Aquaculture Collaborative Research Support Program

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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 2006 to 31 July 2007. 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 (through Fall 2007).

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. The current reporting period includes an unfunded extension (1 July 2007 through 30 June 2008) for closing out project and program objectives.

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 II.
PROGRAM HIGHLIGHTS

This reporting year marked the final funded period of the highly successful Aquaculture CRSP. ACRSP ended this reporting period after an unfunded two months, and for awhile teetered on the edge of termination. Indeed, this annual report was only made possible through a last minute program extension. The Aquaculture CRSP was slated to end on 30 June 2007. Most activities had been completed by 2007, 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, began negotiating a no-cost extension with USAID in March 2007. The final year’s focus would be on outreach and capacity building, with the expectation of accelerated outputs through June 2008.

Obtaining a no-cost extension was not an easy feat, and in ways was as difficult as securing funding. In April 2007, USAID denied the Management Entity’s (ME) written request for a no-cost extension citing similar treatment for other CRSPs. Other CRSPs had also requested extensions but were denied. The ME realized it had contract language from Office of Management and Budget circulars allowing a one-time no-cost extension, but instead elected to pursue an extension through the proposal mechanism. The Director wrote more than three major revisions to the original denied proposal, finally achieving success two weeks before the entire program was to expire permanently. Just before the ACRSP’s termination date of 30 June 2006, USAID finally signed official paperwork allowing for a 12-month unfunded extension. This put a large and urgent burden on the ME to process its subcontracts with CRSP universities prior to their expiration on 30 June 2007.

In its extension plan, the ME agreed to a phase-out strategy for its many projects. Projects were assigned stepped completion dates depending on a number of factors including students, research underway, whether a participating country was no longer part of the AquaFish CRSP, and funding balance. Projects that had operated in countries that no longer were part of the new AquaFish CRSP were given an opportunity to complete their Exit Strategies to allow for a graceful departure and sustained linkages. Countries lost though the competitive bidding process in the new AquaFish CRSP were valuable to the CRSP, and excellent work had been underway through collaborations that spanned many years. Exit strategies were enacted for Peru, Brazil, Colombia, Ecuador, Thailand, Bangladesh, Honduras, and South Africa.

The first set of projects to be phased out occurred on or before 30 June 2007 and included those that fell under the following US university subawards with the ME: Cornell University (Mexico); University of Arkansas at Pine Bluff (Peru; on 5/31); Oregon State University (Kenya); Oregon State University (Mexico); and University of Georgia (Honduras). Although costs must be expended before each project’s subcontract end date (30 June in most the above cases), subcontractors typically are allowed a 60-day grace period for submitting reports and deliverables. The ME performs a compliance check after the grace period ends, or all deliverables are received, and prior to paying final invoices. The second set of projects to be phased out will occur on 30 September 2007 for the following US university subawards with the ME: Florida International University (Philippines); Oregon State University (International Institute of Fisheries, Economics, and Trade, IIFET); Purdue University (Tanzania); University of Hawaii at Hilo (Mexico). The third set falls outside this reporting period, but includes the remainder of ongoing projects; most have students completing degrees, and are finishing their Exit activities.

As reported last year, 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 a changing world’s 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
During this reporting period, Oregon State University (OSU) 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$1.27M from USAID with about another US$1M provided by leveraged funding and university matching.

The Aquaculture CRSP has a long and successful track record in capacity building. Over 700 students have earned university degrees—over 500 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 4,500 people in developing countries.

A jointly funded project with Heifer International engaged new communities in the ACRSP enterprise. ACRSP and the Indigenous Environmental Network, through funding from Heifer International, Inc., completed a novel 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 Director at OSU secured funding for this concept, and after much background work, the project held the last exchange in Mexico in March 2007. Reports, photos, and participant feedback on the exchange are available from the ACRSP website.

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 project was completed this year, with the ME assisting in project implementation for researchers in Honduras, Kenya, Mexico, the Philippines, and Thailand. Several posters and presentations resulted, as well as South-South exchanges initiated and paid for by the Host Countries.

The Aquaculture CRSP continued its ambassador program as a means to foster closer ties with USAID field missions, and to provide a smooth transition to the AquaFish CRSP. The Management Entity established the ACRSP Ambassador program to engage USAID Missions in advanced understanding of the CRSP and the aquatic resources sector, provide qualified on-the-ground professionals to act as resources to the Missions, and help link Mission needs with CRSP 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 continued being active in leveraged projects during this reporting period. USAID-Kenya Business Development Service worked with CRSP researchers at Moi University. ACRSP researcher Kevin Fitzsimmons and Amrit Bart
engaged in Tsunami outreach by partnering with another USAID project (SUCCESS) and the private sector.

- The Management Entity sponsored international professional meetings, including World Aquaculture Society, held in San Antonio, Texas (February 2007) and the Seventh International Symposium on Tilapia in Aquaculture in Veracruz, Mexico (September 2006).

- In Fall 2006, the ME released a scope-of-work for final year project funding, and organized virtual panel reviews with external evaluators throughout Fall and into Winter 2007. Projects that received funding under “Category I” capacity building awards included University of Arizona, University of Georgia, The Ohio State University, IIFET at OSU, Southern Illinois University at Carbondale, and two at Auburn University. “Category II” travel grants were awarded to University of Hawaii at Hilo, Purdue University, Oregon State University, University of Michigan, and Cornell.

- The ME organized and chaired the annual program meeting which was held before WAS in Texas. The Director worked closely with TC co-chairs to organize the annual technical meeting, also held in Texas. External evaluators from the Challenge Program on Water and Food, IWMI, Sri Lanka; the UN Food and Agriculture Organization (FAO), Rome; and the University of Tasmania, Australia assessed project outputs and focus. A farewell reception and slideshow covering over 20 years of CRSP researchers in action capped off the CRSP Annual Meeting. At WAS, the CRSP had its own session filled with CRSP research, which was also the focus of other sessions. Also at WAS, the Director presented a Lifetime Achievement Award to Dr. Kevin Fitzsimmons, CSP researcher from the University of Arizona and Past President of WAS.

- The ME published Research Reports (Notices of Publication), the Twelfth Work Plan Addendum I and II, Aquanews, EdOp Net and a number of other reports and manuals that can be accessed through the ACRSP website. The ME created posters for presentation at the following scientific conferences: WAS Texas (Feb 2007); AASA Capetown (Oct 2007). ME staff also participated in broader aquaculture discourse through journal and proposal reviews.

- The ME’s Library Donation Project continued to be appreciated by host country participants and their institutions. More donated library materials from OSU faculty at the OSU Valley Library were shipped to host country libraries this year than any previous year. Due to recent changes with the costs of posting overseas packages, however, current plans are to wind down the Library Donation Project through the final year of the program. The ME is also evaluating lower cost methods of shipping as almost all host country libraries still need scientific journals and books to enhance their collections.

- The ME organized and hosted the successful CRSP Council meeting in Portland, Oregon in August 2007. 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 Director participated included periodic conference calls, and a steering committee meeting with NASULGC held in July 2007 in Washington DC.

- Although the ACRSP grant is slated to end in 2008, a 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.
RESEARCH HIGHLIGHTS

The Aquaculture CRSP strives to conduct high quality research, education, and outreach activities through its partners at US and Host Country institutions. Research conducted during the current reporting period continued to address critical issues in topic areas such as Aquaculture and Human Health Impacts, Sustainable Development and Food Security, Production System Design and Integration, Indigenous Species Development, Water Quality and Availability, Economic/Risk Assessment and Social Analysis, Applied Technology and Extension Methodologies, Seedstock Development and Availability, and Fish Nutrition and Feed Technology. During this period the various CRSP projects completed their remaining investigations as part of the program’s overall effort to meet its USAID contract obligations and move towards final close-out. The following highlights represent some of the exciting scientific research carried out in fish feed and nutrition, reproduction, optimal culture techniques, and technology transfer, among other topics. Abstracts of these investigations are contained in the Research Projects section (pp. 21-123). Full technical reports can be found in the ACRSP 25th Annual Technical Report.

Philippines

- An experiment was undertaken to determine the culture period and stocking density required for Nile tilapia (*Oreochromis niloticus*) to reach an average weight of approximately 600 g at a stocking size of 50-120 g. The highest percent fillet recovery was observed in fish sizes ranging from 601-700 g, 701-800 g and 501-600 g with mean values of 36%, 34.99% and 34.03%, respectively. Economic analysis showed that fish stocked at a density of 1/m² had better cost benefit ratio compared with fish stocked at a density of 2/m², suggesting that rearing of Nile tilapia at a density of 1/m² was more profitable for the production of tilapia for the fillet market in the Philippines.

- In studies on the expression of the insulin-like growth factor I (IGF-I) gene in Nile tilapia (*Oreochromis niloticus*), determinations of hepatic IGF-I mRNA levels found them to be significantly correlated with the growth rates of individual juvenile fish reared under different feeding regimes and temperature conditions. These findings suggest that hepatic IGF-I plays a key role in controlling growth in Nile tilapia. A sensitive PCR assay for measures of hepatic IGF-I mRNA levels for Nile tilapia was developed and could prove useful to assess current growth rates in this species.

- A tilapia-shrimp polyculture study designed to assess the contribution of tilapia in a greenwater system was conducted on the island of Negros, in the central part of the Philippines. In terms of direct cost of production, a greenwater system (probiotics + tilapia) was around 10-15% lower than a closed/semi-closed system (probiotics alone) due to a significantly lower aeration requirement. In the green water system, there was also a more stable plankton environment during the early months of culture, which promoted better survival of shrimp.

Amazon

- Nutritional studies were conducted to determine the effects of supplemental dietary components on Amazonian fishes. One study aims to quantify the reproductive performance and gamete quality of *Colossoma macropomum* broodfish fed diets containing different levels of long-chain highly unsaturated fatty acids, and to assess
the viability and stress tolerance of the resultant progeny. Standard energy sources in prepared fish diets such as wheat are not economical in the Amazon region, therefore another study addresses the suitability of alternative feedstuffs – native Amazonian plants – as energy sources for important Amazon fish species.

**Mexico**

- In Mexico, the investigation “Incorporation of the native cichlid *Petenia splendida* into sustainable aquaculture: Reproduction systems, nutrient requirements and feeding strategies” has significantly contributed to the development of a technological package for the culture of the native cichlid tenhuayaca (*Petenia splendida*). Information on reproduction in captivity, larval rearing conditions, and feeding during different stages of development has generated an important starting point for the management and conservation of native cichlids. Broodstock stocking ratios of 1:2 (male:female) produced greater numbers of fry than other tested ratios, reaching 81,364 over 70 days of experimentation. The results of larval stocking density work indicated that the optimal density for *P. splendida* was between five and ten larvae/L. A diet study produced important results in two areas: a) the development of a practical diet that can be used for larvae, juveniles and adults and b) the utilization of alternative ingredients in the diets (i.e. wheat gluten), which reduces costs by using lower amounts of fish meal. Experiments using larvae, juveniles, and adults provided similar results regarding the amount of fish meal that can be replaced with wheat gluten. Even though *P. splendida* is considered to be a carnivorous cichlid, fish meal replacement in diets ranging from 25 to 50% (in relation to protein) can be used.

- A selective breeding program using males and females obtained from an F3 generation (Egypt strain) was undertaken. The results indicate that the improved Egypt line performs better than the control and wild lines, in general having better reproductive performance, survival, and growth. This work was conducted as a collaborative effort between Universidad Juarez Autónoma de Tabasco, Oregon State University, the ACRSP, and the office for Agriculture and Fisheries Development in Tabasco, Mexico.

- Because methods for the elimination of synthetic steroids from aquaculture facilities are important for maintaining safety standards in the industry, other research conducted in Mexico examined the “Elimination of methyltestosterone (MT) from intensive masculinization systems: use of solar irradiation and bacterial degradation.” Results from this research indicate that large amounts of MT in the water can be completely removed when activated charcoal is used in a Recirculating Aquaculture System (RAS) and partially removed by either exposure to sunlight and/or biofiltration, encouraging the use of RASs in aquacultural facilities that conduct masculinization of fish using synthetic steroids.

- A small-scale (single or multi-family use) recirculating aquaculture module for raising tilapia was designed and demonstrated in Mexico. A small family farm (Los Fierro) in La Piedra at Alvarado, Veracruz, was the site of the demonstration project. The module shows promise for widespread adaptation, and a user manual was developed for the particular design created.

- A Center for Aquaculture Technology Transfer (CETRA) was created in Mexico and housed at the University of Tabasco. CETRA’s goals are to support and guide aquaculture commercial enterprise development in an environmentally sustainable fashion; to that end it has established a network of academic and economic resources in Mexico and the United States that can provide extension.
services for meeting Mexico’s sustainable aquaculture development goals. CETRA builds or will build upon past, present and future research, extension and outreach efforts made by the CRSP/USAID programs and all other pertinent efforts. The major means of outreach by CETRA is through its website (http://www.cetra.org.mx), which contains full information about CETRA, members, and results of workshops conducted.

**Africa**
- The African catfish, *Clarias gariepinus*, is considered to have excellent flavor and is therefore popular as a food fish. For producers to meet the increasing demand for fingerlings, techniques are being investigated to significantly improve these survival rates. The primary objective of two studies in Kenya was to assess management strategies that might contribute to improved growth and survival of African catfish juveniles. 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, while larvae reared in darkness had better growth and survival rates than those reared in illuminated aquaria. A second study determined that a 40-day stocking density of 25 fish/m² resulted in highest larval growth and survival rates.

- Assessment of habitat and water quality has been very important in identifying sources of impairment to streams and rivers as registered by changes in aquatic community structure. One study assessed the response of benthic macroinvertebrates to changes in habitat and water quality along River Moiben, which drained land under forestry, agricultural and residential use. The study revealed that benthic macroinvertebrates were responding to changes in habitat and water quality along this important river basin.

**Southeast Asia**
- Several experiments in countries of Southeast Asia focused on assessing the environmental impacts of culture systems in local waters. Companion studies in Nepal, Vietnam, and Bangladesh examined the benefits of integrating caged species with tilapia in ponds, while other studies in Thailand, Vietnam, and Bangladesh focused on nutrient recycling and optimal culture paradigms for freshwater prawns.
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 is 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 the Aquaculture CRSP. Gaining a better understanding of water and aquaculture is a matter of great interest to the 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; the relationships between aquaculture and women/underrepresented groups; and the availability of financial resources for small farmers.
APPLIED TECHNOLOGY AND EXTENSION METHODOLOGIES
Developing appropriate technology and providing technology-related information to end-users is a high priority. The program encourages efforts that result in 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 is a primary goal. 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 is 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 of such human health crises as AIDS/HIV and aquaculture production.
Collaborating Institutions

US and Host Country Partners

The Aquaculture CRSP’s multidisciplinary team of researchers and advisors represents 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
- 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, Hilo

Subcontracting US Institutions
- Michigan State University
- North Carolina State University
- Texas Tech University
- University of Rhode Island
- University of Tennessee
- University of the Virgin Islands

Collaborating Institutions
- Brooklyn College, New York
- Texas Sea Grant
- University of Puerto Rico

Joint Project Participants
- Bemidji State University, Minnesota
- Heifer International, Arkansas

Work undertaken in the reporting period was outlined in the Twelfth Work Plan and its addenda. Activities involved investigations in 21 countries:

- Bangladesh
- Bolivia
- Brazil
- China
- Colombia
- Dominican Republic
- Ecuador
- 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:

- Asian Institute of Technology, Thailand
- Bangladesh Agricultural University, Bangladesh
- Can Tho University, Vietnam
- Central Luzon State University, Philippines
- Centro de Transferencia Tecnologica Para la Acuicultura (CETRA), Mexico
- Comunidad Indígena Sarayaku, Ecuador
- Department of Fisheries, Kenya
- Ecuador–USAID, Ecuador
- Egerton University, Kenya
- Embrapa Meio Ambiente, Brazil
- Empresa Brasilia de Pesquisa, Brazil
- Escuela Agrícola Panamericana, Zamorano, Honduras
Fisheries and Aquaculture Development
Division, Tanzania
Fondo Nacional del Desarrollo Pesquero, Peru
Foundation Chile, Chile
Fundación Arcoiris, Ecuador
Hainan University, China
Huazhong Agricultural University, China
Institute of Agriculture and Animal Science, Nepal
Instituto Amazónico de Investigaciones Científicas SINCHI, 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 Tecnologico del Mar, Veracruz, Mexico
Kasetsart University, Thailand
Moi University, Kenya
National Freshwater Fisheries Technology Center, Philippines
Peace Corps, Ecuador
Research Institute for Aquaculture No. 1, Vietnam
Sao Paulo State University, Brazil
Servicio Nacional de Aprendizaje, Colombia
Sokoine University of Agriculture, Tanzania
Southwest University, China
Stellenbosch University, South Africa
Ujong Batee Aquaculture Research and Education Center, Indonesia
Universidad Estadual Paulista, Brazil
Universidad Federal do Amazonia, Brazil
Universidad Juárez Autónoma de Tabasco, Mexico
Universidad Mayor de San Simón, Bolivia
Universidad Nacional de la Amazonia Peruana, Peru
University of the Philippines in the Visayas
University of Puerto Rico, Puerto Rico
University of San Carlos, Guatemala
Wuhan University, China
Zhejiang University, China
TRAINING HIGHLIGHTS

Although the ACRSP is nominally a research program, its participants have always made an effort to infuse elements of training, outreach, and information dissemination into the program, and this has added a great deal of value to the research being conducted. This effort has included both formal and informal approaches, beginning from the inception of the program in 1982. Informal training has occurred through one-on-one mentoring of co-Principal Investigators, research station managers, staff, and technicians, and students, not only at the research stations themselves, but also in the university and other institutional settings and at national and international conferences. A great deal of unofficial (and perhaps undocumented) training has occurred through this mechanism.

More formal educational efforts have included both non-degree and degree training. Non-degree training has mainly taken the form of seminars and workshops conducted to teach specific knowledge and skills to farmers, field technicians, extension agents, and others involved in aquaculture development in the various countries in which the CRSP has been active. Degree training has of course included the selection and support of promising students working towards Bachelor’s, Master’s, and Doctoral Degrees. We highlight here some of the workshops conducted and some of the degree training carried out during the past reporting year.

Workshop Highlights

Kenya Project

- Following over 15 short courses (2- and 3-weeks each) offered to fisheries extension workers over the previous six years, the project in 2006 (20 November to 1 December) held a Training of Trainers course at Sagana Aquaculture Centre. Ten top fisheries officers were selected for this training, with the expectation that they will continue to offer courses in pond construction and management and fish farming economics to farmers and incoming fisheries officers in the future, i.e., following the end of Aquaculture CRSP activities in Kenya. The text for this session was a “nearly-final” draft of the project’s A New Guide to Fish Farming in Kenya. As part of their training, the members of the group were charged with the dual tasks of preparing and presenting training modules (PowerPoint presentations) on selected chapters of the new manual and making suggestions for final improvement and editing of the manual. The course was highly successful, with outputs including the beginnings of a new set of PowerPoint training modules to go along with the manual in addition to the many useful editing suggestions that were received.

Tanzania

- The Tanzania project conducted a farmers training workshop involving 25 existing fish farmers from three Morogoro region districts and a district in Kilimanjaro region. Three Fisheries professionals from each District also attended the training with the aim of making them aware and be able to advise properly when a farmers seeks their assistance. The training was held from June 18th through 22nd 2007 at the Institute of Continuing Education of Sokoine University of Agriculture. The training sessions focused on general pond construction engineering, working equipment, pond management, pond fertilization and live food production in the pond, hatchery and pond management,
artificial catfish reproduction, fish enemies and fish diseases and their control, fish farming activity record taking and keeping. Teaching modules were developed by resource persons from University of Arkansas at Pine Bluff, USA; Fisheries and Aquaculture Division - Tanzania, and the Department of Animal Science - Sokoine University of Agriculture. Assistance provided by the Kenya project included sending two resource persons from Moi University, who also provided teaching materials for the training.

Central America

- Several workshops on Pond Design and Watershed Analysis Training were conducted in Central America during the year. These included courses in San Luis, Costa Rica, from 24-25 February, 2007, David, Panama, on 5 May, 2007, and in Canas, Costa Rica, on 7 May, 2007. In San Luis, seven farm workers from the community participated in a pond design workshop sampler program. Attendance at the David and Canas workshops were 37 and 20, respectively. Translation into Spanish and Spanish-language handouts were provided, along with a CD Rom that contained English and Spanish versions of the three spreadsheet programs and the handouts used.

- Also in Central America, a seminars and a workshop were conducted in Mexico in support of an investigation entitled Testing Three Styles of Tilapia–Shrimp Polyculture in Tabasco, Mexico. The first was a seminar on “Tilapia-shrimp polyculture practices,” conducted at the Universidad Juárez Autónoma de Tabasco (UJAT) on 21 November, 2006, and the second was a workshop on the same topic for farmers and government workers, conducted in Hermosillo, Sonora, from 1-2 December, 2006.

- Following a highly successful first workshop in Hermosillo, Sonora (Mexico) in December 2005, under an investigation entitled First Sustainable Aquaculture Technology Transfer Workshop, and related to the development of a small-scale (single or multi-family use) recirculating aquaculture module for raising tilapia, three additional workshops were held: one at Boca del Río, Veracruz (March, 2006), one in Mexico City (July, 2006), and a third in Boca del Río, Veracruz (September, 2006). Each of these workshops had its own uniqueness. The Veracruz workshop in September 06 had 140 people attending this 3 day workshop, which was held immediately before the international conference on tilapia at the same site.

- The second workshop of the aquaculture exchange project entitled The Eagle of the North and Condor of the South Exchange Project was held in Mexico from 14-18 March, 2007. This exchange project brought together native Americans from north and south central America to share experiences, constraints, and ideas for development.

- Two workshops on Aquaculture Collaboration in Mexico were held in Mexico, the first in Guanajuato on 20 November 2006, and the second in Chapingo on 22 November 2006. These workshops were for agricultural engineers and agricultural faculty and students, respectively.

Southeast Asia

- In Thailand, three workshops on BMPs for Pond Bottom Soil Management were conducted in early 2007, the first at Kasetsart University on 23 January, the second at the Samut Prakarn Fisheries Station on 26 March, 2007, the third at the Supan Buri Fisheries Station on 9 April, 2007. The audiences for these workshops were faculty members, graduate students, extension agents, government scientists, and vendors.

- As part of CRSP efforts to assist in recovery efforts in areas traumatized by the 200x tsunami, two workshops were held in early
2007. The first was for fish farmers in Ranong, Thailand, on 14 March and the second was for shrimp farmers in Banda Aceh, Indonesia, on 18 March. Both workshops were on the topic of polyculture (fish-shrimp/seaweed).

South America

- Two international training courses [The Sixth International Training Course of Prominent Amazonian Aquaculture Species; Basic (55 participants) and Advanced (174 participants)] were held in Balbina Brazil, from 4 to 8 June, 2007. These courses assisted in further improving the basic knowledge on fish production techniques for some invited producers, including both men and women from both indigenous and mestizo origins.

USA

- At the University of Arkansas at Pine Bluff, a workshop on Food, Fiber, Farming – Water Animals was conducted for a group of Girl Scouts on 21 April 2007. The workshop included six activities needed to earn badges.
- At Oregon State University, the ACRSP provided support for a workshop for Oregon pond owners called Pond School 2007, the second in what is hoped will be an annual event to assist pond owners with issues such as site selection, pond construction, and pond management.

Long-Term Training

At the beginning of this reporting year, 92 students were receiving CRSP support for long-term studies (programs leading to BS, MS, or PhD degrees), either in the US or at Host Country institutions. Students of 17 nationalities, including Ecuador, Eritrea, Panama, Guatemala, Uganda, Honduras, Taiwan, Mexico, Vietnam, China, Nepal, Bangladesh, Thailand, the Philippines, Kenya, Peru, and the USA, were recipients of this training. Twelve Host Country and twelve US institutions in a total of eleven countries provided the training, as follows:

<table>
<thead>
<tr>
<th>Institution</th>
<th>Number of Students</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Host Country Institutions</strong></td>
<td></td>
</tr>
<tr>
<td>Asian Institute of Technology, Thailand</td>
<td>8</td>
</tr>
<tr>
<td>Central Luzon State University, the Philippines</td>
<td>11</td>
</tr>
<tr>
<td>Moi University, Kenya</td>
<td>8</td>
</tr>
<tr>
<td>Universidad Juárez Autónoma de Tabasco, Mexico</td>
<td>22</td>
</tr>
<tr>
<td>Wuhan University, China</td>
<td>3</td>
</tr>
<tr>
<td>Huazhong Agriculture University, China</td>
<td>3</td>
</tr>
<tr>
<td>Bangladesh Agriculture University, Bangladesh</td>
<td>3</td>
</tr>
<tr>
<td>Can Tho University, Vietnam</td>
<td>2</td>
</tr>
<tr>
<td>Escuela Agrícola Panamericana el Zamorano, Honduras</td>
<td>4</td>
</tr>
<tr>
<td>Institute of Agriculture and Animal Science, Nepal</td>
<td>1</td>
</tr>
<tr>
<td>Research Institute of Aquaculture No. 1, Vietnam</td>
<td>1</td>
</tr>
<tr>
<td>Universidad Nacional de la Amazona Perú, Peru</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>67</strong></td>
</tr>
<tr>
<td><strong>US Institutions</strong></td>
<td></td>
</tr>
<tr>
<td>Ohio State University</td>
<td>3</td>
</tr>
<tr>
<td>University of Arizona</td>
<td>3</td>
</tr>
<tr>
<td>University of Arkansas at Pine Bluff</td>
<td>1</td>
</tr>
<tr>
<td>Auburn University</td>
<td>1</td>
</tr>
<tr>
<td>Southern Illinois University</td>
<td>1</td>
</tr>
<tr>
<td>University of Michigan</td>
<td>3</td>
</tr>
<tr>
<td>Texas Tech University</td>
<td>1</td>
</tr>
<tr>
<td>Michigan State University</td>
<td>1</td>
</tr>
<tr>
<td>University of Georgia</td>
<td>1</td>
</tr>
<tr>
<td>Florida International University</td>
<td>1</td>
</tr>
<tr>
<td>University of Hawai’i</td>
<td>1</td>
</tr>
<tr>
<td>Oregon State University</td>
<td>8</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>25</strong></td>
</tr>
<tr>
<td><strong>Grand Total</strong></td>
<td><strong>92</strong></td>
</tr>
</tbody>
</table>

Of these 92 students, 42 were women and 50 were men (46 and 54%, respectively), reflecting the CRSP’s efforts to achieve gender equality in its training efforts. When the three major categories of long-term training—BS (including BA), MS, and PhD programs—are viewed separately, a similar gender distribution pattern can be seen, as follows:
**BS programs**: 20 women (47%) and 23 men (53%)
**MS programs**: 20 women (49%) and 21 men (51%)
**PhD programs**: 3 women (38%) and 5 men (62%)

Over half (54%) or 49 of these students completed their degree programs as of May 23, 2007. The remaining students are continuing their programs and are expected to finish by the end of the grant period or soon thereafter (estimates subject to verification).

Graduate theses completed during this reporting period included the following:


Martinez-Mejia, Pablo. 2006. Understanding small and medium scale tilapia culture in Nicaragua. PhD, Auburn University, USA.

Moreno, Ana Gabriela Trasvina. 2007. Aplicación de un sistema de calidad para el aprovechamiento del recurso hídrico en una granja de producción aquicola. MS, Instituto Tecnológico de Boca del Rio, Mexico.


Patt, Heather Elisabeth. 2006. Vulnerability assessment of soil and water conservation adoption in two subwatersheds of the Nzoia Basin, Kenya. MS, Michigan State University, USA.

Schwantes, Vicki. 2007. Social, economic, and production characteristics of freshwater prawn *Macrobrachium rosenbergii* culture in Thailand. MS, University of Michigan, USA.

