating future export possibilities.

## BIVALVE MARKET STUDY IN PACIFIC MEXICO

*Twelfth Work Plan, Economic/Risk Assessment and Social Analysis 6 (12ERA6)*  
Abstract

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## ABSTRACT

This work proposes to build on past and current efforts on the Pacific Mexico coast designed to promote viable aquaculture alternatives other than shrimp mariculture with the goal of optimizing returns and benefits to rural, coastal communities. Previous work conducted by a multi-institutional, international team since 1997 has built a solid foundation for diversification of aquaculture in Pacific Mexico, emphasizing the use of native species, particularly those low on the food chain and with low culture technology requirements. Among the leading candidates are bivalves, which are currently cultured and harvested extensively along the Gulf of California Coast, with most production occurring as a result of fisheries. Great potential exists to expand current aquaculture production through strengthening existing operations and developing new species of bivalves for culture.

This work will be conducted in the context of a long-standing, multi-institutional effort to develop and implement management plans for two important and extensive wetlands areas on the Pacific Coast of Mexico: Bahía Santa María (BSM), Sinaloa State, and Boca Camichin, Nayarit State. The latter is the site of a thriving, small-scale oyster industry based on the native Mexican oyster, *Crassostrea cortezensis*. Although BSM has some oyster culture, stakeholder interest is strong in developing more oyster culture and developing other species of valuable bivalves. During the past two years of collaborative work, bivalves (clams, oysters, pen shells, etc.) were identified as the culture candidates with the most potential to offer an alternative to shrimp farming for coastal communities of Mexico. Shellfish culture also offers more opportunities for participation of women and other marginalized groups due to their ease of culture and low-input requirements. Bivalves, however, are particularly demanding in the area of sanitation and food quality because they are filter feeders and are sensitive to post-harvest contamination. Resolving water quality, handling, processing, marketing, and transportation issues related to production of safe bivalves will not only help improve the benefits and reduce risks associated with this form of culture, but will also serve as a model for improved sanitation for other species such as finfish, which are targeted for development.

The Pacific Aquaculture Center/University of Hawaii at Hilo (PACRC/UHH), the Universidad Autónoma de Sinaloa (UAS), Autonomous University of Nayarit (UAN), Research Center for Food and Development (CIAD), Coastal Resources Center/University of Rhode Island (CRC/URI), Regional Center for Education for Sustainable Development (CREDES), Sinaloa Aquaculture Institute (ISA), Sinaloa Committee for Aquaculture Sanitation (CESASIN), community groups, and industry cooperators have been working together under

ACRSP funding for two years. The University of Alaska/Sea Grant and the University of Louisiana Sea Grant College Program have also been recently integrated into the regional Latin America initiatives of the collaborators. Economists from CIAD (Francisco Cordero Martinez) and the University of Alaska (Quentin Fong) will take the lead on this work.

There is little information on marketing channels, opportunities, prices, and consumer preferences for bivalves. There is also a lack of clarity as to the regulatory nature of this field and the requirements for implementation of existing regulations. While the coastal communities involved in this work in Sinaloa and Nayarit are surrounded by major cities (e.g., Culiacan), tourist destinations (Acapulco, Mazatlan), and are close enough to the US to export bivalves, more information is needed on the economics and markets to inform current and future efforts.

Important research questions to be answered are: What prices is the market willing to pay for the BSM bivalves? What is the volume or quantity demanded? What are the current federal and state regulations concerning shipping of bivalves and environmental considerations for culture systems? Are regulations that prohibit transportation of live food due to disease transmission concerns? What regulatory measures are needed to assure safe shipping of bivalves? What is the supply outlook for bivalves in the main local, regional, and national markets? And finally, can BSM's and Nayarit's producers be suppliers of high quality bivalves in the domestic or international markets? If not, what are the constraints to growth? This work intends to address these questions.

#### **CROSS-SECTORAL AND INTERNATIONAL EXTENSION EXCHANGE AND LEARNING**

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

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#### **ABSTRACT**

Building individual and institutional capacity for extension and community outreach is key to achieving aquaculture development and natural resources management goals. Capacity building for professionals working in extension or community development was the overall objective of this work. The ACRSP Cross-Sectoral and International Extension Exchange and Learning Workshop built on past and current extension efforts and extended them into new areas of learning. This included 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 Mazatlán, Mexico, on 14–16 June 2004 during which training in extension methodologies, tools, and approaches was provided in a Training-of-Trainers mode. Participants included aquaculture extension agents and NGO representatives from Mexico, representatives from other Aquaculture CRSP initiatives (Mexico, Peru, Honduras) and project personnel from other innovative aquaculture extension efforts (UCA/Nicaragua and Ecocostas/Ecuador). Participants from non-aquaculture sectors such as agriculture, public health, community development, and rehabilitation of the handicapped were able to share their methods and lessons learned to help strengthen aquaculture extension methods within a community development context. An additional two days were spent planning and reviewing the progress of the research associated with three case studies linked to the extension effort. Course materials from the workshop were compiled and distributed widely for the benefit of extension workers elsewhere. Further work required to build extension capacity was also scoped out and an agenda developed for future efforts.

#### **CONNECTIVITY OF WATER RESOURCE STATUS, ENVIRONMENTAL QUALITY, AQUACULTURE, AND HUMAN HEALTH**

*Eleventh Work Plan, Aquaculture and Human Health Impacts  
Research 1 (11AHHR2)  
Abstract*

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#### ABSTRACT

This research attempts to elucidate relationships between human health, water resources, and aquaculture status and development in the States of Sinaloa and Nayarit, Pacific Mexico coast. Water quality and the volume available for aquaculture and coastal habitat conservation were found to be deteriorating, adversely affecting aquaculture through chemical, bacterial, and viral contamination. Solid waste disposal by communities and industry is affecting human health and opportunities to establish aquaculture. Impacts caused by aquaculture activities are minimal, limited to some shrimp farms. Water availability is also decreasing due to prioritization of other economic activities, which affects reservoir fisheries and aquaculture, as well as changing water quality in downstream shellfish growing areas. Poor water quality may affect the future expansion of shellfish culture and threatens the existing industry. Gnathostomosis is an emerging health issue and can impact communities farming freshwater fish. Raising awareness is needed for all stakeholders, as is support for community-based health, development, and aquaculture initiatives. Improved extension services have been key in past successes, and more attention is required in this area for aquaculture to succeed.

#### 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 Impacts  
Research 3 (11AHHR3)  
Abstract*

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#### ABSTRACT

This work undertook to assess the level of participation in, and benefits derived from aquaculture for women, minority groups, and handicapped individuals in Sinaloa and Nayarit, Mexico. Shrimp farming, the most important form of aquaculture in the region, was perceived by members of surrounding communities as offering, at best, a mix of benefits and negative impacts, despite clear economic benefits to the regional economy. For other forms of aquaculture, participation by women and minority groups is limited. Often their participation is viewed as playing a supporting role to a male family member and they do not



have decision-making power. But all groups interviewed expressed positive attitudes towards greater inclusion of women and minority groups. Two good models of participation by women and handicapped individuals are discussed in this work: 1) oyster cultivation cooperatives of Nayarit; and 2) PROJIMO, an NGO operated by and for handicapped individuals. Lessons learned for future aquaculture development initiatives are detailed.

**FOOD SAFETY AND HANDLING: INCREASING LOCAL CONSUMPTION OF AQUACULTURE PRODUCTS AND IMPROVING QUALITY**

*Eleventh Work Plan, Disease, Predation Prevention, and Food Safety Research 1 (11DPPR1)*  
*Abstract*

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**ABSTRACT**

This research attempts to elucidate relationships between human health, water resources and aquaculture status and development in the States of Sinaloa and Nayarit, Pacific Mexico coast. The focus was on characterizing issues of sanitation, food quality, and safety that affect aquaculture production, economic returns, and public health. Three topics were studied: 1) potential oyster growing areas of Bahia Santa Maria (BSM), a major wetlands area of Sinaloa State; 2) shrimp farming areas of BSM; 3) reservoir farming/fishing of finfish; and 4) oyster farming areas of Boca de Camichin, Nayarit. A particular emphasis was put on issues related to bivalve sanitation since a culture of introduced and local species of bivalves is growing.



# Kenya Project: Production Technology

Kenya  
Subcontract No. RD009A-01 (OSU)



F. LAGAT

Kenya Project research began in 1997 at Sagana Fish Farm, Central Province, in collaboration with the Kenya Fisheries Department (FD) under Memoranda of Understanding with Oregon State University (OSU) and Auburn University (AU). Additional Memoranda of Understanding were also established with Moi University and companion site institutions in Malawi. In 2002 the OSU / Kenya Project began focusing primarily on training, targeting farmers, fisheries officers, and university students, with research on techniques for removing constraints to African catfish (*Clarias gariepinus*) fingerling production being carried out in conjunction with graduate student training at Moi University.

Activities during this reporting period have continued this approach. Short courses conducted in 2005 and 2006 focused on simple, low-cost techniques for spawning, hatching, and rearing juvenile catfish, and Moi University graduate students have continued experiments to evaluate additional techniques for increasing the survival of catfish fry to the fingerling stage.

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## Staff

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James Bowman                              US Co-Principal Investigator

*Moi University, Eldoret, Kenya (Lead Host Country Institution)*

Charles Ngugi                              Lead Host Country Principal Investigator  
Victoria Boit                              Graduate Student (Kenya; from September 2004)  
Stephen Njau                              Graduate Student (Kenya; from September 2004)  
Elizabeth Nyanchiri                      Graduate Student (Kenya; from July 2006)  
James Mugo                              Graduate Student (Kenya; from July 2006)  
Mary Makhutu                              Undergraduate Student (from September 2004)  
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*Kenya Fisheries Department, Nairobi, Kenya (collaborating Host Country Institution)*

Nancy Gitonga                              Host Country Co-Principal Investigator (through July 2006)  
Bethuel Omolo                              Host Country Co-Principal Investigator (through March 2005)  
Benson Thiga                              Host Country Co-Principal Investigator (from April 2005)

## Work Plan Research

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

- Aquaculture training for Kenyan extension workers, fish farmers, and university students/12ATE3. A progress report was submitted for this investigation.
- Studies on strategies for increasing the growth and survival of African catfish (*Clarias gariepinus*) juveniles reared for stocking or for use as bait/12SDA2. A progress report was submitted for this investigation.
- Kenya training-of-trainers and regionalization of aquaculture training activities/12ATE11. A progress report was submitted for this investigation.
- Kenya capacity building: Student research and thesis support/12SDA5. A progress report was submitted for this investigation.

## Workshops/Seminars/Educational Outreach

Two primary schools from Kenya and one secondary school (Kobujoi high school) from Uganda visited the Moi University Fish Farm in Eldoret. Charles Ngugi helped Uasin Gishu High School with technical advice on how to renovate their fish pond. He also gave technical advice to the St. Patrick's Primary School to help them renovate two fish ponds.

Charles Ngugi, Bethuel Omolo, William Mureithi, Leah Cherop, Julius Nzeve, and James Mugo helped to train five fish farm managers from Uganda at the Moi University

On 2–5 April 2006, the Moi University Department of Fisheries and Aquatic Sciences held a four-day seminar for 20 fish farmers from several districts in Western Kenya. The event was organized by the HCPI in collaborations with the Director of Fisheries through the District Fisheries Officer, Uasin Gishu.

Ngugi visited the Dominion fish farm on 27–31 March 2006 to discuss with Enos Mac-Were, the fish farm project manager, catfish propagation and marketing. On 28 March 2006, accompanied by two ACRSP grad students (Victoria

Boit and Stephen Njau), the ACRSP staff visited fish farmers in Trans Nzoia and Bungoma to discuss breeding of catfish and how they were responding to market demand.

Jim Bowman was contacted by Patrick Huffman, of the non-profit group "Nomad Charities", about possible assistance in setting up an aquaculture project near Makindu, Kenya. Huffman and Ngugi are in contact to further discuss the possibility. Huffman visited the university and promised to come back if he required additional information.

## Presentations

Boit, Victoria C., Charles C. Ngugi, and James R. Bowman, 2006. Effects of three feeding regimes and two light regimes on the growth and survival of African catfish *Clarias gariepinus* fry in aquaria. Aqua 2006, Florence, Italy, 8–13 May 2006.

Ngugi, Charles C., 2005. Factors influencing growth and survival of African catfish *Clarias gariepinus* juveniles and their implications for aquaculture development in Kenya. 7th Conference of the Aquaculture Association of Southern Africa, September 2005.

Ngugi, Charles C., 2005. Tilapia/Cichlids project (ACRSP HC PIs), Tabasco, Mexico, October 2005.

Ngugi, Charles C., Elizabeth Nyanchiri, Joseph Rasowo, and James Bowman, 2006. The effect of different stocking ratios on yields of tilapia *Oreochromis niloticus* and African catfish *Clarias gariepinus* in fertilized earthen ponds (Poster). Aqua 2006, Florence, Italy, 8–13 May 2006.

Thiga, Benson, 2006. Tilapia culture in Kenya. HCPI project workshop in Kenya, Fisheries Headquarters, Nairobi, Kenya, 23 January 2006.

## Theses

Kamau, R., D. Omwansa, 2005.. Growth and Survival of African catfish, *Clarias gariepinus* (Burchell, 1822) Fry reared in Happas at different Stocking Densities. Moi University. M.Sc. Thesis. September 2005.

## AQUACULTURE TRAINING FOR KENYAN EXTENSION WORKERS, FISH FARMERS, AND UNIVERSITY STUDENTS

*Twelfth Work Plan, Applied Technology and Extension Methodologies 3 (12ATE3)*

*Abstract*

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### ABSTRACT

The ACRSP, the Moi University (MU) Department of Fisheries and Aquatic Sciences, and the Fisheries Department of the Government of Kenya have expended considerable effort on aquaculture training at various levels during the past decade. Target audiences for this training have included fish farmers, fisheries extension workers, undergraduate students, and graduate students. Training for fish farmers and extension workers has typically been conducted through farmer field days and two- and three-week short courses. Training for undergraduates typically has involved providing small stipends and supervision for "senior projects" in some aspect of aquaculture appropriate to Kenya. Training for graduate students has been done by providing scholarship support for formal degree programs, both abroad and at Kenyan Universities.

This investigation was undertaken to continue these training efforts in Kenya. Specific objectives have been to train up to 34 extension workers and six advanced farmers in hatchery management techniques, to provide on-farm training in simple techniques for spawning, hatching, and rearing catfish juveniles in ponds for up to 12 farmers, to provide stipend support for four undergraduate students training in aquaculture at MU, and to provide scholarship support for two Master's-level (M.Sc.) university students at MU.

All objectives of this investigation have been met, with the exception that the two M.Sc. students have not finalized their theses for submission to the MU Graduate School. Two two-week short courses were given to selected FD Fisheries Assistants (extension workers), KMFRI research officers, and advanced fish farmers. The courses were held at Sagana and Moi University, from 16–31 April and 15–28 August respectively. Twenty individuals were trained in each session. The courses focused on the African catfish (*Clarias gariepinus*) fingerling production process, from maintenance of broodstock through brooder selection, spawning, incubation, hatching, and rearing of fry to the

fingerling stage. In addition, two on-farm training sessions were conducted for advanced farmers during 2005 and early 2006. The first fish farmers training was held at both Chepkoilel campus and Kesses next to Moi University main Campus from 19–21 May 2005. The second training was held at Chepkoilel Campus from 2–5 April 2006. The training consisted of hands-on spawning/hatching/rearing work conducted by the farmers themselves under the guidance of a host farmer and one or more experienced technicians from MU and the FD. Four MU undergraduate students received support for their senior project work and two graduate students received full scholarship support. The graduate students have completed their field work and data analysis and are currently in the final stages of preparing their thesis for submission. It is expected that they will graduate by December 2006.

Completion of this investigation will benefit Kenya and the region in many ways. Extension workers and fish farmers will be able to apply new knowledge to increase *Clarias* fingerling production on government and private farms. An increased supply of *Clarias* fingerlings will provide Lake Victoria Nile perch fishers with a reliable source of bait and fishing pressure on immature *Clarias* in the lake will decrease. A steady supply of *Clarias* fingerlings will also help producers in areas where *Clarias* is gaining popularity as a cultured food fish, and farmers producing *Clarias* fingerlings will enjoy an additional source of income. Increases in fish production realized through all these avenues will contribute to human health and welfare in the region.

