

# AQUACULTURE COLLABORATIVE RESEARCH SUPPORT PROGRAM

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TWENTY-FIFTH ANNUAL ADMINISTRATIVE REPORT  
1 August 2006 to 31 July 2007



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AQUACULTURE  
Collaborative Research Support Program

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

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## INTRODUCTION

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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 through 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

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. Both CRSPs were managed by Oregon State University during this reporting year, although only the ACRSP is the subject of this Annual Administrative Report.

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- 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/m<sup>2</sup> had better cost benefit ratio compared with fish stocked at a density of 2/m<sup>2</sup>, suggesting that rearing of Nile tilapia at a density of 1/m<sup>2</sup> 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 green-water system was conducted on the island of Negros, in the central part of the Philippines. In terms of direct cost of production, a green-water 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/m<sup>2</sup> 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.

## PROGRAM AREAS & THEMES FOR THE TWELFTH WORK PLAN

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

Current Aquaculture CRSP projects focus on one of three program areas:

**Production Technology**

**Watershed Management**

**Human Welfare, Health, and Nutrition**

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

### **ENVIRONMENTAL IMPACTS ANALYSIS**

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

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

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

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

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

### **INDIGENOUS SPECIES DEVELOPMENT**

Domestication of new and indigenous species may contribute positively to the development of local communities as well as protect ecosystems.

At the same time, the development of new species for aquaculture must be approached in a responsible manner that diminishes the chance for negative environmental, technical, and social impacts. Efforts that investigate relevant policies and practices 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 Sarayuku, 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 Tecnológico 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  
Universidade Estadual Paulista, Brazil  
Universidade 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, Gautamala  
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 cat fish 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.
- The Third Interinstitutional Workshop of the Working Group to develop an integrated management plan for the Camichin Estuary, sponsored under an ACRSP investigation, was held on 24 November, 2006. This working Group has members from state, municipal and national government.

#### *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:

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

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:

Boit, Victoria Chepkirui. 2006. Effects of three feeding regimes and two light regimes on growth and survival of African catfish (*Clarias gariepinus*, Burchell, 1822: Family Clariidae) larvae. M.Phil., Moi University, Kenya.

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 acuicola. MS, Instituto Tecnológico de Boca del Rio, Mexico.

Njau, Stephen N. 2007. Effect of hatchery rearing duration and stocking density on growth and survival of the African catfish (*Clarias gariepinus*, Burchell, 1822) larvae reared in hapas suspended in a static pond. M.Phil., Moi University, Kenya.

Nyanchiri, Elizabeth Mwikali. 2006. The effect of different stocking ratios on the yields of tilapia (*Oreochromis niloticus*) and African catfish (*Clarias gariepinus*) in fertilized earthen ponds. M.Phil., Moi University, Kenya.

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

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### 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
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*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)
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*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

Wang Huangxin	Undergraduate Assistant
You Zhengyong	Undergraduate Assistant
Zhang Yifei	Undergraduate Assistant
Zhou Ling	Undergraduate Assistant

*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
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### Work Plan Research

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

- 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.
- effluents from an intensive catfish (*Clarias macrocephalus* X *C. gariepinus*) culture pond to irrigate rice crop. In: S. Ohgaki, K. Fukushi, H. Katayama, S. Takizawa, C. Polprasert (eds.), Southeast Asian Water Environment I - Biodiversity and Water Environment. International Water Association, IWA Publishing, London, UK, pp. 181-188.
- Watanabe, W.O., K. Fitzsimmons and Yang Yi, 2006. Farming Tilapia in Saline Waters. In: C. Lim and C.D. Webster (eds.), Tilapia: Biology, Culture, and Nutrition. The Haworth Press Inc., NY, USA, pp. 347-447.
- Wan, H., B.Y. Song, Y. Yi, Z.H. Ni, W.M. Wang and B.X. Xiong, 2006. Biological treatment technique of wastewater from aquaculture and its application. Fisheries Science and Technology Information, 33(3): 99 - 102 (in Chinese).
- Chowdhury, M.A.K., Yang Yi, C. K. Lin and E.R. El-Haroun, 2006. Effect of salinity on carrying capacity of adult Nile tilapia *Oreochromis niloticus* L. in recirculating systems. Aquaculture Research, 37(16): 1627 - 1635.
- Yi, Y., A. Wahab and J.S. Diana, 2006. On-station trials of different fertilization regimes used in Bangladesh. Journal of Aquaculture in the Tropics, 21(1), 45-57.
- Bart, A.N., S. Choosuk and D.P. Thakur. 2006. Spermatophore cryopreservation and artificial insemination of black tiger shrimp, *Penaeus monodon* (F). Aquaculture Research, 17:523-528.
- Trung, D.V., A.N. Bart. 2006. A preliminary study on the maturation and reproduction of *Spinibarbus denticulatus* (Oshima 1926), an indigenous species of northern Vietnam. Asian Fisheries Science, 19: 349-362.
- Hasan, M., and A.N. Bart. 2006. Carp seed traders in Bangladesh: Sources of livelihoods and vulnerability resulting from fish seed mortality. Asia Pacific Journal of Rural Development, 16(2)97-119.