Vera Cruz, Emmanuel Manalad. 2006. Insulin-like growth factor-I gene expression as a growth indicator in Nile tilapia *Oreochromis niloticus* L. PhD., Florida International University, USA.
RESEARCH PROJECTS

Southeast Asia Project: Production Technology

Thailand, Bangladesh, Nepal, Vietnam, China
Subcontract RD010E-04

The Aquaculture CRSP 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 exists with 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), and Southwest University.
Staff

The University of Michigan, Ann Arbor, Michigan (Lead US Institution)
James Diana  Lead US Principal Investigator
C. Kwei Lin  US Co-Principal Investigator
Vicki Schwantes  MS Student (USA)
Barbara Diana  Research Assistant
Lauren Theodore  MS Student (USA)

Asian Institute of Technology, Pathumthani, Thailand (Lead Host Country Institution)
Amrit Bart  Lead Host Country Principal Investigator
Yang Yi  Host Country Principal Investigator
Derun Yuan  Ph.D. Student (China)
Rai Sunila  Ph.D. Student (Nepal)
Sultanul Arifin Shameem Ahmad  Ph.D. Student (Bangladesh)
Nguyen Phu Hoa  Ph.D. Student (Vietnam)

University of the Virgin Islands, St. Thomas, USVI
James E. Rakocy  US Co-Principal Investigator

Institute of Agriculture and Animal Science, Rampur, Chitwan, Nepal
Madhav K. Shreshtha  Host Country Co-Principal Investigator
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)

Can Tho University, Can Tho, Vietnam
Nguyen Thanh Phoung  Host Country Co-Principal Investigator
Ly Van Khanh  Research Assistant (Vietnam)
Tran Van Bui  Graduate Assistant (Vietnam)

Bangladesh Agricultural University, Mymensingh, Bangladesh
Md. Abdul Wahab  Host Country Co-Principal Investigator
A. T. M. Shariful Alam  Graduate Assistant
Mostaque Ahmed  Graduate Assistant
Md. Shah Alam  Graduate Assistant
Md. Asaduzzaman  Research Assistant

Hainan University, Haikou, China
Lai Qiumin  Host Country Co-Principal Investigator
Chen Xuebei  Undergraduate Assistant
Qiu Yunhao  Undergraduate Assistant
Sun Jie  Undergraduate Assistant
This subcontract was awarded funding to conduct the following Twelfth Work Plan investigations:

- New paradigm in farming of freshwater prawn (*Macrobrachium rosenbergii*) with closed and recycle systems: Thailand /12PSD1a. A final report was submitted for this investigation.
- New paradigm in farming of freshwater prawn (*Macrobrachium rosenbergii*) with closed and recycle systems: Vietnam /12PSD1b. A final report was submitted for this investigation.
- New paradigm in farming of freshwater prawn (*Macrobrachium rosenbergii*) with closed and recycle systems: Bangladesh /12PSD1c. A final report was submitted for this investigation.
- Optimization of fertilization regimes in fertilized Nile tilapia (*Oreochromis niloticus*) ponds with supplemental feed /12PSD2. A final report was submitted for this investigation.

- Use of rice straw as a resource for freshwater pond culture (Thailand and Bangladesh) /12PSD3A. A final report was submitted for this investigation.
- Use of rice straw as a resource for freshwater pond culture (Thailand) /12PSD3B. A final report was submitted for this investigation.
- Student exchange program to strengthen capacity in environmental studies of aquaculture: Part I - Integrated shrimp/Gracilaria culture in Hainan Province of China /12PSD9A/China. A final report was submitted for this investigation.
- Student exchange program to strengthen capacity in environmental studies of aquaculture: Part I - application of phytase in Nile tilapia feed /12PSD9B / Thailand. A final report was submitted for this investigation.
- On-farm trial of integrated cage-cum-pond culture systems with high-valued climbing

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Huazhong Agricultural University, Wuhan, China

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

Southwest University, Chongqing, China

Yao Weizi Host Country Co-Principal Investigator
Yu Xiaodong Graduate Assistant (China, Male)

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)

Zhejiang University, Hangzhou, China

Shao Qingjun Host Country Co-Principal Investigator
perch (*Anabas testudineus*) in cages suspended in carp polyculture: Bangladesh/12ATE1a. A final report was submitted for this investigation.

- **On-farm trial of integrated cage-cum-pond culture systems with high-valued African catfish (*Clarias gariepinus*) in cages suspended in carp polyculture ponds:** Nepal /12ATE1b. A final report was submitted for this investigation.

- **On-farm trial of 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 final report was submitted for this investigation.

- **Reproductive performance and growth of improved tilapia, *Oreochromis niloticus/12ATE2*.** A final report was submitted for this investigation.

- **Aquaculture CRSP sponsorship of the Second International Symposium on Cage Aquaculture in Asia/12ATE12.** A final report was submitted for this investigation.

- **Promoting environmentally-friendly integrated cage-cum-pond culture systems/12ATE13.** A final report was submitted for this investigation.

- **Impact of Nile tilapia (*Oreochromis niloticus*) introduction on the indigenous species of Bangladesh and Nepal/12EIA3.** A final report was submitted for this investigation.

- **Student research to assess environmental impacts of cage aquaculture in Mei Zhou Bay in Fujan Province of China/12WQA6.** A final report was submitted for this investigation.

- **Assessment of coastal and marine aquaculture development for low trophic level species/12ERA1.** A final report was submitted for this investigation.

- **Controlled reproduction of an important indigenous species (*Spinibarbus denticulatus*) in Southeast Asia/12ISD1.** A final report was submitted for this investigation.

**Publications**


Theses

Cao, L., 2007. Application of phytase in all-plant feed for Nile tilapia. MS thesis, Huazhong Agricultural University, China (conducted at AIT as an exchange student).


Presentations/Conferences
Yang Yi. 2006. Integrated Aquaculture and Sustainability. The East Asian Sea Congress, Haikou, China, December 2006


Cao Ling. 2007. Effects of microbial phytase on the pre-treatment of all-plant feedstuff and replacement of inorganic phosphorous in Nile tilapia (Oreochromis niloticus) feed. WAS 2007, San Antonio, USA, February / March 2007

James Diana. 2007. Use of cages in pond aquaculture to reclaim wastes from intensive feeding of fish. Workshop on Cage Aquaculture in Egypt, Cairo, Egypt, May 2007


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

Twelfth Work Plan/Production System Design and Integration Research 12PSD1A/Thailand Final Report

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Yang Yi and Yuan Derun
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Asian Institute of Technology
Pathumthani, Thailand

ABSTRACT

The objective of this survey was to assess the current state of production for the giant river prawn (Macrobrachium rosenbergii) in Thailand and assess the feasibility for adoption of a nutrient recycling system. A socioeconomic and technical survey of 100 prawn farmers was conducted during 1 May-31 July 2005 in Thailand. The majority of respondents were male (70%) and average age was 46 ± 1. Most farmers (77%) had completed an elementary level of schooling (4 years) and experience on the farm as owner, manager, or both averaged approximately 10 ± 1 years. Most respondents (92.9%) obtained information about prawn culture from their neighbors and only 19% received formal training. Monoculture was the dominant system (96%) while remaining farmers utilized polyculture with prawns and white shrimp (Litopenaeus vanneimei). The most common management strategy included nursing postlarvae for 30 to 60 days and harvesting with the combined method, culling only the largest market-sized individuals beginning at 5 months followed by every 30 to 45 days (66% of farmers used this system).

Achievements

James Diana completed an eight-year term as Associate Dean for Academic Affairs in the School of Natural Resources and Environment, and was honored by the naming of the “Jim Diana Scholarship in Aquatic Ecology” at the University of Michigan, April 28, 2007.
Culture practices at the time of this survey were intensive. Most farmers stocked at densities below 20 pieces m−2 and average production was 2,338 kg ha−1 yr−1. However, some farmers utilized stocking densities and obtained production values above those described as semi-intensive. Also, commercially produced, nutritionally complete feed was most common, water exchange and aeration was utilized to maintain suitable water quality, and water quality management throughout the cycle was practiced if respondents had the resources. After the culture period, water was generally discharged directly into canals without treatment. Average net profits were 3,918 US$ ha−1 yr−1. Variables that significantly affected yearly gross prawn production (kg ha−1 year−1) included feed inputs (kg ha−1 year−1), frequent water exchange, and stocking prawns directly (R2 = 0.299). Yearly net profits (US$ ha−1 year−1) were most influenced by gross prawn production (kg ha−1 year−1), feed inputs (kg ha−1 year−1), and years of experience of the respondent (R2 = 0.795).

A recycling system that isolates production from the environment and integrates organisms which retain nutrients was simulated for 50 of the surveyed farms. Net profits were lower than average survey results. However, recycling systems do have promise; many farmers seemed to be aware of the environmental effects of current production and attributed multiple problems to water pollution. External pollution was severe for 16% of respondents, moderate for 46%, not an issue for 38%, and was perceived to be caused by multi-user effects. Major problems identified were diseased or poor quality seed supply (67%), disease outbreak within the crop (64%), and external pollution (37%).

In 2005 the freshwater prawn industry in Thailand was valued at US$79,096,000 and ranked 3rd behind China and India (FAO 2005). To maintain this level of production, alternative systems are necessary and must balance adequate environmental benefits and economic returns similar to or better than monoculture.

NEW PARADIGM IN FARMING OF FRESHWATER PRAWN (Macrobrachium rosenbergii) WITH CLOSED AND RECYCLE SYSTEMS

Twelfth Work Plan/Production System Design and Integration Research 12PSD1B/Bangladesh Final Report

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

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

ABSTRACT

The study was conducted to understand the status and practices of giant freshwater prawn (Macrobrachium rosenbergii) production systems in four different zones of Bangladesh during January to July 2005. A total of 100 farmers were interviewed, using semi-structured questionnaire and participatory rural appraisal tools.

Farmers reared post larvae (PL) at 10 to 37.5 individual m−2 in small ponds or in the trench of ghers with water area averaging 332 m2. About 49.0% farmers stocked hatchery-produced PLs due to shortage on supply and high price of wild PLs. Farmers used urea, triple super phosphate (TSP), and cowdung to produce natural foods. Mean survival of PLs was 67.5%. In grow-out farming systems, farmers reared prawn juveniles in ponds and/or ghers. Many farmers (30%) did not practice integrated culture, 40% integrated prawns with paddy rice, 10% integrated prawns
with dike crops, and 20% combined all three. Farmers used processed feed, homemade feed and snail meat, at an average rate of 4.5% body weight per day. The peak season of partial harvesting was from October to January, and small prawns were reared up to next season and harvested in the following year from August to September. The average annual yield of prawn was estimated at 390.2 kg ha-1.

There were a large number of problems for prawn farming. For long-term prawn farming in the study areas, adequate bank credit at very low interest, quality seed production and improved management skills are needed.

NEW PARADIGM IN FARMING OF FRESHWATER PRAWN (Macrobrachium rosenbergii) WITH CLOSED AND RECYCLE SYSTEMS

Twelfth Work Plan/Production System Design and Integration Research 12PSD1C/Vietnam Final Report

Nguyen Thanh Phuong, Ly Van Khanh Le Quoc Viet and Tran Van Viet College of Aquaculture and Fisheries Can Tho University, Can Tho City, Vietnam

Yang Yi and Yuan Derun Aquaculture and Aquatic Resources Management School of Environment, Resources and Development Asian Institute of Technology Pathumthani, Thailand

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

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. Seventy-six prawn farmers were randomly selected during the first survey, among which 15 farmers were from Co Do district and 27 farmers from Thot Not district of Can Tho City, and 34 farmers from Thoai Son district of An Giang province. For the second survey, 21 farmers were selected from Co Do district, 16 from Thot Not district and 22 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 changes of giant freshwater prawn farming including development trends as well as technical, socio-economic and environmental aspects.

Prawn farming in the rice-prawn alternative culture model was continuing expansion in the Mekong delta. There were improvements of culture techniques and net return. Average production in 2004 was 1,452 kg ha-1 crop-1, and in 2005 was 1,035 kg ha-1 crop-1. However, average net return in 2005 was 48,788,000 VND, which was 40% higher than that in 2004. Stocking density of prawn in 2005 was lower than that in 2004, and the stocking density of 8-12 post-larvae per square meter would be suitable for the rice-prawn alternative culture model. The technology should be further improved in terms of farm preparation, feed and feeding, stocking and water management.

OPTIMIZATION OF PHOSPHORUS FERTILIZATION REGIME IN FERTILIZED NILE TILAPIA (Oreochromis niloticus) PONDS WITH SUPPLEMENTAL FEED

Twelfth Work Plan/Production System Design and Integration Research 12PSD2 Final Report
ABSTRACT
An experiment was conducted in fifteen 200-m² earthen ponds at the Asian Institute of Technology, Thailand during 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 completely block design: 100%, 75%, 50%, 25% and 0% of 7 kg P ha⁻¹ wk⁻¹. Nitrogen fertilization rate was fixed at 28 kg N ha⁻¹ wk⁻¹ for all the treatments throughout the experiment. Sex-reversed all-male Nile tilapia of about 100 g size were stocked at 3 fish m⁻², 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 sink in the sediment. Economic analysis showed that all the 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 economic return and nutrient loss in sediment.

USE OF RICE STRAW AS A RESOURCE FOR FRESHWATER POND CULTURE

In order to assess the feasibility of rice straw as periphyton substrates for freshwater fish culture, three on station trials were carried out. Experiment one was conducted to determine the appropriate loading level of rice straw in 5-m² fertilized cement tanks without stocking fish. There were seven different loading rates of rice straw each in triplicate: 0, 625, 1,250, 2,500, 5,000, 10,000 and 20,000 kg ha⁻¹ (dry matter basis). The loading rate of 625 kg ha⁻¹ was best, and water quality deteriorated with increased loading rates of rice straw. Periphyton grown on rice straw surface alone could contribute a maximum fish production of 1,825 kg ha⁻¹ y⁻¹.
Experiment two was conducted to optimize the number of rice straw mats used in fertilized 40-m² ponds stocked with rohu (*Labeo rohita*), catla (*Catla catla*), mrigal (*Cirrhinus mrigala*), common carp (*Cyprinus carpio*) and silver carp (*Hypophthalmichthys molitrix*). There were six treatments in triplicate each: a) no rice straw mats (control); b) using rice straw mats to cover pond dikes; c) suspending one (1x 625 kg ha⁻¹) rice straw mat in water column; d) suspending two (2 x 625 kg ha⁻¹) rice straw mats in water column; e) suspending three (3 x 625 kg ha⁻¹) rice straw mats in water column; and f) suspending four (4 x 625 kg ha⁻¹) rice straw mats in water column. The results showed that three straw mats per pond gave the highest total weight gain of fish (0.44± 0.07 t ha⁻¹ 90 days -¹) among all treatments (P<0.05).

In experiment three, plankton-based carp polyculture system was compared with two periphyton-based carp polyculture systems using rice straw mats (3 straw mats per pond, 3x625 kg ha⁻¹) or kanchi (390 bamboo side shoots per pond) as substrates in fertilized ponds. Rice straw and kanchi treatments gave 38% and 47% higher total weight gains than that in the control (P<0.05), due probably to periphyton and bacterial biofilm from substrates. The rice straw treatment appeared to be more economical than the control and kanchi treatments.

This study demonstrated that rice straw which is widely available at low-cost in South Asia can be used to increase fish production through the development of bacterial biofilm and periphyton. The technology is simple, cost effective and appropriate for resource poor farmers.

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

Twelfth Work Plan/Production System Design and Integration Research 12PSD3B/Thailand Final Report

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**ABSTRACT**

An experiment was conducted with different rice straw loading rates in fertilized earthen ponds at the Asian Institute of Technology, Thailand to assess effects of rice straw mats on growth performance of Nile tilapia (*Oreochromis niloticus*), water quality, periphyton, plankton, bacterial biofilm and benthos. There were six treatments with three replicates each: (1) control (without rice straw mats); (2) rice straw mats of 5x0.5 m covering dikes; (3) one rice straw mat of 5x1 m in the water column; (4) two rice straw mats; (5) three rice straw mats; and (6) four rice straw mats. All ponds were fertilized weekly with urea and triple super phosphate at rates of 28 kg N and 7 kg P ha⁻¹ week⁻¹. Sex-reversed all-male tilapia of 24.7±3.0 g in size were stocked at 2 fish m⁻² on day 39 after placing straw mats in the ponds.

Tilapia growth performance was not significantly different among treatments, except the treatment with two straw mats, which had 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. Rice straw loading had no significant effect on measured water quality parameters, plankton density, bacterial biofilm or benthos. A sharp decline in dissolve oxygen concentration was observed in the rice straw treatments after placing the mats in the ponds. Eighty-seven genera of phytoplankton were identified, belonging to
the following groups in order to total number: Bacillariophyceae, Chlorophyceae, Cyanophyceae and Euglenophyceae. Three genera, namely, Cyclotella, Microcystis and Euglena were dominant among all identified 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 toward the end of the experiment. Total benthic invertebrate abundance was also not significant different among treatments, and oligochaete was the dominant group. Rice straw loading to fertilized ponds did not enhance tilapia growth and yield, and had no apparent effect on major water quality parameters, plankton community, bacterial growth and benthos. However, rice straw mat structure collapsed during the early experimental period (15 days after stocking fish) and the rice straw sank, so the full potential of rice straw as a substrate for periphyton attachment was not realized in this study.

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ABSTRACT
This study focuses on two types of integrated aquaculture systems used in Yingbin Bay, Hainan Province, China: a shrimp (intensive) and abalone system, and a shrimp (semi-intensive), seaweed and duck system. The specific goals of the study were to 1) evaluate water and sediment quality in ponds for these two integrated farming systems; 2) determine common farming methods in the region; and 3) evaluate effects of integrated culture on water quality in Yingbin Bay. In order to accomplish these goals, a combination of on-site water and soil quality analysis, as well as interviews, were conducted from March to June 2006.

The two integrated systems varied greatly in their design and management. The shrimp and abalone system was comprised of three intensive shrimp ponds that were fed by abalone effluent and groundwater. The shrimp, seaweed and duck system was comprised of one semi-intensive shrimp pond and one seaweed and duck pond. The farmer used the seaweed and duck pond for biofiltration of his shrimp effluent, such that water was recirculated between the two ponds. Both integrated systems were able to maintain water quality adequate for shrimp growth. However, both systems failed to meet Global Aquaculture Alliance’s standards for total phosphorus and total suspended solids. The seaweed and duck pond was hypothesized to have lower nutrient concentrations relative to all of the shrimp ponds in the study due to seaweed’s ability to uptake nutrients, but nitrate and total phosphorus concentrations were much higher in the seaweed and duck pond than in...
the shrimp ponds. Other nutrient parameters in the duck and seaweed pond were found in concentrations similar to those in the intensive shrimp ponds.

Total ammonia and phosphate concentrations decreased downstream through the Yingbin Bay culture area, implying that water quality improved on an upstream to downstream gradient. This may be the result of aquaculture activities utilizing nutrients flowing downstream. However, total phosphorus, and COD concentrations did not decrease (and in some cases increased). In particular, high total phosphorus concentrations were observed throughout the study ponds and bay in April (as high as 1.70 mg/L); phosphate concentrations did not increase as dramatically, indicating that the phosphorus source was not inorganic fertilizer.

STUDENT EXCHANGE PROGRAM TO STRENGTHEN CAPACITY IN ENVIRONMENTAL STUDIES OF AQUACULTURE PART B: APPLICATION OF PHYTASE IN NILE TILAPIA FEED

Twelfth Work Plan/Production System Design and Integration Research 12PSD9B Final Report

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ABSTRACT

This study was conducted at the Asian Institute of Technology to assess effects of the pretreatment in all-plant based diets with microbial phytase on phosphorous utilization and growth performance of Nile tilapia (*Oreochromis niloticus*).

Pretreatment trials were conducted using phytase at graded doses to determine the optimal dose of phytase. Available P levels increased significantly with the increased doses of phytase and the dose of 1,000 U kg-1 was most efficient. Based on the pretreatment trials, plant based diets for Nile tilapia were formulated by pre-treating with phytase at 1,000 U kg-1. Experimental diets were supplemented with graded levels of mono calcium phosphate (MCP) at 25, 18.75, 12.5, 6.25, and 0 g kg-1 diet. In addition, there were three controls: one phytase control, one inorganic P control and one pre-treatment control. The results showed that diets pre-treated with phytase gave better growth performance, feed conversion ratio and protein efficiency ratio of Nile tilapia compared to the phytase control diet and pretreatment control diet (P<0.05). There were no significant differences in growth performance of Nile tilapia between the inorganic control diet and phytase pre-treated diets supplemented with MCP at 25, 18.75 and 12.5 g kg-1 (P>0.05), which resulted in significantly better performance than those at 6.25 and 0 g kg-1 (P<0.05). Dietary interaction effects of phytase were observed for phosphorus retention efficiency and phosphorus load. Apparent digestibility coefficient of P (ADCp) was improved significantly by phytase pretreatment (P<0.05). No significant difference was detected on ADCac of crude protein among all experimental diets (P>0.05).

Phytase can be used to efficiently pre-treat all-plant based diets at a dose of 1,000 U/kg while inorganic P can be supplemented at 12.5 g kg-1 to ensure that the adequate amount of P is available to juvenile Nile tilapia.
ON-FARM TRIAL OF INTEGRATED CAGE-CUM-POND CULTURE SYSTEMS WITH HIGH-VALUED CLIMBING PERCH (Anabas testudineus) IN CAGES AND CARPS IN PONDS IN BANGLADESH

Twelfth Work Plan / Applied Technology and Extension 12ATE1A Final Report

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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 (Hypophthalmichthys molitrix, Catla catla, Labeo rohita, Cirrhinus cirrhosus, Puntius sarana and Cyprinus carpio) stocked in the open water of 18 rural farmers’ ponds for 150 days in Mymensingh region of Bangladesh. One or two 1-m³ cage per 200 m² pond area was suspended in each of 12 earthen ponds, and the remained 6 ponds served as controls without cages. Climbing perch fingerlings of 2-3 g in size were stocked at 200 and 400 fish per m³ in cages, while carp fingerlings of 8-15 g size were stocked at 1 fish per m³ in all eighteen ponds, giving caged climbing perch to open-pond carps ratios of 1:1 and 2:1, respectively. Caged climbing perch were fed commercial pelleted feed (32% crude protein; Saudi Bangla Co. Ltd., Bangladesh) for the first 90 days and grower feed (38% crude protein) for the rest days. Feeds were supplied at 10% body weight per day for the first month and at 5% body weight per day for the rest of the culture period. No fertilizers were applied in the treatment ponds with cages, while the control ponds were fertilized every 2 weeks at rates of 2,000 kg cowdung, 25 kg urea and 25 triple supper phosphate per hectare. No additional supplemental feeds were supplied for open-pond carps.

Survival of climbing perch was 61.7% in the 1:1 ratio treatment, which was significantly higher than that (30%) in the 2:1 ratio treatment (P<0.05). There was no significant difference in survival of carps between treatments (P>0.05). Final mean weights of climbing perch were not significantly different between the treatments (P>0.05), while final mean weights of carps in the control were significantly lower than those in the two treatments (P<0.05). Total net yield of climbing perch in the 1:1 ratio treatment was 0.13±0.01 t ha-1 crop-1, which was significantly higher than that (0.10±0.01) in the 2:1 ratio treatment (P<0.05). Total net yield of carps was significantly lower in the control than in the two treatments (P<0.05).

FCR was high in both treatments (11.3 and 25.1), and FCR in the 1:1 ratio treatment was significantly lower than in the 2:1 ratio treatment. Overall, FCR was better in the low density treatment. Survival of every carp species was significantly lower in the control than that in the two treatments. Net and gross yields of each carp species were significantly higher in the two treatments than those in the control. Net revenues were positive but low in all treatments. Large size climbing perch fingerlings stocked at low density may be suitable for integrated cage-pond culture, but more on-farm trials are necessary to develop the technology.
ON-FARM TRIAL OF INTEGRATED CAGE-CUM-POND CULTURE SYSTEMS WITH HIGH-VALUED AFRICAN CATFISH (Clarias gariepinus) IN CAGES AND CARPS IN PONDS IN NEPAL

Twelfth Work Plan / Applied Technology and Extension 12ATE1B
Final Report

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ABSTRACT
An on-farm trial was conducted for 164 days in 18 earthen ponds of 85-130 m² in surface area at three sites in Nepal to adopt integrated cage-cum-pond systems to local conditions and to verify the best results of an on-station trial. One cage (1.5 x 1.5 x 1.0 m) with water volume of 2 m³ was suspended in ponds. There were two treatments: (1) carps at 1 fish m⁻² in open ponds without cages (control); (2) African catfish (Clarias gariepinus) at 100 fish m⁻³ in cages and carps at 1 fish m⁻² in open ponds (cage treatment). Each trial site had 3 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) of 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, giving a stocking ratio of silver carp, bighead carp, common carp, rohu and mrigal as 4:2:2:1:1 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⁻³ d⁻¹.

Mean total weight, harvest size, growth, gross and net fish yield, survival, and feed conversion ratio of African catfish were 23.1±2.1 kg cage⁻¹, 212.7±12.4 g fish⁻¹, 1.3±0.1 g f-1d⁻¹, 23.1±2.1 kg cage⁻¹ crop⁻¹, 20.6±2.1 cage⁻¹ crop⁻¹, 54.9±1.0 % and 2.8±0.2, respectively. Most of the growth and production parameters of silver and bighead carps were significantly higher in the control than in the cage treatment (P>0.05). The net and gross yields of carps in the control were significantly higher than in the cage treatment (P<0.05) while the combined net and gross yields of catfish and carps were significantly higher in cage treatment than in the control (P<0.05). Both the control and cage treatment produced positive net returns with 1,252 NRs per 100-m² pond in the control, and 1,859 NRs per100-m² pond in the cage treatment in one culture cycle. The results of this trial showed that African catfish has potential to be cultured in the integrated cage-cum-pond culture system, but it is necessary to avoid the winter season for culture. Also, growth and survival of African can be improved by stocking larger size fingerlings and by providing better quality feed.

ON-FARM TRIAL OF INTEGRATED CAGE-CUM-POND CULTURE SYSTEMS WITH HIGH-VALUED CLIMING PERCH (Anabas testudineus) IN CAGES AND NILE TILAPIA (Oreochromis niloticus) IN PONDS IN VIETNAM

Twelfth Work Plan / Applied Technology and Extension 12ATE1C
Final Report
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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 adopt the integrated cage-cum-pond systems to local conditions. Five farmers’ earthen ponds of 100 m² 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 2 fish m⁻² in all ponds, while climbing perch (Anabas testudineus) fingerlings (8-10 g size) were stocked in a 4-m³ cage suspended in each treatment pond. Stocking density of climbing perch was the treatment variable and was 50, 100, 150, and 200 fish m⁻³, giving caged climbing perch to open-pond Nile tilapia ratios of 1:1, 2:1, 3:1, and 4:1. There were also control ponds without a cage (0:1), and control ponds were fertilized weekly with urea and diammonium phosphate (DAP) at 28 kg N and 7 kg P ha⁻¹ week⁻¹. 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⁻¹ day⁻¹) of climbing perch was significantly higher in the 1:1 ratio treatment than those (0.16 – 0.17 g fish⁻¹ day⁻¹) in the 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⁻¹, and 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 (93.0%) in the 3:1 ratio treatment, intermediate (86.8%-89.3%) in the 0:1, 1:1, and 2:1 ratio treatments, and lowest (84.0%) in the 4:1 ratio treatment (P<0.05). Growth of Nile tilapia, ranging from 1.17 to 1.78 g fish⁻¹ day⁻¹, was not significantly different among treatments (P>0.05), while the 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 m² 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.

REPRODUCTIVE PERFORMANCE AND GROWTH OF IMPROVED TILAPIA, Oreochromis niloticus

Twelfth Work Plan/Applied Technology and Extension 12ATE2  
Final Report

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ABSTRACT
This study compared the growth, survival, sexual maturation and various reproductive parameters of four tilapia strains, three of which have been improved through various selective breeding approaches (GIFT, IDRC and Fishgen-selected) and a local stock (Chitralada) was included as a non-improved control. The four strains were originally cultured in extensive culture systems with fertilization only. Growth (weight and length) and reproductive parameters (gonadosomatic index, hepatosomatic index, and stages of sexual maturation) were measured on fish sampled every 21 days. Based on staging of gonad development, GIFT were found to become sexually mature marginally later than the other two strains. At 9 months of age, broodstock from each strain were stocked in 5m² breeding hapas with 5 males and 15 females per hapa and four replicate hapas per strain. Broodstock were sampled for eggs every week and data collected on fecundity and inter-spawning interval for the four strains over the 17 months. Seasonal and environmental variances appear to be the major determinants of egg/fry production with the only strain difference observed being a lower relative fecundity in GIFT. Across all strains, fecundity per female increased over time while fecundity per unit weight of female remained constant. SF and ISIs fluctuated widely between individual fish, and ISIs were even highly variable within individual females making it very difficult to identify trends. Many females spawned very infrequently and means of identifying fecund females could have significant impacts upon hatchery efficiency.

AQUACULTURE CRSP SPONSORSHIP  
OF THE SECOND INTERNATIONAL  
SYMPOSIUM ON CAGE AQUACULTURE IN ASIA
Twelfth Work Plan/ Applied Technology and Extension 12ATE12  
Final Report
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ABSTRACT
The objectives of this activity were to organize a special session on environmentally-friendly integrated cage-cum-pond culture system at the Second International Symposium on Cage Aquaculture in Asia (CAA2), to provide travel support for five invited speakers on the special session from Aquaculture CRSP institutions in Asian countries, to provide travel support for four or more contributors from Aquaculture CRSP institutions in Asian countries, to provide three environment awards to recognize research that addresses environmental concerns of cage aquaculture, and to provide three best student paper prizes to recognize the their academic performance.