## STUDIES ON STRATEGIES FOR INCREASING THE GROWTH AND SURVIVAL OF AFRICAN CATFISH (*CLARIAS GARIEPINUS*) JUVENILES REARED FOR STOCKING OR FOR USE AS BAIT

*Twelfth Work Plan, Seedstock Development and Availability 2 (12SDA2)*

*Abstract*

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### ABSTRACT

The African catfish, *Clarias gariepinus*, is endemic to Kenya. It is considered to have excellent flavor and is therefore popular as a food fish. With a growing interest in aquaculture, some fish farmers are turning to the production of catfish fingerlings to sell for stocking in earthen ponds as well as for baitfish in the Lake Victoria Nile perch long-line



fishery. Although spawning of *Clarias* is not a major problem, sufficient quantities of fingerlings are not being produced, due to low and highly variable rates of survival. Survival rates range from 1 to 50% in ponds, with a rate of 25% (egg to 5-gram fingerling) considered good. For producers to meet the increasing demand for fingerlings, however, techniques must be found to significantly improve these survival rates.

The primary objective of these studies has been to assess management strategies that might contribute to improved growth and survival of juvenile African catfish. Two studies were conducted by graduate students (M.Sc. candidates) at Moi University, Eldoret, Kenya, in 2005 and 2006. In one study, catfish larvae were stocked into 18 30-L glass aquaria in the hatchery, where they were offered three diet sequences and reared under two light regimes for a period of 30 days. The diet sequences tested were an *Artemia*-chick mash sequence, a rotifer-chick mash sequence, and chick mash only. Nine aquaria were illuminated and nine were darkened. Offering live feeds (*Artemia* or rotifers) prior to switching to a prepared feed (chick mash) led to better growth and survival than rearing larvae on the prepared feed only. Larvae reared in darkness had better growth and survival rates than those reared in illuminated aquaria.

The second study consisted of two separate experiments. In the first experiment, catfish larvae were reared in the hatchery for periods of 1, 5, 10, and 15 days prior to being stocked into hapas in ponds, where they were reared up to a total of 60 days. Larvae reared for 10 days prior to the transfer showed the best growth and the second best overall survival. For the second experiment, all larvae were reared in the hatchery for 10 days and then transferred to hapas, where they were stocked at densities of 25, 50, 100, and 200 fish per m<sup>2</sup> and reared for 42 days. In this experiment, stocking fish at 25 per m<sup>2</sup> resulted in the most growth and the best survival among the treatments.

All fieldwork and statistical analysis has been completed and the theses are being written. Master's theses are expected to be complete and submitted to the Graduate Committee in the School of Natural Resource Management for approval by the end of September. A final report detailing this experimental work will be completed by 30 April 2007.

The findings of this research will be applied to *C. gariepinus* fingerling production on government and private farms in Kenya. They will also be included in a new fish farming handbook being prepared under ACRSP sponsorship, providing farmers and extension workers with access to the latest information. Application of new techniques will ultimately result in increased supplies of *Clarias* fingerlings, and resulting increases in aquaculture and fishery production will contribute to human health and welfare in the region.

## KENYA TRAINING-OF-TRAINERS AND REGIONALIZATION OF AQUACULTURE TRAINING ACTIVITIES

*Twelfth Work Plan, Applied Technology and Extension Methodologies 11 (12ATE11)*

*Abstract*

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### ABSTRACT

This activity addresses new (2005–2006) objectives for the OSU/Kenya project, including conducting additional training courses (one training-of-trainers course for Fisheries Officers followed by two pond construction and management courses for fisheries assistants, taught by the new trainers) in Kenya and providing support for the participation of Kenyan PI Charles Ngugi in training courses held in other countries in the region.

The intent of training trainers in Kenya is to increase the number of individuals who can effectively teach basic pond construction and management techniques to extension agents and farmers. It is expected that 10 Fisheries Officers will be selected to be trained as trainers and that they will then conduct two further short courses for up to 15 Fisheries Assistants each.

Supporting the participation of Charles Ngugi in training courses in Tanzania, Ghana, or other countries is intended to make the experiences and materials developed by the Kenya Project available for training efforts in the region as a whole, as well as to encourage regional collaboration in aquaculture training efforts. Ngugi is skilled in the practical aspects of pond construction and pond and hatchery management and he has a teaching style that makes the subject matter highly accessible to trainees, whether they are farmers or extension workers. He has previously traveled throughout the region and his fluency in both Swahili and English will enable him to easily fit in and make valuable contributions to training courses in other countries. These activities are scheduled to take place between September 2006 and April 2007.

## KENYA CAPACITY BUILDING: STUDENT RESEARCH AND THESIS SUPPORT

*Twelfth Work Plan, Seedstock Development and Availability 5 (12SDA5)*

*Abstract*

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### ABSTRACT

This activity addresses new objectives for the OSU / Kenya Project for the 2005–2006 year. During this year we will provide scholarship support for the research and thesis work of two new graduate students currently pursuing aquaculture studies at Moi University, Eldoret, Kenya. We will also provide stipend support for three undergraduate aquaculture students working on senior projects. This work may be conducted either at Moi University, Eldoret, or Sagana Fish Farm, Sagana. Support is also provided for one of our current graduate students to present research results at the “AQUA 2006” conference in Florence, Italy.

Research topics being undertaken by the new students include work on 1) the fecundity and energetics of tilapia (*Oreochromis niloticus*) brooders conditioned under different feeding regimes and 2) yields of Nile tilapia and African catfish (*Clarias gariepinus*) reared together in different stocking ratios. It is expected that they will complete their fieldwork on these topics by September 2006 and finish their theses by late spring 2007.

Current graduate student Victoria Boit traveled to Florence, Italy, to present the results of her research in the CRSP session of AQUA 2006 on Saturday, May 13, 2006. Her presentation was entitled “Effects of three feeding regimes and two light regimes on the growth and survival of African catfish *Clarias gariepinus* fry in aquaria.” Victoria is in the final stages of preparing her thesis and is expecting to submit it to her committee by September 2006.





# Africa Project: Production Technology

Kenya, Ghana, Tanzania

Subcontract No. RD010E-E (UAPB)

Subcontract No. RD010E (PU)



This three-country Africa Project was initially proposed as part of the Eleventh Work Plan. At that time, ACRSP research in the region was primarily carried out at the Sagana Fish Farm in Kenya. Both Tanzania and Ghana were evaluated as prospective Aquaculture CRSP host countries during the Seventh Work Plan and Eleventh Work Plan activities involved further investigation into the involvement of Tanzania and Ghana as ACRSP host countries—specifically the compliance of these two countries with BIFAD guidelines and suitability as ACRSP research sites. Consequently, a full research project was submitted for funding in the Eleventh Work Plan. One of the researchable priority areas identified by the 2002 Africa Expert Panel was insufficient knowledge of the economics of aquaculture. Good quality information is necessary for aquaculture policy planning and private investment in Africa. To this end, researchers at the University of Arkansas at Pine Bluff partnered with colleagues at the Ministry of Agriculture (Tanzania), Sokoine University of Agriculture (Tanzania), Ministry of Food and Agriculture (Ghana), University of Science and Technology (Ghana), Ministry of Agriculture and Rural Development (Kenya), and Moi University (Kenya) conducted market-related research at all three host countries. An additional investigation involving Purdue University is being carried out during the Twelfth Work Plan to convene fish farmer training sessions in Tanzania associated with pond and fish health management, principles and benefits of record keeping, and assessing and evaluating costs and benefits.

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**Work Plan Research**

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

- Farmers training in Tanzania/ 12ERA3. A progress abstract was submitted for this investigation.

In addition, the following Eleventh Work Plan investigations are ongoing during the reporting period:

- Cost evaluation and benefit assessment of fish farming in selected African nations/ 11ERAR2. A final abstract was submitted for this investigation.
- An economic assessment of aquaculture in rural Africa: The case of Tanzania, Kenya, and Ghana/ 11ERAR3. A final report was submitted for this investigation.
- A cross-national analysis of the potential economic impact of aquaculture in Africa/ 11ERAR4. A final abstract was submitted for this investigation.

**Presentations**

Quagrainie, K., 2006. Economic Analysis of Nile Tilapia *Oreochromis niloticus* Production in Tanzania, Kenya and Ghana. AQUA 2006, Firenze, Italy, 9–13 May 2006.

Kaliba, A., 2006. A GCE Analysis of the Potential Economic Impacts of Aquaculture Promotion in Sub-Saharan Africa. AQUA 2006, Firenze, Italy, 9–13 May 2006.

Quagrainie, K., 2005. Tilapia farming: a comparison of enterprise profitability among Ghanaian farmers. Aquaculture Association of Southern Africa, Grahamstown, South Africa, 12–16 September 2005.

Amisah, S., 2005. Fish farming in southern Ghana: some preliminary findings on opportunities and constraints for sustainable fish production and commercialization. Aquaculture Association of Southern Africa, Grahamstown, South Africa, September 2005.

Osewe, K., 2005. Status of fish farming and socio-economic structure and situation of farmers in Tanzania. Aquaculture Association of Southern Africa, Grahamstown, South Africa, 12–16 September 2005.

Ngugi, C., 2005. Factors influencing growth and survival of African catfish *Clarias gariepinus* juveniles and their implications for aquaculture development in Kenya. Aquaculture Association of Southern Africa, Grahamstown, South Africa, 12–16 September 2005.

**FARMERS TRAINING IN TANZANIA**

*Twelfth Work Plan, Economic/Risk Assessment and Social Analysis 3 (12ERA3)*  
Abstract

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#### ABSTRACT

The Tanzania Fisheries and Aquaculture Development Division depends on farmer training workshops as a major means of sustainable technology transfer in addition to extension services. Most on-farm research activities are conducted by the Sokoine University of Agriculture in collaboration with Kingorwila National Fish Center, Fisheries and Aquaculture Development Division. Both institutions are in the Morogoro Region. The proposed training will involve 25 fish farmers from different participating villages in the Morogoro Region. The training is important for developing model fish farmers who will participate in future research activities and extend the knowledge to other fish farmers in the region.

The training will be a five-day workshop that will be conducted in collaboration with Mkindo Farmers Training Center. The major topics to be covered are pond construction, pond management, fish health, fish nutrition, economics of production, and marketing. Training instructors will come from Sokoine University of Agriculture in Tanzania, Kingorwila National Fish Center, Moi University in Kenya, and University of Arkansas at Pine Bluff, US. The workshop is scheduled to take place in November 2006. The training activities will be based on training modules and trainees include women and household members who manage fish ponds.

It is anticipated that farmers will acquire knowledge that will be used to improve farm productivity. The training will help to accelerate the adoption process of improved technical innovations (through farmer-to-farmer knowledge transfer).

#### 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 Report

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#### ABSTRACT

Record keeping is an important management tool necessary for business planning and development. If small- and medium-scale fish farming enterprises can be sustained, developed, and profitable, the steps should be taken to teach farmers basic valuation methods for costs and benefits at the farm level as well as principles of record keeping. The project involved training sessions for selected fish farmers in Kenya and Ghana. In Kenya, the five-day workshop trained fish farmers in pond record keeping and business management. Twelve small-scale fish farmers and hatchery owners participated in the training. The session focused on cost and benefits of constructing good ponds, how to increase fish production through better pond management, pond financial management, and pond record keeping. Results from this workshop showed that farmers found analyzing production records necessary to identify weaknesses in farm operation. Farmers also recognized that record keeping was valuable for gaining potential bank loans. In Ghana, the training involved 85 farmers. The focus of the training was record keeping and economic analysis, i.e., how to calculate costs and profits. The workshop was conducted in collaboration with Ashanti and Brong-Ahafo regional farmer associations. Results from this workshop showed that farmers appreciated the importance of record keeping and were able to value homemade inputs, identify and list all various farm records, and also identify aspects of fixed costs, recurrent costs, revenues, and profits.

#### 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 Report

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## ABSTRACT

Economic assessment of aquaculture in rural Tanzania, Kenya, and Ghana was examined using representative Nile tilapia production systems in each nation. The study used a dynamic economic model to analyze the profitability of three Nile tilapia production cultures that included a mixed-sex tilapia culture without catfish predation, mixed-sex tilapia culture with catfish predation, and hand-sexed, all-male tilapia culture. The model simulated individual fish growth, taking into account fish population dynamics in the pond. In Kenya, the results suggest that mixed-sex tilapia culture, though economically feasible and profitable, was inferior to all-male tilapia cultures. Switching from no catfish predation to predation culture did not significantly increase operational cost. The realized gross profit margins were 45% for a 200 m<sup>2</sup> pond and about 19% for a 634 m<sup>2</sup> pond. With the exception of mixed tilapia without predation in the 634 m<sup>2</sup> pond, the realized gross profit margins were generally over 40%. Introduction of catfish predation in the pond decreased profit margin from 46% to 43% for a 200 m<sup>2</sup> pond but increased profit margin from 19% to 42% for a 634 m<sup>2</sup> pond. Culturing hand-sexed all-male tilapia increased gross profit by 46% and 56% for 200 m<sup>2</sup> pond and 634 m<sup>2</sup> pond, respectively. In Ghana, the mixed-sex tilapia culture with catfish predation and hand-sexed all-male tilapia culture was economically attractive. Switching from polyculture to monoculture did not significantly increase operational cost. The realized gross profit margins were about 26% for polyculture and 35% for monoculture. By culturing hand-sexed all-male tilapia, gross profit margins increased from 26% to 39% for a 2,000 m<sup>2</sup> pond and from 26% to 46% for a 4,000 m<sup>2</sup> pond. In Tanzania however, though economically feasible, the mixed-sex tilapia culture did not generate enough profits for long-term business survival. Switching from no predation to predation culture did not significantly increase operational costs. The realized gross profit margins were 2% for a 150 m<sup>2</sup> pond and 4% for a 300 m<sup>2</sup> pond, which were not high enough to justify a mixed-sex tilapia culture without predation. Introduction of catfish predation in the pond increased the profit margin to 27% for a 150 m<sup>2</sup> pond and to 23% for a 300 m<sup>2</sup> pond. The culture of hand-sexed all-male tilapia increased gross profit margin to 47% and 30% for 150 m<sup>2</sup> and 300 m<sup>2</sup> ponds, respectively. These results suggest that technical assistance to rural aquaculture in Africa would be best with research and extension geared towards developing Nile tilapia production systems based on all male sex tilapia and not polyculture. Since a mixed-sex culture with catfish predation was economically feasible in all countries, it should represent a second best alternative for Nile tilapia production systems. Farm sizes differed among the three countries and research efforts would be needed to determine optimal farm size for each country. Optimal farm size ensures efficient use of resources. Under improved production systems, the models showed profits were high enough to justify investment through borrowed capital.

## 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 Report*

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## ABSTRACT

There is increased interest and policy support towards aquaculture development in Africa. Aquaculture development programs have the potential of creating new jobs, improving food security among poor households, providing stability to household income flow, and increasing farm level efficiency and sustainability. This study used computable general equilibrium models for Ghana, Kenya, and Tanzania to estimate the effects on poverty alleviation from aquaculture production activity and productivity growth in intermediate inputs and primary factors. Using the head count ratio measure of poverty, it was determined that, in Ghana, about 17% of agricultural farmers and about 19% of public sector employees lived below the poverty line of GHC665,300. The percentages for the private sector employee, non-farm, self-employed and miscellaneous households were, respectively, 8%, 21%, and 20%. In Kenya, more than 50% of the population lived below the poverty line of KES14,868 in 2001. The most affected were female-headed households in rural areas. In Tanzania, 38% of rural households and 23% of urban households lived below the poverty line. With aquaculture expansion, the general results of the study suggest that there will be positive effects in per capita income for all households in Ghana and Kenya. In Tanzania, some rich households will experience income loss due to resource shift from the fisheries and manufacturing sectors to aquaculture. The measure of poverty gap decreased in all household groups in all countries with aquaculture expansion. This was the result of decreases in poverty lines associated with decreases in relative price, and increases in the minimum income associated with income expansion. Sectoral-linkages incorporated in the models suggest that aquaculture development is promising for sector-specific policy support to enhance poverty alleviation programs among poor households in Sub-Saharan Africa.