## Publications

Yang Yi, L.M. Lan and C. K. Lin, 2006. Using

- Md. Asaduzzaman, M.S., M.A. Wahab, Yang Yi, J.S. Diana and C. K. Lin, 2006. Bangladesh prawn-farming survey reports industry evolution. *Global Aquaculture Advocate*, 9(6):40-43.
- Yakupitiyage, A., S.L. Ranamukhaarachchi, Yang Yi and R. Mizanur, 2007. Nutrient accumulation in tilapia pond sediment and its agricultural uses. In: A.J. van der Zijpp, J.A.J. Verreth, Le Quang Tri, M.E.F. van Mensvoort, R.H. Bosma and M.C.M. Beveridge (eds.), *Fishponds in Farming Systems*, Wageningen Academic Publishers, pp.89-104.
- Gao, Z.X., W.M. Wang, K. Abbas, X.Y. Zhou, Y. Yi, J.S. Diana, H.P. Wang, H.L. Wang, Y. Li, and Y.H. Sun, 2007. Haematological characterization of local *Misgurnus anguillicaudatus*: comparison among diploid, triploid and tetraploid specimens. *Comparative Biochemistry and Physiology Part A: Molecular & Integrative Physiology*, 147: 1001-1008.
- Cao, L., W.M. Wang, C.T. Yang, Yang Yi, J.S. Diana, A. Yakupitiyage, Z. Luo, and D.P. Li, 2007. Application of microbial phytase in fish feed. *Enzyme and Microbial Technology*, 40(4): 497- 507.
- Schwantes, V., J.S. Diana and Yang Yi, 2007. Freshwater prawn farming in Thailand – Cooperation keeps intensive production profitable. *Global Aquaculture Advocate*, 10(1):70-73.
- Hasan, M., and A.N. Bart. 2007. Effect of capture, loading density and transport stress on the mortality, physiological responses, bacterial density and growth of Rohu, *Labeo rohita* fingerlings. *Fish Physiology and Biochemistry*, On-line publication: DOI: 10.1007/s10695-007=9136-9137.
- 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.
- Trung, D.V., and A.N. Bart. 2007. Controlled reproduction of an important indigenous fish species, *Spinibarbus denticulatus* (Oshima, 1926), in Southeast Asia. *Aquaculture Research*, 38: 441-451.
- Tsadik, G., and A.N. Bart. 2007. Characterization and comparison of variations in reproductive performance in Chitralada strain Nile tilapia, *Oreochromis niloticus* (L.). *Aquaculture Research*. 38: 1066-1073.
- Clark, M., and J.S. Diana. Shrimp aquaculture brownfields: social, environmental and economic issues determining rehabilitation options. *Society and Natural Resources*. In review.
- Tain, F., and J.S. Diana. 2007. Impacts of aquaculture extension on small-scale *Oreochromis niloticus* production in Northeastern Thailand. *Society and Natural Resources*, 20: 583-595.

### Theses

- Schwantes, V.S. 2007. Social, economic, and production characteristics of freshwater prawn *Macrobrachium rosenbergii* culture in Thailand. MS Thesis, University of Michigan, Ann Arbor.
- 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).
- Khatun, Mst. M., 2007. Comparisons of growth and economic performance among monosex and mixed-sex culture of mud crab (*Scylla olivacea*) using locally available feeds in pens in the tidal flats of mangrove forests, Bangladesh. MS thesis, AIT.