Due to the limited papers, many sessions were merged. Thus, the session on environmentally-friendly integrated cage-cum-pond culture system was merged with the session on
environmental impacts of cage aquaculture to be the session on environmental impacts and management. ACRSP researchers (Prof. James S. Diana and Prof. C. Kwei Lin) co-chaired the session. Among five invited speakers supported by ACRSP travel grants, two could not attend CAA2, due to urgent tasks in their organizations. Four Chinese researchers, including one MSc student, were selected for ACRSP travel supports to attend CAA2. Environment Awards were given to three papers selected by a committee co-chaired Prof. James S. Diana and Prof. C. Kwei Lin, while the Best Student Paper Prizes were awarded equally to three papers selected by an independent committee appointed by Asian Fisheries Society.

PROMOTING ENVIRONMENTALLY FRIENDLY INTEGRATED CAGE-CUM-POND CULTURE SYSTEMS

Twelfth Work Plan/ Applied Technology and Extension Methodology Research 12ATE13 Final Report

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ABSTRACT
The objectives of this activity are to produce a manual on the environmentally friendly integrated cage-cum-pond systems developed by Aquaculture CRSP, to produce promotional brochures in different languages, and to promote the integrated cage-cum-pond systems through the manual, promotional brochures and workshops to be held in different countries.

A manual on environmentally friendly integrated cage-cum-pond culture systems and four brochures on the integrated cage-cum-pond culture systems in Chinese, Bengali, Nepalese and Vietnamese languages have been developed. A workshop was combined with the session on environmental impacts of cage aquaculture in the 2nd Symposium on Cage Aquaculture in Asia held in Hangzhou, China on 3-8 July 2006, during which three papers on the integrated cage-cum-pond culture systems were presented. Three workshops were held in Kathmandu of Nepal on 8 June 2007, in Bangladesh Agricultural University, Mymensingh of Bangladesh on 14 June 2007, and in Can Tho University, Can Tho City of Vietnam on 26 June 2007.
IMPACT OF NILE TILAPIA (*Oreochromis niloticus*) INTRODUCTION ON SMALL INDIGENOUS FISH SPECIES OF BANGLADESH AND NEPAL

Twelfth Work Plan/Environmental Impacts Analysis 12EIA3
Final Report

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ABSTRACT
Small indigenous species (SIS) of fish are important to rural poor in Bangladesh and Nepal as these species are relatively cheap, consumed whole and contain nutritive values higher than many cultured species. There is concern that introduced tilapia may compete with SIS, causing not only the loss of biodiversity but also affecting health of the rural poor. Therefore, this study was conducted to assess the effect of Nile tilapia on changes in population structure, recruitment

and diet with three important indigenous species in simulated natural ponds. Experiments were conducted at Bangladesh Agricultural University and at the Institute of Agriculture and Animal Science in Nepal. In each location, nine earthen ponds of 100 m² surface area and 1.0 m average depth were used. In each location a completely randomized design with three treatments were used and each treatment had three replicates. The treatments were: mixed-sex tilapia with the three indigenous fish species; mono-sex male tilapia with SIS; and SIS without tilapia. In both sites, gut content analysis and electivity indices indicated that all the fish species were selective in their food habits, and that there was potential competition for food organisms among all species. In Bangladesh, population densities and biomasses of mola (*Amblypharyngodon mola*), punti (*Puntius sophore*) and chela (*Chela cachius*) were significantly higher in the SIS and SIS with monosex-tilapia treatments compared to mixed-sex tilapia with SIS. Total fish biomass in both tilapia treatments was three times higher than in the control. In Nepal, population density and biomass of pothi (*Puntius sophore*) was significantly higher in the SIS treatment compared to the tilapia treatments, while tilapia did not affect recruitment or biomass of darai (*Esomus danricus*) or faketa (*Barilius barna*)

STUDENT RESEARCH TO ASSESS ENVIRONMENTAL IMPACTS OF CAGE AQUACULTURE IN MEI ZHOU BAY IN FUJAN PROVINCE OF CHINA

Twelfth Work Plan/Water Quality and Availability Research 12WQA6
Final Report

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ABSTRACT
The objectives of this study were to investigate integrated cage/seaweed culture systems, to estimate the environmental conditions throughout the culture area, to assess the potential effects of seaweed on reuse of nutrients derived from cage culture, and to enhance the environmental awareness of undergraduate and graduate students, farmers and local government staff.

This study was conducted at Quangang area of Mei Zhou Bay, Hui An, Fujian Province during October 2006 – May 2007. A survey was conducted by interviewing 100 farmers using a structured checklist and open-ended type of questionnaires. Field measurements were conducted by collecting water samples monthly from three water depths at four locations (cage culture area, seaweed culture areas, at the mouth of the small bay, and at the mouth of Mei Zhou Bay) for analyses of major water quality parameters. A workshop was held to report the findings of this study.

There were 2,700 net-cages of 36 m3 in volume in the study area, with the major culture species of red drum (*Sciaenops ocellatus*), red seabream (*Pagrosomus major*) and Japanese seabass (*Lateolabrax japonicus*). The culture periods for seaweeds were October – December 2006 for *Porphyra spp.* and January – May 2007 for kelp (*Laminaria japonica*). The average water depth was about 18 m.

The results showed that average concentrations of TN, TAN, nitrite-N and nitrate nitrogen were significantly lower at the mouth of Mei Zhou Bay than those in the cage culture area (P<0.05), while there were no significant differences in TP, TOC, or chlorophyll a among all sampling stations (P>0.05). The highest concentrations of the nutrients occurred almost in December 2006 and January 2007, when culture of *Porphyra spp.* was terminated and kelp culture just started, while the lowest concentrations occurred almost in November 2006 and February 2007, which were the fast growing periods for seaweeds.

ASSESSMENT OF COASTAL AND MARINE THE STATUS AND FUTURE OF NEAR SHORE AQUACULTURE FOR LOW TROPHIC LEVEL SPECIES

Twelfth Work Plan / Economic Risk Assessment 12ERA1  
Final Report

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ABSTRACT
Many look to the production of low trophic species such as seaweed and bivalves in near shore ecosystems as a way to make aquaculture systems “sustainable.” Low trophic aquaculture systems are rapidly expanding worldwide in the near shore, and are touted as capable of solving eutrophication problems. After reviewing the literature to date on low trophic culture in near shore ecosystems, it is apparent that low trophic aquaculture can be done in an ecologically friendly way, but that our limited knowledge of near shore ecosystem functioning makes it difficult to say that any one system is truly ecologically, culturally and economically sustainable. After providing a review of the current literature on low trophic near shore
aquaculture, we propose a theoretical model for its future continued development, called Low trophic, Ecological Aquaculture in the Near shore, or LEAN. This model moves away from the concept of sustainable development and focuses on the principles of ecological aquaculture developed by Barry Costa-Pierce, applying them specifically to near shore and low trophic aquaculture.

CONTROLLED REPRODUCTION OF AN IMPORTANT INDIGENOUS SPECIES, (Spinibarbus denticulatus) IN SOUTHEAST ASIA

Twelfth Work Plan/Indigenous Species Development 12ISD1 Final Report

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ABSTRACT

Preliminary studies were conducted to understand some basic reproductive parameters of the indigenous carp, Spinibarbus denticulatus as a prelude to more specific research studies and subsequent development of hatchery technology. The study objectives were to: 1) understand the seasonal pattern of gonad development, sexual maturation, and various reproductive parameters; and 2) induce this species to spawn in captivity using natural and artificial methods.

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

Induced breeding trials indicated that natural induction methods (rain simulation, decreased/ increased water depth and flow) did not stimulate mature females to spawn in ponds. A series of locally available hormones (e.g., HCG, LHRHa+Domperidone, CPE), singly or in combinations, was used to induce females to ovulate. Administration of LHRHa, CPE, and HCG were effective in inducing ovulation for S. denticulatus. However, LHRHa or CPE induced ovulation more consistently compared to HCG. Fertilization rate and hatch rates were also higher
in LHRHa or CPE than HCG induced group. Individual females released 4.2 - 9.4 x 10^3 eggs when stripped, and egg numbers were correlated with BW of the female. Simultaneous injection of LHRHa and domperidone was required to achieve high success in induced spawning of S. denticulatus. Furthermore, no clear advantages were evident to the other hormone combination strategies.
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 coupled with studies underway in the Thailand Project. 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; with Florida International University (FIU) assuming US project leadership. FIU also executed a Memorandum of Understanding with CLSU and recently graduated a doctoral candidate who is a faculty member at CLSU.

Aquaculture CRSP Philippines Project research has emphasized the refinement of tilapia grow-out technologies to produce fish more economically. Additional studies have focused on the production of fillets for the export market and on the utility of gene expression as a means of instantaneous assessment of growth in Nile tilapia. The latter group of studies has provided a rapid and inexpensive means of determining growth rate – measurement of expression of the insulin like growth factor-I gene is vastly thriftier than the large-scale grow-out studies that have been standard for the measurement of growth. Increasingly, collaborative researchers at North Carolina State University have been involved in the technical and extension aspects of the Philippines Project research.
Staff

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North Carolina State University, Raleigh, North Carolina
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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 final report 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


Vera Cruz, E.M. and Brown, C.L. (submitted) Dynamics of increase in Insulin-Like Growth Factor-I mRNA expression in Nile Tilapia, Oreochromis niloticus, in response to elevated temperature.

Presentations/Conferences
Bolivar, RB. Comparison on the Use of Cast Net and Seine Net in Fish Samplings in Ponds. Presented at 7th International Symposium on Tilapia in Aquaculture 6-8 September, 2006.

Bolivar, RB. Sugarcane Bagasse as Periphyton Substrate in the Culture of Nile Tilapia (Oreochromis niloticus) in Fertilized Ponds. Presented at 7th International Symposium on Tilapia in Aquaculture 6-8 September, 2006.

Workshops/Seminars/Educational Outreach


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

Twelfth Work Plan / Production System Design and Integration 12PSD5 Final Report

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

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

Twelfth Work Plan / Production System Design and Integration 12PSD6 Final Report

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ABSTRACT
The experiment was undertaken to determine the culture period of Nile tilapia to reach
approximately an average weight of 600 g at a
stocking size of 50-120 g. The grow out study
was conducted in six 500 m² earthen ponds.
GET-ExCEL Nile tilapias were stocked at a
density of 1 pc m-2 (Treatment I) and 2 pcs m²
(Treatment II). Analysis of variance revealed no
significant differences in the initial weight of the
fish between treatments (P>0.05). After a culture
period of four months, fish in Treatment I had a
mean weight of 590.17 g while in Treatment II,
the harvested fish had a mean weight of 512.99
g. However, analysis of variance likewise did
not show significant difference on 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 and 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
± 313.05 kg ha-1) and Treatment II (8,256.43 ±
423.16 kg ha-1) and on fish biomass in Treatment
I (219.84 ± 15.93 kg) and Treatment II (327.77 ±
21.91 kg). The highest percent fillet recovery
was observed in fish sizes ranging from 601-700
g, 701-800 g and 501-600 g with mean values of
36%, 34.99% and 34.03%, respectively. Economic
analysis showed that Treatment 1 had better cost
benefit ratio compared with Treatment II. This
suggests that rearing of Nile tilapia at a density of
1 pc m⁻¹ was more profitable for the production of
tilapia for fillet.
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 (CLSU, the Philippines), and the Asian Institute of Technology (Thailand).

The project began with FYD Corporation as the primary partner, but after the first year, business changes within the corporation required that we switch the partnership to the Cruz Corporation. Philip Cruz worked with the CLSU and University of Philippines in the Visayas to complete the research and prepare the report.
Staff

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Ujung Batee Aquaculture Center, Department of Fisheries, Banda Aceh, Indonesia

Hassanuddin Hassan  Host country Collaborator
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Work Plan Research

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

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

Publications


Presentations

TILAPIA-SHRIMP POLYCulture IN
NEGROS OCCIDENTAL, PHILIPPINES

Twelfth Work Plan / Production System Design
and Integration 12PSD7
Final Report

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Abstract
The project conducted trials at farms in Negros Island in the Philippines and reported on the transition of shrimp farms to polyculture systems with tilapia encouraging “green water” systems. The results were reported at several conferences and workshops and is in press as an article in the Journal of the World Aquaculture Society.

Most farms in Negros have now adopted the tilapia-shrimp system and find that it improves the desired green algae bloom, without decreasing the population levels of other groups of phytoplankton. The results also demonstrate that there are reduced incidences of Vibrio bacterial infections and White Spot viral infections. The causation is not determined, but a probiotic effect is postulated in the case of Vibrio infections. Overall health and reduced stress are thought to be a factor in reduced viral infection. Many research groups are now exploring bio-floc systems which have similar characteristics to the tilapia-shrimp polyculture systems explored in this research.
The Amazon Basin Project (initially called the Peruvian Amazon 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 Federal do Amazonas (UFAM-Brazil), Arcoiris Foundation (Ecuador), Instituto de Investigaciones de la Amazonia Peruana (IIAP, Peru) 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 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 (FONDEPES, Peru), Universidad Mayor de San Simón (UMSS, Bolivia), Instituto Nacional de Pesquisas da Amazonia (INPA-Brazil), Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA, Brazil), Instituto de Investigaciones de la Amazonía SINCHI (Colombia), Servicio Nacional de Aprendizaje (SENA Leticia, 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 included a series of workshops designed to promote sustainable aquaculture development throughout the region.
Staff

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William N. Camargo            Co-Investigator and Project Coordinator
Jesse Trushenski                 Co-Investigator

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Ruguang Chen                 Research Assistant (China)

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Jacques Rinchard              US Co-Principal Investigator
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Sylvana Ferrer               Collaborator
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Marcela Nuñez A.                    Collaborator

Fundacion Arcoiris, Ecuador
Luis Arevalo A.                      Collaborator
Ricardo Burgos M.                   Collaborator

Instituto Tecnológico Saleciano, Ecuador
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Peace Corps, Ecuador
Kirk Leach                          Collaborator

Ecuador USAID-Arcoiris
Edgar Guillen                        Collaborator

Comunidad Indígena Sarayaku, Ecuador
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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:

- Aquaculture Outreach in the Amazon Basin/12SDF7. A final report was submitted for this investigation.
- Sixth International Aquaculture Training Course in the Amazon Region/12SDF9. A final report was submitted for this investigation.
- Egg Hatching Quality of Amazonian Fishes/12ISD5. A final report was submitted for this investigation.
- Influence of Dietary Fatty Acid Composition on Reproductive Performance of of Colossoma macropomum/12ISD6. A final report was submitted for this investigation.
- Effects of Native Peruvian Feedstuffs on Growth and Health of Colossoma and Piaractus/12FNF1. A final report was submitted for this investigation.
- Reproduction of Pacu and Surubim and New Paradigm in Nutrition of Tropical Fish/12FNF4. A final report was submitted for this investigation.
- Workshops for the Cultivation of New Species in Brazil and Peru/12ATE16. A final report was submitted for this investigation.

Publications


Sink, R.T., and R.T. Lochmann. 2007. An enzyme-linked immunosorbert assay is not effective for sampling blood plasma insulin concentrations in red pacu, Piaractus brachypomus, and black pacu, Colossoma macropomum. Journal of Animal and Veterinary Advances, in press.


Thesis

Presentations/Conferences

Lochmann, R., R. Chen, W. Camargo and C. Kohler. 2006. Effects of practical carbohydrate sources on growth and health of gamitana (Colossoma


Dabrowski, Konrad, 2006. Perspectivas para o desenvolvimento de dietas artificiais adequadas para a alimentação de larvas e juvenis de pixes [Perspectives for the development of adjusted artificial diets for the feeding of juvenile larval fish]. Workshop: Larvicultura de Peixes Neotropicals. Center of the Sao Paulo State University in Jaboticabal, Brazil. 12 August 2006.


Workshops/Seminars/Educational Outreach
Konrad Dabrowski conducted a series of lectures for graduate students on Fish nutrition at Bento Gonçalves, Brazil, on August 14, 2006.

The workshop for farmers (6 males, 3 females) titled 1st Basic Training Course on Economic Fishculture Aspects was held in Iquitos, Peru from 28-29 October, 2006.

A Workshop titled Fish Nutrition and Cage Culture was held in the Cahuide Indigenous Community for eleven participants (3 females, 8 males), Alto Itaya river, Peru from 28-29 Jan. 2007.

William Camargo traveled in May 2007 to Colombia, Peru, Bolivia and Brazil to meet HC personnel (country scientists, government officials, extension agents, farmer organizations, farmers, and NGOs) and to inspect collaborative work performed. He also traveled to hold the 6th International Aquaculture Training Course with prominent Amazon Species in the city of Balbina, Brazil, from 5-8 June 2007.

AQUACULTURE OUTREACH IN THE AMAZON BASIN

Twelfth Work Plan/Sustainable Development and Food Security 12SDF7 Final Report

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ABSTRACT
Outreach activities significantly benefited over 187 producers and vocational high school students (73 females and 114 males) in the Amazon Basin (Colombia, Ecuador and Peru). Activities provided by the three CRSP-funded extensionists included aquaculture training courses that contained theoretical and/or practical information. Thirty producers (6 females and 24 males) were from the Peruvian communities of Cahuide, Melitón Carbajal, 12 de Octubre, and 28 de Enero. Fourteen producers (1 female and 13 males) lived along the Leticia-Terapaca Road, Columbia. Thirty were members of the Sarayaku indigenous community in Ecuador. Fifty-two high school students (38 females and 14 males) were from Instituto Superior Pedagógico Público de Loreto, Peru. Seventeen producers (5 females and 12 males) were members of the Asociación de Acuicultores de la Región Loreto, Peru. Forty-four high school students (21 females and 23 males) were from the Instituto Superior Tecnológico Pedro A. Del Aguila Hidalgo, Peru.

A survey was administered to 35 producers along the Iquitos Nauta Road in the Peruvian Amazon. The producers surveyed were 94% male, 71% from the Iquitos area, 43% between the ages of 45 to 54, and have an average of 2.6 individuals per household. Sixty percent own their farm and most (89%) have lived there for more than 20 years. Thirty-seven percent of the farms are 2 to 4 ha in size and the ponds are irregular in size with clay soils. Fifty-one percent of the ponds are spring fed, 29% use precipitation, and 20% are fed by creek water. In conjunction with the fish production, all farmers raise multiple agriculture crops, such as plantain (14%), anona (13%), pomarosa (11%), yucca (9%), papaya (8%), avocado (8%), pineapple (5%) and other crops (16%), as well as raising terrestrial animals such as hens (32%), pigs (12%), ducks (11%) and cows (3%), among others. The major fish cultured include gamitana Colossoma macropomum (28%), boquichico prochilodus nigricans (20%), paiche Arapaima gigas (19%), sabalo Brycon erythropterus (15%), and paco Piaractus brachypomus (9%). Only 33% feed a balanced diet while 23% feed fruits. Thirty-seven percent responded that fish generate more profit than chickens (20%), fruits (17%) or corn (9%). All producers responded it was advantageous having a fish pond and that it is compatible with other household activities; 98% indicated that fish ponds are a better alternative land usage for their farm. Profitability is the most important factor in fish culture to 51% of those responding and poaching was the greatest threat to the success of 41%. The value of the extensionists is evidenced by the fact that 98% of the producers have contacted them in almost one year. Support included provision of technical assistance, tools, fish, lime, feed and money.

The Spanish-language production manual for Colossoma and Piaractus compiled by the WP 10 and WP 11 update was published in November 2007. The Amazonian aquaculture website, developed in WP10, was maintained. This site is an important tool to communicate the work done by research institutions in the USA, many Amazon Basin nations, and elsewhere (over 16,000 hits from Oct. 2006 through Dec. 2007).
SIXTH INTERNATIONAL AQUACULTURE TRAINING COURSE IN THE AMAZON REGION


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ABSTRACT

The Sixth International Aquaculture Training Course with Amazon Species was part of a series of events taking place since 2002, all having been successfully organized by Southern Illinois University Carbondale (SIUC) in the Amazon region. The outreach activities have been implemented with the collaboration of several Amazon institutions and funded partially by the United States Agency for International Development (USAID) and the Aquaculture Collaborative Research Support Program (A/CRSP).

The 6th International Aquaculture Training Course with Amazon Species was held in the city of Balbina (Presidente Figuereido, Amazonas State), Brazil, 4-8 June 2007. The course consisted of two intensive training courses, one for small-scale producers/NGO personnel/indigenous communities and another for large-scale producers/professionals/students of governmental and non-governmental personnel conducting aquaculture research and/or extension activities in the Amazon Basin. A record number of participants, 229, attended (76 females and 153 males). The basic course was presented to 55 producers from indigenous communities. The advanced course was presented to 174 professionals/students. Participants of both courses included members from 33 indigenous communities, 15 small-scale producers, 80 students, 90 professionals and 11 docents. All the participants conduct aquaculture research and/or extension activities with native Amazon species. The following countries, with the number of participants in parentheses, participated: Bolivia (6), Brazil (172), Chile (1), Colombia (13), Ecuador (10), Peru (10), Poland (1), Surinam (3), USA (2) and Venezuela (11).

The main objectives of the course were to 1) train participants on the use of technological tools (pond construction, broodstock selection and handling, spawning techniques, incubation, larviculture, grow out, 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., Pseudoplathystoma sp. and Ampullaria sp.). A CD-ROM displaying all the course material for the Amazon aquaculture-training course was also produced.
EGG HATCHING QUALITY OF AMAZONIAN FISHES

Twelfth Work Plan/Indigenous Species Development 12ISD5
Final Report

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ABSTRACT

Two pacu *Piaractus brachypomus* broodstock (1 male and 1 female) were maintained under standard broodstock conditions (pH < 7, temperature 26±1 °C, alkalinity near 34 mg L-1 measured as CaCO₃, and hardness near 12.5 mg L-1) at La Terraza Aquaculture Research Facility, Universidad Nacional de Colombia (Colombia) during July 2007. Fish were induced to spawn by carp pituitary extract injections and milt from the male broodstock was added to the egg mass for fertilization. To evaluate Mg²⁺ and Ca²⁺ as egg hatching success factors, the fertilized egg mass (approximately 85,800 eggs) was divided into 39 aliquots by weight (approximately 2,200 eggs per aliquot) and placed randomly in 2.0 L polyethylene aerated hatching jars with water of a given hardness and Mg²⁺ and Ca²⁺ concentration (according to each treatment), suspended in a temperature controlled water bath maintained at the same temperature (26±1 °C) as that of the broodstock. Continuous aeration was provided. The treatments were: standard hatchery water (control) and water modified to obtain four levels of hardness (30, 60, 90, and 120 mg L-1, with three replicates), each with different Mg²⁺ and Ca²⁺ proportions: 0:100, 50:50, 80:20 and 100:0 (obtained by the addition of a stock solution previously prepared with analytical grade CaCl₂ and/or MgCl₂ to the hatchery water). After 10 min., dead or unfertilized eggs were removed manually from each hatching jar. New water was replenished (100%) daily in each jar, maintaining the original ion proportion for the respective treatment. Mg²⁺ and Ca²⁺ ions in each treatment were analyzed by an Atomic Absorption Flame Emission Spectrophotometer to maintain the Mg²⁺ and Ca²⁺ content for each treatment. Hatching rate (HR), post-hatch survival (PHS) and larval length were considered as a final indicator of egg and larval quality. After hatching, larvae were maintained in the incubators for 36 h to calculate PHS. Water temperature (27 ± 1 °C), D.O. (5.9 ± 1.4 mg L-1), pH (6.3 ± 0.15), and conductivity (130.6 ± 33.4 µS cm⁻¹) were monitored three times per day; CO₂ (5.0 mg L⁻¹) and ammonia were monitored once daily; and hardness, alkalinity, ammonium (0.41 ± 0.02 mg L⁻¹), nitrite (0.12 ± 0.07 mg L⁻¹), and nitrate (0.64 ± 0.02 mg L⁻¹) were monitored once weekly; all parameters were within permissible levels for *P. brachypomus* egg hatching and subsequent larval survival. The control water was characterized by having low alkalinites (34 mg L⁻¹) and hardness (13 mg L⁻¹). *P. brachypomus* egg fertilization rate improved significantly (p<0.05) up to 60 mg L⁻¹ CaCO₃ water hardness. *P. brachypomus* egg HR increased significantly (p<0.05) as water hardness was increased from 13 to 120 mg L⁻¹ CaCO₃, independently of Mg²⁺ concentration. PHS decreased as Ca²⁺ concentrations increased and as Mg²⁺ decreased including the control (13 mg L⁻¹ CaCO₃), at all four tested water hardness levels (30, 60, 90, and 120 mg L⁻¹ CaCO₃). *P. brachypomus* larval lengths were affected by Ca²⁺: Mg²⁺ proportions at water hardness levels at 30, 90, and 120 mg L⁻¹ CaCO₃ with the most significant (p<0.05) being those at the 100:0 (Ca²⁺: Mg²⁺) proportions. The highest FR, HR and PHS were obtained at the 50:50 ratio (Ca²⁺: Mg²⁺), particularly at water hardness below 60 mg L⁻¹ CaCO₃, and 11.9 mg L⁻¹ Ca²⁺ and 7.6 mg L⁻¹ Mg²⁺.
**ABSTRACT**

In August 2007, spawning was initiated and gametes were successfully collected from two *Colossoma macropomum* females and five males within 24 h following priming and resolving doses of luteinizing hormone releasing hormone (LHRH, 25 µg/kg intramuscular injections, given 12 hours apart). Each clutch of eggs was fertilized with milt from 2+ males and incubated in MacDonald jars at approximately 26 ±1 °C. Hatching activity began at approximately 36-48 hours post-fertilization and was completed within 72 hours post-fertilization. Although no attempts were made to quantify fertilization success or hatch rate, qualitative observations suggested high rate of success for both parameters. Five days after hatching, the fry were transferred to two, 0.1 acre ponds that had been filled with screened surface water. Approximately one month after stocking, the ponds were harvested and yielded approximately 1000, 2-4 cm fingerlings. This effort represents the first successful spawning and larval rearing of *C. macropomum* at Southern Illinois University Carbondale.

Unfortunately, for the purposes of the nutritional study, both mature females were from the low-HUFA treatment, preventing comparison between the dietary treatment groups. We believe the low rate of spawning success was due to the immaturity of most of the broodfish (~3-4 years of age at spawning). However, the fatty acid composition of the eggs from both females was determined. Compared to oocytes from white bass *Morone chrysops* (freshwater, temperate species) fed the same corn-oil based feed, *C. macropomum* oocytes contained more saturates and less unsaturates. 20:5n-3 and 22:6n-3, and total highly unsaturated fatty acid (HUFA) content were lower in *C. macropomum* oocytes, but the n-3 to n-6 ratio was the same for both species. Although saturates appear to be important constituents for *C. macropomum* oocytes, perhaps increasing membrane structural integrity at warmer temperatures, higher-than-expected levels of n-3 and HUFA suggest these FA may serve a functional role in oocyte/embryo development of *C. macropomum*. We have begun a repeat feeding trial and hope to collect gametes from a greater number of individuals during the 2008 spawning season to further address this hypothesis.
ABSTRACT

Colossoma macropomum (black pacu, “gamitana”) and Piaractus brachypomus (red pacu, “paco”) are high-value foodfish species native to the Amazon Basin. Natural supplies of these fish cannot meet market demand and aquaculture production is intensifying. Standard energy sources in prepared fish diets such as wheat are not economical in the Amazon region, and greater use of native feedstuffs as energy sources is desired. However, there is little research to document the suitability of alternative feedstuffs as energy sources for Characids. We conducted two separate feeding trials to determine the effects of a control diet (containing wheat) versus diets with one of three native Amazonian plant feedstuffs on the performance of C. macropomum (Trial 1) and P. brachypomus (Trial 2). The native feedstuffs were pijuayo (Bactris gasipaes), plátano (Musa paradisiaca), and yucca (Manihot sculenta), which are all widespread in the Amazon region. Diets were formulated to contain similar amounts of total protein and energy and differed only in the test feedstuff (wheat, pijuayo, plantain or yucca) being evaluated primarily as an energy source. Gamitana (22.5 ± 0.03 g initially) or paco (2.56±0.01 g initially) in 4 (trial 1) or 3 (trial 2) tanks per diet were fed one of seven practical diets containing 30% wheat bran (control), cooked or uncooked pijuayo, cooked or uncooked plantain, or cooked or uncooked yucca. Fish were fed the diets to satiation twice daily for 12 weeks. Weight gain (g), feed conversion ratio (FCR), liver glycogen and dry matter, hematology (hematocrit, hemoglobin, and mean corpuscular hemoglobin concentration), and immune parameters (lysozyme and alternative complement activity) were measured to assess diet effects. Weight gain, FCR, survival, and alternative complement activity did not differ by diet for either species. In addition, lysozyme (measured only in paco) did not differ by diet. Hepatosomatic index, liver glycogen, and some of the hematomal parameters were affected by diet, but the effects were not consistently associated either with the type of feedstuff or the the form (cooked or uncooked). The effects also were different for the two species, but the gamitana were 10 times larger than the paco initially, so the effects of fish size and species could not be separated. In paco, the cooked yucca and cooked plantain resulted in higher concentrations of hepatic glycogen indicating that cooking increased the available energy of these feedstuffs. Cooking had no effect on hepatic glycogen accumulation in Colossoma fed any of the feedstuffs, indicating that cooked feedstuffs did not contain more available energy than uncooked feedstuffs for this species. However, relative to wheat bran all of the feedstuffs tested were effective energy sources for C. macropomum and P. brachypomus and increased use of pijuayo, plátano, and yucca may reduce diet cost and enhance sustainability of Characid culture in Amazonia.