# Kenya Project: Watershed Management

Kenya  
Subcontract No. RD010E-G (UG)



*E. WILLIAM TOLLNER*

The Kenya Project: Watershed Management (previously titled the Africa Project) was conceived during the Eleventh Work Plan. The overall goal of the project is to apply a multidisciplinary approach to develop and demonstrate improved and integrated sustainable management of watershed resources through stakeholder participation. This project came to fruition during the Twelfth Work Plan through collaboration between US researchers at the University of Georgia and Michigan State University and Kenyan researchers affiliated with several departments at Moi University, Egerton University, and the Kenya Department of Fisheries. Ongoing research efforts include: compiling the land-use practices, policy, and tenure regimes in the Nzoia River Basin; assessing the aquatic ecological health of selected representative sub-watersheds; determining hydrologic baselines of the watershed; and developing an appropriate stakeholder involvement model for long-term sustainability of these efforts. Substantial progress is being made towards each of these objectives. The overall goal of the project remains capacity development at Moi University in order for it to become a regional leader in watershed assessment and management.

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Nancy Gitonga Host Country Co-Principal Investigator (through July 2006)

## Work Plan Research

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

- Land-use practices, policies, and tenure regimes in the Nzoia River Basin/ 12EIA5. A final abstract was submitted for this investigation.
- Hydraulic, water quality, and social assessment of the Nzoia River Basin/ 12ERA2. A progress abstract was submitted for this investigation.
- Ecological assessment of selected sub-watersheds of the Nzoia River Basin/ 12WQA4. A progress abstract was submitted for this investigation.
- Determination of hydrologic baselines for the Nzoia River Basin/ 12WQA5. A final abstract was submitted for this investigation.
- Building the capacity of Moi to conduct watershed assessments/ 12EIA4. A final abstract was submitted for this investigation.

## Workshops/Seminars/Educational Outreach

Carried out field reconnaissance with two students. During this period we visited the government and administrative officials (chiefs, etc.) to introduce us (students and staff and the study, to the local community (8 November 2005; 16 November 2005)

On 23 November 2005, carried out a guided reconnaissance trip with the administrative and political leaders in the study area to sensitize them and the community on our study. We also identified and proposed temporary weather stations and identified suitable local institution that can support us with security and readings of the weather records.

On 1 December 2005, onsite training on sampling procedures was conducted for six field assistants was of the on sampling procedures. Preliminary sampling and analyses continued

through 12 January 2006. The sample location was established using a GPS (January 17, 2006).

ACRSP staff held discussions on potentials for aquaculture in east and central Africa. They also discussed fisheries and watershed management while attending the seventh meeting of AASA in South Africa. A meeting with lectures from Jomo Kenyatta University, Department of Hydrology was conducted concerning their possible involvement in the project. We wanted to involve their personnel and physical resources in carrying out hydrological work given their past experience in similar watersheds.

## LAND-USE PRACTICES, POLICY, AND TENURE REGIMES IN THE NZOIA RIVER BASIN

*Twelfth Work Plan, Environmental Impacts Analysis 5 (12EIA5)  
Final Abstract*

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#### ABSTRACT

Identification of current soil and water conditions and conservation practices is an initial step toward development of appropriate technologies for land-use management plans. In Western Kenya, land-use activities for two villages along the Kapoiet River and two locations along the Moiben River typify maize production potential and its cultural significance. Research objectives include identification of the: 1) types of soil and water conservation (SWC) practices in use, 2) factors that influence the adoption of SWC practices, and 3) characteristics of those who adopt SWC practices. Data were acquired in each location through participatory rural appraisal activities ( $n=4$ ), informant interviews ( $n=8$ ), household questionnaires ( $n=172$ ), and personal observation. Household respondents indicated that 59% apply organic fertilizer, 56% plant grass strips, 29% build terraces, and 29% leave land fallow. Significant relationships existed between the use of SWC methods and region-specific household characteristics (e.g., wealth, number and type of livestock, acreage and land ownership, and perception of soil conditions). People who adopted SWC practices had an interest and knowledge of SWC purpose and implementation. Steep slope conditions and financial resources also influenced adoption of SWC practices. If implemented, specific SWC methods act to prevent erosion and subsequent loss of soil fertility. Identifying opportunities to increase farm capacity to adopt conservation practices will contribute to meeting the demands for high maize production from this region, while also improving local and regional soil and water quality.

#### HYDRAULIC, WATER QUALITY, AND SOCIAL ASSESSMENT OF THE NZOIA RIVER BASIN

*Twelfth Work Plan, Economic/Risk Assessment and Social Analysis 2 (12ERA2)*  
Abstract

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#### ABSTRACT

Assessing risks and assets aids in understanding how livelihood strategies reflect changes in vulnerability. Mitigating risks is dependent on people's ability to pool

and accumulate assets on either an individual basis or community-wide level. In Western Kenya, livelihood strategies along the Kapoiet River and Moiben River reflect the role of financial, human, natural, physical, and social capital. Research objectives include identification of 1) risks and assets and 2) strategies used to manage and enhance the capital resources in the Kapoiet and Moiben regions. Data were acquired in each location through participatory rural appraisal activities ( $n=4$ ), informant interviews ( $n=8$ ), household questionnaires ( $n=172$ ), and personal observation. Participatory, risk-ranking activities identified health issues, communication infrastructure, insecurity, water, markets, unemployment, and leadership as major concerns. Notable identified assets included local natural resources, churches, police posts, governmental extension services or representatives, non-governmental organizations and community-based organizations. Involvement in community self-help groups, altering farming strategies, and seeking outside assistance were strategies people used to help reduce risks and strengthen assets. Assisting communities in identifying opportunities for risk reduction and asset enhancement may contribute to more effective land management and poverty alleviation strategies.

#### ECOLOGICAL ASSESSMENT OF SELECTED SUB-WATERSHEDS OF THE NZOIA RIVER BASIN

*Twelfth Work Plan, Water Quality and Availability 4 (12WQA4)*  
Abstract

E. William Tollner  
Biology and Agriculture Engineering Department  
Driftmier Engineering Center  
University of Georgia  
Athens, Georgia, USA

Mucaí Muchiri, Odipo Osano, and Geoffrey Karanja  
Moi University  
Eldoret, Kenya

William Shivoga  
Egerton University  
Njoro, Kenya

#### ABSTRACT

During the six months of the study, 73 macroinvertebrate taxa were encountered representing 13 orders and 51 families with a total abundance of 13,910. The major taxonomic groups encountered were Diptera, Ephemeroptera, Coleoptera, Oligochaeta, Trichoptera, Gastropoda, and Odonata representing 37%, 22%, 11%, 11%, 10%, 5%, and 2%, respectively. Other groups collected in small numbers include Hemiptera, Plecoptera, Hirudina, Crustacea, Arachnida, and Lepidoptera.

During the study, it was generally observed that abundance was lowest during the dry period. It increased progressively during the onset of the rainy season but started to decline during the peak and spates in July–August. However, the spates and heavy flows did not affect taxon richness

although abundance was greatly affected. At this period, the river was characterized by large quantities of suspended matter and high sediment loads. Discharge also increased by more than ten times.

Non-recording rain gauges were installed in order to collect data on the amounts of precipitation that will help in predicting the quantities and rates of runoff generated during rain events. To facilitate in the collection of this data, we have trained research assistants to collect and record rainfall data. Data on suspended solids collected before the onset of rains will assist in making comparisons. Increased turbidity of Moiben River waters have been noted during rain events, with suspended solids recorded at greater than 20mg L<sup>-1</sup>. Hence the sampling process has been coupled with education of the community by the relevant authorities, targeting those cultivating close to the river, on best management practices to reduce soil erosion.

We have also collected and examined groundwater samples for contamination with atrazine and nitrates. Our preliminary results indicate higher levels of contamination at the start of farming activities. The extent and knowledge about use of pesticides and fertilizers are obtained by use of questionnaires. The possible effects on health of the inhabitants will be established using results from the questionnaires and medical records available at medical facilities.

#### **DETERMINATION OF HYDROLOGIC BASELINES FOR THE NZOIA RIVER BASIN**

*Twelfth Work Plan, Water Quality and Availability 5 (12WQA5) Final Abstract*

Herbert Ssegane and E. William Tollner  
Biology and Agriculture Engineering Department  
Driftmier Engineering Center  
University of Georgia  
Athens, Georgia, USA

Mucaï Muchiri  
Moi University,  
Eldoret, Kenya

Nancy Gitonga  
Department of Fisheries  
Nairobi, Kenya

Geoff Habron  
Michigan State University  
Lansing, MI

#### **ABSTRACT**

A software suite consisting of GoogleEarth, GoldenGraphics Surfer, and UTS TKSolver was assembled and preliminarily evaluated for assessing the potential of soil erosion due to large-scale agricultural development, which can enter and damage the Nzoia River basin in Kenya. Based on comparisons of elevations obtained with handheld GPS units onsite and measurements made with GoogleEarth software, we determined elevation data, area measurements,

and watershed cover assessments can be used to assess the relative potential for agricultural practices to contribute to sedimentation in streams. The Moore's Bridge subwatershed, located near Eldoret, Kenya on the Moiben River, was selected as the first to study. An extensive analysis of the components of the Universal Soil Loss Equation and the US Forest Service sediment delivery ratio method was made. Based on the fact that rainfall in the central to south African region is close to that in the US and that crops common to the US are in production, we feel confident that the US experience is applicable. Soils of the region are of the Ultisol and Oxisol classification, similar to soils in the southeast US. Using the Universal Soil Loss Equation coupled with the US Forest Service sediment delivery ratio method, we determined that topography could be easily mapped and assessments made of erosion potential. Preliminary results suggest that agricultural pollution is not a serious issue in this particular region.

#### **BUILDING THE CAPACITY OF MOI UNIVERSITY TO CONDUCT WATERSHED ASSESSMENTS**

*Twelfth Work Plan Economic/Risk Assessment and Social Analysis 4 (12EIA4)*

E. William Tollner  
University of Georgia  
Athens, Georgia, USA

Mucaï Muchiri,  
Moi University,  
Eldoret, Kenya

Nancy Gitonga,  
Department of Fisheries  
Nairobi, Kenya

Geoff Habron  
Michigan State University  
Lansing, Michigan, USA

#### **ABSTRACT**

The diverse knowledge of social scientists, hydrologists, and agronomists is crucial for a watershed assessment team. Diversity is important for both host country and US PI counterparts. Remote sensing techniques coupled with ground truth data by the social scientist, hydrologist, and crop scientist make a comprehensive assessment a doable undertaking. The proposed assessment table was found to produce needed results. We found the methodology was not inherently linear. Due to the great distances and diversity of the team members, the aspects of the table are developed with a degree of opportunism. The process is in the general sense linear. Although the analyses laboratory has been slow to form and become recognizable, the expertise base is solidifying and an excellent foundation for future work is in place.



# Global Project: Watershed Management

Thailand, Brazil, South Africa  
Subcontract No. RD010A-07 (AU)



KHALID SALIE



BRIGITTE GOETZE

The complex ecological interactions among nutrients; primary, secondary, and heterotrophic productivity; and fish yield are known as pond dynamics. Previous ACRSP research in pond dynamics focused on the influence of pond bottom soils on water quality and productivity. In Thailand, Auburn University, and the Thailand Department of Fisheries are collaborating to analyze research results and produce Best Management Practices (BMPs) for pond soils. During the past year, the pond soil BMPs have been formatted as a list of BMPs and notes on implementation of each BMP. This material also has been translated into Thai for use by fish farmers in Thailand. In South Africa and Brazil, workshops will be convened through a partnership between Auburn University, Stellenbosch University (South Africa), Universidade Estadual Paulista (Brazil), and Embrapa Environment (Brazil) to train local stakeholders in appropriate methods to develop BMPs that are suitable for the local aquaculture industry and environment. An ACRSP manual illustrating the necessary approach to develop BMPs for responsible aquaculture has been prepared and will be printed. This manual will be useful for prospective fish farmers in other locations who are interested in developing aquaculture BMPs for their local aquaculture sectors.

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**Staff**

*Auburn University, Auburn Alabama*

Claude E. Boyd	US Principal Investigator
Chhorn Lim	US Co-Principal Investigator
Idsariya Wudtisín	Ph.D. Student (Thailand, through 2005)

*University of Stellenbosch, Stellenbosch, South Africa*

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

*Kasetsart University, Bangkok, Thailand*

Mali Boonyaratpalin	Host Country Principal Investigator
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*Embrapa Meio Ambiente, Jaguariúna, SP, Brazil*

Julio Queiroz	Host Country Principal Investigator
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*Universidade Estadual Paulista, Jaboticabal, São Paulo, Brazil*

Lúcia Sipaúba-Tavares	Host Country Co-Principal Investigator
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**Work Plan Research**

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

- Best practices for management of aquaculture pond soils in Thailand/12EIA1. A final abstract was submitted for this investigation.
- Workshops on guidelines for developing aquaculture best management practices/12EIA6. A final abstract was submitted for this investigation.

**Publications**

Silapajarn, K., O. Silapajarn, and C.E. Boyd, 2005. Evaluation of lime requirement procedures and liming materials for aquaculture ponds in Thailand. *Journal of Applied Aquaculture*, 17:77–88.

**Theses**

Wudtisín, Idsariya, 2005. Bottom soil quality in ponds for culture of catfish, freshwater prawn, and carp in Thailand. Auburn University. Ph.D. dissertation.

**Presentations**

Boyd, C.E., 2005. Recent advances in environmentally responsible Aquaculture. Bi-annual Conference of the Aquaculture Association Southern Africa, Grahamstown, South Africa, September 2005.

Boyd, C.E. Boyd, 2006. Indicators for assessing environmental performance of aquaculture. AQUA 2006, Annual Meeting of the World Aquaculture Society, Florence, Italy, 9–13 May 2006.

**Workshops/Seminars/Educational Outreach**

Boyd, C.E., 2005. Best Management Practices. Bi-annual Conference of the Aquaculture Association of Southern Africa, Grahamstown, South Africa, 15–16 September, 2005.

**BEST PRACTICES FOR MANAGEMENT OF AQUACULTURE POND SOILS IN THAILAND**

*Twelfth Work Plan, Environmental Impacts Analysis 1 (12EIA1) Final Report*

Mali Boonyaratpalin  
Department of Fisheries  
Jatujak, Bangkok, Thailand

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

**ABSTRACT**

Sediment samples were collected from 42 catfish (*Clarias* hybrid) ponds, 40 freshwater prawn (*Macrobrachium rosenbergii*) ponds, and 18 carp (*Puntius* spp.) ponds in Thailand. Regression analysis revealed that pond age (1 to 30 years) was not a major factor influencing the physical and chemical composition of pond sediments. Sediment depth, F + S horizon thickness, and bulk density of the S horizon were greater ( $P < 0.05$ ) in carp ponds than in catfish and prawn ponds. This resulted because sediment was removed from catfish and prawn ponds more frequently than from carp ponds. Total carbon, organic carbon, and total nitrogen concentrations were greater ( $P < 0.05$ ) in carp ponds than in prawn and catfish ponds. Few ponds had sediment organic carbon concentrations above 3%, and carbon:nitrogen ratio values did not differ ( $P > 0.05$ ) among ponds for the three species. Total phosphorus and other sediment phosphorus fractions increased in an ascending order from prawn ponds to carp ponds to catfish ponds. Sediment sulfur concentrations also increased in the same ascending order. There were no differences in major or minor nutrient concentrations in sediment that would influence aquacultural production. Although there were significant correlations ( $P < 0.05$ ) between various sediment

quality variables, no single variable or group of variables would be useful in estimating sediment quality.

Pond bottom management practices used by producers in Thailand included drying pond bottoms between crops, liming, tilling, and periodic sediment removal. These practices have maintained relatively good bottom quality. They should be continued in Thailand and adopted in other places.

The particular combination of BMPs needed to assure environmentally-responsible operations varies among culture techniques and species. Different combinations of BMPs are necessary in different regions and at different sites, and BMP development should be done at a relatively local level.

More specific information on the content of the workshops is contained in a report submitted to ACRSP in June 2006.