### Presentations/Conferences

- Yang Yi. 2006. Minimizing Environmental Impacts of Aquaculture through Integrated Systems. International Conference on Environmental and Public Health Management: Aquaculture and Environment, Hong Kong, China, December 2006

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

Yang Yi. 2007. Minimizing Environmental Impacts of Aquaculture through Integrated Systems. International Symposium on Food and Water Sustainability in China 2007, Macau, China, January 2007

Wang Weimin. 2007. Aquaculture and its waste management in China. WAS 2007, San Antonio, USA, February / March 2007

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

Yang Yi. 2007. Environmental impact of cage culture in rivers: a case study in Vietnam. Workshop on Cage Aquaculture in Egypt, Cairo, Egypt, May 2007

Yang Yi, 2007. Tilapia Culture in China and Thailand. Aquaculture Feed Extrusion, Nutrition, & Feed Management, Cairo, Egypt, June 2007

### 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.

### 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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### 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  $46 \pm 1$ . Most farmers (77%) had completed an elementary level of schooling (4 years) and experience on the farm as owner, manager, or both averaged approximately  $10 \pm 1$  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 vannamei*). 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).

Culture practices at the time of this survey were intensive. Most farmers stocked at densities below 20 pieces m<sup>-2</sup> and average production was 2,338 kg ha<sup>-1</sup> yr<sup>-1</sup>. 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<sup>-1</sup> yr<sup>-1</sup>. Variables that significantly affected yearly gross prawn production (kg ha<sup>-1</sup> year<sup>-1</sup>) included feed inputs (kg ha<sup>-1</sup> year<sup>-1</sup>), frequent water exchange, and stocking prawns directly ( $R^2 = 0.299$ ). Yearly net profits (US\$ ha<sup>-1</sup> year<sup>-1</sup>) were most influenced by gross prawn production (kg ha<sup>-1</sup> year<sup>-1</sup>), feed inputs (kg ha<sup>-1</sup> year<sup>-1</sup>), and years of experience of the respondent ( $R^2 = 0.795$ ).

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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### **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<sup>-2</sup> in small ponds or in the trench of gher with water area averaging 332 m<sup>2</sup>. 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 gher. 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<sup>-1</sup>.

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

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#### **ABSTRACT**

Two surveys on giant freshwater prawn (*Macrobrachium rosenbergii*) farming were

conducted in the Mekong delta, Vietnam. The first survey was carried out during March - April 2005 and the second during May - June 2006. These two surveys were conducted in the same locations. 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<sup>-1</sup> crop<sup>-1</sup>, and in 2005 was 1,035 kg ha<sup>-1</sup> crop<sup>-1</sup>. 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

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### ABSTRACT

An experiment was conducted in fifteen 200-m<sup>2</sup> 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<sup>-1</sup>wk<sup>-1</sup>. Nitrogen fertilization rate was fixed at 28 kg N ha<sup>-1</sup>wk<sup>-1</sup> for all the treatments throughout the experiment. Sex-reversed all-male Nile tilapia of about 100 g size were stocked at 3 fish m<sup>-2</sup>, and fed at 50% satiation feeding rate during the culture period.

Mean weight, mean weight gain, daily weight gain and net fish yield were not significantly different among treatments ( $P > 0.05$ ). Water quality parameters were not significantly different among treatments, except total Kjeldahl nitrogen, total phosphorus and soluble reactive phosphorus. Nutrient budget showed that higher rates of phosphorus fertilizer input resulted in higher phosphorus 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

Twelfth Work Plan/Production System Design and Integration Research 12PSD3A/Thailand and Bangladesh  
Final Report

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### ABSTRACT

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-m<sup>2</sup> 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<sup>-1</sup> (dry matter basis). The loading rate of 625 kg ha<sup>-1</sup> 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<sup>-1</sup> y<sup>-1</sup>.

Experiment two was conducted to optimize the number of rice straw mats used in fertilized 40-m<sup>2</sup> 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<sup>-1</sup>) rice straw mat in water column; d) suspending two (2 x 625 kg ha<sup>-1</sup>) rice straw mats in water column; e) suspending three (3 x 625 kg ha<sup>-1</sup>) rice straw mats in water column; and f) suspending four (4 x 625 kg ha<sup>-1</sup>) 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<sup>-1</sup> 90 days<sup>-1</sup>) 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<sup>-1</sup>) 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<sup>-1</sup> week<sup>-1</sup>. Sex-reversed all-male tilapia of 24.7±3.0 g in size were stocked at 2 fish m<sup>-2</sup> 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.