REPRODUCTION OF PACU AND SURUBIM AND NEW PARADIGM IN NUTRITION OF TROPICAL FISH

Twelfth Work Plan / Fish Nutrition and Feed Technology 12FNF4
Final Report

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ABSTRACT
Our aim was to assist students involved in long term training towards the completion of their degrees under the mentorship of CRSP researchers. The task at hand was successfully accomplished when on December 7, 2007, Ms. Yongfang Zhang defended her dissertation entitled “Amino Acid Metabolism and Requirement in Teleost Fish during their Early Life Stages and Implications in Fish Formulated Diets”. A short summary of her dissertation work is given below (studies on Nicaraguan cichlid). Furthermore, we completed experiments with pacu juveniles in Brazil utilizing a new imbalanced complimentary diet feeding strategy. The response of free amino acids in the body was examined and used to elucidate the mechanism governing the depression/enhancement of individual amino acids levels in response to the presence or deficiency of indispensable amino acids in the diet. Studies on silver arowana addressed the transition from endogenous yolksac feeding to external feeding, feed acceptance and characterization of lipid and fatty acid profiles in the fish body. Osteoglossid fish, the oldest linage of teleosts, appear to have selective utilization of essential fatty acids accumulated in yolk reserves and these findings stand to make a significant contribution toward the formulation of a starter diet for this species.

WORKSHOPS FOR THE CULTIVATION OF NEW SPECIES IN BRAZIL AND PERU

Twelfth Work Plan/Applied Technology and Extension Methodologies 12ATE16
Progress Report

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ABSTRACT
Workshop on “Larviculture of Neotropical Fish” took place in Manaus June 2 and speakers included Portella, M., Jomori R. (CAUNESP) and Dr. Bernardo Baldisserotto (Federal University of Santa Maria), who were supported by CRSP funds. It was attended by at least 100 participants, graduate students, local producers, and researchers from Peru, Bolivia, Ecuador, Venezuela and Colombia. Two investigators from INPA presented their findings on propagation of Amazonian fish and live food composition of early stages of tropical fishes. The second workshop organized by M. Sandoval took place in the auditorium of the Universidad Nacional Agraria de la Selva (UNAS) and there was over 140 persons in attendance, among them 15 producers, 65 students and 45 other professionals.
Central America Project: Production Technology

Honduras, Guatemala, El Salvador, Nicaragua, Costa Rica, Panamá, Belize, Dominican Republic
Subcontract RD010E-16
Subcontract RD010E-17

Honduras has been an ACRSP host country since the program’s inception in 1982, excluding a brief interruption from 1998 to 1999 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 occurs in Nicaragua, Dominican Republic, Guatemala, El Salvador, Belize, Panama and Costa Rica 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, production of training materials and website information (www.acuacultura.org).

The ACRSP program in Central America during the last five years has trained over 700 individuals in the fundamentals of tilapia culture, fingerling production and pond design using a variety of strategies including low cost inputs such as animal manures and fertilization. Fish farmers have been trained on selection and management of tilapia brood stock and in techniques for tilapia reproduction and fingerling production over the past three years. It has been clear that trained individuals and competently advised fish producers also need institutional support to ensure that the local aquaculture industry develops on a sound footing, thus among the participants on the training event are included a great number of NGOs extension agents and government officials from all the countries involved. Our more recent activities include work and training in Honduras, Panama, Costa Rica and Belize.
Work Plan Research
This subcontract was awarded funding to conduct the following Twelfth Work Plan investigations:

- Improvement of tilapia fingerling production and availability in Central America/12SDA6. A final report was submitted for this investigation.

- Understanding the aquacultural knowledge and information system for commercial tilapia production in Nicaragua: economics, institutions, and markets/12SDF2. A final report was submitted for this investigation.

- Pond design and watershed analyses training/12WQA1. A final report was submitted for this investigation.

Publications


Tollner EW, Meyer D, Triminio-Meyer S, Molnar JJ. Spreadsheet tool for levee pond design and costing in developing countries. (Manuscript in preparation for submitting to Aquaculture Engineering)


**Theses**


**Other Publications**


**Conferences/Presentations**


**Workshops/ Educational Outreach**

Meyer, D. and S. Meyer (organizers). 2007. International workshop on tilapia and fingerling production. Two day meeting held in David, Panama in associations with the Zamorano Alumni Association of Panama and the Universidad Santa Maria (USMA) de Panama.

hield in Canas, Costa Rica in association with the Zamorano Alumni Association of Costa Rica and the Colegio de Riego del Tropico Seco (CURDTS).

Meyer, D. and S. Meyer (organizers). 2007. International workshop on tilapia and fingerling production. Two day meeting held in Belize in associations with the Zamorano Alumni Association of Belize, the Belize Fisheries Department, and the Fisherman’s Cooperative of Belize.

Tollner, E.W. (instructor) and P. Paz (translator). 2007. International workshop on Pond Design and Modeling. Training held in David, Panama in association with the Zamorano Alumni Association of Panama and the Universidad Santa Maria (USMA) de Panama.


IMPROVEMENT OF TILAPIA FINGERLING PRODUCTION AND AVAILABILITY IN CENTRAL AMERICA

Twelfth Work Plan/Seedstock Development and Availability 12SDA6

Final Report

ABSTRACT

Locally generated research results are more relevant when technicians and extension agents are discussing production options with farmers. Both Nile (Oreochromis niloticus) and red tilapia strains (Oreochromis sp.) are cultured in Central America. Each genetic line has several advantages and disadvantages for the farmer to consider in selecting a fish for culture. We compared the reproduction of Nile and red tilapia in two environments: 7.5 x 2.0 x 1.0 m concrete tanks and in compartments in earthen ponds in Honduras. All experimental units were covered with predator netting (25 mm mesh) and the water in the concrete tanks was continuously aerated. Each earthen pond was divided into two 100 m² compartments by fiber-glass window screening (1.5 mm mesh) supported in the vertical position by 12 mm mesh plastic netting and wooden stakes. A similar biomass of adult females was stocked in each of four pond compartments (23.2 kg/compartment) and each of four tanks (6.5 kg/tank) with a 3:1 sex ratio of adult fish. Production cycles were of 20 and 30 days duration for the tanks and pond compartments, respectively. We repeated the trial in the tanks and performed three replicates in the ponds. The mean total production of tilapia fry/m² was significantly greater from the concrete tanks in comparison with the ponds. We harvested an average of 38,700 and 23,550 fry from each concrete tank, and 117,153 and 63,361 fry from each pond compartment, for the Nile and red tilapia, respectively. Survival of the Nile tilapia fry (85%) was significantly greater than for the red tilapia (58%) during the subsequent 30-day hormone treatment period. More adult red tilapia died than Nile fish during these trials. Overall mortality was significantly greater when the adult fish of both lines were stocked and managed in the earthen ponds compared to the concrete tanks. Nile tilapia have several advantages over red tilapia and are the fish of choice for farmers interested in beginning the commercial production and sale of fingerlings. Taking into account the significantly greater numbers of Nile fry produced both in the concrete tanks and in the earthen ponds and their better survival rate during sex reversal, the costs for reproducing the Nile fish is lower than for the red tilapia. Under market conditions
for Zamorano, the economic benefits are much higher for producing and distributing Nile fingerlings compared to red fish. The empirical results were complemented by a series of training events in Panama, Costa Rica, and Belize that presented fundamental principles of tilapia reproduction, grow-out production, and fish handling to over 50 producers in each country. An intensives session on pond design and construction analysis was presented to interested producers in each locale. The two-day sessions also featured dialogue over production problems, management practices, and other practical aspects of tilapia culture in Central America.

UNDERSTANDING THE AQUACULTURAL KNOWLEDGE AND INFORMATION SYSTEM FOR COMMERCIAL TILAPIA PRODUCTION IN NICARAGUA: ECONOMICS, INSTITUTIONS, AND MARKETS

Twelfth Work Plan/Sustainable Development and Food Security 12SDF2
Final Report
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ABSTRACT
Small and medium scale tilapia culture in Nicaragua has been practiced for over 20 years. During that period, it went from production systems including mixed-sex culture and the use of animal manures, and/or inorganic fertilizers to implementing more intensive pond and cage production systems. In addition, it went from being a national economic development activity supported heavily by the government, to a localized enterprise, still supported by the government, but at a substantial lower level.

This paper provides an economic and financial analysis of several tilapia culture enterprises identified in 2005. The study includes an enterprise budget analysis, a break-even price analysis, the estimation of the internal rate of return of the enterprises, and a sensitivity analysis. The results indicate that fingerling production, as the Nicaraguan government promoted it was not profitable. The three-phase grow-out production systems also promoted by the government yielded low levels of profitability. The members of a cooperative that operate with an 80% subsidy presented the most profitable enterprise. The results also indicate that without the subsidy the members of the cooperative would not be able to stay in businesses. Finally, cage culture seems like a profitable alternative if the proper production parameters are implemented.
ABSTRACT
The overall project objective was to conduct training in pond design and watershed analysis for technical staff and managers in Central American nongovernmental organizations and governmental resource management agencies. Variable rainfall distribution and terrain make surface water harvesting and storage a challenge in many developing countries. The development of watershed assessment tools and pond design tools served as a basis for numerous training programs in Honduras and other Central American countries.

The specific object of this study is to collect and develop cost information required to equip extension, nongovernmental organization (NGO) agents, contractors and engineers for surface water development and aquaculture enterprise development in Honduras and Latin America. A spreadsheet-based computational tool was developed in English and Spanish on the Microsoft Excel® platform. Knowing the original land slope and desired pond volume, one may compute excavation amounts that provide an acceptable cut-fill balance. The model computes projected costs in local currency. Guidelines are provided for establishing pond bottom elevations and achieving the desired water depth. The model is relevant for hillside or levee ponds customarily used in aquacultural production. The model is not suitable for a watershed catchment pond. The model completes a package for designing hillside and levee pond-based aquaculture systems. Coupling these with other cooperative development concerns such as marketing association provides a platform for helping groups of people in a watershed to realize further the potential of enlightened self-interest in developing common solutions to water problems. The economic analyses software tool is the third of three tools that comprise the basic suite of tools and accompanying presentations used for technician training and development.
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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Laine Frantz           Undergraduate Student
Carlos Alberto Cuenca Soria  Collaborator
Marta Jaroszewska       Visiting Scholar (University of Nicolai Copernicus, Poland)

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

- Incorporation of the Native Cichlid *Petenia splendida* into Sustainable Aquaculture: Reproduction Systems, Nutrient Requirements and Feeding Strategies /12ISD3. A final report was submitted for this investigation.

- Continuation of a Selective Breeding Program for Nile Tilapia to Provide Quality Broodstock for Central America /12SDA3. A final report 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 final report was submitted for this investigation.

- Elimination of Methyltestosterone from Intensive Masculinization Systems: Use of Ultraviolet Irradiation of Water /12WQA2. A final report was submitted for this investigation.

- Elimination of methyltestosterone from intensive masculinization systems: Use of Solar Irradiation and Bacterial Degradation /12WQA3. A final report was submitted for this investigation.

- Testing Three Styles of Tilapia-Shrimp Polyculture in Tabasco / 12PSD8. A final report was submitted for this investigation.

Publications


Uscanga-Martínez, A., Álvarez-González, C.A., Civera-Cerecedo, R., Contreras-Sánchez,
W.M., Márquez-Couturier, G., Hernández-Llamas, A., Goytortua-Bores, E.  
Effect of dietary protein level on growth and body composition of juvenile native cichlid Tenguayaca *Petenia splendida* fed semi-purified diets. Submitted.

**Presentations/Conferences**


Arias-Jiménez Gabriela, Ulises Hernández-Vidal and Wilfrido Contreras-Sánchez. 

Polyculture of tilapia and shrimp. WAS – Latin America Chapter San Juan, Puerto Rico

Polyculture of tilapia and shrimp.  
Aquaculture Mexico, Hermosillo, Mexico.

**Theses**


**Workshops/Seminars/Educational Outreach**

The laboratory of Aquaculture at UJAT has an outreach program that involves in situ training and visits to farms in several municipalities of the state. Common request for training in UJAT facilities is native fish reproduction and larviculture. At least 10 visits are conducted every month and 3-4 training groups request practical courses each reproduction season. Thanks to workshops in Honduras, Guatemala and Costa Rica, UJAT has increased collaboration ties with scientists from Central America.

Title: Mass fry production techniques for *Atractosteus tropicus* and *Petenia splendida*  
(Workshop)  
Location: Guatemala City  
Date: September 25-29, 2007  
Audience: Farmers, researchers, students and extension agents

Title: Biology and culture of *Atractosteus tropicus*  
(Workshop)
INCORPORATION OF THE NATIVE CICHLID *PETENIA SPLENDIDA* INTO SUSTAINABLE AQUACULTURE: REPRODUCTION SYSTEMS, NUTRIENT REQUIREMENTS AND FEEDING STRATEGIES

Twelfth Work Plan/Indigenous Species Development 12ISD3 Final Report

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**ABSTRACT**

Our experiments have significantly contributed to the development of the technological package for the culture of the native cichlid tenhuayaca (*Petenia splendida*). Information on reproduction in captivity, larval rearing conditions and feeding during different stages of development has generated an important starting point for the management and conservation of native cichlids. The aim of this investigation was to address three research areas: 1) reproductive performance with different sex ratios; 2) intensive fry culture using high stocking densities and 3) protein requirements for fry, juvenile and adult growth using practical diets. To determine the best broodstock stocking rates, three male/female sex ratios were evaluated (1:1, 1:2, and 1:3). Each treatment consisted of three 2 m-diameter tanks that were divided into six spawning compartments. Fertilization rates, hatching success and larval survival were evaluated from each spawning. Reproductive behavior was also observed in each tank. The effect of stocking density was evaluated using sex reversed Petenia fingerlings. Fish were stocked at densities of 0.5, 1, 5, 10 and 20 fish/L using 70-L cylindrical-conical fiber glass tanks connected to a recirculating system. The use of vegetable meal at different life stages (larvae, juveniles and adults) was also studied by replacing fish meal with wheat gluten at different percentages (0, 25, 50, 75 and 100%). The control groups consisted of *Artemia nauplii* for larvae, or commercial feeds for carnivorous species (Silver Cup™).

The 1:2 male/female ratio produced the largest number of fry, reaching 81,364 over 70 days of experimentation. This treatment produced more than 5,000 fry/Kg of female than the other ratios and more than one thousand fry per day. The average number of eggs produced per female (2,325), fertilization and hatching rates (above 97%), and survival during the early stages (100%) were high for this species. The results obtained using different stocking densities indicated that the optimal density for *P. splendida* was between five and ten larvae/L. This density resulted in good growth and survival. Stocking densities of 0.5 and one larvae/L provided the best growth, but the number of fish produced per tank was significantly reduced. The diet study produced important results in two areas: a) the development of a practical diet that can be used for larvae, juveniles and adults and b) the utilization of alternative ingredients in the diets (i.e. wheat gluten) which reduces costs by using...
lower amounts of fish meal. Experiments using larvae, juveniles and adults provided similar results regarding the amount of fish meal that can be replaced with wheat gluten. Even though *P. splendida* is considered to be a carnivorous cichlid, fish meal replacement in diets ranging from 25 to 50% (in relation to protein) can be used.

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

Twelfth Work Plan/Seedstock Development and Availability 12SDA3
Final Report

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**ABSTRACT**

Despite the establishment and long use of tilapia culture as a major economic activity and as a high-quality source of food, the emergence of this activity from a technical standpoint has been minimal. In Latin America, broodstock and seed supply have been identified as one of the major constraints to production increases. Inadequate availability and quality of fry and broodstock is considered a research priority. In Mexico, there has been little effort given to the conservation and genetic selection of tilapia. This is despite the fact that these fish were introduced over 35 years ago, resulting in benefits related to food production. Genetic improvement in aquaculture offers an opportunity to increase production, enhance product quality and increase profitability for aquaculture enterprises. We have continued a selective breeding program using males and females obtained from an F3 generation (Egypt strain). Female selection was based on highest total length, and male selection was performed using individuals with the best condition factor. Each selected broodstock group was placed in 200 m² concrete ponds using a sex ratio of 3 females to 1 male for every 3 m². From the fry obtained, three selections were performed. The first was conducted at 60 days of age, the second at 135 days (at this point the fish were separated by sex) and the last at 11.5 months. Our results indicated that the improved Egypt line performed better than the control and the wild lines. Fry produced from the Egypt line (F5) had higher growth than the fry obtained from the control and the wild line (after three selections). Significant differences were observed for both meat production (measured as fillet yield) and condition factor. In both cases, the Egypt line had higher values (31.2% and 1.98, respectively). Reproductive performance measured as fry production was significantly higher in the Egypt line. The improved Egypt line produced 54% more fry than the control line and 65% more than the wild line. In general, the improved Egypt line had better reproductive performance, survival and growth. This study was conducted as a collaborative effort between UJAT, OSU, the Aquaculture Collaborative Research Support Program (ACRSP) and the office for Agriculture and Fisheries Development (SEDAFOP) in Tabasco. This combined effort has allowed us to work at the “Jose Narciso Rovirosa” hatchery (using 200, 1000 and 2000 m² ponds) and to use fish first selected by Mario Fernandez in 2003.
DEVELOPMENT OF AQUACULTURE TECHNIQUES FOR THE INDIGENOUS SPECIES OF SOUTHERN MEXICO, *Centropomus undecimalis*: SEX DETERMINATION AND DIFFERENTIATION AND EFFECTS OF TEMPERATURE.

Rwelfth Work Plan/Seedstock Development and Availability Research 4 12SDA4
Final Report

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Abstract

The results of this study successfully established that wild common snook begin their gonadal sex differentiation within the first few months of life as males, and that they remain in an immature state for at least during their first two years of life. Experiments were conducted in the laboratory to determine the effects of temperature and estradiol-17beta on the pattern and timing of gonadal sex differentiation using wild-caught juvenile snook. The treatments were successfully applied. However, the results of the temperature manipulation yielded inconclusive results due to the unexpected lack of development of the gonads; and the estrogen exposure experiment suffered a catastrophic incidence of mortality. Overall, these observations in the laboratory indicate that wild young snook may have difficulty adapting to laboratory environments and that husbandry techniques need to be further refined for this species. In this regard, in a pilot trial we were able to wean juvenile snook to accepting prepared diets. This development will greatly facilitate continued research and development of common snook husbandry techniques.

ELIMINATION OF METHYLTESTOSTERONE FROM INTENSIVE MASCLINIZATION SYSTEMS: USE OF ULTRAVIOLET IRRADIATION OF WATER

Rwelfth Work Plan/Water Quality and Availability Research 12WQA2
Final Report

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ABSTRACT
Masculinization of tilapia fry by oral administration of 17alpha-methyltestosterone (MT) is considered the most successful method employed; however, under certain conditions this technique is sometimes unreliable. Furthermore, significant “leakage” of MT into the pond environment may occur from uneaten or unmetabolized food. This leakage poses a risk of unintended exposure of hatchery workers, as well as fish or other non-target aquatic organisms, to the steroid or its metabolites. This study tested the hypothesis that MT could be eliminated from the water used in intensive sex-inversion systems using UV light. Water was recirculated through 5,000 l tanks with or without UV sterilizers. Fish were stocked at 2,500/m³ for each experimental unit. Fish in exposure tanks received MT-treated feed (60 mg/kg food for 28 days); fish in the control tanks received food without MT. Water samples were collected daily and extracted with Sep-Pak cartridges and MT content was determined by radioimmunoassay. Our results indicated that the use of MT-enriched food produced a significant masculinization of Nile tilapia fry. Fish in the control group averaged 46% males, while fish treated with MT had 92 and 91 % males. We found very low levels of MT in most water samples suggesting that in the presence of fish; both UV light and biofiltration can effectively remove the steroid from masculinization tanks.

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

Twelfth Work Plan/Water Quality and Availability Research 12WQQA3
Final Report

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ABSTRACT
One of the major problems in aquaculture is the elimination of culture wastes from water. The amount and type of residues will depend on the species cultured, the stage of development and the feeds used. Steroids are commonly used in aquaculture for sex reversal of fish. Methods for the elimination of synthetic steroids from aquaculture facilities are important for maintaining safety standards in the industry. We have previously reported that considerable amounts of 17alpha-methyltestosterone (MT) leak into the environment during dietary treatments, remaining in the water for several minutes and potentially accumulating in sediments. The goal of this investigation was to determine whether biofiltration, charcoal or sunlight could eliminate MT from culture water. Two experiments were conducted at the Laboratory of Aquaculture at UJAT, in Tabasco, Mexico. MT content of water was determined by radioimmunoassay at Oregon State University. Results from this research indicate that large amounts of MT in the water can be completely removed when activated charcoal is used in a Recirculating Aquaculture System (RAS) and partially removed by either exposure to sunlight and/or biofiltration. Activated charcoal in a RAS can efficiently remove MT in less than 24 hours of treatment. Both sunlight and biological
filtration follow a very similar pattern of MT degradation, suggesting that these treatments can eliminate the synthetic steroid if water is exposed for a significant amount of time. The results from this investigation encourage us to keep promoting the use of Recirculating Aquaculture Systems in aquacultural facilities that conduct masculinization of fish using synthetic steroids.

TESTING THREE STYLES OF TILAPIA-SHRIMP POLYCUltURE IN TABASCO, MEXICO

Twelfth Work Plan/Production System Design and Integration 12PSD8
Final Report

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ABSTRACT

The polyculture systems surge nowadays is a solution for the bacterial and viral diseases in the traditional systems of shrimp monoculture. The main goal of this study was to reactivate the culture systems in the community of Puerto Ceiba, Tabasco, through three shrimp-tilapia polyculture systems; sequential, with tilapia in supply pond, simultaneous with tilapia in cages in ponds, and simultaneous with tilapia loose in ponds with shrimp. These ponds were modified for the polyculture trials. Fifteen 10 x 20 m ponds were modified and used as the experimental units. Control ponds stocked with shrimp at 30 PL’s/m², make up water from other tilapia ponds. The treatments correspond to T1 (Shrimp + water from Tilapia pond): Shrimp were stocked at 30 PL’s/m², make-up water from a 0.1 ha pond stocked with 0.5 tilapia /m² (500 fish). T2 (Shrimp + Tilapia): Shrimp were stocked at 30 PL’s/m² and tilapia at 0.5 fish/m² (500 fish), make up water from supply channel, and T3 (Shrimp + Tilapia (cage)). An additional treatment used as control (Shrimp) with only 30 PL’s/m². The final statistical analysis of weight growth of the experiment, showed statistical differences (P<0.05) where the treatment shrimp (control) showed the highest weight (12 ± 1 g) of all treatments. The length showed statistical differences (P<0.05) where the shrimp treatment (control), showed the highest length (11 ± 0.3 cm) with respect to the other treatments. The treatment shrimp+tilapia (cage) showed the second best growth in length being statistically greater than the treatments shrimp+water of tilapia pond and shrimp+tilapia. In these two treatments, shrimp+tilapia was greater statistically than shrimp+water of tilapia pond.
The Mexico Project: Human Welfare, Health and Nutrition was developed during the Eleventh Work Plan and continued through the Twelfth Workplan. 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, Hilo (lead US institution), University of Rhode Island, Universidad Autonoma de Sinaloa (Mexico) and Ecocostas (Ecuador). The outcomes from these cases allowed the team to focus on key sanitation and health issues during Year 12. Although all aquaculture activities in Mexico were found to have associated health issues that potentially affect human health and farm economics, bivalve culture was identified as both a prime opportunity and challenge given the priority of establishing bivalve culture in Mexico and the risk of human borne pathogens carried by bivalves. Hence, a market study was conducted in conjunction with the University of Alaska and CIAD to identify the best market opportunities and desirable attributes for the products. Additionally, outreach on the need for improved shellfish sanitation and related policy issues was conducted to a wide range of stakeholder.
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**Work Plan Research**

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

- Water quality monitoring and identification of pollution sources leading towards classification of bivalve growing waters/12AHH1. A final report was submitted for this investigation.
- Outreach and planning for implementation of bivalve growing areas classification and related sanitation action items/12AHH2. A final report was submitted for this investigation.
- Bivalve Market Study in Pacific Mexico/12ERA6. A final report was submitted for this investigation.

**Publications**

Haws, M.C. and J. Supan. 2007. Edible bivalve culture in Hawai`i, bridging the past, present and future: a white paper. Pacific Aquaculture and Coastal Resources Center, University of Hawai`i Hilo.


**Presentations/Conferences**


**Thesis**


**Workshops/Seminars/Educational Outreach**


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

Twelfth Work Plan / Aquaculture and Human Health Impacts 12AHH1 Final Report

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ABSTRACT

Bivalve culture is an important and growing segment of the aquaculture industry in Mexico and globally. Shellfish sanitation issues were identified in previous CRSP-sponsored research as an impediment to continued growth, export potential, human health and consumer perception of the product. Water sampling for coliform bacteria was conducted at two major oyster cultivation sites in Mexico to identify specific areas within oyster culture sites that would be adequate to assure safe production of oysters and other bivalves. Boca Camichin is an estuarine area located in Nayarit, Mexico where there is an active oyster culture industry using the native species “Pleasure Oyster”, Crassostrea corteziensis. Bahia Santa Maria (BSM-Santa Maria Bay) is an estuary/coastal lagoon system in Sinaloa, Mexico, where the Japanese oyster, C. gigas is cultured. Water quality standards for shellfish growing waters in Mexico are address in the Official Mexican Regulation NOM031-SSA1-1993 which establishes the following for approved shellfish growing waters:

For total coliform bacteria, the median or geometric average should not exceed 70 NMP /100 ml; no more than 10% of the samples should exceed 230 NMP/100 ml with a serial dilution of 5 tubes or 330 NMP / 100 ml with a serial dilution of 3 tubes.

For fecal coliform bacteria: the median or geometric average should not exceed 14 NMP /100 ml; no more than 10% of the samples should exceed 43 NMP /100 ml with a serial dilution of 5 tubes or 49 NMP / 100 ml with a serial dilution of 3 tubes.

U.S. standards are similar although coliform levels used for standards are slightly lower (FDA 2003; 2007).

Water sampling was conducted 5 times between February 2006 and January 2007 at Boca Camichin at 30 sampling stations, and 5 times between March 2006 and January 2007 at Bahia Santa Maria at 37 sampling stations. Laboratory analysis of coliform bacteria was conducted at the Autonomous University of Sinaloa, Marine Science Department, Mazatlan, Mexico, using a 3 tube, serial dilution method.

For samples taken from Boca Camichin, the highest concentration of total coliform bacteria was found in July, September and December (median > 110 NMP/100ml) and the lowest concentrations were found in February, 2006 and January 2007 (median ranging between 55 and 93 NMP/100ml). The highest concentration of fecal coliform bacteria was found in September (median = 93 NMP/100 ml; average = 84.62 NMP/100ml) and the lowest concentration was found in February 2007 (median = 10.5 NMP/100 ml; average = 17.6 NMP/100 ml).