#### **WORKSHOPS ON GUIDELINES FOR DEVELOPING AQUACULTURE BEST MANAGEMENT PRACTICES**

*Twelfth Work Plan, Environmental Impacts Analysis 6 (12EIA6)  
Final Report*

Khalid Salie and Lourens de Wet  
University of Stellenbosch  
Stellenbosch, South Africa

Julio Queiroz  
Embrapa Meio Ambiente  
Sao Paulo, Brazil

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

#### **ABSTRACT**

Sustainability and environmental protection are major issues in aquaculture. Unsustainable projects are economically damaging, and they usually are the endeavors that cause the most environmental harm. Two main reasons for some aquaculture projects' failure to achieve economic and environmental sustainability are selection of inferior sites and application of inappropriate management procedures. The aquaculture industry has been embroiled in controversy about its environmental record and its long-term sustainability.

In response to these criticisms, aquaculture organizations began to develop codes of practice and best management practices (BMPs) for voluntary adoption by their members or clients. Thus, a workshop on development of BMPs for pond aquaculture was held in South Africa in September 2005 and in Brazil in March 2006. As one might expect, these instruments are highly variable in content and format. However, the better ones are developed through a collaborative, transparent stakeholder process involving several rounds of review and revision. The BMPs are designed to prevent or mitigate possible negative impacts identified in an environmental assessment of the industry.

Consumers are becoming more environmentally aware and are seeking products with a good environmental record. An increasing number of brokers and institutional buyers of fish, shrimp, and other aquatic products are seeking to do business with farms that use environmentally-responsible culture methods. This trend is expected to continue, and BMPs will become an important environmental and marketing tool in aquaculture.





### Global Project:

## Human Welfare, Health and Nutrition

Subcontract No. RD010E-F (IATP)

Marine environments have considerable potential for aquaculture production in the context of international development. This potential could be larger than previously anticipated if aquaculture systems can utilize both protected nearshore and exposed offshore locations. To this end, this project assessed the potential for low trophic species aquaculture in exposed and offshore environments. Researchers identified the strengths and weaknesses of low trophic species for offshore aquaculture within the framework of progressive development. of international development. This potential could be larger than previously anticipated if aquaculture systems can utilize both protected nearshore and exposed offshore locations. To this end, this project assessed the potential for low trophic species aquaculture in exposed and offshore environments. Researchers identified the strengths and weaknesses of low trophic species for offshore aquaculture within the framework of progressive development.



**Staff***Institute for Agriculture and Trade Policy, Minneapolis, Minnesota (Lead US Institution)*

Mike Skladany

US Principal Investigator

Ben Belton

Research Assistant

**Work Plan Research**

This subcontract was awarded funding to conduct the following

Twelfth Work Plan investigation:

- Ex ante assessment of coastal and marine aquaculture development: Charting comparative strengths and weaknesses of low trophic species for offshore aqua-culture in developed and developing countries/12ERA5. A final report was submitted for this investigation.

**EX ANTE ASSESSMENT OF COASTAL AND MARINE  
AQUACULTURE DEVELOPMENT: CHARTING THE STRENGTHS  
AND WEAKNESSES OF LOW TROPHIC SPECIES FOR OFFSHORE  
AQUACULTURE IN DEVELOPED AND DEVELOPING COUNTRIES**

*Twelfth Work Plan, Economic/Risk Assessment and Social  
Analysis 5 (12ERA5)*

Ben Belton and Mike Skladany  
Institute for Agriculture and Trade Policy  
Minneapolis, Minnesota

**ABSTRACT**

This report examines the ex ante development of low trophic marine organisms in exposed ocean conditions with an emphasis on the developing world. Overall, we found an overwhelming preference for high-value finfish culture regardless of location; high value product being deemed necessary to offset the large costs and risks associated with farming in exposed ocean sites. This focus has tended to obscure attention on the primary utilization of low trophic marine species in the development of exposed ocean culture systems. Drawing from a series of case studies, interviews and literature review, we first provide a series of sustainable developmental criteria that must be met; site selection, biological and economic factors related to culture systems, property rights, environmental standards and contributing to community development and avoiding user conflicts need much more consideration. We then examine ten low trophic candidate species in terms of their sustainable development potential. Our findings reveal that at present, sponge, blue mussel and perhaps pearl culture may warrant some further examination. For developing countries, offshore aquaculture of low trophic species must compete with near shore systems that hold marked advantages in terms of economic and social economies of scale. In exposed ocean environments, high investment costs, established technology, managerial expertise and achieving efficient economies of scale in both production and post-harvest phases will remain significant obstacles for future sustainable development efforts in developing countries.



# Global Production: Production Technology

Subcontract No. RD010A-11 (UA)

Networking with international colleagues and publishing research findings in internationally recognized outlets are of utmost importance for the development of professional careers and for fostering long-term relationships based upon credible scientific capabilities, both in and between developed and developing countries. The Aquaculture CRSP has been sponsoring conference sessions, pre-conference professional awards, and proceedings development for various events in the past. However, these activities were not brought to the forefront as an integral part of Aquaculture CRSP outreach until developed as individual investigations for inclusion in the Eleventh and Twelfth Work Plans. Collaborators from the University of Arizona and Universidad Juárez Autónoma de Tabasco presently help organize these activities.

**Staff***Oregon State University, Corvallis, Oregon*

Richard Johnston                      Lead US Principal Investigator  
 Ann L. Shriver                         Research Associate

*University of Arizona, Tucson, Arizona*

Kevin Fitzsimmons                      Lead US Principal Investigator  
 (from June 2006)  
 Enue Sicarios                              (from June 2006)  
 Pablo Gonzalez Alanis                      Ph.D. Student (from August 2004)  
 Mario Hernández Acosta                      (from August 2005)

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

Remedios Bolivar                         Lead Host Country Principal Investigator

*Universidad Juárez Autónoma de Tabasco, Villahermosa, Mexico*

Wilfrido Contreras-Sánchez                      Host Country Principal Investigator

Pablo Martinez                              Graduate Student  
 (Mexico)

**Work Plan Research**

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

- Special sessions, travel and poster awards at 2005 and 2006 World Aquaculture Conferences and Aquaculture America–2006/ 12ATE9. A progress abstract was submitted for this investigation.
- Aquaculture CRSP sponsorship of the Seventh International Symposium on Tilapia in Aquaculture/ 12ATE10. A progress abstract was submitted for this investigation.
- ACRSP Support for International Institute for Fisheries Economics and Trade Meeting, Portsmouth 2006/12ATE15

**Publications**

Contreras-Sanchez, W. and Fitzsimmons, K. (Editors), 2006. Tilapia, Sustainable Aquaculture from the new Millennium, Proceedings of the Seventh International Symposium on Tilapia in Aquaculture, pp. 389  
 Fitzsimmons, K., Morrison, C. and Wright, J., 2006. Atlas of Normal Histology of Tilapia. World Aquaculture Society, pp. 96.

**SPECIAL SESSIONS, TRAVEL AND POSTER AWARDS AT 2005 AND 2006 WORLD AQUACULTURE CONFERENCES AND AQUACULTURE AMERICA–2006**

*Twelfth Work Plan, Applied Technologies and Extension Methodologies 9 (12ATE9)*  
*Abstract*

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 University of Arizona  
 Tucson, Arizona, USA

Remedios Bolivar  
 Freshwater Aquaculture Center  
 Central Luzon State University

Nueva Ecija, Philippines

Wilfrido Contreras Sanchez  
 Universidad Juárez Autónoma de Tabasco  
 Villahermosa, Tabasco, Mexico

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

**ABSTRACT**

Aquaculture CRSP sessions were organized and conducted at the US Aquaculture meetings in Las Vegas, Nevada in February 2006, and at the World Aquaculture Meetings in Bali, Indonesia and Florence, Italy in May 2005 and May 2006, respectively. These sessions were well attended and included a full compliment of presentations of Aquaculture CRSP-sponsored research. In conjunction with these sessions, pre-conference professional awards were provided to at least three scientists involved in the research who were not able to otherwise attend the conference on project funds. These awards were determined based upon scientific merit, quality of the submitted conference abstract, participation in Aquaculture CRSP-sponsored research, and regional distribution.

A second aspect of this project was a series of meritorious student poster awards at the same conferences mentioned above as well as the US Aquaculture Meetings in New Orleans in 2005. Three awards, as cash plus certificates, were presented to the top three student posters. The posters were judged on scientific quality, contribution to the core Aquaculture CRSP principle of sustainable aquaculture practices, and appearance and use of graphics. Publicity of the awards was wide spread with photos appearing in newsletters, aquaculture industry magazines, and various websites.

The project has been successful by improving recognition of the quantity and quality of research supported by the Aquaculture CRSP. Much of the industry recognized and appreciated work done by many leading aquaculture scientists but had been unaware that the Aquaculture CRSP was a primary sponsor. By organizing these specific sessions

and awards, the contributions of the Aquaculture CRSP and USAID sponsorship have been more widely recognized.

**AQUACULTURE CRSP SPONSORSHIP OF THE SEVENTH INTERNATIONAL SYMPOSIUM ON TILAPIA IN AQUACULTURE**

*Twelfth Work Plan, Applied Technologies and Extension Methodologies 10 (12ATE10)*  
*Abstract*

Kevin Fitzsimmons  
University of Arizona  
Tucson, Arizona, USA

Wilfrido Contreras Sanchez  
Universidad Juárez Autónoma de Tabasco  
Villahermosa, Tabasco, Mexico

**ABSTRACT**

The Seventh International Symposium on Tilapia in Aquaculture (ISTA) will be held from 6–10 September 2006 in Veracruz, Mexico. Aquaculture CRSP is one of the co-sponsors for the symposium. The Aquaculture CRSP has also been a co-sponsor of two earlier ISTAs in Brazil and the Philippines. Two books are being published in conjunction with the Seventh ISTA: the ISTA proceedings and an Atlas of Tilapia Anatomy and Normal Histology. Aquaculture CRSP will be the co-publisher of both volumes. Sixty-seven papers have been accepted for presentation and inclusion in the proceedings. Aquaculture CRSP is contributing to the publication of 1,000 copies of each of the books. Half the books will be distributed to the participants and the other half will be available for other Aquaculture CRSP projects. The final day of the symposium will be devoted to farm tours highlighting small-scale tilapia farms in the state of Veracruz.

In addition to the main conference, a Recirculating Aquaculture Workshop will be held for three days immediately prior to the Seventh ISTA. This workshop already has 90 participants pre-registered. The Aquaculture CRSP is also supporting travel and participation in the ISTA from two project Principal Investigators (Contreras from Mexico and Bolivar from the Philippines). The project is also supporting travel and participation of five Mexican graduate students to participate in the Seventh ISTA. A final report of the conference will be provided after the conclusion of the symposium.

**ACRSP SUPPORT FOR INTERNATIONAL INSTITUTE FOR FISHERIES ECONOMICS AND TRADE MEETING, PORTMOUTH 2006**

*Twelfth Work Plan, Applied Technologies and Extension Methodologies 15 (12ATE15)*  
*Final Report*

Ann L. Shriver  
Oregon State University  
Corvallis, Oregon, USA

**ABSTRACT**

The USAID-funded Aquaculture Research Collaborative Support Program provided financial support to the 2006 biennial conference of the International Institute of Fisheries Economics and Trade, over the period July 1, 2005 through July 31, 2006. The primary goals of this activity were to strengthen the IIFET network's capacities in aquaculture economics and seafood marketing, enabling the development of improved international research relationships, to build participation both at the conference and beyond in the area of aquaculture economics and social science development, and to improve recognition of the significance of the role of aquaculture in meeting world demand for fish products. To accomplish these goals, activities under the MOU included offering a variety of awards designed to enable and encourage participants, especially those from developing countries, to better participate in the conference, to share their research and benefit from exposure to the research of others. Two types of awards were offered: pre-conference professional awards, and best student paper awards. Under the former category, participants were selected based on their submission of an abstract describing their presentation on a relevant aquaculture-related topic; selection was carried out by IIFET Executive Director Ann Shriver in consultation with the Conference Scientific Committee. Of the selected participants, four received assistance and were able to attend the conference.







# Global Project: Joint Initiative

Mexico

Subcontract No. RD010E-H (CU)



During the 2004–2005 reporting period, the Aquaculture CRSP leveraged funds with the National Sea Grant College Program to initiate a partnership for global extension, capacity building, and institutional development in aquaculture and aquatic resources management. The initiative provided a means for longtime Aquaculture CRSP host countries to access the Sea Grant extension network while providing Sea Grant with international capacity building and open access to a broad network of new US and international partners.

One project was funded through a Request for Proposals for this initiative released in December 2004, which established new linkages between Cornell University and two Mexican institutions: Universidad Juárez Autónoma de Tabasco and Instituto Tecnológico del Mar, Veracruz. Additional partners in this project include New York Sea Grant, University of Arizona, Rhode Island Sea Grant, Brooklyn College, Texas Sea Grant, Puerto Rico Sea Grant, and La Fundación Chile. This project aims to establish a Center for Aquaculture Technology Transfer for all of Mexico that is narrowly focused in its scope and patterned after the Sea Grant Program model. Additional investigations will develop a recirculating aquaculture system module for family use and convene the first Annual Sustainable Aquaculture Technology Transfer Workshop in Mexico.

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**Staff***Cornell University (Lead US Institution)*

Dale Baker	Lead US Principal Investigator
Michael Timmons	Collaborating Scientist
David Belcher	Collaborating Scientist

*Universidad Juárez Autónoma de Tabasco, Villahermosa, Mexico (Lead Host Country Institution)*

Eunice Perez Sanchez	Lead Host Country Principal Investigator
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*Texas Sea Grant, Houston, Texas*

John Jacob	Collaborating Scientist
Ralph Raybum	Collaborating Scientist

*Brooklyn College, Brooklyn, New York*

Martin Schreiberman	Collaborating Scientist
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*University of Rhode Island, Narragansett, Rhode Island*

Barry Costa-Pierce	Collaborating Scientist
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*University of Puerto Rico, Mayaguez, Puerto Rico*

Ruperto Chapparro	Collaborating Scientist
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*University of Arizona, Tucson, Arizona*

Keven Fitzsimmons	Collaborating Scientist
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*Instituto Tecnológico del Mar, Veracruz, Mexico*

Margarita Cervantes Trujano	Collaborating Scientist
Ana G. Travina-Moreno	Graduate Student (Mexican)
Gerardo A. Garcia-Moreno	Graduate Student (Mexican)

*Foundation Chile, Santiago, Chile*

Martin Hevia	Collaborating Scientist
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*Centro de Transferencia Tecnológica Para La Acuicultura (CETRA), Villahermosa, Mexico*

Francisco Aguilar	Collaborator
Santiago Quevedo	Collaborator
Carmen Mar Tovar	Collaborator
Mariana Hurtado	Collaborator
Carlos Altamirano	Collaborator
Ourdes Badillo	Collaborator
Lus Mercedes Acuna	Collaborator
Eduardo Mava	Collaborator
Cesar Luna	Collaborator
Gerardo Gonzalez	Collaborator
Laura Carrillo	Collaborator

**Work Plan Research**

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

- Establishment of the Center for Aquaculture Technology Transfer/ 12ATE5. A progress abstract was submitted for this investigation.
- Development of a recirculating aquaculture system module for family/multi-family use/ 12PSD4. A progress abstract was submitted for this investigation.
- First Annual Sustainable Aquaculture Technology Transfer Workshop/ 12SDF4. A progress abstract was submitted for this investigation.

**ESTABLISHMENT OF THE CENTER FOR AQUACULTURE TECHNOLOGY TRANSFER**

*Twelfth Work Plan, Applied Technology and Extension Methodologies 5 (12ATE5)*  
*Abstract*

Dale Baker and Mike Timmons  
Cornell University  
Ithaca, New York, USA

Eunice Perez Sanchez  
Universidad Juárez Autónoma de Tabasco  
Villahermosa, Mexico

**ABSTRACT**

The Centro de Transferencia Tecnológica Para La Acuicultura (CETRA) has been established at Universidad Juárez Autónoma de Tabasco in Mexico (UJAT). The Center includes a consortium of Mexican universities and public/private foundations that have an associated interest in aquaculture. Its goal is to support and guide aquaculture commercial enterprise development in an environmentally sustainable fashion. CETRA has established the initial network of academic and economic resources in Mexico and the United States that provide extension services for meeting Mexico's sustainable aquaculture development goals. A website has been created towards this end: [www.cetra.org.mx](http://www.cetra.org.mx)

CETRA has elected its first director (Dr. Eunice Perez Sanchez of UJAT), its first co-director (Dr. Margarita Cervantes Trujano of ITBOCA), and developed its mission statement.