**STUDENT EXCHANGE PROGRAM  
TO STRENGTHEN CAPACITY IN  
ENVIRONMENTAL STUDIES OF  
AQUACULTURE PART A: PRELIMINARY  
ASSESSMENT OF INTEGRATED SHRIMP/  
SEAWEED, SHRIMP/ABALONE, AND  
SHRIMP/SEAWEED/DUCK FARMING  
PRACTICES IN YINBIN BAY, HAINAN  
PROVINCE, CHINA**

Twelfth Work Plan/Production System Design  
12PSD9A  
Final Report

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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<sup>-1</sup> 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<sup>-1</sup>. Experimental diets were supplemented with graded levels of mono calcium phosphate (MCP) at 25, 18.75, 12.5, 6.25, and 0 g kg<sup>-1</sup> 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<sup>-1</sup> (P>0.05), which resulted in significantly better performance than those at 6.25 and 0 g kg<sup>-1</sup> (P<0.05). Dietary interaction effects of phytase were observed for phosphorus retention efficiency and phosphorus load. Apparent digestibility coefficient of P (ADC<sub>p</sub>) was improved significantly by phytase pretreatment (P<0.05). No significant difference was detected on ADC<sub>c</sub> 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<sup>-1</sup> 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-m<sup>3</sup> cage per 200 m<sup>2</sup> 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 m<sup>3</sup> in cages, while carp fingerlings of 8-15 g size were stocked at 1

fish per m<sup>2</sup> 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 super 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  $0.13 \pm 0.01$  t ha<sup>-1</sup> crop<sup>-1</sup>, which was significantly higher than that ( $0.10 \pm 0.01$ ) 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 m<sup>2</sup> 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 m<sup>3</sup> was suspended in ponds. There were two treatments: (1) carps at 1 fish m<sup>2</sup> in open ponds without cages (control); (2) African catfish (*Clarias gariepinus*) at 100 fish m<sup>-3</sup> in cages and carps at 1 fish m<sup>2</sup> 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<sup>-1</sup> d<sup>-1</sup>.

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<sup>-1</sup>, 212.7±12.4 g fish<sup>-1</sup>, 1.3±0.1 g f<sup>-1</sup>d<sup>-1</sup>, 23.1±2.1 kg cage<sup>-1</sup> crop<sup>-1</sup>, 20.6±2.1 kg cage<sup>-1</sup> crop<sup>-1</sup>, 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-m<sup>2</sup> pond in the control, and 1,859 NRs per 100-m<sup>2</sup> 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 12ATE 1C  
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 m<sup>2</sup> in surface area were selected in each of the three sites for the on-farm trial. Nile tilapia (*Oreochromis niloticus*) fingerlings (8-10 g size) were stocked at 2 fish m<sup>-2</sup> in all ponds, while climbing perch (*Anabas testudineus*) fingerlings (8-10 g size) were stocked in a 4-m<sup>3</sup> cage suspended in each treatment pond. Stocking density of climbing perch was the treatment variable and was 50, 100, 150, and 200 fish m<sup>-3</sup>, giving caged climbing perch to open-pond Nile tilapia ratios of 1:1, 2:1, 3:1, and 4:1. There were also control ponds without a cage (0:1), and control ponds were fertilized weekly with urea and diammonium phosphate (DAP) at 28 kg N and 7 kg P ha<sup>-1</sup> week<sup>-1</sup>. No fertilizer was added into treatment ponds. Pelleted feeds containing 32%, 26-28%, and 22% crude protein were given twice daily to caged climbing perch during the first, second and remaining months at rates of 5%, 3% and 2% body weight per day, respectively.

Survival of climbing perch, ranging from 85.5% to 91.1%, was not significantly different among sites and treatments. Daily weight gain (0.28 g

fish<sup>-1</sup> day<sup>-1</sup>) of climbing perch was significantly higher in the 1:1 ratio treatment than those (0.16 – 0.17 g fish<sup>-1</sup> day<sup>-1</sup>) in 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<sup>-1</sup>, 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<sup>-1</sup> day<sup>-1</sup>, 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 m<sup>2</sup> pond). The on-farm trial has demonstrated that the high-valued climbing perch may provide potential for the integrated cage-cum-pond culture system, but it is necessary to improve FCR of climbing perch in order to increase the profitability of the system.