For all sampling events, levels exceeded the legal standards for approved shellfish growing areas. Based on these results, Boca Camichin would be classified as a restricted shellfish growing area such that oysters may be cultured, but would be required to undergo depuration before sales. Given that Boca Camichin is a major oyster producing area where social sector (cooperative) farmers own the farms and from which product is widely distributed, these results have serious implication both for regional public health and for the economic well-being of the farmers. Inadequate human waste disposal in the community that surrounds Boca Camichin is most likely the source of contamination. Future CRSP-sponsored research will focus on finding cleaner areas near Boca Camichin where oysters can be relayed and depurated until steps can be taken to address community sanitation issues that impact shellfish sanitation. Public outreach begun as part of the CRSP efforts will continue. In the case of Bahia Santa Maria where shellfish growing waters met standards for approved growing grounds, oyster culture trials can now move forward, as well as on-going water quality monitoring.
OUTREACH AND PLANNING FOR IMPLEMENTATION OF BIVALVE GROWING AREAS CLASSIFICATION AND RELATED SANITATION ACTION ITEMS

Twelfth Work Plan / Aquaculture and Human Health Impacts 12AHH2 Final Report

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ABSTRACT

This investigation is part of a larger effort to elucidate relationships between human health, water resources and aquaculture status and development in the States of Sinaloa and Nayarit, Pacific Mexico Coast. Culture of oysters (Crassostrea corteziensis and C. gigas) and other bivalves is an important industry for small-holder aquaculture along the Pacific Mexico Coast, but shellfish sanitation issues are a key impediment to expanding and improving this form of aquaculture. Improving the policy, regulation and implementation of adequate shellfish sanitation will positively impact both human health and the economic welfare of coastal communities. 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 work achieved four principal objectives. The first was to disseminate the results of research conducted as part of Investigation 12AHH1, “Water Quality Monitoring and Identification of Pollution Sources Leading towards Classification of Bivalve Growing Waters.” This research involved water quality monitoring of two significant bivalve growing sites in Nayarit and Sinaloa states where the oyster species Crassostrea corteziensis (Pleasure Oyster) and Crassostrea gigas (Japanese oyster) are cultured, and outreach was required to convey the purpose of the studies and final results to oyster growers and institutional stakeholders. Informational workshops were therefore held before and after each periodic water sampling during a period of one year. Secondly, results from previous CRSP sponsored research also required dissemination and these results were included in all the workshops conducted as part of this investigation. Thirdly, it was deemed important to work with two multi-institutional working groups, the Management Committee for Bahia Santa Maria (BSM) and the Council for Conservation and Development of the Camichin Estuary (CCDCE) which are comprised of representatives from public and private institutions as well as stakeholders drawn from important stakeholder groups such as fishers, women’s groups and aquaculture farmers, to conduct awareness raising as to the nature of shellfish sanitation, problems that were occurring and to find solutions to these issues. Fourthly, a component of capacity building was included for Latin American students at the
University of Hawaii Hilo and Louisiana State University as a means of partially addressing the lack of capacity for shellfish culture and sanitation in Latin America. Additional awareness raising activities were also conducted such as a Regional Workshop for Shellfish farmers and attendance of project Principal Investigators at international conferences to present research findings.

**BIVALVE MARKET STUDY IN PACIFIC MEXICO**

Twelfth Work Plan/Economics, Risk Assessment and Social Analysis 12ERA6 Final Report

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**ABSTRACT**

This research is part of a larger effort to elucidate relationships between human health, water resources and aquaculture status and development in the States of Sinaloa and Nayarit, Pacific Mexico Coast. Oyster culture (*Crassostrea cortezensis* and *C. gigas*) is an important industry for small-holder aquaculture along the Pacific Mexico Coast, but little work has been done to assess its economic value nor assist producers in improving market opportunities. A market study was conducted for oysters grown by social (cooperatives) groups of farmers in Bahía Santa María (BSM), Sinaloa, México, as part of a multi-activity effort conducted with the beneficiaries in order to help them to successfully produce and commercialize their oyster production. This study provides them with market information from the demand side, including consumer preferences.

The market study focused on information from three sources: a) local demand near production sites; b) regional main tourism destinations places such as Mazatlán (State of Sinaloa), Puerto Vallarta (State of Nayarit) and Los Cabos (State of Baja California Sur), whose restaurants and hotels might be an important source of demand; and c) national wholesale markets, specifically two of the most important seafood markets in Mexico, La Nueva Viga (Mexico City) and Zapopan (Jalisco). For the first case, on-site personal interviews were conducted with 15 potential sellers in towns and cities close to BSM. This market is considered the most feasible, immediate choice for the producers, considering their projected production capabilities. For the second phase of the study a mail survey was conducted, sending in total 86 questionnaires to individual restaurants, or hotel-restaurants in the three cities which are tourism destinations, but the response rate was very low (2) and not much could be analyzed from them. For the final source of information, secondary-source information from wholesale markets was gathered and analyzed to determine the feasibility of producer’s entry into larger markets.
The results show that selling directly to local buyers (restaurants and mobile kiosk “carreta” owners) is the best marketing strategy to follow for the stakeholders, considering their current low production capacities, but mainly due to the characteristics of this local market. The study revealed preferences for the local (Crassostrea cortesiensis) oyster over C. gigas, a market window for product with consistent year-round supply; preference for larger sizes and which is perceived as safe for human consumption. The stakeholders are advised to take advantage of a possible 0.50-1.00 peso increase in price per piece that buyers will pay when the said characteristics are met.

In sum, stakeholders from this project may consider taking a price premium offer by survey respondents from local markets by delivering a high quality, larger sized oyster with safety guarantees. With products that include the said characteristics, a long-term commercial relationship that is based on trust and personal communications can then be established with buyers. The timing may be right for the stakeholders to develop markets and buyer-seller relationships in the markets surveyed based on one-on-one interviews, which guarantees the price premium offered by the buyers. In a few years more there will be more products on the market, and the price elasticity of demand may turn negative. Finally, wholesale markets are not recommended to the stakeholders, since the local market is large enough to absorb current production, but also due to a reduced margin profit in La Viga and Zapopan markets. The stakeholders would find it very difficult to sustain a high-volume supply of oyster, which is required to compete for these markets.
Kenya Project: Production Technology

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 later established with Moi University (MU) and companion site institutions in Malawi. In 2002, under the CRSP Tenth Work Plan, the OSU/Kenya Project began working primarily through Moi University’s Department of Fisheries and Aquatic Sciences, focusing mainly on aquaculture training. Target groups included officers of the Kenya Fisheries Department, who are responsible for aquaculture extension work in Kenya, as well as university students and farmers. Graduate (MS) students at Moi University conducted research to identify methods for improving survival of African catfish (*Clarias gariepinus*) through the fry-to-fingerling rearing phase, on appropriate stocking ratios for Nile tilapia and African catfish reared together, and on the effects of feed protein levels on gonadal developmental characteristics in Nile tilapia.

Activities during this final reporting period have been directed towards completing all investigations begun under the Kenya Project and handing over equipment and supplies to the appropriate Kenyan institutions as part of the project close-down process. The four remaining Moi University graduate students supported by the CRSP all finished their experimental work and three of them finished their theses and received their degrees. The fourth student is writing his thesis and is expected to graduate by June 2008. During this final year several additional workshops were conducted in Kenya, including a “training of trainers” workshop held in November 2006 and two subsequent short courses for FD fisheries assistants conducted by the newly trained trainers. The project also contributed to regional efforts by sending two resource persons from Moi University to assist in the farmers training course held in the Morogoro region of Tanzania in 2007 under an investigation led by the CRSP/Purdue project.
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Mary Makhutu  Undergraduate Student (from September 2004)  
Lauryn Mutai  Undergraduate Student (from September 2004)  
Spencer Otieno  Undergraduate Student (from September 2004)  
Ruth Muhonja  Undergraduate Student (from September 2004)  

*Kenya Fisheries Department, Nairobi, Kenya (collaborating Host Country Institution)*

Benson Thiga  Host Country Co-Principal Investigator (from April 2005)  
Betty Nyandat  Host Country Co-Principal Investigator (from November 2006)

**Work Plan**

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 final report was submitted for this investigation.
- **Kenya Training of Trainers and Regionalization of Aquaculture Training Activities/12ATE11.** A final 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 final report was submitted for this investigation.
- **Kenya capacity building: Student research and thesis support/12SDA5.** A final report was submitted for this investigation.

**Theses**


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

Twelfth Work Plan / Applied Technology and Extension Methodologies 12ATE3 Final Report

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

Bethuel Omolo  Fisheries Department, Government of Kenya
Chris Langdon and James Bowman, Department of Fisheries and Wildlife Oregon State University, Oregon, USA

ABSTRACT

The Aquaculture CRSP, the Moi University (MU) Department of Fisheries and Aquatic Sciences, and the Fisheries Department of the Government of Kenya (FD) have expended considerable effort on aquaculture training at various levels during the past decade (1997-2007). 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 6 advanced farmers in hatchery management techniques, to provide on-farm training in simple techniques for spawning, hatching, and rearing African catfish (Clarias gariepinus) juveniles in ponds for up to 12 farmers, to provide stipend support for 4 undergraduate students studying aquaculture at MU, and to provide scholarship support for two Master’s-level (MSc) university students at MU. The focus of this set of activities has been on catfish aquaculture, particularly on developing improved fingerling production techniques and transmitting these new techniques to extension personnel and farmers.

All objectives of this investigation have been met. Two two-week short courses were given to selected FD Fisheries Assistants (extension workers), Kenya Marine and Fisheries Research Institute (KMFRI) technicians, and advanced fish farmers. The courses were held at Sagana and Moi University, on 16th-31st April and 15th – 28th August, respectively. Twenty individuals were trained in each session. The courses focused on the African catfish (Clarias gariepinus) fingerling production process, including maintenance of broodstock, 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 session was held on the Chepkoilel Campus and at Kesses Division, Uasin Gishu District, next to the Moi University Main Campus from 19th to 21st May 2005. The second training was held at Chepkoilel Campus from 2nd to 5th April 2006. The training session 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. Both graduate students have completed their coursework and research and have submitted their theses for review by their graduate committees. Ms. Boit’s thesis was sent to the Graduate School and reviewed by examiners and her defense was held on 30th May 2007. She successfully defended her thesis, made her corrections, and graduated on 19 October, 2007. Mr. Njau’s thesis was reviewed by his committee, submitted to the graduate school, and sent to the external reviewers in July 2007. Based on the reviewers’ comments, a date for his defense will be set.

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.

KENYA TRAINING OF TRAINERS AND REGIONALIZATION OF AQUACULTURE TRAINING ACTIVITIES

Twelfth Work Plan / Applied Technology and Extension Methodologies 12ATE11
Final Report

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James Bowman
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ABSTRACT
This activity addressed supplemental training objectives for the OSU/Kenya project, including conducting a “training-of-trainers” (TOT) course for Fisheries Officers and two pond construction and management courses for Fisheries Assistants, taught by the newly trained trainers. In addition, support for the participation of Kenyan PI Charles Ngugi in training courses held in other countries in the region was provided.

The Sagana TOT course was followed by two two-week courses taught by the newly trained trainers under supervision by Dr. Ngugi. These courses occurred at Moi University Chepkoilel Campus, between January 22nd and February 2nd, 2007 and at Sagana Aquaculture centre, from 16th to 27th April, 2007. A total of 30 individuals received training during these two courses.

Regionalization of our training efforts was achieved through assistance provided to the CRSP project in Tanzania by Dr. Charles Ngugi, who provided experience, training materials, and general support for a farmers training course at Sokoine University of Agriculture in Morogoro, held from 18th to 22nd June 2007. Twenty-five farmers and several district fisheries professionals participated in this course. Dr. Ngugi drew on the experience of the over 19 short courses held between 1999 and 2007 in Kenya, along with teaching modules and a new training manual developed for those courses, to assist with preparations for and the conduct of their farmers training course. CRSP student James Mugo Bundi also participated in this effort.

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 / Indigenous Species Development 12SDA2
Final Report

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

Bethuel Omolo
Fisheries Department, Government of Kenya

Chris Langdon and James Bowman
Department of Fisheries and Wildlife
Oregon State University, Oregon, USA
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 the studies described here has therefore been to assess management strategies that might contribute to improved growth and survival of African catfish juveniles. Two studies were conducted by graduate students (MSc candidates) at Moi University, Eldoret, Kenya, in 2005 and 2006. In one study, catfish larvae were stocked into eighteen 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 their culture was continued up to a total of 60 days (hatchery plus pond). 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/m² and reared for 42 days. In this experiment, stocking fish at 25/m² resulted in both the most growth and the best survival among the treatments.

All field and statistical work has been completed and student theses have been submitted either to graduate committees or to the Graduate School.

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 greater fish consumption and thus to human health and welfare in the region.

KENYA CAPACITY BUILDING: STUDENT RESEARCH AND THESIS SUPPORT

Twelfth Work Plan/Seedstock Development and Availability 12SDA5
Final Report

Charles C. Ngugi
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James Bowman
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Oregon State University, Oregon, USA

ABSTRACT
In this investigation the OSU/Kenya Project provided support for students pursuing aquaculture studies at Moi University, Eldoret, Kenya during the 2005-2006 academic year. This
included two one-year scholarships for two students working on Master of Science (MSc) degrees as well as short-term stipends for three undergraduate students working on their senior projects. The work was conducted primarily at Moi University, Eldoret. Support was also provided for one of our previous graduate students to present research results at the “AQUA 2006” conference in Florence, Italy.

Research topics undertaken by the two new graduate students included work on 1) the fecundity and energetics of tilapia (*Oreochromis niloticus*) brooders conditioned under different feeding regimes and 2) yields of Nile tilapia (*Oreochromis niloticus*) and African catfish (*Clarias gariepinus*) reared together in different stocking ratios. Both students have finished their coursework and the research phase of their programs and are currently writing their theses, with the expectation that one will have earned her degree by December 2007 while the other one will complete it later; by June 2008.

Graduate student Victoria Boit traveled to Florence, Italy, to participate in “AQUA 2006” from 9-13 May, 2006, where she presented the results of her research in the CRSP session on Saturday, May 13. 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 has since submitted her thesis to the Moi University Graduate School for approval, and her defense was held on 30th May 2007. She her submitted her final copy and will graduate in December 2007.
The Fisheries and Aquaculture Development Division, Department of Natural Resources and Tourism, Tanzania has few fisheries personnel employed at all levels; from the districts to the national level, so extension services for fish farmers and aquaculturists are tremendously inadequate. Though the Fisheries Division has been organizing some on-site training on pond management, the scale has been very small and participation has been low. This Aquaculture CRSP training program was quite unique in that farmers were brought to a central location from different regions of Tanzania to learn not only from Tanzania government fisheries personnel, but also university faculty from Tanzania and Kenya. Fisheries personnel acknowledged that this training program had much more depth, imparted more practical knowledge, and facilitated sharing among fish farmers than what the Ministry has been doing. With resources, continuation of this training program will increase farmers’ knowledge on aquaculture technology as well as skills for technology adoption and farm management. Future training programs will also target fisheries extension officers to enable them better serve the farmers.
Aq uAc u lTu r e co lAb o rA Ti v e re s eAr c h su p p o rT pr o g rAm

This subcontract was awarded funding to conduct the following Twelfth Work Plan investigation:
• Farmers Training in Tanzania/12ERA3. A final technical report was submitted for this investigation.

Publications

Presentations

FARMERS TRAINING IN TANZANIA
Twelfth Work Plan/Economics, Risk Assessment and Social Analysis 3 (12ERA3)

Kwamena Quagrainie
Purdue University, USA

Aloyce Kaliba
University of Arkansas at Pine Bluff, Arkansas, USA

Staff

Purdue University, West Lafayette, Indiana (Lead US Institution)
Kwamena Quagrainie Lead US Principal Investigator

University of Arkansas at Pine Bluff, Pine Bluff, Arkansas
Aloyce Kaliba US Co-Principal Investigator

Fisheries and Aquaculture Development Division, Department of Natural Resources and Tourism, Tanzania
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Regina Nzyekusanga Research Assistant

Sokoine University of Agriculture, Morogoro, Tanzania
Berno Mnembuka Host Country Co-Principal Investigator
Ephraim Senkondo Host Country Co-Principal Investigator

Department of Fisheries, Moi University, Kenya
Charles C. Ngugi Collaborator
James Mugo Collaborator
Kajitanus Osewe  
Fisheries and Aquaculture Development  
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Berno Mnembuka  
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Ephraim Senkondo  
Department of Department of Animal Science, Sokoine University of Agriculture, Tanzania

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

ABSTRACT
Aquaculture in Tanzania is dominated by subsistence private fish ponds and farm ponds, owned by smallholder farmers. Aquaculture competes with other rural agricultural industries for land, water, labor and nutrients. This project set out to provide training on pond management, fish feed and fish health management to fish farmers, teach farmers principles and benefits of record keeping, and also teach farmers simple methods for assessing and evaluating costs and benefits.

The training workshop involved 25 existing fish farmers. The training was held from June 18th through 22nd 2007 at the Institute of Continuing Education Conference Hall of the Sokoine University of Agriculture, Morogoro, Tanzania. The training sessions focused on general pond construction, pond management, pond fertilization, fish food production in ponds, hatchery management, artificial catfish reproduction, control of fish predators and fish diseases, and fish farming record keeping. The training utilized techniques such as illustrations, open discussions, sharing of experiences, and questions and answers. There were some practical hands-on sessions as well that involved catfish artificial breeding, catfish and tilapia sex identification, and fertilizing ponds using poultry manure. Farmers also had laboratory experience examining microorganisms from pond water under microscopes. The medium of instruction was Kiswahili because all farmers understood and were able to communicate very well in Kiswahili as it is the national language. Trainees also visited the ponds and hatchery site at Kingolwila Fish Center.

Overall, the training was successful. Farmers engaged in open discussions, where many shared their fish farming experiences freely. This session was quite lively and brought out technological deficiencies in current farming methods. Study topics were translated into Kiswahili, and hard copies distributed to farmers. An evaluation questionnaire was administered to the participants at the end of the program. Catfish artificial reproduction and record keeping were rated the most important issues learned, but when asked where changes would be made in their operations, most indicated improvements in hatchery and pond management. When asked about new management techniques learned, most indicated areas in pond management or hatchery management. Most of the farmers promised to make changes to their farm management styles and even try to breed catfish. About a third indicated they learned new record keeping techniques.

In summary, the farmers appreciated this training very much. Farmers have been attending many formal and informal training on fish farming but they indicated this training gave them much technological knowledge and hands-on practice on things that will help them improve their fish operations. From this training, fish farmers can start keeping farm records and also manage their farms better and potentially increase yield and therefore revenues. With knowledge of spawning catfish, farmers can make additional income by hatching their own catfish and also selling some to other farmers.
Waterhed 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 on the watershed scale. 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.
Work Plan Research
This subcontract was awarded funding to conduct the following Twelfth Work Plan investigations:

- Building the Capacity of Moi University to Conduct Watershed Management/12EIA4. A final report was submitted for this investigation.
- Building the capacity of MOI University to have a working GIS Lab and the First Generation GIS Model of the Nzoia/12EIA8. A final report was submitted for this investigation.
- Ecological Assessment of Selected Sub-Watersheds of the Nzoia River Basin/12WQA7. A final report was submitted for this investigation.
- Determining Hydrologic Baselines for the Nzoia River Basin/12WQA8. A final report was submitted for this investigation.

Publications

Theses

Presentations
• Tollner, E.W. and S. Mani. 2007. An evolving course in thermodynamics. Presented at the ASEE annual meeting, Honolulu, HI., USA
• Ssegane, H. and Tollner, E. W.. 2007. Tools for remote watershed assessment. Presented at the ASEE annual meeting, Manhattan, KS., USA
• Tollner, E. W. and H. Ssegane. 2007. Tools for remote watershed assessment. Presented at the ASABE meeting, Minneapolis, MN., USA
• Ssegane, H. and E.W.Tollner. 2007. Remote sensing tools for assessing watersheds. Poster presented at the American Ecological Engineering Society annual meeting, Manhattan, KS., USA
• Ssegane, H. and E.W.Tollner. 2007. Tools for assessing watersheds. Poster presented at Georgia Water Professionals Meeting, Atlanta, GA., USA

**Linkages**

We held discussions on potentials for aquaculture in east and central Africa, fisheries and watershed management while attending the 2007 WAS meetings in San Antonio. Two PIs from Moi University were present. Project planning for the remainder of the project was completed, including an upcoming workshop at Moi.

In June 2007, a 3-day GIS workshop was held at Moi University in Eldoret, Kenya. The workshop was computer based and was designed to feature the project-sponsored GIS laboratory at Moi. The workshop was given by Moi personnel and supplemented by UGA investigators and an African student who was studying at UGA. Four CRSP-funded students from Moi presented short summaries of their thesis work. The workshop included a half-day field excursion to several watersheds around the Moi area where GPS data were collected and used in the workshop. Workshop attendees were Moi faculty, personnel from the Kenya Department of Fisheries and selected Moi students. As a result of the GIS workshop, the UGA student from Africa and other students of Moi investigators have developed continuing GIS-related activities.

**BUILDING THE CAPACITY OF MOI UNIVERSITY TO CONDUCT WATERSHED MANAGEMENT**

Twelfth Work Plan / Aquaculture and Human Health Impacts 12EIA4 Final Report

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Driftmier Engineering Center
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Mucai Muchir, 
Moi University
Eldoret, Kenya

Nancy Gitonga
Department of Fisheries
Nairobi, Kenya
Twelfth Work Plan / Water Quality and Availability 12WQA7

Final Report

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

Twelfth Work Plan / Water Quality and Availability 12WQA7

Final Report
ABSTRACT

Assessment of habitat and water quality has been very important in identifying sources of impairment to streams and rivers as registered by changes in aquatic community structure. This study assessed the response of benthic macroinvertebrates to changes in habitat and water quality along River Moiben, which drained land under forestry, agricultural and residential use. Habitat and water parameters were assessed and measured at eight stations along the river, which were selected to correspond to different land uses. Benthic macroinvertebrates were sampled at the stations using a surber sampler. Metrics were selected that reflected the structural and functional composition of benthic macroinvertebrates at the sampled stations. These were correlated against habitat quality index and water quality parameters to determine their interrelationships. Of the twenty metrics tested, 10 met the test criteria and were included in the final index. The study revealed that benthic macroinvertebrates were responding to changes in habitat and water quality along the river.

DETERMINING HYDROLOGIC BASELINES FOR THE NZOIA RIVER BASIN

Twelfth Work Plan/Water Quality and Assessment 12WQA8
Final Report
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.

During 2007, two workshops on pond soil management were held in Thailand, and workshops on aquaculture BMPs were convened in Brazil and South Africa. The text for the ACRSP manual mentioned above was used in the workshops and proved a useful training tool.
Work Plan Research
This subcontract was awarded funding to conduct the following Twelfth Work Plan investigation:

- Workshops on Better Practices for Sustainable Aquaculture/12EIA7. A final report was submitted for this investigation.

Publications
ABSTRACT
Workshops on the development and use of best management practices (BMPs) in aquaculture were held in Brazil, South Africa, and Thailand. In Brazil, the workshop on guidelines for developing aquaculture BMPs was attended by over 250 individuals. A committee was formed to consider BMP adoption in aquaculture licensing in Brazil. In South Africa, the focus was on the use of BMPs to prevent negative environmental impacts of cage culture. The main outcome of the workshop was to promote BMPs for achieving compliance with water quality regulations imposed on aquaculture. This workshop was attended by 33 people representing a wide range of stakeholders. The three workshops in Thailand were primarily for the purpose of presenting pond soil BMPs developed from previous ACRSP research to small-scale fish farmers. Thus, the focus was on using BMPs as a way of extending research results.
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. Specifically the Universities organized a major international aquaculture conference (ISTA 7) and provided travel awards for CRSP scientists to participate in international conferences in South Africa, Italy, Indonesia, Mexico and the US. We also developed a student poster award which recognized the three best student posters dealing with sustainable aquaculture during conferences in the US, Indonesia and Italy. Lifetime achievement awards were also bestowed on three CRSP scientists recognizing their contributions.
Staff

University of Arizona, Tucson, Arizona USA

Kevin Fitzsimmons  Lead US Principal Investigator
(lead US PI)
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 Martínez Graduate Student (Mexico)

Work Plan

This subcontract was awarded funding to conduct the following Twelfth Work Plan investigations:
- Special Sessions, Travel and Poster Awards at 2007 World Aquaculture Conferences, Site Descriptions Update/12ATE18. A final report was submitted for this investigation.

SPECIAL SESSIONS, TRAVEL AND POSTER AWARDS AT 2007 WORLD AQUACULTURE CONFERENCE, SITE DESCRIPTIONS UPDATE

Twelfth Work Plan/Applied Technologies and Extension Methodologies 12ATE18 Final Report

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ABSTRACT

An Aquaculture CRSP session was organized and conducted at the US Aquaculture meetings in San Antonio TX in February 2007. In addition, funds were used to support travel and participation for six host country scientists and nine graduate students to attend the meeting. The session was well attended and included a full compliment of presentations of ACRSP sponsored research. The travel awards were determined on merit; depending on contribution to the research, quality of the abstract, participation in earlier ACRSP sponsored research and quality of the Power Point presentation developed for the conference.

A second aspect of this project was a series of awards for student posters presented at the same above mentioned conference. Three awards, cash plus certificates, were presented to the top three student posters. The posters were judged on scientific quality, contribution to the core ACRSP principle of sustainable aquaculture practices, and appearance and use of graphics.

The third aspect of the project was an updating of site descriptions for the various ACRSP projects. Dr. Remedios Bolivar coordinated the collection and submission of the reports to the Home office for inclusion in final report.

The present project, 12ATE18, has been successful by improving recognition of the quantity and quality of research supported by the ACRSP. Much of the industry recognized and appreciated work done by many leading aquaculture scientists but had been unaware that the ACRSP was a primary sponsor. By organizing these specific sessions and awards, the contributions of the ACRSP and USAID sponsorship have been much more widely recognized.
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 Tecnologico del Mar, Veracruz. Additional partners in this project included New York Sea Grant, University of Arizona, Rhode Island Sea Grant, Brooklyn College, Texas Sea Grant, Puerto Rico Sea Grant, and La Fundacion Chile. This project aimed to establish a Center for Aquaculture Technology Transfer for all of Mexico that was narrowly focused in its scope and patterned after the Sea Grant Program model. Additional investigations developed a recirculating aquaculture system module for family use and convened the first Annual Sustainable Aquaculture Technology Transfer Workshop in Mexico.
**Staff**

**Cornell University, Ithaca, New York, USA (Lead US Institution)**
- Dale Baker: Lead US Principal Investigator
- Michael Timmons: Collaborating Scientist

**Universidad Juárez Autónoma de Tabasco, Villahermosa, Mexico (Lead Host Country Institution)**
- Eunice Perez Sanchez: Lead Host Country Principal Investigator

**Texas Sea Grant, Houston, Texas USA**
- John Jacob: Collaborating Scientist
- Ralph Raybum: Collaborating Scientist

**Brooklyn College, Brooklyn, New York USA**
- Martin Schreibman: Collaborating Scientist

**University of Rhode Island, Narragansett, Rhode Island USA**
- Barry Costa-Pierce: Collaborating Scientist

**University of Puerto Rico, Mayaguez, Puerto Rico**
- Ruperto Chapparro: Collaborating Scientist

**University of Arizona, Tucson, Arizona USA**
- Keven Fitzsimmons: Collaborating Scientist

**Instituto Tecnologico del Mar, Veracruz, Mexico**
- Margarita Cervantes Trujano: Collaborating Scientist
- Ana G. Trasvina-Moreno: Graduate Student (Mexican)
- Gerardo A. Garcia-Moreno: Graduate Student (Mexican)

**Foundation Chile, Santiago, Chile**
- Martin Hevia: Collaborating Scientist

**Centro de Transferencia Tecnologica Para La Acuicultua (CETRA), Villahermosa, Mexico**
- Aguilar, Francisco: Collaborator
- Quevedo, Santiago: Collaborator
- Mar Tovar, Carmen: Collaborator
- Hurtado, Mariana: Collaborator
- Altamirano, Carlos: Collaborator
- Badillo, Ourdes: Collaborator
- Acuna, Luis Mercedes: Collaborator
- Mava Eduardo: Collaborator
- Moreno, Ana: Collaborator
- Luna, Cesar: Collaborator
- Gonzalez, Gerardo: Collaborator
- Carrillo, Laura: Collaborator
Work Plan
This subcontract was awarded funding to conduct the following Twelfth Work Plan investigations:
- Establishment of the Center for Aquaculture Technology Transfer / 12ATE5. A final report was submitted for this investigation.
- Development of a recirculating aquaculture system module for family and multi-family use / 12PSD4. A final report was submitted for this investigation.
- First Annual Sustainable Aquaculture Technology Transfer Workshop / 12SDF4. A final report was submitted for this investigation.

Thesis
Moreno, Ana GT. 2007. Aplicación de un sistema de calidad para el aprovechamiento del recurso hídrico en una granja de producción acuícola. MS thesis.

Establishment of the Center for Aquaculture Technology Transfer
Twelfth Work Plan / Applied Technology and Extension Methodologies 12ATE5
Final Report
Dale Baker and Mike Timmons
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Eunice Perez Sanchez
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Villahermosa, Mexico

Abstract
A Center for Aquaculture Technology Transfer (CETRA) was created in Mexico. CETRA headquarters were housed at the University of Tabasco. Members of CETRA consisted of aquaculture professionals from the university, government, and private sectors. CETRA’s goals are to support and guide aquaculture commercial enterprise development in an environmentally sustainable fashion. CETRA has established a network of academic and economic resources in Mexico and the United States that can provide extension services for meeting Mexico’s sustainable aquaculture development goals. CETRA builds or will build upon past, present and future research, extension and outreach efforts made by the CRSP/USAID programs and all other pertinent efforts. CETRA members are now effectively networked through the CETRA website and by an annual meeting structure to revisit CETRA structure and elect new members to the CETRA Board of Directors.