**CETRA Mission Statement:**

Administer sustainable aquaculture technology transfer to the Mexican private sector through an inter-institutional collaborative network that encompasses all phases of the process.

The center has built upon the research, extension, and outreach efforts recently made by the CRSP/USAID programs on the east and west coasts of Mexico and the summer 2004 extension meeting of US and Mexican universities of the Gulf of Mexico. It supports the ACRSP program area of Production Technology in a way that patterns the US Sea Grant program. CETRA networks over 15 universities and institutions throughout Mexico through its centrally based website and director. It is focusing initially on the single theme of sustainable aquaculture production.

**DEVELOPMENT OF A RECIRCULATING AQUACULTURE SYSTEM  
MODULE FOR FAMILY/MULTI-FAMILY USE**

*Twelfth Work Plan, Production System Design and Integration 4 (12PSD4)*

*Abstract*

Dale Baker and Mike Timmons  
Cornell University  
Ithaca, New York, USA

Eunice Perez Sanchez  
Universidad Juárez Autónoma de Tabasco  
Villahermosa, Mexico

**ABSTRACT**

This project is developing a freshwater recirculating aquaculture system for small-scale tilapia production that is appropriate for a family unit. A design and management manual is being developed.

**FIRST ANNUAL SUSTAINABLE AQUACULTURE TECHNOLOGY  
TRANSFER WORKSHOP**

*Twelfth Work Plan, Sustainable Development and Food Security 4 (12SDF4)*

*Abstract*

Dale Baker and Mike Timmons  
Cornell University  
Ithaca, New York, USA

Eunice Perez Sanchez  
Universidad Juárez Autónoma de Tabasco  
Villahermosa, Mexico

**ABSTRACT**

A series of workshops on indoor, water-recirculating aquaculture systems were conducted. A one-day workshop was held at Hermosillo on 28 November 2005 (approximately 200 people were in attendance); a two-day workshop in March 2006 (approximately 20 people in attendance); and a four-day workshop held in July 2006 at the Universidad Autónoma Metropolitana Unidad Xochimilco (Mexico City) (approximately 20 people in attendance). A three-day September workshop has been planned (80 people pre-registered) to be held in Veracruz in conjunction with the ISTA 7 (international tilapia conference) and Instituto Tecnológico del Mar. Each of these workshops was very successful with high ratings on their quality. Each had a major focus on commercial production systems, both large-and small-scale.







# Host Country Principal Investigator Exchange Project — Final Report

## **SITE VISITS AND INFORMATION EXCHANGE ON CICHLID CULTURE AND THE ADOPTION OF AQUACULTURE CRSP TECHNOLOGIES IN AQUACULTURE CRSP HOST COUNTRIES**

*Twelfth Work Plan, Applied Technologies and Extension Methodologies 7 (12ATE7)*

## **COMPARISON OF THE IMPLEMENTATION OF CRSP TECHNOLOGIES IN FIVE AQUACULTURE CRSP HOST COUNTRIES**

*Twelfth Work Plan, Applied Technologies and Extension Methodologies 8 (12ATE8)*

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With the Aquaculture CRSP's support of relevant research and promotion of sustainable aquaculture around the world, the base of knowledge and institutional capacities of the program's numerous participating Host Countries have grown considerably. As the ACRSP looks toward the future, it becomes increasingly important that its research results and extension methods be shared among workers at locations continents apart. In order to fulfill this prominent need, the ACRSP in 2004 implemented the Host Country Principal Investigator Exchange Project as a new way to share the program's discoveries and techniques among its host country research partners.

In mid-2005, Aquaculture CRSP Host Country Principal Investigators (HCPIs) from Honduras, Kenya, Mexico, the Philippines, and Thailand initiated a series of five site visits and workshops whose primary purpose was to exchange information about tilapia culture technologies, especially those developed by ACRSP. Emphasis was placed on technologies that have been successfully introduced and are currently widely practiced. Technologies that had been tested but not adopted were also evaluated. Two of

five planned site visits and workshops were completed in July 2005 and reported on in the previous ACRSP Annual Report. HCPIs convened in Thailand from 19 to 22 July, 2005, holding seminars, touring facilities at the Asian Institute of Technology, and visiting fish farms afterwards. From Thailand, the group moved to the Philippines on 23 July. Seminars and a tour of facilities at the Freshwater Aquaculture Center, Central Luzon State University, were held on 25 July, followed by visits to tilapia farming operations around Luzon.

The remaining scheduled site visits and workshops were completed during this reporting year. These included visits to Mexico (1 to 8 October, 2005), Honduras (9 to 13 October, 2005), and Kenya (23 to 29 January, 2006). As with the visits in Thailand and the Philippines, each site visit consisted of opening seminars, in which the host PIs described their country's aquaculture research and extension facilities and institutions and visiting PIs made presentations about theirs, followed by tours of the host country's facilities and visits to representative fish farms in the field.

In Mexico, the PIs were given a tour of UJAT's research facilities, where research is focused not only on tilapia but also on several species of native cichlids and other promising aquaculture species such as gar. Field tours included stops at several cooperatively operated tilapia production facilities and one mid-size commercial farm that have received assistance from UJAT's staff.

In Honduras, HCPIs received tours of tilapia research facilities at both the present ACRSP site at Zamorano and the former "El Carao" site in Comayagua. They also visited small-scale operations in the mountains, a medium-scale cooperative cage culture operation on Lake Yojoa, and the very intensive, large-scale, commercial operation of Aqua-Corporacion de Honduras at Río Lindo.

In Kenya, tours of government facilities included a visit to Sagana Fish Farm in Central Province and the Wakhungu Demonstration Fish Farm in Busia, Western Province. The PIs also visited Moi University's Chepkoilel campus and the Moi University Fish Farm in Eldoret. Visits to private farms included stops at several small-scale operations in western Kenya and at the large-scale production facility now under development by Dominion Farms, near Lake Victoria. There were also visits to the Nairobi fish market and to the largest fish processor in the country.

In all the countries visited, it was clear that tilapia culture is a growing business with a lot of potential. The main difference among these five countries is the stage of development of the industry that can be seen at this time. In discussions about the relative levels of development of tilapia farming in their respective countries, the group was able to identify some common factors that constrained development in earlier years as well as factors that had eventually allowed subsequent rapid development:

#### Early constraints to development:

- The initial use of *O. mossambicus* as the primary culture species;
- Reliance on mixed-sex culture, leading to overpopulation and stunting;
- Insufficient supplies of fingerlings;
- Lack of feeds or poor quality feeds;
- Problems of perception—tilapia seen as "poor man's fish" and therefore not desirable.

#### Factors leading to rapid development:

- The switch to Nile tilapia (*Oreochromis niloticus*) as main culture species;
- Development and selection of improved lines and strains of *O. niloticus*;
- Development of techniques to produce males for stocking (sex reversal);
- Expansion of all-male production to commercial scale (quantity);
- Manufacturing of affordable, quality fish feeds.

Project participants have reported a number of interactions and benefits that resulted from these exchange visits. For example, the Honduras participants reported that as a result of discussions held during the Mexico workshop about

the culture of native species, a technician from Zamorano (Honduras) was sent to attend a short course on the biology and reproduction of snook held on the UJAT campus (Mexico) in April 2005. He received support from both the Honduras and Mexico ACRSP programs for this training. At Zamorano, they are now experimenting with a local species of "snook" (*Centropomus undecimalis*) for the first time. This study is evaluating whether snook will accept or feed on tilapia fry, pieces of tilapia fillet, and floating pellets. The experiment is being conducted and maintained in 300 L fiberglass tanks with leveraged funding.

As another example, the HCPI at Zamorano independently followed up with AIT (Thailand) researchers about efforts to define production parameters for successful management of marine shrimp and tilapia polyculture systems. This topic had been discussed during the HCPI exchange visit in Thailand in July 2005. The information was needed to respond to local efforts to diversify production using tilapia on shrimp farms in southern Honduras.

Yet another example is that the Government of Kenya paid for four Kenyan Fisheries Officers to attend professional training at AIT. A tailor-made training course at AIT was developed for Kenyan extension workers following the Thailand workshop, where the visiting PIs were impressed and excited by the extent to which the production of monosex tilapia seed had been developed and commercialized. In response, AIT officials organized a course entitled "Tilapia and Catfish Seed Production and Aquaculture Feed Technology." The course was conducted from 8 to 26 May 2006 at AIT. One of the trained officers was from Sagana Fish Farm, the site for most of the ACRSP's early pond research (1997 to 2002). While this training was fully funded by the Kenya Fisheries Department, the visit to Thailand under the HCPI Exchange Project was the catalyst for its development.

Other interactions resulting from these visits took the form of "Echo Seminars" held in each participating country. HCPIs have begun holding echo seminars in each of their countries after completion of all the site visits. The intention of conducting echo seminars was for the participating PIs to share new information gained with others in their respective countries, or regions, to further spread the word about successful tilapia production technologies.

In Kenya, for example, a total of four echo seminars were given, three in the Western Region (Bungoma, Busia, and Kisii Districts) and one in Central Kenya at Sagana Fish Farm. Four Fisheries Officers from the Nairobi office conducted the seminars, in which a total of 28 participated. These presentations generated great interest among the participants, who identified the following technologies from visits to other sites as likely to be useful in Kenya:

- The staged feeding strategies (early and delayed) practiced in Philippines;
- The cage-cum-pond fish production practice from Thailand;
- The selective breeding program in Mexico gave Kenyans ideas to start doing something to improve the quality and quality of fingerlings.

In all these site visits, another positive “spin-off” effect was the additional exposure to new technologies and ideas. For each of the five HCPIs in this exchange, there were many co-workers who learned and benefited from the presentations, discussions, and site visits.

In Honduras, a short course on tilapia production was taught to 13 participants in July 2006. The course materials included information on the culture of native cichlids in Mexico and the intensive management of tilapia broodstock in suspended hapas as well as artificial incubation techniques for embryos and newly-hatched fry as observed in Thailand.

As a result of the training at AIT mentioned above, Sagana Fish Farm in Kenya has developed a project for the production of 3 million sex-reversed tilapia fingerlings annually. This will be a medium-term program that will require time to be fully developed, so the short-term plan is a scaled-down version designed to produce 250,000 sex reversed, all-male tilapia fingerlings annually. This initiative will make use of the already existing facilities at Sagana and by June 2007, the first batch of sex-reversed fingerlings is anticipated.

In the Philippines, the Kenyan HCPI realized the impact that well-developed brochures can have on the dissemination of fish farming information. Brochures were available for most activities conducted at the Freshwater Aquaculture Center of Central Luzon State University. This was seen as a challenge for Kenya, and immediately after the visit, the staff at Sagana Fish Farm, with assistance from the Fisheries Department, produced a brochure highlighting some of their activities at Sagana. This may be one of the reasons why there has been a significant increase in the number of individuals coming to Sagana to seek fish-farming information.

In the Philippines, it was also observed that small boats are sometimes used to spread fish feed in large ponds to more evenly distribute the feed. At Sagana, this practice was adopted immediately after the Philippines workshop; a small wooden boat is now being used to broadcast the fish feed in Sagana’s larger ponds, which are more than one hectare in size. Officers who have worked at Sagana for a long time think that this could explain why the sizes of the fish from fisheries ponds have increased tremendously.

In summary, all participating PIs learned about technologies that are in practice elsewhere and took that knowledge home to share with colleagues and to consider for implementation.

Extensive outreach occurred during the course of this activity or immediately following it. These included:

- Seminar presentations given by the participating PIs in the workshops at each site. Host PIs typically gave more detailed presentations, covering information about tilapia culture in the country visited and about their own institution and others involved in aquaculture. Visiting PIs also gave presentations, briefly describing the state of tilapia farming in each of their own countries;
- Echo Seminars given by the participants following the final site visit. These were opportunities for those who visited other countries and regions to share their overall experience with additional colleagues at home;
- A poster presentation at Aquaculture America 2006, Las Vegas. This was a chance for the HCPIs, with support from the ACRSP management office, to report on the findings of a comparative study they conducted in preparation for their exchange visits;
- Brochures produced according to examples seen during visits to other sites;
- Incorporation of new information into teaching curricula at participating institutions;
- Short courses taught outside the university setting, for example in extension programs;
- An article has been written and submitted for publication in the WAS publication *Aquaculture*; and
- Material is being compiled for preparation of an ACRSP best practices publication.

Several participants, as well as some outside observers, have commented that this project may possibly be one of the best things the ACRSP has done in its twenty-plus year history. It is difficult to pinpoint the exact reasons for this, but some of the positive points identified have included:

- The experience for PIs from countries where tilapia farming (and fish farming in general) is just beginning to develop. For these PIs, many new ideas and technologies were seen in action, spurring ideas of how similar practices could be applied back home to improve production. In particular, those from areas where chronic fingerling shortages hamper production were impressed by the mass production techniques already in use in Thailand and the Philippines. The ready availability of good-quality commercial fish feeds in Thailand, the Philippines, and Honduras was also noted;
- The establishment of solid linkages that will allow this group of scientists to communicate, consult, and collaborate with each other with or without ACRSP assistance. These linkages can potentially lead to increased training opportunities in specific areas of need, for example Kenya’s need to send some of their staff to Thailand for training in fish seed production and feed development technologies;
- Initial discussions about drafting a Memorandum of Understanding to allow for future collaboration among the participants, with or without ACRSP assistance;
- In-depth discussions about the possibilities for conducting collaborative research in the future, including work on the best tilapia strains for use in various environments.







# Aquaculture Exchange Project

## THE EAGLE OF THE NORTH AND THE CONDOR OF THE SOUTH AQUACULTURE EXCHANGE PROJECT

*Twelfth Work Plan, Sustainable Development and Food Security 6 (12SDF6)*

A joint initiative of the Aquaculture CRSP and Heifer International

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Wilfrido Contreras

*"All Indigenous Peoples and cultures communicate with the water world. Water life has supported Indigenous Peoples for all time. Many Indigenous People recognize the turtle, whale, or salmon as their crest, totem, or clan. Fish, shellfish and other aquatic life remain an integral part of Indigenous Peoples life-way and culture."*

*"Today the water life is threatened. The many reasons include industrial development, urban expansion, and instances of uninformed, non-sustainable agriculture. Aquaculture offers promise for expanding upon Indigenous Peoples' health and sustainability of the water world. Properly developed, aquaculture enhances core cultural objectives such as biodiversity, sustainability, food security, and community wellness."*

-Eagle/Condor project proposal

North and South Native American communities face many of the same constraints and hold similar perspectives on the culturally relevant use of technology and indigenous knowledge.

While Indigenous People have practiced aquaculture for thousands of years, the *science* of aquaculture is relatively recent. In North America, tribal governments have initiated at least 50 active aquaculture projects for Indigenous Peoples that primarily focus on economic development through the creation of jobs while also supporting aquatic rearing practices that incorporate traditional cultural values. Further efforts to integrate aquaculture into indigenous culture in both the North and South can directly address issues of biodiversity, sustainability, food security, and community wellness. However, further exploration of these issues has not yet been pursued to any great degree on either continent. Currently, indigenous aquaculturists work in relative isolation from each other and from other non-indigenous aquaculture-oriented organizations.

The Aquaculture CRSP has partnered with Heifer International in a project that spans four countries—the United States, Canada, Mexico, and Peru—to identify challenges to watershed management and human health and examine how aquaculture can responsibly and sustainably fit into indigenous ways of life. This partnership is working to formulate strategies that address and eliminate constraints to aquaculture development specifically in the context of Indigenous Peoples. This collaborative work is intended to serve as a future link to other indigenous and non-indigenous organizations that work with aquaculture. Specifically, the Eagle-Condor project is creating opportunities for indigenous representatives of tribal governmental projects, universities, organizations, and community-based groups to participate in a training exchange program in aquaculture. Two workshops were planned to be held in the South, one in Peru and one in Mexico, to bring

North American natives ("Eagles") and South American natives ("Condors") together. It is hoped that this fusion will reinforce indigenous knowledge and the shared "cosmovision" of Indigenous Peoples.