## 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 5m<sup>2</sup> 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 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 m<sup>2</sup> 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 FUJIAN 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 Quangan 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 m<sup>3</sup> 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 ( $2.54 \pm 0.34$  kg) than females ( $3.46 \pm 0.45$  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 ( $0.7 \pm 0.1$  mm diameter.). Two distinct egg groups ( $0.7 \pm 0.1$  mm, 36% and  $1.0 \pm 0.2$  mm, 54%) were observed in February. Three distinct size groups were observed during March ( $1.1 \pm 0.03$  mm,  $1.6 \pm 0.01$  mm and  $2.1 \pm 0.03$  mm). 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 ( $3.1 \pm 0.4$  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  $8.42 \pm 0.36$  million cells per ml with only a small amount ( $3.3 \pm 0.2$  ml) of total expressible milt per male. However, when induced with LHRHa ( $10 \mu\text{g kg}^{-1}$ ) the milt production increased to  $6.2 \pm 0.5$  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<sup>3</sup> 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.



## RESEARCH PROJECTS

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### Philippines Project: Production Technology

Philippines  
Subcontract RD010E-20



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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Christopher L. Brown	Lead US Principal Investigator
Emmanuel M. Vera Cruz	Graduate Student (Philippines) – completed PhD in 2006
R. Moncarz	Collaborator

*Central Luzon State University, Science City of Muñoz, Nueva Ecija, Philippine (Lead Host Country Institution)*

Remedios B. Bolivar	Lead Host Country Principal Investigator
Eddie Boy T. Jimenez	Research Associate
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Federico G. Sagun	Field Assistant (hired on June 01, 2005 – February 15, 2006)
Jayson V. Isais	Field Assistant (hired on January 09, 2006 to present)
Jayson P. Angeles	Undergraduate Student (Filipino; from June 16, 2005)
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Emma M. Vera Cruz	Undergraduate Student (Filipino; from June 2005 to March 2006)
Apple Joy M. Balbin	Undergraduate Student (Filipino; from June 2005 to October 2005)
Rayzon John M. Espinosa	Undergraduate Student (Filipino; from June 2005)
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Ruben R. Reyes Collaborator  
Ma. Jodecel C. Danting Collaborator  
Joyce L. Cuanan Collaborator

### 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

Bolivar, R.B, Jimenez, E.B.T. and Brown, C.L (2006). Alternate-Day Feeding Strategy for Nile Tilapia Grow Out in the Philippines: Marginal Cost–Revenue Analyses. North American Journal of Aquaculture. 68:192–197.

Vera Cruz, E., Brown, C.L., Luckenbach, J.A., Picha, M.E., Borski, R.J., and Bolivar, R.B. (2006). PCR-cloning of Nile tilapia, *Oreochromis niloticus* L., insulin-like growth factor-I and its possible use as an instantaneous growth indicator. Aquaculture 251:585-595.

Vera Cruz, E.M. and Brown, C.L. (in press) The influence of social status on the rate of growth, eye color pattern and Insulin-like Growth Factor-I gene expression in Nile tilapia, *Oreochromis niloticus*. Accepted by Hormones and Behavior.

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

Bolivar, RB. Grow-out Production Systems and Management. Presented at Enhancement Training on Agricultural Technologies for Extension Workers of PICAT Pilot Sites in Nueva Ecija: Tilapia Production and Hatchery Management. October 2006. Science City of Muñoz, Philippines

International Conference on Bridging Gaps in Agriculture Research and Development Toward Sustainable Development. April 11, 2007. Science City of Muñoz, Philippines

Bolivar, RB. Cost Containment Options in Semi-Intensive Tilapia Pond Culture: Evaluation of Tilapia Feeding Strategies. Presented at Regional Tilapia Forum 2007. May 24, 2007. Science City of Muñoz, Philippines

## 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 m<sup>2</sup> earthen ponds. GET-ExCEL Nile tilapias were stocked at a density of 1 pc m<sup>-2</sup> (Treatment I) and 2 pcs m<sup>-2</sup> (Treatment II). Analysis of variance revealed no significant differences in the initial 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 ( $5,250.93 \pm 313.05$  kg ha<sup>-1</sup>) and Treatment II ( $8,256.43 \pm 423.16$  kg ha<sup>-1</sup>) and on fish biomass in Treatment I ( $219.84 \pm 15.93$  kg) and Treatment II ( $327.77 \pm 21.91$  kg). The 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<sup>-1</sup> was more profitable for the production of tilapia for fillet.















































































































































































































































































































































