Development of a Recirculating Aquaculture System Module for Family/Multi-Family Use
Twelfth Work Plan / Production System Design and Integration 12PSD4
Final Report
Dale Baker and Mike Timmons
Cornell University, New York, USA

Eunice Perez Sanchez
Universidad Juárez Autónoma de Tabasco
Villahermosa, Mexico

Abstract
A small scale recirculating aquaculture module for raising tilapia was designed. The nitrification system used was a fluidized sand filter. A packed column was the primary means of controlling other water chemistry and a combination of settling and screen filtering was used for settleable solids removal. The production capacity of the system was approximately 100 to 500 kg per year, depending upon loading conditions and the tolerance for risk. The small scale system module shows promise for widespread adaptation, although it is unlikely that the system developed in this design will be that vehicle.
FIRST ANNUAL SUSTAINABLE
AQUACULTURE TECHNOLOGY TRANSFER
WORKSHOP

Twelfth Work Plan/Sustainable Development
and Food Security 12SDF4
Final Report

Dale Baker and Mike Timmons
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Villahermosa, Mexico

ABSTRACT
A series of four workshops were conducted over the course of the CRSP project. The first was held in Hermosillo, Sonora, December 2005. Attendance at this workshop exceeded 200 people. This workshop was used also as the lead into the first organizational meeting of CETRA. At this first meeting in December 2005, CETRA set a goal of conducting 3 additional workshops: Boca del Río, Veracruz (March, 2006), Mexico City (July, 2006) and Boca del Río, Veracruz (Pre-ISTA September, 2006). Each of these workshops had its own uniqueness. The Veracruz workshop in September 06 had 140 people attending this 3 day workshop, which was held immediately before the international conference on tilapia at the same site.
Recent interest in indigenous aquaculture has given rise to a number of bold new initiatives resulting in the Indigenous Aquaculture Network (IAN) and the “Eagle of the North and Condor of the South Aquaculture Exchange Project,” supported by Heifer International and the Oregon State University Aquaculture Collaborative Research Support Program (ACRSP). This report discusses the background and rationale behind the project, participants, and activities conducted during the second exchange visit in Mexico from March 7-14th, 2007. The report on the first exchange visit in Peru appears in the ACRSP 24th Annual Administrative Report; the full final report for this project appears in the ACRSP 25th Annual Technical Report. Highlights concerning water issues and feedback from both Eagles and Condors are incorporated with the objective of defining the “next steps” for developing innovative projects of this kind.
INTRODUCTION

At the 2002 Native Food Summit, organized by the First Nations Development Institute, a landmark fisheries and aquaculture workshop brought together diverse Indigenous practitioners of fish culture. At this workshop three key findings emerged: (1) For some indigenous communities, nations and bioregions fish and other aquatic resources are frequently overlooked in terms of contributing to community food sovereignty and sustainability, (2) Fish culture and harvest is integrated and embedded in rich cultural and traditional practices, knowledge and spirituality that underscore community well-being and life-ways. At the same time, many of these traditional aquatic practices are threatened by a number of Western developmental factors, and (3) Many fisheries, aquatic and cultural resource specialists are often isolated and have little opportunity to share their extensive knowledge of fish-cultural practices with others from different bioregions.

Building on these findings, the “Indigenous Aquaculture Network” (IAN) was launched through two small grants from the Homeland-Marisla Foundation over the period 2003-2005. The IAN provided American Indian fish-cultural practitioners a vehicle to exchange and share information through web-based technologies such as a list-serve, conference calls, a web page, and information gathering on Tribal fish cultural practices (http://www.ienearth.org/ieniaqua/). Highlights were annual convenings held in Minneapolis, Minnesota in 2004 and at Camp Indianola, Washington in 2005. A total of 40 American Indian fish-cultural specialists attended these two sessions. Wavering funding commitments by foundations and organizational realignment by non-profit organizations that hosted the IAN resulted in a period of inactivity despite strong continuing interest by network members.

Parallel to these early efforts of the IAN, the Indian Nations Initiative of Heifer International and the USAID-supported Aquaculture Collaborative Research Support Program (ACRSP) initiated a joint “Eagle of the North and Condor of the South Aquaculture Exchange Project” in 2004. The project planned for two groups of American Indian fish-cultural practitioners (“Eagles”) to exchange and share information with Indigenous South and North American counterparts (“Condors”), in Peru and Mexico respectively. Heifer International supported the North American component while ACRSP supported in-country activities for Eagles and Condors. Subsequently, Heifer International (through the Indian Nations Initiative) sub-contracted the Bemidji, Minnesota based Indigenous Environmental Network (IEN) to arrange all logistics of Eagle travel (http://www.ienearth.org). The first exchange took place when an Eagle delegation spent April 22-28, 2006 in the Pucallpa region of Peru. The Mexican trip occurred from March 7-14, 2007 and is the major focus of this report.

THE EAGLE-CONDOR PROJECT

a. Concept and Purpose

The concept behind the Eagle-Condor Exchange Project begins with the realization that indigenous cultures are present throughout every major bioregion of the world. As they have for millennia, many indigenous communities are situated near and dependent on water-based resources for livelihoods, health and well-being. Traditional aquaculture practices covering many geographical locations have been reviewed by Beveridge and Little (2002), Costa-Pierce (1987; 2002), Fitzsimmons (2000), Hickling (1962) and Ling (1977). More recently over fishing has depleted many wild fish stocks and in some cases the expansion of modern industrial aquaculture (especially salmon farming in some areas of the Pacific Northwest) threatens indigenous life-ways due to environmental externalities that affect already stressed wild capture fisheries. At present, there is much speculation regarding aquaculture’s fit with indigenous communities. On one hand, aquaculture is viewed as a form
of economic development. In this regard, aquaculture projects have had decidedly mixed results. On the other hand, the IAN attempts to view the potential of aquaculture from more of a balance between culture and technology that emphasizes traditional knowledge in anchoring and operating fish facilities regardless of the species or system deployed.

The Eagle-Condor Project is a collaboration that serves as a link to other Indigenous Peoples and organizations that work with fisheries and aquaculture. As a collaborative effort, the Eagle-Condor Project works to create opportunities for Indigenous Peoples in regards to aquaculture and aquatic resources. Because this exchange takes place in the western hemisphere between the north and south this project was designated as “The Eagle of the North and the Condor of the South Aquaculture Exchange Project.” It is being carried out with the hope that this exchange will reinforce Indigenous Knowledge, Culture and the cosmovision of Indigenous Peoples.

Objectives: The exchange program builds the initial foundation to further explore appropriate Indigenous aquaculture models and technology linked to:
1. Appropriate indigenous economic and community development pathways;
2. Aquaculture’s role and contribution to biodiversity, sustainability, food security, and community wellness;
3. Aquaculture and traditional ecological knowledge;
4. Aquaculture information transfer and network building between the North and the South;
5. Organization of aquaculture in communities;
6. Aquaculture in the context of aquatic resources management;
7. Planning for aquaculture and fisheries development; and
8. Expanding educational and training opportunities

Why an Exchange Program is Important: The Eagle of the North and the Condor of the South Aquaculture Exchange Project is important for a number of reasons. The Project:
1. Creates an initial organizational framework to evaluate aquaculture in terms of indigenous culture;
2. Allows for balance between more economically-oriented and more community-based projects;
3. Brings together Indigenous People from the North and South to learn from and share with each other in a comprehensive manner; and
4. Provides in-depth learning experiences and an opportunity to help envision aquaculture practices in a manner that can benefit Indigenous People and the water world.

As the above indicates, the Eagle-Condor Project begins with initial country visits and workshops to begin the process of exchanging information and establishing linkages. It is envisioned that these initial communications will evolve into more complex cultural exchanges with an aim to create concrete project activities in the longer term. We found that to bring Eagles and Condors together, a number of daunting cultural, logistical, and experiential barriers required concerted efforts by the contracting and sponsoring agencies. As a result of the Peruvian and Mexican experiences we feel we have a much better grasp on what this kind of effort entails for future activities.

b. Sponsoring Agencies
“The Eagle of the North and the Condor of the South Aquaculture Exchange Project” is jointly sponsored by Heifer International (http://www.heifer.org) and the Aquaculture Collaborative Research Support Program (http://pdacrsp.oregonstate.edu/).

c. Collaborating Institutions in Mexico
In Mexico, the Eagles were hosted by the Universidad Juarez Autonoma de Tabasco (UJAT) (http://www.ujat.mx/). Biological Sciences Division, (http://www.dacbiol.ujat.mx) in Villahermosa, Tabasco. There are
approximately 1,300 students who undertake studies in Biology, Ecology and Environmental Engineering in the Biological Sciences Division. The Division also undertakes a noteworthy effort pertaining to aquaculture research and outreach in the region. Dr. Wilfrido Contreras Sanchez directs this division and was primarily responsible for logistics and hosting the Eagles throughout the visit. On site visits, Mr. Ulises Hernandez Vidal, a biological sciences faculty member, was responsible for the daily itinerary and other accommodations. In Chiapas we also met up with Mr. Alejandro Musalem, Heifer International’s Country Director for Mexico. Mr. Musalem provided a very valuable contribution to this exchange as he interfaced with both Eagles and Condors. A quick study, he was intent on exploring the possibilities of developing Heifer-funded aquaculture projects in some of the Condor villages. Before departing, he met with the Condors to discuss on-site follow up and Heifer requirements and information needs for project development.

**d. Justification and Significance**

While Indigenous Peoples have long-standing cultural relationships with the water world, they often do not have much say or input into how these resources are managed, developed or incorporated into wider society. External pressures from western development forces have threatened traditional aquatic resource use and cultural survival throughout much of the world. The Eagle-Condor Aquaculture Exchange Project seeks to improve upon Indigenous Peoples’ standing in relation to the water world. Using aquaculture as a point of departure, participants are able to revitalize traditional knowledge on the interlinked water world. In particular, Eagles and Condors view the water world from cultural and technical dimensions that address educational, community and empowerment concerns. The significance of such an effort lies in the fact that there is nothing like the Eagle-Condor Aquaculture Exchange Project in the aquatic resources field. Indeed, the international activities and dimensions of such a collaborative effort promise to bring forth a new and perhaps better understanding of the water world for a broad array of practitioners.

**THE INDIGENOUS PEOPLE OF MEXICO**

**a. Overview**

As of 2005, Mexico’s population was over 100 million people, with an indigenous population of about 8 to 10 million, where language is designated as the primary criterion (http://www.travelyucatan.com/maya/mayan_demography.php). Throughout Mexico’s history as a modern nation-state, indigenous populations have been negatively impacted by colonialism, war, discrimination and continuing hardships. More recently, the impacts of NAFTA and a legacy of poverty and neglect by the Mexican Government have sparked widely publicized conflicts in Chiapas and also lesser known areas of Tabasco (Collier and Quaratiello 1999; Vinding 2003; http://warresisters.org/nva0597-2.htm). Currently 62 groups (http://en.allexperts.com/e/i/in/indigenous_peoples_of_mexico.htm) speak distinct indigenous languages (http://www.indians.org/welker/mexnat1.htm). It should be noted further that official census figures of indigenous populations often vary because of the recent resurgence of indigenous identity movements across Mexico. These movements have been closely tied to improving social and economic conditions in the communities (http://www.travelyucatan.com/maya/mayan_demography.php). As a result there was a blend of both Indian and campesino elements in each community visited by the Eagles during this workshop. All Condors spoke Spanish with only one able to speak Chontal.

**The Chontal Mayans**

The Condors all identified themselves as Chontal. There are two distinct indigenous-ethnic groups of Chontal, one consisting of those who live in the coastal lowland area of Tabasco (the Chontal de Tabasco) and the other consisting of those who live in the mountainous parts of Oaxaca (the Chontal de Oaxaca). Although exact reasons
for the origins of these two distinct groups are uncertain, some speculation exists which attributes the cultural differences to warfare, colonialization and physical terrain (http://www.houstonculture.org/mexico/oaxaca2.html). The coastal lowland Chontal reside in approximately twenty one towns in the low lying areas of Tabasco.

The Chontal de Tabasco are predominantly engaged in crop agriculture of corn, beans, yucca, and rice, the raising of livestock and handicrafts. To a lesser degree they fish many of the lakes, rivers, lagoons and wetlands. They also hunt on occasion.

Despite being in the oil producing region of Tabasco, we did not encounter any direct evidence of overt conflict between villagers and the state-owned oil monopoly Pemex. There were however, news reports of a farmer-led blockade at the entrance of one of the oil facilities in Tabasco. Nonetheless, the Chontal of Tabasco have been at the forefront of a struggle with this corporate giant for a number of years. Chontal and campesino activists have charged Pemex with gross neglect, human rights violations and severe environmental degradation of communal and small holder property. In 1992 the National Commission on Human Rights reported that:

“Nearly 800 hectares, property of communal and smallholders, have been totally destroyed with hydrocarbon residues. The damage has affected subterranean waterways, and domestic wells in the affected zone that only produce salt water and are contaminated with hydrocarbons. Diverse species of fish have been extinguished or are in danger of disappearing . . . . . gastrointestinal illnesses have severely affected the young population of the region and have caused the death of some children, predominantly due to the consumption of contaminated water.” http://warresisters.org/nva0597-2.htm

The Commission charged Pemex and the Mexican Government to repair and compensate communities and small land holders whose land has been negatively impacted by pipelines, wells and spills. At present thousands of reclamation demands have been met by Pemex. There are still tens of thousands of pending claims from Chontal, mestizo fishermen and campesinos that are largely unrecognized by Pemex. In Simon Sarlat, a small town visited by the Eagles, an oil spill led to a blockade that shut down the oil wells for one week. At the edge of the United Nations-recognized La Centla Biosphere Reserve, Pemex continues to operate wells and dredge canals, leading to widespread environmental degradation, local discontent, and a resurgence of Chontal indigenous identity (http://warresisters.org/nva0597-2.htm; http://www.nationsencyclopedia.com/mexico/Michoac-n-Zacatecas/Tabasco.html).

The Chol

More than two thousand years ago, the Chol lived in what is now known as Guatemala and Honduras. Subsequently they split into two main groups, with one group migrating to present day Chiapas. The Chol are closely related to both the Chontal in Tabasco and the Chortí of eastern Guatemala. The primary economic activity of the Chol is agriculture, with corn, sugar cane, rice, coffee, and some fruits cultivated in small plots.

The Chol inhabit parts of Northern Chiapas and Southern Tabasco. They are one of the larger indigenous groups in the southern part of the Country. Much like the Chontal of Tabasco, the Chol have experienced economic and social hardships. On our trip to the village of Guerrero we observed absentee ownership of tourist resorts along the Balsas River and a number of large cattle ranches. These ranches started from the partially paved road and went into the surrounding hills, despoiling the area. Students at the Universidad Intercultural del Estado de Tabasco performed Chol songs and greeted the Eagles in their language.
Chol is spoken by 140,000 speakers, accounting for 17% of Chiapas' total indigenous population. The Chol identify themselves as “the miliperos,” the people whose livelihoods have revolved around the cultivation of maize, a sacred food. (http://www.houstonculture.org/mexico/chiapas.html).

The Lacandon Maya
The Lacandon Maya are well known throughout the world. They are a small indigenous group consisting of 700 people living in three villages amidst the Lacandon rainforest of Chiapas (http://www.geocities.com/RainForest/3134/). Historically they have been a relatively secluded group that in part resisted the inroads made by western missionaries and others. In 1970 they were relocated by the Mexican Government to the villages of Lacanja, Metzabok and Naha. Eagles and Condors visited the latter two villages. Metzabok consisted of 64 residents, with some Lacandon wearing traditional clothing while others villagers were dressed in more conventional ways. The Lacandon sustain their communities though elaborate farming methods, hunting and fishing. They also act as guides in the nearby rainforest and have great knowledge of the forest, which is used for a variety of purposes, including medicinal plants (Kashanipour and McGee 2004).

Since the 1950s, the Lacandon have been under pressure from outside forces that threaten their traditional way of life. Yet they are highly adaptable. The small communities we visited had cars, trucks, televisions, and other modern commodities. The area has witnessed a steady stream of immigrants who undertake deforestation and other destructive practices, including cattle ranching. Over the past few decades, the population in this rainforest area increased from a few thousand to well over 200,000 today, consisting mostly of impoverished campesinos who make a swidden agriculture subsistence living from the recently cut rain forest. We were told by one member of the NaHa community that poaching of animals and plants is also a serious issue. Christian missionaries have been somewhat successful in converting some Lacandon to Protestant evangelical denominations. As a result, traditional belief systems have been forgotten in some of the communities. In NaHa, the Eagles and Condors were allowed to take part in a traditional Mayan ceremony where a spiritual elder vividly explained his opposition to Christianity and his resolve to carry on indigenous cosmologies and ways of thinking. This testimonial had a profound impact on all participants. Importantly, in 1971 the Lacandon were given land rights by the Mexican government to over 615,000 hectares of the Chiapas rain forest. As a result, a number of younger Lacandon act as “forest rangers” and are responsible for keeping the area under Lacandon oversight.

Water Issues Faced by the Chontal of Tabasco
Water issues faced by the Chontal of Tabasco range from immediate to long-term. In Tucta, Simon Sarlat, and Buena Vista, water quality affects productivity for fish culture. At Tucta, the main water issue was cleaning the large lagoon system of noxious water lettuce in order to access and improve the productivity of the system. It was clear to the Eagles that more detailed and reliable information was needed when proposed pond culture and hatchery development projects were discussed by respective members of Simon Sarlat and Buena Vista. Water quality parameters are also important at Boca Chilapa, but these are of a longer-term duration. Because it is situated on the banks of the Grijalva River, downstream from the capital of Villahermosa, concerns for a clean water source to run the hatchery and cage culture projects are paramount. Given that all of these communities are situated in the major oil producing region of Mexico and that environmental degradation of water resources occurred in the area during massive flooding in 1997, careful monitoring of water quality remains a critical factor. In the related water issues area, it seems that aquaculture of gar (Atractosteus tropicus) and native cichlids such as Tenhuayaca (Petenia...
splendida), Castarrica (Cichlasoma urophthalmus), and Paletas (Cichlasoma spp.) offers much growth potential. An Eagle observation that was seconded by the Condors pertains to the beginnings of an aquaculture network in the Tabasco region. As the activity grows among the smallholder communities will enough seed be available? Will proper rearing techniques be practiced? Will adequate and cost-effective feed be sourced? We were surprised to see no composting in cichlid ponds and were not able to obtain a reason why this low cost practice was not undertaken. The genetic integrity of broodstock would be another long-term consideration, given what appears to be the formation and organization of burgeoning aquaculture activities in the region. We also noted that there is no current research on fish diseases, as the aquaculture program at UJAT is relatively recent.

PROFILES OF WORKSHOP PARTICIPANTS

**Eagles**

David Vanderhoop, Wampanoag, resides on Martha’s Vineyard in the town of Aquinnah, Massachusetts. He holds a B.Sc. in Fisheries Biology from the University of Alaska and has had extensive experience with both capture fisheries and aquaculture. Mr. Vanderhoop currently directs the Wampanoag Aquinnah Shellfish Hatchery and is responsible for the hatchery and a related oyster grow-out operation. Currently the Wampanoag grow oysters for profit and are experimenting with scallops, hard-shelled clams, and soft-shelled clams. They also undertake natural enhancement of shellfish stocks and monitor water quality in the tidal areas.

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Tom Edwards, Jr. is a Lummi tribal member with the Lummi Indian Business Council from 1981-2002, the Lummi Natural Resources Department since 2002 and with the Lummi Schelangen (Our Ways of Life) Department. He works in a number of areas including fisheries, forests and the preservation of sacred sites. Mr. Edwards’ work entails the application of cultural teachings to natural resources and the protection and restoration of these resources.

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Brenda Jo McManama is Seneca from New York State and has been involved in indigenous issues for the past 15 years. She first worked with committees fighting mountaintop removal in the coalfields of West Virginia. She also worked closely with state and local government in instituting truthful and comprehensive history of American Indian culture with the West Virginia History and Culture Department, Secretary of State Ken Heckler, and the governor’s office with various Native American Graves Protection and Repatriation Act (NAGPRA) issues. Ms. McManama was also an assistant editor at Aquaculture Magazine for four years (2001-2005), helping to educate industry participants on growing problems of indigenous issues surrounding fisheries resources and emerging native owned/operated aquaculture efforts. She was a participant at the 2005 Pacific Northwest Convening of the Indigenous Aquaculture Network in Seattle, Washington, and assisted in the compiling of reports, creation of media/press releases, and distribution of reports/electronic media/materials after the conference. Ms. McManama is currently working as a writer and web designer in Western North Carolina as well as continuing administrative and editorial duties for IAN activities.

PO Box 705
Fairview, NC 28730
William Simmons is Choctaw and currently resides in San Francisco where he works for the International Indian Treaty Council (http://www.treatycouncil.org/), one of the oldest IPO's (Indigenous Peoples Organizations). 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.

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Condors

Both Mr. Feliciano Lazaro and Mr. Melesio Perez are Camellones Chontales who live in Nacajuca. Both are members of a 20 member farmer group that works a large lagoon-dyke system on the outskirts of the village. This area is estimated at 150 hectares with 75 hectares of lagoons. The group also operates a restaurant at the site.

Both Mr. Manuel Jermanez Velazquez and Mr. Ricardo Valascez reside in Rancheria Boca Chilapa/Centla. This Chontales river community exists in a line system with households located on the banks of the Rio Grojalva, approximately 60 kilometers upstream from the Gulf of Mexico. This community ran a two year old cooperative based fish hatchery for stocking of local ponds and net pens. A number of native cichlids and gar were produced. From all of the Eagle impressions, Boca Chilapa was a solid running egalitarian community with strong leadership and full participation from other community members. In some respects it could be seen as a model community that is successfully adopting aquaculture to create more employment and food.

Mr. Thomas Jermanez and Mr. Pepe May Cano live in Buena Vista, a Chontal community situated on the shore of Santa Anita Lake. The villagers make their living by fishing and agriculture. In particular these two participants are part of a 20-family cooperative that is seeking to build a fish hatchery on the shores of Santa Anita Lake.

Mr. Birolio May was the senior person on this trip and resides in the Chontal community of Simon Sarlat. He discussed a failed effort to raise tilapia and a small group of farmers who were seeking to build large roadside ponds a few kilometers outside of the village on the road to Buena Vista.

Contacts

Mr. Musalem directs Heifer International’s Mexico country program. Trained as an agronomist, Mr. Musalem has been Heifer’s Country Director for the past three years. Mr. Musalem attended the Second Native Food Summit held in Milwaukee, Wisconsin in September 2004. From that meeting he identified aquaculture as a potential future Heifer Project activity. The Eagle-Condor exchange provided Mr. Musalem an opportunity to undertake a closer examination of potential Heifer sites, projects and activities.

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Dr. Skladany 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. Dr. Skladany assisted with the organizing of the Indigenous Aquaculture Network. He has written extensively about aquaculture/ fisheries in a number of academic and popular publications. Currently he teaches Sociology at the University of Tennessee.
Dr. Wilfrido Contreras-Sanchez acted as the in-country coordinator and planner for the exchange project. Currently he directs the Biological Sciences Division at the Universidad Juarez Autonoma de Tabasco. Dr. Contreras also runs the aquaculture research and outreach efforts at the university.

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Mr. Ulises Hernandez Vidal was responsible for our daily activities and accommodations throughout the trip. He is a professor of Biology at the Universidad Juarez Autonoma de Tabasco.

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Ms. Candita Victoria Gil Jimenez is the rector of the Universidad Juarez Autonoma de Tabasco. She is also the first woman rector of the university. The Eagles paid a formal courtesy call to her office. She expressed her delight in having such a delegation and encouraged the Eagles to seek out further collaborations and exchanges with the University.

e-mail: rectoria@ujat.mx

Project Leaders
Indigenous Environmental Network
Tom Goldtooth, Dine’/Dakota, is the executive director of the Bemidji, Minnesota based Indigenous Environmental Network. For the past twenty years he has been involved at the international level on a number of Indigenous treaty, environmental and cultural survival issues. The IEN acted as a coordinating entity sub-contracted by Heifer International to plan, arrange logistics and execute the Eagles trip to Peru and Mexico.

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Dr. Hillary Egna is Director of the Aquaculture CRSP and senior research faculty for the College of Agricultural Sciences at Oregon State University. Dr. Egna is one of two main originators of this exchange project, along with Kathy Knott, formerly of Heifer International. Dr. Egna has over 25 years of experience in international research and development, and has worked in 19 countries. Hillary first became involved in international aquaculture in 1982 while working in Central America. Her academic background is in resource geography, natural resources, fisheries and aquaculture. Professionally, Hillary has been engaged in projects that focus on poverty reduction and means to improve people’s livelihoods through the careful use of water resources.

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Dr. James Bowman is senior research faculty in the Department of Fisheries and Wildlife at Oregon State University. He has been involved in aquaculture since joining International Voluntary Services as a Fisheries Extension Worker in Laos in 1969. Jim completed his MS in aquaculture at Auburn University (1979) and his PhD at OSU in 1992. He has been associated with the ACRSP in various capacities since coming to OSU in 1984. His current involvement is Coordinator for
the Kenya Project and as Outreach Coordinator for the ACRSP. As Outreach Coordinator he has helped coordinate logistics for this innovative information exchange project.

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THE WORKSHOP AND SITE VISITS MARCH 7-14th

a. Itinerary

Wednesday March 7th
The Eagles arrive in Villahermosa, Mexico where they are greeted at the airport by Dr. Wilfrido Contreras-Sanchez, Director of the Biological Sciences Division of the Universidad Juarez Autonoma de Tabasco.

Thursday March 8th
Unlike the workshop in Peru, the Eagles previously requested that more time be spent visiting Condor villages and so no formal presentations were made. As a result, the trip provided a number of opportunities for more interactive experience as a total of eight diverse villages were visited.

Prior to departing to the Universidad Juarez Autonoma de Tabasco, Biological Sciences campus, the Eagles met their student translators: Jesus Michael, Valentina Vazquez, and Angel Morales. Throughout this trip they did a stellar job in providing fluid translations. Upon arriving at the university the Eagles and Condors briefly introduced themselves:

Eagle Introductions:
William Simmons (Choctaw) acted as a representative for the Indigenous Environmental Network (http://ienearth.org). He summarized the history and efforts of Indigenous Peoples at the international level. Mr. Simmons emphasized that early struggles over fishing rights sparked a revitalization of Indigenous identity in North America. Mr. Simmons was followed by Dr. Michael Skladany who briefly discussed the history of the Eagle-Condor Aquaculture Exchange Project. Tom Edwards (Lummi) gave a broad overview of Lummi efforts in land-use and environmental planning based on traditional law. Tribal cultural preservation is also a prominent feature of Lummi initiatives. David Vanderhoop (Wampanoag) introduced himself as coming from the “People of the First Light” – the Wampanoag. He touched on the operation of the Wampanoag Shellfish Hatchery at Martha’s Vineyard, Massachusetts. Brenda Jo McManama (Seneca) concluded with a few remarks regarding indigenous relationships, perspective and vision for this exchange, a brief overview of her background and involvement in the Indigenous Aquaculture Network.

Condor Introductions:
Feliciano Lazaro and Melesio Perez, (Chontal) introduced themselves as residents from Tucta (Nacajuca). They stated that they were members of a farmers group who operated agricultural and aquacultural activities on a large 150 hectare lagoon-dyke site located near the village. Victor Manuel Jeramanez Valazquez and Ricardo Valascez (Chontal) introduced themselves as part of a large farmers group from Rancheria Boca Chilapa/Centala. This area borders the Grojalva River and is laid out as a line system along the river bank. The farmers group here runs a gar-cichlid hatchery as well as a net pen grow out operation. Pepe May Cano and Thomas Jermanez (Chontal) introduced themselves as members of Rancheria Buena Vista. This village sits on the shore of Santa Anita Lake. Their goal is to build a hatchery on lakeshore property. The farmers group here has 20 member families. Finally, Birolio May (Chontal) from Simon Sarlat/Centala discussed a failed Tilapia grow out effort and his group plans to build a large pond in the vicinity of the village.

Dr. Wilfrido Contreras-Sanchez, Director of
the Biological Sciences Division, Universidad Juarez Autonoma de Tabasco, gave an overview of the Division’s aquaculture research and outreach program. Dr. Contreras began by discussing early A/CRSP involvements upon his return from Oregon State University where he received a PhD in fisheries. From 1998-2006, the Biological Sciences Division has worked with six species. They are gar, tilapia, three native cichlid species, and more recently, snook. The program emphasizes native species for aquaculture. Dr. Contreras remarked on the Division’s personnel, basic and applied research, and extension efforts involving native cichlid and gar culture. He noted that there is no on-going work on fish diseases and that they are beginning to evaluate and source locally based feeds for cultured species.