During this reporting period, the first of the two planned workshops took place, with a group of seven "Eagles" visiting sites in the Ucayali Region of Peru between 22 and 28 April 2006, to learn from and exchange information with members of the Shipibo-Conibo indigenous group.

#### WORKSHOP PARTICIPANTS

##### Members of the Condor group:

- *Juan Chavez Muñoz*, a Shipibo elder from the village of Camaria, is regional and technical coordinator for the Integrated Research and Rural Development Association (AIDER), a Peruvian non-profit organization based in Pucallpa. Mr. Munoz assists in framing and communicating the developmental goals and objectives of the Shipibo people.
- *Thomas Chavez*, Shipibo from the village of Calleria, is one of the principal members of his village and works in communal forest management. His training and involvement includes working with members of not only his home village of Calleria, but also with the villages of Preferida de Charashmana, Puerto Belén, Curia, and Caimaria.
- *Santiago Nunta Cauper*, Shipibo from a village located up the Calleria river from Pucallpa, a 7-hour trip in traditional canoes. The 65 families living in this village support themselves by harvesting the Aguaje fruit as well as fishing and hunting.
- *Rafael Lomas*, Shipibo from the village of Calleria. Mr. Lomas assists with the marketing of Shipibo women's crafts, which are sold through the village cooperative. The cooperative is also learning how to manage the forest resources, such as the trees that dye is derived from, so that they will be available for years to come.

##### Other Peruvians assisting with and participating in the workshop:

- *Dr. Otto Flores*, a director of the National Intercultural University of the Amazon who was invited to the workshop to introduce the university's creation and future contribution to the Indigenous People of Peru in the coming years. The Eagles also visited the University campus to view the projects in agriculture and to hear presentations from different departments.
- *Humberto Sampayo Vasquez*, regional director of the Indigenous Regional Organization of Masisea, ARDIM, which is an organization that brings together indigenous groups across Peru. Their main objectives are working with the government of Peru in free-trade issues and protecting the economic and environmental interests of Indigenous People.
- *Fred Chu*, a senior IAP researcher. He is also a doctoral candidate in Biology / Aquaculture at Southern Illinois University in Carbondale, Illinois. He acted as the in-country coordinator and planner for the exchange project.

Eagles representing the North:

- *David Vanderhoop*, Wampanoag, from Aquinnah, Massachusetts, has a degree in Fisheries Biology from the University of Alaska and extensive experience with both capture fisheries and aquaculture.
- *Tom Edwards, Jr.*, a Lummi tribal member, works in fisheries, forestry, and the preservation of sacred sites.
- *Wilson Wewa*, of Paiute and Nez Perce descent and member of the Warm Springs Confederated Tribes of Oregon, has worked with the National Forest Service, Bureau of Land Management, US Army Corps of Engineers, and the US Attorney's office on preserving traditional use areas, sacred sites, and repatriation.
- *Jeff Thomas*, Muckleshoot tribe, has a degree in Biological Sciences and is currently a fisheries biologist for the Puyallup Tribe. Works on recovery of wild salmon stocks through habitat protection and restoration.
- *Larry W. Campbell*, Swinomish Indian Tribal Community. Mr. Campbell's work has spanned 25 years and has involved the tribe's governmental committees as well as works in intergovernmental affairs, public relations, community development, spiritual traditions, and cultural activities.
- *Brenda Jo McManama*, Seneca from New York State, has been involved in indigenous issues for the past 15 years. She served as assistant editor for Aquaculture Magazine from 2001 to 2005, helping educate industry participants on growing fisheries resource issues of indigenous groups and emerging native-owned and operated aquaculture efforts.
- *William Simmons*, Choctaw. Mr. Simmons currently works for the International Indian Treaty Council. For the Eagle-Condor Exchange project, Mr. Simmons represented the Indigenous Environmental Network, whose work in the international arena coincides with that of the Council. Mr. Simmons has had a long involvement with issues pertaining to indigenous rights, sovereignty and the environment.

##### Other Participants:

- *Mike Sklandany*, teaches sociology at the University of Tennessee. He holds degrees in biology, resource economics and graduated with a PhD in Sociology from Michigan State University in 2000. Prior to entering graduate school, Mike worked in fisheries and aquaculture development in rural and coastal Thailand (1977-1985) as well as a brief stint in Rwanda, Africa in 1994. Skladany assisted with organizing Indigenous Aquaculture Network and the first and second "Indigenous Aquaculture Network" meetings in Minneapolis (2004) and in Seattle (2005).
- *Mariano Rebza Alfaro*, an aquaculture specialist who briefed the Eagles on the paiche cage demonstration project at Caimito. Alfaro provided an overview of the status of wild paiche and the partial results of the cage culture project.
- *Paul Smith*, Heifer International

Because of this exchange, Eagles and Condors were able to establish a relationship that cut across continents. It took a few days for the two groups to establish sufficient trust to feel comfortable in exchanging insights, views, and

ideas, but once trust was established, reactions from both Eagles and Condors were overwhelmingly positive, with the following comments being representative of how the participants felt about the exchange opportunity and the benefits derived:

#### Condor comments:

*"I'd like to thank the Eagles for being here. We would have liked it if you had gotten to spend more time with us in our village—to share our food, medicines and to share the way Shipibo people live. And how we are surviving. My people didn't think they had enough time to show you who we really are—our traditions and customs. Maybe the next meeting we can host you in our village for a few days. Maybe cook you some piranha and let you know how good they taste. We used to think we were the only people—now we know there are many tribes. ... We don't want this to be the last meeting. We would like to also invite your children to come and stay with us and learn what it is to be Shipibo. And we would like to send our children to your homes to learn about your life as well. This will make our relationships stronger."*

— Juan Chavez Muñoz

*"We Shipibo are capable of our own development without outside dependency. Listening to all of you and your struggle, I now feel closer to you. We are beginning to make good decisions and practicing good management of our resources. We need more training and ways to create products from these resources. We will be working on this and next time we meet, you will see our progress."*

— Santiago Nunta Cauper

*"Since I was young I was a fisherman. Now we can't do that so much anymore. It wasn't only the commercial fisherman that took all the fish, the net fishing of our people and the pesticides and other pollution helped to kill some too. But we are working on restoring the fish to the lakes and rivers. We need help in restoring the fish stocks of our lakes and rivers. Thank you for helping us to be strong."*

— Thomas Chavez

*"Thank you to all. Talking about your traditions has given me the strength to keep our Shipibo traditions. Through these talks and getting to know you all and your pride in who you are we will carry that back to our young people. They need to know that it is good to be proud of who they are and where they come from. We will be working more to save our culture and our traditions for them and their children. I hope that we will be able to meet again. We would like you to come back and stay with us in our homes—so we have time to talk more and get to know more about one another. Thank you all for your friendship."*

— Rafael Lomas

#### Eagle comments:

*"I believe we accomplished what we set out to do—building relationships. Without building relationships before we work together we can make mistakes. ... I think this will be a long lasting friendship. ... Thank you for your welcome, this experience has been very profound."*

— Larry Campbell

*"Two weeks ago I had no idea I was coming to visit with people from the Amazon. There is much to learn about the Shipibo people and there is never enough time. I enjoyed Calleria, when the people sang it brought tears to my eyes because I could feel the strength in your hearts. These songs represented the lands, the forests and the clouds. I will never forget that. What I've seen is better than in other places, there the people stand with their hands out—waiting for handouts. Here you are trying to make a better life for your people."*

— Wilson Wewa

*"As opposed to two days ago, I feel very empowered and humbled by the beauty of the Shipibo people."*

— David Vanderhoop

*"... with our management of natural resources we grow physically and spiritually. We can help our resources by restoring them—the fish the plants and the crafts. We can help each other on fish, fields and forests if we continue communication between the North and the South. We can collectively voice our concerns."*

— Tom Edwards, Jr.

Dates for the second workshop to be conducted under this activity are currently being negotiated. The Mexico visit will now likely occur in early 2007.

The Eagle of the North and the Condor of the South Aquaculture Exchange Project will have a number of important benefits, including:

- Creating an initial organizational framework to evaluate aquaculture in terms of indigenous culture and development;
- Allowing for balance between more economically oriented approaches in the North and more community-based approaches to aquaculture in the South;
- Bringing together Indigenous People from the North and South to learn from and share with each other in a comprehensive manner; and
- Providing an in-depth training opportunity to envision the practice of aquaculture in a manner that benefits Indigenous People and their water worlds.







# Matching Aquaculture CRSP Host Country Technical Assistance Needs with Sea Grant Extension Services

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The National Sea Grant College Program (NSGCP) engages a network of 32 university-based programs that conducts scientific research, education, training, and extension projects designed to foster science-based decisions about the use and conservation of US aquatic resources. The Aquaculture CRSP has entered into a partnership with the NSGCP in a novel match-making initiative that couples Sea Grant extension specialists with Aquaculture CRSP Host Country Principal Investigators (PIs) to address international technical assistance needs. The combined efforts of these two programs are providing significant synergies that cannot be attained individually.

The Aquaculture CRSP has active research projects in 22 Host Countries. Broad technical assistance needs for each region and country were requested from key collaborators in each country. Identified technical assistance needs fell into the following categories: watershed management, environment, new species development, food safety, new systems design/engineering, nutrition, harvesting, outreach, and marketing.

Concurrently, the National Sea Grant Office announced this initiative through its extension network. Interested extension specialists were asked to submit an abbreviated 2-page curriculum vita and complete an online application form. Information requested in the online application form included specific areas of technical expertise, previous international work experience, verbal and written language skills, relationship to Sea Grant, and desired role in international technical assistance extension.

Following the Host Country needs assessment and review of applications, appropriate matchmaking was conducted to ensure that needs are addressed through effective extension services. Already one Sea Grant specialist from the University of California at Davis provided assistance to Bangladesh, and another visit is planned for South Africa this Fall.

This initiative is resulting in meaningful benefits to both organizations. For the Aquaculture CRSP, technical assistance needs identified by Host Country PIs are addressed. For its part, Sea Grant will build capacity through increased international experience and awareness, and US producers will benefit from the reverse flow of knowledge back to the US from overseas producers.





# Post Tsunami Training

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### Work Plan Research

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

- Post-Tsunami Training in New Aquaculture Technologies in Thailand and Indonesia/ 12ATE14. A progress abstract was submitted for this investigation.

### Publications

Fitzsimmons, K. 2006. ACRSP Helps to rebuild aquaculture in wake of tsunami. *Aquanews*.

Merican, Zuridah, 2006. Tsunami relief projects in Aceh. *Aquaculture Asia-Pacific*, 2(4):43.

### Presentations

Bart, Amrit, 2005. Post-Tsunami sustainable coastal livelihoods program in Thailand: What are we learning? Washington, D.C., USA, 18 October 2005.

Bart, Amrit, 2006. Integrated and multi-disciplinary approach to sustainable coastal livelihood rehabilitation post-tsunami. AIT, Pathumthani, Thailand, 10 Feb 2006.

Bart, Amrit, 2006. Post-Tsunami rehabilitation – gender implications. AIT, Pathumthani, Thailand, July 2006.

Bart, Amrit, 2006. Human element of disaster rehabilitation. AIT, Pathumthani, Thailand, July 2006.

Fitzsimmons, K., 2006. Restoration with sustainable coastal aquaculture in Banda Aceh after the tsunami. AQUA 2006, Annual Meeting of the World Aquaculture Society, Florence, Italy, 9–13 May 2006

### Workshops/Seminars/Educational Outreach

Three workshops were held in Banda Aceh, (Ladong, Ujong Batee, and Samalanga) regarding sustainable coastal aquaculture for restoration. The workshops were held at the Fisheries College at Ladong on 12 March 2006 and at a village mosque in Samalanga and the Ujong Batee Aquaculture Research and Extension Center on 13 March 2006. A total of 162 people were trained — 60 at Ladong, 52 at Samalanga and 50 at Ujong Batee — through these workshops. We used Power Point to present topics and photographs and initiate discussions. Farmers participated in discussions and were introduced to NGO and governmental experts. Each farmer received a seaweed growing handbook. In Samalanga, farmers and ACRSP staff had the opportunity to visit a group fingerling farm.

### POST-TSUNAMI TRAINING IN NEW AQUACULTURE TECHNOLOGIES IN THAILAND AND INDONESIA

*Twelfth Work Plan, Applied Technology and Extension Methodologies 14 (12ATE14)*  
*Abstract*

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### ABSTRACT

Coastal aquaculture was one of the primary occupations in Aceh province prior to the tsunami of 26 December 2004. Over 30,000 families listed aquaculture as their primary means of income and/or subsistence. When the tsunami struck, many of these people lost lives and had their ponds destroyed. While the relief efforts did a tremendous job of feeding and housing survivors, the restoration activities of rebuilding the economy and especially of restoring aquaculture facilities have been slow.

PIs from the Asian Institute of Technology and University of Arizona collaborated with Aquaculture without Frontiers and other NGOs and the Indonesian Department of Fisheries to conduct a series of workshops, supply materials to the fisheries/aquaculture school, contribute materials and expertise to pond restorations, and provide guidance by e-mail to further these efforts. Specifically, three workshops were conducted in various locations in Banda Aceh, two collections of text and reference books were purchased and delivered to the Ladong Fisheries College and the Ujong Batee Aquaculture Research and Extension Center, and technical advice was provided for three restoration efforts to convert shrimp hatcheries to multi-species facilities working with seaweeds, tilapia, and other invertebrates as well as shrimp.



All parties have agreed in principal that a system of sustainable coastal aquaculture is desirable to follow for restoration of the considerable aquaculture sector in the province. The Aquaculture Collaborative Research Support Program was and is uniquely qualified to provide expertise and guidance towards DEVELOPING the sustainable coastal aquaculture that will be needed to achieve a restoration effort that will effectively raise the standard of living in Aceh.



## APPENDIX 1. AQUACULTURE CRSP HISTORICAL OVERVIEW

The Aquaculture Collaborative Research Support Program (formerly the Pond Dynamics/Aquaculture CRSP) is a cohesive program of aquaculture and aquatic resource management research carried out in selected developing countries and the United States by dedicated teams of US and host country researchers. The Aquaculture CRSP is funded by the U.S. Agency for International Development (USAID), under authority of the International Development and Food Assistance Act of 1975 (P.L. 94-161) and the universities and institutions that participate in the program. Oregon State University serves as the Management Entity for the Aquaculture CRSP and has technical, administrative, and fiscal responsibility for the performance of grant provisions.



HILLARY EGNA

Aquaculture CRSP activities were formally initiated on 1 September 1982 after several years of planning. Throughout its existence, the Aquaculture CRSP has received four grants from USAID and developed a flexible research agenda to meet changes in local and regional research needs, an evolving international development context, changes at USAID, and budget fluctuations. Flexibility has not compromised research robustness, as teams of esteemed researchers in the US and host countries conduct research activities through collaborative efforts. Excellence is maintained through external peer-review and programmatic evaluation.