The Eagles and Condors took a tour of the University grounds that included a visit to a medicinal plant arboretum. Dr. Alejandro Magana explained to the group what each plant was and how it was used for medicinal purposes. Salamone Paramo and Alfonso Alvarez took the Eagles and Condors on a tour of the aquaculture facilities. Here we saw broodstock and fingerling production for both gar and native cichlids. Mr. Paramo discussed the introduction of an invasive species of Amazonian catfish through the aquarium trade. The fish has no natural predators in this part of Mexico and has proliferated to the point where it comprises upwards of 50% of the total biomass of various lakes and lagoons. Fishermen complain that the fish gets caught in nets due to a pectoral spine, thereby forcing them to cut their nets. The aquaculture program is looking into the possibility of turning this invasive species into a source of local fish meal for gar and other cultured species.

We estimated the size of the area at 150 hectares, evenly divided between land and water. Native cichlids are spawned and raised to juvenile size until they are released into the lagoon ponds for eventual capture by fishermen. On the walking tour we observed plants used for thatch and local crafts, small corn fields, sour orange and banana orchards, medicinal plants, a pumping station and chicken feed machine. We were further informed that farmers worked these plots on a private basis.

Upon our return to the restaurant, the ensuing discussion with the Condors centered around a number of issues. We could clearly see that the complex was underperforming because more than half the canals in the lagoons were choked with a very prolific invasive, and noxious water lettuce. Condors remarked that a large and almost constant effort was needed to remove this plant. The cost to remove this plant with professional services and equipment was prohibitive so farmer group members used nets to collect the plants and deposit them on shore.
The dyke soil was still considered poor quality for growing of some crops and fruit trees. These comments were elaborated upon by the Condors.

The majority of the discussion was focused on land tenure issues. Tucta farmers stated that since this land was still owned by the Mexican Government, they must pay both land and water concessions. The fee for this right acted as a disincentive to create a more productive area. In fact, one member stated that “our rights are limited” and that we want to be “owners of the land and water and be able to leave it to our children.” The discussion then turned to how one can obtain better land and water rights, with some of the other Condors offering suggestions and even assistance. The residents of Tucta agreed that they would invite the Governor of the Province to visit the complex. Resident Condors envisioned a fully functioning restaurant, ecotourism and handicrafts to complement fish and crop production. It was mentioned that a number of manatees lived in the lagoon, which along with other rare birds and animals, would attract tourists. Some discussion also took place on using iguanas for clothing and food purposes. Overall, Condor residents of Tucta have received training and assistance from the university, stocked fingerlings in the lagoons, and envision the lagoon-dyke complex as a means to improve their livelihoods. While the Eagles mainly listened to this exchange they collectively offered words of encouragement to the Condors.

On our way back to Villahermosa we stopped in the larger populated area of Camellones Chontales de Tucta, Nacajuca, to visit with a traditional medicine man, Mr. Alehandro Castro Isidara. He pointed out a number of plants, including marigolds, used for treating specific maladies. Mr Isidara remarked that he counsels many residents and provides several of his remedies for their comfort.

Saturday March 10th

The Eagles and Condors departed Villahermosa for Rancheria Boca Chilapa/Centala. This area borders the Grojalva River and households are situated along the Rio Grojalva in a line system. Upon arriving we received a tour of the 32-member cooperatively owned gar-cichlid hatchery. Only in its second year of operation, the hatchery is producing approximately 50,000 gar fingerlings per annum. A number of large circular tanks, fry tanks and settling tanks are used to operate this facility. Total investment cost was approximately U.S. $200,000 with the source coming from the Mexican government. The 32 members include 17 men and 15 women. The Eagles were briefed by a young village woman who was quite knowledgeable about running the facility. The methods used are carried out meticulously, especially the care of fry and fingerlings, and most of this work is carried out by the women members of the group. The hatchery is used to augment natural restocking in the river as well as supply local fish farmers with seed stock.

Recently, through a grant partially funded by the FAO, the Boca Chilapa coop had begun grow-out cage culture operations in a backwater area of the Grojalva River. Both gar and cichlids were being raised to market size. We also observed other fish cages situated in front of homes during our 10 minute boat ride to the cage complex. Overall, the Boca Chilapa cooperative made a highly favorable impression on the Eagles. It seemed at least through a fleeting tour of the village that strong leadership and a high degree of conflict-free cooperation was evident. When asked if aquaculture had potential for small-scale farmers and fishers of this region, the president of the cooperative Mr.Velazquez responded “absolutely, very great potential.”

Upon returning from the cage culture project, the Eagles were welcomed with a local snack break provided by the residents of Boca Chilapa consisting of native cichlid, tortillas and pazol (a popular regional corn based drink). In the
ensuing exchange, the Eagles asked questions concerning out-migration and employment opportunities in the area. The Condor residents from Boca Chilapa responded that they had been successful in creating more jobs and the children returned to the village after attending school in different regions of the Province. The women in particular seemed pleased with the hatchery, because it provided close-to-home opportunities to earn a share of the revenues distributed at the end of the spawning season.

The Eagles and Condors then traveled for about an hour downriver for lunch at a rustic restaurant situated on a tributary of the Grojalva River. We were informed of an incoming tide some 40 kilometers upstream from the Gulf of Mexico. The terrain was coastal, with vast expanses of tidal swamps and grassy wetlands.

The Eagle and Condor parties next made their way through the large village of Simon Sarlat. A few kilometers outside the village we stopped by the roadside and were greeted by a small farmers group who described their failed past experiences with tilapia culture. We surmised that the fish died due to lack of oxygenation in the pond they were being reared in. At this site, the farmers group described to us their project idea to enlarge and deepen the roadside ditch using an industrial dredge for fish culture purposes.

As dusk was approaching the Eagles and Condors traveled to Buena Vista where they met with another 20 member family cooperative and taken to a recently cleared site on the shores of Santa Anita Lake, a large natural body of water. Co-op members explained to us their desire to build a hatchery at this site. The co-op president even produced detailed engineering/design drawings of the hatchery and explained that an environmental impact study had been performed in preparation for plans to use net pens for grow-out in the lake. The costs for this facility were estimated at approximately U.S. $150,000 by the co-op spokesperson.

At each stop Eagles introduced themselves and discussed where they came from, conditions back home for Indigenous People and a bit of their individual tribal histories. We noted early on that the Chontalles did not seem to have a strong ethnic-indigenous identity, as only a few spoke Chontale and the dress was that of the campesino. Throughout this trip the Eagles continued to evoke and bring forth strong cultural traditions and spirituality through song and prayer. It was notable in this regard that by the time the trip ended, our Condor counterparts had also begun to introduce themselves by their ethnic-indigenous affiliation.

Sunday March 11th
Eagles and Condors departed Villahermos for a three hour trip to Palenque, Chiapas. Upon arrival in Palenque the Eagles and Condors visited the famous Mayan ruins on the outskirts of the town. For many Eagles and Condors alike this was a very moving experience.

The Eagles and Condors then traveled to Misol Ha which is not actually a village but a Chol-run tourist destination situated at the base of a large verdant waterfall. The complex contains a large restaurant, gift shop and small cottages for overnight visits. In addition the Tourist Bureau operates a 1,000 square meter pond to supply the restaurant. Another larger pond had just been created to increase production of native cichlids. This was the only area where we saw a large number of foreign tourists as well as tour buses. The Eagles and Condors met with the President of the Tourist bureau who discussed some of the history behind this development. He mentioned that this project began over 20 years ago and eventually the Tourist bureau learned how to run it. Operating a business proved to be an obstacle and while the facility employs up to 75 people, it was noted that the restaurant needs a new roof and that the cottages require constant upkeep. Approximately 900 foreign and 1,400 Mexican tourists stay overnight here on a yearly basis.
Monday March 12th
The Eagles and Condors departed Palenque for Metzabok, a small 65-person Lacandon village reached only by 50 kilometers of poorly maintained one-lane dirt-clay road. Accompanying us was Ms. Manuela Morales Hernández, a biologist who works for the National Commission for the Protection of Natural Areas. Upon arriving in Metzabok, Eagles and Condors were guided in two hand-rowed fiberglass boats across a deep, clear pristine mountain lake surrounded by rain forest that has been entrusted to the Lacandon by the Mexican Government. Upon arriving at a rock outcropping wall that plunged into the lake, our guide Mr. Rafael Tarano explained the significance of the hieroglyphics in terms of Lacandon cosmology. Tucked away behind the rock wall was a cave situated at the end of a small indentation. The Eagles were greatly moved by this experience. No pictures were taken due to respect and reverence for this sacred site. The Eagles performed a small prayer-ceremony to honor the spirits at this site.

From Metzabok we traveled about 25 kilometers to NaHa, a well-known Lacandon village of 200 people situated at another large rain forest preserve (Kashanipour and McGee 2004). After a meal of chicken in a squash corn sauce we walked a trail that led into the rainforest, identified by the term “cloud forest” denoting the high pine forest (over 3,500 ft above sea level). This village was located at an altitude of approximately 4,000 feet. At a small 100-acre lake we turned around and went back to the village. The Eagles where then invited by a spiritual elder who performed a traditional Mayan ceremony, an event that was not part of the day’s agenda. This ceremony greatly impacted all present. As dusk was unfolding we drove for approximately 2.5 hours to reach the asphalt road to return to Palenque.

Tuesday March 13th
At breakfast Mr. Alejandro Musalem, the Country Director for Heifer Mexico, spoke with the Condors outlining his impressions for future project development. Mr. Musalem indicated to the Eagles that he was especially interested in the group at Buena Vista. The Eagles outlined a number of low-cost aquaculture activities that could possibly be initiated in rural Tabasco. The Eagles further noted that a rural aquaculture network was emerging among the Condors as a direct result of this trip. The majority of Condors had never traveled to this extent. We noted that the response to Mr. Musalem’s talk was well received by the Condors and promises were made to do further follow up work on the part of Heifer.

Eagles and Condors departed Palenque for Tapijulapa, Tacotalpa, Tabasco and visited a Chol village called Guerrero located in a mountain valley. The area is very scenic with the Balsas River a popular summer season tourist destination. This area is not without conflict between social classes and with the Mexican Government. It was pointed out to us by Mr. Raymundi Auri, a sociology instructor at the nearby Universidad Intercultural del Estado de Tabasco (Intercultural University of Tapijulapa), that the area was plagued with absentee ownership of river frontage and large cattle farms. Upon arriving in Guerrero we had to traverse two foot bridges over the river and a stream. Mr. Asuncion Perez Demecio led us on a tour of a three-tank Cichlid grow out operation. Water was supplied to the tanks from a nearby stream. Mr. Demecio was a recent graduate of the Intercultural University. Total investment in this two year old facility, which was run cooperatively by seven families, was approximately US$12,000. Fish were produced for local consumption and brought US$2.50 per kilogram. In response to questions by the Eagles, Mr. Demecio responded that “we can create employment and help our families.” The cooperative members received training from the Council of Pueblo Indians.

Upon leaving Guerrero we traveled to the three year old Intercultural University of Tapijulapa
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(http://www.ueit.edu.mx). We were greeted by the rector, Mr. Pedro Patas Luciano, and other faculty members and were led to a small outdoor area to watch a Chol-Mayan play performed by students (in English) from the languages and cultural division. Mr. Luciano informed us that the school had approximately 300 students drawn from the immediate region of Tabasco. Many were the first in their families to attend an institution of higher learning. Approximately eighty percent of the student body attends with full scholarships and the other twenty percent pay US $100 per month. Their overall vision, architecture and curriculum revolve around Mayan cosmology and involvement with the local elders in order to revive and sustain the rich indigenous history and culture. The Eagles and Condors then took a small lunch break and proceeded to individual classrooms where we met and answered questions from a very enthusiastic group of students.

Upon leaving the University we proceeded to a restaurant where we held our final exchange with the Condors. This session was led by Dr. Michael Skladany and Brenda Jo McManama. While time was short we were able to obtain input from the Condors as discussed below. In short, the Condors were extremely thankful for this opportunity – one that they had never imagined before.

Wednesday March 14th
The Eagles depart Villahermosa for the United States.

RESULTS/OUTCOMES

a. Specific Water-Quality issues faced by the Condors

Making better use of abundant water resources was evident at most of the Condor Chontal sites visited. In Tucta the overabundance of noxious water lettuce and hyacinth greatly inhibited the productivity of the lagoons. In Boca Chilapa water quality is considered excellent for the full running of the hatchery and cage demonstration project. Yet, the Eagles pointed out that the intake from the Grojalva River is downstream from Villahermosa where pollution could eventually become an issue. In Simon Sarlat, villagers described a site where the water quality was poor and an early fish culture project was terminated due to mass mortality of tilapia. Perhaps better site selection would improve future efforts to culture fish. In Buena Vista the abundant lake water seemed sufficient for hatchery operations but a more detailed water quality analysis needs to be undertaken.

b. Feedback From Workshop Participants

1. Eagles
The Eagles felt that this was an extraordinary trip because they were able to observe village life in its everyday settings. In particular the Eagles responded very favorably to the cooperative hatchery at Boca Chilapa. The proposed hatchery at Buena Vista also showed future potential, a matter that will be taken up by Heifer Mexico. The Eagles felt that a Condor network for aquaculture was a viable development due to this trip.

On the other hand the proposed pond at Simon Sarlat left many doubts. Outside of pond construction with a backhoe, not much emerged as to other costs and benefits. The relatively isolated location of the pond site raised concerns as to daily management and safe keeping. The Eagles suggested to Heifer that perhaps more scaled down low-cost projects could be substituted in this case as there are a number of water sources closer to the village.

The highlight for the Eagles (as well as many Condors) was clearly the ceremony witnessed in NaHa. Eagles also remarked that Condors had begun to proudly identify themselves by their indigenous-ethnic identity by the end of the trip. At the beginning of the trip we had to ask each Condor their indigenous-ethnic background.
Eagles were focused on the next steps and were pleased to find that there was a strong Heifer country presence on this trip. Throughout the visits, the Eagles emphasized the strength of traditional culture and spirituality to the Condors through an inclusive demonstration of songs and prayer. Regardless of the “technical” dimensions of a particular activity or project, the Eagles felt that strengthening traditional culture and life-ways held the key to community well-being.

On future trips of this kind it was suggested that the Eagle delegation consist of an expanded delegate pool, that more youth be brought along as part of a mentoring program, and that more Eagle women be involved in these exchanges. An expanded delegate pool should come from other representative regions of North America, including the South East, South West and Upper Mid West.

2. Condors
The Condors were asked a series of questions regarding their impressions of this trip. Given that we were running late they were broken down into groups based on their villages to expedite the process. The collective responses were overwhelmingly favorable.

Feliciano Lazaro and Melesio Perez
Mr. Lazaro responded by saying that “I liked the way the different groups are working together at Boca Chilapa, Simon Sarlat, and Buena Vista.”

Mr. Perez stated, “I like the way we all have the same interests. It is useful to see our partners all involved in the same struggle. I was very pleased to feel a sense of connection with the others. The exchange of ideas was useful. I was very impressed with the Intercultural University as they are rescuing traditions that might be lost otherwise.”

Victor Manuel Jeramanez Valazquez and Ricardo Valascez
Mr. Valazquez mentioned that “This trip was very concrete – excellent. I hope that this isn’t the last time. In the future we might want to make it bigger and longer.”

Mr. Valascez echoed the sentiments of Mr. Valazquez, “My impressions are the same as my partners. It was excellent to see how people live. We don’t even dream about this kind of opportunity. Please continue doing this activity.”

Pepe May Cano and Thomas Jermanez
Mr. Cano remarked that “The farmer groups we met are well organized. The trip was fun and I hope that we do it again in the near future.”

Mr. Jermanez stated that “It was beautiful were we stayed at and where we visited. I hope to do it again soon.”

Birolio May
Mr. May said that “This trip is something that I will tell my daughter and grandchildren about. In my life I thought that I would never see these kind of activities and sights. Thank God we had this opportunity. We all left our work back home to make this trip and hopefully we will return one day.”

In a more general discussion of questions on how to improve exchanges of this kind, group responses emerged. Condors mentioned that perhaps the inclusion of project development personnel from the Mexican government or aid organizations like Heifer could accompany the group. The likelihood of future development aid was a prime concern for the Condors. Condors were very appreciative for being exposed to new ideas and the opportunity to see how others worked. Overall, the Condors felt that they became “stronger” and were inspired to persist in attaining their project goals. They felt they received a “force that has a lot of power and is something we could teach our children.” The Condors from Tucta also expressed their desire for more training such as that received by villagers in Misol Ha in terms of running a business catering to tourists.
Finally, Eagle Tom Edwards added that “we need to educate each generation and if we do so we will see positive change in our communities.”

CONCLUSION

In sum, this trip was very stimulating for Eagles and Condors alike. For Eagles, articulating the “next steps” in terms of developing future concrete activities is paramount. Building upon the IAN seems to be the key organizational mechanism for doing this. For Condors, obtaining funding and developing small-scale projects in terms of a strengthened network faces a number of constraints. At Tucta, land issues are a major obstacle requiring a concerted long term solution. The Boca Chilapa hatchery and cage culture demonstration project seemed to offer relatively unimpeded avenues for expansion. Simon Sarlat villagers would need a better site at which to begin small-scale aquaculture. At Buena Vista, a careful analysis of all the biological, economic and social variables needs to be conducted in order to evaluate the proposed hatchery site.

It is apparent that the involvement of Heifer Mexico is the key intermediate organization that would provide a link towards future aquaculture development. The Eagles suggested to Mr. Musalem that a number of low-cost aquaculture demonstration activities that could be carefully organized with attention to social and cultural variables. Eagles emphasized that culture or strengthening traditional livelihoods and life-ways held the key to any type of aquaculture development activity, both at present and into the future.

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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.

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 talented 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.

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 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 allowed the Aquaculture CRSP to continue 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.

In 2004 a USAID SPARE Panel made the following statements that clearly establish the context in which this CRSP operates. “Fisheries and aquaculture products are globally important sources of much needed, high quality, aquatic animal proteins, and invaluable providers of employment, cash income, and foreign exchange. Fisheries products are the world’s most widely traded foods, with commerce dominated by the developing countries. Fisheries products are the primary protein sources for some 950 million people worldwide, and are an important part of the diet of many more. In comparison to other sectors of the world food economy, however, the fisheries and aquaculture sectors are poorly planned, inadequately funded, and neglected by all levels of government. This neglect occurs in a paradoxical situation: fishing is the largest extractive use of wildlife in the world; and aquaculture is the most rapidly growing sector of the global agricultural economy... The lack of US engagement in international fisheries and aquaculture not only compromises America’s financial position: an important part of our Nation’s food security is at risk; and our domestic fisheries and aquaculture industries are rapidly losing their competitive position.”

The motivation for change was USAID’s desire to end old CRSPs and initiate new ones. USAID wanted to realign the dated CRSP portfolio to better meet a changing world’s 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 was issued 24 May 2006. Oregon State University competed against a number of other fine universities to win the award for the new CRSP. Because of a good faith agreement with the CRSP Council, USAID allowed the Aquaculture CRSP and the new Aquaculture & Fisheries (AquaFish) CRSP to operate concurrently. Both are managed by Oregon State University, although only the ACRSP is the subject of this Annual Administrative Report.

The Pond Dynamics and Aquaculture (PDA) CRSP began in 1982 (ME: OSU) and focused on research to optimize productivity of aquaculture pond systems. In 1996, this mandate expanded to include aquatic resource systems more generally, and the name was changed to Aquaculture CRSP. Then in 2006, a newly mandated Aquaculture & Fisheries CRSP was hotly competed among US universities, with a transparent peer review process managed by USAID but involving other agencies. OSU won the competitive bid for the new AquaFish CRSP in September 2006. There were at least 5 eligible proposals (consortia in some proposals meant more than 5 universities bidding). Before the competition, USAID did a sub-sector review utilizing outside experts, then a table study (Rubin et al.), and finally an international comment period.
In the final funded year of ACRSP, in 2006, over 700 students had been trained with university degrees – over 500 with advanced graduate degrees – in disciplines related to business, ecology, health, agriculture, and natural resources. ACRSP offered short-term trainings and topical workshops to over 4500 people in developing countries. At its height, ACRSP managed a portfolio of 21 direct subcontracts with US universities and had extended sub-contracting relationships with another 7 US institutions, involving 24 countries. Technologies developed by ACRSP include Decision Support Software; the world’s largest database on ground-truthed pond variables; pond construction techniques allowing improved use of up to 13 million hectares (ha) of land in SE Asia; and novel feeding technologies to reduce costs by about $400/ha, translating into a 17% increase in the net value of the crop.

In 2007, the new AquaFish program selected 6 projects, involving 22 host country institutions with 12 US universities and partners in 13 countries: Kenya, Tanzania, Ghana, Mali, Guyana, Mexico, Nicaragua, China, Philippines, Indonesia, Cambodia, Nepal, and Vietnam. The AquaFish CRSP CA/LWA has four major themes: Improved Health and Nutrition, Food Quality, and Food Safety; Income Generation for Small-Scale Fishers; Environmental Management for Sustainable Aquatic Resources Use; Enhanced Trade Opportunities for Global Fishery Markets. Already 92 student degree-training opportunities have been identified for this new program. The goal is to create global partnerships that develop sustainable solutions in aquaculture and fisheries for improving health, building wealth, conserving natural environments for future generations and strengthening poor societies’ ability to self-govern.

1http://pdacrsp.oregonstate.edu/miscellaneous/F%26A_Subsector_Final_Rpt.pdf
APPENDIX II: PROGRAM PARTICIPANTS

PROGRAM MANAGEMENT OFFICE STAFF
Oregon State University, Corvallis, Oregon USA
Hillary Egna     Director
Karl Kosciuch    Research Projects Manager (through April 2007)
Dwight Brimley   Office/Business Manager

UNITED STATES AGENCY FOR INTERNATIONAL DEVELOPMENT
Washington, DC USA
Harry Rea     Cognizant Technical Officer

ADVISORY BODIES
External Program Advisory Council
Christine Crawford     Chair University of Tasmania, Hobart, Australia
Jason Clay           World Wildlife Fund
Nathanael Hishamunda  FAO, Rome
Marcia Macomber       CGIAR Challenge Program on Water and Food

Ex-Officio Members
Harry Rea     USAID
Hillary Egna   Oregon State University

Institutional Representatives
Patricia R. Alvarez     Florida International University
Roy Arnold             Oregon State University (interim)
Linda L. Brainard     Cornell University
Lawrence A. Davis            University of Arkansas at Pine Bluff
Peter J. Gerard           University of Michigan
Barbara A. Goswick      University of Arkansas at Pine Bluff
Colin Kaltenbach        University of Arizona
Ricki McMillan          Institute for Agriculture and Trade Policy
Anne J.M. Moffat       Ohio State University
C. Michael Moriarty     Auburn University
Gordhan L. Patel      University of Georgia
Lee Anne T. Peters     University of Arizona
Prudence M. Rice      Southern Illinois University at Carbondale
Rose Tseng            University of Hawaii at Hilo
2006–2007 Technical Committee Member Co-Chairs
Jim Diana                     University of Michigan
Claude Boyd                    Auburn University

Material and Methods Subcommittee
Suyapa Meyer                  Zamorano
Yang Yi                       Asian Institute of Technology
Kevin Fitzsimmons             University of Arizona

Research Area of Expertise
Social and economic aspects
Environmental effects
Production optimization

Technical Progress Subcommittee
Bill Tollner                  University of Georgia
Maria Haws                    University of Hawaii
Kwamena Quagrainie            University of Arkansas

Environmental effects
Production optimization
Social and economic aspects

Work Plan and Budget Subcommittee
Nancy Gitonga Kenya           Kenya Department of Fisheries
Wilfrido Contreras-Sánchez    UJAT
Remedios Bolivar              Central Luzon State University

Social and economic aspects
Environmental effects
Production optimization

Ex-Officio Members
Harry Rea                     USAID
Hillary Egna                  Oregon State University

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, Philippines
- The University of Hawaii at Hilo and Universidad Autónoma de Sinoloa, Mexico
- Purdue University and Fisheries and Aquaculture Development Division, Tanzania
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 CRSP program budgets and associated cost share amount as of July 31, 2007. Official financial reports are submitted to USAID via the Management Entity’s Research Accounting Office.

<table>
<thead>
<tr>
<th></th>
<th>USAID Funds(^1)</th>
<th>Non-Federal (Cost Share)(^2)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Research</td>
<td>$11,718,633</td>
<td>$2,617,795</td>
<td>$14,336,428</td>
</tr>
<tr>
<td>Special Activities</td>
<td>1,694,709</td>
<td>305,221</td>
<td>1,999,930</td>
</tr>
<tr>
<td>Research Support</td>
<td>3,780,670</td>
<td>810,768</td>
<td>4,591,438</td>
</tr>
<tr>
<td>Total Research</td>
<td>$17,194,012</td>
<td>$3,733,784</td>
<td>$20,927,796</td>
</tr>
<tr>
<td>Program Management(^3)</td>
<td>$4,299,212</td>
<td>n/a</td>
<td>$4,299,212</td>
</tr>
<tr>
<td>Grand Total</td>
<td>$21,493,224</td>
<td>$3,733,784</td>
<td>$25,227,008</td>
</tr>
</tbody>
</table>

\(^1\)Reflects funding received under all USAID obligations through 7/31/07
\(^2\)Cost share figures reflect subcontract commitments
\(^3\)Cost sharing is not required for management operations
APPENDIX IV: PUBLICATIONS

I. Regional Research: Central America and the Amazon Basin

A. Honduras Projects

1. ASIAN INSTITUTE OF TECHNOLOGY

   Publications

2. AUBURN UNIVERSITY

   Theses

   Publications
   • Boyd, C.E. and B.W. Green, 1998. Dry matter, ash, and elemental composition of pond-cultured tilapia (Oreochromis aureus and O.


- Teichert-Coddington, D.R. and B.W.


**Presentations**


- Green, B.W., D.R. Teichert-Coddington, and


Trejos-Castillo, E. Fish culture as a sustainable rural livelihood: Case study of the functioning clusters of successful small-scale tilapia producers in Santa Barbara, Honduras. Presented to the Agricultural Workers Conference, Tuskegee University, Alabama, December 2002.


3. ESCUELA AGRÍCOLA PANAMERICANA EL ZAMORANO

Theses


- Marco Guevara (Ecuador). 2006. Using
Natural Products For Sex Reversal In Tilapia. Senior Thesis for the Department of Aquaculture, Panamerican Agricultural School, Honduras.


Publications


Presentations
Meeting of the American Association for the Advancement of Science, at Washington, DC, 17–18 February 2005.

4. UNIVERSIDAD NACIONAL AUTÓNOMA DE HONDURAS

Theses
• Echeverria, M.A., 1992. Primary production in Tilapia nilotica production ponds fertilized with triple superphosphate. B.S. thesis, Department of Biology, Universidad Nacional Autonoma de Honduras, Tegucigalpa, Honduras. (in Spanish)
• Garces, C., 1986. Quantitative analysis of zooplankton in fish ponds fertilized with triple superphosphate during the rainy season. B.S. thesis, Department of Biology, Universidad Nacional Autonoma de Honduras, Tegucigalpa, Honduras. (in Spanish)
• Hernandez, Carlos, W.N., 1992. Respuesta de fitoplancton y zooplancton a fertilizante orgánico y alimento en estanques piscicolas. B.S. thesis, Department of Biology, Universidad Nacional Autonoma de Honduras, Tegucigalpa, Honduras. (in Spanish)
• Sherman, C., 1992. All female culture of Tilapia nilotica in ponds fertilized with chicken litter. B.S. thesis, Department of Biology, Universidad Nacional Autonoma de Honduras, Tegucigalpa, Honduras. (in Spanish)

5. UNIVERSITY OF ARKANSAS AT PINE BLUFF

Theses

Publications


Presentations


6. UNIVERSITY OF GEORGIA

Publications


7. UNIVERSITY OF TEXAS, AUSTIN

Publications

B. Mexico

1. THE OHIO STATE UNIVERSITY, COLUMBUS

Publications

Presentations
- Rodriguez, G. and K. Dabrowski. Studies on the use of phytochemicals as an alternate to methyltestosterone to produce monosex populations in Nile tilapia (Oreochromis niloticus) for aquaculture. 2004 OARDC Annual Conference, at The Ohio State University, Wooster, Ohio, 2004.

2. UNIVERSITY OF ARIZONA

Publications
- McIntosh, D., K. Fitzsimmons, J. Aguilar, and


Presentations

3. UNIVERSIDAD JUAREZ AUTONOMA DE TABASCO

Theses
September 2005.