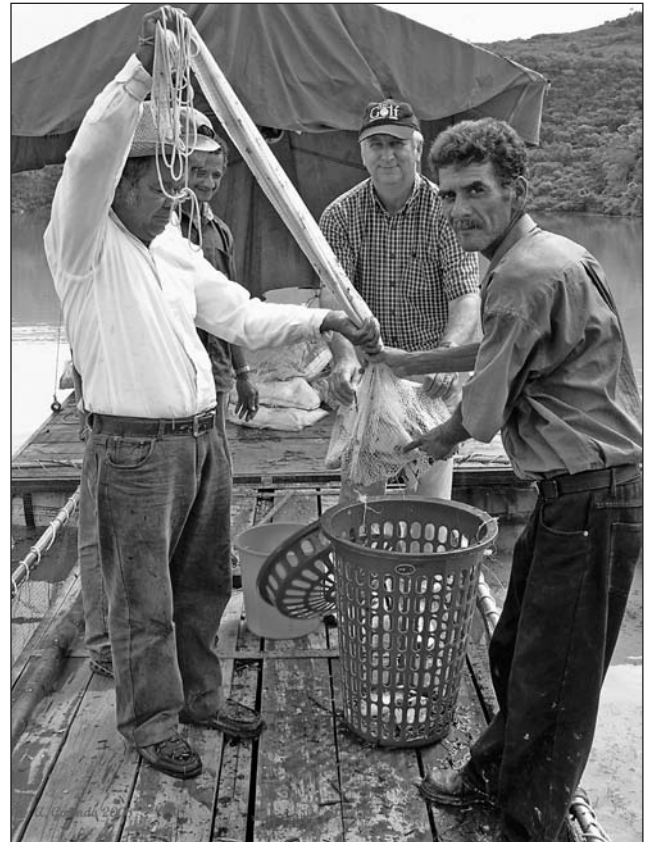
Aquaculture CRSP projects began from 1982 to 1987 with participation from government agencies and educational institutions in six countries—Honduras, Indonesia, Panama, the Philippines, Rwanda, and Thailand. Researchers at all sites conducted three cycles of standardized global experiments during which the Aquaculture CRSP emphasized statistical analysis of the collected data and model construction. In the mid- to late-1980s, the program conducted variations on the standardized global experiment to meet country-specific research and information needs. However, funding constraints during 1986 and 1987 forced a reduction in operations that eventually resulted in a concentration of activities in fewer countries (Rwanda, Thailand, Honduras, and Panama).

The third grant phase (submitted for funding to USAID as the 1990–1995 Continuation Plan) represented new directions for research. Moving away from the sole study of biological phenomena, several new projects funded at this time included economics research, gender studies, on-farm studies, and technology transfer. The 1993-94 reporting period was a tumultuous year for the Aquaculture CRSP. Civil war in Rwanda challenged the resolve of Aquaculture

CRSP researchers as many of their Rwandan colleagues lost their lives to violence. Despite adversity, the Aquaculture CRSP helped with evacuation while continuing its research activities elsewhere.

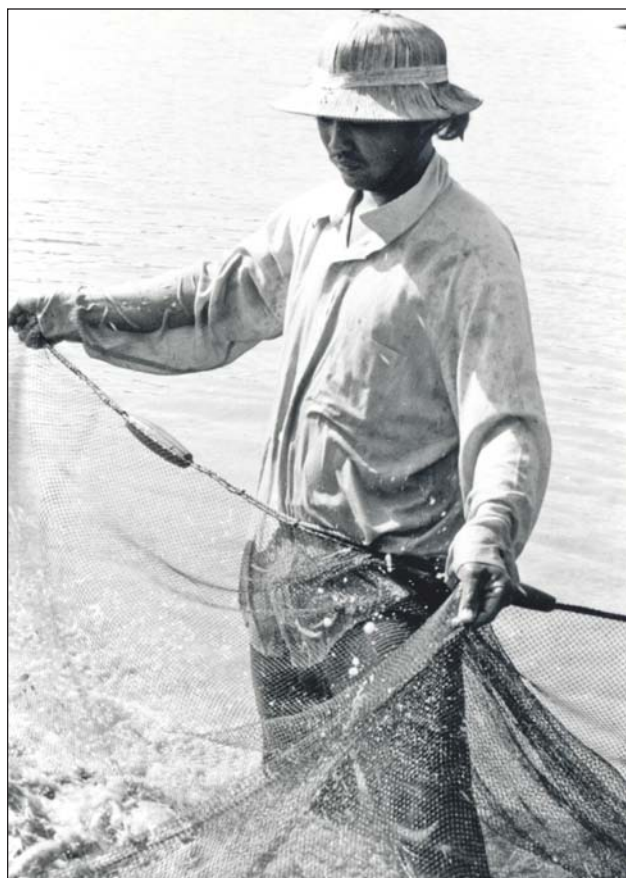
USAID underwent significant restructuring during the Thirteenth Annual Administrative reporting period (1 September 1994 to 31 August 1995) to better serve the strategic and humanitarian goals of US foreign policy. While USAID restructuring had little effect on day-to-day operations, the reporting bureau for the Aquaculture CRSP changed from the Bureau of Science and Technology to the Global Bureau, Sustainable Technology Division of the Office of Agriculture and Food Security in the Center for Economic Growth. Considerable review and consultation determined the new focus of the Aquaculture CRSP research portfolio for the next five years, which led to the development of the Continuation Plan 1996–2001.

Meanwhile, the Africa Site Selection Team initiated a search for a new host country in East Africa following the unexpected departure from Rwanda in 1994. At the 1996 Aquaculture CRSP Annual Meeting, the Site Selection Team recommended the Sagana Fish Culture Farm in Kenya as a prime site for Aquaculture CRSP activities in Africa. This relationship still exists today. Finally, the Aquaculture CRSP made a giant leap into the information age in December 1995 by going online with its own website.



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The Continuation Plan 1996–2001 represented a significant evolution of the program. Proposed research emphasized an approach to aquaculture development that addressed environmental effects and social and economic aspects, as well as production optimization. This fourth grant ushered in a new era of oversight, as the Aquaculture CRSP modified its original advisory structure to increase representation among participating institutions and provide an effective mechanism for new institutions to be represented on the Board of Directors and Technical Committee. The Program Management Office introduced systemic confidential peer-review for proposals and publications. These changes resulted in improved experimental design and a greater relevance of Aquaculture CRSP activities to the needs



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of their host countries. Research oversight was further accomplished through the design of impact indicators, developed jointly by the principal investigators and the Program Management Office (PMO) and based upon the results framework of the Aquaculture CRSP Continuation Plan 1996–2001. These quantifiable characteristics of research activities were applied to all project subcontracts issued under the new grant and were collected by the PMO at the end of each investigation. USAID supported repeated extension of the Continuation Plan 1996–2001 past its original end date, and the Aquaculture CRSP acts within this most recent grant to this day.

A program like the Aquaculture CRSP that yields a positive impact on the daily lives of individuals in developing countries while maintaining a global scope encounters a challenge when it operates in the face of continual short-term extensions and funding uncertainty. The Aquaculture CRSP confronted this very situation with increased flexibility in its funding mechanisms, project horizons, and research focus.

The initial extension of the Continuation Plan 1996–2001 was allocated to fulfill all objectives originally proposed as part of the five-year grant but could not be addressed owing to annual budget cuts over the grant period.

Projects funded after 2002, within the Eleventh and Twelfth Work Plans, focus on three program areas – Production Technology; Watershed Management; and Human Welfare, Health, and Nutrition. The Aquaculture CRSP peer-review process was further enhanced at this time through adoption of peer-review panels modeled after the National Science Foundation's acclaimed process.

In 1996, the Aquaculture CRSP reached its tenth year of operations under the existing grant. Hoping to extend the program into 2006–2007, the Aquaculture CRSP Director submitted an Extension Plan for funding at the request of USAID. This one year of supplemental funding will allow the Aquaculture CRSP to finish research involving graduate students and focus on outreach activities to further ensure the long-term impact of the program.

The Aquaculture CRSP is also in the midst of an aggressive era of cooperation as it seeks to leverage its funds with other government agencies and NGOs. Two notable examples of leveraging have created separate partnerships with the National Sea Grant College Program and Heifer International. Both partnerships have resulted in rewarding outreach and training programs, connecting the Sea Grant extension network with long-time host country investigators to meet technical assistance needs and providing an exchange between Native Americans of the North and South in aquatic resource management issues. Finally, at the behest of its international participants, the Aquaculture CRSP has initiated a Host Country Principal Investigator information exchange activity related to cichlid culture. This project completed its site visits involving long-time Aquaculture CRSP investigators from Honduras, Kenya, Mexico, the Philippines, and Thailand to observe and exchange information related to each country's experience with cichlid culture to further advance production and environmental sustainability in each home country.



## APPENDIX 2. PROGRAM PARTICIPANTS

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### PROGRAM MANAGEMENT OFFICE STAFF

*Oregon State University, Corvallis, Oregon*

Hillary Egna Director

Danielle Clair

Joan Westfall

Chris Bridger

Dwight Brimley

Associate Director of Operations (through August 2005)

Office/Financial Manager (through June 2006)

Research Projects Manager (through August 2006)

Office/Business Manager (from May 2006)

### UNITED STATES AGENCY FOR INTERNATIONAL DEVELOPMENT

*Washington, DC*

Harry Rea

Cognizant Technical Officer

### ADVISORY BODIES

#### External Program Advisory Council

Christine Crawford

Jason Clay

Nathanael Hishamunda

Marcia Macomber

Chair University of Tasmania, Hobart, Australia

World Wildlife Fund, Washington, D.C.

FAO, Rome

CGIAR Water for Food Challenge Program, Sri Lanka

#### *Ex-Officio Members*

Harry Rea

Hillary Egna

USAID

Oregon State University

#### Institutional Representatives

Patricia R. Alvarez

Roy Arnold

Linda L. Brainard

Lawrence A. Davis

Peter J. Gerard

Barbara A. Goswick

Colin Kaltenbach

Ricki McMillan

Anne J.M. Moffat

C. Michael Moriarty

Gordhan L. Patel

Lee Anne T. Peters

Prudence M. Rice

Rose Tseng

Florida International University

Oregon State University

Cornell University

University of Arkansas at Pine Bluff

University of Michigan

University of Arkansas at Pine Bluff

University of Arizona

Institute for Agriculture and Trade Policy

Ohio State University

Auburn University

University of Georgia

University of Arizona

Southern Illinois University at Carbondale

University of Hawaii at Hilo

#### 2006–2007 Technical Committee Members

##### *Co-Chairs*

Jim Diana

Claude Boyd

UM

AU

##### *Material and Methods Subcommittee*

Suyapa Meyer

Yang Yi

Kevin Fitzsimmons

Zamorano

AIT

UA

##### *Research Area of Expertise*

Social and economic aspects

Environmental effects

Production optimization

##### *Technical Progress Subcommittee*

Bill Tollner

Maria Haws

Kwamena Quagrainie

UG

UH

UAPB

Environmental effects

Production optimization

Social and economic aspects

##### *Work Plan and Budget Subcommittee*

Nancy Gitonga Kenya

Wilfrido Contreras-Sánchez

Remedios Bolivar

DOF

UJAT

CLSU

Social and economic aspects

Environmental effects

Production optimization



*Ex-Officio Members*

Harry Rea	USAID
Hillary Egna	OSU
Chris Bridger	OSU

**2005–2006 Honors and Awards Committee Members**

Chris Bridger	OSU
Steve Sempier	Mississippi State University
Kevin Fitzsimmons	UA
Wilfrido Contreras-Sánchez	UJAT
Jim Bowman	OSU
Kwamena Quagrainie	Purdue University
Jim Diana	UM
Kwei Lin	AIT
Remedios Bolivar	CLSU

**AQUACULTURE CRSP MEMORANDA OF UNDERSTANDING**

Memoranda of understanding, representing formal ties between US and Host Country institutions, have been established 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 Amazonía 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
  - The University of Hawaii at Hilo and Universidad Autónoma de Sinoloa, Mexico
  - Purdue University and Fisheries and Aquaculture Development Division, Tanzania
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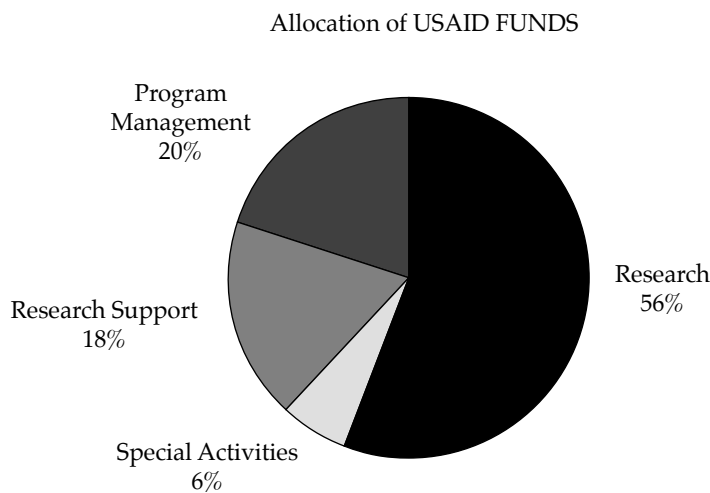
## APPENDIX 3. FINANCIAL SUMMARY

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This section summarizes the allocation of USAID and non-federal funds for Aquaculture CRSP research activities and program management. This unaudited information is intended to provide a cumulative overview of ACRSP program budgets and associated cost share amounts as of July 31, 2006. Official financial reports are submitted to USAID via the Management Entity's Research Accounting Office.

	USAID Funds /1	Non-Federal (Cost Share) /2	Total
Research	\$11,238,205	\$2,257,384	\$13,495,589
Special Activities	1,309,709	291,474	1,601,183
Research Support	<u>3,630,674</u>	<u>782,231</u>	<u>4,412,905</u>
Total Research	16,178,588	3,331,089	19,509,677
Program Management /3	<u>4,044,635</u>	<u>N/A</u>	<u>4,044,635</u>
Grand Total	<u>\$20,223,223</u>	<u>\$3,331,089</u>	<u>\$23,554,312</u>

1. Reflects funding received under all USAID obligations through 7/31/06; 2. Cost share figures reflect subcontract commitments; 3. Cost sharing is not required for management operations.





## 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

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- 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.
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## APPENDIX 5. LINKAGES

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Developing and maintaining links among collaborating universities and government ministries, departments of agriculture, and the private sector around the world forms a significant ancillary contribution to the CRSPs research effort and to the goal of meeting food security needs in the developing world. The following list includes informal linkages and connections made by ACRSP researchers in the field as well as those maintained by the Program Management Office.

Acuarios Leticia, Colombia  
Alabama Catfish Producers Association, Montgomery, Alabama  
Alaska State University  
Alpha Aquaculture, Kenya  
American Association for the Advancement of Science (AAAS), Washington, DC  
American Association of State Colleges and Universities  
American Fisheries Society, Bethesda, Maryland  
American Red Cross  
American Tilapia Association, Arlington, Virginia  
Aqua Technics, Carlsborg, Washington  
Aquacorporacion, International, Honduras  
Aquaculture for Local Community Development Programme (ALCOM), Harare, Zimbabwe  
Aquaculture without Frontiers  
Arid and Semi-Arid Lands (ASAL) Project, Government of Kenya, Laikipia, Kenya  
Asian Development Bank, Tarahara, Nepal  
Asian Institute of Technology, Thailand  
Asociación Nacional de Acuicultores de Honduras (ANDAH), Tegucigalpa, Honduras  
Association for International Agriculture and Rural Development (AIARD), Washington, DC  
Auburn University, Alabama  
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  
Bemidji State University, Minnesota  
Board for International Food and Agricultural Development (BIFAD) Washington, DC  
BRAC, Bangladesh NGO  
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  
Central Luzong State University, Philippines  
Centro de Adiestramiento de la Agricultura Sostenible (CEASO), Honduras  
Centro Internacional de Agricultura Tropical (CIAT), Cali, Colombia  
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 Comunidad Indigena Sarayuka, Ecuador  
Cruz Aquaculture, Philippines  
Golfo de Fonseca (CODDEFFAGOLF), Tegucigalpa, Honduras  
Commonwealth Agricultural Bureau International, Comunidad Indígena Sarayuku, Ecuador  
Consejo Nacional de Ciencia y Tecnología (CONACYT), Mexico  
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  
Cooperative for Relief and Assistance Everywhere (CARE), Bangladesh, Honduras, Peru, and Atlanta, Georgia  
Cornell University, Ithaca, New York  
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  
David and Lucile Packard Foundation  
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 Environmental Management, County of Hawaii  
Department of Environmental Studies, Kenya  
Department of Fisheries, Ministry of Livestock and Fisheries Development, Kenya  
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  
Dominion Fish Farm, Kenya  
Ecocostas, Ecuador  
Ecuador USAID-Arcoiris  
Egerton University, Njoro, Kenya  
Ejido Rio Playa, Comalcalco, Tabasco, Mexico  
El Carao Fish Culture Station, Comayagua, Honduras  
Embrapa Environment, Brazil  
Embrapa Meio Ambiente, Brazil  
Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA) Environmental Laboratory, Campinas, Brazil  
Empresa de Pesquisa Agropecuária e Extensão Rural de Santa Catarina (Epagri), Brazil

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- Empresa Nacional de Energia Electrica, Tegucigalpa, Honduras  
 Escuela Agrícola Panamericana, Zamorano, 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  
 European Inland Fisheries Advisory Commission (EIFAC), Rome, Italy  
 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 and Aquaculture Development Division, Tanzania  
 Fisheries Department, Ministry of Food and Agriculture, Ghana  
 Fisheries Industry Technology Center/University of Alaska Kodiak & University of Alaska Fairbanks Sea Grant Marine Advisory Program  
 Fisheries Society of Africa (FISA), Nairobi, Kenya  
 Florida International University  
 Fondo Nacional de Desarrollo Pesquero (FONDEPES), Lima, Peru  
 Food and Agriculture Organization of the United Nations (FAO), Rome, Italy  
 Foreign Agricultural Service, Research and Scientific Exchange Division  
 Forum for Organic Resource Management (FORMAT), Nairobi, Kenya  
 Foundation Chile, Santiago, Chile  
 French Red Cross, France  
 Fundacion Arcoiris, Ecuador  
 FYD International Farm, Philippines  
 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  
 Global Water Sustainability, Florida  
 Growel Formulations Pvt. Ltd, India  
 Hainan University, China  
 Heifer International, Arkansas  
 Henry Spira/GRACE Project on Industrial Production, School of Hygiene and Public Health, Johns Hopkins University  
 Hofstra University, Hempstead, New York  
 Huazhong Agricultural University, Wuhan, China  
 Inland Water Resources and Aquaculture Service (FIRI), Rome, Italy  
 Institut Pertanian Bogor (IPB), Bogor, Indonesia  
 Institute for Agriculture and Trade Policy, Minneapolis, Minnesota  
 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  
 Institution for Research in Food and Development, Hermosillo, Sonora, Mexico  
 Instituto Amazónico de Investigaciones Científicas SINCHI, Colombia  
 Instituto Colombiano de Desarrollo Rural INCODER, Bogota, Colombia  
 Instituto de Investigaciones IMANI, Colombia  
 Instituto de Investigaciones de la Amazonía, Peruana, Peru  
 Instituto del Mar del Perú (IMARPE), Callao, Peru  
 Instituto Nacional de Pesquisas da Amazonia, Brazil  
 Instituto Politécnico Nacional, Mexico City, Mexico  
 Instituto Tecnológico Saleciano, Ecuador  
 Instituto Tecnológico del Mar, Veracruz, Mexico  
 Instituto Tecnológico Saleciano, Ecuador  
 Integrated Pest Management CRSP, Blacksburg, Virginia  
 Inter-African Committee on Oceanography, Sea and Inland Fisheries  
 International Center for Research in Agroforestry (ICRAF), Nairobi, Kenya  
 International Development Research Centre (IDRC), Ottawa, Canada  
 International Higher Education Linkages Project (IHELP), Washington, DC  
 International Institute of Fisheries Economics and Trade  
 International Service for National Agricultural Research (ISNAR), Honduras  
 International Sorghum and Millet (INTSORMIL) CRSP, Lincoln, Nebraska  
 Japan International Cooperation Agency (JICA), Japan  
 Jomo Kenyatta University, Nairobi, Kenya  
 Kasetsart University, Thailand  
 Katholieke Universiteit Leuven (KUL), Belgium  
 Kellogg Foundation, Dominican Republic  
 Kenya Fisheries Department, Kenya  
 Kenya Marine and Fisheries Research Institute  
 Kenya Medical Research Institute (KEMRI), Nairobi, Kenya  
 Kenyatta University, Nairobi, Kenya  
 Kibos Fish Farm, Kenya  
 Kwame Nkrumah University of Science and Technology, Kumasi, Ghana  
 La Fundacion Chile  
 Ladong Fisheries College, Indonesia  
 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  
 Mercy Corps, Portland, Oregon, USA

- Michigan State University  
Microcredit Summit Campaign, Washington, DC  
Ministry of Agricultural Development, Panama  
Ministry of Agriculture, Animal Husbandry, and Fisheries, Entebbe, Uganda  
Ministry of Education, Dominican Republic  
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  
Moi University, Kenya  
Naivasha Wildlife Training Institute  
National Agricultural Library, Washington, DC  
National Agricultural Research Council, Nepal  
National Agriculture University (NAU), La Molina, Peru  
National Aquaculture Centre, Zomba, Malawi  
National Center for Genetic Engineering and Biotechnology (BIOTEC), Thailand  
National Council for Science and Technology, Mexico  
National Freshwater Fisheries Technology Center, Philippines  
National Inland Fisheries Institute (NIFI), Bangkok, Thailand  
National Museums of Kenya, Nairobi, Kenya  
National Research Initiative, Thailand  
National Sea Grant College Program  
National Shrimp Culture Advisory Group, Tegucigalpa, Honduras  
National Technical Information Services (NTIS), Springfield, Virginia  
National University of Colombia  
Nature Conservancy's Indo-Pacific Resource Center in Australia  
Nepal Agricultural Research Council, Lalitpur, Nepal  
Network of Aquaculture Centres in Asia-Pacific (NACA), Bangkok, Thailand  
New York Sea Grant  
Nong Nam University, Vietnam  
Noorul Islam College of Engineering, Tamil Nadu, India  
North Carolina State University, Raleigh, North Carolina  
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  
Oregon State University, Oregon  
Organization of African Unity, Addis Ababa, Ethiopia  
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  
Puerto Rico Sea Grant  
Purdue University, Indiana  
Quisqueya University, Haiti  
Red de Desarrollo Sostenible Honduras (RDS-HN), Honduras  
Regional Center of Education and Qualification for Sustainable Development (CREDES), Mazatlan, Mexico  
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  
Royal University of Agriculture, Nepal  
Rural Reconstruction Program (PRR), Santa Barbara, Honduras  
Sagana Women's Group, Sagana, Kenya  
San Paulo State University, Brazil  
Sao Paulo State University, Brazil  
Sarasawathi Foundation, Thailand  
Science and Math Investigative Learning Experiences Program (SMILE), Oregon State University  
Secretaria de Agricultura e Abastecimento do Estado de Sao Paulo, Brazil  
Secretaría de Agricultura y Ganadería, Honduras  
Sichuan Provincial Fisheries Association, Ziyang, Sichuan Province, People's Republic of China  
Sinaloa State Committee for Aquaculture Sanitation (CESASIN)  
Sisaket College of Agriculture and Technology, Thailand  
Socio-Economic Development Centre (SEDEC), Binh Thuan Province, Vietnam  
Soil Management CRSP, Honolulu, Hawaii  
Sokoine University of Agriculture, Tanzania  
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  
Southern Illinois University at Carbondale,  
Southwest University, Chongqing, China  
Special Program for African Agricultural Research (SPAAR), Washington, DC  
Stellenbosch University, South Africa  
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 Sea Grant, Houston, Texas  
Texas Tech University, Lubbock, Texas  
Thai Lux, Thailand  
Thailand Department of Fisheries  
The Ohio State University, Ohio



- The University of Michigan, Michigan  
 Training and Occupation for Disabled Association, Poi Pet, Cambodia  
 Uganda Wetlands and Resource Conservation Association (UWRCA), Uganda  
 Ujong Batee Aquaculture Research and Extension Center, Indonesia  
 United Aqua Farms, Bangladesh  
 United States Department of Agriculture (USDA), Washington, DC  
 United States Fish and Wildlife Service (USFWS), Washington, DC  
 United States Food and Drug Administration (FDA), Washington, DC  
 Universidad Autónoma de Sinaloa, Mexico  
 Universidad Autónoma Metropolitana, Mexico City, Mexico  
 Universidad de Santiago de Compostela, Santiago, Spain  
 Universidad Juárez Autónoma de Tabasco, Mexico  
 Universidad Mayor de San Simón, Bolivia  
 Universidad Nacional Agraria La Molina, Lima, Peru  
 Universidad Nacional de Colombia  
 Universidad Nacional de la Amazonia Peruana, Peru  
 Universidad Nacional Federico Villareal, Lima, Peru  
 Universidad Nacional Mayor de San Marcos, Lima, Peru  
 Universidad Técnica de Machala, Machala, Ecuador  
 Universidade de São Paulo, Brazil  
 Universidade Estadual Paulista, Brazil  
 Universidade Federal de Minas Gerais, Belo Horizonte, Minas Gerais, Brazil  
 Universidade Federal do Amazonas, Brazil  
 Universität Hohenheim, Stuttgart, Germany  
 Université Nationale du Rwanda, Butare, Rwanda  
 University of Agriculture and Forestry, Ho Chi Minh City, Vietnam  
 University of Alaska, USA  
 University of Arizona, Fairbanks, Alaska, USA  
 University of Arkansas at Pine Bluff, USA  
 University of California, Davis  
 University of Cantho, Vietnam  
 University of Delaware  
 University of Fisheries, Nhatrang, Vietnam  
 University of Georgia, USA  
 University of Hawaii at Hilo, Hawaii  
 University of Nairobi, Kenya  
 University of Oklahoma  
 University of Puerto Rico, Mayaguez, Puerto Rico  
 University of Rhode Island, Kingston, Rhode Island  
 University of San Carlos, Guatemala  
 University of Science and Technology, Ghana  
 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 the Virgin Islands, St. Thomas, USVI  
 University of Wales, Swansea, UK  
 University of Washington, Seattle, Washington  
 University of Wisconsin-Madison, Madison, Wisconsin  
 Veracruz World Trade Center  
 Vincent Foundation, Haiti  
 Virginia Polytechnic Institute, Blacksburg, Virginia  
 Wageningen University, The Netherlands  
 West African Rice Development Association (WARDA), Bouaké, Côte d'Ivoire  
 Western Regional Aquaculture Consortium (WRAC), Seattle, Washington  
 Wetlands Conservation Program, Mazatlan, Mexico  
 Winrock International, Lima, Peru  
 World Aquaculture Society (WAS), Baton Rouge, Louisiana  
 World Aquaculture Society Tsunami Relief Fund (WAS-TRF)  
 World Bank, Washington, DC  
 World Conservation Union (IUCN), Nairobi, Kenya  
 World Fish Center (ICLARM), Penang, Malaysia  
 World Neighbors, Honduras  
 World Wildlife Fund, Washington, DC  
 WorldFish (ICLARM)  
 Wuhan University, China  
 Xiamen University, China  
 YSI, Inc.  
 Zamorano Alumni Association, Dominican Republic  
 Zhejiang University, China
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## APPENDIX 6. ACRONYMS

ACIAR	Australian Center for International Agricultural Research	FIU	Florida International University
ACRSP	Aquaculture Collaborative Research Support Program	FONDEPES	Fondo Nacional de Desarrollo Pesquero (National Fund for Fishing Development)
ADR	Adoption/Diffusion Research	FSR	Food Security Research
AFCRSP	Aquaculture and Fisheries Collaborative Research Support Program	FTE	Full-Time Equivalent
AIT	Asian Institute of Technology	GAFY	Gross annualized fish yield
AMR	Administrative Management Review	GIFT	Genetically Improved Farmed Tilapia
ANDAH	Asociación Nacional de Acuicultores de Honduras	GIS	Geographic Information System
AO	Agreement Officer (USAID)	GISR GIS:	Planning, Policy, and Global Data Analysis Research
ASF	Animal Source Foods	HACCP	Hazard Analysis and Critical Point Control
ASMR	Aquaculture Systems Modeling Research	HC	Host Country
ATA	American Tilapia Association	HSI	Hepatosomatic index
ATR	Appropriate Technology Research	HTML	Hypertext Markup Language
AU	Auburn University	IAAS	Institute of Agriculture and Animal Science
BAU	Bangladesh Aquacultural University	IARC	International Agricultural Research Center(s)
BIFAD	Board for International Food and Agriculture Development	IATP	Institute for Agriculture and Trade Policy
BIOTEC	National Center for Genetic Engineering and Biotechnology, Thailand	ICLARM	International Center for Living Aquatic Resources Management
BOD	Biochemical oxygen demand	IARC	International Agricultural Research Center(s)
BOD	Board of Directors	IEE	Initial Environmental Examination
BRAC	Bangladesh Rural Advancement Committee	IEHA	Initiative to End Hunger in Africa
CAS	College of Agricultural Sciences	IIAP	Instituto de Investigaciones de la Amazonia Peruana (Research Institute of the Peruvian Amazon)
CESASIN	Sinaloa State Committee for Aquaculture Sanitation	IIFET	International Institute of Fisheries Economics and Trade
CF	Condition factor	IGF-1	Insulin-like growth factor 1
CFS	China Society of Fisheries	IMANI	Instituto de Investigaciones, Colombia
CIAT	Centro Internacional de Agricultura Tropical	IMNC	Information Management and Networking Component
CIFAD	Consortium for International Fisheries and Aquaculture Development	INCODER	Instituto Colombiano de Desarrollo Rural, Bogota, Colombia
CIO	Conflict of Interest	INPA	Instituto Nacional de Pesquisas da Amazonia
CLSU	Central Luzon State University	IPM	Integrated Pest Management
CONACYT	Consejo Nacional de Ciencia y Tecnología (National Council for Science and Technology)	ISTA	International Symposium on Tilapia in Aquaculture
CREDES	Regional Center of Education and Qualification for Sustainable Development, Mazatlan, Mexico	IR	Institutional Representative(s)
CRSP	Collaborative Research Support Program	IWMI	International Water Management Institute (an IARC)
CTO	Cognizant Technical Officer	JCARD	Joint Committee on Agricultural Research and Development
DBT	Database Task Force	LHRHa	Luteinizing hormone-releasing hormone analog
DIGEPESCA	General Directorate of Fisheries and Aquaculture	LIFD	Low-income food-deficit
DO	Dissolved oxygen	LOE	Level of Effort
DOF	Department of Fisheries, Kenya	ME	Management Entity
DTAP	Development Themes Advisory Panel(s)	MEAR	Marketing and Economic Analysis Research
E2	Estradiol	MOU	Memorandum of Understanding
EdOp	Net Educational Opportunities Network	MRC	Mekong River Commission
EEP	External Evaluation Panel	MSU	Michigan State University
EGAT	Bureau for Economic Growth, Agriculture, and Trade (USAID)	MSY	Maximum Sustainable Yield
EIP	Emerging Issues Panel	MT	17-methyltestosterone
EPAC	External Program Advisory Council	NAR	Net annualized revenue
ER	Effluents and Pollution Research	NARS	National Agricultural Research System (of
FAO	Food and Agriculture Organization, United Nations		
FFR	Feeds and Fertilizers Research		

	Host Countries)	UT	University of Texas
NASULGC	National Association of State Universities and Land-Grant Colleges	UV	Ultraviolet
NAU	National Agriculture University	VSS	Volatile suspended solids
NB	Nota Bene	WAS	World Aquaculture Society
NGO	Nongovernmental organization	WIDeST	Web-Based Information Delivery System for Tilapia
NOAA	National Oceanographic and Atmospheric Administration (US)	WWF	World Wildlife Fund
NSR	New Aquaculture Systems/New Species Research	YSI	YSI Inc. (formerly Yellow Springs Instruments Co.)
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		
PI	Principal Investigator		
PMO	Program Management Office		
PPEC	Proposal Planning Executive Committee		
PRR	Rural Reconstruction Program		
PU	Purdue University		
RCE	Regional Center(s) of Excellence		
RCR	Reproduction Control Research		
RFA	Request for Assistance		
RFP	Request for Proposals		
SANREM	Sustainable Agriculture and Natural Resource Management (a CRSP)		
SIUC	Southern Illinois University at Carbondale		
SINCHI	Instituto Amazónico de Investigaciones Científicas, Colombia		
SMILE	Science and Math Investigative Learning Experiences Program		
SPARE	Strategic Partnership for Agricultural Research and Education		
SRP	Soluble reactive phosphorus		
TA	Technical Application		
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		
UA	University of Arizona		
UAPB	University of Arkansas at Pine Bluff		
UCD	University of California, Davis		
UG	University of Georgia		
UH	University of Hawaii		
UJAT	Universidad Juárez Autónoma de Tabasco		
UM	The University of Michigan		
UO	University of Oklahoma		
US	United States		
USAID	United States Agency for International Development		
USDA	United States Department of Agriculture		
USVI	University of the Virgin Islands, St. Thomas		