- Ramon-Zapata, F. Frecuencia de alimentación y su efecto sobre el desarrollo, crecimiento y supervivencia de las larvas de pejelagarto, Atractosteus tropicus, en condiciones de laboratorio. B.S. thesis, Universidad Juárez Autónoma de Tabasco, Mexico.

**Publications**

- Vidal-López, J.M. Masculinización de crías de la mojarra tenhuayaca Petenia splendida, mediante bioencapsulado del esteroide 17α-metiltetosterona en nauplios de Artemia salina.

**Presentations**

- Contreras-Sánchez, W. Bioencapsulation


• Contreras-Sánchez, W. Masculinization of Nile tilapia, Oreochromis niloticus, using a combination of short immersions in the synthetic steroid trenbolone acetate and high temperatures. AQUAMAR Internacional 2002, at Cancún, Mexico, 3–7 September 2002.

• Contreras-Sánchez, W. Nile tilapia line selection. Presented at Villahermosa, Tabasco, Mexico, 8 August 2003.

• Contreras-Sánchez, W. Use of clean technologies for aquaculture to eliminate MT from intensive masculinization systems. Presented at Villahermosa, Tabasco, Mexico, 8 August 2003.


- Martínez-Garcia, Rafael, November, 2007. Polyculture of tilapia and shrimp. WAS – Latin America Chapter San Juan, Puerto Rico

5. UNIVERSIDAD AUTÓNOMA DE SINALOA, MAZATLAN

Thesis

Presentations

C. Nicaragua

1. UNIVERSITY OF ARKANSAS AT PINE BLUFF

Theses

Publications

D. Panama ~ Aguadulce

1. AUBURN UNIVERSITY

Theses
Publications


Presentations


- Lore, D., H. Tunon, and R. Visuetti. Efecto de la aplicacion de abonos organicos, concentrados y pescado fresco (Dormitator...


- Torres, A. Produccion de Penaeus stylirostris bajo la influencia del Penaeus vannamei, en estanques experimentales de agua salobre con y sin alimentacion durante la epoca seca. Presented to the First National Scientific Congress, at University of Panama, Panama, December 1984.

2. UNIVERSITY OF PANAMA


E. Panama ~ Gualaca

1. AUBURN UNIVERSITY


2. UNIVERSITY OF PANAMA


E. Panama ~ Gualaca

1. AUBURN UNIVERSITY


2. UNIVERSITY OF PANAMA


2. UNIVERSITY OF PANAMA

**Theses**

- Serrano, A., 1987. Economics of tilapia production in monoculture or in polyculture with prawns, and utilizing manure or a commercial pellet as the nutrient input in Gualaca, Panama. B.S. thesis, University of Panama, Panama.

2. INSTITUTO DE INVESTIGACIONES DE LA AMAZONIA PERUANA

**Publications**


Presentations
- Alcántara, F. Performance of Piaractus brachypomus and Colossoma macropomum stocked in ponds at different densities in Iquitos, Peru. Presented to Development of Aquaculture in the Amazon, at Instituto de Investigaciones de la Amazonia Peruana, Iquitos, Peru, 30 November–4 December 1999.
- Alcántara, F. Status of aquaculture in the Peruvian Amazon. Presented to Development of Aquaculture in the Amazon, at Instituto de Investigaciones de la Amazonia Peruana, Iquitos, Peru, 30 November–4 December 1999.

3. SOUTHERN ILLINOIS UNIVERSITY AT CARBONDALE

Publications
- Video: Acuacultura en la Amazonia Peruana, experiencia en la carretera Iquitos-Nauta. SWA TV, July 2003. 7 min. Audience consists of general public, over 1,000. (In Spanish)

Presentations


- Chu-Koo, F. Evidence of the seed dispersal role of Colossoma macropomum reared in aquaculture in the Peruvian Amazon. Presented to the International Congress of Ichthyology, at Manaus, Brazil, August 2003.


4. THE OHIO STATE UNIVERSITY

**Theses**


**Publications**


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


- Ostaszewska, T., K. Dabrowski, M.E.
Palacios, M. Olejniczak, and M. Wieczorek, 2005. Growth and morphological changes in the digestive track of rainbow trout (Oncorhynchus mykiss) and pacu (Piaractus mesopotamicus) due to casein replacement with soybean proteins. Aquaculture 245:273–286.


Presentations
- Dabrowski, K. New developments in diet formulations for larval fish: peptides and growth enhancers. Attended by approximately 60 people from the Institute of Aquaculture, Ministry of Natural Resources (CEPTA, IBAMA), and staff and students from the University of Sao Paolo, Pirassununga, 29 October 2002.
- Dabrowski, K., K. Ware, and M. Tesser. Larval and juvenile rearing of pacu Piaractus mesopotamicus using live food and formulated diets (Poster presentation).
- Dabrowski, Konrad, 2006. Perspectivas para o desenvolvimento de dietas artificiais adequadas para a alimentação de larvas e juvenis de pixes [Perspectives for the development of adjusted artificial diets for the feeding of juvenile larval fish]. Workshop: Larviculutra de Peixes Neotropicals. Center of the Sao Paulo State University in Jatobaticabal, Brazil. 12 August 2006.
- Rodriguez, G., K. Dabrowski, K.J. Lee, M. Teresk, W.M. Contreras, G. Morales, and M. de Jesus Contreras. Interaction of two antioxi-
Dants, Quercetin and Vitamin C and impact on the growth performance of tilapia (Oreochromis niloticus). Oral presentation to Aquamar Internacional, at Cancun, Mexico, 3–7 September 2002.


5. UNIVERSIDAD NACIONAL DE LA AMAZONIA PERUANA

**Theses**


6. UNIVERSIDAD NACIONAL MAYOR DE SAN MARCOS

**Publications**


7. UNIVERSITY OF ARKANSAS AT PINE BLUFF

**Publications**


**Presentations**


II. Regional Research: Africa

A. Egypt

1. AUBURN UNIVERSITY

Publications


Presentations


2. CENTRAL LABORATORY FOR AQUACULTURE RESEARCH, ABBASSA, EGYPT

Publications


Presentations


3. MICHIGAN STATE UNIVERSITY

Publications


4. OREGON STATE UNIVERSITY

Theses


Publications


Presentations

B. Kenya

1. AUBURN UNIVERSITY
Theses

Presentations
• Osure, G. Evaluation of growth and reproductive performance and microsatellite
variability of four strains of Nile tilapia, Oreochromis niloticus. Seminar presented at Auburn University and Wageningen University.


Publications


2. MOI UNIVERSITY

Theses


Publications


Presentations

• Muchiri, M. Break-even price and investment costs under different loan schemes for small-scale fish farmers in Kenya. Presented to IIFET 2000, at Corvallis, Oregon, 10–14 July 2000.


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


• Ngugi, C. On Farm Trials; the Kenyan experience. Presentation given to farmers in Kampala, Uganda, 14 July 2003.

• Ngugi, C. Potential for fish farming in Uganda. Presentation given to farmers in Kampala, Uganda, 14 July 2003.

• Ngugi, C. Working with fish farmers to develop aquaculture. Presentation given to farmers in Kampala, Uganda, 14 July 2003.


3. UNIVERSITY OF NAIROBI

Theses


Presentations


• Meso, B. Application of fish pond effluent to French beans through drip irrigation at Sagana, Kenya. Presented to the Soil Science Society of East Africa (SSSEA) Silver Jubilee


4. UNIVERSITY OF GEORGIA

Theses


Publications


Presentations

- Ssegane, H. and Tollner, E. W.. 2007. Tools for remote watershed assessment. Presented at the ASEE annual meeting, Manhattan, KS., USA
- Tollner, E. W. and H. Ssegane. 2007. Tools for remote watershed assessment. Presented at the ASABE meeting, Minneapolis, MN., USA
C. Rwanda

1. AUBURN UNIVERSITY

Theses

Publications

Presentations


2. UNIVERSITÉ NATIONALE DU RWANDA Theses


- Hatangimbabazi, J.D., 1989. Description des communautés planctoniques des différentes habitats de quelques étangs piscicoles de Rwasave (Butare). (Description of plankton communities in different habitats of fish ponds at Rwasave (Butare).) Mémoire présenté en vue de l’obtention du grade de Licencié en Biologie Animale, Université Nationale du Rwanda, Butare, Rwanda.


- Murangira, J., 1992. Contribution à l’étude de la productivité de quelques graminées fourragères vis à vis trois fréquences de coupe. (Comparative productivity of eight forage grasses at three cutting frequencies.) Rapport de stage, Ecole Agricole et Vétérinaire de Kabutare, Butare, Rwanda.


Publications

Presentations


3. OREGON STATE UNIVERSITY
Theses


Publications


Presentations


• Seim, W. Using Eco-region classification to order pond management strategies. Presented to the U.S. Forest Service Workshop on Warm Water Fish Management, at Bend, Oregon, 1993.

• Tubb, R. The reduction of estradiol by liver enzymes in carp and rainbow trout. Presented to Toxicology Meetings, at New Orleans, Louisiana, March 1986.

4. UNIVERSITY OF ARKANSAS AT PINE BLUFF
Publications


Presentations


D. Tanzania

1. PURDUE UNIVERSITY
Presentations


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

2. KWAME NKRUMAH UNIVERSITY OF 
SCIENCE AND TECHNOLOGY 
Presentations 
• Amisah, Steve, 2005. Fish farming in southern 
Ghana: some preliminary findings on 
opportunities and constraints for sustainable 
fish production and commercialization. 
Aquaculture Association of Southern Africa, 

3. UNIVERSITY OF ARKANSAS AT PINE BLUFF 
Publications 
• Kaliba, A. R., K.O. Osewe, E.M. Senkondo, 
Economic Analysis of Nile Tilapia Production 
in Tanzania. Journal of World Aquaculture 
• Kaliba, A. R., S. Amisah, L. Kumah and K.K. 
Quagrainie. 2007. Economic Analysis of 
Nile Tilapia Production in Ghana. Quarterly 
Journal of International Agriculture 
46(2): 101-115.

Regional Research: Southeast Asia 

A. Indonesia 

1. INSTITUT PERTANIAN BOGOR 
Theses 
niloticus Trewavas production by increasing 
surface area for attached microorganisms. B.S. 
thesis, Faculty of Fisheries, Institut Pertanian 
Bogor, Indonesia.
• Gartini, T., 1986. Flow rate dependent changes 
in turbidity and phosphorus in the water 
conditioning system at Darmaga. B.S. thesis, 
Faculty of Fisheries, Institut Pertanian Bogor, 
Indonesia.
• Harahat, I.S., 1987. Changes of nitrogen 
concentration of the Nile tilapia ponds which 
were fertilized with chicken manure. B.S. 
thesis, Faculty of Fisheries, Institut Pertanian 
Bogor, Indonesia.
• Haryani, G.S., 1985. The growth rate, 
mortality, and feeding habits of Tilapia 
nilotica (L.). B.S. thesis, Faculty of Fisheries, 
Institut Pertanian Bogor, Indonesia.
• Litasari, L., 1985. The composition and 
abundance of macrobenthos in relation to pond 
productivity. B.S. thesis, Faculty of Fisheries, Institut Pertanian Bogor, Indonesia.
• Radiastuti, F., 1986. The balance of nitrogen 
from an irrigation canal that flows through a 
water conditioning system in Darmaga. B.S. 
thesis, Faculty of Fisheries, Institut Pertanian 
Bogor, Indonesia.
• Subyakto, S., 1985. The relationship between 
chlorophyll a and Secchi disk visibility in 
tilapia fish ponds at Darmaga, Bogor. B.S. 
thesis, Faculty of Fisheries, Institut Pertanian 
Bogor, Indonesia.
• Suratman, I.F., 1985. Composition and 
abundance of zooplankton in Tilapia 
nilotica (L.) fish ponds fertilized with triple 
superphosphate at Darmaga. B.S. thesis, 
Faculty of Fisheries, Institut Pertanian Bogor, 
Indonesia.
• Tumbelaka, R., 1986. Primary productivity of 
aquaculture ponds at Darmaga. B.S. thesis, 
Faculty of Fisheries, Institut Pertanian Bogor, 
Indonesia.
• Widjaja, 1985. Flushing rate of experimental 
Tilapia nilotica (L.) ponds at Darmaga and its 
relationship to some physical and chemical 
factors of the ponds. B.S. thesis, Faculty of 
Fisheries, Institut Pertanian Bogor, Indonesia.
• Yulianti, S., 1986. Removal of detergents 
in irrigation canal water by the water 
conditioning system at Darmaga, Bogor. B.S. 
thesis, Faculty of Fisheries, Institut Pertanian 
Bogor, Indonesia.
• Yulisto, 1985. Effect of fish predation on 
macrobenthos density in aquaculture ponds. 
B.S. thesis, Faculty of Fisheries, Institut 
Pertanian Bogor, Indonesia.
2. MICHIGAN STATE UNIVERSITY

Theses

Publications

Presentations
- McNabb, C.D. Application of limnological technology to fish pond management. Presented to the National Institute of

- McNabb, C.D. Limnology of fish ponds in Java. Presented as part of the Visiting Scientists Seminar Series, to the College of Fisheries and Marine Science, Agricultural University of Malaysia, at Serdang, Malaysia, February 1986.

Other


B. The Philippines

1. CENTRAL LUZON STATE UNIVERSITY

Theses


**Publications**

Presentations

- Bolivar, R.B., 2005. Fisheries Information and Learning Center, a facility established through the ACRSP. Presented to the orientation program for Central Luzon State University fisheries students in the first semester, 21 June 2005.
- Bolivar, RB. Comparison on the Use of Cast Net and Seine Net in Fish Samplings in Ponds. Presented at 7th International Symposium on Tilapia in Aquaculture 6-8 September, 2006.
- Bolivar, RB. Sugarcane Bagasse as Periphyton Substrate in the Culture of Nile Tilapia (Oreochromis niloticus) in Fertilized Ponds. Presented at 7th International Symposium on Tilapia in Aquaculture 6-8 September, 2006.
strategies. CLSU College of Fisheries, Science City of Munoz, Nueva Ecija, Philippines, 6 December 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. 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.


2. UNIVERSITY OF ARIZONA

Publications


• Fitzsimmons, K. 2006. ACRSP Helps to rebuild aquaculture in wake of tsunami. AquaneWS.


• Watanabe, W., K. Fitzsimmons, and Yang Yi,
Aquaculture Collaborative Research Support Program


3. UNIVERSITY OF HAWAII

Theses

Publications
• Haws, Maria, 2005. SUCCESS Program off to a Strong Start. Aquanews, 20(3):1,3.


Presentations


4. UNIVERSITY OF THE PHILIPPINES IN THE VISAYAS

Theses


Publications


C. Thailand

1. ASIAN INSTITUTE OF TECHNOLOGY

Theses

- Arifin, Z., 1996. Efficacy of liming and


- Cao, L., 2007. Application of phytase in all-plant feed for Nile tilapia. MS thesis, Huazhong Agricultural University, China (conducted at AIT as an exchange student).


- Luong, N.T. Stocking Ratios of Hybrid Catfish (Clarias macrocephalus x C. Gariepinus) and Nile Tilapia (Oreochromis niloticus) in Intensive Polyculture System. M.S. thesis, AIT.


Hasan, M., and A.N. Bart. 2007. Improved survival of rohu, Labeo rohita...
(Hamilton-Buchanan) and silver carp, Hypophthalmichthys molitrix (Valenciennes) fingerlings using low-dose quanildine and benzocaine during transport. Aquaculture Research, 38: 50-58.


- Tsadik, G., and A.N. Bart. 2007. Characterization and comparison of variations in reproductive performance in


Presentations

- Bart, A. Research paper writing for publication in international journals in aquaculture and fisheries. 7 day workshop, at Rajandrapur, Bangladesh, Audience included aquaculture and fisheries university faculty from 5 universities, 1–7 February 2003.
- Bart, A. Research proposal writing for external funding in aquaculture and fisheries. 7 day workshop, at Rajandrapur, Bangladesh, audience included aquaculture and fisheries
• Cao Ling. 2007. Effects of microbial phytase on the pre-treatment of all-plant feedstuff and replacement of inorganic phosphorous in Nile tilapia (Oreochromis niloticus) feed. WAS 2007, San Antonio, USA, February/March 2007
December 2004.


- Thakur, D.P., Y. Yi, J.S. Diana, and C.K. Lin, 2004. Effects of fertilization and feeding strategy on water quality, growth performance, nutrient utilization, and economic return in Nile tilapia (Oreochromis niloticus) ponds. Presented to the Sixth International Symposium on Tilapia in...
Aquaculture, at the Bureau of Fisheries and Aquatic Resources, Manila, Philippines, 12–16 September 2004.

• Thien, P.C., Y. Yi, and K. Fitzsimmons, 2004. Effects of adding shrimp (Penaeus monodon) into intensive culture ponds of Nile tilapia (Oreochromis niloticus) at different densities. Presented to the Sixth International Symposium on Tilapia in Aquaculture, at the Bureau of Fisheries and Aquatic Resources, Manila, Philippines, 12–16 September 2004.


• Yi, Y., J.S. Diana, and C.K. Lin, 2004. Supplemental feeding for red tilapia culture...
in brackishwater. Presented to the Sixth International Symposium on Tilapia in Aquaculture, at the Bureau of Fisheries and Aquatic Resources, Manila, Philippines, 12–16 September 2004.


- Yi, Y. Brief introduction of PD/A CRSP activities in the past two decades. Seminar, audience consisted of government workers, at the BRAC center, Dhaka, Bangladesh, 26 June 2003.

- Yi, Y. Fertilization strategies for tilapia culture developed by PD/A CRSP. Seminar, audience consisted of government workers, at the BRAC center, Dhaka, Bangladesh, 26 June 2003.


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5. UNIVERSITY OF ARIZONA

Publications


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10. UNIVERSITY OF MICHIGAN
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- Lin, C.K., J.B. Hambrey, and J. Szyper.


Developing and maintaining linkages among collaborating universities, government, NGOs, and the private sector around the world forms a significant ancillary contribution to the CRSP’s 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
- 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 Adiestamiento 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 Indígena Sarayuka, Ecuador
• Cruz Aquaculture, Philippines
• Golfo de Fonseca (CODDEFFAGOLF), Tegucigalpa, Honduras
• Commonwealth Agricultural Bureau International, Comunidad Indígena Sarayuku, Ecuador
• Consejo Nacional de Ciencia y Tecnologia (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 Salaam University, Dar es Salaam, 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
• 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 Research and Food Development, Mexico
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 Tecnologico 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 Quality 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
- Secretaría de Agricultura e Abastecimiento do Estado de Sao Paolo, 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, Chongging, 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
Aquaculture Collaborative Research Support Program

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 Agriculture and Trade Policy, Minnesota, USA
• 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
<table>
<thead>
<tr>
<th>Acronym</th>
<th>Full Form</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAAS</td>
<td>American Association for the Advancement of Science</td>
</tr>
<tr>
<td>AARD</td>
<td>Agency for Agricultural Research and Development</td>
</tr>
<tr>
<td>AARM</td>
<td>Aquaculture and Aquatic Resource Management</td>
</tr>
<tr>
<td>AASA</td>
<td>Aquaculture Association of Southern Africa</td>
</tr>
<tr>
<td>ACRSP</td>
<td>Aquaculture Collaborative Research Support Program</td>
</tr>
<tr>
<td>ADC</td>
<td>Apparent Digestibility Coefficient</td>
</tr>
<tr>
<td>ADCp</td>
<td>Apparent Digestibility Coefficient of P</td>
</tr>
<tr>
<td>AFITA</td>
<td>Asian Federation on Information Technology in Agriculture</td>
</tr>
<tr>
<td>ALCOM</td>
<td>Aquaculture for Local Community Development Programme</td>
</tr>
<tr>
<td>ANOVA</td>
<td>Analysis of Variance</td>
</tr>
<tr>
<td>APO</td>
<td>Asian Productivity Organization</td>
</tr>
<tr>
<td>ASAE</td>
<td>American Society for Agricultural Engineers</td>
</tr>
<tr>
<td>ASAL</td>
<td>Arid and Semi-Arid lands</td>
</tr>
<tr>
<td>AIARD</td>
<td>Association for International Agriculture and Rural Development</td>
</tr>
<tr>
<td>BFAR</td>
<td>Bureau of Fisheries and Aquatic Resources</td>
</tr>
<tr>
<td>BIFADEC</td>
<td>Board for International Food and Agriculture Development and Economic Cooperation</td>
</tr>
<tr>
<td>BMP</td>
<td>Best Management Practice</td>
</tr>
<tr>
<td>CAA2</td>
<td>Second International Symposium on Cage Aquaculture in Asia</td>
</tr>
<tr>
<td>CA/LWA</td>
<td>Cooperative Agreement/Leader with Associates Award</td>
</tr>
<tr>
<td>CARE</td>
<td>Cooperative for Relief and Assistance Everywhere</td>
</tr>
<tr>
<td>CAUNESP</td>
<td>Centro de Aquicultura de Universidade Estadual Paulista</td>
</tr>
<tr>
<td>CENAIM</td>
<td>Centro Nacional de Acuicultura e Investigaciones Marinas</td>
</tr>
<tr>
<td>CETRA</td>
<td>Center for Aquaculture Technology Transfer (Centro de Transferencia Tecnologia Para la Acuicultura)</td>
</tr>
<tr>
<td>CEASO</td>
<td>Centro de Adiestamiento de la Agricultura Sostenible</td>
</tr>
<tr>
<td>CFAES</td>
<td>College of Food, Agricultural, and Environmental Sciences</td>
</tr>
<tr>
<td>CGIAR</td>
<td>Consultative Group on International Agricultural Research</td>
</tr>
<tr>
<td>CIDA</td>
<td>Canadian International Development Agency</td>
</tr>
<tr>
<td>CIESIN</td>
<td>Consortium for International Earth Science Information Network</td>
</tr>
<tr>
<td>CIFA</td>
<td>Counterintelligence Field Activity</td>
</tr>
<tr>
<td>CLAR</td>
<td>Central Laboratory for Aquaculture Research</td>
</tr>
<tr>
<td>CODDEFFAGOLF</td>
<td>Comité para la Defensa y Desarrollo de la Flora y Fauna del Golfo de Fonseca</td>
</tr>
<tr>
<td>CONAM</td>
<td>Consejo Nacional del Ambiente</td>
</tr>
<tr>
<td>COPESCAL</td>
<td>Comisión de Pesca Continental para América Latina</td>
</tr>
<tr>
<td>CRIFI</td>
<td>Central Research Institute for Fisheries</td>
</tr>
<tr>
<td>CRSP</td>
<td>Collaborative Research Support Program</td>
</tr>
<tr>
<td>CSCPRC</td>
<td>Committee on Scholarly Communications with the People’s Republic of China</td>
</tr>
<tr>
<td>CURDTS</td>
<td>Colegio de Riego del Tropico Seco</td>
</tr>
<tr>
<td>DANIDA</td>
<td>Danish International Development Agency</td>
</tr>
<tr>
<td>DAP</td>
<td>Diammonium Phosphate</td>
</tr>
<tr>
<td>DFID</td>
<td>Department for International Development</td>
</tr>
<tr>
<td>DHA-EPA</td>
<td>Docosahexaenoic acid – Eicosapentaenoic acid</td>
</tr>
<tr>
<td>DNA</td>
<td>Deoxyribonucleic Acid</td>
</tr>
<tr>
<td>DOF</td>
<td>Thailand Department of Fisheries</td>
</tr>
</tbody>
</table>
EARTH Escuela de Agricultura de la Region Tropical Humeda  
EFCE European Federation of Chemical Engineering  
EIFAC European Inland Fisheries Advisory  
EMBARAPA Empresa Brasileira de Pesquisa Agropecuária  
ESPOL Escuela Superior Politécnica del Litoral  
FA Fatty Acid  
FAO Food and Agriculture Organization of the United Nations  
FARMESA Farm-Level Applied Research Methods in Eastern and Southern Africa  
FCR Feed Conservation Ratio  
FD Kenya Fisheries Department  
FDA Food and Drug Administration  
FIRA Fideicomisos Institutos en Relación con la Agricultura  
FIRI Inland Water Resources and Aquaculture Service  
FISA Fisheries Society of Africa  
FORMAT Forum for Organic Resource Management  
FPX Federación de Agroexportadores de Honduras  
GIS Geographic Information System  
GMP Good Management Practices  
GMT Genetically Male Tilapia  
GPS Global Positioning System  
HAU Huazhong Agricultural University  
HCMC Ho Chi Minh City  
HR Hatching Rate  
HUFA Highly Unsaturated Fatty Acid  
IAN Indigenous Aquaculture Network  
IBAMA Instituto Brasileiro do Meio Ambiente E Dos Recursos Naturais Renováveis  
ICRAF International Center for Research in Agroforestry  
IDRC International Development Research Centre  
IEN Indigenous Environmental Network  
IFAC International Federation of Automatic Control  
IGF-I Insulin-Like Growth Factor I  
IHELP International Higher Education Linkages Project  
IMARPE Instituto del Mar del Perú  
INTSORMIL International Sorghum and Millet  
IPB Institut Pertanian Bogor  
IPO Indigenous Peoples Organizations  
ISNAR International Service for National Agricultural Research  
ISTA International Symposium for Tilapia in Aquaculture  
ITBOCA Instituto Tecnologico de Boca del Rio  
IUCN World Conservation Union  
IWMI International Water Management Institute  
JICA Japan International Cooperation Agency  
KEMRI Kenya Medical Research Institute  
KMFRI Kenya Marine and Fisheries Research Institute  
KUL Katholieke Universiteit Leuven  
LVEMP Lake Victoria Environmental Management Program  
MCP Mono Calcium Phosphate  
mRNA Messenger Ribonucleic Acid  
MS Master of Science  
MSc Master of Science  
MT Methyl Testosterone  
MU Moi University  
NACA Network of Aquaculture Centres in Asia-Pacific  
NAGPRA Native American Graves Protection and Repatriation Act  
NAJA North American Journal of Aquaculture  
NARP North Africa Regional Program  
NCRAC North Central Regional Aquaculture Center  
NGO Non-Governmental Organization  
NIFI National Inland Fisheries Institute  
NPH Nuestros Pequeños Hermanos  
NRAES Natural Resource, Agriculture, and Engineering Service  
NTIS National Technical Information Services
OSU Oregon State University

PACON Pacific Conference on Mariculture Science and Technology

PCCMCA Programa Cooperativo Centroamericano para el Mejora de Cultivos Alimenticios

PCR Polymerase Chain Reaction

PDA Pond Dynamics and Aquaculture

PhD Doctor of Philosophy

PHS Post-Hatch Survival

PI Principal Investigator

PL Post Larvae

PRADEPESCA Programa Regional de Apoyo al Desarrollo de la Pesca en el Istmo Centroamericano

PROCITROPICS Programa Cooperativo de Investigacion y Transerencia de Tecnologia Agropecuaria

PROMIPAC Programa de Manejo Integrado de Plagas para América Central

RAS Recirculating Aquaculture System

RDS-HN Red de Desarrollo Sostenible Honduras

RNA Ribonucleic Acid

SAO Southeast Asian Outreach

SACRED Sustainable Agricultural Centre for Research and Development

SADC Southern African Development Community

SCALE Cambodia Aquaculture at Low Expenditure

SE Southeast

SEDEC Socio-Economic Development Centre

SENA Servicio Nacional de Aprendizaje

SEAFDEC Southeast Asia Fisheries Development Center

SEDAFOP The Office for Agriculture and Fisheries Development, Tabasco

SEPROR Secretaria de Produção Rural

SIDA Swedish International Development Cooperation Agency

SIS Small Indigenous Species

SPAAR Special Program for African Agricultural Research

SSSEA Soil Science Society of East Africa

SWU Southwest University

TC Technical Committee

TMDL Total Maximum Daily Load

TOT Training-of-Trainers

TVRI Television of the Republic of Indonesia

UDP-GT UDP-glucuronyl transferase

UFAM Universidad Federal de Amozonas

UGA University of Georgia

UJAT Universidad Juarez Autónoma de Tabasco

UJRN United States – Japan Natural Resources

UMSS Universidad Mayor de San Simón

UN United Nations

UNAL Universidad Nacional de Colombia

UNAS Universidad Nacional Agraria de la Selva

US United States

USAID United States Agency for International Development

USLE Universal Soil Loss Equation

USMA Universidad Santa Maria

USEPA United States Environmental Protection Agency

USFWS United States Fish and Wildlife Service

USGS United States Geological Survey

UWRCA Uganda Wetlands and Resource Conservation Association

VND Viet Nam Dong

WAS World Aquaculture Society

WCCA World Congress on Computers in Agriculture

WHO World Health Organization

WU Wuhan University

WARDA West African Rice Development Association

WP Work Plan

WRAC Western Regional Aquaculture Consortium